The obsidian sources and distribution systems emanating from Gaua and Vanua Lava in the Banks Islands of Vanuatu

Volume 1

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To the best of my knowledge, the research presented in this thesis is my own except in cases where I acknowledge the work of other researchers. This thesis has not been submitted in any form for any other degree at this or any other university.

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Abstract

This thesis examines 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 the technology of stone artefacts. Two major bodies of data are incorporated: (1) geochemical analysis of obsidian from sources and archaeological assemblages using laser ablation – inductively coupled plasma mass spectrometry data (LA-ICPMS) and (2) technological analyses of flaked artefacts using quantitative attribute data.

Fieldwork to locate intact sources combined with comprehensive geochemical analysis of obsidian outcrops in Northern Vanuatu was required as there was previously no clear understanding of the number of obsidian outcrops exploited in the past and their associated elemental compositions. Preliminary geochemical research suggested that more than the two identified obsidian outcrops may have been utilised. To assess the presence of additional obsidian sources, surface collections of artefacts throughout the Banks Islands as well as excavated assemblages from sites in Vanuatu and adjacent areas were also geochemically fingerprinted. The research showed that the two known source regions on the islands of Vanua Lava and Gaua are indeed the only existing sources and that no additional outcrops were exploited. Furthermore, the internal variation of the two sources is very limited. Consequently, artefacts previously associated with putative additional obsidian sources in the Banks Islands, such as artefacts found in Fiji, were shown not to be derived from Vanuatu.

To analyse changes in the production, distribution and consumption of lithic artefacts throughout the research area, assemblages were selected covering the entire 3000-year timeframe of human occupation in Vanuatu and the Southeast Solomons. In total 21 assemblages were analysed to understand the processes shaping social interaction between communities. To provide a theoretical framework for explaining changes in the intensity of interaction, economic approaches to resource maximisation in the production and consumption patterns of transported material were assessed. It is concluded that because they depend too much on the notion of the scarcity of resources in their evaluation of the concept of value, these theoretical orientations were insufficient to explain the pattern of spatial and temporal distribution of the lithic artefacts. Alternative models are proposed that focuses on the importance of environmental factors. Variations in the frequency of ENSO over time create risks that can be mitigated by increased communication and social interaction resulting from exchange of stone raw material. In context of this interpretation, obsidian is seen as an item reflecting and strengthening interaction networks, but it is assumed that it was not the main force initiating or shaping these networks.

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Abbreviations

AD (obsidian)	Admiralty Islands
BAII	Bismarck Archipelago Indigenous Invention model
BI	Banks Islands
CA	Correspondence analysis
EDXA	Energy dispersive x-ray analysis
EF (obsidian)	East Fergusson
EF-Teouma	Efate - Teouma
EF-Arapus	Efate - Arapus
ENSO	El Niño / Southern oscillation
ETP	Express Train to Polynesia model
HBE	Human behavioural ecology
HFSE	High Field Strength Elements
LA-ICPMS	Laser ablation - inductively coupled plasma mass spectrometry
LIA	Little ice age
MC-LA-ICPMS	Multi collector - Laser ablation - inductively coupled plasma mass spectrometry
MFM	Mobile Founding Migrant
ML-Lequesdewen	Mota Lava - Lequesdewen
ML-Saywoume	Mota Lava - Saywoume
MNF	Minimum number of flakes
MORB	Mid-Ocean Ridge Basalt
MWP	Medieval warm period
NAA	Neutron activation analysis
OFT	Optimal Foraging Theory
OIB	Oceanic Island Basalt
PAAP	Pacific Area Archaeological Project
PCA	Principal components analysis
PIXE-PIGME	Particle induced x-ray emission - Particle induced gamma-ray emission
PNG	Papua New Guinea
RSC	Reef / Santa Cruz
SEM	Scanning electron microscopy
TI	Torres Islands
TI-Kurvot	Torres Islands - Kurvot
VCIII	Voyaging Corridor - Triple I model
VCHSS	Vanuatu Cultural and Historical Site Survey
WF	West Fergusson
WNB	West New Britain
XRF	X-ray fluorescence analysis

- Chapter 1 -

1. Introduction

This thesis examines the history of social interaction within communities in the Vanuatu Archipelago (formerly the New Hebrides) and between Vanuatu and other regions in the Western Pacific as reflected by variations in lithic raw material sources and the technology of stone artefacts. Two major bodies of data are incorporated: (1) geochemical analysis of obsidian from sources and archaeological assemblages using laser ablation – inductively coupled plasma mass spectrometry data (LA-ICPMS) and (2) technological analyses of flaked artefacts using quantitative attribute data.

"Are islands islands?" has recently been asked and discussed by Matthew Spriggs (2008a). This controversy has been a debate in island archaeology since its beginnings (Boomert & Bright 2007; Fitzpatrick *et al.* 2007). Especially in Pacific archaeological research the hypothesis of islands as being isolates has a long history (Goodenough 1957; and for a discussion of this concept see Bellwood 1996; Spriggs 2008a; Terrell *et al.* 1997). The large geographical distance between islands has been assumed to have hindered an earlier colonisation of the southern and eastern Pacific in the Pleistocene. It is also assumed that large distances between islands were an obstacle in the maintenance of social interaction networks once these islands were colonised (Kirch 1986), which in turn intensified the process of cultural diversification. The idea of islands in the Pacific as being isolated from each other has been challenged by Gosden and Pavlides (1994). Instead of identifying the ocean as a barrier in the flow of people and information, they proposed that, rather, it helped shape a highly mobile society and fuelled social interaction between distant communities. To assess whether these large sea-gaps between different islands in the Pacific were a help or a hindrance in maintaining communication networks, it is necessary to examine the intensity and possible changes in social interaction through time. Social interaction between communities is, however, notoriously difficult to detect in the archaeological record.

The combination of geochemical and technological analyses of lithic assemblages, nevertheless, gives a unique insight into cultural activities in the landscape, the nature of interaction between human communities, and their interaction with local environments (see Collerson & Weisler 2007 for evidence of social interaction in previously presumed "isolated" islands). Each set of data examined in this thesis has a special role in the understanding of different aspects of procurement, distribution and utilisation of stone artefacts. Earle (1982:3-4; see also Hayden 1998; Hunt 1988; Torrence 1982, 1986) recommended three steps to be followed in analysing exchange networks: (a) sourcing of the commodities, (b) describing the spatial patterning, and (c) reconstructing the organisation of exchange. Tracking the movement of obsidian between distant groups has been particularly productive in various parts of the World, including the Pacific, for the analysis of exchange systems and social interaction.

Obsidian is a natural volcanic glass that develops when high silicate (rhyolitic) lava cools very quickly (shock cooling) during a volcanic eruption. The shock cooling restricts the emergence of crystals in the matrix of the material and results in a homogeneous amorphous rock, which is very brittle and can easily be flaked producing very sharp edges. The rather complex nature of its origin is the reason that obsidian deposits have a geographically discrete distribution: not every volcanic eruptions and indeed not all volcanic islands develop obsidian deposits. Furthermore, even when obsidian deposits developed on islands, not all outcrops were exploited by humans continuously throughout the past (Ambrose, Bird *et al.* 1981; Ambrose & Johnson 1986). Currently, five major centres of prehistoric obsidian exploitation are known in the Western Pacific: West New Britain and the Admiralty Islands in the Bismarck Archipelago, the D’Entrecasteaux Islands of South Papua New Guinea, the Banks Islands of Northern Vanuatu and in the general area of Tonga (Figure 1.1).

Most remarkable in the spatial distribution of this special raw material is indeed its long-distance transportation associated with the colonisation of the Pacific during the Lapita period. During colonisation, obsidian from the Bismarck Archipelago was moved distances of over 3500 km into the Western and Central Pacific and also back into Southeast Asia (Bellwood & Koon 1989). Because of the impressive distribution of the West New Britain sources little attention has been placed on the Vanuatu obsidian sources, as their distribution was much more limited. However, the Vanuatu obsidian sources have been chosen as a case study in this thesis because they give a unique insight in social interaction during the earliest colonisation and, more importantly, the changes in social interaction during the long history of human occupation of the islands after the initial colonisation some 3000 years ago.

Beginning in the 1960s, technological innovations made systematic research on the geochemistry of different materials possible. A whole suite of analytical methods allowed archaeologists to identify the place of origin of materials used to make artefacts. The very homogenous matrix of obsidian makes it one of the materials most commonly geochemically analysed, but a wealth of other materials (like ceramics) have proven possible to be sourced. Because of its unique geochemical attributes and its perceived importance as an item of cultural meaning, obsidian has been a focus of archaeological research in the Pacific. Torrence (2005) suggests that the occurrence of obsidian artefacts in domestic contexts implies mundane functions of this raw material; which was also proposed by Specht and Koettig (1981) and Fullagar (1992; 1993). Additionally, Specht (1981) mentions that obsidian was still in use in Papua New Guinea for shaving purposes in the 20th century. Functions such as tattooing and scarification have been suggested (Ambrose in press; Kononenko & Torrence 2009; Sand & Sheppard 2000; Specht 1981). On the other hand, ceremonial applications for certain pre-Lapita obsidian tools are proposed by Araho et al. (2002). In the context of the Kula exchange system of South Papua New Guinea, MacIntyre (1983:212) describes obsidian as ‘pasa’ – a subsidiary decorative item. In a more general approach, Kirch (1988) suggests the idea of obsidian as a prestige good and the exchange of it as an insurance: a ‘lifeline’ back to the homeland for colonising groups. Using a more substantivist approach, Sheppard (1993) attempts to split the transport of obsidian from its utilisation as a raw material at its final destination and recommends that these two spheres be considered separately.

To understand the type of social interaction occurring at different times in the past and to explain how these interaction might have been changed through time, general theoretical concepts are discussed in Chapter 7. In this thesis two different bodies of theory are applied, economic theory and theoretical ecology (Bamforth & Bleed 1997). Although these theories are not mutually exclusive (Bousman 1993, 2005), they differ in their approach to the archaeological record. Incorporating both bodies of theory, it will be discussed whether Banks Islands obsidian (BI-obsidian) was distributed as a commodity, following the rules of resource economisation, or as a symbolic object, in a context where social concepts such as gift exchange shaped the interaction network. Furthermore, the thesis attempts to explain whether the identified changes in the distribution of raw material can be correlated with environmental stress. In this context risk minimising strategies of communities might have played an important role in the evolution of social interaction networks in the southwest Remote Oceania.

In the next section four general research question to be addressed in the thesis are discussed. This is followed by a section clarifying the terminology used in this thesis and a general timeline for the Lapita colonisation and post-Lapita cultural diversification. That section is followed by a brief summary of previous research on the Banks Islands in general and a more detailed description of previous knowledge of the Northern Vanuatu obsidian sources and distribution of artefacts made from Banks Islands raw material. The chapter concludes with a brief outline of the thesis structure as a whole.

Thesis aims and research questions

The aim of this thesis is to contribute to the understanding of factors influencing social interaction in southwest Remote Oceania from the initial colonisation of these islands. For this purpose the spatial and temporal distribution of the Northern Vanuatu obsidian raw material is examined and compared to non-obsidian flaked artefacts throughout the research area. Four general questions will be addressed in detail to achieve this aim and are presented below. These general research questions will be considered in detail in Chapter 8. However, several specific issues became apparent during research that only concern one of the two bodies of data (geochemistry or lithic technology), for example, the internal geochemical variation of the two Northern Vanuatu obsidian sources. These issues will be addressed separately in the two results chapters (Chapters 5 and 6).

Question 1. Are the same processes of interaction and exchange active through time or can we detect differences? And are these differences or similarities raw material dependent?

Is the Lapita period exemplary for the series of events shaping the archaeological record of Remote Oceania, or is it exceptional with differences through time that might explain the evolution of cultural diversity more conclusively? Furthermore, which factors could have been responsible for the archaeological record as we see it today (Spriggs 1992:222; 1997:154-161): trade system contraction, local adaptation, socio-political transformation, absorption or secondary migration? In addition to the discussion of ideas about the evolution of cultural diversity, consideration of the environmental context which might have influenced colonisation of Remote Oceania in the first place and cultural diversification in the following periods is gaining importance in recent Pacific research. Not only catastrophic events, such as volcanic eruptions (Ambrose, Bird *et al.* 1981; Grattan & Torrence 2008b; Torrence & Grattan 2002; Torrence *et al.* 1996), but also long-term variability in climate, for example (Anderson *et al.* 2006; Kennett *et al.* 2006), are perceived to have had major impacts on how humans shaped their societies and their social networks. In Chapter 7 the theoretical framework of cultural evolution is discussed in relation to environmental conditions. Modelling of risk management strategies has been identified as one general quality to explain human behaviour in the context of environmental factors. Although the dataset might be too fragmented to address these models in detail, it does allow consideration of alternative explanatory frameworks.

Question 2. How was the spatial distribution of obsidian in Vanuatu organised?

Several models for the analysis of spatial distribution of particular raw materials have been developed previously and are discussed in this thesis. Renfrew (1975) distinguished ten different modes of exchange, from direct access through to market exchange, as means of explaining the archaeological record of raw material distribution. In this thesis, geochemical provenancing of the two Northern Vanuatu sources themselves and the lithic assemblages of 21 sites throughout Vanuatu and the Polynesian outlier of Tikopia, in the Southeast Solomon islands, are combined with a technological analysis of flaked stone assemblages.

Special focus will be given to the lack of resource optimising reduction in lithic technology which has been detected in several assemblages in the past (Halsey 1995; Sheppard 1993). This phenomenon is in sharp contrast with the transport of raw materials up to several thousand kilometres. Although BI- obsidian was not transported comparable distances to the West New Britain (WNB) sources, its geographical distribution covers distances of up to 1200 km and therefore the question of whether this resource was treated similarly to WNB obsidian must also be addressed in this work.

Question 3. Can established models of West New Britain and Admiralty Islands obsidian exchange organisation in the Pacific be adapted to explain the spatial distribution of BI-obsidian?

Chapter 2 describes models of exchange proposed for different parts of the Western Pacific. These models are based mostly on geochemical data, rather than technology, and are much more developed for the Lapita period than for the post-Lapita period. The main foci of these models are: (a) whether we can speak of an exchange system at all; (b) whether the Lapita period shows one generalised exchange system or several interconnected contemporaneous ones; and (c) whether localised specialisation of artefact production and resource transportation occurred.

For the post-Lapita period a series of contracting exchange networks with increasing complexity is one explanation of the archaeological record. Alternative possibilities include the break-up of one complex exchange system into several more localised ones with decreasing complexity but increasing specialisation (Allen 1984; Kirch 1988), or even the complete break-down of communication with increasing isolation of distant communities due to the geographical distances over which exchange networks had to be maintained (Ambrose 1978; Bedford & Clark 2001; Pawley 1981).

Because of the long-term occurrence of the BI-obsidian in sites covering nearly the whole time-frame of human occupation in parts of southwest Remote Oceania, these raw materials give a unique insight not only into social interaction during the earliest colonisation but, perhaps more importantly, into the changes in social interaction during the long history of human occupation of the islands after initial colonisation some 3000 years ago. Therefore, they are exceptionally well suited to test models of social interaction developed in other areas of the Western Pacific.

Question 4. What implications does obsidian exchange have for the understanding of social interaction in Pacific history?

Chapter 7 summaries the conceptual frameworks in which previous ideas of 'exchange networks' were based in general and more specifically in the Pacific. Although the connection between ecology and exchange has been discussed previously, much work has focused on internal economic mechanisms, such as exchange of prestige goods, to explain the development of long distance transportation of raw material, especially in the Lapita period. The largely under-theorised discussion of the value of this raw material and the interrelated reasons for establishing interaction networks are addressed in that chapter. Chapters 7 and 8 discusses possible alternatives for explanations as to why this raw material was transported over long distances.

Although none of the concepts – social, economic or ecological – are mutually exclusive, and in fact may be interdependent, they are chosen here to represent different approaches to the concept of value and the reasons why certain raw materials are transported to distant places. As examples one can cite the scarcity of resources in neoclassical economics or the distances items travel in the more classical economic theory. The idea that the utility value of these raw materials was low has been discussed before (Sheppard 1993; Torrence 2005), but it has been held that their value could be explained by social factors such as ethnic markers (connection to a homeland) or exchange of prestige goods (representing status-enhancing external contacts) (Green 1991a; Kirch 1988). In this work another factor will be discussed: the concept of risk reduction through maintaining external contacts in a variable and unpredictable environment (Torrence 2004).

Setting the scene: Terminology, general timeline and previous research

A summary of previous research in Vanuatu and adjacent islands in the Southeast Solomons will now be given. This section concentrates first on describing a general terminology used hereafter and the general timeline in which this thesis operates. In the second part it summaries previous knowledge about the distribution of BI-obsidian.

Near Oceania and Remote Oceania

Geographically, Near Oceania includes the islands of New Guinea, the Bismarck Archipelago, and the northern and central Solomon Islands. Remote Oceania consists of the eastern part of the traditional area of Melanesia, the southeast Solomon Islands, Vanuatu and New Caledonia and Fiji, and all of Micronesia and Polynesia (Figure 1.1).

These two general geographical areas abut by the Southeast Asian islands and Australia to the west (Green 1995:6, Figure 1).

The terms Near and Remote Oceania originate from the realisation that the older expressions ‘Melanesia’, ‘Micronesia’ and ‘Polynesia’ (cf. Sand 2003:6, Figure 11) did not sufficiently take into account intra-regional differences (Green 1991b, 1995; Pawley 1981; Spriggs 1984a, 1997; Thomas 1989). Green argued for the adoption of the new terms, based on the long history of human occupation of today’s New Guinea and the Solomons, and the comparatively recent colonisation of the Southern, Central and Eastern Pacific Islands. The discussion of these two terms is of special importance for the understanding of Vanuatu’s cultural history as it emphasises the difference between the first ‘crucial’ steps into previously uninhabited lands (Bedford 2007; Bedford & Spriggs 2008) and the complex history of interaction from the late Pleistocene onwards in Near Oceania (Spriggs 1996; White 1996a; Wickler 2001; Wickler & Spriggs 1988).

In contrast to ‘Melanesia’, in historical semantics ‘Polynesia’ is still seen by some scholars as possessing an internal historical and particularly linguistic coherence (Earle 1997; Green 1995). However, even in this general area of more recent human settlement, significant differences can be seen between the western part and the eastern ‘marginal’ Polynesian islands, which might be a result of the later colonisation of the eastern Polynesian islands during the last 1500 or less years (Anderson 2001; Green 2003) rather than during the Lapita period.

Lapita and post-Lapita

The most accepted view of ‘Lapita’ is that it is a new ethnic identity (Spriggs 1997, 2003a, 2007) in the western Pacific and an important mobilising and legitimating force with shared identity, norms and values (Green 2002). Its spread was not random, but directional (Irwin 2008:22) by small, widely dispersed and highly mobile colonising populations (Bedford 2006b:263). This interpretation of the archaeological record is not undisputed and neither is the evolution of the Lapita phenomenon in Near Oceania (Ambrose 1997; Chiu & Sand 2007; White 1999). The different approaches to the emergence and persistence, decline or continuation of Lapita will be discussed in detail in Chapter 2.

Green (2003:110) summarised seven archaeologically identifiable characteristics of the 'Lapita Cultural Complex': (a) dentate stamped pottery decoration; (b) widespread obsidian transportation with the focus on Kutau/Bao obsidian from West New Britain and incorporation of Admiralty Islands obsidian into long-distance exchange networks; (c) the Lapita adze/axe kit; (d) fishing gear; (e) certain shell artefacts; (f) the tattooing complex; and (g) proto Oceanic **Rumaq*[1] houses. Additional features are: (h) animal domesticates (pig, dog and chicken, Spriggs 2007:114); (i) common oceanic food plants; (j) sailing technology; and (k) bark-cloth manufacture. Several of these attributes can be traced back to local innovations of the indigenous communities of the Pleistocene and early/middle Holocene in New Guinea (such as most of the food crops, cf. Denham & Haberle 2008; Denham *et al.* 2003). Others had their direct ancestry in the islands of Southeast Asia (such as the pottery decoration, cf. Hung 2008; Tsang 2007).

The post-Lapita period has been interpreted differently for Near and Remote Oceania. On the one side the Lapita phenomenon is argued by some as having persisted in Near Oceania for a long time (up until 2000 BP) albeit with regional transformations (Ambrose 1997, 2002; Summerhayes 2007; Summerhayes & Scales 2005; see for a contrasting view Felgate 2003; Garling 2003; 2007; Spriggs 2002). On the other side, in Remote Oceania, the Lapita period is generally agreed to end very quickly in Remote Oceania (Bedford 2006b; Bedford & Spriggs 2008; Clark & Anderson 2001; Sand 2001; Sheppard & Walter 2006). Whether the Lapita period was superseded by another 'cultural complex' defined by a Melanesia-wide Incised and Applied Relief pottery (IAR) (Golson 1972; Kirch & Yen 1982; Spriggs 1984a) or by independent cultural evolutions in separate smaller interaction spheres (Bedford & Clark 2001; Clark 2003; Sheppard & Walter 2006) will also be discussed in detail in Chapter 2.

In the later part of the post-Lapita phase, an intensification of communication throughout the islands is recognised (Bedford & Clark 2001; Kirch 2000; Spriggs 1997), with a 'backflow' of groups from the Central Polynesian islands to the West, as seen in the Polynesian outliers of the Solomons (Kirch & Yen 1982) and south-central Vanuatu (Bedford 2006b; Shutler *et al.* 2002). The post-Lapita period 'ends' with the

[1] A rectangular house built on surface level (Green & Pawley 1999).

first contact of indigenous communities with European explorers and the resulting widespread social dislocations caused by these meetings from the 16th century onwards (Scarr 1990). In this context it is important to note that the long-term influence of European contact not only caused a heavy depopulation of the islands through disease and forced labour. It is also considered that certain concepts of political and social organisation, now seen as 'traditional' in Melanesia – for example the 'big man' concept of Service (1962) and Sahlins (1963) – might derive from the culture contact between indigenous people and European colonial authorities (Spriggs 1997:231; 2008b).

A general timeline for colonisation and culture change in Vanuatu

Human expansion (Figure 1.2) into Vanuatu is now generally perceived to have started around 3100 BP (Bedford 2006b; Bedford & Spriggs 2008; Galipaud & Swete-Kelly 2007a). The archaeology of the post-Lapita period (Figure 1.3) in Vanuatu (see Chapter 2 for a detailed discussion of different models for post-Lapita cultural evolution) was the focus of Stuart Bedford's PhD thesis (Bedford 2000a). He concluded from the re-assessment of several sites in central Vanuatu – especially on Efate – and new-found sites on Malakula and Erromango, that the phase of dentate-stamped Lapita pottery was very short lived and probably ended prior to 2700 BP in Vanuatu (Bedford 2006b, 2007; Bedford & Spriggs 2008). Early occurrence of new ceramic motifs during the late Lapita phase in Vanuatu, for example the Arapus ceramics (roughly 2900 BP) from northern Efate, give evidence for independent cultural evolution shortly after the initial colonisation of the Archipelago. The separation in ceramic styles between Efate and the southern Islands (as evidenced on Erromango) occurred during this early phase of increasing regionalisation. However, interaction spheres among the islands to the north of Efate (Epi and the Shepherd group) show similarities in their ceramic tradition up until 1800 BP (Bedford & Spriggs 2008). These islands seem to mark the boundary of an interaction sphere as it is now thought that the later ceramic traditions of Erueti and Mangaasi are not found in northern Vanuatu. Although Ward (1979) found decorated pottery on Pakea (Banks Islands Group) which he identified as Mangaasi, this pottery seems to represent an independent regional style dissimilar to the Central Vanuatu ceramics. In general, ceramic production and use appear to have ceased in Central Vanuatu around 1000 BP or slightly before. Ceramic production persisted for much longer periods in the North and on a number of islands up until European contact. More recently, fieldwork undertaken by Bedford and the author in 2006 detected additional ceramic use up until ~600 BP in the Banks Islands (see also Bedford & Spriggs 2008:107), challenging Ward's assumption of a cessation of ceramic use in the Banks Islands Group at about 2000 BP. This had already been suggested by Kirch and Yen (1982) for the Sinapupu phase ceramics on Tikopia and pottery from Vanikoro (Kirch 1983), and is newly emphasised by petrographic analyses of temper sands for pottery (Dickinson 2001; but, see Bedford 2006b:183, for a discussion of dissimilarities in the pottery motifs between the Southeast Solomons and Vanuatu).

Obsidian research and the history of archaeology in Vanuatu

Early European explorers and natural historians

Brenchley 1873 and Codrington 1891

The first written record of Obsidian in Vanuatu was written by Julius L. Brenchley (a natural scientist) in 1873. On the cruise of the Curacoa he reported the existence of obsidian on Tanna:

> "[...] Obsidian is also to be found there, and a stone which has all the appearance of the Nephrite of New Zealand, and of which the natives sometimes make bracelets" (Brenchley 1873:212).

He most likely confused obsidian with some other volcanic rock on this island or was recalling seeing it elsewhere in the Vanuatu Archipelago, he also mentioned the interest of the Vanua Lava people in bottle glass "[...] they made the sailors understand that they were very desirous to have empty bottles, which they seemed to prize beyond anything" (Brenchley 1873:235), and possibly used for the production of tools.

The first description of actual use of volcanic glass as a raw material for stone tool production was given in a footnote in Codrington's description of Melanesia in 1891:

> "[...] In the Banks' Islands, Torres Islands, and Santa Cruz, they had only shell adzes, and used obsidian flakes for cutting and scraping. In the Solomon Islands, except in Rennell and Bellona, and the New Hebrides, the implements were of stone, and flakes of chert were used [...]" (Codrington 1891:16).

The history of archaeological research

The history of archaeological research in Vanuatu was summarised in detail by Bedford (2006b). Therefore, only a short summary of research done in the last 40 years is given here. Until recently, research was very much focused on establishing a ceramic cultural sequence in Vanuatu and analysing indigenous adaptations to subsistence and sustainability of food production. The work on the ceramic record has therefore been more substantial than that on stone artefacts. Archaeological work in Vanuatu began in the early 1960s after the PAAP (Pacific Area Archaeological Project) named the New Hebrides as a centre for further research in the Pacific. The first western archaeologists who came to Vanuatu were the Shutlers in 1964. In a joint French-American mission, they conducted work first on the southern Islands of Aneityum, Aniwa, Erromango, Futuna and Tanna. Archaeological research further north in Santo, Malakula and adjacent islands by the Shutlers was only very brief. As the French counterpart in this mission, José Garanger started work on Efate and the Sheppard Islands. Most famous of his many surveys and discoveries in Central Vanuatu are the excavations at the Mangaasi site in northern Efate in 1964 and 1966/67 and the excavation of the large communal burial on the small Island of Retoka in 1966/67. Retoka is commonly thought of the burial of Roi Mata, Mangaasi his village. Both were recently awarded UNESCO World Heritage Status. Garanger also conducted several excavations on Tongoa in the Sheppard Islands.

In 1968 and 1972 Hedrick undertook excavations on the small Island of Malo. The early dates obtained from his excavated sites set the origin of human settlement to at least 3000 BP. He also described in detail the pieces of obsidian found at these sites which Wal Ambrose was able to successfully provenance to the obsidian sources of Talasea and Lou in Papua New Guinea (Ambrose 1976; Ambrose, Bird *et al.* 1981). Hedrick's PhD thesis was never finished and the artefacts themselves have subsequently gone missing. Also in 1972 Les Groube of the ANU chose the Island of Aneityum as an interesting target for a new expeditions, but unfortunately he could not detect any stone artefacts or ceramics in his 4 meter deep excavation in the Imkalau Valley. That year he also conducted fieldwork in the Banks Islands of northern Vanuatu. There he found several mounds of anthropogenic material on the small Islet of Pakea off the east coast of Vanua Lava which had potential for further research. This triggered the interest of

Graeme Ward who undertook fieldwork seasons in the following two years. In 1973 he visited most of the islands of the Banks group, and carried out several test excavations and surface surveys. In 1974 he returned to Pakea for an extensive excavation season. His PhD thesis presents the results of these excavations in detail (Ward 1979). Graeme Ward was also the person who found the obsidian source on Gaua and sampled eroded deposits of Vanua Lava material close to the source. These samples were examined by Ambrose and became the reference material for BI-obsidians until today.

Following Les Groube's footsteps on Aneityum, Matthew Spriggs started his fieldwork for a PhD in 1978. Several fieldwork seasons followed which concentrated on human impact on the ecosystem of the island. Later surveys and excavations in 1983 and surveys in 1988 concentrated on Erromango. In 1984 most social science and humanities research projects were suspended in Vanuatu, but in 1990 the VHCSS (Vanuatu Cultural and Historical Site Survey) was established under the leadership of David Roe and Jean-Christophe Galipaud (Bedford *et al.* 1999). Since the research ban was lifted in 1994 archaeological research on Vanuatu has been conducted by Matthew Spriggs, Stuart Bedford and Jean-Christophe Galipaud. In 1990 on one of the VCHSS surveys, Jean-Christophe Galipaud examined the area of the new airfield on Gaua where he found several pieces of ceramics and volcanic glasses. This was followed in 1995 by an extensive survey of the western part of Mota Lava where the topographic distributions of underlying reef deposits were researched (Jean-Christophe Galipaud, pers. comm.). Other than on these occasions, however, Galipaud focused mostly on the Islands of Santo, Malo and Torres, where he conducted several surveys and excavations (Galipaud 1998, 2000, 2002; Pineda & Galipaud 1998). Since 2000, Galipaud has concentrated on the survey and excavation of Lapita sites on the island of Aore and the adjacent smaller island of Tutuba (Galipaud & Swete-Kelly 2007b; Galipaud & Swete-Kelly 2007a).

Since 1994, the ANU under the auspices of Matthew Spriggs, who was later joined by Stuart Bedford, got heavily involved in archaeological research on several islands of Vanuatu. Matthew Spriggs conducted surveys and excavations on Erromango (Spriggs 1999) and Aneityum. Meredith Wilson concentrated on Vanuatu Rock-art in her PhD thesis (Wilson 1999, 2002). Stuart Bedford's PhD research, beginning in 1995, focussed on several sites in northern Malakula, on Erromango (Bedford 1999) and Efate (Bedford

2000a). Later research by Bedford included the mainland of Malakula and small islands off the east coast of Malakula (Bedford 2003, 2006a, 2007). Bedford and Spriggs together jointly conducted surveys and excavations on several islands including North Efate (Bedford & Spriggs 2000; Spriggs & Bedford 2001), North Santo, Epi, Northeast Malakula, Ambae and Mota Lava (Bedford & Spriggs 2008). However, a major focus of their research after 2004 has been the burial site of Teouma in southern Efate (Bedford *et al.* 2004; Bedford & Spriggs 2007, 2008; Bedford *et al.* 2006; 2007; 2009).

Previous identification of Banks Island obsidians in- and outside of Vanuatu

The regional distribution of artefacts made from Banks Island obsidian is considerable. Previous research has suggested that Banks Island obsidian can be found in such locations as Fiji in the east, the Southeast Solomon Islands in the north and northern Central Vanuatu in the south. While the geographical distances of this apparent transport are substantial, the number of sites and artefacts is limited. Artefacts made from BI-obsidian have only been reported from five locations outside of Vanuatu in the Pacific (Tikopia, Taumako and Reef / Santa Cruz Islands in the Southeast Solomons and on Lakeba in eastern Fiji). In the following section the archaeological context of these earlier findings are discussed in detail.

Vanuatu

Pakea, Banks Islands

After Les Groube found obsidian artefacts in test excavations in 1972 (Bedford 2006b), Graeme Ward decided to conduct his fieldwork in the Banks islands (Ward 1979). In 1973/74 he spent two field seasons surveying all 13 islands of the Banks Islands Group and conducted a major excavation at the site of Pakea of the South-east coast of Vanua Lava. The excavated stratigraphy appears to represent episodic habitation of the island from the early third millennium BP until about 1000 BP, although the dates for the upper levels are not perfectly clear (Ward 1979:6-9). During his excavations of different midden deposits Ward (1979:6-13) separated seven levels which were later summarised into five layers. The initial occupation sometime between 3100 BP and 2400 BP is separated from the later deposits by a sterile beach deposit (Ward 1979:Figure VI-6).

Reoccupation occurred in Level II between 2400 BP and 2000 BP and probably ends at around 1000 - 800 BP. There appears to have been a hiatus of habitation between Levels II and III as the dates do not overlap. Based on this gap in the radiocarbon dates and the difference in the appearance and structure of the sediment, Ward (1979:6-11) assumes a hiatus in the occupation of about 500-600 years, after which continuous habitation of the site was re-established until the final abandonment of the site sometime after 1000 AD. However, considering the small number of radiocarbon dates available, a continuous occupation during this period might equally be possible.

Ward recovered 851 pieces of volcanic glass from his excavation, and selected a small sample for geochemical analysis using x-ray fluorescence analysis (XRF) (Smith *et al.* 1977). From this analysis Ward concluded that (a) the two obsidian sources were 'Circum-Oceanic' (Smith 1974; Smith *et al.* 1977), (b) the two sources were readily distinguishable from other Pacific sources, and (c) they differ significantly from each other. Included in this sample were two artefacts found from a surface collection in south-eastern Vanua Lava and from an early test excavation on Pakea conducted by Les Groube. These two samples (WA252 and WA253) both showed significant lower Rb values from the remaining artefacts and led to the hypothesis that more than the two new-found obsidian sources existed in the Banks Islands (Smith *et al.* 1977:195). Of the 851 excavated artefacts found in Pakea only 21 did not show the vesicular inclusions typical of the Vanua Lava source and can be most likely be provenanced to the Gaua source. Interestingly, the Gaua pieces are concentrated in the later layers of Levels IV to VI, with only two found in Level III and one in Level II.

Ward (1979:8-16, 17) detected only low proportions of utilisable material in the worked obsidian assemblage. He categorised lithic artefacts into three classes: cores, flakes and pieces (which he described as usually very small, broken flakes or cores and therefore perhaps unsuccessful production debitage). The flakes were usually less than 40mm long and showed no marked repetition of form and no deliberate retouch. A large number of artefacts, however, showed edge damage with concave, blunt edges. No microscopic use-wear analysis was conducted, but he assumed from the shape of the edges that a use in woodworking was likely.

The distribution of artefacts throughout the sequence shows a clear pattern (Ward 1979:8-17-19, Table VIII-4, 5 and 6). During initial occupation in Level I no pieces were found. This changes in Level II where 109 artefacts (76 flakes, 3 cores and 30 pieces) were detected. Small concentrations of artefacts were discovered in this level in contrast to the later levels where the distribution of artefacts was less patterned. Extrapolated to a cubic metre of excavated sediment, 27.5 artefacts per m^3 were found in this level with a weight of 40.7g/m^3 (and an average weight of 1.48g, considering all artefacts). In Level III 63 artefacts (32 flakes and 31 pieces) were found. No cores were recovered. The number of artefacts drops to 9.8 artefacts/m^3, weight of artefacts to 10.8g/m^3, while average weight remains relatively constant at 1.48g. The majority of the lithic assemblage was found in the late occupational layers of Level IV-VII. In total, 685 flaked artefacts (495 flakes, 178 pieces and 6 cores) were found. This is a steep increase from the previous occupation level to 33.9 artefacts/m^3, with a weight of 57.2g/m^3 and an average weight of 1.69g. In a more detailed separation of the later levels it became clear that this increase is even more marked in the latest deposits as the numbers of artefacts found in Level IV increased from 9 artefacts/m^3, with an average weight of 1.5g, to 55 artefacts/m^3 with an average weight of 1.8g, in Level VII. Ward interprets this sequence as a change of utilisation over time. Although the sources and properties of the material were similar from the initial colonisation onwards and there were no large differences in mean weight over time, the ratio of flakes to pieces changed considerably. Whether these changes occurred due to "lack of skill" and "re-learning of skill" or derived from changes in resource control could not be assessed at the time (Ward 1979:8-18).

Malo, Santo

In 1972, Hedrick (1980) excavated several sites on the island of Malo off the south coast of Santo. Before his research, no obsidian was known from the islands south of the Banks Islands. At the sites of Naone (NHMa-8) and Batuni'urunga (NHMa-101), both most likely associated with the earliest Lapita occupation (see Bedford 2006b for a discussion), he reported surface findings of flake tools and cores, although most of the artefacts were recovered during excavation from early contexts containing Lapita pottery. He also mentions that obsidian occurs only in very small numbers in archaeological sites on Malo (1980:n.d.). However, he could distinguish three different types of obsidian which we now know relate to the Bismarck Archipelago and both Banks Islands sources. The majority of the flakes were geochemically analysed by Ambrose using NAA (1976:365-366) and sourced to the obsidian outcrops of Talasea in Papua New Guinea (‘Kutau/Bao’ in context of this thesis), but he also detected one sample from the Lou source in the Admiralty Islands. This piece remains the only artefact sourced to this obsidian locality in Vanuatu until today.

In Naone 103 flakes and 99 cores made from chert, jasper and quartz were found. In Batuni’urunga Location B 85 flakes and Batuni’urunga Location C, >65 flakes and >1 core (as no detailed number of flakes or cores were described for Level II). In summary, Hedrick could not detect any formalised stone tool production technique; instead suitable nodules were obtained and artefacts were struck from cores with small hammerstones producing flakes of not standardised size and shape and discarded when the working edge became dull. The large number of cores found on Naone suggests that there was a regular import of cores or that these cores were easily acquired as no rock source has been found on Malo itself. The pattern of edge damage on artefacts made from these raw materials is highly ambiguous. Only two artefacts in Naone show edge damage (~2%) in contrast to 57 artefacts in Batuni’urunga Location B (67%). Evidence of deliberate retouch of flakes was not also not be detected, although one artefact found in Batuni’urunga Location C, might carry secondary retouch.

In total, 25 obsidian flakes were described by Hedrick (8 flakes in Naone, 11 in Batuni’urunga Location B and 6 in Batuni’urunga Location C) with no formal shape and no retouch. Sizes were small, from 3.7mm to 30mm and they carried unusually large amounts of edge damage, which Hedrick interpreted as increased utilisation due to limited raw material availability. However, the damage could also be post-depositional as most of the sites showed high rates of disturbance. Hedrick also mentions the possibility of small core size dictating flake attributes, although one core found on Batuni’urunga (provenance of this core or its location on the site was not described in detail) had an overall length of 50mm.

Further research on Malo was conducted by Jean-Christophe Galipaud (2000). Two site locations, Avunatari and Atanoasao, were excavated. Only the site of Atanoasao proved to have undisturbed deposits dating from the initial colonisation onwards. The lowest layers contained Lapita pottery and were dated to c.2850 BP. An end date for this site is not given. The pottery found in the top layer "lacks the classic characteristics of ancient styles" (Galipaud 2000:48) and one radiocarbon date suggests a deposition of the material around 700 BP. A few obsidian artefacts in some of the excavated layers were submitted for geochemical analysis. Using EDXA Ambrose could source four pieces to the Vanua Lava obsidian source in the Banks Islands (Galipaud 2000:52).

Aore, Santo

Preliminary surveys by Jean-Christophe Galipaud in 2000 on the island of Aore, adjacent to Malo off the south coast of Santo, uncovered dentate-stamped Lapita pottery on several occasions close to the surface in ancient beach deposits (Galipaud & Swete-Kelly 2007b; Galipaud & Swete-Kelly 2007a). It was decided to excavate the site of Makue in 2002-2003 because of the comparably better preservation of the Lapita-aged layers. Galipaud and Swete-Kelly (2007a:157) suggested an initial habitation period at about 3200 BP with a second occupation phase at around 3000 BP and a possible third one at 3000 - 2900 BP. In total, 87 obsidian artefacts were excavated in the two field seasons and physically fingerprinted using density measurements (cf. Ambrose & Stevenson 2004). Two provenances were detected (Galipaud & Swete-Kelly 2007b). One group had a relative density in the range of the Banks Islands and Admiralty Islands sources (both sources showed a large overlap in relative density measurements, cf. Spriggs *et al.* in press; and Torrence and Victor 1995 for discussion of the applicability of this method), and the other group most likely originated from West New Britain sources. Although one piece from the Admiralty Islands was found on Malo, the rather large pieces clustered in the second group suggested a provenance in the Banks Islands. However, the assemblage was dominated by the West New Britain sources. Additionally, a preliminary technological analysis was also conducted. The methods used were consistent with Sheppard (1993) and general measurements of length, thickness and weight was given (Galipaud & Swete-Kelly 2007a:158). Mean maximum length of artefacts is 16.6mm (thickness 3.7mm, weight 0.9g) for the West New Britain artefacts, and 20.2mm (5.1mm, 1.8g) for the probable Banks Islands artefacts (Galipaud & Swete-Kelly 2007a:158, 159, Table 2).

Toga, Torres Islands

Between 1990 and 1994 and again in 1996-1998 Jean-Christophe Galipaud focused on the Torres Islands (1998). At the site *TI-Kurvot*, the lowest layers of which are dated to 2400 BP, he found an abundance of BI-obsidian flakes (Galipaud 1998:167). No detailed geochemical analysis of the material was conducted, but all material was examined for this thesis and a large sample submitted for detailed geochemical analysis (a more detailed description of the stratigraphy will follow in Chapter 4).

Reef / Santa Cruz Islands, South Solomons

Excavations at several Lapita-aged sites in the Reef / Santa Cruz (RSC) Islands the Southeast Solomons uncovered obsidian artefacts in three of the total of 13 sites between 1972 and 1977 (Green 1976, 1979). Excavations on Nendö (Ngangu, SZ-8) and the main Reef Islands (Nenumbo, RF-2, and Ngamanie, RF-6) produced a large assemblage of obsidian and chert artefacts (972 pieces, total weight 2232g) (Green 1987). The sites were redated several times, and the current agreement is that SZ-8 and RF-2 were inhabited at about 3100 - 2900 BP and that the occupation of RF-6 ended about 2700 BP (Green 1991c; Green *et al.* 2008; Sheppard & Walter 2006; Spriggs 1997). The excavated surface sizes of $51m^2$ in SZ-8, $153.5m^2$ in RF-2 and $20m^2$ in RF-6 and sampling procedures employed gave a good indication of the total inhabited area they represent (respective $459m^2$, $153.5m^2$ and $180m^2$) (Sheppard 1993; Sheppard & Green 1991). About 40-50cm depth of cultural deposits were excavated and several wooden structures were detected at these open sites. Green and Pawley (1999) linked the different structures with linguistic data to describe the settlement structure of the well-examined site of RF2, Nenumbo. The distribution of stone artefacts and pottery fragments displayed a striking similarity to the structures of recent dwellings (cf. Baegu fera, Oliver 1989): The highest concentration of obsidian artefacts was outside the main concentration of pottery and domestic features like hearths (Green & Pawley 1999). The concentration of pottery fragments is associated with the main building, putatively a **Rumaq*. North of this structure the concentration of stone artefacts could be associated with a putative 'Men's house', **KamaliR* (Green & Pawley 1999:65, Figure 1.9).

Sheppard (1993:134) calculated the average weight of obsidian per cubic metre in the deposits. He detected a sharp fall-off from $34.6g/m^3$ in SZ-8 to $17.36g/m^3$ in RF-2 and

6.12g/m^3 in RF-6, indicating a decrease of network interaction through time. Parallel to this decrease the amount of chert used in the sites decreased from ~23g/m^3 to 10.5g/m^3. The artefacts were analysed by density measurement and a random sample of 38 artefacts was selected for a detailed geochemical analysis using PIXE-PIGME (Green 1987). The analysis detected a strong focus on the import of Talasea (Kutau/Bao) obsidian. In total only 12 artefacts were sourced to Vanua Lava, 11 were sourced to the Lou obsidian sub-source on the Admiralty Islands and one piece sourced to West Fergusson (Green & Bird 1989). An intensive examination of the artefacts to detect other sub-sources of West New Britain obsidian was unsuccessful.

