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– ARTICLE –

Toki (adze) and Pick Production During Peak *Moai* (Statue) Manufacture: Geochemical and radiometric analyses reveal prehistoric provenance, timing and use of Easter Island's fine-grain basalt resources

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ABSTRACT

Pacific and Rapa Nui (Easter Island) volcanologists, geologists, and geochemists have set the stage for archaeological lithic sourcing studies by providing practical data regarding the island's geodynamic activity, geomorphological formation and dating, and the macroscopic, microscopic, and elemental proprieties of Easter Island stone. Drawing upon this information, and the research collaboration between two active archaeological projects on Rapa Nui – the Easter Island Statue Project and the Rapa Nui Geochemical Project – we trace the prehistoric transfer of basalt resources from the Ava oʻKiri and Pu Tokitoki quarry complexes to the *moai* (statue) quarry at Rano Raraku between AD 1455–1645. Our conclusions better highlight socio-political and economic interaction during Rapa Nui prehistory, while delineating the relationship between adze and pick production and *moai* manufacture. In this article, we report: 1) a synthesis of a five-meter deep field excavation of *moai* RR-001-156 in Rano Raraku; 2) a ^{14}C assessment which dates human presence around *moai* RR-001-156; 3) 31 basalt quarry and source site descriptions; and 4) archaeometric data using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) and principal component analyses of 21 archaeological and 117 geological samples.

Keywords: basalt artefacts, basalt quarries, geochemistry, *moai*, Polynesia, prehistoric interaction, Rapa Nui (Easter Island)

INTRODUCTION

The geochemical study of artefacts, quarries, and sources[5] is a focus of Pacific archaeological studies (Cochrane & Hunt 2017; Kirch & Weisler 1994; Kirch & Kahn 2007; Weisler 1997, 1998, 2002; Weisler [ed] 1997). This research has been invaluable by identifying the locations of stone sources and documenting the different lithic reduction strategies found within Polynesia's quarried landscapes (Clarkson *et al.* 2014; Hermann 2017; Jennings *et al.* 2018; Leach 1993; Leach & Leach 1980; McCoy *et al.* 2012; Turner 1992; Van Tilburg *et al.* 2008a; Weisler 2011; Winterhoff 2007). This research has also accented elite control over highly valued stone resources (Cleghorn 1986; Kirch *et al.* 2011; Lass 1998; McAlister & Allen 2017; Rieth *et al.* 2013; Simpson *et al.* 2017; Stevenson *et al.* 2013), voyaging interaction spheres (Hermann *et al.* 2017; Weisler 1998; Weisler & Sinton 1997; Weisler & Walter 2017), and inter- and intra-island exchange networks in the Austral Islands (Hermann 2013; Rolett *et al.* 2015), in the Cook Islands (Allen & Johnson 1997; Sheppard *et al.* 1997; Walter & Sheppard 1996, 2001; Weisler *et al.* 1994, 2016a), in the Hawaiian Islands (Kahn *et al.* 2008; Kirch *et al.* 2011; Mills *et al.* 2010, 2011; Mintmier *et al.* 2012; Weisler *et al.* 2013), for Henderson, Mangareva, and Pitcairn Islands (Weisler 2002; Weisler *et al.* 2004), in the Marquesan Islands (Allen 2014; Allen & McAlister 2013; McAlister, 2011; McAlister & Allen 2017; Rolett *et al.* 1997;

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[5] We use the term 'source/quarry' as only a few stone locales on Rapa Nui are actual quarries defined by the presence of extraction pits, while other quarries are more properly called 'sources' as tool-quality stone or construction materials were merely collected from the surface (after Weisler & Sinton 1997:180).

Weisler *et al.* 2016b), for New Zealand (Felgate *et al.* 2001; Lawrence *et al.* 2014; Phillips *et al.* 2016), for Samoa and Tonga (Best *et al.* 1992; Cochrane & Rieth 2016; Clark *et al.* 2014), in the Society Islands (Kahn *et al.* 2013), and in the Tuamotu Islands (Collerson & Weisler 2007). This robust record of archaeological and geochemical investigation of artefacts, quarries, and sources has ultimately demonstrated how prehistoric Polynesians possessed a thorough knowledge of Pacific stone. This knowledge allowed them to extract, for example, obsidian, tuff, scoria, and basalt, from numerous quarries and sources throughout Remote Oceania (Green 1991), to create a multiplicity of lithics and remarkable monoliths and megaliths.

Since European discovery of Rapa Nui in 1722 (Figure 1), the island and its stone archaeological remains significantly interested early international researchers (Englert 1948, 1970; Geisler 1882; Heyerdahl & Ferdon [eds] 1961; Knoche 1925; Métraux 1940, 1957; Palmer 1875; Routledge 1919; Thomson 1891). These researchers, along with later investigations, have studied the numerous *moai* statues (Shepardson 2013; Van Tilburg 1994; Vargas *et al.* 2006), *pukao* topknots (Hamilton 2007, 2013; Hixon *et al.* 2017, 2018; Martinson-Wallin 1994; Shepardson *et al.* 2004; Thomas 2014), and *ahu* platforms that have been inferred to serve for ancestor worship, to represent aspects of sociopolitical organisation and economy, and to enforce resource and land ownership rights (Beardsley 1990; Martinson-Wallin 1994; Simpson 2008, 2009; Stevenson 2002). Geochemical research on Rapa Nui has mostly focused on the island's four obsidian deposits (Motu Iti, Orito, Rano Kau, Te Manavai) and corresponding archaeological material to better understand prehistoric access, control, distribution, and use of stone resources (Beardsley *et al.* 1996; Beardsley & Goles 1998, 2001; Bird 1988; Cristino *et al.* 1999; Mulrooney *et al.* 2014, 2015; Stevenson *et al.* 1984, 2013; Thomas 2009). Yet, up to 1998, few studies provided archaeological description of Rapa Nui's fine-grained basalt quarries, sources, and workshops, addressed the major procedures within the *chaîne opératoire* (Sellot 1993) of extraction and reduction for artefacts, and reported accurate and precise geochemical data. Since then, multiple authors have published archaeological site and archaeometric data for Rapa Nui's basalt deposits and lithics (Ayres *et al.* 1998; Fischer & Bahamondez 2011; Harper 2008; Simpson & Dussubieux 2018; Simpson *et al.* 2017; Stevenson *et al.* 2000; Stevenson & Haoa 2008; Vargas *et al.* 2006). Accordingly, these investigations and subsequent elemental profiles for basalt industries have demonstrated the valuable contributions geochemistry offers for prehistoric Rapa Nui interaction studies. This includes providing evidence for the transfer of material from geological sources to habitation, ceremonial, and/or other quarrying sites, and for how this movement perhaps represented opportunistic, communal, kin-based, and/or elite redistribution pathways (see Ayres *et al.* 1998; Peterson *et al.* 1997; Simpson & Dussubieux 2018; Simpson *et al.* 2017). Our current research provides further archaeological and geochemical description of Rapa Nui's fine-grained basalt artefacts, quarries, sources, and workshops by joining the efforts of two on-going projects, the Easter Island Statue Project (EISP) and the Rapa Nui Geochemical

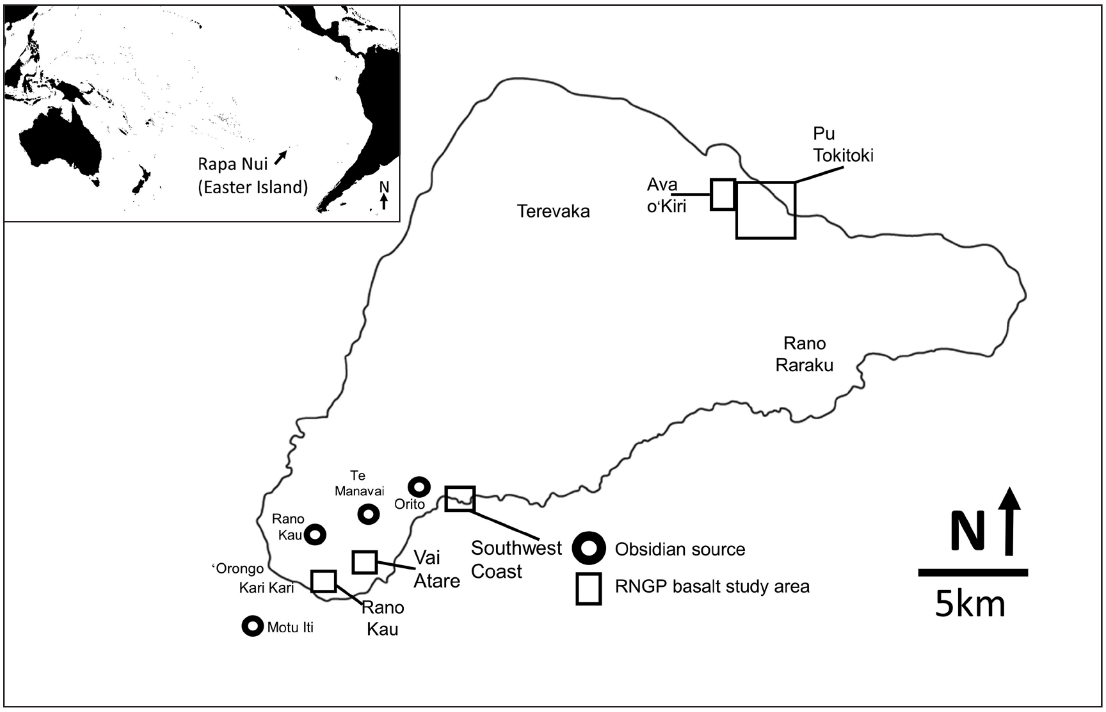

Figure 1. Rapa Nui, obsidian sources, basalt study areas, and locations mentioned in the article.

