Proceedings of the Out of Eurasia Hawai'i Conference, March 02-03, 2023

Trekking Shores, Crossing Water Gaps, and Beyond: Maritime Aspects in the Dynamics of "Out of Eurasia" Civilizations

Edited by **Akira GOTO and Naoko MATSUMOTO**

Pukapuka, a remote atoll in the northern Cook Islands
Photo courtesy by Mr. Kolee TINGA

OUT OF EURASIA

Grant-in-Aid for Scientific Research on Innovative Areas (2019-2023)

Integrative Human Historical Science of "Out of Eurasia"
Exploring the Mechanisms of the Development of Civilization

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Maritime Aspects in the Dynamics of "Out of Eurasia" Civilizations

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Preface

Homo sapiens originated in Africa and migrated eastwards across Eurasia by northward and southward routes. From the eastern edge of Eurasia, they migrated to the Americas and to the islands of Southeast Asia, Australia and Oceania. It is agreed that the migration from Sundaland to Sahul (an ancient continent consisting of the island of New Guinea and the Australian continent) in the islands of Southeast Asia was by sea.

In Japan, obsidian from Kozushima in the Izu Islands was transported by sea to Honshu Island 38,000 years ago. This demonstrates two facts: (1) humans had already migrated to the Japanese archipelago 38,000 years ago, and (2) they already had the ability to sail to the open sea. There are three possible routes of human migration to the Japanese archipelago. (1) Hokkaido Island, which was part of the Pleistocene glacier Sakhalin, could have been reached on foot. (2) Northern Kuyshu, which may or may not have been connected to the Korean peninsula. In both cases, some form of watercraft must have been used to cross aquatic (sea or wetland) environments. (3) The Ryukyu Islands were separated from the Eurasian continent by the sea, and it was necessary to cross the sea to reach these islands (see 1-5 paper).

The migration to America was thought to have taken place on foot across Beringia during the Pleistocene Ice Age, but a new theory has been proposed in recent years. In fact, during the existence of the Laurentide Ice Sheet, people who reached Alaska were able to move southwards, since the Pacific coast of the New World already had settlements at that time. This phenomenon is explained by the fact that migration along the Pacific Ocean was possible (see 1-1 and 1-2 papers).

Although there are still many problems to be solved, these archaeological phenomena indicate that one of the characteristics of the Out-of-Eurasia groups was maritime migration, and this was the main theme of a two-day international meeting held at the Hawai‘i Imin International Conference Center at Jefferson Hall, East-West Center of the University of Hawai‘i at Mānoa on March 2-3, 2023. This volume contains most of the papers presented at the second major international research meeting of the “Integrative Human Historical Science of ‘Out of Eurasia’: Exploring the Mechanisms of the Development of Civilizations”, a five-year research project supported by MEXT Grants-in-Aid for Scientific Research on Innovative Areas that started in 2019 (https://out-of-eurasia.jp/). In addition to 15 project members from Japan, three invited researchers from Japan, seven invited researchers from the United States including Hawai’i, and a Hawaiian colleague from the Polynesian Voyaging Society (see the list of participants). As our project focuses on the interaction of matter and mind through the body, it was important for us to actually gather in Hawai‘i to discuss the issue. It was a valuable experience that we could deepen our discussions while experiencing Hawai‘i 's landscape and material culture while visiting the Bishop Museum, Waimea Valley, and the Polynesian Center on the following day.

During the two-day conference, we shared the latest information on the sea routes used during these maritime migrations and discussed how humans originated in Africa, walked along the coast,

crossed water gaps and moved further out of sight.

In our Out-of-Eurasia project, we have used a triadic niche construction model to identify the importance of these processes. This model explores the process of niche construction in which humans change their environment on their own, and these changes influence the evolution of subsequent generations.

Take Polynesia as an example. Technological changes that enabled Polynesians to undertake long voyages to unexplored remote islands were probably coupled with changes in physical characteristics to withstand and survive the long voyages. At the same time, Polynesian ancestors learned to read natural signs and make inferences to estimate the location of islands and the direction of the sea route. In addition, on the new island, Polynesian ancestors encountered new environments and resources and adapted to this new niche. Although land resources were often limited, Polynesian ancestors then transformed the environment and created a new niche by introducing crops and livestock brought from Eurasia.

Then, in some parts of Polynesia, such as Hawai‘i, Tahiti, or Tonga, society evolved into complex chiefdoms or "states" comparable to ancient civilizations around the world. Many symbolic objects of prestige, monuments, rituals, myths, and so on developed. These changes further modified the social environment and created a new niche.

The keynote lecture by Seth Quintus addresses this very problem of niche construction in the island context of Polynesia. He has shown how niche is constructed through perturbation and relocation, which in turn lead to inception and counteraction. These changes are inherited through three mechanisms: genetic inheritance, cultural inheritance, and ecological inheritance. They are in turn integrated into the emergence of niche construction. He further explores the meaning of ecosystem engineering as a key concept and discusses how organisms, including humans, become entangled in ecological webs with each other and need to respond to the nature of these changing entanglements using agricultural systems on Mangaia in the Cook Islands and O‘ahu in the Hawaiian Islands.

Part 1 presents new methods for elucidating human maritime migrations.

Loren (1-1) proposes a new approach to the submergence of landforms and archaeological sites due to sea-level changes from the Pleistocene to the Holocene to search for traces of early migration to the Americas. Des Lauriers (1-2) provides a detailed analysis of the morphology and technological process of making fishhooks recovered from Terminal Pleistocene sites on the west coast of North America, highlighting the role of boat-using populations living on such islands as Okinawa and the western Pacific coast rim in the early migration to North America. Ōnishi (1-3) discusses the socio-economic significance of animal-skin boats, Kayak or Baidarka (Russian), which may have been used for migration to the Americas, from an ethnoarchaeological perspective based on missionary records.

Watanabe and Yamazaki (1-4) work on reconstructing high-resolution paleoclimates by analyzing coral fossils in tropical waters and explore their relationship to human maritime migrations. Goto (1-

5) reviews the ethnography of indigenous boats on the Pacific rim and islands,and explores the potential for experimental archaeology of grass bundle boats, bamboo/log rafts, and dugout canoes that may have been used during early human maritime migrations.

In Part 2, the problem of body and mind, i.e., physical and psychological aspects in non-Eurasian groups, was discussed.

Pietrusewsky (2-1) provides an overview of craniometric analyses showing the presence of two major divisions, (1). Australia, Tasmania, and geographical Melanesia, and (2). East Asia, Southeast Asia, and Polynesia. The results show a separate origin of the inhabitants of these two major geographic regions, a finding that is consistent with archaeological, historical linguistic, and genetic models. Following this discussion, Seguchi (2-2) reviews the current status of human remains research in the Pacific, including ethical issues.

Yamamoto (2-3) discusses another feature of non-Eurasian populations, highland adaptation, using hemoglobin dynamics among Tibetan highlanders. As a result, he has suggested the possibility of sex differences in the optimal adaptation mechanism with respect to their hypoxic environment.

The remaining three papers are more concerned with the psychological and cognitive aspects of humanity.

Ishii and Matsumoto (2-4) have dealt with a unique artifact of the Jomon, Japan: the *dogu* figure. They argue that the worldview behind the *dogu* consists of the mutual interaction of three worlds: the supernatural, the natural, and human society. Contrary to the modern view of "artifact making," clay, clay spirits, and humans are all involved in the production of both *dogu* and Jomon pottery.

Saiki (2-5) attempts to explore the difference in cognitive tendency to space and coordinate systems by comparing the cognition of geometric figures between Americans and East Asians. Experiments show differences in perceptual span based on orthographic system and asymmetry search with line-length search. He argues that the interaction with material culture will also be an important factor in explaining cultural variability.

Matsugi (2-6) points to the symbolic importance of long-distance maritime trade rather than the Marxist model of a social hierarchy based on increasing productive forces. In particular, the reliance on maritime trade in ironware created a worldview unique to the Japanese archipelago in terms of social status. This suggests that the Japanese archipelago achieved a social complex unique to maritime societies, distinct from mainland China and the Korean peninsula.

Part 3 focused on the recent practice of LiDAR research in Japan and the Pacific Islands.

Sekiguchi, Iwashiro, and Hojo (3-1) demonstrated a newly developed system called arcAstro-VR, which integrates DTM obtained by LiDAR with the astronomical simulation system Stellarium. They applied this system to the settlement site of Yoshinogari (Yayoi period) to investigate how the orientation of the site was related to astronomical phenomena. Ryan (3-2) shows the results of LiDAR research on Kofun mounds in the Okayama Plain. In particular, he shows the spatial framework of the

mounds together with ancient major roads.

Comer *et al*. (3-3) pioneered LiDAR research on Nan Madol, Pohnpei, the largest stone monuments in the Pacific. Their research, which analyzed the topographic context of Nan Madol, has led to a significant finding that this religious city was supported by a complex agricultural system built on the adjacent island, Temwen. *Potter et al*. (3-4) have provided a new approach to elucidate the development of navigational knowledge in the Caroline Islands of Micronesia. They used a combination of satellite data to model the complexity of ocean dynamics and examined satellite images of ocean currents, wave and bathymetry patterns, sea surface temperature (SST), and wind products to understand indigenous navigational cues from ocean dynamics.

Part 4 discussed monuments of Japan and the Pacific Islands.

Ishimura (4-1) has analyzed the seascape of the Kofun period of Japan by using topographic simulation (Kasimir) and proposed that coastal burial mounds could serve not only for religious purposes but also as navigational markers (traditional *yama-ate* method, i.e., triangulation by observing mountain peaks).

Kahn (4-2) has combined ethnohistorical, linguistic, and archaeological data to explain multisensory perceptions of scents, sounds, and visual spectacles in the development of religious monuments in the Society Islands. In particular, she has analyzed how chiefs and priests designed the religious space in which the '*Oro* war cult was performed as a national-level ceremony.

Yamaguchi(4-3) used a direct historical approach based on written documents of marae ceremonies by Western explorers. He has shown in detail how and why such documents were written by examining the interaction of several agents, such as chiefs, priests, ordinal inhabitants, and Westerners.

The presence of megalithic monuments is widespread in Melanesia, but their study has lagged behind that of Polynesia. Nojima (4-4) has approached the reality of an ethnographically recorded rank-grading system (*suqe*) through ethnoarchaeological analysis of men's meeting place and traditional dance in the Banks Islands.

Thus, the two-day conference may have raised more questions than it answered, but we believe it was a success in testing new geophysical, archaeological, ethnographic, physical anthropological, physiological, cognitive, and psychological methods for approaching the Integrative Human Historical Science "Out of Eurasia".

This conference gave us many clues on how to approach the issue of human migration, especially maritime migration, and how to understand the formation of civilizations in different regions.

<Acknowledgement>

We would like to express our sincere gratitude to the participants of the two-day conference at the East-West Center and to the authors of this collection of papers.

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What Polynesian Agriculture Teaches Us About Niche Construction

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Introduction

Humans are successful because we are able to construct our own environments that counteract conditions that would otherwise inhibit our ability to survive (Boivin et al. 2016; Ellis 2015; Smith 2007). This is most evident in how we change the environment to promote the growth of plants (Quintus and Allen 2023). We share the ability to construct environments suitable to our species with other organisms; this general behavior and the evolutionary process it gives rise to are called niche construction (Odling Smee et al. 2003). Simply, niche construction is the process by which organisms modify their own evolutionary trajectory or that of other organisms through their own behavior. Organisms co-create their environment so that the selective context of that generation and subsequent generations are modified.

The islands of Polynesia have long been thought of as laboratories or model systems for the investigation of ecology and human-environment dynamics (Kirch 2007; Vitousek 2002). Model systems are particular cases that exemplify well some process in such a way that it is likely that the case provides insights into the process more generally. Here, I argue that Polynesian agriculture is one such model system for the process of niche construction. As a model system, it exemplifies the process of niche construction and provides insights that other examples do not given the unique cultural and ecological characteristics of Polynesia. In particular, I draw attention to the notion of emergent attractors.

Niche Construction Theory

All organisms, even those that are small and short-lived, have some effect on the surrounding environment. The process of niche construction occurs when those environmental changes cascade to affect the evolution of that organism or other organisms (Laland et al. 2019). Such niche construction can work in two ways: perturbation and relocation (Odling Smee et al. 2003). Niche construction through perturbation occurs when an organism modifies the environment, thereby counteracting or creating new selective pressures working on itself or other organisms. Relocation refers to the creation or counteraction of selective pressures through the movement of an organism. Within these categories are two other dimensions: inception and counteraction. Inception occurs when novel selective pressures are the outcome of the organism’s behavior, whether intentional or not. In contrast, counteractive niche construction occurs when a behavior is meant to counteract selective pressures caused by rapid changes in external conditions.

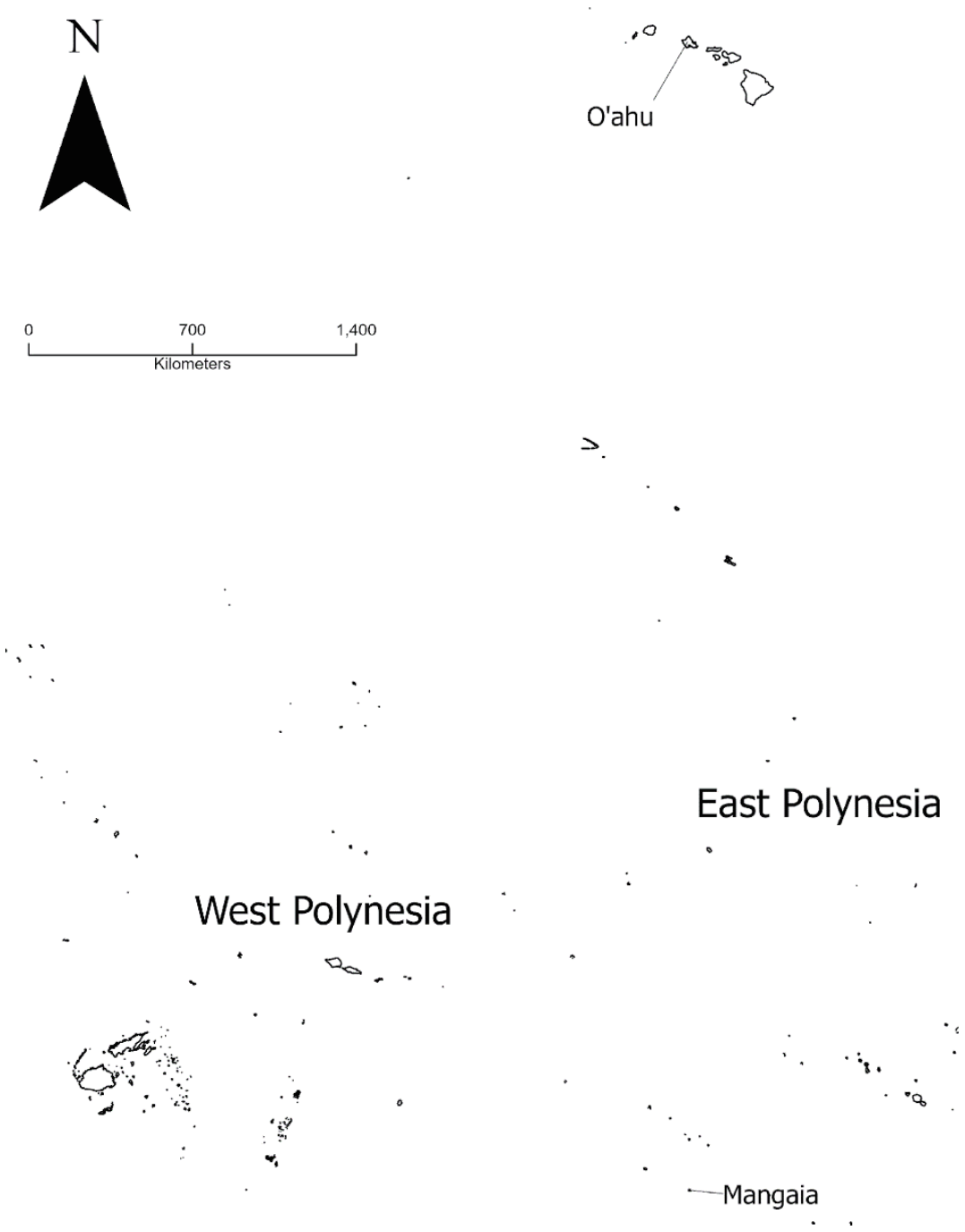

Figure 1. The islands of the eastern Pacific with Mangaia and O‘ahu labelled.

Evolutionary change requires some mechanism of inheritance. Conventionally, such inheritance has been through genes or cultural learning. Niche construction adds a third form of inheritance in ecological inheritance (Odling Smee and Laland 2011). Through ecological inheritance, outcomes of perturbations

Figure 2. An excavated boundary wall in the Kāʻu Field System, Hawaiʻi Island.

(ecosystem engineering) or relocation are experienced by the organisms or other organisms. Similar to cultural learning, ecological inheritance can occur across generations, not just between generations. Unlike most examples of cultural learning, the effects of changes in the environment caused by different organisms can accumulate or counteract each other. All these elements are inherited, not just those elements that are the result of a single species. In essence, organisms become entangled in ecological webs with each other and need to respond to the nature of those changing entanglements.

There are few practices where entanglements are more clearly seen than in agriculture (Ingold 1995). By its nature, agriculture involves several organisms and changes to the environment (Fuller et al. 2011). While human engineering is rightfully the focus of investigation, other organisms also influence elements of the environment that are cultivated (Quintus et al. 2023b). Humans and other organisms respond to the accumulation of these modifications, both behaviorally and biologically. It is this reciprocal causation that produces trajectories of agricultural change (Morrison 2014; Quintus and Allen 2023).

Polynesia and Polynesian Agricultural Niche Construction

The Polynesian triangle occupies a vast region of the southern and eastern Pacific, ranging from New Zealand to Rapa Nui and Hawai‘i. Within the region are two cultural areas: West and East Polynesia (Figure 1).

West Polynesia is the geographically smaller of these two areas, constituted by Tonga, Sāmoa, Niue, ‘Uvea, Futuna, and adjacent smaller islands. These islands are closer together than those in East Polynesia, though there is still substantial geological complexity as the region straddles the resource-important andesite line. The expansive nature of East Polynesia encompasses both geological and ecological complexity, ranging from the subartic islands of southern New Zealand to the tropical environments of Central East Polynesia.

The entire region shares a linguistic heritage, leading to the definition of Polynesia as a cultural area in a classic sense (Kirch 2020), but there are substantial temporal differences in settlement. West Polynesia was first settled by groups using Lapita pottery, a material cultural marker of the first settlement of Remote Oceania that appears in the Mussau group of the Bismarck Archipelago some 3200-3400 BP (Kirch 2021) and in Remote Oceania by 2900-3000 BP (Sheppard et al. 2015). The earliest record of Lapita in West Polynesia comes from Tonga at 2850 BP (Burley et al. 2015) and, then, Sāmoa shortly thereafter (Petchey 2001). Populations spread across West Polynesia at this time, eventually abandoning Lapita ceramics (Burley et al. 2015; Clark et al. 2016; Petchey and Kirch 2019), but did not extend to the east for at least 1700 years. Central East Polynesia appears to have been settled around 1100-1000 BP at the earliest (Sear et al. 2020). The ends of the Polynesian triangle were settled later, with Hawai‘i occupied by 1000-800 BP (Athens et al. 2014), Rapa Nui around 800-700 BP (Hunt and Lipo 2008), and New Zealand by 700-650 BP (Bunbury et al. 2022).

While there has been some recent debate (Wilson 2018), there is general agreement that populations that inhabited East Polynesia ultimately derive from West Polynesia on linguistic and biological grounds (Kirch and Green 2001). This shared heritage provides an opportunity to assess the evolution of once-shared cultural practices across vast environmental variability (Kirch 2020). This is true, especially, of agricultural change (Kirch 1982; Quintus and Cochrane 2018). A shared set of techniques was inherited and used across the region, originally brought to each island by voyagers at different times. As Yen (1973) remarks, the colonists to each island inherited an accumulating endowment along each proceeding step. This endowment, which is also referred to as a transported landscape of tangible and intangible components, was subject to novel environmental characteristics at each island destination. These characteristics of shared cultural heritage, environmental variability, and movement make the region a useful place to explore and refine notions of niche construction (Quintus and Cochrane 2018).

Nothing speaks to the power of niche construction more than the relocation and adaptive radiation of cultural practices. It is by human agency that those transferred cultural practices are exposed to novel selective environments in that new location (Quintus and Cochrane 2018). Indeed, it may have been this initial introduction that produced the catalyst for the long-term development of agronomic diversity (Kirch 1982; Yen 1973), as such the same kinds of techniques were adapted for use in a wide range of environments. The development of lithic mulches (Figure 2) , for instance, was only beneficial in the arid environments outside the core tropics of Polynesia (Allen 2004; Barber 2010; Wozniak 2001). Likewise, the use of tree crops took on variable roles on different islands to align with unique patterns of environmental characteristics (Quintus et al. 2019).

Relocation, though, is not restricted to regional movement. Rather, local movements play a role in the development of agronomic diversity, such as the staggering of planting locations (Lepofsky 2003). Such staggering takes advantage of different environmental conditions, such as the different seasonality of rainfall, to alleviate constraints to community growth. This can result in genetic and morphological changes to plants, a kind of gene-culture evolution, manifested in substantial varietal development that responds to different ecological conditions and that play different social roles. Furthermore, these strategies may require the evolution of cultural systems to enhance cooperation or collaboration (Kagawa-Viviani et al. 2018).

Relocation also brought about environmental change as humans cleared land for cultivation and settlement. This resulted in a well-documented processes of hillslope erosion and coastline or valley infilling (Spriggs 1997). As argued by Spriggs, this process redistributed key environmental resources and reduced marine productivity in favor of terrestrial expansion (see also Kirch and Yen 1982). This seems to have been a ubiquitous process across Polynesian high islands and may have been one of the more important factors driving initial communities to invest more heavily in agricultural lifestyles (Kirch 1988, 2006; Quintus 2018; Quintus et al. 2023a; Spriggs 1997). While such geomorphological changes may have

been beneficial, at least for some, other unintentional changes were less useful. This includes the reduction or elimination of seabird populations, which modified nutrient cycles and made some areas less productive. This is the case, especially, on geologically old islands (Swift et al. 2018) but has also been documented on younger islands (Swift et al. 2021), though a nutrient rebound was documented in the latter case. These changes, which start at the beginning of cultural sequences, cascade and accumulate across the rest of cultural sequences to have profound impacts on the environment and cultural practices of individual islands.

Polynesian agriculturalists employed a wide range of techniques to manipulate the environment within which they cultivated. Many of these techniques dealt with the management of water and moisture. This included techniques to retain moisture (Ladefoged et al. 2003), transport water (Kirch and Lepofsky 1993), and drain excess water (Quintus et al. 2016). In turn, these techniques alleviated key constraints of the environments within which communities lived and produced new sets of selective environments for the development and long-term evolution of plants. The construction of infrastructure cascades through the social system. Once infrastructure was in place, less labor is required for the continued cultivation of the area (Kirch 1994, 2006). It also made landscapes more attractive to subsequent generations.

Landscape Change, Emergent Attractors, and Politics in Polynesia

What has received less attention in the niche construction literature is the production of environments, through past ecosystem engineering, that attract human settlement by concentrating resources, infrastructure, or labor. However, this is a well-documented process in the archaeological literature and a process well illustrated across Polynesia. The attraction acts to modify the trajectory of cultural evolution by producing environments that may be more conducive to political control, defense, agriculture, or other behaviors. While several cases could be used to illustrate these patterns, I will use the cases of Punalu‘u Valley on O‘ahu and Mangaia, Cook Islands (see locations in Figure 1).

Punalu‘u

Punalu‘u is located on the windward coast of O‘ahu. Archaeological research in the valley has generally been limited, though several recent projects have built a cultural sequence (Filimoehala et al. 2015; Morrison et al. 2022; Quintus et al. 2023a). Much of this work has targeted agricultural landscapes, especially those on the colluvial slopes with more limited investigation on stream-side irrigation systems.

The earliest agricultural practices in the valley appear to be related to water control. Small, rudimentary alignments were built across Punalu‘u stream in the 12th to 13th century AD (Quintus et al. 2023a). These alignments served two purposes. First, they likely slowed the flow of water by acting as check dams. Second, these alignments likely aided in the accumulation of fine sediments because of their action as check dams. Over time, the accumulation of sediments that began with the construction of rudimentary alignments in a stream or along a stream bank led to the development of an arable landform

Figure 3. A buried alignment interpreted as a retaining wall in Punalu‘u Valley, O‘ahu.

perched above the stream itself (Figure 3). This, in turn, led to further investment in the landform in the form of formalized pondfield systems (*lo‘i*). These systems were largely in place by the end of the 15th century with further maintenance through the rest of the precontact sequence.

A different trajectory is visible on the colluvial slopes of the valley. There, agricultural activities may have begun as early as the 14th century AD, but substantial investments did not occur until the 16th century

AD and later (Morrison et al. 2022). These systems were rain-fed and integrated arboreal species (Kirch 1977), though the nature of the system likely changed through time. The pace of construction increased through time and non-agricultural infrastructure was placed in the field system. This includes a large *heiau* (ritual structure) (Filimoehala et al. 2015) that is physically integrated into the surrounding agricultural landscape.

The sequence of agricultural development in Punalu‘u follows predictions of an ideal free distribution wherein more marginal or less productive areas were used after more productive ones (Quintus et al. 2023). Irrigation in Polynesia is far more productive than rain-fed agriculture, even in a windward valley that receives substantial precipitation (see Kirch 1994). Still, later developments in the valley suggest that rain-fed agriculture began to be prized and, perhaps, indirectly controlled or managed by elites. Large *heiau* are symbols of power in late precontact Hawai‘i (Kolb 1994), and their construction was a means to establish claims to land or resources.

The attraction of rain-fed landscapes was emergent through a process of niche construction. Initially, investments in colluvial slopes were in the form of arboreal species (Morrison et al. 2022). These arboreal species are attractive since they are productive but require little labor investment (Kirch 2006). They are also persistent and can be transgenerational (Quintus et al. 2019). The presence of arboreal species at the start of the rain-fed sequence begins a positive feedback loop wherein increased production facilitated increased population growth, which facilitated more investment in agricultural facilities and further investment. Rain-fed production is labor limited, but the large land available meant that it had substantial productive potential once labor was available. Furthermore, production was enhanced by the introduction of and experimentation with sweet potato sometime after the initial settlement of the islands. The combination of labor, the product of prior agricultural change and the development of infrastructure on the landscape, and the availability of sweet potatoes, relocated from South America through Central East Polynesia, enhanced the attractiveness of colluvial slopes. The end result was that communities and leaders sought the once more marginal zone as it offered opportunities for expansion. It is not that irrigation became less productive, as it did not. Rather, opportunities for expansion and surplus production were in colluvial slopes and other dryland locations as labor grew and sweet potatoes became available.

Mangaia

Mangaia represents a different trajectory, one that involved the consequences of substantial unintentional ecological change (Kirch 1996). Located in the Cook Islands, it is on the western boundary of East Polynesia. The island is unique in that it is geologically old and is skirted by upraised limestone, the remnants of a former fringing reef, that abuts the original volcanic landmass. This limits the kinds of resources available for exploitation, but also presented some opportunities throughout the cultural sequence.

Food production at the beginning of the sequence is suggested to have been relatively expansive, with shifting cultivation used as a primary strategy across the hillslopes of the island (Kirch 1994). Like elsewhere in Oceania, the use of shifting cultivation, specifically the clearing of vegetation, produced extensive erosion. These early settlers also relied on wild fauna, which led to the reduction, extirpation, or extinction of bird species (Steadman and Kirch 1990). There are two important outcomes of this. First, the reduction in seabird populations modified the cycling of nutrients on these old volcanic islands, which are posited to have resulted in declines of P and N (Kirch 2017). Second, the loss of land birds disrupts previously intact mutualism, such as seed and pollen dispersal, which impacts the reproduction of some forest species. This, combined with the loss of nutrients on hillslopes through erosion, resulted in substantial forest loss on the volcanic hillsides. This also resulted in a loss of productivity on these hillslopes. At the same time, sediments that eroded from the hillslopes were deposited in a set of alluvial valleys across the island, increasing opportunities for irrigation and agroforestry (Kirch 1994).

Alluvial valleys are circumscribed in the sense that they are dense concentrations of resources surrounded by areas of low productivity. This configuration of resources is predicted to give rise to territoriality as communities seek to obtain access to productive land (Field 2003), and territoriality is well attested in the oral traditions of Mangaia (Goldman 1970). In fact, the nature of political and religious systems were substantially changed on Mangaia in response to the concentration of resources. Leaders became those who were successful in warfare, as a marker of *mana* (supernaturally-derived power). Rongo, whose cognate across East Polynesia Lono was the god of fertility and some forms of agriculture, became the god of both agriculture and warfare; a unique combination that highlights the power of both forms of human behavior on the island (Kirch 2017; Kirch et al. 1995).

The emergent attraction of agricultural lands on Mangaia, largely produced through a process of faunal exploitation, soil erosion, and alluvial valley formation, led to a substantial change in the trajectory of a host of other cultural practices. Instead of being a location, however, where labor was brought to work, the emergent attraction of the alluvial valleys of Mangaia produced a different pattern of negative despotism wherein people were excluded (Weitzel and Codding 2022).

Conclusions

Social and environmental changes to agricultural landscapes ramify throughout those social systems and environments across generations (Morrison 2006, 2014). The changing attractiveness of landscapes and resources through time is one example of this process. Landscape attractiveness is a product of the resources available, the labor necessary to modify the landscape, the subsistence techniques that could be used, and the other options available to a community. Each of these factors are subject to change through time, including through ecosystem engineering. As illustrated in the cases of Mangaia and Punalu‘u, ecosystem engineering leads to changes in the evolution of political systems and food production as

landscape changes cascade and begin to interact at larger spatial and social scales. It is the cultural evolutionary impact of this ecosystem engineering that makes this an example of the niche construction process.

As landscape attractiveness is not just a factor in human decision-making or settlement, extending to most animals, emergent attraction is like a process found in non-human organisms as well. While dynamic versions of ideal distribution models have been used to examine human decisions, such models could be extended to explain changes in non-human behavior in constructed environments. In this way, a consideration of human niche construction, in this case from Polynesia, can provide novel predictions of non-human behavior.

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Part 1

Exploring Maritime Migration: Methods and Materials

Searching for Submerged Late Pleistocene Archaeological Evidence Along the Northern Pacific Rim

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Abstract

The Coastal Migration Theory posits that the earliest human migration to the Americas occurred during the late Pleistocene along the northern Pacific Rim and as such, the earliest sites in the Americas should be found in coastal settings. The unique archaeological challenges associated with identifying and analyzing submerged sites are addressed, as these locations are often hidden or degraded due to marine transgression and associated geomorphic actions. However, through targeted exploration of key archaeological zones—including protected embayments, submerged river valleys, and underwater caves—meaningful insights into early human migration routes and adaptations to varying environments can be uncovered. Central to this research strategy is the use of advanced methodologies, such as side-scan sonar, sub-bottom profiling, marine coring, and the analysis of cored sediments to find and study submerged archaeological sites. This approach to finding early coastal sites can be built upon by discovering and examining resource rich areas like late Pleistocene estuaries throughout the northern Pacific Rim region. This comprehensive approach has the potential to further illuminate the complexities of the CMT, significantly expanding our understanding of early human history, migration patterns, and environmental adaptations.

Introduction

The archaeological questions of how and when humans initially travelled to the Americas is significant and associated studies have primarily focused on an overland route through Beringia and southward past North American continental glacial ice via an "ice-free corridor" (IFC) (Haynes 1964, 1980; 1982; 1987; Haynes 2002; Potter et al. 2018) or instead around the western edge of the glaciers along the northern Pacific coastline (Figure 1; Heusser 1960; Macgowan and Hester 1962; Laughlin 1967; Bryan, 1978; Fladmark 1978, 1979; Easton 1992; Busch 1994; Dixon 1993, 1999; Gruhn 1994; Mandryk et al. 2001; Erlandson 2002; Erlandson et al. 2007; Braje et al. 2017, 2020; Davis and Madsen 2020). The overland model has been traditionally used to explain the appearance of the Clovis Paleoindian Tradition shortly before 13,000 cal BP (e.g., Haynes 2002; Potter et al. 2018), which for some signals the initial entry of humans into North America and, as such, is sometimes called the "Clovis-first hypothesis".In contrast, the Pacific coastal route of entry has

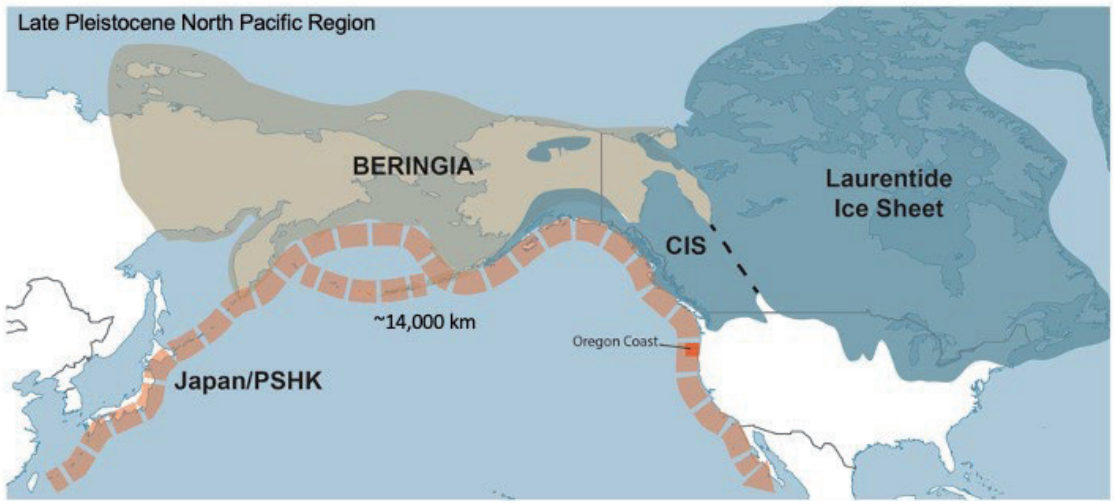

Figure 1. Map of the north Pacific region during the late Pleistocene, showing the extents of Beringia, North American ice sheets, and the hypothesized coastal migration route along the edge of the Cordilleran Ice Sheet (CIS) from east Asia to the Americas (orange dashed line) (map modified from Davis and Madsen 2020).Davis and Madsen 2020).

featured prominently in models that argue for human presence in the Americas before the appearance of the Clovis Paleoindian Tradition (e.g., Dillehay 1997; Dillehay et al. 2008, 2012; Waters et al. 2018; Williams et al. 2018; Davis et al. 2019, 2022). Recently, Davis and Madsen (2020) argued that the archaeological discovery of repeated instances of human occupation south of the North American continental ice sheets predating the appearance of the Clovis Paleoindian Tradition and before any possible opening of an IFC between the Laurentide and Cordilleran ice sheets has falsified the long held Clovis-first hypothesis. The authors note that an array of geological, paleoenvironmental, and archaeological data is now sufficiently large that it requires an organizational framework within which to consider the processes and chronology underlying the only reasonable alternative for the initial Pleistocene peopling of the Americas: A Pacific coastal migration along and ultimately south of North America's continental ice sheets.

Davis and Madsen (2020:2-4) articulate a Coastal Migration Theory in this way:

> 1. The progenitors of the First Americans were Early Upper Paleolithic (EUP) foragers who originated in interior northeast Asia and made their way by various land and sea routes, including a northern route, possibly down the Amur River valley (Izuho et al., 2020; Jeong et al., 2016) and through northern China, and a southern route, possibly through southern China and Taiwan (Gakuhari et al., 2019; Izuho et al., 2020), to coastal Pacific areas ranging from South Korea to the Japanese archipelago and to its extension in the convergent island area that emerged during late Pleistocene marine regression known as the Paleo-Sahkalin-Hokkaido-Kuril (PSHK) area.

These populations merged prior to LGM, giving rise to daughter populations in the PSHK area which eventually evolved into such diverse groups as the Jomon in more southerly Japan, northeastern Siberians such as the Itelmen and Chukchi, and ancient Native Americans (Jeong et al., 2016).

2. Between ~40-30 ka these foragers adopted mixed and variable terrestrial, near shore, and maritime subsistence adaptations along this northwestern Pacific coastal margin, with the degree of specialization differing from area to area.

3. Starting in the EUP period, they developed both a stone tool technology characterized by unifacially and bifacially-worked stemmed projectile points and sea-going vessels capable of reaching pelagic fishing grounds and obsidian source areas scores of kilometers from the coast. A number of these populations may have become isolated in the PSHK region, allowing for genetic bottlenecks to develop via genetic drift.

4. By about 20 ka, sea levels as much as 130 m lower than modern, and correspondingly shorter travel distances between islands and refugia, allowed ocean-going coastal foragers in the PSHK to begin to expand along the Kamchatka peninsula to the southern margin of the Bering Land Bridge and Aleutian Islands to the coastlines of southern Alaska and British Columbia.

5. Sometime between ~20-16 ka these gradually expanding Late Upper Paleolithic populations reached coastal margins south of the Cordilleran glaciation. Once there, they applied generalized coastal fishing/foraging adaptations to wetland, terrestrial, nearshore, and maritime resources, which allowed more specialized daughter populations to expand rapidly inland, along major waterways and onto lake-margin habitats, and down the coast to South America through a variety of differing coastal habitats. Over the course of the next 3000-5000 years these populations expanded inland from the coast, developing specialized terrestrial hunting and gather adaptations which eventually led to later Clovis and other Paleoindian complexes.

Determining whether this Coastal Migration Theory is viable requires, as with any theory, explicit tests of its various implications. In the case of the Coastal Migration Theory, most of the testable hypotheses involve the discovery and exploration of geological deposits and archaeological sites around the northern Pacific Rim dating to the last glacial period from ~23-16 ka. Simply put, if the First Americans initially migrated from northeast Asia into the Americas along the northern Pacific Rim during this time, then we should find the earliest archaeological sites in preserved paleolandscape

features that predate ~16,000 cal BP. However, if this hypothesis is false, then no such evidence will be found in last glacial period deposits along the coastlines of southern Alaska and British Columbia. Finding archaeological evidence of an initial coastal migration is challenging because postglacial marine transgression and glacioisostatic adjustments worked in tandem to submerge, erode, and otherwise obscure such sites, if they indeed exist. How then should archaeologists search for archaeological evidence along the theorized Pacific coastal migration route?

The U.S. Bureau of Ocean Energy Management (BOEM) and the U.S. National Oceanic and Atmospheric Administration (NOAA) have provided funding in recent years to conduct offshore investigations to evaluate whether late Pleistocene terrestrial landscape features and any archaeological sites they may contain exist along the Washington, Oregon, and California coastlines (ICF International et al. 2013; Braje et al. 2019; Klotsko et al. 2020). These projects have led to the development of a methodological approach that focuses on modeling submerged coastal landscapes, deploying marine geophysical survey techniques to find submerged and buried paleolandforms, coring potential submerged paleolandforms, and seeking to recover associated archaeological evidence from intact submerged contexts. In the sections that follow, I provide a summary of the methods and results of our recent work and offer suggestions for how the search for submerged landscapes and associated archaeological sites could be expanded to evaluate the Coastal Migration Theory more fully.

One Approach to Finding Submerged Pleistocene Coastal Sites

The discovery of submerged late Pleistocene coastal sites can be facilitated through a systematic, multifaceted approach that combines advanced technology and geological knowledge. The first step involves constructing a digital model of the ancient coastal paleolandscape. In the BOEM and NOAA-funded projects mentioned above, we employed the following steps. First, we combined bathymetric information and relative sea level history data to build a coastal paleolandscape model of the terrestrial landscape that existed on the now-submerged continental shelf. Once this model is created, the next step is to develop a site location potential model for the submerged paleolandscape (Figure 2).

Here, high probability areas for archaeological occupation are identified, hinting at regions where traces of ancient human activities might be found. The third step focuses on collecting marine geophysical data (Figure 3).

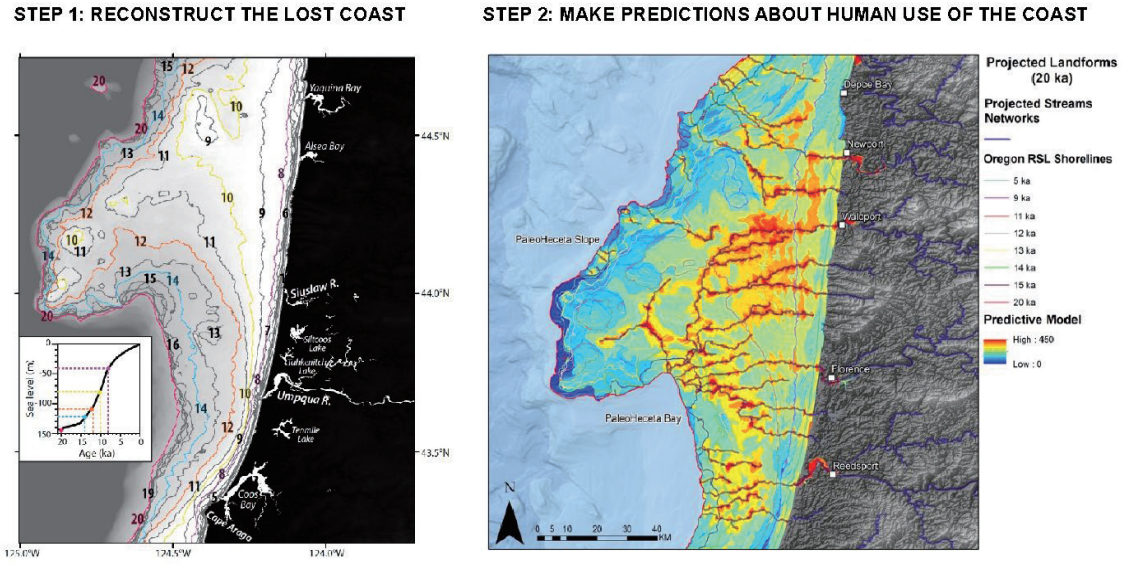

Figure 2. Maps showing reconstructions of relative sea level (at left) and site location potential (at right) along Oregon's central coast.

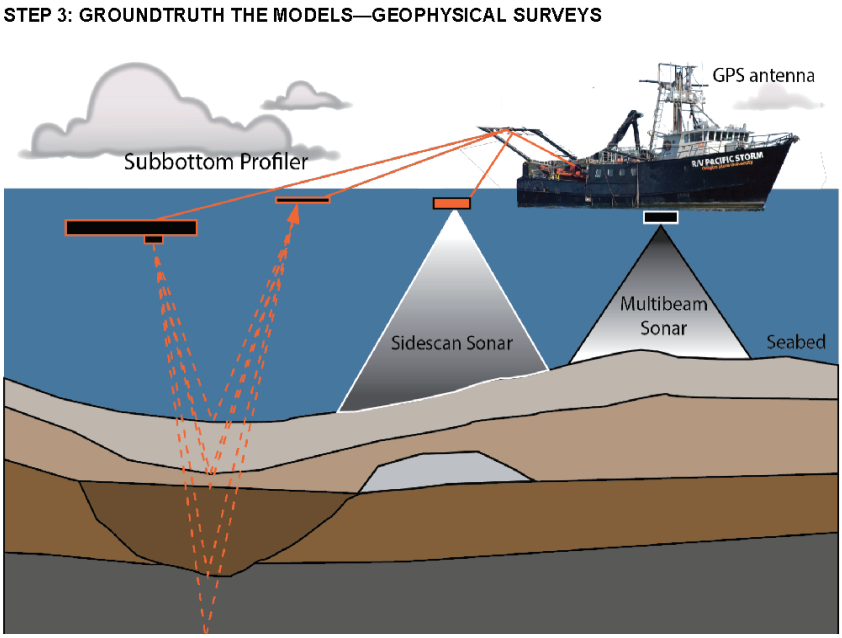

Figure 3. Diagram showing the marine geophysical technologies used to map the seafloor and see into its deposits.

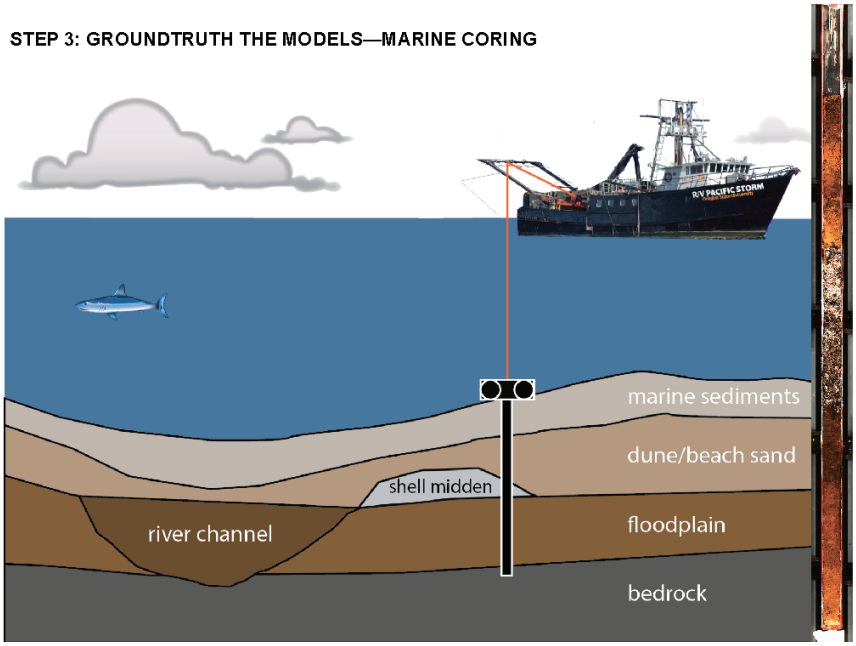

Figure 4. Diagram showing the use of a vibracore to sample submerged and buried landform deposits. The core at right is an example of the kind of terrestrial stratigraphic sequence that might be expected to come from a cultural shell midden buried by aeolian dune sands and soil development (cf. Kirkpatrick 2019).

This process is integral to improving our understanding of the seafloor's surface, as well as assessing the buried stratigraphic record for signs of preserved paleolandscape features and potential archaeological sites. Following the geophysical data collection, marine cores from selected targets are gathered and their contents are studied (Figure 4).

Analysis of the core samples provide an opportunity to characterize the physical sedimentary properties of observed geophysical signatures, establish a chronostratigraphic sequence for landscape change from subaerial coastal to submerged marine environments, and hold the potential for discovering archaeological evidence of late Pleistocene human occupation along the North Pacific coastline.

Thinking about site formation in submerged settings

With the warming climate and melting ice at the end of the Pleistocene leading to rising sea levels, coastal landscapes were gradually submerged, first flooding low-lying areas and then higher elevations, causing a direct loss of human habitation, and forcing human migration to higher ground or areas more inland. Archaeological sites on these now-submerged landscapes faced various fates: some were washed away, some buried under sediment layers, while others were preserved in place. The underwater conditions, while sometimes causing disturbance and degradation of artifacts, can, in some instances, preserve organic materials not usually conserved in terrestrial sites. Today, these submerged Pleistocene-era archaeological sites, found globally in diverse underwater contexts, provide rich

historical insights. They can be found on the continental shelves, exposed during the last glacial period and offering vast habitation spaces; in submerged river valleys, which were crucial human migration paths and settlement areas during the Pleistocene; and in underwater caves, which sometimes safeguard well-preserved traces of human occupation, such as artifacts, cultural features, and human skeletal remains.

The survival of archaeological sites positioned in island archipelago areas amidst marine transgressions hinges on a variety of factors that protect these sites from erosion or complete destruction. A primary factor is rapid burial - if a site is swiftly buried by sediment instead of being subjected to erosion during the initial stages of transgression, it can effectively be shielded from any subsequent erosive forces of waves and sea action. This blanket of sediment preserves both the archaeological context and materials. Geomorphic features also play a critical role in protecting and preserving sites. Archaeological sites located within caves, rockshelters, or dunes are provided with a natural shield against marine transgression and a stable preservation environment. Human intervention can sometimes protect sites as well. The construction of buildings, walls, landscape modifications, or even the intentional burial of sites could offer some defense against rising sea levels. However, such defenses are not expected to have been created by late Pleistocene coastal forager societies. In certain regions, the process of isostatic rebound, wherein the Earth's crust rises in elevation due to the melting of ice sheets, could counteract sea-level rise, preventing specific areas from submersion and thereby protecting archaeological sites. Finally, natural ecosystems like mangroves and coral reefs can serve as barriers against wave action and erosion, assisting in the preservation of nearby archaeological sites. Even with these protective factors, marine transgression can still lead to the loss of numerous coastal and island archaeological sites. Therefore, urgent efforts are needed to identify, document, and if feasible, excavate these threatened sites.

Archaeological sites perched on elevated landforms were most likely subjected to erosion due to transgressive wave action, potentially resulting in the obliteration of the archaeological record in large areas. Conversely, archaeological materials that collected in lower landscape areas such as stream valleys or bays might have been preserved as alluvial and estuarine sediment aggraded in conjunction with marine transgression (Figure 5).

This process could subsequently lead to the burial of any archaeological evidence situated close to sites found on neighboring shorelines or riverbanks, thereby protecting it from the erosive forces of marine transgression. Concentrating our efforts on uncovering submerged and buried alluvial and embayment deposits from where estuaries would form provides a promising avenue for unearthing artifacts, features, and even sedimentary ancient DNA (sedaDNA) related to late Pleistocene coastal peoples.

The exploration for sedaDNA in submerged estuaries on the Pacific continental shelf presents a compelling opportunity for archaeologists studying Pleistocene human occupation of the northern Pacific Rim. Estuaries, with their confluence of salt and freshwater and frequently anoxic conditions, can be ideal environments for DNA preservation. Historically, such areas have seen intensive human

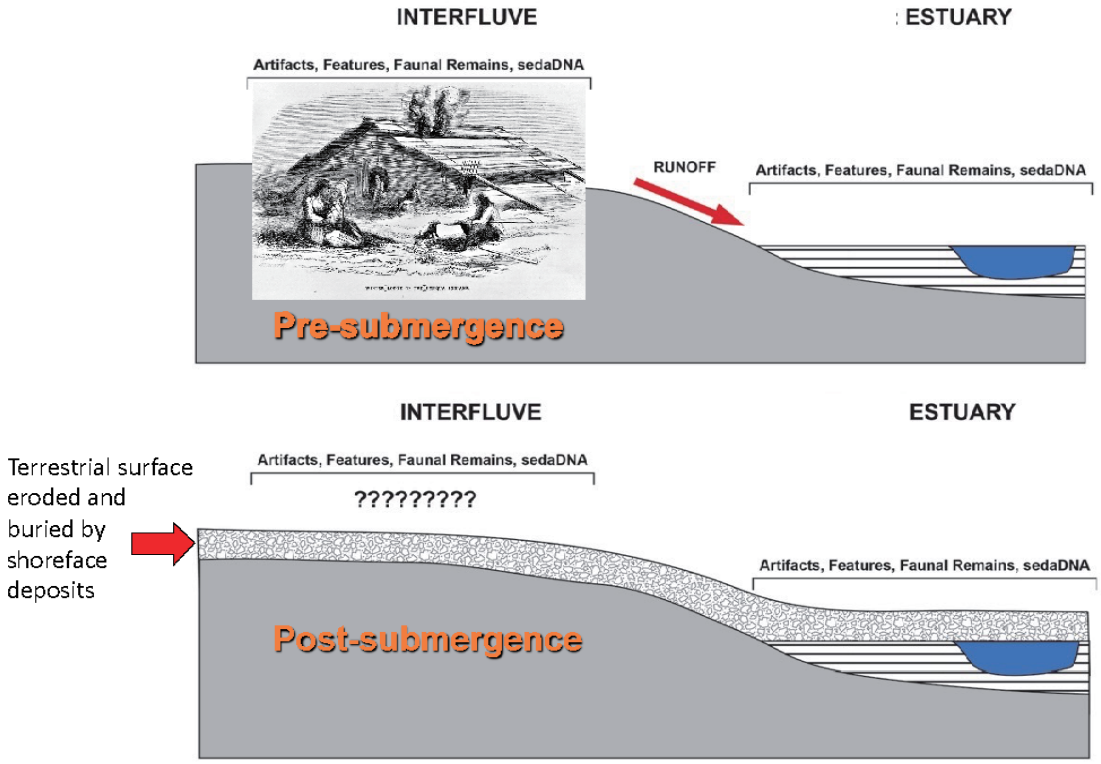

Figure 5. Diagram showing a hypothetical active cultural state of coastal occupation that contributes archaeological materials to estuary deposits and adjacent interfluve shoreline areas. Following marine transgression and submergence, the interfluve area may have experienced significant erosion and degradation of its associated archaeological record, while deposits in the adjacent estuary zone may have buried by aggrading alluvial sediments prior to marine transgression.

activity and settlement due to the rich availability of resources such as fish, shellfish, and waterfowl, suggesting the likelihood of Pleistocene human presence. Analysis of sedaDNA offers an invaluable lens into this past human presence and their dietary habits, as DNA from plant and animal species utilized for food or other activities, or even ancient human DNA introduced into estuary environments via surficial runoff from nearby settlements, could be uncovered. Beyond this, sedaDNA can help in reconstructing past environments, indicating the presence of specific plant and animal species, and tracking changes over time, thereby illuminating the environmental contexts and adaptations of Pleistocene humans. Importantly, with the end of the Pleistocene marking significant sea-level rises, many human habitation sites were submerged, transforming the continental shelf and submerged estuaries into an underexplored archaeological frontier. The study of sedaDNA in these locations could unlock access to these elusive submerged sites. Lastly, considering the northern Pacific Rim's speculated significance in human migration routes during the Pleistocene, sedaDNA evidence could provide critical insights into these migration patterns. Despite the inherent challenges, these factors make a strong case for archaeologists to delve into the study of sedaDNA in submerged estuaries on the Pacific continental shelf.

Conclusion

While intact archaeological sites containing late Pleistocene-aged artifacts, features, and other cultural evidence may yet be found in submerged landscapes along the northern Pacific Rim, having escaped the destructive power of rising post-glacial sea levels, searching for this evidence is arguably a specialized field of study that will require the development of methods for narrowing down and identifying submerged and buried site evidence in areas where taphonomic processes favored site formation and preservation. Because much of the late Pleistocene coastal landscape of the northern Pacific Rim is submerged at depths below which traditional underwater archaeology methods may be used with ease, we must imagine other ways of conducting research. An alternative approach to finding archaeological evidence of early cultural occupation along the Pleistocene northern Pacific coastline would be to search for, identify, and sample through marine coring estuarine deposits that may retain artifacts, features, and sedaDNA (Figure 6).

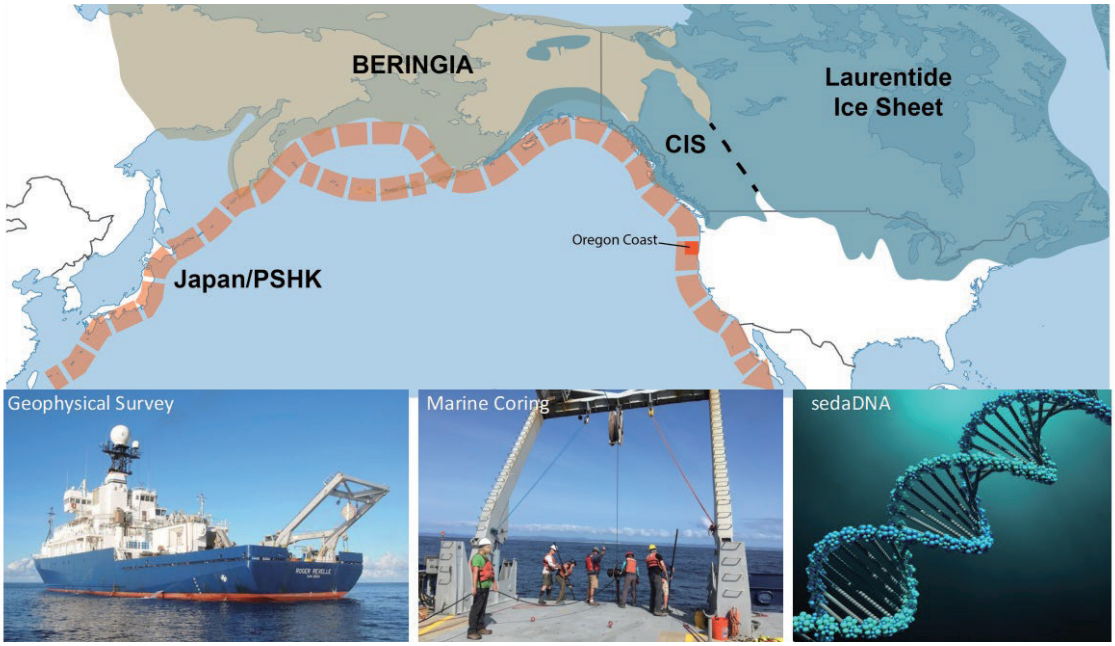

Figure 6. A coordinated research program involving geophysical surveys, marine coring, and study of cored sediments (for artifacts and sedaDNA) in estuarine environments around the northern Pacific Rim may lead to the discovery of late Pleistocene human presence in now-submerged landscape contexts.

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Form, Function, and Design of Terminal Pleistocene Shell Fishhooks of the Pacific Rim: Coincidental Convergence or Shared Knowledge?

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The Terminal Pleistocene was a period of remarkable change for humanity, within a relatively short span of a few millennia, events would unfold that would lay the human ecological foundations for the historical processes that continue to shape our present day lives. Both people and the world they lived in were at a tipping point of irreversible change and movement. Widespread extinctions, migrations, displacements, floods of legendary scale, and the second and last genuine "discovery" of continental scale landmasses by behaviorally modern humans all happened between 16,000 and 13,000 years ago (e.g. Clark et al. 1996; Smith et al. 2022; Neri et al. 2015). The cultural traditions of hunting and gathering people all around the western Pacific Rim – accumulating for tens of thousands of years – were tested, transformed (e.g. Nakazawa et al. 2011), and displaced (see Norman et al. 2024), but not destroyed. Along the shore of the Western Pacific, there were communities of skilled boatwrights and fishermen that lived along the beaches and islands strewn along an immense East-facing coastline that looked out over deep, blue ocean that seemed to have no end. These populations had been expanding for thousands of years, as evidenced by occupation of even relatively smaller offshore island archipelagos like the Ryukyus (see Kaifu et al. 2020).

Their movements along the Pacific Rim – both clockwise and counterclockwise – clearly began before the Terminal Pleistocene climate crises became acute (e.g. O'Connor 2007; Kuzmin and Glascock 2007; Buvit et al. 2016). but what began as a trickle of population movement, became a flow once the collapse of Beringia's ecological systems began (Faith 2011; Murchie et al. 2021), and populations would have been not only driven, but drawn along in their migration routes and later dispersal, metaphorically resembling a gravity driven siphon.

Early sites in the Americas like Cooper's Ferry in Idaho, dating to just shy of 16,000 years ago (Davis et al. 2019) indicate that occupation of the Western Hemisphere began before the drowning of Beringia, but the number of sites seems to explode in the Americas after 14,500 BP (the date most commonly cited for the meltwater pulse 1A event, Clark et al. 1996). This may indicate that early "pioneering" populations reached the Americas slightly earlier (Gruhn 2023), only to be followed by subsequent waves of migrants fleeing the inundation of coasts and islands of the North Pacific (Buvit et al. 2016; Dobson et al. 2021; Cassidy et al. 2022). This complex, multi-staged process would fit more closely with most documented and/or archaeologically identified migrations in human history.

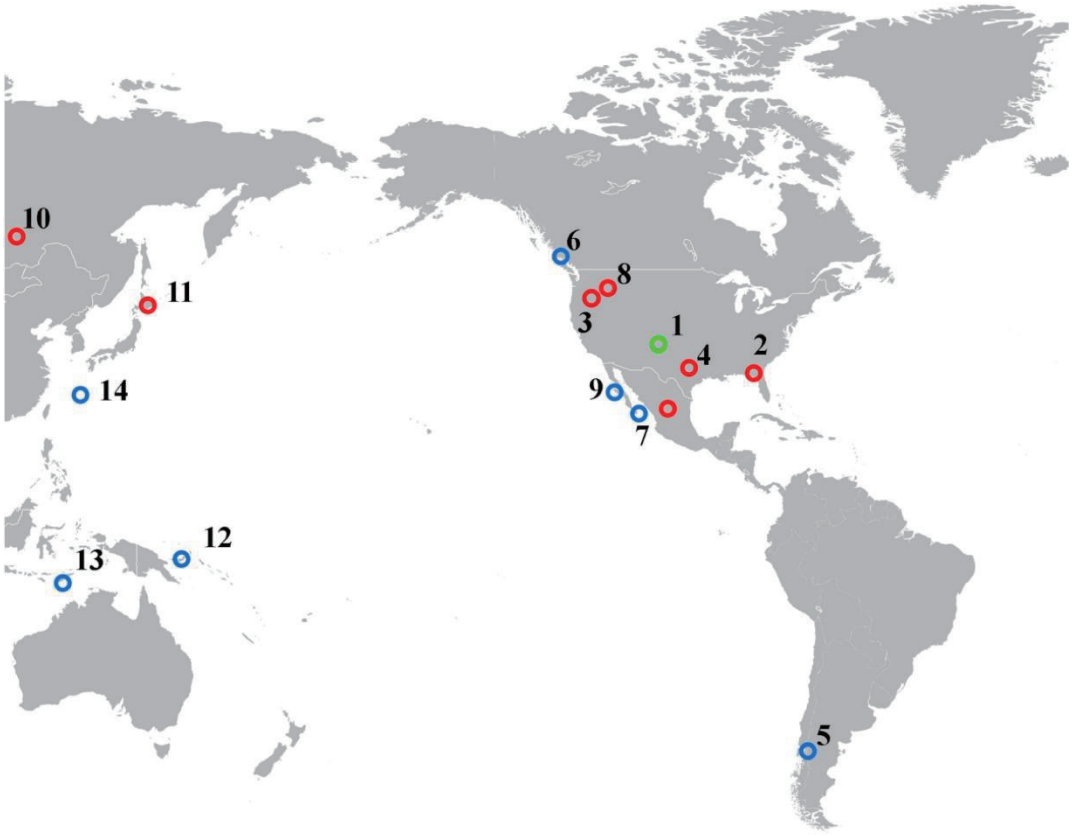

Figure 1. Map of the Pacific Rim and adjacent regions. 1. Folsom archaeological type site, New Mexico; 2. Page-Ladson Archaeological Site, Florida; 3. Paisley Caves, Oregon; 4. Gault/Friedkin Clovis Site; 5. Monte Verde, Chile; 6. Triquet Island, British Columbia, Canada; 7. Espiritu Santo Island, Baja California Sur, México; 8. Cooper's Ferry, Idaho; 9. Isla Cedros, Baja California, México; 10. Lake Baikal, Russia; 11. Hokkaido, Japan; 12. New Ireland and New Britain, Papua New Guinea; 13) Isla Alor, Indonesia and East Timor; 14. Sakitari Cave, Okinawa, Japan.

The post-Pleistocene history of Ireland (see Woodman 2011; McLaughlin et al. 2016) provides one such example, where over time, multiple groups sequentially contributed to initial settlement, technological developments and genetic diversity of later populations. It may be that the old model of 100 people showing up at the south end of the Ice Free Corridor and being the sole ancestors of all later First Nations is no longer very tenable, for reasons other than the route itself (e.g. Fix 2005; Moore 2001; Waters 2019) .

So, if this is the story that we developed, how shall we test its veracity? The sample size of ancient DNA data points is increasing (Bisso-Machado and Fagundes 2021), but still very small (see Raff 2022). Far too small, in my estimation, for them to be used as sole arbiters of hypotheses. Additionally, the time resolution of those genetic data are still inadequate to provide more than very general connections between populations (e.g. da Silva Coelho et al. 2021), especially when you have samples separated by gaps of thousands of years with no corroborating evidence to fill in that empty

data space. Radiocarbon dates provide simple presence-absence data but tell us little about whether our model of how-and-why is close to the mark.

If we want to know about our hypothesized boatwrights and fishermen, what better archaeological marker for them than their fishing tackle? We can identify some of the earliest fishhooks in the world along the Western Pacific Rim (Fujita et al. 2016; Langley et al. 2023), and shortly after the earliest people arrive in the Americas, we see the earliest unequivocal fishhooks in the Americas along the Eastern Pacific Rim margin of the continents (Des Lauriers et al. 2017; Fujita 2014; also Alcalde and Flores 2020, though somewhat later in time). We here describe some of these early hooks from Isla Cedros, Baja California, México (Figure 1**)** and compare them to other Pleistocene fishhook assemblages from the Pacific. We propose that this technological tradition was either brought as part of the early migrants' conceptual toolkit, or that the knowledge of and design for these objects was transmitted during the 'settlement' phase (see Rockman and Steele 2003) following initial entry of earlier pioneering populations into the Americas.

The populations of the Western Pacific Rim must have been expanding in the Late Pleistocene, especially since permanent occupation of small offshore island groups (see Ihara et al. 2020) does not typically occur if populations are contracting, nor during periods when island size itself was decreasing – as would have been the case *during* eustatic sea level rise (Cherry and Leppard 2018). Populations across this region, from Okinawa to Indonesia were making and using shell hooks by the beginning of the Terminal Pleistocene (e.g. Kealy et al. 2020). We do not presume that the hooks in Indonesia and Okinawa had separate origins, why should we assume that the Eastern Pacific examples are independent, especially given the demonstrable direction of population movement from west to east along the Pacific Rim (see Davis and Madsen 2020)? Early hooks are present over at least 1000 kilometers of coastline in Baja California, as evidenced by their presence On Espiritu Santo island (Fujita 2014), on the mainland between Playa Tecolote and La Paz (Fujita and Ainis 2018:297), and the robust assemblage recovered from Isla Cedros (Des Lauriers et al 2020). This was not an isolated idiosyncratic development of a single community, but a tradition shared across a wide area. Although dates firmly placing this technology in the Terminal Pleistocene are currently unavailable from South America, the technology is very much present there during the Early Holocene (Llagostera 1992; Scheinsohn 2003) and may simply require further research to push the antiquity back to the range identified on the Baja California Peninsula. If so, this technological tradition would have been shared from Northern Chile to Central Baja California *at the very least*.

This is particularly interesting if we think about the cultural implications of such a widely shared tradition. Obviously, different styles of hook have advantages for catching different kinds of fish and for different fishing techniques (see Stewart 1977 for a unparalleled compendium of this notion for the Northwest Coast of North America). This is not necessarily true for terrestrial weaponry, as a spear tipped with almost any style of point can be used to kill a giant ground sloth or a Pleistocene kangaroo or a camel. There is a specificity to maritime technologies that is not fully replicated in most terrestrially deployed weaponry. Even specifically aquatic projectile weaponry has unique design

Figure 2. Single-piece, shell fishhooks from Isla Cedros, Baja California, México (top), and Okinawa Japan (bottom). Bottom image from Fujita et al. 2016.

characteristics (e.g. leisters vs. toggling harpoon heads, see Ballester 2018:70). The fact that the early Pacific Rim hook assemblages are so remarkably similar in design (Figure 2**)** means that the people using them were likely using the same kinds of techniques to catch similar kinds of fish, so the similarity is not just in the technology, but in the application. This would strongly argue against the independent development of this tradition on Isla Cedros, around La Paz, and in Coastal Peru and Chile. Just as it makes sense to imagine that the Okinawan and Indonesian hooks share a common cultural tradition, it makes sense that the early hook traditions of the *Pacific* coast of the Americas are likewise related to one another.

