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Landscapes of exchange in the Willaumez Peninsula, West New Britain, Papua New Guinea

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Abstract

The well-preserved tephrostratigraphy stretching across the Willaumez Peninsula in West New Britain, Papua New Guinea, provides a unique opportunity to monitor landscapes of cultural exchange over a considerable period of human history, extending from the Pleistocene to the recent past. An approach integrating pXRF geochemical characterisation and measurements of reduction intensity is used to analyse a substantial sample of obsidian artefacts from the FRI site and 25 test pits in the Isthmus region, located at the base of the Willaumez Peninsula. Obsidian exchange is shown to have been a persistent feature of social life, but variations in the mix of sources used and the kinds of objects transferred may also indicate changes in how social networks were constructed. As the frequency and severity of volcanic events decreased through time and population rose in response, the role of obsidian in creating links may have been partially replaced by other objects, such as stone axe blades.

Social role of exchange

In many areas of coastal Papua New Guinea, relatively large quantities of flaked obsidian artefacts are ubiquitous within archaeological contexts (e.g. Fredericksen 1997; Gaffney et al. 2018; Golitko et al. 2012; Irwin and Holdaway 1996; Mialanes et al. 2016; Shaw et al. 2021; Summerhayes 2009; Summerhayes et al. 1998; White et al. 2006). Obsidian was also distributed widely by people colonising other parts of Melanesia (e.g. Reepmeyer 2021; Summerhayes 2009). Since obsidian can only be acquired from a few sources but was often transported over long distances, it seems reasonable to assume that this raw material was highly prized. Evidence from a growing number of studies, however, shows that consumption patterns do not fit those expected for a raw material that is valued. Except for the highly worked stemmed tools (e.g. Torrence et al. 2013), throughout history in Melanesia obsidian was treated in a very unsystematic, casual and wasteful manner (e.g. Allen and Bell 1988; Hanslip 2001; Sheppard 1992, 1993; Torrence 2011) and neither the size nor quantity of artefacts decreases in a consistent linear fashion with distance from the raw material sources (Galipaud et al. 2014; Reepmeyer 2021; Specht 2002), as might be expected in a down-the-line exchange system (e.g. Renfrew 1977; Torrence 1986:115–138). The stone tool

technology used to process obsidian primarily yielded irregular and highly varying flake forms struck from nodules in an unsystematic manner. Retouched tools are rare. These patterns conform well to the definition of what Binford (1979, cf. Parry and Kelly 1987; Nelson 1991) originally termed an 'expedient technology': that is, made with little effort, used briefly and discarded quickly. The largely unretouched tools were employed in a wide variety of tasks, mainly associated with cutting relatively soft materials (e.g. Kononenko 2011, 2012), functions that could easily have been carried out with other materials close at hand and more easily procured, such as bamboo, shells, thorns, rat's teeth, etc.

The expedient nature of obsidian assemblages in Melanesia raises an important question. Why was this raw material procured from outcrops, transported over a considerable distance, and then treated in such a wasteful manner? Peter Sheppard (1993) first addressed this issue with respect to obsidian assemblages at Lapita sites on the Reef–Santa Cruz Islands. He proposed that for people who had moved into uninhabited lands away from social safety nets, the role of obsidian was not primarily as a raw material for useful tools, but as an exchange good that would create and strengthen social bonds. Once the exchange had been made, the obsidian itself had lost its value and, consequently, it was consumed in a seemingly careless fashion. Subsequently, in their hypothetical reconstruction of changes in exchange patterns in the Willaumez Peninsula (WP) of West New Britain, Papua New Guinea (Figure 9.1), Torrence and Summerhayes (1997) and Torrence (2004a) also argued that the exchange of obsidian was mainly directed at social rather than economic ends.

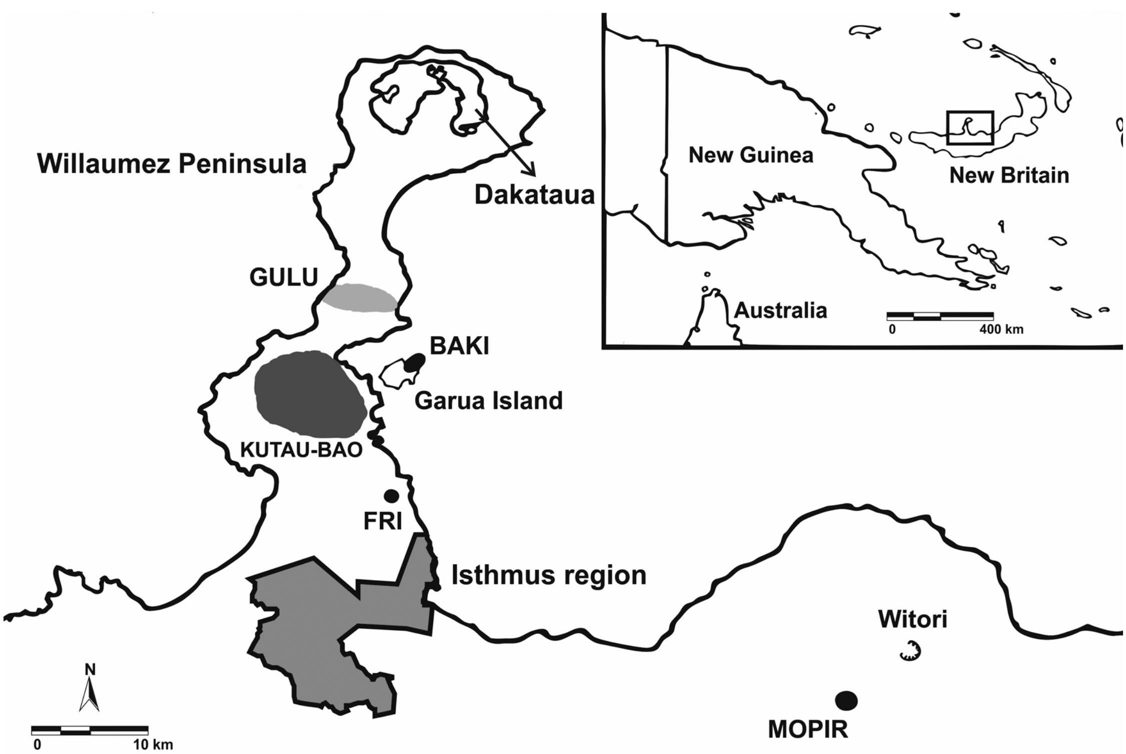

Figure 9.1: The Willaumez Peninsula showing the location of the Isthmus region, FRI site, obsidian sources and the volcanic centres at Dakataua and Witori.

Source: Illustration by authors.

Building on these ideas, Torrence (2005, 2011) proposed that obsidian was often selected as an object for exchange because its physical properties (i.e. discrete sources, black colour, lustrous surface, conchoidal fracture) made it ideal for cementing social relations. Most recently, Reepmeyer (2021) has suggested another social role for this distinctive raw material. He argues that obsidian was used in Remote Oceania as a marker of ethnic identity so that the early colonists coping with the risks associated with moving into an unfamiliar environment could easily recognise people they could trust.

Obsidian has also played an important role in creating and strengthening social connections among communities across time and in other parts of the world (e.g. Kristensen et al. 2019; Freund 2018; Lazzari and Sprovieri 2020; Peterson et al. 1997; Torrence 2005). All small groups depend on external links for their survival, because regular access to marriage partners is necessary for social and biological reproduction. Exchange systems of various forms are therefore extremely widespread throughout the recent and deep past. The benefits of social ties are especially high in environments with extreme levels of selection, such as those that experience 'frequent, very severe environmental perturbations' serious enough to cause local extinctions (Torrence and Doelman 2007:43). As discussed by Torrence (2016, 2019), the adoption of systems of exchange can reduce the impacts of environmental disasters by increasing a society's 'resilience', defined as the ability to maintain continuity by avoiding or withstanding failure (Conolly and Lane 2018; Lorenz 2013), and therefore reducing its vulnerability to future environmental forcing agents (Riede 2019).