Project (RNGP). The EISP has produced multiple archaeological assemblages with associated temporal contexts, extensive spatial databases and mapping resources, and integrated previously unpublished field notes along with the field notes from other archaeological researchers (Van Tilburg 1994; Van Tilburg & Pakarati 2012, 2014; Van Tilburg *et al.* 2008a, 2015a,b). The RNGP aimed to expand its research by geochemically analysing other known collections of archaeological basalt from Easter Island to better understand how the prehistoric acquisition, exchange, and use of this stone may highlight spatial and temporal patterns of sociopolitical, ideological, and economic interaction (Simpson 2014; Simpson *et al.* 2017; Simpson & Dussubieux 2018). As such, this paper presents the resultant study that: 1) provides EISP excavation syntheses and a radiocarbon dating regime for human activity around *moai* RR-001-156 found in Rano Raraku; 2) reports RNGP site descriptions for 31 basalt quarries, sources, and workshops from five study areas of the island; and 3) presents LA-ICP-MS (laser ablation-inductively coupled plasma-mass spectrometry) results, including major, minor, and trace elements, for 117 quarry and source samples and 21 stratigraphically recovered pieces from Rano Raraku. Conclusions from our combined EISP and RNGP research delineate the relationship between Rapa Nui's basalt sources and archaeological materials, while illustrating the manufacture, timing, transfer to, and use of basalt artefacts in Rano Raraku. In turn, our results elucidate sociopolitical and economic interaction on Rapa Nui during the prehistoric period.

EASTER ISLAND STATUE PROJECT

Founded in 1982 as a collaboration with the *Universidad de Chile* archaeological team then established on Rapa Nui (Cristino *et al.* 1981; Vargas *et al.* 2006), the EISP had as its central goal documenting *moai* in all of their locations and situations. At the initiation of the Rapa Nui island-wide archaeological survey (1968–1976), 16 site categories were defined, one of which was designated as 'unclassified' (McCoy 1976: 14–15, Table 1). Categories were described structurally but also interpreted functionally in the field, with function being defined largely by Rapanui terminology as applied by field workers. The survey goal was to create a matrix of localized and identified archaeological sites and features. However, of the 11,913 archaeological features constituting 6,927 sites that were identified, only 11 of the original 16 taxonomic categories are available (Cristino *et al.* 1981; Vargas *et al.* 2006). Consequently, this has demanded resurvey and reclassification. Although data are frequently summarized by counts and percentages, they cannot be employed in analytical research unless taxonomic definitions are attached to survey points and symbolized on maps. While *ahu*, *moai*, and *pukao* are part of the original taxonomic list, 'quarries' and 'sources', and the interpretive differences between these site classes (see Weisler & Sinton 1997), are not. Therefore, the EISP expanded its inventory and taxonomy to include these latter categories, along with the broader complexities of other archaeological, geological, and palaeoecological data. Thus, the data compilation between the EISP and the RNGP presented a unique opportunity for both projects.

RANO RARAKU – THE MOAI QUARRY

Rano Raraku was an important site for prehistoric quarrying on Rapa Nui, serving as the major focal point for the ancient island culture to fabricate *moai*. The volcano is one of the many satellite cones that developed from Terevaka's secondary and tertiary volcanic activity (Baker 1967; Gonzalez-Ferran *et al.* 2004). It is an eroded tuff cone, presently filled with freshwater, the level of which has varied significantly during 2018. The cone formed through sub– to shallow marine volcanic activity and primary magmatic fragmentation creating hyaloclastites and hyalotuffs (Drief & Schiffman 2004; Dunn *et al.* 2015; Gioncada *et al.* 2010; Honnorez & Kirst 1975). The exact date of formation is unknown, but a minimum age of 0.21 Ma is reported by Vezzoli and Acocella (2009). The northwest section of Rano Raraku contains fine reddish ash, while the southern skirt contains tuff of sideromelane slightly altered to palagonite that includes volcanic glass fragments (felspathic microlites), crystals, and clasts (Charola *et al.* 1994; Ginocada *et al.* 2010; Dunn *et al.* 2015; Van Tilburg *et al.* 2008b; Vezzoli & Acocella 2009; Wender *et al.* 1996). The youngest fragments of Rano Raraku are vesicular, scoriaceous basaltic lapilli that are embedded into the layers of hardened volcanic ash. Tuff deposits at Rano Raraku also include augites, phenocrysts of olivine with some alteration to iddinsite, clinopyroxene, plagioclase lath, apatite, Fe-Ti oxides, and opaques (Ginocada *et al.* 2010; Van Tilburg 1994; Vezzoli & Acocella 2009).

Regarding the monolithic sculptures carved from Rano Raraku's workable tuff, EISP mapping and excavations build directly upon previous mapping by Routledge (1919), Cristino *et al.* (1981), and Vargas *et al.* (2006), but add original digital and spatial information about *moai* and their production. This georeferenced database includes new records for 304 complete *moai*, 68 heads only, 15 torsos, and 22 sculptural fragments (Van Tilburg *et al.* 2015a). This does not include shaped blocks, which are often *moai* in early carving stages. Therefore, with so much prehistoric activity focused at Rano Raraku, we argue that the volcano served as a continuously evolving ideological, sociopolitical, and economic focal point for the ancient culture, as well as a richly productive horticultural sub-zone. Despite issues centred on the colluvial nature of the soil deposits due to deforestation and the intense industrial activity focused on the upper slopes (Dunn *et al.* 2015), Rano Raraku is one of the more significant archaeological landscapes having potential to better understand interactive human use patterns and archaeological basalt materials from Easter Island.

Moai crater excavation (RR-001-156 and RR-001-157)

To establish the history of human use in Rano Raraku, the EISP survey team conducted high-resolution digital mapping of the quarried bedrock surface and subsurface excavation (Van Tilburg *et al.* 2008a; Van Tilburg & Pakarati 2012, 2014). The decision to re-excavate two standing statues (RR-001-156 and RR-001-157; Figure 2) in Quarry Section 02 of Rano Raraku's inner basin was based on the poor documentation of earlier excavations (Routledge 1919), the significant iconographic data (rock art) on both statues, and the probable presence of additional quarries downslope (Skjølsvold 1961). The geological composition of Quarry Section 02 is a cross-bedded lapilli hyalotuff (Van Tilburg *et al.* 2008a). While the episodic depositional history remains to be fully analysed, it appears that a 2m layered colluvium was deposited due to upslope soil disturbance caused by deforestation and *moai* quarrying (Dunn *et al.* 2015). Thus, this excavation also addresses the history of erosion and deposition in the inner crater basin.

The EISP excavated a series of 1 × 1 m foci (squares) to a depth of 5 m and the complete stratigraphy associated with *moai* RR-001-156 (Figure 3) was exposed for lithostratigraphic sampling and micromorphologic description including: Munsell colour, texture, structure, and the nature of contacts and clasts (Van Tilburg & Pakarati 2014; Van Tilburg *et al.* 2015a,b). Of central interest was the 1624 complete *toki* (adzes from prepared blanks) or *toki* fragments and picks (flaked boulders) found around both statues. Using these artefacts, Fischer and Bahamondez (2011) conducted a non-destructive portable X-ray fluorescence analysis (pXRF) of 170 *toki* and picks to illustrate that elements Zr, Ca, K, Rb, and Ti appeared useful for discriminating the geochemical variability of basalt artefacts. Results also uncover the existence of at least two main raw material sources of the *toki* and picks used in Rano Raraku. This includes 85% of analysed artefacts which were reportedly made from a source of mugearite and 13% of artefacts likely coming from a benmoreite source (Fischer & Bahamondez 2011). While Fischer and Bahamondez (2011) report the existence 15 basalt quarries located through field survey, no geochemical results from these sites were reported. Therefore, to build upon previous work, we can now compare the geochemical profiles of EISP archaeological samples with the elemental signatures attained from RNGP quarries and sources under study. This, in turn, will allow for the identification of the stone material used to make the adzes and picks found at Rano Raraku.

Archaeological dataset

Table 1 presents the basalt archaeological samples (n=21) geochemically analysed in this investigation. They include

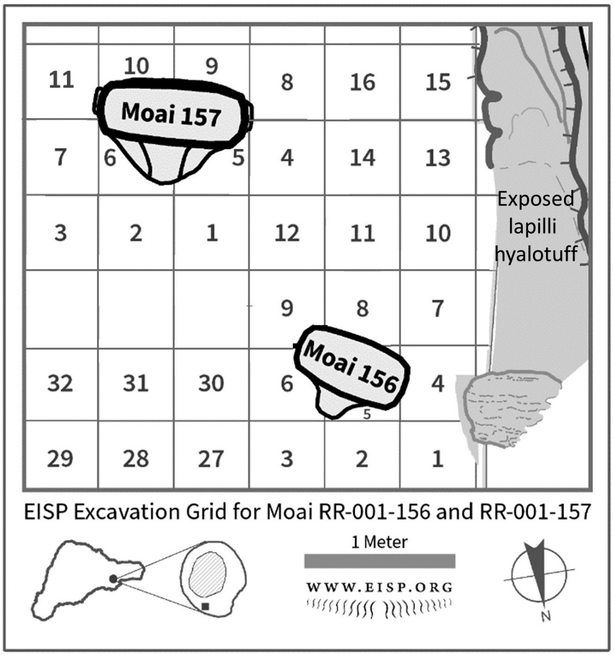

Figure 2. EISP excavation grid for RR-001-156 and RR-001-157 (Cartography by A. Hom/EISP).

Figure 3. Excavated *moai* RR-001-156 (Photo by B. Tuki Haoa/EISP).

specimens that were recovered in excavation of RR-001-156 squares seven and nine at depths from 0–5 m. Four complete picks recovered around *moai* RR-001-156 were also elementally characterized. Table 1 also displays object trait measurements including recorded depth, length, width, and weight. A brief description defines the artefact type.

Radiocarbon samples

Thirty-two radiocarbon determinations were achieved from materials recovered during EISP excavations in Rano Raraku. In this paper, we report a selected set, achieved on *Broussonetia papyrifera* (paper mulberry) materials collected in the front of RR-001-156 in squares 1–4, 6 at depths reaching to 420 cm (Figure 2). Radiocarbon dating was conducted at the Beta Analytic Commercial Laboratory.

