Combined geochemical and geochronological analyses of stone artefacts provide unambiguous evidence of intra- and inter-island interactions in Polynesia

Aymeric Hermann, Lucie Sauzéat, Hervé Guillou, René Maury, Catherine Chauvel, Céline Liorzou, Eric Conte

Title Page

Title:
Combined geochemical and geochronological analyses of stone artefacts provide unambiguous evidence of intra- and inter-island interactions in Polynesia.

Short title:
Combining geochemical and geochronological data for provenance studies of stone artefacts from Polynesia.

Authors affiliation:

1. Aymeric Hermann
Department of Social Science, University of French Polynesia, 98702 Fa'a'ā, French Polynesia; ArScAn, UMR 7041 (CNRS), Maison de l'Archéologie et de l'Ethnologie, 92023 Nanterre, France.

2. Lucie Sauzéat
ISTerre, UMR 5275 (CNRS), Université Grenoble Alpes, 38000 Grenoble, France.

3. Hervé Guillou
Laboratoire des Sciences du Climat et de L'Environnement, UMR8212, LSCE/IPSL, CEA-CNRS-UVSQ, Bat.12, Avenue de la Terrasse, 91198 Gif-Sur-Yvette, France.

4. René C. Maury
Géosciences Océan, UMR 6538 (CNRS), Université de Bretagne Occidentale, 29280 Plouzané, France.

5. Catherine Chauvel
ISTerre, UMR 5275 (CNRS), Université Grenoble Alpes, 38000 Grenoble, France.

6. Céline Liorzou
Géosciences Océan, UMR 6538 (CNRS), Université de Bretagne Occidentale, 29280 Plouzané, France.

7. Eric Conte
CIRAP, University of French Polynesia, 98702 Fa'a'ā, French Polynesia; UMR 7041 ArScAn, Maison de l'Archéologie et de l'Ethnologie, 92023 Nanterre, France.

Corresponding author: A. Hermann, BP 111-180, 98709 Mahina, Tahiti, French Polynesia; Phone no: 00689218611; Email: aymeric.hermann@upf.pf

Keywords: Provenance studies; geochemistry; geochronology; Polynesia; adzes; voyaging

Abstract

Stone tool geochemistry provides hard evidence for post-settlement voyaging and inter-island contacts in East Polynesia. This offers promising information on inter-community exchange networks that are not documented by ethnographic accounts. Drawing on "geochemical fingerprints", provenance studies have slowly integrated geological data in order to better constrain the origin of archaeological material. However, the occurrence of overlapping geochemical signatures within Polynesian islands can cause difficulties when attempting to differentiate sources. Identifying clear geochemical characteristics for each island is therefore critical for a comprehensive understanding of the interaction patterns in East Polynesian societies. In this paper, we combine major and trace element data with isotopes as well as ^{40}Ar-^{39}Ar ages to constrain the local procurement networks that were occurring on the island of Tupua'i (Austral-Cook chain). We also demonstrate that some Tupua'i archaeological material originated from Eiao Island (Marquesas chain) circa 2,000 km north. This represents the first hard evidence for inter-island connections between the Austral and the Marquesas Archipelagos.

Highlights

- New geochronological technique used to establish the provenance of stone artefacts
- Combining geochemistry and geochronology improves sourcing of basaltic artefacts
- A geological setting for Central Eastern Polynesia is defined
- Procurement networks for adze production in Tupua'i (Austral Islands) are described
- Long-distance exchange is evidenced between the Marquesas and the Austral Islands

1. Introduction

The long-distance transfer of prestige goods was an important aspect of the mobility between Pacific islands societies before European contact (Green and Kirch, 1997; Weisler, 1997). Based on geochemical sourcing, it has been possible to identify exotic commodities in archaeological sites and therefore to document wide-scale inter-community interactions during and after the colonization period, in both the western Pacific and eastern Polynesia (see Hermann, 2015 for a review).

Geochemical analysis of stone artefacts has been increasingly used in the last 20 years in order to document inter-island and inter-archipelago transfers of stone tools in Central Eastern Polynesia (CEP), where long-distance interactions during the first few centuries after East Polynesian colonization have been widely documented (e.g. McAlister et al., 2014; Weisler and Kirch, 1996; Weisler, 1997, 1998, 2002; Weisler et al., 2016a). Ethnographic accounts do not provide information on long-distance exchange in East Polynesia because these interactions date from a remote period of history. Therefore, only a comprehensive and high-precision examination of stone artefacts involving all required geochemical and geochronological analysis can allow for a proper reconstruction of ancient interaction patterns in CEP.

Focusing on stone artefacts from several archaeological sites on Tupua'i Island (Austral-Cook chain), we present a detailed provenance analysis based on two specific aims: (1) documenting intra-island movement of raw material as a part of local procurement strategies and adze production processes, and (2) providing evidence for inter-island transfers of artefacts.

2. Geological setting and source discrimination in Polynesia

In CEP, provenance analyses of stone tools were first based on petrographic features (Weisler, 1993), then on major and trace element compositions (Mills et al., 2010; Kirch et al., 2012; Kahn et al., 2013; McAlister et al., 2014; Rolett et al., 2015; Walter and Sheppard, 1996; Weisler and Kirch, 1996; Weisler, 1998, 2002), and more recently on Sr, Nd and Pb isotopic ratios (Collerson and Weisler, 2007; Weisler et al., 2016a; Weisler and Woodhead, 1995; Woodhead and Weisler, 1997). **Except for the above isotopic analyses, most** sourcing studies have focused on quarry sites in order to trace the origin of archaeological artefacts. However, we argue here that provenance studies of stone artefacts must rely on the acquisition of wide and reliable geological data related to this specific geological setting, as most prehistoric quarries in Polynesian islands have yet to be identified. Further complicating matters, several Polynesian islands show similar geochemical characteristics, while others exhibit different but partly overlapping geochemical signatures (Chauvel et al., 1992; Chauvel et al., 2012; White and Duncan, 1996; Zindler and Hart, 1986). One must therefore examine the temporal and geochemical evolution of each island chain in order to constrain the origin of specific basaltic material.

The islands of CEP are distributed across four linear chains (Austral-Cook, Pitcairn-Gambier, Society and the Marquesas) spreading over a large part of the South Pacific Ocean due to the Pacific Plate motion towards the NW (Fig. 1). Corresponding hotspots are located underneath young volcanoes at the south-eastern tip of each archipelago. Over the last 20 years, a systematic program of detailed geological mapping, associating geochemical and age data, was conducted in French Polynesia by the National institute for geological survey (Bureau de Recherches Géologiques et Minières). This led to considerably better characterizations of intra- and inter-island petrologic, geochemical, and age variations in the Austral (Chauvel et al. 1997; Maury et al., 2013; Maury et al., 2014a), Gambier (Delavault et al., 2015), Society (Cordier et al., 2016; Guillou et al., 2005) and Marquesas Islands (Chauvel et al., 2012; Guillou et al., 2014; Maury et al., 2014b).

Major element compositions are variable both within a given island and between different islands. The total alkali/silica diagram (**SiO_2 versus K_2O+Na_2O**) provides a useful classification of igneous rocks, from mafic to felsic and from tholeiitic to silica-undersaturated, and these petrographic groups are often specific to volcanic edifices or periods of magma emplacement. TAS classification can be combined with TiO_2 versus MgO plots in order to identify geochemical variations within volcanic edifices, and therefore discriminate a number of localities as potential sources of rock supply.

Trace element variations can also be used to differentiate different geological units that share the same petrographic characteristics. As summarized by Dupuy et al. (1989), Polynesian lavas display selective enrichments in incompatible elements: alkali and alkali earth elements (K, Rb, Ba, Sr) as well as high field strength elements (Nb, Zr, Ti, Hf) and light rare earth elements (La, Ce, Nd). Consequently, trace element data combined with major element data can be used to assign artefacts to a geological source at a restricted geographical scale, typically within an island or a specific volcanic edifice.

Plume-related basalts have been documented as chemically and isotopically heterogeneous because of the dynamic evolution of the mantle over time (White and Duncan, 1996; Chauvel et al., 1992; Chauvel et al., 2012; Delavault et al., 2015). Four main geochemical mantle end-members, characterized by specific isotopic compositions, have been identified in CEP islands. The HIMU (High ^{238}U/^{204}Pb) signature, characterized by low ^{87}Sr/^{86}Sr and very high ^{206}Pb/^{204}Pb, is found in lavas from Ra'ivavae, Tupua'i, Rurutu and Mangaia. The EM (Enriched Mantle) signatures, defined by higher ^{87}Sr/^{86}Sr ratios and lower ^{143}Nd/^{144}Nd, Nb/Th and Ta/La ratios (White and Duncan, 1996; Chauvel et al., 1992), are present in the source of Rarotonga and Pitcairn volcanics as EM1 (Enriched Mantle type I), while EM2 (Enriched Mantle type II) dominates that of most Society and Marquesas islands (Zindler and Hart, 1986; White and Duncan, 1996; Chauvel et al., 1992). Compared to EM2, EM1 shows even lower ^{87}Sr/^{86}Sr and ^{143}Nd/^{144}Nd ratios together with rather low ^{206}Pb/^{204}Pb. The identification of such isotopic signatures provides obvious information for provenance analysis.

Moreover, most Polynesian archipelagos show correlations between island ages and corresponding distances to the presumed hotspot area located at the SE end of the volcanic chain (Delavault et al., 2015; Maury et al., 2013; Maury et al., 2014; Guillou et al., 2005; Guillou et al., 2014; Turner and Jarrard, 1982; Guillou et al., 1994). As a result, the general age progression along volcanic chains provides another variable that can be used for source discrimination. Hence our use of geochronological analyses to further constraint exotic sources and identify the provenance of stone artefacts from archaeological contexts.

3. The study site: Tupua'i (Tubuai) Island, Austral-Cook chain

Tupua'i (23º23'00"S, 149º27'00"W), together with Mangaia (Southern Cook chain), is well known for the unusual 'HIMU' isotopic signature of its lavas, which display very high ^{206}Pb/^{204}Pb ratios (Maury et al., 2013; Vidal et al., 1984). The island was mapped between 1989 and 1995 by the BRGM team (Maury et al., 1994; Maury et al., 2000; Maury et al., 2013). Three types of basalt rocks (alkali basalts, basanites and nephelinites) and three types of intermediate lavas (basanitic tephrites, tephrites and peralkaline phonolites) were emplaced between 10.04 and 8.77 Ma. Such a relatively high-resolution geological study allows us to postulate that local sources are well constrained on the island. Additionally, several quarry sites, including the Tanataetea site, have been identified as possible sources of fine-grained basalt procurement (Hermann et al., 2012; Hermann, 2013, 2016).

The archaeological material examined in this paper consists of 48 samples, including 23 surface-collected artefacts from quarries and domestic or ceremonial sites, and 25 artefacts from the Atiahara site, located at the north coast of Tupua'i (Table 1, Fig. 2). This well-stratified site consists of a succession of 4 cultural layers and 3 sterile sand deposits of aeolian and marine origin. The cultural sequence corresponds to a succession of four domestic occupations that were dated between AD 1215 and 1390 based on radiocarbon dates on wood charcoal (Hermann et al., 2015). In total, the Atiahara assemblage includes 43 polished adzes, 75 preformed and recycled adzes, and more than 2,600 flake wastes and flake tools distributed over a total excavated area of 216 m^2 (Hermann, 2013, 2016). Based on macroscopic observation of artefacts, we consider that the 25 samples submitted for geochemical analyses represent the diversity of exploited raw material on the site.

4. Material and methods

Major and trace elements were measured by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) for 48 samples at PSO/IUEM (Plouzané, France): 25 from the Atiahara site, 16 from surface sites, and 7 from quarry sites and outcrops. The list and locations of the archaeological and geological samples are shown in Table 1. Eight samples were then selected for Sr and Pb isotopic analyses: 3 artefacts from deep layers of the Atiahara site (At3-229-064, At3-317-065 and At3-395-066), 2 geological samples from Tupua'i quarries (Tan1-006 and Pahatu8-059), and 3 geological samples from Mangaia (Cook Is.) collected by P.V. Kirch in the valleys of Mata'are, Veitatei and Keia (Table 1). Sr isotopes were analysed by Thermo Scientific Triton Mass Spectrometer (TIMS) at PSO/IUEM (Plouzané, France) and Pb isotopes were determined using a Nu Plasma Multicollector - Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS) at the ENS Lyon (France). Finally, one Mata'are quarry sample from Mangaia and two adzes from Atiahara (At3-229-064 and At3-317-065) were dated by the 40Ar/39Ar method at LSCE. Further details on analytical procedures are described in Supplementary Data - Appendix A.