Stimulated by the pioneering studies of Wiessner (1982) and Cashdan (1985, 1990), who described how exchange systems among the Kalahari Bushmen helped ensure that widely dispersed, small groups had access to necessary resources despite demographic and environmental challenges, this paper proposes that obsidian exchange helped build resilience to the effects of infrequent but catastrophic volcanic eruptions in the WP region of West New Britain, Papua New Guinea (Figure 9.1). When viewed over very long time periods, changes in the character of social networks created by obsidian exchange can be linked to the character of the volcanic forcing agents. The study expands on previous obsidian characterisation studies in the WP region by using a substantially enlarged dataset acquired with portable X-ray fluorescence (pXRF) technology, combined with a study of lithic technology focusing on reduction intensity. The results confirm the general patterns previously reported, but also contribute further information about the variety of social strategies adopted by small social groups subject to regularly occurring environmental disasters.

Study area and sample selection

The Willaumez Peninsula on New Britain Island in Papua New Guinea (Figure 9.1) is an excellent setting for investigating the relationships between the risks inherent in highly active volcanic environments and the ways in which populations developed a measure of resilience through using exchange to amplify social networks. During the period of human occupation, beginning at least by c. 40,000 BP, the region has been impacted by seven large volcanic events (volcanic explosivity index (VEI) 5 or greater) that would have necessitated abandonment for at least four to five generations, if not longer, as well as several smaller events that would have created hardships, although on a lesser scale (Neall et al. 2008; Torrence 2016:Table 1; Torrence et al. 2004; Torrence et al. 2009). We predict that as a consequence of repeated experience of environmental catastrophes in the WP, societies developed mechanisms that enabled them to sustain or improve their resilience. Torrence (2016) has proposed that formalised systems of exchange would have helped establish safety nets, facilitate safe evacuation, secure refuges until return was possible and provide essential backup during recolonisation.

Between 1999 and 2002, archaeological research took advantage of the extensively studied tephra stratigraphy (Machida et al. 1996; McKee et al. 2011; Neall et al. 2008) (Figure 9.2a) to conduct an archaeological study of buried contexts (Specht and Torrence 2007a; Torrence 2000, 2001, 2002a, 2008; Torrence and Doelman 2007; Torrence et al. 1999), using the landscape approach developed on Garua Island (Torrence 2002b; Torrence and Stevenson 2000). To monitor changes in the way exchange operated, obsidian assemblages from two areas situated between the two major obsidian sources at Kutau-Bao and Mopir were selected for analysis: the Isthmus region, located at the intersection of the WP and mainland New Britain, and the site of FRI (Figure 9.1). A key feature of both settings is the well-studied and dated regional tephrostratigraphy (Figure 9.2a), reconstructed through collaborative archaeological and geological research (Machida et al. 1996; McKee et al. 2011; Neall et al. 2008). The sequence is comprised of a series of layers derived from eruptions of the Witori and Dakataua volcanoes (Figure 9.1). Dates for the components of the stratigraphy have been obtained from Bayesian analyses of radiocarbon dates recovered from soils formed on the volcanic deposits (McKee et al. 2011; Petrie and Torrence 2008). A summary of the key stratigraphic layers, associated dates, and periods used in the study is presented in Tables 9.1 and 9.2.

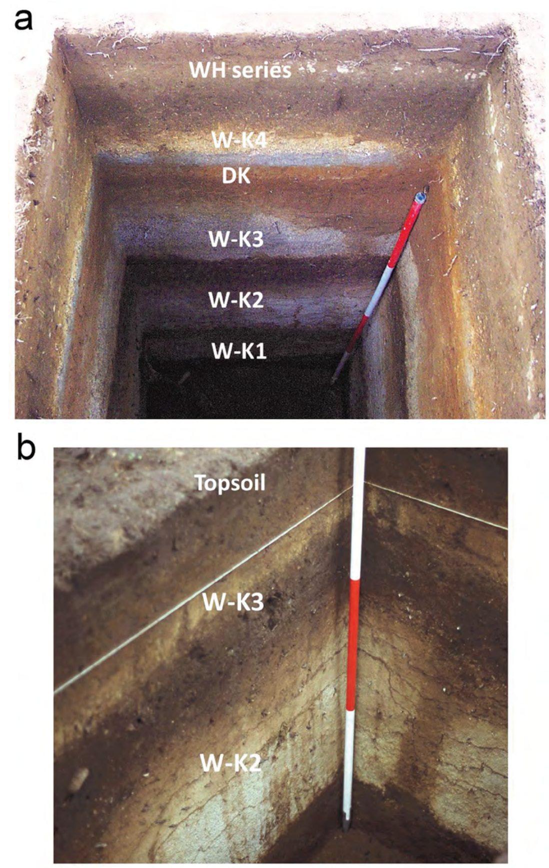

Figure 9.2: The tephrostratigraphy of the region defines the chronological phases used to monitor cultural change.

Notes: (a) Isthmus region; (b) FRI II.

Source: (a) Illustration by authors; (b) illustration by authors based on photograph by Jim Specht.

Given changes in the depth of tephras with increasing distance from the volcanic centres, not all layers are well preserved across the study area (see Torrence et al. 2009 for isopachs of tephras). Possibly due to heavy rains and subsequent erosion during the event, the W-K1 tephra which marks the boundary between Periods 2 and 3 is frequently absent in stratigraphic profiles. Where W-K1 is missing, the deposits underlying W-K2 have been treated as a separate time slice, called Period 3.2 because they may contain a mixture of Periods 2 and 3. Periods 7 and 8 are grouped together because it was difficult to discriminate among the thin W-H tephras in the field. Period 1, which is equivalent to the earliest settlement of the region during the late Pleistocene and early Holocene, is not represented in this sample as it has only been reliably documented at the Kupona Na Dari site (FABM) (Torrence et al. 2004).