RAPA NUI GEOCHEMICAL PROJECT

As basalt adzes, chisels, and picks were necessary tools for woodworking, canoe building, *moai*, *pukao* and *ahu* stone sculpting (Simpson *et al.* 2017; Van Tilburg 1994), understanding their manufacture and distribution can inform on prehistoric economy and social interaction through time (Best *et al.* 1992; Duff 1959; Emory 1968; Weisler 1997, 1998; Weisler 1997 [ed]). Therefore, for more than four years, the goals of the RNGP have been: 1) to locate and archaeologically document Easter Island's prehistoric basalt quarries and sources; 2) to demonstrate how the ancient Rapanui were expert geological miners who developed multiple basalt reduction sequences to make portable artefacts; and 3) to identify patterns of prehistoric sociopolitical and economic organization and interaction inferred through the transfer of basaltic material (Simpson 2014, 2015a, 2016a, 2017a, 2018; Simpson & Dussubieux 2018; Simpson *et al.* 2017). Over four field seasons between 2014–17, the RNGP, along with many representatives of the Rapa Nui community (see acknowledgments), surveyed, documented, and geoarchaeologically sampled 81 fine-grained basalt mines, quarries, sources, and workshops in five study areas (Figure 1). These study areas were chosen as they contained the most surface and sub-surface evidence for the operational sequence of basalt artefact manufacture on Easter Island. Site locations were provided by past publications, local informants and officials, and reconnaissance survey. Our documentation process included identifying the *chaîne opératoire* (Sellot 1993) of basalt tool making, measuring geological quarry, source, and workshop areas, noting GPS coordinates with a Garmin eTrex 20x Worldwide, and taking photos and videos with a Nikon D3400 SLR camera fitted with an AF-S DX Nikkor 16–85 mm f/3.5 lens and a DJI Phantom drone quadcopter fitted with a Hero GoPro4 digital video camera. Our geological sampling procedure extracted between one to seven geological samples per site

Table 1. EISP *archaeological samples from the excavation of moai* RR-001-156 *subjected to geochemical analysis.*

RNGP #	EISP #	Moai #	Square #	Depth (cm)	Length (cm)	Width (cm)	Weight (g)	Specimen description
RR1	RR-001-156-183	156	7	120	7.5	4.5	52.05	Polished flake/debitage
RR2	RR-001-156-200	156	7	200	7.0	5.1	93.74	Flake/debitage with platform
RR3	RR-001-156-132	156	7	220–320	8.5	5.1	102.28	*Toki*/pick fragment with cortex
RR4	RR-001-156-038	156	7	320	4.8	3.1	13.88	*Toki* fragment/debitage with reduction scars
RR5	RR-001-156-052	156	7	375–424	6.2	3.9	37.27	Flake/debitage
RR6	RR-001-156-049	156	7	373–425	8.1	5.0	65.85	Flake/debitage with reduction scars
RR7	RR-001-156-117	156	7	475–500	7.0	3.7	36.84	*Toki* or pick fragment/debitage with reduction scars and cortex
RR8	RR-001-156-023	156	9	0-25	9.6	5.9	131.05	Pick fragment/debitage with reduction scars
RR9	RR-001-156-106	156	9	100–200	6.3	2.6	11.81	Polished *toki* fragment
RR10	RR-001-156-055	156	9	180	12.0	6.7	249.75	Pick fragment with cortex
RR11	RR-001-156-216	156	9	200	4.9	3.9	17.68	Core/pick fragment
RR12	RR-001-156-216	156	9	200	7.3	6.2	247.42	Polished fragment
RR13	RR-001-156-206	156	9	220	5.1	3.4	28.97	Polished fragment/*poro* (beach stone)
RR14	RR-001-156-062	156	9	220–320	5.9	4.0	18.92	*Mata'a* (biface)/debitage
RR15	RR-001-156-062	156	9	220–320	3.4	3.0	35.23	*Toki* fragment
RR16	RR-001-156-153	156	9	434	7.6	6.2	68.53	Polished flake/scraper with retouching
RR17	RR-001-156-169	156	9	434–496	6.94	5.1	38.26	Debitage/*poro* (beach stone) fragment
RR18	n/a	156	n/a	n/a	858	16.0	900.00	Complete pick
RR19	n/a	156	n/a	n/a	>1kg	19.0	900.00	Complete pick
RR20	n/a	156	n/a	n/a	810	15.0	850.00	Complete pick
RR21	n/a	156	n/a	n/a	560	15.5	700.00	Complete pick

(20g in total), depending on overall size (see Weisler *et al.* 2016b for an improved sampling protocol). Ten grams were curated in the island's Sebastián Englert Anthropology Museum (MAPSE) for future analysis, while the other 10g were brought to The University of Queensland (UQ) and The Field Museum of Natural History (TFM) for review and geochemical analyses. For LA-ICP-MS examination, we selected the 31 largest quarries and sources that exhibited the most complete evidence for basalt stone procurement, reduction, and artefact manufacture; especially sites that contained extensive *in situ* remains including: worked outcrops, cores, blanks, preforms, extensive debitage, and complete and fragmented artefacts (Table 2; see supplemental data for complete RNGP quarry and source site descriptions).

Table 2. *RNGP quarries, sources, and workshops under geochemical analysis.*

RNGP site No.	Study Area	Type	Area m²
29	Ava o'Kiri	Quarry/Workshop	264
57	Ava o'Kiri	Quarry/Workshop	420
7	Pu Tokitoki	Quarry/Workshop	800
9	Pu Tokitoki	Quarry/Workshop	660
32	Pu Tokitoki	Quarry/Workshop	609
33	Pu Tokitoki	Quarry/Workshop	500
35	Pu Tokitoki	Source/Workshop	182
43	Pu Tokitoki	Quarry/Source/Workshop	195
45	Pu Tokitoki	Quarry/Workshop	180
46	Pu Tokitoki	Quarry/Workshop	110
48	Pu Tokitoki	Quarry/Source/Workshop	1000
49	Pu Tokitoki	Quarry/Workshop	420
50	Pu Tokitoki	Quarry/Workshop	360
52	Pu Tokitoki	Quarry/Workshop	660
54	Pu Tokitoki	Quarry/Workshop	198
63	Pu Tokitoki	Quarry/Workshop	102
68	Pu Tokitoki	Quarry/Source/Workshop	700
69	Pu Tokitoki	Quarry/Workshop	156
25	Rano Kau	Quarry/Source/Workshop	1200
11a-b	Southwest Coast	Quarry/Workshop	33
13	Southwest Coast	Quarry/Workshop	68
14	Southwest Coast	Quarry/Workshop	123
17	Southwest Coast	Quarry/Workshop	38
81	Southwest Coast	Quarry/Workshop	40
84	Southwest Coast	Source/Workshop	90
89	Southwest Coast	Quarry/Workshop	33
91	Southwest Coast	Source/Quarry/Workshop	49
21	Vai Atare	Source/Workshop	16
22	Vai Atare	Source/Workshop	84
77	Vai Atare	Quarry/Workshop	21
78	Vai Atare	Quarry-workshop	45

Ava o'Kiri and Pu Tokitoki complexes (Figure 4)

The Ava o'Kiri and Pu Tokitoki study areas demonstrate significant evidence for the intensive production of fine-grained basalt tools (Ayres *et al.* 1998; Simpson 2015a,b,c, 2016b; Simpson & Dussubieux 2018; Simpson *et al.* 2017; Stevenson *et al.* 2000; Stevenson & Haoa 2008). In Pu Tokitoki alone, there are more than 42 documented surface features, representing the largest tool quarry and source complex on Rapa Nui. This study area contains multiple quarries, sources, and workshops, including the largest of these sites found to date (RNGP#48; Figure 5). Sites in the Pu Tokitoki region are normally focused around certain features: 1) *puku* (outcrops) that were mined for their different stone make-up; 2) *pu* (pit repositories) that held cobblestones used in the stone reduction sequence; and 3) stone reduction areas which contain hammer stones, cores, blanks, preforms, and very thick distributions of debitage, attesting to the intensive production of basalt artefacts (Figure 5). At Ava o'Kiri, there are at least seven sites that are found within the *ava* (gully). These sites display indication for both fine- (tool grade) and coarse-grained basalt stone extraction and reduction.

Southwest coast mining complex (Figure 6)

Some of the most fascinating basalt mines, quarries, and sources are found on Rapa Nui's southwest coast (Simpson, 2015a, 2016b; Simpson & Dussubieux 2018). In total, there are 21 sites, that, very in size from small *keho* (flat basaltic laminates) chipping-stone workshops (1m in length), to greatly excavated *keho* mines (15 m in depth). While the presence of complete tools is not common, there is heavy debitage in many caves and at cliff sites, highlighting the amount of stone removed from, and reduced at the southwest coast mine complex (Figure 7). Most sites are found

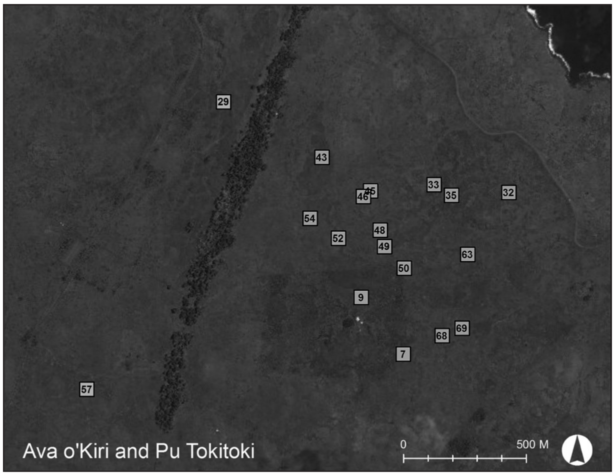

Figure 4. RNGP sites in Ava o'Kiri and Pu Tokitoki under geochemical analysis (Photo courtesy of ESRI, Digital Globe; Cartography by A. Hom/EISP; Simpson 2017b)..