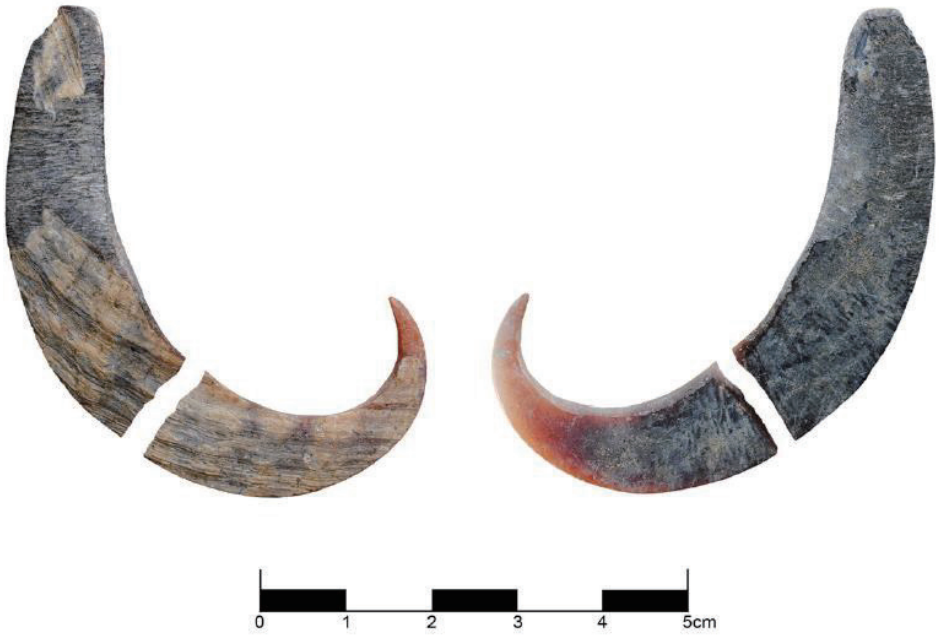

Figure 3. Single-piece mussel (*Mytilus sp.*) shell fishhook from the Cerro Pedregoso site (PAIC-44) Isla Cedros, Baja California. Note the well-preserved evidence of manufacturing techniques and the "waist" below the top of the shank created by grinding.

Unlike later Polynesian (e.g. Allen 1996) and Alta California (e.g. Vance 2000) examples, no knob or notch was carved into the shaft for hafting of the Baja Californian or South American examples, indicating that the line attachment was of a fully lashed variety, and would have had an axis of tension obliquely transverse to the shank of the hook, rather than parallel. This is supported by well preserved examples (Figure 3**)** displaying a "waist" below the end of the shank, especially in the mussel-shell variety. Abalone examples are almost always of green abalone (*Haliotis fulgens*) and occasionally of pink abalone (*H. corrugata*) *the epidermis of which species* are rough and ribbed, creating friction and purchase for the lashing, in addition to the creation of the 'waist' as a hafting zone. One effect of this on the function of these hooks would have been to create increased resistance to the downward pull on the tip of the hook as more tension is applied, as well as maintaining the force more parallel to the laminae of the nacreous shells used. This would have contributed to less force being applied perpendicular to the laminae, focusing downward force along the strongest axis of the hook base material.

The hooks within this assemblage vary in size more than in overall design, though two variants can be proposed, some approach a J-shape, while others are closer to circular or C-shaped (Figure 4). The largest examples indicate that quite large fish were targeted by these hooks, while smaller hooks would have been for commensurately smaller fish. The J-shape is more commonly manufactured from mussel shell, while the circular examples are more frequently made from Abalone. They lack barbs or major degrees of recurve, meaning that once a fish was hooked, constant pressure would have had

Figure 4. Single-piece abalone (*Haliotis* sp.) shell hook from the Richard's Ridge (PAIC-49) site on Isla Cedros, Baja California. This example shows the 'C' shaped configuration more common at Espiritu Santo Island in contrast to the 'J' shape of many other examples in the Isla Cedros assemblage.

to be maintained on the line, suggesting that they might have been more difficult to use in water zones with heavy swash or surge like sandy surf or rocky intertidal.

We have a fair idea of the manufacturing *chaîne operatoire*, based upon numerous unfinished examples found broken or abandoned partway through the process. The makers appear to have selected the flattest portion of the shell in both mussel and abalone raw material sets. For the mussel, this meant that they were selecting a portion nearest the newest part of the shell. Additionally, their oriented their mental template of the finished product so that the bottom curve of the hook would parallel the natural growth bands of the shell. For the abalone, the orientation seems to have focused on locating the natural ripples and valleys of the epidermis of the shell perpendicular to the long axis of the shank of the hook. This was almost certainly to facilitate more secure line attachment. Once the raw material had been selected and a blank obtained by breaking away the more curved or irregular portions of the shell, the general form of the hook was achieved by chipping rather than cutting, drilling, or sawing.

This is interesting, since later Holocene examples from Alta California utilize drills and reamers to create the central perforation, and this may emphasize their more circular form. It is even possible that the manufacturing method influenced the final form as much as any intentional design did. Think about the difference between wheel thrown pots vs. coiled or otherwise hand-built. Given that these

Figure 5. Small grooved-pebble line weight from Cerro Pedregoso, Baja California, México.

hooks appear to have been individually crafted, it means that the makers were free to create them to whatever dimensions or shapes they desired, making them each the product of intentional crafting rather than dependent upon a mold or die.

Following chipping them to their general form, great care was taken to grind them down to a fine point at the hook and very smooth margins for the shank and curve. Faceting is present in this grinding, indicating that it is not simply the 2 dimensional outline that matters, but the smoothing and evening out of the curve. As with other examples of technologies finished through grinding, having a smooth, even surface even increases the strength, by grinding down any small cracks or divots produced during the roughing-out phase.

These hooks were also used in conjunction with stone line weights, the most common form being carefully grooved pebbles (Figure 5). This type of weight would have been located at the terminal end of the fishing line, indicating that the hooks would have either been integrated into the main line or attached via leaders, since the "end" of the line was occupied by the weight. While sufficient for allowing the line to be cast and travel to the bottom, these weights are not so heavy that they would have allowed a hook to maintain position in the surf zone, providing another argument against their use in that microenvironment. It also suggests that the targets of these hooks included fish that were not exclusively surface feeders.

Experimental replication *and use* of Late Holocene Alta California shell fishhooks (McKenzie 2007) has strongly indicated that these hooks are excellent at catching fish with particular mouth anatomy, and ineffective at catching fish with different configurations. Fish with protrusible jaws are the most likely target for these hooks, while cartilaginous fish and fish with thick tissue surrounding the mouth are less easily caught – if at all – by these hooks. Seabass, perch, halibut, and even small grouper can be caught with shell hooks, while cartilaginous sharks and rays, as well as fish with more

Figure 6**.** Well-made stone ring from Cerro Pedregoso. These items – of varying thicknesses and weights – have been recovered from three separate early sites on Isla Cedros, thought their function remains enigmatic.

distinctive mouths like moray eels and triggerfish would not be appropriate targets for shell fishhooks (McKenzie 2007).

Additionally, fish with heavy jaws and teeth capable of crushing shell would not have been caught by these hooks. California sheephead (*Semicossyphus pulcher*), which preys upon shellfish and crustaceans, would have made short work of these hooks. The highly consistent presence of these fish in the assemblages from all time periods on Isla Cedros indicates that these hooks were only one of the methods used by the early Islanders to catch a remarkably diverse set of icthyofauna. Harpoons and nets were almost certainly used as well.

Figure 7. A sample of the finished bifaces/projectile points from Terminal Pleistocene contexts on Isla Cedros.

Evidence for nets is strongly suggested by the abundance of very small fish vertebrae identified the smelt family in most of the Terminal Plesitocene midden deposits, and further confirmed by the

presence of larger notched stone weights. Enigmatic stone rings (Figure 6) have also been recovered at multiple Terminal Pleistocene sites, including PAIC-44 and -88. These are of unclear function, but several of the hypotheses include their use as ring weights for bottom nets for crab and lobster (both identified in some frequency in early faunal assesmblages), or involved in the manufacture of cordage, line, and rope. These nets could have been deployed along sandy beach stretches whose presence is indicated by the frequent occurrence of Pismo clams (*Tivela stultorum*) or possibly from boats. According to local fishermen, their use in rocky open stretches of shoreline would not have been productive, and would have certainly led to significant damage to the "costly" and time consuming nets.

The use of harpoons or spears for some fishing is inferred by several lines of evidence other than the obvious presence of bifacial projectile points (Figure 7). 1) sheephead would not have been caught by single piece shell hooks due to their aforementioned crushing jaws; 2) They are ambush predators of the kelp forests and thus not very susceptible to being caught in nets – in fact, in repeated trips with modern net fishermen on Isla Cedros, I have never seen a sheephead caught in a weighted set net. 3) The presence of both Red (*H.* rufrescens) and Pink (*H.* corrugate) abalone in early molluscan assemblages indicates that early islanders were diving to obtain these species which are always found below low tide water levels. In many areas where traditional diving techniques were documented or continue to be practiced, the use of the natural environment to aid divers is well documented (e.g. Martinez 2004; Lim et al. 2012). Whether it be the coral reefs, vertical walls, or as is likely in the case of Isla Cedros, long, vertical kelp (*Macrocystis pyrifera*) stalks, traditional divers will make use of these features to be able to dive deeper or longer to better exploit submarine resources. So the presence of the habitually 'deeper' species of Abalone, combined with these other factors, lead us to propose that at least some of the fish in the Isla Cedros assemblages were being hunted by diving spear fishermen (e.g. Mesquita and Issac-Nahum 2015).

One additional point is worth highlighting. From multiple lines of evidence, including the design of the hooks and their use in a non-terminal location on the line along with the presence of fish species such as Ocean whitefish (*Caulolatilus princeps*) which are not known, - not by traditional fishermen on Isla Cedros nor Departments of Fish and Game management in Baja or Alta California – to be caught from shore (Bellquist et al. 2008), we can confidently infer the presence of open-water capable watercraft on Isla Cedros during the Terminal Pleistocene. Ocean Whitefish also are not known to occupy the kelp understory nor the space between the kelp and the shore. This means that to catch them, early Cedros Islanders were travelling in their boats as much as 2km offshore *just to fish*. This does not suggest a limit to the watercraft's capabilities, but merely a "floor" of seaworthiness. Additionally, many of the fish species recovered – Ocean whitefish included (Esgro et al. 2020) – are not found in shallow water where they could be seen like trout or salmon in a river, but in deeper water up to 80-90 meters. To ability to consistently know where to fish in deep water seems magical to the uninitiated, as anyone who has even spent time with knowledgeable fishermen can attest. Such

seemingly intuitive understandings are almost always the product of multigenerational wisdom (*sensu* Ingold 2021).

The fact that they were fishing deepwater species means that the early islanders had to produce large lengths of cordage, since tying and splicing short sections is cobbled together and ineffective, particularly for longer lengths of cordage. The nets would have required immense amounts of cordage, since they were catching very small fish with some of them, implying relatively small gauges for these nets. The production of masses of processed fiber and its use in the spinning of large quantities of string, twine, rope, and fishing line would have been a ubiquitous sight in the settlements of the Terminal Pleistocene on Isla Cedros. An addendum to this is that they early Islanders had access to a species of *Agave* for their principal fiber source (see Hulle et al. 2015). This was fortunate, since *Agave* plants produce one of the plant fibers with high tensile strength, display excellent lashing properties, and display resistance to deterioration in saltwater (Bakar et al. 2020).

The fact that hook and line fishing was daily practice for early Cedros Islanders, who were also deploying large nets from boats, coupled with their diving from these substantial craft (possibly similar to those described by Des Lauriers 2005) to access the understory of the kelp forest where the abalone thrive speaks of a rich and truly maritime tradition of subsistence. These are not people who just arrived from the plains of West Texas, nor likely to have been the descendants of hunters of the frozen conifer forests of Siberia. These were people of the Sea. Even to those who love her, the ocean can be fickle, and is always slow to give up her secrets. The knowledge of how to exploit the full panoply of the sea's resources, from the shore to the depths, and from the humblest periwinkle to powerful cetaceans and pinnipeds *takes time*. The breadth of experience evidenced by the full faunal assemblage from the early Isla Cedros sites is staggering, and in an odd twist of history, eclipses even Late Holocene sites for the range of maritime environments and species exploited (Des Lauriers 2010).

This is part of what is meant when we say that to gain further insight into the processes that led to the peopling of the Americas, we must apply an historically contextualized, anthropologically relevant and environmentally situated model for the migration and settlement of the Americas. We must go beyond simply noting the presence of people on an island, because identifying and undertstanding their capabilities vs. their challenges and opportunities will allow us to better understand both the decision-making process and the lived experience of these ancestors of the First Nations of the Americas.

By focusing on their technological systems and implied concomitant knowledge systems (see Ingold 2013), we can demonstrate their intention and ability to actually explore and settle coastlines and islands. The mere presence of people can occur in any number of ways, from the purposeful to the unintentional, and even non-human colonization of islands by mammoth occurred on the paleoisland of Santa Rosae off of Alta California (e.g. Muhs et al. 2015).

However, the ability to distinguish between the "good places" from the not-so-good is something borne of experience, and trial and error probably does not result in expansive, successful colonization from British Columbia to Tierra del Fuego in under 2,000 years. We are actually at a

very good position from a research perspective, since we are left with only two reasonable hypotheses to explain this data; 1) people were here *much* longer that currently understood, or 2) they brought a huge amount of knowledge with them, and at least in the case of the inhabitants of the Pacific Coast, important pieces of that knowledge may have travelled from as far away as the Ryukyu Islands.

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Aleutian Kayak under the Colonisation of the North Pacific Coast: Techniques of the Body concerned with Building and Steering Aleutian Kayak in the Russian Colonial Era

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Keywords*: Aleut, baidarka, body technique, fur trade, Russian-American Company.*

Introduction

Western Europe's imperialism had significant impacts globally and affected various societies in the peripheral zones of Asia, Africa, Oceania, and Latin America. Notably, the sociocultural structures of the indigenous groups in those areas have been drastically altered and reconstructed to this day - from personal ideologies to behavior. In the interdisciplinary studies on colonialism, including anthropology and history, acculturations caused by imperialism are one of the main study concerns and have produced various findings.

Founding on this consideration, this paper examines the influence of Western colonialism, based on modern civilization, on the personal bodies and minds of the indigenous societies on relatively remote islands in the Pacific zone. It focuses explicitly on the Aleutian Kayak building and steering mechanism during the Russian colonial era, investigating the relationship between technical choices and colonialism. This examination aims to explore through a case study to comprehend one of the non-verbal histories embodied in folk articles. These include material cultures extending to the producing techniques inherited by bodies of the indigenous people - unrecorded in historical documents nor bequeathed orally. Thus, this study has the potential to provide a new perspective on the relationship between Russian imperialism and the indigenous societies in the Arctic zone of the Northern Pacific, providing existing findings based on linguistic data.

Aleutian Kayak of the Hakodate City Museum of Northern Peoples

In this paper, the Aleutian Kayak: Baidarka (Russian), displayed at the Hakodate City Museum of Northern Peoples, Japan[1)], is the leading object motivating this study (Figure 1) It has been conjectured that the Kayak was collected on Simushir island at the center of the Kuril Islands by a group of Japanese inspectors in 1876. This was the following year of the conclusion of the Treaty of Saint Petersburg, in which the Kuril Islands were given to Japan by Russia in exchange for Russia taking control over the entirety of Sakhalin Island (Baba 1943). In other words, due to this treaty, the Japanese inspectors were dispatched to Simushir island; therefore, the Aleutian Kayak housed in the

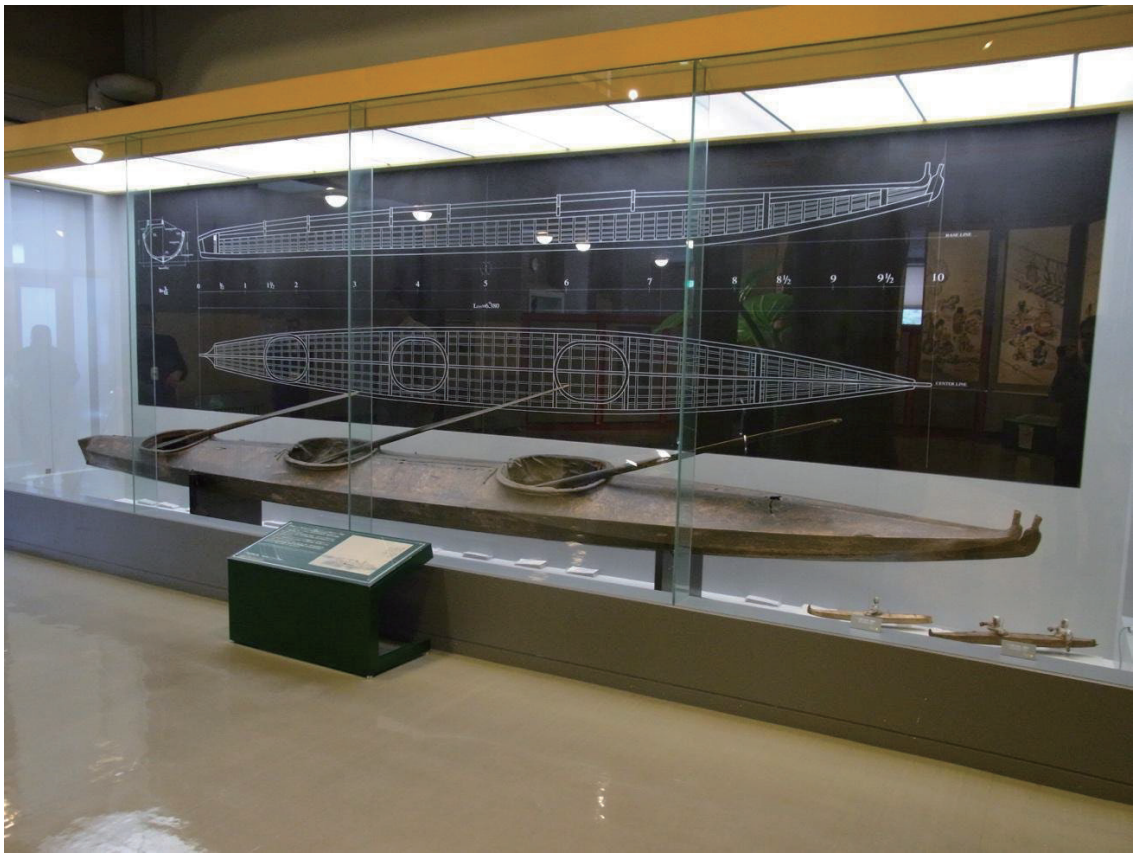

Figure 1. Aleutian kayak owned by the Hakodate City Museum of Northern Peoples, Japan

Hakodate City Museum of Northern Peoples, Japan, at present, was collected.

It is presumed that the *Unangan* or the *Unangas* built this collection, the indigenous people of the Aleutian Islands, known as the Aleut, as named in the colonial era (Jochelson 1933)[2]. Unsurprisingly, this Kayak's builder was the indigenous people of the Aleutian Islands; however, it is intriguing that it was collected on Simushir island, far from the homelands of the Aleut people. This background will be discussed subsequently, as this problem is crucial. Incidentally, the three-hatch model of this Kayak is known to be displayed in just three collections worldwide today. Such a rare structure of this collection is essential in comprehending the impact of colonial influences; hence, this detail will also be explored further.

This paper will begin by grasping the basic information on the native Aleut history and society to study the background of this collection extensively. Until today, the native Aleut are known as the indigenous people in the Aleutian Islands, Northern Pacific. After the mid-18th century, the native Aleut were acceleratingly affected by imperial Russia. Notably, Russian colonialism and capitalism urged the native Aleut to produce fur as commodities for trade as they were excellent sea mammal hunters. The fur trade in the Arctic zone and the Northern Pacific coast were carried out under one of the colonial rules of Western European imperialism. This movement operated as a factor in constructing the world system beginning in the 16th century (cf. Oswalt 1980; Crowell 1997).

Figure 2. Map of the relation areas with this article

Therefore, imperial Russia eventually forced the migration of the native Aleut to the Kodiak Island, or Simushir and Urup of the Kuril Islands, for the production of fur trade commodities (Fedoroba 1973: 205). The native Aleuts were engaged in sea mammals, especially sea otters, hunting with other indigenous groups, including the Kuril Ainu and the Alutiiq[3] (Figure 2).

In 1875, the Treaty of Saint Petersburg resulted in the Russian Kuril Islands becoming the territory of Japan; thus, the Japanese inspectors visited the Simushir island in 1876 and collected the Kayak[4]. With this historical background, it can be suggested that the Aleutian Kayak displayed in the Hakodate City Museum of Northern Peoples was brought about by Russian colonialism.

Form and Structure of Aleutian Kayak

Considering these socio-historical backgrounds, this paper attempts to grasp the characteristics of the form and structure of this Aleutian Kayak. The following data is based on the March 2010 co-examination with Ikunori Suzawa, a canoe builder and canoeist. In this examination, opinions were exchanged about the form and structure of the Aleutian Kayak, as well as building and steering techniques. However, the main facts on the building and steering techniques are established on undue reliance on Suzawa's perspectives and investigations as a canoe builder and a canoeist (Oya and Suzawa 2013).

(1) Boat Form

The most remarkable feature of this collection is the long and lean boat shape constructed by the extremely narrow beam (Figure 3). Nevertheless, this feature of an extremely long and narrow boat shape can also be recognized as typical of Aleutian Kayaks in comparison to other indigenous Kayaks, including the Alutiiq and the Chugach (Oya and Suzawa 2013: 12, 14) (Table 1).

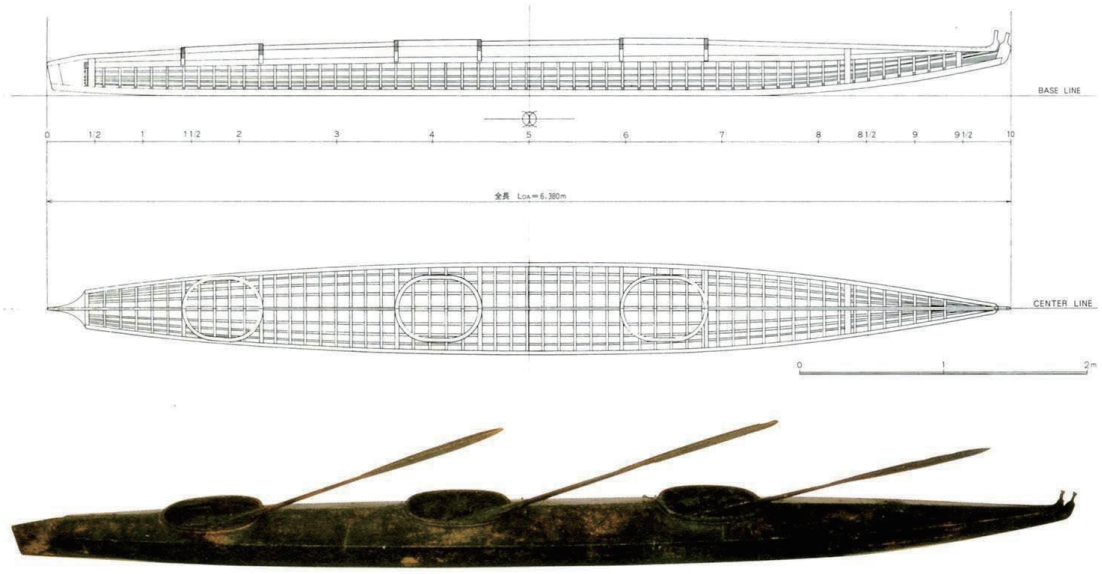

Figure 3. Boat shape and structure of the Aleutian kayak at the Hakodate City Museum of Northern Peoples (original information from Hasebe 2003: 158)

	Aleut Type				Kodiak and Chugach Type		
Owned by	Hakodate City Museum of Northern Peoples, Japan	Phoebe A. Hearst Museum of Anthropology, UC Berkeley, USA	Portland Art Museum, USA	National Museum of Natural History, Smithsonian Institution, USA	National Museum of Denmark	Washington State History Museum, USA	Kunstkamera (Peter the Great Museum of Anthropology and Ethnography), Russia
Length	638.0cm	581.4cm	617.2cm	701.0cm	434.0cm	596.2cm	807.0cm
Width	37.4cm	43.2cm	57.5cm	63.5cm	65.6cm	75.0cm	79.2cm
Aspect ratio	1 : 17.1	1 : 13.5	1 : 10.7	1 : 11.0	1 : 6.6	1 : 7.9	1 : 10.2

Table 1. Comparative chart of boat shapes of kayaks owned by museums at present (adapted from Oya and Suzawa 2013: 12)

On the sea, such a feature shape is poor for stability but retains high sailing speed. In other words, this boat shape is suitable for high-speed and short-range navigation but unsuitable for safe long-range navigation. From such findings, Aleutian Kayaks have an advantage in travelling at high speed to a fixed destination in a short range; however, they are unsuited for safe navigation in long-range travels due to inflexible adaptation to changes in weather and tidal currents.

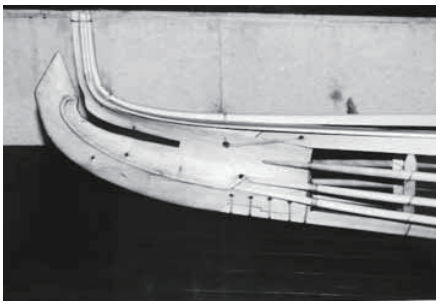

Figure 4. block construction of stem (original information from Oya and Suzawa 2013: 13)

(2) Boat Structure

This collection is constructed by the frame structure, mainly the keel, considered the common feature of the Aleutian Kayaks. Notably, the keel of the Aleutian Kayak is assembled by parts composed of two or three pieces (Laughlin 1980: 34-36). It can be seen in Figure 4 that the feature of the hull construction, the keel, stem, and stern

on the block construction are all composed of various parts.

This structure can alleviate the impact and pressure of wind or waves, preventing upsetting and wrecks. In addition, gunwales of this collection are not directly joined with stem and stern; the stem is constructed by different parts, which are composed of the lower side, unified with the keel with the upper side separated (Oya and Suzawa 2013: 13). These constructions can also be considered as same devices to alleviate the impact and pressure of wind or waves and prevent upsetting.

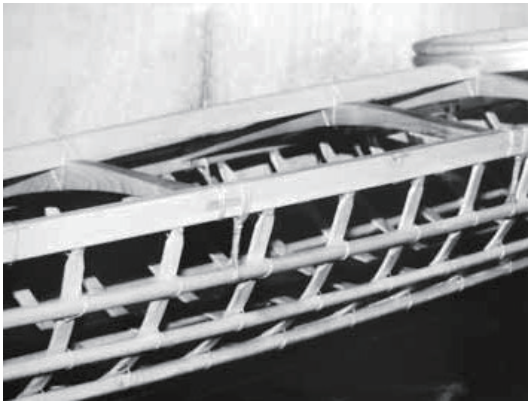

Figure 5. deck beams on the ship side (original information from Oya and Suzawa 2013: 13)

An observation can be made that the side of the ship has no specific construction for protecting wind and waves, except for deck beams (Figure 5). In addition to the extremely narrow boat shape, this side structure is vulnerable to impacts and pressures from both sides, compared with the front and back.

Studying these features, the design concept and construction of the Aleutian Kayak can flexibly respond to impacts and pressures from the stem and stern side, while both sides are relatively frail. The curiosity about the chosen design concept and construction with such contrasting differences is crucial; Thus, this issue will be revisited accompanied by the relationship with Russian colonialism.

(3) Cockpit Form and Structure

The cockpit is commonly characterized as a significant feature of the Aleutian Kayak. The entire shape of the cockpit on this collection's deck is oval, contrasting with the circular shape of the Alutiiq's and the Chugach's Kayaks. This oval is a signature feature of the Aleutian Kayaks and is understood to be influenced by the traditional seating posture of the native Aleut.

The embarkation and steering of the Aleutian Kayak are by knee extension posture (Jochelson 1933: 11) (Figure 6), as opposed to the straight sitting posture of the Alutiiq and the Chugach. It can

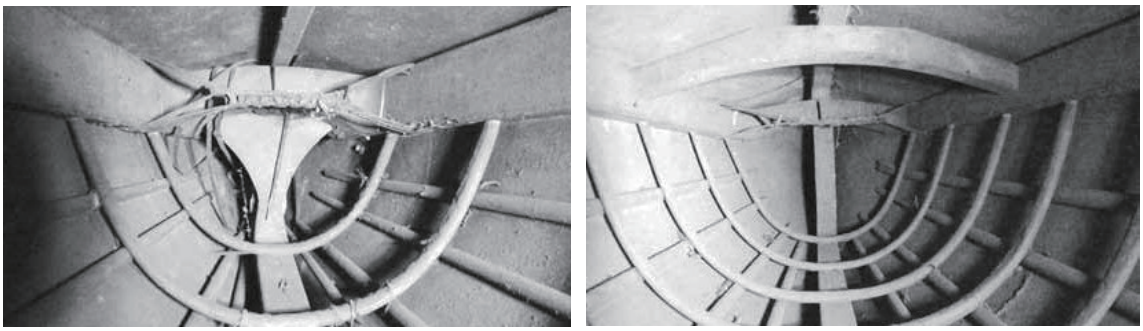

Figure 6. Inside of the cockpit
(original information from Oya and Suzawa 2013: 15)

be seen from the ethnographic records that the native Aleut mocked the sitting posture of the Alutiiq; therefore, those postures have been recognized as unique to each ethnic group. Borrowing from the French sociologist M. Moss's theory, "techniques of the body" (Moss 1936), the Aleutian Kayak's embarkation and steering posture is an organic process of embodiment based on a lifetime of sociocultural training.

In addition, an ethnographic record shows that Russian colonialists struggled to sit in an Aleutian Kayak with the same posture as the native Aleut (Veniaminov 1984: 160). Furthermore, the aim of this lifetime training is embodying: by embracing the "techniques of the body," the knee extension posture is not only to steer the Kayak but also to build lithe muscles - this is necessary to hunt sea mammals, as the harpoon is thrown with the spear thrower while in this posture (Laughlin 1980: 28-29).

It is difficult for other people to embark on the Aleutian Kayak, as generally, the forms and structures of the seats are molded to adjust to the embarkation posture of a specific person (Lantis 1984: 173). Therefore, the fabrication of deck beams must be arranged for the body size of each owner, catering to the various leg lengths and knee positions.

However, the deck beams of this collection are equally arranged and are built to embark on various body shapes, securing a relatively wide space around the cockpit. These results indicate the likelihood of this collection being built not as an order-made for a specific person but ready-made for the general. This possibility identifies a remarkably different feature compared to what is reported in ethnographies of typical order-made Aleutian Kayaks.

Background of Technical Choices under Colonialism

Considering the results of examinations, this paper attempts to investigate the relationship between the Aleutian Kayak and colonialism. It was assumed that the proportion of Aleutian Kayaks with extremely long and narrow boat shapes was chosen to acquire high sailing speed in exchange for stability on the sea. However, the cruise by an Aleutian Kayak was originally for more than just short-range navigation for hunting at a specific site - before Russian colonization, long-range navigation was common during an extended period for interregional exchanges or exploration and tracing of sea mammals (Oshima 1996: 87).

A question is raised from a contrasting environment before and after the Russian colonization: Why are the Aleutian Kayaks, built after the Russian colonization, constructed to prioritize high speed at the cost of stability?

A possible argument for such a technical choice could be the Russian colonial rule pressured by the requirement of capitalism. As is well known, Russian imperialism's primary purpose in expanding to the North American continent was to monopolize the fur trade bringing great wealth to the world market (Veltre 1990: 176; Fisher 1996: 123). Russia had to depend on the native Aleut and other indigenous people, as the capturing of sea mammals (including sea otters and seals) as fur trade commodities required highly skilled hunting and sailing techniques (Townsend l975: 563; Crowell

l997: 13)[5]. Therefore, with colonial rule, Russian capitalism (mainly the Russian-American Companies) forced the natives in the Aleutian Islands to focus on hunting sea mammals solely as fur trade commodities.

It can be assumed that such a situation also affected the Aleutian Kayaks and caused significant changes for the utilizers. Under Russian colonial rule, indigenous people, including the native Aleut, were restricted from pursuing subsistence activities for food production and long-distance navigation to obtain living and luxury goods. This means they were forced to exclusively seek the production of fur trade commodities by Russian-American Company. Additionally, such utility of Kayaks reduced necessities and opportunities for long-distance navigation. Trade commodities of sea otters and seals were easily hunted, compared with large sea mammals for food production, which demanded extensive searching and chasing for long distances (Laughlin 1980: 32-33)[6].

As compensation, the native Aleuts were supplied luxury items, prestigious goods, and foods and necessities for daily life by colonialists. As a result, in complete disregard of their wishes, engagement in their daily activities of food production and lifestyle necessities grew unnecessary.

With these historical movements, the drastic social change of the native Aleut, induced by Russian colonialism and capitalism, is a plausible leading force in building the Aleutian Kayak represented in the Hakodate City Museum of Northern Peoples, Japan collection. For example, the Kayak presents the features of the release from subsistence activities, including food production and daily necessities, and long navigation became redundant. In exchange, natives in the Northern Pacific under Russian colonial rule increased the production of fur trade commodities; therefore, to a degree, it shows that the native people had to engage in sea mammal hunting even under bad weather[7].

These backgrounds directed the native people's craftmanship in constructing boat design based on resisting wind and waves from front and back and both sides with their watermanship (Laughlin 1980: 43-44). Because cruising by the Aleutian Kayak in the colonial era could concentrate on short-range movement for hunting sea mammals alone, their boat steering skills were trained to cope with

Figure 7. A ship model seated the western colonialist at the center cockpit (original information from Iqyax - Own work, GFDL, https://commons.wikimedia.org/w/index.php?curid=11247891)

wind and waves under bad weather, resulting in selecting a boat shape extremely narrow and long for high speed.

In the same way, boat building shifting from order-made to ready-made can also point out the influence of colonialism. It is recorded in ethnographies that these boats have seated various colonialists, including merchants, administrators, even missionaries, and others, at the center of the three-hatch model (Figure 7). This is why a relatively wide space for the embarkation of unspecified persons is made in the center of the three-hatch model. In sum, excluding the front and back cockpits[8)], the central seat did not require a build to be order-made.

Conclusion

These investigations can lead to a conclusion that the Aleutian Kayak's technical choices in the colonial era reflect Russian imperialism and capitalism represented by Russian-American Company. Specifically, the native Aleut society was reconstructed by Russian imperialism - a sustainable lifestyle consisting of highly intensive sea mammal hunting resulting in the Kayaks' building and steering technical choices adopting specialized speed for short distances at the expense of stability on the water.

This study briefly demonstrates the theoretical perspectives on utilizing Aleutian Kayaks at places forced of emigration. The native Aleut were undoubtedly engaged in sea mammal hunting by Russian-American Company with the Kuril Ainu or the Alutiiq, who were indigenous at each settlement from ethnographic and historical documents.

However, the "techniques of the body" have been discussed - the steering of the Aleutian Kayak and the native Aleuts' hunting skills were manifested from the long-term training from childhood. Hence, it explains the difficulties for other ethnicities to practice the same hunting activities as Aleutian Kayaks; therefore, the Aleutian Kayaks were introduced and built in places that forced the native Aleut to emigrate. In other words, the introduction to and instructions for the Aleutian Kayaks were indispensable to pursuing the production of the fur trade. This implies that other native people, excluding the native Aleut, struggled to steer and carry out sea mammal huntings on the Aleutian Kayaks. Hence, the Aleutian Kayaks that landed on the Central Kuril Islands, far from the Aleutian Islands, were for the Aleut's hunting purposes. Additionally, the Central Kuril Islands are famous as one of the voyage choke points due to fast sea currents and uncertain weather. To pursue the production of fur trade commodities in such an environment, the Kayak-building and steering techniques of the native Aleut were crucial. This is especially why the Russian colonialists forcibly emigrated the Aleut.

Moreover, the native Aleut were engaged in the division of labor with various ethnicities at the Kuril Islands and the Kodiak Islands. Through the cockpit, boat form, and structure, it is assumed that the collection at the Hakodate City Museum of Northern Peoples was built as a ready-made Kayak for boarding by nonspecific persons. Considering this finding, there is the possibility that other ethnic groups, together with the native Aleut, had sat on this Kayak collection and engaged in sea mammal

hunting to produce fur trade commodities.

However, the steering of the Aleutian Kayak is suspected to be difficult for other ethnic groups, except for the native Aleut; thus, the contribution of other indigenous people's are assumed to be limited. For example, other ethnic groups, such as the Antique and the Kuril Ainu, may have played a role as younger novices seated at the front cockpit in the colonial era. The Aleutian Kayaks represented in the Hakodate City Museum of Northern Peoples collection were indeed utilized multiculturally and initiated by Russian imperialism.

The form and structure of the Aleutian Kayaks built during the Russian colonial era have been elucidated through discussion. They were chosen not only by simple environmental adaptations and cultural traditions but also by strong influences from Russian imperialism, including, Russian-American Company. In other words, it is plausible that colonial powers persuaded required technical choices.

These findings were led by the sociocultural environment surrounding indigenous peoples. The producing and utilizing Aleutian Kayaks under colonization were ascribed through examinations of technical practices on steering and building as activities of human bodies. It is not an exaggeration to state that such a result could be regarded as a non-verbal history embodied in folk articles. On existing anthropological and historical research, colonial histories are studied through comparatively large perspectives over individual-level-based history and ethnographic records. For that reason, the approach based on material culture, which has been neglected for a long time in anthropological studies, can become the new frontier in investigating non-literate societies' histories.

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Notes

1) The basic information on the Hakodate City Museum of Northern Peoples, Japan, can be seen in the following URL.
https://www.hakodate.travel/en/sightseeing-spots/historic-building/hakodate-city-museum-of-northern-peoples/

2) Aleut was the ethnonym named by Russian and other European colonialists. They call themselves *Unangax, Unangan, and Unanga* at present.
3) As a side note, the Kuril Ainu are the indigenous people of this area. Still, the Alutiiq named, such as Koniag Eskimo by European colonialists, were also forced to migrate for sea mammals hunting from Kodiak Island by imperial Russia.
4) In the report of this group of Japanese inspectors, the observation and purchase of a skin boat made from sea mammals for hunting sea otters in Urup of the Central Kuril Islands were recorded (Sato 1875). Despite different islands, this boat is assumed to be a collection owned by the Hakodate City Museum of Northern Peoples through the researched document.
5) On condition of calm at sea under fine weather, even European colonialists could steer a baidarka sufficiently. However, navigating the Baidarka to conduct sea mammal hunting, particularly on the rough sea, was very difficult, except for the native Aleut (Laughlin 1980: 43). Thus, fur trade commodity production depended on indigenous people, including the native Aleut's indispensability.
6) In the case of whales and large sea mammals, after the harpoon head pierced games, wrestling was generally necessary with those on the sea for a long time and distance. Additionally, large sea mammals were more important for their subsistence than small ones, such as sea otters, due to their more significant caloric contents.
7) As pointed out earlier, the native Aleut can steer stable sailing on rough seas under severe weather.
8) Aleutian Kayaks were originally single and double-hatch models only, and the triple-hatch models were not built before Russian colonisation. Incidentally, expert hunters were seated in the back cockpit for training younger novices in the front, so double-hatch models held significant purposes.

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Corals: A high-resolution Window for Mature and Human Memories

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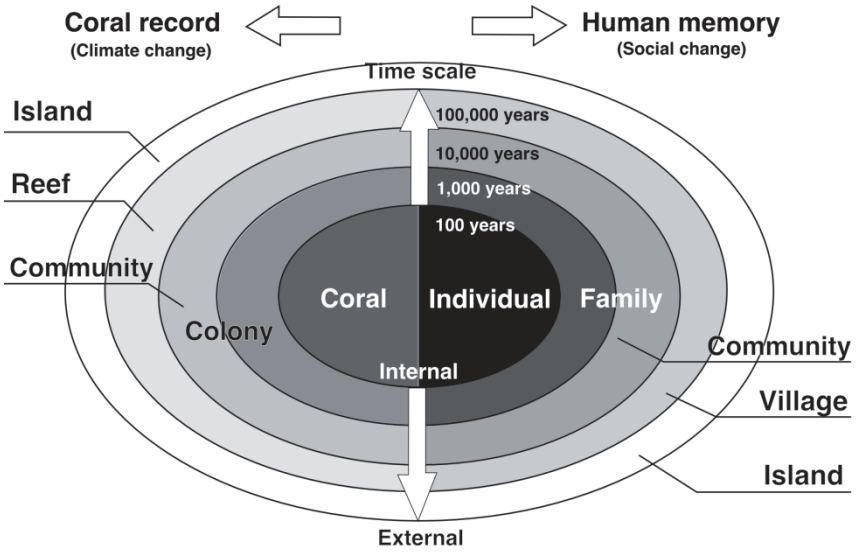
Reef corals are distributed present today in tropical and subtropical oceans. They can be found in a significant fraction of the geologic record, with a range extending back to 500 million years ago. Their carbonate skeletons grow with tree-like annual rings, and its microstructural and geochemical analysis along the direction of coral growth can reconstruct the environmental changes on a weekly to monthly scale over centennial to millennium years of corals alive. In other words, reef corals precisely record climatic and environmental information on the time scale experienced as the human life scale. The precise dating and geochemical records of coral fossils make possible a direct comparison between high-resolution environmental information and human history after the late Pleistocene. We demonstrate a new method for the comprehensive reconstruction of coral and human memories using combined approaches by high spatiotemporal resolution geoscientific analysis on coral reefs and phenomenological reduction in drama and theatre to understand the relationship between the vulnerability and resilience to environmental changes between nature and human from the past to future.

Keywords: Coral annual bands, High-resolution paleoenvironment reconstruction, Drama and theater, Phenomenological reduction

The relationship between nature and humans in the past and future

Global environmental change in the Anthropocene is determined by the complex interplay of natural and social changes. What will the relationship between humans and nature be like in the future? Climate change has greatly affected marine and terrestrial ecosystems and has significantly impacted human life, including migration, settlement, lifestyle, and culture. In addition, the frequency and magnitude of regional-scale environmental changes, such as typhoons, floods, droughts, earthquakes, and volcanic eruptions, have significantly impacted how people think and live by influencing the dynamics of local communities, their lifestyles, and their economic sustainability. On the other hand, economic development through industrialization and the unification of information and lifestyles through globalization have made our lives more vulnerable to climate change and environmental events. We should explore the resilient human-nature relationship in rapidly changing global environments in the future with multiple layers at different spatiotemporal scales.



Similarities and differences of structures with spatial and temporal scales between corals and humanity

Figure 1. Similarity and differences in space and time between coral and human memories.

Corals have long drawn great interest due to their geological, ecological, and biological importance and usefulness to humans, animals, and plants in marine and land ecosystems. Their skeletons continuously grow, with different shapes of coral colonies and topography of coral reefs, up to one of the most significant biological architectures, which supports a wealth of diverse life in nutrient-poor regions. Corals are surviving and adapting to the drastic change in Earth's history and create nanometres to planetary scale complex structures throughout geological time, including 1) the calcification process in each coral polyp, 2) growing and changing morphology in coral colonies, 3) creating a coral ecosystem with co-existence of different coral species and other organisms, 4) developing coral reef topography with accumulating living and dead parts of skeletons and other sedimentary materials, and 5) forming coral island and archipelago with uplifted activities and/or sea level changes. Such multi-level structures and phenomena observed in corals resemble those in human being with the developing processes and interactions among human individuals, families, communities, and societies (Figure 1). Both corals and human beings grow and survive in different environments with spatial and temporal progress of extension and development. In contrast with structures and phenomena, the strategy for surviving abrupt environmental changes seems very different between coral reef ecosystems and human societies.

Corals as high-resolution memories for environmental changes

Corals continuously accumulate calcium carbonate skeletons as they grow, providing a record of environmental conditions throughout the colony's lifespan. Coral sclerochronology, a combined approach using physical and chemical analyses along the major growth axis, can provide a wealth of information about the environmental and physiological changes experienced by corals for hundreds

of years (*e.g.,* Gagan et al.,2000). Isotopic, geochemical, and skeletal growth analyses of certain massive corals (e.g., *Porites, Orbicella*) in tropical shallow reefs have been successfully used to reconstruct seasonal- to century-scale variation in environmental parameters (e.g., temperature, salinity, light intensity, nutrient dynamics, marine pollution, and ocean pH) and coral growth (e.g., skeletal density, linear extension rate, and calcification rates). The stable oxygen isotope ratio ($\delta^{18}O$) in shallow-water corals, even their fossils, is widely used to reconstruct sea surface temperature (SST) and sea surface salinity (SSS) because the $\delta^{18}O$ in the carbonate minerals that comprise the coral skeleton reflects both the water temperature and the chemical composition of the surrounding seawater (e.g., Epstein et al., 1953, Watanabe et al., 2011). Coral $\delta^{18}O$ is biologically mediated and precipitated under isotopic disequilibrium from seawater $\delta^{18}O$ (e.g., Weber and Woodhead, 1970); however, the offset from equilibrium is assumed to be relatively constant within the same coral species. Carbon isotope ratios ($\delta^{13}C$) preserved in coral skeletons have also been used as an indicator for environmental parameters such as sunlight and dissolved inorganic carbon (DIC). However, the factors controlling coral $\delta^{13}C$ are more complicated due to the complex pathways and sources of carbon from the ambient seawater to the coral skeletons (e.g., Watanabe et al., 2017). The skeletal barium to calcium ratio could record the changes in upwelling events from deeper water layers to the surface ocean (e.g., Yamazaki et al., 2021). Ocean transportation and wind direction are also recorded as the changes in amplitude of $\Delta^{14}C$ and manganese concentration in coral skeletons (e.g., Grottoli and Eakin, 2007, Shen et al., 1992). Nutrient dynamics and ocean currents are also reconstructed by analyzing $\delta^{15}N$ signals in the organic materials in coral skeletons. Because reef corals live in coastal areas between land and ocean, the coral records could capture both global marine environmental changes (e.g., global warming, ocean acidification) and loral to regional scales of events on land and coastal areas (e.g., earthquake, Tsunami, typhoon, volcanic eruption, drought, coastal development).

The rapid calcification rates of reef coral skeletons and their precise geochemical indicators allow the marine environment experienced by reef corals to be compared on the same scale as human lives. Moreover, the long-lived massive corals could survive during several hundred years with tracking century-scale environmental changes (Figure 2).

We introduce some examples from our works. Yamazaki et al. (2015) reconstructed 51-year changes in the origin of nitrogen inflows through rivers from reef coral skeletons at Shiraho Coral Reef on Ishigaki Island. We revealed that the concentration of nutrients flowing into coral reefs varies with changes in coastal land use. From the seasonal variations in water temperature in Omani fossil reef coral skeletons, we found a correspondence between the disappearance of the Mesopotamian civilization's largest empire and the strength of winter storms (Watanabe et al., 2019). In long-lived sclerosponges, which grow a calcium carbonate skeleton like reef corals, we captured the evolution of lead pollution's origin in the atmosphere, revealing the impact of human activities on the environment (Ohmori et al., 2014). The world's largest bivalve, the giant clam, which forms a daily growth band, can reconstruct past typhoons, showing that it is possible to capture weather phenomena that humans experienced (Watanabe et al., 1999, Komagoe et al., 2018). Our future challenge is to superimpose

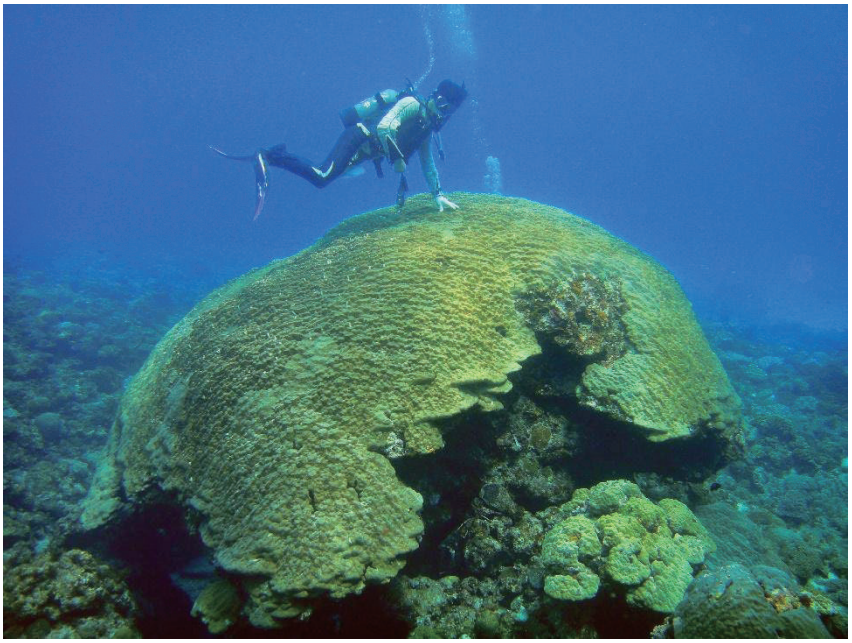


Figure 2. Long-lived massive *Porites* coral colony at Kikaijima Island. The hermatypic corals grow with annual rings in their skeletons, and the growth rate is ~1 cm/year.

these high temporal-resolution paleoenvironmental indicators with human memories.

Phenomenological reduction in drama and theatre

We demonstrate a new method for the comprehensive reconstruction of coral and human memories using combined approaches by high spatiotemporal resolution geoscientific analysis on coral reefs and phenomenological reduction in drama and theatre to understand the relationship between the vulnerability and resilience to environmental changes between nature and human from the past to future. Skeletons of reef-building corals record environmental information during their lifetime at very high resolution, from weekly to seasonal, providing natural environmental data at the exact temporal resolution as human life. On the other hand, further back into the past, the temporal resolution of information on people's daily life is less available than those for environmental data recovered from coral skeletons. Therefore, the time gap in people's daily life in the past is complemented by imagination and aggregation through phenomenal reduction by utilizing drama and theatre. The information about people and nature required in the theatrical process is feedback to the researchers, then science and art are iterated to complement each other in time, human action, and life. After watching the play, the researcher will develop a research theme to enhance information resolution in their research field further and enhance the resolution of the play through information from the memories, customs, and daily life of the residents. In addition, researchers and residents will hold workshops to create future scenes together with artists to embody their vision of the future as future collective knowledge.

Drama and theatre in Kikaijima Island, Amami islands in Japan

Kikaijima Island in the Amami Islands, Japan, has been uplifted over the past 100,000 years, exposing coral fossils from various periods. Humans have stayed on Kikai Island for at least the past 8,000 years. Modern, it also has a rich coral reef ecosystem at the boundary between tropical and temperate seas and more than 30 settlements that have been maintained for a very long time by water stored in the limestone springs of the coral reefs. Kikaijima Island has maintained its cultural diversity in the face of drastic changes in environmental and social variables. The population is also declining and aging. It is a place that could serve as a model for future aging societies. The fossil coral records from Kikaijima Island revealed the changes in the East Asian monsoon over the past 8000 years (Garas et al., 2022), and archaeological sites have been discovered from prehistoric to medieval times, allowing a direct comparison of the environment experienced by the island's inhabitants. We obtained the high spatiotemporal resolution geoscientific data using high-resolution and precision coral geochemical analysis along with coral skeletal annual bands (e.g., $\delta^{18}O$ and Sr/Ca ratio) and high-spatiotemporal hydrodynamic model simulation to compare with the community-based life histories deduced from field works and interviews with residents, human and social science fields of scientists such as anthropologist and sociologist, and artists in Kikaijima Island. We generated a life-based database that combined environmental factors in climate/environmental changes and human behavior and lifestyle on local and regional scales of social changes. We applied drama and theatre to synthesize all kinds of scientific and societal data, knowledge, and narratives together in the drama-making process (Figure 3).

Figure 3. Long-lived massive *Porites* coral colony at Kikaijima Island. The hermatypic corals grow with annual rings in their skeletons, and the growth rate is ~1 cm/year.

Drama is one of the oldest arts of human beings and a way to express the change and trouble that occurred inside the individual or group at various times and places. All processes of making, playing, watching, discussing, and revising the drama could be involved different fields of scientists, artists, and residents in local communities with different generations. Throughout such processes, phenomenological reduction in drama and theatre would be occurred by visualizing conditions and environments in which human-made their decision and the psychological and emotional structures. We evaluated the reaction and propagation in community members of sciences, artists, and residents using tracking propagation of emotion, behaviour pattern, and decision changes. Combined approaches using high-resolution coral records and phenomenological reduction in drama and theatre would help better understand the relationship between nature and humans in unpredictable future Earth and among people of different abilities and generations on a local community scale.

Collective future knowledge with inter to transdisciplinary research among scientists, artists, and local communities.

We hypothesize that individuals, groups, and societies have been transformed and maintained in response to climate and environmental change experienced over generations. Their indigenous knowledge would be unique to each region responding to environmental changes and disasters. However, the local environmental changes due to global environmental issues do not become personal and collective because of the differences in scale and problem awareness between global and region-specific issues. To transparent from global environmental issues to personal affairs, the approaches will approach identifying and solving local problems through a mechanism that enables science, art, and community to emerge and collaborative knowledge for the future. This study compares the relationship between climate/environmental change and people/society from the past to the present using coral and other high-resolution environmental proxies on a scale of one day to several years. Through the various processes of theatrical performances, we will develop a high-resolution history of the "high-resolution relationship between humans and nature" in the region, showing how global environmental change and local environmental incidents have changed the thoughts, actions, and lives of people and formed conventional knowledge in the region today. Furthermore, we propose a future vision (future collective knowledge) that promotes empathy and collaboration among researchers from different fields and local stakeholders and an environmental adaptation strategy close to our own experience using a theatrical process. The resolution and imagination of each discipline are enhanced, and a collective future-oriented collaboration involving local communities would be established by using drama to bring together the perspectives and methods of different research fields in the natural sciences and the humanities, and social sciences.

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The Watercraft of Out-of-Eurasia Groups: A Review, a Re-evaluation and Prospects

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Abstract

Coastal migration and transcending water bodies is an important topic in the human history of the Out-of-Eurasian populations. A necessary part of the discussion is the evaluation of the means of water transportation, namely boats. A boat here refers to a primitive means of transportation propelled by natural forces using natural materials, i.e., plants and animals. Plant materials can include wood, branches, bark, and grass. Animal materials can be animal hides, entrails, or bones. Natural propulsion can be river currents, ocean currents, wind, and human power. Classic studies by Hans Suder (1930) and Gerd Koch (1984) on the global distribution of boats show a diverse and complex distribution of boats in the Pacific Rim, where the Out-of-Eurasia group's spread. This presentation will review research on the nested distribution of boats in the ethnography of the New World, and Sunda/Sahul continents. I will then discuss the current status of early migrations to the Japanese archipelago and report on the results of an experimental archaeological study in the Ryukyu Islands 30,000 years ago. Different types of boats were tested in this experiment: grass-bundle boats, tamboo rafts and dugout canoes. A successful paddling voyage from Taiwan to Yonaguni Island was finally made by dugout canoe. However, several problems remained: (1). diversity of island environment (e.g. availability of logs for constructing dugout canoe), (2). transportation of domestic and semi-domestic animals (e.g. Ryukyu wild boar), (3). presence/absence of sail, (4). cognitive/navigation aspects (e.g. invisibility of Yonaguni Island during the voyage).

I will explore these problems in relation to 3D niche construction model.

***Keywords**: boat, watercraft, grass-bundle boat, bamboo raft, dugout canoe, Ryukyu Islands*

Indigenous Watercraft of the Pacific Rim

Coastal migration and crossing water gaps are important themes in the human history of Out-of-Eurasia groups (e.g. Leppard & Runnels 2017). The migration of human groups from Eurasian Continent to islands of Southeast Asia (e.g. Sundaland in the late Pleistocene) and further to Oceania was inevitably made by watercraft. Recently, it has become increasingly recognized that early migrations to the Americas were also by sea and required watercraft. So we are faced with the necessity of the evaluation of the means of water transportation, i.e., boats (e.g. Leppard et al 2022).

Figure 1. Distribution of Indigenous Boats in North America (modified from Koch 1984: Abb.1 on page 202)

The boat is defined as a primitive means of transportation propelled by natural forces using natural materials, i.e., plants and animals. Plant materials include wood, branches, bark, and grass. Animal materials can be animal hides, entrails, or bones. Natural propulsion can be river currents, ocean currents, wind, or human power.

A worldwide study of indigenous boats is given by Hans Suder (1930), Gerd Koch (1984), and most recently by Sean McGrail (2001).

The primitive watercraft would be a float. McGrail's model for the creation of buoyancy, which is essential for boats, includes two types of boats (McGrail 2001: Fig.1.4): rafts and grass bundle boats, in which a number of individually buoyant elements are put together; and single boats, such as roundwood, bark, or hide boats, in which a hull is built. He classified them into two broad categories.

Then let us examine the details of the type and distribution of boats by looking at examples from Americas.

In the Arctic region of North America, the Inuit and Aleuts are using skin-boat, *kayak-umiyak*. The material used is marine mammal skins, which are formed into a boat shape using a wooden or bone frame. South of that, inland and the Atlantic coast of Canada, bark boats are widely used. On the other hand, in the Pacific Northwest coast of Canada where lumber is abundant, dugout boats had developed.

Dugouts are also a dominant type in the lower Mississippi Basin. In the middle and upper Mississippi River, animal skin boats, especially round boats made of buffalo skins, are characteristic. In the dry areas from the West Coast to Mexico, grass bundle boats predominate. However, the

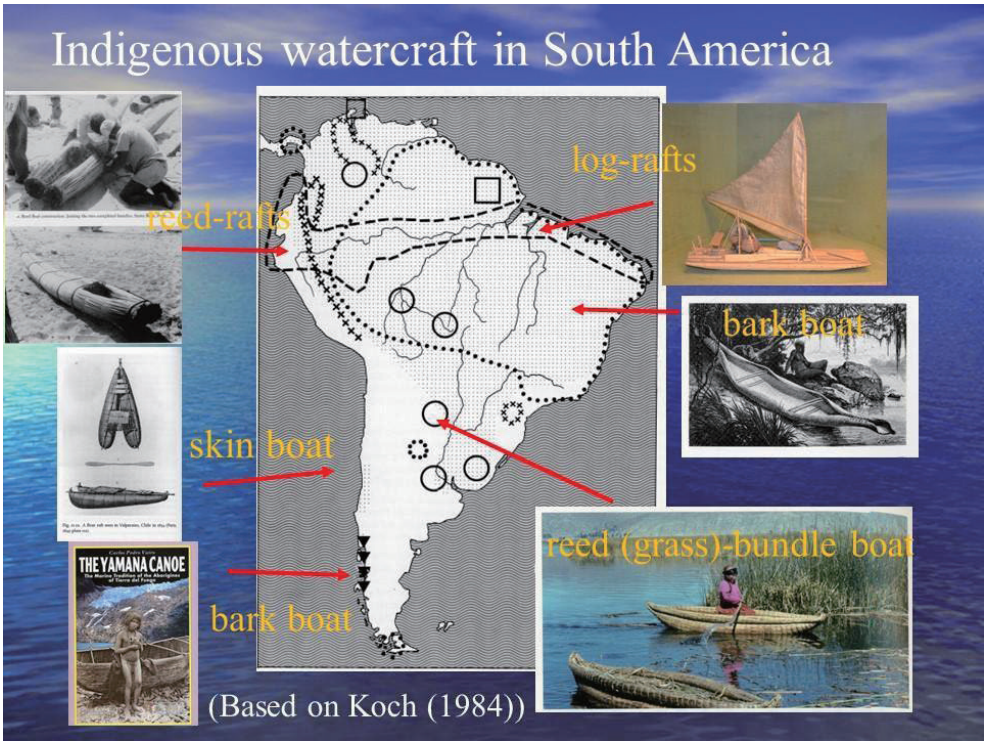

Figure 2. Distribution of Indigenous Boats in North America (modified from Koch 1984: Abb.1 on page 238)

Chumash and other tribes off the southwestern coast use plank boats (Figure 1).

Heizer and Massey (1938) had provided more detailed distribution of various types of boats, such as, grass-bundle boats, log rafts, dugouts and plank canoes on Californian Coast.

In South America, bark boats are used in the Amazon lowlands, and also by the Yagan people in the southern tip of South America. In the Amazon, dugout boats are also used. On the Peruvian coast, grass bundle boats made of reed or log rafts made of balsa wood are used. Unique type of grass bundle boats was used on Peruvian coast and Lake Titikaka. Skin boats made from seal skins were also used (Figure 2).

These complex distributions of boats along the Pacific rim of the Americas provide hints about the migration of the Out-of-Eurasian populations. Boats of different principles may represent waves or layers of human migrations at different times. Although the Inuit who use animal skin boats are late comers, it is possible that animal skin boats were used for transportation along the southern coast of Beringia, where early migrations may have taken place. On the other hand, the oldest sites of the Americas have been found along the Pacific coast of South America as far as Chile. If the early migration of the Americas took place along the Pacific coast, the dugout, grass bundle boats, or log rafts are the candidates as the means of transportation.

At the same time, however, such a distribution may indicate human plasticity. In other words, for the purpose of moving along the coast and crossing water gaps, humans may have built boats of

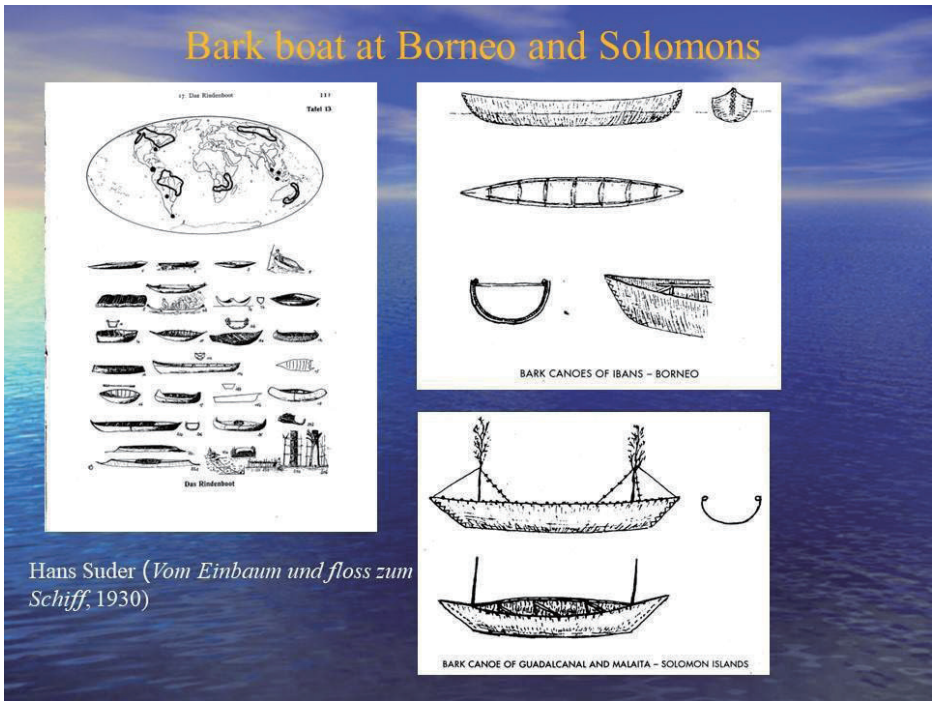

Figure 3. Bark Boats of Borneo and Solomons (Vairo 1995: p. 109 & 107)

various structures and forms, using locally available materials. This may indicate the plasticity of human abilities and technology.

The distribution of boats on the western side of the Pacific rim is also complex, and I will take a brief look at the distribution of indigenous boats in Southeast Asia and Oceania.

Human settlement in Oceania is divided into two stages. The first stage is the migration from Sundaland to Sahul, by the Homo sapiens groups who are the ancestors of the Australian Aborigines and Papuans. This took about 40,000 to 60,000 years ago in the Late Pleistocene. In ethnography, the Australian Aborigines used bark boats and log rafts, while the Tasmanians used a special type of boat called a bark-bundle raft. Several experiments have been already conducted on the use of bamboo rafts, in order to cross from Sundaland to the Sahul continent (Bednarik 1998, 1999).

A. Horridge argued the possibility of raft with sail used in early Austronesian migration (1984: Fig.91), and A. Anderson et al. suggests the possibility of raft with sail for the migration to Remote Oceania (Anderson et al. 2006).

We do not exclude the possibility of raft in these early migration periods, dugout boats or canoes are predominant from the islands of Southeast Asia to Oceania. In parts of Polynesia and Melanesia, double canoes or multi-hull canoes were used for migration and trade. Most people agree that outrigger-canoes were used in the second stage of human migration, i.e. the migration of the Austronesian groups, about 5,000 years ago. The most conspicuous feature of Austronesian canoes is the attachment of outrigger for stabilizing the narrow hull.

Double-outrigger type is dominant in Southeast Asia, and single-outrigger type is used in Oceania, although in calm waters in Solomons and Aotearoa (New Zealand), the canoes tend to lose outrigger

device. But the double/single contrast should be understood as functional as well as historical: in some parts of Indonesia, fishermen detached one side of outrigger to the easy use of fishing nets lowered from that side of the canoe.

Some argue that the outrigger of the Austronesian groups was sought on the Chinese mainland, although Austronesian Taiwan aborigines' boats lack outrigger (Wu 2021). Although the origin of outrigger in Asian continent should not be denied, we should re-evaluate the significance of co-existence of bark boats, log rafts, and grass bundle boats in Southeast Asia and Oceania, where outrigger canoes predominate (Goto 2023). Bark boats were used in tropical forest areas, such as, Borneo and Solomons (Figure3) (Vairo 1995), and grass-bundle boats were used by Australian aborigines, the Rapa Nui, and New Zealand Maori (Figure 4) (McGrail 2001).

Figure 4. Maori gras-bundle boat (Toitu Otago Settlers Museum in Otago; photo by Akira Goto)

Figure 5. Bamboo raft used for fishing on Ilocos Coast of the Luzon, the Philippines; photo by Akira Goto)

Most widely used watercraft other than outrigger canoe is rafts. Rafts were used in relatively warm water between 40 degrees North and South. In Ilocos coast of Luzon, the Philippines, bamboo rafts have been used for coastal fishing together with double-outrigger bangka boats (Figure 5). This is a part of bamboo raft tradition Bashi Strait in which Taiwan Amis' raft is a counterpart (Goto 2023).

In Oceania rafts continued to be used together with outrigger canoes for specific purposes, such as a means of escape and as a boat for women to be used during menstruation period (Schori 1959).

A few have suggested that the early migration of Austronesian groups to Oceania was by raft, and that the Lapita group used rafts with sails (e.g. Anderson et al. 2006). A. Horridge argued that rafts with sail in Brazil originated in Asian type (Horridge 1968).