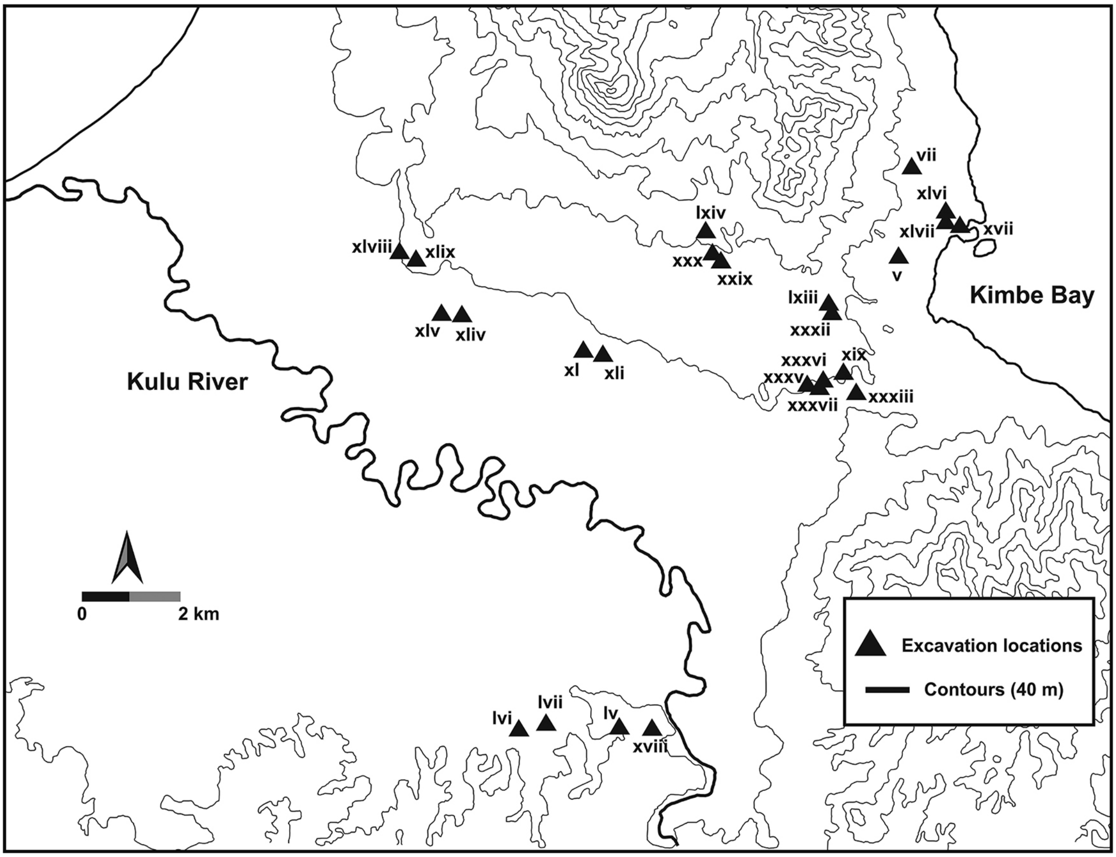

Figure 9.3: The 25 test pits from the Isthmus region used in the study are spread around the edges of the Kulu River floodplain, along the coastal divide and on the coastal plain.

Source: Illustration by authors based on a draft by Trudy Doelman.

To trace changes in the procurement, exchange and production of obsidian artefacts through time in the Isthmus region, a sample of 1614 artefacts was selected from 25 one-metre-square test pits (Figure 9.3). Excellent preservation of the volcanic stratigraphy was the most important criterion for sample selection, ensuring that the finds could be confidently assigned to chronological phases. The second aim in choosing samples was to reflect environmental variation across the region in terms of proximity to the coast and variation in elevation. Some of the local settings were radically altered after the W-K2 event, when areas in what are now the inland, upland regions that were originally situated near the sea became completely landlocked after volcanic sediment flooding down from hills to the south filled in the tidal basin (Torrence et al. 2009). Finally, since the sample sizes in some of the layers of the selected test pits were quite small, it was necessary to augment these with artefacts from the same stratigraphic context in a nearby test pit. This explains why the number of test pits in Table 9.1 differs among the periods.

Table 9.1: Isthmus region test pits: Tephrostratigraphy and chronology.

Period	Stratigraphic position	Approximate date	Test pits (N)
7/8	WH series up to present	post 500 cal. BP	9
6	Between Dk/W-K4 & WH series	c. 1300–500 cal. BP	16
5	Between W-K3 & DK/W-K4	c. 1600–1300 cal. BP	12
4	Between W-K2 & W-K3	c. 3200–1600 cal. BP	14
3.2	Below W-K2 where W-K1 is not preserved	pre 6000–3200 cal. BP	12
3	Between W-K1 & W-K2	6000–3200 cal. BP	9
2	Pre W-K1	pre 6000 cal. BP	8

Notes: Dk = the Dakataua eruption, known as the Dk event; W-K = Witori eruptions, numbered as W-K1 through WK-4.
Source: Authors' data.

As the difference in distance between the sources and the test pits in our sample is negligible, we included an additional assemblage of 613 obsidian artefacts from the FRI site at Walindi Plantation (Figure 9.1). Located at about 1 km inland from the present coastline, FRI is spread over several ridges situated at c. 95 m above sea level, with a commanding view of the ocean (Specht et al. 1991; Specht and Torrence 2007b; Torrence et al. 1990). Several trenches and test pits were excavated at the site in 1989 by Jim Specht, assisted by Glenn Summerhayes and a team of volunteers from the Australian Museum. The sample of obsidian artefacts used here is derived from Trench II, where the volcanic stratigraphy was well preserved (Table 9.2; Figure 9.2b). Phase 4 at the top of the site (c. post 500 BP) 'contains items of European date' (Specht et al. 1991:284). The W-K4/Dk horizon that marks the boundary between Periods 5 and 6 in the Isthmus was not preserved at this location, so the chronological divisions are slightly different from those identified in the Isthmus region.

Table 9.2: FRI Trench II, Walindi Plantation: Stratigraphy and chronology.

FRI phase	Isthmus period	Stratigraphic position	Approximate date
4	7/8	Topsoil	c. post 500 BP
3	5, 6	Post W-K3	1600–500 cal. BP
2	4	Between W-K2 and W-K3	3200–1600 cal. BP
1	2, 3	Pre W-K2	pre 3200 cal. BP

Source: Authors' data and Specht (pers. comm. 2021).

Detecting exchange

Inferences about the history of obsidian exchange in the study area stem from two methods: (1) geochemical characterisation of the artefacts and (2) position of the artefacts within the reduction sequence in which a nodule was converted into fragments, some presumably used as tools.[1] Our characterisation study of obsidian artefacts in the WP benefits from a long history of field research at the West New Britain obsidian outcrops (e.g. Fullagar et al. 1991; Specht 1981; Specht et al. 1988; Torrence et al. 1992) coupled with geochemical studies mainly employing the PIXE-PIGME technique pioneered by Roger Bird (Bird et al. 1981, 1997; Summerhayes 2009; Summerhayes et al. 1993, 1998), together with subsequent studies of source variation using LA-ICP-MS (e.g. Ambrose

1 The complete geochemical and lithic technology datasets used in this study can be freely accessed at zenodo.org/record/8274857.

et al. 2009; Reepmeyer et al. 2016).[2] Following key developments in instrumentation, portable X-ray fluorescence analysis (pXRF) of obsidian source material and artefacts has greatly enlarged the number of samples that can be measured at relatively low cost. In addition, constraints on the selection of samples due to artefact size have been lessoned considerably, thereby greatly reducing potential sampling biases (e.g. Torrence et al. 2013; Mialanes et al. 2016; Mulrooney et al. 2014, 2016). It is now feasible to analyse large numbers or even entire archaeological assemblages (e.g. Sheppard et al. 2010). Building on these significant developments, we used a Bruker Tracer 5i pXRF spectrometer equipped with an 8-µm Be detector window to analyse 613 samples from Trench II at site FRI (Figures 9.1 and 9.2b) and 1614 artefacts from 25 one-metre-square excavations in the Isthmus region (Figures 9.2a and 9.3).

The Tracer 5i instrument has an X-ray tube with a Rh target and a 20 mm^2 silicon drift detector with a typical resolution of less than 140 eV at 250,000 cps. Nine elements were measured: Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr and Nb. The in-built obsidian calibration program, based on many years of development by Bruker, was used to convert XRF measurements to elemental values. Precision and accuracy of the calibrated results were evaluated as satisfactory by comparison between measurements of the well-characterised obsidian standards WNB4198 (Wekwok AD2000) and WNB4209 (Kutau-Bao source) taken before, during and after runs with results from Bird et al. (1997) analyses using PIXE-PIGME (Table 9.3).

Table 9.3: Precision and accuracy of pXRF instrument.