Figure 5. RNGP#48 Rapa Nui's largest fine-grain basalt quarry with multiple *puku,* seven *pu*, numerous adze forms, artifacts, and extensive debitage (Photo by Simpson).

from 2–3 m to 60m above sea level. They appear to be concentrated around exposed *keho* slab deposits (between 2–50 cm of width) that run horizontally as stratigraphic lenses throughout the southwest coast study area. Instead of focusing on *puku* that exhibited multiple stone types as in Ava o'Kiri and Pu Tokitoki, the prehistoric Rapanui at the southwest coast targeted specific geologic stratigraphy that contained fine-grained, tabular *keho* stone. These basaltic laminates are ideal sized to create *toki, hoe* (knife), and *mangai mā'ea* (stone fishhook). There are also easily accessible linear deposits of *kie'a* (mineral pigment) and beach stone (*poro*) deposits, making the southwest coast an important location for stone and mineral pigment raw material (Figure 7).

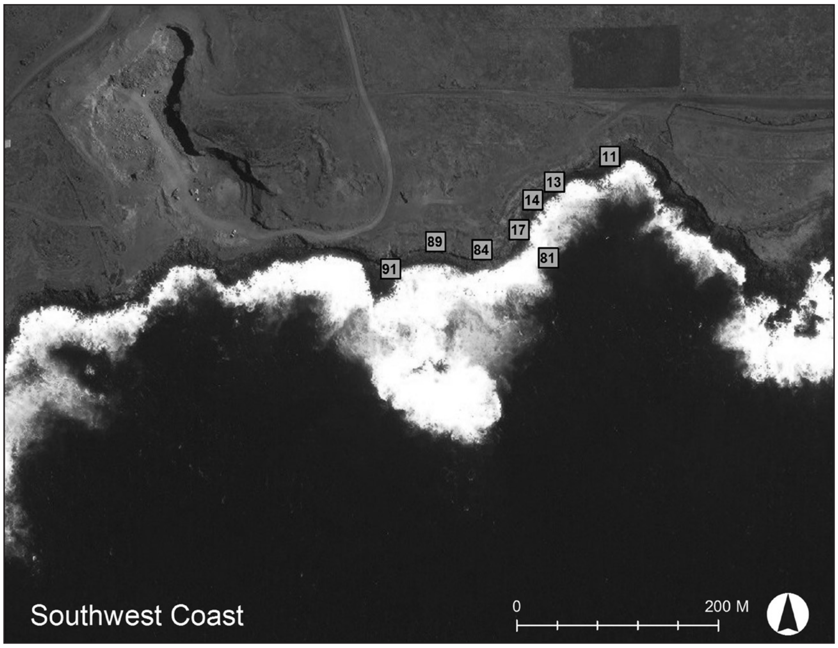

Figure 6. RNGP sites in the southwest coast under geochemical analysis (Photo courtesy of ESRI, Digital Globe; Cartography by A. Hom/EISP; Simpson 2017b).

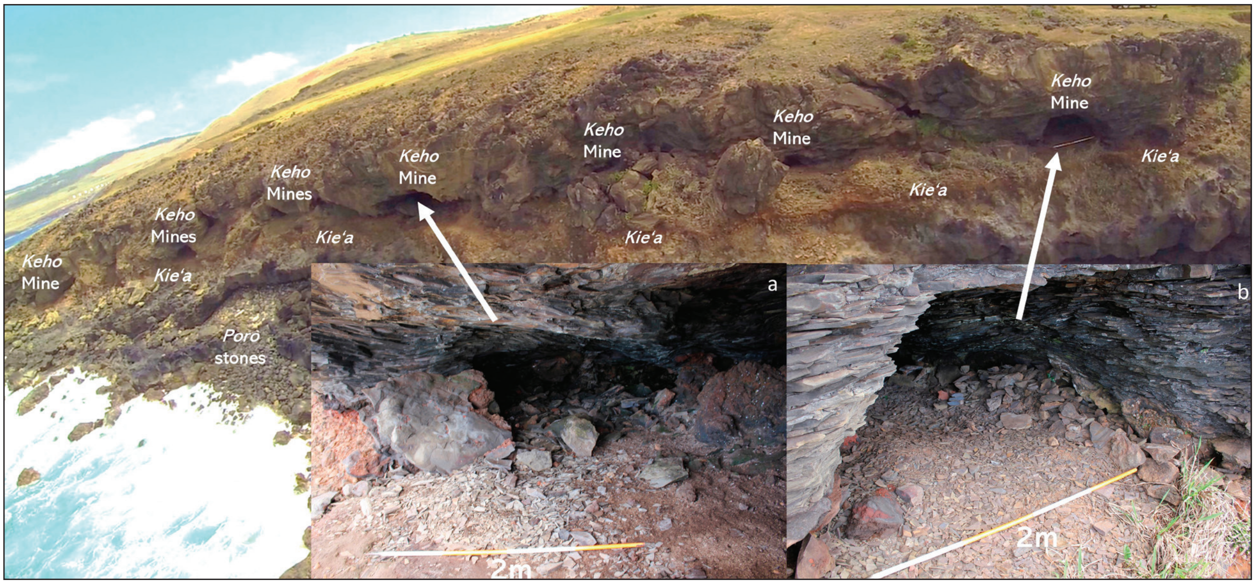

Figure 7. RNGP#11 Southwest coast mine complex with RNGP sites #11(a) and #13(b) (Photo by Simpson).

Rano Kau and Vai Atare complexes (Figure 8)

Areas within Rano Kau and Vai Atare show substantial evidence for stone extraction and reduction (Simpson, 2015a, 2016b; Simpson & Dussubieux 2018). In Vai Atare, 11 locations were documented, while in Rano Kau, two considerable stone extraction sites were recorded. Unlike the evidence from other fine-grained tool quarries and sources, hammer stones, adze blanks, preforms, and pockets of debitage (smaller than 20cm) are rarely found. There is also a lack of *pu* in both areas, with many mining sites taking advantage of surface and cliff benmoreite flows. *Keho* slabs at both Rano Kau and Vai Atare range from very large (~2 m) to smaller 20 cm blocks, with many quarries showing large voids, suggesting intensive stone extraction (Figure 9). While it is evident that a great amount of *keho* stone was removed within the Rano Kau and Vai Atare study areas, we hypothesise that most of this stone was

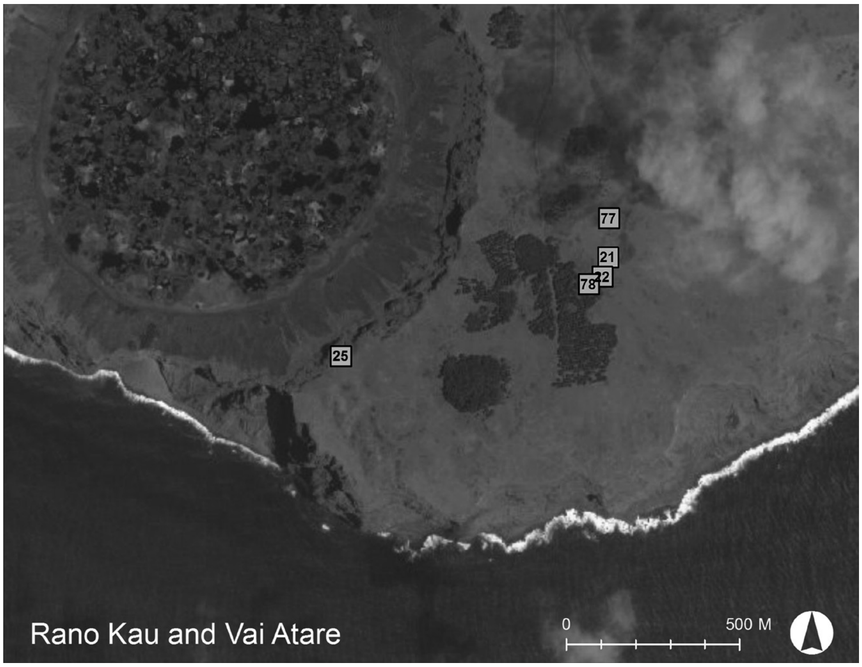

Figure 8. RNGP sites in Rano Kau and Vai Atare under geochemical analysis (Photo courtesy of ESRI, Digital Globe; Cartography by A. Hom/EISP; Simpson 2017b).

Figure 9. RNCG#25: *Keho* quarry in Rano Kau (Photo by Simpson).

used to build the house walls and cantilever ceilings at the ceremonial village of ʻOrongo (Figure 1). This includes the reconstruction of ʻOrongo in the 1970s, which used local material from the Rano Kau area (Mulloy 1975). In short, we find little physical evidence at these quarries and sources to suggest that stone from these two study areas was used *in situ* to manufacture portable artefacts.

ANALYTICAL METHODS AND RESULTS

LA-ICP-MS analysis at TFM's Elemental Analysis Facility (EAF)

LA-ICP-MS was chosen over other analytical methods (including XRF) as this technology 'is generally highly sensitive and can achieve high-precision results for trace elements, [and] has been widely used to trace the provenance of ancient stone artefacts for reconstructing patterns of interaction' (Ma *et al.* 2011: 890). Our methodology followed Carter and Dussubieux (2016) and Simpson and Dussubieux (2018). Analyses were conducted at TFM's EAF using a Thermo ICAP-Q ICP-MS connected to a New Wave UP213 laser for direct introduction of solid samples. The parameters of the ICP-MS are optimized to ensure a stable signal with a maximum intensity over the full range of elemental masses and to minimize oxides and double ionized species formation (XO^+/X^+ and $X^{++}/X^+ <1$ to 2%). For that purpose, the flow of argon, the radio-frequency power, the torch position, the mirror, lenses, and detector voltages are adjusted using an auto-optimization procedure (see Dussubieux *et al.* [eds] 2016 for further discussion regarding ICP-MS operating procedures).