Sheppard (1993) did not separate different obsidian varieties from each other in his technological reanalysis of the material and his results are therefore discussed for all obsidian found. In his analysis of the Reef / Santa Cruz assemblage, Sheppard used the three artefact-type categories of cores, flakes and "chunks" or angular shatter, which is similar to other lithic analyses in the Pacific at that time (Allen & Bell 1988; Best 1984; Hedrick 1980; Kennedy 1981; Lawlor 1978; Lilley 1986; McCoy 1982; McCoy & Cleghorn 1988; Ward 1979). Focussing on core reduction strategies, Sheppard (1993:129) detected simple free-hand direct impact reduction with little core preparation or standardisation for both obsidian and chert. Bipolar reduction could not be unambiguously identified. Interestingly, 66% of all detected chert and obsidian cores (n = 35) were found in site RF-2, while the youngest site RF-6 contained only three cores. In general, obsidian cores were small at the point of discard (Length: 14.5mm – 17mm, 8.98g – 13.03g), although Sheppard (1993:130) states that 35% of cores were not fully exhausted. There is a steady decline in the size of chert cores detectable throughout the sequence.

Sheppard's analysis of the debitage identified that about 70-77% of the obsidian assemblage consisted of flakes compared to only 50% flakes in the chert assemblage. Whether this reflects a more careful reduction of obsidian cores than chert cores is unclear as the number of flakes with feather termination is lower in the obsidian assemblage (40%, compared to 60% for chert flakes). Overall, artefacts in the youngest site of RF-6 were always shorter (13.7mm (20.2mm for cherts) compared to 18.6mm – 19.6mm (22.2mm – 26.3mm for cherts) and lighter (1.06g (1.78g for cherts) compared to 1.86g – 2.39g (3.57g – 7.35g for cherts), although the sample size (n = 954 (479 for cherts) to n = 27 (32 for cherts) artefacts) has to be considered. Similar to other sites during the Lapita period the total amount of utilised artefacts was low (excluding 'gravers') (Kononenko 2008). However, no separate detailed use-wear analysis was conducted. It has to be noted that a large amount of so-called 'gravers' were found, which is the only formal tool known from Lapita period assemblages in Remote Oceania. Gravers have only been found made from obsidian sourced to Kutau/Bao in West New Britain. In total 133 artefacts of this type were identified, but only in the two earlier sites (Sheppard 1993:132, Table 7).

Sheppard (1993:134-135) interpreted the data as not supporting an optimisation strategy of raw material consumption. The size of artefacts does decline over time, and this could be understood as a fall-off of in network interaction as both obsidian and chert were imported into the sites (Sheppard 1996). Different raw materials might have been selected for different tasks, as seen in the larger number of points made from chert. The question of whether the patterns of transport and technology show trends of reduced risk minimisation in sedentary populations (Sheppard 1993:135) required more research and remained unanswered at that time.

Tikopia, Southeast Solomons

The largest assemblage of Northern Vanuatu obsidian outside of the Banks Islands Group has been found on Tikopia, a Polynesian outlier in the Reef Santa Cruz Islands. In 1977-78, Kirch and Yen (1982) excavated several sites and transects throughout the island and found an abundance of obsidian flakes from the Banks Islands. The archaeological excavations suggest three habitation phases. The initial colonisation phase (Kiki) was dated to around 2900 - 2100 BP and is associated with a very small amount of Lapita pottery. This phase was followed by a post-Lapita phase (Sinapupu) from 2100 - 750 BP associated with "Mangaasi" style ceramics (Kirch 1985), although this is an association that was recently challenged by Bedford (2006:182-183). Bedford describes, based on his research of the ceramic sequence of Central Vanuatu, the connections between Tikopia and Vanikoro and Vanuatu as "less than secure" (2006b:183), supported by the identification of only four obsidian artefacts from the Banks Islands sources in the Sinapupu phase (Kirch & Yen 1982:256, Table 35). However, geochemical research on pottery tempers (Dickinson 2001, 2006) ascertained similarities between Vanikoro, Tikopia and the Banks Islands. Dickinson concluded (2006:63) that ceramic wares of the Sinapupu phase could well have derived from both Vanikoro and the Banks Islands. The cultural sequence of Tikopia was completed by the most recent phase (Tuakamali), which dated from 750 BP until European contact (c. 200 BP), with all obsidian artefacts found sourced to the Banks Islands.

In total, 639 volcanic glass flakes were excavated from seven single sites and a transect consisting of ten sites, of which 595 were allocated to the three different cultural phases. Only 14 flakes were classified as obsidian and 625 as basaltic glass (Kirch & Yen 1982:256, Table 35). None of the 14 obsidian flakes were securely associated with the later two cultural phases. One piece associated with the Tuakamali phase was probably intrusive. Provenance studies were conducted using density measurements and additionally using thin sections. The thin sections of thirteen artefacts identified seven groups. Group III, a “white very clear glass (with) […] no large phenocrysts”, and VI, a “mottled dark- and light-brown glass with […] feldspars oriented […] around several large phenocrysts” (Kirch & Yen 1982:258), were tentatively interpreted as Talasea (Kutau/Bao) obsidian based on the additional density measurements, but the Kukuia source in the West-Fergusson islands could not be ruled out (Kirch & Yen 1982:260). The remaining groups, which consisted of a “relatively opaque and banded glass” (Kirch & Yen 1982:260), were associated with the BI-obsidian sources. These density measurements were recently revised by Spriggs et al. (in press) who could not find Kutau/Bao obsidian in the dataset; however three pieces were associated with the Lou source on the Admiralty Islands. An additional detailed geochemical analysis of the dataset using PIXE-PIGME supported this source allocation (Bird 1996; Spriggs *et al.* in press). The analysis of the PIXE-PIGME data was not unambiguous: two artefacts (TK4 No.1-5 associated with ANU3418 and ANU3419, and TK1 J5-72 associated with ANU3429 and ANU3430) were sourced to both Northern Vanuatu sources at the same time. All of these thirteen artefacts are re-examined in this thesis using LA-ICPMS and 38 additional artefacts have been submitted for PIXE-PIGME analysis. The results are presented in Chapter 5.

The remaining 232 artefacts were made of “fine-grained chert” and “chalcedony”, but showed a complicated petrographic variability and most likely originate from several sources. The fine-grained chert is creamy beige in colour and an origin from Ulawa was suggested (Kirch & Yen 1982:260; see also Sheppard 1996; Ward 1976). The group termed “chalcedony” showed frequent impurities and inclusions and a local source was assumed.

Kirch stressed the contact with the Banks Islands as especially defining for the cultural history of Tikopia (Kirch & Yen 1982:338-341). The myth of the origin of the Tafua line (Firth 1961) as well as a description by Codrington (1891) of the arrival of several canoes from Tikopia during his visit to the Banks Islands in the late 19th century support contacts between these islands from the initial colonisation of Tikopia onwards. Additionally, genetic studies show a high similarity of several markers between the Islands of Tikopia and the Banks Islands (Kirch 1985, correcting Blake 1983).

In his preliminary technological analysis of the Tikopia assemblage, McCoy (1982) used a behavioural theoretical framework to understand stone tool technology and reduction strategy. Comparable to Ward’s classification of three different artefact categories, McCoy separates cores, flakes and chipping-waste. Similar to Hedrick’s results, no formal tools were identified. Again no distinction was made between tools (although *pièces esquillées* were found, and preliminarily identified as tools) and debitage, although McCoy (1982:269) detected a “modicum of control and regularity” in reduction and suggested different functions of artefacts with parallel or ‘sub-parallel’ edges. However, no separate use-wear analysis was conducted to identify possible functions of these artefacts.

Concerning changes in raw material utilisation, McCoy states that both cores (n = 10) and flakes (n = 13) were considerably larger in the earliest Kiki phase (23.9mm (18.6mm for flakes) compared to 16.2mm (15.1mm for flakes) in the Tuakamali phase), although the much larger assemblage size of 194 cores and 372 flakes in the Tuakamali phase has to be considered. An assessment of reduction strategies during the Sinapupu phase is difficult as only two cores and one flake were found in deposits from this period. Bipolar reduction of cores was dominant throughout the sequence with diffuse bulbs prominent on 75% (25% crushed platform) of flakes in the Kiki phase and 87.5% (22.7% crushed platform) in the Tuakamali phase (although see Cotterell & Kamminga 1987; Sheppard 1993; Shott 1989 for a discussion of these attributes as applicable for the identification of bipolar reduction). The presence of cortex on only 30% of the cores

(11.1% of flakes) in the Kiki phase compared to 44.8% of cores (34.2% of flakes) with cortex in the Tuakamali phase was interpreted as deriving from an import of already decorticated cores into Tikopia in the earliest phase. This alternative was seen as more likely than a resource maximisation strategy in the Kiki phase (McCoy 1982:269; see also Allen & Bell 1988:94), based on the prevalence of bipolar reduction throughout the sequence.

The Tikopia assemblage is re-analysed in this thesis and now consists of 576 artefacts. Thirteen artefacts were destroyed for previous petrographic analysis using thin sections and the remaining 50 other artefacts were not included in the accessible Bishop Museum collection. These artefacts are classified as 'lost' for the purpose of this thesis.

Taumako, Southeast Solomons

In 1977/78 Leach and Davidson excavated several sites in the Taumako Islands group of the southeast Solomons (Leach & Davidson 2008). They only found obsidian artefacts on one island, Lakao, at the site of Te Ana Tavatava. In total, 84m^3 of archaeological material was excavated, but obsidian and pottery fragments were only found on the surface. The main part of the excavation consisted of several built-up layers of coral floors on top of the earlier occupation of the site. Potsherds found in *in situ* layers were deposited before the occupation of the village began and were dated to 2790 - 2540 BP. In addition, *Tridacna* shell breast pendants were found which were dated to the third millennium BP (Leach 1985:118). Two later wells that cut through the earlier archaeological deposits were assumed to be the probable source of the surface scatter. The preferred interpretation of this evidence is that the pottery was locally manufactured and the obsidian artefacts were exchanged at the same time (Leach 1985). The hypothesis of a local production of the excavated pottery was further supported by research on the temper, which did not detect similarities between Vanuatu volcanic rocks and the temper sands used in Taumako (Dickinson 2006:62).

As described before, the age of the six pieces is not clear as they were found on the surface of the site in connection with abundant, mainly plain-ware, sherds. Furthermore, the deposits seem to be mixed as sherds were also recovered with typical Lapita bowl forms (Leach 1985:118). The six artefacts were geochemically analysed using PIXE-PIGME and the data were interpreted using the 'Popper's Razor' method developed by

Leach and Manly (1982). The method takes into account unequal within-source variance and uses a modified Mahalanobis (D2) distance to calculate a sample's distance from the statistical centroid or group centre of an obsidian source. Artefacts 78.320, 78.322 and 78.323 scored highly on the comparison test with standardised distances to source centroids of <1.5σ (<1.1σ using Element ratios) to the Vanua Lava source (Leach 1985:121, Table 2). Artefact 78.319 scored 2σ and/or 2.5σ, but was still interpreted as belonging to the Vanua Lava sub-source. Two artefacts could not be unambiguously geochemically fingerprinted to a known obsidian source.

In addition to the six obsidian artefacts, 511 chert artefacts were found distributed through all excavated layers (Leach & Davidson 2008). The chert was described as being from silicified corals and a possible source on Lakao Island was assumed (Leach & Davidson 2008:119). In their assessment of the time frame of utilisation of chert raw material, they suggested a continuous use of chert artefacts from the initial occupation onwards. They also detected a “sizeable” amount of worked artefacts which were classified based on use-wear studies in: ‘knives’ and ‘saws’, ‘hammerstones’, ‘notch scrapers’/’spokeshaves’, uni-directional ‘edge scrapers’, ‘nose scrapers’ and ‘awls’ (Leach & Davidson 2008:119-122).

Lakeba, Fiji

The Lakeba obsidian collection consists of 20 flakes (Table 1), with 17 flakes derived from two rock shelter sites (Laselase site 2(b) and Qaranipuqa site 197) and three flakes from two open sites nearby (Ulunikoro site 47 and Wakea site 196). Nineteen of the flakes were originally analysed with PIXE-PIGME for eighteen elements at the ANSTO facility in Lucas Heights, Sydney. Sixteen artefact element/element ratios were then compared to element/element ratios from 66 obsidian sources in Indonesia, Australia and the Pacific (Best 1984:433-434) using the 'Popper’s Razor' multivariate discrimination method (Leach & Manly 1982).

Seven obsidian flakes were excavated from the Qaranipuqa rock shelter (Site 197), with three flakes from the deepest layers (Layer T, R-O) sourced to Tafahi in northern Tonga (Best 1987). A radiocarbon date on charcoal from Layer T returned an age of 2870-2330 cal. BP (NZ4596, 2540 ± 127 BP) indicating movement between Tonga and east Fiji during the early settlement phase. The remaining four obsidian flakes from Layer

F1 were sourced to northern Vanuatu. Layer F1 was not radiocarbon dated, but Layer F3 about 20 cm below F1, was ^{14}C dated to 1920-1420 cal. BP (NZ4592, 1770 ± 90 BP), while Layer E2 above F1 was dated to 920-700 cal. BP (NZ4905, 892 ± 63 BP). Ten obsidian flakes were excavated from the Laselase rock shelter (Site 2b), with most located in Layer H and Layer J1. All of the flakes were sourced to northern Vanuatu (Table 6.7, Best 1984:434). Layer J1 was dated by a marine shell determination to 850-660 cal. BP (NZ5182, 1200 ± 40 BP). Three obsidian flakes from upper levels of the Ulunikoro fortification (Site 47) and the Wakea coastal flat (Site 196) could not be unambiguously attributed to a source (Best 1984:434).

The three obsidian flakes from the lower layers of the Qaranipuqa site (c. 2500 BP) sourced to Tonga were a "glossy black vesiculated glass, one with faint layering, and none showing cortex" (Best 1984:434). The obsidian from the middle and upper layers of Qaranipuqa and Laselase sourced to Vanuatu was different, with 13 of 14 flakes described as "a dense grey black lustrous glass, eight of these show a flat rough textured striated cortex" (Best 1984:433). The remaining three flakes of analysed obsidian from Ulunikoro and Wakea that could not be attributed to a source with PIXE-PIGME were similar in hand specimen to the early obsidian from Qaranipuqa that was sourced to Tonga (Best 1984:433).

To summarise, the elemental comparison of the Lakeba obsidian collection identified three groups. The first group, dated to c. 2500 years ago, came from northern Tonga. The second group of obsidian flakes, dated to c. 1700 years ago, was identified as coming from northern Vanuatu. The third group of three flakes could not be attributed to a source. On the basis of the PIXE-PIGME obsidian results, Best (Best 2002:31) outlined a Vanuatu-Fiji connection at around 1700 BP (these dates were challenged by Clark 1999 who suggested a later date of approximately 1200 BP). The archaeological distribution of Vanuatu obsidian was confined mainly to the north of that archipelago, suggesting contact between people from northern Vanuatu and Fiji. Further, Best identified ceramic traits in Fiji that had parallels with ceramic designs in Vanuatu, suggesting that Fijian pottery had been influenced by post-colonisation contact with Vanuatu. For this thesis 18 of the found 20 artefacts were re-analysed using LA-ICPMS, and the results are presented in Chapter 5.

The spatial distribution of Banks Island obsidian

Summarising the state of research, Banks Islands obsidian was found in a widespread area of west Remote Oceania. Starting from the initial colonisation onwards, this material was transported through the Vanuatu Archipelago and reached the southern Islands off Santo. However, no obsidian had been found in Vanuatu before the current project south of Malo and Aore. Although Lapita-aged sites had not been found in the Banks Islands themselves (until 2007, see Chapter 5), the occurrence of BI-obsidian in Lapita deposits elsewhere proves that these obsidian deposits were known from the beginning of settlement.

No BI-obsidian was found in Lapita-aged deposits in Fiji, Tonga or Samoa. However, the detection of BI-obsidian in later deposits on Lakeba Island in eastern Fiji suggested a probable extension of communication and exchange across the large sea-gap in the post-Lapita period (Best 1984, 1987, 2002; Burley 2005; Cochrane 2008). Whether this hypothesis can be supported by further, more detailed obsidian sourcing will be scrutinised in this thesis.

The spatial distribution to the north of the Banks Islands Group is better established. BI-obsidian was found on several islands in the Southeast Solomons during the Lapita and post-Lapita phases. The intensification of obsidian transportation into Tikopia during the latest Tuakamali phase suggests a shift in interaction networks and has been interpreted as the expression of a regional communication sphere (Bedford & Spriggs 2008; Sheppard & Walter 2006), established during Lapita times and which intensified in the latest period after 1000 BP until contact with European explorers.

Thesis structure and chapter outline

Chapter 2 discusses previous models for the colonisation of the Pacific as well as models for social interaction and the evolution of cultural diversity in the post-Lapita period, particularly in Remote Oceania. In the second part of the chapter, specific models for exchange systems of obsidian in the Lapita period and their evolution in the post-Lapita period are addressed.

Chapter 3 gives the geological and environmental background of the research area and discusses recent palaeo-climatic data, focussing on ENSO variability and attendant unpredictability of subsistence resources during different periods in the past.

Chapter 4 presents the general archaeological context of the lithic assemblages excavated during the 2006 field season. Already published archaeological background for the remaining lithic collections analysed in this work, and not excavated by the author, are presented.

Chapter 5 examines the detailed geochemical data collected, focussing on the clarification of various questions raised in the past about the number of obsidian sources in the Banks Islands, their internal geochemical variation and the distribution of BI-obsidian. Detailed research aims are identified as (a) whether there are more than the previous two obsidian sources utilised in Vanuatu, (b) the provenance of the remaining obsidian artefacts found in the sites, and (c) how the spatial distribution of artefacts throughout the research area was organised. Questions about the comparability of different analytical methods utilised in the past for geochemical fingerprinting are also addressed.

Chapter 6 discusses the results of the technological analysis of the lithic assemblages, focussing on the description of the most likely extraction process used for the exploitation of the Northern Vanuatu sources. In addition, following from a more general analysis of the pattern of spatial and temporal distribution of BI-obsidian, these patterns are examined in relation to raw material dependency.

Chapter 7 discusses the theoretical framework in which research questions and data analyses in the previous chapters can be placed. The focus is on the theoretical discussion of the value of obsidian raw material. Different approaches and previous attempts at explaining the evolution of exchange systems are discussed with specific reference to their underlying theoretical assumptions. Alternative approaches to the economic definition of value are presented, focussing on the consideration of environmental variability in shaping contact networks for the reduction of risk in an unpredictable environment.

Chapter 8 discusses the models introduced in Chapter 2 and 3, and identifies which of these models might be most viable in explaining the pattern of temporal and spatial distribution of BI-obsidian encountered in the archaeological record.

In the concluding Chapter 9 the different arguments for changing interaction patterns in southwest Remote Oceania evident in the geochemistry of artefacts and sources, in the spatial distribution of BI-Obsidian artefacts, in the processes of transportation and in the resulting assessment of obsidian in southwest Remote Oceania are summarised. The chapter concludes with some suggestion for future directions in lithics research in Remote Oceania.

- Chapter 2 -

2. Understanding cultural diversification in the Pacific: current models and hypotheses

Introduction

This chapter presents the research background in which the thesis operates. A number of models have been proposed previously to explain changes in the scale and nature of social interaction in the western Pacific region. On the one hand these models attempt to explain the origin of the evolution of what we call today the 'Lapita Cultural Complex' and on the other hand the cultural diversification seen in Near Oceania and southwest Remote Oceania in the post-Lapita phase. These models are largely contradictory and disputed, but they help to define a theoretical framework for the analysis of social interaction in general and more specifically the analysis of exchange throughout history in Near and Remote Oceania.

Following from general ideas of cultural evolution, the chapter discusses more specific models concerning the evolution of exchange systems, and here especially long-distance exchange of certain types of obsidian. As obsidian and its distribution is the main focus of this work, different models, which explicitly try to explain changes in raw material distribution will be discussed separately. Both parts of this chapter, (a) models for social interaction and (b) exchange systems, are chronologically subdivided into the Lapita and the post-Lapita period, because it is generally agreed upon, with a few exceptions (for a summary, cf. Terrell *et al.* 1997), that the processes of social interaction in the Lapita period and the post-Lapita period in Remote Oceania (and in Near Oceania) followed separate trajectories.

Colonisation and social interaction

The Lapita period or 'Boats from the West?'

The problem of equifinality in distinguishing social interaction through migration of people or the diffusion of ideas – especially in the spread of new agricultural systems – is a recurring event in archaeological research worldwide (Anthony 1990). In the case of Pacific studies the oversimplification on both ends of the spectrum of possible models, pure migration ('Express Train to Polynesia', ETP) or pure indigenous invention ('Bismarck Archipelago Indigenous Invention', BAII), was helpful in the past to make sense of the very complex situation of human interaction archaeologists encountered during the beginning of archaeological, linguistic and biological research in the Western Pacific. A fast migration of one people starting from Taiwan into the central part of Remote Oceania gave an implicit reason for the initial colonisation of Remote Oceania (Smith 1995:375). From the perspective of Remote Oceania, the BAII model explains cultural evolution in Near Oceania, but has little explanatory power in itself for the rapid migration of people into Remote Oceania. Why are people suddenly colonising the vast areas of Remote Oceania, if the Lapita Cultural Complex was not a sudden invention but developed over a long period of time out of a close communication network that connected the different communities in Near Oceania? In addition, Irwin noted (1992:43) that a substantial advance in voyaging skills was necessary to colonise Remote Oceania, but there is no clear indication of a sudden invention of this technology or that this technology was not known in pre-Lapita times (Anderson 2003).

The shortcomings of these models gave rise to another set of models which focus on the interconnection of communities and the flow of information and people. Rather than seeing the advent of the Lapita Cultural Complex as one migration of people which swept over Southeast Asia into the Pacific, the alternative of a continuous migration which is halted by several steps of pulse and pause, fuelled by favourable environmental conditions, and resulting in a widespread mixing of peoples and ideas, is currently seen as the most plausible explanation for the archaeological record we encounter. Both the 'Voyaging corridor – Triple I' (VCIII) models and the 'Mobile Founding Migration' (MFM) models therefore try to combine the evidence supporting the ETP and BAII models. In the following each of these four models for the Lapita dispersal is described in detail, following the naming and structure of Green's (2003) survey (cf. Table 2.1).

Express Train to Polynesia (ETP) or Fast Train

The 'Express Train to Polynesia' model (ETP) was one of the first developed to explain Austronesian expansion into the Pacific and the rise of Lapita in Near Oceania (Bellwood 1978, 1985; Green 1979; Shutler Jr. & Marck 1975). This model describes this expansion as a fast succession of migrations (most probably of the same people), starting from Taiwan through Island Southeast Asia and into Near and Remote Oceania (Bellwood 1978:244). In contrast with the Voyaging corridor –Triple I (VCIII) model (described below) these migrations did not include extensive mixing of populations and culture traits on the way (Diamond 1988), but these people carried their already established material-culture repertoire, the 'Lapita Culture Complex' (Summerhayes 2001:25), out of Southeast Asia into Remote Oceania (Spriggs 2000:51). Support for this model comes mostly from earlier studies of molecular biologists (Lum & Cann 1998, 2000; Lum *et al.* 1994; Redd *et al.* 1995; Richards *et al.* 1998; Sykes *et al.* 1995). Similarly, linguists (Greenhill & Gray 2005:51) still see some signals reflecting the sequence of movements predicted by the 'Express Train' in their data (but see Gray *et al.* 2009, for a contrasting view). Archaeologists Bellwood and Dizon (2008:23) see the model as still applicable to the spread of Lapita into west and central Remote Oceania, although not valid for the process of Neolithisation in Island Southeast Asia.

Bismarck Archipelago Indigenous Inhabitants (BAII)

The Bismarck Archipelago Indigenous Inhabitants model (BAII) summarises different approaches to an indigenous evolution of the Lapita culture complex in the Bismarck Archipelago. Proponents of this model focus on the long history of human occupation in Near Oceania and see the influx of new people, language and technology. The model, first outlined at the onset of the Lapita Homeland Project (see also White & Allen 1980), was created in response to the Migration model favoured at that time by Shutler and Marck (1975), Bellwood (1978) and Green (1979). According to Green (2003) the Bismarck Archipelago Indigenous Inhabitants (BAII) model stresses long-term continuity, encompassing a series of shorter-term incremental changes, and rules out any "need to believe in migrations at all" (White *et al.* 1988:416).

In the last three decades a wide variety of archaeological research has found several indications of continuities between the pre-Lapita and the Lapita period. For example Gosden (1992) claimed that by 3500 BP all the major domestic plants and animals were already introduced (Gosden 1992:57). He describes the area from island Southeast Asia through to the Solomons as a 'melting pot' of developed forms of subsistence, trade and social groupings from the late Pleistocene to the late Holocene (Gosden 1992:61) and explicitly stresses that these developments derive not from a migration of people, but from a series of long-term complex social and subsistence changes (Gosden 1992:57; see also Gosden & Pavlides 1994).

Much progress has been made in the detailed research of obsidian sourcing and distribution in the Bismarck Archipelago (Fredericksen 1997; Summerhayes 2009; Torrence 1992, 2004; Torrence *et al.* 1996; White 1996b; White & Harris 1997). This research indicates that obsidian exchange networks connected most of the islands of New Ireland, Admiralties and the Bismarck Archipelago and into the northern Solomon Islands from the late Pleistocene onwards. These networks were not static over time but evolved dynamically in an ever-changing reorientation of human interaction. Recently, Torrence and Swadling (2008) have argued that social networks established in the mid-Holocene by exchanging stone mortar pestles (Swadling 2004) and obsidian stemmed tools (Araho *et al.* 2002) may have helped to fuel the distribution of Lapita innovation throughout Near Oceania. At the time Lapita appeared, mid-Holocene networks were probably undergoing fluctuations due to major changes in the landscape triggered by factors such as volcanic eruptions (WK-2, for a detailed discussion, see below). As a consequence, already established social networks at this time may have facilitated innovations from outside the region (Torrence & Swadling 2008:613).

Summarising, White (1999:13) stated, that rather than a migration of people only the ideas and innovations were introduced. These innovations were restructuring an already existing culture, introducing technology - like new arboriculture, root crops (see also Kennedy 2008; Yen 1995), shell working, stilt villages - seen on voyaging from the general area of West New Britain into the west (cf. Kennedy 1983:120), and not replacing it.

Voyaging Corridor - Triple I (VCIII)

In 2003 Green combined the idea of the 'voyaging corridor' with his model of Lapita evolution/dispersal through the process of Intrusion, Integration and Innovation (Triple I model, cf. Green 1991a; Allen & Gosden 1996; Spriggs 1996), in the 'Voyaging-Corridor – Triple I' model (VCIII). It emphasises the 'complex synergy' of regular interactions between Oceanic Austronesian-speaking migrants and diverse groups of indigenous populations (Green 2003:103; see also, Allen & Gosden 1996:193). In the VCIII model *Intrusion* stands for those elements which constitute new additions from outside, *Integration* for cultural elements in the Lapita Cultural Complex which could have been derived from those components already present and *Innovations* for elements which are first evident in Lapita itself (cf. Terrell & Welsch 1997:554).

Spriggs (1997:88-90) and Kirch (1997), proposed several cultural elements which were introduced into Near Oceania. These elements include (a) pottery; (b) the “Lapita stone adze kit”; (c) a range of distinctive shell ornaments; (d) the extent of obsidian exchange; (e) full-on agriculture; (f) animal husbandry; and (g) Lapita as the founding culture in Remote Oceania. There is now a wide range of evidence, especially from linguistic (Gray *et al.* 2009; Pawley 2007; also Spriggs 1996:339) and genetic research supporting this case (Cox 2005; Friedlaender *et al.* 2007; Friedlaender *et al.* 2008; Lum & Cann 2000; Lum *et al.* 2002; Matisoo-Smith & Robins 2004; Merriwether *et al.* 2005; Larson *et al.* 2007).

However, recent research suggests, that most of the root crops were already established by the advent of the Lapita cultural complex. In a series of recent publications Denham et al. (Denham 2006; Denham & Haberle 2008; Denham *et al.* 2004; Denham *et al.* 2003) argued for an independent invention of domesticated crops (especially taro and banana) and agricultural techniques in the early- and mid-Holocene in the Highlands of PNG. They concluded that the concept of an introduction of a complete neolithic culture package with the spread of Lapita is misleading and should be abandoned (Denham 2006:180). Similar, Green (2000) noted several aspects of the material culture which had predecessors in the Bismarck Archipelago and therefore are integrated elements of pre-Lapita contexts, for example shell tools occurred in several sites from the early Holocene onwards. Lithic technology and especially obsidian exchange are additional, important evidence for a long continuity in Near Oceania. In obsidian exchange we see best the important factor of 'time-depth' needed in the interpretation of the 'integration' element (Lape 2003:106; Spriggs 1996:343-344).

Summerhayes (2001:26) categorised this model together with the BAII model, in a group which focuses on the development of the Lapita Culture Complex in the Bismarck Archipelago before colonising groups left the area for Remote Oceania. However, this model does not, strictly speaking, emphasise the indigenous adaptation of the Lapita Culture Complex in Near Oceania, but rather the input of new ideas from migrant communities (Bellwood 1997:219-236; Spriggs 2003a:65). Therefore, the classification here follows Greenhill and Gray (2005) who summarise this model as the process of ‘Pulse and Pause’ (Moore 2001), where one pulse of migration occurred from Taiwan to the Philippines (for a discussion of the earliest ceramic dates of northern Luzon, see Tsang 2007), and was followed by a several hundred year long pause. The next pulse, which saw a spread into Near Oceania, coincides with the development of the Lapita culture. The third pulse of colonisation occurred in marginal Western Polynesia, and was followed by the final two pulses around 1,000 and 800 years ago in East and South Polynesia (Anderson 2001, 2003; also Green 2003:99, Table 2).

Mobile Founding Migrant (MFM)

The final set of models explicitly attempts to explain colonisation of Remote Oceania is based on a detailed analysis of mobility (Figure 2.1). This includes the so-called Mobile Founding Migrant (MFM) models, now mainly associated with recent publications of Atholl Anderson (2000; 2001; 2003). Although separated in this chapter much similarity can be recognised between the ‘pulse and pause’ oscillating migration model (VCIII) and the assumption of a dual system of stable phases which are relatively sedentary and following unstable phases of high mobility in the MFM model (Anderson 2001:18).

Contrary to the now “neo-traditional perspective” (Anderson 2003:173) that return voyages between newly colonised islands were common (Irwin 1992), Anderson proposed the hypothesis that seafaring people of the Pacific used simple maritime technology. Return voyages from once-colonised islands was therefore uncommon, and interaction between islands strongly limited. The MFM model is based on the hypothesis that cyclic phases of sedentariness and high mobility are driven by the continuous growth of populations together with limited resource (food) supply (Anderson 2001:21, Figure 4; adapted by Green 2003:98, Figure 2). The underlying assumptions are based on Optimal Foraging Theory (OFT) (see next chapter, and Kennett *et al.* 2006; Winterhalder 2002). The model (Figure 2.2) assumes that population growth cycles through four different stages, from slow to exponential growth until carrying capacity of an area and population density form an equilibrium (which is asymptotically unstable). Thereafter population growth slows down until the limits of resource availability are reached; the underlying equation therefore forms an S-Shaped curve (Keegan 1995:403, Figure 2). In the context of human dispersal this model suggests that the first point of equilibrium (the point where the curve changes from monotonically increasing to monotonically decreasing) reflects a target population (Keegan 1995:405, Figure 3). Human dispersal at this point would be directed toward optimising access to critical resources (Keegan 1995:406). At the second point of equilibrium, when the carrying capacity of an area would have been reached, human dispersal would look like a 'wave of advance' (cf. Ford 2003; Renfrew 2002).

Anderson could detect an acceleration in the eastward expansion of colonisation in the archaeological data with a simultaneously weakening of the colonising impulse (Figure 2.1), noticeable in the shorter span of Lapita settlement in west and central Remote Oceania (Anderson 2001:17-18, Figure 1; modified in Green 2003:96, Figure 1). Based on this model "initial social and ecological conditions were, […] quite different to those encountered when the Lapita migration moved into its later, highly mobile, phase in Remote Oceania" (Anderson 2001:19). The rapid movement of people into Remote Oceania would display an unstable cycle, whereas the migration into Near Oceania would occur in a stable cycle and could be explained by the 'wave of advance' model. However, whether these processes were driven by a "higher rate of natural increase in population, faster fragmentation or a different pattern of settlement mobility" is entirely unclear (Anderson 2001:19).

The post-Lapita period or 'No more boats from the West?'

The discussion of models for the understanding of cultural evolution after initial colonisation in the Lapita period is not only a temporal, but also a geographical one. South-East Asia and Near Oceania (Sand *et al.* 2007) were foci for the evaluation of phylogenetic or reticulate models for the evolution of the Lapita complex (Bellwood 1996; Spriggs 2008a). In this later period theoretical modelling, therefore, also changes from the explanation of colonisation to the explanation of cultural diversification once these islands were inhabited. Interestingly, the theoretical approaches explaining social interaction in this period follow the same trajectories as in the Lapita phase. They continue to be phylogenetic or reticulate-based: cultural evolution in post-Lapita times is seen as either continuous or discontinuous, based on secondary migration, interaction networks or isolation (Spriggs 1992; 1997:152-161).

In the following section these different approaches are discussed. It has to be stressed that although these models are presented separately they are not mutually exclusive (Spriggs 1997:152-153). As some of these models describe different processes resulting in culture change, several processes could be active during particular times in the past. To illustrate these points, with the focus on southwest Remote Oceania, three different models are presented: (a) adaptation through continuous interaction; (b) adaptation in a reduced interaction network; and (c) through a second migration.

Local adaptation in continuous interaction through exchange networks / systems

Terrell et al. (1997; 2001) argue for a widespread interaction network in Lapita times throughout the whole area of Lapita dispersal, mainly as a critique on the 1950's concept of Pacific Islands as isolated. They see Lapita commodity exchange, clearly recognisable by the two most pronounced transportable items, pottery and obsidian, as a trade good exchange system of populations sharing the same inheritances (Clark & Terrell 1978). Extended to the post-Lapita period they follow Harding (1994) in their argument, who generally saw the social process of 'trade' or 'exchange' as a prominent characteristic of pre-contact Melanesia. The cultural diversification we can see in this region today would therefore have developed through continuous interaction between connected communities (Terrell *et al.* 1997:168). Isolation is seen as being actively avoided by communities for social and survival reasons (Terrell *et al.* 1997:175). Allen (1985:51, discussed in detail below) proposed the same hypothesis in his model of a cyclic trade system (Figure 2.3), when he suggested that the post-Lapita period is characterised by "periods of trading intensity initially escalating, then becoming unstable and eventually breaking down. In the long term there is overall growth in the complexity of systems, complemented by a reduction in their geographical extent" (cited in Spriggs 1997:154).

It was in the context of a continuous widespread long-distance commodity exchange network that the concept of long-term development of the 'Incised and Applied Relief Tradition' (IAR) as a direct successor of the Lapita Cultural complex was established (Golson 1972; Kirch & Yen 1982; Spriggs 1984a, 1997; and for a more recent revival Garling 2003; 2007). In his research on ceramic assemblages in the Lapita/post-Lapita transition period, Wahome recognised a decline in the number and style of pottery motifs, but also continuity in the decoration of pottery in Near and Remote Oceania in the immediately post-Lapita phase (Wahome 1997:118; 1999).

The social-political aspect of exchange systems was discussed by Friedman (1981) and Kirch (1988) and will be discussed in more detail in the 'lithics' section of this chapter. Instead of seeing Lapita commodity exchange as a 'trade' system they suggested a prestige good system, which over time developed into the various socio-political systems found in the Western Pacific today (Spriggs 1997:155). The competition for control over long-distance exchange reinforced a hierarchical structure. The contraction of exchange systems is associated with the breakdown of political hierarchies as the risk of long distance exchange of commodities outweighed the costs of maintaining these hierarchic structures in a context where there was a long-term increase in (short distance) trade-network intensity instead (Spriggs 1997:157).

Local adaptation through reduced interaction starting directly after initial human colonisation and intensified short distance interaction networks after 1000 BP

Contrary to Terrell's view of a continuous interaction network defining cultural diversification in the post-Lapita period in Remote Oceania, this set of models focuses on the local adaptation and evolution of cultural diversity through relative isolation (Anderson 2004) and a rapid disruption of long-distance exchange networks soon after initial colonisation of these islands (Bedford 2006b; Bedford & Spriggs 2008:106-107; Spriggs 2003b:207). Spriggs (1997:155) summarised this model based on Pawley (1981) as representing a local cultural and linguistic diversification with only minor external influence. Rather than a continuation of extensive interaction networks, populations focused on the intensification of settlement and agriculture. In this context exchange networks ceased because they were not necessary to sustain individual communities.

The concept of a Melanesia-wide Incised and Applied Relief tradition (IAR) was criticised for being "largely assumed" (Bedford 2000b; Bedford & Clark 2001:70; Bedford & Spriggs 2008:106) and based on small and very fragmented assemblages. More localised research in several areas throughout Near and Remote Oceania to assess detailed cultural sequences has identified increasing differences in vessel form and motif design in the ceramics of the post-Lapita period (Bedford 2006b; Sheppard &

Walter 2006; Bulmer 1999; Clark 1999; Sand *et al.* 2001). Similarities of pottery styles in regions with IAR are just "superficial" and most likely appeared due to shared inheritance from Lapita rather than continuing connections (Bedford & Clark 2001).

Bedford and Clark (2001:70) state their data show interaction ceased with the end of the Lapita period representing a cessation of migration due to social and environmental conditions. The unity of ceramic styles which were reflecting efforts to maintain geographically-based social institutions in the Lapita period, were superseded by "increasingly independent trajectories" soon after the initial Lapita settlement until 1000 BP. This ceramic diversification would therefore indicate a decrease in the importance of such institutions and their replacement with more localised traditions. The same conclusion was put forward by Bedford and Spriggs (2002:150) in their analysis of post-Lapita non-ceramic artefacts in Vanuatu.

In the time period post-1000 BP, however, interaction increased again, most likely in the whole Pacific region, evidenced for example through the increase of Vanuatu obsidian transportation, *Terebra* shell and lenticular stone adzes (Bedford & Clark 2001:71). Following from this argument they suggested that a "significant portion" of cultural diversity encountered at first European contact developed during this phase of increased contact.

Second migration from Near Oceania

In the context of the 'Express Train to Polynesia' model in which social interaction in the Pacific was explained through the migration of people rather than through indigenous invention or adaptation the changes in the cultural sequences of Remote Oceania would have been associated with the subsequent migration of people from Near Oceania (Shutler Jr. & Marck 1975; for more recent discussions, cf. Spriggs 1997:158-159, 2003:207, Burley 2005:339, Burley & Clark 2003:237, Cochrane 2008). The application of this model is particularly evident in the interpretation of the ceramic sequence of Fiji, where points of significant stylistic change are viewed as the result of migrations from Vanuatu to Fiji (Burley 2005:341-343; Cochrane 2008), primarily because of the identification of Vanuatu obsidian on Lakeba Island, east Fiji (Best 1984:431-434; 2002:31).

This hypothesis is grounded on the assumption of a sequence of widespread very similar pottery traditions, starting from Lapita until the IAR/Mangaasi ware (Golson 1968), and the identification of discontinuity of pottery styles after Lapita (White & Murray-Wallace 1996:43). Rejecting Terrell's 'trade scenarios' to explain the coexistence of Lapita and IAR ceramics at sites on Watom (see also Green 1982 for an early rejection of this approach), Anson (1999:101) states that migration scenarios involving the arrival of successive groups of peoples into Central Melanesia might need to be reconsidered.

More importantly, the postulated Vanuatu migration to Fiji in the post-Lapita period supports an intrusionist explanation for the greater amount of biological, cultural and linguistic variation seen in Western Pacific populations, which contrasts with the comparative homogeneity of Polynesian groups in the East Pacific (summarized in Clark 2003). Likewise, Spriggs (1997; 2003b; 2004) argues that the 'Melanesian phenotype' which several researchers identify in Vanuatu, New Caledonia and Fiji (in contrast with a more 'Polynesian phenotype' in east Remote Oceania) must originate from a significant post-Lapita migration from the main Solomon Islands or further north into Vanuatu, New Caledonia and Fiji. This migration links the general area of southwest Remote Oceania, including Fiji, with communities further west. Following from this assumption, similarities in post-Lapita pottery styles might originate in the continuous connection of distant groups (for a discussion of this interpretation of human genetics, cf. Clark 2003; Cox 2008).

The lithics perspectives

In the previous section general models for social interaction and cultural diversification in the western Pacific were presented. In this section it is discussed how different scholars linked the question of changing social interaction between communities in the Western Pacific with changes in the exchange of lithic artefacts, especially obsidian. Summerhayes (2009) recently summarised the extensive literature on obsidian exchange in the Western Pacific. Therefore, only a brief overview of current ideas and hypotheses is given here.

Transportation of obsidian raw material has a long history in the Western Pacific. According to Summerhayes (2009), earliest indications of the transportation of obsidian reaches back as far as into the Pleistocene around 20,000 years ago, when obsidian from

Gulu and Mopir on mainland West New Britain (WNB) was transported to different sites on New Ireland (Summerhayes & Allen 1993; but see, Torrence, Neall *et al.* 2004 for a discussion of Gulu and Baki transportation pre-20,000 years). The evidence for obsidian transportation increases at the end of the Pleistocene, when additional obsidian sources, as the Kutau/Bao source on WNB (Torrence 2004) and some Lou obsidian in the Admiralty Islands in the Pamwak rock shelter (Ambrose 1997), were found at a distance from the original obsidian outcrop. The spatial distribution pattern of obsidian in Near Oceania becomes more complex in the early- and mid-Holocene. Mopir continued to be dominant in archaeological sites outside of the West New Britain mainland. However, increasing Kutau/Bao obsidian is now present, especially at sites close to the source area (Torrence 2004:118, Figure 10.3). It has been suggested that early changes in the transportation of obsidian from different obsidian sources in the Willaumez Peninsula might be connected to the volcanic activity in the region, which influenced the accessibility of obsidian outcrops over time (Ambrose, Bird *et al.* 1981; Torrence 2004; Torrence, Neall *et al.* 2004; Torrence *et al.* 1996). In addition, Summerhayes recently proposed that transport of obsidian raw materials during these earlier phases of human habitation in New Guinea was connected to mobility patterns of small hunter-gatherer groups, and were not evidence for a wide-spread exchange system (Summerhayes 2009).

An important change in the distribution of obsidian and lithic technology occurred sometime prior to 6000 BP when for the first time 'stemmed tools' (Araho *et al.* 2002) appeared in Near Oceania. These tools were produced from different varieties of obsidian, Kutau/Bao, Mopir, Gulu and Baki. Use-wear and residue studies on these tools suggested multi-functional applications (Fullagar 1993; Torrence 2002), including ceremonial functions (Araho *et al.* 2002) and usage as portable cores in relation to hunter-gatherer mobility patterns (Torrence 1992, 2005). The multi-functional aspect of these tools is discussed by Araho et al. (2002) as especially important for an assessment of social interaction connected with their exchange. They warn against a one-sided interpretation of these artefacts solely as prestige goods of high ceremonial value and propose that the multi-functionality of the item suggests a similar multiple role in different spheres of economic and social interaction. During the 'life-history' of one artefact it could have passed from an utilitarian application close to the source, to a prestige good after it was exchanged with communities at greater distance from the source.