	Wekwok AD2000					Kutau-Bao				
	pXRF WNB4198 (*N* = 27)			PIXE-PIGME (Bird et al. 1997) (*N* = 12)		pXRF WNB4209 (*N* = 27)			PIXE-PIGME (Bird et al. 1997) (*N* = 12)	
Elements	Mean	SD	RSD (%)	Mean	SD	Mean	SD	RSD (%)	Mean	SD
Mn	465	20	4	520	17	459	20	4	523	22
Fe	13,968	309	2	17,000	500	8343	219	3	10,500	55
Zn	66	4	5	n/a	n/a	59	3	5	n/a	n/a
Ga	14	2	14	n/a	n/a	9	1	11	n/a	n/a
Th	11	1	10	n/a	n/a	1	1	75	n/a	n/a
Rb	145	4	3	161	5	50	2	4	55	4
Sr	63	2	3	72	3	182	4	2	206	9
Y	38	2	5	36	2	21	1	5	20	2
Zr	287	7	2	366	5	142	4	3	151	7
Nb	38	2	5	47	3	2	1	57	1	2

Source: Authors' data and Bird et al. (1997).

The obsidian artefacts were grouped into obsidian chemical groups with discriminant analysis using JMP 14.0 software. The confusion matrix, based on multiple runs of 143 well-characterised samples from the four major obsidian sources in the WP (53 Baki; 32 Kulu; 33 Gulu and 25 Mopir), yielded a 100 per cent successful classification of the samples to their known source. The artefacts were then successfully matched to this source group training set (cf. Pengilley et al. 2019). No outliers were detected. The high level of discrimination of WNB obsidians that is obtained with pXRF is demonstrated in Figure 9.4, which compares the principal components scores for the first two components of both the sources and the artefacts in the study based on the nine elements measured.

2 PIXE-PIGME: proton-induced X-ray emission and proton-induced gamma ray emission, respectively; LA-ICP-MS: laser ablation inductively coupled plasma mass spectrometry.

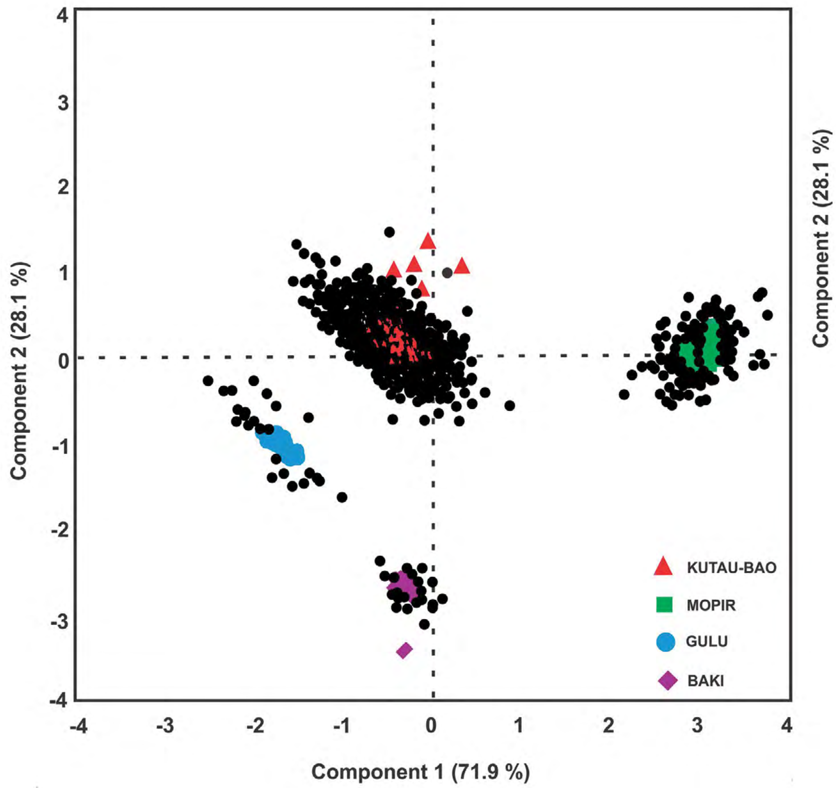

Figure 9.4: Plot of the obsidian source reference samples (coloured symbols) versus artefacts (black dots).

Notes: Using the results of a principal components analysis (JMP) of the calibrated data from the pXRF analysis, the artefacts can be unambiguously assigned to their source.

Source: Illustration by authors.

After considering the movement of obsidian from the different sources based on the geochemical analysis, in the second component of the study we examine patterns of consumption measured by the nature and degree of reduction of nodules in relation to distance from the sources using well-established techniques (e.g. Ditchfield 2016; Eerkens et al. 2008; James et al. 2022; Lin and Premo 2021; Shott, J. 2015; Shott, M. 1994; Sullivan and Rozen 1985). Once a piece of obsidian had been exchanged and the social connection between giver and receiver initiated or consolidated, what was its subsequent role and how was it consumed? Before addressing this question directly, it is useful to consider several potential scenarios (cf. Franco 2014). Beginning at the outcrops, the first key factor is how the raw material was treated. Unfortunately, we lack enough data from the quarries to answer this question and so we consider trajectories based on three potential outputs: (1) unmodified nodules; (2) partially reduced cores or preforms of tools which were finished off and used in other locations; or (3) final artefact form made at the quarries and transported to another location where it was exchanged and then used. A second factor to consider is whether the procured raw material, preform or artefact was consumed directly by the maker or was exchanged and then modified and/or used. Finally, since material acquired from the quarries might be partially consumed before it was exchanged, the number of transactions made in the movement from the source to the final point of discard will affect the character of the archaeological record. Since some artefact life histories could end up with similar outcomes in terms of the composition of the lithic assemblage and distribution across the landscape, it may not be possible to discriminate among all possibilities, but as we try to show, the potential options can be constrained.

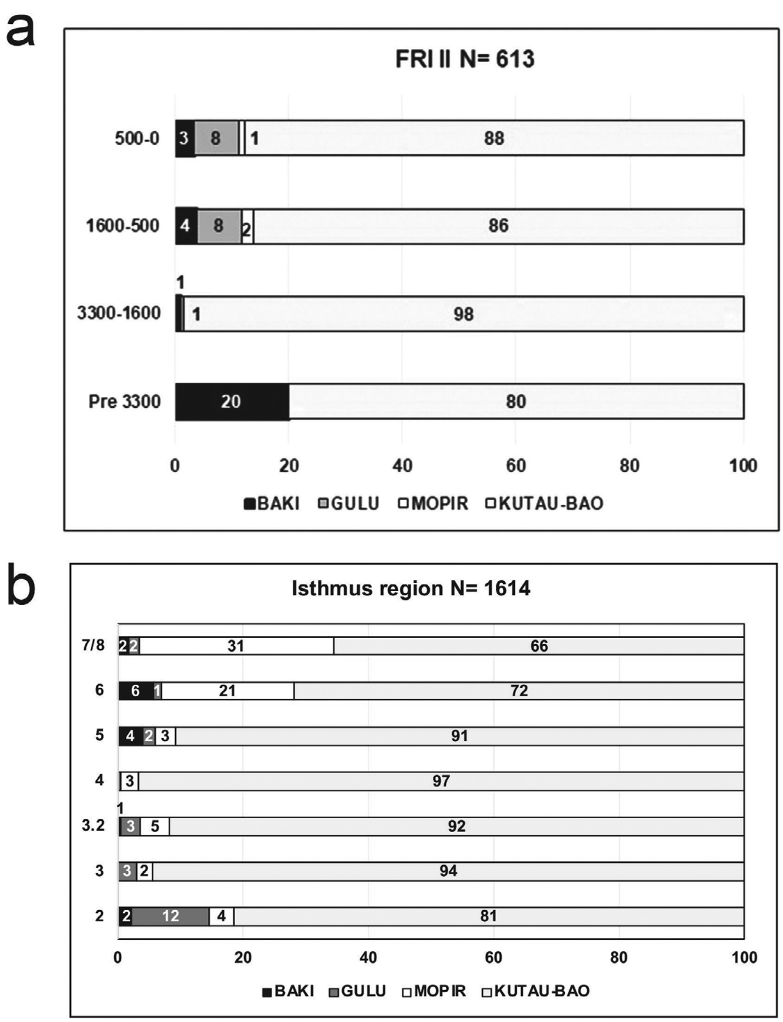

Figure 9.5: Chronological changes in the percentage of obsidian artefacts from each source.

