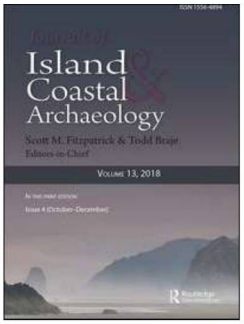

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REPORT

New information from an old discovery: Geological analysis of a stone adze found on Pohnpei, Micronesia

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ABSTRACT

Geological analysis was conducted on a stone adze, which was accidentally dug up from an intertidal dredging site on a reef flat in Pohnpei Island, Micronesia in the 1980s. Detailed geological observations identified the material as metamorphic rock (schist), not basalt as originally reported. This result places its source in the continental rocks of Island Melanesia, most probably New Guinea. The location where it was recovered suggests an age that may well go back to when the island was first settled in the early centuries AD. The eastern Micronesian homeland is often thought to be eastern Melanesia based on linguistic and archaeological evidence. The adze, which may have functioned as a prestige good, was possibly brought from their homeland by early settlers or their immediate successors, or imported from New Guinea by them, suggesting that they still had interaction with the Lapita homeland region even after the decline of Lapita long-distance communications. This is the first artifact found at an early settlement site in Micronesia that is documented to be imported from Melanesia and sheds light on a possible early eastern Micronesian settlers' interaction system.

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KEYWORDS
Stone adze; provenance studies; colonization; Pohnpei; Pacific

Introduction

Recently, our archaeological ability to source artifacts has significantly improved through the adoption of new scientific analytical methods. This progress enables archaeologists to trace prehistoric movement of objects and materials, providing information about social interactions and contacts (e.g., Best et al. 1992; Kirch and Weisler 1994, 297–301; Weisler 1993, 1997). In spite of the extensive exchange networks historically documented in Micronesia, which is the focus of this paper, archaeological studies of prehistoric interactions in the region are less developed compared with relatively well-studied Melanesia and Polynesia due to the absence or limited number of portable artifacts that can be traced to source (e.g., stone adzes, pottery, volcanic glass), especially in eastern Micronesia (Ayres, Goles, and Beardsley 1997, 53; Kirch and Weisler 1994, 298–299).

In this article, we present geological observations on a rare stone adze that was discovered at an underwater dredging site at Mesihsou on Pohnpei Island in eastern Micronesia (Athens 1981) (Figure 1(A)). This find is important because: (1) cutting implements were

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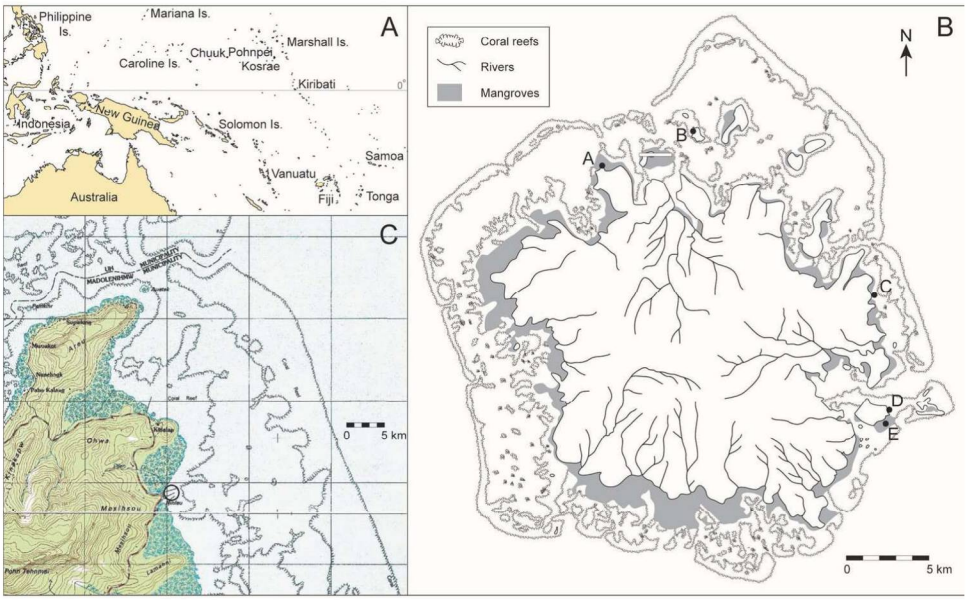

