Stone tools from the ancient Tongan state reveal prehistoric interaction centers in the Central Pacific

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Edited by Patrick V. Kirch, University of California, Berkeley, CA, and approved June 10, 2014 (received for review April 2, 2014)

Tonga was unique in the prehistoric Pacific for developing a maritime state that integrated the archipelago under a centralized authority and for undertaking long-distance economic and political exchanges in the second millennium A.D. To establish the extent of Tonga's maritime polity, we geochemically analyzed stone tools excavated from the central places of the ruling paramounts, particularly lithic artifacts associated with stone-faced chiefly tombs. The lithic networks of the Tongan state focused on Samoa and Fiji, with one adze sourced to the Society Islands 2,500 km from Tongatapu. To test the hypothesis that nonlocal lithics were especially valued by Tongan elites and were an important source of political capital, we analyzed prestate lithics from Tongatapu and stone artifacts from Samoa. In the Tongan state, 66% of worked stone tools were long-distance imports, indicating that interarchipelago connections intensified with the development of the Tongan polity after A.D. 1200. In contrast, stone tools found in Samoa were from local sources, including tools associated with a monumental structure contemporary with the Tongan state. Network analysis of lithics entering the Tongan state and of the distribution of Samoan adzes in the Pacific identified a centralized polity and the products of specialized lithic workshops, respectively. These results indicate that a significant consequence of social complexity was the establishment of new types of specialized sites in distant geographic areas. Specialized sites were loci of long-distance interaction and formed important centers for the transmission of information, people, and materials in prehistoric Oceania.

Polynesian archaeology | geochemical sourcing | complex societies

Archaeological evidence for prehistoric interaction is critical to understanding the role of intersocietal contact and the power strategies used by elites in the formation of complex societies. In the first half of the second millennium A.D., a powerful and complex society emerged in the Tonga Islands (Fig. 1) that was unique in the Pacific for the way it aggregated an entire archipelago under a single political system. Considered a maritime empire/chiefdom (1–3), Tonga has recently been categorized as a primary/archaic state that, along with the late-prehistoric polities of the Hawaiian Islands, were the most complex societies in prehistoric Oceania (4, ref. 5, p. 146). The ancient Tongan state/chiefdom was headed by the paramount Tui Tonga (Lord of Tonga) and administered by closely related chiefly families, and it was exceptional in Polynesia for a network of political and economic relationships that extended to other islands and archipelagos (2, 6). The control and redistribution of exotic goods is posited as an important source of capital used to support political centralization (7, 8), but it has not been feasible to model prehistoric interaction in the expansive Tongan state using archaeological data because of the paucity of excavations at the central places of the chiefdom and the likelihood that most imports were made in perishable materials that tend not to preserve in tropical contexts (9–11). As a result, it has been unclear how far Tongan influence extended, whether the political economy involved control and distribution of prestige exotic goods by elites and whether the polity's interaction sphere was only one of several prehistoric networks responsible for the movement of people, goods, and ideas in the Central Pacific.

This article reports the analysis of a significant lithic artifact assemblage recovered during recent excavations of sites of the Tongan polity, which was manifested by the construction of religo-political centers containing monumental architecture on the island of Tongatapu (297 km^2), where the political hierarchy was legitimized in ceremonial events, particularly chiefly funerals and the regular presentation and redistribution of tribute from islands within and beyond Tonga (12). Geochemical analysis of lithics is used here to determine the spatial extent of Tongan interaction and to test a hypothesis that the acquisition of nonlocal lithics—and by extension other exotic items that are poorly represented in the archaeological record—was an important source of power for Tongan elites.

Refining Interaction

The Tongan Islands consist of about 160 uplifted limestone and volcanic islands with a total land area of 748 km^2 (Fig. 1), which were first settled about 2,800 y ago by Lapita people (13). The core islands are divided into three groups spread over 330 km, comprising the southern Tongatapu Group, the Haapai Group, and the northern Vavau Group, with several small outlying islands located to the north (Tafahi–Niuatoputapu, Niuafoou) and south (Ata). The prehistoric peak population of Tonga is estimated to be around 30,000–40,000 people, about half of whom

Significance

The Tongan state was the only maritime polity in Oceania to encompass an entire archipelago and, through long-distance voyaging, to extend its influence to other island groups through political and economic exchanges. Stone tools recovered from the central places of the Tongan state were geochemically analyzed to provide the first archaeological assessment of maritime interaction in the Central Pacific, with a high proportion of tools (66%) identified as long-distance imports from Fiji, Samoa, and the Society Islands. Exotic lithics were an important source of political capital used by Tongan elites, and an important consequence of centralization was the development of interaction centers through which people, products, and information about political organizations reached many parts of the prehistoric Pacific.

Author contributions: G.R.C. and C.R. designed research; G.R.C., C.R., N.M., J.W., W.R.D., and H.M.-W. performed research; G.R.C. and C.R. analyzed data; and G.R.C. and C.R. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1406165111/-/DCSupplemental.

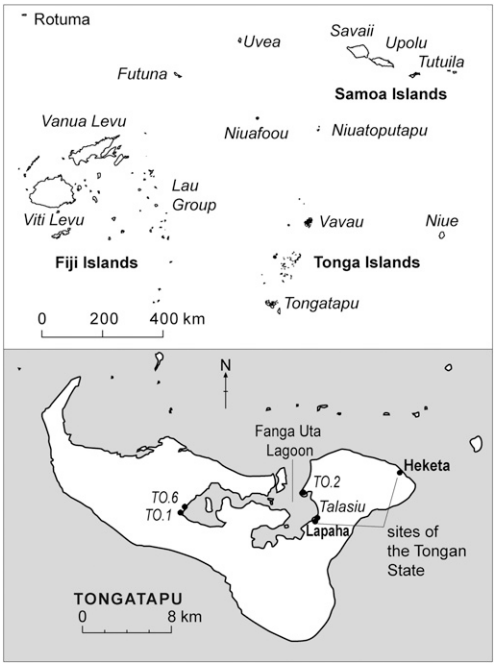

Fig. 1. (*Upper*) Location of Tonga and the main islands in the Central Pacific. (*Lower*) Tongatapu sites with significant lithic assemblages in italics and the location of Lapaha and Heketa, the central places of the Tongan state.

lived on the southern island of Tongatapu (Sacred Tonga), where the central places of the Tongan polity were raised (2, 14, 15). Tongatapu is a limestone island and all volcanic rock artifacts, including adzes, flakes, grindstones, hammer stones, and cooking stones found in archaeological contexts, were imported from volcanic islands within, or beyond, the Tongan archipelago.