5. Results

5.1. Major and trace element analysis

Major and trace element data from artefacts, quarries, and geological outcrops in Tupua'i, with additional data from other islands of the Austral-Cook chain (Mangaia, Ra'ivavae, Rapa Iti) and the Marquesas (Eiao) are shown in Tables 2 and 3. In Tupua'i, three types of basalt rocks (alkali basalts, basanites and nephelinites) and related intermediate lavas (tephrites) share the same silica-undersaturated and incompatible element-enriched signature typical of many Polynesian ocean island basalts (Dupuy et al., 1989). Their genesis is ascribed to low partial melting degrees of enriched mantle that decrease from alkali basalts to nephelinites (Caroff et al., 1997). Lavas from Tupua'i and the Mata'are quarry in Mangaia (Cook archipelago) display depletions in Rb, Ba, Th and K relative to Nb, La and Ce (Fig. 4c). This is considered characteristic of an HIMU affinity (Chauvel et al., 1992; Chauvel et al., 1997).

Almost all archaeological artefacts share the petrographic and geochemical features of Tupua'i lavas. The samples were clustered in 6 groups and associated with different possible sources based on petrographic groups and TiO_2-MgO plots (Fig. 3).

- Clusters 1 and 2 match the fine-grained basanites found at the Tanataetea quarry and analysed as samples Tan3-005 and Tan1-006 (Table 2 and 3; Fig. 4a and 4b).
- Cluster 3 corresponds to a peculiar group of basanites that are petrographically characterized by the presence of recrystallized olivines and a dark green colour on polished surfaces. The source of this rock remains uncertain at this stage, as several lava flows in the Austral-Cook chain display the same trace element patterns, including RV-11, RV-27 and RV-35 on mount Rairua in Ra'ivavae (Maury et al., 2013), at Mata'are quarry in Mangaia, and TB-3 on Rereti'i ridge in Tupua'i (Table 2 and 3; Fig. 4c). A rock sample from adze At3-229-064 was therefore selected for further isotopic analyses in order to constrain the geological origin of these artefacts.
- Clusters 4 and 5 are tephritic rocks similar to those found in several locations on Herani volcano in Tupua'i, including geological samples TB-137 and TB-243 (Table 2 and 3; Fig. 4d and 4e).
- Cluster 6 corresponds to sample At3-317-065, which has been identified as an alkali basalt adze fragment (Table 2). This aphyric rock is very different from highly porphyritic alkali basalts from the oldest Tupua'i volcanic edifice and does not show the typical features of HIMU-derived Tupua'i lavas. Its major and trace element compositions are very similar to those of Eiao Island (Marquesas) artefacts and uppermost alkali basalts that derive from a dominantly EM2 mantle source and display relatively smooth enrichments in the most incompatible elements (Table 3; Fig. 4f; Caroff et al., 1995; Charleux et al., 2014).

5.2. Sr and Pb isotope analysis

The Sr and Pb isotopic compositions of the geological samples collected in Tupua'i quarry sites and of most artefacts except sample At3-317-065 show obvious similarities with previous data published for the island (Fig. 5, Chauvel et al. 1992; Maury et al., 2013; Schiano et al., 2001). Two of the adzes collected in the Atiahara site (At3-229-064 and At3-395-066, Table 4) show lead and strontium isotopic compositions consistent with Tupua'i lavas: an average of $^{87}Sr/^{86}Sr = 0.702804 \pm 0.000008$ (2σ)

and $^{208}Pb/^{204}Pb$ = 40.1638 ± 0.0020 (2σ) for sample At3-229-064, and an average of $^{87}Sr/^{86}Sr$ = 0.702797 ± 0.000008 (2σ) and $^{208}Pb/^{204}Pb$ = 40.261498 ± 0.0023 (2σ) for sample At3-395-066. These values are very close to the average compositions of Tupua'i island: $^{87}Sr/^{86}Sr$ = 0.702840 ± 0.000225 (2σ) and $^{208}Pb/^{204}Pb$ = 40.2249 ± 0.5828 (2σ) (Fig. 5). In contrast, adze At3-317-065 shows a lesser radiogenic Pb composition, with an average of $^{208}Pb/^{204}Pb$ = 38.9991 ± 0.0020 (2σ) and is more radiogenic in Sr with an average of $^{87}Sr/^{86}Sr$ = 0.703922 ± 0.000008 (2σ) (Table 4, Fig. 5). Interestingly, this sample shares isotopic similarities with both Rapa Iti in the Australs and Eiao in the Marquesas (Table 4, Fig. 6). Therefore this sample was dated by the ^{40}Ar-^{39}Ar method to better constrain its origin.

5.3. Geochronology

^{40}Ar-^{39}Ar plateau ages, isochron ages, and total fusion ages are given in Table 5 and Appendix C. The isochron ages are considered more reliable than the plateau ages because the isochron approach makes no assumption regarding the trapped component, and it combines estimates of analytical precision and internal disturbance of the sample (scatter around the isochron).

The plateau age of the mildly altered Mata'are sample (Mangaia, Cook Is.), calculated from 7 steps out of 10 with 78.8% of the gas released, is 20.17 ± 0.63 Ma. This coincides with the isochron age of 20.03 ± 0.66 Ma that we retained to take into consideration the non-atmospheric value of the $^{40}Ar/^{36}Ar$ intercept, which may indicate subtle excess $^{40}Ar^*$ (Table 5). This data fits a previously measured K-Ar age for Mangaia, the oldest high island in the CEP (19.3 ± 0.6 Ma; Turner and Jarrard, 1982; Fig. 7).

The age spectra of adze At3-229-064 demonstrate an exponential decrease from high ages at low temperature steps to the age plateau, which correlates with an increase of the K/Ca ratio. The plateau age, calculated from 6 out of 10 steps (i.e. 60% of the gas released), is 10.32 ± 0.32 Ma; equivalent to the total fusion age (10.41 ± 0.30 Ma) and the isochron age of 10.30 ± 0.32 Ma. This age fits the previously known range of activity of Tupua'i (10.04-8.77 Ma by the unspiked K-Ar method; Maury et al., 2000; Fig. 7), further demonstrating the local origin of this artefact.

The plateau age of adze At3-317-065 is calculated from 10 out of 11 steps corresponding to the 81% of the gas released. This plateau age (5.61 ± 0.21 Ma) is equivalent to the isochron age (5.68 ± 0.24 Ma) and to the total fusion age (5.59 ± 0.21 Ma). Available K-Ar ages for Eiao Island (5.52-4.98 Ma; Guillou et al., 2014) fit that of Atiahara adze sample At3-317-065 (Fig. 7), while those of Rapa Iti lavas are younger (4.8-4.1 Ma; Maury et al., 2013). Furthermore, other contemporaneous volcanoes in the Gambier (6.26-5.66 Ma; Delavault et al., 2015; Guillou et al., 1994) and in Ra'ivavae of the Australs (10.6-5.4 Ma; Lassiter et al., 2003; Maury et al., 2013) have clearly different isotopic characteristics (Figs. 5 and 6). Therefore, this age result corroborates the geochemical evidence for an exotic origin of adze At3-317-065 from Eiao (Marquesas), circa 2,000 km north of Tupua'i.

6. Discussion

6.1. Assessing geological provenances without ambiguity

Archaeometric studies of stone tool assemblages provide major insights for tracing patterns of mobility within and between Pacific islands. Previous work has shown that Sr, Nd and Pb isotopic data used together with major and trace element data permits assignment of artefacts to sources, because they provide additional constraints on their geochemical signatures (Collerson and Weisler, 2007; Hermann, 2013, 2016; Weisler et al., 2016a).

However, even the entire set of information available through rock chemistry (element and isotope analysis) can be insufficient to properly discriminate islands of origin. This is due to similar rock types arising across CEP islands, but also to trace element patterns and isotopic compositions both overlapping between different islands, as we show for Eiao and Rapa iti, as well as for Mangaia and Tupua'i (Figs. 4, 5 and 6). In such cases, we argue that cross-referencing isotopic and geochronological data can provide enough proxies to unambiguously assign a source to a given artefact (Fig. 7). For instance, a strong HIMU geochemical signature and an age circa 20 Ma would readily identify any artefact or raw basalt as originating from Mangaia Island, because these two characteristics combined have no known equivalent in Polynesia. Associating ^{40}Ar-^{39}Ar (which can be performed on a 120 mg sample, see Supplementary Data - Appendix A) with major, trace elements and Sr, Nd, Pb isotopic analysis therefore proves to be the most accurate way to constrain stone artefact provenance in intraplate volcanic islands of the Pacific. **Due to the time consuming irradiation of the samples by specific nuclear reactors (as described in Appendix A), Ar-Ar dating cannot be used routinely in provenance studies, but can be used to solve particular issues of source-assignment. For example, Ar-Ar dating would help separate possible Tupua'i-sourced artefacts from Mangaian ones in the Tangatatau site recently discussed by Weisler and colleagues (2016a).**

6.2. Local procurement strategies and adze production process

Major and trace element data show a clear clustering of the geological samples collected in Tupua'i, **which corresponds to the geochemical variability previously identified for the island (Maury et al., 1994; Maury et al., 2000; Maury et al., 2013). We identify several local procurement sources of basanite, tephrite and phonolite, including the previously undocumented Pahatu and Tanataetea quarries. Most of the artefacts collected in domestic contexts were made-up of basanites from the Tanataetea quarry and the Panee area, as well as of tephrites from the Herani volcano.**

The distribution of flaked basalt boulders or dykes, adze preforms, and knapping wastes (flakes and discarded blanks) within the island suggests an organized form of adze production**,** in quarries and procurement areas on one hand, and in coastal settlements on the other. It has been shown that stone knapping activities involved both specialized craftsmen working in permanent workshops in the vicinity of fine-grained basalt quarries of Tanataetea and Pahatu (Fig. 2) and non-specialists within domestic contexts like the Atiahara site (Hermann, 2013, 2016, in press). Additionally, the Atiahara site assemblage shows uneven distribution of fine-grained basalt and difficult access to good-quality raw material, which can be interpreted as an aspect of the control by pre-European social elites over local valued resources.

6.3. Inter-archipelago transfers of artefacts: a Marquesas-Australs connection

Our identification of an Eiao adze (At3-317-065) within the Atiahara site in Tupua'i is the first hard evidence of a link between the Marquesas and the Austral Islands soon after the settlement of CEP by Polynesian communities. This provides new insights into the potential scale of ancient long-distance interaction in the region.

This artefact was associated with the layer 3, which has been dated to the second half of the 14th century (1345-1395 cal. AD; Hermann et al., 2015). Nonetheless, this adze show obvious maintenance before it has been discarded and recycled as a wedging stone in the filling of a posthole. Thus, it is possible that this valuable object was acquired by Tupua'i people prior to this date and was then later transferred to the Atiahara residential area. In either case, the chronological context associated with the adze fits our current understanding that long-distance interactions were active in CEP at least until the 15th century AD.

7. Conclusion

Long-distance transfers of stone adzes in Central Polynesia were first interpreted in the terms of independent "interaction spheres" in CEP (Rolett, 2002; Weisler, 1998, 2002). To the contrary, our data and a number of more recent studies (Clark et al., 2014; Collerson and Weisler, 2007; McAlister et al., 2014; Weisler et al., 2016a) indicate that early inter-archipelago interactions extended beyond the limits of restricted regions.

Furthermore, we provide a clear chronological context for an adze imported from Eiao to Tupua'i. This directly corresponds to Weisler et al.'s (2016a) recent call for more stratigraphic sequences with imported material as necessary for better understanding the nature and the evolution of early inter-community interactions in CEP.

Additionally, our methods described here demonstrate that an integrated use of geological data in provenance studies help to unambiguously assign a source to a given artefact, and thus to refine current understanding of the spatial extent of adze production processes and inter-community exchange systems among Eastern Polynesian chiefdoms.

