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Modelling Prehistoric Social Interaction in the South-western Pacific: a View from the Obsidian Sources in Northern Vanuatu

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Abstract. This paper investigates the history of social interaction within communities in the Vanuatu Archipelago and between Vanuatu and other regions in the Western Pacific as reflected by variations in lithic raw material sources and technology of stone artefacts. Past research determined an apparent contradiction between long-distance transportation of obsidian, indicating high value, and the under-utilisation of the raw material at the place of discard, indicating low value. The paper concludes that because previous hypotheses depend too much on the notion of the scarcity of resources in their evaluation of the concept of value, they are insufficient to explain the pattern of spatial and temporal distribution of lithic artefacts. Rather than focusing on the intrinsic value of obsidian raw material for individuals or communities, it is more useful to view it as a marker of group identity in a complex system connecting discrete populations in mitigating risk in unpredictable new environments. These new environments included pre-established populations, which might be hostile to new arrivals. The necessity for this complex system quickly disappeared once the colonisers arrived in regions uninhabited by prior populations.

Introduction

Obsidian has been a focus of archaeological research in the Pacific for its unique geochemical attributes that allow identification of distance and directionality in raw material transport, which enables interpretations about its importance as an item embodying cultural meaning (Sheppard, 1993; Torrence, 2005). During the period when Lapita pottery was made some 3000 years ago, obsidian travelled long distances from source locations in West New Britain, Papua New Guinea, as far East as Fiji and West to Sabah in Malaysia (Sheppard, 2011). This long-distance transportation of obsidian over several thousand kilometres has raised questions why people selected obsidian from particular sources, and how this transport might have been organised.

The appearance of Lapita pottery in Remote Oceania (the islands to the south and east of the main Solomon Islands chain) has been associated with a migration of groups out of the Bismarck Archipelago Papua New Guinea region (Kirch, 1997; Spriggs, 1997). These groups have been described as potentially small and highly mobile initially leaving only a small footprint of human occupation; primarily, but not exclusively, on small off-shore islands (Bedford and Sprigg, 2008). The small size and low number of initial groups have been hypothesised to be prime cause explaining subtle difference in the archaeological record of Lapita sites (Bedford, 2019), and this differentiation has been associated with the emergence of 'localised ethnic identities' (Green and Kirch, 1997: 30). The detailed process of this population movement is unclear (Sheppard, 2011), as are likely reasons for it. Different explanations have been proposed, summarised as push and pull factors (Lilley, 2000), such as demographic pressures (Bellwood, 2011), environmental disasters (Grattan and Torrence, 2007), and the search for pristine environments with abundant food resources (Lilley, 2019). Each of these reasons might have played a part at some stage in the process, but the archaeological record is unlikely to preserve clear evidence for them (Kirch, 1997: 253; see also Anthony, 1990).

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Before the appearance of Lapita pottery in the Bismarck Archipelago, the main obsidian technology on New Britain comprised the production of complex stemmed obsidian tools, some of which have associated with high social value connected with prestige and status (Araho *et al*., 2002; Torrence, 2005). In contrast, Lapita pottery sites mark a substantial shift to a simple technology of small and medium sized flakes produced by direct percussion, bipolar hammering or crushing, only a few of the artefacts display retouch or use-wear (Torrence, 1992; Sheppard, 1993; Kononenko *et al*., 2010).

The combination of distance and social organisation has been used to explain the social value of obsidian and to define Lapita as a hierarchical society in which obsidian as a prestige object allowed actors to acquire social status and power (Kirch, 1997; cf. Earle and Spriggs, 2015). However, the lack of an elaborate lithic technology and of evidence for resource optimisation presents a conundrum as this pattern does not fit into common models of distribution of long-distance transported raw materials with high value (Torrence, 2005). The dominant interpretation of the role of obsidian in Lapita societies currently is that it was transported for its social value connecting populations to a founding 'homeland' (Green, 1987: 246; Kirch, 1988: 113; Sheppard, 2011). These interpretations have also been applied to artefact assemblages from Vanuatu (Reepmeyer *et al*., 2011; Galipaud *et al*., 2014; Constantine *et al*., 2015).

In this paper, I go a step further and propose that obsidian transportation did not define hierarchical status of individuals or connect people to their point of origin, but rather it was used as a marker of group identity in a complex system connecting discrete populations in the mitigation of risk in unpredictable new environments. Initially, these new environments included pre-established populations which might have been hostile to new arrivals. The need for marking identity disappeared quickly once the colonisers arrived in uninhabited regions.

This paper examines these assumptions and tests the validity of economic models in defining obsidian transportation through a combination of geochemical data and basic measurements of obsidian artefacts within the methodological framework outlined by Torrence (1986) and Hodder (1978). Summarising previously published works, it argues that although the obsidian artefacts show a clear trend of down-the-line movement, this by itself cannot explain the necessity to transport the raw material. The paper proposes that the correlation of changes in identity marking and intensities of interaction within environmental constraints is more productive in understanding the organisation of obsidian transport.

Background and some theoretical considerations

Values of obsidian

The function of obsidian artefacts in past societies in the Pacific has seen a wide range of interpretations. Use-wear/residue studies have pointed out the exceptional sharp edges of the material and identified a wide range of functions for these tools: processing of siliceous soft wood, non-siliceous soft and hard wood, non-woody plants and soft elastic skin, including possible tattooing and scarification (Kononenko *et al*., 2010; Kononenko, 2012; Torrence *et al*., 2018). Mundane functions of obsidian have been emphasised as obsidian discard occur mainly in domestic contexts (Torrence, 2005). Low value of obsidian has also been suggested because of the small amount of energy required for expedient reduction and curation of the raw material (Fredericksen, 1994; Hanslip, 2001). Unfortunately, functional approaches alone do not explain long-distance transportation of obsidian or the choice by communities to import obsidian from one source only (Torrence *et al*., 1996; Torrence and Summerhayes, 1997); more so as use-wear studies of other raw materials such as chert and quartz display the same aforementioned functions, with the main difference being a shorter use-life for obsidian artefacts (Kononenko *et al*., 2010).