Notes: (a) FRI II; (b) Isthmus region.

Source: Illustration by authors.

Geochemistry and social exchange

The results of the pXRF characterisation analysis are presented in Tables 9.4 and 9.5 and Figures 9.4 and 9.5. In both the Isthmus region and at FRI II, stone acquired from the Kutau-Bao obsidian source was by far the dominant raw material, although its abundance varied through time, with notable changes following major volcanic events. This result is perhaps not surprising since the Kutau-Bao outcrops contain ample quantities of excellent quality raw material and cover a much larger area than the Baki and Gulu outcrops (Figure 9.1) (Torrence et al. 1992). Fission track dates for the formation of the obsidian sources show that Kutau-Bao is probably the only source which has emerged since human occupation of the region, probably not until 12,000 years BP (Torrence et al. 2004:Table 5). The impact on communities of observing the eruption in which Kutau-Bao appeared might also have been a factor in its popularity (Torrence in press). Variations in the consumption patterns of the primary source of obsidian imply changes in the social mechanisms responsible for its distribution.

Table 9.4: FRI II, Walindi Plantation: Chronological change in counts and weights of obsidian artefacts from each obsidian source.

Phase	Counts					Weights (g)				
	Baki	Gulu	Kutau-Bao	Mopir	Total	Baki	Gulu	Kutau-Bao	Mopir	Total
4	6	14	156	2	178	7.7	44.3	322.6	2.7	377.3
3	2	4	44	1	51	5	9.4	108.3	0.5	123.2
2	4	2	363	0	369	7.5	0.4	724.4	0	732.3
1	3	0	12	0	15	14.1	0	21.6	0	35.7
Total	15	20	575	3	613	34.4	54.2	1177	3.1	1268.7
%	2	3	94	1<	100	3	4	92	<1	100

Note: The percentages of each source based on counts are reported in Figure 9.5a.

Source: Authors' data.

Table 9.5: Isthmus region: Chronological change in counts and weights of obsidian artefacts from each obsidian source.

Period	Counts					Weights (g)				
	Baki	Gulu	Kutau-Bao	Mopir	Total	Baki	Gulu	Kutau-Bao	Mopir	Total
7/8	3	3	115	55	176	4.2	0.9	179.0	110.8	294.9
6	21	5	266	78	370	20.9	0.6	466.6	135.6	623.7
5	6	3	137	5	151	7.1	0.5	351.9	9.2	368.7
4	0	1	177	5	183	0	0.1	284.4	10.5	295.0
3.2	1	6	177	9	193	0.2	6.8	211.5	9.5	228.0
3	0	11	343	9	363	0	25.7	546.6	9.3	581.6
2	4	22	145	7	178	1	26.6	180.6	5.3	213.5
Total	35	51	1360	168	1614	33.3	62.3	2220.7	290.2	2605.5
%	2	3	84	10	100	1	2	85	11	100

Note: The percentages of each source based on counts are reported in Figure 9.5b.

Source: Authors' data.

Turning to the minor sources, obsidian from the Baki and Gulu outcrops are reasonably well represented in the Pleistocene levels of Kupona Na Dari (Torrence 2004a), but since they are only present in very small amounts throughout the Holocene chronological sequences in both our study areas, it is not surprising that there are no consistent trends in their abundance in the sample pits. In FRI, the quantity of Gulu obsidian is consistently small, although it increased after the W-K3 eruption c. 1700 cal. BP (Table 9.4). In contrast, Baki was c. 40 per cent by weight prior to 3300 cal. BP (i.e. Periods 2 and 3), nearly disappeared during 3300–1600 cal. BP, and then only made a minor contribution in the most recent deposits (Table 9.4; Figure 9.5a). The opposite chronological pattern is witnessed in the Isthmus, where Gulu obsidian was most plentiful in Period 2, but subsequently decreased and only contributed very minor amounts later in time (Table 9.5; Figure 9.5b), whereas the Baki source made a brief appearance at the beginning of the sequence, but then immediately disappeared until Period 5 when it reappeared, although it never exceeded 5 per cent of the assemblage (Table 9.5; Figure 9.5b).

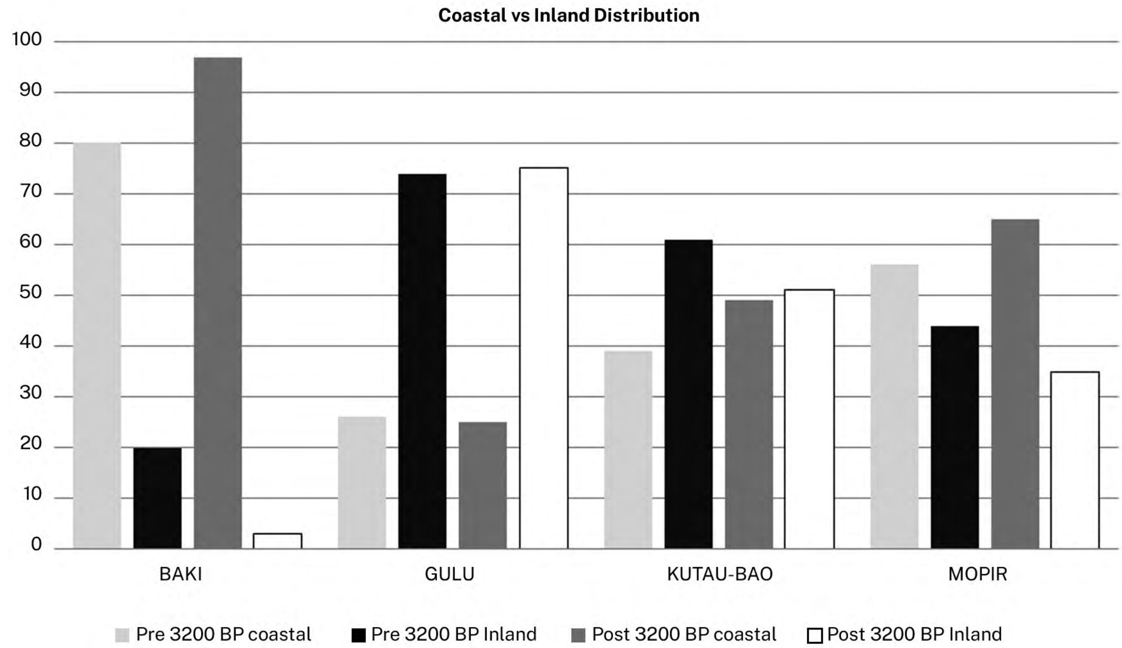

Figure 9.6: The percentage of obsidian artefacts from each source compared between test pits in coastal and inland locations.

Source: Illustration by authors.