The first paramount center to contain chiefly stone architecture, which signals increasing hierarchical organization, was located in eastern Tongatapu and built around A.D. 1300 before being abandoned two to three generations later (16). After Heketa, the chiefdom relocated to Lapaha on the shores of the Fanga Uta Lagoon around A.D. 1350–1400, where the Tongan state reached its greatest extent. Manifested by a monumental central place covering more than 50 ha, the principal monumental structures were stepped royal tombs of the paramount Tui Tonga family, which were faced with slabs of beach rock and reef limestone, some weighing more than 20 tons. Lapaha has 27 stone-faced burial structures that contain more than 2500 tons of quarried and transported carbonate stone (Fig. 2). Radiocarbon dates, architectonic features, and chiefly genealogies indicate the first royal tombs were built A.D. 1300–1400, with the last constructed ~A.D. 1760 (16, 17). Additional constructions marking the chiefly center include ditch systems, roads, earth burial mounds, sitting platforms, bathing wells, standing stones, and a large area of reclaimed land containing a canoe harbor and wharf, which highlight the importance of maritime transport to the polity (2, 15).

Here, we discuss the geochemical analysis of a lithic assemblage associated with the central places of the Tongan state, particularly the monumental royal tombs. Lithic sourcing is an established method of revealing prehistoric long-distance voyaging in Oceania (18, 19). As detailed in *SI Appendix*, chemical analysis of lithics is particularly applicable to the Central Pacific because of the significant geochemical differences in the composition of volcanic rocks within the Tongan Island Arc, and between Tongan Arc rocks and intraplate volcanic islands, like Samoa, located north and east of the "Andesite Line" (18). We analyzed 599 rock samples composed of 567 artifacts and 32 reference samples from northern Tonga, Samoa, Uvea (Wallis), and Rotuma. By island/island group, there are 196 lithic artifacts from Tongatapu and 371 from Samoa (Upolu, Savaii, Apolima). We used six techniques to identify artifacts to a potential source: thin-section petrology, pXRF, XRF, SEM–EDXA, LA–ICP–MS, and MC–ICP–MS, in addition to using reference sample data and the extensive literature on the geology and geochemistry of the Central Pacific (*SI Appendix*). All samples were initially characterized with pXRF (Ti, Rb, Sr, Y, Zr, Nb) to identify groups and outliers (Dataset S1), followed by additional analysis of selected samples using major and trace elements (Dataset S2), radiogenic isotopes (*SI Appendix*, Table S1), and thin-section petrography (*SI Appendix*, Table S2 and Fig. S7).

Studies of prehistoric interaction are complicated by uncertainty about the purpose, directionality, and significance of long-distance contact (20–22). We refine our understanding of interaction in the Central Pacific by, first, constructing a geochemical-based network model of the Tongan state and comparing it with the prestate network on Tongatapu. Second, we contrast the movement of lithics in the Tongan state with Samoa, which in late prehistory was not centralized and contained several chiefdoms (23, 24), including lithics from a monumental site on Savaii (see ref. 25).

Results

Interaction in the Tongan State. There were 66 analyzed lithics from Lapaha (64) and Heketa (2), with "adzes-flakes" comprising 66% ($n = 44$) and decorative grave pebbles (*kilikili*) 34% ($n = 22$) of the assemblage. Artifact location and context is listed in Dataset S1 and *SI Appendix*, Tables S3 and S4, with site locations shown

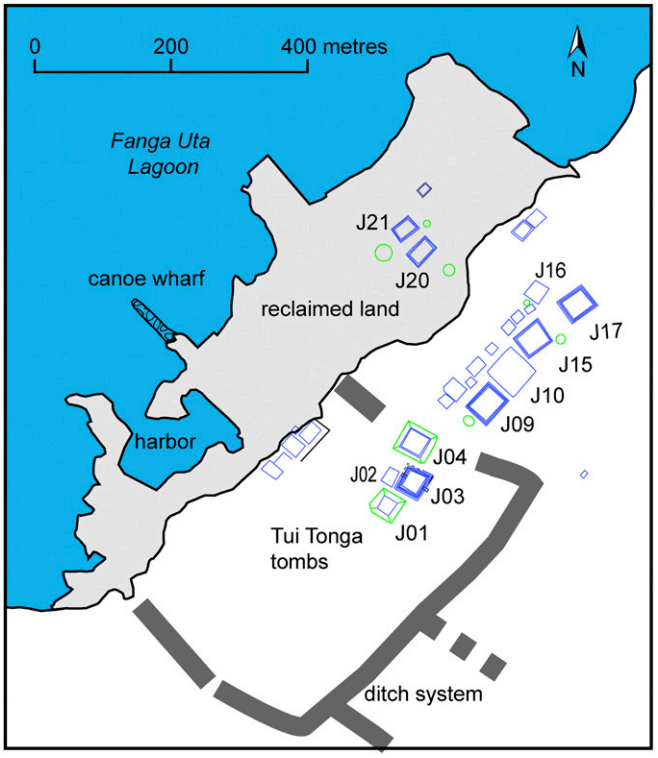

Fig. 2. Plan view of Lapaha showing the location of the largest tombs associated with the Tui Tonga chiefdom labeled by "J" structure number. Lithics associated with tomb wall excavations are listed in Dataset S1 and *SI Appendix*, Tables S3 and S4. Stone tomb walls are outlined in blue, and earth mounds are in green.