It has been suggested that the Lapita complex represents a system of trading goods between communities (Terrell, 1989: 625) with obsidian being a very visual part of the archaeological record. Viewing obsidian as a traded commodity, however, implies that these objects were specifically made for this purpose and were exchanged between people who did not necessarily share the same cultural or economic background (Gregory, 1982; Graeber, 2001). Consequently, it would be expected that a close emotional bond between transactors did not always exist. As a shared identity is presumed not to be essential for trade, individuals could have categorised the value of these objects within the sphere of subsistence (Appadurai, 1986; Earle, 1997). Would short use-life and focus on only one source imply obsidian as a luxury item for the accumulation of wealth? Variations in burial practices at the Teouma cemetery in Vanuatu possibly reflect different social positions of individuals (Valentin *et al*., 2011), but there is no evidence for the accumulation of obsidian by individuals (Constantine *et al*., 2015).

Rather than viewing the value of obsidian as a luxury item, its value might have derived from its physical attributes such as its distinctive glassy appearance, translucency, consistent colour, and its rarity and association with discrete places (Torrence, 2005; McBryde, 1997). The association of obsidian with discrete places, particularly for colonising groups, is reflected in the interpretation of obsidian as a 'lifeline' back to a homeland (Kirch, 1988). Similarly, Specht (2002) argued that such seemingly non-utilitarian behaviour shows that communities consciously attempted to replicate the ancestral societies. In these views, the geographical extension of the Lapita exchange network defined the value of obsidian and emphasised its scarcity and the energy invested in its transport. The transactors in this network shared social institutions and cultural backgrounds, and the exchange of prestige items and valuables contributed to the accumulation of social status in hierarchical communities in a unified exchange system (Green and Kirch, 1997; Green, 2003).

The argument of obsidian representing a 'lifeline' between colonising groups and the 'homeland' was further developed by considering the transport of obsidian separately from its utilisation at its final destination (Sheppard, 1993). The discard of Kutau/Bao obsidian in Lapita sites of the Reef Santa Cruz, Solomon Islands occurred in a non-utilitarian way, and it is argued that the obsidian artefacts were moving through changing spheres of value. The value of obsidian was defined through its role as a material symbol of exchange and not the item of exchange itself (see, for example, Gregory, 1982; Graeber, 2001). Therefore, its value was not measured by its utility, energy investment or scarcity, but derived from its capacity to make social relationships visible (Preucel and Hodder, 1996).

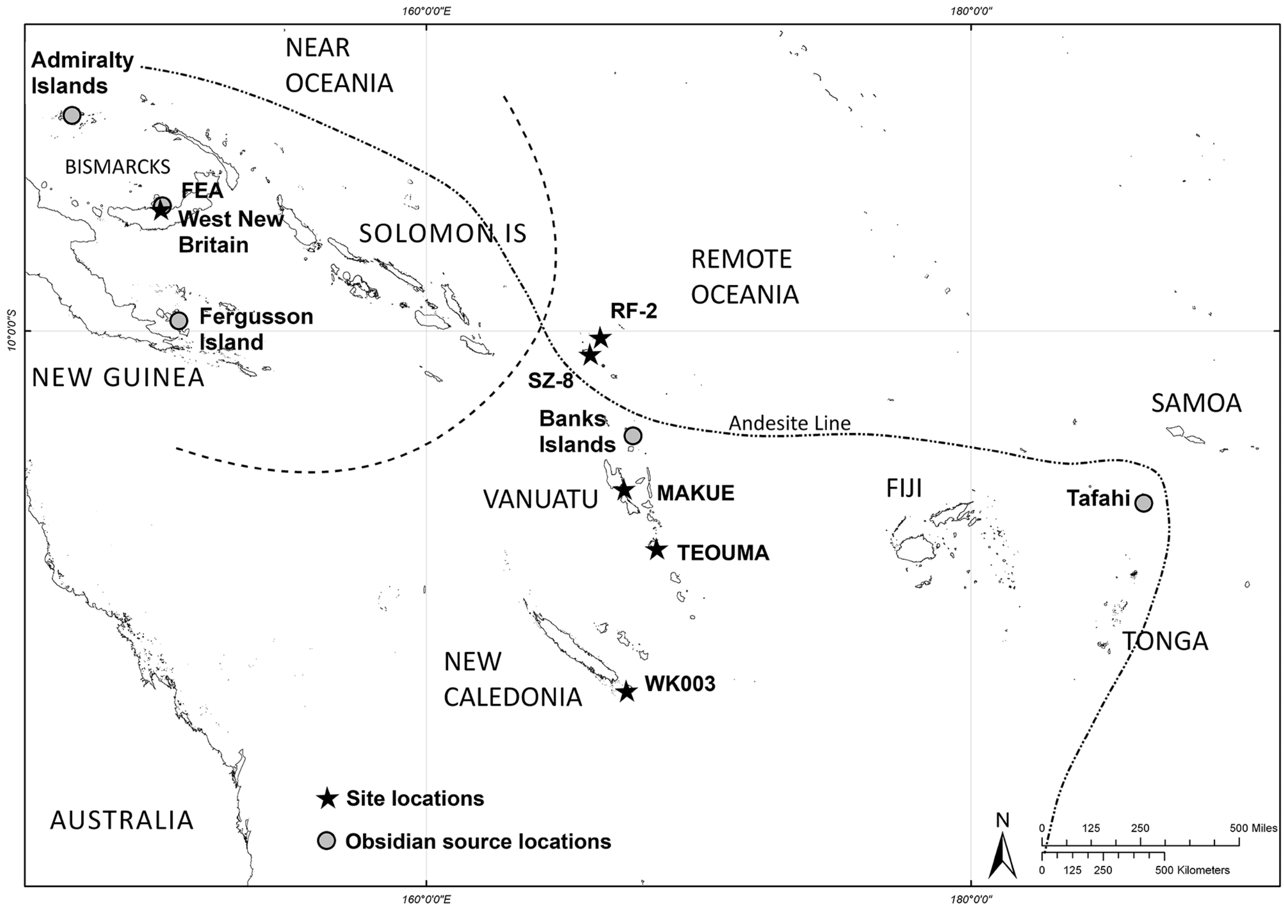

Figure 1. Map of the Western Pacific Islands showing the location of sites discussed in the paper. The division between Near and Remote Oceania lies between the Solomon Islands and sites RF2 and SZ8. The andesite line marks the extent of the island arc geological feature in the Western Pacific.