Acknowledgments

Archaeological fieldwork in Tupua'i and geochemical analysis formed part of A. Hermann's doctoral dissertation research and were carried out with financial support from the Université de Polynésie française and the Centre International de Recherche Archéologique en Polynésie. Special thanks to Prof. Manuel Moreira, and the Geochemistry and Cosmochemistry Laboratory at Institut de Physique du Globe de Paris for facilitating the preparation of archaeological samples. Additional thanks to Prof. Pat Kirch for providing the Mangaian samples and for his useful comments on an earlier version of this paper. A.H. and R.C.M. performed fieldwork in Tupua'i; A.H., L.S., H.G. and C.L. performed analytical research; A.H., L.S., H.G., R.C.M. and C.C. analysed data and wrote the paper. **Finally, we wish to acknowledge the helpful comments by the two anonymous reviewers.**

References

Caroff M, Maury RC, Vidal Ph, Guille G, Dupuy C, Cotten J, Guillou H, Gillot PY (1995) Rapid temporal changes in Ocean Island Basalt composition: evidence from a 800 m-deep drill hole in Eiao shield (Marquesas). J Petrol 36 (5): 1333-1365, doi: 10.1093/petrology/36.5.1333.

Caroff M, Maury RC, Guille G, Cotten J (1997) Partial melting below Tubuai (Austral islands, French Polynesia). Contri Mineral Petrol 127: 369-382, doi: 10.1007/s004100050286.

Caroff M, Guillou H, Lamiaux M, Maury RC, Guille G, Cotten J (1999) Assimilation of ocean crust by hawaiitic and mugearitic magmas: An example from Eiao (Marquesas).

Lithos 46(2): 235-258, doi: 10.1016/S0024-4937(98)00068-1.

Charleux M, McAlister A, Mills PR, Lundblad SP (2014) Non-destructive XRF Analyses of Fine-grained Basalts from Eiao, Marquesas Islands. J Pac Archaeol, 5(1): 75-89.

Chauvel C, Hofmann AW, Vidal P (1992) HIMU-EM: The French Polynesian connection. Earth Planet Sci Lett 110: 99-119, doi: 10.1016/0012-821X(92)90042-T.

Chauvel C, McDonough W, Guille G, Maury RC, Duncan R (1997) Contrasting old and young volcanism in Rurutu Island, Austral Chain. Chem Geol 139: 125-143, doi: 10.1016/S0009-2541(97)00029-6.

Chauvel C, Maury RC, Blais S, Lewin E, Guillou H, Guille G, Rossi P, Gutscher MA (2012) The size of plume heterogeneities constrained by Marquesas isotopic stripes. Geochem Geophys Geosys 13, doi: 10.1029/2012GC004123.

Clark GR, Reepmeyer C, Melekiola N, Woodhead J, Dickinson WR, Martinsson-Wallin H (2014) Stone tools from the ancient Tongan state reveal prehistoric interaction centers in the Central Pacific. Proc Natl Acad Sci USA 111(29): 10491- 10496, doi: 10.1073/pnas.1406165111.

Collerson KD, Weisler MI (2007) Stone adze compositions and the extent of ancient Polynesian voyaging and trade. Science 317 (5846): 1907-1911, doi: 10.1126/science.1147013.

Dalrymple GB, Jarrard RD, Clague DA (1975) K-Ar ages of some volcanic rocks from the Cook and Austral Islands. Geol Soc Amer Bull 86(10): 1463-1467, doi:10.1130/0016-7606(1975)86<1463:KAOSVR>2.0.CO;2.

Cordier C, Chauvel C, Hémond C (2016) High-precision lead isotopes and stripy plumes: revisiting the Society chain in French Polynesia. Geochim Cosmochim Acta 189: 236-250, doi: 10.1016/j.gca.2016.06.010.

Delavault H, Chauvel C, Sobolev A, Batanova V (2015) Combined petrological, geochemical and isotopic modeling of a plume source: Example of Gambier Island, Pitcairn chain. Earth Planet Sci Lett 426: 25-35. doi: 10.1016/j.epsl.2015.06.013.

Diraison C (1991) Le volcanisme aérien des archipels polynésiens de la Société, des Marquises et des Australes-Cook. Téphrostratigraphie, datation isotopique et géochimie comparées. PhD à l'Université de Bretagne Occidentale, Brest, 413 p.

Duncan RA, McCulloch MT, Barsczus HG, Nelson DR (1986) Plume versus lithospheric sources for melts at Ua Pou, Marquesas Islands. Nature 322: 534-538.

Dupuy C, Barsczus HG, Dostal J, Vidal P, Liotard JM (1989) Subducted and recycled lithosphere as the mantle source of ocean island basalts from southern Polynesia, central Pacific. Chem Geol 77: 1-18, doi: 10.1016/0009-2541(89)90010-7.

Green RC, Kirch PV (1997) Lapita exchange systems and their Polynesian transformations: Seeking explanatory models. Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach, ed Weisler MI (New Zealand Archaeological Association, Otago, New Zealand), Monograph 21, pp. 19-37.

Guillou H, Gillot PY, Guille G (1994) Age (K-Ar) et position des îles Gambier dans l'alignement du point chaud de Pitcairn (Pacifique Sud). CR Acad Sci II, 318: 635-641.

Guillou H, Maury RC, Blais S, Cotten J, Legendre C, Guille G, Caroff M, (2005) Age progression along the Society hotspot chain (French Polynesia) based on new unspiked K-Ar ages. Bull Soc Géol France 176: 135-150, doi: 10.2113/176.2.135.

Guillou H, Maury RC, Guille G, Chauvel C, Rossi Ph, Pallares C, Legendre C, Blais S, Liorzou C, Deroussi S (2014) Volcanic successions in Marquesas eruptive centers: a departure from the Hawaiian model. J Volcanol Geotherm Res 266: 173-188, doi: http://10.1016/j.jvolgeores.2013.12.003.

Hermann A (2013) Les industries lithiques pré-européennes de Polynésie centrale: Savoir-faire et dynamiques techno-économiques. PhD dissertation (University of French Polynesia, Papeete, French Polynesia).

Hermann A (2015) Dynamique de peuplement et évolution des réseaux d'échange à longue distance en Océanie. Les systèmes de mobilité de la Préhistoire au Moyen Age, eds Naudinot N, Meignen L, Binder D (XXXV International Meeting of Archaeology end History, Antibes: APDCA), pp 109-125.

Hermann A (2016) Production et échange des lames d'herminette en pierre en Polynésie centrale: les dynamiques techno-économiques dans l'île de Tubuai (Archipel des Australes). La pratique de l'espace en Océanie: Découverte, appropriation et émergence des systèmes sociaux traditionnels, eds Valentin F, Molle G (Séance de la Société Préhistorique Française, Paris: INHA), pp 205-221.

Hermann A, Bollt R, Conte E (2016) The Atiahara Site Revisited: An Early Coastal Settlement in Tubuai (Austral Islands, French Polynesia). Archaeol Ocean 51 (1): 31-44, doi: 10.1002/arco.5070.

Hermann A, Maury RC, Liorzou C (2012) Traçabilité des matières premières lithiques dans les assemblages archéologiques polynésiens: le cas de Tubuai (Archipel des Australes, Polynésie française). Géologues 173: 80-83.

Hermann A, Stone adzes production in Tubuai (Austral islands, French Polynesia): Specialization in a changing chiefdom of Central Eastern Polynesia. J Lithic Studies, in press.

Kahn JG, Sinton J, Mills PR, Lundblad SP (2013) X-ray fluorescence analysis and intra-island exchange in the Society Island Archipelago (Central Eastern Polynesia). J Archaeol Sci 40: 1194-202, doi: 10.1016/j.jas.2012.10.003.

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, doi: 10.1073/pnas.1119009109.

Lassiter JC, Blichert-Toft J, Hauri EH, Barsczus HG (2003) Isotope and trace element variations in lavas from Raivavae and Rapa, Cook-Austral Islands: constraints on the nature of HIMU- and EM-mantle and the origin of mid-plate volcanism in French Polynesia. Chem Geol 202: 115-138, doi: 10.1016/j.chemgeo.2003.08.002.

Liotard JM (1988) Contribution au problème de l'origine des basaltes alcalins: fractionnement haute pression, caractérisation des zones sources, comparaison entre domaine océanique (Polynésie française) et domaine continental, Hoggar algérien, Massif central français. PhD dissertation (University of Montpellier 2).

Maury RC, El Azzouzi M, Bellon H, Liotard JM, Guille G, Barsczus HG, Chauvel C, Diraison C, Dupuy C, Vidal Ph, Brousse R (1994) Géologie et pétrologie de l'île de Tubuai (Australes, Polynésie française). CR Acad Sci Paris II, 318: 1341-1347.

Maury RC, Guille G, Guillou H, Blais S, Brousse R (2000) Notice explicative, Carte Géol France, feuille Rurutu et Tubuai, Polynésie française 1154 (Orléans: BRGM), 81 pp.

Maury RC, Guille G, Guillou H, Chauvel C, Rossi Ph, Pallares C, Legendre C (2013) Temporal evolution of a Polynesian hotspot: New evidence from Raivavae (Austral Islands, South Pacific Ocean). Bull Soc Géol France 184: 385-395.

Maury RC, Legendre C, Chauvel C, Guille G, Blais S, Guillou H, Rossi P (2014a) Geology of the Austral Islands: An atypical hotspot chain. Terrestrial Biodiversity Austral Islands, French Polynesia, ed Meyer JY, Claridge EM (MNHN, Paris), pp 21-37.

Maury RC, Guille G, Guillou H, Chauvel C, Legendre C, Rossi P, Blais S, Pallares C, Deroussi S, Marabal AM (2014b) Géologie des Marquises: des volcans boucliers intra-océaniques effondrés issus d'un point chaud atypique. Géol France 1: 111-135.

McAlister A, Sheppard PJ, Allen MS (2014) The Identification of a Marquesan Adze in the Cook Islands. J Polyn Soc 122(3): 257-274.

Mills PR, Lundblad SP, Field JS, Carpenter AB, McElroy WK, Rossi P (2010) Geochemical sourcing of basalt artefacts from Kaua'i, Hawaiian Islands. J Archaeol Sci 37: 3385-3393.

Palacz ZA, Saunders AD (1986) Coupled trace element and isotope enrichment in the Cook-Austral-Samoa islands, Southwest Pacific. Earth Planet Sci Lett 79 (3-4): 270-280.

Rolett BV (2002) Voyaging and interaction in Ancient East Polynesia. Asian Persp 41(2): 182-194.

Rolett BV, West E, Sinton J, Iovita R (2015) Ancient East Polynesian voyaging spheres: new evidence from the Vitaria Adze Quarry (Rurutu, Austral Islands). J Archaeol Sci 53: 459-471, doi: 10.1016/j.jas.2014.10.018.

Schiano P, Burton KW, Dupré B, Birck JL, Guille G, Allègre CJ (2001) Correlated Os-Pb-Nd-Sr isotopes in the Austral-Cook chain basalts: the nature of mantle components in plume sources. Earth Planet Sci Lett 186: 527-537, doi: 10.1016/S0012-821X(01)00265-5.

Sun SS, McDonough WF (1989) Chemical and isotopic systematics of oceanic basalts: implication for mantle composition and processes. Geological Society Special Publication, Vol. 42, Magmatism in the Ocean Basins, eds Saunders AD, Norry MJ (London: Blackwell), pp. 313–345.

Turner DL, Jarrard RD (1982) K/Ar dating of the Cook-Austral island chain: a test of the hot-spot hypothesis. J Volcanol Geoth Res 12: 187-220, doi: 10.1016/0377-0273(82)90027-0.

Vidal P, Chauvel C, Brousse R (1984) Large mantle heterogeneity beneath French Polynesia. Nature 307: 536-538, doi: 10.1038/307536a0.

Walter RK, Sheppard PJ (1996) The Ngati Tiare adze cache: Further evidence of prehistoric contact between west Polynesia and the southern Cook Islands. Archaeol Ocean 30: 47-65, doi: 10.1002/j.1834-4453.1996.tb00344.x.

Weisler MI (1993) Provenance studies of Polynesian basalt adze material: A review and suggestions for improving regional databases. Asian Persp 32: 61-83.

Weisler MI (1997) Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach. N.Z. Archaeol. Assoc. Monograph, 21, 238 pp.

Weisler MI (1998) Hard evidence for prehistoric interaction in Polynesia. Curr Anthropol 39(4): 521-532, doi: 10.1086/204768.

Weisler MI (2002) Centrality and the collapse of long-distance voyaging in East Polynesia. Geochemical Evidence for Trade and Exchange, ed Glascock MD (Bergin and Garvey, Westport, CT), pp. 257–273.

Weisler MI, Kirch PV, Endicott JM (1994) The Mata'are basalt source: Implications for prehistoric interaction studies in the Cook Islands. J Polyn Soc 103(2): 203-216.

Weisler MI, Woodhead JD (1995) Basalt Pb isotope analysis and the prehistoric settlement of Polynesia. Proc Natl Acad Sci USA 92: 1381-1385, doi: 10.1073/pnas.92.6.1881.