Figure 1. (A) Western Pacific; (B) Pohnpei Island and early settlement sites: A, Ipwal; B, Lenger; C, Mesihsou; D, Imwinsapw; E, Nan Madol (after Miyagi and Fujimoto 1989, 40, Figure 4); (C) the find spot of the stone adze at Mesihsou in Madolenihmw, Pohnpei Island (in circle) (after U.S. Geological Survey 1983).

predominantly made from shell in prehistoric eastern Micronesia; and (2) the find spot in an intertidal zone suggests an antiquity coeval with the earliest known settlement of the island. Numerous shell adzes are found in Micronesian archaeological sites; however, only 13 stone adzes have been recovered in Pohnpei to date (Ayres and Mauricio 1987; Stephen Athens, 2018b). As Ayres and Mauricio (1987) note, some of these adzes found in Pohnpei exhibit Melanesian and West Polynesian forms, suggesting they have been transported from areas outside of Micronesia. In addition, among those 13 adzes, most were found at the Nan Madol site (10) and a stone tomb (one) in a post-second millennium AD context, while the Mesihsou adze under examination here and the Salong adze (see below) are probably of the early settlement phase (ca. 1800–2000 years ago) due to their find spots in intertidal zones. Here, after reporting the results of geological analysis on this significant adze, we will discuss the implications it has for the early history of Eastern Micronesia. As shown by other provenance studies (e.g., Collerson and Weisler 2007), this study will also demonstrate that artifacts recovered from non-archaeological contests can provide important insights into human movement.

The Mesihsou stone adze

Discovery

The stone adze in question was found in dredged reef sand that was brought from Mesihsou, Madolenihmw Municipality, in the western part of the island in 1977 (Figure 1(B)). The dredging took place on an underwater reef flat beside a coastal promontory on Mesihsou, which is an extension from a ridge originating at Pohn Tehnmei