Laser ablation parameters not only influence the sensitivity of the method and the reproducibility of the measurements, but also the amount of damage to the sample. For better sensitivity, helium was used as the gas carrier in the laser. To determine elements with concentrations in the range of ppm while leaving surface traces invisible to the naked eye, the single point analysis mode was used. This mode employs a laser beam diameter of 100 mm, operating at 80% of the laser energy (0.2 mJ) and at a pulse frequency of 20 Hz. A pre-ablation time of 20 seconds was set to eliminate the transient part of the signal, and to be sure that possible surface contamination did not affect the results of the analysis. For each basalt sample, the average of 10 measurements of 45 elements, corrected from the blank, was considered for the calculation of concentrations. The relative large number of measurements insured that a representative volume of material was sampled despite the heterogeneity of the basalt. To improve reproducibility of measurements, the use of an internal standard, Si29, corrected for possible instrumental drifts or changes in ablation efficiency. Concentrations for major elements, including silica, are calculated assuming that the sum of their concentrations (weight % of oxides) is equal to 100% (see Gratuze 1999).

Fully quantitative analyses are possible by using external standards. To prevent matrix effects, the composition of standards must be as close as possible to that of the samples. Two different types of standards are used to measure major, minor, and trace elements. Ideally, we should have used a basalt standard (e.g. USGS standard BHVO-2) but we did not have such a standard in our possession, and in the past, we successfully used glass standards to analyse silica-rich rocks such as carnelian (Carter & Dussubieux 2016). SRM 610, a soda-lime-silica glass doped with trace elements in the range of 500 ppm was used as an external standard. Because certified values are available for a very limited number of elements, concentrations from Pearce et al. (1997) were also used. A second series of standards included Corning Glass B and D which match compositions of ancient glass (Brill 1999; Vicenzi *et al.* 2002; Wagner *et al.* 2012). We assessed accuracy and precision using Corning Glass B and D and found appropriate agreement of values for the major and minor elements (<5%); however, trace element concentrations for these two glasses have never been published (Table 3). Precision is generally more than 10%, but degrades when concentrations are less than 100ppb (0.1 ppm) as these elements are getting close to the limits of detection. In addition, there is no guarantee that the elements are homogeneously distributed in the standards. It is important to note that trace element concentrations in the basalts are generally higher than in the Corning samples. Among the elements selected for statistical analysis, those with the worst RSD were not considered. Accordingly, for most elements, the RSD is better than 10%. Complete major, minor, and trace element values for RNGP and EISP basalt samples, including 17 oxides and 45 elements, are listed in the supplemental data. Using this data, we present a principal component analysis of elements and oxides which geochemically defines Rapa Nui's basalt mines, quarries, sources and workshops, allowing the assignment of a provenance to each EISP sample.

Table 3. *Compared average compositions for Corning Glass B and D. The averages are calculated from 15 compositions measured over the course of the project. Table 3 includes compositions published by Brill* et al. *(1999) and Dussubieux* et al. *(2009) using different ICP-MS. The relative standard deviation (divided by the average concentration for a given element) is calculated giving an indication of measurement precision.*

	CORNING B				**CORNING D**			
	Brill 1999	**Dussubieux *et al.* 2009**	**Average this study**	**RSD this study**	**Brill 1999**	**Dussubieux *et al.* 2009**	**Average this study**	**RSD this study**
SiO_2	61.60%	61.50%	62.50%	0.5%	55.24%	55.60%	55.5%	1%
Na_2O	17.00%	17.60%	16.60%	1.1%	1.20%	1.46%	1.3%	1%
MgO	1.03%	1.01%	1.04%	1.5%	3.94%	3.95%	4.0%	2%
Al_2O_3	4.36%	4.38%	4.35%	1.2%	5.30%	5.36%	5.2%	2%
P_2O_5	0.82%	0.81%	0.91%	7.7%	3.93%	3.94%	3.8%	4%
K_2O	1.00%	1.06%	1.11%	2.7%	11.30%	11.40%	11.4%	1%
CaO	8.56%	8.95%	8.69%	3.7%	14.80%	15.00%	15.1%	6%
MnO	0.25%	0.25%	0.25%	2.3%	0.55%	0.56%	0.6%	2%
Fe_2O_3	0.34%	0.37%	0.36%	3.0%	0.52%	0.53%	0.5%	3%
CuO	2.66%	2.63%	2.54%	6.7%	0.38%	0.37%	0.4%	6%
TiO_2	0.09%	0.10%	0.10%	4.5%	0.38%	0.34%	0.3%	7%
PbO	0.61%	0.53%	0.61%	1.4%	0.48%	0.28%	0.3%	3%
Li	5		11.00	4%	23		27.00	6%
Be			0.10	37%			0.08	46%
B	62		97.00	3%	311		311.00	5%
Sc			6.00	21%			5.00	24%
V	224	168	187.00	2%		95	93.00	3%
Cr			60.00	4%	21		19.00	5%
Ni	786	707	712.00	2%		369	361.00	2%
Co	362		330.00	2%	180		141.00	2%
Zn	1527	1607	1698.00	9%	803	803	831.00	7%
As			18.00	6%			235.00	5%
Rb	9		12.00	5%	46		42.00	6%
Sr	161	161	163.00	8%	482	490	460.00	4%
Zr			166.00	3%			87.00	3%
Nb			0.50	49%			0.70	15%
Ag			63.00	3%			27.00	4%
In			1.00	13%			3.00	8%
Sn	315	242	191.00	7%	787	787	614.00	3%
Sb	3843		2378.00	7%	8103		5092.00	10%

Table 3 *continued.*

	CORNING B				CORNING D			
	Brill 1999	**Dussubieux *et al.* 2009**	**Average this study**	**RSD this study**	**Brill 1999**	**Dussubieux *et al.* 2009**	**Average this study**	**RSD this study**
Cs			0.10	61%			0.22	55%
Ba	1075	627	662.00	2%	4568	2508	2284.00	5%
La			0.40	27%			0.76	15%
Ce			1.00	52%			0.79	44%
Pr			0.10	66%			0.11	68%
Ta			0.20	38%			0.29	8%
Au			0.10	97%			0.10	55%
Y			1.00	19%			0.50	27%
Bi			41.00	6%			12.00	7%
U			0.40	42%			0.23	19%
W			0.20	98%			0.15	68%
Mo			1.70	8%			3.16	10%
Nd			0.20	47%			0.25	40%
Sm			0.07	52%			0.08	53%
Eu			0.07	41%			0.15	43%
Gd			0.07	41%			0.08	54%
Tb			0.03	68%			0.02	68%
Dy			0.09	33%			0.07	33%
Ho			0.04	53%			0.03	50%
Er			0.08	23%			0.06	40%
Tm			0.03	61%			0.02	58%
Yb			0.10	21%			0.08	22%
Lu			0.04	52%			0.03	41%
Hf			4.30	3%			2.28	3%
Th			0.94	8%			0.77	7%

Principal component analysis (PCA)

The approach used here relies on the provenance hypothesis, which implies that 'the variation [of the elemental or isotopic compositions] between sources is greater than that within them' (Wilson & Pollard 2001: 508). In order to examine multivariate patterning in the data, principal component analysis was conducted (Baxter 2003: 73–89). This approach is widely adopted in archaeology for heterogeneous materials including basalt (e.g. Di Piazza & Pearthree 2001). Some elements and oxides (Na_2O, MgO, K_2O, CaO, Be, B, V, Ni, Co, Sr, Zr, Nb, Sn, Ba, Ta, Mo, Th) have significantly different averages when comparing the five sources and therefore were subsequently selected for statistical analysis (Table 4). Before principal components were calculated using JMP 13 statistical software[6], 17 oxides and elements were converted into base-10 logarithms as the different elements have concentrations that can vary by several orders of magnitude (Baxter 2003). Principal component 1 accounts for 64.5% and Principal component 2 for 13.7% of the total variance in the data (Figure 10). Results demonstrate that Ava o'Kiri and Pu Tokitoki have more Sr and CaO compared to the other sources. The southwest coast stone is enriched in Na_2O but depleted in Co, V, and Ni. At Rano Kau and Vai Atare, measurements of Mo, Ta, and Sn are higher compared to the other sources (see Table 4).

Figure 11 plots the five study areas in their elemental space. Notably, elements and oxides used for statistical analysis establish that Ava o'Kiri and Pu Tokitoki, that are found in the same area of the plot, are geochemically similar. This is likely because both study areas are found in the same volcanic flow and include similar geological and total alkali versus silica (sodium oxide [Na_2O] plus potassium oxide [K_2O] against silica oxide [SiO_2]) compositions (Gonzalez-Ferran *et al.* 2004; Simpson & Dussubieux 2018; Vezzoli & Acocella 2009), making elemental discrimination difficult (see also Stevenson *et al.* 2000). Rano Kau and Vai Atare study areas exhibit similar geochemistry, with samples from Rano Kau less variable in elemental space. Geochemically, the southwest coast study area separates from other RNGP study areas, exhibiting a more homogeneous elemental fingerprint.