Weisler MI, Kirch PV (1996) Interisland and interarchipelago transfer of stone tools in prehistoric Polynesia. Proc Natl Acad Sci USA 93(4): 1381-1385.

Weisler MI, Bolhar R, Ma J, St Pierre E, Sheppard P, Walter RK, Feng YX, Zhao JX, Kirch PV (2016a) Cook Island artefact geochemistry demonstrates spatial and temporal extent of pre-European interarchipelago voyaging in East Polynesia. Proc Natl Acad Sci USA, doi: 10.1073/pnas.1608130113.

Weisler M, Bolhar R, Charleux M, Faith JT, Feng YX, St Pierre E (2016b) Determining geochemical variability of fine-grained basalt sources/quarries for facilitating prehistoric interaction studies in Polynesia. Archaeol Ocean, doi: 10.1002/arco.5088.

White WM, Duncan RA (1996) Geochemistry and Geochronology of the Society Islands: New Evidence for Deep Mantle Recycling. Geophys. Mon. 95, pp. 183-206, doi: 10.1029/GM095p0183.

Woodhead JD, Weisler MI (1997) Accurate sourcing of basalt artefacts by radiogenic isotope analysis. Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach, ed Weisler MI (New Zealand Archaeological Association, Otago, New Zealand), Monograph 21, pp. 212-223.

Zindler A, Hart SR (1986) Chemical geodynamics. Earth Planet Sci 14: 493-571, doi: 10.1146/annurev.ea.14.050186.002425

Figure Legends

Fig. 1: Bathymetric map of Central Eastern Polynesia showing its linear island chains and the - 4,000 m isobath. The names of the islands discussed in this paper (Tupua'i, Mangaia, Eiao, Rapa Iti) are in bold characters and their age spans in italics. Hotspot locations are shown as red empty circles.

Fig. 2: **Geological map of Tupua'i (modified from Maury et al., 2000)** showing numbered archaeological samples (red crosses) collected by Hermann between 2010 and 2012, and geological samples (blue crosses) collected by BRGM between 1989 and 1995.

Fig. 3: Plots of TiO_2 versus MgO for the different clusters of Tupua'i stone artefacts and possible sources of procurement. Red crosses correspond to geological samples (TB=Tupua'i, RV=Raivavae, MAN=Mangaia, RI=Rapa Iti) and red squares to quarry sites samples. Circles correspond to archaeological artefacts (grey for the Atiahara site and white for surface finds in Tupua'i). Eiao sD samples are from Duncan et al. (1986), Eiao FC-05-11 is from Collerson and Weisler (2007). Rapa Iti sample is from Palacz and Saunders (1986). Ra'ivavae samples are from Maury et al. (2013). **Error bars are indicated unless smaller than data points.**

Fig. 4: Incompatible element patterns of selected artefacts from Atiahara site and of some of their potential sources. Eiao data are from Weisler and colleagues (2016). Patterns are normalized to the Primitive Mantle (Sun and McDonough, 1989).

Fig. 5: Plots of Pb and Sr isotopic compositions for CEP islands. Stars and squares surrounded by red contours represent archaeological samples analyzed in this paper. Error bars (2σ) are smaller than data points. For each diagrams G stands for granulate and P for powder. Geological data is from the GEOROC database (http://georoc.mpchmainz.gwdg.de/georoc/).

Fig. 6: Magnified plot of Pb and Sr isotopic compositions for CEP islands. Red star represents sample At3-317-065, red and black crosses represent Eiao data. Sample KC-05-11 is a flake originally collected by archaeologist R. Suggs on Eiao (Weisler, pers. com.), and sample D-465 is an Eiao adze found in Makatea: both analyses were published by Collerson and Weisler (2007). Samples 2012-563 and 2012-573 were collected by M. Charleux and published by Weisler and colleagues (2016). Error bars (2σ) are smaller than data points. Geological data is from the GEOROC database (http://georoc.mpchmainz.gwdg.de/georoc/).

Fig. 7: Island ages and isochron dating of artefacts. Geochronological data are from Dalrymple et al. (1975), Turner & Jarrard (1982), Diraison (1991), Maury et al. (2000), Caroff et al. (1999).

Figure 1 :

Figure 2 :

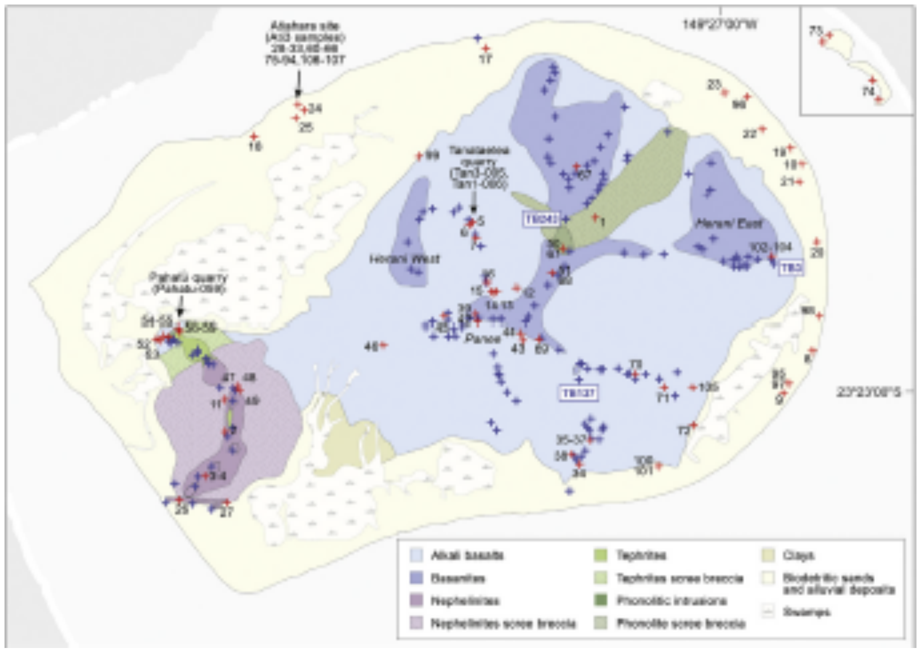
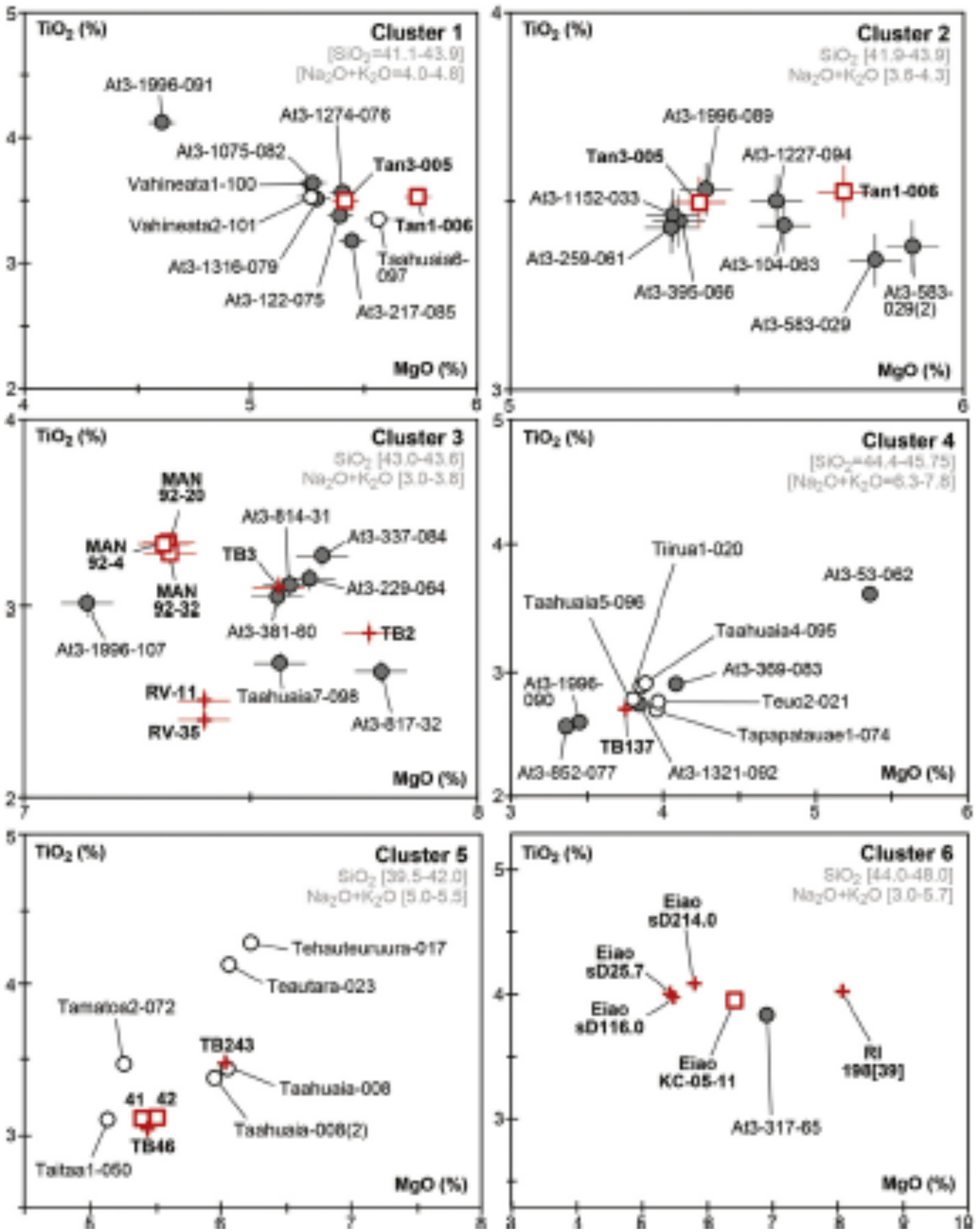
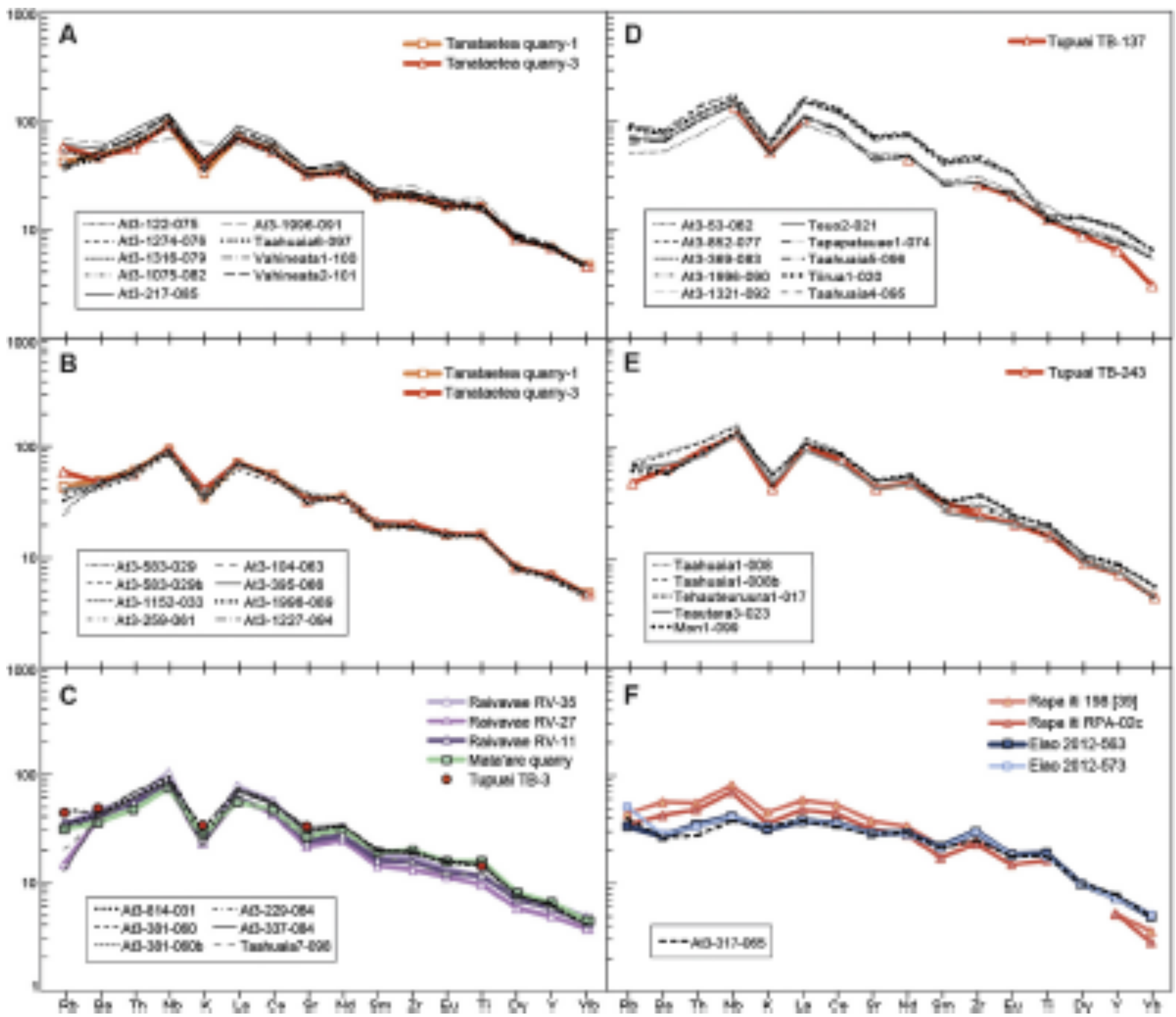