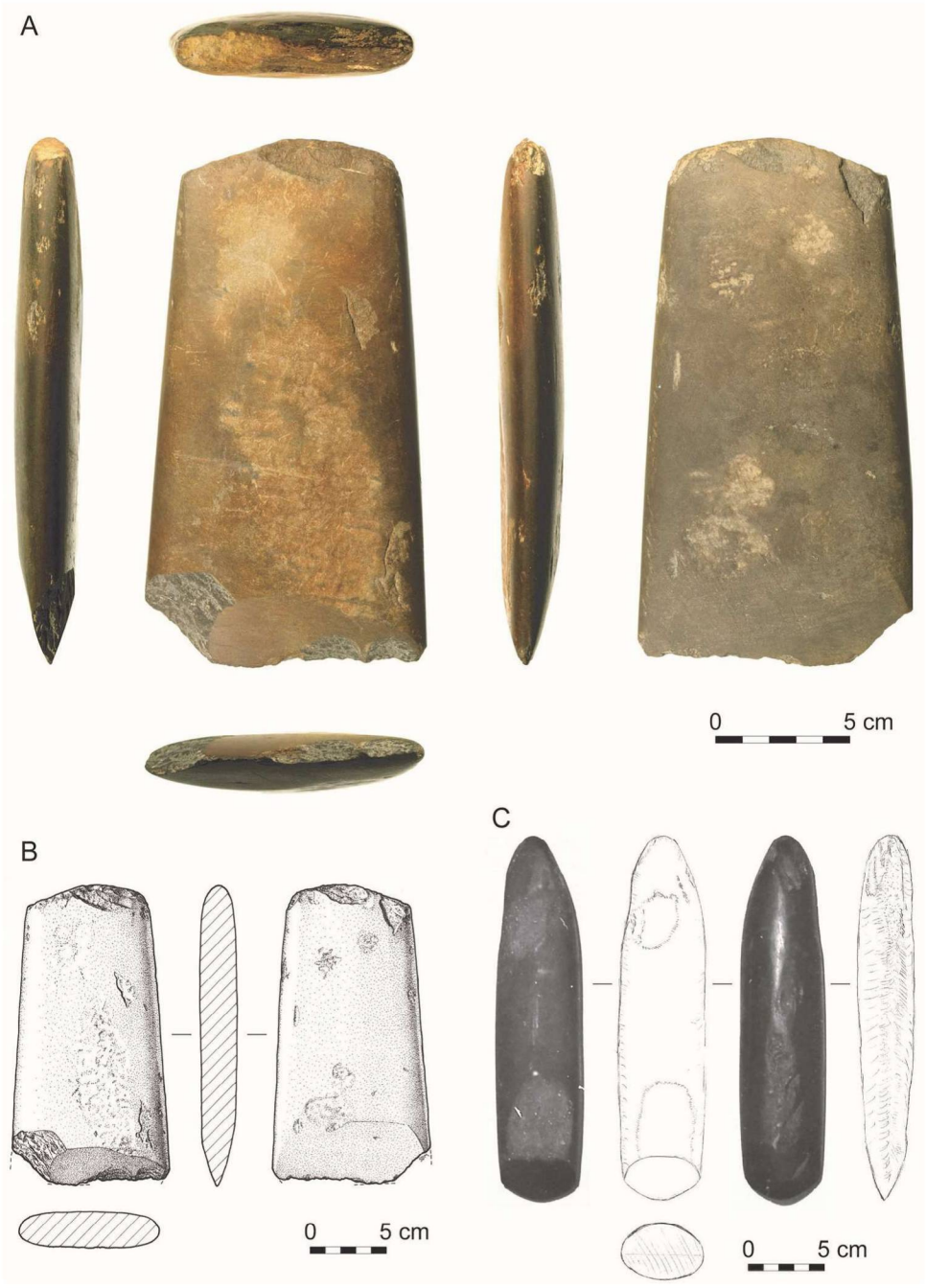

Figure 2. (A) and (B) The stone adze from Mesihsou; (C) the stone adze from Salong (based on Stephen Athens' photographs and drawing).

Mountain (Figure 1(C)). Shell artifacts were observed at the dredging site, suggesting the presence of archaeological deposits in the intertidal zone. The adze was brought to Stephen Athens' attention during his fieldwork in Pohnpei in 1979–1980 (Athens 1981). Athens (1981, 44) assumed that the adze's dark gray, fine-grained stone was basalt and

that it must be quite old due to its recovery in a shallow lagoon as a result of dredging. More recently, this adze, which had been kept at the Pohnpei State Historic Preservation Office, came to the senior author's attention and was loaned to him for detailed geological analysis at the University of Auckland in 2006.

Description

The stone adze (Figure 2(A, B)) is comparatively large and trapezoidal in plan view. One distinctive characteristic is its thinness in comparison with its overall size. Its maximum length is 193 mm, its maximum width 103 mm, and its maximum thickness 27 mm. The cross-section is almost a rectilinear, flattened oval with rounded edges. The cutting edge shows recent damage; however, it was probably straight with slightly rounded edges. It has a clearly flat bevel while the other side is rounder. Thus, as Athens (1981, 44) discusses, it was probably used as an adze. The bevel angle is approximately 40°. The poll section is slightly rounded with the right half of the front view squared-off in cross-section and the left half battered on both the front and back sides.

The surface of the adze is fully ground and well-polished to a glassy finish. However, small areas in slight depressions on both sides and at the poll have pocked surfaces, which suggest the pecking technique was probably used for the final shaping stage after the rough shaping by flaking. The long sides are extremely straight, which indicates the sides were ground vertically on a flat grinder.

Coral adheres to the poll (Figure 2(A)), as it was from the intertidal zone. Coral also adheres to a small "chipped" area on the front side of the poll, which Athens (1981, 44) assumed to be recent. Therefore, this chipping is original in contrast to the other dark-grayish chipping along the blade,[1] which are recent and created during the dredging and/or after the discovery. The color of the front and back sides differ from each other possibly due to effects of post-depositional process. The front side is largely dark grayish, which is similar to the color of the recent chipping parts, while the back side is brownish.

Possible origin and age of the Mesihsou Adze

Geological observation

Based on study of the material in hand, this adze exhibits the very distinctive foliation characteristic of mid-grade metamorphic rock (schist) and as such cannot be sourced to Micronesia, which lacks such metamorphic rock within its basaltic volcanic series (Spengler et al. 1994). Such material can be found from Japan through to the fringe of continental Melanesia, including New Guinea, New Caledonia, and possibly the main Solomons (Cluzel et al. 2012; Coleman et al. 1965; Hill, Baldwin, and Lister 1992; Lus, McDougall, and Davies 2004; Taylor, Goodliffe, and Martinez 1999). Among the source areas, we propose that New Guinea is the closest and most plausible candidate. Consultation and sharing of photographs with John Chappell (2006; Australian National University), who has considerable experience with the geology and adzes of Papua New Guinea, confirmed that the material could be from Papua New Guinea, and that he had identified a small number of adzes in New Guinea made from schist; however, he was

unable to identify a specific source for that material. New Guinea is thus the closest probable source, but we cannot rule out one further to the southeast despite us not knowing of any schist adzes from that area. Green (1976, 259) has also reported a high-grade schist rock imported into an early Lapita site (SE-SZ-8) on Santa Cruz that he attributed to coming from either New Guinea or New Caledonia.