Again, the coexistence of diverse boats shows the possibility of representing different waves of human migration and/or the flexibility of technology to suit the right material for the right purpose.

A Nautical Experiment 30,000 Years Ago in Japan

The oldest Paleolithic sites in the Japanese archipelago have been dated with certainty to 39,000years ago. There proposed three routes to the Japanese Archipelago: the first was a route from Sakhalin to Hokkaido Island that was connected to Sakhalin and Eurasia Continent during the late Pleistocene; the second was a route from Korean Peninsula via Tsusima Island to northern Kyushu Island; the third was a route from Chinese Continent to which Taiwan was connected at that time to Ryukyu Islands (Figure 6).Although human groups could walk from Sakhalin to Hokkaido (but could not cross the Tsugaru Strait until 20,000 B.P.), the second and third route must have been overcome by crossing the sea (Kaifu 2016).

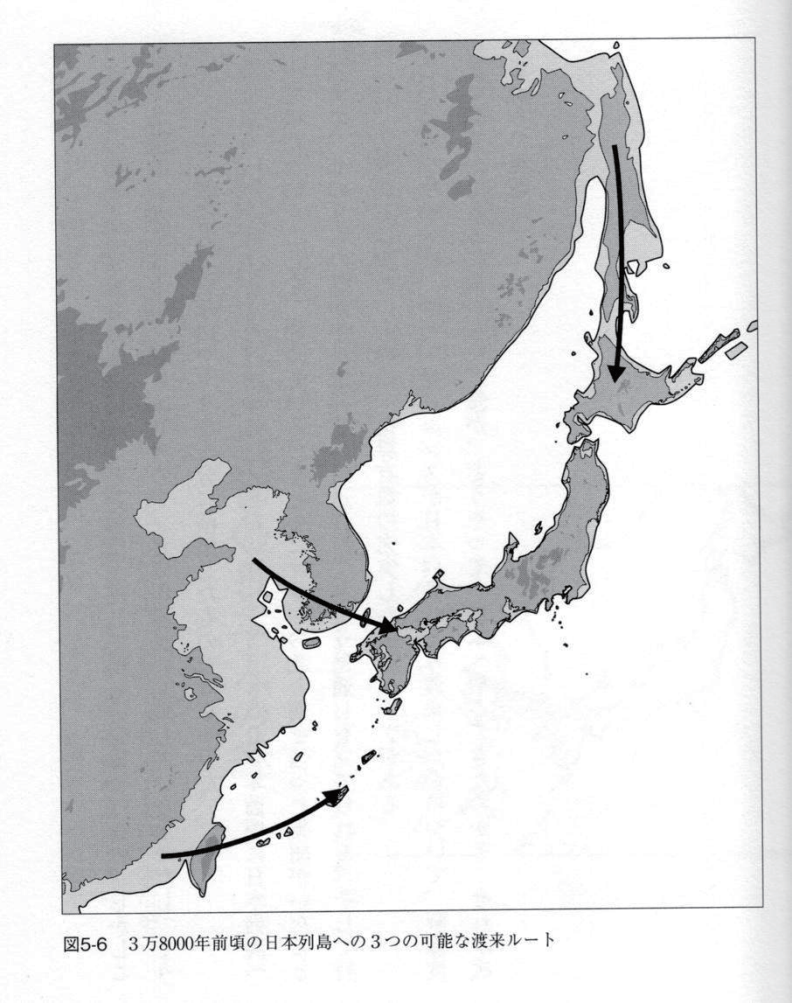

図5-6　3万8000年前頃の日本列島への3つの可能な渡来ルート

Figure 6. Three Earliest Routes to the Japanese Archipelago. (Kaifu 2016: Fig.5-6)

Even at this earliest date (circa 38,000 B.P.), obsidian from Kozushima Islands was used on the Honshu Islands, and therefore the earliest human groups in the Japanese archipelago already had an ability to cross the sea.

Concerning the 3rd route, the Ryukyu Islands were isolated islands at that time, and it was necessary to cross the sea to reach them. We conducted an experiment on the sea crossing. The candidate site was assumed to be Taiwan, where there are Paleolithic sites such as Pahsientung (□ □ □). Taiwan was a part of the Chinese Continent at that time.

Based on buoy discharge experiments, observation data of the Kuroshio Current, and computer simulation, we believed that it would be impossible for humans to reach the Yaeyama Islands in the southern Ryukyu Archipelago from Taiwan only by drifting.

In 2013, Yosuke Kaifu and colleagues began experiments on Yonaguni Island, the island closest to Taiwan, assuming that the island was the first stopover of a group of people coming from Taiwan (Kaifu 2016). Since there is no direct evidence of Paleolithic boats, we decided to experiment with

Figure 7. Grass-bundle Boat made on Yonaguni Island, 2015 (photo by Akira Goto)

Figure 8. Experimental Voyage to Iriomote Island, 2017 (Kaifu 2022: Figure 4)

three types of boats that could be made using materials available on the island, 30,000 years ago. Bark boats, which were mainly used in inland waters, and animal skin boats, which would not have been suitable for warmer waters were both excluded. At the beginning, dugout boats were because there was little evidence of appropriate stone tools (e.g. adze) to carve them around 30,000 B.P.

We first experimented with a grass bundle boat of reed mace, which could be collected from the marsh on the island by using only hand or shells. Reed mace was tied up with ivy, which can be found on the island. We asked Mr. Jin Ishikawa, who had learned to make reed boats on Lake Titicaca in Bolivia, to instruct us. He is now working with native people of the west coast of North America, in order to reconstruct an indigenous reed boat (Figure 7).

After two years of experimentation in nearby waters, two grass bundle boats set out on an ocean voyage in 2016 to Iriomote Island, where human groups who arrived at Yonaguni Island might first migrate to. Each boat was rowed by eight crews including a woman (Figurer8). Two boats departed in August, but on the day of departure, a branch of the Kuroshio Current flowed between two islands. Examining sea current data by Japan Coast Guard, it is known later that strong current swept north, and this is why the boats drifted north. Although this voyage was not successful, we learned that grass bundle boats become heavy when built large enough to withstand ocean voyages, and that their form makes them easily swept away by ocean currents.

In 2017 and 2018, the next experiments were conducted by using bamboo rafts in Taiwan with the help of the Amis people (Figure9). Crude stone flakes modeled on those found in the Pahsientung site were used for cutting bamboo (*Phyllostachys bambusoides*). In 2017s' model, the width of the raft was made as narrow as possible to increase speed. This raft was launched for aiming for the offshore Green Island, but was swept away by the Kuroshio Current and were unable to reach it. The next year, a wider but lighter raft was built, but still could not cross the Kuroshio Current. Another problem was, bamboo tended to be broken earlier than expected during the experiments (Kaifu et al 2020)

Figure 9. Indigenous Ami Bamboo Raft: a Model of Experimental Voyage by Bamboo Raft (photo by Akira Goto)

Figure 10 Dugout Boat used for Experimental Voyage from Taiwan to Yonaguni Island, 2019 (courtesy of Yosuke Kaifu)

At that time, there came the information that a partially polished stone axe had been found in Australia, which could be used to make a dugout boat. Then the next possibility was to experiment to make dugout boats. Mr. Amemiya, nicknamed "Jomon Carpenter," took the lead in the production of the dugout hull of cedar wood (Figure 10). After several experiments in Japan, the dugout boat was further milled and lightened, and set sail from north of Taitung on Taiwan's east coast in 2019 (Kaifu et al 2019).

The voyage of the dugout boat paddled by six people including a woman took two nights, and it was a success. The captain, taking into account the influence of the Kuroshio Current, rowed in a southeasterly direction and eventually reached Yonaguni Island in the northeast under the force of the Kuroshio Current (NHK Close-Up Gendai Project Team 2019).

Although there is a discussion on the possibilities and the imitation of this type of experiment (Cherry and Leppard 2015), we have obtained several insightful findings. By testing three different types of boats, it has been shown that the Kuroshio was a major obstacle and that it would be difficult to cross it without a dugout boat. In addition, considering sea currents in South China Sea between Luzon, Taiwan and Ryukyu Islands, unintentional drift is improbable as a reason of initial migration over the sea (Kaifu at al 2020). This was also true for the transporting obsidian from Kozushima Island in the earliest days of human occupation of Japan.

The voyage was a success, but there are some problems to be discussed further (cf. Leppard et al 2022).

Discussion and Prospects

(1). The islands of Oceania are equally diverse. On the high volcanic islands with large trees, outrigger canoes are built on the basis of dugout boats. On smaller islands such as Tuamotu and the

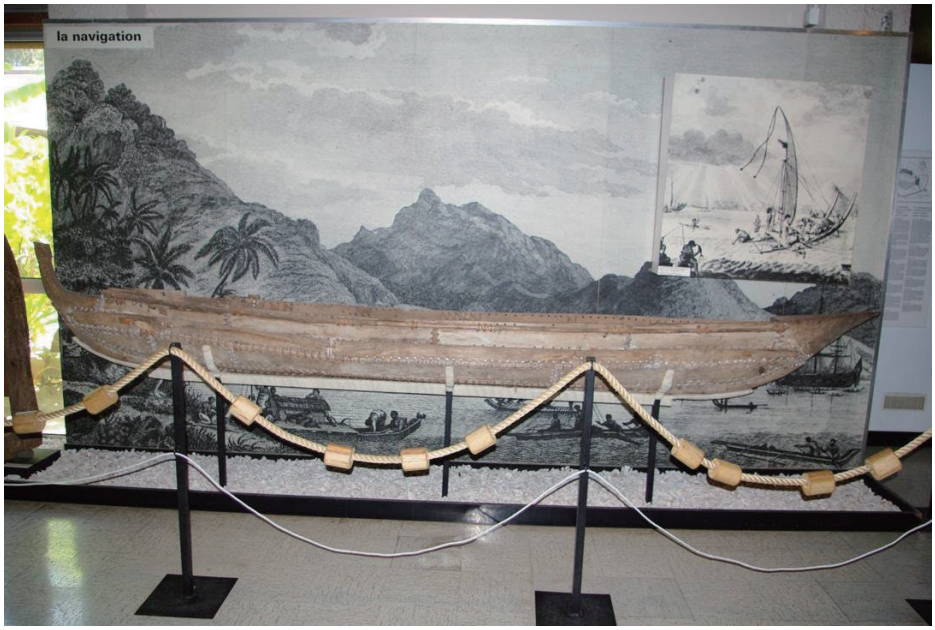

Figure 11. Canoe made by stitching driftwoods from Tuamotu (Tahiti Museum; photo by Akira Goto)

Marshall Islands, however, the lack of large trees has led to the development of stitched boats with hulls made of driftwood and other materials. The figure shows a canoe made by stitching driftwood from Tuamotu (Figure 11).
Chumash canoes may be in the same situation.

The Ryukyu Islands are qualitatively different islands, and their resources are not homogeneous. As suggested by Oceanic cases, on islands with limited terrestrial resources such as the coral islands, the technology to build boats must have been qualitatively different from that on high/volcanic islands.

In order to continue pursuing this question, we have started a new experimental voyage project on Kikai-jima Island, Kagoshima Prefecture, a raised coral island in 2021. Since large trees are not available on Kikai-jima Island, we have experimentally built a grass bundle boat using pampas grass available on the island. It was modeled after the Seri canoes of the Baja California (Figure12).

In the second experiment of last summer, adopting an idea by M. Des Lauriers (2005), we built a hybrid type of boat using driftwood collected at the beach as a bottom, and found it to be more stable and faster than a pure grass-bundle boat (Figure 13). We first made two small bundles of wood, and tied each bundle to the log. Then we made two big bundles and tied them to small bundles (Figure 14). The boat has a maximum speed of 3 knots, and we are planning to cross to the neighboring Amami-Oshima Island in the near future (Figure 15).

(2). The second issue is how to explain the arrival of not only humans but also relatively large animals such as Ryukyu wild boars and deer. Although dugout boats have high wave running ability, their narrow hulls are not suitable for transporting livestock such as pigs and dogs. If the main purpose is to transport, a wider raft would be more advantageous, or it is possible that the deck was built like the Polynesian double-canoe. Okinawa islanders, using *savani*, whose original form was dugout, made

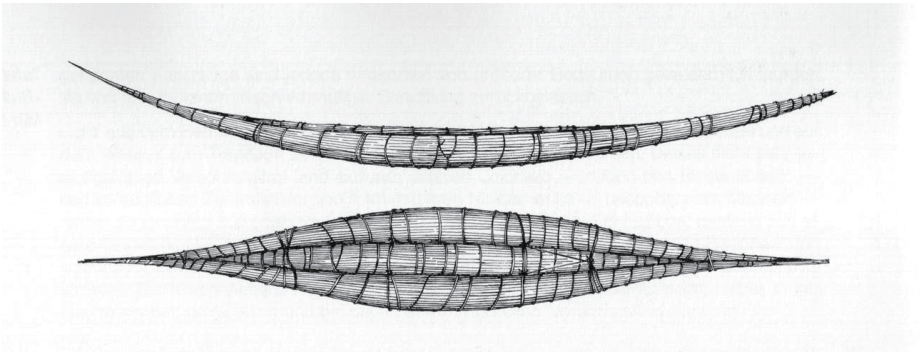

Figure 12. Grass-bundle boats of Seri Tribes, Baja California (Koch 1984: Abb.15 on page 209)

two to four hull boats to transport cattle and large sake pots to Kyushu Island (Figure 16)

(3). The navigation experiments were conducted only by paddling, but the possibility of use of sail remains. Although rafts with sails were recorded by explorers in South America, there is a controversy whether the first inhabitants of the New World who came from Eurasia used sails or they did not, since there is little evidence of indigenous sails in North America (e.g. Doran 1971). In relation to this problem, I would like to mention that only branch with leaves could serve as a sail on Halmahera Island, Indonesia (Figure 17), and I think that primitive sails woven with straw may have been possible, and that it is worthwhile to produce grass bundle boats and rafts with such sails.

(4). Finally, we should discuss the cognitive aspect. When the air is clear, the high mountains of Taiwan are visible from Yonaguni-jima Island. At the same time, Kaifu has confirmed that Yonaguni-jima Island is also visible from high mountains in Taiwan very occasionally (Kaifu et al 2020). Nevertheless, although the first people crossed the sea because they saw Yonaguni-jima Island, when they went out to sea, they could not see the island during the voyage. It takes at least two days from Taiwan to Yonaguni-jima Island, and so there is a time when the target is not visible. In that case, how did they maintain their course? In order to solve this question, it is necessary to refer to the Polynesian case of keeping course when the islands were out of sight.

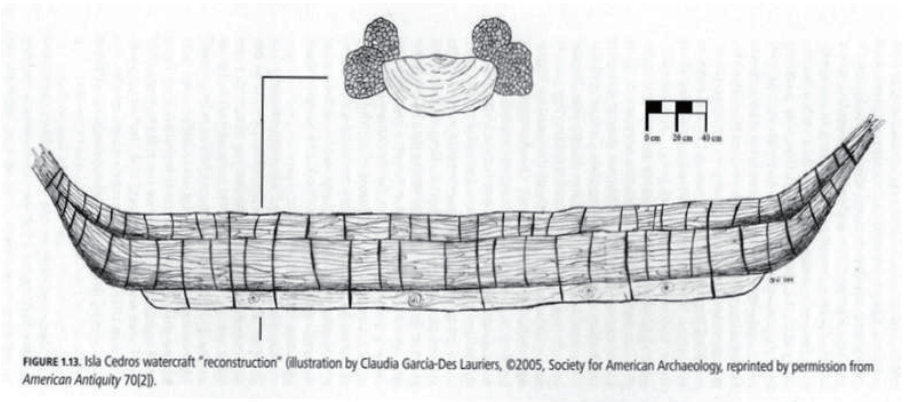

FIGURE 1.13. Isla Cedros watercraft "reconstruction" (illustration by Claudia García-Des Lauriers, ©2005, Society for American Archaeology, reprinted by permission from *American Antiquity* 70[2]).

Figure 13. A Hypothetical Hybrid Boat (Des Lauriers 2005: Figure 3)

Figure 14. A Hybrid Boat Experimentally made on Kikaijia Island, 2022 (photo by Akira Goto)

In conclusion, crossing the sea and reaching a new environment is a complicated problem. The 3D niche model that integrates the evolution of brain, technology, body will lead to new cognition is useful to solve how Out-of-Eurasia groups could trek the shore, cross the sea and migrate to invisible islands.

Figure 15. Experimental Paddling of the Hybrid Boat on Kikaijima Islnad, 2022 photo by Akira Goto)

Figure 16. Double-hulled *Sabani* with sail, Kerama Maritime Museum (photo by Akira Goto)

Figure 17. Canoe using Branch as a Sail, Halmahera Island (photo by Akira Goto)

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Part 2

Human Body and Cognition

Review of the Peopling of the Pacific: A Craniometric Perspective

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Abstract

This paper reviews what is known about the peopling of the Pacific, and more specifically the origins of Polynesians, based on the application of multivariate statistics to measurements recorded in crania from the Pacific-Asia region. Craniometric analyses demonstrate the presence of two great divisions, one that contains all the cranial series from Australia, Tasmania, and geographical Melanesia, and a second that includes cranial series from East Asia, Southeast Asia, and Polynesia. The results argue for a separate origin of the inhabitants of these two major geographical regions, a finding that is consistent with archaeological, historical linguistic, and genetic models. Further indicated is an ancestral Polynesian homeland in the islands of Wallacea. Recent work involving measurements recorded in the earliest Neolithic, and more recent Indigenous Taiwanese; and Pacific Island crania and mandibles are examined. The results obtained from craniometric analyses are further discussed in the context of evidence from recent genomic analyses. Morphometric data continue to reveal important insights into the peopling of the Pacific.

Keywords: Polynesian origins, multivariate statistics, craniometric data, Asia-Pacific, aDNA

Pacific Islands: Geography, Prehistory, and Linguistics

Although based on a faulty perception of Pacific Island culture history (Kirch, 2017), Dumont d'Urville's (1832) tripartite division of the Pacific: Melanesia ("dark islands"), Micronesia ("tiny islands"), and Polynesia ("many islands"), will be used chiefly as geographic referents here. Only the indigenous inhabitants of Polynesia, people who occupy the islands scattered over the central and eastern southern Pacific Ocean, share a common history and culture. The culture-history of inhabitants of Melanesia and Micronesia is more complicated.

Two more useful terms for understanding the prehistory of Pacific peoples based on historical linguistics and archaeology are Near Oceania and Remote Oceania (Pawley & Green, 1973). Near Oceania, comprises New Guinea, the Bismarck Archipelago and the Solomon Islands as far as San Cristobal Island (excluding the Santa Cruz Islands) in the western Pacific. Remote Oceania, encompasses all the Pacific islands north, east, and southwest of Near Oceania. The islands in Near Oceania are generally larger in size and in closer proximity to one another than those of Remote

Oceania. Because of their smaller size, wider distribution, and lack of island intervisibility, advanced navigational skills and transport of horticultural crops and domesticated animals was necessary for the successful colonization of Remote Oceania.

Human occupation of Near Oceania commenced approximately 40-50,000 years ago when the first humans crossed Wallace's Line in Island Southeast Asia, an imaginary boundary that runs between Borneo and Sulawesi and Lombok Strait in Indonesia that separates faunal species found in Australia and Papua New Guinea from those found in Southeast Asia (Kirch, 2017). A more recent major human colonization event brought the first people into previously unoccupied Remote Oceania beginning approximately 3200-3500 years BP. Modern Pacific Islanders derive from a mixture of these two highly divergent ancestral groups, those found in Near Oceania (the so-called "Papuans", a term used to describe the peoples of New Guinea, Bismarck Archipelago, and the Solomon Islands), and a later group that is more closely related to the inhabitants of mainland East Asia.

Focusing on Polynesia, the second more recent major expansion was associated with an eastward expansion of Austronesian-speaking people intertwined with the Lapita cultural complex, a cultural complex known for its distinctive dentate-stamped pottery, obsidian tools, horticulture, and maritime technology, and navigational skills (Kirch, 2017; Petchey et al., 2010). From its immediate origins in the Bismarck Archipelago, perhaps as early as 3350 BP, the Lapita culture expanded through the Solomon Island chain and other islands in eastern island Melanesia, eventually reaching Tonga and Samoa in western Polynesia (Petchey et al., 2010). After a pause of as much as a thousand years, these early Pacific navigators went on to colonize the rest of Polynesia reaching some of the more marginal islands (e.g., Easter Island, Hawai`i, and New Zealand) as late as 700-800 years BP (Hunt & Lipo, 2006). As reported by Hung et al. (2011), the first human expansion into Remote Oceania may have preceded the Lapita expansion by one to two centuries (approximately 3450 BP) with the colonization of the Mariana Islands in geographical Micronesia by way of the northern Philippines.

There is now major consensus among historical linguists, archaeologists, and physical/biological anthropologists that the ultimate origin of these two great colonization events was Southeast Asia. However, the timing and other details regarding the appearance and dispersal of Lapita culture and people, the focus of this review, are still widely debated. Several competing models have been advanced to explain the origin of Polynesians. The "Express Train" model argues that the ancestors of Polynesians, Lapita people, are linked to a relatively rapid expansion of Austronesian-speaking farmers who left mainland Asia or Taiwan approximately 4000 years ago, people who mingled little with indigenous people they encountered along the way in Near Oceania (i.e., Papuans) before going on to colonize Remote Oceania and Polynesia within the last 3000 years (Bellwood, 2023). A genome-wide study of ancient DNA from prehistoric Polynesians supports this scenario (Skoglund et al., 2016).

An alternative model, the "Slow Boat" model, originally based primarily on Y-chromosome data, proposes the proto-Polynesians emerged within Island Southeast Asia as early as 20,000 BP and then moved slowly eastward into Remote Oceania beginning approximately 12,000 BP resulting in

significant admixture with the people of Near Oceania before expanding further eastward into Polynesia (e.g., Oppenheimer & Richards, 2001). Alternative models suggest maritime contacts, some as early as 12,000 years ago (Solheim, 2006), between the peoples of Southeast Asia and Near Oceania. The Triple I model emphasizes the combination of the intrusion of new people and ideas along with integration with the indigenous inhabitants of Near Oceania as well as the innovation of new and unique elements in this region (Green, 1991). Other models have been proposed (see e.g., Kirch, 2010).

Craniometry and Biological Distance Studies

Studies of human skeletons, which provide the most direct evidence for examining the biological relationships of past populations, have a long history in anthropology (Pietrusewsky, 2014, 2019). Studies of cranial morphology, most notably traditional morphometrics (craniometry), continue to maintain a central role in modern biological distance (biodistance) studies. The objectivity of recording cranial measurements, their conservative nature, and amenability to sophisticated multivariate statistical procedures have contributed to their continued popularity in biodistance studies. Further, unlike DNA molecules, cranial measurements are not subject to decay with time. While morphometric variation is subject to nongenetic or environmental influences, there is general consensus that cranial variation is largely shaped by neutral evolutionary processes thus allowing this category of variation to be used as a proxy to genetic data (von Cramon-Taubadel, 2014). The demonstration of a significant genetic component and strong geographic patterning of morphometric variation in humans have further strengthened the use of this category of variation in studies that examine population structure and history.

Multivariate Statistics

Multivariate statistics comprise a family of related mathematical procedures that allow the simultaneous analysis of multiple interrelated variables recorded in individuals from one or more groups. Among the most commonly used multivariate procedures for analyzing traditional and geometric morphometric variation are principal components analysis (PCA), discriminant function (canonical) analysis, and Mahalanobis distance. Various clustering algorithms (e.g., Unweighted Pair Group Method with Arithmetic mean-UPGMA) and other scaling techniques are useful for visualizing the results of multivariate analyses.

Polynesian-South American Relationships

A study by Pietrusewsky and Ikehara (2001) that applied multivariate statistics to craniometric data failed to find evidence for an Amerindian origin of Polynesians. The cranial series from Polynesia and Fiji were well differentiated from South/North America and Greenland (Inugsuk Eskimo) cranial series. This and other analyses of craniometric data corroborate a Polynesian homeland in Southeast Asia, not one in the Americas (e.g., Howells, 1990; Stefan, 2001).

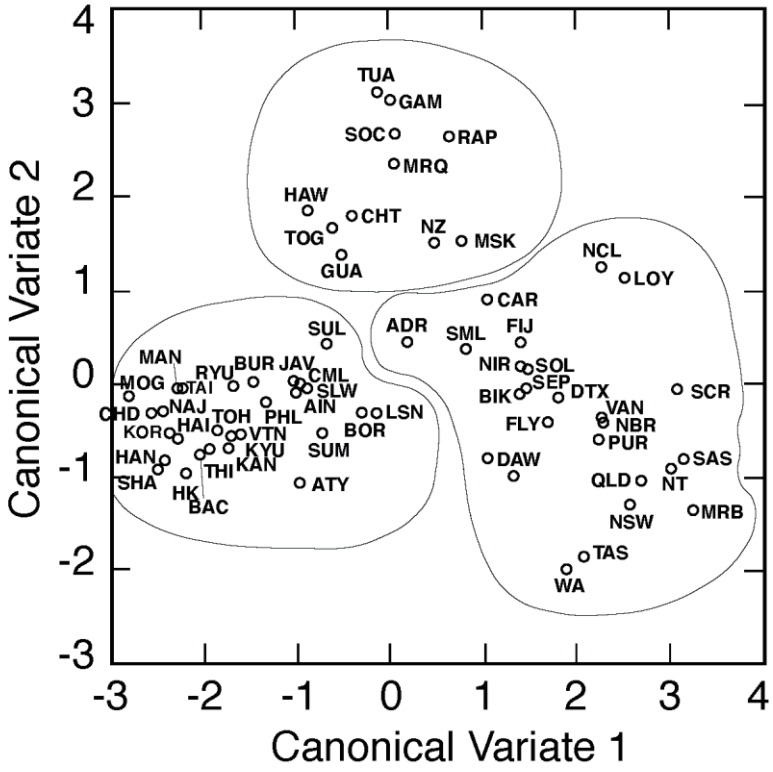

Figure 1. Canonical plot of 63 group means on the first two canonical variates that result from applying stepwise discriminant function (canonical) analysis to 27 measurements recorded in 2,805 male crania from all parts of Oceania, Australia, Southeast Asia and East Asia. [Permission to use this figure, originally published in Pietrusewsky (2005), was given by RoutledgeCurzon (London)]

However, there is convincing evidence for Polynesian contact with South America through the identification of aDNA and dating of pre-Columbian chicken bone from a site in south-central Chile (Storey et al., 2007). Following this study, six adult crania from Mocha Island off the coast of Chile, described as possessing Polynesian morphological features, were analyzed using linear discriminant (LDA) and nearest neighbor discriminant analyses (NNDA) (Matisoo-Smith & Ramirez, 2010). Four of the crania in the study classified with high probability as South American, one as a Buriat (Siberia), and one more as a Latte Period female from Guam. While the authors suggest there is evidence for possible Polynesian contact with South America, the timing and consequences of this contact remains unknown. A provocative new study, that sampled genes of modern peoples living across the Pacific and along the South American coast, argues Polynesians and Native Americans made contact some 800 years ago well before the arrival of Europeans in the Americas and before the settlement of Easter Island (Rapa Nui) (Ioannidis et al., 2020). Fatu Hiva in the Marquesas was cited as the earliest location for contact between Native Americans and Polynesian. Again however, it could not be determined if

journeys made by Polynesians, Native Americans, or both, were responsible for the observed results of this DNA study.

Pacific-Asia Relationships

In order to place Polynesians in a boarder context, the results obtained from applying multivariate statistical procedures to 27 cranial measurements recorded in a total of 2,805 male crania representing a 63 Asian-Pacific groups are presented (Pietrusewsky, 2005).

A plot of the group means for 63 male groups on the first two canonical variates generated by stepwise discriminant analysis (Figure 1) reveals three distinct clusters. The first includes all the cranial series from Australia, New Guinea, and geographical Melanesia. A second cluster includes all the cranial series representing Polynesia and two from Micronesia (Guam and Marshall-Kiribati). Cranial series from Southeast Asia and East Asia form a third major constellation. The cranial series from the Southern Moluccas, and Admiralty Islands occupy an intermediate position between the largely Polynesian and Australian-Melanesian cranial series. One of the cranial series from Micronesia (Caroline Islands) falls within the Australian-Melanesian grouping.

Applying the UPGMA clustering algorithm to Mahalanobis distances results in the dendrogram in Figure 2. Again, the primary division is between the cranial series from Australia and Melanesia and another that contains all the cranial series from Polynesia, Southeast Asia and East Asia. Within these major divisions there is internal differentiation that generally mirrors geography. It is also worth noting that New Zealand Māori (Polynesia) and Southern Moluccas (Island Southeast Asia) cranial series form a cluster, one that ultimately connects with the Australian-Melanesian branch in this diagram suggesting possible Papuan influence in Polynesia. Guam, representing the Mariana Islands, groups with Hawaii and Tonga-Samoa while two other cranial series from Micronesia (Caroline Islands and Kiribati) cluster with New Ireland, Solomon Islands and other Melanesian cranial series.

Australia/Melanesia versus Southeast/East Asia and Remote Oceania

The presence of two major divisions demonstrated in these results supports archaeological, linguistic, and genetic models that the indigenous inhabitants of Australia, Tasmania, and geographical Melanesia share a common origin that is unrelated to that for the modern inhabitants of Southeast Asia, East Asia, and Polynesia/Micronesia. The sharp separation between Polynesian and Australian-Melanesian series further reinforces archaeological and linguistic models that hypothesize an earlier colonization of Australia, New Guinea, and neighboring regions of Near Oceania and a much later colonization that eventually led to the peopling of previously uninhabited Remote Oceania.

Island Southeast Asia/Polynesian Homeland

The results of craniometric analyses point to an ancestral Polynesian homeland in East/Southeast Asia and not one within geographically adjacent Melanesia. The connection between

New Zealand Māori (Polynesian) and the Southern Moluccas (Island Southeast Asia) cranial series supports a probable Island Southeast Asian homeland for Polynesians. With the exception of the inclusion of the New Zealand Māori series in the Australian clade, there is little to support admixture between the ancestors of the Polynesians and the indigenous inhabitants of Melanesia or the Bismarck Archipelago region of the Pacific. Further, there is no support for a close biological connection between Polynesians and the Ainu series from Japan advocated by some researchers (e.g., Brace et al., 1990). A biodistance study of mandibles, including some from the SAC Lapita site on Watom Island in the Bismarck Archipelago, supports a Polynesian homeland in Wallacea, a group of mainly Indonesian islands that lie between the Sunda and Sahul continental shelves (Pietrusewsky, et al., 2014).

Taiwan Connections

The results of a craniometric analysis that compared five Indigenous Taiwan groups with modern, and near modern crania from the Pacific-Asia region found only the Iron Age series from Taiwan, Shihsanhang site, had a biological connection to Polynesian cranial series (Pietrusewsky & Chang, 2003). The remaining Taiwan Indigenous groups included in this study were found to be more closely related to series from East/Northeast Asia and Southeast Asia.

Mandibular Data- Earliest Neolithic Skeletons from Taiwan

A biological distance analysis involving mandibular measurements found that the earliest Neolithic (Nankuanli East site) series from Taiwan were closest to Ryukyu Islands, and other mandibular series from East and North Asia and showed little or no connection to the inhabitants of Remote Oceania, especially Polynesians (Pietrusewsky et al., 2016). The mandibles associated with the Iron Age Shihsanhang series, on the other hand, while generally related to northern Asian series (e.g., Siberia, Mongolia), also demonstrated connections with some of the Pacific Island series, specifically Hawaii, New Zealand, and the Northern Marianas Islands. Overall, Neolithic and Iron Age Taiwanese were observed to be more closely related to several North Asian groups than to Oceania.

DNA Studies

A study by Skoglund and colleagues (2016), which examined ancient DNA from early Lapita skeletons from Vanuatu and Tonga (3000 to 2500 BP), revealed that the first people in Remote Oceania and Polynesia were distantly related to Neolithic southeastern Chinese and, more closely related to modern and ancient Indigenous Taiwanese and present-day groups found in north-central Philippines. Further, unlike the results of earlier DNA studies, this study showed little Papuan ancestry among Remote Oceanians. The authors argued that the presence of Papuan ancestry observed among modern people of Remote Oceania is likely due to secondary expansion of Papuan people, who trace

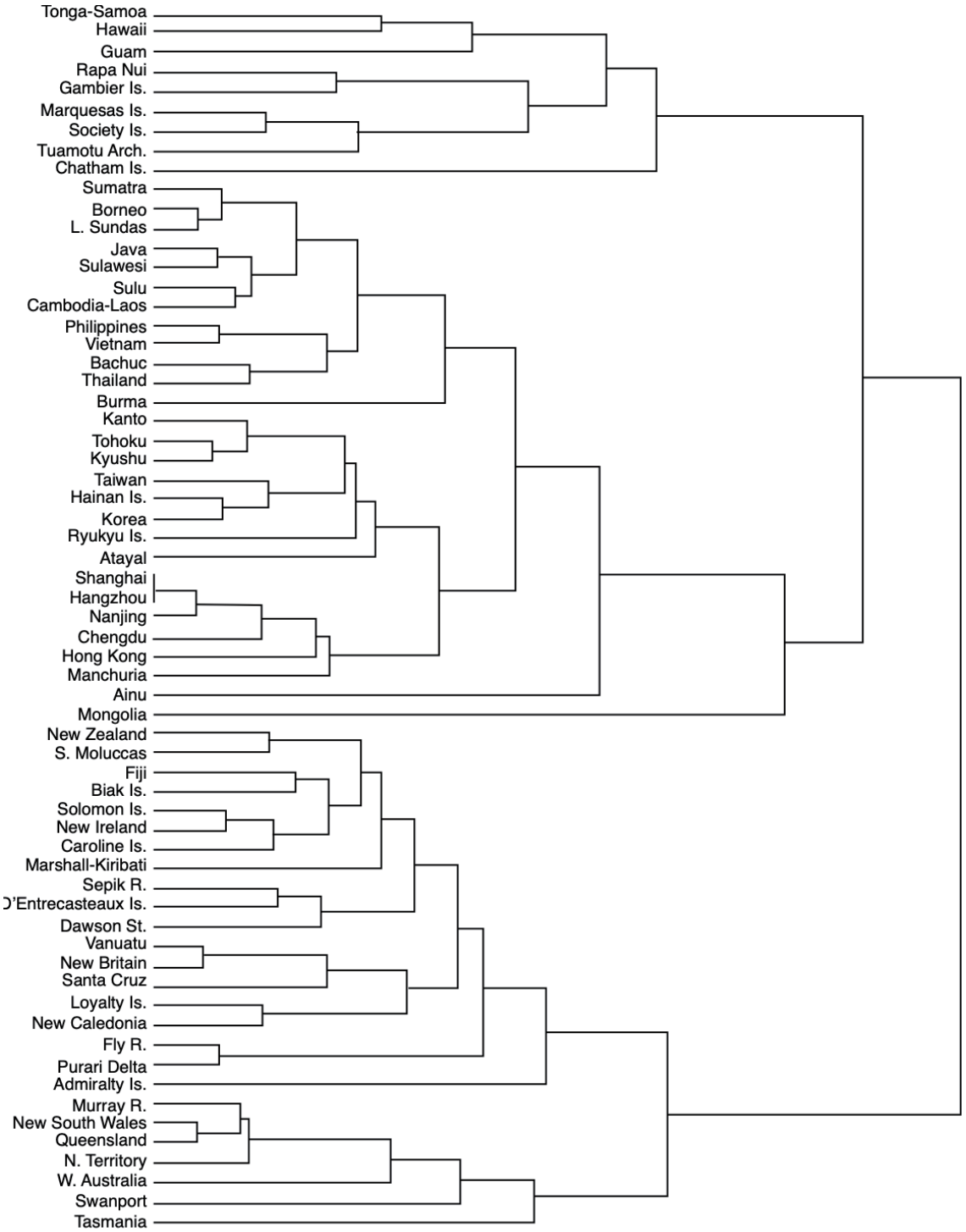

Figure 2. The diagram of relationship that results from applying the UPGMA clustering algorithm to Mahalanobis' distances based on 27 measurements. Two major divisions represented are those that include 1) Southeast Asian, East Asian, and Polynesian cranial series, 2) Australian, Tasmanian, New Guinea and the Melanesian cranial series. [Permission to use this figure, originally published in Pietrusewsky (2005), was given by RoutledgeCurzon (London)]

their ancestry to New Guinea, the Bismarck Archipelago, and the Solomon Islands, into Remote Oceania. Another genomic study, involving the earliest Lapita skeletons form Vanuatu and elsewhere in the South Pacific, demonstrated Papuan expansion into Remote Oceania beginning circa 2,500 BP, an expansion that resulted in the almost complete replacement of Lapita-Austronesians in Remote Oceania (Posth et al., 2018). A follow-up study (Lipson et al., 2020) confirmed the results of earlier genomic analyses that reported the ancestry of the modern inhabitants of Vanuatu was influenced by three major migrations of people over the last 3000 years, including East/Southeast Asian, Papuan, and Polynesian-derived sources.

The population history for Micronesia, also part of Remote Oceania, is more complicated than that for Polynesia. A study that analyses ancient and modern DNA revealed five migratory streams into Micronesia (Liu et al., 2022). Interestingly, the people of the Mariana Islands may derive all of their precolonial ancestry from East Asian sources, making them the only Remote Oceanians without Papuan ancestry.

Comparisons of Craniometric and DNA Evidence

Analyses of craniometric and DNA data demonstrate similarities and differences in reconstructing the population history of the Pacific. Craniometric and DNA evidence demonstrate a dichotomy between inhabitants of Near and Remote Oceania, suggestive of separate origins. There is further agreement that Polynesians are distantly related to East and Southeast Asians. Analyses of craniometric and DNA data also demonstrate that the biological relationships among Micronesians are complicated with evidence of Papuan, Polynesian and East Asian influence in this region of Remote Oceania.

Among the differences, craniometric results point to an eastern Island Southeast Asian homeland for Polynesians rather than Taiwan and/or East Asia as advanced by recent analysis of DNA. While most DNA studies indicate a minimum of twenty-five percent Papuan ancestry in present-day Oceanians, biological distance studies involving cranial measurements find little evidence of Papuan ancestry in Polynesians.

Conclusions

The main focus of this review is to examine biological relationships among the inhabitants of the Pacific and the origins of Polynesians, mainly through the application of multivariate statistics to measurements recorded in crania and mandibles. Limited comparisons with evidence from recent modern and ancient DNA are further made.

Traditional craniometric and genetic data agree that there is a sharp differentiation between the inhabitants of Australia and geographical Melanesia and those living in East/Southeast Asia, Polynesia and Micronesia, a distinction that implies separate origins for the indigenous inhabitants of these two regions.

The results of craniometric and DNA analyses also agree that Polynesians are distantly related to East and Southeast Asians. Biodistance studies using craniometric data further suggest an ancestral Polynesian homeland in Island Southeast Asia or Wallacea, a group of mainly Indonesian islands stretching between the Asian and Australian continental shelves. The Southern Molucca, or Maluku, Islands (e.g., Buru and Seram) in eastern Indonesia reveal salient connections with New Zealand Māori in analyses of traditional craniometric data. The sharp differentiation between Polynesian and the present-day inhabitants of island Melanesia, found in the results of analyses of both craniometric and DNA data, suggests that was little or no admixture between the ancestors of Polynesians and the people they encountered as they passed through island Melanesia on their way to Polynesia. The population history of Micronesia, which includes some of the earliest inhabitants of Remote Oceania, is more complicated showing influence from Papua New Guinea, Polynesia, and East Asia in results based on craniometric and genetic analyses. Additional samples from regions of the Pacific not included in previous analyses would greatly improve our understanding of the population history of the Pacific. Finally, this review demonstrates the great utility of traditional morphometrics for examining the population history of past groups such as those of Polynesia and Remote Oceania.

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“Pacific Paradox” Revisited: Using Osteometric Data

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Ethical considerations

The movement to repatriate indigenous peoples’ remains is becoming increasingly widespread. Anthropologists worldwide acknowledge the demand for the repatriation of human remains as a human rights-based claim, with the goal of holding researchers accountable, making up for past injustices, and restoring humanity.

In my presentation entitled “Pacific Paradox Revisited: Using Osteometric Data” at the International Symposium in Honolulu Hawaii held on March 2, 2023, I shared my analysis of various Polynesians’ postcranial metric data which were collected by an anthropologist from the American Museum of Natural History, New York City, NY, and the National Museum of Natural History (Smithsonian Institution), Washington D.C. in 2005. Recently, it has become encouraged to work with native descendant communities who have an interest in learning about their own history of their ancestors. However, I have not asked permission from the descendant communities of Polynesians to use and study this data.

Legally, I can publish my manuscript of the proceedings. However, the use of data without obtaining permission from the descendant communities will perhaps be questioned in this climate. Also, this study using data from Polynesian ancestral remains may possibly offend the indigenous people and their descendant communities.

Now that I am acquainted with Dr. Edward Halealoha Ayau, Hui Iwi Kuamo‘o, the Native Hawaiian organization’s executive director, and the federal NAGPRA Review Committee, I have learned about their 33-year-long repatriation efforts. Currently, they are requesting the repatriation of unlawfully acquired ancestral remains housed in one Japanese University to their home.

My goal is to interact with lineal descendants, ancestral communities, descendant communities, and communities of care to gain knowledge on how to handle human remains and data in an ethical and respectful manner.

In conclusion, I choose not to publish my research in this case.

Lunch time at the conference

Unique Hemoglobin Dynamics in Female Tibetan Highlanders

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Hypoxic Adaptation in Tibetan highlanders

There are more than 140 million people living above 2500 m worldwide (Moore, 2001). In Tibetan highlanders, Hb concentrations doesn't increase even at very high altitudes (over 4500 m), and it remain the same or are only slightly elevated above the sea-level mean. These observations suggest that high-altitude erythrocytosis is not an adaptive response among Tibetan highlanders (Beall, 2006; Erzurum et al., 2007). Accordingly, Moore et al. (Moore, Niermeyer, & Zamudio, 1998) argued that Tibetans are better adapted to high altitudes than Andeans because adaptation is a time-dependent process, and Tibetans have inhabited high altitudes for 25,000 years or possibly even 50,000 years, while Andeans have inhabited high altitudes for only 10,000 years (Lu et al., 2016; Ossendorf et al., 2019; Rademaker et al., 2014; Zhang et al., 2018). Even among Tibetan highlanders who have acquired such a hypoxic adaptation, a slight increase in Hb is seen as the altitude increases, and some people are classified as having polycythemia (Tashi et al., 2014). In the case of Tibetan highlanders, it has been reported that Hb concentrations may also increase due to an imbalance of the hypoxic adaptation mechanism resulting from aging and changes in eating habits (Okumiya et al., 2016). However, Hb levels generally tend to decrease with aging (Mahlknecht & Kaiser, 2010). Similarly, it is assumed that the ability of Tibetan highlanders to synthesize Hb decreases with aging.

Tsarang village, Mustang district, Nepal, used to be in the Mustang Kingdom (Figure 1). The ancestors of Loba people living in Mustang is same with other Tibetans (Darnal, 2017). Moreover, the Mustang Kingdom restricted interactions with outside populations for a long period of time (Erzurum et al., 2007). Therefore, by conducting a survey in Tsarang, where the population retains the genetic characteristics and has not yet been strongly influenced by modernization and changes in eating habits, we sought to clarify the pure relationship between aging and Hb levels in a hypoxic environment among Tibetan highlanders (Arima et al., 2021).

Field survey in Tsarang

We conducted health checkups and questionnaire survey for Tsarang residents in 2017. Age, body mass index (BMI), SpO_2 (%), systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), grip strength (grip, kg), Hb (g/dL), HbA1c (%), and vascular diameter (VD, mm) were the variables used for analysis. Pulse pressure (PP, mmHg) was calculated as the difference between the SBP and the DBP. Increased pulse pressure, which is systolic blood pressure minus diastolic blood pressure, is recognized as a risk of arteriosclerosis and cardiovascular disease (Stembridge et al., 2019).

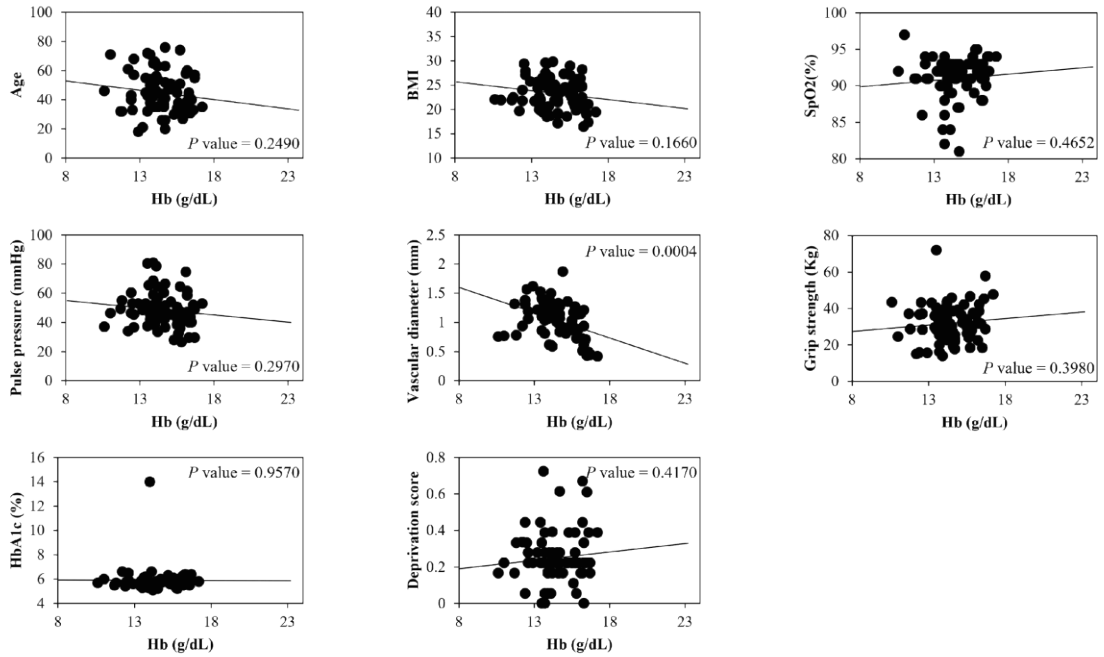

Figure 1. Linear regression analysis of Hb and each variable in males.
Each variable was plotted against the Hb concentration in male participants. The p value indicates the result of linear regression analysis of Hb and each variable. Only vascular diameter was found to be significantly correlated with Hb.

The multidimensional poverty index (MPI) developed by the United Nations Development Program was adopted to evaluate the poverty level of residents. The deprivation score (D score), representing the poverty level of individuals, was calculated using the three dimensions of education, health, and standard of living. We used D score as poverty index of individuals in this study. Poverty was defined as a D score of 0.33 or higher.

Anthropometric and biochemical characteristics of participants by sex

In this study, we focused on Hb; the data from 76 males and 103 females as final objects were used. A summary of the medical examination results, which comprises the values of 10 items including age, body mass index (BMI), oxygen saturation (SpO_2), systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), vascular diameter (VD), hemoglobin (Hb), glycated hemoglobin (HbA1c), and deprivation score (D score), is shown in Table 1. There was no age difference between the sexes (p = 0.4238). Additionally, BMI, SpO_2, HbA1c, and D scores did not differ significantly between males and females. There were significant sex-based differences in SBP, DBP, PP, VD, and Hb, and these values were higher in males than in females.

Sex	Male	Female	
n = 179	n = 76	n = 103	p value
Age	44.66±1.55	46.47±1.66	0.4238
BMI	23.00 (21.05 – 26.20)	23.10 (20.45 – 25.40)	0.5872
SpO_2	91.50 (90.00 – 93.00)	91.00 (89.50 – 93.00)	0.6062
SBP	126.0 (116.4 – 139.5)	113.0 (106.8 – 126.2)	<0.0001
DBP	78.50 (72.38 – 85.75)	74.50 (66.75 – 80.50)	0.0031
PP	47.50 (42.00 – 53.00)	42.00 (35.50 – 47.00)	0.0001
VD[a]	1.08 (0.83 – 1.26)	0.98 (0.74 – 1.13)	0.0148
Hb	14.50 (13.70 – 15.70)	13.10 (12.30 – 14.10)	<0.0001
HbA1c[b]	5.80 (5.60 – 6.00)	5.85 (5.70 – 6.10)	0.0516
D score[c]	0.22 (0.17 - 0.28)	0.22 (0.22 – 0.33)	0.2251

Table 1. Anthropometric variables, biochemical data and poverty index by sex.
Values are presented as the mean ± SE or median (1st quartile–3rd quartile). Data were analyzed by Student's t-test or the Wilcoxon ranksum test. The D score was considered poor at ≥ 33.3%.
a: 2 participants could not be measured due to severe deformation of finger joint or machine troubles
b: 14 participants could not be measured due to blood viscosity or machine troubles.
c: 2 participants did not answer the question with questionnaire.

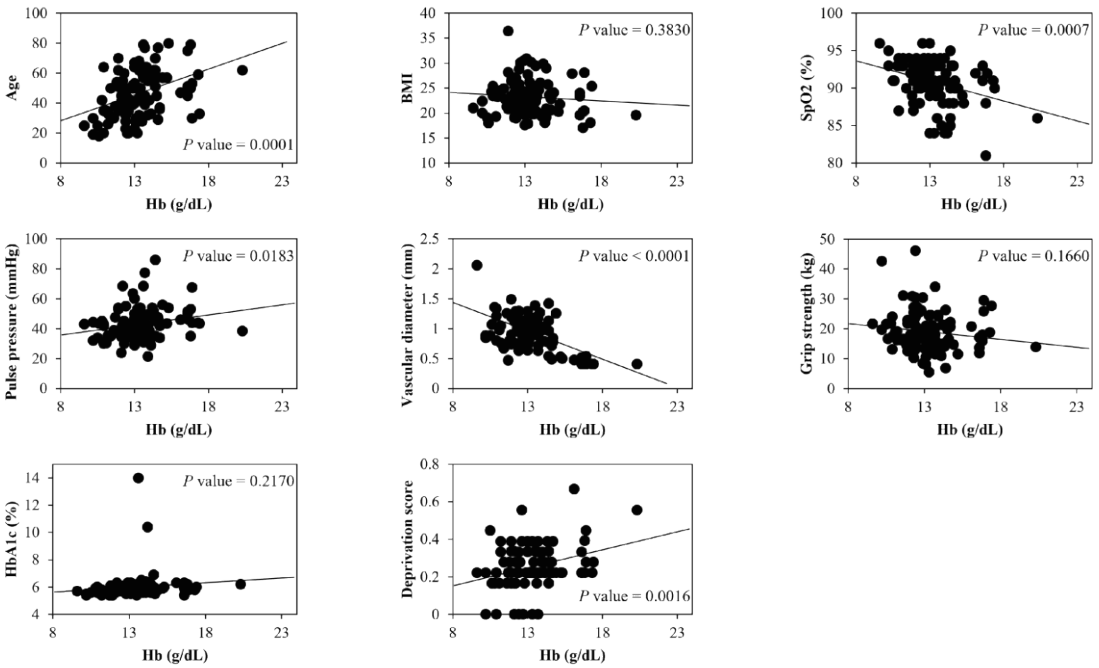

Figure 2. Linear regression analysis of Hb and each variable in females.
Each variable is plotted against the Hb concentrations of female participants. The p values indicate the results of the linear regression analysis of Hb and each variable. Age, SpO_2, pulse pressure, vascular diameter and deprivation score were significantly correlated with Hb.

Variables	Male				Female			
	Estimate	Std. error	t value	Pr(>|t|)	Estimate	Std. error	t value	Pr(>|t|)
Intercept	-0.022119	0.120431	-0.184	0.8549	0.013247	0.073509	0.18	0.8574
Age	-0.176713	0.147861	-1.195	0.2368	0.239542	0.118526	2.021	0.0465
BMI	-0.030468	0.147861	-0.22	0.8270	-0.068577	0.079534	-0.862	0.3910
SpO_2	0.005151	0.143904	0.036	0.9716	-0.109567	0.095932	-1.142	0.2567
PP	-0.035679	0.131199	-0.272	0.7866	0.164115	0.080165	2.047	0.0438
HbA1c	0.067793	0.128064	0.529	0.5985	0.025044	0.08176	0.306	0.7601
Grip	0.055435	0.124306	0.446	0.6573	-0.008568	0.083129	-0.103	0.9182
D score	0.015942	0.123832	0.129	0.8980	0.229531	0.07571	3.032	0.0032
VD	-0.401727	0.127334	-3.155	0.0025	-0.551756	0.074537	-7.402	<0.0001

Table 2. Results of the multiple regression analysis with Hb as the objective variable.
Only vascular diameter was found to be significantly correlated with the Hb value in males. In females, age, pulse pressure, vascular diameter and deprivation score were strongly correlated with the Hb value.

Hb dynamics and related variables

The correlations between Hb and other variables were examined by linear regression analysis. The results for males are shown in Fig 1, and the results for females are shown in Figure 2. Only VD was associated with the Hb level in males. In females, age, PP, and the D score were positively correlated with Hb, and SpO_2 and VD were negatively correlated. Based on these results, a multivariate analysis was performed to detect the variables correlated with the Hb value that were not influenced by confounding factors (Table 2). SBP and DBP were excluded as explanatory variables, and only PP maintained an association with blood pressure. In males, only VD was correlated with the Hb value, but in females, age, PP, D score, and VD were strongly correlated with the Hb value.

Conclusions

We identified new hemoglobin dynamics among Tibetan highlanders. The Hb level in female inhabitants of Tsarang did not decrease but rather increased with increasing age. As seen in these Hb dynamics, there may be sex-based differences in the optimal adaptive mechanism in Tibetan highlanders with regard to their hypoxic environment.

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Mutual Permeation Model of Things, People, and the Supernatural: Insights from Jomon Pottery and *Dogu* Figurines

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The value scale and worldview of the people of the civilization-forming period differed significantly from the worldview of modern people, which is based on subject-object dualism and mind-body dualism. Analysis of words and concepts in ancient Japanese literature reveals that ancient Japanese islanders before the 8th century considered non-humans autonomous entities equal to humans. The worldview can be represented in a model in which supernatural, natural, and human society mutually permeate each other. According to this model, pottery and dogu clay figurines in the Jomon period are considered to be hybrids that emerged at the center of the intersection of the members of the three societies. Clay, clay spirits, and humans are all involved in producing these artifacts. The body of the clay and the body of the potter physically intermingle by touching each other, the spirits of both become mutually infiltrated and the subject and object mutually interchange as the production proceeds. It is essential to recognize that this is entirely different from our method of making artifacts, in which people unilaterally control materials. The pottery and clay figurines produced by such mutual permeation of three parties are not only twins of clay but also children of clay spirits and human beings. A new understanding of the artifacts is obtained by examining the Jomon pottery and clay figurines from the perspective of the mutual permeation model. As the pottery and clay figurines are twins made from clay, which is of the same rank as humans, void images of the human, or animal, body, i.e., cranium, digestive organs, and womb, are projected on them. These were superimposed on the void images of containers to produce a variety of pottery and clay figurines for more than 10,000 years. They all consist of a combination of the above four void images. The analysis suggests that pottery and clay figurines are easily fused as they are closely related as twins in the Jomon worldview.

What the word “mono” represents in ancient period and now

The value scale and worldview of the people in Ancient Japan are very different from those of modern people, whose worldview is based on subject-object dualism and mind-body dualism. In modern Japanese, "mono" means either a person as a subject or an object (Figure 1). It rarely means supernatural beings and spirits. The usage of "mono" in the 8th century encompasses the following

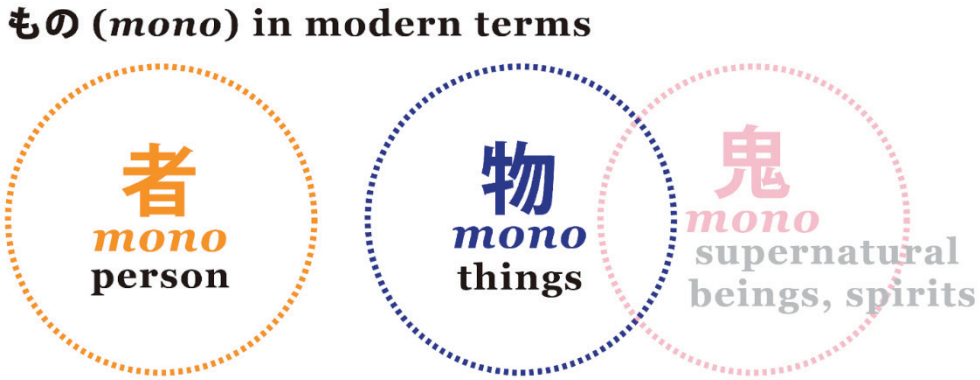

Figure 1. The meaning of "mono" in modern Japanese (Source: Takumi Ishii).

three (Figure 2):

1. mono: things
2. mono: supernatural beings, spirits
3. mono: person

It suggests that the people of the ancient Japanese archipelago did not separate subjects and objects as modern Japanese do.

Mutual permeation model of things, people, and the supernatural

Unlike the modern hierarchical understanding of the world with humans at the top, the ancient Japanese islanders had a worldview consisting of the following three societies (Figure 3).

1. a supernatural society: countless supernatural beings
2. a natural society: plants, animals, and other natural things and phenomena
3. human society.

The three societies are closely related, borderless, and mutually infiltrating. Non-humans are considered autonomous entities equal to humans. Although this model may not be directly applied to prehistoric people, it helps us to understand Japanese prehistoric pottery and clay figurines from a new, more appropriate perspective, as one of the hybrids located at the center of the intersection of the members of the three societies.

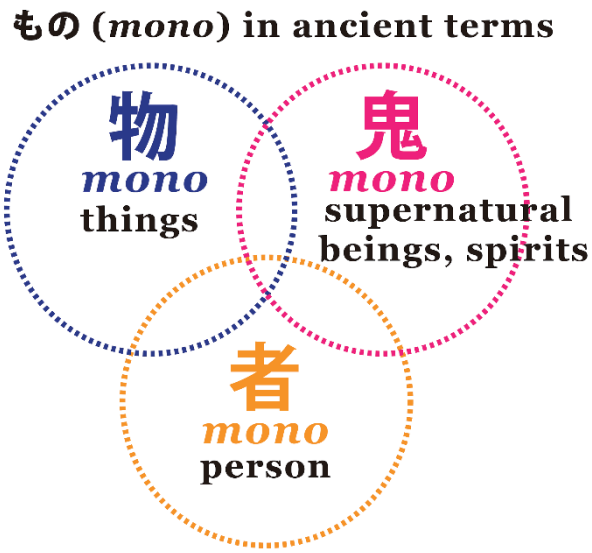

Figure 2. The meaning of "mono" in ancient Japanese (Source: Takumi Ishii).

Pottery ≒ Clay figurines

Pots and figurines are twins with clay as their mother. Clay, the spirit of clay, and the potter are each involved in the production proactively (Figure 4).

Ethnography of the Pueblo pottery making: Clay or clay spirit tells the potter what it wants, and the potter makes the pottery accordingly. While kneading the clay, the potter repeatedly interacts with the clay to make pottery. The body of the clay and the body of the potter physically intermingle by touching each other; both spirits mutually infiltrate, and production proceeds as subject and object continuously interchange (Tokui 1990). Such a sense differs from the currently popular understanding of making artifacts, in which the person unilaterally controls the material.

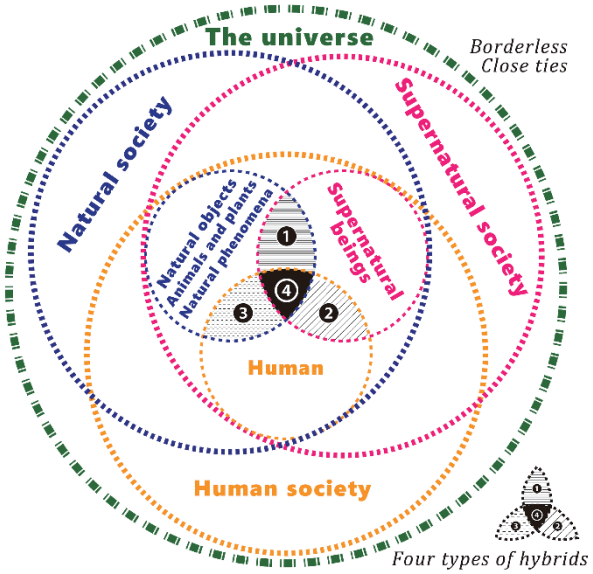

Figure 3. Source: Takumi Ishii.

The clay ≒ People

People dug clay from the earth to produce pottery and figurines with it. People eat foods stewed in pots to survive. Such experiences make people think that clay is a part of the human body and that humans are a part of clay. Clay and human beings are connected through the earth. Clay is not an object to be controlled by human beings, but clay and humans mutually permeate each other physically and psychologically (Figure 5).

The myth that man was created from earth or clay is distributed worldwide. Dead are often buried in the earth. This cycle of life is essential to understand pottery and clay figurines.

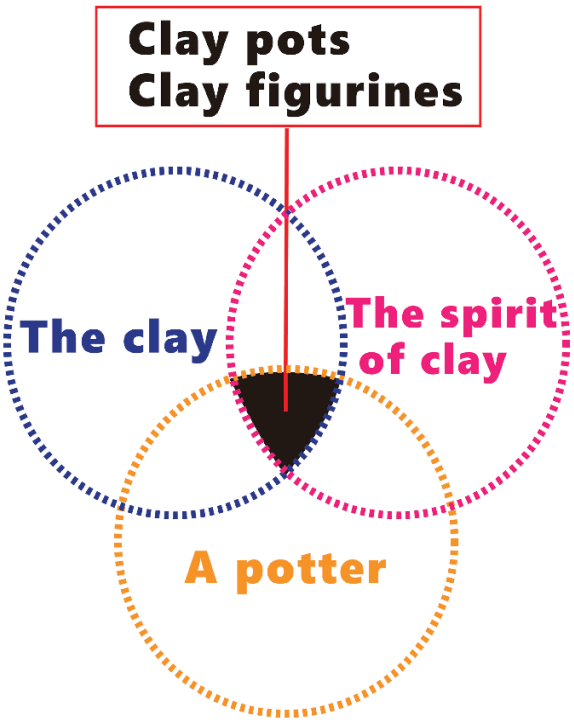

Figure 4. Source: Takumi Ishii.

Another critical aspect of the relationship between clay and humans is the circulation of digested material between humans and pottery through the earth. The digested food from the pottery goes through the human digestive system and returns to the earth like the buried dead. Clay excavated from the earth is transformed into pottery or figurines, thus establishing a cycle of pottery and people through the earth (Figure 6). Strictly speaking, this seems irrational because decomposed organic matter does not immediately turn into clay, but it aligns with the concept of "original oneness" held by the northern hunter-gatherers (Irimoto 2010).

Figure 5. Source: Takumi Ishii.

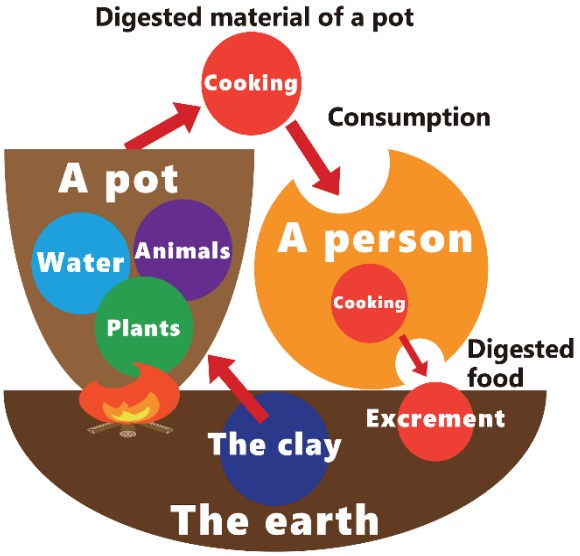

Figure 6. Source: Takumi Ishii.

A combination of void images

So far, we have considered the relationship between clay, people, pottery, and figurines based on the Mutual Permeation Model. Next, we want to examine how these are expressed in the Jomon period's pottery and clay anthropomorphic figurines (*dogu*). The image of a void or container is the key to understanding the long-term development of the Jomon pottery and *dogu* figurines. The human (woman) body has three main voids: cranium, digestive organs, and womb. These were superimposed on the images of containers to produce a variety of pottery ≒ *dogu* figurines over more than 10,000 years. Because of the close relationship between pottery and clay figurines, they easily fused with each other. We tend to see pottery and clay figurines as mere tools. From this point of view, many people would consider the hybridization of pottery with figurines to be a case of anthropomorphism. However, the Mutual Permeation Model suggests that people consider them as subjects of action; therefore, it is natural that each has various unique voids.

Jomon pottery and *dogu* figurines develop in tendem

Over about 10,000 years, the forms of the twin Jomon pottery and clay figurines have changed

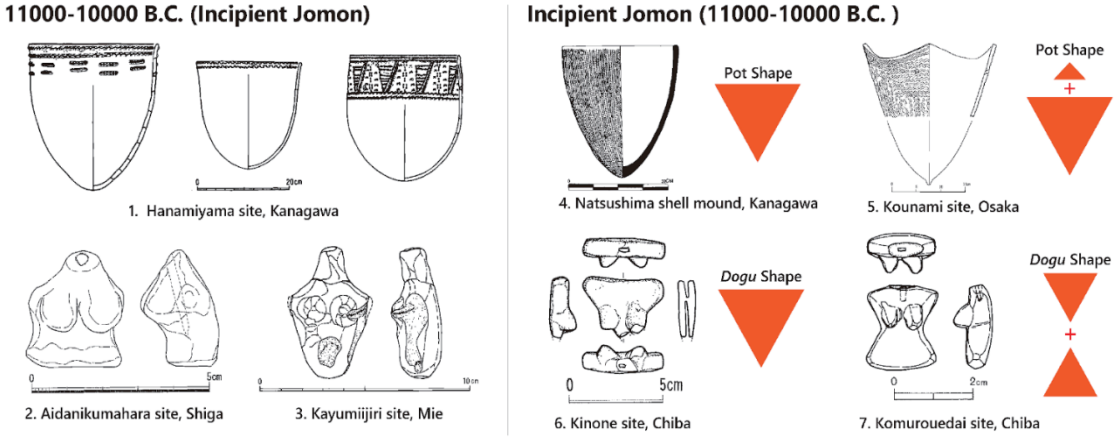

Figure 7. Jomon pottery and Dogu figurines: Incipient and Initial Jomon Period (Source: No. 1, Yokohama 1995. No. 2, Shiga 2014. No. 3, Mie 1997. No. 4, Sugihara 1964. No. 5, Higashi-Osaka 1987. No. 6, Funabashi 1991).

in tandem. The earliest Jomon pottery and clay figurines do not represent faces and limbs. The figurines represent only the upper part of the body and sometimes have a void, possibly representing a digestive organ. Pottery and clay figurines were similar overall, combining conical or triangular shapes (Figure 7).

In the early Jomon period, a representation of a face appeared on some pottery, and a waist-like curve and a foot or pedestal appeared as well. Clay figurines changed in the same way, beginning to express faces and legs. Nevertheless, they could not stand on their feet as their shape was flat (Figure 8).