Figure 12 plots the PCA analysis of EISP archaeologi-

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[6] https://www.jmp.com/en_us/software/preview-jmp13.html

Table 4. *Average compositions with relative standard deviations for the different areas investigated in this study. The number of samples is indicated with the name of the study area. Bold and underlined elements represent those used in statistical analysis.*

	Ava o‘Kiri (9)		Pu Tokitoki (71)		Rano Kau (3)		Southwest Coast (22)		Vai Atare (10)	
SiO_2	56.7%	4%	55.30%	4%	63.90%	1%	61.70%	3%	64.1%	8%
Na_2O	3.71%	16%	3.89%	10%	4.53%	8%	5.10%	6%	4.12%	19%
MgO	**2.81%**	**33%**	**3.01%**	**29%**	**0.68%**	**87%**	**0.70%**	**45%**	**0.62%**	**85%**
Al_2O_3	14.80%	14%	15.00%	10%	16.10%	11%	15.00%	7%	16.6%	18%
P_2O_5	0.90%	19%	0.83%	15%	0.37%	39%	0.33%	18%	0.29%	50%
K_2O	**1.28%**	**20%**	**1.32%**	**16%**	**3.00%**	**14%**	**2.00%**	**8%**	**2.63%**	**20%**
CaO	**6.75%**	**7%**	**7.40%**	**10%**	**2.20%**	**61%**	**3.10%**	**28%**	**2.09%**	**59%**
MnO	0.23%	27%	0.24%	25%	0.18%	36%	0.19%	38%	0.12%	38%
Fe_2O_3	10.70%	21%	10.90%	21%	7.90%	11%	10.00%	20%	8.12%	30%
TiO_2	2.17%	29%	1.95%	30%	0.98%	15%	1.00%	14%	1.20%	57%
Li	7.80	39%	8.84	25%	20.00	35%	9.70	34%	15.00	41%
Be	**2.10**	**24%**	**2.20**	**15%**	**5.10**	**23%**	**3.90**	**41%**	**4.20**	**15%**
B	**3.40**	**29%**	**3.90**	**24%**	**8.50**	**26%**	**6.50**	**28%**	**6.00**	**32%**
Sc	30.00	20%	30.30	20%	25.40	23%	29.00	11%	22.00	16%
V	**122.00**	**25%**	**148.90**	**29%**	**41.60**	**25%**	**0.97**	**34%**	**71.00**	**127%**
Cr	0.67	62%	1.59	41%	5.20	32%	1.30	72%	3.50	84%
Ni	**0.65**	**30%**	**0.87**	**49%**	**6.50**	**86%**	**0.17**	**33%**	**4.70**	**81%**
Co	**20.00**	**33%**	**22.00**	**27%**	**7.50**	**2%**	**2.80**	**40%**	**8.70**	**44%**
Cu	13.00	21%	18.00	30%	19.00	49%	6.70	34%	18.00	34%
Zn	175.00	23%	165.00	18%	183.00	3%	182.00	15%	166.00	36%
As	0.30	61%	0.65	48%	2.10	70%	1.10	70%	1.10	55%
Rb	21.00	36%	21.00	22%	50.00	36%	35.00	36%	56.00	40%
Sr	**240.00**	**20%**	**283.00**	**12%**	**130.00**	**29%**	**208.00**	**9%**	**117.00**	**23%**
Zr	**436.00**	**16%**	**409.00**	**11%**	**883.00**	**13%**	**716.00**	**9%**	**830.00**	**20%**
Nb	**63.00**	**16%**	**60.00**	**11%**	**129.00**	**13%**	**83.00**	**10%**	**108.00**	**17%**
Ag	0.14	18%	0.20	48%	0.71	43%	0.27	20%	0.34	52%
In	0.19	15%	0.25	52%	0.55	51%	0.25	28%	0.34	32%
Sn	**3.70**	**20%**	**3.50**	**17%**	**8.20**	**21%**	**4.90**	**16%**	**7.00**	**27%**
Sb	0.48	56%	1.04	155%	1.20	31%	0.35	71%	1.20	151%
Cs	0.23	36%	0.30	32%	0.67	37%	0.21	55%	0.40	36%
Ba	**190.00**	**13%**	**174.00**	**14%**	**328**	**3%**	**265.00**	**8%**	**273.00**	**20%**
La	39.00	18%	39.00	16%	40.00	48%	40.00	31%	33.00	42%
Ce	96.00	16%	94.00	17%	84.00	49%	86.00	39%	73.00	37%
Pr	14.00	16%	14.00	18%	13.00	47%	13.00	29%	10.00	39%
Ta	**4.40**	**17%**	**3.80**	**19%**	**8.30**	**11%**	**5.10**	**11%**	**6.00**	**31%**
Au	0.02	14%	0.04	98%	0.10	39%	0.04	31%	0.10	160%
Y	61.00	16%	65.00	14%	75.00	35%	72.00	21%	66.00	33%
Pb	2.40	13%	2.90	61%	5.40	21%	3.40	80%	4.00	42%
Bi	0.01	37%	0.07	137%	0.38	98%	0.04	170%	0.12	94%
U	1.10	22%	1.20	32%	3.50	24%	2.00	14%	2.10	34%
W	0.60	18%	0.60	38%	1.50	41%	0.91	36%	1.20	34%
Mo	**2.80**	**18%**	**2.80**	**15%**	**5.50**	**4%**	**3.60**	**18%**	**5.40**	**18%**
Nd	49.00	16%	49.00	15%	42.00	51%	50.00	29%	37.00	39%
Sm	12.00	15%	12.00	15%	11.00	46%	13.00	27%	9.50	37%
Eu	3.70	13%	3.90	15%	3.60	15%	4.90	17%	3.30	27%
Gd	13.00	16%	13.00	15%	11.00	46%	13.00	25%	9.50	36%
Tb	2.50	15%	2.30	17%	2.40	35%	2.40	22%	1.90	34%
Dy	12.00	15%	12.00	15%	12.00	33%	14.00	22%	11.00	32%
Ho	3.00	16%	2.70	17%	3.20	29%	3.20	20%	2.60	31%
Er	6.20	16%	6.30	15%	7.60	27%	8.10	23%	6.30	30%
Tm	1.10	16%	1.00	18%	1.50	26%	1.30	20%	1.10	31%
Yb	5.50	17%	5.70	16%	7.90	19%	7.80	22%	6.50	30%
Lu	1.00	16%	1.00	18%	1.50	27%	1.30	22%	1.20	31%
Hf	11.00	17%	10.00	16%	26.00	14%	18.00	12%	19.00	31%
Th	**4.20**	**21%**	**3.80**	**21%**	**10.00**	**14%**	**6.00**	**11%**	**6.90**	**34%**

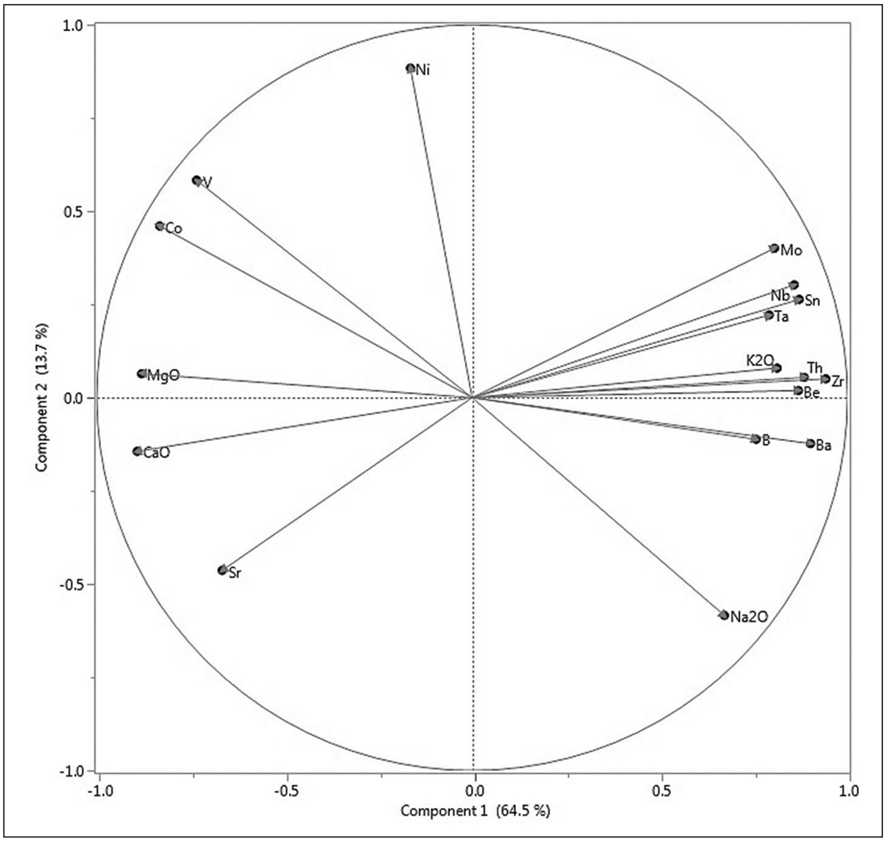

Figure 10. Component loadings by elements included in the PCA.

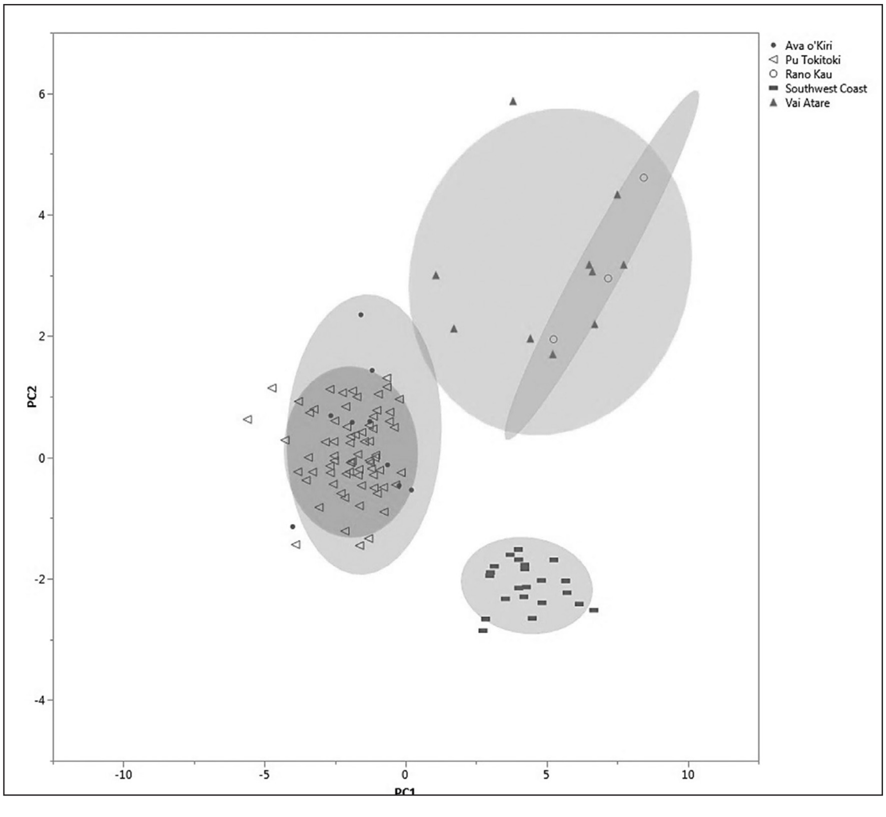

Figure 11. PCA analysis of RNGP study areas (ellipses represent 90% confidence probability).