in Figs. 1 and 2. The majority (90%) of samples were directly associated with the stone-faced royal tombs, and the remainder were from chiefly structures, including a ditch system, canoe wharf, reclaimed land, and carbonate stone quarries. Geochemical results indicate that 44% (29/66) of all Lapaha–Heketa lithics are exotic to the Tonga archipelago, with a clear division between grave pebble manuports, which derive entirely from within the archipelago, and worked adzes-flakes, which are predominantly from outside Tonga (29/44, 66%). Local adzes-flakes and grave pebbles have a trace element geochemistry consistent with an origin from Eua and central Tongan volcanics (Hunga Haapai, Hunga Tonga, Fonuafoou, Tofua, Kao, Late), but not volcanics from northern Tonga (Fonualei, Tafahi–Niuatoputapu, and Niufoou). An adze quarry on Ata island in the south of the archipelago (26) does not appear to have been an important source of adzes in late prehistory. Exotic adzes from Samoa made up 55% of the adzes-flakes category (24/44), with trace elements indicating a source on Tutuila for eight (samples 36, 51, 53, 54, 241, 678, 683, and 707) where significant adze quarries have been reported (24). The Samoan adze category also includes artifacts with a geochemistry indicating currently undiscovered quarries in shield and posterosional volcanic settings on Upolu and Savaii (samples 31, 41, 42, 210–212, 681, and 688). Three lithics have major and trace element values indicating that they do not originate in Tonga nor in Samoa–Uvea–Rotuma, and an east Fijian source is likely for two samples (198 and 224) and possibly sample 708 (*SI Appendix*, Fig. S5). Interaction with west Fiji is demonstrated by worked flakes of plutonic rock found at the J20 tomb at Lapaha. A thin-section analysis identified the quartzose material (sample 692) as hornblende granodiorite, precluding an origin from the intraplate Polynesian islands, and the material most likely represents material collected from a shallow subvolcanic intrusion on Viti Levu or Vanua Levu (*SI Appendix*, Table S2). Lithics from Fiji/?Fiji contribute 9% of the exotic assemblage (4/44). Only two lithics were recovered from the early chiefly center of Heketa, both exotic, with one adze flake from Tutuila (sample 707) and an adze blank (sample 708) potentially from Fiji. An adze fragment from Lapaha made of phonotephrite (203) was an extreme outlier in the pXRF analysis and was examined further with XRF, LA–ICP–MS, and MC–ICP–MS. The sample contained TiO_2 ~2.5wt%, indicating an intraplate origin with unusually high Sr (1330 ppm) and Nb (132 ppm) values that exclude Samoa and point to the high field strength elements-enriched lavas from East Polynesia. Radiogenic Pb, Sr, and Nd isotope ratios measured with MC–ICP–MS (*SI Appendix*, Table S1 and Fig. S6) relate most closely with the Papenoo adze quarry in Tahiti, Society Islands (18), supported by alkali basalt results from Vallee de Punaruu (27).

Interaction in Prestate Tongatapu. Stone tools found at the central places of the Tongan state/chiefdom are dominated by imports from outside the archipelago, indicating frequent long-distance voyaging, but was interaction greater during the time of the Tongan state than in earlier times? To examine prestate interaction, we initially analyzed 115 stone artifacts from ceramic-age sites on Tongatapu dated to B.C. 800–A.D. 200, as there are few archaeological sites from the first millennium A.D. (28, 29). Seven adzes-flakes were removed from consideration, because they were surface finds from sites that had been occupied in the postceramic era and the lithics were not associated with the subsurface ceramic deposit, leaving a total of 108 prestate lithics (*SI Appendix*, Table S6). Adzes-flakes comprise 39% (42/108), and manuports 61% (66/108), of the assemblage. Most lithics (50%) were from the TO.6 site (Tufu Mahina), excavated by Jens Poulsen (30), which has an estimated age of B.C. 350–100 (31). Of the total lithic collection, 14% (15/108) were nonlocal, with the majority of lithics (86%) sourced to Tongan volcanics. Most prestate imports from outside the Tonga Group were adzes-flakes with 33% (14/42) exotic, whereas almost all manuports (65/66) except for a possible import from Fiji (sample 703) are from local volcanic sources within the archipelago (central Tonga, Eua). Lithics associated with ceramic age deposits have probable sources in Samoa (2/42, 5%), Fiji/Rotuma (1/42, 2%), and Fiji/?Fiji (11/42, 26%) (Fig. 3). Lithics assigned to Fiji occur in both basal and upper levels of the TO.6 site (*SI Appendix*, Table S6), and early interaction between Tongatapu and Fiji is attested by lithics at three other ceramic sites (samples 5, 19, 21, and 694) that are sourced to Fiji (Datasets S1 and S2). In contrast, only two adzes (samples 22 and 250) from excavated contexts were sourced to Samoa, and both artifacts were from upper levels of the primary ceramic deposit. The proportion of exotic adzes-flakes in the prestate assemblage (33%) doubles in the Tongan state assemblage (66%) and is accompanied by marked change in procurement with adzes from Fiji succeeded by importation of Samoan lithics.