Incorporating risk

Small groups of highly mobile people are susceptible to risks when engaging with new and unpredictable environments. Risk research is a wide field incorporating risk assessment, risk perception, decision analysis and behavioural responses (Cashdan, 1985: 455, 1990). In archaeological and anthropological applications, the term 'risk' covers several definitions: *effects of stochastic variation in the outcome associated with some behaviour* (Torrence, 1989; Winterhalder, 1986); *the probability of loss* (Wiessner, 1982); and *unpredictable resource variability* (Bamforth and Bleed, 1997).

The important concept of 'uncertainty' is linked to an actor's lack of knowledge about their environment in a situation. Uncertainty, therefore, focuses on a situation in which the actor makes decisions without full knowledge of the underlying probabilities (Cashdan, 1990). This is in contrast to risk, which describes the more objective state in which an individual makes a decision in full knowledge of the probabilities of variation (Clark, 1990). 'Coping with risk' modelling has found wide application, and responses to risk in human societies may include:

1 mobility, either residential or logistical mobility (Winterhalder, 1996)
2 storage, either food stuffs or social obligations (Halstead and O'Shea, 1982)
3 resource intensification (Bird and O'Connell, 2006)
4 resource diversification (Winterhalder, 1996)
5 group foraging (Bliege Bird *et al.*, 2002)
6 technological adaptation and innovation (Torrence, 1989), and
7 exchange, including information and objects (Cashdan, 1985, 1990).

Information exchange based on identity markers as a strategy to mitigate risk has recently been argued by Veth *et al.* (2011) in the context of the colonisation of the Australian continent. Here, in situations of small, highly mobile social groups, there is a high probability that encounters occurred that involved unfamiliar actors. In these contexts, markers of group identity might have mitigated antagonistic encounters and facilitated information exchange.

Sourcing obsidian artefacts in the Western Pacific

Five major obsidian source regions exist in the Western Pacific (Fig. 1): the Admiralty Islands and New Britain in the Bismarck Archipelago, Fergusson Islands of southeast Papua New Guinea, the Banks Islands of Vanuatu, and Tafahi in northern Tonga (Ambrose, 1976; Reepmeyer, 2008; Summerhayes, 2009; Summerhayes *et al.*, 2014). The Bismarck Archipelago obsidian deposits have a long history of research, with multiple sources in the Admiralty Islands (Pam Lin and Pam Mandian, Lou, Hahie, Lepong) and West New Britain (Kutau/Bao, Gulu, Baki, Hamilton and Mopir). Less research has been done of the sources of Fergusson Islands (Igwageta, Iaupolo, Fagalulu, Sanaroa, Aiasuna, Lomonai), the Banks Islands (Vanua Lava and Gaua) in Vanuatu and Tafahi in Tonga.

Kutau/Bao obsidian had its widest distribution during the Lapita period at ca 3100–3000 cal. BP when it was transported about 3500 km eastwards into Remote Oceania, where small numbers of pieces have been found in Lapita sites in Reef/Santa Cruz islands of the southeast Solomons, Tikopia and Vanuatu (Bird *et al*., 1981; Reepmeyer *et al*., 2011), New Caledonia (Sand and Sheppard, 2000) and Fiji (Ross-Sheppard *et al*., 2013). Large quantities of Kutau/Bao obsidian artefacts in Remote Oceania are limited to the Reef/Santa Cruz sites in the Solomon Islands (Sheppard, 1993). From the thousands of artefacts found at those sites, only 12 were sourced to Vanua Lava, 11 to the Lou in the Admiralty Islands and one piece to West Fergusson (Green, 1987; Green and Bird, 1989). Admiralty Island obsidian artefacts are very rare in Remote Oceania, and on Tikopia in the Solomon Islands it is only present in the earliest deposits (Kirch and Yen, 1982; Kirch, 1986; Spriggs *et al*., 2010; McCoy *et al*., 2020), and only one piece has been confirmed in Vanuatu (Ambrose, 1976; Reepmeyer *et al*., 2011: 218).

Until the excavation of the sites in northern and central Vanuatu only small quantities of obsidian were found beyond the Reef/Santa Cruz Islands (Galipaud and Swete-Kelly, 2007; Reepmeyer *et al*., 2011). Transportation of Banks Islands obsidian started with the earliest colonisation of northern and central Vanuatu (Galipaud and Swete-Kelly, 2007; Reepmeyer *et al*., 2011), and similarly in eastern Fiji, where late Lapita sites received obsidian from the Tafahi source in Tonga around 2700–2600 cal. BP (Reepmeyer *et al*., 2012).

Long-distance transportation of obsidian ceased after the Lapita period with the exception of Tikopia, where Admiralty Islands obsidian replaced Kutau/Bao obsidian in the late Lapita—post-Lapita phase around 2500 cal. BP (Kirch and Yen, 1982; Kirch, 1986; Spriggs *et al*., 2010; McCoy *et al*., 2020). Central Vanuatu did not receive any Bismarck Archipelago obsidian, and only a few pieces from the Banks Islands' sources reached neighbouring islands, indicating a low level of inter-island contacts. Around 1000 cal. BP Banks Islands obsidian was more frequent on neighbouring islands, reflecting increased in inter-island contacts (Reepmeyer, 2008), and around the same time Tongan obsidian reached Polynesian outliers to the west (McCoy *et al*., 2020).