cal material versus RNGP study areas. Although many artefacts are sourced to Ava o'Kiri and Pu Tokitoki and less to the southwest coast, there are some artefacts which plot outside PCA probability ellipses. This detection may indicate that our analyses have not completely captured the geochemical variability of RNGP study areas, or that they have identifed quarries and sources that the RNGP has not located and/or analysed. Possible settings for these unknown quarries and sources include locations in the archaeological '*corrales*' (enclosures) found in the centre of the island (Stevenson *et al.* 2005; Vargas *et al.* 2006), or on unsurveyed cliff faces as found on Poike (Simpson *et al.* 2017). Contradicting the proposition by McCoy (2014) and geoarchaeological sourcing results of Ayres et al. (1998) and Harper (2008), not one adze under study was provenanced to Rano Kau or Vai Atare. This result, along with the limited archaeological site evidence for *in situ* tool making (i.e. cores, blanks, preforms, and debitage), suggests the limited use of Rano Kau and Vai Atare basalt for portable artefact making.

Radiocarbon dating

Broussonetia papyrifera samples returned dates of AD 1460–1635 (2 samples), AD 1455–1630 (1 sample), AD 1465–1645 (1 sample), and AD 1460–1640 (1 sample). Other determinations correlate with these dates but also reveal disturbance and mixing in some areas. While Bayesian probabilities for all radiocarbon determinations is in preparation, Figure 13 presents ^{14}C radiometric results, plotting: Beta/sample ID, square location, sample level (cm), and calibrated date (calAD) for the activity around *moai* RR-001-156. Moreover, Table 5 provides radiometric reporting as mandated by the *Journal of Pacific Archaeology*.

DISCUSSION

Schiffer's publications (1976, 1987) encourage archaeological investigations to consider the cultural and natural transforms that create the archaeological record and how post-depositional processes affect site formation and influ-

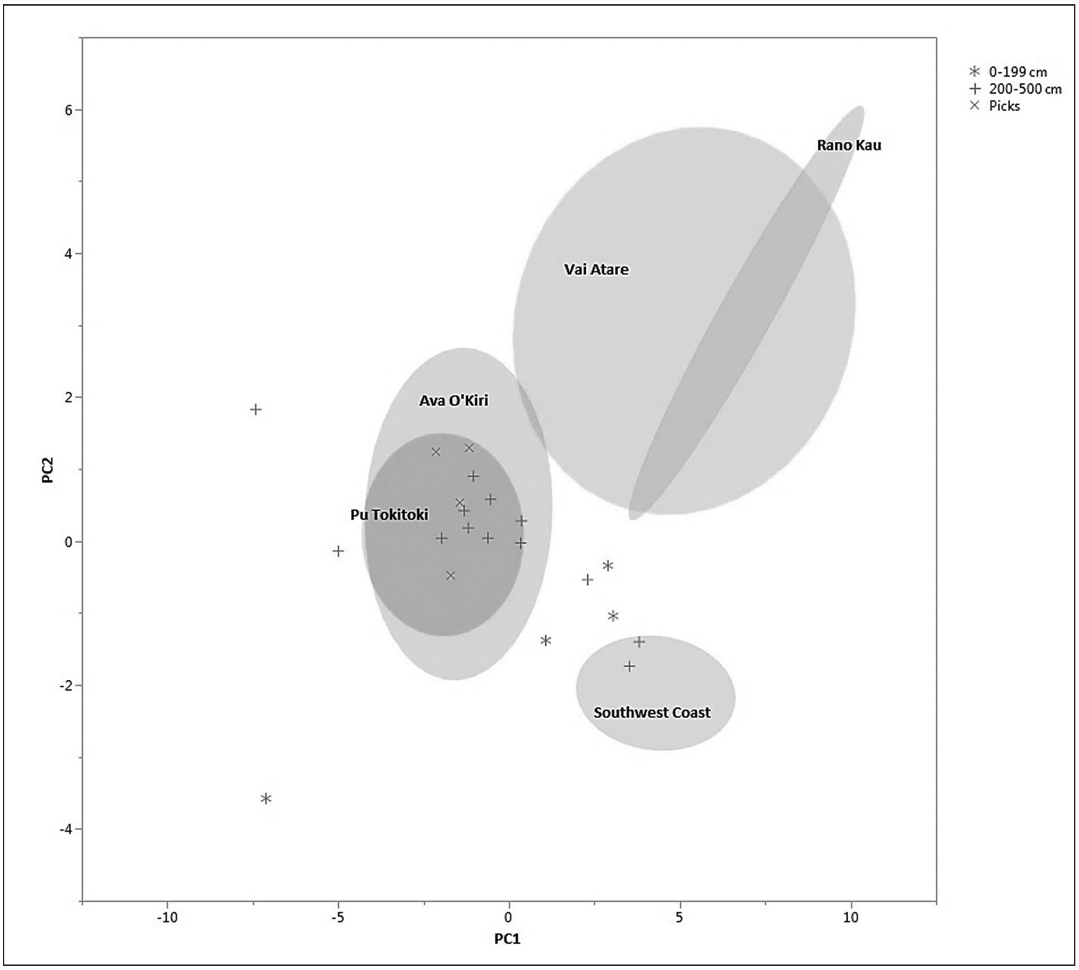

Figure 12. PCA analysis of EISP archaeological samples and RNGP study areas (ellipses represent 90% confidence probability).

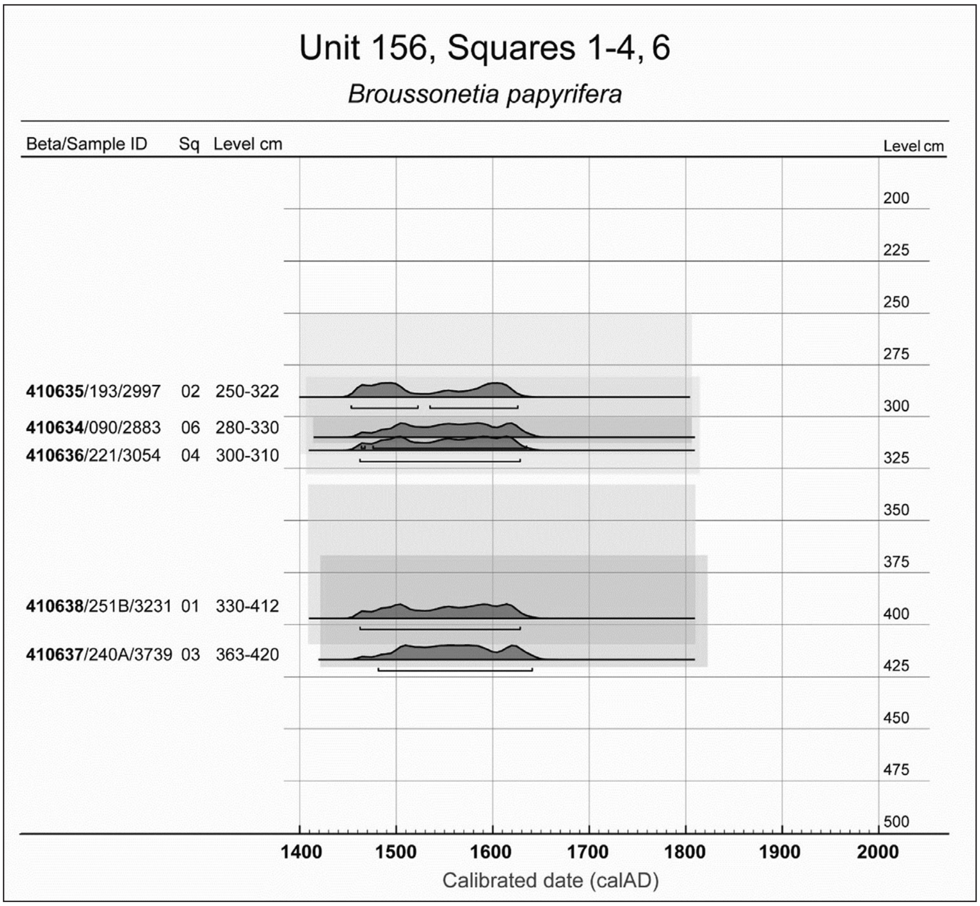

Figure 13. Radiometric data from *Broussonetia papyrifera* samples at RR-001-156 plotting beta/sample ID, square location, level cm, and calibrated date (calAD).