149°27'00"W
23°23'00"S
Alkali basalts
Basanites
Nephelinites
Nephelinites scree breccia
Tephrites
Tephrites scree breccia
Phonolitic intrusions
Phonolite scree breccia
Clays
Bioclastic sands and alluvial deposits
Swamps

Figure 3 :



Cluster 1
TiO_2 (%)
MgO (%)
At3-1996-091
At3-1274-076
At3-1075-082
Tan3-005
Vahineata1-100
Vahineata2-101
Tan1-006
At3-1316-079
Taahuaia6-097
At3-122-075
At3-217-085
Cluster 2
At3-1996-089
Tan3-005
At3-1227-094
At3-1152-033
Tan1-006
At3-259-061
At3-104-083
At3-396-066
At3-583-029(2)
At3-583-029
Cluster 3
MAN 92-20
MAN 92-4
MAN 92-32
At3-814-31
At3-337-084
TB3
At3-229-064
At3-1996-107
At3-381-80
TB2
RV-11
RV-35
Taahuaia7-098
At3-817-32
Cluster 4
Tiirua1-020
At3-53-062
Taahuaia5-096
Taahuaia4-095
At3-369-083
At3-1996-090
Teuo2-021
Tapapatauae1-074
TB137
At3-852-077
At3-1321-092
Cluster 5
Tehauteuruura-017
Teautara-023
Tamatoa2-072
TB243
Taahuaia-008
41
42
Taahuaia-008(2)
TB46
Taitaa1-060
Cluster 6
Eiao sD214.0
Eiao sD25.7
Eiao sD116.0
Eiao KC-05-11
RI 198[39]
At3-317-65

Figure 4 :



A
Tanataetea quarry-1
Tanataetea quarry-3
B
C
Raivavae RV-35
Raivavae RV-27
Raivavae RV-11
Mata'are quarry
Tupuai TB-3
D
Tupuai TB-137
E
Tupuai TB-243
F
Elao 2012-563
Elao 2012-573
At3-317-065
Pb
Ba
Th
Nb
K
La
Ce
Sr
Nd
Sm
Zr
Eu
Ti
Dy
Y
Yb
1000
100
10
1

Figure 5 :

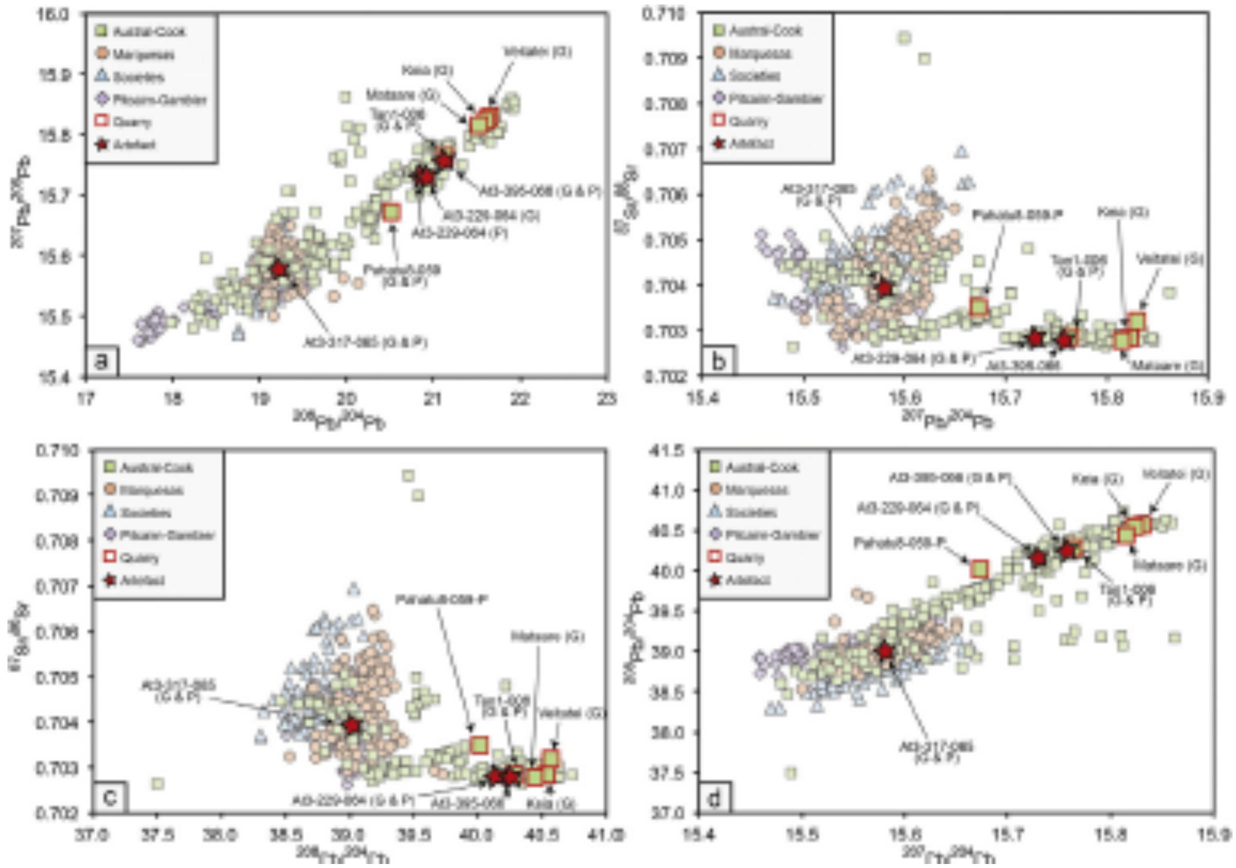


Figure 6 :

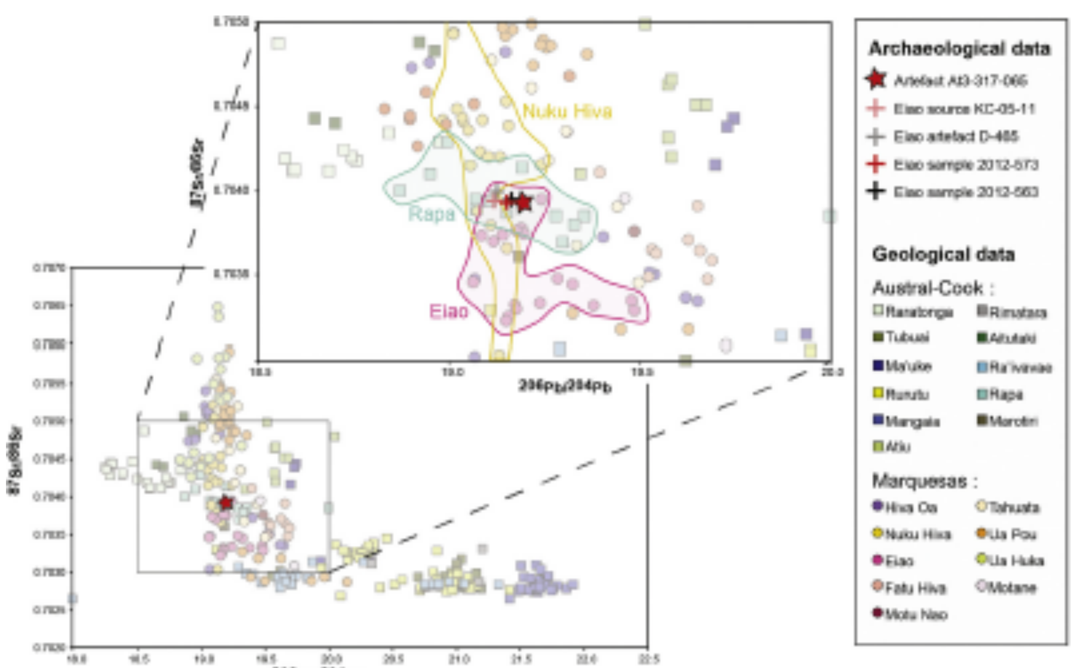
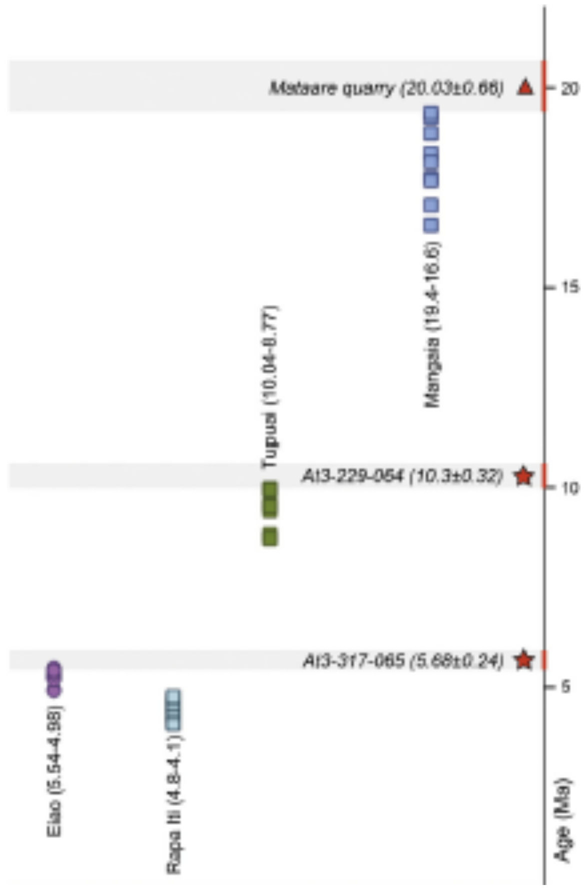


Figure 7 :



Tables Legends

Table 1: List, GPS location and description of archaeological samples collected in Tupua'i.

Table 2: Major element oxide values (wt%) and trace element values (ppm) of Tupua'i artefacts.

Table 3: Major element oxide values (wt%) and trace element values (ppm) of related sources.

Table 4: Sr and Pb isotopic ratios of artefacts and related sources.

Table 5: Summary of $^{40}Ar/^{39}Ar$ data from incremental heating experiments.

Table 1 - List, GPS location and description of archaeological samples collected in Tupua'i.