It seems likely that the uses of the two minor sources reflect social ties involving only a small sector of the population that chose to interact outside the wider network dominated by people who used Kutau-Bao obsidian. Through time, obsidian from Gulu is most common among the Isthmus test pits situated in the inland regions (Table 9.5; Figure 9.6). Possibly it was primarily transported directly south from the major outcrops on the western side of the WP and then was carried inland, rather than moving east along the north coast as in the case of the bulk of the other obsidians. This route would have been especially convenient before the W-K2 eruption, because there was a large bay located in what is now the flood plain of the Kulu River (Figure 9.1; Torrence et al. 2009). In contrast, Baki obsidian is most common in coastal locations, which makes sense given its location on Garua Island (Figures 9.1 and 9.6).

In both the Isthmus and at FRI the most striking pattern in obsidian consumption is the largest peak of Kutau-Bao obsidian in the period immediately following the W-K2 eruption (c. 3300–1600 cal. BP or Period 4), representing 97 and 99 per cent of the samples respectively (Tables 9.4 and 9.5; Figure 9.5). The loss of Baki obsidian at FRI II is contemporary with its drastic decline at sites situated near the outcrops on Garua Island (Torrence 2004a; Torrence and Summerhayes 1997). Torrence and Summerhayes (1997) and Torrence (2004a) argued that the monopoly of Kutau-Bao obsidian at this time implied the existence of a specialised exchange system, perhaps along the lines described by Mead (1930) for coastal villages in the southern part of the Admiralty Islands. In this model, each community specialises in a raw material or product (e.g. obsidian, pottery, baskets, fish, taro, etc.), even if residents can easily produce the material locally, and they acquire other products through trade. This kind of exchange system is an effective way to integrate small, isolated groups by promoting the regular social interchange necessary for facilitating marriage ties and access to assistance when needed. The adoption of an exchange system that ensures frequent intercourse also

makes sense for a population recolonising a region following the large-scale W-K2 volcanic eruption, at a time when small, isolated groups would have been susceptible to fluctuations in population size that could lead to failure.

Given the mix of obsidian sources in both regions, the formal trading system may have begun to break down after 1600 cal. BP. After the W-K3 eruption, the pXRF results show a gradual decline in the percentage of Kutau-Bao obsidian in favour of more heterogeneous assemblages comprising the minor sources Gulu and Baki (Tables 9.4 and 9.5; Figure 9.5). Possibly through time, a well-integrated exchange system focusing on Kutau-Bao obsidian was gradually replaced by a more fluid situation in which people negotiated their social connections independently. In the Isthmus, a change to a more individualised pattern of social interaction was further accentuated in Period 6 (1300–500 cal. BP) following the W-K4/Dk event (McKee et al. 2011), when the dominance of Kutau-Bao was significantly diminished and continued to fall in Period 7/8.

Another key element in the history of obsidian procurement in the Isthmus is the pattern of occurrence of obsidian from the Mopir obsidian source, located to the east in the Hoskins Peninsula (Fullagar et al. 1991) (Figure 9.1). During the Pleistocene, Mopir was the most common obsidian source represented at the Kupona Na Dari site, comprising 36 per cent of the assemblage (Torrence et al. 2004), but by the early Holocene (Periods 2–3) its incidence had declined markedly in the wider Isthmus region, where it comprised only c. 4 per cent (Table 9.5). The actual quantities of Mopir obsidian before and after W-K2 are admittedly small, but there is no significant change in the proportions they make up of the total assemblage (Figure 9.5b). Contrary to previous suggestions that Mopir disappeared from assemblages in the region because the W-K2 volcanic event increased the difficulty of reaching the outcrops (e.g. Summerhayes et al. 1998; Torrence 2004a; Torrence et al. 1996), in the WP it is present in roughly the same very small proportion before and after the eruption. It is worth noting that Mopir is also present, again in small quantities, in assemblages elsewhere in New Britain during Period 4, contemporary with Lapita pottery (White and Harris 1997).

Mopir continued as a minority source up until the W-K4/DK event, marking the boundary of Period 6. At this point, however, the proportion of Mopir obsidian increased markedly and continued to grow in Period 7/8. Similarly, all three artefacts from FRI II assigned to the Mopir source were recovered from post 1600 cal. BP contexts in Phase 3 (Table 9.4; Figure 9.5a). The rise in the contribution of Mopir obsidian after the Dk and W-K4 volcanic events (which McKee et al. (2011) show occurred very close together in time) may represent a significant change in the structure of regional social networks in the WP. It seems likely that the volcanic disasters played a role in the shift from the dominance of Kutau-Bao to a marked rise in the amount of Mopir obsidian in the Isthmus, but had less impact further north at FRI. Based on a Bayesian analysis of radiocarbon dates that bracket the eruptions, the Isthmus region was abandoned for c. 100 years following the W-K4 eruption. In contrast, since W-K4 tephra has not been identified near the Kutau-Bao sources, the immediate local consequences of that event were probably minimal. However, dates from Garua Island indicate the northern part of the WP was abandoned for c. 235 years after the Dk event, which occurred just slightly earlier (Petrie and Torrence 2008:Table 7), indicating that the northern WP was much more seriously impacted by the larger magnitude Dakataua eruption (Machida et al. 1996). The decline in Kutau-Bao obsidian in the Isthmus, and to a lesser extent at FRI, may be the consequence of reduced population sizes near the sources. When the Isthmus community returned after W-K4, opportunities for social networks to the north-west were probably still scarce and so people may have looked to the east for alternative lifelines. Through the process of initiating and reinforcing ties through exchange and marriage ties, they acquired obsidian from the Mopir source.

Evidence for a reorientation of social networks to the east in the most recent periods is also indicated by the novel importation of ground stone axes produced from raw material in the Hoskins Peninsula where Mopir is also situated (Pengilley et al. 2019).

Tracing exports from the quarries

Building on the characterisation study, the reduction analysis explored the nature of social relations through the material that was exchanged. A limitation of the study is the lack of excavated data that could provide information about how raw material was treated at the obsidian outcrops before it was distributed. An examination of the five general classes of artefacts—cores, flakes, microflakes (less than 1 cm^2), nonflake debris (often termed 'shatter') and tools—shows that in the Isthmus region the assemblage is dominated by flakes (85–92 per cent) (Table 9.6). The scarce cores (1 per cent) all preserve multidirectional flake scars, indicating that they had been heavily reduced in an unsystematic manner, possibly in the context of use rather than primarily as a source of flakes. Not surprisingly, given their rarity in other assemblages in West New Britain, there are no formal tools (Kononenko 2011; Torrence 2011). A very few small stemmed tools, all made on casual flakes (cf. Kononenko et al. 2010), have been recovered from the Isthmus test pits, but none occurred in our sample. The tools identified in the assemblage (4 per cent) are comprised of flakes with irregular, light, marginal retouch or edge damage. It is probable that some unmodified flakes had been selected for use because of the specific shape of the cutting edge, although Kononenko (pers. comm. 2020) has found that edge characteristics are not a reliable predictor of wear patterns in obsidian assemblages in this region. Given the results of Kononenko's (2011) usewear analyses of assemblages from Garua Island, it is likely that many of the flakes in our sample had also been used in a casual manner for a short period (cf. Torrence 1992, 2011). The expedient consumption of obsidian supports Sheppard's (1993) proposition that it was social relations that stimulated its movement rather than its value as a utilitarian good.