The emergence of Lapita, as has been described in the last section, is suggested as being connected with a series of substantial changes in Near Oceania. Elaborate lithic technology disappears with Lapita – stemmed tools were not found in Lapita contexts. But the occurrence of a long-distance exchange of obsidian over several thousand kilometre in the archaeological recorded raised questions as to why people living in this period transported obsidian raw material from particular sources over these long distances and how this transport could have been organised.

Generalised obsidian exchange network system

In an influential paper, Ambrose (1978) discussed the possibility of specialised trading of obsidian artefacts in the Bismarck archipelago. His main critique of the earlier literature on prehistoric exchange in Near Oceania was the uncritical adoption of ethnographically-described complex specialised exchange systems seen in recent times in Melanesia, to explain exchange systems which might have existed in the past. He came to the conclusion that the ethnographic record does not adequately describe archaeological data, because there is a marked discrepancy between the prehistoric and modern dispersal of, in his case, Admiralty Islands obsidian (Ambrose 1978:330). Therefore, a procedure had to be established to invent new models to approach questions of prehistoric exchange. This procedure includes three steps of research:

1. Develop appropriate archaeological methods for studying exchange,
2. Adopt a diachronic approach,
3. Examine and question models for specialised exchange/trade over time.

In his analysis of the archaeological data, Ambrose emphasised the open-endedness of the distribution of Admiralty Islands obsidian in prehistoric times, especially in the Lapita period. At this time obsidian was found covering the whole Bismarck Archipelago and through the island chains of the Solomons into Vanuatu. Associated with a "strong conservatism" in pottery design and decoration, the range of raw materials used in sites in southwest Remote Oceania are restricted to a few distant sources, rather than the use of those close at hand (Ambrose 1978:331). Distribution of these raw materials occurred in a large-scale ‘generalised exchange network system’ in which communities exchanged items along a chain of newly-settled islands. This is in direct opposition to the specialised trading system in which individual specialised traders transported items of high value between communities. However, Ambrose (1978:332) acknowledged problems in the connection between a movement of one people, sharing language and the motivation to settle previously-uninhabited islands with the independent evolution of complex exchange systems in the Western Pacific and the general lack of specialised exchange in the Central and East Pacific.

Ambrose (1978:332) assumed an increasing isolation of distant communities when he states that one result of transporting commodities over long distances, evidenced in the Admiralty Islands obsidian distribution in Lapita times, would be a strong decrease in inter-community communication. This decrease is intensified when distant communities are no longer connected through a direct link to the ‘homeland’, but only through a chain of settlements back in the direction of the colonisation pulse.

He suggested that the reason for transportation of obsidian and maximising external trade might have been the acquisition of wealth in the competition for “internal ceremonial” success. This ‘ethic’ occurs independently of the grade of specialisation in Melanesian ‘trading’ networks. Rather than the centralised social systems of Polynesia, where intra-group stratification is based on a hierarchical system and dependent on personal inheritance in lineages, Melanesian group specialisation was explained through stratification and craft-specialisation *between* groups.

The hypothesis that the Melanesian specialized maritime trade developed from a ‘generalised exchange network system’ strongly influenced interpretations of Lapita obsidian exchange in subsequent research (Allen 1984; Fredericksen 1994:196-198; Friedman 1982; Green 1987:247; Kirch 1991:160; 1997:254).

Based on the hypothesis of a generalised exchange system some assumptions have been made concerning the underlying social structure of the Lapita society. Kirch (1988) proposed a system of Lapita exchange between hierarchically-organised settlements, identified not only by long-distance exchange of several commodities, but especially in ‘shell valuables’ which he considers as prototypes of the shell money ethnographically documented for Melanesia (Kirch 1991:155). Lapita settlements were not connected in a socially-equal and unrelated trade, but were intimately linked as hierarchically-ranked communities in which older, more sedentary (and more westerly) settlement sites were the source of prestige goods and valuables (Kirch 1988:113). These exchanges were used to maintain 'ties' with their relatives (in the Lapita 'homeland'), by importing "luxury and status maintaining" objects with social and ideological meanings (Green 1987:246; cited in, Kirch 1988:113). Therefore, long-distance exchange was an essential component of the successful Lapita dispersal and colonisation strategy (Kirch 1988:104).

According to Kirch, over time this system breaks down into several smaller less complex exchange systems (Kirch 1990:126, Table 2). He saw in the archaeological record of the post-Lapita exchange system on the South Coast of New Guinea, "the progressive development of central places, such as Motupore and Mailu, dominated by increasingly specialist traders" (Kirch 1988:103). Kirch agreed with a model proposed by Friedman (1982) that explains the evolution of 'big man' societies of Melanesia and 'theocratic feudalism' of Polynesia as transformations of an earlier Oceanic social structure characterized by four primary elements:

1. Generalised exchange,
2. Monopoly over prestige-good imports that are necessary for marriage and other crucial payments, i.e., for the social reproduction of local kin groups,
3. Bi-lineal tendency in the kinship structure (asymmetrical),
4. Tendency to asymmetrical political dualism (Kirch 1988:113).

Kirch sees Friedman's interpretation that the characteristic small-scale intensive short-distance trading systems typical of big-men societies in much of Melanesia were a long-term result of the increase in trade density as supported by his research. Similarly to Ambrose, both Friedman and Kirch explain the development of these societies by the lack of monopoly over external exchange, which leads to an internal competition for power through the conversion of trade wealth into "competitive feasting" (Friedman 1981:184; also Kirch 1990:129-130).

Contrary to Kirch's hierarchical structure of the Lapita exchange system Allen (1984:445) sees the initial exchange system as spatially large and not ecologically or economically diverse. The social interaction of pottery exchange was based on kinship and obsidian exchange was down-the-line (Renfrew 1977). For the development of exchange systems in the post-Lapita period (albeit in another region) Allen with his cyclic 'wave' model (1984:444; 1985), assumed an increasing complexity of the interaction networks with his cyclic 'wave' model. Two hypotheses were put forward in this model:

1. There is a reduction over time in the spatial extent of trading networks, and a concomitant increase in specialisation and diversification within smaller units,

2. The severity of a systemic collapse is likely to be proportional to the level of specialization (or complexity) obtained in the trading system, and will be most apparent amongst the entrepreneurial group manipulating the system (Allen 1984:442).

Complexity is defined by: (a) an increase in the diversification of food production systems; (b) increasing local population densities; (c) increasing village level economic diversifications; (d) a growing efficiency in transport and communication; (e) an increasing knowledge and efficient exploitation of distant market potentials; and (f) a continued flexibility of home base social organization (Allen 1984:443). The model proposed a cyclic breakdown of exchange systems. However, the overall complexity increased due to an 'accelerating' curve. Additionally the initial trading system had a defined spatial extent which divided over time into a series of more localized systems (Allen 1984:445). A high level of complexity was accompanied by increasing local specialisation, but decreasing long-term stability (Allen 2000:170).

Fredericksen (1994:195-197; 1997) evaluated Ambrose's model (a generalised exchange network system), Kirch's model (hierarchical structure of Lapita settlements, with a decrease complexity of exchange networks in the post-Lapita period) and Allen's model (generalised exchange system during Lapita and increasing complexity in the post-Lapita period) in his PhD thesis concerning the origin of specialised stone artefact reduction technology in the Admiralty Islands. He concluded that deficiencies occurred in all three models. Although Fredericksen (1994) found his data on the exchange of Admiralty Islands obsidian as supporting a generalised exchange model, he also noted that obsidian artefact reduction technologies are 'expedient' (Binford 1979; Gould 1980). He assumed a low value for obsidian because of this lack of technological complexity. Instead of assuming a widespread 'trade' network in Lapita times, he identified the first indication of large-scale production only with the occurrence of minimally retouched weapon points at the Umleang site (post 2100 BP). Accompanying this is a change to a more specialised production of artefacts within more sedentary settlements systems, in which particular groups had more direct control over localised raw materials, and an increased population. The formation of “historic patterns” of economic specialisation occurred most likely sometime after 1920 BP and before 750 BP when minimally retouched blades appeared for the first time in the archaeological record. He sees this as a response to rising demand from a larger consumer market. Similar to Ambrose’s view of increasing isolation, Fredericksen identified a trend in the development of local specialised economies, which was replicated independently in different regions.

Multi-modal specialised exchange network

The hypothesis of a ‘generalised exchange network system’ for Lapita is not undisputed. Evaluating exchange models from Clark and Terrell (1978), Green (1982) proposed a specialised trade model for the long-distance exchange of obsidian during Lapita times. He expanded this model after the detailed analysis of the archaeological assemblages of the Reef / Santa Cruz Islands (RSC) sites (Green 1987). This new model of interregional contact was based on four different layers of interaction:

1. Direct access (distance: between 26-56km),
2. Local reciprocity (distance: between 46-100km),
3. One-stop reciprocity (distance: between 275-380km),
4. Down-the-line exchange (distance: more than 1,500km) (Green 1996:125).

Criticism of the Remote Oceania focus of this model was expressed by several authors (Kirch 1990:119; see also Terrell 1989). They assumed different relationships between Near Oceania communities, because genetic, linguistic and cultural complexity in the Bismarck Archipelago was substantially greater. Kirch (1990:119) also stated that the assumption of Lapita exchange as being ‘static’ is wrong, something which can be seen for example in the dynamic changes in imports into the Lapita sites on Lakeba Island, Fiji (Best 1984:631). Furthermore, Kirch (1991) argued that this model was applicable only to the RSC sites as the emphasis of the down-the-line exchange to acquire high-quality material from the far West (in this case Kutau/Bao obsidian from the Willaumez Peninsula in West New Britain) was not replicated in other sites of Remote Oceania. Green agrees when he states that only "a pale reflection" of the extended long-distance interaction between the RSC sites and West New Britain can be seen in sites further east in Remote Oceania (Green 1996:125). However, if the long-distance down-the-line aspect is downplayed in this model, Green suggests it to be reasonably well suited to explain interaction networks for particular locations in Remote Oceania (e.g. Fiji, Best 1984; Tikopia, Kirch & Yen 1982; New Caledonia, Sand & Ouetcho 1991). Therefore, exchange systems in the Western Lapita province were in the order of a 400km radius, where highly regular, repeated interactions were common (Green & Kirch 1997:28).

In summary, the multiple exchange systems model emphasises the large number of different systems of exchange, which were not affiliated with a single widespread exchange system through the whole of Remote Oceania. Consequently the model describes the Lapita exchange network as "a loosely linked series of complex multi-modal intra- and inter-island systems rather than a single, extensive, elaborate integrated network" (Green 1996:119). It is important to note that in this model Kirch's (1988) interpretation is adopted of obsidian as a status-enhancing commodity which was imported into the archaeological settlements in west and central Remote Oceania to maintain ties with relatives in their homeland (see above, Green 1987:246).

Torrence and Summerhayes (1997:79) also challenged the hypothesis of a single generalised, non-specialised trade system that covered the whole area of Lapita dispersal. They argued that a single, unitary exchange system can automatically be deduced from the spatial distribution of raw material from a single source. A down-the-line process of exchange also does not necessarily mean that every participant was involved in a single exchange system (cf. Renfrew 1977). On the contrary they were part of multiple exchange systems such that long-distance and localised exchange existed side by side. However, in consideration of the long history of obsidian exploitation, they proposed that the Lapita period was the only period where specialist exchange was present. The hypothesis of a specialist exchange system during Lapita was based on the large amount of Kutau/Bao obsidian imported into sites on Garua Island in West New Britain, although Garua Island had local high quality obsidian sources (Baki obsidian). According to Torrence and Summerhayes (1997:80), specialised exchange in this case means that only one group holds a monopoly over a particular resource. It seems that people living in this area chose selected commodities from a limited number of places despite having a wide range of options. This suggests that exports of obsidian were "controlled in some way" (Torrence 2004:122). It could also indicate that social or ideological factors existed which regulated exchange and that only particular varieties of obsidian were considered to be suitable for export (Torrence & Summerhayes 1997:76). They concluded, therefore, that a system of trade among specialised communities existed, which appeared to be similar to ethnographically described systems throughout Melanesia (Torrence & Summerhayes 1997:80). Different exchange networks existed contemporaneously for short- and long-distance exchange, and these networks incorporated different processes of exchange.

However, according to White (1996b:203), it is unclear whether the distribution of the obsidian was conducted by every form of exchange systems from 'specialist traders' to down-the-line networks in either Lapita or post-Lapita period. In the discussion of the complexity of interaction networks especially in the post-Lapita phase White (1996b:204) argued that all such trading networks 'leaked' material from one network to the other, even if to the participants these networks appeared to be closed. In the case of the southeast Papuan islands, obsidian here is seen as a utilitarian tool which was introduced to communities along already established lines of exchange which 'touched' source areas (White *et al.* 2006). White et al. (2006:107) also detected suggestions for an economising behaviour in communities in the Southeast Papuan islands further away from sources, as the artefacts found in these sites are regularly smaller and typical recycled or reflaked. Furthermore, White (1996b) stressed, the importance of a long continuity of obsidian distribution networks in the Bismarck Archipelago, which might suggest that the distribution system did not change over time.

The argument of an economising behaviour in lithic technology is discussed by Specht (2002) and Sheppard (1993) for the Lapita period. In his comparison study of different Lapita and post-Lapita assemblages, Specht (2002) identified a consistent high mean weight of artefacts independent of the distance to the source. He concluded from this evidence that obsidian raw material must have been an item of high value and its acquisition was connected to status and prestige, similar to the argument of Kirch (1988) as described above. Sheppard's (1993:135) approach to obsidian artefacts differs from Specht, as Sheppard proposes that the acquisition of the raw material was not the focus, but instead the social interactions connected with an exchange of obsidian (this approach is discussed in more detail below and again in Chapter 7).

Summerhayes (2003b; 2003a; 2004b) developed his model of the evolution of different interaction spheres during Lapita times in the Bismarck Archipelago from the assumption of different local exchange systems. Based on extensive geochemical provenancing of lithic assemblages in the northern and eastern parts of the Archipelago he detected a shift from predominantly West New Britain obsidian in the early Lapita phase (3400 BP - ~2900 BP) to predominantly Admiralty Islands obsidian in the middle Lapita phase (~2900 BP - ~2600 BP). In the late Lapita phase (~2600 BP - 2200 BP) West New Britain obsidian dominates the assemblages in East New Britain, but not Mussau. Summerhayes (2004b:154) interpreted the evolution of two different interaction spheres as reflecting a ‘colonisation pulse’ in the early Lapita phase and the development of a down-the-line exchange system with a less mobile population in the middle Lapita phase (Summerhayes 2009).

Biogeographical approaches

Alternative approaches have also been proposed to the perception of obsidian as a ‘trade good’ during Lapita or a status-enhancing commodity, acquisition of which was connected to power and prestige. Focusing on the highly mobile population during the Lapita expansion, Gosden and Pavlides (1994) criticised the model of increasing inter-island isolation during Lapita and post-Lapita times as the sole cause of evolving divergence. Instead of a series of small settlements interconnected by trade relations, they suggest a highly mobile population in a “super-community of immense scope” (Gosden & Pavlides 1994:168), which was interconnected through continuous travelling and revisiting of certain spots in the landscape. In their discussion of the archaeological evidence, especially from the Arawe Islands in the Bismarck Archipelago, they came to the conclusion that none of the evidence supports large sedentary settlements with an extensive agricultural system. The low discard rates of artefacts (pottery and stone) and the low level of material culture in use at any one time suggest a different settlement pattern than identified today. Procurement of portable artefacts such as pottery and stone was not accomplished through exchange but through mobility, in which small groups were in continuous contact with each other. Although not explicitly stated in Gosden and Pavlides' model this interaction could incorporate the acquisition of raw material through embedded procurement (Binford 1979). Embedded procurement of raw material, meaning that raw material was collected during 'other activities', was already proposed for the Bismarck Archipelago by Torrence et al. (1996:220). However, direct access to obsidian sources and embedded procurement of Kutau/Bao-obsidian, have been discussed and rejected by Torrence and Summerhayes (1997) for their specialist trade model in West New Britain / Garua Island. In their opinion, the mobility model does not sufficiently explain the obsidian distribution of only one variant of obsidian outside of West New Britain. Nor does it explain the change from planned stone artefact reduction technologies in pre-Lapita times to the expedient technology usually associated with sedentary communities in the Lapita period (Torrence 1992; Torrence & Summerhayes 1997; but see Marwick's (2005) discussion of expedient technologies and mobility).

In his summary of archaeological research in the southern New Guinea coastal area, Irwin (1991) identified different stages of social interaction. Obsidian distribution began with the colonisation of the area through people with 'Early Papuan Ware' pottery. After initial colonisation the exchange systems cycled through stages of "deepening regional isolation", "pottery style transformation" and "interaction, specialisation and exchange" (Irwin 1991). Only in the later stages could Irwin and Holdaway identify an obsidian exchange system in 'trader' mode (Irwin & Holdaway 1996:227). The earliest obsidian distribution was described by them as occurring in a "coloniser mode", in which an "initial burst of colonisation could carry a pulse of valuable non-bulky item, like obsidian, further than it might travel again" (Irwin & Holdaway 1996:228). Only after the colonising event took place did communities in newly inhabited regions start to interact in a 'trader' mode that followed the described trends of increasing complexity and specialisation.

Irwin and Holdaway (1996) applied this approach in comparing the obsidian distribution in Mailu and RSC sites, to distinguish short episodes of colonisation from the later evolution of a regional trade network between established communities (Irwin & Holdaway 1996:225). They detected a large amount of imported obsidian artefacts compared with local cherts in the earliest period. This is a trend which is reversed in the middle period but is similar again in the last period, albeit with significantly different core sizes and mean numbers of flaked scars per core. The distribution of obsidian artefacts in the RSC sites (Sheppard 1993) is seen to follow similar trajectories as the Mailu sites. Irwin and Holdaway see a "rapid drop" in the number of artefacts from the earliest site SZ-8 to the later sites of RF-2 and -6. This drop is explained through the change from first colonisation to subsequent exchange through trade (Irwin & Holdaway 1996:232). Directly after the 'coloniser' event Irwin and Holdaway detect a decrease in the amount of intra-regional exchange and in the specificity of the goods exchanged. Furthermore, analogous to Fredericksen in the Admiralty Islands they also identify a late emergence of specialised trade in obsidian exchange along the New Guinea coast. Most importantly they state that although there are changes in the amount of obsidian found in different layers the reduction technology does not change. However, while they could not detect any form of specialisation in the technology they suggest that the amount of obsidian transported might indeed be a sensitive indicator for the amount of external contact by inhabitants of the Mailu islands (Irwin & Holdaway 1996:233). Similarly, Specht (2002:46) summarises his analysis of the archaeological record of obsidian exchange as showing that "current exchange models may prove to relate only to a secondary, post-colonising, phase and even then only to some parts of the Lapita distribution".

The interpretation of obsidian in the RSC sites differs significantly from Sheppard's conclusion of a comparable utilisation of obsidian in all three sites (Sheppard 2004; Sheppard & Walter 2006), based on the large amount of obsidian found in the RSC sites and the lack of reuse of the material. Sheppard and Walter (2006:59) argued for a continuous direct contact of these founding communities with West New Britain from the initial colonisation until the cessation of the Lapita period several hundred years later. The distance over which the material was transported suggests a high complexity of the interaction network and Sheppard also describes the discard of obsidian as "according to another set of commodity (utilitarian) values" (Sheppard 1993:135), which would account for a non-economical interpretation of obsidian transportation in Lapita times. Similarly, Specht (2002:44-45) argued that such seemingly non-utilitarian behaviour shows "the capacity of the colonists to continue using obsidian in the same way as in their ancestral home" and, furthermore, it provides a witness of "the conscious attempts to replicate the ancestral societies" (see also Green & Kirch 1997:30).

Torrence (2005:367) also notes that the association of this material with "distant persons, places or times" could have been a "key element in the operation of many ancient exchange systems". The RSC sites are therefore seen by Sheppard and Walter (2006:59; see also Green & Kirch 1997) as unique. These sites might represent the first stepping stone of human exploration into uninhabited regions during the Lapita period and thus are indicative of "far greater complexity and technical proficiency". However, only when the Lapita people continued the colonisation process further into Remote Oceania might the existing interaction systems have been "stretched beyond breaking point" (Sheppard & Walter 2006:59). This would mean that communities further to the east might not have been directly connected with the original 'homeland' in West New Britain anymore, but rather with the newly-established settlements in the Southeast Solomons.

Conclusion

My review of social interaction and obsidian exchange in the literature of archaeological research in the Western Pacific started with an assessment of models for Austronesian language dispersal and the 'Lapita Cultural Complex', because it is widely accepted that Austronesian speakers were the first to colonise west and central Remote Oceania (Bedford, Sand *et al.* 2007). The Lapita phenomenon is currently identified as a new ethnic identity in the western Pacific and an important mobilising and legitimating force with shared identity, norms and values (Chiu & Sand 2007; Green 2002). Its spread was not random but directional (Irwin 2008:22), and carried out by small, widely dispersed and highly mobile colonising populations in Remote Oceania (Bedford 2006b:263). After 2700 BP the Lapita period ended more or less abruptly in west and central Remote Oceania, although it apparently continued in parts of Near Oceania. Several researchers see a contraction of interaction spheres in the immediate aftermath of the Lapita dispersal. Whether this is accompanied by a disruption of the multi-layered exchange network postulated for the Lapita period is still in dispute, as is the chronology of the disruption and the question of whether it occurred simultaneously or in succession in different areas. This period of disruption of long-distance interaction was succeeded by increasing long-distance interaction in the last 1000 years (Clark & Bedford 2008).

Different approaches to explain the archaeological record of obsidian exchange have been proposed in the past. Instead of considering obsidian as a valued commodity which was exchanged to enhance prestige in a hierarchical society or to reinforce social structures developed over centuries (Green & Kirch 1997; Kirch 1991; Specht 2002), Gosden and Pavlides (1994) as well as Irwin and Holdaway (1996) have questioned whether obsidian in the Lapita period can be classified as a "trade good" at all (also Fredericksen 1997; Torrence 2005). Direct access and embedded procurement was rejected by Torrence and Summerhayes (1997) for obsidian exchange in West New Britain. They supported Green's (1996) proposal of a complex multi-level interaction network in which local specialist networks co-existed with wider more generalised interaction networks. The social component of obsidian as an identity enhancing marker was emphasised, especially in the case of colonisation of the vast areas of Remote Oceania (Green 1991a; Green & Kirch 1997; Kirch 1991, 2000; Sheppard 1993; Specht 2002; Torrence 2005, 2004). In this context obsidian was valued for its possibility to establish a 'link' to the 'Lapita homeland', which enabled distant communities to replicate their ancestral societies (Specht 2002). Finally, Sheppard (1993) proposed that obsidian should not merely seen as an item *for* exchange but rather a symbol *of* exchange.

- Chapter 3 -

3. Area of research and environmental constraints

Introduction

This chapter is structured in two parts. The first part will describe the general geological setting for the obsidian sources, the discrete distribution of obsidian deposits in the Pacific and a more general geological and geomorphological description of the Islands of Vanuatu with a focus on the Banks Islands. The second part will discuss the key environmental parameters relevant to changes in human behaviour in the Western Pacific, with a special focus on El Niño / Southern Oscillation (ENSO) variability and effects.

General geology

Most islands in the Southwest of the Pacific (including Fiji, Vanuatu, Solomon Islands and the outer islands of Papua New Guinea) are derived from volcanic activity due to oceanic and continental plate movements. Exceptions include New Caledonia and New Zealand which can be defined as continental remnants. The alignment of island chains in the Pacific follows either the boundaries of tectonic plates, which can run parallel to continental margins, but are not dependent on it, or the movement of tectonic plates. Therefore they often occur either at right angles or parallel to the trends of underwater mountain ranges (Nunn 1999:8). Only a short summary of the complex processes of island origin are given in this chapter (for reviews of the geo-scientific data of this region and some implications for archaeological research, see Dickinson 2001, 2006; Dickinson & Burley 2007; Nunn 1998, 1999).

Plate tectonics

The geology and geomorphology of the Pacific region are defined by the long-term processes of plate tectonics. The solid section of the earth's surface is separated into a series of moving plates, which "float" on top of a section of hot, viscous rock. Plates which form the earth's surface can be broadly divided into 'continental' and 'ocean' plates, with continental plates forming most of the earth's surface landmass. Plate boundaries can be convergent or destructive, divergent or constructive / rock producing, and transverse, where two plates slide along each other in a strike-slip boundary (Tarbuck & Lutgens 2008).

The Pacific basin is dominated by the Pacific plate which defines the ocean-floor of most of the Pacific. The plate subducts at its eastern margin under the South American Plate and has a long transverse boundary with the North American Plate named the San Andreas fault. Important for research on obsidian is that the Pacific plate subducts the Indo-Australian plate at its western boundaries from the region of eastern Papua New Guinea, here fragmented into the Bismarck and Solomon plates, through the Solomon Islands and Vanuatu down to the Matthew and Hunter Islands in the south. It is subducted by the Indo-Australian plate in the Tonga-Kermadec trench and has a transverse boundary with this plate in the general region of Fiji.

Subduction processes at convergent boundaries between tectonic plates result in the development of deep sea trenches and adjacent island arcs, where liquefied solid rocks of the subducted plate rise to the surface resulting in volcanism. This process is the origin of most of the island arcs in the south-western Pacific including the islands of Vanuatu. The region of Eastern PNG, Solomon Islands and Vanuatu form a particularly complex mosaic of minor plates, subduction zones and faults, which defines the highly complex geochemistry of that area as described in the next chapter. In contrast to the island-arc chains of the south-western Pacific, Central Pacific islands are derived from anomalous convection zones (mantle plumes) in the oceanic plates, so called ‘hot spots’. At these locations, magma from the underlying viscous lithosphere rises to the surface, forming volcanic mounts. The alignment of these island chains therefore does not follow plate boundaries, but instead the movement of the tectonic plate over these hot spots.

Volcanism

Two aspects of volcanism are of interest for understanding obsidian. On the one side, volcanism produce rocks, including obsidian, which were used and transported by humans throughout the Pacific, but on the other side, volcanic eruptions are serious environmental hazards which can influenced human behaviour.

Magmatic rocks can be classified by rock-forming processes. If rocks have an igneous origin, but are formed in great depth inside the earth's mantle rather than through volcanic eruptions, they are called igneous plutonic rocks (such as granite). These rocks are rare in the Pacific as the main processes forming the islands are extrusive processes, resulting in igneous volcanic rocks (such as basalt). Obsidian is a special form of igneous volcanic rock which forms in quickly cooled felsic lava (lava with a high silicate content). Because of the 'shock' cooling of the lava, crystal formation is hindered, resulting in an amorphous structure of the rock. Usually a lava with a silicate content of >70% is needed to form high quality obsidian (Smith 1974; Vinx 2005). Lower silicate content would result in a less viscous lava which tends to cool more slowly with the increasing chance of growing crystals, and would therefore form andesites, dacites or basalts, in decreasing order of their silicate content. However, occasionally lavas with lower silicate content cool quickly and form lower grade volcanic glasses which tend to fracture unpredictably with therefore a reduced possibility to produce usable tools in the flaking process.

Volcanism as natural disasters

As described above, the impact of natural disasters on social interaction has become a focus of archaeological research. Volcanic eruptions are variable in their scope and magnitude. The US geological survey distinguishes between eight levels of magnitude in its Volcanic Explosivity Index (Newhall & Self 1982), based on the measured or assumed amount of ejected material. The eruption of a volcano like Mt. Tambora on Sumbawa, defined as a level 7 eruption, had not only local, but global catastrophic impact (Oppenheimer 2003; but cf. Grattan *et al.* 2002 for discussion of magnitude of event in correlation with impact on social interaction). Associated with volcanism is increased seismic activity which has to be included in the assessment of the effect of volcanism on social interaction. In 2007 alone, the Advanced National Seismic System (ANSS) catalogue (Advanced National Seismic System 2009) counted more than 200 earthquakes in the general area of Vanuatu with a magnitude of 4 and higher.

Nevertheless, the majority of volcanic eruptions are of a much smaller scale and might have supported social interaction rather than having a disastrous impact, resulting in destruction, extinction and displacement. Recently, Grattan and Torrence (2008a:9-11) presented three aspects of volcanic eruptions, which are defined as 'positive' factors influencing environmental constraints and human behaviour:

1. Physical enhancements: tephra-fall from volcanic eruptions can increase soil fertility in adjacent areas, resulting in higher yields,

2. Social and residential flexibility: long-term cultural adaptation to risky environments might result in strengthening social networks as insurance against natural hazards,

3. Populations as active actors in shaping their social reality: natural disasters are conceived as social processes and are incorporated in oral traditions transmitting knowledge about previous events and successful adaptation strategies.

The relationship of natural disasters with the development of social networks as an adaptation strategy is important. Torrence and Doelman (2008) defined two major aspects of social networks in catastrophic events:

1. If people are displaced, they need access to resources (land and food) in the newly settled area,

2. During re-colonisation of a previously uninhabited area, 'lifelines' back to populations in more secure areas can act as an 'insurance' in case of failure (Torrence & Doelman 2008:52).

Spatial distribution of obsidian sources in the Pacific

It will be discussed in Chapter 7 that the 'value' of obsidian derives in part from its rarity because it is only found in small discrete sources. In this way it is different from other utilised rocks in archaeological contexts, such as cherts, basalts or quartz, which occur in widespread geological formations in the Pacific (Sheppard 1996). The localised distribution of obsidian deposits and their restricted size make them "a particularly good candidate to represent a homeland or a distant place" (Torrence 2005:364).

In the Western Pacific four major areas of obsidian sources are known: (a) West New Britain in the Bismarck Archipelago; (b) the Admiralty Islands, also in the Bismarck Archipelago; (c) the D'Entrecasteaux Islands of southern PNG; and (d) the Banks Islands of Northern Vanuatu. Each of these areas have two or more sub-sources. Additionally, smaller sources of obsidian are known from at least one island of Tonga and several sources of low grade basaltic glass are known from the Central Pacific islands, but these are not the subject of this thesis.

The East Melanesian Biodiversity Hotspot, as defined by the Conservation International Foundation (Conservation International 2005), includes more than 1600 islands. However, the exact number of islands in the Western Pacific is still under consideration. Although most of these islands have a volcanic origin, obsidian deposits could only possibly be found on less than 2% of them. These numbers include obsidian sources which were never utilised by human populations such as the very recently formed obsidian deposits on the Tuluman Islands, Admiralty Island group (Wal Ambrose, pers. comm.). This is due to complex geological factors, such as viscosity, elemental composition, and pace of cooling, which has to come together to develop natural glasses in sufficient amounts for human exploitation. The geochemical composition of these different sources will be discussed in detail in the next chapter. In relation to its general geology, all the sources of the Western Pacific (as well as the obsidian sources from Tonga) originate from island arc volcanism. This is in contrast with the Central Pacific basaltic glass sources, which derive from intra-plate volcanism and show a distinctively different major and trace element distribution (Figure 3.1).

Area of Research

The nation of Vanuatu (Figure 3.2) consists of a series of about 80 islands of relatively young age, which are part of the New Hebrides Arc, located about 500-1500 km southeast of the Solomon Islands Arc, 500 km northeast of New Caledonia and 1000 km west of Fiji. The New Hebrides Arc is situated east of the New Hebrides Trench, where the Indio-Australian plate is subducted under the Pacific plate. Besides the islands of Vanuatu, the New Hebrides Arc also includes the islands of the Reef / Santa Cruz group in the Southeast Solomon Islands (Greene *et al.* 1988).

The New Hebrides Arc is part of a narrow chain of Tertiary to Quaternary volcanic Island Arcs which extend from New Zealand in the south to New Guinea in the north. The Banks Islands are predominantly of late Tertiary to Recent age (Figure 3.3) and lie on a narrow chain of volcanism at 167°17` - 167°40` E, 13°30` - 13°58` S (Ash *et al.* 1980; Mallick & Ash 1975). Geological information suggests three volcanic episodes formed the Islands of Vanuatu (Mitchell & Warden 1971). The rocks produced by these volcanic events are also assigned to three separate provinces. In the late Oligocene to the middle Miocene the rocks of the Western Belt formed the Islands of Malakula, Santo and Torres Islands, mostly built up through calc-alkaline submarine lavas. The later Eastern Belt consists of Maewo, Pentecost, western Epi and central Efate which were shaped through mainly submarine volcanic activity in late Miocene and early Pliocene times, producing tholeiitic (Magnesium-rich pyroxene) and high-Aluminium lavas and clastic rocks. The third and last main volcanic activity formed the Central Chain from the late Pliocene into the Holocene, again through tholeiitic and high-Al basalts, but also through hypersthene (Magnesium- and Iron-rich pyroxene) and quartz-rich rocks (Rothe 2005; Vinx 2005). All of the Banks Islands lie in this central chain. The level of volcanism decreased in the Terminal Pleistocene and Holocene; however a renewed subaerial growth was detected on Gaua in the last 2000 years. As described above, the seismic activity on the Banks Island and the whole of Vanuatu is "generally intense, but variable" (Mallick & Ash 1975:2). In general, the hypocentres in the south of the New Hebrides Trench are shallower than in the North and lie at the northern end of the trench deeper than 100 km.

Geology of the Banks Islands

As described above, the Banks Islands (Figure 3.4) are part of the Central Chain that formed in the late Pleistocene and Holocene. The group consists of 13, mainly surfaced volcanic islands (only the Reef Islands northeast of Vanua Lava are coral atolls with no exposed igneous bedrock) and is dominated by the two large islands of Gaua (Santa Maria) and Vanua Lava. Both islands cover an area of approximately 100 km^2. As these two islands contain the only obsidian deposits found on Vanuatu, a more detailed geological description is relevant.

Gaua (Santa Maria)

The island of Gaua (Figure 3.5) is a large basaltic shield volcano of Pleistocene and Holocene age (Macfarlane *et al.* 1988:70). The recent cinder cone Mt. Garat is located on the southwest side of the big crater lake which fills the caldera of an earlier eruption. The maximum depth of the crater lake is approximately 100m and is separated from the fluid magma below by a thin layer of solid rock. The most recent eruption of Mt. Garat was in 1973/74 and the volcano is still active.

The general geology of the island is characterised by two phases of volcanic activity: an older phase, the remnants of which are two hill masses in the southwest of the island, and a younger phase producing the volcanic rocks which form the remainder of the island. These are mainly subaerial and range from basic olivine basalts to pyroxene andesites (Mallick & Ash 1975:4). The geological map shows mainly undifferentiated basaltic and andesitic lava flows, with bedded tuffs only recognisable on the crater rim. Pyroclastic flow deposits can be found on the western side of the island and a large area of andesites is located on the north-western side (Mallick & Ash 1975:6). The obsidian source, described in more detail in the next chapter, is located in the main undifferentiated sequence in the north-northeast part of the island.

Vanua Lava

The general geology of Vanua Lava (Figure 3.6) is more complex than Gaua. The geological origin of the island involved a series of episodes of volcanic activity of the same age as Gaua, with three distinctive phases of sediment production, the latest again being of recent age (Ash *et al.* 1980:4). The oldest rocks are remnants of former basaltic stratovolcanoes mostly rugged and upstanding massifs in the eastern and south-eastern part of the island. The second episode of volcanic activity produced the current western and north-western coastline, as well as part of the inland, and consists of andesites and agglomerates. The third and latest episode can be recognised through a series basaltic-andesitic and andesitic lavas on the central axis of the island and around the well preserved central cones of Mt. Suretimeat.

The western side of the island is especially important for the origin of obsidian on Vanua Lava. High silicate andesite, agglomerates and tuffs shape the Irsa Lion Formation which is dated to the late Pleistocene. This formation is succeeded inland by bedded tuffs, undifferentiated andesites and basaltic lavas, and pyroclastic cone deposits of late Pleistocene to recent age. Pyroclastic flows are a common source of obsidian and obsidian occurs in this context as (a) a precursor to the following lava flow, or as (b) xenolithic material from an earlier deposit dislocated by the following eruption (Hughes & Smith 1993:84-89). The obsidian source on Vanua Lava is located at the northern end of the Irsa Lion Formation in the transition zone of bedded tuffs and undifferentiated andesites and basaltic lavas, and is described in more detail in the next chapter. The combination of earlier high-silicate andesites and later pyroclastic flow deposits might explain the series of small obsidian nodules embedded in ash layers, which is similar to the Baki source as described by Bird et al. (1997:65-66; but see Torrence, Neall *et al.* 2004:114 for a correction).

Soils and Flora

The soils of Vanuatu have been mapped in detail by Quantin (1972-1979), who could distinguish five different soil types: (a) very recent volcanic ash soils, mostly connected to active volcanoes; (b) recent (immature) volcanic soils, found on islands of the Central Belt and prominent in the Banks Islands; (c) older (mature) volcanic soils, which cover most of the big islands of the Western Belt; (d) old volcanic soils which are poorly developed, associated with older volcanic activity; and (e) recent alluvial soils, for example found at the PeLav river mouth on Vanua Lava.

Although a comprehensive description of the vegetation is still to be written, Mueller-Dombois and Fosberg (1998) summarised the existing literature and distinguished six different regional vegetation types:

1. Lowland rainforest

Lowland rainforest is the dominant vegetation on the south-eastern side of all islands and extends up to altitudes of 500-600m. This zone can be further subdivided into (a) high-stature forests on old volcanic ash; (b) medium-stature forests heavily covered with lianas; (c) complex forest scrub densely covered with lianas; (d) alluvial and floodplain forests; (e) *Agathis-Calophyllum* forest; and (d) mixed-species forests without gymnosperms and *Calophyllum*.

2. Mountainous cloud forest and related vegetation

Mountainous forests covers the area higher than 500-600m up to about 1000m on most of Vanuatu's islands. It consists of stunted trees with gnarled crowns, trunks and branches covered with bryophytes and filmy ferns. These types of forest are sometimes associated with peaty bogs over strongly leached acid soils (often waterlogged). Closer to the summits, these forests are replaced by treeless low scrub and herbaceous patches.

3. Seasonal forest, scrub, and grassland

On the northwest side of most islands, the leeward effect of rain shadow areas of mountain ranges results in dryer conditions. Associated with these weather patterns are three different vegetation types: (a) semi-deciduous transition forests, which includes important areas of indigenous tree gardens, where for example, *Gyrocarpus americanus* (the canoe tree) is cultivated; (b) *Acacia spirorbis* forest, an open formation dominated by this endemic acacia variant with an undergrowth of shrubs, grasses, ferns and sedges; (c) *Leucaena* thickets, savannas and grassland, situated in the driest and windiest parts of these areas with dominant thickets and grassland, which can be found, for example, high on the northern slopes of Ureparapara.

4. Vegetation on new volcanic surfaces

New volcanic surfaces are usually only sparsely vegetated. Coloniser plants, like grasses, ferns, shrubs and occasionally flowers and herbs can be found. Tree ferns and trees are only rarely encountered. A zonation of coloniser plants can be detected with lichens and herbaceous ferns being the first to appear on new soils, followed by tree ferns, pandans and palms with an undergrowth of tall grasses and shrubby trees.

5. Coastal vegetation, including mangroves

Coastal vegetation can be separated into strand and mangrove areas. Similar to the western Melanesian islands, like the Solomon Islands, strand vegetation consists of a frontal herb zone, associated with creepers, grasses and sedges and followed by a shrub zone with bushes and low-stature trees, and lastly littoral forest. Mangroves in contrast are more localised on sheltered coasts and cannot be found on all islands.

6. Secondary and cultivated woody vegetation

These forests develop in response to shifting cultivation and disturbance of larger areas through cyclones. They are defined through fast growing, heliophytic colonisers. Lowland rain forests and seasonal forest areas are particular influenced by anthropogenic activities and are dominated by secondary vegetation. According to Mueller-Dombois and Fosberg (1998:104), distinctions between primary and secondary vegetation in these patches are difficult to make as research on the vegetation history of

Vanuatu is still in its early stages and more detailed research is needed. However, the cultivated woody vegetation mainly refers to coconut plantations. Introduced species into Vanuatu for horticulture include several forms of starchy root-crops like taro (*Colocasia esculenta*), yam (*Dioscorea sp.*), sweet-potato (*Ipomoea batatas*, European introduction), manioc (*Manihot esculenta*) and breadfruit (*Artocarpus altilis*) (see Horrocks & Bedford 2005; Horrocks *et al.* 2009; Kirch & Yen 1982:31-37; and Yen 1995 for a more detailed summary of cultigens).

Fauna

The current state of research about faunal remains and human impact on the endemic biota in Vanuatu was recently summarised by Bedford (2006b). These data are still very fragmented and, similarly to the vegetation data, a comprehensive description of the native fauna (with the exception of birds) does not exist. However, Bedford (2006b:257-258) states that with the arrival of humans on the islands an extinction of “pristine” faunal resources can be detected, including several flightless bird species, a land crocodile (*Mekosuchus kalpokasi*) and a giant tortoise species. Turtle and large shellfish such as *Trochus niloticus* can only be found reduced in size in later deposits. In general, fishing and marine resource exploitation was (and is) a major component of the diet. Reef fish species especially, can be found in abundance in archaeological sites, but also pelagic fish and bottom-dwelling taxa found in deeper waters were also exploited (Kirch 1997).

Introduced species include pigs and chicken, as well as two associated species of rats, *Rattus exulans* and *Rattus preator*. The focus on foraging of certain food resources, and in this context the depletion thereof, was only short lived. Soon after initial colonisation, a sustainable equilibrium with a heavy reliance on horticulture was established. Bedford (2006b:258) concluded from the findings of the early EF-Arapus site on Efate, that there was “the utilisation of a broad spectrum of exploitation zones where both opportunistic and selective hunting and gathering” of native resources was practised.

Population

Everywhere on the islands traces of a denser population in the last two centuries can be detected. Mostly stone structures of abandoned villages can be found which predominantly date back not more than 300 years (e.g. Bedford 2006b). Soil stratigraphy in such sites is generally less than 10 cm deep with underlying weathered sterile tephra. Current extrapolations assume a maximum population density of about 4,000-6,000 people on Vanua Lava and Gaua before European contact. The current population is about 2,500 people on each island. In total, the Banks Islands today host a population of approximately 10,000 people with a rising tendency. Serious depopulation in the 19th and early 20th century almost caused an extinction of the local population. Because of these factors, there is a severe break in the oral history and tradition.

The focus of some part of the population is to revitalise *kastom* habits, but as much information is lost, a mixture of old traditions with new habits evolves in the culture of these Islands (Huffman 1996).

Palaeoclimate

Basic climatic patterns in the Pacific

Due to the geographic location of Vanuatu, the climate varies from the wet equatorial zone in the north, including the Banks Islands, with about 4,000 mm annual rainfall, to a dryer subtropical climate in the south with less than 2,000 mm rainfall per year. Average temperatures range between 21°C and 27°C and average humidity between 75% and 80%. The wet season usually lasts from November to April with an average of four to six tropical cyclones of hurricane strength per year.