Around 3500 B.C., in the early Middle Jomon period, clay figurines developed limbs and suddenly became able to stand on their own. This development began the fusion of pottery and clay figurines (Figure 9). The head of some figurines was formed like a bowl-shaped vessel. Some of the figurines have swelled bellies, which may be an emphasis on the uterus void or the digestive organs void.

These are other examples of pottery-figurine fusion in the Middle Jomon period. Japanese archaeologists have called them pottery decorated with figurines or human faces. However, in many cases, pottery is actually a part of the body of a clay figurine converted into a container. It is more appropriate to regard them as "clay figurine-shaped pottery."

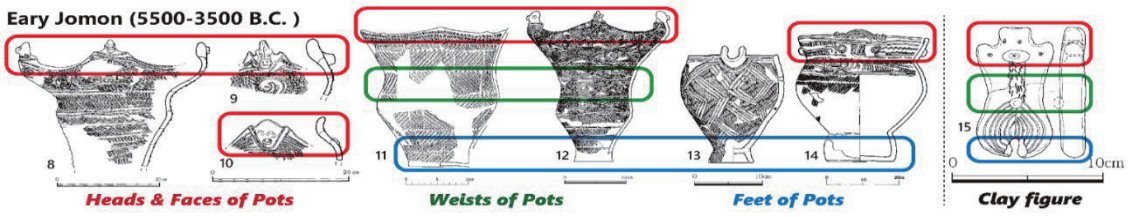

Figure 8. Jomon pottery and *Dogu* figurines: Early Jomon Period (Source: No. 8, 9, 10, Annaka 1998. No. 11, Miyagi 1986. No. 12, 13, Annaka 2014. No. 14, Rikuzentakata 2006. No. 15, Iwate 1982).

There are scattered instances of figurines with an actual representation of the digestive canal as a hole that runs from the mouth of the figurine through the inside of the body to the lower end. It is an expression of explicit awareness of the digestive organs. This kind of expression continues to the end of the Jomon period. In the Late Jomon period, the hybridization pattern of pottery and figurine became more diverse. These "anthropomorphic containers" OR "containerized figurines" are consciously designed to contain liquids or fine solid substances poured from the head. Perhaps it was essential to the Jomon people to pass the contents through the head to digestive organs and the uterine void of the figurine.

A fascinating example is a large, hollow clay figurine of the Late Jomon period excavated from the Chobonaino site in Hokkaido, Japan. It has two holes on its head, which initially had two horn-like parts, like a similar example from the Tabatahigashi site. If you pour liquid into the hole in the head, it will drain through the hole between the legs. Pottery with the same function is widely distributed in the Japanese archipelago during the late Jomon period. Probably it is thought that the liquid is collected in the void of the clay figure's body and expected to impart special power to the liquid by passing through the digester of the clay figure.

An extreme example of hybridization between pottery and *dogu* figurine

The awareness of the VOID in pottery and figurine hybrids continued to the end of the Jomon period. Large, hollow, clay figurines of the Late Jomon period consisted of the image of multiple vessel types that have existed since the Late Jomon period. The cranial void of the *Shakoki-dogu* from the Final Jomon period is shaped like an incense burner, and the limbs are like upside-down vessels. If the figurine combines the symbolism of these vessels, we may consider the possibility that the holes in the lower half of the body also have symbolic meanings. It has an open head and holes in the mouth, navel, vulva, and anus. These holes are generally considered air holes to prevent rupture during firing, but they are also essential outlets for the digestive organs and the uterus void. Therefore, as with the Chobonaino example, the holes in this figurine were probably intended to allow the liquid poured from

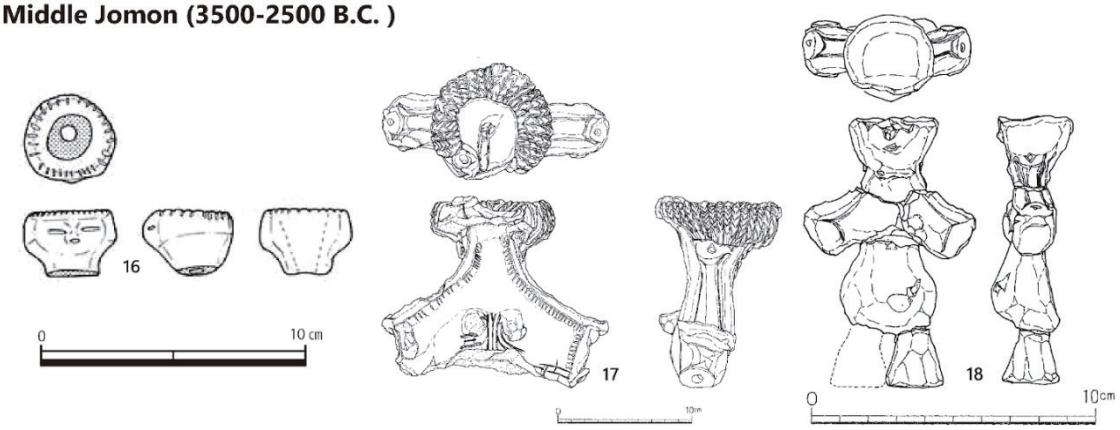

Figure 9. *Dogu* figurines with voids: Fusing the images of container and human body (Source: No. 16, Yamanashi 1987. No. 17, 18, Yao 1985).

the head to pass into the body and be excreted through the anus and pubic region.

Transformation from *dogu* figurines to *dogu*-shaped pottery

In the Yayoi period, when rice paddy cultivation and metalware were adopted in the Japanese archipelago, figurines were transformed. In the Yayoi period, clay figurines lost their feet, and the holes in the body's lower half were closed to form a flat bottom. It eventually turned into a jar with a face. The contents of the vessel do not pass through the body but are just contained inside the body. It suggests that the symbolism of the digestive void is overshadowed, and the symbolism of the uterus void is emphasized. In this case, these clay figurines may have been vessels to pray for the rebirth of the dead, or they may have been thought of as a kind of guardian of the dead since they contain the bones of the dead. The body of the vessel may have been thought of as a substitute for the body or outer skin of the dead. These pottery figures lose their external orientation when the holes in their lower bodies are blocked. They become tools for strengthening the internal ties of human society, linking the relationships between the living and the dead. In other words, these physically closed containers function only within a closed human society. Considering this from the Mutual permeation model, the partition between human society and other societies was strengthened in the Yayoi period, and human society was transformed into a closed society. In other words, as human society grew larger ,the flat relationships and ties between things, people, and the supernatural that had existed before have begun to be broken down by humans.

Conclusion and questions

This presentation discussed how humans interacted with various materials to create tools and environments and construct their world and mind by examining the Jomon period pottery and clay figurines. This study is an attempt to update the triadic niche construction model, which is the theoretical foundation of the “Out of Eurasia” project (Iriki and Taoka, 2012; Iriki et al., 2021; Matsumoto, 2022), based on actual archaeological analysis. The formation of interpenetrating relationships among people, clay, pottery, and human-shaped artifacts undergirded the Jomon people's worldview and society. The collaboration between the materiality of clay and humans led to the construction of a new cognitive niche.

On the other hand, the groups that expanded into the Pacific started out with pottery but lost them along the way. Did this have any effect on their worldview and identity? What were the interactions with materials and the production of artifacts that formed the core of the Polynesian islanders' worldview and the sense of being human after they lost their pottery? To what extent are the different characteristics of the core material influential in shaping society and culture? These questions need to be examined in the future.

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How Do Cultural Artifacts Shape Visual Attention?
A Computational Model Analysis of Cultural Variability in Visual Search

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Abstract

Cultural variability in cognition has often been accounted for by general concepts such as holistic-analytic processing based on social learning. However, more implicit and automatic behaviors, such as visual attention and eye movement, appear to be difficult to learn through imitation, and alternative accounts based on interaction with material cultures (such as letter use) are possible. The current study contrasted these two accounts by saliency-map model simulations of recent evidence for stimulus-specific cultural difference in visual search. Recently, Ueda et al. (2018) reported that search asymmetry for line-length, that is, the search for a long line being more efficient than the search for a short line, was observed among American participants, but it disappeared with East Asians. This lack of search asymmetry in East Asians is stimulus-specific, such that asymmetry with tilt-vertical search was significantly stronger with East Asians than Americans. The current study used a saliency map model that can account for search asymmetry. and manipulated perceptual span. The holistic-analytic processing account predicts a larger span in East Asians than Americans, while the orthographical system account predicts a smaller span in East Asians than Americans based on reading studies. The simulations revealed that observed search asymmetry can be accounted for by assuming that perceptual span is larger among Americans than East Asians, which is consistent with the orthographical system account. The simulation also predicts a novel phenomenon of reversed search asymmetry with line-length search, more efficient search with a short line target, with even smaller perceptual span, which is recently observed with Taiwanese participants. These results suggest that stimulus-specific cultural difference in visual search likely reflects differential perceptual span derived from reading experiences, rather than the holistic-analytic processing. The interaction with material culture may be a more important factor to explain cultural variability in visual cognition than previously considered.

Introduction

Physical and social environments have profound effects on our cognitive processes and produce substantial variability across cultures, including thinking (Nisbett et al., 2001), moral judgment (Awad et al., 2020), emotion (Jack et al., 2009), attention (Masuda and Nisbett, 2001) and perception (Segall, Campbell and Herskovits, 1963). In particular, recently studies on cultural universal and variability using a large-scale corpus data have been conducted with language (Jackson et al., 2019), human songs (Mehr et al., 2019) and other human behavior. Also, experimental studies on cultural transmission are using tasks involving tool use and tool making (Caldwell & Millen, 2009; Derex Bonnefon, Boyd & Mesoudi, 2019). These studies have been investigating human overt behavior, and a major theoretical framework to account for the cultural variability and cultural evolution of cognition is social learning (Mesoudi, 2011), learning through observation, including imitation, education and group activities. Although they are important determinants of cultural diversity in higher level cognitive processes, it remains elusive whether social factors can also account for cultural variability in early level cognitive processes including attention and perception.

In contrast to overt behavior, covert behavior such as attention, working memory and cognitive control is typically not observable from behavior, suggesting that social learning may not be a major factor of cultural variability and cultural evolution. An alternative underlying mechanism is interaction with cultural artifacts such as tools, buildings and letters. In cognitive archaeology, Malafouris (2013) proposed material engagement theory, emphasizing the role of the interaction with cultural artifacts in cultural evolution. In the current study, we focus on our recent finding of cultural difference in covert behavior in visual search tasks, and offer an account for the cultural variability based on interaction with cultural artifact, namely, letters. In the following, we briefly introduce reading studies revealing the effect of writing system on cognitive processes. Then, we describe our recent findings of stimulus-specific cultural differences in visual search, followed by our simulation experiment using a computational model to account for the behavioral data. Finally, we discuss the implications and future directions.

Writing systems modulates cognitive processes in reading

Interaction with letters includes writing and reading, which eliminates spatiotemporal limits of speaking and listening. Reading is related to both explicit and implicit aspects of our cognitive processes. Through reading, we acquire lexical, syntactic, semantic and world knowledge, which is explicit and socially transmitted. Thus, cultural variability related to knowledge is likely built through social learning. In contrast, reading is based upon various general cognitive processes including attentional and eye movement control, working memory and executive control. These general cognitive processes are largely implicit and automatic. Letters have shown substantial effects on general processes in visual cognition (Dehaene and Cohen, 2007). Different orthographical systems used by different cultures impose cultural

variability in perceptual span in reading (Inhoff and Liu, 1998; Li et al., 2022), Stroop interference (Biederman and Tsao, 1979), symmetry judgment in object recognition (Pegado et al., 2014) and brain activity during reading (Bolger, Perfetti and Schneider, 2005; Nakamura et al., 2005; Szwed et al., 2014). Among them, modulation of perceptual span in reading is relevant to the current study, thus we briefly introduce the general findings.

Perceptual span is the amount of information that can be processed with a single fixation. Perceptual span of English readers is 18-20 characters, whereas that of Chinese readers is 5 characters (Inhoff and Liu, 1998; Li et al., 2022), reflecting the complexity of alphabetical and Chinese characters. One remaining question is whether cultural difference in perceptual span is specific to reading behavior, or the difference affects cognitive processes other than reading. If the cultural difference in perceptual span affects other cognitive processes, it may account for our recent finding of stimulus-specific cultural difference in visual search. Next, we describe our finding of stimulus-specific cultural differences.

Stimulus-specific cultural difference in visual search

Recently, evidence for cultural difference in processing of basic visual features has been reported using visual search tasks (Cramer, Dusko and Rensink, 2016; Ueda et al., 2018). In the literature of visual search, search asymmetry is a robust phenomenon such that swapping target and distractor items produces great change in search efficiency. For example, searching for a circle with a bar among circles is quite easy, whereas searching for a circle among circles with a bar is quite difficult. Recent studies (Cramer et al., 2016; Ueda et al., 2018) revealed that search asymmetry is not culturally universal. Search asymmetry for line-length search, that is, search for a long line is more efficient than search for a short line, was observed with American participants, replicating previous works (Treisman and Souther, 1985), but it disappeared with East Asians (Ueda et al., 2018). Moreover, the lack of search asymmetry in East Asians is stimulus-specific, such that search asymmetry with tilt-vertical search was significantly stronger with East Asians than Americans (Ueda et al., 2018). Asymmetry with line-length search is reduced in recent immigrants to Canada, suggesting that duration of exposure to Western culture modulates the strength of search asymmetry (Cramer et al., 2016).

Stimulus-specific cultural differences in search asymmetry impose great challenges to theories accounting for cultural differences in cognition. A dominant view in cultural psychology in which social learning is a major determinant of cultural differences cannot explain why direction of cultural differences changes with stimuli. A major account of cultural variability of cognition is holistic and analytic cognitive styles: Americans tend to employ analytic cognitive style, whereas East Asians tend to employ holistic style (Nisbett et al., 2001). Holistic and analytic cognitive styles are independent of stimuli perceived, leading to a failure in accounting for the results. Similarly, a view emphasizing roles of interaction with artifacts has difficulty in accounting for the stimulus-specific cultural difference, because line length and

tilt are basic and culturally universal features, which apparently unrelated to perceptual span derived from letter complexity.

The literature revealed that visual search is composed of complex interactions of stimulus-driven and goal-directed mechanisms (Wolfe, 2001), and it is not straightforward to predict how a single factor such as perceptual span or holistic and analytic processing affects visual search behavior. Therefore, to explain the stimulus-specific cultural difference in search asymmetry, analyses based on computational modeling of visual search are necessary. A standard computational model for visual search and eye movement is the saliency map model, which represents saliency of each point of visual scene and guides attention and eye movement to the most salient point (Itti and Koch, 2001). Saliency map models can successfully simulate eye movement in visual search and behavioral characteristics in visual search such as pop out in feature search and inefficient conjunction search. In the current study, we chose Attention as Information Maximization (AIM) model as a platform, because it successfully simulated search asymmetry with simple shapes (Bruce and Tsotsos, 2009). Unlike many computational models including a classic saliency map model (Itti and Koch, 2000), the AIM model can simulate search asymmetry by using a set of basis functions derived from natural images.

In the simulation study with the AIM model, we addressed perceptual span as a potential mechanism underlying cultural differences. With regard to the perceptual span, the analytic-holistic and the orthographical system accounts provide the opposite predictions. The analytic-holistic account (Nisbett et al., 2001) predicts that Americans and East Asians correspond to models with small and large perceptual spans. In contrast, the orthographical system account predicts that Americans and East Asians correspond to models with large and small processing spans, respectively, because letters used by East Asians are more complex, and perceptual span in reading is known to be wider with alphabetical readers than with Kanji character readers (Inhoff and Liu, 1998; Li et al., 2022). In the AIM model, span of visual processing can be implemented by information pooling area, which defines area of feature pooling for the saliency computation.

Methods

Experimental data to be simulated. Results of two cultural comparison experiments using line-length and tilt-vertical search tasks (Ueda et al., 2018) were simulated. Both compared the magnitude of search asymmetry between participants in Japan and in North America (USA and Canada). In the line-search task, participants from North America showed significant search asymmetry with the advantage of long line search, whereas participants from Japan showed no asymmetry. In the tilt-vertical search task, Japanese participants showed significantly stronger search asymmetry with the advantage of tilted line search than

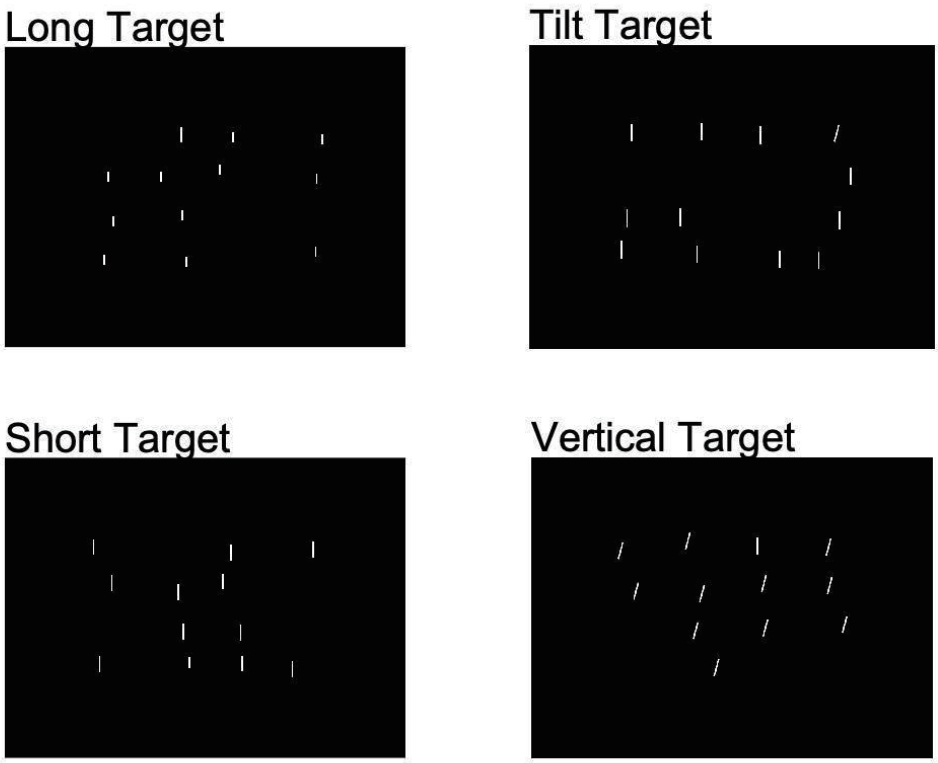

Figure 1. Examples of search displays used in the simulation. Left column denotes displays for the line-length search task: Long target display (top) and Short target display (bottom). Right column denotes displays for the tilt-vertical search task: Tilt target display (top) and Vertical target display (bottom). Search displays were formed using the same algorithm as Ueda et al. (2018). Beside set size 12 shown above, set sizes 3 and 6 were also used.

North Americans.

Computational model. I utilized the Attention as Information Maximization (AIM) model (Bruce and Tsotsos, 2009) using 25 features of 21×21 filter size, with the following modifications. We used basic image-based basis functions that is equivalent to Bruce and Tsotsos (2009), sampling random 100 patches from 3600 natural images drawn from the Corel stock photo database depicting outdoor natural scenes. To examine the effects of information pooling area, standard deviation of Gaussian envelop was systematically manipulated ranging from 1 pixel to 30 pixels, corresponding to 0.027° to 0.81° of visual angle with the search display in the experiments.

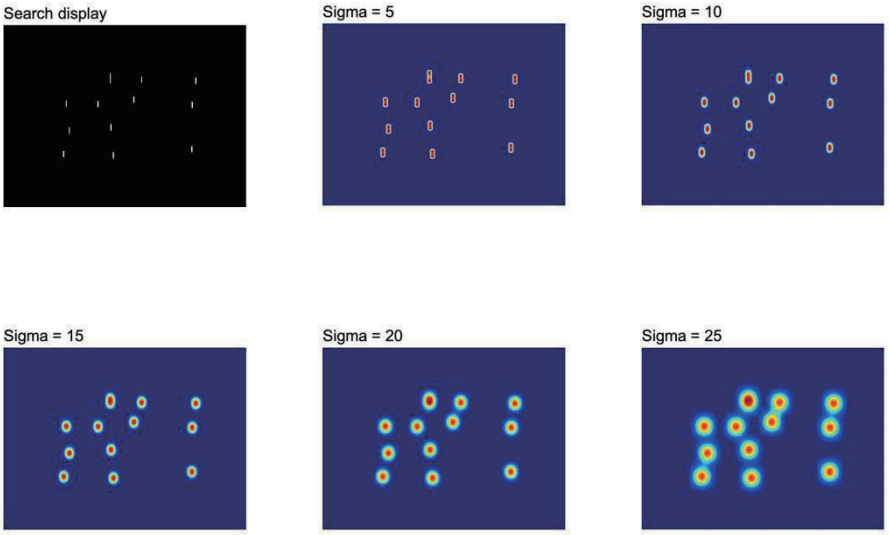

Figure 2. An example of line length search display of long line target with set size 12, and saliency maps with various σ values. As σ increases, the difference in the maximum saliency for long and short lines becomes more apparent.

Simulations. Search displays for simulations were constructed with the same procedure as the experiments showing cultural difference (Ueda et al., 2018). Search display subtended 16.3° wide and 9.7° high. Set sizes were 3, 6, and 12, and search items were randomly distributed in a 4×4 invisible matrix, and their location was randomly jittered within each cell. Search items were white on the black background. For line length search, long and short lines were 1.1° and 0.7°, respectively. For the tilt-vertical search, the length was 1.2°, and the tilt item was 15° rotated clockwise. Examples of line-length and tilt-vertical search displays are shown in Figure 1. For each set size and target condition, 20 search displays were used. Only target present displays were simulated. For each search display, saliency map was obtained with σ of Gaussian envelop from 1 to 30 pixels, resulting in 30 maps.

Search asymmetry index. For each search display, the index called *Rmax*, reflecting search efficiency, is defined as the ratio of the maximum saliency value in the region of target to the maximum saliency of distractor region. Search asymmetry index (SAI) for a pair of search displays with target A and B is *log (Rmax(A)/Rmax(B))*. Thus, positive and negative SAIs indicate more efficient search with target A and target B, respectively, and zero SAI means no search asymmetry. Variability of SAI is evaluated by taking 60 pairs of displays having the same set size with different targets.

Results

Figure 2 shows examples of saliency map for a line-length search display with different information pooling areas (σ). As σ becomes larger, the saliency map becomes diffused and the difference of saliency between target and distractor becomes more apparent.

Effects of perceptual span.

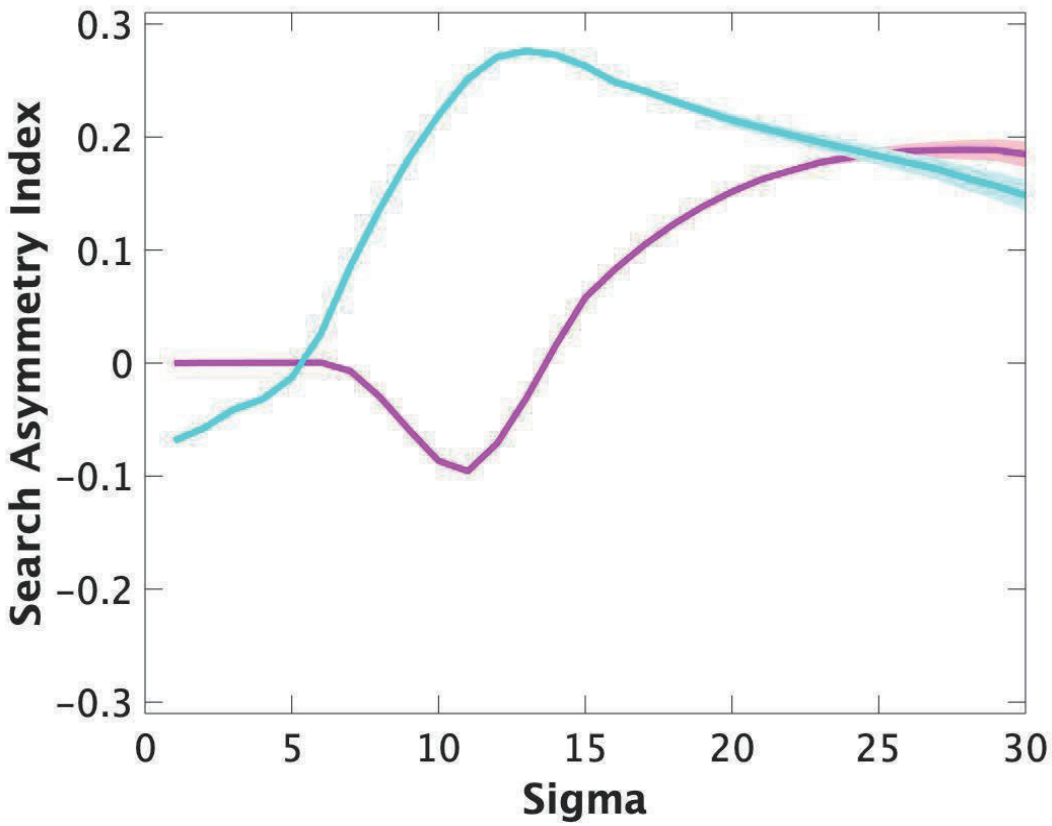

Figure 3. Search Asymmetry Index (SAI) as a function of σ values. Magenta and cyan denote line-length and tilt-vertical search, respectively. SAI value of 0 indicates no search asymmetry, and positive and negative values indicate asymmetry for long or tilt, and for short or vertical, respectively. Shaded areas denote 95% CI. With the assumption that American and East Asian participants have perceptual span of 30 pixels (0.8° in visual angle) and of 15 pixels (0.4°), respectively, empirical results can be successfully reproduced.

SAI as a function of σ (Figure 3) shows that line-length search and tilt-vertical search revealed distinctive effects of σ on search asymmetry. In the line-length search, SAI for long line target shows its peak with the largest σ, around 25-30 pixels, corresponding to 0.7°-0.8° of visual angle in the experimental

context. Furthermore, with smaller □, peaked at 10 pixels, there was a substantial reversed search asymmetry, reflecting the advantage of short line. In contrast, in the tilt-vertical search, SAI for tilt target shows its peak around 13 pixels, which is substantially smaller than the line-length search, and SAI gradually declines as σ increases. Notably, the interaction of σ and search task in SAI nicely fits with the observed stimulus-specific cultural differences in search asymmetry. If we assume that American and East Asian participants have □ of 0.8° and of 0.4°, respectively, the model simulation can account for substantial search asymmetry with both line-length and tilt-vertical for Americans, and the lack of asymmetry with line-length but even stronger asymmetry with tilt-vertical search for East Asians.

Discussion

Simulations using the AIM model revealed that a difference in perceptual span can account for the stimulus-specific cultural differences in visual search asymmetry: the lack of search asymmetry with line-length search, and the stronger search asymmetry with tilt-vertical search with East Asians compared with Americans (Ueda et al., 2018). This pattern of empirical data can be simulated with the assumption that Americans have larger perceptual span in saliency computation in visual search than East Asians. The simulation results are consistent with the orthographical system view (Li et al., 2022), postulating that East Asians have smaller perceptual span than Americans, but are the opposite to the prediction from the holistic-analytic cognitive style view of cultural difference (Nisbett et al., 2001), which postulates that East Asians have larger span than Americans.

Novel prediction from the simulation results

The current simulation study revealed one unexpected result: reversed search asymmetry with line-length search. As shown in Figure 3, the search asymmetry index is substantially negative, peaked at 10 pixels of σ. This puzzling finding is in fact a piece of supporting evidence for the orthographical system view, because recently we discovered a significant reversed search asymmetry with Taiwanese participants (Ueda et al., 2019). In Taiwanese participants, short-line search was more efficient than long-line search. Note that this finding is consistent with the perceptual span data for Japanese and Taiwanese. Taiwanese people are known to have even smaller perceptual span than Japanese, reflecting the fact that Taiwanese people use complex Chinese characters, whereas Japanese people use mixture of Kanji-characters and Kana.

Attention, saliency map and search asymmetry

Saliency map models have been proposed as a representation of saliency distribution in the whole visual field to guide overt and covert attention (Bruce and Tsotsos, 2009; Itti and Koch, 2000). Eye movement and/or focused attention are assumed to be deployed to the point of highest saliency, to examine whether

it is a search target in visual search. Thus, the manipulation of information pooling area in the current study in fact examined the nature of parallel computation for attentional guidance, which differs from theoretical arguments in the literature of culture and cognition. The perceptual span in the reading study (Inhoff and Liu, 1998; Li et al., 2022) addresses the span of foveal processing of text reading, and the holistic-analytic cognitive style account (Nisbett, et al., 2001) addresses the width of attention in object and scene recognition.

The simulation results of the current study indicating a larger perceptual span in Americans than East Asians are consistent with the results in the reading studies, supporting the orthographical systems account. However, some issues remain to be addressed. The most important one is whether perceptual span with the foveal vision is generalizable to peripheral vision. Our life in modern society, in which texts are scattered around a visual scene and need to be efficiently detected and searched, suggests that it may be the case, but this is an empirical question to be examined with future experiments. Another important issue is domain specificity of perceptual span in reading. The culturally different perceptual span may be specific to reading, or may have more general impacts. This issue is related to a more general question of the plasticity of human cognition by interactions with cultural artifacts (Malafouris, 2013). The interaction may modulate cognitive processes directly related to the artifact use, or may have wider impacts on cognition.

The holistic and analytic style account remains ambiguous regarding the underlying cognitive processing. Although smaller perceptual span is naturally associated with narrower focus of attention, different relationship can be postulated. For example, narrower focus of attention may be the result of compensatory mechanism for coarse stimulus-driven representation. A saliency map constructed with a large perceptual span becomes more spatially blurred, and subsequent attentional processing needs to have a narrower focus. Although the larger processing span and analytic attention are not necessarily contradictory, more detailed mechanisms need to be defined for further discussion.

Implications for cultural differences in visual cognition

Both cultural psychology and cultural evolution studies emphasize the role of social factors, such as interpersonal relationship and social learning, in cultural differences in cognition (Mesoudi, 2011; Nisbett et al., 2001). Although social factors play important roles in various culturally specific cognitive processes, the current study indicates another important factor, interaction with cultural artifacts. Visual words are known to play significant roles in our visual cognition (Dehaene and Cohen, 2007), and the current study suggests that their effects are not limited to language related functions such as reading, but visual cognition in general. We still need more direct causal evidence for the role of visual word processing in cultural difference in visual search, but it is worth noting that culturally mediated physical environment is an important factor to understand how human beings are adapted to their culture (Malafouris, 2013).

Social learning and interaction with artifacts are not mutually exclusive, and they contribute different aspects of cultural evolution of cognition according to their characteristics in an adaptive fashion. Social learning, which needs to be observational, acts on explicit aspects of human cognition, such as tool making, social interaction, and group decision making. Interaction with artifacts contributes to form more implicit aspects of human cognition, such as perception, attention and eye movements. Although perception and attention include both explicit and implicit components, explicit control of perception and attention is rather limited, and we lack explicit knowledge about the majority of everyday behavior. For example, we have poor memory for our own eye movement in visual search (Võ, Aizenman and Wolfe, 2016). Thus, we have difficulty in imitating other person's eye movements and visual search behavior, which makes social learning of eye movements and visual search difficult. Cultural variability in our visual cognition likely emerges from interaction between explicit social learning and implicit learning through artifact use, and future studies need to elucidate its underlying mechanisms.

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Monument, Ritual, Worldview, and Social Stratification in Prehistoric and Protohistoric Japan from a Aaritime and Water Perspective

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National Museum of Japanese History

There was a major shift at the end of the 20th century in the so-called traditional "prime mover" argument about what caused the social complexification of the prehistoric and proto-historic period of the Japanese archipelago.

Until the 1980s, under the strong influence of Marxism, the prevailing theory was that the monopoly of the surplus created by the increase in agricultural production led to the growth of the ruling class, or that the uneven development of agricultural productive forces led to stratification among groups (Kondo 1983). In contrast, since the 1990s, there has been much discussion about how the development and control of long-distance trade, as well as the increase in agricultural productivity, has promoted stratification and social integration (Tsude 1991).

In this discussion, iron was considered to have been the most important material which could be obtained through long-distance trade. Archaeological and written sources indicate that before the middle of the 6th century AD, people in the Japanese archipelago used iron materials imported mainly from the Korean peninsula for production tools such as farming implements and weapons, as iron could not be obtained domestically. In other words, from the first century BC, when iron became to be used widely, until the sixth century AD, when it became possible to produce domestically, the economic structure of the Japanese archipelago was dependent on external societies for its main resources (Tsude 1991, Matsugi 2001).

This period coincides with the process of development of social complexes in the Japanese archipelago, from the emergence of local chiefdoms to the establishment of the early state over a wide area. This tells us that the main economic mover which led to the promotion of social complexity in the Japanese archipelago was long-distance trade, mainly in iron. As the Japanese archipelago is

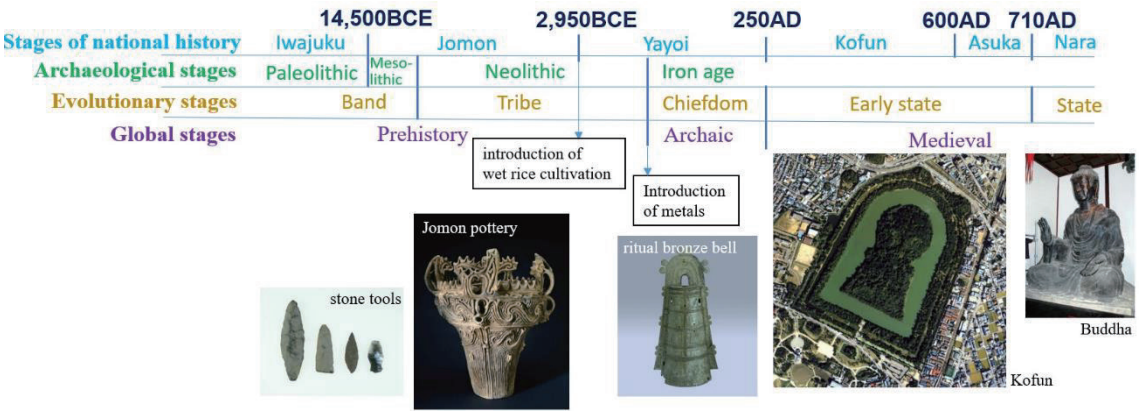

Figure 1. Stages of social complexity of the Japanese archipelago

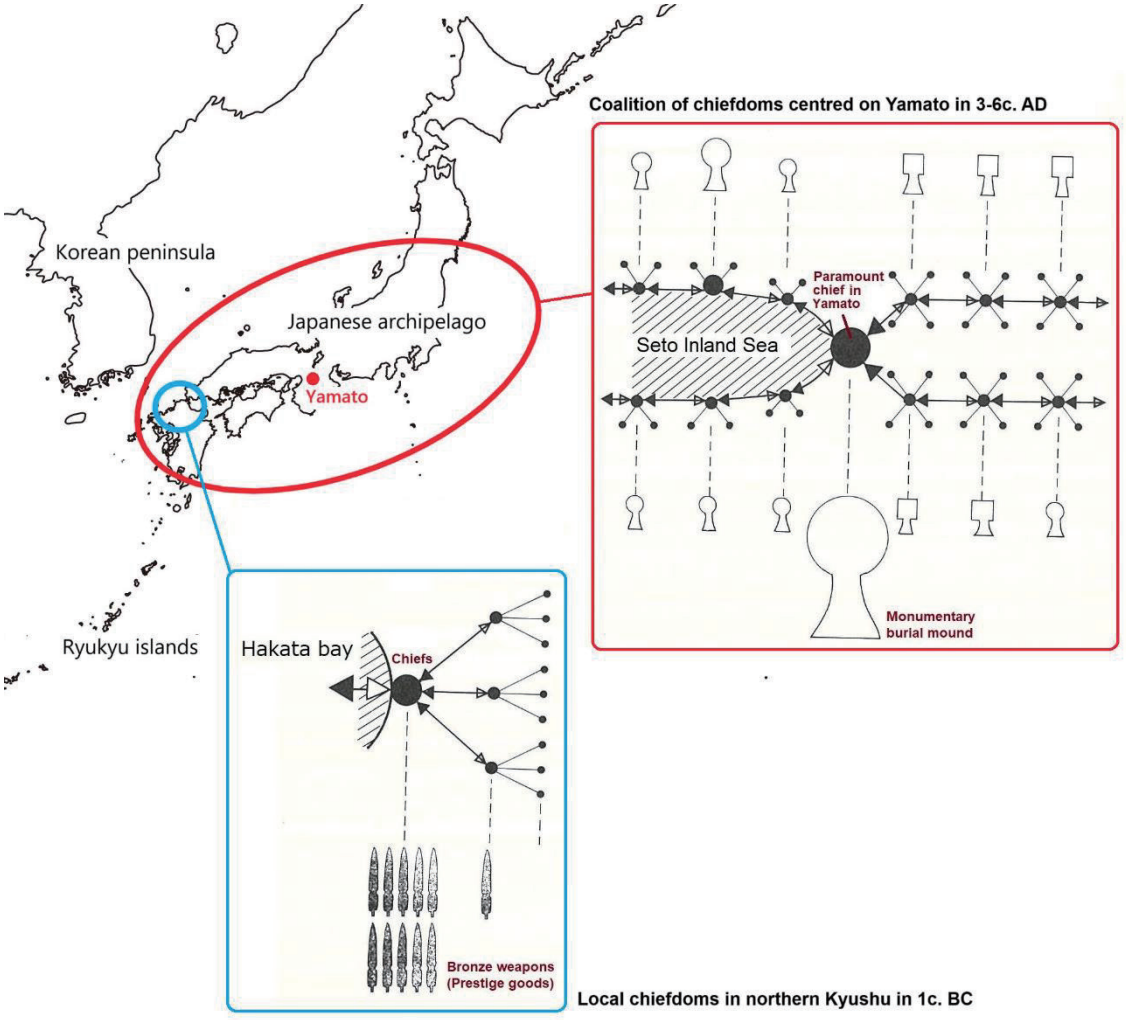

Figure 2. Socio-political formation of the Japanese archipelago in 1c.BC and 3-6c.AD (from Matsugi 1995)

surrounded by sea, its long-distance trade was ocean-based. The aim of this paper is to outline the development process of this long-distance trade using archaeological material.

The stages of social complexity and long-distance trade

The stages of social complexity of the Japanese archipelago are showed in a single diagram (figure.1). The social complexity of the Japanese archipelago has been reconstructed mainly by the process of monumental development of the elite burials. Most of the social complexity processes in the Japanese archipelago were not accompanied by cities. Nor did they develop military systems to control large domains. The reason for this is that the Japanese archipelago is an island country, and small areas along its coasts were originally highly independent. Controlling the distribution of goods and commodities that linked them together was important for creating political power. Maritime is essential for the distribution of goods in island countries.

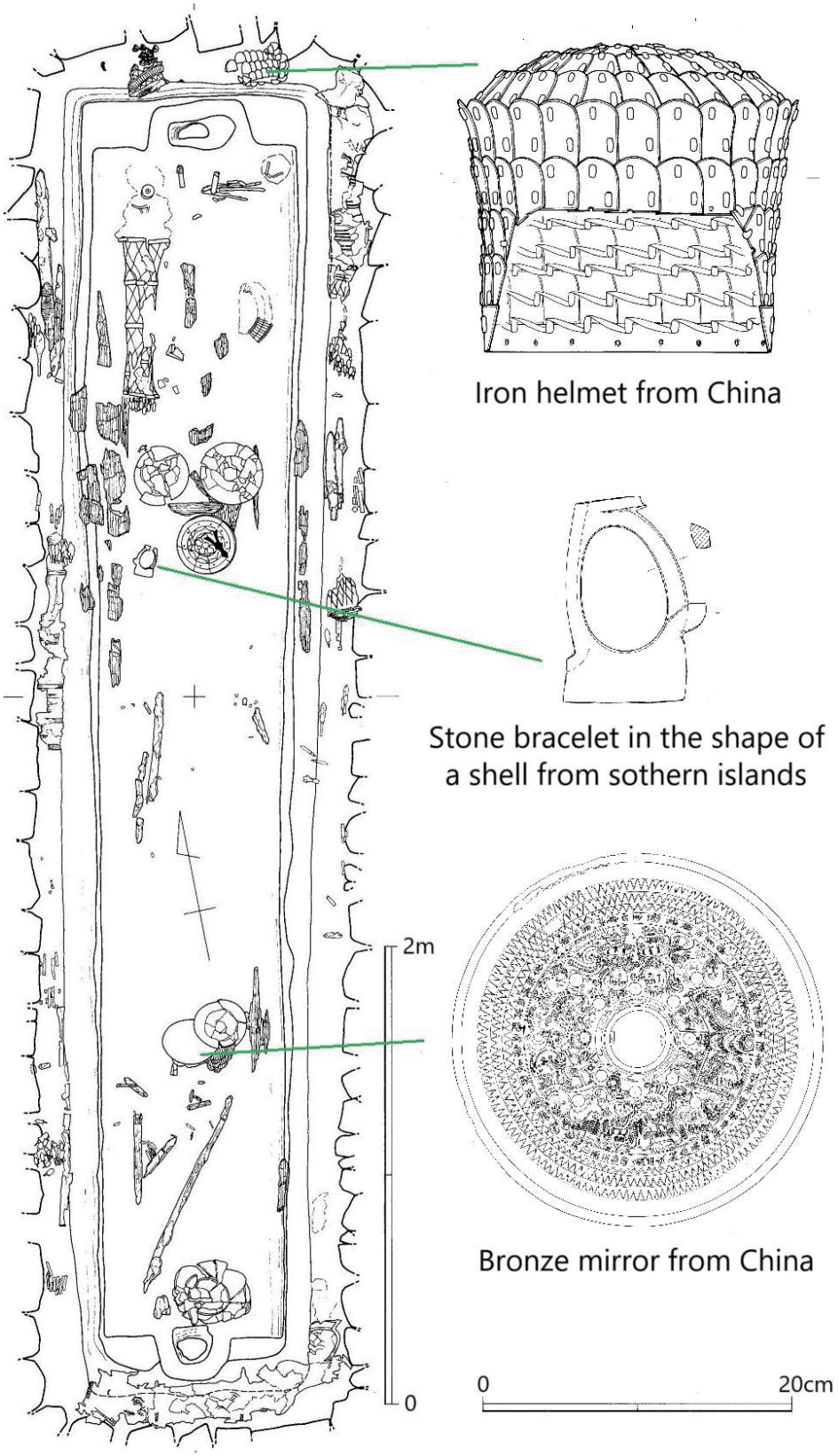

Figure 3. Stone chamber and its exotic offerings of Yukinoyama burial mound
(from Tsude etc (eds.) 1996)

As the first stage of social complexity in the Japanese archipelago, local chiefdoms emerged in northern Kyushu (present Fukuoka prefecture) in the 1st century BC, stimulated by the Chinese continent and Korean peninsula across the sea. These chiefdoms were hierarchically linked with the acquisition and distribution of iron materials from the Korean peninsula, with the two most powerful chiefdoms on the Hakata Bay coast as the core (shown in blue in figure 2). The chiefs showed their authority with locally produced bronze weapons, as well as bronze mirrors from China and shell bracelets from the southern Ryukyu islands. Showing a connection to the distant world was important to their status (Matsumoto 2000).

The second stage was the establishment of a broad-based coalition of chiefdoms centred on Kinki region in the middle of the 3rd century (present Nara and Osaka prefectures). It is indicated by the extensive construction of chiefly burial mounds (kofun) with a common style. There was a paramount chief buried on the largest mound in Yamato in the central Kinki region, but local chiefs buried on the mounds of reasonable size also maintained their independence and participated in the coalition (shown in red in figure 2). This coalition is considered to be supported by long-distance trade (Tsude 1991). Iron materials from the southern part of the Korean peninsula were the most important, supporting production of each community in the Japanese archipelago before the middle of 6th century, when iron materials began to be extracted in the archipelago. As they were transported by ship, it must be appreciated that the Japanese archipelago was essentially a maritime society up to the middle of 6th century. This point is often overlooked.

Furthermore, drawing on traditions from the Yayoi period, bronze mirrors from China and fine stone products in the shape of shell bracelets from southern Ryukyu islands were also offered to the chiefs' burials to show their authority. It can be argued that the authority of the chiefs in prehistoric Japan, a maritime society, was preserved by showing that they had differential access to and from the distant world (Matsumoto 2000).

As a typical example, in the Yukinoyama burial mound in Shiga prefecture, overlooking Lake Biwa which was an important transport route connected to the sea by the Yodo River, Chinese bronze mirrors and iron helmets, and a shell-shaped fine stone bracelet showing the connection with the southern sea were offered to the chiefly burial (figure 3). Such examples were standard among the chiefly burial mounds from the 3rd and 4th centuries and are too numerous to enumerate.

Distribution of chiefly burial mounds and the worldview

In recent years, chiefly burial mounds showing a close relationship with the sea and the water systems connected to it have attracted attention as 'maritime-type burial mounds (Hirose 2015 etc.). They were very numerous until the 3-5th century (figure 4), when iron materials were imported from the Korean peninsula and became less common from the 6th century onwards (figure 5), when they could be produced domestically.

Furthermore, recent attempts at cognitive archaeology and landscape archaeology have revealed

that the largest and most elaborate of these burial mounds, in the late 4th and early 5th century, are themselves constructed to create a connection with the distant world by sea.

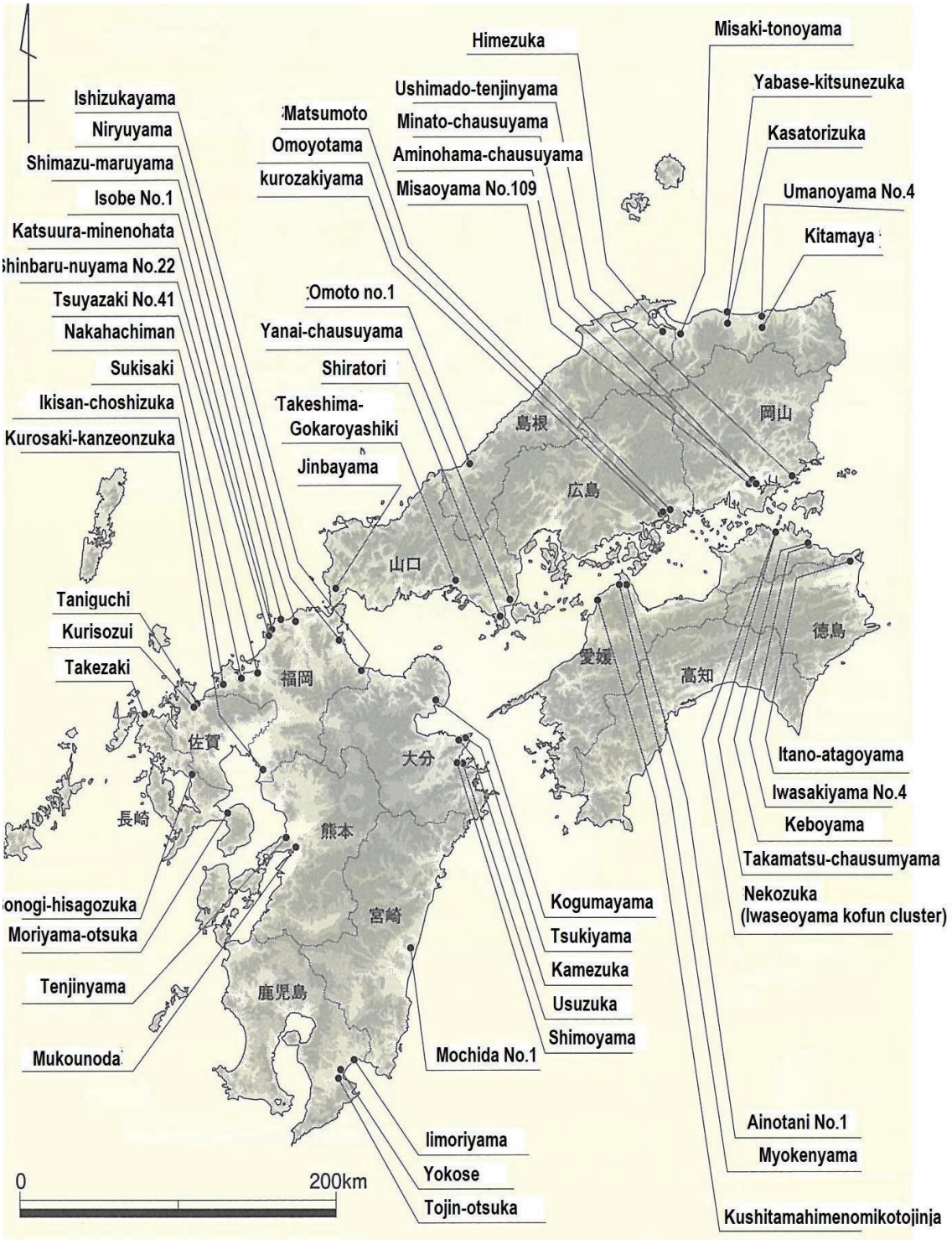

Figure 4. Distribution of maritime-type burial mounds in southwestern Japan in 3-5c. AD (from Kanagawa Archaeology Foundation (ed.) 2015)

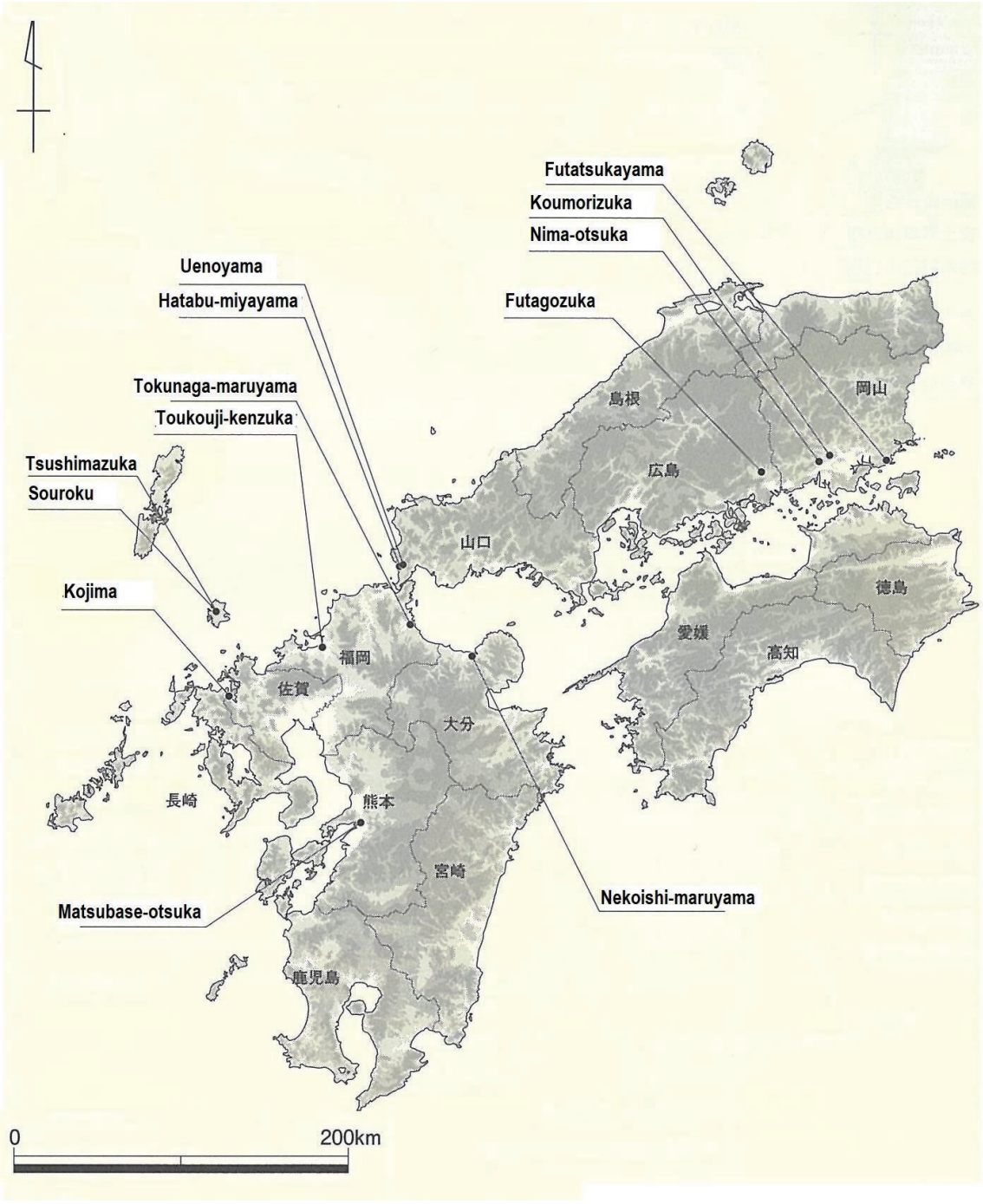

Figure 5. Distribution of maritime-type burial mounds in southwestern Japan in 6c. AD (from Kanagawa Archaeology Foundation (ed.) 2015)

These mounds have a real or virtual water surface surrounding them created by a moat or an empty moat. An island or land-tied island is built at the point where the mound is reached from outside the moat. Their fronts are sometimes shaped like a cove, and waterfowl or boat-shaped *haniwa* terra-

cotta figures are placed on and by them. They indicate that a boat which crossed the surface of the water arrived here. The dead chief arrived at the mound with his or her boat and was buried at the top of the mound (figure 6, board of education (ed.) 2005)

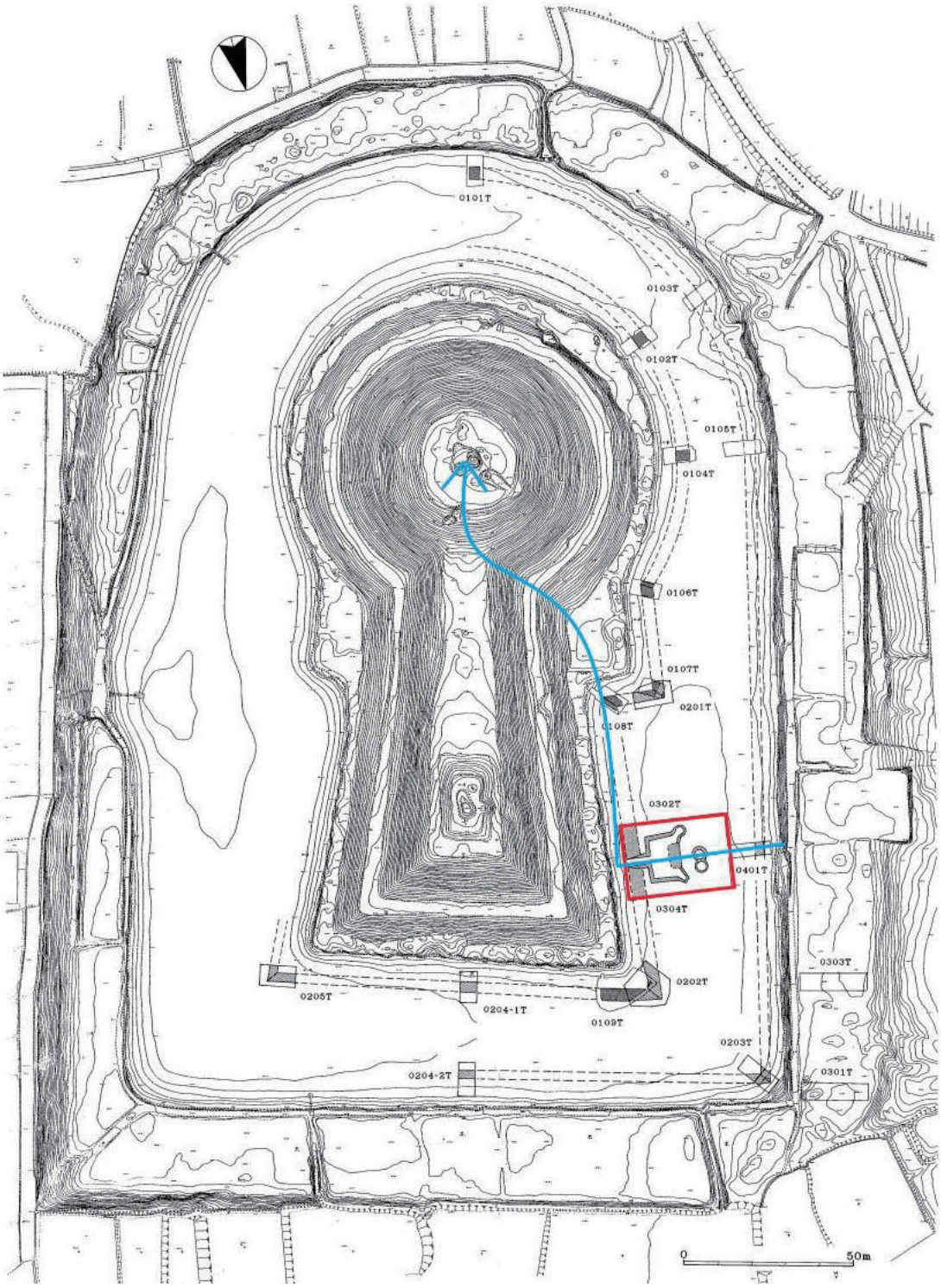

Figure 6. Mound, moat and land-tied island of Suyama burial mound (Kouryou town board of education (ed.) 2005)

海の遠距離交渉と陸の遠距離交渉 **Interaction by sea and lands**

		海を隔てた遠距離交渉 Interaction by sea	陸続きの遠距離交渉 Interaction by lands
移動の日常性・頻度 Ordinariness and frequency of transfer	情報・物資・器物 Information, material, goods	非日常的な場合が多い Mainly non-ordinary	日常的な場合が多い Mainly ordinary
	人 Persons	断続的・偶然的あるいは定期的 Intermittent, contingent or periodical	継続的・不定期的 Constant, random
移動の時間 / 距離 Time and distance of transfer		長い、一時的 Long, temporary	短い、累積的 Short , cumulative
移動のメンバー（人の場合） Members of transfer (migration)		メンバーの限定性が強い（船での移動） Limited members (on board) 運命共同体的 Sharing a common destiny	メンバーの限定性は弱い Non-limited members
移動に関する記憶 Recollections of transfer		出発点と到着点が明確 Clear leaving and arriving points 濃密・エピソード的・物語的 Rich, episodic, narrative	常套的 Ordinary
移動した人や器物の出自・故郷・アイデンティティの表示性 Manifestation of identity of transfering persons or goods		相対的に強い Relatively strong	相対的に弱い Relatively weak
移動する人工物の性質 Character of transfering goods		儀礼的な人工物が多い Mostly for ritual use	日常的な人工物・資源が多い Mostly for dairy use

Table 1. Interaction by sea and land (from Matsugi 2007)

Wada 2009, Matsugi 2024 in print). The waterfowl has been identified as a migratory swan or goose, which also symbolized the distant world. In other words, it is assumed that the burial mounds of this period were recognized as the other world beyond the water and were built as such. It is thought that there existed a worldview in which the chief, who was a mediator between the other world before his or her death, was positioned in that other world after the death. The motif of a boat carrying the dead chief appears repeatedly throughout the Kofun period. The actual boat which is thought to have actually carried the body of the chief was excavated from the moat of the Suyama burial mound in Nara prefecture.

Conclusion

As we have seen above, the authority of the chiefs in the Japanese archipelago was created by their economic and cognitive traffic with the distant world. In particular, the Japanese archipelago is surrounded by the sea, and many long-distance trades and traffic were mediated by the sea. Table 1 shows how sea-mediated long-distance trade has higher cognitive inducement than land-mediated trade. The representations and discourses related to sea-mediated long-distance negotiations were so powerful that they created a worldview unique to the Japanese archipelago related to social status. This, combined with the economic dependence on iron materials imports through long-distance trade, indicates that the Japanese archipelago achieved a social complex unique to the maritime societies, different from mainland China and the Korean peninsula.

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Part 3

Innovative Research Methods

arcAstro-VR for Archaeoastronomy

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We are developing arcAstro-VR, a computer system that reconstructs archaeological remains from actual measurements and records and allows us to experience the simulations of past astronomical phenomena in a virtual 3D space. arcAstro-VR is based on Stellarium, an open-source desktop planetarium software package that can accurately reproduce the past starry sky. It can be visualised with astronomical data, and various verifications of the relationship between the archaeological remains and background celestial phenomena can be performed by moving freely in the VR space and changing the settings. The latest version (Ver0.17.3, released on December 22, 2022) is compatible with Meta Quest (Oculus Quest), and by connecting to a PC with MetaLink, we can experience a VR space through an HMD. In addition, a compass map display function centred on the marker that is the starting point of the auxiliary line, a dome master output that can be projected 360 degrees on the dome with a fisheye lens, and a function that simulates the reflection from the water surface by setting the water surface at any location, etc. have been added. arcAstro-VR is open source, licensed under the terms of the GNU General Public License version 3, and available for Windows (Windows 8 and above) and macOS (macOS 10.14 and above). (See https://arcastrovr.org/en/ for details). As an example of using arcAstro-VR, a virtual reproduction model of the Yoshinogari ruins in Saga Prefecture, Japan, was constructed.

Keywords: archaeoastronomy, Virtual reality (VR), 3D simulations

Introduction

Ancient people constructed monuments aligned with specific directions for various reasons, many related to their beliefs and practices. One common reason was to align the monument with the movements of the sun, moon, planets, and stars [Belmonte, 2015; González-García, 2015; Ruggles, 2015a, b]. For example, many ancient civilisations constructed structures aligned with the solstices and equinoxes, which were important events in their calendars. Another reason for building monuments aligned with specific directions was to reflect cosmological beliefs. For instance, some ancient cultures believed specific directions were associated with particular deities or powers, so they built their monuments accordingly. Similarly, some cultures believed that aligning a monument with certain celestial bodies or directions could confer spiritual or magical power.

Sometimes, aligning a monument with a specific direction also serves practical purposes. For example, some monuments were aligned with prevailing winds or important trade routes [Martinsson-

Wallin, 2014]. Overall, the reasons for building monuments aligned with specific directions were likely varied and complex and often reflected the beliefs and practices of the cultures that created them. Many ancient civilisations did not leave behind written records explaining their monuments' purpose or design intentions. As a result, researchers have to rely on indirect evidence and interpretations to understand astronomical and other means of connections.

For several reasons, verifying the relationship between a monument's alignment and the stars' movements can be difficult. The Earth's rotation axis undergoes long-term cyclic changes known as precession. Over thousands of years, this can alter the positions of stars in the night sky relative to the Earth's surface. As a result, even if a monument was accurately aligned with certain stars or celestial events at the time of its construction, it may not align precisely with those same objects today. In addition to changes in the apparent position of celestial bodies in the past, the state of preservation of the remains itself is not necessarily good. It may also be necessary to investigate places that are not easily accessible or where historic structures have been destroyed by natural disasters such as earthquakes or deliberate human actions. Furthermore, it is difficult to observe over months or years, requiring investigations at specific dates such as the solstice. Therefore, developing a computer system that can reconstruct interesting remains from actual measurements and records and experience the effects of past astronomical phenomena simulations in a virtual 3D space is desirable.

arcAstro-VR, a simulation software that can be used for archaeoastronomy, began development in 2019 to meet such needs (Sekiguchi & Takata, 2020). Initially, we planned to use the Teotihuacan ruins in Mexico to test functionality. However, due to the corona crisis, acquiring data from the Teotihuacan ruins did not proceed as expected. To test the usefulness of *arcAstro-VR*, in 2021, the beta version was verified using data from the Yoshinogari ruins in Saga Prefecture, Japan. Based on the results, we have made necessary improvements and added useful functions, and this time we report on the version updated as Ver0.17.3, released on December 22, 2022. In Ver0.17.3, new functions such as VR experience using HMD, compass map display function, 360-degree dome projection using a fisheye lens with dome master output, water surface reflection, etc., have been added.

This paper briefly introduces the goals of *arcAstro-VR* development, what this software can do, newly added functions, and examples using the Yoshinogari ruins data.

***arcAstro-VR* development goals**

Our objective is to create software capable of simulating and verifying the orientation of ancient ruins and the relative positions of celestial bodies in the historical sky. To that end, the following development goals were set:

1. Astronomically correct sky simulation, which applies to prehistoric studies.
2. Gives realistic simulations of daylight, twilight, and night skies and presents the horizon with panoramic views.
3. A panorama view can be created from on-site photographs or renderings of 3D models from each viewpoint to study the architectural line of sight along the axis of the building (or, similarly, a row

of upright stones, etc.).

4. When a known point or structure needs to be investigated in virtual space, it can load or extend to load 3D landscapes.
5. Accurately georeferenced 3D models can be loaded into virtual space, and the ability to identify and observe the line of sight combined with past sky reproductions and simulations to reconstruct archaeological structures and accurately reproduce virtual 3D models. It can be loaded into a computer system at any time.
6. Can clearly explain and demonstrate these phenomena to a large audience.
7. Allows virtual reconstruction to recreate a site's appearance as it might have been in the past rather than its current degraded state.
8. Possible to reconstruct not only a single building but also a large-scale collection, such as a town, by using a real-time simulation that allows the user to move around in it freely.

arcAstro-VR

arcAstro-VR is a VR application designed for PC, offering a captivating experience that replicates topographical landscapes, 3D data of archaeological remains, and astronomical occurrences (Figure.1). Utilizing LiDAR and photogrammetry survey data enables users to immerse themselves in a realistic 3D visualization. The software allows unrestricted movement within the virtual reality space, allowing users to adjust settings and perform diverse verifications, enhancing the exploration and understanding of various terrains and celestial events. "The formats that can be read as terrain and building data are GeoTIFF file formed for terrain (Figure.2) and 3D file formats such as obj, fbx, ply, etc., for building data (Figure 3).