Since sample sizes from the Gulu, Baki and Mopir sources are small, interpretations of past behaviour based on assemblage composition alone are tentative (Tables 9.6, 9.7). The make-up of the assemblage sourced to Gulu is distinctive from the other sources, possibly reflecting change through time, since most of it dates to Period 2 (pre 6000 cal. BP). The relatively high proportion of Gulu microflakes and nonflake debris, together with a single core, is possibly indicative of waste from tool manufacture rather than assemblages comprised of discarded tools. Another major difference among the assemblages is the absence of cores sourced to Mopir despite the relatively large sample of artefacts recovered.

Table 9.6: Isthmus region: Assemblage composition by obsidian source.

Category	Baki		Gulu		Kutau-Bao		Mopir		Total	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Cores	0	0	1	2	21	2	0	0	22	1
Flakes	31	88	35	68	1150	84	154	92	1370	85
Microflakes	1	3	6	12	50	4	5	3	62	4
Nonflake debris	2	6	5	10	81	6	5	3	93	6
Tools	1	3	4	8	58	4	4	2	67	4
Total/%	35	2	51	3	1360	84	168	10	1614	100

Source: Authors' data.

Table 9.7: FRI II: Assemblage composition by obsidian source.

Category	Baki		Gulu		Kutau-Bao		Mopir		Total	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Cores	1	7	1	5	7	1	0	0	9	1
Flakes	13	86	18	90	528	92	3	100	562	92
Nonflake debris	0	0	1	5	26	5	0	0	27	4
Tools	1	7	0	0	14	2	0	0	15	3
Total/%	15	3	20	3	575	94	3	1<	613	100

Source: Authors' data.

The incidence of cortex, defined as the unmodified surface of an obsidian block extracted from the outcrops, is a useful indicator of how intensely raw material has been worked. The degree of reduction at the sites is a consequence of the form in which the material left the quarry together with the number of exchange episodes through which it passed. Given that FRI and the Isthmus region are within 10 or 22–33 km, respectively, of the Kutau-Bao obsidian outcrops, one would expect the preservation of cortex on some artefacts if raw nodules had been the main quarry output, because the number of exchanges among different communities over this short distance is unlikely to have been very high.

In contrast, the distance from the Mopir outcrops (45–55 km) should be large enough that cortex would have been removed from the initial quarried nodules moving 'down-the-line' among multiple recipients. As expected, the very small number of Mopir artefacts at FRI probably arrived as flakes and do not retain cortex. In contrast, during Periods 6–7/8 in the Isthmus, when there are reasonable sample sizes for Mopir obsidian, only 86–89 per cent are non-cortical, compared to 95–97 per cent for Kutau-Bao (Table 9.8), indicating differences in the exchange patterns from the two obsidian sources, either in terms of the form in which obsidian was transported and/or a smaller number of links between Mopir and the places where the obsidian was discarded.

Table 9.8: Comparison of chronological change in the incidence of non-cortical artefacts in the Isthmus regions and FRI II (based on Tables 9.4 and 9.5).

ISTHMUS					FRI II				
Period	Kutau-Bao		Mopir		Phase	Kutau-Bao		Mopir	
	N	%	*N*	%		*N*	%	*N*	%
7/8	112	97	49	89	4	149	84	2	100
6	252	95	67	86	–	–	–	–	–
5	120	88	0	0	3	42	71	1	100
4	174	98	0	0	2	334	75	0	0
3.2	174	98	0	0	1	14	100	0	0
3	339	99	0	0	–	–	–	–	–
2	142	98	0	0	–	–	–	–	–

Source: Authors' data.

At FRI, cortex is absent in the Kutau-Bao assemblage dating pre 3300 cal. BP, suggesting that either quarried raw nodules passed through several hands, each of which consumed some of the nodule before exchanging it onward, or more likely, decorticated, preformed or finished artefacts were exchanged . In later periods at FRI, when cortical flakes range between 25 and 29 per cent of the total, unworked nodules or only partially worked preforms were imported. In contrast, by the

time obsidian reached Isthmus consumers, there was practically no original surface of the nodule remaining on the imports, although the larger incidence of cortex in Period 5, after the W-K3 event, might be significant as this is also the time when the dominance of Kutau-Bao obsidian decreased. To track changes in the imports further, we consider additional indices for measuring changes in the degree to which obsidian nodules were reduced.

Reduction intensity and exchange

Since by far the largest proportion of the artefacts in the Isthmus region are noncortical flakes (Table 9.8), obsidian must have been imported as either preforms or finished objects. To refine the description of the assemblage, we used a method for characterising reduction intensity that focuses on dorsal scars. Following previous approaches (e.g. Andrefsky 1998; Callahan 1979; Shott 1994; Symons 2003), the obsidian archaeological assemblages were grouped into three stages.

1. Initial stage reduction: flakes with cortex covering more than 50 per cent of the dorsal surface. They have little or no platform preparation and tended to be the larger artefacts.
2. Mid-stage reduction: flakes with one or two dorsal scars. The majority of these preserved no cortex.
3. Late-stage reduction: flakes with three or more dorsal scars and including all the microflakes. No cortex was preserved on these flakes.

Sample sizes for Baki and Gulu obsidian artefacts were considered too small for this analysis, but the proportion of the various reduction stages for Kutau-Bao and Mopir obsidian (Periods 6–8) in the Isthmus region is depicted in Figures 9.7b and 9.7c.

Beginning with the consumption patterns for Kutau-Bao, the major change through time occurred between Periods 3 and 4, when there is a marked decrease in late-stage reduction. This pattern reflects the simultaneous change at FRI from 100 per cent noncortical artefacts to a quarter retaining some cortex (Table 9.8; Figure 9.7a). The absence of cortex and the large numbers of flakes with multiple dorsal scars (late-stage reduction) in Periods 2 and 3 in the Isthmus suggest that a preform or finished artefact was produced at the obsidian quarries and then exchanged. It is notable that at this time large, highly retouched stemmed blades and flakes were made at all the obsidian quarries, although the focus of production was at the Kutau-Bao outcrops (Araho et al. 2002; Torrence et al. 2013). Several stemmed tools have been recovered from a disturbed context in the Isthmus region at site FABN, located near test pits xlviii and xlix (Figure 9.3). Torrence (2004b; Torrence et al. 2013) and Specht (2005) have argued that stemmed tools were valuable objects that established or enhanced social status, but this does not preclude their being recycled following the transaction or ceremony in which they played a role. It is even possible that stemmed tools were deliberately destroyed as part of a ritual and the resulting flakes were recycled.

Moving through time into Period 4, contemporary with the near monopoly of Kutau-Bao obsidian in both areas there is a marked increase in mid-stage reduction. This indicates that the material leaving the quarries had not been converted into a final product but was only partially worked or reduced. If the dominance of a single obsidian source does signify a specialised exchange system, as proposed above, it is interesting that the people residing at the obsidian quarries were not controlling the exports to the same degree as they had previously. Obsidian was clearly circulating in a partially preformed state, since initial reduction is absent, but not in the final form, as previously. From Period 5, when the dominance of Kutau-Bao obsidian began to decline, the material imported into the Isthmus region was less worked prior to discard, as indicated by the appearance of flakes from

initial stage reduction, and this trend continued. It seems likely that in Periods 5–8 access to the quarries was less regulated. People could more freely obtain unworked nodules and/or these passed through fewer exchange partners before reaching the Isthmus in a less reduced stage than during the exchange of stemmed tools in Periods 2–3.