Morphological traits

Previous typological studies of early Oceanic stone adzes focus on cross-section as the key feature (e.g., Best 1984; Green 1971; Green and Davidson 1969; Poulsen 1987). According to those studies, the Mesihsou specimen has a flat oval cross-section and is classified as an oval adze (e.g., Best Type II, Green Type II, Poulsen Type 2a), which is one of four forms, along with rectangular, plano-lateral, and plano-convex, identified as a Lapita-early Polynesian adze kit (Green 1971, 2003, 110, Table 5), and is found in Lapita sites from Watom in the Bismarcks through the northern Solomons, Fiji, and Tonga (Wickler 2001, 181). However, the Mesihsou adze is unique in terms of its size and morphology. According to our brief survey of the size of stone adzes from Lapita and post-Lapita periods it is exceeded in size by only a few stone adzes (e.g., a SE-RF-2 Main Reef Islands Lapita adze [Green 1979, 38 Figure 2.4; Sheppard 2010, 247, Figure 3]). The unique morphological feature described above, its thinness, is probably due to the high fracture toughness of the schist, which allows for the production of a strong yet thin adze.

Location

The find spot of the stone adze at Mesihsou provides us with some information on its age. The adze was highly likely associated with a submerged early settlement site, because Pohnpei has undergone some subsidence (Fujimoto and Miyagi 1993) and early settlement sites are characteristically found in intertidal zones: Ipwal (Galipaud 2001, 2004), Lenger (Nagaoka 2008), Imwinsapw,[2] and Nan Madol (Athens 1990a; Ayres, Haun, and Mauricio 1983) (Figure 1(B)). These sites are associated with calcareous sand temper (CST) pottery and are dated around the first centuries AD, when radiocarbon dates are available (Athens 1990a, 21; Ayres 1983, 140; Galipaud 2001, 54 Table 2, 2004, 45), in comparison to subsequent non-CST pottery sites found at non-intertidal locations (e.g., Bryson 1989; Nagaoka 2008). The coastal location of early settlement sites is consistent with archaeological data from other high volcanic islands in eastern Micronesia, such as Chuuk (Shutler, Sinoto, and Takayama 1984) and Kosrae (Athens 1990b). Because long-distance voyaging tends to have decreased after the colonization period in other parts of Oceania (Kirch 2017, 104–105), this exotic adze was most likely transported by early settlers or their immediate descendants in the early settlement period, as discussed below.

Salong adze

A similar stone adze that provides a relatively contemporaneous and comparative sample was found by a resident in an intertidal zone at Salong along the shoreline on the north side of Temwen Island in Pohnpei in 1984. This complete stone adze was brought

to Stephen Athens, who took photographs and made drawings of it (Figure 2(C)). The adze is thin and extremely long with a maximum length of 24.1 cm, maximum width of 5.6 cm, and maximum thickness of 3.8 cm. It has an oval cross-section and has a highly polished, almost glassy, surface. Unfortunately, we cannot conduct geological analysis on the specimen because it was recently lost.

Although the material was reported as being basalt by Athens (2018b), in our opinion, the possibility of it being an imported adze is high. Not only does the discovery location suggest its antiquity, going back to the settlement phase, but the oval cross-section of the adze (e.g., Best Type II, Green Type II, Poulsen Type 2s)—which is argued to be part of the Lapita-early Polynesian adze kit (Green 1971, 2003, 110, Table 5)—is widely found in Lapita sites in Melanesia and west Polynesia, but not Micronesia (Wickler 2001, 181). If this adze is of an early Oceanic age, it is probably one of the longest adzes reported from that period.

Discussion and conclusion

Significance of the finding locations

The find spot of the Mesihsou adze shares common geographical and environmental characteristics with other early settlement sites in Pohnpei (Figure 1(B)), suggesting that there were similar colonizing strategies by these first settlers related to their maritime orientation. First, those sites are located in the intertidal zone, which is common in both early eastern Micronesian sites and Lapita sites in Melanesia and West Polynesia and are interpreted as evidence of stilt villages (Rainbird 1999, 453–454; see also Athens 2018a, 285). Second, those early sites are proximate to reef passages as noted for early sites in eastern Micronesia by Rainbird (1999, 453). The Mesihsou site is also located 2.8 km south of the Alohkapw Harbor (Figure 1(C)). Third, these early sites are predominantly located in the northeastern half of the island to the windward of the northeasterly trade wind, where the fringing reef flat platforms are less developed and narrow along the coastline, although we do note the absence of systematic survey for early settlement sites along the coast around the island, except for Galipaud's (2001, 2004) efforts. This distributional tendency, albeit based on limited data, is possibly caused by different site visibility due to the differential development of coastal mangrove forest. As such, we need to wait for future studies to confirm this hypothesized early settlement strategy. In sum, current evidence indicates these coastal locations were preferred by early settlers to provide easy passage for (presumably large) canoes and access to the lagoon and ocean, which facilitated their marine resource exploitation and long-distance voyages to other islands.