Sample no.	Sample type	Site, Provenience	Coordinates (UTM)	Alt.	Description
Tan3-005	Artefact	Tanataetea workshop	6 K 246605 7414013	49 m	Adze preform type 3A
Tan1-006	Artefact	Tanataetea quarry	6 K 246591 7413998	53 m	Natural prism
Taahuaia1-008	Artefact	Field Taahuaia	6 K 250777 7412610	5 m	Adze fragment distal
Tehauteuruura1-017	Artefact	Field Mataura	6 K 246806 7415934	4 m	Adze type 1A (12 cm)
Tiirua1-020	Artefact	Field Taahuaia	6 K 250840 7413757	4 m	Adze fragment distal (6 cm)
Teuo2-021	Artefact	Field Taahuaia	6 K 250641 7414663	5 m	Adze fragment type 1A distal (8 cm)
Teautara3-023	Artefact	Field Taahuaia	6 K 249593 7415533	4 m	Adze type 2C (5 cm)
At3-583-029	Artefact	Atiahara, Layer 3 (K5)	6 K 244479 7415453	-	Massive flake fragment
At3-814-031	Artefact	Atiahara, Layer 4 (Q5)	6 K 244479 7415453	-	Adze
At3-817-032	Artefact	Atiahara, Layer 4 (Q5)	6 K 244479 7415453	-	Prism
At3-1152-033	Artefact	Atiahara, Layer 4 (W3)	6 K 244479 7415453	-	Adze preform (fragment)
PaneeSouth-041	Geological	Dyke Panee south 1	6 K 246721 7412828	338 m	Dyke
PaneeSouth-042	Geological	Dyke Panee south 2	6 K 246735 7412845	344 m	Dyke
Taitaa1-050	Artefact	Taitaa summit 1	6 K 247725 7413705	418 m	Flakes
Taitaa2-051	Artefact	Taitaa summit 2	6 K 247643 7413485	416 m	Flakes
Pahatu2-053	Artefact	Petit Pahatu workshop 1	6 K 242813 7412629	35 m	Adze fragment (preform)
Pahatu8-059	Artefact	Petit Pahatu workshop 3	6 K 243032 7412771	13 m	Adze preforms, flakes
At3-381-060	Artefact	Atiahara, Layer 3 (H4)	6 K 244479 7415453	-	Adze preform
At3-259-061	Artefact	Atiahara, Layer 1/surf	6 K 244479 7415453	-	Adze preform
At3-53-062	Artefact	Atiahara, Layer 5 (N12)	6 K 244479 7415453	-	Adze preform
At3-104-063	Artefact	Atiahara, Layer 6 (N13)	6 K 244479 7415453	-	Flakes
At3-229-064	Artefact	Atiahara, Layer 7 (L14)	6 K 244479 7415453	-	Polished adze fragment
At3-317-065	Artefact	Atiahara, Layer 3 (B3)	6 K 244479 7415453	-	Adze fragment
At3-395-066	Artefact	Atiahara, Layer 4/5 (H2)	6 K 244479 7415453	-	Adze fragment
Tamatoa2-072	Artefact	Surface, Field Tamatoa 2	6 K 249306 7411711	10 m	Flakes
Tapapatauae1-074	Artefact	Motu Tapapatauae, shore	6 K 253781 7415930	-1 m	Flakes
At3-122-075	Artefact	Atiahara, Layer 5 (M13)	6 K 242774 7412337	-	Adze roughout
At3-1274-076	Artefact	Atiahara, Layer 4/5 (X2)	6 K 244479 7415453	-	Polished adze fragment
At3-852-077	Artefact	Atiahara, Layer 3 (F1)	6 K 244479 7415453	-	Adze preform
At3-1316-079	Artefact	Atiahara, Layer 4 (V1)	6 K 244479 7415453	-	Flake
At3-1075-082	Artefact	Atiahara, Layer 4/5 (Q3)	6 K 244479 7415453	-	Polished adze fragment

At3-369-083	Artefact	Atiahara, Layer 3 (J4)	6 K 244479 7415453	-	Adze preform (fragment)
At3-337-084	Artefact	Atiahara, Layer 3 (L10)	6 K 244479 7415453	-	Polished adze fragment
At3-217-085	Artefact	Atiahara, Layer 6 (L12)	6 K 244479 7415453	-	Adze roughout
At3-1996-089	Artefact	Atiahara, Layer 3 (K11)	6 K 244479 7415453	-	Adze preform (fragment)
At3-1996-090	Artefact	Atiahara4, surface	6 K 244479 7415453	-	Adze preform (fragment)
At3-1996-091	Artefact	Atiahara, Layer 3 (K13)	6 K 244479 7415453	-	Adze preform (fragment)
At3-1321-092	Artefact	Atiahara, Layer 5 (T1)	6 K 244479 7415453	-	Adze preform (fragment)
At3-1227-094	Artefact	Atiahara, Layer 4 (Y2)	6 K 244479 7415453	-	Adze preform (fragment)
Taahuaia4-095	Artefact	Field Taahuaia	6 K 250482 7412134	4 m	Adze preform (fragment)
Taahuaia5-096	Artefact	Dry riverbed Taahuaia	6 K 249991 7415499	3 m	Adze roughout (fragment)
Taahuaia6-097	Artefact	Field Taahuaia	6 K 250443 7412081	5 m	Flake
Taahuaia7-098	Artefact	Field Taahuaia	6 K 250840 7412876	6 m	Adze preform
Mon1-099	Artefact	Surface, chez Monette	6 K 246017 7414889	12 m	Adze preform
Vahineata1-100	Artefact	Vahineata,FieldTamatoa1	6 K 248878 7411067	14 m	Adze
Vahineata2-101	Artefact	Vahineata,FieldTamatoa2	6 K 248878 7411067	14 m	Adze
Reretii-102	Geological	Reretii	6 K 250252 7413593	60 m	Prism
At3-1996-107	Artefact	Atiahara, Layer 5 (O11)	6 K 244479 7415453	-	Dyke

Table 2- Major element oxide values (wt%) and trace element values (ppm) of Tupua'i artefacts

Sample	Location	Petrographic group	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
At3-583-029	Atiahara, layer 3 (K5)	Basanite	42.87	3.345	15.37	14.15	0.200	5.80	11.34	2.91	1.13	0.461	1.67	99.26
At3-583-029b	Atiahara, layer 3 (K5)	Basanite	41.92	3.382	14.74	14.25	0.200	5.89	11.44	2.73	0.95	0.436	3.44	99.38
At3-814-031	Atiahara, layer 4 (Q5)	Basanite	43.09	3.116	13.18	13.86	0.201	7.51	13.22	2.78	0.89	0.481	0.89	99.22
At3-817-032	Atiahara, layer 4 (Q5)	Basanite	44.51	2.670	11.89	12.82	0.201	8.73	13.75	2.00	0.65	0.345	1.47	99.03
At3-1152-033	Atiahara, layer 4 (W3)	Basanite	42.88	3.448	15.78	15.40	0.216	5.37	10.81	3.08	0.98	0.508	0.97	99.44
At3-381-060	Atiahara, layer 3 (H4)	Basanite	43.37	3.060	13.26	13.80	0.202	7.36	12.85	2.77	0.93	0.486	1.07	99.16
At3-381-060b	Atiahara, layer 3 (H4)	Basanite	43.18	3.053	13.11	13.60	0.197	7.31	12.37	2.79	0.93	0.475	1.07	98.10
At3-259-061	Atiahara, layer 1/surf	Basanite	42.86	3.464	15.83	15.45	0.217	5.36	11.01	3.13	1.06	0.506	0.50	99.38
At3-53-062	Atiahara, layer 5 (N12)	Tephrite	45.19	3.609	15.19	15.31	0.217	5.36	7.23	4.72	1.45	0.816	0.46	99.56
At3-104-063	Atiahara, layer 6 (N13)	Basanite	42.67	3.436	15.74	15.27	0.215	5.60	10.62	2.96	1.16	0.502	1.10	99.27
At3-229-064	Atiahara, layer 7 (L14)	Basanite	43.45	3.158	13.05	14.00	0.202	7.78	13.24	2.73	0.79	0.488	0.87	99.75
At3-317-065	Atiahara, layer 3 (B3)	Alkali basalt	47.12	3.85	14.92	13.67	0.168	6.93	9.18	3.27	1.01	0.51	-0.39	100.24
At3-395-066	Atiahara, layer 4/5 (H2)	Basanite	42.34	3.430	15.76	15.36	0.213	5.35	10.80	3.11	1.01	0.493	0.73	98.59
At3-122-075	Atiahara, layer 5 (M13)	Basanite	43.40	3.379	16.12	15.03	0.213	5.39	10.19	3.29	1.36	0.493	1.08	99.94
At3-1274-076	Atiahara, layer 4/5 (X2)	Basanite	43.49	3.564	16.05	15.60	0.218	5.41	10.60	3.64	1.16	0.488	-0.47	99.76
At3-852-077	Atiahara, layer 3 (F1)	Tephrite	45.76	2.574	15.36	14.09	0.243	3.36	7.23	6.44	2.00	1.798	0.22	99.08
At3-1316-079	Atiahara, layer 4 (V1)	Basanite	43.28	3.512	15.88	15.47	0.217	5.29	10.60	3.45	1.34	0.504	0.47	100.02
At3-1075-082	Atiahara, layer 4/5 (Q3)	Basanite	43.81	3.639	15.67	14.65	0.209	5.28	10.48	3.97	1.05	0.558	0.04	99.35
At3-369-083	Atiahara, layer 3 (J4)	Tephrite	45.03	2.900	15.11	14.74	0.240	4.08	7.81	5.38	1.88	1.914	0.89	99.97
At3-337-084	Atiahara, layer 3 (L10)	Basanite	43.35	3.282	12.82	14.08	0.202	7.93	13.61	2.66	0.64	0.448	0.43	99.46

At3-217-085	Atiahara, layer 6 (L12)	Basanite	43.45	3.177	15.89	14.80	0.227	5.45	10.97	3.77	1.30	0.604	0.49	100.13
At3-1996-089	Atiahara, layer 3 (K11)	Basanite	42.79	3.531	15.68	15.60	0.219	5.43	11.00	3.08	0.97	0.470	0.87	99.65
At3-1996-090	Atiahara4, surface	Tephrite	46.35	2.609	15.41	14.19	0.249	3.45	7.37	6.18	2.01	1.803	0.10	99.72
At3-1996-091	Atiahara, layer 3 (K13)	Basanite	43.14	4.122	15.26	14.10	0.197	4.61	10.86	2.69	1.86	0.581	3.13	100.55
At3-1321-092	Atiahara, layer 5 (T1)	Tephrite	45.57	2.746	17.09	13.21	0.243	3.85	9.80	4.85	1.51	0.744	0.99	100.60
At3-1227-094	Atiahara, layer 4 (Y2)	Basanite	42.99	3.501	15.84	15.33	0.217	5.59	10.50	3.30	0.98	0.494	1.11	99.86
At3-1996-107	Atiahara, layer 5 (O11)	Picrite	37.31	3.023	12.32	17.94	0.310	4.86	12.75	1.96	0.33	1.520	6.65	98.96
Taahuaia1-008	Field Taahuaia	Low silica basanite	41.86	3.452	14.03	14.59	0.198	6.04	12.34	4.04	1.33	0.800	2.24	100.92
Taahuaia1-008b	Field Taahuaia	Low silica basanite	40.79	3.384	13.81	14.03	0.189	5.95	11.87	3.98	1.31	0.771	2.24	98.32
Tehauteuruura1-017	Field Mataura	Low silica basanite	41.56	4.281	14.65	16.84	0.230	6.22	7.89	4.68	1.69	1.212	0.28	99.54
Tiirua1-020	Field Taahuaia	Tephrite	45.42	2.894	15.09	14.85	0.238	3.86	7.90	5.99	1.83	1.917	-0.25	99.74
Teuo2-021	Field Taahuaia	Tephrite	45.60	2.768	17.00	13.26	0.235	3.97	9.66	4.88	1.49	0.758	0.48	100.10
Teautara3-023	Field Taahuaia	Low silica basanite	41.47	4.138	15.01	14.91	0.215	6.06	11.05	4.21	1.43	0.651	0.51	99.65
Taitaa1-050	Taitaa-1	Low silica basanite	41.86	3.097	15.04	14.22	0.218	5.13	10.97	4.16	1.36	0.770	2.59	99.40
Taitaa2-051	Taitaa-2	Basanite	43.23	2.356	11.44	13.31	0.200	11.80	12.91	2.19	0.70	0.385	1.47	99.99
Tamatoa2-072	Field Tamatoa	Low silica basanite	42.25	3.469	16.04	14.15	0.233	5.26	10.08	4.36	1.40	0.640	0.77	98.64
Tapapatauae1-074	Motu Tapapatauae	Tephrite	45.23	2.709	17.10	12.99	0.232	3.95	9.25	4.96	1.50	0.754	0.42	99.10
Taahuaia4-095	Field Taahuaia	Tephrite	44.43	2.906	14.89	14.55	0.236	3.87	7.51	5.50	1.77	1.801	1.30	98.77
Taahuaia5-096	Dry riverbed Taahuaia	Tephrite	45.22	2.792	16.71	13.35	0.241	3.80	9.51	4.81	1.48	0.722	1.74	100.37
Taahuaia6-097	Field Taahuaia	Basanite	43.10	3.351	15.21	14.38	0.202	5.57	11.68	2.94	1.15	0.479	1.57	99.63
Taahuaia7-098	Field Taahuaia	Basanite	43.02	2.720	13.85	14.32	0.210	7.40	13.18	2.46	0.66	0.355	1.48	99.66
Mon1-099	Huahine, Monette's	Low silica basanite	41.46	4.358	14.50	16.77	0.234	5.98	7.76	4.93	1.68	1.190	0.40	99.26
Vahineata1-100	Field Tamatoa	Basanite	43.84	3.629	15.50	14.79	0.219	5.27	10.48	3.80	1.04	0.542	0.63	99.73
Vahineata2-101	Field Tamatoa	Basanite	43.67	3.553	15.04	14.79	0.211	5.27	10.98	3.54	1.02	0.550	2.01	100.62

Table 2- cont.