Interaction in Samoa. Two lithic collections from Samoa were used to examine whether the Tongan chiefdom acquired more exotic lithics than other stratified societies in the Central Pacific. The first assemblage is essentially a surface collection of 330 adzes/adze fragments from Samoa (Upolu, Savaii, Apolima) (32). There is substantial continuity in the Samoan adze sequence, and although the relative age of individual tools cannot be determined precisely, the majority is associated with postceramic sites and probably date, therefore, to the past 1,500 y (32, 33). To test the proposition that exotic lithics were especially important to the Tongan state, we analyzed a collection of 41 stone tools and manuports from the Pulemelei Mound site. The Pulemelei Mound is a monumental stone mound with a volume of 17,000 m^3, surrounded by more than 1,000 smaller stone platforms, indicating it held an important position in the settlement hierarchy and was coeval with the stone architecture of the Tongan state (34). Both assemblages are museum collections and could only be examined with nondestructive pXRF. Lithics found on Upolu, Savaii, and Apolima ($n = 371$) originate overwhelmingly (99.2%) from Samoa. There are three possible imports (samples 144, 174, and 552) from Uvea in the Samoa adze-flake assemblage. Two are adze-flakes from the Pulemelei Mound (samples 144 and 178). However, reference samples and local manuports used in mound construction in the Pulemelei area are indistinguishable from reference material from Uvea, indicating, parsimoniously, a local origin [Uvea (average of samples 633–639)/Pulemelei (average of samples 663–667, 673); Ti = 22,866/21,943, Mn = 1,580/1,489, Rb = 29/32, Y = 25/26, Zr = 210/201, Nb = 35/43]. Sample 552 is a surface-collected adze from Upolu that has similar trace element values to a reference sample from Upolu (622) and is also probably local.

The proportion of exotic and local lithics in each of the three assemblages is summarized in Fig. 3, with Tongatapu receiving substantial quantities of stone tools from other island groups—even though fine-grained adze rock was available in Central Tonga and on Eua—whereas Samoan lithics derive from local sources within the archipelago.

Discussion

Based on our geochemical analyses, there was extensive movement of lithics into the Tongan state, with stone tools sourced from volcanic islands in the Tonga archipelago as well as Fiji, Samoa, and remarkably Tahiti, 2,500 km east of Tongatapu. The core area of the Tongan state covers an area of 500,000 square km and has a periphery zone up to seven times larger if the Society Islands are the source of Lapaha sample 203. A larger interaction zone is supported by traditional history of Tongan arrival on islands such as Tikopia and Anuta and linguistic evidence that Tongans traveled to Rotuma, Tokelau, and Tuvalu (35–37). Nonetheless, a comparison of lithic movement in prestate

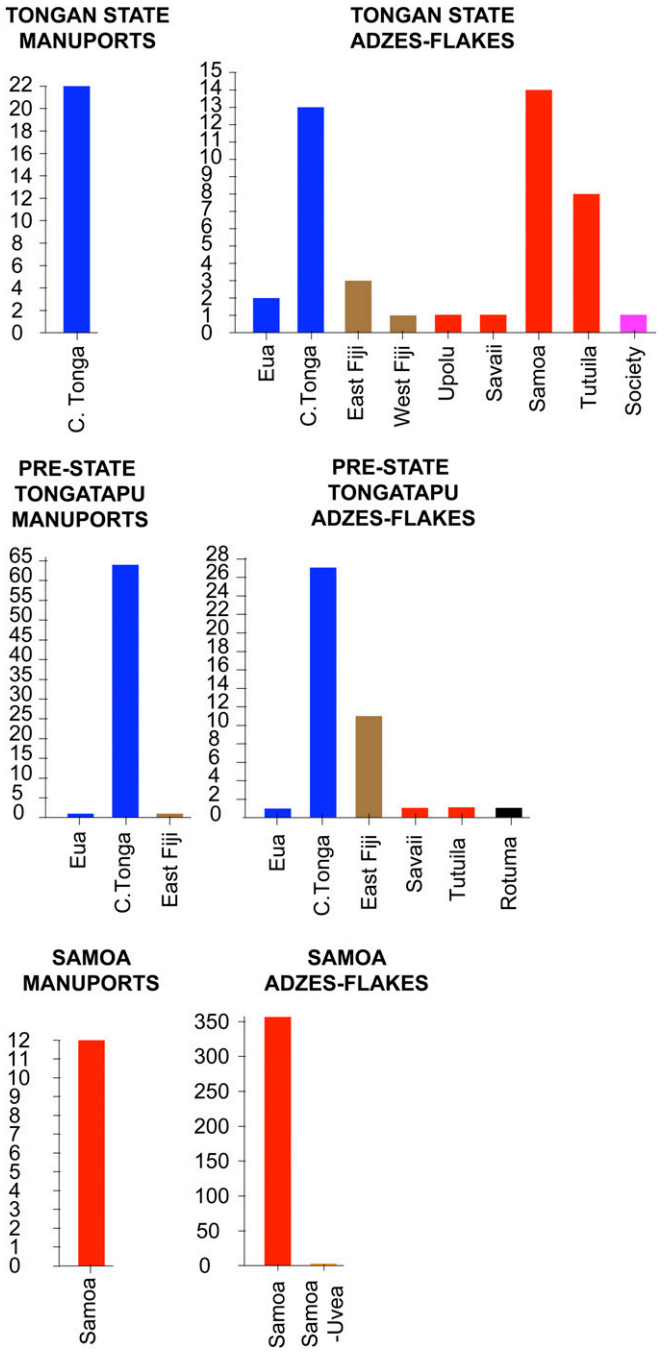

Fig. 3. Summary of lithic sourcing results for the Tongan state (*Top*), prestate Tongatapu (*Middle*), and Samoa (*Bottom*). In the Tongan state, manuports ($n = 22$) are entirely local compared with adzes-flakes, where the majority (29/44) are nonlocal (66%). In prestate Tongatapu, manuports are almost entirely local (65/66) compared with adzes-flakes, where a smaller proportion (14/42) are nonlocal (33%), including a number sourced to east Fiji (11/42, 26%). Samoan lithic collections differ from those of Tonga in the large number of local adzes-flakes ($n = 356$, 99.2%), demonstrating overwhelming use of local stone sources. Local production of Samoan lithics contrasts with the extensive dispersal of Samoan adzes in Oceania (Fig. 4).