The annual weather pattern of the islands of Vanuatu is determined by two fundamental processes. First, the Intertropical Convergence Zone (ITCZ) and the Coriolis Effect (Hadley cells), which determines the trade winds in the Pacific. Secondly, connected to this process, the Walker circulation, which is a model describing the tropical air flow from east to west. These two patterns develop through atmospheric motion, which is driven by the uneven distribution of incoming solar radiation on the earth's surface. Areas around the equator receive more solar radiation, which results in an overall net heat gain around the tropics. At higher latitudes the incoming radiation is much less, resulting in an overall net heat loss. Both the atmosphere and the oceans respond to this imbalance by transporting heat away from the equator, and associated with this are very large, vertical cumulus clouds which move evaporated moisture into the upper atmosphere from where it is transported towards the poles. At the same time, that the earth's rotation deflects these airflows in an eastward direction, the Coriolis Effect, results in strong westerly winds, the Trade Winds, which become stronger the higher the latitude until about 25-35ºS where the subtropical high pressure system is situated. This pressure system derives from the cooling and increasing density and diversion of the air, additionally enhanced by the Coriolis force, which causes the air to slow down and subside. In this high pressure system, the airflow is therefore directed to the surface, from where it flows northwards until it meets the ITCZ where it rises again. The most persistent feature in the Pacific of this high-pressure belt is the anticyclone in the southeast Pacific, close to Easter Island. The climate of islands of the south Pacific is therefore strongly influenced by this northern airflow, called the south-eastern Trade Winds. Annual weather patterns are related to the movement of the ITCZ, which moves considerable distances in the western Pacific and is relatively stable in the eastern Pacific. In the winter months (May-September), the ITCZ is located just south of the equator and bends southwards in the summer months (November-February). With the bending of the ITCZ southwards the south-eastern Trade Winds are deflected further west becoming easterlies (Linacre & Hobbs 1977; Nunn 1999). The Walker circulation describes the tendency of air to ascend over the Indo-Pacific warm pool (especially Indonesia) and to flow as an upper westerly current to the east, descending over the Eastern Pacific (at about 90ºW) after which the air flows back to the west forming the easterlies, as described above. The easterly trade winds, which blow in lower altitudes, therefore move warm air and surface water to the west resulting in wet and warm conditions over the Western Pacific and dryer and cooler climates in the East Pacific.

Associated with these atmospheric weather patterns are ocean currents. Ocean currents are influenced by the earth's rotation, local tidal movements and strong surface winds. Wind driven currents, so called drifts, can be particularly strong and reach up to 4 knots of velocity. In the South Pacific, oceanic currents circulate anticlockwise around the large Easter Island high-pressure cell, driven by the strong easterly Trade Winds. These currents transport warm surface water westwards, where it sinks to lower levels and flows as a strong undercurrent at depth eastwards where it rises to the surface along the South American coast. Fluctuations in the Walker circulation and the spatial distribution of sea surface temperatures (SST) are called El Niño – Southern Oscillation (ENSO) events. The identification of a physical connection between fluctuations in the annual warm water currents (El Niño) and the oscillation of the Pacific weather pattern is a relative recent discovery. Until the end 1960s, these processes were studied separately from each other, but it is not yet clear what causes the transition from "normal" weather patterns to El Niño or La Niña events. However, it has become obvious that these processes can develop into catastrophic proportions of global impact, as the outcomes of the El Niño / La Niña event from 1997/1998 have shown (Suplee 1999).

An El Niño episode is characterised by a cyclic breakdown of the Walker circulation, with the result that relatively warm water and moist air extend in an eastern and southern direction in the East Pacific. The East Pacific therefore heats up and the south-eastern trade winds weaken and may eventually reverse. Equatorial surface currents, fuelled by the strong easterly Trade Winds, which would usually transport waters along the equator to the west, do not continue, resulting in lower SST's in the Western Pacific and warmer SSTs in the East Pacific (McPhaden 1999). Along the equator, where cloud development is already concentrated, cloudiness intensifies and storm clouds are drawn eastwards. In these periods, usually dry, desert-like environments in the coastal areas of Central and South America experience torrential rainfalls and flooding, whilst the Western Pacific, usually warm and wet, experiences dry and drought conditions. Occasionally El Niño events are followed by La Niña events where the usual weather pattern is intensified, resulting in very strong Trade Winds and wetter than usual conditions in the Western Pacific associated with storms and flooding in this region.

ENSO variability in the late Holocene

ENSO variability and its impact on Pacific weather patterns has been the focus of much scientific research in the last decade (Brown *et al.* 2008; Hilton 1998; McPhaden *et al.* 2006; Wang & Fiedler 2006). Human reactions to changing climates in the Pacific have also come into focus in archaeological research. Allen (2006) has recently summarised current research of possible impacts of climate change in the last millennium on human societies in the Pacific. Similarly, research by Nunn (1998; 1999; 2007) focused on the climatic variability of the last millennium and its influences on social organization of societies and human movement. Both authors focus on the so-called 1300 AD event, which marks the change from the Medieval Warm Period (MWP) from 750-1250 AD to the Little Ice Age (LIA) from 1350-1800 AD. There is still disagreement on the scope of this event for human settlement patterns, resource use and voyaging strategies. While Nunn (1999; 2007) promoted the idea that increased precipitation and sea level fall (due to atmospheric cooling) about AD 1300 had dramatic environmental effects, Allen concurs only insofar that there are perturbations detectable in the environmental record. However, a detailed interpretation of the scope of these perturbations needs further research. She based her critique of Nunn's assessment of the AD 1300 event as 'catastrophic' based on an idea of the teleconnection of Pacific weather patterns with palaeoenvironmental data collected in the Northern Hemisphere.

Both authors agree, however, that either of these phases, the MWP and the LIA, have distinctive climatic signatures. Rather than the interpretation of the MWP as a warmer and wetter period and the LIA as cooler and dryer than today's climate (as identified in the environmental record of the Northern Hemisphere), Allen proposes cooler conditions in the MWP in the Central Pacific, and warmer and stormier conditions in the LIA. Whilst these conditions are inverse to the ones specified by Nunn, a marked temperature increase could have been as disruptive for Pacific peoples as a decline, given the sensitivity of tropical reefs to thermal stress (Flett & Haberle 2008). Additionally, given the size of the researched area, Allen concludes that we have to expect significant heterogeneity in Pacific climates over time. Therefore, the Western Pacific could have experienced strong variability in climatic patterns during ENSO events, whilst Easter Island and the Galapagos could have been relatively unaffected (Flett & Haberle 2008; Genz & Hunt 2003). However, there is general consent that the amplitude and frequency of ENSO events have increased since the mid Holocene.

Several proxies exist to assess palaeoclimate fluctuations. The earlier teleconnections proposed by Nunn (1999:289) were based on the River Nile streamflow data. The more recent publications by Allen (2006:524) and Anderson et al. (2006:4) used as proxies data collected from the Southern Hemisphere, like Palmyra coral $\delta^{18}O$ data (Cobb *et al.* 2003) or the reconstructed ENSO record of the Laguna Pallcacocha (Figure 3.7) in Ecuador (Moy *et al.* 2002). Especially the Laguna Pallcacocha record suggest a slightly earlier date for the 1300 AD event as there is a peak in the number of ENSO events between 1200 and 1300 AD.

Figure 3.7 shows ENSO events and intensity during the last 4000 years. Important for human colonisation of the Pacific and possible later environmental impact on social organisations is that initial colonisation of Remote Oceania occurred during a phase of intense ENSO frequency, which lasted until about 2600 BP. After 2600 BP Pacific climate continued into a phase of low ENSO activity interrupted by the 1400 BP event, which was a short period of intense ENSO activity. This phase of relatively stable climatic conditions ended about 1000 BP (the 1200 - 1300 AD event), when the Pacific climate shifted into the phase of the LIA of increased ENSO amplitude and frequency.

As noted before, Pacific climates show a significant heterogeneity. Salinger et al. (1995; 2001) could identify four separate zones in the Pacific where ENSO variability influences local weather patterns to different extents. These zones are not "isomorphic" to any "regions traditionally defined and used by Pacific social scientists and biologists" (Allen 2006:528). They are more or less latitudinal oriented and are heavily influenced by the South Pacific Convergence Zone (SPCZ, as part of the ITCZ), which is a band of low level wind convergence, cloudiness, and precipitation that extends across the central Pacific from Vanuatu in the west to the Austral Islands in the east. As described by Nunn (1999), the SPCZ is not stationary, but moves northeast during El Niño activities, resulting in increased cyclonic frequency. Zone C1, which includes New Caledonia, South Vanuatu, South Fiji and most of the Tongan islands, and C4, including most of Central and North-Eastern Polynesia, are areas with a more stable climate during El Niño events. Whereas zone C2, Northern Vanuatu, the Solomon Islands and the Marianna Islands, as well as eastern New Guinea, and C3, North Fiji, Samoa, Cook Islands and Austral Islands, are strongly influenced by the position and shifting of the SPCZ during El Niño events.

Climatic explanations have often been rejected as overly deterministic, but long term climatic changes have continuously altered the biogeography of the region. In a recent paper, Anderson et al. (2006) combined the approach with the environmental record of ENSO variability in the Pacific. They showed a correlation between an increase in the frequency of ENSO events and phases of intensive human dispersal in the Pacific. During periods of strong El Niño activity easterly winds, which would usually obstruct human dispersal into the East, are weakened and partially reversed. Together with the proposals of increasing population pressure during unstable phases in the MFM model, changing wind directions, which ease the accessibility of islands further to the East, could have enhanced the chance of a population movement sufficient to colonise these new islands.

Conclusion

The assumption that fluctuation in food availability was a well known phenomenon in the life of Pacific islanders is not new. Indications of "drought-induced famines" in Western Pacific islands were already reported in Malinowski's early ethnographic research from the Trobriands (referenced in Harris 1968:566). Recent research on the effects of the 1997/1998 El Niño suggests that this event alone killed 16% of world corals and reduced reef-related fisheries by 25-50% (Allen 2006; Hughes *et al.* 2003; Wilkinson *et al.* 1999). Similarly, Field (2004) detected significant perturbations in the archaeological record (including an intensification in exchange of subsistence goods) in Fiji which might be related to increased resource stress (Allen 2006:530). Although Allen (2006:531) suggests that archaeological research should move ahead from simple correlations and "plausible correlations" between the archaeological data and environmental constraints, the concept of unpredictability of resource outcome during phases of high environmental variability is taken here as the conceptual framework to introduce a novel approach for the explanation of spatial and temporal changes in the distribution of obsidian in Vanuatu.

- Chapter 4 -

4. Archaeological surveys, analysed obsidian sources and lithic assemblages

Introduction

Chapters 1 and 2 outlined the previous research that has been done in the study area along with ideas about the colonisation of the Western Pacific, the evolution of social interaction and cultural diversity in general, and models of obsidian exchange in particular. In this chapter approaches to data collection and the results of the archaeological fieldwork season of 2006 are presented. As the main focus of this thesis is the analysis of the evolution of social interaction in southwest Remote Oceania based on tracking the spatial distribution of material culture, fieldwork and data collection concentrated first on the detailed identification and assessment of obsidian outcrops exploited by the local population in the past. Secondly, artefact assemblages were selected which cover the whole time-frame of human occupation of the research area. These assemblages were then geochemically fingerprinted to securely identify the source of the raw material used. Thirdly, the assemblages were analysed using a quantitative attribute analysis to assess production and consumption patterns of different raw materials.

Approaches to fieldwork and data collection

In consideration of these research aims the fieldwork and the data collection was designed to identify and sample all obsidian outcrops of the research area. Besides the detailed sourcing of the selected assemblages from the Vanuatu Archipelago and adjacent islands, a second objective of the research on obsidian assemblages is to identify additional, undetected obsidian sources in the study area. The comparison between intra-source variation of source samples and artefacts, as will be discussed in Chapter 5, is of particular importance. Finally, it was attempted to identify and excavate sites which cover the whole time-frame of human occupation of the surveyed islands. To increase the sample size of assemblages analysed and particularly to increase the area covered by this research all excavated assemblages which contained flaked artefacts in the Vanuatu Archipelago and an adjacent island to the north, Tikopia, are included.

Following this structure the chapter is separated into three parts. First, the systematic approach applied in this fieldwork to the detection and recording of obsidian outcrops is given. This is followed by the geological and geomorphological setting of the two obsidian outcrops surveyed in the Banks Islands. The second part of the chapter describes surface surveys and excavations of archaeological sites conducted by the author during the 2006 field season. Finally, detailed information on stratigraphy and chronology of assemblages excavated by fellow scholars included in this study is presented.

Methodology

Following recommendations by previous scholars (Ambrose 1976; Glascock *et al.* 1998; Torrence *et al.* 1992), it was attempted to locate as many obsidian outcrops as possible on the Banks Islands. To achieve this aim, analysis of geological maps (Ash et al. 1980; Mallick & Ash 1975), previous knowledge about the location of obsidian outcrops (Ward 1974, 1979) and field exploration with the help of local guides on six of the most prospective islands (Gaua, Mota Lava, Pakea, Rah, Ureparapara and Vanua Lava), based on their geological setting, were conducted.

Geological Maps

A detailed geological survey of the Islands was conducted during the 1960s and 1970s by the Geological Survey of the New Hebrides (summarised in Ash *et al.* 1980; Mallick & Ash 1975). Although the main focus was the survey of mineral deposits worthwhile for mining, the maps produced give a good indication of the general geological history of the Islands as outlined in Chapter 3. Based on these maps, islands with a low potential for obsidian deposits, here defined through a lack of high silica rocks, were excluded from the surface survey. Islands excluded were Mota, Mere Lava, Merig and the Reef Islands.

Field notes of Graeme Ward

The detailed description of Graeme Ward's fieldwork during 1973-1974 in the Banks Islands in his PhD thesis (Ward 1979) was further enhanced by personal fieldnotes. The detailed assessment of the Gaua obsidian source by Ward suggested that obsidian nodules and flakes found on the shores of the islands might have their origin in uphill deposits. It was assumed that the same context also applied to the Vanua Lava source. Therefore it was deemed necessary to survey the area described by Ward in the northwest of Vanua Lava. Furthermore, based on the assumption of Ward and Smith et al. (Smith et al. 1977:184; Ward 1979:8-14) that the identified variation in the Rb content of artefacts from Pakea suggests more than two obsidian sources exploited in the past, the identification of possible additional obsidian outcrops on the island was focus of the fieldwork.

In contrast with the general survey of the islands by Ward and his later focus on subsistence strategies and the general cultural sequence of the Banks Islands, this thesis concentrates particularly on the identification of sites with obsidian. Whilst all sites which were encountered on the surface survey were recorded, only sites with a high possibility for a well defined stratigraphy for further archaeological excavation are presented in detail (Appendix 2).

Fieldwork

Fieldwork in Vanuatu was conducted during ten weeks from May to August 2006. During the field period, eight of 13 islands of the Banks Islands of northern Vanuatu were visited. In the first week of fieldwork the islands Vanua Lava, Mota Lava, Rah and Pakea were visited to establish communication with the local community and to assess local knowledge of possible locations of obsidian outcrops. It quickly became clear that there was only limited knowledge of obsidian in the local population. Therefore, based on the previous knowledge of the location of possible obsidian outcrops in the Banks Islands and a potential survey area of more than 700km^2, it was decided to concentrate the survey on the two main islands, Vanua Lava and Gaua, and the adjacent island of Ureparapara.

In this fieldwork it was attempted to follow a systematic approach to source allocation as proposed by Glascock et al (1998:22). Therefore, it was necessary to locate and sample all likely obsidian sources in the region. Ward's (1979:8-14) proposal that there was more than one obsidian source on Vanua Lava was the starting point for a surface survey of the whole island. In his fieldwork he collected obsidian nodules on beach deposits in the northwest of Vanua Lava (Losa Bay) and he suggested a primary obsidian deposit somewhere further uphill.

In 2006, a first visit to Ward's source location on Vanua Lava by Stuart Bedford and the author, and a short surface survey of the area detected neither secondary nor primary deposits. Based on the local information the area further north was also visited and a dense scatter of obsidian flakes covering the surface in the village of *Ambek*, about one hour (by foot) further north, was detected. The following short surface survey of the uphill area did not result in the detection of obsidian outcrops. Based on the assumption that coastal locations represent obsidian eroded from *in situ* deposits, it was therefore decided to inspect all creeks in the south, west and north of the island. The east of the islands was omitted as geological maps and short surface surveys showed that this side of the island is a recent alluvial plain, with only minor chances of eroded material visible on the surface. The same approach to a systematic survey of possible source distribution was chosen on the Island of Gaua where the whole length of the coastline was surveyed.

Whereas geological maps of the Islands Mota Lava, Pakea, Rah and Ureparapara displayed a low possibility in detecting additional sources of obsidian deposits, a short surface survey was also conducted to find potential archaeological sites for future research.

Site survey and survey record sheet

GPS was also used to determine the location of each accessed prehistoric and proto-historic site. Additional site dimensions, basic geomorphologic/geologic features, site character and examined surface concentration of artefacts was recorded (Appendix 1). When applicable, a more detailed analysis of stone artefacts onsite was conducted.

Surface Surveys and the detection of obsidian outcrops

The fieldwork period was centred on the Banks Islands of northern Vanuatu, which include eight of 13 islands of the TORBA Province. This research focus was chosen as previous research showed that the potential for primary obsidian deposits on these islands was most likely (Smith *et al.* 1977:184; Ward 1979:8-14).

The detection of obsidian outcrops was seriously impeded by the lack of knowledge in the local population about obsidian outcrops as expected by previous research. Ward (1979:3-18) described a widespread knowledge of obsidian use still existing within the older generation of the indigenous population. The author, however, only rarely encountered individuals who had any knowledge whatsoever of obsidian use or deposition. The word in the local language describing obsidian (black stone: *mevin* on Vanua Lava, *mivin* on Gaua, or *marvin* on Mota Lava / Rah) was already mentioned by Ward (1974) and was verified by this research.

One possible cause of this lack of knowledge is the heavy depopulation which occurred after European contact with the islands and the spread of diseases through colonisers, missionaries, whalers and other explorers arriving in the Islands (Scarr 1990). Additionally, sometimes – forced labour recruitment, so called black-birding, had a heavy toll on the demographic structure of the island communities (cf. Sand 2002). The author could only collect one mythological reference where the mythical creator deity used obsidian tools to create light. One further mythological reference concerning obsidian use is the tradition of making ‘thunder’ with obsidian. These traditions are always connected to special places of ‘magic’.

Furthermore, systematic surface surveys in densely vegetated tropical environments causes difficulties (Torrence *et al.* 1992:85). However, the surface survey confirmed the preliminary assumption that not all of the islands had the appropriate geological formations to produce obsidian as only Vanua Lava and Gaua have obsidian deposits exposed on the surface. Two source areas were identified: the *Ambek* area in north-western Vanua Lava and the *Namasari* region in northern Gaua (Figure 4.1 and Figure 4.2). After the locations of the two obsidian exposures were identified, a relatively large suite of fifteen samples from three different locations from Vanua Lava and fourteen samples from four different locations from Gaua was collected. Additionally, once the source areas were identified, the geographic extent of each source was determined using GPS (Table 4.1).

Ambek, north-western Vanua Lava

Previous geological surveys of the area described the primary petrographic context of this area as holocrystalline basaltic andesite flows, porphyritic andesites and latite andesites. These types are partly accompanied and partly covered by finely bedded pumice tuffs and pyroclastic cone deposits, which are found on the entire western part of the island (Ash *et al.* 1980; Barsdell *et al.* 1982). Approximately three kilometres inland from the village of *Ambek* (S13 44.610, E167 25.624) a two kilometres long ridge strikes in a roughly north-western direction and terminates at the top of the volcanic cone. At around 250m to 350m above current sea level on the southern side of the ridge a landslide scarp is well preserved (S13 44.422, E167 25.443). A 150m wide semicircle of ground has slipped 3-4m. Two test pits were dug at this general location to identify whether this landslide covered possible underlying primary deposits. The test pits revealed mixed weathered pyroclastic deposits of at least 1m to 1.5m depth. Springing from this area the *Bemon* River runs to the bay south of the village of *Ambek* and about half way down it cuts through surface deposits and unearths partly rolled pebbles of obsidian (Plate 1). Fifteen obsidian samples were collected from different locations of this secondary source from river cut profiles and within the river bed. It was attempted to sample all locations of possible obsidian outcrops. Additionally, samples were collected with different macroscopic attributes, such as colour, texture and cortex. A summary of locations and an assessment on the accessibility of different source locations is given in Table 4.1. In general, samples from the different locations have a lustrous black to grey-black appearance. Small white to beige-white sharp edged macroscopically visual phenocrysts with diameters of up to 0.8mm are embedded in the matrix and are the most prominent feature. Samples which displayed a banded texture were collected, however, these samples are not dominant in the collection. The cortex is heavily pitted and wherever the matrix is exposed it seems to weather to a more green-greyish colour.

The largest nodule has a diameter of over 15cm (Plate 1). In this general locality, obsidian of poor quality has been washed out by rainwater and stacked between big boulders of mixed fine grained types of andesitic rocks and iron-rich tuff. The larger samples (>15cm diameter) are heavily shattered and are therefore not useable for flaking. However, smaller nodules (~10cm diameter) of good quality for stone tool production were also observed and collected. Large plagioclase crystallisations, which occur as regularly distributed visible phenocrysts, indicate inhomogeneity at small scales. Most of the nodules show a rough cortex of irregular shape, sometimes containing air bubbles. Only occasional linear patterns were detected. The surveyed creek is only seasonally aquiferous in its upstream course. During the field season (in the dry season) the whole area was densely vegetated and only had limited accessibility. Therefore, an assessment of the exploitation capabilities of this exposure is difficult as no traces of human activity in this particular area were identified.

Namasari, northern Gaua

The source area in northern Gaua is slightly different to the one found on Vanua Lava. It was first documented by Graeme Ward in 1973 (Ward 1974). The main feature of the area is the *Namasari* River (Plate 1) which drains in a northern direction from close to the central crater rim (S14 15.158, E167 33.095) to the *Losa Lava* Bay (S14 12.676, E167 34.068). The area is densely dissected by several creeks which feed the main river bed of the *Namasari* River. These creeks cut through one extensive lava flow and unearth volcanic glass pebbles of different sizes in several locations (Plate 1). Whereas the volcanic groundmass is described as comparatively undifferentiated (Mallick & Ash 1975) with a small compositional range from olivine basalts to basic andesites, the lava flow itself consists (close to the surface) of a weathered iron rich tephra. One profile (S14 14.707, E167 33.193) has been found where this stratigraphy is exposed (Plate 1). The topsoil layer consists of a highly weathered iron-rich pyroclastic clay with rare basaltic cobbles. It is underlain by a pebble-rich clay with a high glass content. This is the main obsidian bearing layer at this location. It is situated ~2-3m beneath the surface and consists of mostly small glass nodules (diameter of not more than 5 to 8cm). This set of layers is located on top of basaltic and andesitic blocks, which can also be found eroding in the riverbed. The deposit is a classic pyroclastic flow, consisting of two parts: the *basal flow*, which contains larger, coarse boulders and rock fragments, and an *ash plume* above it. This structure results from turbulences between the flow and the overlying air (Hughes & Smith 1993). An XRD sample taken from this location (Figure

4.3) confirmed this interpretation of a highly weathered tephra, as only clay minerals were detected.

Six test pits were excavated along the lava formation and in most cases a small sample of volcanic glass was unearthed below 1.5m. Although no human activity in the form of mining (pitting or quarrying) was detected, good quality nodules with sizes up to 20cm in diameter were collected from riverbeds (Plate 1). Additionally, one site in this region was called '*mivin*' (local name for obsidian) (cf. Appendix 1), indicating that this area might have been perceived as a good source for this raw material.

The same approach to sample collection as in the Vanua Lava source was applied (see Table 4.1). At a macroscopic level, the first samples collected in the river mouth suggest the presence of at least two sub sources on Gaua. The collected samples are black to dark-grey in appearance. The surface is lustrous, but also rough, which suggests a low silicate content. In contrast to the clearly defined cortex found in the Vanua Lava samples, nodules displayed only weathered surfaces with no or very thin (< 0.5mm) rolled cortex. Samples collected were divided into opaque and non-opaque groups. However, one piece was found where both features were present. All samples show a very homogeneous matrix with no phenocrysts and are macroscopically easy to distinguish from pieces found on Vanua Lava.

Tongoa

Surface samples from a secondary beach deposit on Tongoa (Anthony Crawford, pers. comm.) were also analysed. These samples are black pitchstones with a large amount of phenocrysts. In their macroscopic appearance, these samples resemble the Vanua Lava obsidian, however, with a less glassy and rougher surface. The origin of this source might be connected with the Kuwea eruption in 1452 AD (Robin *et al.* 1994; Witter & Self 2007), which fragmented the southern part of the island of Epi, separated the islands Tongoa, Ewose, Valea, Tongariki and Buninga from each other and formed a large submarine caldera in this area (Hoffman 2006). The magnitude of this eruption is still under discussion, Witter and Self (2007:317) described this eruption as the largest producer of sulphate aerosols in the last seven centuries. Together with description of the eruption as a high silicate (dacitic) event, the collection of mostly black glass clasts in offshore samples becomes comprehensible (Carney reference in Hoffman 2006). The relatively late development of this pitchstone source makes an extensive utilisation of these rocks unlikely. However, it could determine an *ante-quem* date for the use of glassy rocks for the production of tools.

An assessment of the obsidian sources in Northern Vanuatu

Pyroclastic flows are a common source for obsidian worldwide. Associated with these events are welded tuffs and a blocky structure of the deposits. Hughes and Smith (1993) also mention the higher variation in these sources, as well as a linear pattern in the Zr/Sr distribution (cf. Bird *et al.* 1997; see Torrence, Neall *et al.* 2004 for a detailed discussion). This distribution pattern can be identified in both sub-sources of the Banks Islands group (Figure 4.4), which provides a second argument for higher variability in their composition, besides the beginning crystallisation in the Vanua Lava source. However, the origin in a pyroclastic flow is not necessarily the determining factor for a higher variability in the geochemical composition of a source. This is particularly evident in the Gaua source as depositional information suggests an origin in a pyroclastic flow, but the geochemical analysis identified a high homogeneity in the source.

Potential for source exploitation

The potential for source exploitation can be assessed through the availability and accessibility of deposits (Table 4.1, see also Torrence, Bonetti *et al.* 2004). For the Vanua Lava source it is assumed that the accessed source locations represent secondary deposits. Nodules of obsidian were collected from river beds where flakeable cobbles of different sizes were found. Only two locations with obsidian cobbles exposed on the surface were located, one approximately 3km inland from the beach and one in a coastal situation. Although access to the upland location was difficult due to the dense vegetation covering the whole area, these conditions were not necessarily the same in the past. Furthermore, the detection of a landslide covering the area might have impeded an assessment of a more accessible outcrop during fieldwork. Additional evidence for this hypothesis is provided by the large amounts of flaked artefacts in the general location of Ambek and further south in Lesa, which indicates exploitation of deposits larger than the ones identified during the fieldwork.

It has been discussed for the Gaua source that accessible obsidian outcrops were found spreading over an area of at least several km^2. Parts of the surveyed area were also covered by a landslide, further proof of the high rate of volcanic activity in the Banks Islands. Traces of mining activities, such as pits, could not be detected. It is suggested that similar to the Vanua Lava source past people collected water-rolled river cobbles that were exposed on the surface, as one settlement site, with its name suggesting a relationship to obsidian, was located close to the main river where flakeable cobbles were found exposed on the surface. In addition, a large amount of good quality obsidian nodules were also found in the coastal location of the Namasari river mouth.

Based on the current slightly different accessibility of the two obsidian sources, it is suggested that the Gaua source should occur as the dominant obsidian variant. However, as will be shown in the following it is not. Only in the earliest phase of human occupation during the Lapita period is it assumed that raw material from both sources were transported in similar amounts over similar distances in the Vanuatu Archipelago and beyond. Whether this pattern has natural causes, for example through a change of accessibility during different time periods, or represents a conscious decision of the local population to prefer one obsidian variant over the other will be discussed in Chapters 6 and 8.

Access restrictions

The identification of access restrictions in the artefact record is particularly difficult (Torrence 1986:169). Good indications for access restrictions would not derive from the lithic record, but rather from the general archaeology, like access restricting stone features. Centralised mining activities at a primary source might also imply access restrictions. This can be evaluated by the artefact record. For example, water-rolled surfaces on unworked nodules, cores and flakes would indicate the utilisation of secondary deposits. Another proxy for access restrictions recently discussed by Torrence (2004:116-117) in terms of the Pacific obsidian sources, is the habitation of the area. According to Torrence it is unlikely that direct access to a source would occur without establishing a relationship with the people living in the area.

Although extensive surface surveys were conducted in both source locations and abandoned earlier habitation sites were detected throughout the area, no access restricting structures were found. The high amount of water-rolled surfaces on cores and flakes suggest that secondary deposits in riverbeds and costal locations were the primary sources of the raw material. The wide-spread occurrence of obsidian nodules, especially at the Gaua source with several possible locations with good accessibility suggest that access restrictions were not significantly inhibiting exploitation of the raw material. Naturally, a lot more research has to be done to address the lack of archaeological knowledge about possible structures. For example, during the fieldwork season in 2006 the author examined access restricting 'taboo' signs made from perishable raw materials such as certain banana leaves or crossed sticks, which are honoured by the local community. Therefore, the preservation conditions in tropical environments might make a final assessment of these issues impossible.

Finally, in Chapter 7 the theoretical framework for the assessment of the value of this raw material will be discussed. Previous interpretations of obsidian as a "trade good" for the accumulation of wealth and power are criticised and interpretations presented showing that gift exchange might be the more likely explanation for the spatial distribution pattern of this raw material. In light of this interpretation, monopoly over this resource would have been unlikely as the value of the material would not have derived from the acquisition thereof, but instead through the social relations involved.

Surface surveys and the detection and excavation of archaeological sites

This section will describe the archaeological context of the newly analysed flaked lithic material discussed in this thesis. Several as yet unpublished stratigraphies from sites mainly in the Banks Islands will be presented and the age of the different layers discussed (where applicable and where sufficient radiocarbon dates are available)[1]. In

[1] In this research 21 sites from Vanuatu and adjacent islands are included. As the data available for these sites is very limited, this study will not focus on site formation processes and site function in general. A large percentage of the analysed assemblages are also surface collections where no information about the function of the site can be given. As this is the first comprehensive study of lithic material in Vanuatu it was necessary to assume that most of the assemblages, if not all of them, derive from similar site types. The only site with a particular specialised function is the Teouma burial site. However, even the artefacts from this site might originate to a large degree from an adjacent settlement/midden site (Bedford *et al*. 2009, Reepmeyer *et al*. in press). It is acknowledged that future, more comprehensive research on site function might result in new data showing the impact of site function on the production and distribution of lithic artefacts.

the fieldwork campaign during May-August 2006, several sites were accessed where no lithic material was found (for a description of these sites, see Appendix 1).

Vanua Lava

Ambek

After identifying the Ambek region as an area with high potential for detecting previous occupation, possibly of Lapita age, two test pits (1m by 1m each) were dug to analyse the stratigraphy of the area. Test pit one was excavated in the village area near a local house above the river (Plate 2). The site was chosen mainly because a single fairly rounded pot sherd was found on the surface. The first assumption was that it was possibly brought up to the surface by excavations from an adjacent house post. The sediment was trowelled only and excavated in 10cm spits (Plate 2).

Layer 1: 0-30cm below surface, is a darkish brown silty sediment with large amount of obsidian artefacts. Ten centimetres below the surface an oven structure was detected consisting of a circle of basalt pebbles (cf. Plate 2). This structure continues until about 25cm below surface. Obsidian artefacts are most numerous in the top 20cm of the stratigraphy with decreasing numbers at greater depth.

Layer 2: 30-70cm below surface has a similar colour to Layer one, but with an increasingly sandy texture. The number of artefacts sharply decreases in this layer.

Layer 3: below c.70cm only sterile soil with many water-rounded cobbles can be found. No pieces of obsidian were detected in this layer. The sedimentation is most likely fluvial, the Bemon River being nearby. The test pit was dug in one quarter square to 130cm under the surface but no change in sediment composition has been found.

Test pit two is located south of the river on higher ground close to the beach. The site was chosen because it showed signs of previous habitation (large boulders in alignment and obsidian artefacts found on the surface).

Layer 1: 0-20cm below surface. The upper part of the stratigraphy frequently revealed obsidian flakes, plain sherds and charcoal, along with frequent fine, eroded basalt cobbles. This composition continues until 60cm under the surface in a dark sand-rich soil.

Layer 2: at c.60cm below surface the sediment becomes increasingly tephra-rich. Most of the material found in the first 10cm of this layer is most probably derived from the upper layer and marks the earliest reoccupation of the site after the tephra fall. The tephra-rich matrix continues until 90cm below the surface. Obsidian (including a large core), shell, pottery (plain and rim) and charcoal are frequently to be found. The number of water-rounded cobbles increases in the lower parts of the test pit.

Layer 3: Below 90cm, the tephra becomes increasingly sandy and the number of artefacts decreases sharply.

Layer 4: At -100cm below surface only a sterile black sand deposit can be found. The test pit was dug until 155cm below the surface, but no artefacts were found.

Two radiocarbon dates were taken from Layer one at about 20cm below the surface and Layer two at about 90cm below the surface (Plate 2). Layer 1 can be dated to 374 ±30 BP (on charcoal)[2] and Layer 2 to 390 ±31 BP (on burnt nutshell)[3]. These dates were surprising, as a dynamic sedimentation history in the Banks Islands was previously not known. However, this data correlates well with information collected from the local population of recurring earthquakes and minor volcanic activity in the area. For future research, these results are important as we have to assume that earlier cultural deposits on the Banks Islands (at least on the larger islands of Vanua Lava and Gaua with still active volcanoes) might be buried under a large amounts of natural sediments, which makes detection of these sites difficult.

Of general archaeological interest is the detection of ceramics in the upper layers of test pit two. In contrast to Ward's (1979) assumption of a cessation of ceramic production in the Banks Islands at approximately 2000 BP, the use of ceramics until sub-recent times (600 years ago and later, Bedford & Spriggs 2008:107) was substantiated. Stuart

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[2] Date from Waikato Wk-19647, conventional radiocarbon dates, cf. Stuiver and Polach 1977. Calibrated with OxCal v3.10 Bronk Ramsey (2005).

[3] Date from Waikato Wk-19648, conventional radiocarbon dates, cf. Stuiver and Polach 1977. Calibrated with OxCal v3.10 Bronk Ramsey (2005).

Bedford's (pers. comm.) assessment of the decorated pottery excavated at Ambek and additional pieces found during a short survey on the Island of Pakea suggest a regional diversification beginning immediately after the Lapita period.

Lesa

Lesa village, located approximately one hour (by foot) south of Ambek, reveals a similar scatter of obsidian artefacts on the surface. Directly to the south runs the PeLav River which is one of the major rivers on Vanua Lava. Eroded obsidian artefacts in the riverbed and unworked nodules of obsidian led to the assumption that the source area for this material is somewhere upriver. Extensive surface survey of this area could not reveal any more artefacts in the riverbed or adjacent sedimentation. It is therefore concluded that the accumulation of obsidian artefacts in the village is anthropogenic and not derived from alluvial deposition of river sediments.

One concentration of artefacts in the central village area was detected, and this location was chosen for a test pit (one square metre). Surprisingly, the stratigraphy revealed a much shallower sequence than Ambek. Similar to Ambek, Layer one is a silty sediment tephra with a large amount of obsidian artefacts. However, only the first 20cm shows any sign of habitation (Plate 3), at 100cm below the surface a sterile darkish brown silty sediment with a large amount of water-rolled cobbles was observed, and in the lower parts of the stratigraphy increasingly sandy texture. This lower, sterile material is most probably associated with alluvial sedimentation of the adjacent PeLav River.

Movono

A surface scatter of obsidian artefacts was detected on the western side of a plateau approximately 30 minutes uphill from the village of Vetiboso (Plate 3). The artefacts were found mainly in an erosion gully along a coconut plantation fence line. Obsidian artefacts are presumably eroding out of top soil deposits only. Adjacent to the surface scatter is an earth mound: possibly a midden deposit. One test pit was dug to examine the stratigraphy and sample this area, but it revealed no anthropogenic deposition of any material.

Ureparapara

Lepewuala

The area of Lepewuala (Plate 4) is situated on the south-western side of the large Dives Bay, west of the central village and directly adjacent to a small creek. At about 100m from the beach, a scatter of obsidian artefacts (20 pieces / 100m^2) was found. Several artefacts have a rolled surface and most probably eroded from the uphill village area. Although the artefacts show a similar texture to the obsidian found from Vanua Lava, the pieces also display a greenish gloss, which was first interpreted as probably deriving form a different source. A survey of the uphill settlement site (*Nakamal*) (UR1B-C) revealed no artefacts on the surface; several test pits dug close to the stone structure did not contain any artefacts.

Yetow

The area of Yetow (Plate 4) is situated on the eastern most side of Ureparapara on the northern part of the crater rim. The site is situated on a steep slope facing northeast and is covered with a large number of basalt blocks and a loose scatter of obsidian artefacts. It is a series of stone structures (old Nakamals), the exact age could not be defined. However, in association with one Nakamal, one bottle of European origin has been found (most probably 18th or 19th century). Obsidian artefacts found on this site possibly derived from Vanua Lava, and did not show the greenish gloss found on artefacts from the central bay. Several artefacts seem to be of better quality; one or two pieces are made from bottle glass.

Gaua / Santa Maria

Lebunga (GA 14C)

Lebunga in the northeast of Gaua is currently used as a communal garden area (Plate 5). The plateau covers an area of about 1 km^2, and is situated about 200 meters above current sea level. Sediment deposition is heavily disturbed by recent gardening activities. At several locations stone structures can be found which were identified as Nakamals from previous settlement. Occasionally, a small scatter of obsidian artefacts was detected surrounding these structures, but no concentration of artefacts were found.

Approximately 300m east of the stone structures (Plate 5), at the eastern border of the plateau, a series of four midden deposits associated with a dense scatter of basalt and tuff fire-cracked rocks, as well as obsidian artefacts were found. The concentration of artefacts covers an area of about 200m^2. Four small test pits were dug in the area, but they revealed of more then 10cm of mostly disturbed humus. Directly below this humus deposit, layers of undisturbed, sterile tephra were found. No anthropogenic features were detected. As the artefacts were only found in the disturbed top soil layers of the garden area and are therefore not in situ an extensive surface collection was conducted. The collected material is of Gaua origin and consists mostly of large flakes, cores and shatter.

Tarasag

The site is located in the old part of the village of Tarasag (Plate 5). Similar to TP1 in Ambek this site was chosen for excavation, because a single ceramic fragment in association with bottle glass flakes was found on the surface in an former open area of the village. This area is surrounded by several stone walls marking previous inhabitation. One 1 by 1m test pit was excavated until sterile deposits were reached. The sediment was trowelled only and excavated in 10cm spits (Plate 5).

Layer 1: 0-48cm below surface. This is a dark grey and brownish silty sediment, very disturbed by bioturbation (mainly plant roots). Frequently basalt pebbles can be found. Anthropogenic findings in this layer include several burnt animal bones physically associated with several pieces of obsidian. Additionally, one piece of flaked bottle glass at about 30cm below the surface was observed together with obsidian flakes.

Layer 2: 48-60cm below surface. Tephra deposits continue below 48cm under the surface, but the bioturbation becomes less pronounced; and similarly basalt cobbles are encountered less often. At about 55cm below surface, dark grey features in the south-western part of the square were detected. These features included several fire-cracked rocks and are interpreted as oven structures. They were excavated separately until 68cm below the surface. However, no artefacts were found in this feature.

Layer 3: below 60cm. This layer is a sterile, yellow-brown silty tephra. Only sparse bioturbations were detected and the oven structure does not continue below 68cm. The test pit was dug to 90cm below the surface, but no further artefacts were found.

One radiocarbon date was taken from Layer 1 at about 40cm below the surface (Plate 5). It produced a modern date of 117.8 ±0.7 %M (on charcoal)[4].

Mota Lava

Based on surveys conducted in the mid 1990s by Jean-Christophe Galipaud (pers. comm.), Mota Lava was identified as an island with a high potential to preserve Lapita aged sites. Although Galipaud himself detected no Lapita sites on Mota Lava, two surface surveys of the western part of the island and several excavated test pits in 2006 showed that an abundance of pot sherds and obsidian artefacts were found on the surface and in deposits below. Therefore, Stuart Bedford and Matthew Spriggs conducted a field season in 2007 in which the general area of the 2006 test excavation was examined in more detail and several test pits were excavated to analyse the stratigraphy of the western part of the island.

ML-Lequesdewen

At a distance of approximately 200m from the western shoreline, several concentrations of ceramics were detected on the surface in 2006. The concentrations are located on an uplifted reef deposit approximately 5-8m above current sea level (Plate 6). One test pit measuring 1 by 1m was excavated in 2006 in the centre of a raised area. The site is an area if current habitation, and the spoil heaps of previously excavated material by the local population displayed fragments of pottery with large amounts of shell. Most probably associated obsidian flakes were found in the wider surface area in the surrounding the site.

Layer 1: 0-30cm below surface is a grey brown midden deposit which displays frequent obsidian artefacts and pot sherds associated with a large amount of shell.

[4] Date from Waikato Wk-21681, conventional radiocarbon dates, cf. Stuiver and Polach 1977. Calibrated with OxCal v3.10 Bronk Ramsey (2005).

Layer 2: 30-50cm below surface, is a beach deposit consisting of a yellow sand, and might be deposited by tropical cyclones. No artefacts were found in this deposit.

Layer 3: 50-90cm below surface, below 50 cm the sand deposits are increasingly grey in colour, and frequently a concentration of shell associated with obsidian artefacts can be found around 70-80cm, followed by more frequent pottery fragments at 80-90cm.

Layer 4: 90-125cm below surface, is a beach deposit of sterile white sand with frequent coral. It is assumed that these sediments are the undisturbed deposits laid down before initial occupation. Below 115cm increasing coral cobbles can be found.

Several separate sondages in a more extensive fieldwork program undertaken by Stuart Bedford and Matthew Spriggs in 2007 confirmed this stratigraphy. During the field work season in 2007, five radiocarbon dates were taken from three test pits. They confirmed an age for Layer 3 deposits of 2900 - 2400 BP (Table 4.2), which defines the initial colonisation of the island as occurring during the Lapita period (Stuart Bedford and Matthew Spriggs, pers. comm.).

ML-Saywoume

Situated approximately 700m inland from the western shore several concentrations of ceramic fragments associated with a scarce surface scatter of obsidian flakes were found. The area is a recent garden where additionally a series of small mounds consisting of shell and basalt fragments (fire-cracked rocks) was detected. The pottery found on the surface is very eroded, most probably because of garden activities. One mound in the centre of the concentration of fire-cracked rocks and ceramics was excavated in a 1 by 1m test pit.

Layer 1a: to 20cm below surface, consists of a dark grey tephra with frequent fire-cracked rocks and rounded potsherds. The soil is more silty in the lower parts.

Layer 1b: 20-55cm below surface, is a similar silty sediment, but increasingly brown coloured, with frequent bioturbations (plant roots) and increasing amounts of pot sherds, shell, fire-cracked rocks and coral. Obsidian artefacts are only rarely encountered.

Layer 2: 55-70cm below surface, is a brown tephra with a higher sand content. No ceramic fragments and only occasional shell and coral were found, associated with one obsidian artefact.

Layer 3: 70-110cm below surface, consist of yellow sand deposits. Several features were found which continued into these deposits, especially in the north-eastern part of the test pit. The excavated sediment of these features seemed to be burnt and included a large amount of fire-cracked rocks and burnt shell. Below 95cm under the surface, no burnt sediment can be found, the deposits are increasingly silty sand with frequent coral, and no artefacts were encountered.

Two radiocarbon dates were taken from Layer 1b at about 30cm below the surface and from Layer 2 in the transition zone to Layer 3 at about 70cm below the surface (Plate 6). Layer 1 was dated to 1862 ±41 BP (on marine shell)[5] and Layer 2 to 2078 ±35 BP (on marine shell)[6].