Implication for Micronesian settlement

Past archaeological investigations offer some insight into the origins of early eastern Micronesian settlers. The most diagnostic artifact in early prehistory is CST plain pottery, which is widely found in Chuuk, Pohnpei, and Kosrae. This pottery is often compared with post-Lapita plainware extensively distributed from Melanesia to West Polynesia. Largely based on typological comparison of early plain pottery and linguistic evidence, Ayres (1990) argues that the homeland was in the southeast Melanesia–west Polynesia region. In contrast, Athens (1990a, 29) narrows this down to the southeast

Solomons or northern Vanuatu area. More recently, after summarizing past archaeological data, Kirch (2017, 157–158) concludes the outer eastern/southeastern Solomons or immediately adjacent regions as the most plausible origin.

The discovery of the Mesihsou adze suggests that Micronesian settlers still had connections with the Lapita homeland in the Bismarck–New Guinea region after the end of Lapita period, when extensive interactions systems are generally thought to have contracted (Kirch 2017, 104–105). This is supported by the presence of crystal quartz, which possibly had the same origin, in the earliest deposits in Pohnpei (Athens 1990a, 30) and Kosrae (Athens 1995, 86). A recent discovery of an obsidian flake originating from the Admiralty group at an early settlement site in Pohnpei (Nagaoka 2008; Nagaoka and Sheppard, forthcoming) also supports this model. We do not need to presume that Micronesian settlers departed directly from their proposed homeland in eastern Melanesia for Micronesian islands, as assumed by previous colonization simulation studies (Irwin 1992; Montenegro, Callaghan, and Fitzpatrick 2016), but they could have easily followed existing interaction networks from their homeland to the Lapita homeland region before embarking for a new land in the north.

It is not possible to determine that the Mesihsou adze was transported from New Guinea to a proposed Micronesian homeland in Melanesia (southeast Solomons–north Vanuatu region) and then to Pohnpei with a distance of at least 3800 km, or from New Guinea to Pohnpei at a distance of 1300 km, by early settlers or their immediate successors within a few generations. Although there has not been any archaeological evidence found in eastern Micronesia that shows post-settlement return voyages from Micronesia to Melanesia, those lithic artifacts transported from the Lapita homeland region discussed above (i.e, Mesihsou adze, crystal quartz from Pohnpei and Kosrae, obsidian flake from Pohnpei) indicate that occasional, or even frequent, long-distance voyaging must have occurred in the Micronesia–Melanesia region during the colonization phase, suggesting the latter route is more plausible. This is parallel with Athens' (1990a, 29) proposal that eastern Micronesian islands were probably colonized by closely related but different groups based on the variable characteristics shown in early plainware found in Chuuk, Pohnpei, and Kosrae. Anderson et al. (2006, 2) also have suggested that "initial colonization across previously uninhabited regions of Remote Oceania was strongly episodic at a millennial scale," and that a colonization pulse to central and eastern Micronesia ca. 1800–2000 years ago was facilitated by trade wind reversals caused by intensified ENSO conditions. This would have enabled windward sailing, which they suggest was lacking in maritime technology of the time (but see also Irwin and Flay 2015). Possible emergence of habitable atolls in the region by that time as suggested by Irwin (1992, 116) and others (Dickinson 2009; Weisler, Yamano, and Hua 2012) may have facilitated the colonization process. Thus, central and eastern Micronesian settlement was achieved through intensive long-distance voyages, probably including two-way voyages between both the Lapita-Micronesian homeland region and newly settled islands and among the latter islands.