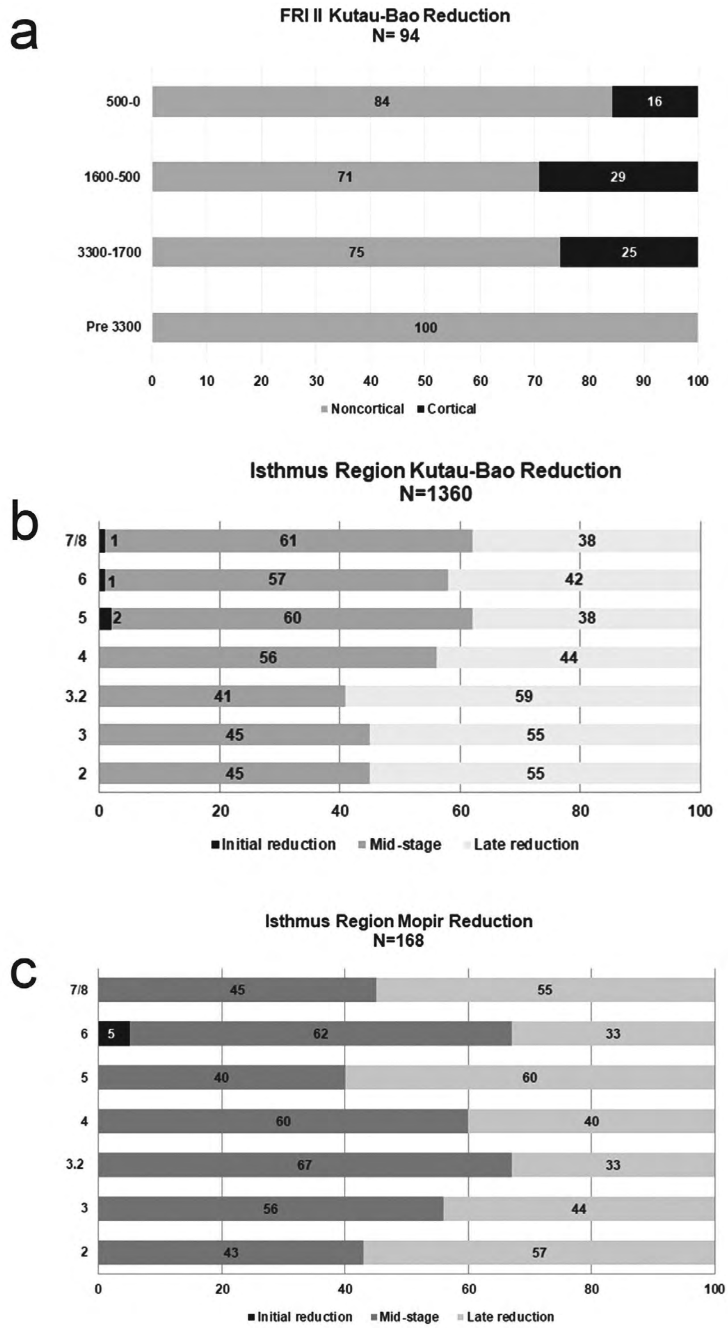

Figure 9.7: Changes in reduction stages through time at FRI and in the Isthmus region.

Notes: (a) FRI II Kutau-Bao reduction based on the percentage of cortical versus noncortical artefacts; (b) Isthmus region: changes in the degree of reduction for Kutau-Bao obsidian based on the percentage of artefacts at different stages; (c) Isthmus region: changes in the degree of reduction for Mopir obsidian based on the percentage of artefacts at different stages.

Source: Illustration by authors.

The exchange networks incorporating Mopir obsidian can also be inferred based on the mix of reduction stages for the most recent two periods with adequate sample sizes (Table 9.4; Figure 9.7c). As noted above, after the combined disaster of W-K4/Dk, larger amounts of Mopir obsidian were imported into the Isthmus area, indicating a significant shift in social connections. Given the incidence of initial and mid-stage reduction in the samples together with the amounts of cortex (Table 9.8), it also seems likely that partially or unworked nodules were exchanged through the reoriented social networks, much the same as with Kutau-Bao at this time.

Building resilience through social networks

Reconstructed using a combination of geochemical source characterisation and stone tool technology, the history of obsidian exchange within the Isthmus region of the WP in West New Britain in the period from the late Pleistocene up to the recent past is an excellent illustration of how populations have coped with the challenges of living in an active volcanic environment. In Periods 2 and 3 (pre 6000–3200 cal. BP), formalised valuables in the form of stemmed tools were made at all the sources, but only those comprised of Kutau-Bao obsidian arrived at FRI or the Isthmus region, where they were subsequently expended and converted into flakes and debris. The additional presence of very small quantities of Baki or Gulu obsidian at this time suggests that a few groups also established networks outside the ceremonial exchange in which Kutau-Bao circulated. Following the W-K2 event, in Period 4 (3200–1600 cal. BP) a much more tightly integrated exchange system was adopted in which only nodules or preforms from the Kutau-Bao source were used, possibly in exchange for other local specialities. This Kutau-Bao–dominated network began to break down after the W-K3 event. In Period 5 (1600–1300 cal. BP) and subsequently, there was a gradual shift from a well-coordinated pattern to one in which individuals forged their own exchange links, thereby reducing the length of the chain connecting the sources with the consumers. Finally, since the Dk disaster had a major impact on groups who controlled the Kutau-Bao obsidian sources in the northern WP (Periods 6–8, 1300 cal. BP onward), residents in the Isthmus region broadened their social networks to the east, resulting in an increase in Mopir obsidian and the introduction of stone axes produced in the same region.

The long history of obsidian consumption in the WP illustrates the importance of exchange for groups with low and unstable population levels as a result of volcanic activity. Although obsidian was not essential for utilitarian tasks, we argue it played a crucial role in creating and solidifying the social networks that sustained the small populations following a disaster as well as supporting colonising groups when they returned. When the scale of the volcanic eruptions diminished and smaller areas were subject to very serious impacts, however, there was more scope for people to diversify in terms of how and with whom they made connections. For example, in line with a reduction in the severity and spatial scale of the volcanic disasters experienced in the WP (Machida et al. 1996), there was a decrease in the length of time during which the area was abandoned (Petrie and Torrence 2008). Consequently, population levels in the Isthmus region probably rose over time, as reflected by the steadily increasing rate of discard for obsidian artefacts per year as illustrated in Table 9.9 (cf. Torrence 2016:10, Table 2). With decreased environmental challenges and a growing population, groups were able to solve their needs locally and the requirement for strong nonlocal connections was reduced. Consequently, the exchange systems that distributed obsidian were gradually loosened up and possibly played a lesser role in social life. The change in the role of obsidian probably created opportunities for alterative social and ceremonial practices.

Table 9.9: Discard rates for the Isthmus region based on data from 67 test pits.

Period	Number of artefacts discarded per year
3	0.3
4	0.9
5	1
6	1.4
7/8	1.8

Source: Torrence (2016:Table 2).

To test our proposal for the role of exchange in creating and strengthening social networks that ensured adequate resilience among groups inhabiting places prone to severe environmental perturbations, future studies could compare and contrast the distribution and use of obsidian in other areas of Papua New Guinea (e.g. Admiralty Islands or the south coast of the mainland and adjacent archipelagos) or indeed in other regions of the world with different environmental histories and challenges. It is interesting to note, for example, that Fergusson Island obsidian does not have the same persistence through time as the New Britain sources (e.g. Golitko et al. 2012; Irwin and Holdaway 1996; Mialanes et al. 2016; Shaw et al. 2021). Can changes in the mix of obsidian sources at sites in the Admiralty Islands (e.g. Fredericksen 1997) be connected with the volcanic history of Manus Island? With the advantages of portable technology, there are now many exciting possible avenues for examining relationships between obsidian exchange, social strategies and risks caused by environmental variation.

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