Case study: Northern Vanuatu obsidian distribution patterns

Vanuatu (Fig. 1) is located at a critical crossroad for the colonisation of the Pacific Ocean (Bedford and Spriggs, 2008). It is the first archipelago south of Solomon Islands in the Western Pacific that was, crucially, uninhabited until the Lapita period at the end of the second Millennium cal. BP, and it acted as an important stepping-stone for colonising populations migrating East to Western Polynesia and South to New Caledonia (Bedford *et al*., 2019). The early archaeology of Vanuatu has seen significant advancements recently which showed that Lapita colonisation started in Vanuatu around 3000 cal. BP, was only very short-lived and underwent rapid changes, with new ceramic typologies appearing at around 2800–2700 cal. BP (Bedford *et al*., 2019).

Materials and methods

Sites included in this study

The interpretations presented in this study are based on the combination of geochemical (for methods, see Ambrose *et al*., 2009) and technological analysis (Andrefsky, 2005). The technological dataset covered 2441 artefacts drawn from recent excavations and legacy collections; sites from Vanuatu totalled 1990 artefacts (Table 1). The legacy collections included assemblages from the Torres Islands (Galipaud, 1998), Tikopia (held at the Bishop Museum, Hawaii; Kirch and Yen, 1982), and Pakea Island in the Banks Islands (held at the Australian National University, Canberra; Ward, 1979). The more recently excavated assemblages from Vanuatu covered sites on Mota Lava (Bedford and Spriggs, 2008) and Ambek on Vanua Lava (Reepmeyer, 2008) in the Banks Islands; Makue on Aore Island (Galipaud and Swete-Kelly, 2007; Galipaud *et al*., 2014); and Teouma on Efate Island (Reepmeyer, 2010; Reepmeyer *et al*., 2011). These data were compared to published data from the FEA site on Boduna Island, close to the Kutau/Bao source (Specht and Summerhayes, 2007), SZ-8 on Nanggu and RF-2 on Nenumbo in the Reef/Santa Cruz Islands (Sheppard, 1993) and KVO003 site (St Maurice/Vatcha) on the Île des Pins, New Caledonia (Sand and Sheppard, 2000).

Ambek, Vanua Lava Island

The village of Ambek is located on the western side of Vanua Lava close the Bemon River, which is a secondary source of Vanua Lava obsidian (Reepmeyer, 2008). Two 1×1 m test pits were dug to analyse the stratigraphy of the area. Test pit 1 was excavated in the village area near a local house above the river inside a dense concentration of surface obsidian artefacts and test pit 2 in close vicinity of the Bemon River. Both sites were excavated to 70 cm under surface and revealed dense obsidian artefact concentrations in the topmost 30 cm in a dark grey-brown silty sand. The artefact-bearing layers were dated to 374±30 BP (charcoal; Wk-19647) and 390±31 BP (charred nutshell; Wk-19648) respectively (Bedford and Spriggs, 2008).

Lequesdewen, Mota Lava Island

Several surface concentrations of ceramics and obsidian occur on a reef deposit uplifted to 5–8 m above current sea level and at approximately 200 m from the western shoreline of Mota Lava Island. The site is within the current village and the spoil heaps of material dug up by the local population include pottery fragments and large amounts of shell. A 1×1 m test pit in the centre of a raised area revealed cultural deposits overlying a sterile beach at 90 cm below surface. Bedford and Spriggs (2014) identified the site as Lapita-age in several additional sondages.

Saywoume, Mota Lava Island

Situated approximately 700 m inland from the western shore of the island are several surface concentrations of ceramic fragments and a thin scatter of obsidian flakes. The area is a recent garden with several small mounds of shell, basalt fragments (fire-cracked rocks) and eroded pottery, most probably a result of gardening activities. Excavation of one mound revealed a stratigraphy of 70 cm with cultural materials. Two marine shell samples date the site to 1862±41 BP (Wk-21683) and 2078±35 BP (Wk-21684) (Reepmeyer, 2010).

Table 1. Summary of sites with basic statistics of the obsidian samples (in mm and g) used in the study; *na* = not available, $\bar{x}$ = mean; σ = standard deviation.

		West New Britain obsidian								Banks Islands obsidian								source / literature
site		weight		length		width		thickness		weight		length		width		thickness		
	N	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
Papua New Guinea, Bismarcks																		
Boduna Island, FEA	963	3.5	*na*	*na*	*na*	*na*	*na*	*na*	*na*	—	—	—	—	—	—	—	—	Specht, 2002; Specht & Summerhayes, 2007
Solomons, Reef / Santa Cruz																		
Nanggu, SZ-8	329	2.4	3.1	19.6	12.4	18.6	7.8	5.6	2.7	—	—	—	—	—	—	—	—	Sheppard, 1993
Nenumbo, RF-2	625	1.9	2.9	18.6	7.0	17.3	7.2	5.2	3.1	—	—	—	—	—	—	—	—	Sheppard, 1993
Tikopia sites	451	—	—	—	—	—	—	—	—	1.0	1.8	15.1	5.1	13.7	5.3	4.5	1.8	new data
Vanuatu																		
Aore Island, Makue	61(20)	0.9	*na*	16.6	*na*	*na*	*na*	3.7	*na*	1.8	*na*	20.2	*na*	*na*	*na*	5.1	*na*	Galipaud & Swete-Kelly, 2007
Efate, Teouma	48(6)	1.1	1.1	16.1	6.1	14.2	5.8	5.1	2.6	2.4	1.3	22.6	6.2	17.0	3.8	7.0	2.0	Reepmeyer, 2010; new data
Vanua Lava, Ambek	454	—	—	—	—	—	—	—	—	2.1	2.6	18.8	6.4	16.1	6.1	5.9	2.8	new data
Pakea Island, Pakea	851	—	—	—	—	—	—	—	—	1.7	*na*	*na*	*na*	*na*	*na*	*na*	*na*	Ward, 1979
Mota Lava, Lequesdewen (early)	34	—	—	—	—	—	—	—	—	1.3	2.1	15.7	6.5	13.7	6.6	5.4	3.4	new data
Mota Lava sites (late)	223	—	—	—	—	—	—	—	—	1.7	2.0	17.9	6.5	13.5	5.5	5.3	2.5	new data
Torres Islands sites	319	—	—	—	—	—	—	—	—	1.4	1.8	16.4	5.5	14.2	5.1	5.4	2.6	new data
New Caledonia																		
St Maurice/Vatcha, KV0003	4	0.3	0.3	14.5	7.5	9.3	5.2	2.0	1.4	—	—	—	—	—	—	—	—	Sand & Sheppard, 2000