Terrain data

Figure 4 gives the data flow chart of various survey measurements. *arcAstro-VR* utilizes shade relief data in a raw 16-bit grey image file format, divided into nine tiles arranged in a 3x3 grid on a wide-area base terrain to form the VR space. Each tile can be expanded to cover an extensive range of 100 x 100 kilometres, creating a total terrain size of 300 x 300 kilometres. Additionally, the shading data within a single tile can have a horizontal resolution of 24 meters for the wide-area terrain, as it can contain up to 4096 x 4096 pixels. The vertical resolution, representing heights from -1000m to 9000m, is 15.26 centimetres, calculated based on the 16-bit (65536) height representation. The wide area terrain data must undergo orthorectification, spherical correction, and optical correction (equivalent to Earth format correction). Additionally, users can create small terrains with customizable resolution and variable extent, with the smallest possible terrain being one tile measuring 4096 x 4096 pixels. Each pixel's resolution can be specified within a 0.1 to 10 meters range. To facilitate the creation of wide and narrow area topography, the "*terrain4aAVR*" plugin for the GIS software "QGIS" can be downloaded from the Plugin Download page of the *arcAstro-VR* WEB

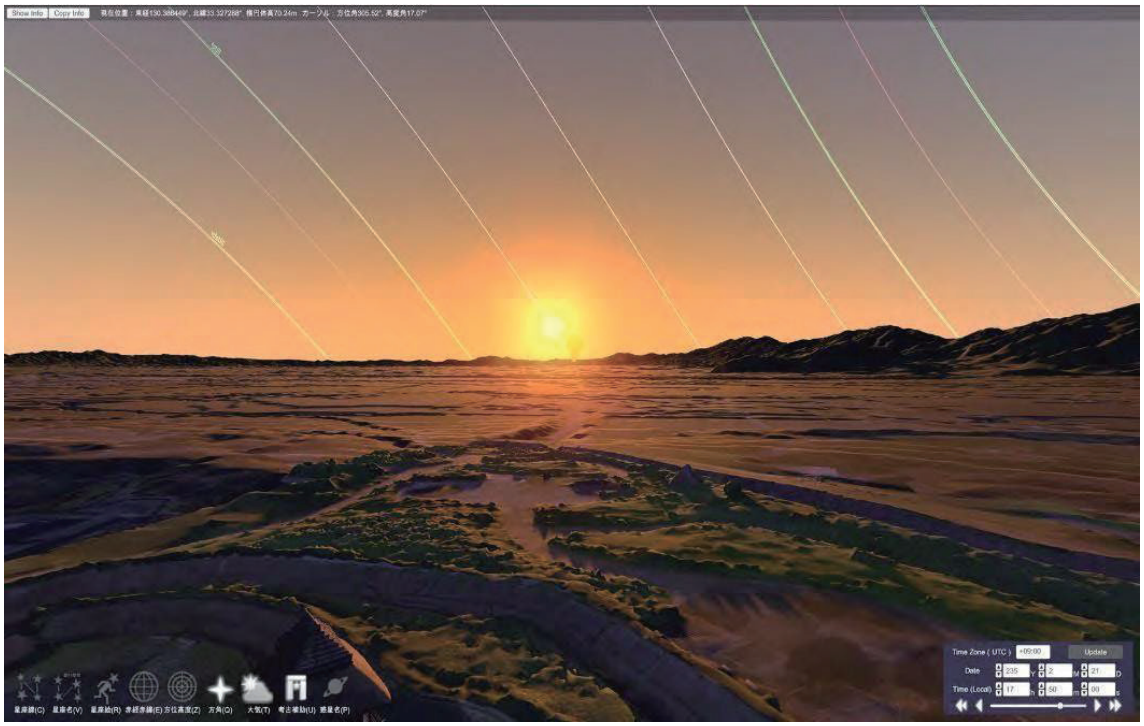

Figure 1. PC monitor display example of *arcAstro-VR*

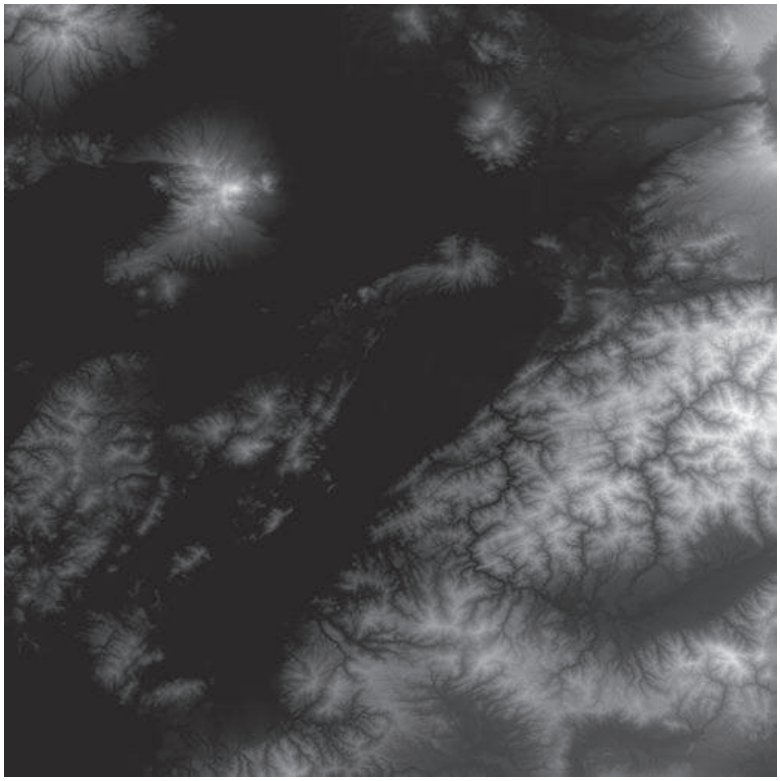

Figure 2. GeoTIFF: Planar image data with elevation in grayscale

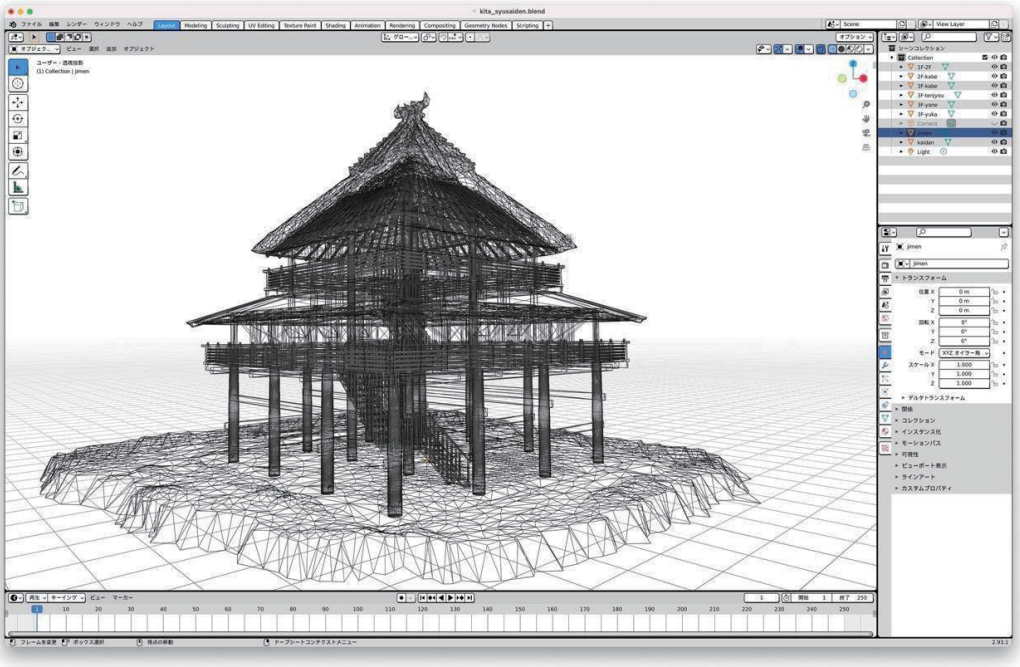

Figure 3. 3D data in which points, lines and planes are arranged with xyz coordinates.

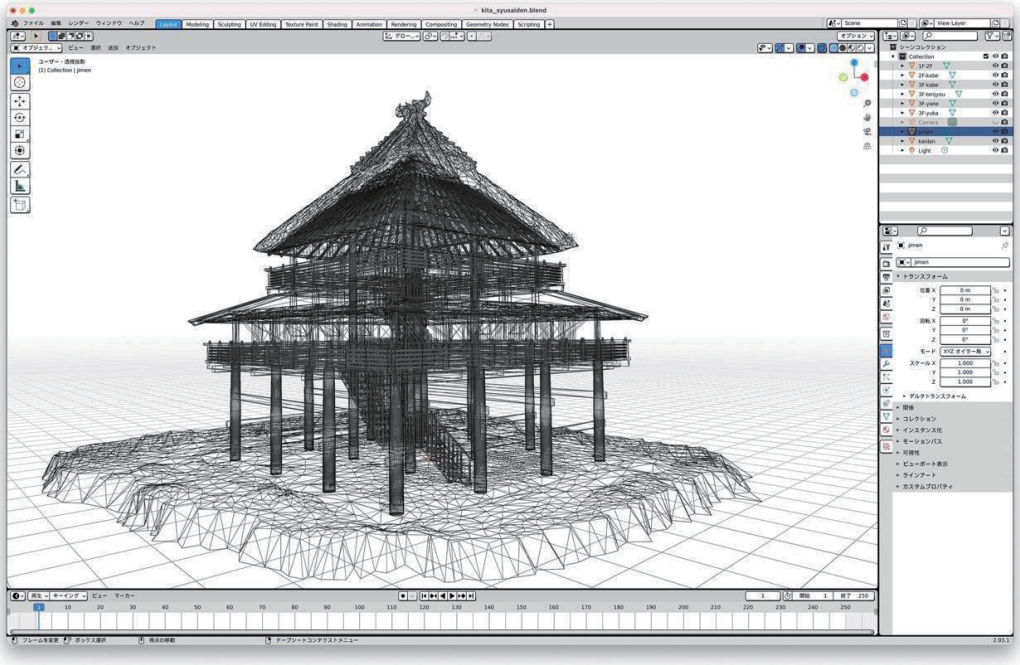

Figure 4. The flow of data creation from various survey measurements

(https://arcastrovr.org/download.html?id=plugin).

In addition to this wide-area topography and narrow-area topography, 3D models of remains (in some cases, topography such as tunnels that cannot be represented by elevation data) are superimposed and reproduced in VR space (Figure 5).

Wide-area and narrow-area topography are superimposed at the centre coordinates, and the centre coordinates are defined as the coordinates specified by centre in dataset.txt. Coordinates can be specified in WGS84 (latitude and longitude), planar rectangular coordinate system (19 system), or UTM coordinate system. When creating terrain with QGIS, specify and create the above centre coordinates. For details on the settings, see sections 4-3 of the *arcAstro-VR* Manual Version 0.17, “Creating a setting file (dataset.txt)".

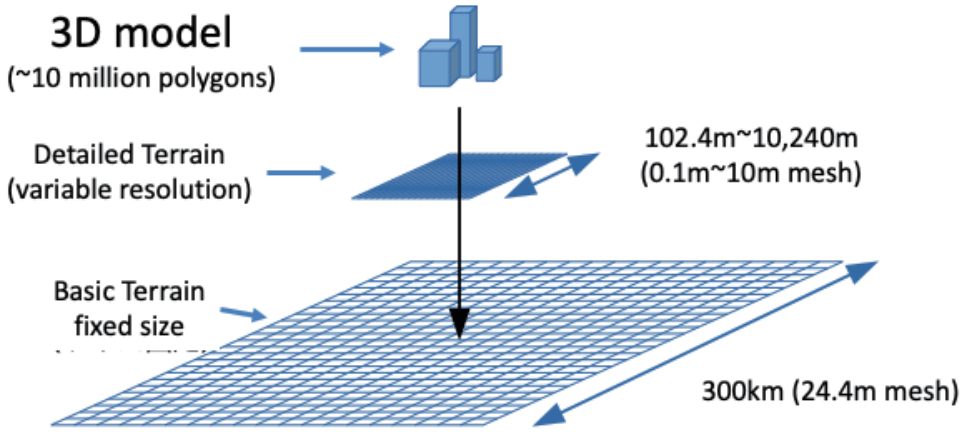

Figure 5. Terrain reproduction in *arcAstro-VR*

Astronomical projection

In collaboration with the astronomical simulator *Stellarium* (http://stellarium.org), we present a way to replicate the celestial panorama in *arcAstro-VR*. *Stellarium* is free software for Windows, Mac, and Linux and offers standard compatibility with VSOP87 (Bretagnon & Francou, 1988) for calculations from -2000 to 6000 years. Moreover, we have extended the support to include DE430 (Folkner et al., 2014), enabling detailed calculations from 1550 AD to 2650 AD, and DE431 (Folkner et al., 2014), covering a wide range from -13,200 BC to 17,191 AD. Leveraging *Stellarium*'s Remote Control (Plugin) and Skybox Tiles (Script) functions, we seamlessly transfer *Stellarium* sky images to *arcAstro-VR*, facilitating their display within the virtual environment (Figure 6).

Stellarium provides standard support for VSOP87/ELP2000-82B to calculate solar system objects, along with higher accuracy extensions DE430 and DE431. The VSOP87 model ensures accuracy within 1″ for Mercury, Venus, and the centre of gravity of the Moon-Earth system over 4000

years before and after 2000 AD, with a guaranteed accuracy of 6,000 years before and after. On the other hand, DE430 and DE431 are lunar and planetary ephemerides compiled and published by JPL (Jet Propulsion Laboratory), an agency of NASA, primarily for planetary exploration (Folkner et al., 2014). DE430 covers the time range from December 21, 1549 (Julian day: 2287184.5) to January 25, 2650 (Julian day: 2688976.5), while DE431 spans from August 15, 200 BC (Julian day: -0.3100015.5) to March 15, 17191 (Julian day: 8000016.5). Notably, the expression accuracy in arcAstro-VR is lower than the calculation accuracy of VSOP87, making the incorporation of DE430 or DE431 unnecessary.

What you can do with *arcAstro-VR*

arcAstro-VR can import 3D model data, manipulate and customise 3D models by displaying, hiding, and moving them, and adding markers and auxiliary lines for enhanced analysis. The VR space offers free movement options through various input methods, such as a mouse, keyboard, and game controller, granting a seamless and interactive experience. One of the most important features of *arcAstro-VR* is its ability to provide highly accurate reproductions of astronomical events from 2,000 B.C. to 6,000 A.D., enabling users to witness celestial scenes throughout the ages. Additionally, the software ensures realism by verifying sunlight, shadows, and water surface reflections using the sun and moon as light sources. To discover the full potential of *arcAstro-VR*, visit the official website at https://arcastrovr.org/en/.

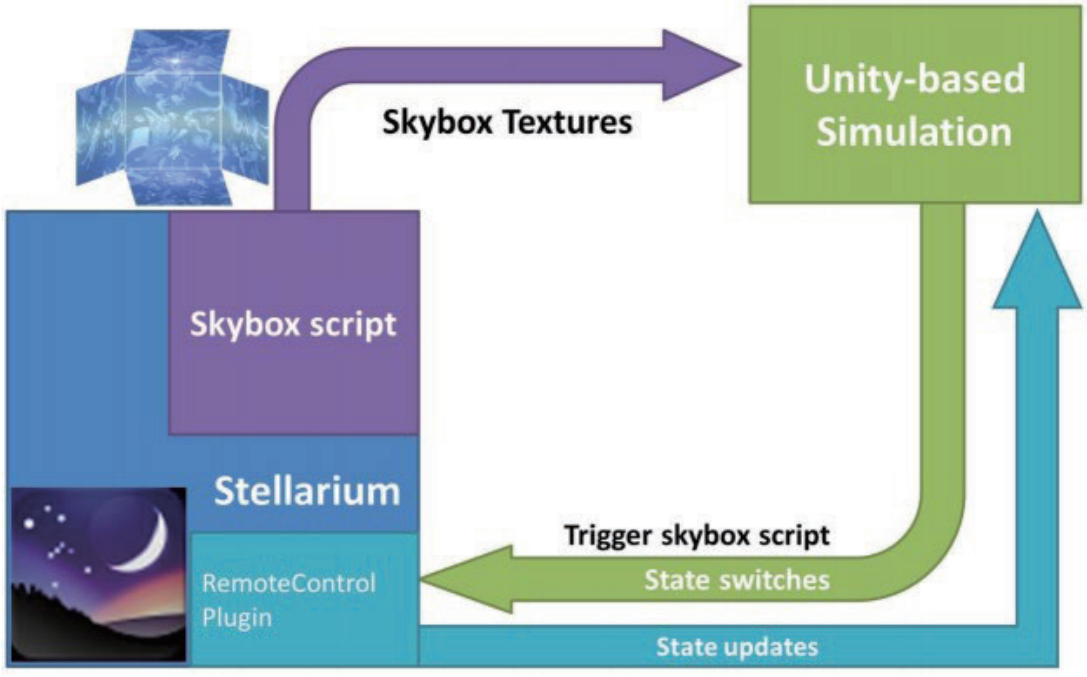

Figure 6. Linkage diagram of *arcAstro-VR* (Unity program) and Stellarium

Overview of the functions added to Ver0.17.3

Compass Map Feature:

A new function has been introduced to make visualizing the building's alignment easier in *arcAstro-VR*, allowing the recording of direction information for improved building orientation visibility. By pressing the "Map" button on the right side of the auxiliary line information, a compass map centred on the starting point marker of the auxiliary line is presented (Figure 7). This enables users to easily comprehend the direction of the building in relation to its surroundings. To facilitate data management, users can utilize the "Copy Information" button at the bottom left of the information window, which captures the information displayed and saves it to the clipboard. The copied data is organized in a tab-delimited format, making it easy to paste into spreadsheet software, where it is automatically divided into separate cells for clarity. Furthermore, users can store the modified or newly added information by clicking the "Save" button at the bottom right of the information window, creating a new dataset.txt with the relevant changes or additions. This functionality, which includes an ortho map directly above the building with the added direction, significantly improves the accuracy and convenience of analyzing architectural layouts in *arcAstro-VR*.

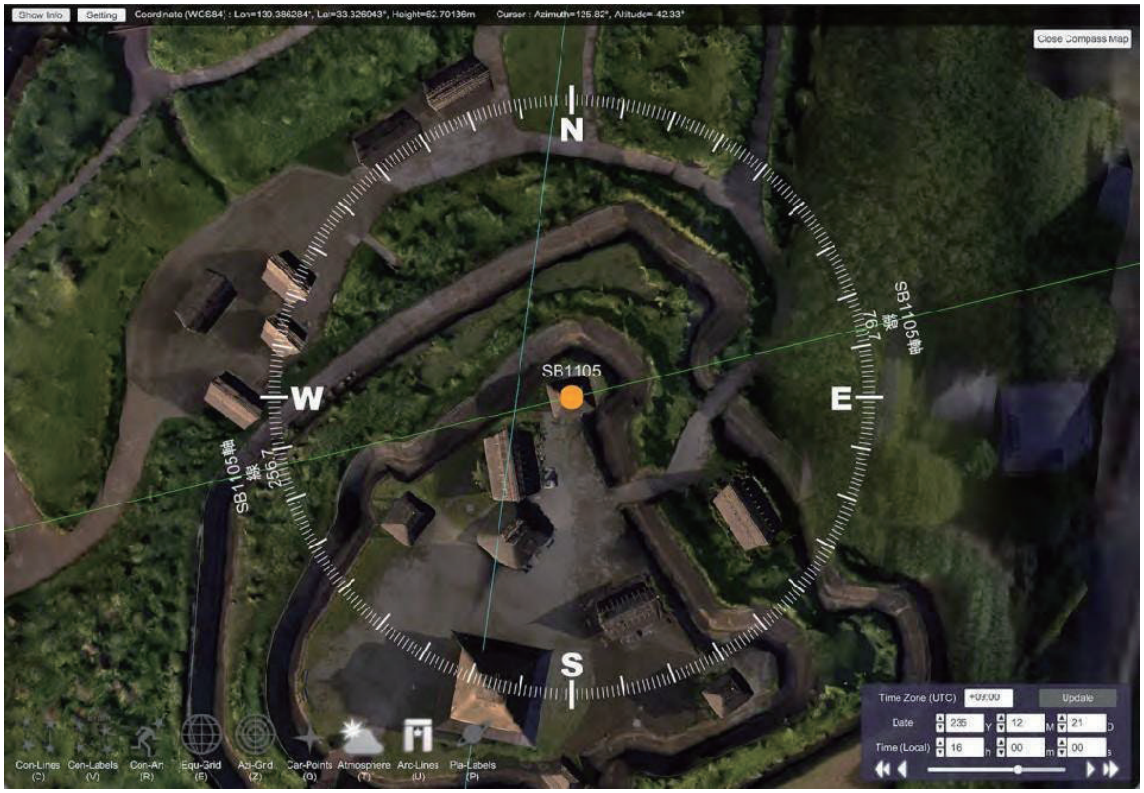

Figure 7. Compass Map Feature of *arcAstro-VR*

Dome master output support:

The latest feature in *arcAstro-VR* introduces support for Dome Master output, revolutionizing projection capabilities. This new functionality allows users to achieve immersive 360-degree projections on domes using a fisheye lens in the specialized Dome Master format (Figure 8).

The angle of view can be precisely specified, allowing customized visual perspectives. Additionally, users can set the azimuth angle, enabling precise orientation and alignment of the projection. The advanced direction can also be fixed, enhancing the projection's accuracy and stability. With these tools, *arcAstro-VR* can recreate ancient scenes, simultaneously bringing experiences to more people.

HMD support:

arcAstro-VR uses a Head Mount Display (HMD) to provide users with a highly immersive viewing experience, offering 6 degrees of freedom (6DOF). The supported HMDs include Meta (Oculus) Rift, Quest, and Quest2, which can be connected to a PC in Quest Link or Air Link mode. To ensure smooth operation, the PC must support OpenXR. However, it's important to note that OpenXR is currently not supported on Mac systems, so only Windows PCs are compatible. Additionally, users should be aware that running *arcAstro-VR* with OpenXR requires a high-performance GPU and ample memory. For checking PC compatibility with each HMD, please refer to the compatible PC table provided by the manufacturer.

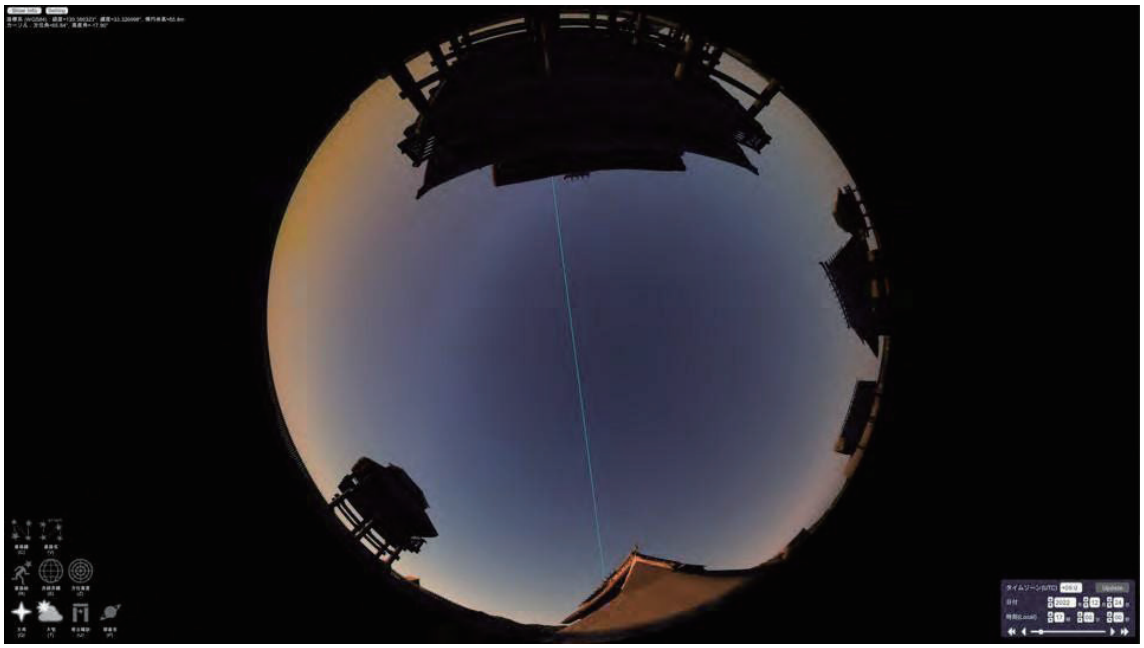

Figure 8. Dome master output of arcAstro-VR

Water representation:

In *arcAstro-VR*, the representation of water surfaces introduces a new level of realism and accuracy to the virtual environment. Users can easily install water surfaces at any desired location, enhancing the immersive experience (Figure 9).

The software also provides a sophisticated simulation of reflections on water, adding depth and dimension to the visuals. Furthermore, *arcAstro-VR* utilizes a directional light source to achieve lifelike shadows based on celestial bodies' azimuth altitude like the sun, moon, and Venus. These angles are calculated using *Stellarium*, ensuring high-precision lighting and shadow effects. *Stellarium*'s reliance on VSOP87 guarantees the accuracy of calculated angles for Venus, Earth, and the Moon within 1″ (0.00028 degrees) over a wide period of 4000 years before and after the year 2000. *arcAstro-VR*'s parallel light source setting further refines the angular accuracy, offering a 0.001-degree precision. This level of accuracy allows the simulation of light and shadows in *arcAstro-VR* to match the celestial sphere's diurnal motion, rotating at 15 arcseconds (0.004 degrees) per second, achieving a time resolution of approximately 0.25 seconds. As a result, *arcAstro-VR* creates realistic lighting and shadow effects.

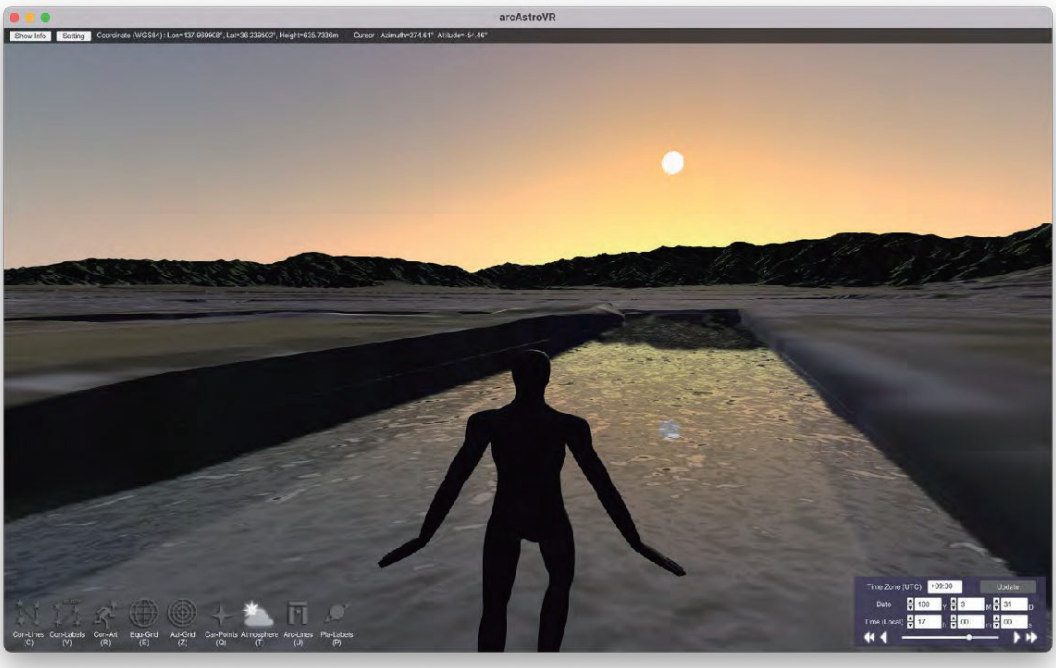

Figure 9. Water representation of arcAstro-VR

3D modelling of the “Yoshinogari” ruins

Beta version (Ver0.14.4) of *arcAstro-VR* was released on April 1, 2022, to identify software defects, points that need improvement, and functions that need to be added through trial use. At the beginning of the development plan, we planned to use *arcAstro-VR* to verify the Teotihuacan ruins, but due to the corona disaster, we could not go to the site and collect data as expected. Instead, we

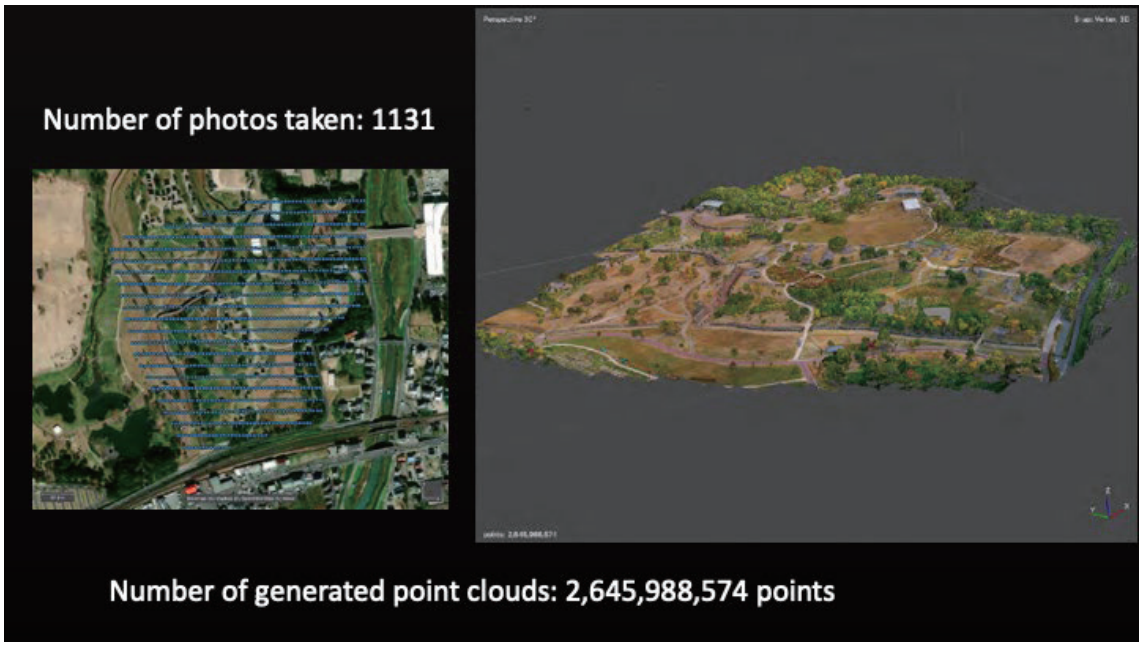

Figure 10. Aerial survey of the "Yoshinogari" Ruins: South Area

tested using data from the Yoshinogari ruins in Japan.

Between 2021 and 2022, a comprehensive 3D survey and modelling of the Yoshinogari ruins took place (Figure 10), involving collecting spatial data to create a point cloud classified into different categories such as terrain, trees, and buildings. Noise reduction techniques ensured accuracy, and a low-polygon terrain model was automatically generated. Manual methods were used to create low-polygon models for buildings based on the classified point cloud data. Normal maps were employed to enhance visual quality and add detailed features to the low-polygon structures, while texture maps further refined the models. The final result was a fully completed 3D model, visually representing the Yoshinogari ruins. The survey utilized three 3D conversion methods: photogrammetry with drones, 360-degree camera video shooting, and LiDAR scanning with iPhone/iPad. Combining these techniques and utilizing Agisoft *Metashape* software generated high-precision models for terrain and buildings, while low-polygon models were optimized with normal maps. The 360-degree camera and LiDAR scanning complemented the photogrammetry process and enabled accurate representations in some otherwise difficult conditions. The building 3D models were created and textured using integrated point cloud data, CG software *Blender*, and *Metashape*, resulting in accurate and visually captivating renditions of the structures.

Caution must be taken that *ArcAstro-VR* has certain limitations when dealing with 3D data, particularly when the entire Yoshinogari area is converted to 3D, as the highest polygon output becomes too heavy to handle efficiently. High resolution for finer detail and a balance between keeping the model manageable and responsive, i.e. a low polygon count is needed. Considering the hardware specifications required for the smooth functioning of *arcAstro-VR*, such as a Radeon Pro 580 GPU,

Intel Core i7 CPU, and 20GB of memory in a desktop PC (e.g., iMac from 2017), it is reasonable to aim for a total of 2 million polygons or less for a model to work efficiently within the platform. By adhering to these constraints, users can create and experience 3D models in *arcAstro-VR* optimized for performance without sacrificing quality or functionality.

Conclusion

arcAstro-VR is now fully operational and can be utilized effectively in archaeoastronomical investigations. The recent test conducted on the Yoshinogari ruins demonstrated its ability to achieve sufficient accuracy in fulfilling its purpose. In the next update, we would like to add functions such as importing wide-area terrain data from Cesium ion, etc., and fix various bugs while fully releasing and supporting it. During the "4th Archaeological Astronomy Conference" on December 19, 2021, at Yoshinogari Historical Park in Saga Prefecture, Y.H., a co-author of this paper, presented the findings of investigating the correlation between the Yoshinogari site and celestial body movements using *arcAstro-VR* (Hojo, Y. 2022). The following year, at the "6th Archaeological Astronomy Conference" held on December 25, 2022, in the same location, 3D data of the south inner enclosure was included, unveiling the structures of the Yoshinogari site along with the presentation of sunrise and moon calendars.

The verification results were shared as videos https://arcastrovr.org/movie/yoshinogari2021.mp4 and https://arcastrovr.org/movie/yoshinogari2022.mp4, showcased during the concurrent event "Yoshinogari Hikari no Hibiki" at Yoshinogari Historical Park and made available on the *arcAstro-VR* Web page.

Acknowledgments

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LiDAR Surveying of Ancient Mounded Tombs (*kofun*) in Japan

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Abstract

Airborne LiDAR surveying allows for the detailed mapping of areas that were long difficult through traditional surveying methods, either because of the extensive dimensions or prohibitive terrain and vegetation. Commonly utilized around the world, LiDAR technology has been increasingly employed in recent years within Japan, as well. The Department of Archaeology at Okayama University has been conducting LiDAR surveys of Kofun-period (mid 3rd to early 7th century AD) mounded tombs located within Okayama Prefecture over the past three years, including the Zōzan mounded tomb group, Sakuzan mounded tomb, Tottori-kamitakatsuka mounded tomb, Sarayama mounded tomb group, and the Tenjin mounded tomb group. In this paper, the author presents the results of the LiDAR surveys conducted at the Zōzan mounded tomb group and addresses areas for further research.

Introduction

Airborne LiDAR surveying allows for the detailed and accurate mapping of areas that would otherwise be difficult through traditional surveying methods. It is a useful method of surveying that can be used for expansive areas or areas with difficult terrain or heavy vegetation. Commonly used in archaeology around the world, LiDAR is now increasing in use within Japan, as well. The team from Okayama University (MITSUMOTO Jun, SEIKE Akira, YAMAGUCHI Yuji, and Joseph RYAN) has been conducting LiDAR surveys of mounded tombs belonging to the Kofun period (mid 3rd to early 7th century AD) throughout Okayama Prefecture. In this paper, the author presents the results of the LiDAR surveys conducted at the Zōzan (Tsukuriyama) mounded tomb group.

1. Mapping of archaeological sites in Japan

Traditional methods of surveying archaeological sites in Japan include the plane table and the total station. While the former is analog and the latter digital, they both entail physically traversing in full the area to be surveyed. While this allows the archaeologist to directly experience subtle shifts in terrain and utilize those experiences in the creation of a survey map, it can be difficult in areas of dense vegetation or uneven terrain.

The use of laser scanners to digitally map archaeological sites is becoming more common. In 2014, Okayama University utilized a tripod-mounted laser scanner (Faro Focus 3D) to digitally map the Tsukura mounded tomb, a 38.5m-long square keyhole tomb located in Okayama City, Okayama Prefecture (Mitsumoto 2020). While such laser scanners allow for the convenient capture of ground

data, the extent of capture is limited as the device is mounted to a tripod. Additionally, low-lying vegetation must be removed for suitable ground point capture.

This limitation can be overcome by mounting the scanner on an aerial vehicle, whether a drone or airplane. A well-known example in Japan of the use of aerial surveying is the Red Relief Image Map produced by Asia Air Survey Co., Ltd. of the Niizawa-senzuka mounded tomb cluster in Kashihara City, Nara Prefecture. This dense cluster of around 600 tombs dating to the end of the 4th to the middle of the 6th century would be difficult to survey using traditional methods. Aerial surveying allowed for a comprehensive understanding of the tomb cluster and the relationship between the tombs and their surrounding topography, in addition to the discovery of new tombs.

Aerial laser surveying of archaeological sites has increased since around 2010. However, equipment, insurance, and other maintenance expenses are costly. The specialized nature of UAV equipment and software also makes it not typically feasible for archaeological institutions to own and utilize LiDAR equipment. Archaeologists therefore usually end up commissioning surveying companies. Such reliance on external companies, however, requires the close coordination of the archaeologists and technicians, as the research questions, goals, and desired data can significantly differ between the two.

Since FY 2019, the Out of Eurasia project has enabled the Okayama University team to purchase the necessary equipment and implement LiDAR surveys across Okayama Prefecture. Within Japan, LiDAR can be used to effectively map lowland archaeological sites, hillforts, mounded tombs, and medieval castles. Of these various uses, the Okayama University team has applied a LiDAR approach to the ancient mounded tombs (*kofun*) of the Okayama area.

Kofun were mounded tombs that were built between the middle of the 3rd century to the beginning of the 7th century. It has been estimated that over 160,000 earthen mounded tombs were built during the Kofun period, over 5000 of which were of the characteristic keyhole shape. It has been suggested that the sociopolitical ranking system of the Kofun period was manifested in tomb shape and size (Tsude, 1991). Kofun can therefore be highly instructive for understanding ancient Japanese society. But in order to fully utilize them as tools to interpret the past, it is necessary to analyze their shape, size, and relationship to the surrounding landscape – LiDAR proves highly effective for this purpose.

2. Drone-based airborne LiDAR survey

LiDAR stands for “light detection and ranging”. Like sunlight through the leaves, laser pulses sent out from the drone hit the ground and rebound to the sensor, allowing the acquisition of coordinates. 100,000s of laser pulses a second are sent and received, allowing highly accurate and detailed survey maps even under thick vegetation. Attaching LiDAR to a drone allows for aerial laser surveying and the efficient capture of detailed topography over extensive areas. This presents a significant departure from traditional surveying methods, which required the direct traversing of the survey area.

The Okayama University team utilizes a Phoenix LiDAR Systems miniRANGER attached to a

DJI Matrice 600 Pro. The Trimble R2 is utilized as a GNSS receiver. LiDAR surveys have been conducted on major Kofun-period tombs and tomb groups throughout Okayama Prefecture: Multiple surveys were conducted of the Zōzan tomb group in Okayama City, from March 20-21, 2020, July 4-5, 2020, and February 6, 2021; one survey was conducted of the Sakuzan (Tsukuriyama) mounded tomb in Sōja City on November 28, 2020; one survey was conducted of the Tottori-kamitakatsuka mounded tomb and its environs in Akaiwa City on April 18-19, 2021; one survey was conducted of the Sarayama tomb cluster in Tsuyama City on January 22 and 25, 2022; and one survey was conducted of the Tenjin tomb cluster on January 11-12 and 17, 2023.

A software called Litchi is used to prepare a drone flight plan. Battery life limits a single flight to around 15 to 20 minutes or approximately 4.5 km. Drone flight speed depends on the necessary point cloud density: in areas of thick vegetation, the drone is flown at a slower speed (5 m/s) in order to increase the number of returns; in cases where an extensive area must be covered, the drown is flown at a faster speed (8 m/s). The Okayama University team typically adopts a drone altitude of 65 m above ground level at all times.

After point cloud capture, software (Inertial Explorer and Spatial Explorer) is utilized for post-processing GNSS/IMU and LAS exporting. Subsequently, Terrasolid TerraScan (or a similar software) is utilized for point cloud classification and filtering. This process removes vegetation, buildings, and other captured objects that do not belong to the archaeological site, leaving only the ground surface of the mounded tomb. Seasonal vegetation can greatly affect point capture: For example, during the summer months, thick undergrowth can obscure the actual ground surface and complicate the filtering process. It the case of Japan, higher quality ground point capture can be achieved by surveying during colder months.

3. LiDAR survey of Zōzan

In this section, let us review previous surveys conducted of the Zōzan (Tsukuriyama) mounded tomb and its surrounding subsidiary tombs before introducing the LiDAR survey conducted by the Okayama University team. The research results presented below can be found in more detail in our previous publication (Mitsumoto et al., 2023).

The Zōzan tomb group is located in Okayama City, Okayama Prefecture (Figure 1).

Zōzan is a keyhole mounded tomb measuring approximately 350 m in length. It is the fourth largest tomb throughout Japan and the largest tomb outside of the Kinki region. It is surrounded by six smaller subsidiary tombs. In addition to archaeological excavation by the Okayama City Board of Education and the Okayama University Department of Archaeology, several surveys have been conducted of the tombs.

The first modern survey was an aerial photography-based mapping commissioned in 1985 by Okayama City and Okayama Prefecture (Figure 2A; Okayama-ken-shi Hensan-iinkai, 1986). A contour map was produced from aerial photos and adjusted as necessary based on on-site

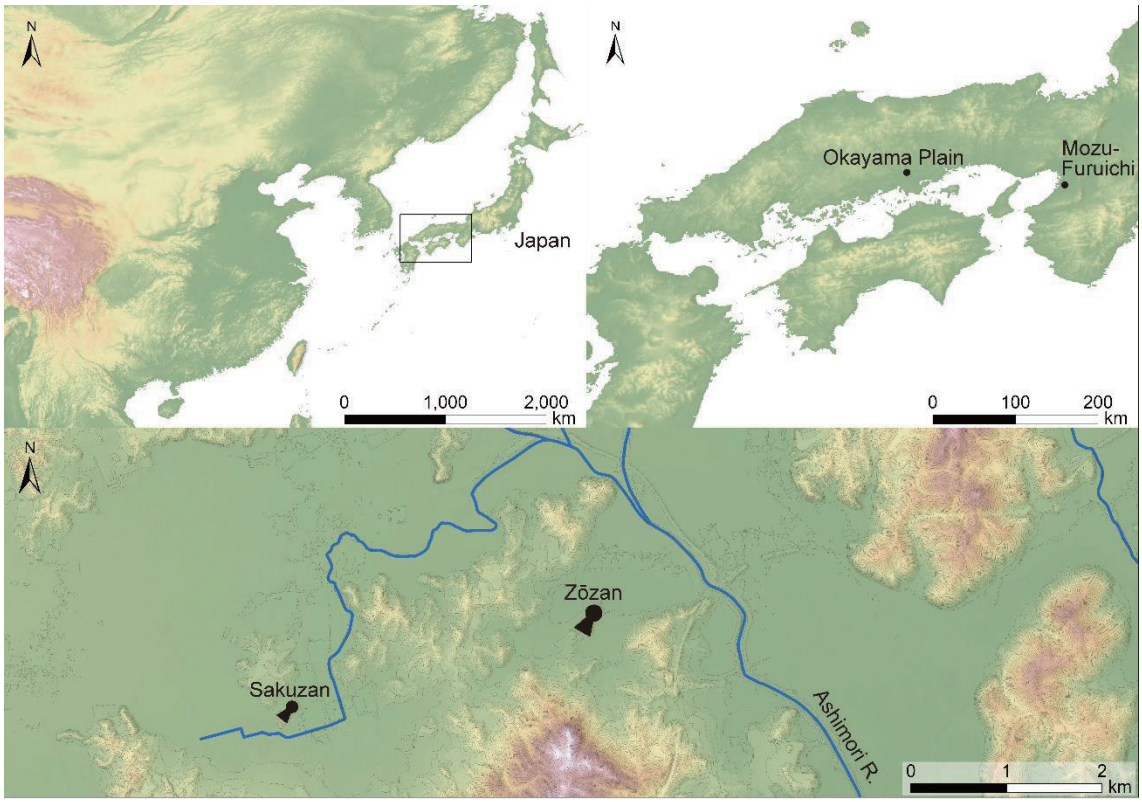

Figure 1. Location of the Zōzan mounded tomb (Mitsumoto et al., 2023).

confirmation. Subsequently, a plane table-based survey was conducted in tandem with a total station-based digital survey under Professor Niiro Izumi of Okayama University in order to compare and contrast these methodologies and their results (Figure 2B; Niiro, 2008, 2012). A DEM produced from aerial photographs was subsequently combined with the digital mound data acquired through this project in order to situate the tombs within the landscape (Figure 2C; Teramura, 2008). In 2014, the Okayama City Board of Education conducted additional surveys utilizing aerial photography and digital survey methods (Figure 2D; Okayama-shi Kyōiku-iinkai 2014). While these surveys have produced high-quality maps of the mounded tombs, they have mostly relied on aerial photography or a combination of total station-based digital surveying and existing municipal maps. While a consideration of the relationship between the tombs and the surrounding landscape requires direct survey of the surrounding terrain, the expansive area across which these tombs are located has prevented such efforts utilizing traditional survey methods. A deeper understanding of the tomb group in relation to the surrounding topography requires a comprehensive mapping of both the tombs and the surrounding landscape. It was against this backdrop that the Okayama University team conducted LiDAR surveying of the Zōzan tomb group and its environs. An approximately 1 km2 area was surveyed through a combination of 11 flights (Figures 3 & 4).

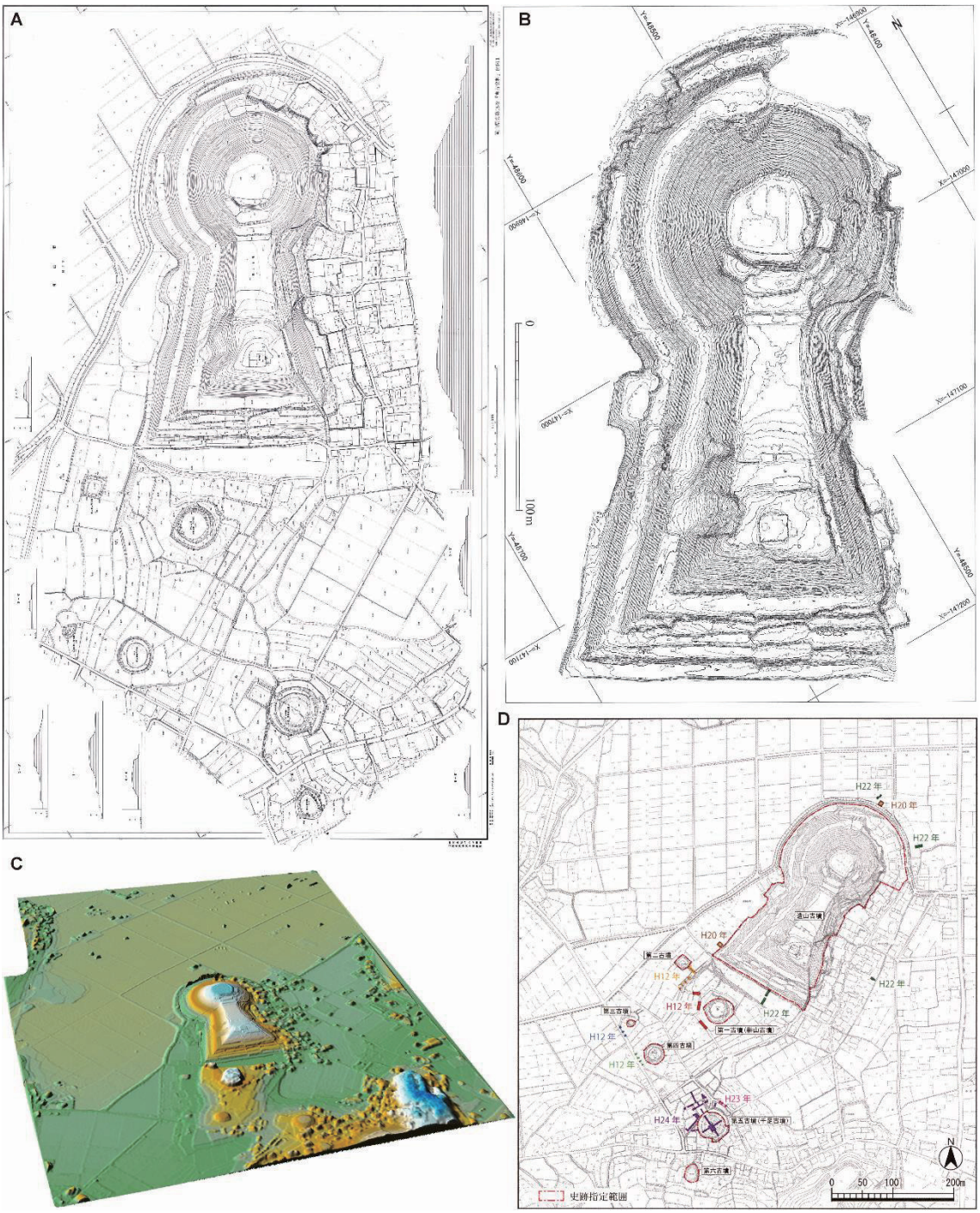

Figure 2. A history of surveys conducted on Zōzan and its environs: A) after Okayama-ken-shi hensan-iinkai, 1986: supplementary fig. 1; B) after Niiro, 2008: fig. 2; C) after Teramura, 2008: fig.9; D) after Okayama-shi Kyōiku-iinkai, 2014: fig. 16 (Mitsumoto et al., 2023).

Figure 3. Orthophoto of the Zōzan tomb group and its surroundings. Subsidiary tombs are indicated by numbers (Mitsumoto et al., 2023).

After filtering, the point cloud comprised 28,120,002 points, or approximately 20 points per m2. While differing in total area, this represents a significantly more detailed point cloud than that acquired via the Faro Focus 3D survey of the Tsukura mounded tomb mentioned above (319,375 points).

LiDAR surveying of the area allows consideration of the relationship among the tombs of the tomb group and between the tomb group and the surrounding terrain. The first area that can be considered is order of tomb construction and alteration of the landscape. Previous trench excavations revealed that the construction of Zōzan involved the considerable leveling, cutting, and working of the hill to the south (Niiro, 2012). It is apparent from the LiDAR data, however, that construction of the whole tomb group must have required large-scale development of the natural hill. Combining the LiDAR data with the order of tomb construction suggested from typochronological research on the

Figure 4. LiDAR map of the Zōzan tomb group and its environs. Black arrows indicate rice paddies and land plots that have been interpreted as remains of the moat in the modern landscape (Mitsumoto et al., 2023).

haniwa that adorned the mound surfaces (Yasukawa, 2019) reveals that tombs were constructed from higher to lower elevation (Figure 5). Interestingly, the ancient San'yō thoroughfare, which was built in the late seventh century as part of a national infrastructure project, runs directly between Tombs 5 and 6. Although the tombs had been built long before the late seventh century, the location of the three largest fifth-century keyhole tombs of the region (Zōzan [350 m], Sakuzan [282 m] and Ryōgūzan [206 m]) along this highway suggests that a road had long existed there. While it is feasible that the highway was later built to pass by these impressive mortuary monuments, the fact that keyhole tombs had all but lost their sociopolitical significance by the 7th century rules against this possibility. Additionally, as it would have been logistically difficult to build a thoroughfare between the closely located tombs without damaging them, we can infer that an existing thoroughfare had been repurposed in the 7th century infrastructure project.

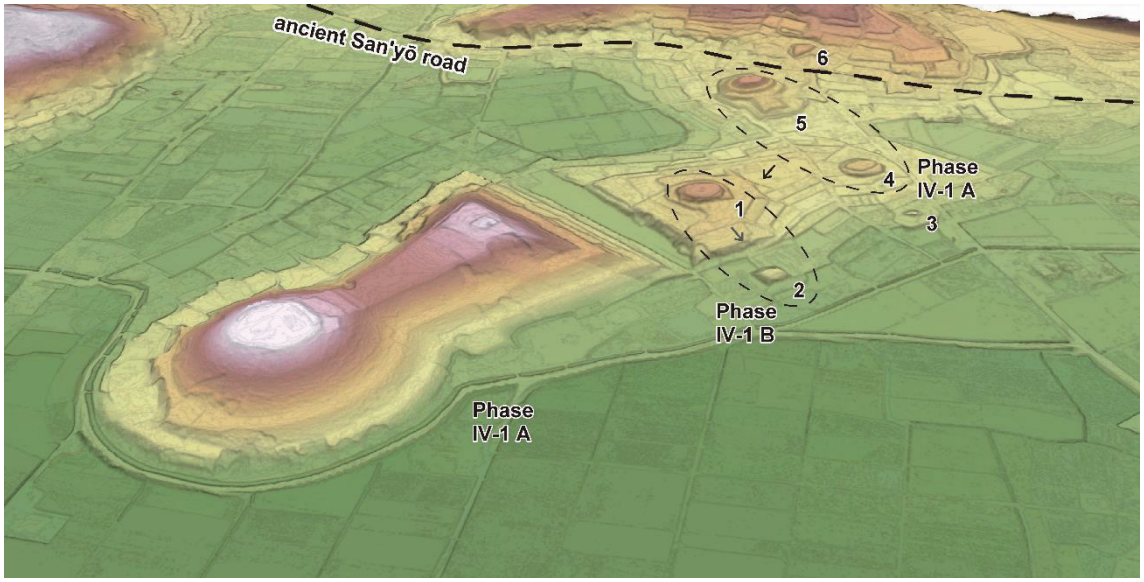

Figure 5. Bird's-eye view of the tomb group. Arrows indicate order of construction. Typochronological phases of haniwa after Yasukawa, 2019 (Mitsumoto et al., 2023).

This would suggest that the cutting away of the hill to make the tomb group was not simply a project to construct the burials of powerful regional elite, but also involved the construction of a major road, which was likely one element of a burgeoning transportation network. Construction of the Zōzan tomb group was therefore likely situated at the crossroads of politics, economy, and ritual.

The second area of inquiry that our LiDAR data can contribute to is the debate over whether a moat once surrounding Zōzan. The paramount tombs of the Kinki political center (the Mozu-Furuichi tomb group in Osaka, now a UNESCO World Heritage Site) were equipped with a moat surrounding their mounds and this mortuary style was often adopted by subservient elite throughout the Japanese archipelago, as the fundamental sociopolitical mechanism of center-periphery interaction was based on the sharing of mortuary ritual and mounded tomb culture. The question of whether Zōzan was also equipped with a similar surrounding moat is intimately related to the level of political connection between the Kibi region and the Kinki political center.

The results of previous trench excavations of the areas directly outside the mound have been interpreted as suggesting the existence of a surrounding moat and this interpretation is further supported by the shape of the modern rice paddies and land plots to the east and northeast of the mound (Figures 4 & 6; Niiro, 2012). While no such moat can be inferred from the standardized layout of the modern rice paddies on the western side of the mound, a map from 1887 reveals that similar curved rice paddies once existed there as well (Okayama-shi Kyōiku-iinkai 2014: Figure 7). Debate continues over the existence of a moat, however, with some suggesting that the features found through archaeological excavation belonged not to a moat but to a natural waterway (Kusahara, 2014).

The microtopography reconstructed from our LiDAR data reveals sagging in the area of the proposed moat (Figure 6).

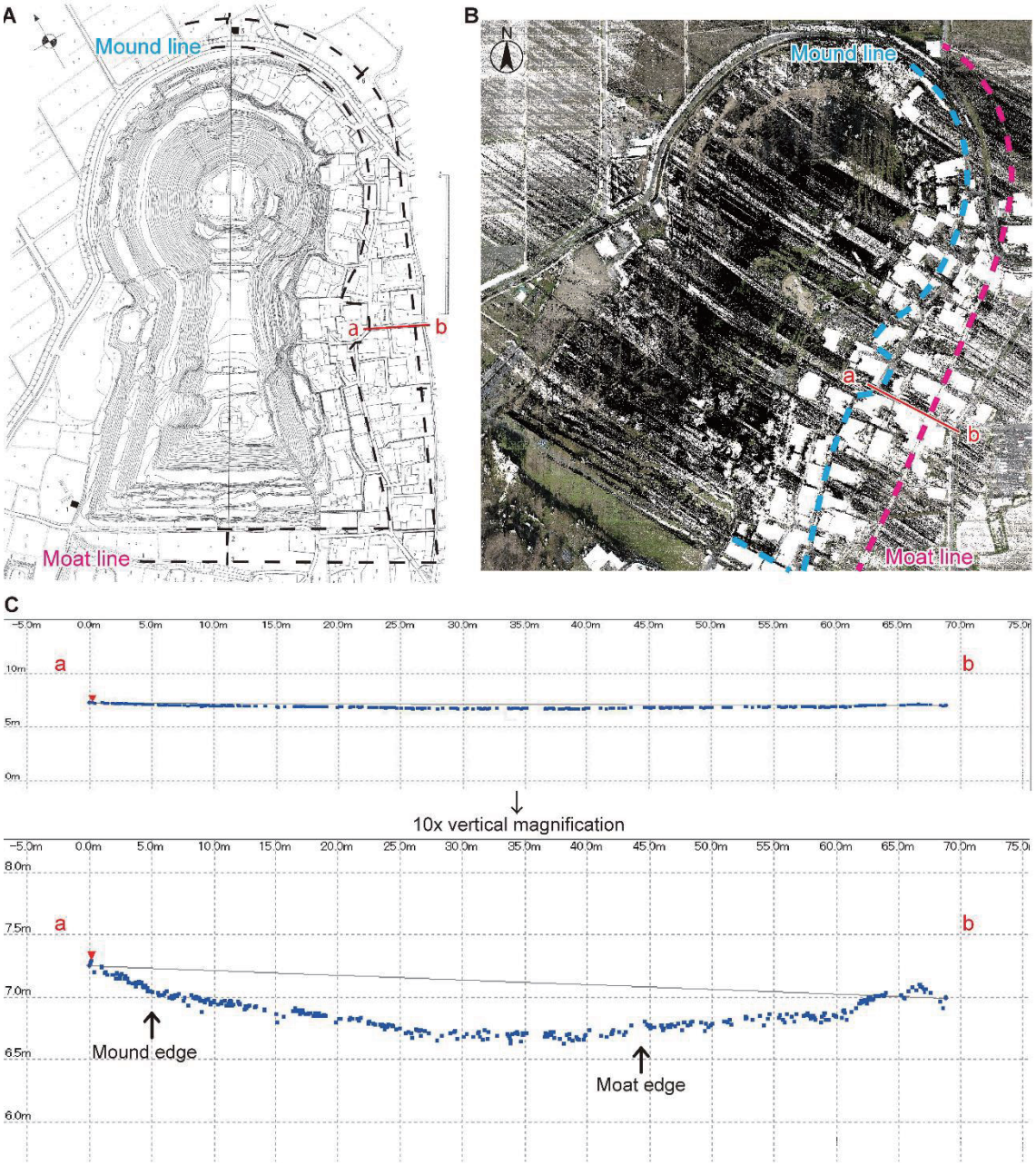

Figure 6. Cross-section of the area of the proposed moat: A) a–b line indicated on survey map of Zōzan (after Niiro, 2012: fig. 2.23; B) LiDAR point cloud, with location of a–b line indicated; C) cross-section of the a–b line shown in original (top) and 10x vertical magnification (bottom) (Mitsumoto et al., 2023).

This depression may be explained by the settling of backfill into a once-open moat. While not definite, it would seem likely that Zōzan had indeed between equipped with a moat similar to the paramount tombs of the political center. The Okayama University team is currently conducting a series of surveys utilizing multispectral imaging in order to further consider the possible existence of a moat; this approach analyzes differential growth of vegetation both inside and outside the area of the proposed moat in order to clarify the existence of a previous channel of water.

Conclusion

Drone-based airborne LiDAR survey is fast, accurate, and efficient compared with traditional mapping methods. It allows for the comprehensive and extensive mapping of a site in unison with the surrounding topography; with traditional surveying methods, this was difficult due to the various types of terrain and elevation levels. It also facilitates new understandings of archaeological sites: This applies not only to the discovery of new sites, but also to new understandings of existing sites. This may include clarifying the size and shape of tombs, which can lead to understanding ancient society and politics, quantitative analysis of mound volume, which can help answer such questions as "how much soil was piled up to build these funerary monuments?", and understanding the relationship between sites or mounded tombs and the surrounding landscape, which allows for a data-based landscape-archaeology approach.

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Uncovering the Environmental Conditions at the Nan Madol World Heritage Site through Airborne LiDAR and Satellite SAR Data: The Development of a Monumental Stone Landscape

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Here we examine models created from airborne LiDAR data and a wide variety of satellite sensors that reveal the environmental conditions on the island of Pohnpei in the Federated States of Micronesia, with a specific focus on the Nan Madol World Heritage Site. These environmental conditions greatly rewarded the investment of human labor to create landesque capital in the form of wealth, food security, and prestige. These environmental conditions so conducive to the formation of landesque capital are described and discussed. As labor investments and landesque capital increased over hundreds of years, Nan Madol was constructed.

Nan Madol is a World Heritage Site located on the western Pacific Island of Pohnpei in the Federated States of Micronesia. It is the highest of the four high volcanic island groups in the Federated States of Micronesia, and it is hundreds of miles from the other three. It is surrounded more closely by more than one hundred coral atolls. The site of Nan Madol is built on a coral reef flat on Temwen Island, which nearly touches the main island. It consists of about 100 humanly contrived islets, most of which have structures built atop them. Many of these structures are elaborate, having chambers for living areas, rituals, and burials. The islets and structures were primarily built of columnar basalt, which is found on the adjacent main island, and coral.

This ritual and political center is about 1.25 x 0.5 km. Some argue that it is the earliest stone monumental landscape in the Pacific (McCoy et al., 2016). Why would this impressive, sophisticated feat of engineering that clearly required an enormous number of hours of human labor be found on a tiny island in Remote Oceania, in the far western Pacific? We argue here that it is because of environmental factors that are almost unique in Micronesia and that yielded outsized returns on labor investments. This is a hypothesis whose testing awaits further research on the magnitude of agricultural intensification on Pohnpei. However, we present here reasons to think that final evidence to support it can be found, possibly through fieldwork such as the analysis of soil samples.

Due to their isolation, the islands of remote Oceania are ideal laboratories for the study of human-environmental interaction. Satellite and airborne technologies offer tools that can provide unprecedented insights into this relationship. In our study, the implications of what is seen in the images and models created from data collected from satellites and aircraft was greatly enhanced by

Figure 1. Nan Dowas at Nan Madol displaying the columnar basalt from which it was constructed.

working with holders of indigenous knowledge, who can identify what is seen in these data products with the knowledge used in traditional navigation.

Co-Production

Here we acknowledge the vital collaboration with master traditional navigator Larry Raigetal, who provided crucial interpretations of what is seen in the images and models generated from remotely sensed data. We refer to this collaboration here as co-production. Co-production between traditional knowledge holders and developers, on the one hand, and users of remotely sensed data, on the other, has just begun, but it may provide huge benefits to understanding the natural and cultural processes that have shaped the world we live in. We can hope that this understanding can contribute to finding solutions to the myriad of existential threats to humanity that have resulted in large part because colonial powers have disrupted the network of humans and nature that had largely sustained livable environments.

Using Remotely Sensed Data

Archaeologists have traditionally examined the material left by past societies, often by conducting excavations that irreversibly disturbed the material evidence left behind by previous inhabitants of the earth. Today, using airborne and satellite remote sensing technologies, entire

landscapes, and seascapes, can be studied. These technologies are non-destructive. At the scale of land- or seascapes, or at even greater scales, remote sensing data can be used to identify areas that offer special attractions for human occupation. Even more to the point of this paper, data products and models can be interpreted by traditional knowledge holders to identify those land- and seascape characteristics that are of greatest importance to people. Such characteristics might relate to a land- or seascape's potential to yield increased food security or prestige with a relatively minimal input of human labor. Both food security and prestige motivate groups occupying marginal locations within a given region to form alliances. These alliances, in turn, are necessary to protect the enhanced productivity and subsequent wealth that is amassed in especially productive environments from groups that remain unallied.

Nan Madol and Landesque Capital

Enhanced food security and prestige are potential yields of labor that is invested in the development of landesque capital. The concept of landesque capital originates in the work of Amartya Sen (1959). It has been further employed by Hakansson and Widgren (2014) and later used by geographers and anthropologists in exploring storage structure as it relates to exchange in the service of food security and prestige economy (Bayliss-Smith and Hviding, 2015, 2012). It refers to the choice of land use techniques that serve important economic, social, and ritual purposes (Hakansson and Widgren, 2014).

We offer the World Heritage Site of Nan Madol as an example of how complex, monumental landscapes tend to emerge at certain locations. Such locations must possess the resources that can be enhanced by labor to increase landesque capital return at lower marginal cost than at competing locations. We suggest that if such a location occurs within a backdrop of environments that do not possess such resources to an equal or greater degree, then that location becomes the most attractive target for investment in landesque capital. These optimal locations offer opportunities that are clear to human groups who seek such benefits as the security of the wealth provided by abundant sources of food and defense against groups that would take that food.

The approximately 100 islets and the structures built on them at the site of Nan Madol, inscribed on the World Heritage List in 2016, are remarkable in many ways: as an engineering feat, as an aesthetic achievement, and as a testament to the enormous investment of human labor that was required to construct it. Until now, only a few scholars have suggested that agricultural intensification was present on Pohnpei to a degree that would provide a sound base for the socio-cultural complexity seen cast in stone at Nan Madol (Ayres, et al: 2015). This is understandable because our survey of historic accounts (those dating from the advent of the colonial era on Pohnpei) record only that agro-forestry was practiced. Also, exploration by survey using small excavation test units would not reveal the pattern of terraces and fields that bear witness to intensive agriculture, lacking the synoptic view provided by remote sensing.

The scarce discussion of the possibility of agricultural intensification on Pohnpei might also be due to the widely accepted and admired idea of the Breadfruit Revolution (Petersen, 2006). The central argument is that the introduction of the breadfruit in Micronesia was the catalyst of a uniquely Micronesian culture. It made possible the human habitation of the hundreds of atolls that emerged between circa 4,000 and 2,000 years ago by providing a crucial source of food that, along with fish, coconut, and eventually small patches of wet taro, could support small populations on atolls. It is relevant to the points raised in this paper that, even so, life was likely precarious given the frequent extreme weather events in Micronesia. On each of the atolls, human populations number in the hundreds at most, and their past populations left behind no monuments constructed of durable, long-lasting materials. We acknowledge here that Petersen's proposal of a Breadfruit Revolution is a valuable contribution to understanding how the islands of Micronesia were populated and how they were knit together culturally to some extent by this common subsistence base, but we propose here that the Breadfruit Revolution would not have provided a sufficient economic base or incentive for the socio-cultural complexity that is suggested by the fact of the construction of Nan Madol.

Nan Madol in the Context of Human Movement into Micronesia

Remote sensing data collected from satellite and airborne sensors are used here to elucidate how the post-mid-Holocene drawdown likely influenced the seascape in ways that influenced the chronology and pattern of human occupation of the islands of Micronesia.

The special environmental conditions apparent in images and models generated from data collected by aerial and satellite platforms over Nan Madol and the island of Pohnpei illuminate the differences between environmental conditions there and those of the hundreds of atolls in the Central and Eastern Caroline islands in Micronesia. Pohnpei offered much greater environmental diversity than did these atolls, and it is especially important that some environmental features could be modified in ways that greatly increased wealth and prestige with a relatively small input of human labor. These differences, we argue, would not only have made Temwen Island an attractive location for the monumental construction, but they also would have provided incentives for populations on atolls to form alliances with Nan Madol.

Navigation and the post-mid-Holocene Drawdown

This interaction of human groups from different islands was possible only after master navigators refined navigational knowledge in ways that opened pathways among coral atolls and high volcanic islands. Hundreds of atolls emerged during the post-mid-Holocene drawdown. Also, following the drawdown, the environmental dynamics of the areas surrounding these newly emerged atolls changed, and seamounts had greater influence on the seascape in their near vicinities. Certain species of animals, including fish, mammals, and birds, were attracted to the habitats that developed near seamounts and coral atolls. These served as additional waypoints used by traditional navigators

(Raigetal, personal communication, 2022). Atolls and seamounts also changed ocean dynamics including wave and current patterns.