Sample	Rb	Sr	Ba	Sc	V	Cr	Co	Ni	Y	Zr	Nb	La	Ce	Nd	Sm	Eu	Gd	Dy	Er	Yb	Th
At3-583-029	25	795	301	21	334	13	46	55	29	211	62	46	93	45	9.0	2.7	7.9	5.9	2.9	2.1	5.0
At3-583-029b	24	760	278	22	341	20	47	57	29	207	59	41	84	41	8.3	2.6	7.4	5.7	2.9	2.1	4.4
At3-814-031	21	641	296	31	319	153	49	104	29	209	64	49	95	45	8.9	2.6	7.6	5.7	2.8	2.0	5.2
At3-817-032	20	447	181	43	355	366	53	132	25	168	41	31	65	33	6.8	2.1	6.2	4.8	2.7	1.9	2.7
At3-1152-033	16	634	310	19	390	3	48	29	30	217	66	48	95	46	8.8	2.6	7.6	6.0	2.7	2.2	4.8

At3-381-060	31	607	302	32	315	151	50	103	29	218	69	50	98	46	9.1	2.6	7.8	5.6	2.7	2.0	5.7
At3-381-060b	28	622	301	31	317	154	50	103	28	218	67	51	97	46	8.9	2.6	7.6	5.8	2.6	2.1	5.8
At3-259-061	23	646	316	19	390	4	43	30	30	220	67	48	93	46	9.0	2.7	7.6	6.1	3.0	2.3	5.0
At3-53-062	32	1035	368	13	152	3	34	12	38	342	81	64	129	64	12.4	3.8	10.3	7.4	3.7	2.8	6.6
At3-104-063	25	638	307	18	379	3	47	30	29	215	66	48	93	46	9.2	2.7	7.9	6.0	3.2	2.2	4.7
At3-229-064	20	617	279	33	341	160	51	107	29	211	62	48	94	46	8.7	2.7	7.8	5.7	2.8	2.0	5.0
At3-317-065	26	603	187	22	307	71	47	115	36	284	27	26	61	40	9.3	3.0	9.4	7.3	3.7	2.4	2.4
At3-395-066	26	621	302	19	382	4	48	30	30	215	65	47	93	46	9.0	2.6	7.6	6.0	2.8	2.3	4.6
At3-122-075	34	681	335	18	370	3	46	28	31	230	74	51	101	48	9.2	2.8	7.8	6.1	2.8	2.4	5.9
At3-1274-076	24	664	314	19	397	3	49	29	30	218	66	48	97	47	9.2	2.8	7.7	5.9	2.8	2.3	5.2
At3-852-077	58	1564	586	7	71	2	24	3	49	545	125	115	236	106	19.4	5.5	14.6	9.6	4.2	3.3	11.7
At3-1316-079	32	635	314	19	388	3	49	31	31	220	68	49	98	47	8.8	2.7	7.9	6.0	2.9	2.3	5.5
At3-1075-082	25	779	367	19	332	12	46	42	32	235	78	57	113	53	10.6	3.1	8.8	6.5	3.0	2.3	6.3
At3-369-083	58	1470	521	8	104	3	28	6	47	485	112	106	221	102	18.7	5.4	14.3	9.3	4.2	3.1	10.4
At3-337-084	8	690	277	34	354	168	53	113	28	211	59	47	94	46	8.6	2.7	7.6	5.7	2.8	2.0	5.1
At3-217-085	38	772	390	16	325	7	47	46	32	250	85	62	121	56	10.5	3.1	8.5	6.3	3.0	2.4	7.0
At3-1996-089	20	628	298	19	400	21	49	30	30	216	64	47	93	46	8.9	2.7	7.6	6.0	3.1	2.3	4.9
At3-1996-090	59	1542	563	7	74	17	24	5	49	535	127	115	228	106	19.0	5.5	14.9	9.7	4.3	3.2	11.4
At3-1996-091	44	738	442	16	378	23	40	53	33	290	48	42	90	51	10.5	3.1	9.4	6.8	3.2	2.3	5.0
At3-1321-092	39	931	479	8	168	7	30	4	36	301	104	77	145	64	11.3	3.4	9.4	7.0	3.6	2.6	9.2
At3-1227-094	20	730	323	19	383	4	49	30	30	216	67	48	94	47	8.7	2.8	7.6	6.0	2.6	2.3	5.3
At3-1996-107	12	1244	504	9	142	6	51	167	56	561	213	170	320	134	23.4	6.7	17.8	11.7	4.9	3.4	20.6
Taahuaia1-008	47	1029	628	19	307	58	48	78	35	329	117	83	159	70	13.3	3.8	10.3	7.2	3.2	2.1	9.7
Taahuaia1-008b	44	1014	596	19	300	56	46	75	34	319	113	84	160	71	13.2	3.8	10.7	7.3	3.3	2.0	9.5
Tehauteurura1-017	45	1044	407	14	209	9	46	40	39	395	98	75	153	74	13.9	4.2	11.7	7.9	3.8	2.8	7.2

Tiirua1-020	54	1468	540	8	112	3	28	6	46	489	115	105	214	99	18.1	5.3	14.8	9.4	4.2	3.2	10.1
Teuo2-021	43	910	483	9	176	3	31	2	36	305	103	77	146	64	11.7	3.4	9.6	6.9	3.4	2.7	8.7
Teautara3-023	41	883	486	17	373	4	48	51	33	261	94	65	126	61	11.8	3.4	9.9	6.6	3.0	2.2	7.1
Taitaa1-050	49	996	560	14	242	9	45	57	34	329	124	90	163	70	12.5	3.7	10.4	7.1	3.5	2.5	11.4
Taitaa2-051	24	507	245	34	304	666	59	303	24	172	54	41	81	39	7.41	2.3	6.4	4.9	2.6	1.8	4.2
Tamatoa2-072	35	879	457	13	292	3	39	13	33	256	91	66	128	59	11.5	3.3	9.3	6.7	3.1	2.4	7.0
Tapapatauae1-074	45	974	448	8	164	2	29	2	34	301	104	78	150	64	11.7	3.6	9.8	7.0	3.3	2.7	8.8
Taahuaia4-095	47	1407	527	8	100	13	29	8	47	485	114	102	206	98	17.9	5.2	13.8	9.2	4.1	3.1	10.1
Taahuaia5-096	40	901	468	9	178	14	31	12	36	304	103	75	142	64	11.5	3.4	9.4	6.9	3.4	2.6	8.7
Taahuaia6-097	24	663	309	21	334	18	48	56	30	219	64	46	91	45	8.5	2.7	7.6	6.0	2.9	2.2	5.2
Taahuaia7-098	13	563	262	33	377	45	53	82	27	170	54	41	79	39	7.5	2.2	6.2	5.1	3.0	2.1	4.6
Mon1-099	39	1057	397	14	212	25	48	45	40	408	100	75	152	76	13.8	4.1	11.1	7.9	3.9	2.7	7.6
Vahineata1-100	23	770	367	19	334	24	46	45	32	236	79	55	108	52	9.7	3.1	8.6	6.4	2.8	2.2	5.9
Vahineata2-101	24	791	372	18	325	24	46	44	32	239	81	56	109	53	10.5	3.2	9.3	6.7	3.0	2.2	6.1

Table 3 - Major element oxide values (wt%) and trace element values (ppm) of related sources.

Sample	Archipelago	Island	Location	Sample type	Petrographic group	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
Tan3-005	Austral-Cook	Tupua'i	Tanataetea workshop	Quarry	Basanite	43.71	3.496	15.86	15.75	0.220	5.42	11.18	3.29	1.18	0.505	0.41	101.02
Tan1-006	Austral-Cook	Tupua'i	Tanataetea quarry	Quarry	Basanite	43.93	3.529	15.86	15.92	0.230	5.74	10.89	3.33	0.99	0.529	0.59	101.55
Pahatu2-053	Austral-Cook	Tupua'i	Pahatu workshop 1	Quarry	Phonolite	57.37	0.024	18.58	5.38	0.247	0.09	0.85	8.72	4.70	0.051	2.41	98.43
Pahatu8-059	Austral-Cook	Tupua'i	Pahatu workshop 3	Quarry	Phonolite	59.20	0.040	18.47	5.99	0.302	0.08	1.08	8.63	4.36	0.045	2.33	100.53

PaneeSouth-041	Austral-Cook	Tupua'i	Panee south slope	Geological	Low silica basanite	41.76	3.123	14.92	14.42	0.215	5.38	11.11	5.09	1.40	0.780	1.17	99.37
PaneeSouth-041b	Austral-Cook	Tupua'i	Panee south slope	Geological	Low silica basanite	41.36	3.071	14.73	14.22	0.212	5.36	10.88	5.05	1.40	0.774	1.17	98.24
PaneeSouth-042	Austral-Cook	Tupua'i	Panee south slope	Geological	Low silica basanite	41.39	3.131	14.89	14.12	0.212	5.49	11.12	4.43	1.53	0.770	1.67	98.76
Reretii-102	Austral-Cook	Tupua'i	Herani cliff	Geological	Tephrite	45.23	2.745	16.93	13.16	0.237	3.83	9.58	4.83	1.49	0.748	1.10	99.89
TB-2	Austral-Cook	Tupua'i	Reretii	Geological	Basanite	44.00	2.880	12.32	13.86	0.200	8.56	12.55	1.66	0.40	0.490	3.13	100.05
TB-3	Austral-Cook	Tupua'i	Reretii	Geological	Basanite	43.40	3.110	13.80	14.45	0.203	7.37	12.00	2.77	1.02	0.510	1.47	100.10
TB-46	Austral-Cook	Tupua'i	Panee	Geological	Low silica basanite	41.65	3.070	14.98	14.78	0.230	5.44	11.13	4.29	1.36	0.850	1.41	99.19
TB-137	Austral-Cook	Tupua'i	Panee south ridge	Geological	Tephrite	45.75	2.700	17.30	13.21	0.250	3.75	9.43	4.85	1.55	n.a	1.18	99.97
TB-243	Austral-Cook	Tupua'i	Taitaa north ridge	Geological	Low silica basanite	41.10	3.480	15.35	14.90	0.230	6.03	11.34	3.95	1.25	0.650	1.36	99.64
Mata'are (a)	Austral-Cook	Mangaia	Mata'are	Geological	Basanite	44.029	3.353	15.11	14.38	0.195	5.583	11.40	3.16	0.83	0.450	1.36	99.85
Keia (a)	Austral-Cook	Mangaia	Keia	Geological	Basanite	45.570	1.807	16.93	11.58	0.202	2.360	7.64	3.28	1.84	0.840	7.18	99.23
Veitatei (a)	Austral-Cook	Mangaia	Veitatei	Geological	Basanite	44.814	3.274	13.39	12.92	0.196	5.370	10.84	2.75	1.06	0.45	4.34	99.41
92-32 (b)	Austral-Cook	Mangaia	Mata'are	Quarry	Basanite	44.87	3.288	14.45	13.16	0.186	5.93	12.21	3.01	0.82	0.437	n.a	98.36
92-20 (b)	Austral-Cook	Mangaia	Mata'are	Quarry	Basanite	45.20	3.349	15.21	13.09	0.197	5.89	11.66	3.44	0.84	0.456	n.a	99.33
92-4 (b)	Austral-Cook	Mangaia	Mata'are	Quarry	Basanite	45.08	3.344	15.04	13.17	0.200	5.87	11.60	3.28	0.82	0.454	n.a	98.86
2009-330-b (c)	Austral-Cook	Mangaia	Mata'are valley	Quarry	-	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
2009-331-b (c)	Austral-Cook	Mangaia	Mata'are valley	Geological	-	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
RV-11 (d)	Austral-Cook	Ra'ivavae	Rairua	Geological	Basanite	44.60	2.520	15.60	12.70	0.180	6.40	12.40	2.63	0.77	0.340	1.54	99.68
RV-27 (d)	Austral-Cook	Ra'ivavae	Rairua	Geological	Basanite	43.86	2.067	13.53	12.45	0.196	10.45	12.01	2.17	0.70	0.314	1.73	99.47
RV-35 (d)	Austral-Cook	Ra'ivavae	Rairua	Geological	Basanite	43.70	2.410	15.50	13.50	0.213	6.40	12.26	2.62	0.70	0.410	1.70	99.41
KC-05-11 (e)	Marquesas	Eiao	Surface	Artefact	Alkali basalt	47.83	3.96	15.44	n.a	0.170	6.41	9.22	3.33	1.05	0.54	n.a	87.95
2012-563	Marques	Eiao	Surface	Artefact	Alkali	48.8	4.12	15.48	13.93	0.171	6.54	9.64	3.14	0.961	0.592	n.a	103.38

(f)	as				basalt												
2012-573 (f)	Marquesas	Eiao	Surface	Artefact	Alkali basalt	46.45	3.89	14.71	13.20	0.162	6.34	9.11	3.02	1.01	0.54	n.a	98.44
198-39 (g)	Austral-Cook	Rapa iti	Surface	Geological	Alkali basalt	44.2	4.03	14	12.88	0.150	8.1	10.86	2.6	1.37	0.61	n.a	98.8
RPA-02 (h)	Austral-Cook	Rapa iti	Surface	Geological	Alkali basalt	44	3.58	11.69	13.55	0.160	13.1	9.95	2.46	1.07	0.59	0.5	100.65

*References : (a) This study (sampled by PV Kirch) ; (b) Weisler et al. (1994) ; (c) Weisler et al. (2016a) ; (d) Maury et al. (2013) ; (e) Collerson & Weisler, (2007) ; (f) Weisler et al. (2016b) ; (g) Palacz & Saunders (1986) ; (h) Liotard (1988).