Lapita/post-Lapita prestige goods exchange

In Lapita and post-Lapita adze assemblages, stone adzes are generally much less common than shell adzes at individual sites (e.g., Reef Santa Cruz [Doherty 2007, 321],

Anuta [Kirch and Rosendahl 1973], Tikopia [Kirch and Yen 1982], Taumako [Leach and Davidson 2008]) and probably held high prestige, as this important item was a material symbol of status and *mana* in succeeding Oceanic societies (e.g., Leach 1993, 39–41). For instance, they are hypothesized to have been exchange media and were transported for long distances in the Lapita period (e.g., Kirch 1997, 236). The Mesihsou specimen was probably produced as a trade item at or near its quarry area. Similar adzes with identical rock type, therefore, can be expected to be discovered at other Lapita and post-Lapita sites. Due to its large size and transported distance, the adze may have functioned as a prestige good, which limited persons in a community could access through long-distance exchange and/or possibly also existed as an heirloom passed down through generations. As Green and Kirch (1997, 29 also see Green 1987, 246) argue for imported Bismarck obsidian in daughter communities during the Lapita period, this stone adze transported from the homeland area was a possible source of their social power, manifesting their genealogical and symbolic linkage to the ancestral land, and marking their ascendance in a community.

Overall, our examination of this Pohnpeian stone adze has identified what appears to be the first artifact of Melanesian origin in an early settlement site within Micronesia, adding new evidence of early Oceanic interaction into regions that were previously uninhabited.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes

1. A few small white dots can be observed on this part; however, it is difficult to determine that they are remnants of coral adhesion.
2. During the archaeological survey in search of early settlement sites conducted by Jean-Christophe Galipaud and Nagaoka in 1999, pottery and oven stones were found in a dredging area indicated as D on Figure 1(B).

References

Anderson, A., J. Chappell, M. Gagan, and R. Grove. 2006. Prehistoric maritime migration in the Pacific Islands: A hypothesis of ENSO forcing. *The Holocene* 16 (1):1–6. doi:10.1191/0959683606hl901ft

Athens, J. S. 1981. A stone adze from Ponape, Eastern Caroline Islands. *Asian Perspectives* 24: 43–6.

Athens, J. S. 1990a. Nan Madol pottery, Pohnpei. *Micronesica* Suppl 2:17–32.

Athens, J. S. 1990b. Kosrae pottery, clay, and early settlement. *Micronesica* Suppl 2:171–86.

Athens, J. S. 1995. *Landscape archaeology: Prehistoric settlement, subsistence, and environment of Kosrae, Eastern Caroline Islands, Micronesia. Report prepared for the Kosrae State Government, Federated States of Micronesia*. Honolulu: International Archaeological Research Institute, Inc.

Athens, J. S. 2018a. Archaeology of the Eastern Caroline Islands, Micronesia. In *The Oxford handbook of Prehistoric Oceania*, ed. E. Cochrane and T. Hunt, 271–301. Oxford: Oxford University Press.

Athens, J. S. 2018b. Email to author, November 23, 2018.

Ayres, W. S. 1983. Archaeology at Nan Madol, Ponape. *Bulletin of the Indo-Pacific Prehistory Association* 4:135–42. doi:10.7152/bippa.v4i0.11215

Ayres, W. S. 1990. Pohnpei's position in Eastern Micronesian prehistory. *Micronesica* Suppl 2: 187–212.

Ayers, W. S., and R. Mauricio. 1987. Stone adzes from Pohnpei, Micronesia. *Archaeology in Oceania* 22 (1):27–31. doi:10.1002/j.1834-4453.1987.tb00160.x

Ayres, W. S., A. E. Haun, and R. Mauricio. 1983. Nan Madol archaeology: 1981 survey and excavations. Report submitted to the Ponape State Historic Preservation Committee, Federated States of Micronesia, and the Trust Territory of the Pacific Islands Historic Preservation Program, Saipan.

Ayres, W. S., G. G. Goles, and F. R. Beardsley. 1997. Provenance study of lithic materials in Micronesia. In *Prehistoric long-distance interaction in Oceania: An interdisciplinary approach*, ed. M. I. Weisler, 53–67. Auckland: New Zealand Archaeological Association Monograph 21.

Best, S. B. 1984. Lakeba: The prehistory of a Fijian Island. PhD diss., University of Auckland.

Best, S., R. Green, R. Parker, and P. Sheppard. 1992. Necromancing the stone: Archaeologists and adzes in Samoa. *Journal of the Polynesian Society* 101 (1):45–85.

Bryson, R. U. 1989. Ceramics and spatial archaeology at Nan Madol, Pohnpei. PhD diss., University of Oregon.

Chappell, J. 2006. Email to author, July 25, 2006.