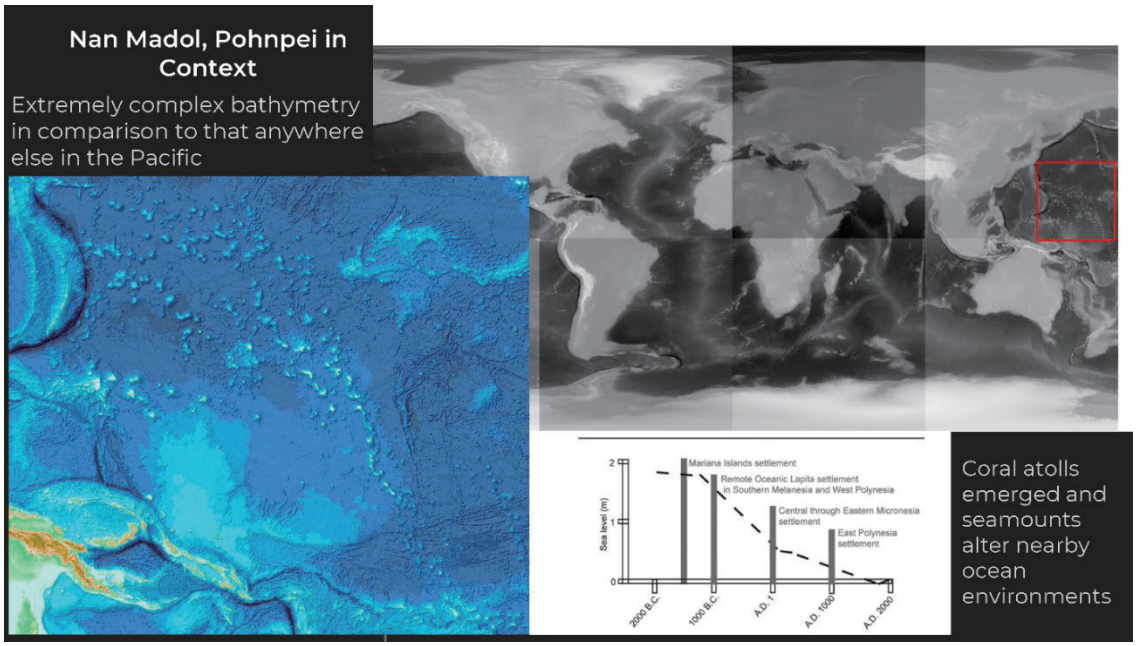

Figure 2. Bathymetry of Micronesia. During the post-mid-Holocene Drawdown, Coral Islets Emerged and Seamounts had Greater Influence on Surrounding Ocean Environments, Altering the Seascape

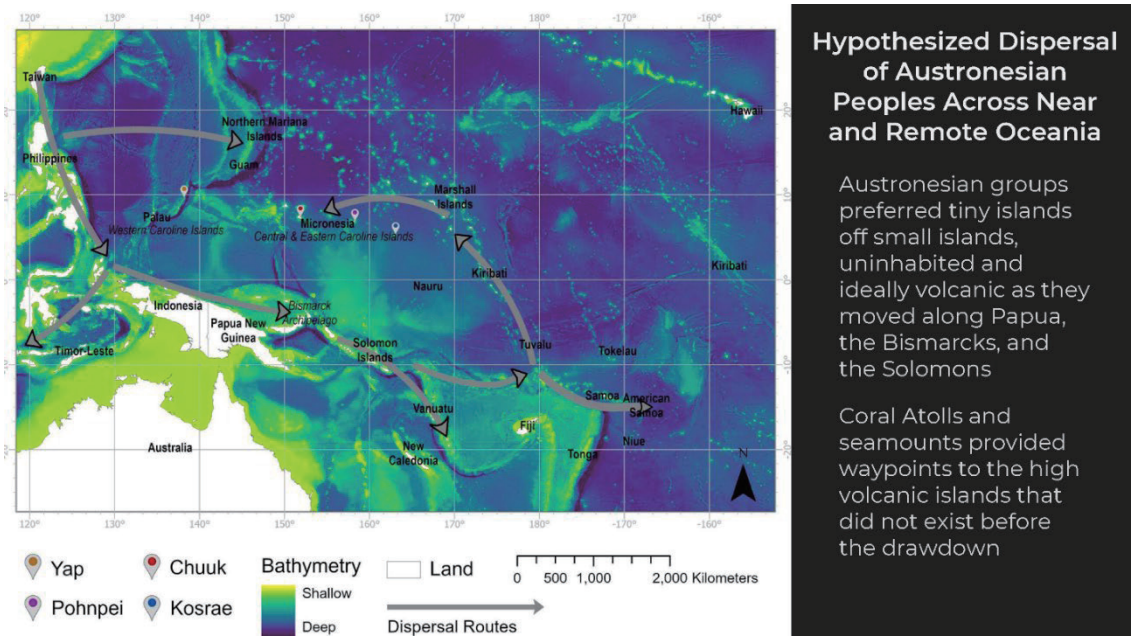

Figure 3. Hypothesized Dispersal of Humans into Micronesia

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As people learned to navigate in this area of Remote Oceania, they inhabited the atolls and the few high volcanic islands (less than 1% of all the islands). The highest of the volcanic islands is Pohnpei, which offered much greater environmental diversity than did the atolls, could support much larger populations, and overall, provided an environment that would produce great returns in terms of wealth and security. This would not be possible on any of the atolls.

Certain extreme effects of the post-mid-Holocene drawdown on human activity in the region are due to the complexity of the bathymetry of Micronesia. An area of high tectonic plate activity and the location of hotspots, many bathymetric protuberances were transformed into atolls and shallow seamounts by the drawdown. The high volcanic islands, notably Nan Madol, had emerged millions of years before.

Once master navigators had mastered the seascape that emerged after the post-mid-Holocene drawdown, the following environmental features on Pohnpei attracted settlement at Nan Madol, providing incentives for the investment of labor to enhance the productivity of the area in terms of both wealth and prestige.

Location of Nan Madol within the Pohnpei Island Fringing Reef

Nan Madol is located at the only place on Pohnpei where the land directly abuts a fringing reef that is exposed to the open ocean. This means that Nan Madol is situated such that it enjoyed proximity to several environmental zones—dry land, shallow coral reef, mangrove habitat in surrounding bays, and an unusually deep area (see Figure 7) all within the fringing reef. This provided ready access to a great variety of crustaceans and both coral reef and pelagic fish. The most productive coral reefs are

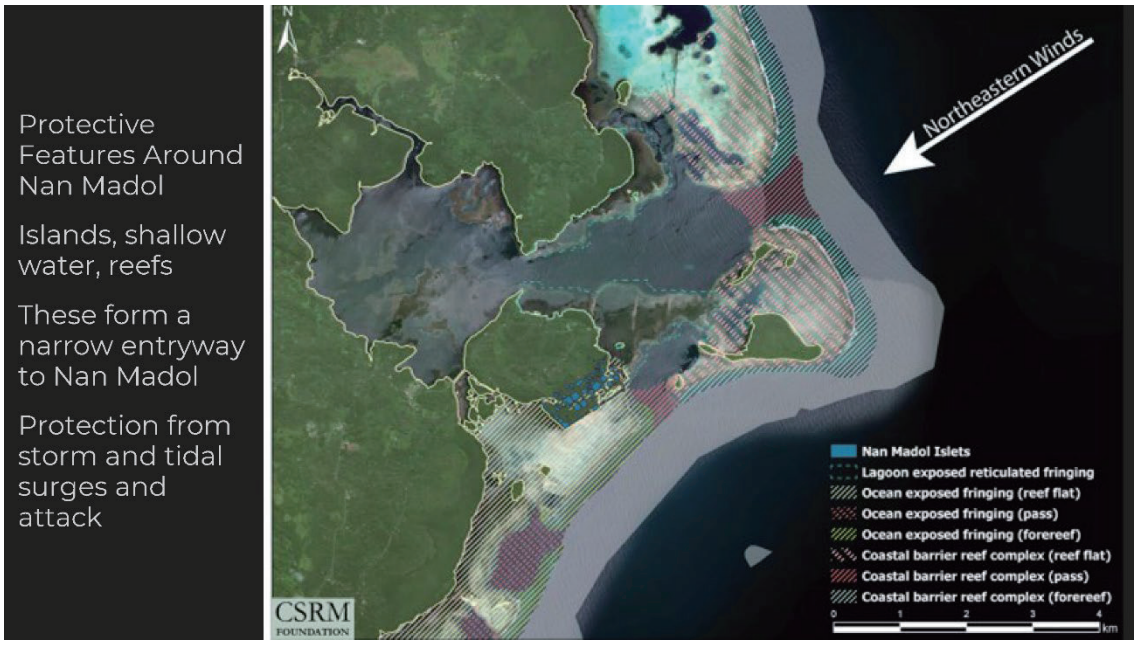

Figure 4. The Fringing Reef at Nan Madol

those that receive a great flow of cooler water from the open ocean, with highest performing reefs being those where waves and tides drive the flow rate from the ocean to the reef (Rogers, et al., 2016).

Natural Defense Against Destructive Weather Events

The location also provides protection from storms. Seasonal strong winds come from the northeast or east. These can blow at a constant rate of 30 or more miles per hour, with much stronger gusts. Nan Models is protected from storm surges, which can be especially destructive during unusually high tides and strong winds by an array of natural defenses: small islands, shallow water, and reefs. These natural buffers seem to have been enhanced by aligning basalt boulders along the edge of the coral reef flat upon which Nan Madol was constructed, as seen in figures 6.a and 6 b.

An Area of Micronesia Less Prone to Typhoons

The western Pacific is the region of the earth with the greatest number of typhoons, including those termed super typhoons, and tropical storms of all kinds Encyclopedia Britannica Online, https://www.britannica.com/science/tropical-cyclone/Tracking-and-forecasting). Pohnpei, and thus Nan Madol, is in a subregion where such storms have occurred, but are historically rare.

Natural Defense Against Attack

The location of Nan Madol also offered significant barriers against attack from competing groups. It can be expected that the site's wealth and prestige would have offered ample motive for such attacks. The same small islands and shallow water that buffered winds and tides were integral to this defense. The easiest approach by sea to Nan Madol is through a narrow opening among the small islands and

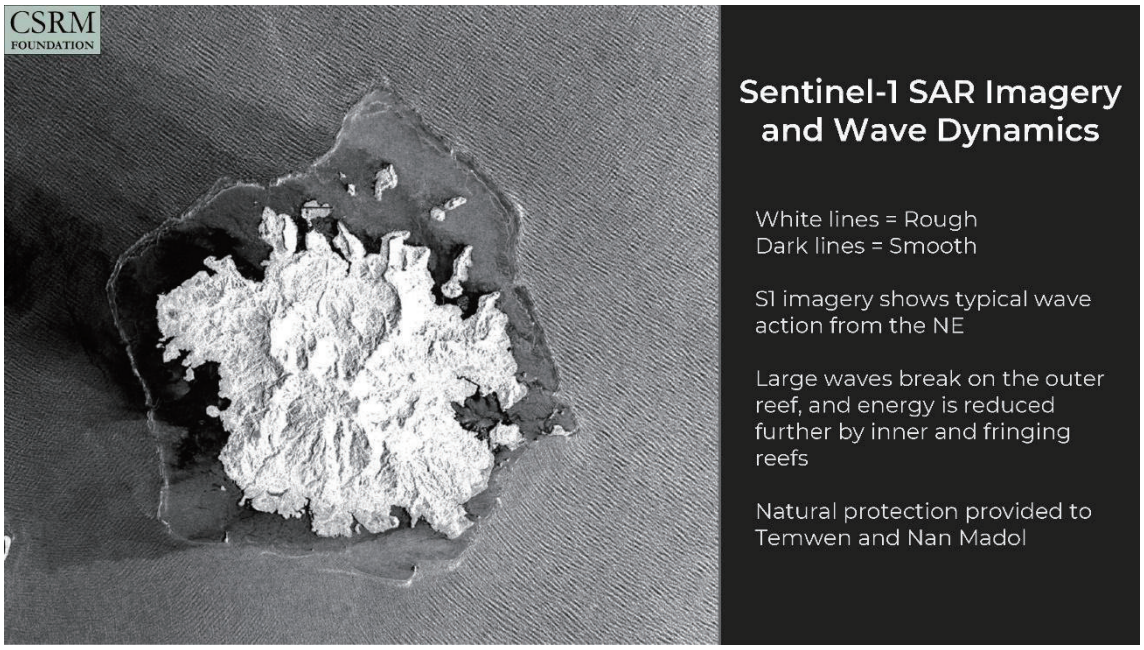

Figure 5. Typhoon Paths from 2000 to 2011

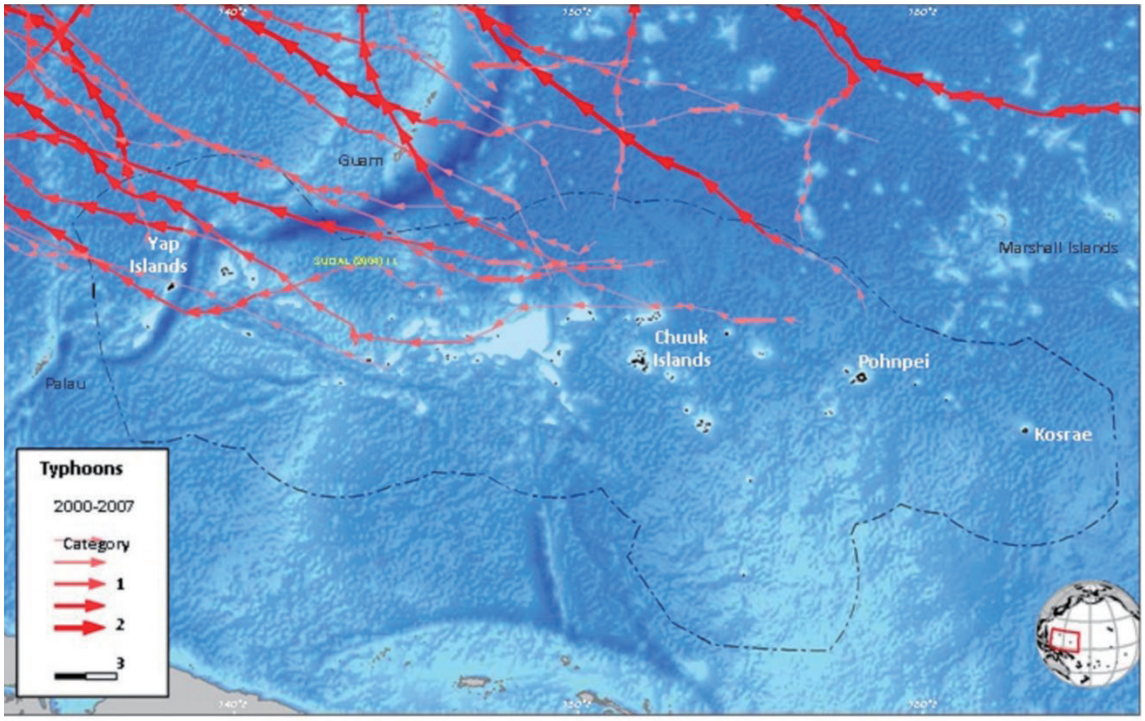

Figure 13.4. The path, intensity, year and name (when available) of typhoons passing near the FSM from 2000-2007. Many Pacific typhoons are not named or the names are not recorded in the typhoon database. Map: K. Buja. Source: http://weather.unisys.com/

Figure 6. Typhoon Paths from 2000 to 2011

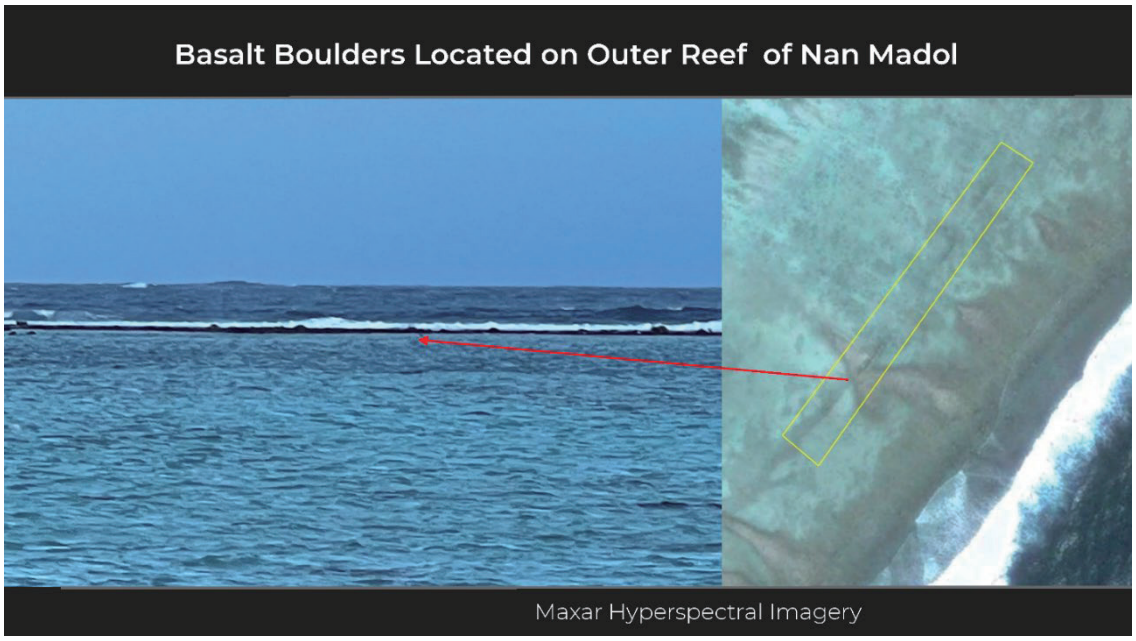

Figure 7a. Basalt Boulders on the Edge of the Coral Reef Flat Where Nan Madol Was Built

areas of shallow water. Attackers using this route would first have to get past the small islets, which could be used as redoubts. Once through the narrow opening to Nan Madol formed by islets and shallow water, attackers could be caught in a crossfire as they would have to pass between the islets and Nan Madol.

Ready Supply of Stone Pre-formed for Construction of Islets and Monuments

Columnar basalt occurs naturally on Pohnpei. The basalt columns are usually hexagonal but may have from 3 to 12 sides. The columns are remarkably similar in size and shape, and so they can be stacked to form foundations and structures much like cut logs used to build a log cabin. Thus, the labor required to use the columns as building materials is much less than what would have to be expended to use stones that were not so conveniently shaped by nature. The shaped stones used in Inca, Greek and Roman architecture, those used in the construction of Medieval cathedrals in Europe, South America, and elsewhere, or those used on the wats of Southeast Asia are a few examples, among many, of the historical use of building stone more costly in terms of labor. Oral history states that those who built Nan Madol settled at Sokehs Ridge first, but that the environmental conditions there were not ideal, so they moved in a clockwise direction to the location of Nan Madol. Columnar basalt at or near locations on the shoreline such as Sokehs Ridge could have been loaded on rafts and moved to Nan Madol (McCoy et al., 2016 found, based on pXRF analyses, that basalt pieces used to build Nan Madol were quarried from Sokehs, among other locations on Pohnpei). Assembling the columnar basalt into foundations and columns would have been facilitated by the ability to move rafts through the shallow waters on the coral reef flat where Nan Madol was built.

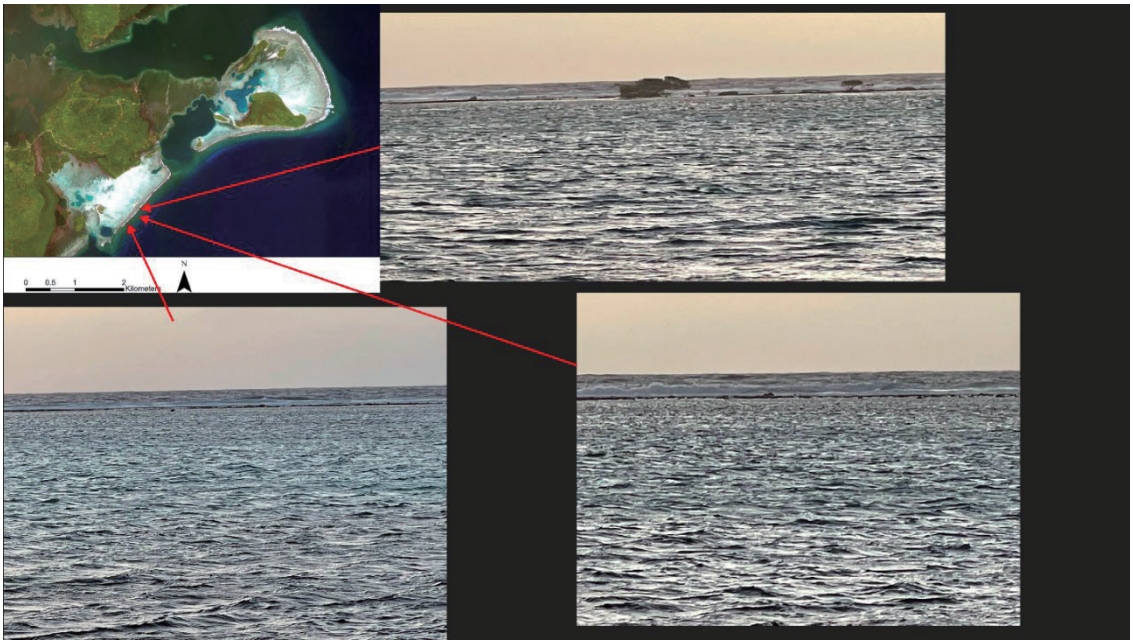

Figure 7b. The Placement of Basalt Boulders on the Edge of the Coral Reef Flat

A Landscape Adjacent to Nan Madol Suited to Agricultural Intensification

Temwen Island is a volcanic caldera, one that was formed about 15 million years ago (Spengler, 1990). As such, the circumference of the caldera is in the form of concentric rings falling away in steps. These may have provided the basis for the raised mounds and depressions in between that are visible in Figures 9.a. and 9.b. The lower, wetter areas may have been suitable for raising taro, while the higher, drier ones may have been suitable for other crops, including yams, bananas, and coconuts. Water need not have been diverted from streams for irrigation, because annual rainfall on Pohnpei ranges from four to five meters per year (Primo, 1992), though in certain cases, drainage may have been necessary. A well-watered terraced agriculture system can be much more productive than the swidden agriculture that is often practiced in heavily vegetated environments: Spriggs (1984) suggests that irrigated systems for growing taro can generate yields at least four times higher than what is possible with swidden agriculture. On coral atolls, taro is typically grown in terraced pits, which are lined with rocks and filled with a mix of soil and organic matter. The pits are designed to capture and retain rainwater and to provide a fertile growing medium for the taro plants (Levin, et al. (2019). One can compare the expected yield from small pits on atolls with the relatively immense area covered by Temwen Island with what by many indications appear to be terraced agriculture and pond fields.

A vast archaeological landscape was revealed by a 2019 LiDAR survey of Nan Madol and the adjacent Temwen Island (Comer, 2019). Models generated from LiDAR data revealed features that comprise terrace-like features, water channels, and earthen berms. Field inspection revealed channels that were positioned in such a way as to potentially drain areas that may have been suitable for taro cultivation. An agricultural landscape extensively exploiting most of Temwen Island's surface would

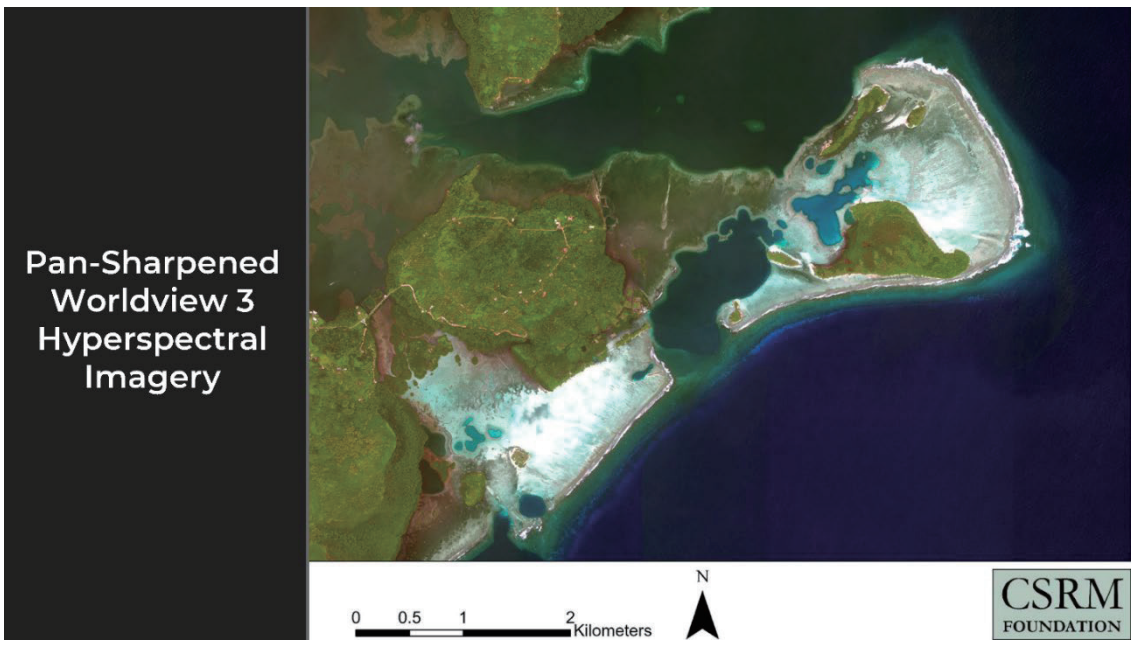

Figure 8. Natural Defenses at Nan Madol

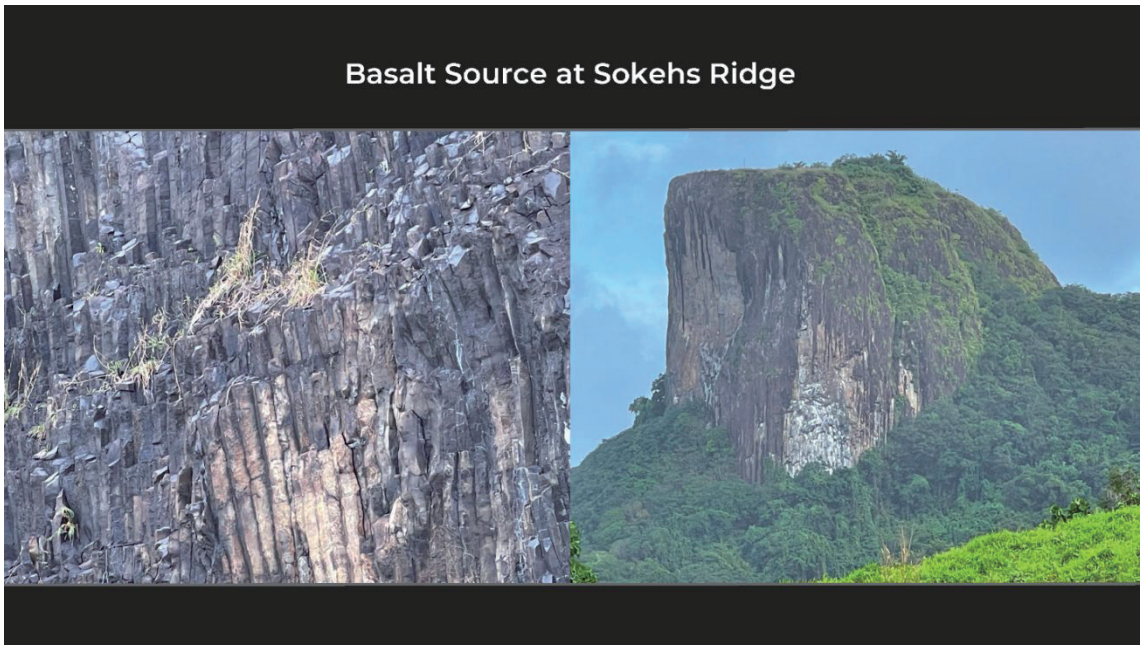

Figure 9. Sokehs Ridge Source of Columnar Basalt

have contributed to the food security of the group that managed it. Further, even when storms remove all aboveground vegetation used for food, wet taro constitutes a storehouse of food that can be consumed until other crops grow back. We suggest that these environmental conditions—including the extent of cultivable land (particularly in such proximity to the reef and ocean), the caldera landform, and the volcanic soils—made Temwen Island an ideal choice for the allocation of landesque capital investments.

The geometric patterns seen in the center of Temwen Island closely resemble field systems seen in Near Oceania. One example is found in New Caledonia, where wet taro was cultivated in wet ditches between raised mounds, upon which dryland crops were planted (Sand, 2012). Recent LiDAR survey in locations in Remote Oceania not as far removed at Pohnpei has also identified evidence of intensive agriculture, such as has been found at the island of Efate in Vanuatu (Bedford et al., 2018)

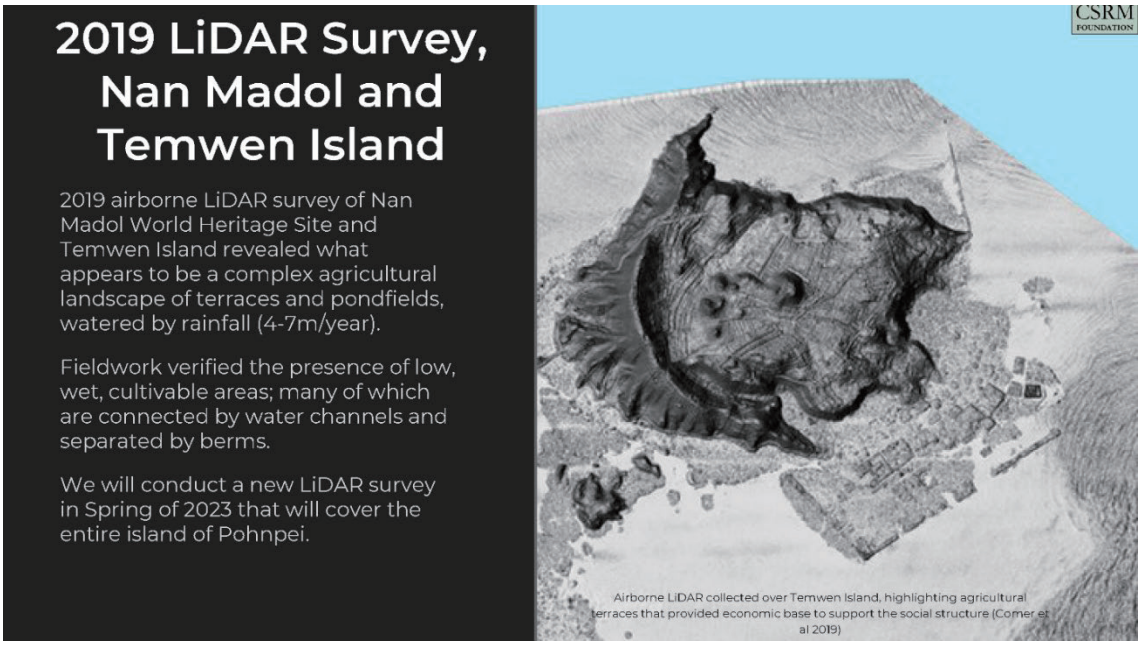

Figure 10a. Results of 2019 LiDAR Displaying Archaeological Landscape of Nan Madol and Temwen Island

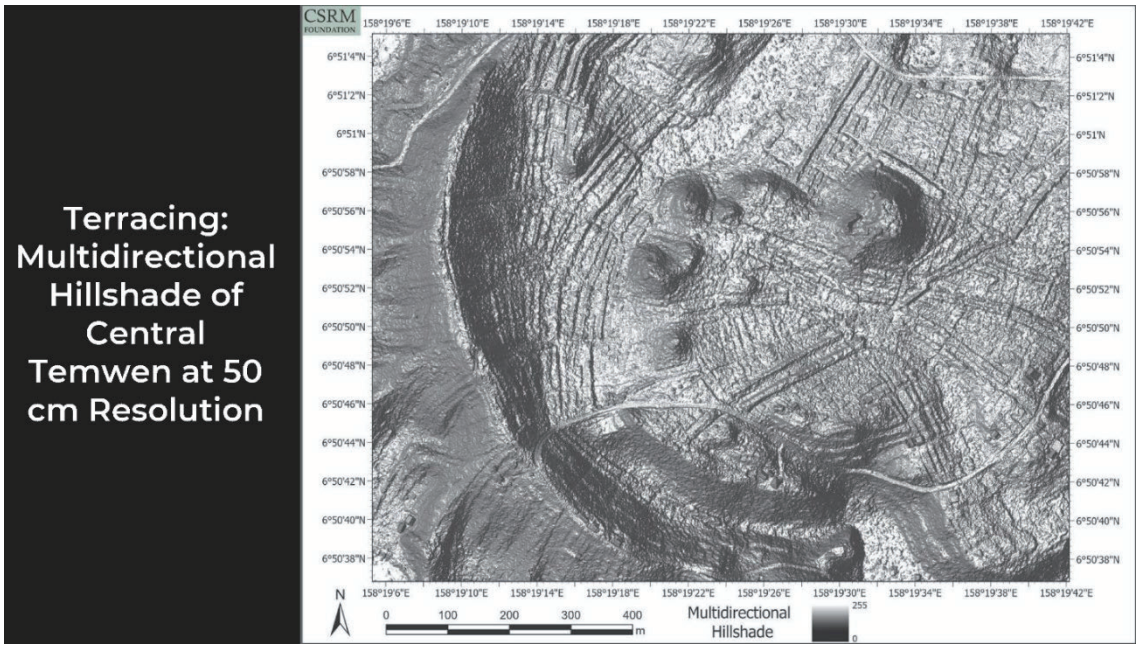

Figure 10b. Closeup of LiDAR Image from 2019 Survey Showing Apparent Agricultural Features

Conclusion

We apply here the concept of landesque capital as a partial explanation for the appearance of the remarkable monumental landscape of Nan Madol, with its many stone structures built on approximately 100 humanly constructed islets. Nan Madol represents a monumental landscape of a magnitude and complexity that is almost unparalleled in the islands of the Pacific. The confluence of environmental characteristics identified here sets Temwen Island apart from other locations on Pohnpei and from the region's atolls and, we suggest, offered gains in food and prestige at lower marginal cost than at competing locations, making it an ideal choice for landesque capital investment. As an achievement, the construction of Nan Madol may be less appreciated than it might have been had it not been in a distant area of the Pacific, away from other major islands and continental landmasses, and covered with dense vegetation that conceals the magnitude and fine engineering and workmanship that was required for its construction.

The earliest dates obtained from Nan Madol are from approximately 50 CE, taken from an old beach surface beneath one of the islets (Ayres, 1993). This date is consistent with the chronology of the post-mid-Holocene drawdown, providing time for the expert navigators of that era to learn to follow a route marked by the coral reefs and seamounts after the drawdown, and to thereafter institutionalize this navigational knowledge and practice. Our hypothesis is that once this had been accomplished, the environmental assets outlined in this paper offered great return on labor investment for centuries; over those centuries, landesque capital increased, and Nan Madol was constructed.

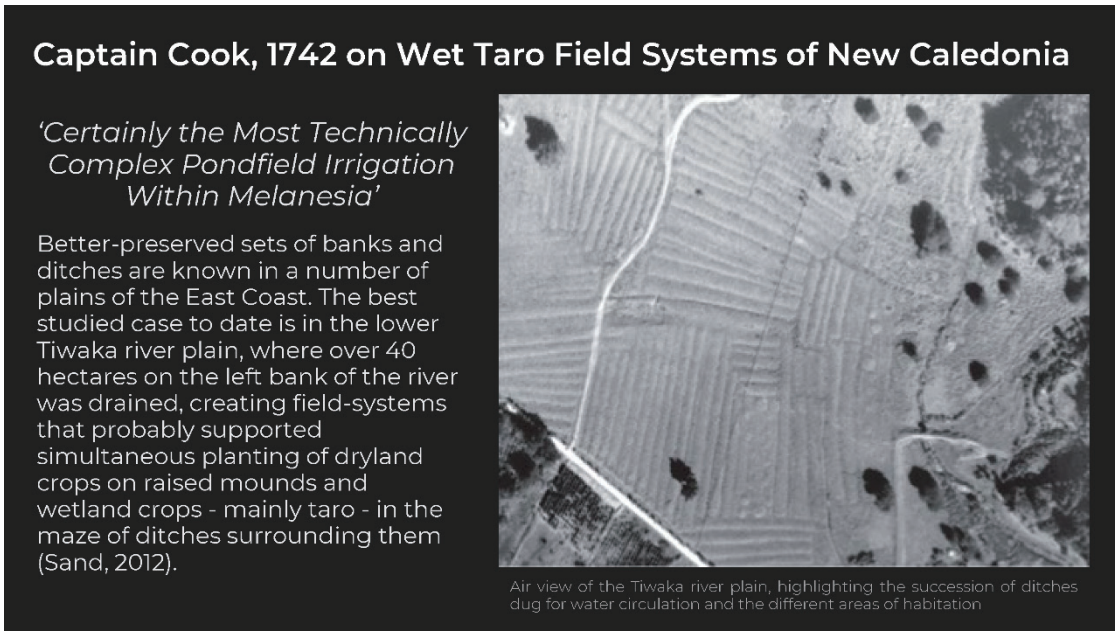

Figure 11. Wet Taro Pondfields and Raised Berms for Dryland Crops in New Caledonia

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Satellite Data Demonstrating the Need for Refined Navigational Knowledge Essential to Cultural Development in the Caroline Islands

Mitch PORTER, Doug COMER, Jake COMER, Ben HOLT, Brittany LOCKHART, Bruce CHAPMAN, Adrian BORSA, Larry RAIGETAL, Eleanor ALVAREZ, Natya REGENSBURGER, Kelsey DRISCOLL

Abstract

The World Heritage Site of Nan Madol in Pohnpei, Micronesia, an archaeological landscape inscribed on the World Heritage List in 2016, exhibits abundant material evidence of a highly complex culture in the Caroline Islands. We argue that such cultural complexity in the Caroline Islands resulted partly from the institutionalization of advanced navigational knowledge. This navigational knowledge was essential to the maintenance of economic, political, and social connections among the high volcanic islands and the myriads of economically vulnerable humanly populated coral atolls in the Caroline Islands. Maintaining these connections required highly sophisticated navigational knowledge that allowed its holders to move among the atolls and high islands including Pohnpei and Nan Madol. We used a combination of satellite data including multispectral and SAR to model the complexity of ocean dynamics in the equatorial zone near Pohnpei. We examined satellite imagery of ocean currents, wave and bathymetry patterns, sea surface temperature (SST), and wind products to understand ocean dynamics and navigational cues used by traditional navigators. The analysis of both large- and small-scale ocean features illustrates the significance of refined traditional navigation in establishing and sustaining an inter-island network in the Caroline Islands.

Introduction

The present study aims to investigate the navigational factors that led to the institutionalization of navigation and complex cultures in the Caroline Islands. Nan Madol, a unique archaeological landscape built on a coral reef flat and inscribed on the World Heritage List in 2016, provides abundant material evidence of a highly complex culture. The initial settlement c. 2500-2000 BP (Ayres, 1990; Levin, 2016; Seikel, 2011) and the construction of Nan Madol itself dates back approximately 1000 years (Ayres and Sheller, 2003; Seikel, 2011). The Saudeleur dynasty, a succession of rulers that maintained a preponderance of power over Pohnpei between approximately 1200 and 1600 CE, built Nan Madol and established a political and economic center in one of the planet's most remote regions (Bernart, 1977; Hanlon, 2019). We contend that the institutionalization of advanced navigational knowledge was a significant contributing factor to the complexity of this seafaring culture. Our research delves into the traditional marine knowledge passed down from generation to generation through oral history and songs, taking hundreds of years to perfect the art of sailing in the highly variable equatorial Pacific. In particular, we focus on how ocean currents and surface features served

as wayfinding points when navigating Micronesia and the Caroline Islands (Lewis, 1994; Rowe, 2007). By employing various modes of satellite data to model the complexity of ocean dynamics in the equatorial zone near Pohnpei, we aim to visualize the ocean surface features used as navigational aids when trading within the Carolines. **Co-Production**

An important collaborator on this project is Larry Raigetal, a practicing master navigator from Lamotrek atoll in Yap, Micronesia. Mr. Raigetal's extensive knowledge and expertise in traditional navigation strategies have proved invaluable to our research, enabling us to corroborate or refine information provided by imagery and models generated from satellite data. The models highlight the waypoints and ocean dynamics that he employs in navigation. This is knowledge that he has received from scores of generations of master navigators and that he is passing along to succeeding ones.

Study Area and Datasets

The study area of our research is the Caroline Islands, an archipelago of small islands and atolls scattered across the Federated States of Micronesia. This region is distinctive due to its remote location within the highly variable intertropical convergence zone, amid a complex oceanic landscape marked by numerous bathymetric features. The bathymetry of Micronesia is notably intricate, characterized by hundreds of shallow seamounts and atolls (Lewis, 1994). Our investigation will primarily focus on the Central and Eastern Caroline Islands, shown in Figure 1.

Data employed in our research was collected by Sentinel-1 and -2, ALOS-PALSAR-1 and -2, Planet satellites, General Bathymetric Chart of the Oceans (GEBCO), as well as datasets in NASA DAACs, including Ocean Surface Current Analysis Real-Time (OSCAR) from PODAAC and NASA National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC).

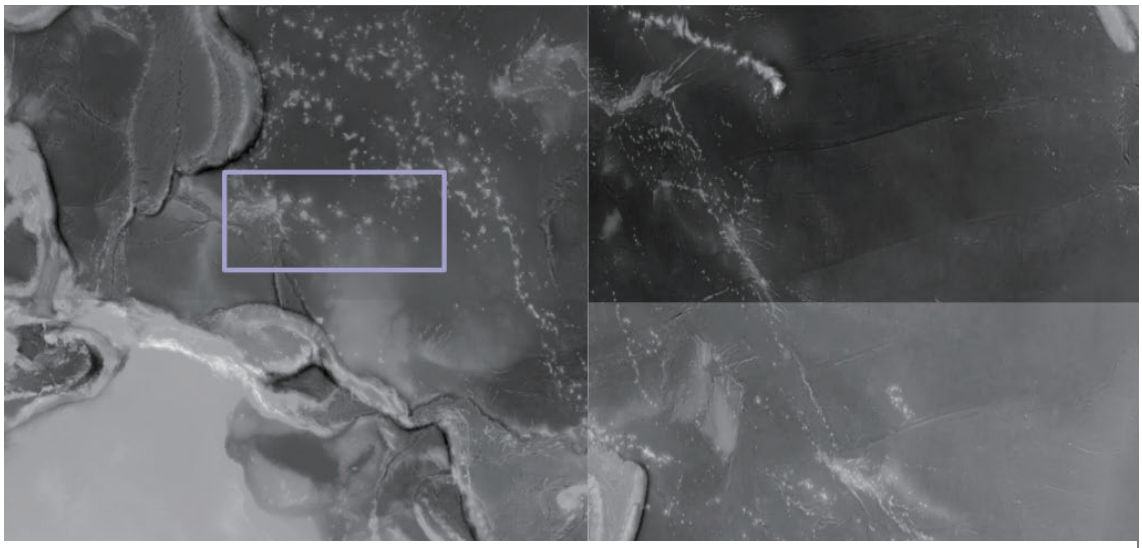

Figure 1. GEBCO bathymetric chart of the equatorial Pacific, with the central and eastern Caroline Islands contained in the purple box.

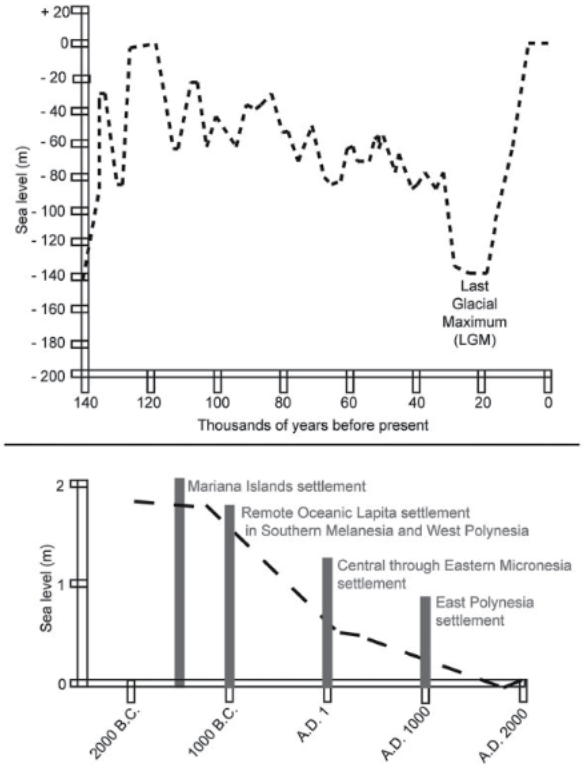

Figure 2. Sea level history in meters (m). Top - large-scale view in thousands of years. Bottom - detail of last 4000 years most relevant in Pacific.

Settlement of Micronesia

The bathymetric features of Micronesia are of great significance, as they played a crucial role in the settlement of remote Oceania around 3000 years ago, and more specifically, the settlement of Pohnpei in the Caroline Islands approximately 2000 years ago. These dates correspond with the onset of the post mid-Holocene drawdown, which began over 3000 years ago seen in Figure 2.

The first wave of settlement originated from southern geographic Melanesia around 3000 years ago, followed by a second wave approximately 2000 years ago, which led to the settlement of central and eastern Micronesia (Carson, 2014, 2018). As sea levels decreased, shallow seamounts became atolls or drew closer to the surface, resulting in altered wave patterns and surface features that served as important navigational aids. Generations of navigators accumulated knowledge of bathymetric features in conjunction with other navigational methods, thereby enabling the settlement of Micronesia and, ultimately, Pohnpei.

Figure3 illustrates our hypothesized dispersal of Austronesian people that ultimately resulted in the settlement of the Caroline Islands. We emphasize that the late Holocene drawdown facilitated the emergence of new wayfinding points like atolls and shallow seamounts, followed by the successful settlement of Micronesia over hundreds of years.

Institutionalizing Traditional Navigation

Highly pertinent to our observation that ancient navigators would have over time learned to deal successfully with the complexities of navigation through a maze of winds, currents, and wave patterns that must be mastered to find one's way to the Carolines north of the equator - and then to sail among them - is the evidence of institutionalization of those skills that persists today. Traditional navigation knowledge is still vital in Micronesia. Master navigators, such as Raigetal, have kept the complexities of navigation alive, passing the knowledge necessary to move among hundreds of islands in Micronesia from generation to generation.

By institutionalization, we refer to the embedding of behavior and practices as norms in a society. By the eighteenth century, Western observers provided accounts of large schools where training in navigation was provided. Among the most well-documented was a school in Tahiti. During Captain Cook's voyage on the *Endeavor* in 1769, he encountered Tupaia, a master navigator who taught at a school in Taputapuatea, a site that was considered to be sacred in the Society Islands. Tupaia demonstrated that he had knowledge of 130 islands and the means by which to sail to them (Winkler, 1901). Tupaia was a high chief, a priest, and a navigator (Lewis, 1994). J.R. Forster noted that, in Tahiti, "geography, navigation, and astronomy were known only to a few (Richards, 2008). Winkler noted in 1901 (page 505) that in the Marshall Islands it was "strongly and religiously forbidden to divulge anything concerning this art [navigation] to people." Ve'ehala told D. Lewis that the secrets of Tongan astronomy were held in secret by a hierarchy of chiefly families;

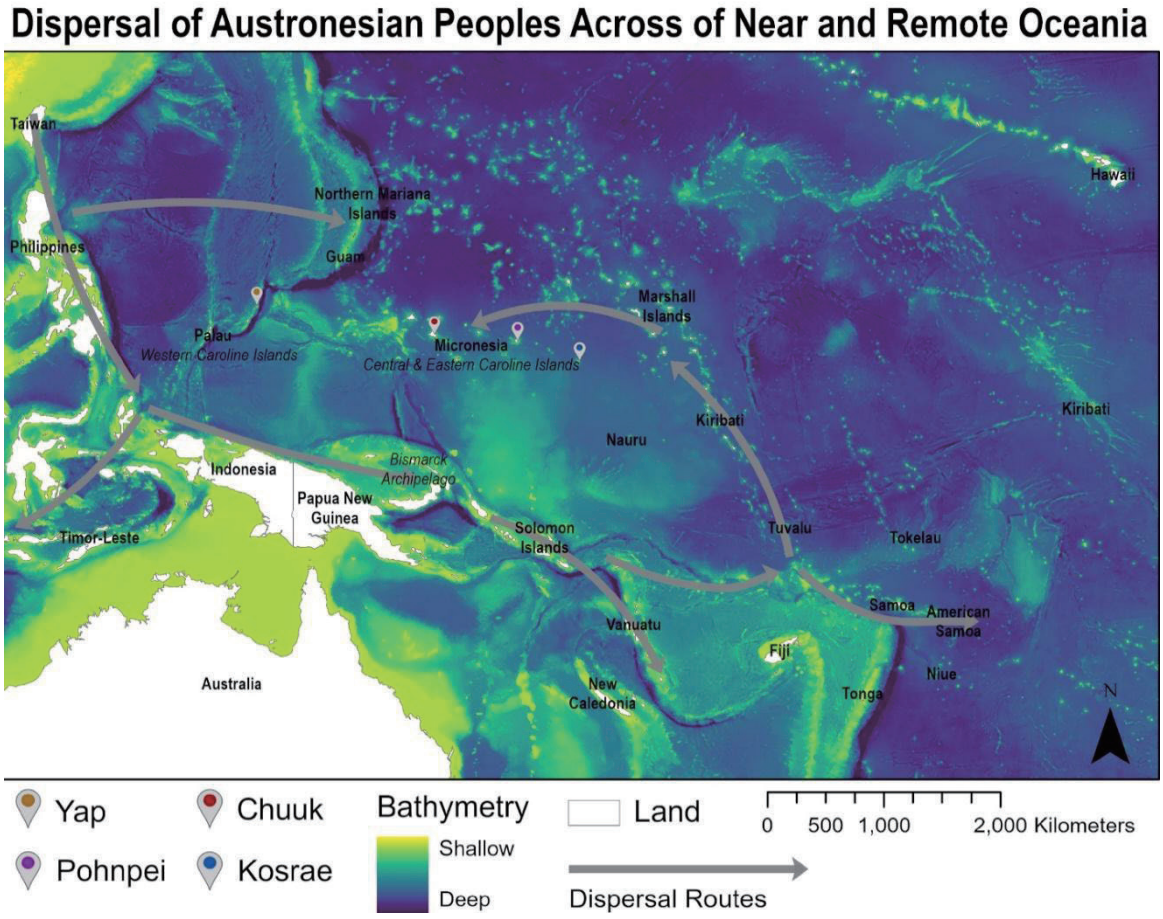

Figure 3. Hypothesized dispersal of Austronesian peoples across Near and Remote Oceania.

according to Lewis, a member of the Tuita navigator said to Ve'ehala that his secrets were such that only he and the devil knew them (Lewis, 1994).

Thus, navigational knowledge was embedded in the ideology of the Pacific Islands. Colin Richards, an anthropologist greatly influenced by phenomenological thought, puts it this way: “voyaging is argued to be a strategy for the negotiation and transformation of Polynesian social identity through a phenomenological intersection of materiality, cosmology and practice” (Richards, 200815: 206). In any case, it should be clear that navigation had become a source of prestige, one that would be lost if navigators were to cease voyaging.

Such institutionalized navigational knowledge would have allowed people to move confidently and frequently among the islands of Micronesia. Almost all of those islands, more than 99% of them, were coral atolls. On each coral atoll, human habitation would have been difficult or impossible to sustain without links to other islands. Human populations grow during weather cycles that provide abundant nourishment, but such nourishment can be drastically reduced by climate cycles and severe weather events. Institutionalized navigation made possible trade and kinship networks that could provide support when severe weather events depleted food stores, or when inter-island conflicts arose. As Carson (2018: 280) notes, typhoons pose a constant threat in Micronesia, more than in any other part of the Pacific, and in some regions they occur every few years. Storm surges often destroy homes and crops, while intense winds strip trees and vegetation. Micronesia is also an area where droughts occur at unpredictable intervals. Inter-island networks were also necessary to provide marriage partners for inhabitants of coral atolls, where population numbers were typically small.

In the Caroline islands, the development of institutionalized navigational knowledge and trade networks was necessary for survival on atolls dispersed throughout the archipelago. The islands' unique geography and oceanography presented numerous challenges to navigators, who developed specific and reliable wayfinding techniques. These included using marine life and seabirds as geolocators, gaining a master understanding of wave patterns and the influence of shallow bathymetric features on these patterns, and using celestial bodies to navigate and stay on course Lewis, 1994; Rowe, 2007). It is important to differentiate land-finding techniques between navigating by the swells in the open sea and land-finding techniques based on the distortion of swells by islands. Our analysis focused primarily on wave distortion, distinguishable in satellite imagery.

Ocean Dynamics and Climatology Indicated by Satellite Systems

Carolinian navigators have decoded the labyrinth of currents spanning the Pacific Ocean's expansive 1900-mile east-west and 840-mile north-south expanse through centuries of accumulated wisdom and observation at sea. This mastery over the ever-changing seascape reflects in their sailing skills and advanced culture.

To understand ocean current dynamics in our study area, we employed the Ocean Surface Current Analysis Real-time (OSCAR) dataset to model seasonal ocean currents in the Western Pacific at the four volcanic high islands from 1993 to 2020: Yap, Chuuk, Pohnpei, and Kosrae. These islands provided enormously more environmental diversity than coral atolls (Paulay, 1994), and thus were logically attractors for human populations. We visualized ocean currents during different seasons and climate modes – El Nino Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) - to understand the complexities traditional navigators faced while settling and establishing trade networks with these four high islands in the Western

Pacific. ENSO and PDO are important climate modes that are classified by SST patterns. ENSO is an interannual climate pattern that is classified by SST patterns in the central and eastern Pacific, and PDO is a longer-term climatic cycle that is classified by SST patterns in the North Pacific. ENSO and PDO both have global oceanic and atmospheric teleconnections, so we investigated the seasonal impacts of these events in the Caroline Islands.

Our study focused on PDO impacts on winds and equatorial currents in the Western Pacific, in combination with the ENSO cycles, and what these suggest in terms of Pacific navigation among islands in and near the equatorial zone. The Caroline Islands, located 5-10 degrees north, are uniquely positioned to be strongly influenced by the seasonal shift of the Intertropical Convergence Zone (ITCZ) and equatorial currents (Waliser & Gautier, 1993). PDO events are classified as positive (negative) when SST in the North Pacific are anomalously warm (cool) according to the NOAA PDO index. Similarly, ENSO events are classified as El Niño (La Niña) when SST values in the eastern and central Pacific are anomalously warm (cool) according to the Niño 3.4 index.

Our findings reveal that the equatorial counter current (ECC) and south equatorial current (SEC) exhibit significant spatial and temporal intensity variations throughout the year. An inverse relationship between ECC and SEC becomes apparent when comparing positive and negative PDO events within the same season. Specifically, we observed a stronger ECC and a weaker SEC during positive PDO events than negative PDO events.

When analyzing OSCAR data, positive and negative zonal velocity values are important to understanding ocean currents. Positive (negative) velocity values indicate the intensity of ocean currents moving west-to-east (east-to-west). Because our study area is the ITCZ, positive (negative) zonal current

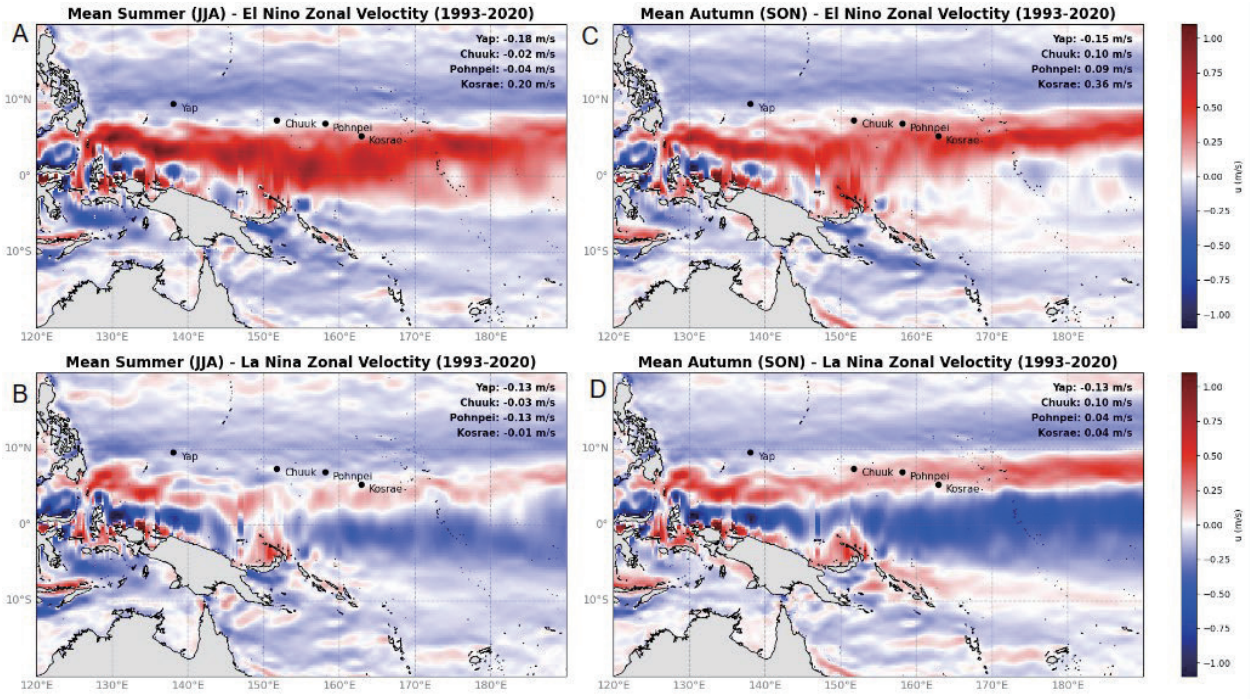

Figure 4. Zonal velocity currents during a) Summer El Niño, b) Summer La Niña, c) Autumn El Niño, and d) Autumn La Niña. Red (blue) represents intensity of currents moving west to east (east to west).

velocities are indicative of regions in the ECC (NEC or SEC). We identified the following trends when we analyzed seasonal OSCAR data during positive and negative PDO events:

1) Kosrae exhibits the highest variability in mean zonal velocity (-0.11 m/s to 0.32 m/s), primarily due to its latitude at 5 degrees North. Kosrae shifts in location between the north equatorial current (NEC), the middle of the ECC, and the SEC depending on the PDO event and season.

2) Pohnpei (-0.15 m/s to 0.08 m/s) and Chuuk (-0.05 m/s to 0.10 m/s) display moderate mean current velocity variability, oscillating in location between the NEC and ECC depending on the season and PDO event.

3) While there is limited spatial variability between positive and negative PDO events within the same season, the intensity varies significantly between PDO events.

Using the OSCAR dataset, we conducted a similar analysis of ocean currents during ENSO events. We modeled the seasonal ocean currents of the Western Pacific during El Niño and La Niña ENSO events. The ECC showed a stronger intensity during El Niño events than La Niña events, particularly during the summer and autumn (Figure 4).

We observed an inverse relationship between the ECC and SEC when comparing El Niño and La Niña events within the same season. We identified several key findings:

1) Kosrae again demonstrated the highest seasonal variability in mean zonal velocity (-0.13 m/s to 0.36 m/s), with a mean current difference of 0.32 m/s between El Niño (0.36 m/s) and La Niña (0.04 m/s) events in the autumn (this difference primarily arises from the spatial variability of the ECC).

2) There is significant variability in the location and intensity of the currents between El Niño and La Niña events within the same season.

3) During El Niño (La Niña) events in the summer and autumn, the ECC is extensive and strong (narrow and weak), while the SEC reduces in intensity (intensifies) and shifts entirely south (north).

Our study's findings on the variability and strength of equatorial currents in the Pacific Ocean, specifically the equatorial currents, hold significant implications for voyaging and navigation in the Caroline Islands. Notably, these insights shed light on the remarkable navigational knowledge of Micronesian land finders who have been navigating Remote Oceania for over a thousand years.

The dynamics of the currents throughout the Carolines make it an exceptional region, where the average set direction cannot simply be inferred from prevailing winds or steady currents. Gladwin (2009) suggests that accounting for these currents is integral to the navigation instructions between island pairs in the Carolines. Our remotely-sensed satellite data and interdisciplinary approach underscore the nuanced understanding of these currents Micronesian way finders hold. Lewis (1994) highlights an example of navigators understanding highly variable currents in the Carolines. When sailing from Truk to Puluwat and depending on the current, voyagers may encounter either Tamatam located 20 miles north, or Uranie Bank, a deep reef extending southeast from Puluwat. The ability to adapt to such contingencies reveals the skill and adaptability of Micronesian way finders as the voyage necessitates navigation strategies that account for the variations in current directions.

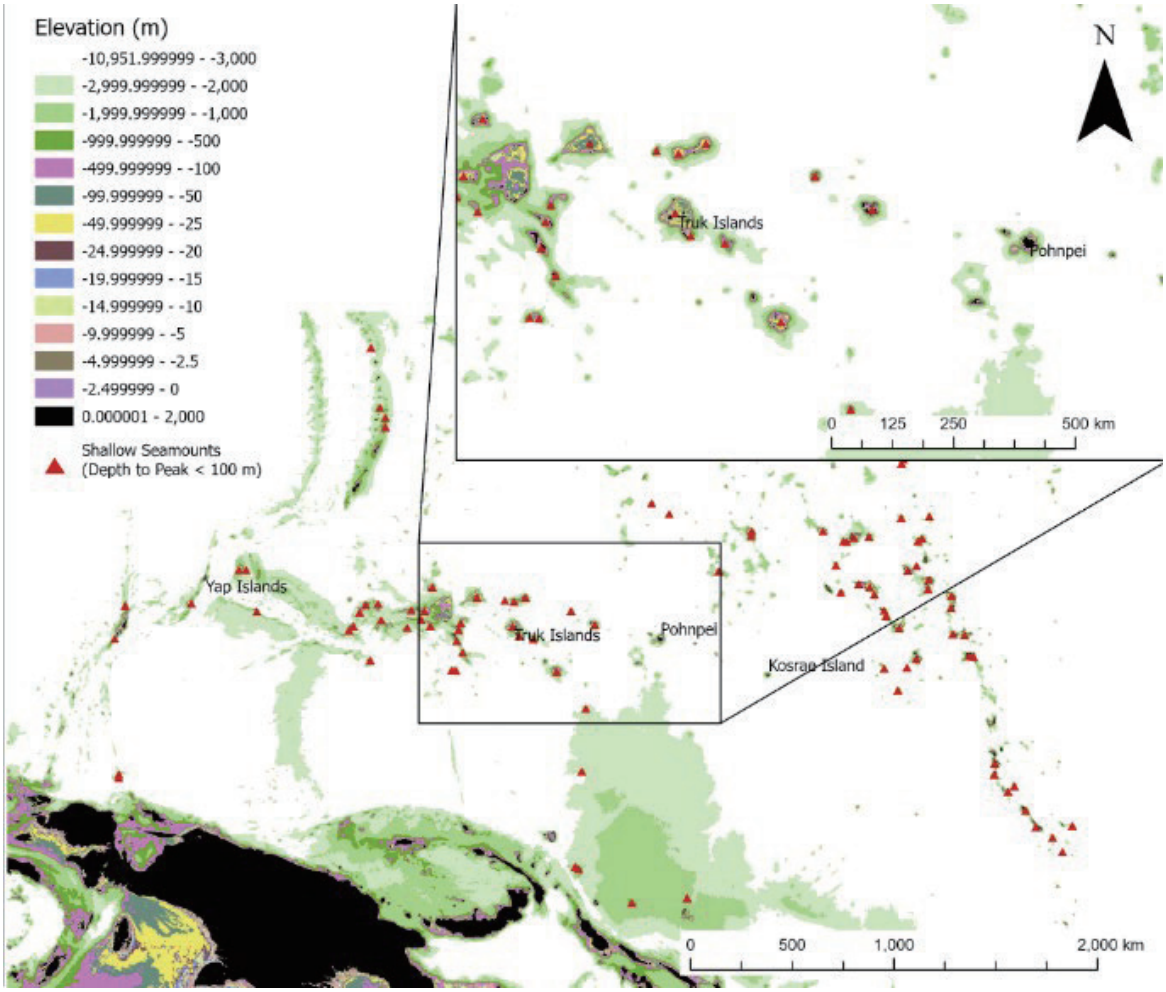

Figure 5. Bathymetric chart adapted of the Caroline Islands, with seamounts less than 100 meters in depth shown by red triangles.

The high islands of Yap, Chuuk, Pohnpei, and Kosrae are uniquely positioned within the influence of the NEC, ECC, and SEC, which exhibit dynamic spatial and intensity variations throughout the year, particularly during Positive and Negative PDO events and El Niño and La Niña ENSO events.

The Micronesian way finders' ability to navigate these waters, especially given the substantial variability in mean zonal velocity around islands such as Kosrae, testifies to their remarkable navigational knowledge passed down through generations. Influenced by climate modes and seasonal changes, the interplay between the NEC, ECC, and SEC presents a complex navigational challenge that these way-finders have mastered through generations of observational learning and adaptation.

Wave Diffraction

Expanding our investigation into the bathymetry of the Caroline Islands, we delve deeper into the interplay between local equatorial currents and bathymetric influences on ocean surface characteristics. Figure 5 shows the complex bathymetry of the central Caroline Islands. An abundance of shallow bathymetric features in Micronesia provided valuable navigational markers (Genz, 2014; Lewis, 1994). Shallow seamounts less than 100 meters below the ocean surface significantly impact surface characteristics. Shallow seamounts extend from the central Carolines to Pohnpei and led to the formation of sea lanes

between the east and central Carolines over time. Sea lanes like this are created through systematically experiencing and embedding knowledge of the surrounding ocean cycles and the influence of seamounts, atolls, and islands on wave diffraction (Genz, 2014).

In "We, the Navigators," (1994), David Lewis thoroughly explains the processes of refraction and reflection that occur when an island disrupts open ocean swells. As land friction slows the inshore ends of swells, they refract, gradually bending until aligned with the coast. Divided by the island, these refracted portions navigate both sides of the island, meeting on the leeward side. This convergence creates an area where, as the Gilbertese describes, 'the waves move up and down' (Lewis, 1994). Conversely, waves towards a perpendicular coast are reflected from where they came. These reflected and refracted waves can be detected from tens of kilometers away (Genz, 2014). The synthetic aperture radar (SAR) images from Sentinel-1 (Figure 6) and ALOS-1 (Figure 7) demonstrate the reflection and refraction phenomena described by Lewis. White lines within these images represent areas of rough ocean surfaces resulting from the dominant northeastern swell, while blue arrows indicate the wave direction. Notably, in the upper right of Figure 6a, distinct wave patterns directed toward Pohnpei can be observed. Swells distant from the island maintain a southwest trajectory, while those near the island are diffracted by the island's bathymetric features,

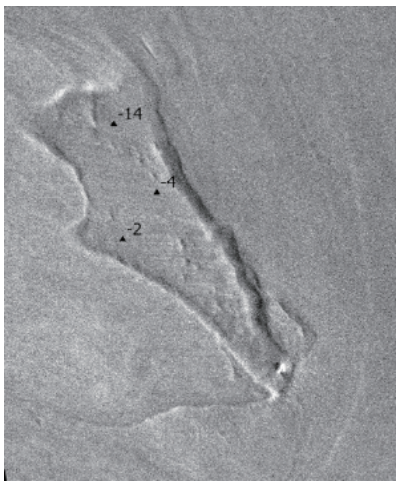

Figure 6. ALOS-1 SAR imagery of an atoll in Near Oceania, demonstrating wave diffraction and refraction.