Tonga demonstrates that a significant proportion of stone tools (33% of adzes-flakes) came from outside the Tonga Islands during the first thousand years of human occupation (B.C. 800–A.D. 200). Fiji appears to have been an important source of lithics in early Tongatapu, and this matches linguistic data indicating an early dialect association between east Fiji and southern Tonga (38–41).

The oldest center of the Tongan state is Heketa, where the first monumental stone architecture was built (16). It is notable that interaction with Samoa and potentially Fiji is seen during the initial period of state formation (~A.D. 1200–1300), although a larger lithic assemblage is needed to examine both early state, and immediately prestate state, interaction. Many of the Lapaha adzes-flakes found in foundation trenches used to hold the carbonate facings of the royal tombs were deposited while shaping the stones and are associated with slab debitage. The largest Lapaha tombs have recently been placed in a chronological sequence using radiocarbon dates and architectonic features (17). The oldest tomb (J17), with an estimated age of A.D. 1350, has lithics from Samoa and central Tonga, whereas later tombs J03 and J21 (A.D. 1550–1650) have lithics from Samoa (Fig. 2). The adze with a likely source in the Society Islands (sample 203) came from the foundation trench of the four-tiered J09 tomb that is notable for having a large average slab length (3.3 m). The dating of this tomb is uncertain, but architectonic features indicate an age ~A.D. 1550–1700 (15, 17), a century after long-distance interaction stopped in East Polynesia (42). The J20 tomb has lithics from several sources including volcanic islands within Tonga (central Tonga, Eua), Samoa (Upolu–Savaii, Tutuila), and Fiji (west Fiji plutonic, east Fiji volcanic). Made of large reef–limestone blocks rather than beach rock slabs, the J20 tomb is the largest worked stone structure in the Pacific (14) and contains more than 500 tons of quarried limestone. In Tongan traditions, the J20 tomb is linked to the 29th Tui Tonga (A.D. 1550–1600), who had close connections with chiefly families in Fiji and Samoa (23, 43), suggesting that exotic lithics found in funerary contexts at the J20 tomb derive from the mobilization of valuables in the paramount's extensive web of family/political connections (see refs. 44, 45).

In addition to chiefly funerals and marriages, political centralization was manifested in the first fruits (*inasi*) festival, which was a major ceremony attended by chiefs and people from all over Tonga. In the ceremony, the Tui Tonga mediated with the god Hikuleo to ensure bountiful crop yields, and for this, the paramount was "... greatly reverenced throughout the island, and supported in splendour and dignity by the contributions of the different districts" (ref. 12, p. 91). An *inasi* witnessed in the 19th century when the influence of the paramount Tui Tonga was severely diminished noted tribute goods arriving from throughout the Tonga Islands as well as Uvea and Niuafoou, respectively, 870 km and 600 km distance from Tongatapu. Imported items included yams, pearl shells, megapode eggs, fine mats, *Touchardia latifolia* fiber for attaching hooks to large trolling lures and making fishing nets, sea bird young, fish from a sacred lake, two kinds of iron wood, and arrowroot (46). The influx of people to the central place at such times numbered in the thousands (ref. 12, p. 93; ref. 47, p. 343) and was accompanied by vast quantities of goods and manufactured products, including, we suspect, stone adzes.

Recent work on adze production sites on Tutuila Island in American Samoa has identified the emergence of nucleated workshops at ~A.D. 1200 that specialized in the production of basalt tools (24). Our analysis of 330 Samoan stone tools reveals that few lithics were imported into Samoa, and this is supported by a study of lithics from the monumental Pulemelei Mound site. Clearly, the elites of Tonga and Samoa were using stone tools differently, with a high proportion of exotic lithics imported to the central place of the Tongan state, whereas parts of Samoa, especially Tutuila, focused on the specialized production of high-quality adzes. A Samoan tradition mentions a short-lived Tongan presence on Tutuila that was repelled, suggesting that Tongans may have attempted to control adze production (ref. 23, p. 480). We agree with Helms (ref. 48, p. 213), who notes both procurement

and production of nonlocal goods provides new forms of political capital to leaders.

The different strategies used by leaders in the Central Pacific can be further visualized by showing the distribution of adzes sourced to Samoa/Tutuila and the lithic network of the Tongan state (Fig. 4). Samoan adzes occur on islands spread over 5,000 km of the Pacific Ocean, with tools from workshops on Tutuila widely esteemed for the high-quality basalt and artisanal skill involved in production. Although craft specialization and control of adze circulation delivered chiefly wealth, it did not, apparently, result in the high political status of Tutuila in the Samoan archipelago (23, 24). In short, the contrasting distribution of lithics in the Tongan state and Samoa–Tutuila corresponds neatly with archaeological expectation. The political center of an expansive maritime polity in southern Tonga contains a high proportion of imported lithics, whereas the prestige products of nucleated adze workshops on Tutuila were widely distributed outside Samoa, including the transport of a large number to the Tonga state. We anticipate that the lithic network in Fig. 4 will be expanded and modified as evidence for prehistoric interaction derived from biological, linguistic, genealogical, and archaeological research, particularly that focused on specialized sites, is acquired.