Archaeological assemblages excavated by fellow researchers and included in the comparison data set

TORBA province

Torres Islands

The Torres Islands are the northernmost located island group of Vanuatu. They lie between the Banks Islands and the Santa Cruz Islands of the southern Solomons, at a distance of 95km from Vanua Lava, 130km from Gaua and 170km from Vanikoro, Reef / Santa Cruz Islands. The Island group consists of four main islands, from north to south: Hiw, Tegua, Loh and Toga. Surface surveys conducted by Galipaud in 1996-1998 (Galipaud 1998) on Tegua and Toga resulted in the detection of several archaeological sites with an occupation record of approximately 2500 years. A test pitting program conducted in 1996 detected obsidian artefacts in one site (Litetona) on the northwest coast of Tegua. Eight artefacts made from obsidian (*de verre volcanique*)

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[5] Date from Waikato Wk- 21683, conventional radiocarbon dates, cf. Stuiver and Polach 1977. Calibrated with OxCal v3.10 Bronk Ramsey (2005).
[6] Date from Waikato Wk- 21684, conventional radiocarbon dates, cf. Stuiver and Polach 1977. Calibrated with OxCal v3.10 Bronk Ramsey (2005).

were found on the surface of the site associated with flakes from other raw materials, and mainly plainware and, according to Galipaud, Mangaasi style pottery (Galipaud 1998:161-163).

Toga

During the field season of 1996, several test pits were excavated by Galipaud on the southernmost island of the Torres Islands, Toga. During a surface survey of the island concentrations of obsidian artefacts and shell were detected in the village area of *TI-Kurvot* on the southeast side of the Island. Several test pits were excavated at a distance of 100m from the village. The stratigraphy of the sondages, described in detail by Galipaud (1998:166, Figure 7), reveals a series of grey-brown sand and dark brown sandy soils, in several test pits broken up by a 10-20cm thick layer of white sand most probably deposited from a tropical cyclone. The stratigraphy is covered by a 20-40cm below surface thick layer of dark brown humus. Obsidian artefacts, ceramic fragments and shell were found frequently throughout the stratigraphy. Particularly at about 30cm below the surface a rich layer of cultural material were detected. The white sand deposits are mostly sterile and followed by grey silty sand at about 75cm below surface, which contains a large amount of cultural material, especially pottery fragments and faunal remains. This series of brown grey sands and dark brown sandy-soils can be detected until approximately 110cm below the surface and overlies the sterile sediments deposited before initial occupation of the site. Unfortunately, the cultural layers of the main test pit 1 could not be dated. However, two radiocarbon dates (on charcoal) were taken from adjacent test pit 3 where a similar stratigraphy as described was detected. The layers predating sterile sand deposits in the middle of the sequence produce in an age of 2460 ±40 BP (Galipaud 1998:167).

TI-Kurvot

In 1998, Galipaud returned to the village of TI-Kurvot to confirm the stratigraphy excavated in 1996. The stratigraphy of the excavated site is not yet published, but confirms the results from the 1996 test pitting program. In 1998, two 1m by 1m excavations were conducted close to the test pits analysed in 1996.

The stratigraphy can be separated into six different layers (Plate 7). Layer 1: 0-25cm below surface, is a dark brown, humus-rich sand and correlates to Spit 1 and 2 of the 1996 excavations. It is followed by Layer 2: 25-~50cm below surface, which is a brown-grey sand previously described as Spit 3. Layer 3: 50-100cm below surface, is the sterile white sand deposit and correlates to Spit 4. Layer 4: 100-120cm below surface, is a mottled grey sand, similar to Spit 5. Layer 5: (a) 120-130cm below surface, is a silty brown sand with (b) a lense of banded light brown sand at the bottom of the layer, detectable only in parts of the profile. Layer 6: 130-160cm below surface, consists of a grey-brown sand. Layer 5 and 6 were previously summarised as Spit 6 and the series of Layers 4 to 6 can be dated to approximately 2450 BP.

SANMA province

Santo

Port Olry

Bedford and Spriggs (2008) conducted a fieldwork campaign in 2006 focusing on Big Bay and the northeast of the island of Santo. Several excavated test pits in the area of Port Olry resulted in the detection of Lapita-aged layers with shell impressed ceramics and plainware. Associated with these findings are obsidian artefacts mainly at depths of 20-80cm. Four radiocarbon dates dated this layer to around 2750 - 2350 BP (Bedford & Spriggs 2008:104, Table 1). These dates were confirmed by the ceramic typology, which showed typical late Lapita designs.

Matantas

The village of Matantas is situated in the south-eastern part of Big Bay, Santo. During the same field season, Lapita-aged layers were identified in the village area. Similar to the site of Port Olry shell impressed ceramics and plainware as well as occasional dentate-stamped sherds were found in the Lapita Layers, again associated with several obsidian artefacts. In addition a series of chert, basalt and quartz flakes were found.

MALAMPA province

Malakula

Uripiv (Vilavi) and Serser (Wala)

Excavations by Stuart Bedford of several test pits during 2001-2002 resulted in the detection of a well-defined Lapita layer beneath a silty sediment (in some parts beneath a sand deposits from tropical cyclones) at a minimum of 50cm under the surface (Bedford 2003:154; Horrocks & Bedford 2005:68). The site is situated approximately 50m from the shore at about 6-7m above current sea-level on the western side of the islands. Although the geological history of Malakula is very variable, with the main island most probably uplifting at a faster pace than the outer islands, these islands were habitable during the Lapita period (Bedford 2003:154). Lapita ceramics were found in the earlier layers dated to c.3000 BP (Table 4.2). However, no obsidian was detected in these layers. The only obsidian artefact associated with this site was one piece found on the surface. The site Serser on Wala was found in a similar location as Uripiv and dentate-stamped Lapita pottery and other midden remains were excavated on uplifted reef deposits (Bedford 2003).

Vao

In 2003-2004 Bedford (2003:153; 2006a:547-549) excavated several test pits and made three larger excavations, about 3m by 2m in size, on the western side of the small island of Vao off the east coast of the main island of Malakula. The excavations were conducted in 10cm spits and the sediment was dry sieved. Lapita pottery was excavated from about 140cm below the surface and in the transition zone between the "concentrated Lapita cultural horizon" (Bedford 2006a:549, Figure 4) and the underlying soft sterile sand. Obsidian artefacts were found associated with ceramic fragments only in the Lapita layer. The Lapita layer was dated to 2900 - 2700 BP.

SHEFA province

Epi

Mafilau

In 2006, Bedford and Spriggs (2008) excavated a large mound feature located at the village of Mafilau on the west Coast of Epi island. The stratigraphy of more than 4.5m was dated to about 2800 - 2500 BP (Bedford & Spriggs 2008:104, Table 1). Although the ceramics show only "partial" similarities to the ceramics typical for the Erueti period on Efate, some distinctive shell artefacts were also found. Although the stratigraphy was dated to the Erueti phase, pottery decorated with Mangaasi-style motifs was found on the surface close to the site, possibly indicating continuous habitation into this period (Bedford & Spriggs 2008:106).

Efate

North Efate sites

The site of EF-Arapus was excavated during four field seasons 1999, 2001, 2002 and 2003 (Bedford 2006b; Bedford & Spriggs 2000; Spriggs & Bedford 2001). Bedford (2006b:44-48) recently summarised these excavations and their stratigraphy. The main outcome of the extensive test pitting program was the detection of an additional layer of settlement predating the previously known Mangaasi horizon to the northeast (Bedford 2000b). Situated approximately 150m from the shore, the site covers an area of at least 125m by 15m and overlaps only in the north-northwest part (in direction of the shoreline) with later Erueti deposits (Bedford 2006b:41, Figure 3.9). The EF-Arapus layer have been dated to c.2900 - 2800 BP with the following Erueti Layer at 2800 - 2200 BP (Bedford 2006b:47). Although an extensive amount of cultural material, mainly ceramic fragments, faunal remains and marine shells, was excavated, no obsidian was found. However, several flaked artefacts made from pitchstone, chert, basalt and quartz were analysed.

EF-Teouma

Only a short summary of the already detailed description (Bedford et al. 2004; 2006; in press) of the stratigraphy of the site will be given here. The Lapita aged cemetery site EF-Teouma is situated on an uplifted reef terrace approximately 800m inland from the current shoreline. Shortly before initial human settlement, a tephra deposit levelled out the reef terrace so that burials had to be dug in the tephra into recesses of the reef bedrock, as well as into upper beach deposits immediately adjacent. There is some evidence, still under investigation, for a contemporary small-scale settlement focus immediately to the east of the cemetery area. After the initial period of cemetery use, there was a short hiatus in use of the site. Settlement deposits of up to one metre were later deposited on top of the burials, seemingly after the earlier function of the site was forgotten or discounted.

Since the discovery of the EF-Teouma site in 2004, four field seasons have resulted in the excavation of $275m^2$. The first three field seasons concentrated largely on the cemetery area to recover information from areas that had been damaged by quarrying but not completely destroyed. Layer discrimination in the cemetery area is difficult as burial in-fills are generally indistinguishable from the unweathered tephra into which they were dug. The overlying occupation horizon is, in contrast, a very distinctive dark grey midden/tephra deposit with only a thin transition zone between the two. The earliest use of the site was probably around 3100 - 3000 BP (Layer 3) with an Erueti phase occupation phase commencing after about 2800 BP (Layer 2) (Bedford et al 2006:818). The site was abandoned no later than 2500 BP as no late Erueti (c.2500 - 2300 BP) pottery has been recovered. Renewed research beginning in 2008, which focuses on undisturbed areas to the southeast, should provide a more detailed picture of the overall stratigraphy of the site.

TAFEA province

Erromango

The small set of flaked stone artefacts from the island of Erromango were found at the site of Ponamla (Bedford 2006b:32-35; Spriggs 1999) where initial occupation was dated to around 2500 BP. The site was identified as a large settlement site with intensive cooking activities (Spriggs 1999:324-325). Almost all artefacts with unclear physical attributes were defined as natural and not analysed in this thesis. Several artefacts found on the surface had an unclear temporal context and were included in the later phases of occupation of this island.

An assessment of excavated sites in Vanuatu

Much focus of archaeological research of the past decade has been on detecting Lapita-aged sites in Vanuatu. This gap in research was closed with the detection of now more than 21 archaeological sites (on Erromango, Efate, Malakula, Malo, Aore, Tutuba, Mafea Island and most recently on Mota Lava in the Banks Islands) (Bedford & Spriggs 2008:103). The ceramic chronology of the post-Lapita period in Central Vanuatu has also become much clearer through excavations by Bedford and Spriggs on Efate, Malakula, Epi and Santo (Bedford 2000b, 2003, 2006b, 2006a; Bedford & Clark 2001; Bedford *et al.* 2004; Bedford & Spriggs 2000, 2002, 2008; Spriggs 1982; Spriggs & Bedford 2001).

Although the post-Lapita cultural sequences in Central and South Vanuatu can now be described as “robust” (Bedford & Spriggs 2008:107), much work remains to be done in Northern Vanuatu. The current hypothesis of Bedford and Spriggs (Bedford & Spriggs 2008:107) on the evolution of cultural sequence in Vanuatu is that the post-Lapita period is strongly influenced by regional diversification starting in immediately post-Lapita times. Therefore, the ceramic sequence has to be divided into a southern, central, northern and far northern region (Bedford & Spriggs 2008:107).

Conclusion

This chapter has given a detailed assessment of the location and geological origins of the two obsidian sources in the Banks Islands (as well as additional information on a pitchstone source on the island of Tongoa). Furthermore, the surface survey on several islands near Vanua Lava and Gaua provided no indication of the existence of further obsidian outcrops in the general area of Northern Vanuatu. An initial assessment of the potential for human exploitation and possible access restriction was also made. This information will now be validated in the next chapter through detailed geochemical analysis. In addition to the obsidian sources accessed in the fieldwork period in 2006, a description of the archaeological setting of all sites in Vanuatu considered in this thesis has been given in this chapter.

- Chapter 5 -

5. Results: Geochemical characterisation of sources and artefacts

Introduction

Since the beginning of geochemical research in the late 1960s, the analysis of obsidian sources for provenance studies in the Pacific has seen the application of a wide range of different analytical methods (Ambrose 1976; Ambrose & Duerden 1982; Ambrose, Duerden *et al.* 1981; Bird *et al.* 1981; Duerden *et al.* 1987; Sheppard 1989; Summerhayes *et al.* 1998; Wall 1976; Ward 1979). With the improvement of the instrumentation starting from X-ray Fluorescence analysis (XRF) and Neutron Activation Analysis (NAA) Particle Induced X-ray Emission – Proton Induced Gamma-ray Emission (PIXE-PIGME, further description see below) quickly became the most widespread used method in sourcing obsidian artefacts in the Pacific (Ambrose 1978; Ambrose & Duerden 1982; Duerden *et al.* 1987; Fullagar *et al.* 1989; Green 1987; Leach & Davidson 1981).

Whereas excellent results were achieved by using X-ray Fluorescence analysis (XRF) for the bulk analysis of major elements and several trace elements and Neutron Activation Analysis (NAA) for trace elements, it was especially the possibility of the non-destructive application in particular which made PIXE-PIGME the method of choice for chemical studies of archaeological artefacts in the Pacific. This did not change until recently with the development of a portable XRF apparatus (Sheppard & Lin 2008; Sheppard *et al.* in press). The future will show if this method is precise enough to replace PIXE-PIGME as a non destructive method. Since the late 1990s Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES) and later Inductively Coupled Plasma – Mass Spectrometry (ICPMS) became popular due to their superior precision and accuracy in isotopic measurement as well as the wide range of elements which can be analysed by these methods (Falkner *et al.* 1995; Jarvis *et al.* 1992; Koppenaal *et al.* 2004; Speakman & Neff 2005b).

Most of the above mentioned methods, apart from PIXE-PIGME, need a more or less complicated sample preparation. XRF, NAA, ICP-AES and other analytical methods (like AAS, Atomic Absorption Spectrometry or OES, Optical Emission Spectrometry) require the samples to be in the form of a powder or in solution. For this kind of preparation, a sufficiently large amount of sample material is needed. As some of the artefacts found on archaeological sites in the Pacific are rather small (some <1cm^2), applying these methods would leads to the complete destruction of the artefact. The development of laser ablation as an injection method radically reduced the amount of sample material needed.

In this study Laser Ablation – Inductively Couple Plasma – Mass Spectrometry (LA-ICPMS) was employed. Speakman and Neff (2005a:10) have recently described the "tremendous potential" of LA-ICPMS for providing chemical characterisations of archaeological materials. In connection with a Scanning Electron Microscope (SEM) coupled with an Energy Dispersive X-ray analysis (EDXA) for the measurement of major elements and the calibration of ICPMS, this method is able to analyse almost every element of the periodic table with a precision of <5% (>2σ). Besides the large suite of elements measured with this method, arguments for using this method include:

1. minimal sample preparation,
2. speed of the analysis (>70 samples per day),
3. no size restriction on artefacts (a problem especially with PIXE-PIGME, see below), and
4. low cost.

To be able to compare the newly collected material with the results of extensive previous research, especially for the obsidian sources of New Guinea, the source samples subjected to ICPMS were also reanalysed by PIXE-PIGME at ANSTO.

This chapter discusses the results of the EDXA-SEM and LA-ICPMS analysis conducted on 510 source samples and artefacts from the Western Pacific (detailed counts of isotopes are only mentioned in the text where necessary; the complete dataset can be found in Appendix 2). The chapter is structured such that the comparison database from selected obsidian sources in the Western Pacific is discussed first, followed by the description of analysed artefacts from Northern Vanuatu and Central

Vanuatu and adjacent regions in the research area and their implications for the total assemblage.

Approaches to the geochemical data

In the previous chapters, the research design and broader questions to be answered with this work were discussed. Although modelling social interaction in the Western Pacific is the ultimate aim of this thesis, a sound database for the more theoretical abstract questions outlined in Chapters 2 and 8 is needed.

Aim 1: Define the intra-source variation in the geochemical composition of each Northern Vanuatu obsidian source and assess whether additional unknown obsidian sources from the general area of Vanuatu were used in the past.

Previous research indicates that BI-obsidians were distributed over distances of up to 600km (Best 1984; Green 1987; Hedrick 1980; Kirch & Yen 1982; Leach 1985). However, the analysis of the spatial distribution was based on only a small number of source samples (Ambrose 1976; Ward 1979). Additionally, the database was interpreted as incomplete because of the unusually low amounts of Rb in two samples from the site of Pakea (Duerden *et al.* 1987; Smith *et al.* 1977). In addition, Ward (1979) suggested the possibility of the existence of additional obsidian outcrops, based on information from the local community.

The extensive research on fingerprinting obsidian sources in West New Britain proves the usefulness of a detailed geochemical database, for a sound assessment of utilisation and distribution of raw material become possible. This defines the first aim of the geochemical analysis: to attain the same high standard of source characterisation as already developed for the Admiralty Islands and West New Britain in the Bismarck Archipelago of PNG.

Aim 2: Investigate the correlation between the different methods of geochemical research of LA-ICPMS and PIXE-PIGME.

Until recently, PIXE-PIGME was the only analytical method in which whole artefacts have been non-destructively analysed (cf. Sheppard & Lin 2008). Furthermore, PIXE-PIGME has been the method of choice for much of the long history of geochemical research on fingerprinting obsidian sources in the Pacific, in the last three decades (Ambrose & Duerden 1982; Ambrose, Duerden *et al.* 1981; Bird 1996; Bird *et al.* 1997; Duerden *et al.* 1987; Green 1987; Leach & Davidson 1981; Summerhayes 2009; Summerhayes *et al.* 1998; Summerhayes *et al.* 1993; Torrence *et al.* 1999; Torrence *et al.* 1992; Torrence *et al.* 1996; White & Harris 1997; White *et al.* 2006). This produced a database of several thousand samples, collected from both sources and archaeological contexts, which achieved an unambiguous discrimination of sources, especially in Near Oceania. A second necessity for comparison was the re-analysis of Kirch and Yen's (1982) Tikopia collection. This collection stored in the Bishop Museum, Hawaii, could not be examined using a destructive technique.

Aim 3: Examine the range of obsidian varieties transported and utilised in Vanuatu.

Two questions are posed: (a) Do archaeological sites excavated in the known range of the Banks Islands distribution contain artefacts which can not be unambiguously sourced to one of the Vanuatu obsidian sources and (b) if these artefacts did not origin in Vanuatu, where do they come from?

Previous research on obsidian artefacts in Vanuatu has shown that at least four different sources of obsidian were utilised in the past: Kutau/Bao, Admiralty Islands, Vanua Lava and Gaua (Ambrose 1976; Galipaud 2000; Hedrick 1980; Ward 1979). For the analysis of past human contacts and exchange networks an unambiguous provenance of artefacts has to be established.

Methodology

Sampling method

Sampling methods used for the geochemical analysis included a mixture of probabilistic and non-probabilistic sampling. Due to the destructive technique used in this work, the technological analyses of the assemblage were completed first. After assessing the complete assemblage macroscopically, distinctive pieces detected in the technological analysis were selected, as well as a random sample of 1%-5% of the assemblage.

Sample preparation

The invention of laser ablation radically reduced sample preparation. However, several requirements for the analysis by LA-ICPMS and EDXA-SEM must still be met:

1. a flat surface is preferable, although not a necessity,
2. since the analytical chamber of the SEM consists of a vacuum to maximise the amount of time spent to analyse several samples, changing sample-mounts should be minimised. It is possible to place a whole artefact into the vacuum chamber of the microscope, but for the bulk analysis of artefacts this technique is not applicable,
3. the same is imperative for the ablation chamber of the ICPMS. The chamber has light excess pressure of a helium/argon gas mix. After opening of the chamber a stable atmosphere lacking oxygen has to re-established.

In line with to these prerequisites samples were washed in an ultra-sonic bath for 10 minutes and then cut with a 200µm diamond wire saw to minimise material loss of the sample. The fluid which moisturises the wire while sectioning the sample was a mixture of plain water and detergent. An approximately $1mm^2$ piece was sectioned from each sample and bedded in an epoxy resin. The constructed mount can carry up to 40 samples. Excess resin was removed from the sample mount using sandpaper. Finally the mount was polished. For the EDX analysis the samples were coated with a 30nm thick carbon film to avoid charging.

Energy Dispersive X-ray Analysis with Scanning Electron Microscopy (EDXA-SEM)

The method of Energy Dispersive X-ray Analysis - Scanning Electron Microscopy (EDXA-SEM) combines two different analytical methods in one machine; an X-ray measuring device and an electron microscope. The source for both methods is a concentrated electron-beam, emitted from a tungsten filament cathode, which hits the sample. This beam reacts with the sample and emits electrons which are detected by a scintillator-photomultiplier which produces a so-called secondary electron image (Reed 2005). The same concentrated electron-beam, which is the source of the secondary electron image, reacts with the sample and emits X-rays (electromagnetic radiation). The emitted photons (or light waves) have different energy levels which can be measured through a semiconductor. Each arrival of a photon creates a pulse on the conductor. Different elements create different pulse outputs and can thus be distinguished and measured. This x-ray spectrum allows quantitative analysis of element spectra to a detection limit of about 50ppm and therefore is useful for the analysis of major element composition (Goldstein *et al.* 1992; Tykot 2004). The energy level rates from 0 to 15 keV.

In this study, a JEOL JSM6400 Scanning Electron Microscope with an Oxford ISIS Energy-Dispersive X-ray Analyser, which has an ATW window (especially sensitive for light elements), at the ANU Electron Microscopy Unit was used. For processing the collected data, Oxford instruments Link ISIS 3.3 software was employed. Due to the detected inhomogeneity of the Vanua Lava source a decision was made to analyse the same area with EDXA as has been used in LA-ICPMS (86µm and 105µm after a new ablation chamber was installed). Exciting an area of more than 200µm with EDXA can result in a loss of precision (Reed 2005, Wal Ambrose pers. comm.). On the other hand a higher resolution in using EDXA could produce different results to the ablated area with LA-ICPMS. Therefore a resolution of x1000 was chosen.

Calibration was conducted to the NIST612 standard and to an additional arbitrary ANU2000 standard, which is a high-quality, homogenous obsidian from the Wekwok sub-source on Lou, Admiralty Islands (Ambrose, Duerden *et al.* 1981; Duerden *et al.* 1987). The x-ray wavelengths were measured for 100 seconds. In total four runs were accomplished to limit possible variation in the analysis. Major elements (Pollard *et al.* 2007) analysed through this method include Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn and Fe. The analysis showed that P, S and Cl gave inconsistent values in the different runs and therefore they were excluded from later analyses. The mean of the four runs was used. The major advantage of this method is that microscopic crystals (microphenocrysts) in the material, which can interfere with results, are also measured.

Laser Ablation – Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS)

Inductively Coupled Plasma Mass Spectrometry (ICPMS) was developed in the late 1980s as a method to chemically characterise solid rocks (Koppenaal *et al.* 2004). Its application has steadily increased since this time and it is now well established in Earth Sciences research (Falkner *et al.* 1995). ICPMS has also been successfully applied in archaeology since the early 1990s (Speakman & Neff 2005b). Its commercialisation and the development of laser ablation (the use of a laser to ablate small quantities of material from the sample) as an alternative to sample induction in particular has made it a fast, reasonably inexpensive and almost non-destructive technique and it quickly became adapted to a wide range of archaeological applications (Bugoi *et al.* 2004; Gratuze 1999).

Basic configuration for this analytical method includes:

1. a laser ablation system,

2. an ion source,

3. a mass spectrometer (Jarvis *et al.* 1992).

The laser ablation system consists of an UV laser and the ablation chamber (Longerich *et al.* 1996). The ablation chamber was specifically designed so that less gas is needed to transport the ablated material to the ICPMS (Eggins *et al.* 1998). The carrier gas used at the Research School of Earth Science laboratory at the ANU (conventional ICPMS) is a helium/argon mix. Digital imaging identifies the position where the ablation takes place.

The ion source is an argon plasma torch (7000 K) at atmospheric pressure. The sample material, which is vaporised through the ablation process and mixed with the carrier-gas, enters as an aerosol into the plasma where it is broken down into atoms. At the temperatures prevailing in the plasma the chemical elements are ionized, which means each atom loses its most loosely-bound electron to form a singly charged ion. In this way, charged ions are accelerated through a quadrupole Mass Analyser in a vacuum at room temperature to an elemental detector. During measurement time, the radio frequency in which the four rods of the Mass Analyser are electrically charged is changed continuously. Due to their different atomic mass and charge, ions are more or less deflected by the electromagnetic field emanating from these rods so that only ions of a certain mass-to-charge ratio will reach the detector for a given ratio of voltages.

This allows the scanning of a whole sample by varying the voltages, or the focus on a particular ion for a more detailed analysis (for further reading, cf. Jarvis *et al.* 1992).

The system used in this study is an AGILENT 7500S Inductively Coupled Plasma Mass Spectrometer combined with an EXCIMER laser ablation system. The UV laser, operating at a wavelength of 193nm is capable of ablating silicate, oxide and sulphide phases using an aperture to define pit diameters from about 20 to 200µm. The pit diameter is controlled by the beam size, and only minimal residual melt occurs (Eggins *et al.* 1998). Beam diameters for best ablation results depend on chemical and structural features of the sample (e.g. for clay >100µm). A laser diameter of 86µm before, and 105µm after the installation of a new laser ablation system (still an EXCIMER laser)[1], were chosen because they produced count rates of 10^3-10^6 for most trace elements, allowing use of the same low count rate part of the detector system. The frequency of the laser pulse used for obsidian is 5Hz, which results in a steady stream of volatised sample material (approximately 0.1µm of material is ablated with each pulse). Each sample was ablated for at least 40 seconds with a drilling depth of about 30µm. Detection limits are generally a few to 10s of ppb for an ablation pit of 86µm and/or 105µm in diameter (Charlotte Allen, pers. comm.).

Calibration Protocol

Because all materials ablate somewhat differently, giving different counts per second per ppm for each material, a natural glass as compared to the synthetic standard NIST612 is used for an internal standard. In this case SiO_2 was used. Essentially the count rates for all elements are ratioed to silica and the average of the laser on element/Si ratio is multiplied by the SiO_2 content of the glass as determined by EDXA. Three ablations on each sample were conducted (Lee & Sneddon 1994). After analysis of 10 ablations (~15min.), the standard was remeasured to exclude possible variation in analysis conditions. 41 isotopes (major and trace elements, and three Pb isotopes) were collected.

[1] In mid 2008 a new ablation chamber was installed in the laboratory (all artefacts after ANU9373 were analysed with this new set-up). However, this has no impact on the measured isotope composition of samples (Charlotte Allen pers. comm.).

Multi-Collector LA-ICPMS analysis (MC-LA-ICPMS)

The application of radiogenic isotope analysis is new for the analysis of obsidian artefacts in the Pacific. The experimental set-up of a Multi-Collector LA-ICPMS (MC-LA-ICPMS) is similar to conventional ICPMS, only that the single quadrupole collector is now replaced by a series of collectors. This allows a higher precision in the analysis of the geochemical composition of samples. Collerson and Weisler (2007) could successfully apply the method of MC-LA-ICPMS on basalt adze-sources in the Central and Eastern Pacific. However, logistic constraints and the high costs of analyses restricted the application of this method to only two samples. The results of this analysis are discussed in detail in the Lakeba, Fiji, section.

Particle Induced X-ray Analysis – Particle Induced Gamma-ray Analysis (PIXE-PIGME)

Particle Induced X-ray Analysis – Particle Induced Gamma-ray Analysis (PIXE-PIGME) was first applied to the characterisation of chemicals in the early 1970s (Bird & Williams 1989). This procedure in which a sample is excited with a proton beam accelerated by a van de Graaf accelerator produces a series of high quality measurements of elements in ppm (parts per million). At the ANSTO facilities in Lucas Heights, Sydney, a 2.6 MeV Beam with a beam current of 10 to 200 nA and a beam diameter of 2 to 10 mm is usually the platform. But these features can vary according to the necessities of research (Summerhayes *et al.* 1998).

Torrence *et al*. (1999), based on earlier work from Ambrose *et al*. (1981), Bird *et al*. (1981), Ambrose & Duerden (1982), and Summerhayes *et al*. (1998), describe the method as best suited to analyse three elements (F, Na, Al) by PIGME and twelve (Si, K, Ca, Ti. Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb) by PIXE. Similarly, Bird and Williams (1989) describe the excellent sensitivity of PIXE for elements between $20<Z<40$ and $60<Z<90$, which includes the above mentioned elements. In total a fully analysis of all major elements (excluding H, C, N and O) can be achieved. The analysis of trace elements, however, is limited (Cohen *et al.* 2002).

Data Processing

Multivariate statistical analyses

Provenance studies in the Pacific are largely based on the use of multivariate statistical analyses to identify similarities and dissimilarities between the chemical compositions of different sources. Several different methods have been employed: Principal components analysis (PCA), correspondence analysis (CA), various forms of cluster analyses (K-means, Hierarchical, etc.), regression analysis, discriminant analysis, Popper's Razor, etc (Leach & Manly 1982; Baxter 2006). For a first assessment of the data structure, unsupervised multivariate statistical analyses (PCA and K-means Cluster Analysis) were used in this study (SPSS 2006). Absolute ppm counts of all elements were processed using logarithmic (log 10) transformation.

Multivariate statistical analyses are very helpful in re-arranging complex datasets to display underlying similarities and dissimilarities. They can, however, sometimes also obscure information as their main aim is to reduce the complexity of multi-dimensional data. Approaching complex data structure with the help of statistical methods is reasonable and most of the time is a quick method, but we have to be aware that we are arguing with incomplete data. These analyses assume that the chance of correctly identifying a source rises with the amount conformity between the chemical composition of the analysed artefact and the source (Goffer 2007; Pollard *et al.* 2007; Wilson & Pollard 2001). While this assumption is probably correct, it is restricted by the amount of intrasource variation. Once the dissimilarity between intrasource variation and artefact is too high, this approach leads to erroneous interpretations. If all obsidian sources in the Pacific were known and sampled in detail, no artefact should plot outside the variance of each source. Erroneous sourcing should therefore only happen if the chemical compositions of two or more sources show an overlap (as is the case with some of the Admiralty Islands and West New Britain obsidian sources, see Summerhayes *et al.* 1993; Torrence, Neall *et al.* 2004; Torrence *et al.* 1992).

Comparison of diagnostic elements and ratios

Multivariate statistical analyses are therefore always supported by the examination of several diagnostic elements and ratios. The geological distinction between oceanic and circum-Oceanic Cenozoic volcanics, including obsidian, based on the alkalinity (K and Na content compared to Aluminium) is known (Chayes 1964). Additionally, the higher content in Fe, Na, F, Zr, Nb as well as generally Rb and Y and a lower amount in Al, Ca, Sr and Ba in Oceanic sources has been detected previously (Smith *et al.* 1977). For the intra-regional comparison of obsidian sources especially, differences in Sr, Zr and Y were used. This separation of volcanic rocks from different provinces in the Pacific is still in use, but the extensive geochemical research over the last few decades has led to the more detailed distinction between volcanic rocks of island Oceanic provenance and volcanic rocks from island arcs.

With the improvement of the analytical techniques in the early 1980s and especially to secure long term precision and accuracy of elemental measurements, absolute ppm counts of F, Na, Al, Si, K, Ca, Ti, Mn, Fe, Rb, Sr, Y, Zr and Nb were expanded by nine ratios (Al/Na, Zr/Fe, Y/Fe, Sr/Fe, Rb/Fe, Mn/Fe, Ca/Fe, K/Fe, F/Na). Especially the element of F proved to be especially helpful in distinguishing sources from each other (Bird 1996; Bird *et al.* 1981; Bird *et al.* 1997; Summerhayes *et al.* 1998). Unfortunately, analysing F and Zinc (Zn) with LA-ICPMS is problematic, because the ionisation potential of F exceeds that of the carrier gas argon, which means that F cannot be effectively ionised (Falkner *et al.* 1995:412), and there is an overlapping of the atomic weight of ^{64}Zn/^{70}Zn with isotopes of ^{64}Ni and ^{70}Ge (Goffer 2007).

However, the high precision and accuracy of LA-ICPMS now gives the opportunity to not only distinguish obsidian sources and examine in detail the intra-source variation in elemental composition, but also to reveal the genesis of these sources. In this study 35 isotopes (^{31}P, ^{45}Sc, ^{49}Ti, ^{51}V, ^{55}Mn, ^{59}Co, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{95}Mo, ^{118}Sn, ^{133}Cs, ^{138}Ba, ^{139}La, ^{140}Ce, ^{141}Pr, ^{144}Nd, ^{147}Sm, ^{153}Eu, ^{158}Gd, ^{159}Tb, ^{162}Dy, ^{166}Er, ^{169}Tm, ^{174}Yb, ^{175}Lu, ^{181}Ta, ^{186}W, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, and ^{238}U) gave consistent results and were selected for further research. In addition data on 13 chondrite normalised rare earth elements (^{139}La, ^{140}Ce, ^{141}Pr, ^{144}Nd, ^{147}Sm, ^{153}Eu, ^{158}Gd, ^{159}Tb, ^{162}Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{174}Yb and ^{175}Lu) were collected. Based on this wide suite of analysed isotopes comparisons between different volcanic rock types can be made, which narrows the identification of previous unidentifiable artefacts to particular areas.

Mantle Normalised Trace Element Diagrams and Chondrite Normalised Rare Earth Element Patterns

Supplementary tools applied in this work are mantle normalised trace element diagrams (spider-diagrams) and chondrite normalised rare earth element diagrams. These are tools commonly used by geochemists to display relative elemental abundances in specific rocks for the identification of fractionation processes in the melt (Sun & McDonough 1989). Mantle normalised trace element diagrams are typically arranged in a way that incompatible elements (elements which tend to not fractionate easily in the melt) are plotted to the left of the diagram and in decreasing order of their incompatibility to the right. Trace element distribution can be used to compare igneous rocks from different volcanic regions with each other.

For example, it is well accepted now that island arc magmas are systematically depleted in Ta, Nb, Zr, and Ti (HFSE, high field strength elements) (Albarède 2003). This produces a trace element distribution which is easy to distinguish from so-called OIB, Oceanic Island Basalt. Their genesis is not based on subduction of two or more tectonic plates, but more on weak zones (hot spots) in Oceanic plates which produce intra-plate volcanism. Igneous rocks formed by this process are on average less depleted in their trace elements (Albarède 2003). A good example of obsidian sources with an OIB pattern are the Samoan obsidian sources (Sheppard 1989), which show a significantly different trace element distribution to the Vanuatu sources, which show an obvious island arc pattern.

Comparison Database

In this section on the established comparison database, problems in the comparison of different analytical methods and the provenance of analysed artefacts from different sites throughout Vanuatu and the Southern Solomons are discussed.

Northern Vanuatu obsidian sources

In total 29 samples directly collected by the author from the two Vanuatu source areas were analysed to identify possible intrasource variation and to provide the basis for later comparison with artefacts from archaeological sites throughout southwest Remote Oceania. The two sources are easily distinguished by their different Si, Al and Na content (Table 5.1). Vanua Lava material has, on average, a consistent Si content of more than 330,000ppm (SD 1,150ppm), with 73,600ppm Al (SD 550ppm) and 33,000ppm Na (SD 760ppm); Gaua material ranges around only 300,000ppm Si (SD 780ppm), 88,000ppm Al (SD 250ppm) and 42,000ppm Na (SD 480ppm) content. Both sources show high Fe concentrations of between 23,000ppm (SD 1500ppm) and 27,000ppm (SD 400ppm). Consistent with the basic difference between these two sub-sources, in the more silicate-rich (Vanua Lava) sub-source and the more silicate-poor (Gaua) sub-source, the titanium contents differ by a factor of two, the more silicate-rich source being Ti poor. In addition, the more compositionally evolved silicate-rich source has lower Rb as well as lesser Sr, but a distinctively higher Rb/Sr ratio. Especially distinctive is the high K_2O content of the northern Vanuatu sources, which matches the overall high alkaline geochemical composition of the Northern New Hebrides Arc (Barsdell *et al.* 1982). In addition, to the before mentioned elements, most of the analysed elements show a highly distinctive distribution, only Mn (900-1,000ppm) and Pb (19-21ppm) show similar amounts. Especially Pb in particular is therefore a good discriminator for the Northern Vanuatu sources as a whole against other Pacific sources.

In addition to the two northern Vanuatu obsidian sources, a separate pitchstone source on Tongoa was analysed. The detection of an additional source for a glassy raw material was important in light of several pitchstone artefacts from Epi and Efate, the chemical composition of which showed dissimilarities with all obsidian sources in the Western Pacific. Silicate and Aluminium contents of this source are similar to the Gaua sub-source (Si ~308,000ppm, SD ~1300ppm; Al ~81,000ppm, SD ~330ppm). Na (~32,000ppm, SD ~840ppm) and K (~22,500ppm, SD ~30ppm) contents are considerably lower and Fe (~38,000ppm, SD ~1100ppm) and especially Ca (~30,000, SD ~680ppm) are significantly higher. This trend is replicated in the trace element distribution with high Ti (~4,250ppm, SD ~18ppm), a very low Rb/Sr ratio and low Zr and Ba contents. Additionally, it seems that the high Pb amount is restricted to the northern Vanuatu sources alone as the Tongoa pitchstone only contains ~9ppm Pb (SD 0.05ppm). Although no artefact is sourced to this location it is included in the dataset to give an example of a high silicate glassy volcanic rock from a location in central Vanuatu.

PCR of a dataset containing 31 samples from the three source locations (Vanua Lava 14, Gaua 15 and Tongoa 2) detected K, Rb, Zr, Sn, Er, Tm, Yb, Lu and Ta as well suited to distinguish these samples from each other (Table 5.2). PCA on the selected elements supports the detected differences in the major element composition (Figure 5.1). The first two components explain 99.5% of the variance, with the first component explaining 81.5% of the total variance and the second component 18%. A clustering of the three locations is unambiguous.

Intrasource variation

One major concern of Pacific geochemists was the possibility of further obsidian sources in the Banks Islands (Smith *et al.* 1977; Ward 1979). Based on the analysis of two artefacts from Pakea (cf. Chapter 1) which showed a significantly different Rb composition than the remaining artefacts from Pakea and the information of local guides that additional obsidian sources could be found on the island (Ward 1979:8-14), the hypothesis of further obsidian sources on Vanua Lava was argued. The notion of a "non-systematic variation" of rubidium in comparison with the other trace elements, which match closely (Smith *et al.* 1977:192-193), had already been made in the earlier studies.

To assess the intrasource variation in the Vanua Lava source, elemental analysis 14 source samples and additionally 182 artefacts provenanced to the Vanua Lava source are given in Table 5.3. The standard deviations of the major and trace elements which are well above detection limits are usually less than 5% in the source samples alone (as described above, 5% variation has to be expected for machine variability). If all artefacts are included in the Vanua Lava set, the variability is slightly increased (elements with variability scores over 5% are for the Vanua Lava sub-source: V (36.1%), Mn (5.3%), Co (11.1%), Cu (21.4%), Sr (8.5%), Sn (5.8%) Ba (5.1%) and Pb207 (6.6%); for the Gaua sub-source: V (5.5%), Sc (9.8%), Cu (15%), Sr (9.2%) and Ta (6.2%).

A PCA on all Vanua Lava artefacts (Figure 5.2a) and the source samples does not show particular groupings, rather a distribution along vectors with a high variability. Similar results can be seen in the Gaua artefact and source sample distribution (Figure 5.2b), but also a distinctive grouping can be detected. However, this grouping corresponds with the different machine runs conducted and can be therefore attributed to machine variability. In total, the Vanua Lava source shows a slightly higher internal variation than the Gaua source (average of 5.08% in contrast to 4.03% across all elements measured with LA-ICPMS), which can be related to the progressive crystallisation process in the Vanua Lava source.

In total, 283 artefacts are attributed to the Banks Island obsidian sources. These artefacts came from very variable backgrounds diachronically distributed through the whole of human settlement in this area. None of these artefacts show a high variability, that might define a third or more sub-sources in the Banks Islands. The internal variation in the two sub-sources is low, with only single artefacts displaying a higher variability than the preset machine conditions. Both sources show a high Sr variability which can be attributed to fractionation processes in the melt, as plagioclase crystallisation influences the Sr distribution in the melt.

Comparison with previous data

Different methods of chemical analysis usually detect elements with different precision. As already mentioned previous analysis of the Banks Islands sources used NAA (Ambrose 1976; Wall 1976), XRF (Smith *et al.* 1977), PIXE-PIGME (Bird 1996; Bird *et al.* 1981; Duerden *et al.* 1987; Smith *et al.* 1977) and EDXA (Galipaud 2000). The detailed elemental composition measured by these different methods are discussed in the following.

Neutron Activation Analysis resulted in an elemental composition of U 2.72 (0.18), Mn-Na 70.5 (0.76), Sc 71.2, Pa 10.5, Ta 0.5 and Ce 17.8 for the Vanua Lava sub-source (Wall 1976:348) and a slightly higher uranium value of 3.01 (0.07) and Mn-Na 69.5 (0.29) for the Gaua sub-source. Uranium and tantalum seem to be comparable as the LA-ICPMS data showed similar values of 2.6 (0.02) for U and 0.4 (0.01) for Ta in the Vanua Lava source and U 2.8 (0.02), and T 0.3 (0.004) for the Gaua sub-source. The remaining elements of Sc, Pa and Ce (Pa is not measured with LA-ICPMS) show considerable differences in the Vanua Lava source of Sc 9.9 and Ce 49.5. Ambrose (1976:371) defines the distinctively higher ratio of Mn/Na as significant for the provenance of Banks Island obsidian. Whereas using ICPMS we can detect a high ratio of Mn/Na 0.026 (0.027) in the Banks Island obsidian compared to for example, the

WNB sources, we can also detect a higher Mn/Na ratio of 0.035 in the Manus obsidian source and even 0.036 in one of the East Fergusson sources.

XRF analysis conducted by Smith et al. (1977) first defined an overall trace element database for further comparison studies between artefacts and sources. The authors defined Sr and Zr in combination with Nb as reliable indicators for provenance. The abundances of Zr in comparison to Sr in the Oceanic glasses to circum-Oceanic glasses permits a regional identification of obsidian sources (Smith *et al.* 1977: 192, Figure 1). Whereas a direct comparison between the data shows a slight variability (Vanua Lava: Sr [79 to 102], Rb [96 to 101], Y [36 to 45] and Zr [261 to 315]; Gaua: Sr [177 to 216], Rb [106 to 110], Y [24 to 30] and Zr [189 to 230]), we can see that by trend the element distribution follows similar patterns. Additionally, the high values of Pb were already detected in the sources, an attribute which was also noted in the LA-ICPMS data. Additionally, a high agreement between XRF and EDXA data can be identified; especially high values for K and Fe make the Banks Island obsidian highly distinctive. The same artefacts analysed by XRF were reanalysed using PIXE-PIGME (Bird 1996; Bird *et al.* 1981; Duerden *et al.* 1987). The major advantage of PIXE-PIGME being a non-destructive analytical technique more than equalises its weaknesses in precision and accuracy (Tykot 2004). Therefore, the high standard deviation published by Duerden et al. (1987:234-235) in the obsidian catalogue is more likely to represent machine inaccuracies than real intra-source variation as mentioned above (see also the elemental composition re-analysed by XRF for selected source samples Table 5.3).

Comparison of PIXE-PIGME and LA-ICPMS

All source samples collected from the two Northern Vanuatu sources were separately analysed by PIXE-PIGME. The necessity to use PIXE-PIGME to re-assess the collected LA-ICPMS data is twofold. The first objective was to analyse source samples which were systematically collected in the field in 2006. The focus was to incorporate previous, extensive research on Pacific obsidian sources (Bird 1996; Summerhayes 2004a; Torrence *et al.* 1992) with the new data collected in 2006/2007. The advantage of PIXE-PIGME as a non-destructive analysis was important to re-analyse the Tikopia collection, as the permission to sample more than a tiny percentage of the re-analysed material could not be acquired.