Pakea, Pakea Island

Graeme Ward's (1979) excavations on Pakea Island in 1973–1974 revealed a stratigraphy of episodic habitation from the early third millennium BP until about 1000 BP. The initial occupation (layer III) dated to between 3100 BP and 2400 BP is separated from the later deposits by a sterile beach deposit. Reoccupation occurred in Layer II between 2400 BP and 2000 BP and probably ended around 1000–800 BP. Based on this gap in dates and differences in the appearance and structure of the sediment, Ward (1979) assumed an occupation hiatus of about 500–600 years, after which habitation of the site was continuous until the final abandonment of the site sometime after 1000 AD.

Teouma, Efate Island

Details of the lithic assemblage of the Teouma site have been published in Reepmeyer *et al*. (2011) and Constantine *et al*. (2015). The cemetery site was excavated from 2004 to 2016 and is dated to 3000–2700 cal. BP (Bedford and Spriggs, 2014; Petchey *et al*., 2014). The analysed obsidian was only found in the earliest midden deposits or associated with burial fill.

Torres Islands

The Torres Islands are the northernmost island group of Vanuatu. Surface surveys on Tegua and Toga Islands by Galipaud (1998) located several archaeological sites with occupation records covering approximately 2500 years. Eight obsidian artefacts found on the surface of one site on Tegua were associated with non-obsidian flakes and mainly plainware and Mangaasi style pottery (Galipaud, 1998: 161–163). Excavations revealed a series of grey-brown and dark brown sandy soils that were interrupted in several test pits by a 10–20 cm layer of white sand that probably represents a tropical cyclone deposit. Above this was a 20–40 cm thick layer of dark brown humus. Obsidian artefacts, sherds and shells were found throughout the stratigraphy but were more common at about 30 cm below surface. The white sand deposits were mostly sterile and at about 75 cm below surface sealed grey silty sand containing much cultural material, especially pottery fragments and faunal remains. This series of sands and dark sandy-soils continued to approximately 110 cm below surface and overlay the sterile pre-occupation sediments. Two charcoal samples from levels predating sterile white sand produced dates of 2450±40 BP and 2460±40 BP (Galipaud, 1998: 167).

Tikopia sites

The largest quantity of Banks Islands obsidian found outside Vanautu was recovered on Tikopia where excavations revealed three habitation phases (Kirch and Yen, 1982). Recent re-dating of the sites has increased the chronological precision of the cultural sequence (Kirch and Swift, 2017). The colonisation phase (Kiki) started around 3000 cal. BP and was associated with a small amount of Lapita pottery. The post-Lapita Sinapupu phase possibly started as early as 2000 cal. BP or as late as 1600 cal. BP, and the Tuakamali phase lasted from ca 750 cal. BP until European contact. The obsidian assemblage available for re-analysis consisted of only 576 artefacts as 13 were destroyed for previous petrographic analysis using thin sections and 50 were not present in the accessible Bishop Museum collection. The sample analysed totalled 451 pieces (Table 1).

The obsidian samples and regression curves

The present study includes summary data about the mean weights, lengths, widths and thicknesses of the obsidian samples (Table 1). To facilitate inter-site comparisons, Specht (2002) used mean artefact weight as a proxy for the relative abundance of obsidian at sites. This has been argued to be a more robust assessment of raw material transportation as artefact numbers are notoriously skewed by post-depositional breakage, particularly of brittle raw materials such as obsidian (Hiscock, 2002).

Previous studies of obsidian distribution in the Pacific employed Renfrew's (1975) 'modes of exchange' to assess the likely nature of exchange systems: direct access, down-the-line, and central place distribution. In this scheme, communities that could have direct access to the source of raw material constitute the 'supply zone', beyond which is the 'contact zone' where populations cannot access the source of raw material directly but need intermediaries to acquire the raw material, and this is reflected in exponential fall-off of the quantities of goods. Differences in the shape of fall-off curves can be described as linear attenuation for direct access in the 'supply zone'. Outside of the supply zone, down-the-line exchange is identified through an exponential fall-off in the 'contact zone'. Central places are adding discrete peaks of higher artefact abundances in the 'contact zone'.

To assess the likely modes of exchange this study uses the shape of regression curves of mean artefact weights against distance from the source area, as best-fit regression curves investigate the relationships between independent variables. Most applied is linear regression, where a series of datapoints are used to predict unknown parameters in a population (SPSS, 2006). Non-linear regression curves use successive approximations where data is modelled based on specific calculations, which take only parts of the population into account. These can be exponential, logarithmic or polynomial calculations, and commonly result in better curve fittings.