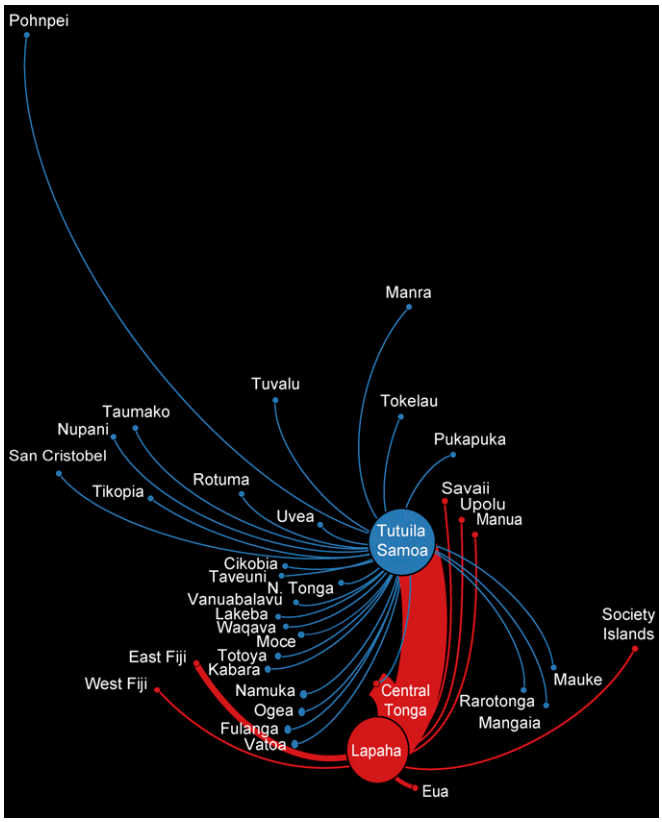

Fig. 4. Central Pacific interaction A.D. 1300–1750 visualized with the Gephi (0.8.1 beta) open-source network analysis program using the GeoLayout function and Winkel tripel projection to illustrate spatial relations. The pattern of adzes-flakes entering the Tongan state (red lines) contrasts with the widespread dispersal of Samoan adzes, especially from quarries on Samoa–Tutuila (blue lines) representing archaeological signatures of a centralized polity and the products of specialized lithic workshops, respectively. Edge weights are numbers of adzes-flakes sourced to a location with Tutuila ($n = 8$) and Samoa unlocalized ($n = 14$) combined (node, "Tutuila Samoa"). The distribution of Samoan adzes in the Pacific is based on previous work (20, 24, 38, 49–55).

Conclusion

Only in Tonga did areal integration under a ruling lineage extend to encompass an entire Pacific archipelago in prehistory. Geochemical analysis of lithics from the Tongan state on Tongatapu demonstrates that although local volcanic sources from within the archipelago were used in tool production, around two-thirds of all adzes-flakes came from other island groups, particularly Samoa and Fiji. The close association of exotic lithics with the royal tombs of the paramount Tui Tonga line illustrates the spatial extent of Tongan leaders' biosocial networks. Elite networks based in part on the exchange of high-status marriage partners in the Central Pacific allowed chiefs to significantly expand their political and economic influence. Regular ceremonial events at Lapaha also concentrated staples and nonlocal valuables that were redistributed as an important source of capital for Tongan elites to maintain and fund a centralized political system dependent on long-distance canoe voyaging. An analysis of prestate lithic transfer shows that interarchipelago connections were a feature of early Tongatapu that intensified with the development of stratified chiefdoms in the second millennium A.D. The import of lithics to the Tongan state and dispersal of Samoan adzes provides archaeological signatures of political centralization and craft specialization, respectively, and demonstrates that a significant consequence of social stratification is the formation of new types of specialized sites in distant geographic areas. Most complex societies in the Pacific only developed in the past 1000 y, and external drivers such as climate change have been proposed to explain the widespread emergence of hierarchically stratified societies (49). However, the lithic networks in Fig. 4 indicate that stratification was accompanied by the development of significant interaction centers in the Central Pacific that had the capacity to transmit information about political organization to many parts of Oceania.

Materials and Methods

Artifact location, site name, estimated site age, lithic type, and sampling are given in Dataset S1 and *SI Appendix*, Tables S3 and S4. "Adze/adze fragments" ($n = 395$) were identified from cross-section attributes or the presence of a recognizable adze portion (no adze quarry production debitage was analyzed; see *SI Appendix*, Table S4). "Flakes" ($n = 21$) were identified by the presence of a bulb of percussion, and "adze-flakes" ($n = 49$) had surface polish/hammer dressing, with the circular shape of several polished flakes indicating heating of adze/adze fragments. "Grave pebbles" (*kilikili*) ($n = 23$) are volcanic water-rolled stones placed on top of burials in Tonga. The "manuport" category ($n = 78$) includes volcanic artifacts brought to Tongatapu, including hammerstones, abraders, grindstones, gaming stones, and cooking stones. Samoan manuports include locally available building material and mound paving stones used in the construction of the Pulemelei Mound on Savaii Island. Reference volcanic samples ($n = 32$) from Samoa, Rotuma, Uvea, and northern Tonga are listed in *SI Appendix*, Table S5.

Sample characterization involved five levels of analysis. First, nonmuseum samples were examined under low-power magnification and divided into informal groups based on grain size, color, and presence and size of inclusions, with 29 selected for thin-section analysis. Descriptions and photographs of thin sections are given in *SI Appendix*, Table S2 and Fig. S7. Second, the complete assemblage ($n = 599$, numbering 567 artifacts and 32 reference samples) was analyzed with pXRF (Dataset S1). Third, outliers and reference and representative group samples in the pXRF results were analyzed with XRF ($n = 62$) and SEM–EDXA ($n = 25$) (Dataset S2). Fourth, trace elements for 87 samples comprising outliers and reference and representative group samples were made with LA–ICP–MS (Dataset S2). Fifth, radiogenic Pb, Sr, and Nd isotope ratios were obtained for two outliers with MC–ICP–MS (*SI Appendix*, Table S1). Description of the regional geology, characterization techniques, and the sample allocation procedure is detailed in *SI Appendix*.

ACKNOWLEDGMENTS. We thank the Nobles of Lapaha the Honorable Kalaniuvalu–Fotofili and Princess Mele Siu'ilikutapu Kalaniuvalu–Fotofili for their assistance and Lord Vaea (Chair of the Tongan Traditions Committee and Minister of Internal Affairs). We are grateful to the Auckland Institute

and Museum, especially Kath Prickett, for access to the Samoa adzes collected by the late Roger Green and Janet Davidson and The Museum of Samoa for permission to analyze lithics from the Pulemelei site. Roland Maas assisted with the radiogenic isotope analyses, and we thank Marshall Weisler and two anonymous reviewers for comments that helped us improve the manuscript. Field work was supported by Australian Research Council Future Fellowship Grant FT0990591 (to G.R.C.) and College of Asia and the Pacific Grant (to C.R.).