Cluzel, D., P. Maurizot, J. Collot, and B. Sevin. 2012. An outline of the geology of New Caledonia: From Permian-Mesozoic Southeast Gondwanaland active margin to Cenozoic obduction and supergene evolution. *Episodes* 35 (1):72–16. doi:10.18814/epiiugs/2012/v35i1/007

Coleman, P. J., J. C. Grover, R. L. Stanton, and R. B. Thompson. 1965. *A first geological map of the British Solomon Islands*. Honiara: Geological Survey Department.

Collerson, K. D., and M. I. Weisler. 2007. Stone adze compositions and the extent of ancient Polynesian voyaging and trade. *Science* 317 (5846):1907–11. doi:10.1126/science.1147013

Dickinson, W. R. 2009. Pacific atoll living: How long already and until when? *GSA Today* 19 (3): 4–10. doi:10.1130/GSATG35A.1

Doherty, M. W. 2007. Post-Lapita developments in the Reef-Santa Cruz Islands, Southeast Solomon Islands. PhD diss., University of Auckland.

Fujimoto, K., and T. Miyagi. 1993. Development process of tidal flat type mangrove habitats and their zonation in the Pacific Ocean. *Vegetation* 106 (2):137–46.

Galipaud, J.-C. 2001. Le peuplement initial de Pohnpei. *Journal de la Société Des Océanistes* 112 (112):49–60. doi:10.4000/jso.1690

Galipaud, J.-C. 2004. Antiquity of settlement in the central Carolines: New data from Pohnpei. In *Micronesia, Visiones desde Europa*, ed. B. Moral, 43–54. Madrid: Asociación Española de Estudios del Pacifico.

Green, R. C. 1971. Evidence for the development of the early Polynesian adze kit. *New Zealand Archaeological Association Newsletter* 14:12–44.
Green, R. C. 1976. Lapita sites in the Santa Cruz Group. In *Southeast Solomon Islands culture history: A preliminary survey*, eds. R. C. Green and M. M. Cresswell, 245–65. Wellington: Royal Society of New Zealand.
Green, R. C. 1979. Lapita. In *The Prehistory of Polynesia*, ed. J. D. Jennings, 27–60. Cambridge: Harvard University Press.
Green, R. C. 1987. Obsidian results from the Lapita sites of the Reef/Santa Cruz Islands. In *Archaeometry: Further Australasian studies*, eds. W. R. Ambrose and J. M. Mummery, 239–49. Canberra: Australian National University.
Green, R. C. 2003. The Lapita horizon and traditions: Signature for one set of oceanic migrations. In *Pacific Archaeology: Assessments and Prospects*, ed. C. Sand, 95–120. Nouméa: Les Cahiers de l'Archéologie en Nouvelle Calédonie 15.
Green, R. C., and J. M. Davidson. 1969. *Archaeology in Western Samoa*, Vol. 1. Auckland: Bulletin of the Auckland Institute and Museum No. 6.
Green, R. C., and P. V. Kirch. 1997. Lapita exchange systems and their Polynesian transformations: Seeking explanatory models. In *Prehistoric long-distance interaction in Oceania: An interdisciplinary approach*, ed. M. I. Weisler, 19–37. Auckland: New Zealand Archaeological Association Monograph 21.
Hill, E. J., S. L. Baldwin, and G. S. Lister. 1992. Unroofing of active metamorphic core complexes in the D'Entrecasteaux Islands, Papua New Guinea. *Geology* 20 (10):907–10. doi:10.1130/0091-7613(1992)020<0907:UOAMCC > 2.3.CO;2
Irwin, G. 1992. *The prehistoric exploration and colonization of the Pacific*. Cambridge: Cambridge University Press.
Irwin, G., and R. Flay. 2015. Pacific colonisation and canoe performance: Experiments in the science of sailing. *Journal of the Polynesian Society* 124 (4):419–43. doi:10.15286/jps.124.4.419-443
Kirch, P. V. 1997. *The Lapita peoples: Ancestors of the Oceanic world*. Oxford: Blackwell.
Kirch, P. V. 2017. *On the road of the winds: An archaeological history of the Pacific Islands before European contact*. Oakland: University of California Press.
Kirch, P. V., and D. E. Yen. 1982. *Tikopia: The prehistory and ecology of a Polynesian outlier*. Honolulu: Bernice P. Bishop Museum Bulletin 238.
Kirch, P. V., and M. I. Weisler. 1994. Archaeology in the Pacific Islands: An appraisal of recent research. *Journal of Archaeological Research* 2 (4):285–328.
Kirch, P. V., and P. H. Rosendahl. 1973. Archaeological investigation of Anuta. In *Anuta: A Polynesian Outlier in the Solomon Islands*, ed. D. E. Yen and J. Gordon, 25–108. Pacific Anthropological Records 21. Honolulu: Bernice P. Bishop Museum.
Leach, B. F., and J. M. Davidson. 2008. *The archaeology of Taumako: A Polynesian outlier in the Eastern Solomon Islands*. Dunedin: New Zealand Archaeological Association.
Leach, H. M. 1993. The role of major quarries in Polynesian prehistory. In *The evolution and organization of prehistoric society in Polynesia*, ed. M. W. Graves and R. C. Green, 33–42. Auckland: New Zealand Archaeological Association Monograph 19.
Lus, W. Y., I. McDougall, and H. L. Davies. 2004. Age of the metamorphic sole of the Papuan Ultramafic Belt ophiolite, Papua New Guinea. *Tectonophysics* 392 (1–4):85–101. doi:10.1016/j.tecto.2004.04.009
Miyagi, T., and K. Fujimoto. 1989. Geomorphological situation and stability of mangrove habitat of Truk Atoll and Ponapc Island in the Federated States of Micronesia. *Science Reports of Tohoku University, 7th Series (Geography)* 39:25–52.
Montenegro, Á., R. T. Callaghan, and S. M. Fitzpatrick. 2016. Using seafaring simulations and shortest-hop trajectories to model the prehistoric colonization of Remote Oceania. *Proceedings of the National Academy of Sciences of the United States of America* 113 (45):12685–90. doi:10.1073/pnas.1612426113
Nagaoka, T. 2008. Archaeological survey of Lenger Island. Report submitted to the Pohnpei State Historic Preservation, Federated States of Micronesia.