The comparison of previous PIXE-PIGME data with the newly collected LA-ICPMS data using PCA on covariance matrices on log transformed data with a reduced dataset of one major (Ti) and one trace element (Nb) as well as eight ratios (Al/Na, Mn/Fe, Zr/Fe, K/Fe, Ca/Fe, Rb/Fe, Sr/Fe, Y/Fe, F/Na were missing due to the mentioned F incompatibility) show a high correlation (r>0.98) with the means of PIXE-PIGME and XRF analyses. Displayed in Figure 5.3 are the first against the second component for all new results, representing 62% of the variance. Due to the expected variability in comparing three analytical methods, a spread in the Vanua Lava material is observed which results in an overlapping between the Vanuatu sources and the West Fergusson sources on the first vector.

Several authors have already mentioned the variability in comparing different analytical methods (Bellot-Gurlet *et al.* 2005; Bugoi *et al.* 2004; Glascock 1999). Variability of up to 20% can be expected (Grahame Bailey, pers. comm.). As the previous results were very encouraging, a detailed comparison between the two methods based on the 29 source samples from the two detected obsidian sources of northern Vanuatu was attempted. Chemical elements were selected for measurement based on previous work which has shown that they produce excellent discrimination: F, Na and Al measured on PIGME and Si, K, Ca, Ti, Mn, Fe, Cu, Co, Fe, Zn, Sr, Y, Zr, Br and Ga measured with PIXE.

The analysis showed a reasonable agreement with previous analyses using PIXE-PIGME (Grahame Bailey, pers. comm.). The comparison of lighter elements (Na, Al, and Si) showed a good correlation between the two methods (Figure 5.4). Ti gave consistently lower results, but is well within the 20% margin. The PIXE-PIGME data on the remaining elements displayed an increasing inconsistency, especially in the trace element identification of the PIXE analysis. In contrast the LA-ICPMS analysis showed consistent results in the quoted elements (also in the further elements identified). In comparison with EDXA analysis these results are repeated (Figure 5.5). First assessment of this issue resulted in a possible Cr and Ni contamination due to the beam hitting the sample holders (for detailed experimental set-up, cf. Torrence *et al.* 1999). A rerun of the comparison dataset, however, did not alter these results, so that we have to presume a machine-induced inconsistency in the analysis of chemical elements, a result similar to that reported in detail by Cohen et al. (2002). The experiment had to be abandoned at this stage due to logistical difficulties. Based on the comparison between the source samples we can conclude that all the trace elements analysed by PIXE in the current run are faulty[2]. The PIGME analyses of lighter elements do give good results and the following provenancing is based on this data. On the basis of comparison with the collected data of previous attempts in comparing these two methods, it is confirmed that at least a variability of 20% between different methods can be expected.

Comparison of LA-ICPMS data between sources of the Western Pacific

Based on the less than encouraging results of the renewed analysis of BI-obsidians with PIXE-PIGME and the high variability in comparison of these two methods with each other, a database consisting of source samples from the detected obsidian sources throughout the Pacific was established. Fortunately, the problem of inter-method comparison had already been identified by Ambrose (Wal Ambrose pers. comm.) and 54 unpublished LA-ICPMS and EDXA-SEM analyses conducted by Ambrose between 2003-2005 on obsidian sources in Western and Central Pacific were included in a comparison dataset with the newly collected data (Ambrose *et al.* 2009). Additionally, 66 source samples from different locations in the Western Pacific were analysed in this work.

West New Britain

In West New Britain, five well-researched obsidian sub-sources in two distinct locations are known. Four sub-sources are located on the Willaumez Peninsular and the adjacent Garua Island. Previously grouped under the term ‘Talasea’, West New Britain obsidian sources can be separated into four different subgroups: Kutau/Bao, Gulu, Baki and Hamilton (Torrence, Neall *et al.* 2004; Torrence *et al.* 1992; Torrence *et al.* 1996). The second location is the Mopir obsidian source situated approximately 50km east (Fullagar *et al.* 1991; Summerhayes *et al.* 1998).

[2] The disappointing results of this analysis derive from the installation of a new beam line at ANSTO in 2005 and are not representative of earlier runs using previous machine set-ups.

In this dataset, 22 samples from the Kutau/Bao sub-source, three samples from the Baki sub-source and only one sample from the Gulu sub-source were analysed. Additionally, three samples from the Mopir sub-source were also included. Attempts have been made to distinguish these sub-sources, especially the Kutau/Bao sub-sources, in more detail, but this has not been successful so far (Bird *et al.* 1997). However, a good discrimination of four of the five sub-sources[3] was achieved using the ratio of nine elements (F, Na, Al, K, Mn, Fe, Rb, Sr, Y, Zr, Nb) (Bird *et al.* 1997:65, Figure 3). Bird et al. mentioned the higher variability of the Baki sub-source in contrast with the high homogeneity in the other sub-sources, especially the Mopir sub-source.

Similar to most of the Western Pacific obsidian sources, the high amount of Potassium (~30000ppm, exception is Mopir with only 18000ppm) and low amount of Ca (~8000ppm) and P (~130ppm) are distinctive in comparison to arc islands obsidian further east on the Tongan–Kermadec Arc (Table 5.1) (cf. below and Reepmeyer & Clark 2010; Smith *et al.* 2003, for obsidian in the southern Tonga-Kermadec Arc). Based on a multiple regression analysis (Principle Component Regression) of 27 samples (Table 5.5) of four of the five West New Britain sub-sources the elements K, V, Rb, Sr, Th, U, P and Mn (both scored low on the first and second value, but high on the third) showed the highest ranking in distinguishing these sub-sources from each other. A PCA of the reduced dataset showed a highly unambiguous distribution of the four sub-sources, the first component represents 81% of the variance, the second 15% and the third 3% (Figure 5.6). The low intra-source variation in the Kutau/Bao and Mopir sub-sources is well detectable, the higher variability of the Kutau/Bao sub-source on the third component is most probably machine induced. Only one sample from the Gulu sub-source was analysed. A first assessment of the Baki sub-source showed only very minor intra-source variability (Figure 5.7). However, as only three samples were analysed from this location, a final assessment of the intra-source can not be made without further data.

[3] Unfortunately, no samples from the Hamilton sub-source were analysed.

Admiralty Islands

Two major source locations in the Admiralty Islands, Manus Province, are known: southwest Manus and the Lou/Pam Islands (Ambrose, Bird *et al.* 1981; Ambrose, Duerden *et al.* 1981; Ambrose & Duerden 1982). The dataset available for this study includes five samples from Manus and 25 samples from Lou/Pam sources. PCR detected Ti, V, Cu, Sr, Zr, La, Ce, Eu and Th as elements with a high ranking in discriminating these source locations from each other (Table 5.6). PCA (with the first component explaining 98% of the variance and the second component explaining 1% of the variance) on the reduced elemental data showed an unambiguous distribution of these two source locations (Figure 5.8). However, the sub-sources of Lou/Pam are difficult to distinguish (Figure 5.9), a result which was already reported in the literature (Ambrose 1976; Ambrose, Duerden *et al.* 1981; Bird 1996). Recently, Torrence et al. (2008) had success in discriminating several Lou sub-sources from each other using PCA on 37 source samples analysed by ICPMS by Ambrose from the Manus Province; especially Wekwok, Umrei/Umleang and other Lou/Baun sub-sources are now clearly distinguishable from each other.

A detailed statistical analysis of 12 Lou/Pam samples analysed by Ambrose and 13 samples analysed by the author was attempted in the current study. The dataset included samples from Pam Mandian (2), Baun (2), Lakou (1), Langpawan (3), Solang (1), Umrei (1), Umleang (2) and Wekwok (13). PCR on the reduced dataset tentatively defined P, Ti, V and Sr as good discriminators of these sub-sources, all other elements score highly ambivalent on the first three scores (Table 5.7). The subsequent PCA on the material showed a possible distribution of the sub-sources. The first component explains 78% of the variance the second 21% and the third 1%. Although there seems to be a certain variability in the geochemistry, the sources Wekwok, Umrei/Umleang and Lou/Baun can be separated from each other, comparing Figure 5.10, plotting the first against the second component, and Figure 5.11, plotting the first against the third component of the PCA.

D'Entrecasteaux Islands

Very little research has been done on the obsidian sources of the D'Entrecasteaux Islands. Previous research detected six sub-sources on these islands (Ambrose 1976:369; Bird *et al.* 1981; Duerden *et al.* 1987; Smith 1974), separated into West and East Fergusson Islands (Green & Bird 1989; White *et al.* 2006), a definition which will be followed in this work.

West Fergusson sources were previously associated with obsidian outcrops on the Kukuia Peninsula and two sub-sources were detected, Fagalulu and Kukuia (samples from secondary deposits close to the village Ioupolo and beach deposits at the Igwageta village). Ambrose achieved a good discrimination of these sources based on geochemical analysis of U and additional density measurements (1976:371, Figure 3; Summerhayes 2004a). Similarly, in his current LA-ICPMS analysis revealed a good possibility for discrimination of the two West Fergusson sources using V, Sr, Y, Zr, Mo, Cs, Gd, Dy, Pb208, Th and U (Table 5.8). The PCA (Figure 5.12) displays a good separation of these two source locations with the first component explaining 82% of the variance and the second component 16%. Two outliers from both outcrops (one from Ioupolo, ANU1897, and one from Igwageta, ANU1905) could indicate a second sub-source in this area. Both samples showed significantly lower P, Sc, Ti, V, Mn, Ga, Rb, Zr, Nb, Ba, Pb208 and Th values and a higher Sn value (Table 5.1). More research is needed to define this variance as intra-source variability or as a separate source location.

East Fergusson sources have been identified at Numanuma Bay (two sub-sources), Dobu Island and Sanaroa Island (Ambrose, Bird *et al.* 1981; Green & Bird 1989). Whereas these sources are easy to separate from the West Fergusson sources using P, V, Ga, Sr and Ba, and indeed from all other Western Pacific obsidian sources, the internal discrimination is not unambiguous (Table 5.9). Only a small set of eight samples was analysed with LA-ICPMS by Ambrose. All sources show a rather high variation in their chemical composition (SD of more than 5%, which is higher than the expected machine variability), indicating the possibility of several additional sources. However, a tentative discrimination of three source locations that parallel the previous results can be given: the single sample from Numanuma Bay (ANU1911) is most probably associated with the two Lamorai samples (ANU308 and ANU1916); the two samples from Dobu Island could display two different events producing obsidian; the same might be true for the three Sanaroa Islands samples, two of them (ANU4928 and ANU4929) showing a high similarity in their chemical composition (Figure 5.13). The PCA on the set (Figure 5.14) explains 82.5% of the variance with the first component and 11% with the second component. The first factor is heavily influenced by P, Mn, Sr, Zr, Ba, Yb and Lu (cf. also Table 5.1). Based on these elements, a good general source discrimination is possible. For a more detailed assessment of possible additional sources more samples from all source location have to be analysed.

Tonga

Five samples from Tonga were included (ANU9368-ANU9372) in the comparison dataset. Two sources on Tonga were detected previously; both of which were located on the island of Tafahi in the northernmost part of the Tongan Island chain (Bird 1996; Duerden *et al.* 1987). Only five source samples have been analysed from this island, but two sub-sources were detected. Both sources are distinguishable from more Western Pacific obsidian sources by their low alkalinity (low K and Na) and high Fe, Ca and P composition. In comparison with the Oceanic obsidian sources of Samoa further north and the Polynesian islands further east we can see a higher depletion of all trace elements (Figure 5.15 - 5.17), characteristic of island arc obsidian sources, compared to OIB trace element distribution (Albarède 2003) which is characteristic of the oceanic obsidian sources. For the separation of these different sub-sources Zr, Mo, Sn, Ba, Nd, Sm, W, Pb^{208} and U were selected. The PCA (first component 95% of variance and the second 5%) shows an interesting distribution mainly on the first component, which is heavily influenced by W, Pb^{208} and U. All of these samples show a similar low K-Na distribution and high Fe, Ca and P values. Additional strongly depleted values of Ba, Pb and Th support the province of these samples as belonging to Tongan Arc obsidian sources.

Summarising the results of the comparison dataset

Principal component regression (PCR) on the complete dataset of 120 source samples from the Western and Central Pacific identified Rb, Zr, Nb, Sn, La, Ce, Nd, Sm, Ta and Th as highly ranking in separating the different sources areas from each other (Table 5.10). The PCA with 96% of the variance explained on the first two components (first

83% and the second 13%) shows an unambiguous distribution of the source areas (Figure 5.18). Unfortunately, the West New Britain sub-sources plot extremely close together, so that a clear direct attribution of artefacts to one of the sub-sources is not possible.

Several elements give a good option for a clearer separation of the sources. On the second score especially V (-2.26) and Cu (-3.08) score high, although both elements show a high internal variability in the Vanuatu sub-sources (Figure 5.19). If V is included in the PCA the first two components together only explain 88% of the variance (first component 69% and second 19%, third 10%), but the different sub-sources, especially the West New Britain sub-source, can be better separated from each other. To test if the visual separation of the PCA is statistically representative an additional K-Means cluster procedure was conducted (Figure 5.20). The identified sources and sub-sources (n=24) were used for the analysis. Clusters of the samples from the two Banks Islands sources are distinct from the other sources as well as from each other. Both clusters reflect intra-source variability with a low standard deviation. Euclidian distances of 0.07 to 0.57 show a reasonably well-defined cluster for the Vanua Lava source (Cluster 12). The Gaua samples (Cluster 7) cluster even closer together. No sample is further from the centre than 0.17.

In addition, primitive mantle normalised trace element diagrams show a distinctive island arc trace elemental distribution in that the HFSE are systematically depleted. It is worth noting that there is an anomalous Sr depletion and Zr enrichment in the Vanua Lava source in contrast with the normal HFSE depletion in arc magmas. The Sr/Eu depletion and especially the Ti depletion can be attributed to the plagioclase and magnetite fractionation processes prominent in this source.

Micro-analytical Techniques: Problems and Achievements

One important observation from the Vanua Lava source study is the variability of some elements. Concentrating on the major elements analysed with the electron beam, plagioclase (Ca-Na alumino-silicates) phenocrysts are macroscopically visible or can be seen microscopically. In addition, microphenocrysts of titano-magnetite (Deer *et al.* 1992) have been identified by EDXA (Plate 8), with sizes reaching up to 100 microns across. Clearly different results in Na, K, Ca, Ti and Fe ensue if differing volumes of glass, plagioclase and titano-magnetite are encountered in an ablation pit, especially if focussed on large microphenocrysts ~100µm (Table 5.12). This indicates a problem of this micro-analytical technique in comparing data from true bulk analysis of rock specimens containing microphenocrysts, like XRF or solution ICP data where no detailed choice of the excited area exists and therefore the average of a much larger sample volume is analysed.

Microphenocrysts

The high count of crystallisations in the Vanua Lava material suggested using these microphenocrysts for fingerprinting Pacific obsidian sources. Acquafredda & Paglionico (2004) have already successfully applied the analysis of microphenocrysts in provenance studies in the Mediterranean. These microphenocrysts can be detected in all Vanua Lava material. The Gaua material is more homogenous and microphenocrysts can only be found in approximately 20% of the samples. None of these microphenocrysts can be found in samples from the Kutau/Bao source of west New Britain. Other sources in this area, like the Hamilton source, however, show microphenocrysts (Robin Torrence pers. comm.). Additionally, one piece from Wekwok, Admiralty Islands, displays small amounts of titano-magnetite microphenocrysts. At this stage the proposal can be made that there is potential for fingerprinting Vanuatu sources by analysing crystallisations in the material. Further research on a wider spectrum of Pacific obsidian sources is needed to verify these suggestions.

Provenancing the excavated artefacts

The database of sources discussed in the previous section will now be used to identify the origin of excavated artefacts in Vanuatu. Implications of spatial and chronological changes will be discussed.

Vanuatu

TORBA province

Vanua Lava

Ambek

In total 483 obsidian artefacts were excavated (318 in test pit 1 in the village area and 165 in Test pit 2 at the beach, cf. site description in Chapter 5) from the two excavations in the village of Ambek at the shore at a distance of not more than 3 km from the secondary source and adjacent to the creek containing small nodules of Vanua lava obsidian. Of the total assemblage, 64 samples were selected for detailed geochemical analysis, thirty-two artefacts from test pit 1, twenty-one from test pit 2, Layer 1, and eleven from Layer 2. All artefacts are sourced to the Vanua Lava source. These included samples which could not be identified as originating from a Vanuatu source on macroscopic characteristics and a simple random sample of the remaining artefacts.

The PCA (61.5% on the first component and 25% on the second) on the material shows an unambiguous distribution within the established Vanua Lava source variance (Figure 5.21). Whereas the overall variance compared to the source samples alone is not significantly influenced by the addition of these artefacts, the intra-source variability increases in the V content, based on several artefacts with exceptionally high amounts of V (ANU9063, 9072, 9074, 9087, 9105, 9106, 9118, 9123). The usual composition of the Vanua Lava source is 1.08-1.72ppm (Mean 1.42, SD 0.34), although one sample collected from the river-mouth (ANU9014) had 2.39ppm V; these artefacts show a variance in the V content from 2.06 to 4.12ppm. This intra-source variability is easily detectable in the spread of the analysed samples in the PCA along the V vector. One artefact (ANU9067) showed an abnormal high content of P (846ppm, compared with the usual 284ppm, SD 12.49), but this high count in P has no impact on the remaining trace element measurements as all of them are within the accepted variance of the source (cf. Table 5.1).

It is important to note that all artefacts identified by macroscopic characteristics as deriving from the Vanua Lava source could indeed be provenanced to this obsidian outcrop. Table 5.12 displays the detailed distribution of analysed artefacts in each Layer. A concentration of the above mentioned V-high artefacts in certain layers can not be detected. The macroscopic appearance of these artefacts is indistinguishable from the remaining artefacts so that a selection process can be excluded.

In summary it should be noted that none of the artefacts in the closest site to the source area can be sourced to an obsidian location outside of Vanua Lava. However, the site gives only a very short impression of the utilisation of this source as the radiocarbon dates indicate a very quick sedimentation of the deposits in the fourth century BP. The late dates for this site suggest a deposition of the material when a widespread distribution of obsidian from other sources in the Western Pacific into Remote Oceania had already ceased. Additionally, no artefacts from the Gaua source were found which makes an exchange of that material to the area close to the source on Vanua Lava highly unlikely.

Lesa

The assemblage excavated from the 1 by 1m test pit in the central village area of Lesa contained 156 artefacts. Although only flakes and small cores were found on the site, larger nodules were found eroded in the riverbed, which were macroscopically identical to the Vanua Lava obsidian. Twenty-two artefacts were selected for geochemical analysis (Figure 5.22).

The PCA (64% on the first component and 23% on the second) displays an exceptionally low variability in the sampled artefacts well detectable through the tight clustering of the artefacts and with an average SD of only 3.8% in the trace element distribution (compared to 2% for the source samples alone and 4.6% for Ambek). None of the samples showed the detected V variability of the Ambek artefacts, although a minor increase in the Ba variability of 8.7% average SD can be detected. Again we can assume these artefacts are relatively recent as they were found only in the topmost layers of the test pit with a maximal layer depth of only 20cm.

Movono and Lion Bay (surface)

The surface collections of two sites in the South (Movono) and West (Lion Bay) of Vanua Lava contain 27 artefacts macroscopically identified as mainly deriving from the Vanua Lava source. One artefact found on the surface close to the shore at Lion Bay was of unusual macroscopic appearance and was selected for a geochemical analysis along with one representative piece from the surface collection of Movono.

The PCA (the first eigenvector representing 69.9% of the variance and the second 18.3%) on the material could unambiguously source the two pieces to the Vanua lava (ANU9421) and the Gaua (ANU9422) source (Figure 5.23). Important to note is that the Lion Bay piece is the only one of the whole analysed Vanua Lava ensemble of 687 artefacts which are sourced to Gaua. Similar to the findings of Ward (1979), it seems that transport of material from Gaua to Vanua Lava occurred only in very minimal quantities.

Ureparapara

Lepewuala

All sites accessed on Ureparapara were surface sites. From Lepewuala, situated inside the old crater at Dives Bay, a sample of 34 artefacts were collected. Macroscopically, all the artefacts had a distinct Vanua Lava appearance, although with a slight greenish patina. One representative artefact was selected for analysis to clarify the assumption of a different source on Vanua Lava selected for import to this island.

The PCA (65.7% on the first eigenvalue and 22.8% on the second eigenvalue) shows an unambiguous sourcing of the one piece to Vanua Lava (Figure 5.24). Although the trace element values are slightly higher than measured for the Vanua Lava source samples alone, these values fall well into the 2δ SD margin and are also well within the internal variation of this source.

Yetow

Forty-three artefacts were collected from the surface site at Yetow. Forty artefacts were macroscopically identical to Vanua Lava material, one artefact showed similarities with the Gaua source and two artefacts are bottle glass. The two bottle glass pieces (ANU9423-9424) and the piece (ANU9425) resembling the Gaua source were selected for analysis.

As described by Brenchley (1873:235), bottle glass seemed to be a highly valued good. Although Brenchley did not describe the functions of these empty bottles, flaked artefacts made from bottle glass indicate a use as raw material for tool production. The geochemical analysis of early historical glassware in the Pacific is not well developed. Therefore, the detailed geochemical composition of the artefacts is presented in Table 5.13. The significant differences in the composition of these two flakes make it unlikely that they derive from the same bottle, although considerable inhomogeneity in historical glassware has been previously detected (Sartowska & Kunicki-Goldfinger 2001).

The PCA (the first eigenvector representing 69.9% of the variance and the second eigenvector 18.3%) on the material could unambiguously source the allegedly Gaua piece to the Gaua source (Figure 5.24). Although the total quantities of the collected material display a focus on Vanua Lava material, this artefact shows that also Gaua material was transported in small quantities to Ureparapara.

Gaua

Lebunga

In total, 152 artefacts were collected from the surface of the site. On grounds of the location of the site, similar to that of the Ambek village sites in Vanua Lava, a large sample of 57 artefacts was selected for geochemical analysis. It has already been stated that the internal variation of the Gaua source is less than in Vanua Lava. If the average SD of analysed trace elements is compared, an increase in the overall variability from 0.9% to 2.6% can be detected (Table 5.3). However, these increments fall well into the 2δ confidence interval which should be applied to elemental analysis using LA-ICPMS.

If the increase in variability is incorporated into the interpretation of the PCA results, (63.1% on the first component and 25.7% on the second) an unambiguous distribution of the artefact provenance can be detected (Figure 5.25). Fifty-five artefacts are sourced to the Gaua source and two artefacts are sourced to Vanua Lava (ANU9254-9255). This is especially interesting as artefacts of the Gaua source were only detected in small quantities on Vanua Lava and none were detected in a similar, close location to the source. Additionally, both artefacts show high V amounts. However, as selective processes were already excluded for the Vanua Lava source, this similarity is tentatively interpreted as coincidence.

Tarasag

Macroscopically, 13 of the 22 obsidian artefacts found in total were assigned to the Vanua Lava source. The remaining nine artefacts have an origin in the Gaua source and of these three artefacts were selected for detailed geochemical analysis. The PCA (63.1% on the first component and 25.7% on the second) on all three flakes unambiguously sourced the artefacts to the Gaua source (Figure 5.26). Similar to the detection of artefacts from Vanua Lava found close to the source in Lebunga, the large number of artefacts found in Tarasag suggests a directional transport of Vanua Lava material into Gaua, at least in the most recent past. Unfortunately, no sites with a larger time depth have been detected in Gaua so that an assessment of the time depth of these findings is not possible.

Table 5.13 presents the geochemical data of the three bottle glass flakes (ANU9428, ANU9431 and ANU9432). Similar to the two artefacts found on Ureparapara, significant differences in the geochemical composition can be detected suggesting that all artefacts came from different glassware. Although based on a very small data base, the interpretation of a the transport of bottle glass among the islands is unlikely, as the piece also shows a significantly different composition to the two flakes found on Ureparapara.

Mota Lava

ML-Lequesdewen (Surenda, Lamelis, Tetyemiulu, Vegsoi)

In total, 256 artefacts were excavated, distributed on two separate Layers (cf. Chapter 5), and 22 artefacts were selected for geochemical analysis. Macroscopically, three different sources of the material were assumed, one piece most probably deriving from a West New Britain source and the remaining artefacts originating from Vanua Lava or Gaua.

The PCA (66% on the first component and 21.7% on the second) on the material show an unambiguous distribution (Figure 5.27). Two artefacts, ANU9399 and ANU9405, could not be attributed to any known source in Vanuatu. Both artefacts have a pitchstone like appearance with large phenocrysts, but with a less lustrous appearance than the Vanua Lava pieces. Although slightly different macroscopically (the reason why these pieces were selected for geochemical analysis), the similarities in appearance are large enough that the piece ANU9399 was wrongly identified as belonging to the Vanua Lava source. In their geochemical composition the two pieces are significantly dissimilar so that the origin in two separate outcrops has to be assumed. Whether these pieces indicate that separate pitchstone sources were being utilised in the Banks Islands is unclear as both pieces were small nodules with no traces of human activity detectable besides the transport into the site. An interesting match between the nodule ANU9405 and one pitchstone artefact from the EF-Arapus site in northern Efate (ANU9434) can be made (Figure 5.34). Although the PCA does not show a perfect match between these two samples, the geochemistry shows a similar compositional pattern (Table 5.14). Whether the dissimilarities between these two samples derive from an origin from two different outcrops or from the larger compositional inhomogeneity in pitchstone deposits needs to be further researched.

The remaining artefacts were identified as originating from the Kutau/Bao source, the Vanua Lava and the Gaua source, as suggested by the macroscopic analysis. The one piece (ANU9389) from the Kutau/Bao source is the first obsidian piece from West New Britain found in the Banks Islands and it is a strong indicator of the initial colonisation of Mota Lava during the Lapita period. Additional evidence for this suggestion is the discovery of a single potsherd from the site which, although strongly eroded, was decorated with a dentate-stamped Lapita design pattern (Stuart Bedford and Matthew Spriggs, pers. comm.).

In summary, 151 artefacts were found in Layer 1 of which 141 pieces originated from the Vanua Lava source and 10 pieces from the Gaua source. The unworked nodules ANU9405 and ANU9399 were also found in this layer. Separated from Layer 1 by the sterile Layer 2, Layer 3 contained 99 artefacts from the Vanua Lava source and six artefacts from Gaua along with the one piece from Kutau/Bao. Although more artefacts made from Gaua material are found on Mota Lava than on Ureparapara, the ratios of 1:14 in Layer 1 and 1:16 in Layer 3 show a clear prevalence of Vanua Lava material. Layer 1 is not yet dated but, in comparison with other sites in the region (Pakea and the sites on Tikopia), the high number of artefacts found suggests recent deposition.

ML-Saywoume

Only a small amount of obsidian artefacts were excavated from the 1m by 1m test excavation of ML-Saywoume which is assumed to date into the early second millennium BP. Eight artefacts were collected from the site, all of them macroscopically identified as originating from Vanua Lava.

Torres Islands

The analysed artefacts derive from two different archaeological formations, surface collections in the village TI-Kurvot (To 15-12) and two test pit programs conducted by Jean-Christophe Galipaud in 1996 and 1998. In total, 339 obsidian artefacts were analysed and 65 pieces selected for geochemical analysis.

Surface

In total, 100 artefacts were collected from the surface. As all artefacts were macroscopically identified as originating from the Vanua Lava source, a simple random sample of 23 artefacts was selected for geochemical analysis. The PCA (with 66% on the first component and 21% on the second) of the artefacts plots unambiguously (Figure 5.28), and all artefacts can be sourced to Vanua Lava.

TI-Kurvot

A total of 239 obsidian artefacts were collected during two test-excavation programs in the village of TI-Kurvot. Macroscopically, 227 artefacts were identified as originating from the Vanua Lava source and only 11 artefacts had an appearance similar to the Gaua source. One artefact had a similar matte surface and large amounts of phenocrysts similar to the pitchstones found on Mota Lava and Epi. For geochemical analysis a simple random sample of 31 artefacts sourced macroscopically to Vanua Lava, nine artefacts of the material most probable originating from Gaua and the one pitchstone sample were selected. One additional artefact first thought to be a piece of worked scoria was also analysed, however, this artefact (ANU9421) is burned coral and will not be discussed any further.

The PCA on the material (62.4% on the first eigenvalue and 24.6% on the second eigenvalue) shows an unambiguous distribution of the artefacts (Figure 5.28). All artefacts besides the already mentioned pitchstone can be sourced either to Vanua Lava or Gaua as assumed by the macroscopic analysis of the material. Layer 1 and 2 contained 197 artefacts of which three artefacts originate from Gaua and 194 from Vanua Lava, representing an overall ratio of 65:1. Of these later deposits 128 artefacts (only one artefact sourced to Gaua) were found in Layer 1 and 69 artefacts (two artefacts from Gaua) were located in Layer 2. In the mostly sterile white sand of Layer 3 only 8 artefacts were found in total. Six artefacts originate from Vanua Lava, one from Gaua and the pitchstone piece. All of these were most probably displaced from the overlying occupation layers. In the earlier occupation Layer 4 most probably defining the initial occupation of the island around 2400 BP, in total 35 artefacts were found of which 28 were sourced to Vanua Lava and 7 to Gaua representing a remarkably low ratio of 4:1.

SANMA province

Santo

Aore

In 2006 a detailed geochemical analysis program was conducted by Jean-Christophe Galipaud, Mary-Clare Swete-Kelly and Robin Torrence using the PIXE-PIGME procedure on obsidian artefacts from Makue, Aore island (Galipaud & Swete-Kelly 2007b; Galipaud & Swete-Kelly 2007a). Unfortunately, this data could not be accessed in this work and a publication is still pending. Three obsidian artefacts were analysed in the collection examined in this thesis. These artefacts originate from surface collections and from within the upper layer of the Makue site.

The PCA (70.5% on the first eigenvalue and 17.2% on the second eigenvalue) on these artefacts plots unambiguously (Figure 5.29). The two artefacts found on the surface can both be sourced to the Kutau/Bao sub-source on West New Britain which indicates a transportation to Aore during initial colonisation in the Lapita period. The one artefact sourced to Vanua Lava was found in the upper Layer. It is unclear whether this artefact indicates a continuous transport of Banks Islands material further south as Galipaud and Swete-Kelly (2007a:155) describe these layers as disturbed, with occasional Lapita ceramic fragments detectable, in addition to the missing indications of a post-Lapita occupation of this site.

North Santo

In the extensive excavation campaign of 2006 by Bedford and Spriggs, only a small number of obsidian artefacts were found in Port Olry and the village area of Matantas. Although a detailed geochemical analysis of the artefacts has not yet been conducted, based on the encouraging results of attempts to source Banks Island obsidian macroscopically a preliminary provenance of the artefacts is given here. In total, 13 artefacts were excavated of which 11 originated from Vanua Lava and two from Gaua. The later dates of the excavated occupational layers at these two sites indicate that there was a continuous transport of both Vanua Lava and Gaua material into North-Santo at least in the direct post-Lapita phase up until 2400 BP.

MALAMPA province

Malakula

In total four obsidian artefacts were excavated from two different sites on the north-eastern outlier islands of Vao and Uripiv. All artefacts were geochemically analysed. The PCA (68.2% on the first eigenvalue and 19.4% on the second) on the material shows a clear provenance of the four pieces, three of them to the Vanua Lava source and one to Kutau/Bao source (Figure 5.30). The single artefact found on Uripiv originates from Vanua Lava; unfortunately it was brought to the surface during trenching, but seems most likely to be associated with the Lapita occupation.

Shefa province

Epi

Two obsidian artefacts from Epi and two pitchstone artefacts from Epi and from adjacent Lamen Island were analysed macroscopically. Two artefacts from Mafilau on Epi were macroscopically identified as coming from Vanua Lava. For a detailed geochemical analysis two artefacts were selected from Mafilau which could not clearly be assigned to the Vanua Lava source although they are macroscopically reminiscent of this source. Both artefacts have a less lustrous and glassy appearance than the obsidian from Vanua Lava, but show large amounts of phenocrysts. In that way, they are similar to the samples collected from the pitchstone source on Tongoa.

From the PCA of the material, no clear provenance can be defined (Figure 5.31). Although the two artefacts share a similar composition in the major elements (Table 5.14), only the Fe_{total} content is different, the trace elements show significant differences so that an origin from two separate sources has to be assumed. A Pb content of 11-13ppm is not distinctive for Northern Vanuatu obsidian sources, although the pitchstone source on Tongoa has Pb content of ~9ppm. Similarly, the Nb content of 4.2-4.7ppm, also slightly higher than Tongoa, suggests a local source on Epi. This is additionally supported by the rare earth element distribution (Table 5.14), which falls into a (albeit wide) variety of igneous rocks from the New Hebrides Arc (Peate *et al.* 1997; Raos & Crawford 2004). Local onshore pitchstone sources on the New Hebrides Arc are not well researched and the rare occurrence of these materials in archaeological contexts suggests that these materials were only utilised occasionally and not systematically, unlike the case with the Northern Vanuatu obsidian outcrops.

Efate

EF-Teouma

The artefacts analysed in this study derive from four field seasons (2004-2006 and 2008 directed by Stuart Bedford and Matthew Spriggs). During the field seasons 2004-2006, initially only areas which were disturbed by recent development activities were targeted, so that a large amount of the found obsidian artefacts cannot be unambiguously allocated to specific layers. Additionally there is clearly a scatter of obsidian outside the main site area and in these thinner deposits it is only rarely possible to allocate pieces to earlier or later post-Lapita as the deposits are shallow and mixed, possibly by agricultural activities of the time. In the 2008 excavation season the focus was to assess the stratigraphy in detail. Therefore undisturbed areas adjacent to the previously excavated area were targeted.

In total 65 obsidian artefacts were found on the site of which 63 were geochemically analysed. The PCA (74.4% on the first Eigenvector and 16.2% on the second) plots unambiguously. Two artefacts (ANU5247/9376 and ANU5248/9377) show low totals in their major element distribution (Appendix 2). Although high in silicate (76-78 wt%), the low amounts in Al (7.3-7.7 wt%) and their crystalline structure make it unclear if these artefacts are glasses at all. Additionally, the significant inhomogeneity in samples taken from two different parts of the artefact hinders a clear assessment of possible sources. However, the Pb content in combination with the Nb content suggests a local provenance most probable from somewhere in Central Vanuatu, if not from Efate itself.

Figure 5.32 displays the PCA (74.8% on the first component and 15.7% on the second) without the questionable artefacts described above. The remaining 63 artefacts can be unambiguously sourced to the two Banks Islands sources and to Kutau/Bao and Mopir in West New Britain. One artefact, directly associated with a burial[4], plots in close

[4] Bag-label: Area 3A, 3.8 grave-fill, Bag-number 8.2466.

distance to the Fagalulu source, West Fergusson. Although the artefact's elemental composition does not perfectly match the composition of the West Fergusson sources as seen in the Appendix 2 and Table 5.1, the Pb content of this piece in particular shows striking similarities with the known source of Kukuia in West Fergusson[5]. This is unusual, as there is only one other possible example of West Fergusson obsidian found in Remote Oceania.

West Fergusson artefacts are only occasionally found outside of the D'Entrecasteaux group (White *et al.* 2006) and mostly in post 1200 BP contexts (Green & Bird 1989:91). Only one piece was found in the Reef/Santa Cruz islands (ANU511: Green 1987; Green & Bird 1989; Kirch 1991), which was at the time of discovery not widely accepted as a valid indicator for connection between these two island groups during Lapita times. Green and Bird (1989:92) discussed the probability of different obsidian outcrops from West Fergusson being utilised during Lapita times and came to the conclusion that the sources on the Kukuia Peninsular were the most likely to be accessible during that time. Although there were a few dissimilarities between the Kukuia source and piece ANU511, for example, a low Ti content and a slightly higher density, Green and Bird (1989:95) concluded that the ANU511 piece as originating from Kukuia "is now well supported and the tentative nature of its previous assignment to this source can be withdrawn". More detailed research on the Kukuia source in West Fergusson is still needed, but the close match of the ANU511 piece from SE-RF-2 Lapita site and the similarly close match of ANU9412 with the same source support the notion that transport of obsidian from the D'Entrecasteaux group, albeit in very small quantities, occurred in the initial colonisation phase of Remote Oceania. As yet no sites of this time period are known from the D'Entrecasteaux group itself, so a further implication is that Lapita-age sites are to be expected there with future research.

The second unusual obsidian artefact (ANU9039) with a clear provenance (Figure 5.32) is one piece from Mopir. The Mopir piece was found outside of the main excavation area in Area 7A in a mixed deposit with several (generally worn) sherds including one

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[5] The artefact ANU9412 was also sent to Peter Sheppard, Auckland, for analysis with P-XRF. Although he couldn't find a close match with any known obsidian source in his database, his analysis of the Pb content of the sample confirmed a possible provenance in the D'Entrecasteaux group, most probably from a yet undiscovered sub-source (Peter Sheppard, pers. comm.).

with Erueti-type decoration (Reepmeyer *et al.* in press). In this trench the layer was underlain by the brownish-orange tephra of Layer 3 containing worn Lapita sherds. The presence of Mopir obsidian dating to the time of Lapita pottery is unusual as the WK-2, Mount Witori eruption caused widespread destruction in West New Britain and covered the Mopir sub-source at the start of the Lapita phase around 3480-3150 cal. BP (modal date 3315 cal. BP) (Petrie & Torrence 2008; Torrence *et al.* 2000). It is therefore not found in early and middle Lapita assemblages in West New Britain, but reappears at the end of the middle and into the late Lapita phase in West New Britain (2900 BP - 2200 BP) and at sites on Watom, off the coast of East New Britain (Anson 2000). Mopir obsidian has also not been found in the Reef Santa Cruz sites, although Green especially focused his geochemical analysis of these artefacts on the detection of source with a different signature than the Kutau/Bao source (Green 1987:244). The implications of the single piece of Mopir obsidian found at EF-Teouma, although in unclear stratigraphical deposition, need to be considered. First, it could support a continued communication between Remote Oceania and the Bismarck Archipelago into the latest Lapita or post-Lapita period as already suggested on other grounds by Sheppard (1993:134). Alternatively, it might open the possibility of a renewed exchange connection with the Bismarck Archipelago towards the end of soon after the Lapita period. Lastly it could have been a residual piece somehow incorporated into early Lapita obsidian transport from West New Britain. Although possible this option is unlikely as no Mopir obsidian has been found in any early Lapita sites in the Bismarcks (Summerhayes 2003b:138; 2004b:150; 2009:117; Summerhayes *et al.* 1993:64-66, Table 4).

The majority of the remaining artefacts were sourced to Kutau/Bao. In total, 54 (two pieces could not be analysed geochemically, but are macroscopically similar to the Kutau/Bao source) artefacts. A relatively large amount of 14.3%, eight artefacts, were provenanced to the Northern Vanuatu sources (five artefacts to Vanua Lava and three artefacts to Gaua). The ratio of 1.7:1 in the quantities of these two sources is distinctive in comparison with the artefact distribution in later sites in the northern part of the research area.

Because the earlier field seasons focused on disturbed areas of the site, a layer allocation is difficult (Table 5.15 shows a tentative assignment of artefacts to specific layers). Four artefacts were found on the surface: all sourced to Kutau/Bao. Artefacts found in Layer 1 (a recent topsoil) and Layer 2 (post-Lapita occupation), are all believed to relate to Layer 3 (early Lapita phase) (Stuart Bedford and Matthew Spriggs, pers. comm.). Ten artefacts originating from Kutau/Bao and one artefact each from Mopir, Vanua Lava and Gaua were detected in these layers. Artefacts found in the transitional Layers 1/3 and 2/3 are also believed to relate to Layer 3 as these layers were disturbed by the later midden activity on the site (Bedford *et al.* 2004; Bedford *et al.* 2006; 2009). Eleven artefacts (eight from Kutau/Bao and one from Vanua Lava) were found in these layers, including the two artefacts with unclear provenance as described above. Layer 3 can be separated into burial fills associated with mortuary features within the cemetery area and early midden deposits to the east. This layer includes the majority of obsidian artefacts found in the field seasons. Twenty-eight artefacts (25 from Kutau/Bao, two artefacts from Vanua Lava and one artefact from Gaua) were found evenly distributed between the burial in-fills and the midden deposits.

Excavations in 2008 helped to clarify the layer distribution of artefacts in the EF-Teouma site. The assumption that all artefacts found in disturbed locations from the earlier excavation belonging to the early Lapita occupational Layer 3 is supported as no obsidian artefacts were found in undisturbed contexts in Layer 2. In total, nine obsidian artefacts were excavated in 2008, a surprisingly low amount which most probably relates to the focus of this field season on the detailed assessment of the post-Lapita sediment deposition. Of these eight artefacts, five originate from Kutau/Bao, and three from the Northern Vanuatu source (one from Vanua Lava and two from Gaua) and the artefact sourced to West Fergusson.

North Efate sites

No obsidian was found in the site of EF-Arapus in North Efate. However, three pitchstone artefacts (ANU9433-ANU9435) were found in two test pits from spits located 50-100cm[6] under the surface. The PCA (70.1% on the first component and 18.2% on the second) on the three artefacts could not identify a source for these artefacts (Figure 5.33). For convenience, the artefact ANU9405, already discussed in the Mota Lava section, was added. Again, the close match of the composition of these

[6] Bag-labels: Arapus ST33/3 -96cm (ANU9433); Arapus ST36 -35-55cm (ANU9434); Arapus ST36 -80-100cm (ANU9435).

two raw materials is notable (Figure 5.34). The EF-Arapus Layer is dated as a probably localised late Lapita / post-Lapita transition phase on Efate which was very short lived (Bedford 2006b:161) and could give an indication of the age of layers excavated on Mota Lava if it is assumed that all artefacts were imported into the sites in the same time period.

Solomon Islands

Tikopia

Much petrographic and geochemical research has been done on the obsidian artefacts from Tikopia. Based on density measurements and thin sections, Kirch and Yen (1982:260) suggest an import of largely West New Britain obsidian in the initial occupation phase, with a shift to predominantly BI-obsidian in the later phases. The artefacts analysed through thin section by Kirch and Yen were later examined using PIXE-PIGME, commissioned by Matthew Spriggs with a density analysis by Geoff Deeble and most recently reanalysis by Michael Hanslip using again density measurements (Spriggs *et al.* in press). Spriggs et al. (in press) largely confirmed the previous research, but could rule out an import of Kutau/Bao obsidian in the earliest deposits in Tikopia.

Based on this preliminary provenance study all artefacts found in Tikopia and archived in the Bishop Museum were analysed macroscopically as well as the other artefacts included in the original PIXE-PIGME runs and currently archived at the ANU. Additionally, 34 artefacts, including macroscopically unusual samples and a random set, were selected for geochemical analysis using the non-destructive method of PIXE-PIGME. Also, the artefacts previously analysed by earlier PIXE-PIGME runs were reanalysed using LA-ICPMS, and three artefacts from the Bishop Museum which gave inconsistent results in the new PIXE-PIGME runs were also analysed with LA-ICPMS.