1. Aswani S, Graves MW (1998) The Tongan maritime expansion: A case in the evolutionary ecology of social complexity. *Asian Perspect* 37(2):135–164.
2. Kirch PV (1984) *The Evolution of Polynesian Chiefdoms* (Cambridge Univ Press, Cambridge, UK).
3. Petersen G (2000) Indigenous island empires: Yap and Tonga considered. *J Pac Hist* 35(1):5–27.
4. Kirch PV (2010) *How Chiefs Became Kings. Divine Kingship and the Rise of Archaic States in Ancient Hawaii* (Univ of California Press, Berkeley, CA).
5. Hommon RJ (2013) *The Ancient Hawaiian State: Origins of a Political Society* (Oxford Univ Press, New York).
6. Neich R (2006) Pacific voyaging after the exploration period. *Vaka Moana. Voyages of the Ancestors. The Discovery and Settlement of the Pacific*, ed Howe KR (David Bateman Ltd., Auckland, New Zealand), pp 198–245.
7. Blanton RE, Feinman GM, Kowalewski SA, Peregrine PN (1996) A dual-processual theory for the evolution of Mesoamerican civilization. *Curr Anthropol* 37(1):1–14.
8. Earle TK (1997) *Exchange in Oceania: Search for Evolutionary Explanations. Prehistoric Long-Distance Interaction in Oceania: An interdisciplinary Approach, New Zealand Archaeological Association Monograph*, ed Weisler MI (New Zealand Archaeological Association, Auckland, New Zealand), Vol 21, pp 224–237.
9. Clark GR, Martinsson Wallin H (2007) Monumental architecture in Western Polynesia: Origins, chiefs and archaeological approaches. *Archaeology in Oceania* 42(Suppl): 28–40.
10. Kirch PV, Green RC (2001) *Hawaiki, Ancestral Polynesia. An Essay in Historical Anthropology* (Cambridge Univ Press, Cambridge, UK).
11. Kaeppler AL (1978) Exchange patterns in goods and spouses: Fiji, Tonga and Samoa. *Mankind* 11(3):246–252.
12. Orange J (1998) *Narrative of the Late George Vason of Nottingham. One of the Troop of Missionaries First Sent to the South Sea Islands by the London Missionary Society in the Ship DUFF. Captain Wilson 1796* (Taulua Press, Nuku'alofa, Tongatapu).
13. Burley D, Weisler MI, Zhao J-x (2012) High precision U/Th dating of first Polynesian settlement. *PLoS One* 7(11):e48769. doi: 10.1371/journal.pone.0048769.
14. Burley D (2007) Archaeological demography and population growth in the Kingdom of Tonga - 950 BC to the historic era. *Long Term Demographic History in the Pacific Islands*, eds Kirch PV, Rallu J (Univ of Hawaii Press, Honolulu), pp 177–202.
15. Clark GR, Burley D, Murray T (2008) Monumentality in the development of the Tongan maritime chiefdom. *Antiquity* 82(318):994–1008.
16. Clark GR, Reepmeyer C, Stone architecture, monumentality and the rise of the early Tongan chiefdom. *Antiquity*, in press.
17. Clark GR *Social Memory and Langi (Royal Tombs) of Lapaha, Tonga. Monuments and People in the Pacific, Studies in Global Archaeology*, eds Martinsson Wallin H, Thomas T (Uppsala Univ, Uppsala, Sweden).
18. Collerson KD, Weisler MI (2007) Stone adze compositions and the extent of ancient Polynesian voyaging and trade. *Science* 317(5846):1907–1911.
19. Kirch PV, Mills PR, Lundblad SP, Sinton J, Kahn JG (2012) Interpolity exchange of basalt tools facilitated via elite control in Hawaiian archaic states. *Proc Natl Acad Sci USA* 109(4):1056–1061.
20. Clark GR (2002) *Adzes of Interaction: Samoan Basalt Artefacts in Fiji. Fifty Years in the Field: Essays in Honour and Celebration of Richard Shutler Jr's Archaeological Career, New Zealand Archaeological Association Monograph*, eds Bedford S, Sand C, Burley D (New Zealand Archaeological Association, Auckland, New Zealand), Vol 25, pp 227–238.
21. Davidson J (1978) Western Polynesia and Fiji: The archaeological evidence. *Mankind* 11(3):383–390.
22. Renfrew AC (1977) Alternative models for exchange and spatial distribution. *Exchange Systems in Prehistory*, eds Earle TK, Ericson JE (Academic, New York), pp 71–90.
23. Krämer A (1994) *The Samoa Islands. An Outline of a Monograph with Particular Consideration of German Samoa. Volume I. Constitution, Pedigrees and Traditions* (Pasifika Press, Auckland, New Zealand).
24. Winterhoff EH (2007) The political economy of ancient Samoa: Basalt adze production and linkages to social status. PhD dissertation (University of Oregon, Eugene).
25. Hodder I (1982) Toward a contextual approach to prehistoric exchange. *Contexts for Prehistoric Exchange*, eds Ericson JE, Earle TK (Academic, New York), pp 1–12.
26. Burley D, Steadman DW, Anderson A (2004) The volcanic outlier of 'Ata in Tongan prehistory: Reconsideration of its role and settlement chronology. *Journal of New Zealand Archaeology* 25:89–106.
27. White WM, Duncan RA (2000) Geochemistry and geochronology of the Society Islands: New evidence for deep mantle recycling. *Earth Process: Reading the Isotopic Code*, eds Basu A, Hart S, Geophysical monograph (American Geophysical Union, Washington, DC), pp 183.
28. Davidson J (1979) Samoa and Tonga. *The Prehistory of Polynesia*, ed Jennings JD (Harvard Univ Press, Cambridge, MA), pp 82–109.