Nagaoka, T., and P. J. Sheppard. forthcoming. Discovery of the first obsidian flake at an early settlement site on Pohnpei, Micronesia. Manuscript in preparation.

Poulsen, J. 1987. *Early Tongan prehistory*. Terra Australis 12. Canberra: Australian National University.

Rainbird, P. 1999. The use of landscape in identifying potential sources of Caroline Island colonisation. In *Le Pacifique de 5000 à 2000 avant le Présent: Suppléments à l'Histoire d'une Colonisation*, ed. J.-C. Galipaud and I. Lilley, 451–60. Paris: Institut de Recherche pour le Développement.

Sheppard, P. J. 2010. Lapita lithic technology. In *Lapita: Ancêtres oceaniens/Oceanic ancestors*, ed. C. Sand, S. Bedford, and C. Chambonniere, 240–50. Paris: Somogy.

Shutler, R., Jr., Y. H. Sinoto, and J. Takayama. 1984. Preliminary excavations of Fefan Island sites, Truk Islands. In *Caroline Islands archaeology: Investigations on Fefan, Faraulep, Woleai, and Lamotrek*, ed. Y. H. Sinoto, 1–64. Pacific Anthropological Records 35. Honolulu: Bernice P. Bishop Museum.

Spengler, S. R., K. J. Spencer, J. J. Mahoney, and G. G. Goles. 1994. Geology and geochemical evolution of lavas on the island of Pohnpei, Federated States of Micronesia. Accessed June 16, 2020. http://www.e2hi.com/wp-content/uploads/2012/10/12_Geology_and_Geochemical_Evolution_of_Lavas_on_the_Island_of_Pohnpei.pdf.

Taylor, B., A. M. Goodliffe, and F. Martinez. 1999. How continents break up: Insights from Papua New Guinea. *Journal of Geophysical Research: Solid Earth* 104 (B4):7497–512. doi:10.1029/1998JB900115

U.S. Geological Survey. 1983. *Topographic map of the island of Ponape, Federated States of Micronesia [map]. 1: 25,000.* Washington, DC: U.S. Geographical Survey.

Weisler, M. 1993. Provenance studies of Polynesian basalt adze material: A review and suggestions for improving regional data bases. *Asian Perspectives* 32 (1):61–83.

Weisler, M., ed. 1997. *Prehistoric long-distance interaction in Oceania: An interdisciplinary approach*. Monograph 21. Auckland: New Zealand Archaeological Association.

Weisler, M. I., H. Yamano, and Q. Hua. 2012. A multidisciplinary approach for dating human colonization of Pacific atolls. *The Journal of Island and Coastal Archaeology* 7 (1):102–25. doi: 10.1080/15564894.2011.616923

Wickler, S. 2001. *The prehistory of Buka: A stepping stone island in the Northern Solomons*. Terra Australis 16. Canberra: Australian National University.