The new PIXE-PIGME data will be discussed first. The detailed elemental compositions of the analysed artefacts are presented in Table 5.16. As already discussed, the PIXE data on heavier elements in particular give inconsistent results. Unfortunately, it can be assumed that all analyses detecting >1000ppm Cr and >500ppm Ni are contaminated. Figure 5.35 presents the results of the data in comparison with source samples previously analysed by PIXE-PIGME in the Pacific (taken from Bird 1996). Although the distribution of the artefacts is unambiguously clear, provenancing is not possible. The picture becomes a little bit clearer if we reduce the comparison dataset to the most probable sources of West New Britain, Admiralty Islands, D'Entrecasteaux group, Banks Islands and Tonga (Figure 5.36). One artefact from the Tikopia sites plots close to the Kukuia source. As it also plots in the F range of the West New Britain sources this artefact will be analysed by LA-ICPMS (ANU9415). Several artefacts, macroscopically identical to the Vanua Lava obsidian, plot in the F range of the Vanua Lava source, however, with a large variability in Na. Two artefacts plot within the Gaua range, which overlaps with the East Fergusson source of Sanaroa. One of these artefacts was also analysed with LA-ICPMS (ANU9414). Finally, five artefacts plot unambiguously within the range of the Admiralty Islands. Of these artefacts one was also selected for LA-ICPMS analysis (ANU9416).

In total, 26 samples were analysed using LA-ICPMS, including the previously analysed 23 samples derived from 13 artefacts and three artefacts with unclear provenance from the newly analysed PIXE-PIGME set. The PCA (67.8% on the first eigenvalue and 20.4% on the second) on the dataset plots unambiguously (Figure 5.37). Only three different provenances, the Admiralty Islands and the two Northern Vanuatu sources, were detected. The results support the interpretation of Spriggs et al. (in press) that no Kutau/Bao obsidian can be detected on Tikopia. However, the provenance of the artefacts previously determined as coming from the 'Banks (Vanua Lava)' or 'Banks (Gaua)' can be refined. All of them originate from the Vanua Lava source. The artefact ANU9414 was sourced to the Gaua source, which proves that material of this source was also transported to Tikopia. The newly-analysed artefact thought to originate from Kukuia or West New Britain can now be unambiguously sourced to the Vanua Lava source, providing further support that West New Britain obsidian was not transported to Tikopia. Finally, the newly-analysed artefact ANU9416, assumed to originate from Admiralty Islands, does indeed have its provenance there. However, an attempt at more detailed sourcing to a separate outcrop in the Admiralty Islands was not successful.

Previously, the provenance of artefacts sourced to the Admiralty Islands was tentatively describe as 'Lou (Umrei)' and 'Pam Lin' (Spriggs *et al.* in press). Based on the dataset analysed by Ambrose and discussed in the previous chapter, a more refined provenance of the artefacts originating from the Admiralty Islands was attempted. Figure 5.38 shows PCA on different variables. Unfortunately, the comparison dataset shows a high variability in the different sub-sourcing and an additional large overlap between the composition of different sub-sources. At this stage, a more specific analysis of the provenance of the five pieces analysed could not be achieved. However, with a larger comparison dataset more clearly defining the internal variation of the different sub-sources, I am confident that these artefacts can be provenanced more clearly.

Fiji

Lakeba

The original PIXE-PIGME analysis (Best 1984) identified three different provenance groups in the Lakeba obsidian assemblage: one group of obsidian was sourced to Tonga, one group to an unknown source in Northern Vanuatu and the last group to one or several unknown sources. In course of the present research evaluating the internal variation of the Banks Island obsidian sources serious doubt arose about the provenance of the twelve artefacts found on Lakeba and the related Vanuatu-Fiji connection.

The LA-ICPMS analysis divided the samples into only two provenance groups (Table 5.17). Group 1, including five obsidian flakes previously identified to Tonga (Table 5.17, ANU9149, ANU9150, ANU9151, ANU9152, ANU9166), and one additional artefact ANU9164. These artefacts were sourced to two different obsidian outcrops in Tonga, along with the three flakes that could not be identified to a source with PIXE-PIGME. The second group contains 12 flakes, 11 of which were previously sourced with PIXE-PIGME to an unknown source in Northern Vanuatu (ANU9165 was not previously analysed, see Table 5.18 and Best 1984:434, Table 6.7).

Included in the comparison dataset are four samples of artefacts from Lapaha on Tongatapu (ANU9350-9353), and six artefacts from sites on Lakeba, eastern Fiji (ANU9149-9152, ANU9164 and ANU9166). All of these artefacts show a similar low K-Na distribution and high Fe, Ca and P values. Additional strongly depleted values of Ba, Pb and Th support the province of these samples as belonging to Tongan Arc obsidian sources. Three of the Lapaha artefacts (ANU9351-9352) and five of the Lakeba artefacts show a high similarity with one sample (ANU9372) from the Hala'Uta outcrop on Tafahi (Figure 5.16). Although the match is not close enough to source these samples unambiguously to Tafahi, it predicts a high possibility of their origin in the region and might indicate an additional unsampled outcrop on this island. The small sample size is not sufficient however, to assess the internal variation of the known outcrop of Hala'Uta. Therefore both possibilities have an equal likelihood. More samples are necessary for a detailed assessment of this issue.

One artefact from Lapaha (ANU9350) and one artefact from Lakeba (ANU9164) show a similar geochemical composition (Table 5.16), but significant differences to the Tafahi sources. Therefore, it can be expected that these artefacts represent a separate obsidian source on the Tongan Arc. Several possibilities for further source locations on Tonga are known (William Dickinson pers. comm.). Interestingly, these artefacts show similarities in their trace element distribution with two basalt samples from Tofua and Vava'vi in Tonga, which were used as raw material for basalt adzes (Collerson & Weisler 2007), as well as a similar chondrite normalised rare earth element pattern (Figure 5.17) to some dacites from Fonualei, Tonga (Ewart *et al.* 1977).

The PCA (71.2% on the first Eigenvalue and 16.2% on the second) shows an unambiguous distribution of artefacts and sources (Figure 5.39). There is a slight overlap between Group 2 samples (previously to Northern Vanuatu sourced artefacts, including the single outlier ANU9158) and the Baki sub-source of West New Britain. However, it shows that they have a different chemical composition to all other Western and Central Pacific obsidian sources including those from northern Vanuatu (Gaua and Vanua Lava). This rules out a Vanuatu origin for the obsidian found in east Fiji. To analyse whether the overlap with the Baki sub-source is valid selected isotopes and isotope ratios (K_2O, Pb, Ta/Th, Nb/Th) were further investigated. K_2O was used as major element as it is particularly distinctive in the Banks Islands sources. Figure 5.40 clearly shows that the similarity of Baki and Group 2 artefacts in the PCA derives from the selected elements and is not evidence of a provenance of these artefacts in West New Britain as they have a distinctively lower SiO2 and higher Fe content than the West New Britain sources.

In addition, the bi-plots clarify the significant dissimilarities between the Vanuatu obsidian sources and Group 2 artefacts, especially in their K_2O and Pb content, but similar in the Th/Ta and Nb/Th ratios. Besides the unequivocal geochemical results the macroscopic appearance of the artefacts further supports a non-Vanuatu origin for the Group 2 obsidian. The absence of plagioclase phenocrysts makes a Vanua Lava origin unlikely and although the artefacts resemble obsidian from Gaua, overall they are less reflective and have a finer texture.

As the elemental composition of the Lakeba Group 2 artefacts demonstrates that they do not derive from Vanuatu it was attempted to provenance the artefacts based on their trace element and radiogenic composition. To investigate possible artefact sources first the trace element data was considered to examine whether they had an origin from Oceanic Island Basalts (OIB) settings similar to the Central and Eastern Pacific obsidian sources or if they derived from an island arc. To examine potential provenance areas for the Lakeba Group 2 obsidian the considerable body of geochemical data collected to understand the origin and processes involved in the production of volcanic rocks was used (Cole *et al.* 1990; Ewart *et al.* 1998; Peate *et al.* 1997; Raos & Crawford 2004; Smith *et al.* 2003; cf. Collerson & Weisler 2007 for a similar approach). The Group 2 artefacts from Lakeba have an Island Arc trace element distribution, and all of the intra-plate volcanic islands in the Pacific can therefore be ruled out as an origin (Smith *et al.* 1977). Additional support for the view that the Group 2 obsidians cannot originate from Vanuatu is that the volcanic rocks of the Central New Hebrides Arc (Peate et al. 1997; Raos and Crawford 2004) are more depleted in the majority of elements than the Group 2 artefacts, particularly the incompatible ones (Figure 5.41).

The Tongan rocks are, on average, more depleted in almost all elements, but have a less prominent Ti depletion (Ewart & Hawkesworth 1987). Most of the rocks from the southern Kermadec Arc are element depleted compared to the Lakeba Group 2 artefacts. While some basalt samples from Macauley Island in the Kermadec Arc have a similar trace element pattern to the Lakeba Group 2 artefacts, the obsidian from Macauley Island (including sample AH594, reanalysed with LA-ICPMS in this study) are very different (Smith *et al.* 2003) and rule out a Kermadec Arc source for the Group 2 artefacts. Volcanic rocks from the Lau Arc in east Fiji are more diverse than rocks from the adjacent Tongan-Kermadec Arc (Cole *et al.* 1990). The Mago Volcanic Group has an element pattern with a broadly OIB distribution, whilst rocks from the Korobasaga and Lau Volcanic Groups have trace elements that are more strongly island arc distributed, but with significantly different Nb/Ta ratios (Ewart *et al.* 1998; Peate *et al.* 2001). No Lau Arc rocks yet reported have a trace element distribution similar to the Lakeba Group 2 artefacts. Overall, rocks from the Tongan-Kermadec Arc and the Lau Arc are more depleted in potassium than the Lakeba Group 2 samples. However, there are rocks from Ono-I-Lau (Cole et al. 1990) with unusually high K_2O values compared to other parts of the Lau Arc, albeit with heavy isotope ratios different from the Lakeba artefacts (see below).

Radiogenic isotopes

The Pb-isotope distribution of the two Lakeba Group 2 samples displays unusually high $^{206/204}$Pb and $^{208/204}$Pb ratios (Figure 5.42) that plot between classic OIBs like Samoan volcanic rocks and Indian and Pacific MORB (Mid-Ocean Ridge Basalt) signatures (Wright & White 1987; Zhu 2007), as well as having $^{206/204}$Pb and $^{207/204}$Pb ratios in the upper range of the Pacific MORB array (Figure 5.43). In this sense they are unlike volcanic rocks from the New Hebrides Arc, which have an Indian and Pacific Ocean MORB distribution (Peate *et al.* 1997:1343; Raos & Crawford 2004:50, Figure 8).

One explanation for the high Pb-ratio of the Group 2 samples is the impact of mantle plumes, or mixture of both MORB and OIB, in the genesis of the parent rock, which has been described for the northern Tongan Arc islands of Tafahi and Niuatoputapu (Clift & Vroon 1996; Falloon *et al.* 2007; Wendt *et al.* 1997), and for some parts of the Fiji Islands such as the Mago Volcanic Group (Cole *et al.* 1990:544, Table 2). Several researchers have also mentioned an OIB influence in the genesis of the younger Fijian volcanic rocks of Viti Levu and adjacent islands (Gill 1984; Gill & Whelan 1989b), and both processes result in unusually high $^{206/204}$Pb, $^{207/204}$Pb and $^{208/204}$Pb ratios like those seen in the Group 2 obsidian. The high Pb-isotopes ratios are also associated with more radiogenic Sr and low Zr/Nb ratios (16-21, compared to MORBs with 40-120) in the northern Tongan Arc (Wendt *et al.* 1997:613) and the Mago Volcanic Group (Cole *et al.* 1990). Therefore, the Pb isotope ratios point towards northern Tonga, but the Group 2 artefacts have a MORB or island arc Zr/Nb ratio (60:1) that along with their high potassium suggests that northern Tonga is unlikely to be the source.

The possibility of a local origin for the Lakeba artefacts from the back-arc spreading area of the Lau basin (Ono-I-Lau, Lau Volcanic Group and Korobasaga Volcanic

Group) is also not supported as these rocks have significantly lower Pb isotope ratios that plot in the distribution of Indian Ocean and Pacific Ocean MORBs (Ewart *et al.* 1998:344-346, Figure 6) and Sr ratios that are less radiogenic than the Group 2 obsidian (Cole *et al.* 1990:547, Table 5; Peate *et al.* 2001; Sun *et al.* 2003).

Intermediate to high Pb-isotope ratios similar to those of the Group 2 artefacts, are found in several volcanic rock series in Fiji. Gill and Whelan (1989b) attribute the high Pb isotope ratios of these younger Fijian volcanic rocks to the impact of OIBs in the genesis of the islands. The best matches with the Lakeba Group 2 artefacts are the shoshonitic and transitional basalts and calcalkaline andesites reported from Viti Levu, Ovalau, Beqa, Ngau, Moala, Totoya and Matuku (e.g. Sambeto or Mamosi Quarry, Gill 1984:448, Table 2; Gill & Whelan 1989a:4563, Figure 1). These rocks developed after the North Fiji basin split in the transition to the younger ocean alkali basalt volcanism around 5-6 million years ago (Gill & Whelan 1989b:4579; Squire & Crawford 2007:311, Figure 11). Gill (1984:445) describes these rocks as medium rich in K, but not Fe enriched, with La/Yb >2 (2.47), K/Rb 475 (481) and K/Nb >8000 (8563) (Group 2 values in brackets, cf. Gill 1984:446, Table 1; Gill & Whelan 1989b:4563, Table 1; 1989a:4582, Table 2). Until now, no volcanic glasses have been recorded on these islands. However, the occurrence of rocks in Fiji that have similar isotope ratios and trace element compositions to the Group 2 artefacts strongly suggests an origin in the Fiji Islands from a small and currently undiscovered obsidian source.

Implications from the characterisation study

Of the 510 artefacts analysed in this study only nine artefacts (1.8%) could not be unambiguously provenanced. All of these are pitchstones with low totals in the major elements distribution (which probably can be explained through a high amount of structural H_2O). The samples were selected from a total pool of 2212 obsidian artefacts through a simple random sampling method with the addition of any macroscopically unusual pieces. In total, 14 source samples and 182 artefacts collected in the research area were sourced to the Vanua Lava source and 15 source samples and 101 artefacts sourced to Gaua. Although there is a slight rise in the compositional variation if all artefacts are included in the assessment, the SD of most of the analysed elements, with exception of Sr (~7% SD in Vanua Lava) excluded, lies well within the 2δ range of the expected, machine-induced, variability. From the collected geochemical data it was concluded that no additional obsidian source exists, but that more research on possible pitchstone sources is needed. However, of the 2665 artefacts (all raw materials) analysed in this study only 15 artefacts were pitchstones which suggest that this raw material was not employed systematically. The 12 artefacts found on Lakeba, Fiji, provides additional confirmation for the geochemical study. These artefacts – previously sourced to Vanuatu – plot outside of the established intra source variation. Detailed research on the geochemistry showed that these artefacts could indeed not be sourced to Vanuatu and not even to the New Hebrides Arc, but most probably to an unknown source on Viti Levu, Fiji.

The comparison study of the new LA-ICPMS data collected from Northern Vanuatu and the previous PIXE-PIGME data showed a reasonably good correlation between the results. As previous authors have stated, a variation of up to 20% between different methods had to be expected and indeed the correlation with the older PIXE-PIGME fell well within this range. Unfortunately, the previously analysed samples originate from insecure geological contexts and it was therefore decided to reanalyse the newly collected 29 source samples. The results of this reanalysis were sobering. Light elements analysed by PIGME showed a good correlation. The PIXE data, however, especially on trace elements, gave very inconsistent results. This most probably derives from Ni and Cr contamination from the analysing beam hitting the carrier of the samples and only partially from the sample itself. After a rerun of the samples continued to give inconsistent results the experiment was abandoned. Comparing these two methods with each other, it quickly becomes clear that these two datasets are not good enough for a direct correlation. To overcome variation in data collections it was attempted to reduce differences between these methods with the application of element ratios. However even the application of 9 ratios in the PCA, which are normally used for identifying sources, the picture does not become clearer. The two datasets plot distinctively from each other.

The ICPMS study has shown that the overwhelming amount of obsidian used in the research area originates from the Northern Vanuatu sources. Of 2665 artefacts analysed, 2145 artefacts can be sourced to either the Vanua Lava or the Gaua source. However, there are several different obsidian varieties which were transported from distances of more than 2400km into Vanuatu.

From the West New Britain sources Kutau/Bao is the most prominent with 57 pieces. As a second West New Britain source Mopir was also transported into Vanuatu, but only one piece was sourced to this location. It is somewhat meagre evidence for a continuous contact of settler communities in Vanuatu, but considering that the state of research is very patchy in Vanuatu, the importance of this artefact should not be ignored.

Similarly, the one piece most probably sourced to West Fergusson should also not be dismissed. This is the second artefact from the D'Entrecasteaux Islands found in Remote Oceania following Green and Bird (1989) first detected one artefact in a Lapita context in the Reef / Santa Cruz Islands. The P-XRF data did not unambiguously support the detailed provenance to Kukuia, however. The geochemistry might be evidence for an as yet undiscovered sub-source on this island (Peter Sheppard, pers. comm.). That more research is needed in this island group is also shown in the lack of recorded Lapita-age sites in this area.

Finally, Admiralty Island obsidian was detected in the Tikopia assemblage. The one artefact provenance to the Admiralty Islands by Ambrose from Malo could not be supported by any new artefacts sourced to this group in Vanuatu. Two alternatives exist as an explanation. First, the state of research in Vanuatu, especially in the late Lapita phase is not far enough advanced to exclude transport of Admiralty Islands obsidian into Vanuatu. Secondly, we need to consider the implications of Summerhayes (2003b; 2003a; 2004b) model of a shift of utilised obsidian from predominantly WNB to Admiralty Islands obsidian in between 2900/2800 - 2700/2600 BP in the eastern Bismarck Archipelago. Contacts with the Bismarcks may have been finished by then, and therefore no obsidian was transported into Vanuatu anymore. Of the two alternatives the former seems arguably more likely than the latter.

Chronological Variation

The archaeological evidence clearly indicates that obsidian from several sources were utilised in Vanuatu in the past. In the following, the distribution of these different sources will be discussed chronologically.

Artefacts from five sites of Lapita age are incorporated into this dataset: the burial site of *EF-Teouma*, Efate; one site on the small island of Vao of the east coast of Malakula; the *Makue* site on Aore Island, Santo; the North Santo sites (Port Olry and Matantas); and the *ML-Lequesdewen* site on Mota Lava. All these sites date in the range of 3000 - 2900/2800 BP and can be associated with the initial occupation of this area.

The most striking feature in the lithic assemblages of this time period is the overwhelming amount of Kutau/Bao obsidian in each of these sites. Although the lithic assemblages found in the sites are small, all artefacts sourced to Kutau/Bao were found in this time period. If artefacts were found in layers with Erueti or Mangaasi style decorated pottery, as is the case in EF-Teouma, then they usually derive from mixed or disturbed contexts or have no clear layer allocation. Similarly the other two 'exotic' obsidian sources identified, Mopir and West Fergusson, most likely derive from layers dated well into the Lapita period.

Even though the focus of transported obsidian into these sites was from sources outside Vanuatu, Banks Island obsidian was also found in all of these sites. Nine artefacts were found in EF-Teouma, two in Vao (also one in the Lapita-aged site of Uripiv), at least 22 artefacts in the site of Makue (Galipaud & Swete-Kelly 2007a:158, Figure 6), 13 artefacts in the North Santo sites, and 105 artefacts in ML-Lequesdewen, although the upper limits of the Layer 3 radiocarbon dates (~2400 BP) range well into the post-Lapita phase. This evidence supports the assumption that Lapita settlers very quickly identified the obsidian sources in the Banks Islands and transported this raw material as far south as the southernmost coast of Efate in Central Vanuatu. However, no Banks Island obsidian has ever been found in any sites further south.

What is surprising in the numbers of artefacts utilised in these sites is the ratio of local material to exotic material. The Makue site has a ratio of local to exotic material of 1:~4; EF-Teouma 1:~6, 2:1 in Vao (although on a very small assemblage size); 13:0 in

NS-Matantas; and 105:1 in ML-Lequesdewen (although without secure age brackets). This shows on the one hand that Banks Island obsidian was more numerous in sites closer to the source and, on the other hand, that this raw material was not completely absent in sites at greater geographic distances than previously assumed.

For the earliest occupation phase on Tikopia the evaluation of artefacts found in the site of TK-4 is difficult. The initial colonisation of Tikopia is clearly associated with the Lapita expansion. However, as the Kiki-phase in Tikopia covers a time period of 800 years, it has a large overlap with the post-Lapita phase as defined in this thesis. Fifteen BI-obsidian artefacts were found in this general time period, but it is unclear if these artefacts derive from the earliest occupational layers of TK-4 in association with Admiralty Island obsidian. In the Layer I on TK-4, Kirch and Yen (1982:117) only mention the occurrence of "several flakes of high-quality, translucent obsidian […], and several flakes of fine-grained chert." For the purpose of this thesis, the 15 artefacts are therefore incorporated in the following into the earlier time period of the post-Lapita phase.

Archaeological sites incorporating the transition to the post-Lapita phase are still rare in Vanuatu. However, the somewhat sketchy picture of this time period shows a radical change in the pattern of obsidian distribution at the end of Lapita. Several sites in Epi and the Erueti and EF-Arapus sites in north Efate can give an initial insight into the changing patterns of obsidian transportation into Central Vanuatu. In addition, the earliest site found on the Torres Islands, *TI-Kurvot*; the site of ML-Lequesdewen in Mota Lava, and the earliest sites on Tikopia and Taumako of the Southeast Solomon Islands are helpful in assessing changing patterns of resource use and transportation of Banks Island obsidian to the North.

No obsidian has been found in the lithic assemblages on Efate post-Lapita. Whether this is evidence for a complete disruption of external contact is questionable as there are pitchstone artefacts found in the EF-Arapus site which may show continued contact with Northern Vanuatu at least in the immediate post-Lapita period on Efate. Ever stronger evidence against a complete disruption of contact from the BI- to the south is disproved by the discovery of three artefacts made from Banks Island obsidian on Epi in the post-Lapita period. Continuous contact into the north is suggested by the discovery of small quantities of BI-obsidian in Taumako, Tikopia and the Torres islands. The quantities of artefacts made from Vanua Lava material is relatively small. Only four artefacts were found on Taumako, in total 15 artefacts on Tikopia (see discussion above) and 35 artefacts in the Torres Islands. It is important to note that besides the import of BI- material into Tikopia through the earliest period of occupation, Admiralty Islands obsidian can also be found in these sites indicating contact of the population with settlements further north in this transition phase.

The archaeological record for much of the time period post 2400 BP and before 1000 BP is even more fragmented than in the direct post-Lapita transition. In general, we can see a further decrease in the number of artefacts found in sites of this time period as only four artefacts were found on Tikopia and only eight artefacts at the site of ML-Saywoume on Mota Lava. Also it seems that the geographical distance over which this raw material was transported also contracts as we do not find any Banks Island obsidian in Central Vanuatu anymore and also not on sites of this time period in Fiji (as previously proposed for the Lakeba site) or the Reef / Santa Cruz islands (although Doherty 2007:304, Table 6.3, mentions three undated sites (SE-SZ-26, SE-SZ-49, SE-RF-19) in RSC containing BI obsidian. However, these sites can also date into the post 1000 BP phase).

This pattern changes again radically in the latest time period (most possibly post ~1000 BP, associated with the Tuakamali phase on Tikopia). Large amounts of obsidian artefacts are now found in Tikopia and the Torres Islands, and also on Mota Lava and Pakea (Ward 1979:8-20, Table VIII-6) in the BI- group itself. Additionally, a more intense exploitation of the Vanua Lava source can be seen in close vicinity of the source itself in the sites of Ambek and Lesa, and in the large assemblages of in the Tikopia and Torres islands sites.

Kirch and Yen (1982:256, Table 35) found 568 artefacts originating from the BI- in this phase on Tikopia, the macroscopic and geochemical analyse identified all but eight artefacts originating from Vanua Lava (the remaining are sourced to Gaua). Similarly, 679 artefacts from Pakea derive from latest occupation (post 1200 BP) of the site. In Mota Lava 150 artefacts were found in the topmost 50cm of the stratigraphy, although undated, and also the excavations in Ambek and Lesa, uncovering 638 artefacts in total, were dated to this time period.

Conclusion

Research on the obsidian sources in Northern Vanuatu has shown that LA-ICPMS is a useful tool in discriminating obsidian sources from each other in the Western Pacific and in unambiguously fingerprinting artefacts made from obsidian. Several research questions have been answered on the internal geochemical variation, comparison of analytical methods and the spatial and temporal distribution of obsidian in Remote Oceania.

It has been shown that the widespread distribution of West New Britain obsidian in Remote Oceania, although impressive in its spatial dimensions, was only short lived. The transport of obsidian from Northern Vanuatu sources on the other hand was confined to a much smaller area, but it continued through time most probably until the first arrival of European explorers on the islands.

A general pattern of changes in the spatial distribution of the interaction system emanating from the Northern Vanuatu sources has been detected. The widest geographical distribution of this raw material was in the Lapita period. This period terminated about 2900/2800 years ago and we can see a contraction of the geographical distribution beginning directly at the start of the post-Lapita phase. This transition most likely lasted until ~2400 BP with reasonably large amounts of raw material transported within this system. The intensity of contacts in the exchange system decreased thereafter with only a small number of artefacts found in sites in the Banks Islands group and adjacent islands to the north. The reanalysis of artefacts from Lakeba makes a contact between Fiji and Vanuatu at this time implausible. Perhaps starting at 1200 BP and slightly later outside the Banks Islands group we can see a peak in the amount of raw material exploited from the sources there and transported throughout the nearby islands. However, the intensification of contact in the latest occupation phase is not correlated with an increase of the spatial distribution of this raw material.

This chapter has considered the spatial and temporal distribution of obsidian, where was the raw material was distributed and in which time frame. In the next chapter these data are set within the context of production, distribution and consumption patterns. The next chapter will explain how people obtained the raw material and why they consumed it in a particular way.

- Chapter 6 -

6. Results: Physical attributes of the assemblages

Introduction

After the identification of the specific source for every artefact in the last chapter, the physical attribute analysis of this chapter concentrates on resource availability and resource utilisation, and on the production of artefacts in relation to their spatial distribution, e.g. reduction intensity. Lithic analysis of Lapita and post-Lapita tool technology in Pacific research is still in its developing phase. Since Allen and Bell's (1988) summary and criticism of Lapita lithics research, several detailed studies of pre-Lapita, Lapita and post-Lapita lithic assemblages have been conducted (Fredericksen 1994; Halsey 1995; Hanslip 2001; Swete-Kelly 2001; Symons 2001), although only a few have been published in detail (Fredericksen 1997; Fullagar 1990; Hiscock 2005; Pavlides 2006; Sheppard 1992, 1993; Torrence 1992; White & Harris 1997).

Experiments and ethnographic research have shown that the people knew and used substitutes for stone tools, like shell or bamboo knives. Or as the early explorers of the South-Sea described:

> "Their arms are heavy wooden clubs, and bows of the same, arrows of reed with wooden points, hardened in the fire, darts with pieces of bone enclosed" (Collingridge 1906).

The artefact assemblages of the Lapita and post-Lapita periods in the Pacific have previously been described as 'expedient' (Binford 1979; Gould 1980), which classifies them as produced in an opportunistic strategy of artefact manufacture with no curation of raw material involved (Fredericksen 1994; Hanslip 2001). Contrary to widespread agreement of scholars describing the technology as simple, direct percussion flaking with little standardised control of the reduction process, this assessment of resource utilisation is not without its critics. The absence of resource maximisation, was proposed by McCoy (1982), Sheppard (1993) and Halsey (1995), resulting in the hypothesis that factors other than utilisation of the raw material are defining its value. However, the opposite opinion, identifying maximisation of resources and interpretation of resources as high value commodities were assumed by Swete-Kelly (2001), Fullagar (1992), Lawlor (1978) and Hedrick (1980).

Approaches to the technological data

In Chapter 1 general research aims of this thesis are described. These general research aims are now specified on the available body of data presented in this chapter.

Aim 1: Determine the extraction processes employed at both Northern Vanuatu sources.

To determine extraction processes active at both sources, a detailed analysis of the obsidian outcrops themselves and the sites in close vicinity are necessary. As one approach, surface surveys of the area were conducted to detect remnants of past mining activities, such as pitting. A second approach concentrates on artefacts found at the source and in the research area in general. The focus is on the physical attributes of the cortex to distinguish between fluvial processes creating secondary deposits and mining of primary deposits in the area. In relation to possible physical extraction methods utilised, the evaluation of dimensions of cores and nodules was undertaken in- and outside the direct source area. Whether extraction processes differ between the sources or whether one source was preferred over the other is also assessed. In addition reduction at the sources itself is correlated with the reduction of transported material, with the focus on core measurements and the core reduction sequences.

Aim 2: Analyse patterns of spatial and temporal distribution of lithic assemblages.

The identification of differences in reduction intensities dependent on the distance to the source is another important aim. Maximising reduction (indicated by the production of flakes) could give an indication of optimising resource utilisation strategies. Especially important in this context are differences in reduction correlated with the distance of transportation. Optimised resource management can usually be detected through an increase in curation or technological changes minimising some kind of cost, e.g. time or labour, or maximising some other attribute, e.g. intensified reduction or usable edge per unit (Hiscock 1994; Kuhn 1994; Sheppard 1987, 1993; Torrence 1989). However, alternative assumptions for reasons of obsidian transportation have to be considered, for example changes of human behaviour in reaction to environmental stress is one alternative which will be described in more detail in Chapter 7. Are there differences in reduction patterns between sites within the same distance groups outlined in the next section? Temporal changes have to be considered in the analysis of transport and communication patterns. Are the same processes active through time or are differences detectable?

Aim 3: Determine whether the observed patterns of spatial and temporal distribution are raw material dependent.

The last aim to be evaluated through the technological analysis is whether differences in reduction and distribution are raw material specific. Several aspects of technology and distribution can be examined for this purpose. Frequency of raw material distribution is one factor to be considered. Additionally, the comparison of reduction intensities of local and transported material might indicate different treatments of raw materials. It has already been discussed that 'exotic' obsidian was only transported into Vanuatu in the initial phase of colonisation. Did this restricted timeframe have an impact on the treatment of the raw material, and furthermore, what was the most likely origin of the artefacts transported into Vanuatu? Can we determine that the people had direct access to the source in West New Britain as proposed for the RSC sites by Sheppard (1993)? It has already been stated that this work does not concentrate on a functional study of the material, instead that reduction technology and distribution is the main focus. However, an assessment of the 'use' is a necessity in the analysis of the value of certain items. Therefore, a detailed use-wear analysis on a small sample of artefacts, both obsidian and cherts, was conducted by Dr. Nina Kononenko, Australian Museum Sydney, and the results are discussed in this chapter. These two separate studies of use-wear provide a preliminary impression of the usage and use-value of different raw materials (and possible differences between them) and in this context a specific type of tool, 'gravers', will also be discussed.

Methodology

The approach used in this work is a quantitative attribute analysis along the lines of standard practice (Andrefsky 2005; Cotterell & Kamminga 1987, 1990; Hiscock 1988, 2002, 2005; Hiscock & Attenbrow 2005; Zimmermann 1988). As Sheppard (1993:122) has noted, the elaborate systems applied to reduction sequences in palaeolithic lithic research are not appropriate for the analysis of opportunistic reduction strategies summarised under the term 'expedient technologies'. My choice of variables will however reflect the mechanisms of exchange and resource utilisation, with an emphasis on an assessment of optimisation strategies. I have selected useful attributes, such as artefact measurements, number of dorsal scars on flakes, cortex and artefact type distribution following previous studies (Halsey 1995; Marwick 2007; Swete-Kelly 2001; Symons 2001).

In this work, artefacts were classified into flakes, blades (elongated flakes with a length:width ratio of more than 2), angular shatter, cores and unworked nodules. One additional category ‘chipping waste’ included all artefacts <10mm. These artefacts were only counted, weighed and the number of pieces with cortex analysed. In consideration of the spatial distribution of the two different obsidian types detected in the Banks Islands and the focus of this thesis on spatial and temporal distribution of Northern Vanuatu obsidian sources, artefacts were separated into three different distance zones, following Specht’s (2002) approach for the West New Britain and Admiralty Islands sources (Figure 4.5):

1. At the source location or directly adjacent (<5km) to the source,
2. Transported material at a distance of greater than 5km and less than 200km (this includes the Banks Islands group, the Torres Islands and North Santo),
3. Material transported distances over 200km and less than 1000km (mainly artefacts found in Central Vanuatu and the Reef / Santa Cruz islands, especially Tikopia)

As a comparison a fourth category was implemented:

4. Artefacts sourced to West New Britain, Admiralty Islands and Fergusson sources (distances of >1000km).

Surface collections from a single island, for example in the Ureparapara sites and all artefacts found on Toga in distance zone 2, were grouped together each to increase statistical significance of these collections. Unfortunately, even with the grouping of surface collections, the assemblage here generally are too small and too spatially fragmented to assess possible temporal changes in the extraction process of the sources.

The sites analysed in this thesis cover the time frame from the initial colonisation until European contact. Based on the small assemblage size in certain time periods the grouping of artefacts into three became necessary. Although this grouping seriously impacts the chronological resolution of the data set, without this step no statistically convincing argument can be made about the quantitative analysis of lithic artefacts. If marked differences in particular time periods can be identified, these are especially considered in the text. The chronological grouping are:

1. Lapita period: initial colonisation phase at about 3100 BP until ~2800 BP,
2. Early post-Lapita period: beginning directly after the initial colonisation at 2800 BP until ~1000 BP,[1]
3. Late post-Lapita period: from 1000 BP until contact time with European explorers.

Where the excavated sites cover more than just one time period (for example early and late post-Lapita periods), the temporal changes in the assemblage will also be addressed.

For the analysis of the extraction process used in the exploitation of the two Northern Vanuatu sources, several attributes can be employed. Whether the utilisation of secondary deposits was an exploitation strategy, for example surface collected nodules exposed through fluvial processes rather than intensive mining or quarrying activities, can be assessed through the condition of the cortex on cores and debitage in archaeological sites. Additionally, physical attributes (here maximum length and weight) of nodules and cores with or without cortex give an indication of the size of cores utilised, which in turn gives a suggestion of size constraints in the production of large flakes. On the other hand physical attributes of flakes with or without cortex,

[1] It has to be noted that this period covers almost half of the entire history of human occupation of the Vanuatu archipelago. Furthermore, the continuities and discontinuities in the immediate post-Lapita period until 2400 BP has been the focus of considerable research in the last decade. However, the grouping applied here is considered to be necessary based on the low number of artefacts found in this time period (only 68 obsidian artefacts were excavated, cf. Table 6.31). Without this grouping artefact numbers are to small to give a statistically convincing argument. Acknowledging the importance of this time period, it is attempted to describe, whenever possible, particularities in the production and consumption patterns of pre- and post- 2400 BP sites separately in the text. Additionally, the selected time periods allows the exploration of effects of ENSO variation within the existing culture-historic structure.

compared to discarded cores are useful in the examination of the intensity of reduction even if we can assume from previous analyses that opportunistic freehand reduction of cores was the method of choice for the production of flakes (Halsey 1995; McCoy 1982; Sheppard 1993; Swete-Kelly 2001; Ward 1979). An assessment of whether previous results are correct in assuming a preference for freehand reduction will also be conducted.

For the analysis of the cycle of production, distribution and consumption of the raw material through space and time, reduction processes in terms of resource maximisation and optimisation strategies will be assessed. Although the limitations of the analysed dataset have already been mentioned, this research will analyse the production of stone artefacts in every distance zone and site separately to identify spatial trends in artefact distribution.

Here several attributes and their interpretation in previous studies will be discussed. Evaluating core reduction strategies in Lapita assemblages in the RSC sites and Makekur, Sheppard (1993) and Halsey (1995) categorised core forms by the orientation and number of flaking platforms and both identified resource maximisation and optimisation strategies based on the occurrence of multiple platform cores. In this study, a different approach is used insofar as cores are not classified by forms. Instead, the number of platforms and the number of rotations are counted separately to assess whether the relationship between these two attributes derives from a maximisation strategy or from a deliberate lack of investment control over the reduction process.

For the assessment of the intensity of the reduction process, recent experimental data provided by Marwick (2007; 2008b; 2008a) will be used as a comparison study of reduction intensities. Although this experiment was especially designed to replicate the Hoabinhian (Hutterer 1977) reduction strategies of Southeast Asia, the evaluation of several attributes, such as 'location of dorsal cortex', 'percentage of dorsal cortex', 'number of scars' on flakes and cores, has also proven to be useful in this study (see also Symons 2001, for a similar approach). In this work the location of dorsal cortex was classified as belonging to one of eight sectors (Figure 6.1). For comparison purposes this classification was further simplified into four categories (primary, secondary, distal and tertiary) as defined by Andrefsky (2005:104, 106), Ahler (2008), Sullivan and Rozen (1985), and Marwick (2007:122; 2008b:1195).

Quantifying lithic assemblages in the Pacific has been problematic in the past (Specht 2002). Several methods of quantification have been proposed, for example frequency of artefacts per m^3 (Green 1991c), weight per m^3 (Sheppard 1993) or frequency of artefacts per m^2 (Fredericksen 1997). For the assessment of the number of flakes in relation to cores the Minimum Number of Flakes (MNF) method as defined by Hiscock (2002) will be used and for the spatial correlation mean weight of debitage will be recorded. In the analysis longitudinal breakage was not separated into left or right, but identified as complete. However, the highest percentage of flakes carrying this attribute in one site was TK-1 on Tikopia with only 7.7%, which indicates that the lack of precision in the analysis of this attribute might not significantly distort the overall picture.

For the examination of macroscopic edge damage, the same definition was applied as proposed by Sheppard (1993:131) and Halsey (1995:68). However, as will be shown in the section 'use-wear' and by Young and Bamforth (1990), in general macroscopic edge damage does not represent a good measure for utilisation as post-depositional processes could have a significant effect on edge conditions. In the description of each distance group this attribute will therefore not be discussed.

Processes of source exploitation

In Chapter 5 a detailed geological description of the sources and their environment was given. It was also stated that the author could not access the primary deposits of obsidian at the Vanua Lava source. However, flakeable nodules of different qualities were readily available that had been eroded from the riverbed. Specht et al. (1988) in their assessment of the Talasea source area on West New Britain describe a similar situation, where the preferred method of extraction for this high-quality obsidian was either from surface collections or digging into loose soil to recover rounded nodules.

One focus of this thesis is the extraction and distribution processes of the two Northern Vanuatu sources and the technological attributes analysed were selected for these purposes. In the analysis of the physical attributes the condition of the cortex on nodules, cores and flakes was examined and the results are present in Table 6.1. In total

1161 artefacts had cortex on the surface and the majority of these artefacts (85.2%) showed some forms of rounding, most probably deriving from fluvial processes. Although this is a strong indication that people used surface collections from riverbeds and beach deposits as the main source extraction, another 30 artefacts (2.6% of the total assemblage) were detected with a rough cortex where rounding processes are unlikely. Twenty-four artefacts with a rough surface derive from the Vanua Lava source, 5 artefacts from Gaua and one artefact from the Admiralty Islands. This might indicate in the case of the Vanua Lava source, that an undisturbed obsidian outcrop could exist, might be buried through a landslide and has not been accessed so far.

In the source description it was stated that good quality material was found in the riverbed of both the Bemon River on Vanua Lava and the Namasari River on Gaua. Although nodule sizes of up to 15cm diameter were detected (and more than 20cm in the case of the Gaua source), most of the better quality nodules were of smaller size. Twenty-two unworked nodules were found in sites throughout the research area, 15 from Vanua Lava and six from Gaua. It is important to note that the detection of unworked nodules was not restricted to distance zone 1 or 2, but that unworked nodules were also discarded at further distances from the sources. For example, one unworked nodule of 20mm maximum length was found in cultural deposits on Tikopia (TK-35 A2-5). Figure 6.2 and Figure 6.3 presents the mean weight and mean length of the excavated nodules. There is a clear decrease in both the mean weight and length from sites close to the source (distance zone 1) to transported material over longer distances, although the drop off is not significant between distance zone 2 and 3. The discarded nodules are rather small with an average of 35.3mm (20g) in the direct vicinity of the source and 23.2mm (2.8g) further away. However, nodule measurements are not defining for the utilisation of the material (rather the opposite), but give an indication on size range of nodules, which were selected for transport over large distances in some cases.

Utilised cores, however, give a direct indication of the procurement and transport of obsidian throughout the research area. Table 6.2 gives the frequency of different obsidian types per distance group. In total 47 cores were found in distance zone 1, 89.4% were carrying cortex (47:42). This ratio drops to 53.7% (54:29) in distance zone 2 and 38.4% (86:33) in distance zone 3. The amount of cortex, if all cores are included, decreases proportionally to the number of cores with cortex from 33.8% to 7.8% (Figure 6.4 and Figure 6.5). When only cores that show cortex are included in the calculation, the mean amount of cortex is surprisingly similar in distance zone 1 and 2 with both showing a mean of around 37.9% (36% for distance 2) cortex coverage. This decreases to 20.3% in distance zone 3, which is similar to the one core with cortex found on Tikopia sourced to the Admiralty Islands and which might be an indicator of more intensive utilisation of cores for the production of flakes at larger distance from the source (this will be discussed at the end of this section). However, cores with cortex were found in all distances in large numbers which probably indicates a transport of these cores in an unworked, or at least not strongly pre-prepared form.

Similar to the discarded nodules, core measurements indicate transport and utilisation of smaller nodules, rather than larger cores which could have been reduced in different stages (Figure 6.6 and Figure 6.7). The mean length of cores found in distance zone 1 is ~30.6mm maximum length, which decreases to 25.8mm in distance 2 and 16.1mm in distance zone 3. This is proportional to the measurements for discarded unworked nodules. This picture is replicated in the mean maximum length and weight of complete flakes (Figure 6.8 and Figure 6.9), which is proportional to all remaining debitage, although the drop in the mean maximum length from 21.3mm (19.3mm, all debitage) in distance zone 1 to 16.1mm (15.7mm, all debitage) in distance zone 3 is much less pronounced than comparable core lengths. This might indicate a length threshold in the production of flakes. Interestingly, there are the high confidence intervals for exotic artefacts imported from the Bismarck Archipelago, which do not seem to show this length threshold and might indicate different procurement and utilisation patterns. However, there are large overlaps in the interquartile ranges which might indicate that these results are statistically insignificant. As a preliminary comparison the median length and weight of flakes with 100% cortex on the dorsal side is given (Figure 6.10 and Figure 6.11). There is a only a reduction of the standard deviation from distance zone 1 to 2 and 3 but with a large overlap in the interquartile ranges; and also the median maximum length and weight decreases only slightly with the distance to the source (the small sample size (22/8/5) has to be considered).

The reduction sequence of artefacts will be examined in detail in the next section. However, as the reduction of cores might give an indication of procurement and extraction processes it is discussed briefly here. Freehand reduction is the most common technique for the production of flakes in the Pacific from the Lapita period onwards (Allen & Bell 1988; Lawlor 1978; Sheppard 1993). Additionally, the examination of bipolar reduction is one technique commonly used in the assessment of resource maximisation, although this interpretation is disputed (Cotterell & Kamminga 1987; Shott 1989). Whether an increase in bipolar reduction can be detected across the research area has to be assessed in relation to changes in procurement pattern or in relation to size constraints of cores. Bipolar cores were found throughout the research area in more or less the same amounts: nine pieces (19.1%) were found in distance zone 1, eight (14.8%) in zone 2 and 14 (16.3%) in zone 3. Mean maximum length of bipolar cores is presented in Figure 6.12. Again, maximum length decreases proportionally to the overall length of utilised cores from 28.1mm in distance zone 1 to 15.3mm in zone 3. Interestingly, there seems to be no unambiguous length threshold when bipolar reduction techniques become more prevalent. Although the mean length of bipolar cores is slightly shorter than the overall average, this reduction technique is applied to cores in small numbers throughout the research area, including the source itself. This seems to match Sheppard's (1993:129) assessment of the reduction strategy identified in the RSC assemblage, where the bipolar technique was not important and most probably used in an opportunistic way.