Results

If we assume that there is a change in the mode of transportation, for example establishing a 'contact zone' where abundances change significantly, linear regression curves will show lower correlation coefficients than non-linear regression curves. A test for this assumption is to calculate both linear and non-linear regression curves for the dataset (Fig. 2A). Best-fit regression curve estimates for Kutau/Bao obsidian show highest correlation with a cubic curve ($r^2 = 0.970$). The shape of the curve with two points of inversion lends support to the down-the-line model. The best-fit estimate displays a sharp drop in mean weights in Vanuatu sites compared to the Reef/Santa Cruz sites and support this hypothesis. The significantly smaller quantities of obsidian artefacts found in Vanuatu and the decrease in mean weight of artefacts support the hypothesis that Kutau/Bao obsidian in Vanuatu did not originate directly from the source, but through down-the-line transfer through the Reef/Santa Cruz sites as intermediaries. This further indicates that a multi-staged transport system might have been an essential part of the colonising strategy of Lapita dispersal.

the distribution of Banks Islands obsidian, the spatial pattern appears to be different. Sites at or near the Banks Islands' obsidian source did not contain evidence for the earliest colonisation phase (Fig. 2B). Therefore, distribution patterns must be inferred from the measurement of artefacts found at distance from the source. There are no strong indicators for down-the-line exchange or resource maximisation techniques at any site throughout the distribution area. On the contrary, especially during the initial colonisation phase and directly post-Lapita, all measured physical attributes show increasing values (Table 1). The spatial distribution does not correlate easily with Renfrew's modes of exchange, as there are no distinctive fall-off patterns. One possible explanation for these random patterns is 'embedded procurement' (Binford, 1979; Torrence *et al*., 1996), whereby people with high settlement mobility obtained raw material in the course of other activities not related to raw material procurement.

In the post-Lapita period this pattern does not change. The Banks Islands' sites continue to show a mixed pattern, whereas elsewhere mean weight decreases with distance from the source. This is particularly evident in the Torres Islands and Tikopia. However, best-fit curves do not reveal significant difference between the linear and polynomial regression curves, which implies that raw material distribution is best explained with direct access.

Assessing the value of obsidian

Hodder (1974, 1978) advanced Renfrew's mathematical exchange models in several publications focussing of identifying equifinality. He used a regression formula that describes the form and steepness of the fall-off curve:

$\text{Log } Y = a - bX\alpha + e$

Here, 'a' represents Y when X = 0; 'b' describes the reverse proportionality of X and Y; and 'e' is the 'standard error of the estimate' (Hodder and Orton, 1976). Torrence (1986) successfully applied this formula in her analysis of the production and distribution of obsidian in the Mediterranean. In the regression analysis, α can be correlated with the value of certain items; for example, low values of α (0.1–0.6) show that items were distributed only over short distances, whereas high values (0.9–2.5), would indicate prestige items.

Relating the steepness of the regression curve for Kutau/Bao obsidian outside of the supply zone with Hodder's equation (Table 2) for mean weight and mean maximum length of artefacts, low values of α have the highest correlation. The most significant correlations ($\delta < 0.01$) are between $0.4 < \alpha < 0.6$. Interestingly, mean maximum length shows a high correlation with $\alpha = 0$ (both significance at $\delta < 0.01$). In general, low values for α imply that obsidian was not a highly valued commodity and cannot be identified as a prestige good. The correlation of curve steepness with α-values is even more pronounced for Banks Islands obsidian (Table 2). In the correlation of distance-decay characteristics α-values of zero score highest and are the only ones statistically significant in the evaluation of nearly all attributes. Additionally, if other values score high in the correlation matrix ($p > 0.99$), then they usually have low α-values (< 0.6).

Discussion

What makes obsidian special? Torrence (2005) posed this question in her important paper on understanding the value of obsidian and its distribution in the Western Pacific. She argued that it is not only the association of obsidian with 'distant people, places and times' that can explain its wide distribution obsidian, but also its physical attributes of brilliance, translucency and colour that are important factors in making it a desirable raw material. Other qualities are its scarcity in terms of natural occurrence and its sharpness.

It has previously been argued that early Lapita sites in the Reef/Santa Cruz Islands, which are at a significant distance from the Kutau/Bao obsidian source, received obsidian through direct contact with the Lapita 'homeland' (Sheppard, 1993, 2011; Halsey, 1995). The results of the present study support that position. It has also been suggested that sites in Vanuatu did not receive Kutau/Bao obsidian directly from the supply zone but were indirectly connected to it through the Solomon Islands (Reepmeyer *et al*., 2011; Constantine *et al*., 2015). The present study supports those conclusions, but it also shows that obsidian distribution in the Western Pacific did not follow simple economic models of resource acquisition. We can detect some forms of distance decay and resource optimisation processes in the abundances of