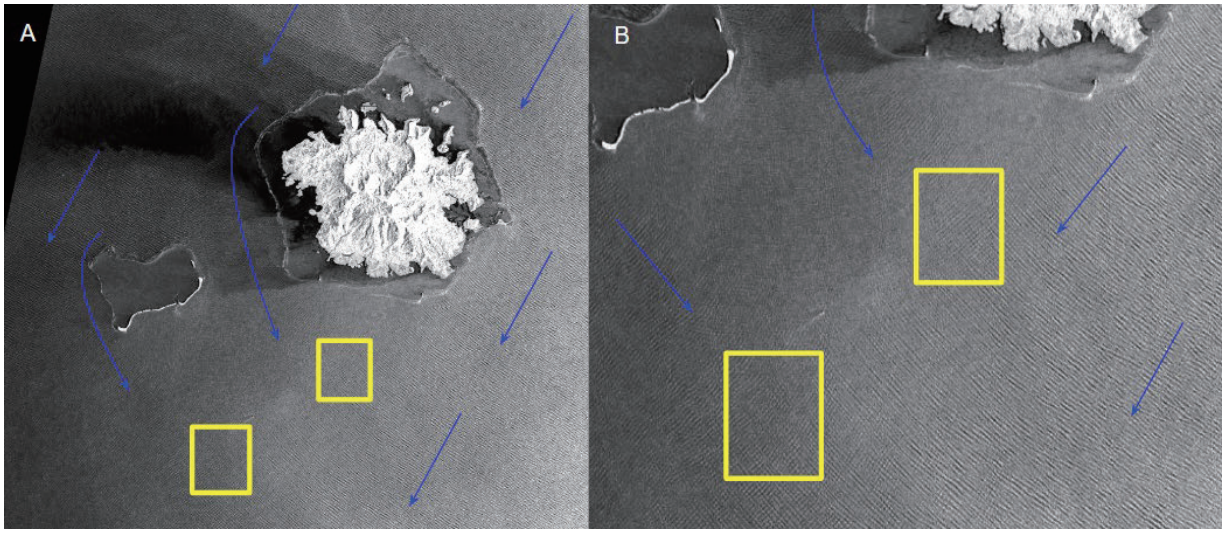

Figure 7. Sentinel-1 SAR imagery showing wave direction and diffraction. Blue arrows indicate direction of waves, and yellow boxes cover the same area in a) and b).

adopting a southeastern orientation. This phenomenon is also apparent on the west side of Pohnpei and Ant Atoll. Here, incoming waves are diffracted towards the southeast. The intersection of the diffracted waves with the primary swells south of the island results in a crosshatch pattern seen south of Pohnpei in Figure 6b. The crosshatch pattern of overlapping waves would result in waves that 'move up and down', as described by the Gilbertese. This conjunction of diffracted waves and the primary swell is an essential navigational tool for traditional voyages. Navigators could infer their proximity to land or shallow seamounts by observing distortions in the main swell caused by diffracted waves.

Analyzing the highlighted areas in the SAR imagery verifies the impact of the diffracted waves from Pohnpei and Ant Atoll on the primary swell. This type of wave interaction is an important navigational marker that Micronesian navigators, such as master navigator Larry Raigetal, have learned to recognize and utilize in the Carolines.

While wave diffraction techniques are utilized less in the Carolines than in other islands like the Marshalls, they still play a vital role in traditional navigation. The presence of birds, cloud formations, and other environmental cues often complement the information provided by wave patterns, giving navigators a holistic view of their environment. Satellite data, such as the SAR imagery presented, provide a unique and powerful insight into the complex science of traditional navigation. By observing the patterns of waves around various bathymetric features, we can decipher the subtle cues that navigators have been trained to recognize and interpret. Moreover, the availability of such data from different periods and weather conditions allows us to discern the versatility of these navigational methods and how they adapt to varying oceanic environments.

Figure 8. Rough white lines appearing outside the outer reef southwest of Pohnpei. These features are indicative of bathymetric patterns and used in traditional navigation.

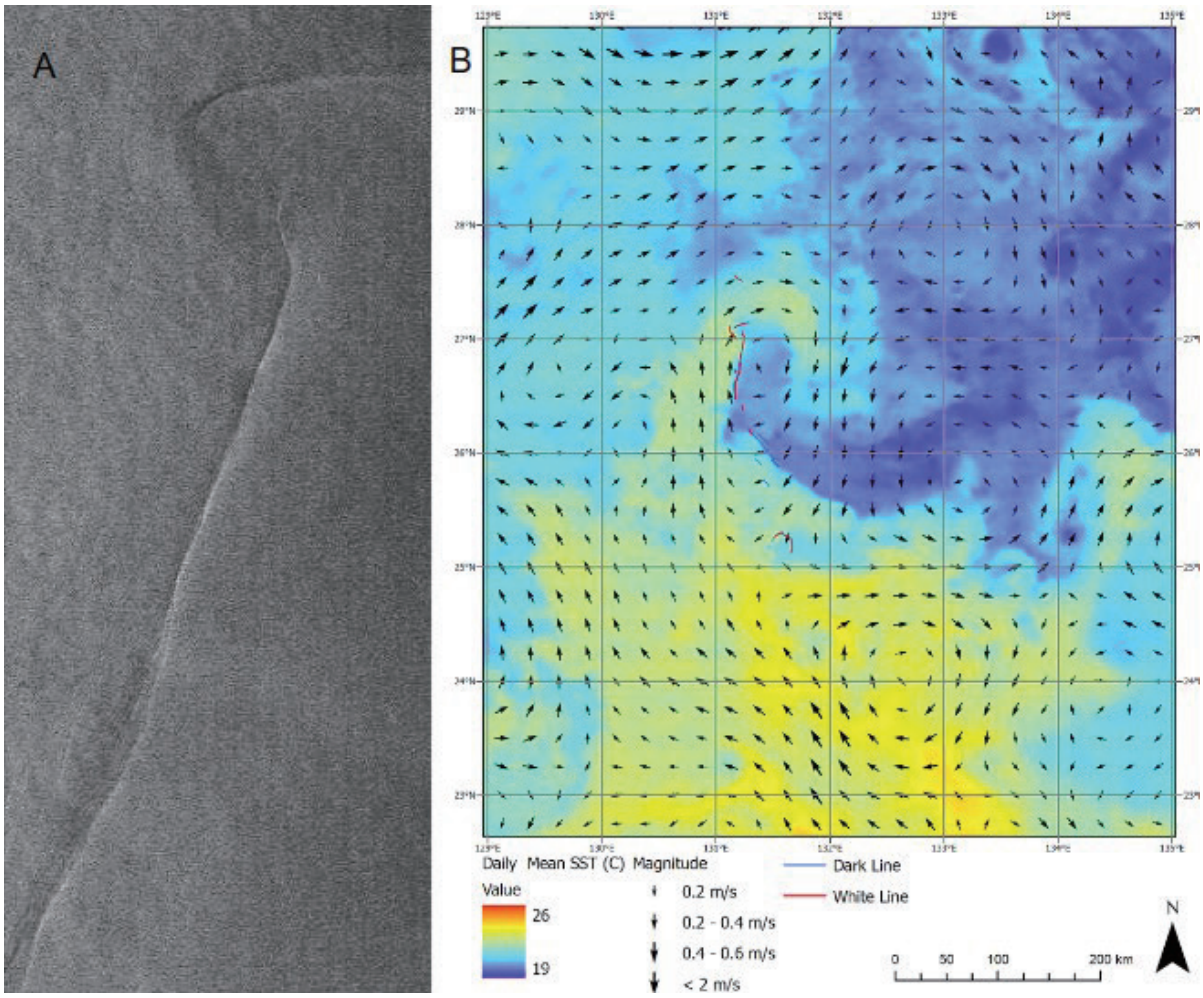

Figure 9. a) ALOS-1 imagery showing a white line of enhanced surface roughness over 1 degree in latitude, and b) Overlay of SST and OSCAR currents at the same location and time as the ALOS-1 image in part a.

Lines in the Sea

The utility of Sentinel-1 SAR imagery in analyzing ocean surface features expands beyond the understanding of diffracted waves and swells, and provides insight on shallow bathymetric features and localized currents. The discernment between rough and smooth surfaces at sea becomes a pivotal aspect in detecting shallow bathymetric features. Figure 8 illuminates this, presenting a series of white lines outside the reef. These rough white lines are waves breaking beyond the typical wave break, indicating the presence of shallow bathymetric features during events with larger waves. Similar phenomena have been observed surrounding atolls and shallow seamounts throughout Micronesia. Consequently, these shallow areas with surface roughness hold potential as navigational markers throughout the region because of the abundance of shallow bathymetric features in the Micronesian seascape.

Extending our exploration into open water, the ALOS-1 SAR image offers insight into surface features associated with productive fronts for open ocean fishes. A striking feature is the presence of a white line, over 1 degree latitude in extent, which is associated with convergence zones and highly productive fronts. Overlaying this white line onto a SST map and ocean current vectors reveals a temperature filament of 2 degrees Celsius and a substantial current gradient (Figure 9). Navigators who understand these patterns

utilize these white lines, which appear as roughened waves, to locate productive fishing areas (Raigetal, Personal Communication 2023), thereby contributing significantly to the local food systems, given the importance of fishes like tuna as a key protein source and a highly valued trade item within the Caroline Islands.

Summary and Conclusion

By studying these satellite images, we begin to understand the complexity and efficiency of the navigational knowledge possessed by traditional navigators. Their ability to read the ocean's surface, understand the influence of underwater formations on wave patterns, and integrate this knowledge with other environmental cues demonstrates a remarkable understanding of their maritime environment.

Our investigation has successfully identified the navigational aids on the ocean surface, utilizing satellite imagery and insights from expert master navigators. The research findings underscore the impact of the late Holocene drawdown on the Micronesian settlement, attributing it to the escalating significance of seamounts and atolls on the ocean surface. The demonstrated wayfinding techniques shed light on the multi-generational efforts dedicated to institutionalizing navigational knowledge, attesting to the remarkable navigational skills of the Micronesian navigators who established a trade alliance network, operating within the highly variable intertropical convergence zone.

The ongoing research into traditional navigation techniques using modern satellite technology also offers knowledge preservation opportunities. As these conventional methods are passed down through generations primarily via oral tradition, there is a risk of losing this intricate knowledge over time. Documenting the science behind these techniques using modern technology can ensure this knowledge is preserved and understood by future generations.

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Part 4

Landscape and Monuments: New Insight

Ancient Sea Scape of Japan: Burial Mounds as Navigation Points

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Introduction

Tens of thousands of burial mounds were constructed in the Japanese archipelago from the 3rd to 6th centuries. This period is called the Kofun period in Japanese history, and the term of Kofun literally means burial mound. The most characteristic type of burial mound in this period is the keyhole-shaped plan view, the largest of which exceeds 500 meters in length. The gigantic burial mounds look like artificial hills and were built as monuments to show the power of kings and chiefs.

The places where burial mounds were built are diverse; some were built on hills and ridges, others on plains and coasts. In particular, burial mounds built along the coast are called 'seashore type burial mounds' and are considered to have been built by chiefs who were involved in maritime economy and transportation (Hirose 2015). Some scholars consider that the 'seashore type burial mound' was also used as a target for navigation (Mori 1986). With a few exceptions (Ishimura 2017), however, few studies have shown what these burial mounds actually look like from the sea.

In this paper, we use GIS software to show how these burial mounds actually look from the sea. We also show that these burial mounds are located at key points of maritime routes, such as ports and straits. Furthermore, we show that these burial mounds were built during a relatively limited time period, from the first quarter to the third quarter of the 4th century. In the background, we consider that there was a historical event that the political power of the Yamato dynasty in the Kinai region advanced the seizure of maritime traffic in the Japanese archipelago.

Sea scapes and ancient navigational skills

Navigation in ancient Japan was basically coastal navigation. Therefore, it was important to be able to visually recognize characteristic landmarks on the land from the sea. By measuring the angle of multiple landmarks from a navigator's point of view, she/he was able to identify her/his position. This skill is called "yama-ate" in Japan, and even today with the development of GPS, some older fishermen can still use this skill (Figure 1). When we are on the sea, however, we cannot see a wide range since the earth is round. Considering the size of an ancient boat and assuming that a navigator's viewing height is 1 meter above sea level, she/he can only see a circle with a radius of 3 kilometers. Anything outside of it will be hidden behind the horizon. As a result, only the parts of distant islands above the horizon are visible, and the parts below it are not visible (Figure 2). Visibility from the sea is limited, so it is common for a high mountain to be used as landmark for navigation. A target at low elevation near the coast may be hidden below the horizon, so the navigator can only see it when approaching it. For these reasons, burial mound used as a navigation point must actually be located in

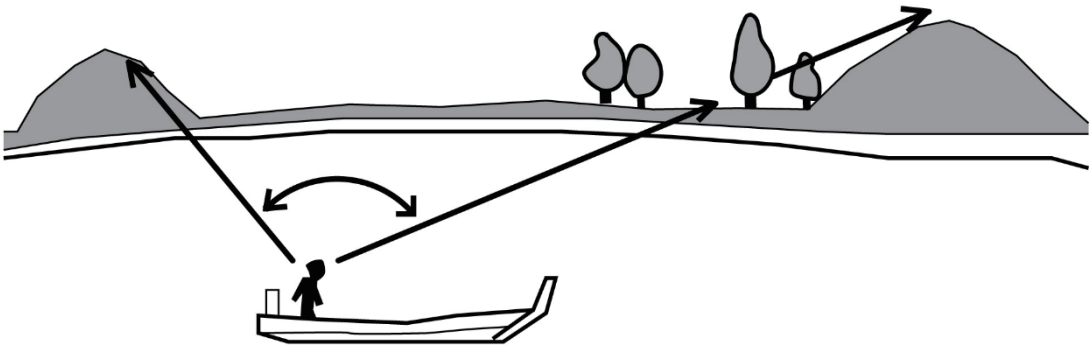

Figure 1. Model of “yama-ate”

a place visible from the sea. In this paper we verify that such burial mounds can actually be seen from the sea by analysis using GIS.

Method and materials

In this paper, GIS software of ‘Kashimir 3D®’ is used to reproduce the images how the burial mounds look from the sea. This GIS software can display landscapes in 3D from arbitrary points and altitudes. We set the altitude to 1 meter to reproduce the view from the sea, for considering the size of boat at that time, it is likely that the height of the viewpoint at sea was quite low.

The following four sites of ‘seashore type burial mound’ are analyzed; the Goshikizuka burial mound (Hyogo prefecture), the Yanai Chausuyama burial mound (Yamaguchi Prefecture), the Shinmeiyama burial mound (Kyoto prefecture) and Amino Choshiyama burial mound (Kyoto

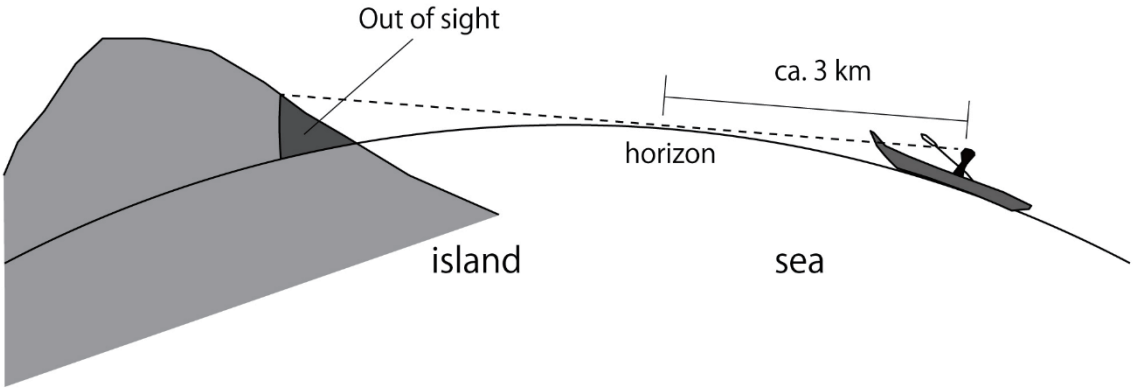

Figure 2. Eyesight from the sea (after Uchida 2009)

Figure 3. Map of research area and locations of the sites

prefecture) (Figure 3). The first two are located by waterways and the latter two by ports.

In this paper the Kofun period was subdivided into four phases: the first half of the Early Kofun period (ca. AD 250-300), the latter half of the Early Kofun period (ca. AD 300-375), the Middle Kofun period (AD 375-475), and the Later Kofun period (AD 475-575), based on the difference of burial facility and diagnostic burial goods (Table 1).

Case study 1: Goshikizuka burial mound

The Goshikizuka is a key-hole shaped burial mound with a length of 194 meters (Figure 4). It is estimated to have been built in the latter half of the Early Kofun period (ca. AD 300-375).

Phase	Date	Burial facility	Diagnostic burial goods
Early KofunPeriod (first half of)	AD 250-300	Vertical stone chamber with wooden coffin	Chinese bronze mirrors
Early KofunPeriod (latter half of)	AD 300-375	Vertical stone chamber with wooden coffin	Variety of Japanese bronze mirrors
Middle Kofun Period	AD 375-475	Vertical stone chamber with stone coffin	Iron armors
Later Kofun Period	AD 475-575	Horizontal stone chamber with stone coffin	Decorated swords

Table 1. A chronology of the Kofun period

Figure 4. Photo of the Goshikizuka burial mound (after URL: https://www.feel-kobe.jp/)

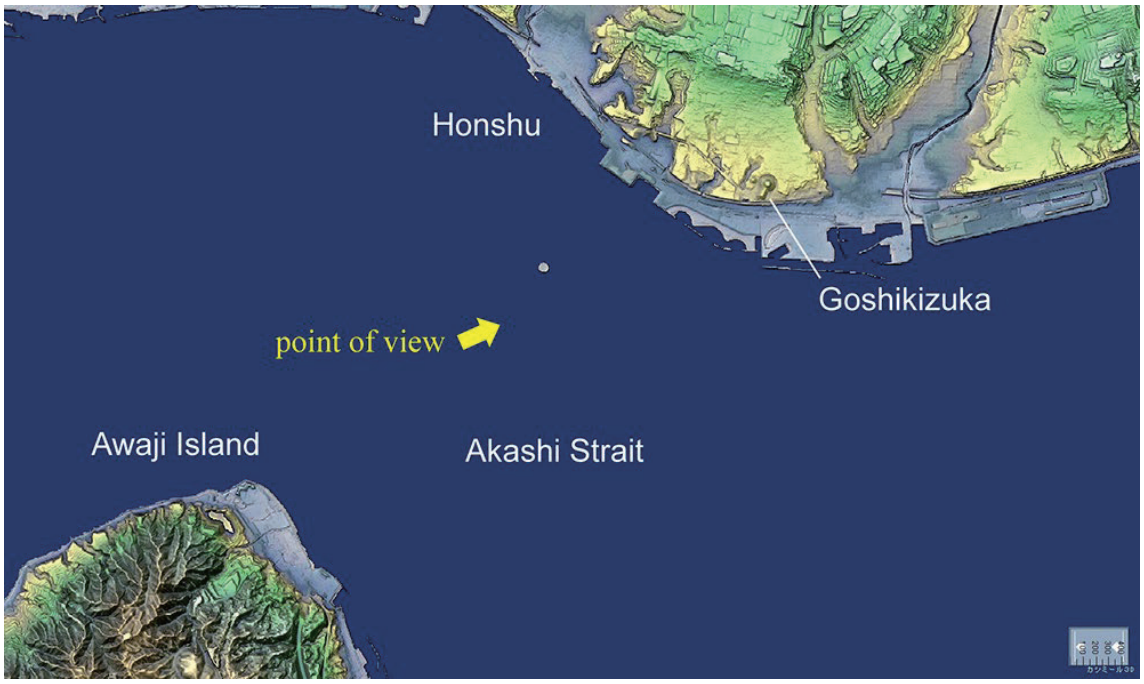

Figure 5. Topographic map around Goshikizuka

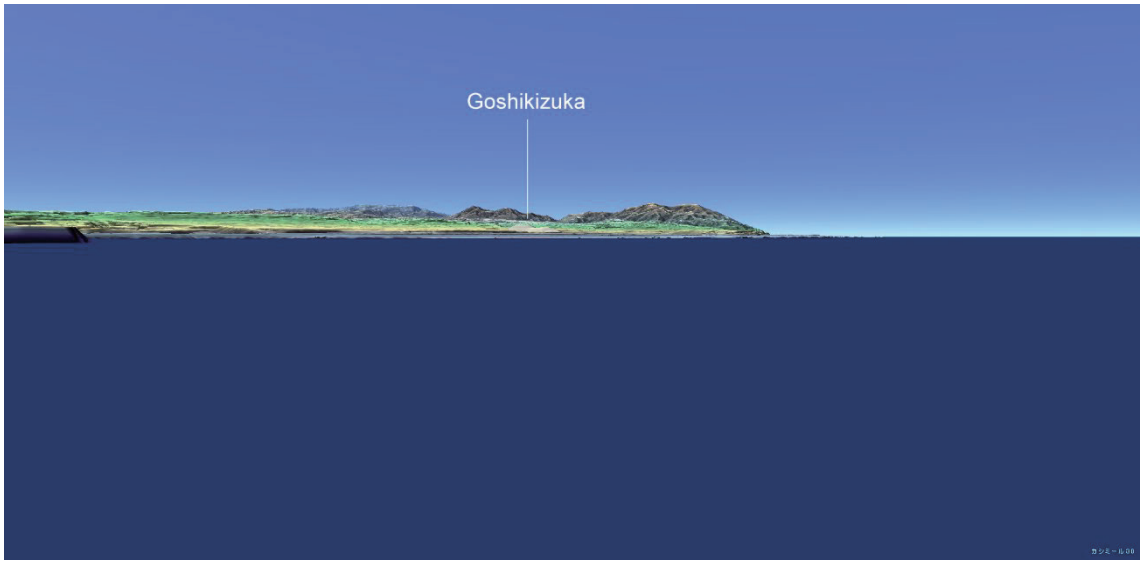

Figure 6. Seascape around Goshikizuka

It is located on the coast of the mainland Honshu overlooking the Akashi Strait (Figure 5) and can be seen well from the sea (Figure 6). The Akashi Strait is the entrance to the Osaka Bay and is one of the rough spots in the Seto Inland Sea with fast currents. The Goshikizuka is positioned in one of the most important places on the sea route of Seto Inland Sea.

Case study 2: Yanai Chausuyama burial mound

The Yanai Chausuyama is a key-hole shaped burial mound with a length of 80 meters. It is estimated to have been built in the latter half of the Early Kofun period (ca. AD 300-375).

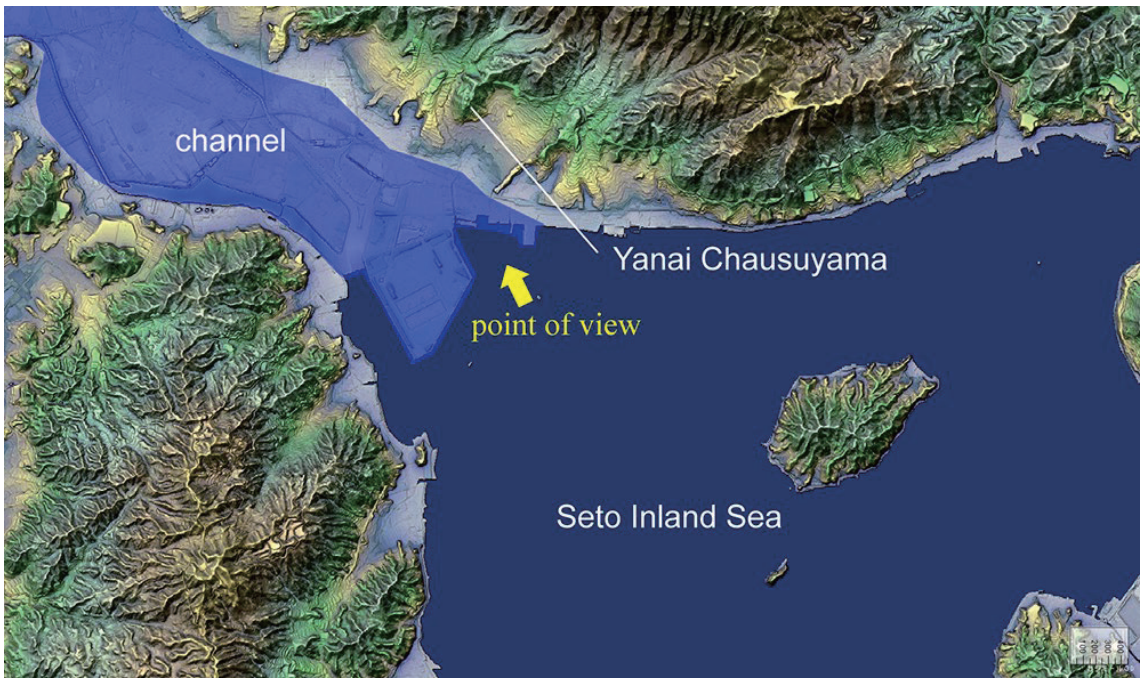

Figure 7. Topographic map around Yanai Chausuyama

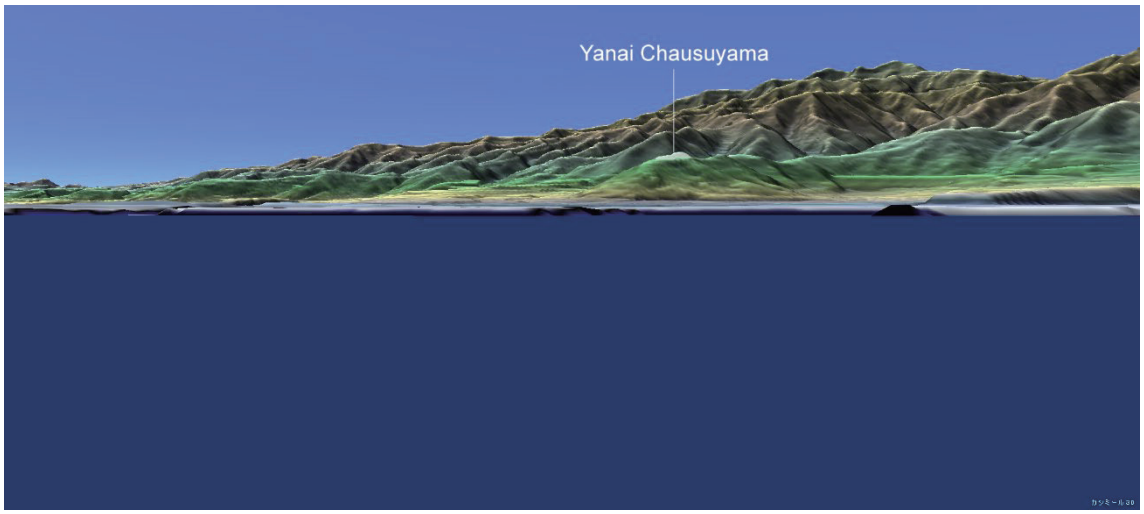

Figure 8. Seascape around Yanai Chausuyama

It is located near the entrance of a channel that once existed (Figure 7). This channel was a shortcut for avoiding the need to go around the Murotsu peninsula, and was an important point for maritime traffic. The Yanai Chausuyama burial mound can be easily seen from the sea near the entrance of the channel (Figure 8).

Case study 3: Shinmeiyama burial mound

The Shinmeiyama is a key-hole shaped burial mound with a length of 190 meters. It is estimated to have been built in the latter half of the Early Kofun period (ca. AD 300-375).

It is located near a lagoon that once existed (Figure 9). It is considered that this lagoon was once

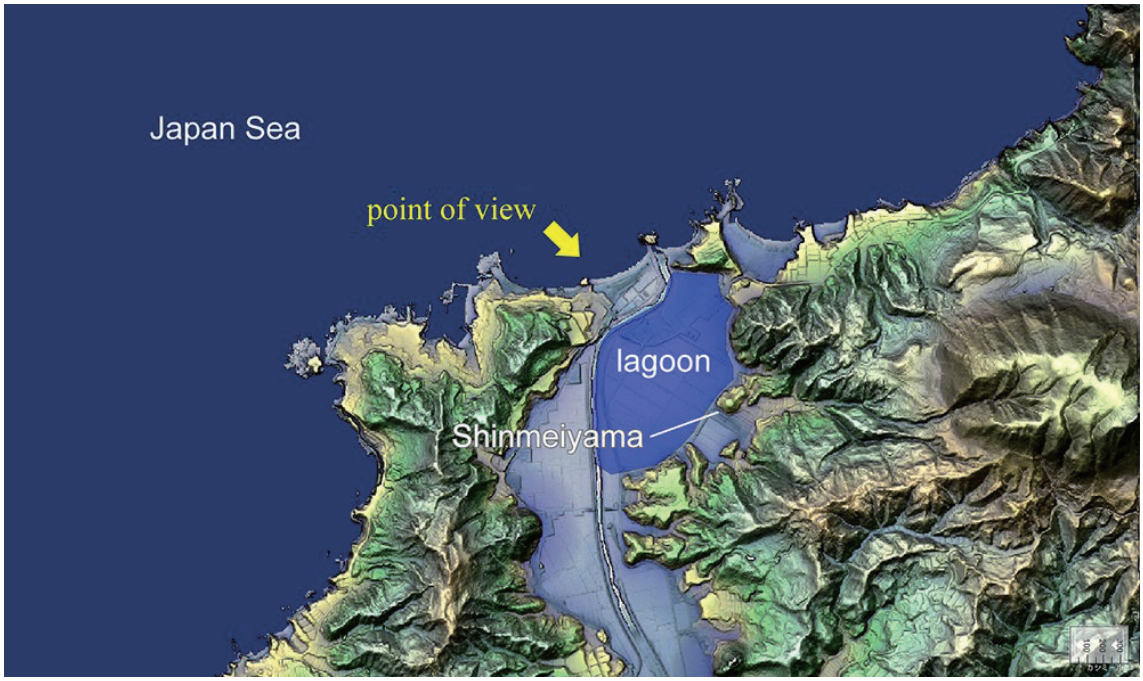

Figure 9. Topographic map around Shinmeiyama

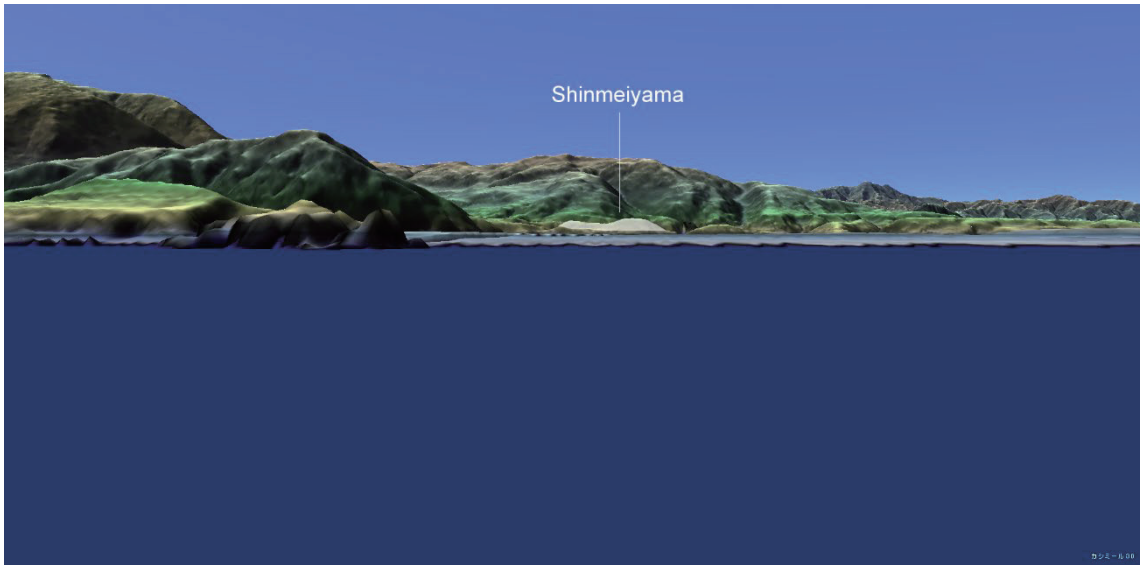

Figure 10. Seascape around Shinmeiyama

used as a good natural harbor. Since the Shinmeiyama burial mound can be easily seen from offshore (Figure 10), we assumed that it was a target for navigation that indicated the position of the port.

Case study 4: Amino Choshiyama burial mound

The Amino Choshiyama is a key-hole shaped burial mound with a length of 201 meters. It is estimated to have been built in the latter half of the Early Kofun period (ca. AD 300-375).

It is located near a lagoon that once existed (Figure 11). It is considered that this lagoon was once used as a good natural harbor, like the case of Shinmeiyama. Since the Amino Choshiyama burial mound can be easily seen from offshore (Figure 12), we assumed that it was also a target for navigation that indicated the position of the port.

Figure 11. Topographic map around Amino Choshiyama

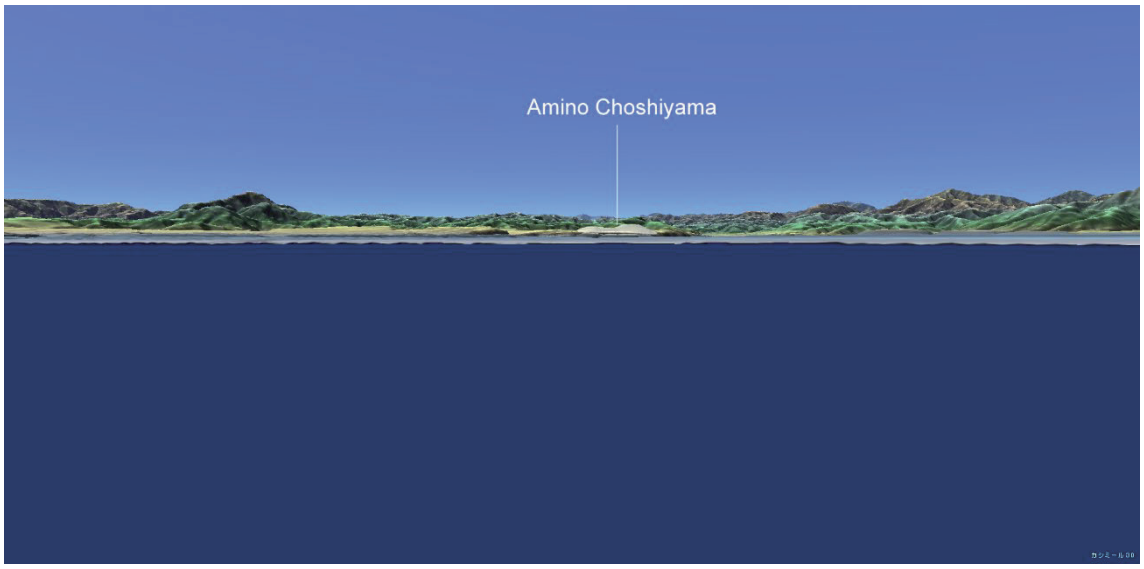

Figure 12. Seascape around Amino Choshiyama

Result

From the above for case studies, the following four outcomes are shown. Firstly, these 'seashore type burial mounds' can actually be easily seen from the sea. Secondly, these burial mounds are located at important points for sea routes such as waterways and ports. Thirdly, it is likely that they were built as navigational landmarks. Lastly, these burial mounds were constructed in a certain period, that is, in the latter half of Early Kofun Period (AD 300-375).

The above outcomes suggest that there was a common factor behind the construction of these 'seashore type burial mounds.' In other words, it is possible that the construction of these burial mounds reflected the political situation at that time. This is because the burial mounds, which are monuments that symbolize power of chiefs, were essentially political products.

Discussion

The period when these 'seashore type burial mounds' were built was also the period when major changes occurred in maritime traffic, which is a change in the route from the Japanese archipelago to the Korean peninsula. The fact that rituals on Okinoshima began during this period suggests that change.

Okinoshima is a small island located between Kyushu Island of the Japanese archipelago and the Korean Peninsula. The Okinoshima rituals are ceremonies to pray for safe voyages on the island of Okinoshima, which were held from the latter half of the 4th century to the end of the 9th century. Along with the rituals, Chinese bronze mirrors and various treasures were dedicated to the island's rocks and rock shelters. These materials are common to the burial goods of tombs, and many of them are distributed mainly in the Kinai region, which was the political center at that time. Based on these facts, it is considered that rituals on Okinoshima were led by an elite group of in the Kinai region. Its purpose is thought to be to establish a new route from the Japanese archipelago to the Korean Peninsula.

The conventional route to the peninsula was an island-hopping route via Iki Island and Tsushima Island; however, compared to that, the route via Okinoshima is a shortcut.

We consider that the change that occurred during this period was due to the fact that the political powers of the Yamato dynasty in the Kinai region promoted to seize the maritime route. It is probable that the 'seashore type burial mounds' discussed in this paper were built by local chiefs with the support by the powers in the Kinai region, in order to improve maritime route within the Japanese archipelago. It is highly probable that these burial mounds served as targets for navigation, not only in a practical sense, but also as a visual demonstration of the control of maritime traffic by powers in the Kinai region.

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Multisensory Experiences of Māʻohi *Marae*: An Ethnohistorical and Archaeological Study of Political Theater in the Pre-Contact Society Island Chiefdoms

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Abstract: In the last decade, archaeologists have turned to understanding political theater, arguing that the development of large centralized polities would have been impossible in the past without heavy reliance on public events. In this paper, I examine public ritual events at chiefly centers and marae (temples) in the late pre-contact Society Islands. Historic documents and archaeological data illustrate the spread of a new war and fertility cult in the Societies in the mid-seventeenth century. The ʻOro war cult brought significant shifts in ceremonial architecture and public ritual and led to an increase in chiefly power. Using ethnohistoric, linguistic, and archaeological data, I examine how large scale religious ceremonies associated with the ʻOro cult developed into a new form of political theater, one rooted in multisensory perceptions of scents, sounds, and visual spectacles. At such spectacles, varied socio-ritual elites asserted their roles as moral leaders and embodiments of community integration. I use diverse lines of data, including site placement, architectural layout, the surrounding natural environment, and the use of fire, sounds, and elaborate elite attire, to paint a multisensory picture of late pre-contact Māʻohi political theater. As I argue, ʻOro rituals not only heightened the visibility of rulers and separated those allowed to participate intimately from others who could not, but they likewise created contexts for the imposition of ideology and its constant negotiation among and between social strata.

Keywords: Political Theater, Ritual, Multisensory, Archaeology, Ethnohistory, Society Islands, Eastern Polynesia

In the last two decades, archaeologists have turned to understanding political theater, arguing that the development of large centralized polities would have been impossible in the past without heavy reliance on public events. In archaeological contexts, Inomata (2006:806-807) has broadly defined political theater as theatrical events including communication between performers and an audience who observe and evaluate the act(s). The theatricality of performance relates both to the use of the body and material images as expressions of shared semiotic systems. It is important to try to access the materiality of such performances, including their sensory experiences and the architecture within which they took place, as the smells, tastes, and sounds of the event have shared meaning. So too the

architecture of a place restricts and affords movement, and the hearing and viewing of the event by the audience, resulting in a shared experience (Inomata and Coben 2006), whether from near or far.

Theatrical performances can be transformative in that they serve as cultural capital, or as valued cultural knowledge that can be converted into political power. Aspects of performative theater, when experienced as shared ritual events, serve as a means of community building, while those in both secular and ritual contexts can clarify and reify hierarchical relations of power (Demarrais 2014). As Demarrias has noted, such events often add gave stability and legitimacy to transitory cultural constructs, and as such, had the ability to both structure social orders and transform them. Likewise, performances and political theater bring attention to asymmetrical power relations in highlighting the specialized knowledge of ritual and craft specialists, as the objects and costumes used in visually stunning multisensory performances often required specialist skills, knowledge, valued materials, and labor for their production (DeMarrais et al. 1996). Political theater is then both a source of integration and conflict. Such processes were central to the management and transformation of centralized polities, a shift common to many complex societies (Inomata 2006; McCoy 2018).

In this paper, I examine public ritual events at chiefly centers and *marae* in the late pre-contact Society Islands of French Polynesia. Historic documents and archaeological data illustrate the spread of a new war cult and fertility cult in the Societies in the mid-seventeenth century. The ‘Oro war cult brought significant shifts in ceremonial architecture and public ritual and led to an increase in chiefly power. Using ethnohistoric, linguistic, and archaeological data, I explore how large scale religious ceremonies associated with the ‘Oro cult developed into a new form of political theater, one rooted in multisensory perceptions of scents, sounds, and visual spectacles. I use diverse lines of data, including site placement, architectural layout, the surrounding natural environment, and the use of fire, sounds, and elaborate elite attire, to paint a multisensory picture of late pre-contact Mā‘ohi political theater. As I argue, ‘Oro rituals not only heightened the visibility of rulers and separated those allowed to participate intimately from others who could not, but they likewise created contexts for the imposition of ideology and its constant negotiation among and between social strata.

Background to the Society Islands

The Society Islands are centrally located in Eastern Polynesia (Figure 1). Settled c. A.D. 950, Mā‘ohi populations lived primarily along the coastline during the first 300 years of settlement. Around A.D. 1250, there was widespread movement into interior contexts and the building of domestic and agricultural site complexes. Around the start of the fifteenth century, the first formalized religious sites, including *marae* and smaller and less elaborate shrines, appear. Such sites become larger and more formalized through time, providing proof for the advent of stratified chiefdoms in the Society Islands (Lepofsky and Kahn 2011; Maric 2012, vol. 1).

Starting as early as A.D. 1650, a new religion, the ‘Oro cult, became a driving force for political expansion, domination, and ultimate consolidation of the Society Islands into ever larger polities

(Kahn 2010; Maric 2016). This new religion ignited an intense period of chiefly competition that resulted in more elaborate styles of monumental and ritual architecture, new settlement patterns, and the intensification of subsistence strategies and sociopolitical hierarchies (Kahn in press). To worship ʻOro, Māʻohi began building specialized styles of *marae* with imposing *ahu* (altars) and new, sprawling chiefly centers on the coast and inland. I have argued that by the late eighteenth century, this cult had become a "quasi-state" state religion, or high religion restricted to the elites, and a key vehicle whereby elites centralized their secular and ritual power (Kahn in press).

Māʻohi Cosmologies and Ontologies

Like many other indigenous societies worldwide, the Māʻohi had impermeable views of relationships between the natural world, the spirit world, and humans as well as relationships between humans, animals, and other material things. Māʻohi ontologies made a basic distinction between people and spirits (ghosts, gods, demi-gods, and the ancestors), who occupied different rooms of the universe (Oliver 1974, 56). While the spirits lived in the darkness, they had to be kept close in order to receive humans' prayers and offerings, thus they were invoked in rituals at temples, shrines, and sacred parts of the landscape. In addition, varied objects or things in the human world, like god figures (*tiʻi*), sculpted wooden planks (*unu*), the wind, heavy rains, trees growing within temple enclosures, or animals (octopus, eels, sharks, birds, among others), could be animated by the spirits (Henry 1928; Oliver 1974). Such beliefs draw our attention to how the natural landscape, including the weather, and its colors, sounds, and smells, and that of animals surrounding Māʻohi temple sites, and in particular their specific configuration during key ritual events, were an integrated part of the multisensory experience of Māʻohi political theater.

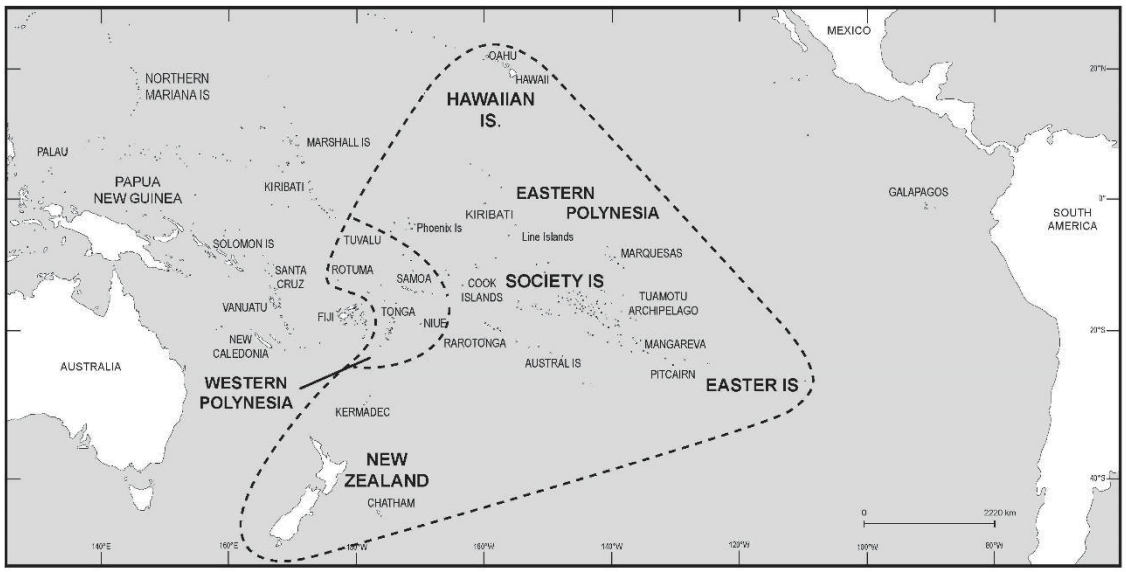

Figure 1. Map of Polynesia, differentiating Western Polynesia from Eastern Polynesia. Note the Society Islands central location in Eastern Polynesia.

The ‘Oro Cult and Political Theater: Ethnohistoric Data

Historic sources document how the ‘Oro cult was intimately associated with ritualized cult ceremonies that marked the changing seasons, rites of passage for the ruling chiefs and their families, the start of war, and other extraordinary events. At such rituals, high priests and high chiefs, the latter adorned in elaborate costumes, orated in highly formalized manners. Only high chiefs associated with the ‘Oro cult could be outfitted in clothing benefiting the status of the gods, such as the red and yellow colored feathered loin cloths, and the *fau* (chief’s headdress), feathered items resembling the first feathered clothing of the god Atea (Alevêque 2018). So too, only the highest chiefs could officiate at ‘Oro ceremonies with royal sacra, notably the *to‘o,* the material representation of ‘Oro clothed in its own red feathers, while offering human sacrifices to the god (Babadzan 2003; Eddowes 1991a:100-101; Henry 1928: 135). Such rituals were practiced at temple sites with processual ramps and restricted entryways, thus the architectural form of the temple sites created another element of drama. Certainly, the use of visually stunning, and ritually symbolic specialized costumes, in addition to the use of ritual sacra in temples with dramatic settings, would have emphasized the pageantry of ‘Oro events.

One of the most important seasonal rites for the ‘Oro cult was the *matahiti*, a multi-scalar, multi-day festival celebrating the new year where surplus goods were funneled from the commoners to land managers, then to the subchiefs, then to the high chiefs, reinforcing the class hierarchy (Morrison 1935, 262-263). Opened by the high chiefs, *matahiti* ceremonies featured the arrival of canoes from each sociopolitical district carrying *‘arioi*, fertility cult members associated with ‘Oro. Grand flotillas of canoes laden with material goods play a prominent role in European explorers‘ accounts, supporting how such events were visually striking to both the islanders and outsiders alike (Oliver 1974: 918, f 25). The protracted ceremony included the public presentation of food staples and prestige goods such as mats, canoes and *tapa* (barkcloth), and the making of sacrifices and other offerings to the gods, chiefs, and priests at royal district *marae* (Babadzan 1993b, 244, 259; 260-261; Kahn and Kirch 2014, 38; Moerenhout 1837, 518-521; Oliver 1974). Several days of feasting, festivities like dance, singing, theater, and sporting events, like wrestling and archery, ensued (Babadzan 1993: 253-254, 268, 1993b, 245-247; Henry 1928, 177; Oliver 1974, 923, 1001-1002). Given the communal nature of such ceremonies, and their wedding of highly visual rituals with secular spectacles, we can confidently define such ‘Oro cult ceremonies as forms of political theater.

The ‘Oro Cult and Political Theater: Archaeological Data

The actual places and spaces where ‘Oro rituals were carried out were also key elements of their political theater. The ‘Oro cult was associated with the construction of ever larger and more elaborate temples and ritual chiefly centers, where the religion’s rituals were carried out. Society Island *marae*,

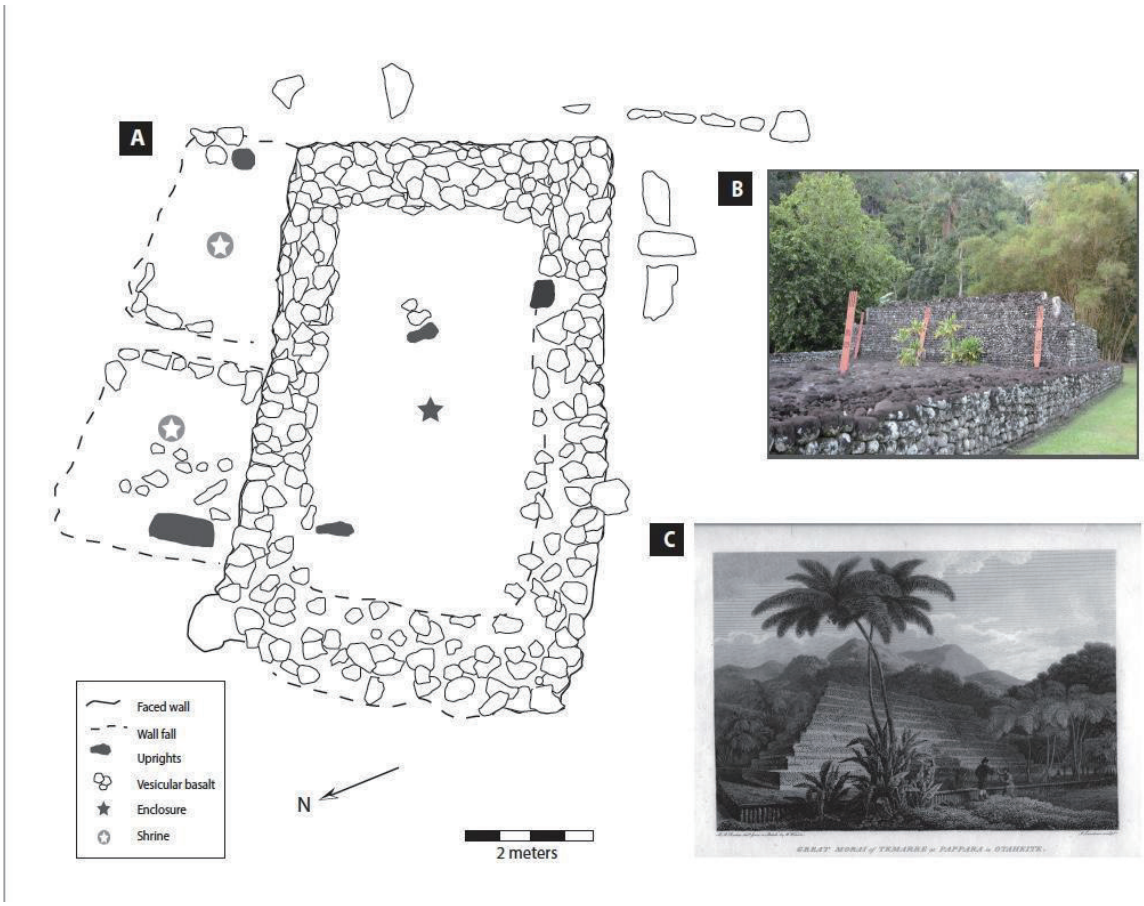

Figure 2a. ScMo-171F, a simple *marae,* note the stone enclosure, stone uprights, and lack of interior *ahu*; 2b: *Marae* Arahurahu on Tahiti Island, note the use of worked rounded stones in the stepped *ahu* and in the enclosing walls, photo courtesy of the author; 2c: *Marae* Mahaiatea on Tahiti Island, as seen during the voyage, lithograph from Wilson 1799.

or temples, start out relatively small and include a stone court or plaza, often enclosed by a walled enclosure (Figure 2a). More elaborate temple forms developed through time and include a stone raised altar at one end of the enclosure. The altar or *ahu* is often fronted by lines of stone uprights which represent the gods. Through time, and particularly after the advent of the 'Oro war cult, we see changes in the size and elaboration of Society Island *marae*, many having to do with *ahu* style. Temples after AD 1650 incorporate coral facing and coral blocks in their *ahu* (Figure 2b). *Ahu* also become stepped in form (Figure 2b, 2c) and include the use of rounded stones (Figure 2b). These rounded stones signaled highly *tapu* contexts where offerings, including human sacrifices, were made to the gods during 'Oro rituals (Kahn 2010; Maric 2016). Such offerings to the gods not only reinforced the chiefs' political and economic power, but so too visually represented how their political power could be used

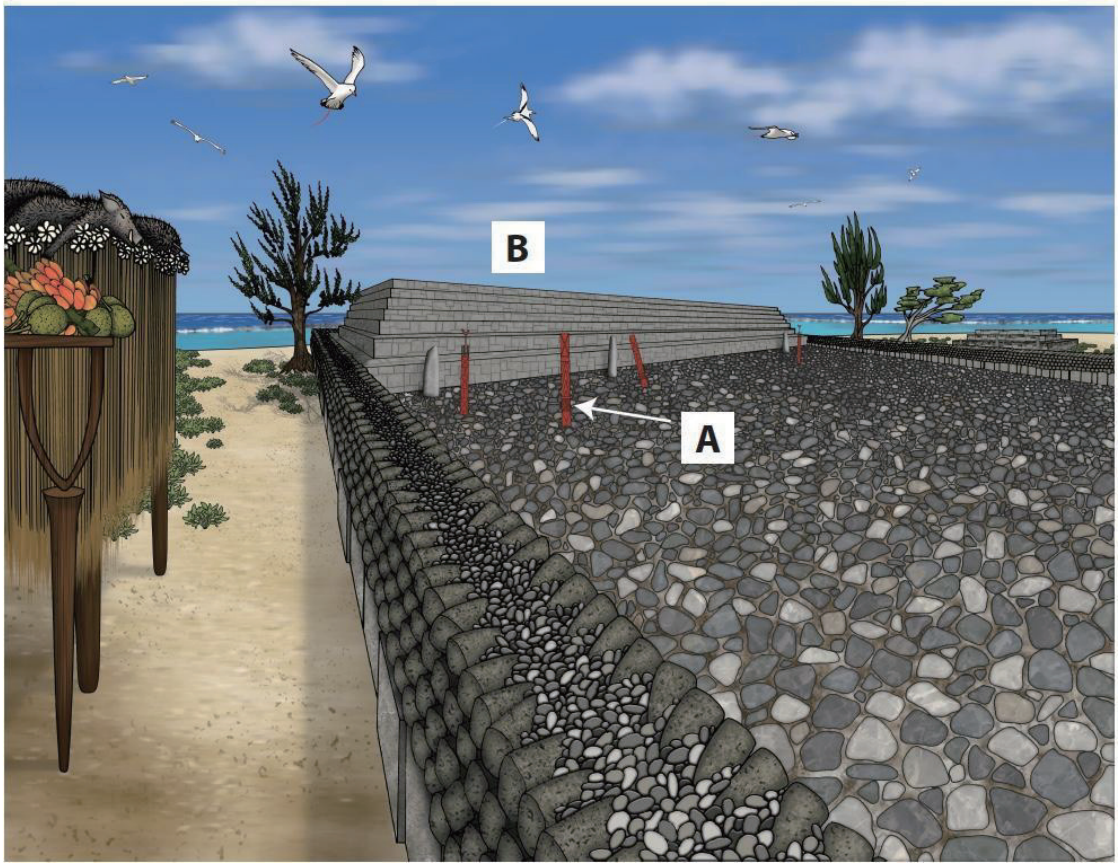

Figure 3. Visual Representation of a Royal District *Marae* dedicated to ‘Oro. A. Sculpted wooden *unu* in front of the *ahu* are seen in red; B. Stepped *ahu* constructed from blocks of coral.

towards coercive ends. Thus, the elaborate temples where ‘Oro style rituals were carried out represent a key avenue towards understanding the role of political theater in this complex chiefdom.

Multisensory Analysis of ‘Oro Style Rituals

How are we to present analyses of Society Island ‘Oro temples and chiefly centers that depict the varied sensory experiences that ritual participants had? Archaeological, ethnohistoric, and historic data are useful in thinking through these concepts, as are visual reconstructions, as presented in Figure 3. Descriptions of royal ‘Oro temples situated on the coast, which were used by only the highest of elite chiefs and priests who embodied the most *mana* (or sacred power), are rare. Tobin (1797), a European explorer, visiting such a royal coastal *marae* in 1792, noted that

> The marae was a platform about a foot high, sixty four feet long by forty two feet broad. At one end, it was raised 4-5 feet (this would be the *ahu*, which the red arrow points to) in steps decorated with carved wooden figures, some of them representing birds and lizards (these are the red sculptures seen here on the court in front of the *ahu*). A few

> upright stones were fixed in different parts of the pavement, (the green circle shown here) and breadfruit and coconut trees were growing amongst them. (text in parentheses are my additions).

We can consider the use of the carved wooden sculptures, or *unu* (see Figure 3[A]), set in the temple court, as a visual signal to bring ritual participants' attention to the most ritually important part of the temple, the *ahu* [B]. But components of royal *marae*, like the sculpted *unu* boards depicting birds, were more than just material representations. Symbolically, birds were considered avatars of the deities; their presence on *unu* signified how the god 'Oro was receiving sacrifices. Birds were also considered givers of good fortune. *Unu* were placed on temples to bring birds into these spaces, as a way to bring the gods and ancestors into these spaces and to entice the birds, and the gods, to feed upon sacrificial food offerings. At coastal *marae* then, not only must we envision the glint of the sun on white bleached coral, and the sounds of waves crashing on the coral reefs nearby, but a cacophony of birds, some sacred like the kingfisher and the heron, feeding upon food offerings.

European explorer and missionary descriptions of Society Island temples tend to emphasize their size and layout and offer only basic descriptions of the rituals carried out in them. Archaeological and survey data can be used to flesh out the sensory experiences of such sites, if we take an interpretive landscape approach (see Hamilton et al. 2016). Coastal *marae* of the 'Oro style often had coral blocks incorporated into their architecture. The example here (Figure 3) has both coral blocks in the *ahu* shown with the red arrows and in the base stones of the enclosure walls, whereas dark grey basalt stones were used as the predominant construction materials. The white to light grey color of coral would have been magnificently offset in the day's sun from the blue of the ocean and the blue of the sky. But coral was more than a visual treatment in Society Island temples. It symbolized Mā'ohi culture's strong connections to the ocean and to voyaging (Handy 1927; see Molle et al. 2023). The color white also was related to the sacred and to death (Kahn and Kirch 2014; Molle et al. 2023). The use of coral offerings at *marae* and use of coral in *marae* architecture likewise transferred *mana* from the ocean to temples, marking them as highly sacred spaces and as agents of fertility (see Henry 1928). In this way, we can view the materials used to construct 'Oro style *marae* as sensual mediums for the expression of culturally shared symbolic ideas (see also Hamilton et al. 2011).

If we shift to lived experiences at temples in interior contexts, such as the back of the 'Opunohu Valley on Mo'orea, descriptions of temple events there often suggest a more somber experience (Eddowes 1991). Historic accounts suggest inland *marae*, particularly those associated with elite lineages, were places to be feared and places of silence. For example, Henry states that "Terrible were the marae of the royal line, their ancestral and national marae! They were places of stupendous silence, terrifying and awe inspiring, places of pain to the priests, to the owners, and to all the people." (Henry 1928: 151). Yet archaeological data sometimes suggest otherwise. One such example is site complex ScMo-124 high in the upper reaches of the valley. The clustering of large numbers of elaborate temple

sites, with other elite structures like council meeting platforms, is indicative of a secondary elite center. Direct linkage between Mā'ohi chiefs' political power, economic prowess, and religious authority was firmly established in the mid-17th century, when first fruit rituals conducted at royal *marae* and at these smaller secondary complexes, ensured the land's potency and fertility.

Tahitian gloss	**Description**	**Scale of Event/Locale**	**Material Items**	**References**
Fa'aari'ir a'a	Office taking, investiture of the chief	Large scale, public; Royal Regional, Royal District, or Community *marae*	Large quantities of feast foods, rolls of high-quality tapa cloth, clothing with feathered decoration, canoes	Henry 1928; Oliver 1974, 1015-1024
Taurua	Public feast associated with the elites	Large scale, public; Royal Regional, Royal District, or Community *marae*	Tapa cloth, canoes, pigs, human sacrifice	Corney 1918; Oliver 1974, 1295-96
Matea, maui fa'atere, haea mati	Political and religious ceremonies prior to commencing a battle	Large scale, public; Royal Regional, Royal District *marae* dedicated to 'Oro	Human sacrifices (to the gods), barkcloth, fine mats, pigs (to the priests)	Ellis 1831; Oliver 1974, 385
----	Mourning ceremony and feasts	Public; for elites at Community *marae*	Large quantities of pigs, other food stuffs, rolls of tapa	Corney 1918, 183-195
Parara'a matahiti	First fruits (harvest ceremony)	Community *marae*	Tribute and feasting goods, brought to the temple; large quantities of hogs, deep sea fish, turtles, baked vegetables, starchy puddings, mats, rolls of cloth, feather ornaments	Babadzan 1993, 237–240; Henry 1928, 177; Moerenhout 1837

Table 1. Large public ceremonies, feasts, and rites of passage in Mā'ohi society at the time of European contact.

By then, the numerous terms for Mā‘ohi elite feasts and rites of passage likely pointed to not only the immense *mana* of chiefs and their families but to the long-standing histories of such traditions (see Table 1). The large size, and public nature of these rituals, replete with the presentation of tribute, sacrificial rites, and offerings became an embodiment of political theater. In one sense, ‘Oro fertility rites stimulated resource abundance and reproduction. Yet such rites also guaranteed that the uppermost echelons of society, or the paramount chiefs, high priests, and members of the fertility cult, drew more benefit from the annual ritual cycle than did commoners. Seasonal rituals reinforced the ideological bonds between paramount chiefs and ‘Oro, paving the way for the extraction of surplus from commoner laborers. By the seventeenth century, if not before, ideology had driven a hard dividing line between socio-ritual elites and the rest of the population, a process that was likewise facilitated by political theater.

How would these inland secondary centers been experienced in the past? Some of the temples here, including 124J, seen in this 3D image (Figure 4), were expansive, at 11 m long, with a high *ahu* constructed of stepped coral blocks rising c. 3+ m up to the sky. We have to imagine such large and imposing temples under the rustling of tree branches with the late afternoon winds. Imagine the dappled sunlight that would shine in between the patches of shade under the towering Banyan trees and the late afternoon visits of birds and their singsongs. Later in the day, sites would be plunged into darkness with the rapid setting of the sun, creating the somber effects described in the historic accounts. Some temples, like 124T, had worked rounded stones marking their designation as ‘Oro war cult temples (Figure 5a). Surface architecture at this site illustrates that there was a stone lined ramp or entryway just below the temple, outlined in Figure 5b in yellow. This ramp can be viewed as an indexical marker of prestige.

It marked space as not only sacred but as special, only to be used by the highest of elites. It also formalized movement in accordance with spatialized strategies of authority, signaling this as a restricted, highly *tapu* place only for those with much *mana* or spiritual authority. My excavations at 124T revealed extensive evidence for the burning of candlenut (*Aleurites moluccana*) along this ramped entryway. This was likely related to the use of the temple for nighttime ceremonies, where fire was used to signal to others in the valley that this site was in use for a *tapu* ceremony.

Other structures, like this raised stone pavement (124X) may have been used in extensive and highly *tapu* mourning ceremonies (Figure 6). Thus, sensory experiences of the sites would track both with the changing times of the year and with extraordinary events. After the deaths of chiefs, their semi-embalmed bodies would have been laid out for public viewing in houses for the dead seen in the lower right. High priests then led lavish mourning ceremonies to elevate high chiefs to the order of the gods in the afterlife (Corney 1918(III):93, 205; Oliver 1974). The high priests donned elaborate mourning masks and costumes, seen at the upper right, for a several day ceremony full of spectacle. In these glinting pearl shell costumes, they carried sculpted war lances tipped with shark’s teeth. Others painted in black, red, and white, held shell tappers in their hands to create a ruckus as a warning

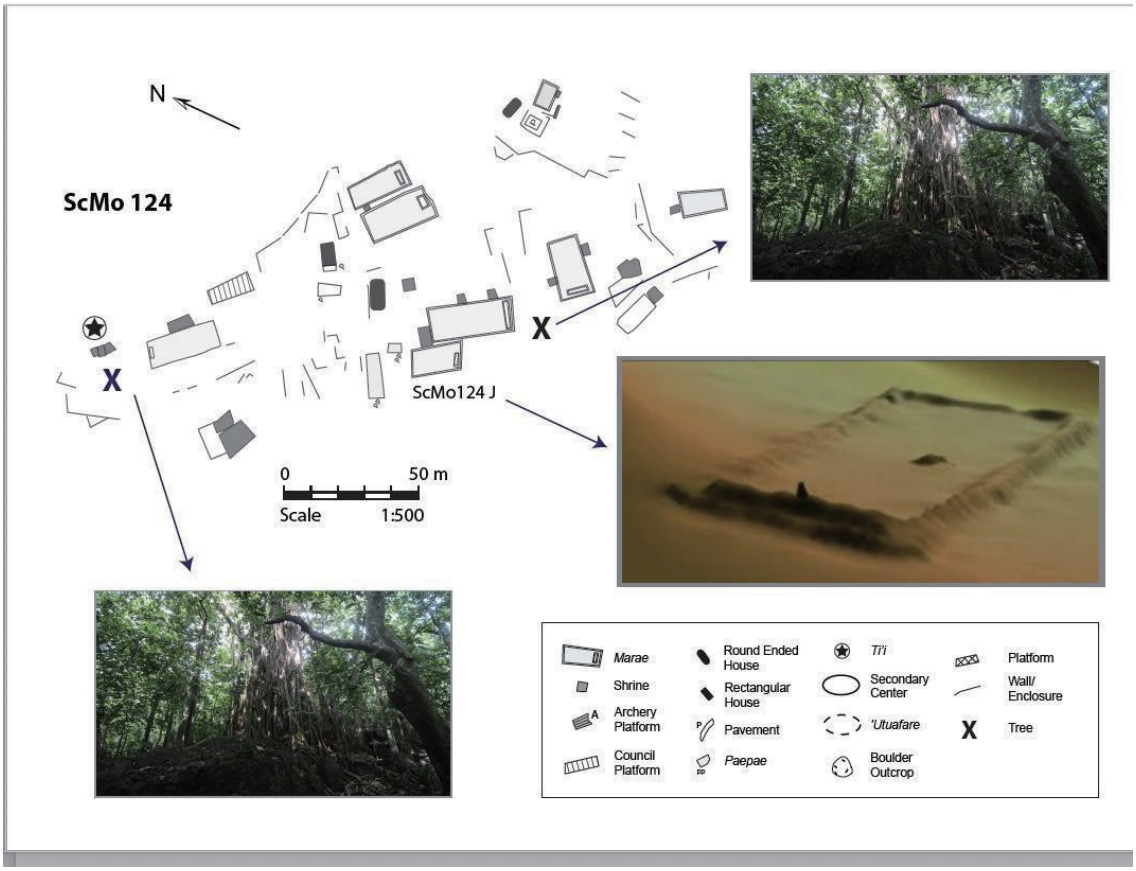

Figure 4. Plan view of ScMo-124 secondary chiefly center, ‘Opunohu Valley, Mo‘orea. Note 3D digital image of *marae* ScMo-124J, which is the larger of the two *marae* that the arrow points to, in addition to the two Banyan trees in this chiefly center (marked by Xs).

symbol. The cacophony of noises would have stood in stark contrast to the days just preceding the public ceremony, when oppressive laws of silence had to be followed (Robineau 1985:114; Salmond 2009). Mourning ceremonies could last days to even months, at the end of which the chief’s bones were put in a secluded place. At site 124 they were tucked under large boulder overhangs.