Table 3 - Cont.

Sample	Rb	Sr	Ba	Sc	V	Cr	Co	Ni	Y	Zr	Nb	La	Ce	Nd	Sm	Eu	Gd
Tan3-005	36	666	325	19	395	4	52	30	31	225	67	48	93	45	9.2	2.8	7.9
Tan1-006	27	675	337	19	392	3	52	30	31	223	67	48	97	46	8.9	2.7	8.1
Pahatu2-053	321	94	380	0.1	3	2	0	0	66	1588	395	275	470	131	18.1	3.8	12.7
Pahatu8-059	275	182	850	0.1	4	2	0.6	0.7	58	1391	373	268	444	128	18.2	3.8	12.4
PaneeSouth-041	49	856	533	14	248	10	45	55	36	330	120	91	169	72	12.6	3.7	10.6
PaneeSouth-041b	52	836	522	14	245	10	41	55	35	328	118	90	167	72	13.1	3.7	10.0
PaneeSouth-042	62	856	553	15	253	15	47	56	37	331	120	90	168	71	12.7	3.8	10.8
Reretii-102	40	890	461	8	172	7	31	3	36	301	105	76	145	64	11.3	3.4	9.1
TB-2	20	497	335	n.a	288	232	56	127	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
TB-3	28	694	340	n.a	318	162	55	127	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
TB-46	48	910	315	15	265	≤10	50	55	38	326	119	90	n.a	72	n.a	3.4	n.a
TB-137	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	29	283	96	71	n.a	60	n.a	3.4	n.a
TB-243	30	870	445	16	342	9	48	33	33	275	96	70	135	63	13.4	3.5	n.a
Mata'are (a)	20	555	249	25	331	30	47	49	30	218	53	39	83	43	8.5	2.6	7.9
Keia (a)	36	877	534	4	49	3	19	5	37	379	102	82	157	69	12.2	3.5	9.6
Veitatei (a)	23	463	287	31	335	492	74	344	28	218	59	43	90	46	9.6	2.7	8.0
92-32 (b)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
92-20 (b)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
92-4 (b)	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
2009-330-b (c)	35	698	337	20	304	29	42	61	28	228	59	47	97	45	8.9	2.7	8.0
2009-331-b (c)	18	560	247	26	325	28	48	44	28	221	55	38	82	41	8.4	2.8	7.8
RV-11 (d)	22	515	280	30	340	95	48	79	27	173	58	41	80	37	7.1	2.1	6.2

RV-27 (d)	10	457	265	33	282	461	55	197	23	146	57	41	76	34	6.3	1.9	5.4
RV-35 (d)	21	582	325	26	329	35	48	60	29	190	73	53	100	44	7.7	2.3	6.7
KC-05-11 (e)	9	421	133	31	324	193	43	77	31	256	24	20	49	33	8.5	2.8	8.5
2012-563 (f)	21	609	194	22	295	74	46	90	34	342	29	26	64	39	9.6	3.1	9.4
2012-573 (f)	32	612	196	22	309	81	45	94	33	342	29	26	63	39	9.5	3.1	9.4
198-39 (g)	28	795	403	n.a	n.a	325	n.a	169	24	278	57	40	96	46	9.8	3.2	n.a
RPA-02 (h)	22	670	296	23	225	391	71	253	24	260	50	33	77	39	7.6	2.5	n.a

Table 4-1: Sr and Pb isotopic ratios of artefacts and related sources (This study)

Archipelago	Island	Sample no.*	$^{87}Sr/^{86}Sr$	± 2σ	$^{208}Pb/^{204}Pb$	± 2σ
Austral	Tubuai	At3-229-064-P	0.702804	0.000008	40.127	0.002
Austral	Tubuai	At3-229-064-G	0.702803	0.000008	40.201	0.002
Austral	Tubuai	At3-317-065-P	0.703912	0.000008	38.996	0.002
Austral	Tubuai	At3-317-065-G	0.703932	0.000008	39.002	0.002
Austral	Tubuai	At3-395-066-P	0.702797	0.000008	40.261	0.002
Austral	Tubuai	Tan1-006-P	0.702803	0.000008	40.268	0.002
Austral	Tubuai	Tan1-006-G	0.702853	0.000008	40.281	0.001
Austral	Tubuai	Pahatu8-059-P	0.703496	0.000008	40.018	0.001
Cook	Mangaia	Mataare-G	0.702791	0.000008	40.443	0.002
Cook	Mangaia	Keia-G	0.702844	0.000006	40.544	0.001
Cook	Mangaia	Keia-G-Dup	0.702838	0.000006	40.539	0.003
Cook	Mangaia	Veitatei-G	0.703186	0.000006	40.571	0.002

* Footnote: P stands for analysis on powder sample, G for analysis on gravels and Dup for complete duplicate analysis.

Table 4-1: Cont.

Archipelago	Island	Sample no.*	$^{207}Pb/^{204}Pb$	± 2σ	$^{206}Pb/^{204}Pb$	± 2σ
Austral	Tubuai	At3-229-064-P	15.730549	0.0007	20.8499	0.0010
Austral	Tubuai	At3-229-064-G	15.72881	0.000943	20.9587	0.0009
Austral	Tubuai	At3-317-065-P	15.579801	0.000954	19.1880	0.0008
Austral	Tubuai	At3-317-065-G	15.579871	0.000763	19.1925	0.0009
Austral	Tubuai	At3-395-066-P	15.76081	0.000748	21.1367	0.0007
Austral	Tubuai	Tan1-006-P	15.761482	0.000696	21.1413	0.0009
Austral	Tubuai	Tan1-006-G	15.764295	0.000526	21.1408	0.0007
Austral	Tubuai	Pahatu8-059-P	15.673399	0.000433	20.5105	0.0005

Cook	Mangaia	Mataare-G	15.815252	0.000523	21.5235	0.0007
Cook	Mangaia	Keia-G	15.822993	0.000535	21.6029	0.0006
Cook	Mangaia	Keia-G-Dup	15.822861	0.00109	21.6029	0.0013
Cook	Mangaia	Veitatei-G	15.830421	0.000642	21.6500	0.0009

* Footnote: P stands for analysis on powder sample, G for analysis on gravels and Dup for complete duplicate analysis.

Table 4-2: Sr, Pb and Nd isotopic ratios of artefacts and related sources (Published data)

Archipelago	Island	Sample no.*	$^{87}Sr/^{86}Sr$	± 2σ	$^{208}Pb/^{204}Pb$	± 2σ
Austral	Tubuai	TBA 17 (a)	0.702761		40.229	
Austral	Tubuai	K109 (b)	0.7028		40.29	
Austral	Tubuai	TBA-11 (b)	0.703178		40.323	
Austral	Tubuai	K-109 (b)	0.702864		40.229	
Austral	Tubuai	TU 23 (c)	0.702832		40.306	
Austral	Raivavae	RV-11 (d)	0.702878		40.15634	
Austral	Raivavae	RV-27 (d)	0.702876		40.20646	
Austral	Raivavae	RV-35 (d)	0.702839		40.152211	
Marquesas	Eiao	2012-563 (e)	0.703935	0.000012	38.9699	0.0024
Marquesas	Eiao	2012-573 (e)	0.703922	0.000011	38.9648	0.0067
Marquesas	Eiao	D116.0 (f)	0.70378		38.998	
Marquesas	Eiao	D214.0 (f)	0.703743		38.999	
Marquesas	Eiao	KC-05-11 (g)	0.70394		40.156	
Austral	Rapa iti	198 [39] (f)	0.7038		39.054	
Austral	Rapa iti	RPA-02c (a)	0.703902		39.03	
Austral	Rapa iti	RA-31 (b)	0.704288		39.019	

* References: (a) Schiano et al. (2001) ; (b) Chauvel et al. 1992 (1992) ; (c) Vidal et al. (1984) ; (d) Maury et al. (2013) ; (e) Weisler et al. (2016b) ; (f) Duncan et al. (1986) ; (g) Collerson and Weisler (2007).

Table 4-2: Cont.

Archipelago	Island	Sample no.*	$^{207}Pb/^{204}Pb$	± 2σ	$^{206}Pb/^{204}Pb$	± 2σ	$^{143}Nd/^{144}Nd$	± 2σ
Austral	Tubuai	TBA 17 (a)	15.763		21.052		0.512875	
Austral	Tubuai	K109 (b)	15.76		21.14		0.512886	
Austral	Tubuai	TBA-11 (b)	15.749		21.039			
Austral	Tubuai	K-109 (b)	15.763		21.052			
Austral	Tubuai	TU 23 (c)	15.734		21.115		0.512891	
Austral	Raivavae	RV-11 (d)	15.726763		20.863603			
Austral	Raivavae	RV-27 (d)	15.728588		20.89702			
Austral	Raivavae	RV-35 (d)	15.724814		20.820474			
Marquesas	Eiao	2012-563 (e)	15.5791	0.001	19.1613	0.001	0.512935	0.000005
Marquesas	Eiao	2012-573 (e)	15.5797	0.0021	19.1499	0.0022	0.512942	0.000005
Marquesas	Eiao	D116.0 (f)	15.591		19.188			
Marquesas	Eiao	D214.0 (f)	15.576		19.195			
Marquesas	Eiao	KC-05-11 (g)	15.727		20.864			
Austral	Rapa iti	198 [39] (f)	15.706		19.327			
Austral	Rapa iti	RPA-02c (a)	15.58		19.07			
Austral	Rapa iti	RA-31 (b)	15.594		18.994			

* References: (a) Schiano et al. (2001) ; (b) Chauvel et al. (1992) ; (c) Vidal et al. (1984) ; (d) Maury et al. (2013) ; (e) Weisler et al. (2016b) ; (f) Duncan et al. (1986) ; (g) Collerson and Weisler (2007).

Table 5: Summary of $^{40}Ar/^{39}Ar$ data from incremental heating experiments.

Sample no. Experiment no.	wt. (mg)	K/Ca (total)	Total Fusion Age (Ma) ± 2 sigma	Age Spectrum*				Isochron Analysis*			
				Increments used (oC)	^{39}Ar (%)	Age ± 2 sigma (Ma)	MSWD	N	MSWD	$^{40}Ar/^{36}Ar$ ± 2 sigma intercept	Age (Ma) ± 2 sigma
Mataare, groundmass											
FG-905 to FG-915	150	0.3	20.1 ± 0.62	749-1079	78.84	20.17 ± 0.63	1.65	7 of 10	1.64	304 ± 8.7	20.03 ± 0.66
At3-229-064, groundmass											
FG-916 to FG-925	150	0.4	10.41 ± 0.3	847-1149	60	10.32 ± 0.3	1.22	6 of 10	1.8	300.7 ± 8	10.32 ± 0.32
At3-317-065, groundmass											
FG-1197 to FG-1207	150	0.2	5.59 ± 0.21	595-1097	81	5.61 ± 0.21	1.16	10 of 11	1.14	293.8 ± 7.3	5.68 ± 0.24

* Footnote: Ages calculated relative to 1.193 Ma Alder Creek Rhyolite sanidine standard