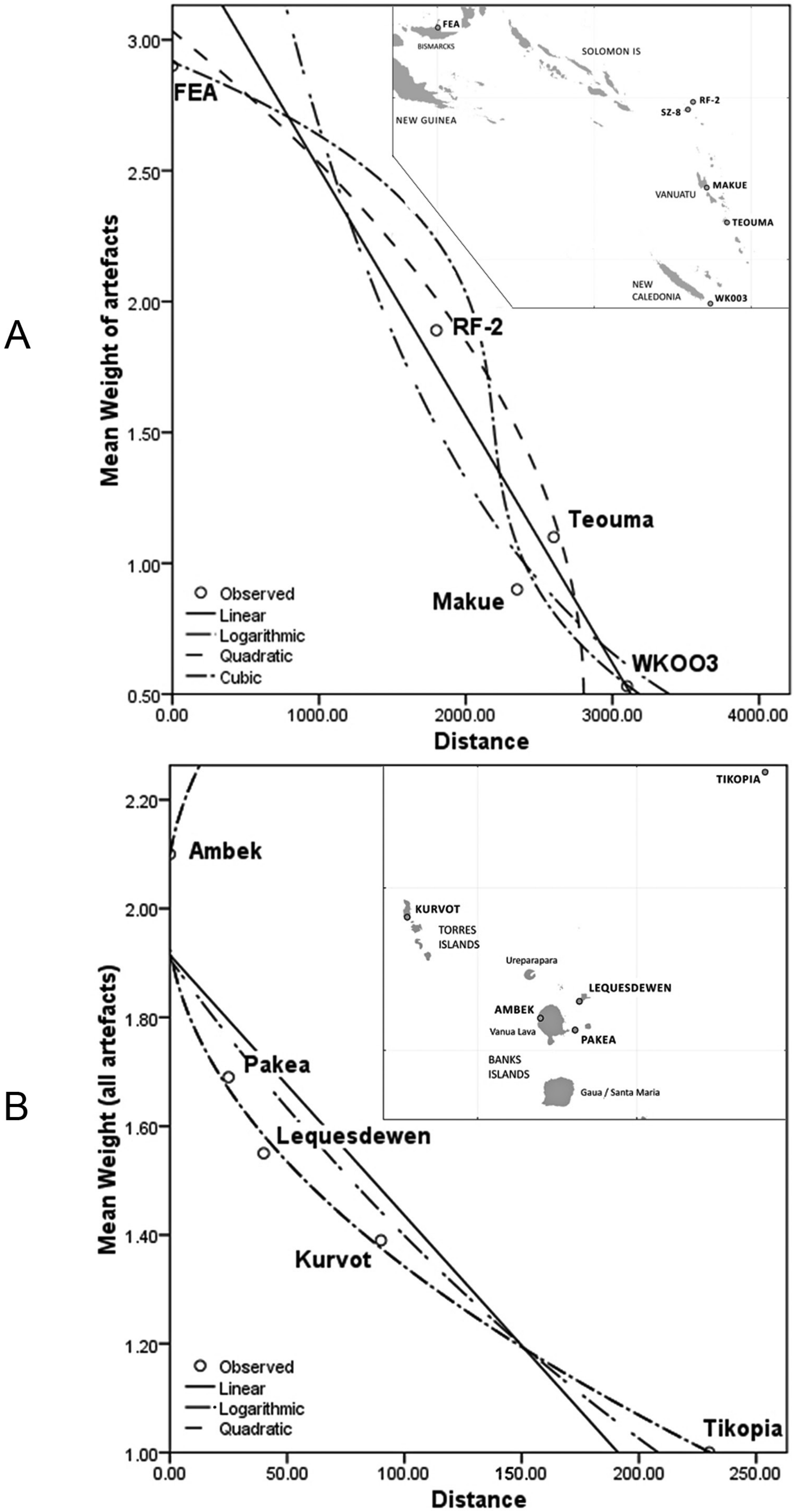

Figure 2. Best-fit estimation regression curves for mean weights (g) and lengths (mm) of West New Britain (*A*) and Banks Islands (*B*) obsidian artefacts against distance from the source.

Table 2. Pearson's correlation coefficient—summary statistics for selected variables for Kutau/Bao (New Britain) and Banks Island obsidian.

value for α	correlation and significance	West New Britain obsidian mean weight (log Y) N = 4	West New Britain obsidian mean length (log Y) N = 4	Northern Vanuatu obsidian mean weight (log Y) N = 5	Northern Vanuatu obsidian mean length (log Y) N = 4
linear					
α = 0	Pearson Correlation	0.977*	0.999**	0.992**	0.999**
		0.023	0.001	0.001	0.001
exponential					
α = 0.1	Pearson Correlation	0.946	0.907	0.874	0.897
	Sig. (2-tailed)	0.054	0.093	0.063	0.103
α = 0.2	Pearson Correlation	0.958*	0.934	0.946*	0.949
	Sig. (2-tailed)	0.042	0.066	0.015	0.051
α = 0.3	Pearson Correlation	0.965*	0.956*	0.985**	0.981*
	Sig. (2-tailed)	0.035	0.044	0.002	0.019
α = 0.4	Pearson Correlation	0.968*	0.973*	0.998**	0.995**
	Sig. (2-tailed)	0.042	0.027	0.000	0.005
α = 0.5	Pearson Correlation	0.967*	0.986*	0.996**	0.998**
	Sig. (2-tailed)	0.033	0.014	0.000	0.002
α = 0.6	Pearson Correlation	0.963*	0.994**	0.984**	0.992**
	Sig. (2-tailed)	0.037	0.006	0.002	0.008
α = 0.7	Pearson Correlation	0.956*	0.998**	0.969**	0.980*
	Sig. (2-tailed)	0.044	0.002	0.007	0.020
α = 0.8	Pearson Correlation	0.947	0.999**	0.952*	0.966*
	Sig. (2-tailed)	0.053	0.001	0.013	0.034
α = 0.9	Pearson Correlation	0.936	0.998**	0.935*	0.951*
	Sig. (2-tailed)	0.064	0.002	0.020	0.049
α = 1	Pearson Correlation	0.924	0.994**	0.920*	0.935
	Sig. (2-tailed)	0.076	0.006	0.027	0.065
α = 1.5	Pearson Correlation	0.858	0.955*	0.858	0.869
	Sig. (2-tailed)	0.142	0.045	0.063	0.131
α = 2	Pearson Correlation	0.800	0.910	0.820	0.824
	Sig. (2-tailed)	0.200	0.090	0.089	0.176

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

obsidian between Reef/Santa Cruz sites and sites in Vanuatu, with obsidian artefacts becoming significantly smaller the further Lapita people penetrated the western Pacific; but the discard of most artefacts was not connected to increased use.