29. Sand C, Addison DJ (2008) *Archaeology in the Polynesian Homeland: The State of Play at the Beginning of the 21st Century. Recent Advances in the Archaeology of the Fiji/West-Polynesia Region, Studies in Prehistoric Anthropology*, eds Addison DJ, Sand C (Univ of Otago, Dunedin, New Zealand).
30. Poulsen J (1987) *Early Tongan Prehistory* (Department of Prehistory, Research School of Pacific Studies, The Australian National University, Canberra), Vols I and II.
31. Spennemann DHR, Head MJ (1998) Tongan pottery chronology, 14C dates and the hardwater effect. *Quat Geochronol* 17(11):1047–1056.
32. Green RC, Davidson J (1969) Description and classification of Samoan adzes. *Archaeology in Western Samoa. Volume 1, Bulletin of the Auckland Institute and Museum*, eds Green RC, Davidson J (The Auckland Institute and Museum, Auckland, New Zealand), pp 21–32.
33. Green RC, Davidson J (1974) *Archaeology in Western Samoa* (The Auckland Institute and Museum, Auckland, New Zealand), Vol 2.
34. Martinsson Wallin H, Wallin P, Clark GR (2007) Excavations at the Pulemelei mound site. *Archaeology in Oceania* 42(Suppl):41–59.
35. Feinberg R (1998) *Oral Traditions of Anuta: A Polynesian Outlier in the Solomon Islands* (Oxford Univ Press, New York).
36. Geraghty P (1994) *Linguistic Evidence for the Tongan Empire. Language Contact and Change in the Austronesian World, Trends in Linguistics, Studies and Monographs*, eds Dutton T, Tryon D (Mouton de Gruyter, Berlin, Germany).
37. Schmidt H (2003) *Loanword Strata in Rotuman. Language Contacts in Prehistory. Studies in Stratigraphy, Current Issues in Linguistic Theory*, ed Andersen H (John Benjamins Publishing, Amsterdam), pp 201–240.
38. Best S (1984) Lakeba: The Prehistory of a Fijian Island. PhD thesis (Univ of Auckland, Auckland, New Zealand).
39. Clark GR, Anderson A (2009) *Colonisation and Culture Change in the Early Prehistory of Fiji. The Early Prehistory of Fiji, Terra Australis*, eds Clark GR, Anderson A (Australian National University E Press, Canberra, Australia), pp 407–437.
40. Pawley A (1999) Chasing rainbows: Implications for the rapid dispersal of Austronesian languages for subgrouping and reconstruction. *Selected Papers from the Eighth International Conference on Austronesian Linguistics*, eds Zeitoun E, Li PJ [Institute of Linguistics (Preparatory Office), Academia Sinica, Taipei, Taiwan], pp 95–139.
41. Reepmeyer C, Clark GR, Sheppard PJ (2012) Obsidian source use in Tongan prehistory: New results and implications. *Journal of Island & Coastal Archaeology* 7(2):255–271.
42. Weisler MI (2002) Centrality and the collapse of long-distance voyaging in East Polynesia. *Geochemical Evidence for Long-Distance Exchange*, ed Glascock MD (Bergin and Garvey, Westport, CT), pp 257–273.
43. Bott E (1982) *Tongan Society at the Time of Captain Cook's Visits: Discussions with Her Majesty Queen Salote Tupou*, Memoir 44 (The Polynesian Society, Wellington, New Zealand).
44. Gunson N (1979) The *hau* leadership in Western Polynesia. *J Pac Hist* 14(1):28–49.
45. Herda P (2007) The political aspects of marriage in traditional Tonga. *Tonga and the Tongans. Heritage and Identity*, ed Wood-Ellem E (Tonga Research Association Business Print Australia Print Group, Melbourne, Australia), pp 179–193.
46. Thomas J (n.d.) *The Ranks of Chiefs*, Microfilm MLMSS 6228, FM4/1439/48 (ML MSS A1961 Mfm. CY446) [State Library of New South Wales (Mitchell Library), Sydney, Australia].
47. Martin J (1991) *Tonga Islands. William Mariner's Account* (Vava'u Press, Tonga).
48. Helms MW (1993) *Craft and Kingly Ideal. Art, Trade, and Power* (Univ of Texas Press, Austin).
49. Nunn PD (2007) *Climate, Environment and Society in the Pacific During the Last Millennium* (Elsevier, Amsterdam).
50. Kirch PV (1988) *Niuatoputapu: The Prehistory of a Polynesian Chiefdom* (Burke Museum, Seattle).
51. Best S, Sheppard PJ, Green RC, Parker R (1992) Necromancing the stone: Archaeologists and adzes in Samoa. *J Polyn Soc* 101(1):45–85.
52. Allen MS, Johnson KTM (1997) Tracking ancient patterns of interaction: Recent geochemicl studies on the Southern Cook Islands. *Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach*, New Zealand Archaeological Association Monograph, ed Weisler MI (New Zealand Archaeological Association, Otago, New Zealand), pp 111–133.
53. Sheppard PJ, Walter R, Parker RJ (1997) Basalt sourcing and the development of Cook Island exchange systems. *Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach*, New Zealand Archaeological Association Monograph, ed Weisler MI (New Zealand Archaeological Association, Otago, New Zealand), pp 85–110.
54. Di Piazza A, Pearthree E (2001) Voyaging and basalt exchange in the Phoenix and Line archipelagoes: The viewpoint from three mystery islands. *Archaeology in Oceania* 36(3):146–152.
55. Leach BF, Davidson J (2008) *The Archaeology of Taumako: A Polynesian Outlier in the Eastern Solomon Islands* (New Zealand Journal of Archaeology Special Publication, Auckland, New Zealand).