Discussion

While preliminary, I have tried to use multiple lines of data to get at the lived experiences of theatrical performances at Society Island *marae* and chiefly centers. The study of ritual theater allows archaeologists to examine interrelations between political, social, and cultural factors. It also illustrates how ritual sites were used for much more than religious ceremonies. It is very likely that the highly ritualized ‘Oro ceremonies, both sacred and secular, at both primary and secondary chiefly centers clearly marked those with high *mana* (sacred power) from those without. At such spectacles, varied socio-ritual elites asserted their roles as moral leaders and embodiments of community integration.

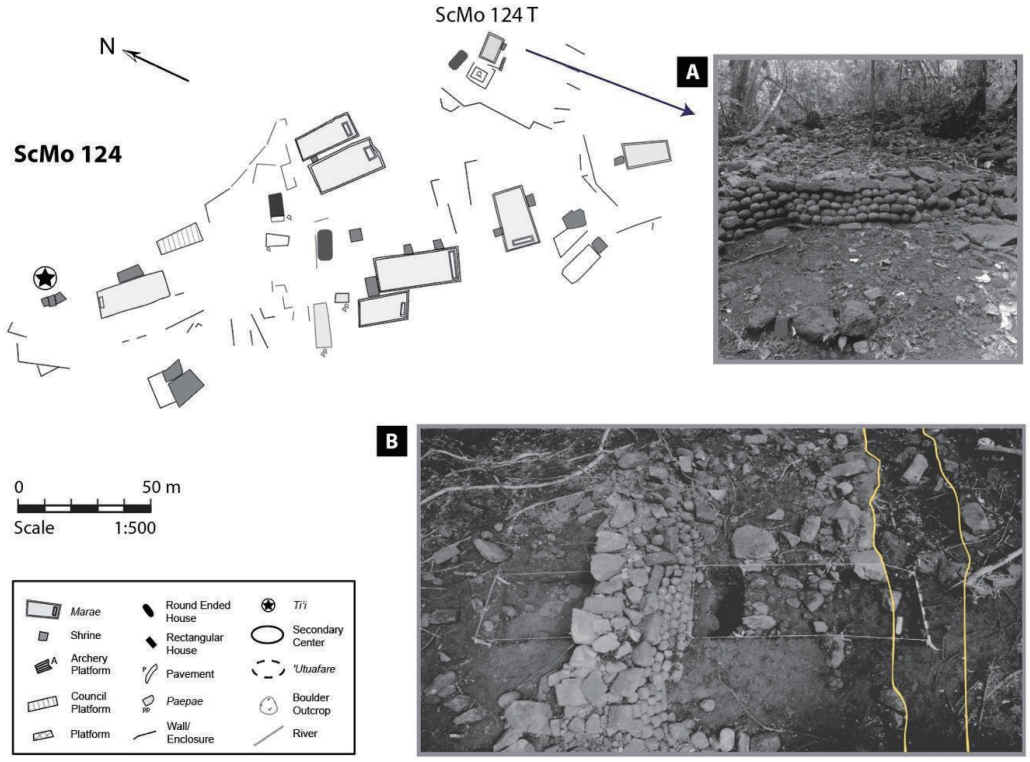

Figure 5. Plan view of ScMo-124 secondary chiefly center, ‘Opunohu Valley, Mo‘orea. A: Photo of 124T enclosing wall, taken to the East. B: Bird’s eye view of 124T, yellow lines highlight where the entry ramp is located on the terrace facing the *marae*.

Yet at the same time, members of the general community would have been well aware of events from which they were restricted, as the sounds, colors, and smells of such events would have been highly visible and easily experienced in residential neighborhoods near ritual centers. Such analyses call into question the larger socio-political implications of theatrical performances, including their role in strengthening social cohesion while at the same time reifying principles of *mana* and *tapu* (taboo, or restrictions) that were the basis of hierarchies of exclusion in the late pre-contact Society Island chiefdoms.

Theatrical performances at secondary ritual centers in the ‘Opunohu Valley likely served as a form of competitive signaling between spatial adjacent communities. The valley has five secondary chiefly centers, four of which are circled in Figure 7, each within relatively close proximity to one another. Here, we can envision that the sites, sounds, and colors of major ritual events, gave physical reality to social communities in competition with one another.

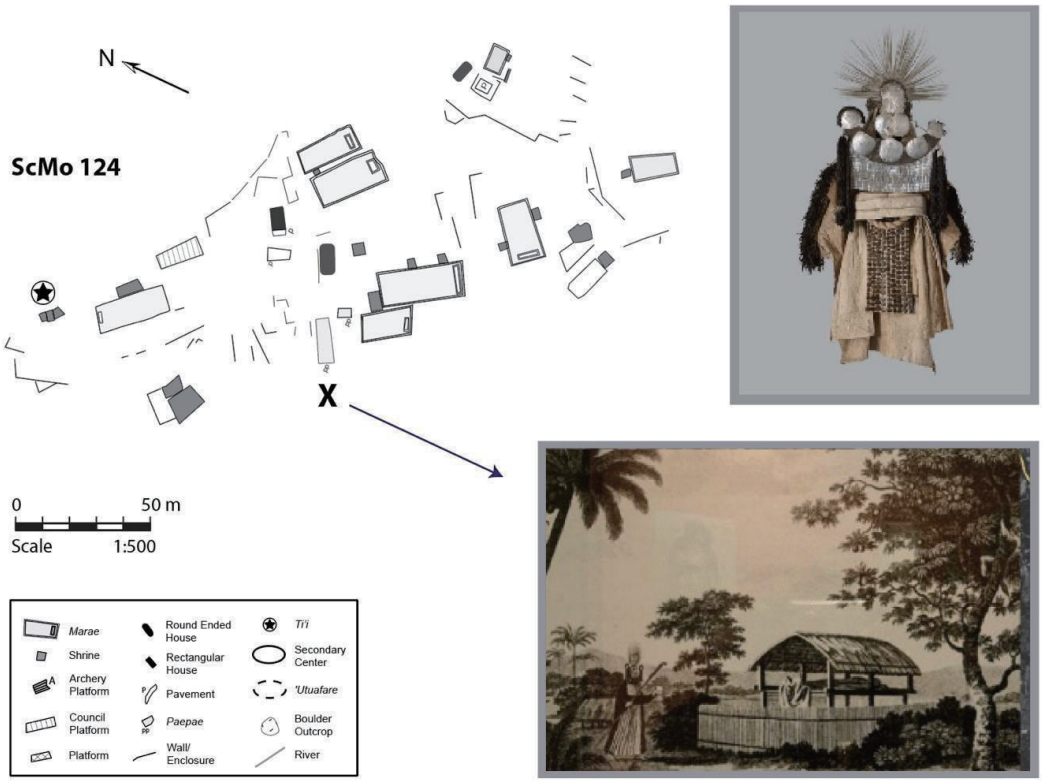

Figure 6. Plan view of ScMo-124 secondary chiefly center, ‘Opunohu Valley, Mo‘orea. X marks the low stone pavement likely used as a foundation for a mourning platform. There, a high priest would have donned the mourning costume (upper right) to perform mortuary ceremonies for the high chief at a *fare tupapau* (bottom right).

We can envision episodes of cyclic competitive events embodied as theatrical performance bringing these four neighborhoods into constant socio-political, ritual, and economic engagement. Sacred participants not only witnessed the bodily presence of others, but their shared experience. Participants, both within the same neighborhoods as the event, and outside of them, would have also experienced elements of the political theater from afar. This reminds us that human sociality is rooted in the sensory perceptions of others.

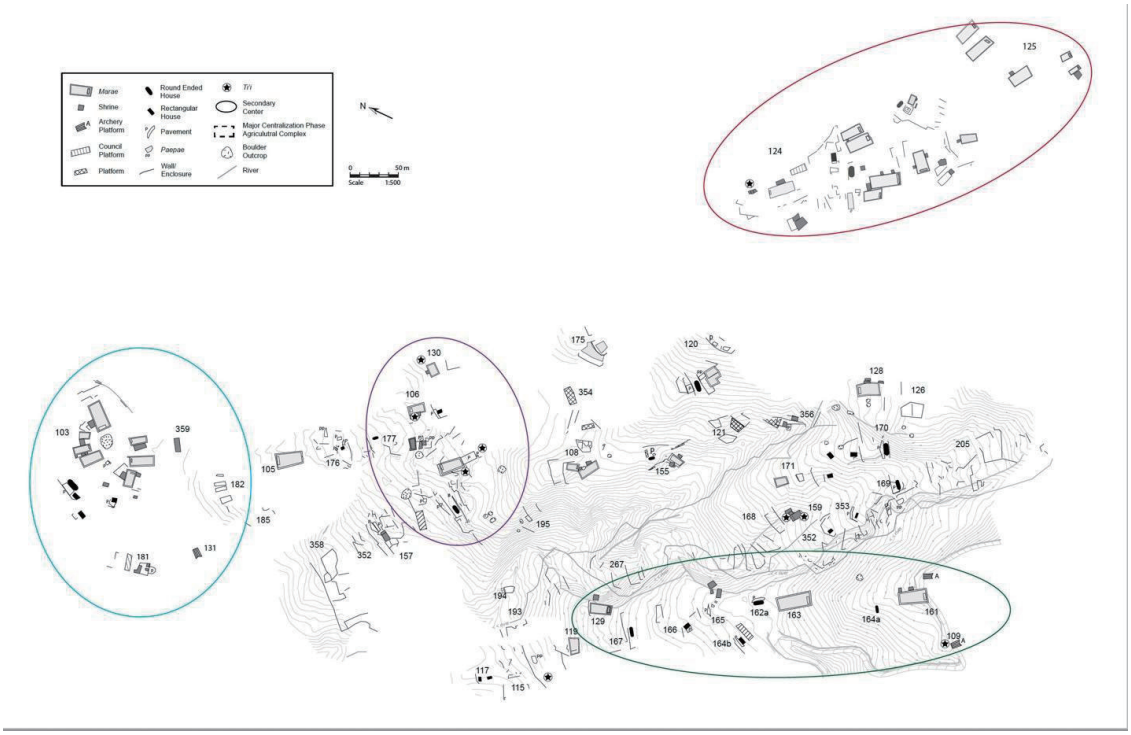

Figure 7. Four secondary chiefly centers in close association, Tupauruuru sector, ʻOpunohu Valley, Moʻorea.

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Direct Historical Approach to Ritual Landscape in Tongareva Atoll, the Northern Cook Islands.

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Keywords: coral atolls, East Polynesia, marae, ceremonial structures, ethnoarchaeology

Introduction

Ceremonial structures are widely distributed among the islands of East Polynesia. They are called marae, me'ae, heiau or ahu. Many of them share basic morphological elements such as "an enclosed or otherwise delineated courtyard, elevated altar area (ahu), and upright stone slabs or carved images" (Kirch 1982: 80), although they are also diversified in their size, orientation, and location. Because of their number, the monumental size of many of these structures, their similarity and their diversity, these ceremonial structures have been viewed as one of most marked cultural phenomena of East Polynesia (Garanger 1967: 383).

The majority of more reliable information was not accumulated until the 1920's when the Bishop Museum systematically carried out archaeological and ethnological surveys (Emory 1943: 9). It is very evident by that time that most of islands were strongly westernized and had lost or were in the process of losing their traditions about such matters as ritual and cosmology. In this situation, salvage surveys of the Bishop Museum yielded a mass of invaluable records. In keeping with this accumulation of archaeological and ethnographic information, both studies of the ceremonial architecture itself and interpretations of prehistoric island societies using it have progressed by employing several perspectives, each reflecting world archaeological trends. They can be classified into three perspectives the culture-historical, processual, and interpretive.

Emory of the museum surveyed 240 archaeological sites throughout the Society Islands and classified marae of the Windward Islands into tree types: inland, intermediate, and coastal. He identified another type for marae in the Leeward Islands. His intention of the quadripartite classification was to propose the developmental and chronological framework of ceremonial architecture; from the simpler inland type through the intermediate and the Leeward types to the more sophisticated coastal type (Emory 1933: 40-1). He vigorously continued a series of surveys and set out morphological similarity and difference in ceremonial structures to infer its developmental and diversifying sequence in East Polynesia (Emory 1943, 1970). His culture historical perspective viewed morphological types as indicators of diffusion of cultural norms.

In the 1960's, the different method of survey has started to be applied to the Polynesian prehistory.

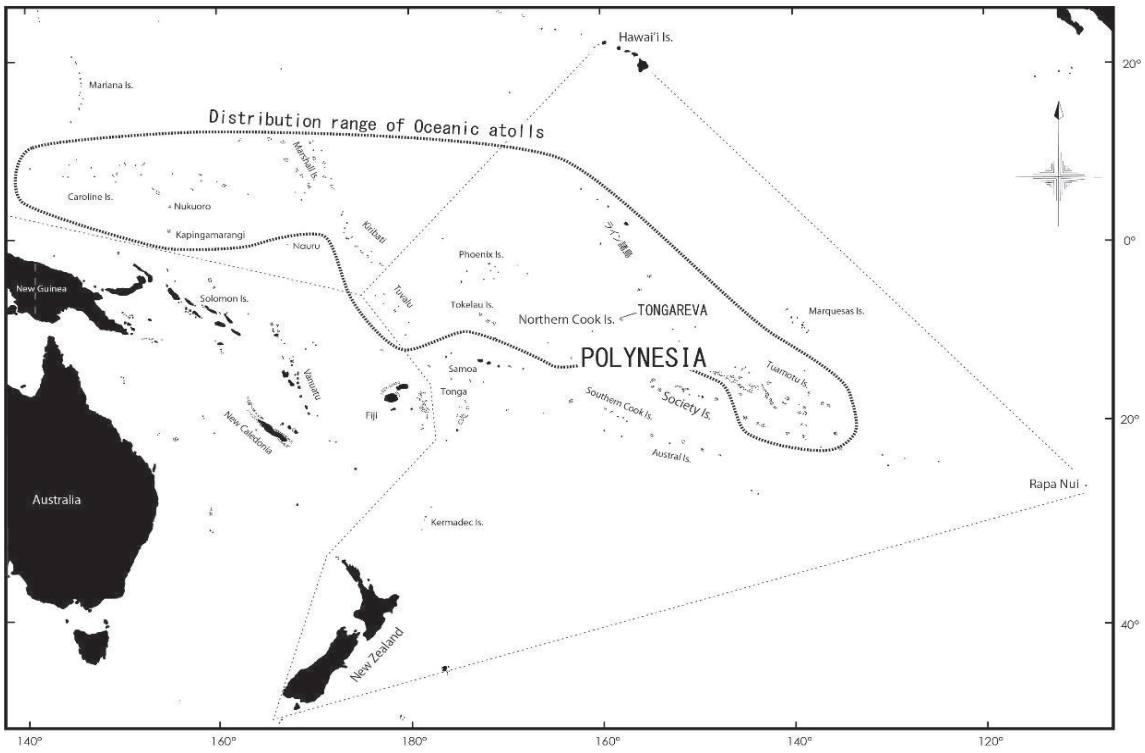

Figure 1. Map of Oceanic atolls

This spatial archaeology included intensive surveys of a given area such as a valley locale, and excavations to reconstruct local cultural sequences. Green demonstrated that some types of marae have contemporaneously functioned in terms of the social differentiation and stratification of 'Opunohu valley in Mo'orea (Green et al. 1967: 162). Thereafter, ceremonial architecture of East Polynesia has mainly appeared in the processual studies of social archaeology aiming at the reconstruction of socio-political structures and focusing on the indices of architectural elaboration. There would have been a shared intention to build a model of evolutionary process of socio-political integration common to various islands (e.g. Kirch 1984).

While most processual studies have referred to marae as an important means, Green & Green (1968), referring to eyewitness historical descriptions and drawings recorded by Europeans as well as ethnographic accounts, exhibited that several archaeological types of marae in the Windward Society Islands were associated with a specific god, Oro. This study demonstrates that a variety of meanings would be encoded in various characteristics and patterns which archaeologists can observe in ceremonial structures. However, such a direct historical approach of ethnoarchaeology has not been fully explored yet in Oceanic studies. Thus, I try to describe Tongarevan marae as a sort of material culture to have invented the social relationship among inhabitants of this atoll who bodily experienced these structures, through the record of direct observations of E.H. Lamont who stayed there in 1853.

Environmental diversity of seemingly uniform atoll islets

There are scattered many coral atolls within the Pacific trade wind zone, the landform of which consists of unconsolidated sand and gravel. Tongareva, lying at the eastern margin of the Northern Cook Islands, is one of such atolls (Figure 1.). Its low and flat islets have the limited vegetation. The visual scene is less colorful, mainly composed with ocean blue, white sand and gravel of beach, green shade of coconut trees, and then reversely white beach and marine blue of lagoon. The subaerial landform of islets is markedly simpler even among Oceanic atolls, but several micro-topographic features are discernible. In the tidal zone of ocean side, cemented beach-deposits (beach rock) occur. This formation is cross-stratified along the beach slope, and conglomerate slabs can be easily quarried from it for marae constructions. There is a mass of coarse debris along the ocean shore, known as storm ridge, which is up to 4 m high above sea level in places. Behind the ridge to the lagoon beach, the flat inland extends. Coral gravel occurs beneath the humus soil, with reducing grain size towards the lagoon. Long islets are provided with brackish or freshwater ponds. These change the saline to brackish pond because of rainfall, but milkfish (*Chanos chanos*) has traditionally been farmed in such a severe environment.

The least modified communities of plants have rarely more than about 15 species. Coconut trees (*Cocos nucifera*) account for about 90 percent of total vegetation (Linton 1933). Where the forest is a little more open, *Pandanus tectorius* is often common and *Morinda citrifolia* is usually present as a subcanopy species. We can observe the more marked, spatial shift of vegetation at margins of islets, especially those of the oceanside. These areas are usually covered with small trees and shrubs.

The drastic changes of Tongarevan society

The people had been dispersed on habitable islets before the European contact, until the mid-19th century AD at least. A historical document states that small households, generally consisting of less than 20 inhabitants, were scattered on these islets (Lamont 1867: 116). The united assemblage of several households formed districts called Huaanga, each of which was controlled by a chief.

The first contact of Tongareva with the European occurred in 1816 AD. Since then, Tongarevan society has suffered some drastic changes. The people instantly converted to Christianity, after the London Missionary Society sent pastors from Rarotonga in 1854 AD (Campbell 1984). They lived in six villages including Mangarongaro, marae in which is discussed later, and each village was constructed around a chapel. In addition, a Peruvian slaver vessel visited Tongareva in 1862 AD and transported a lot of people to plantations in Peru causing the island's population to decline rapidly to just 88 inhabitants (Maude 1986). By 1870 AD, it had recovered to 300, but this number included 111 Gilbertese who were dumped on Tongareva by other Peruvian vessel, and 130 Tongarevan people returning after a period spent working on Tahiti (Campbell 1985). Through this historical process there are currently the only two Villages in the island, Omoka and Te Tautua. All ceremonial structures, thus, have been destructed or buried under the bushes.

Archaeological characteristics of Tongarevan marae

Among architectural features in this atoll, rectangular courtyards called marae are the most impressive ones in number and size (Yamaguchi 1995, 2000). The number reaches 23 sites, and the largest one is about 1600 m^2 in size, and the average size reaches nearly 740 m^2. Tongarevan marae are generally defined as having a rectangular courtyard, uprights and an inner component of either platform type or stone arrangement type.

The general design of courtyards is similar to that of marae recorded from the Society and Tuamotu group, but Tongarevan marae have several unique characteristics which are not discernible in other island groups. One of them is a morphological type of inner component. Eight sites have a platform at an end of courtyards, but more than the half of sites have a set of double stone arrangements existing at the equivalent position to that of platform. The uprights of beach rock slabs stand around peripheries of marae courtyards. Many uprights shaped in various ways such as flanged, knobbed, notched, shouldered, medial curved and perforated shapes. The shaping of uprights suggests the culture historical relation of Tongareva with the Tuamotu Islands (Emory 1934: 6-7), but uprights standing around peripheries of marae courtyard are uncommon in the latter group.

It is evident that most marae lie close to shores, in particular, of the oceanside. Inland areas of larger islets are densely covered with uniform forests of coconut trees reaching 20 m in height, but the oceanside margins of islets are more open and occupied with subcanopy species of less than 5 m in height. Over the more marginal strand areas are predominant shrubs like *Scaevola taccada*, *Pemphis acidula* and *Tournefortia argentea*. Interestingly, all the oceanside marae are located on such open spaces, and it means the spatial separation from dwelling spaces which were in the shade of coconut palm grove on the lagoonside beach ridge. The difference of vegetation certainly enhances the impression on the spatial separation between marae and settlements as well as does the physical

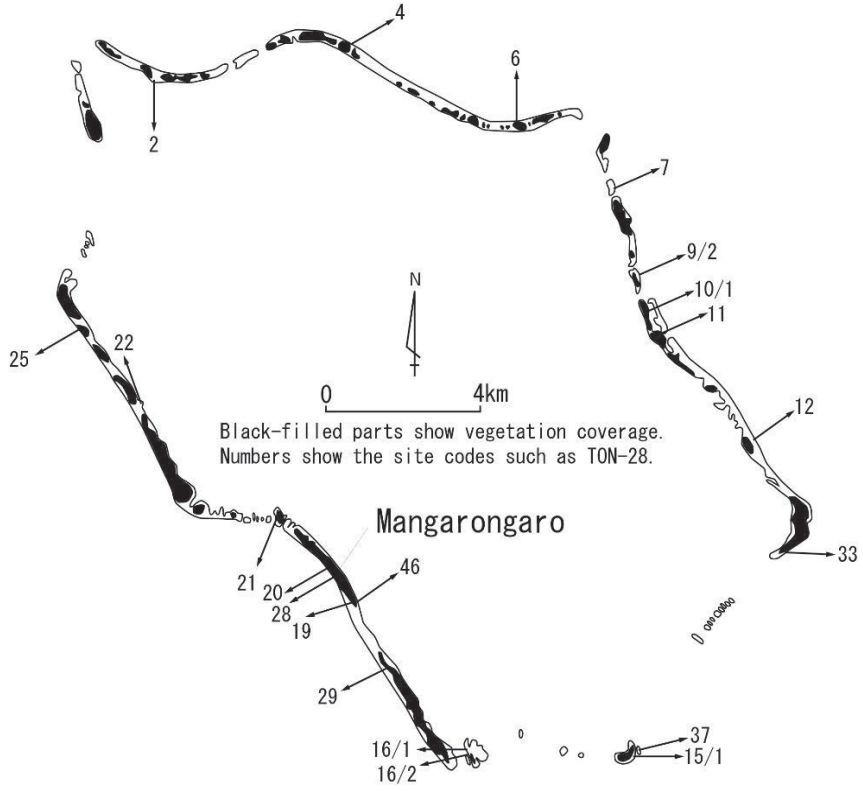

Figure 2. Spatial orientation of Tongarevan marae

distance.

Tongarevan marae exhibit a common characteristic in orientation. Spatial orientation is here defined as the direction of perpendicular axis to the rear of marae which is identifiable from proximity of inner component and existence of taller uprights. Twenty-one sites providing reliable information are oriented toward the ocean (Figure 2.); their perpendicular axis to the rear of courtyard meets at right angle with the adjacent shorelines. In addition, what is more interesting is that even some marae located closer to the shoreline of lagoon — and from which the ocean is not visible — are also oriented toward the ocean. This fact, in addition of prevailing marae location on the ocean side, demonstrates that a common religious meaning which was related to the ocean would be encoded in most Tongarevan marae.

Many ethnographic accounts from East Polynesia delineate that the ocean was recognized as "highest marae" in the ancient Tahitian society (Henry 1928: 143). The souls were believed to reach the world of the dead by passing on, over, or under the ocean, in many islands or island groups such as Tuamotu (Williamson 1933: 82), Marquesas (Williamson 1933: 62-3) and Rarotonga in the southern Cook Islands (Gill 1876: 193). The general relation of gods with the ocean has been reported from many islands in various forms: gods who is the ocean (Tahiti); the home of gods under the sea (Cook Islands and Hawaii); a god living in coral reef (Tahiti); the divinity departing in the boat over the sea (Hawaii); sea gods (throughout Polynesia); and so forth (Kirtley 1971: 3-33). These accounts suggest that the ocean was linked with the Tongarevan concept of sacredness as well.

Encounter of a European trader with islanders

In the early morning of January 7th, 1853, an American sailing vessel, the Chatham, was unknowingly heading for Tongareva Atoll. E.H. Lamont, who had no American citizenship but a substantive owner of the vessel, was a trader who used to work in California and decided to visit the south Pacific islands during the off-peak fall and winter seasons. On the return way to California after his trading around Marquesas, Society and Southern Cook Islands, the vessel was unfortunately stuck on the oceanside reef, and he and his crews forced to stay in the atoll for nearly a year. After rescued by an American whaling vessel, Lamont (1867) published a book 'Wild Life among the Pacific Islanders' based on his diary written during the voyage. It was evaluated as an extremely useful ethnography by a noted anthropologist, Peter Buck (Te Rangi Hiroa), the director of Bishop Museum in the first half of the 20th century, who also surveyed the Tongareva Atoll in 1929 (Buck 1932).

The Chatham was shipwrecked on the coral reef stretching along the southwestern islet, Mangarongaro. The coral reef around here is only about 100m in width at most including the reef edge. Some male inhabitants, noticing the vessel, soon appeared on the beach, shouting menacingly with their frightening looks, and approaching with spears and clubs in hand (Lamont 1867: 106-108). They surged and climbed onto the edge of the vessel and stood on the deck. All of them were excited to see strange things for them, but soon found coconuts in the hold and rush them out. When a person who seemed to be the chief gave a command, everyone stopped their hands and began a fantastic dance to

the song. As soon as it was over, they resumed looting.

From this series of events, Lamont had a strong impression of "savage" on the inhabitants, but they may have not seen Lamont and his crews as pitiable prey. As Sahlins (1993) argued about Captain Cook in 'Islands of History', it is possible that the people objectified as a sort of gods the Westerners who suddenly appeared on a huge sailing vessel from the far reaches of the ocean. Polynesian gods, represented by a visiting god Lono in Hawaii, are elder brothers to humans. while these gods were viewed awful because of their strong mana, the people thought them to bring the fertility, which humans could ritually take away. It is unknown whether the Tongareva people considered the westerners to be gods, but it is certain that they tried to understand Lamont and his crews through their indigenous logics and knowledge. Virtually, the next day, the people ritually adopted the three representatives, including Lamont, through a ritual ceremony held at a marae in Mangarongaro.

Lamont's experience of marae

Lamont was taken to the northern part of Mangarogaro by a group (Lamont 1867: 116-119). There were a cooking shed and three huts, in one of which he stayed overnight (Probably TON-26). The next morning, the people, with spears and clubs in hand, marched toward a larger settlement (probably TON-28), protecting the front and rear of Lamont. Along the way, the inhabitants emerged from small huts scattered in the shade of grove and joined the Lamont's group. When the people of Mangarongaro and the crews of the Chatham were all assembled there, they set out again towards the ocean. After about 15 minutes, the party came to a wasteland of coral gravel and boulder. It was overgrown with pandanus trees, darker than other places, but some upright stones of marae (TON-28 marae) were seen beyond the bush. The Lamont's description finally continues with the ritual ceremony at this marae (ibid.: 120-121).

As the marae were approached, the women and children, who had not been allowed into its courtyard, stopped with looks of fear, while the rest of the men continued onward. All the people had a serious look on their faces. Some even turned pale with fear. Four young men with spears rushed towards the edge of the courtyard, and they faced each other, screaming something like incantations as if to drive away the evil being. Then, all the remaining men rushed into the courtyard. Two priests walked further into its backward with the four young men, splitting on either side, each seated near a tall upright. After the preparations were complete, all the men stepped forward in front of the platform lying at the rear of the courtyard, and the scene advanced to the climax of the ritual:

> 0 Packa, as this chief and high priest was called, on receiving one of the cocoa-nut gods, ascended the altar, and, seating himself in front of a large stone, while he held his god in both hands, began to glance wildly round in every direction, his eyes wandering over the crowd of bowed figures before him. A trembling motion, commencing in his hands, extended through his whole body till every limb shook in the most violent manner, the muscles working and the veins swelling almost to bursting – a sign, as these ignorant creatures believed, that he was

possessed by a spirit. After uttering a few incoherent sentences, which subsided to a low prayer, he lifted his leafy god and struck him violently against the stone before him, repeating the same process with all three. The idols, having thus done their part in the ceremony, were unceremoniously thrown aside amongst a heap of rubbish. (Lamont 1867: 122)

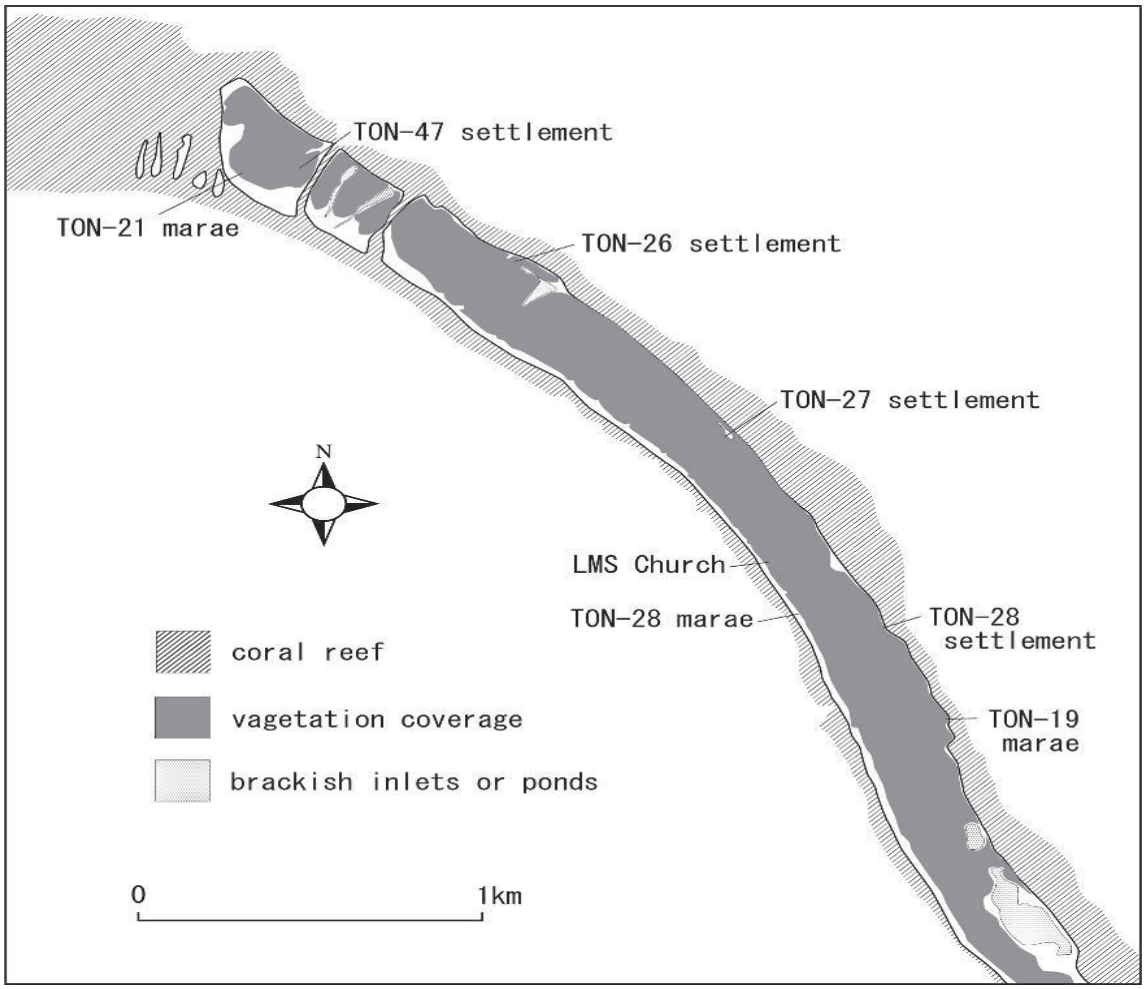

Figure 3. Map of Mangarongaro

After the ritual was over, Lamont and other two men were sitting by the courtyard. The three coconuts, which had been placed on the platform, were also taken out of the courtyard. The husked coconuts were brought there and given to Lamont and two men to eat. As Lamont later learned, they now formally adopted through this ritual ceremony as the sons of either leading person respectively.

Conclusive remarks

The above-mentioned ritual ceremony was held at the marae, which was situated roughly in the center of Mangarongaro, the southwestern islet extending in a gentle arc (Figure 3.). The islet is about 3.2km in length and less than 300m in width. The marae would have been the archaeological structure lying on the oceanside of TON-28 settlement which was firstly reported by Bellwood (1978: 185).

The inhabitants of small settlements, which were dispersed in the islet, joined together with Lamont and his group as they passed by, and finally all gathered in the central settlement. Since Mangarongaro is a long and narrow islet, it can be easily guessed that the walking distance to the meeting point varied depending on where they lived. From there the whole party marched through the coconut groves toward the oceanside. It is only about 200m distant from the central settlement to marae in a straight line, but if it took 15 minutes as Lamont described, they might have taken a detour route to the side of the courtyard. In any case, it is the spatial separation of marae from the settlement does not mean a dichotomy between sacredness and secularity. Rather, the people should be viewed as having bodily experienced a gradual transition from the latter to the former by walking.

The people would have had different experiences of the courtyard respectively as well. The women and children stayed at the outside, while the men proceeded into the inside. Two priests and four young men further stepped forward to the tall uprights standing close to the platform to perform some preliminary rituals. Only the highest chief of Mangarongaro stepped onto the platform at the far end of the courtyard. It is closest to the storm ridge, and its slope makes the platform appear higher in the courtyard. The position of Lamont and other two men is less clear, but they would have been situated between the two priests and in front of the platform. Thus, it can be thought that the distance to the platform, which was the stage for the ritual climax, varied from person to person (Figure 4.). In other words, the ritual ceremony would have been an opportunity for each inhabitant to recognize his own social position by bodily experiencing the relative distance to the platform, which was the focal point attracting attention of everyone. Lamont and his fellows must have also been involved in this web of social relationships according to their positions.

The awe-inspiring expressions of the people could be better understood in terms of the common Polynesian concept of mana, rather than the demons and spirits that Lamont envisioned. Mana is like energy or "procreative power, derived from an ultimate source and diffused, transmitted, and manifested throughout the universe" (Handy 1927: 27). It comes "into individuals or objects only through the medium of gods or spirits" (ibid.: 26). However, a careless contact of a lower person with a higher chief would be dangerous. The superior is drained of his energy, and the inferior suffers "injurious effects as a result of the overload or surcharge" (ibid.: 28). Thus, chiefs and priests must attenuate the mana transmitted by the gods, probably appearing at marae from the ocean, through proper rituals so that their people can enjoy the benefits. Based on this concept of mana, the relative distance to the platform, which is above-mentioned as the index of social relationship, could be also interpreted as the relative strength of mana possessed by each one who attended the ritual ceremony.

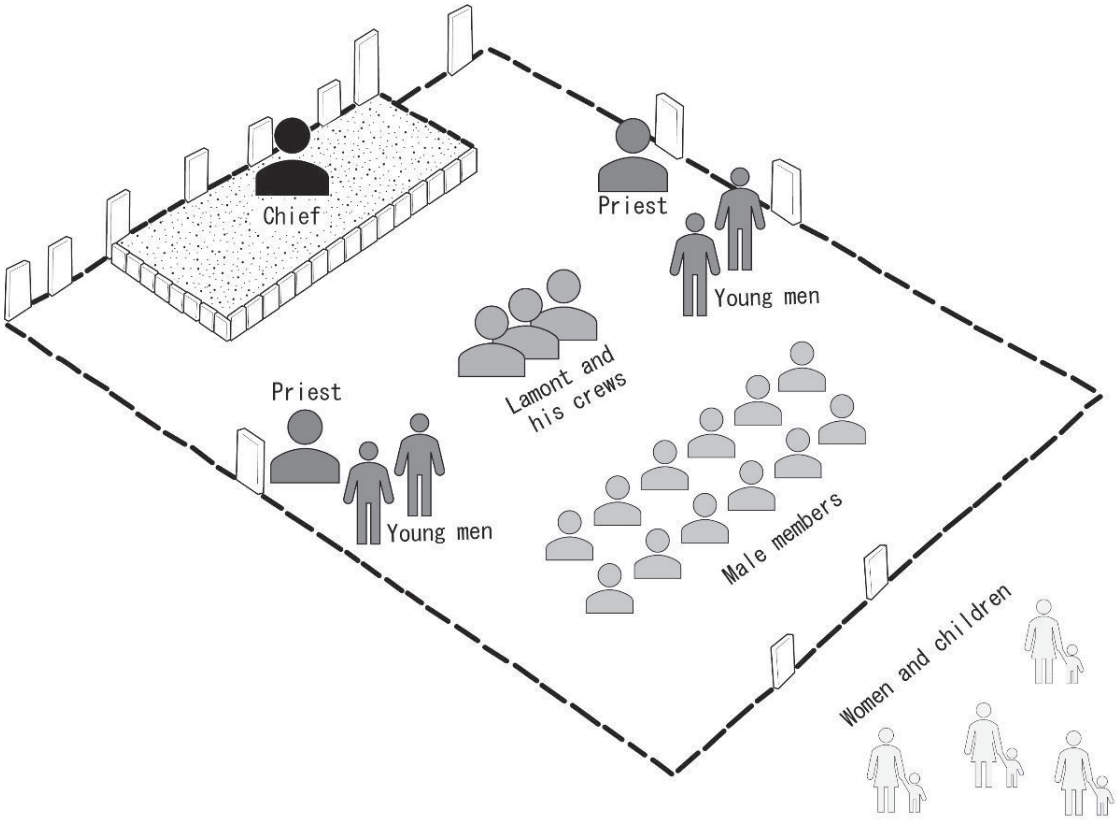

Figure 4. Schematic drawing of marae rituals

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Ceremonial landscape in Island Melanesia: The *gamal* complex of the Banks Islands, Northern Vanuatu

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Introduction: Monuments in Melanesia

Ceremonial constructions such as *marae* in Central Polynesia and *heiau* in Hawaii have been an integral part of archaeological research. Notably, such constructions were treated as an important component to explain the emergence, development and transformation of prehistoric Polynesian chiefdoms (Graves and Sweeny 1993, Earle 1991, Kirch 1990, Kolb 2006, Goto 1989, 1994, and more). In contrast, the development of monumental constructions as well as related archaeological studies are limited in Melanesia. The classic monograph by Riesenfeld (1950) compiles a wide range of 'megalithic culture' in Melanesia, including monoliths, dolmens, stone walls, and alignments. However, such structures did not become the focus of research. This could be partly because they were considered rather trivial in terms of the scale of their constructions, but also because Melanesian archaeology has for many decades a strong emphasis on the research on human dispersal and early settlements associated with the Lapita cultural complex. Another factor would be the lesser development of chiefdoms or sociopolitical integrations in Melanesia, as traditional Melanesian societies were characterized by competitive big man societies that were principally tribal and egalitarian (Sahlins 1963). This might have contributed to the exclusion of Melanesia from the investigation of prehistoric sociopolitical evolution and transformation, in which monumental constructions were treated as important material evidence.

However, there has been a development of research projects dealing with monuments in Melanesia since the early 2000s: such as the study of stone monuments on Uneapa Island, West New Britain (Byrne 2005); Woodlark Island in Milne Bay (Bickler 2006, Bickler and Ivuyo 2002), and the project investigating the Roviana chiefdom in New Georgia, Solomon Islands (Thomas et al 2001, Walter and Sheppard 2001). In Vanuatu, Vanuatu Cultural Centre and a few researchers have recorded late prehistoric and proto-historic sites as part of the sites survey and archaeological programmes (Bedford 2019, Nojima 2015a.b, VCHSS 2004). In this paper, the author describes the cases of monumental constructions in the Banks Islands, northern Vanuatu. The Banks Island structures, along with those on Malakula, display the most prominent formations of monumental landscapes in Vanuatu.

Banks Islands in the Context of Northern Vanuatu Cultural Diversity

Vanuatu, located in central Melanesia, is composed of more than 80 islands of volcanic origin. The Banks Islands along with the Torres Islands constitute the northernmost province of Torba, and they are the most remote and isolated areas in Vanuatu (Figure 1).

Vanuatu has a population of approximately 300,000 according to the census in 2020. Despite its small population, Vanuatu is linguistically diverse and more than 130 indigenous languages are distinguished (François et al 2015). Such linguistic diversity is more pronounced in northern Vanuatu, and larger islands such as Malakula and Santo have dozens of indigenous languages. Even for the Banks Islands, which is just a small group of islands with a total population of 10,000, 15 languages are identified, including a few nearly extinct languages. Neighbouring languages are mutually intelligible, and the chain s of languages eventually link the entire islands in the north (Tryon 1996). This indicates that in northern Vanuatu autonomous local groups were in communication with each other by differentiating the others, which explains considerable cultural diversity (Bonnemaison 1996).

Such interactions and communication spheres are exemplified the extensive inter-island exchange networks ethnographically reconstructed in northern Vanuatu (Huffman 1996). Various goods and resources were once exchanged through this network, including pottery, mats, dyes, pigs, root crops (taro, yams), and shell money among others. The Banks Islands were somewhat isolated from this extensive web of exchange, but the shell money produced on small low-lying islands and islets in the Banks (such as Reef Island, Ravenga, and Motalava) was distributed to the other islands. Furthermore, it is likely that the people in the Banks and Torres Islands had interactions with Polynesian outliers' communities in the southeast Solomons such as Anuta and Tikopia. In fact, these islands are part of the world recognized by traditional Banks Islanders (Vienne 1984), and the prehistoric interaction between the Banks Islands and Tikopia has been confirmed through the distribution of obsidians of the Banks Island origin (Kirch and Yen 1982; Spriggs et al 2010).

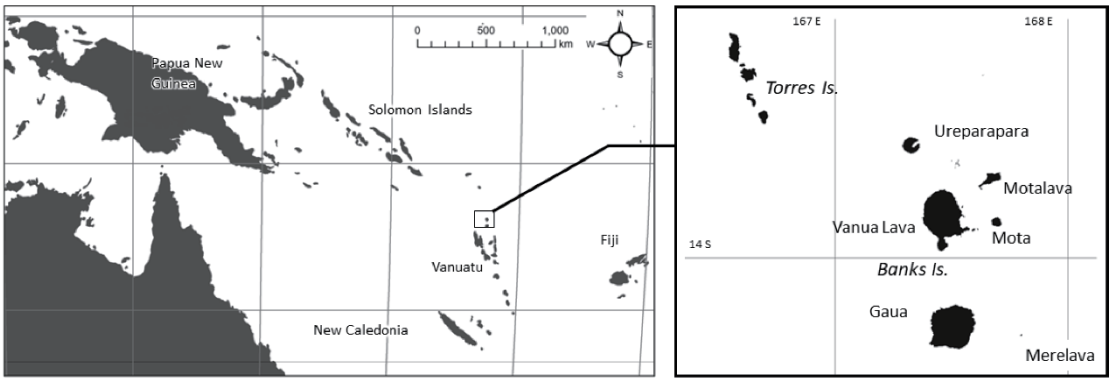

Figure 1. Southwest Pacific and the location of Banks Islands

Table 1 *Suqe* titles recorded in the Banks Islands

Island	Mota		Motalava	Vanua Lava		Ureparapara	Notes
Source	Codrington 1891	Vienne 1971	Vienne 1970	Rivers 1914	Fieldnote 2011	Fieldnote 2023	
# of ranks	18	16	17	10	12	6	
	rurwon				*(serewuriam)*		
Titles	*avrig*	*avrig*	*nepjig*		*evsursur/ evlav*		Small fire / large fire
	qat tagiav	*qatagiav*	*naqaterep*				Entering *gamal*
	avtagataga	*avtagataga*	*neptagtag*	*avtagataga*			Starting feasts
low	*luwuaiav*	*luwaiav*	*nulurep*	*luav*			Entering *salagoro*
	tamasuria	*tamasiria*	*natâusijeg*	*tamatsiria*			
	tavasuqe	*tavatsuqe*	*natwusuq*	*tavatsukwe*		*tovasoq*	Rituals involving entire island
	tavasuqelava	*tavatsuqelava*	*natwusuqlap*	*tavatsukwelava*			
	kerepue	*kerepue*	*nakiebo*	*kerepue*	*kerebō*		'bottom of bamboo'
					*tetuw**	*tetu**	
	mwele	*nemwel*	*nemwel*	*mwel*	*mwel*	*mwel*	'Cycad'; chiefly status and taboos
	tetug	*netetug*	*netetug*		*(*)*	*(*)*	
	lano	*nalan*	*nalan*	*lano*	*lan*	*lan*	
	qoroqorolava	*qorqorlav*	*qorqorlav*	*kworokworolava*	*qōrqōrlav*	*qoiqoilap*	large jokes; large ears; increased taboos
	wometeloa	*womtelo*	*womtelo*	*wometeloa*	*wemetelo*	*womteloa*	eyes of the sun; tusks; stone structures
high	*welgan*						
	wesukut	*wesukut*	*wesukut*		*(*)*		
	wetaur o meligo	*liwantamat*	*liwantamat*		*liwentimiat*		Power equals to spirits
	tiqanwono	*tiqanwono*	*tiqanwono*		*tewrumalag*		
		jonjontej	*jonjontej*		*wesekut**		
					wōtōk		

Table 1. *Suqe* titles recorded in the Banks Islands

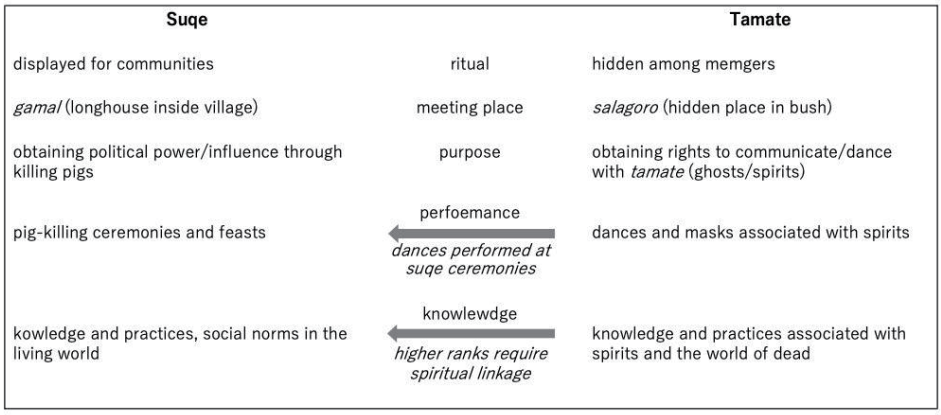

Figure 2. Relationship between *suqe* and *tamate*

Ethnographically, island communities in northern Vanuatu were not socio-politically integrated into chiefdoms. Yet, ethnographers and anthropologists highlighted the existence of distinctive systems of leadership based on grades. Unlike chiefly titles that are inherited hereditary, hierarchically ordered titles in the systems of grade-taking could be acquired one by one with personal abilities, each time by killing certain number of pigs. A greater number of pigs and wealth are required to achieve higher status. Such systems were once practiced throughout northern Vanuatu. While specific details

of the systems are somewhat different by islands, they are roughly divided into two larger groups depending on how the system is called: namely, *maki, mangi* or *nimanggi* in north-central islands, and *suqe* in the areas further north (Jolly 1991).

Interestingly, the most prominent development of monumental constructions in Vanuatu is known in the north in association with the system of grade-taking, not in the area integrated by chiefdoms. The hierarchical order according to the ranks in the systems of grade-taking was represented in the men's meeting house called *gamal* (or *nakamal* in Bislama), which served as a place for individuals who entered the system to be educated. This is one of the major structures that constitute the ceremonial landscape associated with this system. This paper introduces the cases of ceremonial stone structures and the landscape developed in the Banks Islands, which was coined by Rivers (1914) as 'the *gamal* complex'.

The system of grade-taking in the Banks Islands

The system of grade-taking in the Banks Islands is called *suqe* and characterized by a significant number of titles that are hierarchically ordered (Table 1). The number of ranks and titles are exceptionally rich in the Banks Islands, and major titles and their orders are shared throughout the Banks Islands. This suggests that, even though entering the *suqe* and achieving higher titles were personal endeavors, the basic framework of the system was shared throughout the Banks Islands.
Chiefly status begins from the title of *mwel* ('cycad' symbolizing chief), *lan*, *qoroqorolav*, and finally *wometeloa*, meaning 'the eye of the sun.' Pigs play a crucial role in *suqe*, as in the equivalent systems found on other islands in northern Vanuatu, in which pigs (tuskers) are ceremonially killed as sacrifice. In Codrington (1891: 55), such chiefs are called *tavusmele*/*etvusmel*, meaning 'the man who kills (pigs) for *mele*' (François 2013). In the Banks Islands, shell money (*som*) also becomes as important as pigs. For a man to be successful in *suqe* in the Banks Islands, he has to be rich with many pigs and shell money.

In the Banks Islands, *suqe* has been argued in relation to another institution known as *tamate*, or secret societies (Vienne 1996). As its name indicates, *tamate* is related to the dead, ghosts, and spirits. Typical dance performances in the Banks Islands are accompanied by distinctive masks and headdresses, which are the outcomes of *tamate* societies rather than *suqe*. These two institutions are in contrast with each other (Figure 2). *Suqe* defines the social norms and orders in the living world, whereas *tamate* is about the world of the dead. Both institutions are restricted to men and the members only; therefore, it is taboo for women and non-members of the society to enter the group's place of gathering, which is *gamal* (men's meeting house) for *suqe*, and *salagoro* for *tamate*. The *gamal* was one of the basic village components and probably the most prominent architecture when the *suqe* was in practice, having a raised stone platform and many decorative elements to display the status. Even though specific activities inside a *suqe* society are hidden inside the *gamal* and among its members, achieved ranks and titles have to be announced to the public through feasts and various insignias to exercise political influence over the community. In this sense, *suqe* is open to the public.

For advancing in *suqe*, a man needs to have an economic ability to accumulate pigs and shell money, as they are necessary for acquiring each rank. A greater number of pigs and shell money are required as he attains higher ranks. Interestingly, the name and meaning of highest titles such as *wometeloa* and *liwantamat* (see Table 1) imply that they are related to some sort of supernatural powers. Such spiritual aspects associated with higher ranks must have been obtained through participating in *tamate* societies. Although *suqe* and *tamate* are different institutions with different objectives, there are some links between them.

Highly elaborated stone structures to be described in this paper are the remnants of this system recorded in the early Banks Islands ethnographies (Codrington 1881, 1891, Rivers 1914, Speiser 1996 (1923)).

Components of ceremonial space in the Banks Islands

Stone structures in the Banks Islands are one of the most prominent constructions developed in the late prehistoric and proto-historic periods in Vanuatu, along with massive stone features known in Malakula (Layard 1942; Riesenfeld 1950). These constructions were developed in association with the systems of grade-taking. The existence of sophisticated stone structures in the Banks Islands has been known, and brief surveys were carried out by Vanuatu Cultural Centre in the early 2000s (VCHSS 2004), which led the government of Vanuatu to submit 'The Nowon and Votwos of Ureparapara' to the tentative list of UNESCO World Heritage in 2005. However, specific details of structures have been only partially recorded by simply referring to visible structures, and the spatial distribution of structures and the nature of ceremonial landscape associated with *suqe* remain largely unknown.

Figure 3. Rectangular mound with finely piled façade and ladders (Tentur, Southwest Vanua Lava)

Figure 4. Structure at Yepyou known as ’12 steps’ (Ureparapara)

Against this background, detailed recordings involving the mapping of structures have been conducted by the author in cooperation with Vanuatu Cultural Centre to better understand the characteristics of ceremonial landscape in the Banks Islands. Major information was collected during2010–2013 on the islands of Vanua Lava and Motalava (Nojima 2015a.b). Subsequently, another survey focusing on Ureparapara was conducted in 2019–2023[1]. During the survey by the author, the team tried to identify the layout of the entire ceremonial complex. As the mapping of selected sites were carried out on the islands of Vanua Lava and Motalava, it became clear that all sites have shared basic components.

1) Terraces/mounds with brickwork façade and ladders

The most typical ceremonial structures in the Banks Islands are rectangular mounds and terraces, whose frontal side are finely piled with basalt slabs like a sort of brickwork and furnished with steps or ladders of prolonged slabs that were implanted into the finely piled façade (Figure 3). Such structures are called *vetkolkol* (Vanua Lava), *vetwos*, *wona* (Ureparapara), or *nowonwon* (Motalava);

[1] The author’s research in the Banks Islands was funded by the Grant-in-Aid for Scientific Research (C) 23520939 ‘Archaeological investigation of ceremonial stone structures and late prehistoric societies in in northern Vanuatu’ (2011–2013), and the Grant-in-Aid for Scientific Research on Innovative Areas 19H05732 ‘Creation of Artificial Landscape and Development of Spatiotemporal Cognition’ (2019–2023).

however, the proper term to describe the structure itself remains ambiguous as the word *won* or *wonwon* means 'to pile up stones.' For instance, *wona* on Ureparapara means the façade of any house foundation piled with basalt slabs, rather than referring to the entire structure. However, it is this masonry of finely piling up basalt slabs and the attachment of 'ladder' structures that make ceremonial constructions in the Banks islands highly distinctive. While some structures were constructed as rectangular mounds on relatively flat ground surface, prominent features were constructed as terraces utilizing natural slopes of hilly terrain as typically seen on mountainous islands of Vanua Lava and Ureparapara. The most spectacular feature is probably the stepped terraces at Yepyou in northwest Ureparapara, known with the nickname of '12 steps' (Figure 4). According to the explanation of the locals, the height of the structure and especially the number of 'ladders' correspond to the number of ranks achieved in *suqe*.

2) *Gamal* foundations

For most cases, the foundation of *gamal* is constructed adjacent to the high stone structures with ladders or other prominent mound structures. *Gamal* is the meeting house for the *suqe* members and characterized by a very long foundation of the house (generally, 5–6m wide and 15–40m long) that are divided into small compartments corresponding to the number of ranks. Compartment boundaries are marked by aligning stones or placing logs, and each division is equipped with its own fire pit and cooking stones. Divisions for higher ranks are on the frontside of the longhouse and neatly constructed with basalt slabs, whereas divisions for lower graders are on the backside and rather coarsely lined with cobbles and boulders. The frontside of the *gamal* is almost always facing the dance ground, which is the community space. For this reason, the frontal foundation of the *gamal* is often raised and finely finished with *wona* brickwoks, to display the host's abilities and ranks achieved.

3) Dance grounds, other structures and associated objects

In front of these highly notable stone structures is a flat and empty space, or a dance ground, where various public activities took place when the site had been inhabited in the past. Surrounding the dance ground, some additional structures such as house foundations, platforms, and upright stones are arranged to form a sort of small village. Occasionally, there are a series of low platforms paved with basalt slabs; however, all other structures are low in their height and house foundations could be identified as an alignment of cobbles and boulders. Such structures are mostly hidden within dense vegetation, which has made them extremely difficult to locate.

In addition to various stone structures as described above, there are some other features related to the activities at the site. Items related to a high, chiefly status such as conch shell trumpets (bubu) and circled pig tusks are commonly found on top of raised stone structures. Some sites also contain Western materials such as ceramic plates, metals (especially adzes and muskets) and glass objects.

Figure 5. Objects found at ceremonial sites A: stones placed on Tridacna shell (Qetneg, Motalava); B: ‘Tapie’ stone (Yepyou, Ureparapara); C: round stone placed inside a boxhole (Beoyi, Ureparapara)

Occasionally, some objects associated with food magic are found (Figure 5). One of the prominent examples is found at Qetneg in east Motalava, where varieties of stones resembling food crops were filled inside a clamshell. At Yepyou on Ureparapara, a round stone placed on top of a large stone table (known as 'Tapie') was said to have been used for praying for the food, while there was also an opinion among contemporary villagers that the set of stones were used for changing weather. On Ureparapara, round stones were found being rested inside a small boxhole or niche created amid the brickwork façade of raised mound/terrace structures, suggesting that such stones had magical features that could have been only enacted through specific individuals who obtained certain ranks in *suqe*. Such boxholes are so far found on the structures on Ureparapara only, and some are said to have housed a human skull in the past.

Finally, it should be noted that there once were all sorts of upper house structures, decorative objects, and musical instruments such as slit drums that were all made of wood or other plant materials. In the Banks Islands, wood carvings and paintings involving elaborated anthropomorphic expressions are known ethnographically (see photographs on Speiser 1996 (1923)), and such features once decorated the upper structure of the *gamal* as posts and as part of walls.

Conceptualizing the ceremonial space associated with *suqe*

Ceremonial spaces that accompany mounds and terraces with brickwork façade of basalt slabs and structures with ladders are typically located inland, near agricultural lands. This trend is obvious on hilly islands such as Vanua Lava and Ureparapara, and the site such as Tentur in southwest Vanua Lava has abandoned taro irrigation terraces and canals in the vicinity. In the case of Motalava, such sites are only found in the east, where gardens for the entire population of the island are located. Given that pre-Christian settlements were dispersed inland, and people used to live in much smaller groups in the area closer to the source of livelihood, it is understandable that major ceremonial complexes were built around the agricultural land.

Sites with *gamal* remnants do exist on coastal areas; however, unlike inland sites, they do not have any mound/terrace structures using basalt slabs and those with ladders. Instead, structures such as the alignment of large and flat upright stones are more commonly found on coastal areas. Further survey focusing on coastal sites is necessary to provide any concrete explanation, but it might be possible to relate the formation of these sites with the groups who were the major producer of shell money that was indispensable for *suqe* ceremonies in the Banks Islands.

Interestingly, all sites display similar spatial layouts, even though the number and the variety of structures are somewhat different from each other (Figure 6). As already noted, core features of ceremonial spaces are 1) mound and terraces with brickwork façade and ladders displaying the status, 2) the *gamal*, and 3) the dance ground. In most cases, ceremonial spaces are separated into two sides: the *suqe* side and the side for all the others or the public.

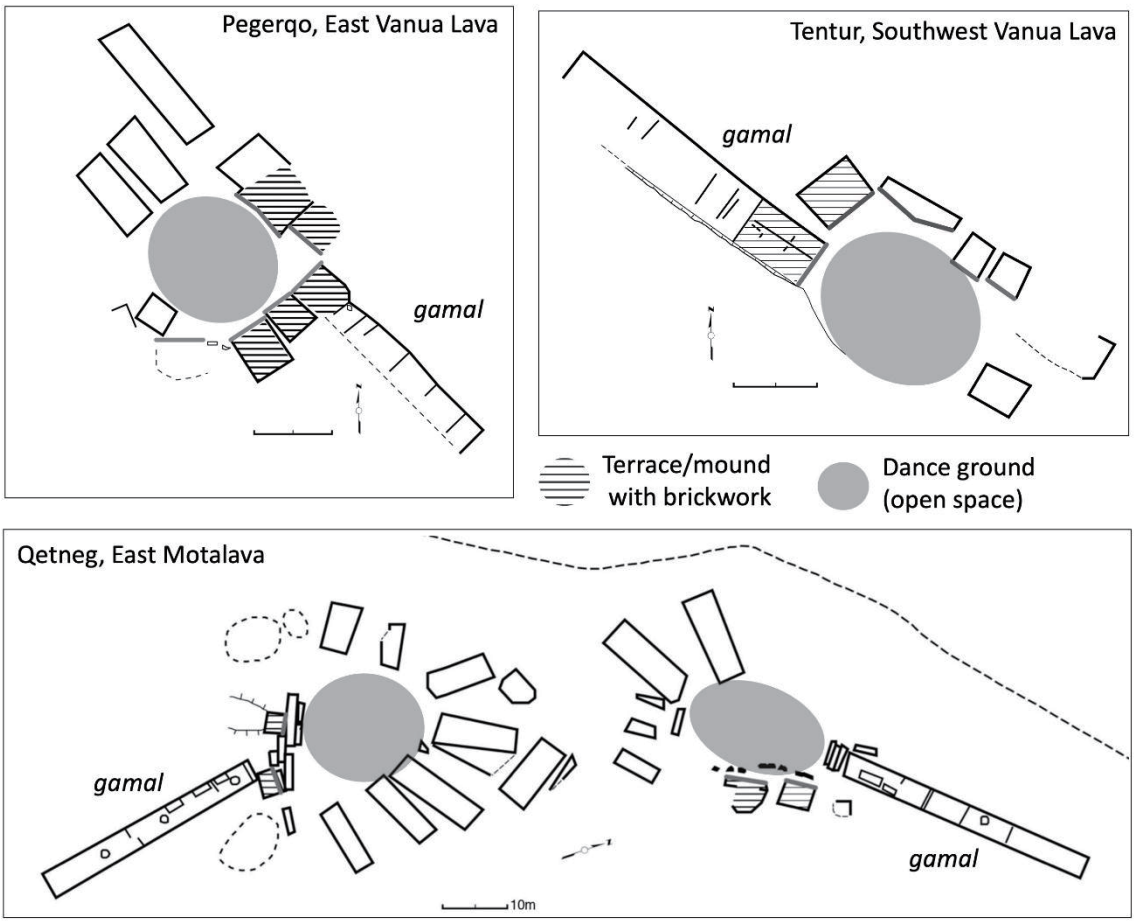

Figure 6. Spatial patterns of *gamal* complex

Generally, structures associated with *suqe* ranks, such as the mound/terrace with ladders and the *gamal*, are concentrated on one side of the dance ground at the centre. This side could be made physically higher with the raised foundation and terraces. Natural slopes are often modified to create high terraces, which would have required less labours than building mounds of the same height. For instance, at Tentur on southwest Vanua Lava, its *gamal* was facing downhill and only the frontal half of its foundation was shaped as a terrace.

In contrast, other structures that are located on the other side of the dance ground are all lower and mostly house foundations, either having a low raised foundation or simple stone alignment. These structures were built with pebbles and boulders, and basalt slabs were rarely used. This is in striking contrast with structures associated with grade-taking, where basalt slabs were effectively used for beautifying the structure to display the status achieved in *suqe*. Some sites such as Qetneg on East Motalava and Pegerqo in East Vanua Lava have foundations of relatively large houses on the opposite

side of *gamal*, which could have been a house for the community including women, children, and non-members of the *suqe*.

Ethnohistoric account depicting the grade taking ritual

While it is widely known that in *suqe* or other equivalent systems of grade-taking, individuals obtain high ranks by ceremonially killing pigs. In Banks Islands, shell money also played a significant role, and it is said that all supporters and individuals contributed to the *suqe* ceremony were paid with shell money. However, such knowledge and stories are too abstract and fragmented to understand the rituals associated with grade-taking, and how the ceremonial space furnished with stone structures was utilized. In this respect, an account cited in Rivers (1914) based on the observation by the missionary provides valuable information.

It depicts a ceremony held in the village of Vatrata in southwest Vanua Lava, in which a renowned high chief named Charles Wunau ascended to the highest rank of *wometeloa*. Notable points are summarized as follows:

1) C. Wunau had to renovate his *gamal* in advance, to add a new room corresponding to the new rank of *wometeloa*.
2) As part of the ritual, he had to pay a lot of shell money and pigs to an old man who is already on the rank of *wometeloa*. This old man initiated the ritual.
3) On the first day, C. Wunau, standing at the centre of the dance ground, receives many bundles of shell money as payments for his past support such as providing food, and so on. In the evening, he had to count the accumulated shell money to make 200 fathoms ready for the payment to the old man. Members of C. Wunau's father's clan supported him in making up for a shortage.
4) Singing and dancing continued at the dance ground in the evening, while a stone oven was prepared in the *tavatsuqe* division of the *gamal*.
5) In the next morning, a group of dancers arrived from a neighboring village to dance with bow and arrows, which was followed by the solo performance by C. Wunau holding shell money and pig's jaws.
6) The second day was mostly for ritually presenting shell money and pigs to the old *wometeloa* man. Pigs were supposed to be killed, but they were just given to the old man after the gesture of tapping the back of each pig.
7) Finally, he lit fire on the *wometeloa* oven in his *gamal* to cook his food, and a cycad tree was planted in front of the *gamal* to celebrate his new rank.

The description tells in detail the process of paying shell money and killing pigs that were ritually performed in public. However, the ritual was considerably affected by Christianization, as pigs were not killed in the ceremony. The story also suggests that *gamal* structures were occasionally reformed to add new division as the person's rank in *suqe* progressed; however, it didn't describe how *vetkolkol* or *vetwos* structures were used in the ritual.

Conclusion

Ceremonial structures in the Banks Islands could be seen as visible expressions of ranks in *suqe*, which were principally achieved by individual abilities and capacities. It could have been this competitive nature of the system of grate-taking that made the construction of refined ceremonial structures more significant. However, the author has not been successful in obtaining sufficient data that explains the chronological development of ceremonial structures and spaces in association with the development of the unique system of grade-taking over time.

Suqe is no longer practiced in the Banks Islands. However, *gamals* still exist in contemporary villages for men's or community meetings, and *salagoros* are maintained in secrecy as a place for learning *kastom* dances and other cultural traditions and expressions. Remnants of old *gamal* structures and other ceremonial constructions as reported in this paper are inherited through the clan, and due to the durable and visible nature of structures built with stones, they function even today as landmarks for descendants to claim the land ownership.

For many sites, memories and stories concerning structures have been long lost; however, the spiritual power associated with *suqe* chiefs are still feared and respected as *tabu* (taboo) by many villagers. Such respect for the sites certainly contributed to the preservation of major structures as part of the history of the island. Being located inland, many sites have been severely damaged by the regrowth of vegetation after the sites were abandoned as people moved down to coastal villages to join the missionary. In addition to physical damages to the structures, loss of knowledge and stories associated with these places are the major challenges for protecting them as the island's heritage.

On the small island of Ureparapara, masonries employing basalt slabs are still inherited, and there are some young villagers who have recreated stone-paved platforms with ladders, mimicking old ceremonial structures. They are not for taking grades in *suqe*, but exemplifies how they value such structures and masonries as their heritage. It is hoped that the work by the author and Vanuatu Cultural Centre would contribute to promoting the significance of these sites as heritage.

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