Purely functional approaches to the transportation of obsidian, whether for its sharp edges or as an item for special functions such as tattooing, do not unambiguously explain the discard of small, hardly used artefacts. Singular artefacts, for example the retouched artefacts in New Caledonia and Fiji, might indicate that the symbolic importance of obsidian in ritual behaviours was a factor in transportation over such distances. On the other hand, these sites also have very few artefacts, which follows the pattern of discard in Vanuatu. At the cemetery site of Teouma only a limited number of artefacts occurred with the burials, and most were found in the midden adjacent to the site (Constantine *et al*., 2015: table 2). The lack of economising behaviour of obsidian utilisation led Earle and Spriggs (2015: 521) to propose that obsidian did not contain social meaning as the created artefacts are 'small and minimally modified flakes would have been unsuited to carry social meaning.' Unfortunately, this approach does not explain the transport of obsidian raw material over thousands of kilometres.

Contrary to these interpretations, I advocate the idea that the value of this raw material derived from the idea of a common origin. Rather than re-creating social worlds (Kirch, 1988; Specht, 2002), the founding Lapita communities in Remote Oceania used obsidian to mark group affiliation in unknown territory where the risk of meeting unfamiliar actors was high and might include antagonistic encounters. This interpretation echoes Chiu's (2007) view of the highly decorated Lapita pottery as also signalling group membership. Chiu argued that specific designs (primarily face motifs) were symbols that facilitated participation in social networks. Relationships created and reinforced through these symbols could, independently of ancestry, enhance engagement with distant communities while colonising new lands (Terrell and Welsch, 1997).

This hypothesis is based on three indicators. First, it is unclear from the archaeological record whether an exchange system for Kutau/Bao obsidian existed at all in Remote Oceania. Sheppard (2011) proposed that the distribution of obsidian could have resulted from direct access and an heirloom effect whereby the obsidian accompanied the colonists on their voyages. Second, if re-creation of social worlds was the main objective of obsidian transportation, it is hard to explain the breakdown of long-distance transport into Remote Oceania at the end of Lapita. Third, it is unlikely that a secondary migration (Posth *et al*., 2018; Spriggs and Reich, 2019) caused this breakdown, as obsidian exchange in the Bismarck Archipelago was apparently not impacted by social disruptions which might have occurred in contact situations (Summerhayes, 2009).

What then was the difference between the Solomon

Islands and Vanuatu that caused the import of obsidian to cease after people migrated further south? At the core of Sheppard's (2011) 'leap frogging' model of early Lapita migration through the Solomon Islands is the hypothesis that the early migrants targeted uninhabited islands with pristine resources and, therefore, they most likely by-passed already populated islands in the main Solomon Island chain. Here, the hypothesis of obsidian as a marker of group identity provides support, as the need for the group identity marker stopped once uninhabited islands were found.

The distribution of Banks Islands obsidian, on the other hand, differs significantly from that of Kutau/Bao obsidian. In the earliest period, its distribution followed irregular trend curves with no indication of distant decay, indicating likely direct access to sources. As a raw material, Banks Islands obsidian was most likely not in as much demand as Kutau/Bao obsidian, as its distribution also points to changing patterns of raw material association (Reepmeyer *et al*., 2011). Banks Islands obsidian never travelled long distances so we cannot assume that the social role of Kutau/Bao obsidian was replaced by Banks Islands' obsidian. The Banks Islands' obsidian reached the Reef/Santa Cruz islands, but only in small numbers. On Tikopia the use of Banks Islands' obsidian only increased significantly after 1000 BP, and there is a clear pattern of distance decay. This increase did not spatially extend the area of distribution or result in the development of more complex exchange networks, as the results show that acquisition of Banks Islands' obsidian was by direct access.

Formal exchange systems for the distribution of obsidian were not detected in either the Lapita or post-Lapita phase. If socio-political transformations in these periods resulted from changes in prestige-good exchange systems which included obsidian (Friedman, 1981; Spriggs, 1997: 156), then we must be cautious as it has been suggested above that an exchange network might not have existed. Intensification of a short-distance exchange network did not directly supersede long-distance transportation of obsidian, but instead there was a long hiatus of limited inter-island communication. However, contra Earle's and Spriggs' (2015) notion that obsidian transportation had no meaning, I argue that the meaning, and thus the usefulness of obsidian disappeared with the establishment of larger populations on islands where communication and interaction were maintained through means other than obsidian as a marker of group identity and where independent regional trajectories of cultural development became prevalent.

Conclusions

The transportation of obsidian from West New Britain and local sources in northern Vanuatu had its widest spatial extension in Remote Oceania during the initial colonisation phase. The Reef/Santa Cruz sites appear to have been within the supply zone for Kutau/Bao obsidian, and so maintained contact with the homeland. Colonisation sites further from the New Britain source, such as Makue and Teouma in Vanuatu, were probably not connected directly to the homeland, but most likely received Kutau/Bao obsidian through the Reef Santa Cruz sites as intermediaries. In contrast, the physical attributes of Banks Islands obsidian artefacts do not unambiguously support one specific mode of exchange, and access to the raw material probably included 'embedded procurement' at the sources.

The statistical analysis fall-off curves allowed assessment of the social value of obsidian in Renfrew's framework of modes of exchange and exploration of motives for the transportation of raw material over such long distances. Obsidian most likely had low economic value, so its contextualisation in an economic framework is not sufficient to understand the archaeological distribution patterns. We must consider alternative ascriptions of value for the Lapita phase, for example the importance of symbols of group affiliation. In risk management, we should not underestimate the importance of easy identification of group affiliation in unpredictable situations when colonising new territories.

The use of symbols of communication did not persisted throughout the long period of low-level interaction after Lapita in which different groups on separate islands developed their own expressions of cultural identity. These communication networks did not result in the development of more complex exchange networks—at least not for obsidian—as the study identified direct access as the mode of distribution for Banks Islands obsidian in later times.

In a theoretical framework of risk minimisation in which interaction intensifies when unpredictable environments increase uncertainty, obsidian as a symbol of group identity might have constituted an easy medium for communication.

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