Table 5. *Radiometric data from five* Broussonetia papyrifera *samples at RR-001-156*

Provenience	Lab No.	Sample Material	$^{13}C/^{12}C$ Ratio (0/00)	Conventional Radiocarbon Age (BP)	Calibrated 2 σ age range (BP)
410635/193/2997 Square No. 2 250–322 cm	Beta-410635	*Broussonetia papyrifera*	−25.7	400 ± 30 BP	Cal AD 1455–1630
410634/090/2883 Square No. 6 280–330 cm	Beta-410634	*Broussonetia papyrifera*	−25.7	380 ± 30 BP	Cal AD 1460–1635
410636/221/3054 Square No. 4 300–310 cm	Beta-410636	*Broussonetia papyrifera*	−26.1	370 ± 30 BP	Cal AD 1460–1640
410638/251B/3231 Square No. 1 330–412 cm	Beta-410638	*Broussonetia papyrifera*	−26.9	380 ± 30 BP	Cal AD 1460–1635
410637/240A/3739 Square No. 3 363–420 cm	Beta-410637	*Broussonetia papyrifera*	−25.9	360 ± 30 BP	Cal AD 1465–1645

ence the interpretations made by archaeologists. Thus, to better describe the Rano Raraku crater, its geomorphological formation, and human use of this tuff volcano to make Easter Island's iconic statuary, a 5m-deep excavation in Quarry 02 focused on the micromorphological recording of lithostratigraphic units around the area of *moai* RR-001-156 (Dunn *et al.* 2015; Van Tilburg & Pakarati 2014; Van Tilburg *et al.* 2015a,b). This fieldwork revealed a 2m embedded colluvium that formed after the initial use of the *moai* quarry. Under this colluvium horizon, 3m was further unearthed until reaching the base of *moai* RR-001-156. Multiple specimens and object raw material types were recovered under the colluvium during excavation. *Broussonetia papyrifera* provided samples for radiometric determination, resulting in five samples with date ranges from cal AD 1455–1645. Also around *moai* RR-001-156 and 157, 1624 basalt *toki*, picks, and fragments were found in association with cores, flakes, and debitage. Portable XRF analysis of the *toki* and picks revealed that at least two unidentified basalt sources were exploited to obtain the raw material used to manufacture the 170 *toki* and picks under study (Fischer & Bahamondez 2011).

Our current study reports more accurate and precise LA-ICP-MS elemental data for EISP samples including four complete picks along with 17 stratigraphically recovered specimens (*toki* and pick fragments, flakes, and cores). This elemental data was compared to the geochemical signatures of 31 mines, quarries, sources, and workshops from five study areas as determined by the RNGP using PCA. Results highlight that each of the four picks found around *moai* RR-001-156 were sourced to the Ava oʻKiri and Pu Tokitoki complexes, establishing a link from these study areas and their basalt resources to the statue quarry at Rano Raraku. This result supports ethnographic observations by Métraux (1940) and geochemical results by Simpson and Dussubieux (2018) who also identified Ava oʻKiri and Pu Tokitoki as the major sources for the stone used in adze and pick manufacture. Of the 17 EISP pieces that were stratigraphically recovered and elementally analysed, four samples were from within the colluvium's 0-199cm depth. All four of these samples were found to be geochemically distinct stone, unknown to the RNGP. The geochemical analysis of 13 archaeological specimens recovered from 2–5 m provides insight to stone material selection and use to fabricate artefacts found in Rano Raraku. Simply, more than 60% of all EISP's basalt samples were elementally sourced to Ava oʻKiri and Pu Tokitoki. Only five samples were found from outside these study areas, with two samples originating from the southwest coast mining complex, and three samples sourced from locations unknown to the RNGP. This pattern, again, shows the preferential use of Ava oʻKiri and Pu Tokitoki stone to make tools to carve *moai* at Rano Raraku. In addition, with a consistent grouping of samples originating from Ava oʻKiri and Pu Tokitoki and the southwest coast, it appears that there were at least two main locations that produced stone for *toki* and pick manufacture. These results support conclusions made by Fischer and Bahamondez (2011), where two sources of basaltic material for *toki* and picks were identified thought pXRF analysis. Yet, Ava oʻKiri and Pu Tokitoki appear to be the principle location for the basaltic material used to make the artefacts recovered around *moai* RR-001-156.

The five (of a total of 35) radiocarbon dates reported here are from the area around RR-001-156 and fall between cal. AD 1455–1645. While it should be noted that the dated charcoal is not in direct association with the archaeological material examined, we suggest that basalt material coming out of the Ava oʻKiri and Pu Tokitoki quarry complex, the southwest coast, and the unknown sources still unidentified by the RNGP, may be cautiously bracketed between AD 1455–1645. Interestingly, this time period has been suggested as a possible peak of *moai* carving where Rano Raraku would have been a major sociopolitical and economic focal point for the prehistoric culture (Fischer 2005; Van Tilburg 1994; Vargas *et al.* 2006). Overall, the evidence in the interior region of Rano Raraku demonstrates that multiple statues were being carved, but not necessarily finished at the same time, creating a necessity to have a quantity of stone tools on hand. Additionally, the oldest surveys of Rano Raraku documented the quarry as being littered with numerous deposits of *toki* and picks (Pinart 1878; Routledge 1919; Skjølsvold 1961). This pattern for the purposeful caching of finished tools has also been documented on Rapa Nui for other stone artefacts including obsidian *mataʻa* (bifaced tool) and handheld figure carvings (Heyerdahl 1975; Heyerdahl & Ferdon 1961; McCoy 1976; Vargas *et al.* 2006). Therefore, we argue that this purposeful caching of *toki* and picks – including the 1624 specimens recovered around *moai* RR-001-156 and *moai* RR-001-157 – does not represent a dramatic abandonment of *moai* carving as has been proposed and linked to the island's alleged 'collapse' (Bahn & Flenley 1992; Diamond 2005), but instead highlights that *tangata māori anga moai* (ancient statue carvers) were well organized and planned ahead by having a surplus of necessary materials on hand and ready to use making Rano Raraku a highly productive megalithic quarry; hence the production of ~1000 *moai*.

We believe that the ability of stone tool makers to produce large quantities of *toki* and picks greatly influenced the pace of *moai* carving at Rano Raraku and may have been the reason for such intensive quarrying at Ava oʻKiri and Pu Tokitoki. Judging from the size of these complexes, and the sheer amount of stone extraction and reduction that took place, we imagine that these basalt quarries and sources were in use from a much earlier time; more so if the island was colonized by AD 1100–1200 (Hunt & Lipo 2006; Mulrooney 2013; Stevenson *et al.* 2015; Weisler & Green 2011). Like Rano Raraku for *moai* and Puna Pau for *pukao*, Ava oʻKiri and Pu Tokitoki likely served as major focal points for stone tool manufacture for generations, with great labour and organisational effort focused on extracting and reducing stone to produce basalt artefacts. This effort produced nearly 50 documented sites dedicated to the production of stone tools, including those used at Rano Raraku. The acquisition of this basalt may have been the work of specialised 'task groups' who visited the area to extract stone on an on-going basis (Stevenson *et al.* 2000:68; see also Simpson and Dussubieux 2018). In turn, the intensive use of Ava oʻKiri and Pu Tokitoki by Rapa Nui's prehistoric stone tool artisans created an anthropogenic landscape by mining *puku* with multiple geologic deposits, excavating *pu* to make pit repositories, and prolifically reducing basaltic material into cores, blanks, preforms, and arguably finished lithics. As such, we maintain that like other skilled experts (McCoy 2014; Simpson *et al.* 2017; Simpson & Dussubieux 2018), *tangata māori anga māʻea* (experts in stone tool manufacture) were recognized as a highly-privileged sociopolitical class and were rewarded for their specialised labour with luxury resources such as fish, lobster, and eels (Métraux 1940). Once artefact manufacture by these experts was nearly complete and/or finished at Ava oʻKiri and Pu Tokitoki, and to a lesser degree from the southwest coast, tools such as *toki* and picks were transferred to Rano Raraku. At this most impressive megalithic quarry, these travelled tools then carved and produced the iconic symbol of Easter Island and its people, the *moai.*

CONCLUSION

This joint EISP and RNGP investigation used multiple data sets to better understand the provenance and the timing of use for basaltic material found in Rano Raraku. The synthesis of these data confirms a major prehistoric connection between the Ava oʻKiri and Pu Tokitoki basalt stone complexes and the *moai* quarry during a time frame preliminarily suggested to bracket AD 1455–1645. Further refinement of this time frame awaits a completed Bayesian analysis of the other radiocarbon determinations. Our results suggest that basalt stone tool makers played a substantial role in the efflorescence of *moai* manufacture, especially during the peak production of Easter Island's celebrated statuary. We argue that this specialised class of master tool makers, along with task groups, where responsible for the creation of Rapa Nui's basalt industries that were used to produce the adzes and picks for *moai* carving. Our work shows that by better delineating basalt tool operational sequences – from stone acquisition at Ava oʻKiri and Pu Tokitoki to artefact use for statue carving at Rano Raraku – we can better appreciate the specialisation of Rapa Nui stone tool manufacture and *moai* fabrication.

To better understand prehistoric sociopolitical and economic interaction on Rapa Nui, we suggest that future studies continue the search for and the analysis of fine-grained basalt quarries and sources. This includes locations around the *corrales* (enclosures) in the centre of the island (Stevenson *et al.* 2005; Vargas *et al.* 2006) and on cliff faces as found on Poike (Simpson *et al.* 2017). Further field survey and documentation in Rano Kau is also needed, as more *keho* quarries and sources were identified by the RNGP, but not surveyed and sampled (Simpson and Dussubieux 2018). Supplementary geochemical analysis of these sites, along with cores, flakes, fishhooks, adzes, and debitage found at ceremonial and habitation sites, will help to uncover the chronology and use of basalt. Futher analysis of museum and private artefact collections (especially those with known spatial and temporal contexts) would also be beneficial. In addition, as no archaeological excavation has ever been conducted on basalt quarries, sources, and/or workshops on Rapa Nui, preliminary excavations of the largest mining sites should provide additional information about the *chaîne opératoire* of basalt tools, generate site-formation evidence, and offer material for radiometric and obsidian hydration dating. Together, this data would provide further timing of basalt quarry, source, and workshop use.

Lastly, the collaboration between the EISP and RNGP provides an example of how the integration of multiple datasets, by projects with different personnel, research designs, and goals, serves to better understand the ancient Rapa Nui culture. As such, we have heeded suggestions by Larsen and Simpson (2014) who recommend that the involvement of more scientific fields (including geochemistry), using synergetic research methods, would better help to demonstrate the sociopolitical and economic complexity that existed during Rapa Nui's past. We hope our example of collaboration is enough to join other island projects in larger synergetic investigations interested in uncovering and better appreciating Easter Island's storied prehistory.

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