Freehand reduction of cores was therefore most commonly used in these assemblages. Single platform cores account for 38.8% (57 pieces) of the total assemblage. The remaining 61.2% are cores with multiple platforms, with the number of platform rotations proportional ($r = .763$, $t = 20.768$, $df = 184$) to the number of flake scars counted on the surface (Figure 6.13). This indicates only limited formal control of the flaking process rather than an identifiable reduction strategy for resource maximisation (Halsey 1995:64). Figure 6.14 presents the average number of flake scars in relation to the distance from the source. There is a decrease in the mean number of flake scars from distance zone 1 (average of 4.9, SD 2.6) to distance zone 3 (average of 3.6, SD 1.7), which could derive from the generally larger cores utilised close to the source. The number of flake scars only increases slightly from zone 2 (average of 2.9, SD 1.7) to zone 3, but with a large overlap in the confidence intervals. It becomes obvious that there is no significant increase in the number of flakes produced from a core, which somewhat contradicts the results from maximum length measurements as the decrease in sizes would have suggested a more intense reduction of cores further away from the source.

Reduction and utilisation in the archaeological sites

In the last section extraction processes and exploitation of the sources were the focus of research. In this section the focus is on lithic reduction strategies, including ideas concerning optimisation and resource maximisation in relation to distance travelled and use of the transported material in comparison with other raw materials like chert, jasper, quartz and basalt. Although there has been no independent examination of the provenance of these raw materials, it is assumed that they most probably derive from local sources and were not transported over long distances. However, Sheppard (1996) has shown, this assumption might be premature. Detailed geological research on possible chert sources throughout Vanuatu has not been conducted to date. Roe's (2007) description of the abundance of cherts in beach deposits on Santa Isabel, Solomon Islands, suggests that similar situations might be found on several islands of Vanuatu. Further research is needed to identify provenances of these raw materials unambiguously. In the following, all sites will be grouped by geographical distance to the source. Differences and trends between the distance zones will be addressed in the more general discussion at the end of this chapter.

Distance zone 1

In total 842 artefacts were found in six different sites in distance zone 1. The archaeological context of the sites has been discussed in detail before. The eight artefacts found in two surface collections at Lion Bay and upstream of Lesa (VL-19) are included in the general dataset in time period three, but not discussed separately. All of the sites are most likely of younger age and were inhabited in time period three beginning from approximately 1000 BP - 800 BP.

Raw materials used in sites in close proximity to the sources originate mainly from these sources (Figure 6.15) and only rarely from other material such as basalt (13 artefacts) or pitchstone (four artefacts, without detailed provenance). Eight of these 17 artefacts were angular shatter with unclear physical attributes so that these pieces could also represent geofacts. Obsidian core measurements and maximum length of complete obsidian flakes were discussed in the previous section. About 65-85% (Figure 6.16) of all debitage consists of flakes, with angular shatter making up the majority of the remaining assemblage. The higher amount of shatter in the Gaua assemblages, especially the Tarasag assemblage, might indicate a less careful reduction of cores in these sites. Figures 6.17 - 6.20 give the mean measurements and 95% confidence intervals of all debitage excavated. The high means of the Lebunga site most probably derives from a sampling bias as artefacts from this site are surface collections. Maximum lengths of debitage from all sites are very similar, ranging from 48mm (Ambek) to 52mm (Lebunga). Although the Lesa site seems to have produced slightly shorter artefacts with a mean of 16.4mm (SD 5.1) and a maximum length of only 38mm. Lesa has a slightly higher percentage of complete flakes (n = 94, 65.7%), than Ambek (n = 254, 60.9%), although a considerably smaller percentage than Lebunga (n = 83, 72.8%) and Tarasag (n = 10, 83.5%). The mean length of cores (24mm, SD 6.8) in Lesa is significantly shorter than in Ambek (32.2mm, SD 16.8) with the maximum length decreasing from 93mm to 35mm. This could result from the location of the site being further away from the source or, it might also show a different selection process of, on average, smaller cores. However, considering the small sample size of only five cores excavated in Lesa, these results should not be overemphasised.

In general, the amount of dorsal cortex on flakes is high with ~27% mean cortex coverage (Table 6.3), but irregularly distributed on the dorsal surface of flakes. Table 6.4 presents the occurrence of dorsal cortex separated into eight sectors. The percentages per site for the simplified classification are shown in Table 6.5. Compared with the experimental data provided by Marwick (2007:Figure 5.9), the data indicate a low reduction intensity. Additional data, like the average number of dorsal scars on flakes (Figure 6.21) support this interpretation. Ratios of MNF to cores are higher in the Vanua Lava sites (Ambek 14.7:1 and Lesa 23:1) than on Gaua (Lebunga 5.6:1 and Tarasag 7.5:1, see also Table 6.6). This suggests a more intense reduction of cores in the Vanua Lava sites which is supported by the larger amount of micro-debitage found on the Vanua Lava sites (n = 94 [18.9% of all debitage] in Ambek, n = 86 [55.1%) in Lesa] compared to the Gaua sites (n = 8 [5.3%] in Lebunga, n = 4 [13.8%] in Tarasag) and through the occurrence of larger amounts of Vanua Lava obsidian transported throughout the research area. However, the possibilities of post-depositional fragmentation and the sampling bias have to be considered.

In the last section, the preference for freehand reduction of cores in the assemblage was noted. Figure 6.22 shows the percentage of flake terminations found in the sites. In all sites, the occurrence of over-shot termination in large numbers indicates a freehand reduction with low control of the point of flaking initiation (it has to be noted, that core rejuvenation episodes might lead to similar results). This interpretation is supported by the low percentage of only 30-50% feather termination, considering terminations other than feather as flaking failure. The mean thickness and confidence intervals of platforms in relation to flake termination shown in Figure 6.22, also supports this interpretation as overshot termination tends to be associated with thicker platforms (although with a large overlap in the confidence intervals). Additional evidence, such as the relationship between the number of flake scars on cores and the number of terminations of flaking surfaces of cores, is presented in Figure 6.13. There is a slight positive correlation ($r = .737$, $t = 12.722$, $df = 46$) between the mean number of terminations on flaking surfaces and the number of flake scars on cores. It seems that although raw material was abundant in all site locations, terminations on flaking surfaces on cores were not seen as an argument to discard nodules.

Distance zone 2

Associated with distance zone 2 are eight sites, all in Northern Vanuatu, including Matantas and Port Olry in North Santo and Kurvot on Toga, Torres Islands (TI-Kurvot). Excavated sites cover the whole sequence of human habitation of Northern Vanuatu, from the initial colonisation (sites from Mota Lava and North Santo) until European contact (sites from Ureparapara, later Layers from Kurvot and Mota Lava). In total, 793 artefacts were found in this distance category (Table 6.7), of which 737 artefacts were made of obsidian (92.9% of the whole assemblage). One artefact found on Mota Lava and sourced to Kutau/Bao is a chip (<10mm maximum length) and will be discussed together with all other found exotic obsidian raw materials in the section 'distance zone 4'. The remaining 56 artefacts (7.1%) are a colourful mix of different raw materials, only jasper (12 artefacts) being more abundant than other rock types.

Figure 6.24 presents the percentage of different raw materials separated by site. It becomes clear that the majority (~90% in each site) of artefacts excavated in the sites were made of obsidian, except the North Santo sites with only 25% of the artefacts made from imported obsidian. Although the sites of the Torres Islands and North Santo fall into the same distance category, people in North Santo seem to prefer local raw materials over imported ones. This might be due to the availability of alternative raw material on Santo in contrast to the Torres Islands, which are coral islands.

In general the percentage of flakes per site seems to increase slightly in comparison to distance zone 1; usually more than 70% of the obsidian assemblages consist of flakes (Figure 6.25). The slight increase in the percentage of flakes in distance zone 2 compared to distance zone 1 might suggest a more careful reduction of cores. Similar, the increase in feather termination in ML-Lequesdewen and in the North Santo sites. In contrast, the decrease of feather termination in TI-Kurvot, the large amounts of over-shot termination in all sites, and an increase in bipolar reduction that can be detected give a very ambiguous pattern (Figure 6.26). Table 6.8 illustrates the number of artefacts found in each site. The ML-Saywoume site is a very small sample. However, considering the small number of artefacts found in time period two in general, the high amount of shatter found in ML-Saywoume might suggest less control of the reduction process during this period.

The calculated total obsidian MNF plus shatter (Table 6.9) seem to decrease from the first to the second time period (n = 92 (mean weight 1.5g, SD 2.2) to n = 29 (mean weight 1.2g, SD 1.2) with a sharp increase to the third time period (n = 451 (mean weight 1.6g, SD 1.8). In contrast, numbers of artefacts made from raw materials other than obsidian, seem to be rather insensitive to temporal changes (Table 6.10). In North Santo only obsidian artefacts in the two earlier phases of occupation has been found. This could be interpreted by assuming that when transport of raw materials from the two sources intensified in the last period of occupation, the North Santo sites were no longer part of the exchange system. Further work is needed to clarify this assumption, as no sites from time period three found so far.

Figures 6.27 - 6.30 give the mean measurements of all obsidian debitage found at the sites. It should be noted that the mean maximum length of all obsidian debitage is generally not different from the mean maximum length of complete flakes (Table 6.11). Differences in length of all debitage and complete flakes are detected in surface collections on Mota Lava (debitage 19.9mm, complete flakes 22.9mm), in the sites of

ML-Saywoume (debitage 17.6mm, complete flakes 20mm) and the North Santo sites (debitage 20mm, complete flakes 15mm). Interestingly, the complete artefacts in NS-Matantas are significantly shorter than the whole assemblage, which could derive from the small sample size of only 12 artefacts and post-depositional processes or from utilisation of only larger pieces. In light of the generally low number of artefacts with use-wear (discussed below), the former interpretation seem to be more likely. Mean maximum length of all debitage separated by time period is surprisingly similar (Figure 6.31). In general the mean minimum flake length threshold seems not to change significantly over time. Mean weight of artefacts show similar measurements throughout the northern part of the research area. Only the artefacts found in North Santo are significantly lighter than in the remaining sites.

In general, the amount of dorsal cortex on flakes does not decrease from distance zone 1 to distance zone 2, although a large difference between sites can be detected (Table 6.12). Although no cores were found in the North Santo sites, the flakes found in this site have the largest amount of dorsal surface covered with cortex (45%). In contrast a smaller percentage of flakes from the Torres Islands assemblage are cortical. However, when cortex *was* found on the flakes, the amount of surface area covered with cortex was seen to be similar at all sites. Similar to distance zone 1, dorsal cortex is very irregularly distributed. The percentages per site for the simplified classification are shown in Table 6.13. The analysis will concentrate on the two largest assemblages of the Torres Islands and Mota Lava, as the sample from the remaining sites is too small to be statistically significant. Both sites show high percentages of tertiary flakes (Table 6.14). Compared with the assemblages found in distance zone 1, a slightly higher reduction intensity might be expected in the Torres Islands. With approximately 50% tertiary flakes and less secondary cortex compared to distal cortex, this assemblage would show a medium reduction intensity on Marwick's scale. In contrast, the ML-Lequesdewen assemblage shows similar percentages to the GA-Lebunga site, therefore a low reduction intensity can be assumed for this site. However, when both assemblages are separated by time period, the low reduction intensity is only valid for the ML-Lequesdewen site in the later period. In the earlier period the dorsal cortex pattern is unclear, with a high amount of primary cortex, but also a high amount of tertiary cortex. The number of artefacts found in time-period 2 in the Torres Islands is too small to give meaningful results for the assessment of reduction intensity during this time. Further investigation of the number of dorsal scars on flakes shows that there is no indication for a generally higher intensity of reduction in distance zone 2 (Figure 6.32) and no major change in frequency over time (Figure 6.33 and Figure 6.34).

In general, ratios of MNF to cores are, in sites where cores were found, very similar to sites in distance zone 1 (TI-Kurvot 10.2:1, UR-surface 8.4:1, ML-Lequesdewen 6.7:1, ML-surface 15:1, Movono 11:1), which does not suggest a more intense reduction in this distance zone. Micro-debitage was found at the majority of sites, its distribution pattern, however, is strongly influenced by the sampling bias (TI-Kurvot: n = 83 (26.1% of all debitage); UR-surface: n = 12 (17.1%); ML-Lequesdewen: n = 69 (30.1%); North Santo: n = 5 (62.5%). This indicates a reduction of cores in these sites. The North Santo sites are exceptional in that no cores were found in these sites. This might indicate a transport of already produced artefacts into these sites. However, considering the high amount of shatter, micro-debitage and high amount of cortex on artefacts, a production of these artefacts at the sites seems more likely.

Non-obsidian artefacts

For comparison with the remaining raw materials the small sample size of only 56 artefacts has to be considered. Table 6.10 and Figure 6.35 present the absolute numbers of artefacts and artefact types in each site and their percentage of the assemblage respectively. Only three sites (TI-Kurvot and the two combined North Santo sites) resulted in almost meaningful numbers of artefacts and the discussion of technological attributes is therefore limited to these three sites.

The North Santo sites alone show a distribution pattern of types of artefacts similar to the obsidian distribution pattern. Although the largest category of artefacts are flakes in all sites, the very high percentages of flakes in TI-Kurvot, with almost no shatter detected, might give a skewed picture. Whether this suggests that people were more careful in the reduction of cores in TI-Kurvot (producing less unusable shatter) is unclear, as the mix of different raw materials has to be considered. In TI-Kurvot seven different raw materials were used with a preference for basalt and limestone (five pieces each). At the North Santo sites only four different raw materials were used, with a majority of flakes and shatter made from jasper (11 pieces), chert (two pieces) and quartz (six pieces). The higher amount of basalt artefacts in TI-Kurvot could be considered as a by-product of the use of basalt adzes, common in the Pacific. Although no polished surfaces were found, an unintentional production of these artefacts can not be excluded. Figures 6.36 - 6.39 illustrate mean length, width, thickness and weight for all debitage. Interestingly, the physical attributes (mean length and weight) of obsidian and the remaining artefacts are very similar at the North Santo sites, which could be interpreted as an additional argument for the low optimisation and resource maximisation strategy for obsidian throughout distance zone 2.

The number of dorsal scars is slightly lower (mean of 1.92, SD 0.76) and the amount of cortex on the dorsal face is also lower (20.7% for all flakes, and 41.1% flakes with cortex only) than the average of obsidian throughout distance zone 2, including the obsidian artefacts found in the North Santo sites. Most of the flakes found were complete (n = 9, 64.3%); which might be due to the material being less brittle than obsidian. Flakes showed a majority of feather terminations (n = 8, 66.7%), however, two artefacts were produced using bipolar technique. The one core found was comparably large (35mm maximum length, 7.3g weight), showed minimal cortex, and was not fully depleted, although a hinge termination was found on one flaking surface. Overall, raw materials other than obsidian were rare throughout distance zone 2. But when they were used, as at the sites on North Santo, no difference in their physical attributes was detected.

Distance zone 3

In total 1029 artefacts were found in nine sites across this zone, 618 artefacts made from obsidian and 411[2] from other raw materials, mainly chert, jasper, quartz and basalt. These numbers included all artefacts, also micro-debitage. As micro-debitage was not considered in the general assessment of physical attributes of artefacts in the previous two zones, these size classes will also be excluded in this section. In total 58 artefacts were micro-debitage: 30 artefacts were BI-obsidian from Tikopia sites alone and 28 artefacts are made from other raw materials.

[2] Three artefacts (two flakes from EF-Teouma, one flake from EF-Arapus) were detected after the analysis was completed and were therefore not included in the statistics.

The dataset of distance zone 3 is dominated by the two large assemblages of Tikopia (n = 538) and EF-Teouma (n = 194). In both sites a large amount of West New Britain and Admiralty Islands obsidian was also found (in total 66 artefacts). These artefacts are discussed in the next section. The dataset selected for this zone therefore includes 963 artefacts, 552 artefacts made from BI-obsidian and 411 artefacts made from other raw materials.

The distribution of obsidian artefacts in this selection is highly skewed, due to the large number of artefacts from Tikopia sites (Table 6.15). In total, 536 artefacts (97.3%) were found on Tikopia compared to only 16 artefacts in all the remaining seven sites of this zone, all of them located in Central Vanuatu. Due to the highly fragmented dataset, artefacts found in Central Vanuatu are clustered into different groups, the boundaries of which are generally islands, such as Malo, Epi, Malakula or Erromango. Only the two sites on Efate, EF-Teouma and the general area of EF-Arapus and Mangaasi, are grouped separately. This does not affect the assessment of the spatial distribution of obsidian as the artefacts derive mainly from single sites on these islands. However, for the evaluation of other raw materials than obsidian, this issue has to be considered.

A preliminary discussion of obsidian distribution was given in the last chapter, therefore only a short summary is given here. The sites grouped into this zone covered the whole era of human occupation in Remote Oceania. Although not all time periods were found in every site, the dataset is complete enough to make preliminary assumptions about BI-obsidian distribution in zone 3. The temporal distribution of BI-obsidian in zone 3 is shown in Table 6.16. In general obsidian numbers in the first two time periods are low with only 35 artefacts found. The majority of obsidian artefacts were found in time period three, which is due to the heavily skewed distribution as mentioned before. In Tikopia 517 artefacts were found in time period three and, in contrast, none were found throughout the whole of Central Vanuatu. If the earlier two time periods are separated, only three artefacts were found in time period two (found in the site Mafilau on Epi) and 13 artefacts were found on Malo, Malakula and EF-Teouma in time period one. However, the large number of artefacts (n = 22) from the Makue site on Aore, analysed by Galipaud and Swete-Kelly (2007a) and most probably originating from Northern Vanuatu (see Chapter 5), are not included in this dataset.

Figure 6.40 presents the assemblage separated by raw materials. In comparison with distance zones 1 and 2, there is a generally strong decrease in the amount of BI-obsidian in the sites, except on the island of Tikopia. Alternative raw materials to obsidian are predominantly (~90% of the assemblages) used in these sites. In Tikopia 232 artefacts (36.3% of the original assemblage) made from "fine-grained chert" and "chalcedony" were found (Kirch & Yen 1982:256, Table 35), but could not be accessed for this study. Kirch and Yen (1982:261) state raw materials occurred in similar amounts throughout the sequence; no concentrations were detected. Also, McCoy (1982:264-266, Table 37 and Table 38) gave a preliminary analysis of the physical attributes of flakes and cores separated by raw material.

In general, the distribution of artefact types follows the same pattern as in the other distance zones (Figure 6.41). Flakes are the dominant form, although the small number of artefacts in the Central Vanuatu sites is notable. The occurrence of angular shatter is important to note for the Central Vanuatu sites, as it impedes an interpretation of the transport of prepared flakes into this general area. However, no cores were found in Central Vanuatu. Considering the number of angular shatter and its interpretation of production of flakes in sites, this might be a result of the very fragmented distribution and a sampling problem. In contrast, the artefact type distribution on Tikopia is very similar to Northern Vanuatu sites in distance zone 2, with about 70% flakes, but smaller percentages of shatter and a larger number of cores. Percentages of feather termination seem to increase when comparing Tikopia to TI-Kurvot, and is now similar to the other sites in distance zone 2. The percentage of bipolar termination does not increase.

Rather than an unambiguous decrease over time in the calculated total obsidian MNF plus shatter (Table 6.17) for all sites, there is a highly individualised occurrence of obsidian artefacts. As described in the previous section, obsidian artefacts in Central Vanuatu do not decrease over time, but disappear completely. Whereas BI-obsidian artefacts were found in several sites in the earliest time period, only Epi had artefacts in the second time period and no obsidian has been found in any of the sites in Central Vanuatu in the last period. In contrast, MNF plus shatter increases from merely 12 artefacts in time period two, to 369 artefacts in the last time period in Tikopia. Other raw material numbers in general seem once again rather insensitive to temporal changes (Table 6.18). There is a slight increase in the overall numbers from time periods one (n

= 156) to two (n = 193). The EF-Teouma site could be seen as representative for this pattern, whereas the sites from Malakula show no changes in the number of artefacts found in each time period. Therefore, the low number of only 62 artefacts in time period three does not seem to be representative and results most likely from the lack of sites excavated from the most recent phase in Central Vanuatu.

Ratios of MNF to cores in Tikopia (2.8:1 in time period two and 4.1:1 in time period three) do not support the hypothesis of a more intense reduction and related resource maximisation in Tikopia. Micro-debitage of BI-obsidian was only found in small numbers on Tikopia (n = 30, 6.7% of all debitage). The general lack of micro-debitage found at sites in Central Vanuatu could be interpreted as transport of flaked artefacts to the sites and contradicts the amount of angular shatter found. This is unexpected, considering the high amount of dorsal cortex found on artefacts transported into this general area.

Figures 6.42 - 6.45 gives the mean measurements of all obsidian debitage found at the sites. Obsidian artefacts found in Central Vanuatu tend to have larger mean maximum length and mean weight than artefacts found in Tikopia. The interquartile ranges of median length and weight (Figure 6.42 and Figure 6.45) only show a slight overlap. The Tikopia artefacts are consistently situated in the bottom size range of other sites, for example EF-Teouma. In comparison with the previous data, the physical attributes important for a reduction assessment (length and weight) seem to decrease the further north the raw material was transported. In association with the data from the Torres Islands there is a decrease in length of approximately 1.3mm for all debitage (the same for complete flakes) and a weight reduction of 0.4g (from 1.4g in TI-Kurvot to 1g in Tikopia). However, both datasets show a large overlap in the SD of 5.1 (5.6) in length and SD 1.9 (1.7) in weight.

Considering the large differences between measurements on Tikopia artefacts and the rest of the dataset, the temporal evaluation will be separated into north (Tikopia) and south (Central Vanuatu sites). In Tikopia mean maximum length of all debitage decreased from 16.7mm (SD 4.7) to 15.2mm (SD 5.1) from time period two to three, but with a large overlap in the interquartile range, indicating that the decrease might be statistically insignificant (Figure 6.46). For the Central Vanuatu sites there is a sharp increase in the length from time period one to two, which derives from the unusually large artefacts found on Epi (Figure 6.47).

In contrast to the decrease in debitage dimensions, the amount of dorsal cortex (Table 6.19) on flakes does not decrease between TI-Kurvot (14.5% of all flakes and 33% for flakes with cortex only) and Tikopia (16.5% of all flakes and 33% for flakes with cortex only). Interestingly, similar amounts of dorsal cortex on sites in Central Vanuatu, for example 20% (35%) in the site EF-Teouma, have been detected. The percentages per site for the simplified classification are shown in Table 6.20. Table 6.21 additionally gives the percentages of the classification for the sites EF-Teouma and Tikopia separated by time period. The reduction intensity does not increase strongly from distance zones 2 to 3 in the northern part of the raw material distribution in time period three. In time period two, the sites show an extremely high amount of tertiary cortex which would suggest a very intensive reduction, but simultaneously a high amount of primary cortex, which makes a clear interpretation difficult. EF-Teouma, in contrast, has a slightly higher amount of tertiary flakes and no primary cortex, suggesting a similar reduction intensity as in the remaining northern sites. The rather unclear picture of artefact distribution and reduction intensity seems to originate in the small number of artefacts found in time period two, as already stated for the last zone. Mean number of dorsal scars (Figure 6.48) shows a slight increase from distance zone 2 to 3, especially in Tikopia. However, this attribute does not follow the described temporal pattern for dorsal cortex, but instead shows a smaller mean in time period two (Figure 6.49).

Non-obsidian artefacts

To compare the results of transported obsidian artefacts to artefacts made from local resources, 411 non-obsidian artefacts were examined. All of the artefacts, besides two, derive from sites in Central Vanuatu. Table 6.22 and Figure 6.50 present the absolute numbers of artefacts types in each site and their percentage of each assemblage. The dataset is skewed because of the large numbers of artefacts found in EF-Teouma (n = 186). The distribution of artefacts through time has already been discussed above. In general, flakes are the most common artefact type (approximately 70% of each assemblage) and cores were only found at four sites (Malakula, Erromango, EF-Teouma and Tikopia). Cores were reduced in a similar fashion to obsidian, also the flake to shatter ratio is similar, so that a reduction of these raw materials different to that of BI-obsidian cannot be identified. The amount of feather termination on flakes decreases to about 50% in comparison to distance zone 2 (Figure 6.51) and is now also similar to the BI-obsidian artefacts found in this distance zone, and bipolar termination occurs in higher numbers.

Raw materials used in the sites range from several different types of chert (one milky-white type seems very common) and jasper through quartz to uncommon varieties like mudstone (Table 6.23). In all sites more than one variety was used to flake artefacts. The large number of basalt artefacts might derive from an unintentional flaking of basalt adzes during use, as discussed before. However, in this database only flakes which did not show polishing on the surface and did not clearly originate from the use of adzes were included.

Figures 6.52 - 6.55 give mean length, width, thickness and weight for all debitage. In general, these physical attributes of the artefacts show a highly ambiguous pattern with large confidence intervals. When standard deviations are considered, there are large overlaps in the interquartile ranges, so that the differences might not be statistically significant (Figure 6.52 and Figure 6.55). Interestingly, median length and weight are not significantly different between BI-obsidian and the remaining raw materials (see also McCoy 1982:264, Table 37, for similar weight measurements (4.2g) for all debitage in the Tuakamali phase on Tikopia), which suggests a similar reduction of these two raw material classes as seen in distance zone 2.

The number of dorsal scars gives the same ambiguous pattern as seen in the debitage dimensions (Figure 6.56). Focusing on the interquartile ranges, these differences again appear statistically insignificant. In summary, the mean number of dorsal scars on flakes increases from distance zone 2 (1.92, SD 0.76) to 2.4 (SD 1.1) to distance zone 3. Dorsal cortex on flakes (Table 6.24) is again highly variable throughout Central Vanuatu, but in general decreases slightly from distance zone 2. These raw materials were therefore more intensively reduced than BI-obsidian, except at the sites on Malakula and EF-Arapus. Table 6.25 gives the amount of dorsal cortex for all sites and Table 6.26 for the sites on Malakula and the EF-Teouma site, separated by time periods. In general there is a higher intensity of reduction in these sites, than for BI-obsidian in all distance zones. The site EF-Teouma in particular shows very large numbers of tertiary flakes. Separated by time period, the amount of tertiary flakes decreases at both sites. The EF-Teouma site shows a stronger decrease (15%) than the Malakula sites (8.6%) and a parallel strong increase in primary flakes of 9.5% (EF-Teouma) and 8.6% (Malakula sites) respectively. There is a very high percentage (~80%) of complete flakes (Table 6.27) at all sites except for EF-Teouma where the percentage is still high (higher than, for example, at sites in distance zone 2), but about 10% lower than in the remaining sites of distance zone 3.

Thirteen cores were found at the sites, ranging from 12mm to 68mm in maximum length (mean 30.1mm, SD 15.5) and 0.8g to 44.6g in weight (mean 11.2, SD 12.9) and therefore are in general longer and heavier than BI-obsidian cores (Figure 6.57 and Figure 6.58). This most likely derives from the occurrence of larger nodules on the islands. The mean number of dorsal scars (Figure 6.59) is slightly lower than for BI-obsidian in distance zone 3, but higher than in distance zone 2. Only five of the 13 cores (38.5% of the whole set) retained some cortex, which is very similar to the ratio analysed in the distance zone 3 dataset for BI-obsidian cores, although if cortex is found, it is usually in larger quantities (mean 42%, SD 24.9).

In summary, the physical attributes of flakes and cores do not give unambiguous support for the hypothesis of a linear, more intense reduction technology of obsidian artefacts in distance zone 3 as cores made from local resources were in general more heavily reduced than comparable obsidian artefacts[3].

Distance zone 4

Included in this group are obsidian raw materials which are “exotic” in Remote Oceania. West New Britain or Admiralty Island obsidian was only found in layers dating to the initial occupation phase or in disturbed layers with unclear temporal context. Artefacts made from Kutau/Bao raw material were found in Lapita layers on the island of Mota Lava, Malo, Malakula and Efate. The artefacts made from Admiralty Islands obsidian found on Tikopia originate from the earliest occupation layer at TK-4

[3] It has been suggested by an anonymous referee, that this pattern might derive from different site types (as mentioned in Chapter 4) analysed in this study. As this is only a pioneering study of the lithic record of Vanuatu more research is needed to verify this hypothesis.

from initial Lapita contexts (possibly late at ~2900 BP). In total 67 artefacts were included in this dataset (Table 6.28), which is highly skewed because of the large number of artefacts found in the EF-Teouma site (n = 56). The type distribution is highly individualised as already observed in distance zone 3. This of course derives from the small sample size and for the following comparison only the larger assemblage of EF-Teouma is used. The amount of flakes in comparison to production failures for the long-distance transported artefacts increases strongly compared with zone 3 (Figure 6.60 and Figure 6.61): in EF-Teouma over 90% flakes are present. Although flakes are the dominant type, shatter and cores have been found in small numbers, indicating a reduction of transported nodules on site.

In total, eight cores were found: four in Tikopia; one from Aore and three at the EF-Teouma site. The large number of cores in comparison to flaked artefacts found on Tikopia is even higher than the flake:core ratio analysed in the previous section (1.3:1). Figure 6.62 and 6.63 give the mean dimensions for cores with 95% confidence intervals. The mean length of the cores is 14.3mm (SD 5.9) and 1.2g (SD 1.4) for the EF-Teouma cores, and 16.8mm (SD 5.9) and 1.4g (SD 1.1) for the Tikopia cores. Although there is a large overlap in the interquartile ranges, which might indicate that these differences are not statistically significant, the pattern of shorter cores in the early Lapita occupation phase and larger cores in the later phases also occurs in the RSC sites, analysed by Sheppard (Sheppard 1993:129, Table 4 and 5). However, the cores excavated in the RSC sites are significantly heavier. There seems to be an minimum length threshold, below which cores are considered to be unworkable. Cortex on cores is exceptionally rare; only one core from Tikopia retained rolled cortex (~20%). Bipolar reduction was common, and four of the cores showed crushing on opposite edges. Following Sheppard's (1993:130) definition of cores which did not bear extensive step termination on flaking surfaces as not being fully exhausted, four cores (50%) can be defined as not exhausted, and four cores show more than three terminations on different surfaces. Additionally the one core found on Aore has a maximum length of 31mm (5.7g), which seem to be unusually large[4] in comparison with the remaining Central Vanuatu assemblages.

Halsey (1995:68) argued that one should abandon the notion of “exhaustion” of cores as it is a highly subjective measurement. Similarities and differences of resource utilisation based on this argument might give a distorted idea of the real processes leading to discarding of cores. Bipolar reduction of cores using anvils, with no indication of pressure or indirect flaking technique, might not decisively support a hypothesis of a resource maximisation strategy (Sheppard 1993:130). However, the high mean numbers of flake scars on cores (5.6, SD 3.3) indicates a more intensive reduction of cores in these sites.

Breakage of artefacts seems to increase in the EF-Teouma site compared to artefacts in distance zone 3. However, this might be due to post-depositional stress and the focus of the earlier excavation season in EF-Teouma on disturbed areas from development activities. Minimum number of flakes plus shatter (Table 6.28) in ratio to cores are 13.7:1, which is slightly higher than can be seen in the BI-obsidian assemblage of Tikopia (but which has an unusual MNF:core ratio), but significantly lower than the calculated ratio from the RSC sites (SZ-8: 51:1, RF-2: 33.9:1, RF-6: 25:1). Possible explanations for this pattern will be discussed in the following sections. Measurements of debitage dimensions are given in Figures 6.64 - 6.67. Mean length (15.7mm, SD 6.1) and weight (1g, SD 1.1) of the EF-Teouma artefacts does not decrease in comparison with distance zone 3 artefacts in Tikopia, but they are significantly shorter and lighter than the earlier RSC sites and the BI-obsidian in EF-Teouma. However, debitage seems to be in general longer than artefacts from the late Lapita RF-6 site, but lighter with a lower standard deviation, which does not derive from thinner or narrower flakes.

Dorsal cortex on flakes is exceptionally rare for these raw materials. Only five flakes show surfaces which could be identified as cortex. This type of cortex was defined as “shiny”, but more eroded than the ventral surfaces with no indication of negative scars. Table 6.29 gives the percentages of the simplified dorsal cortex classification. The high numbers of tertiary cortex on flakes might indicate a high reduction intensity. However,

[4] The technological analysis of the full Makue assemblage on Aore could not be accessed in this thesis because publication of the results is still pending.

the low numbers of primary, secondary and distal cortex make it more plausible that prepared cores, where no cortex was retained on the surface, were transported into these sites. Additional support for this interpretation is provided by the low mean number of dorsal scars on flakes (2.6, SD 1.4).

Tools

Of special interest amongst the assemblages are three artefacts (two artefacts found at the EF-Teouma site and one artefact found in the Makue site) of a tool type known as "gravers" (Sheppard 1992, 1993), for which Sand and Sheppard (2000:239) proposed one possible use as a cutting tool used in scarification (also Hanslip 2001:153). These artefacts were found in large quantities in the RSC Lapita assemblages, as well as in Lapita assemblages in Mussau and New Caledonia (Sand & Sheppard 2000; Sheppard 1992, 1993), and in Makekur in the Arawes Islands (Halsey 1995:70). They have an "alternating retouch" (Tixier 1974) of about 15mm on one edge (Plate 9). Between the dorsal and the ventral retouch is a c.1mm unretouched edge. Sheppard (1993:133) describes this particular retouch as an intentional application, not as a result of use of the artefact. No detailed use-wear analysis has been conducted yet, but obvious use wear or edge damage is not present on the unretouched part. These artefacts were exclusively made from Kutau/Bao obsidian. No artefact made from BI-obsidian carries this retouch and these artefacts were also only found in the initial occupation layers at sites.

Sheppard (1993:133) describes the dimension of these pieces as highly standardised with an average maximum length and width of ~20mm and a maximum thickness of >5mm. The dimensions of the artefacts found in the sites are given in Table 6.30. In general, there is strong agreement between the measurements from Sheppard and the artefacts found in this assemblage, although one artefact is slightly thinner with a maximum thickness of 4mm.

Formalised retouch is exceptionally rare apart from these three tools. Only one further artefact found at the EF-Teouma site could be described as carrying deliberate retouch (Plate 9). The closest match for this particular type of artefact is a chert specimen presented in Sheppard (1993:128, Figure 6-k) as a 'point'. This artefact group resembles, according to Sheppard, recent 'pump drills' in the Solomon Islands.

Although more commonly made from chert, similar artefacts made from obsidian were also found in the earliest RSC sites.

Utilisation of artefacts will be discussed in the following sections, however, the occurrence of edge damage on almost all pieces will be discussed briefly here. Sheppard defined ‘tools’ as those bearing >5mm of continuous macroscopic edge damage on an artefact. According to this definition, 66.5% of flakes, 75% of shatter and all cores were being utilised. However, especially in brittle material like obsidian macroscopic edge damage is considered not to be a good indicator for use (see Odell 1981; Shea 1988; Young & Bamforth 1990, for discussion). Usually we would expect extensive use-wear and marginal resharpening as resulting from the process of utilisation, but these are not present in the assemblage. Considering these arguments, there is no unambiguous evidence for use wear based on macroscopic assessment (Galipaud & Swete-Kelly 2007b; Sheppard 1993).

Use-Wear

The use-wear analysis of artefacts was conducted by Dr. Nina Kononenko, Australian National University, at the Australian Museum, Sydney. The detailed reports of the analyses are attached in Appendix 4. Two sets of artefacts were submitted for use-wear analysis: one set of 71 BI-obsidian artefacts from the site ML-Lequesdewen and one set of in total 31 artefacts made from chert, jasper, quartz, basalt and sandstone from different sites on Malakula. The artefacts were sampled focusing on (a) the ratio of used to un-used obsidian pieces, (b) identifying possible functions of lithic tools and (c) analysing differences in tool-use of different raw materials.

The site of ML-Lequesdewen was selected because of (a) the assemblage size, (b) the location of the site in distance zone 2, which suggested that artefacts were transported to the site deliberately, and (c) the time depth of the site. The whole assemblage of the ML-Lequesdewen site was too large to select all artefacts for a detailed use-wear analysis. Therefore, it was decided to sample all artefacts from two 1m x 1m test pits which covered the whole sequence of human occupation of the site (67 artefacts). Additionally, four artefacts from the same site were selected which show large amounts of edge damage and therefore might allow the assessment of the attribute ‘edge damage’ as an indicator for the amount of use. Artefacts from different sites on mainland

Malakula and the small offshore islands of Uripiv and Vao were not selected primarily to evaluate the percentage of these raw materials used (as was the case for the obsidian artefacts), but to examine whether there is a functional difference in the use of these raw materials compared with obsidian. Therefore, only artefacts were selected which macroscopic indicated a sufficient chance of use-wear.

The selected artefacts were examined using a functional approach which is described in full detail in Kononenko (2008; see also Kononenko 2007). Of the 71 BI-obsidian artefacts submitted from the site ML-Lequesdewen only six pieces carried use-wear. These tools were most probably used for processing (a) siliceous soft wood (like palms and bamboo); (b) non-siliceous soft wood; (c) non-siliceous hard wood; (d) non-woody plants (food plants like tubers); and (e) soft elastic skin. Based on experimental application of use-wear on obsidian artefacts (Kononenko 2008), the function of the artefacts in sawing actions, carving (which includes cutting, scraping and whittling motions), cutting/slicing, scraping and piercing are suggested.

Although the results are only preliminary the use-wear analysis suggests that obsidian use was not restricted to certain functions, but that a wide variety of daily activities such as food processing and wood-working was conducted using obsidian artefacts. However, Kononenko suggests that the combination of small numbers of discontinuous scars, a low density of mostly thin and shallow striations, smooth polish and the occurrence of blood residue on the surface of two artefacts involved in processing soft elastic skin, indicates a use for tattooing purposes or medical treatment. Interestingly, all of the tools were used only in one activity each, multi-purpose tools were not detected. This indicates an opportunistic strategy of tool-use, where artefacts were made for only one particular activity and discarded after finishing this activity rather than being curated and kept for future reuse. Social functions of these artefacts are difficult to evaluate on the basis of use-wear alone as the “daily” activities such as food processing and wood-working could also be conducted in a ritual situation, which the proposed use in tattooing suggests.

In the technological analysis of the assemblage, macroscopic edge damage was only detected on three of the six tools. Additionally edge damage was detected on eight other artefacts which turned out not to be utilised in the detailed use-wear analysis. The very low correlation of edge damage to actually used tools might derive from the lack of skill of the author to identify edge damage properly. However, it might also suggest that the attribute 'edge damage' in general is not a good indicator of use, which makes Sheppard's (1993:132, Table 7; see also Halsey 1995:70 for the Makekur, WNB, assemblages) assessment of the RSC site assemblage as having between 10.7% to 30.8% utilised artefacts disputable. However, these results would support his conclusion that utilisation of artefacts was low and they were used in an opportunistic and utilitarian way.

In the comparison of other raw materials, twelve tools were identified, originating from all sites of the set (including the Lapita sites on Vao and Uripiv and later sites on mainland Malakula). According to Kononenko's analysis the tools in the assemblage were used generally for the same purposes as obsidian tools. Again (a) soft wood; (b) siliceous soft wood; (c) non-siliceous soft wood; (d) non-siliceous hard wood; (e) soft starchy plants; and (f) soft elastic materials were processed. Also the activities like (a) drilling; (b) scraping; (c) sawing; (d) graving; (e) cutting grass; (f) processing skin or hide; and (g) grinding are similar to what could be identified on obsidian tools. Not found on obsidian is so-called "sickle-gloss" which originates from siliceous accretions from cutting grass (a variety of grass are used in house construction), which were detected on one chert flake. Also different from obsidian is the multi-functional use of single tools for graving, drilling, scraping and sawing soft wood; cutting and piercing skin or hide; and crushing and grinding plants. In general it seems that tools of raw materials other than obsidian were used more heavily, although no re-sharpening was detected. This more intensive use could derive from the less sharp, but more durable, edges of artefacts as there is no indication of curation of the raw materials either.

General trends in extraction, reduction and source utilisation

In total, 2665 artefacts were analysed in this work with an additional 431 pieces of chipping waste (Table 6.31). Sourcing of obsidian artefacts in the previous chapter defined a sound geochemical basis for the assessment of spatial trends in the distribution of lithic artefacts throughout the research area. This section will discuss the original research targets and summarise how the new data answer these questions.

In general, artefacts found outside of the source areas retain only cortex with a rolled surface indicating the exploitation of secondary deposits. Based on the geomorphological assessment of the source localities, the collection of river-rolled nodules found in the creeks and beach deposits throughout the area is the most plausible extraction process. Extensive mining activities could not be detected. However, in the case of the Gaua source, the extraction of rounded pieces from shallow pits can not be excluded.

The Vanua Lava source was in general more heavily used than Gaua, as has been discussed in the previous chapter. Outside the areas directly adjacent to the sources (distance zones 2 and 3), 1254 artefacts originated from Vanua Lava and only 51 from Gaua (ratio 24.6:1); there is no change over time as Vanua Lava was more numerous in all time periods. Smith et al. (1977:184) suggest a superior quality of the Gaua glass when he describes the flaking capabilities of the Vanua Lava material as “uneven” based on the vesicular texture of the material. However, the distribution pattern can not be explained through the superior quality of either the Vanua Lava or the Gaua material as the mean maximum length and weight of all debitage found in distance zone 2 and 3 are very similar (Vanua Lava: 17.4mm, 1.6g; Gaua: 17.6mm, 1.3g). The seemingly more homogenous texture of the Gaua material and also its occurrence in larger nodules has no impact on either the selection process or the size distribution of the artefacts.

The examination of the size dimensions of unworked nodules and used cores indicates that unprepared cores were the most likely form in which these raw materials were transported. The production of flakes occurred at each site and there are no indications of transport of flake blanks or even already decorticated cores. Figure 6.68 shows the simplified distribution of cortex on dorsal surfaces separated by site. There is a clear decrease in the percentage of primary cortex on flakes accompanied by a strong increase of tertiary cortex in the transition from distance zone 1 to 2 and 3. However, assemblages outside of the source area have about 50% tertiary cortex on flakes, independent from the distance to source. These findings are supported by the mean amount of cortex for all flakes (Figure 6.69), which decreases in the transition to distance zone 2, but increases slightly from distance zones 2 to 3. When only cortical flakes were analysed (Figure 6.70), the amount only decreases very slightly, indicating a more intensive reduction of cores outside the source area, but no difference between distance zones 2 and 3. Interestingly, the mean amount of cortex on cores decreases significantly from distance zones 2 to 3, a decrease which could not be detected in the amount of cortex on flakes.

The size reduction of cores (Table 6.32) and debitage (Table 6.33) might give an indication of resource maximisation processes involved in the reduction of cores the further away from the source area they are found. This alleged intensification of reduction, however, was not accompanied by a change of technology, as free-hand reduction was preferred throughout the research area and bipolar reduction did not become more important in distance zones 2 and 3. There is also no increase in the amount of flake scars with increasing distance from the source. The hypothesis that multiple platform cores might indicate a more intensive reduction of cores was not supported as there was a strong correlation between mean number of flakes scars on cores and the number of rotations of cores, which is interpreted as a deliberate lack of investment in control over the reduction process rather than a deliberate technological adaptation.

Structural features restricting access were not found on either of the islands, although signs of previous habitation were nearby. Excavations of beach deposits resulted in cultural layers of only a few hundred years of age. The occurrence of only water-rolled surfaces on artefacts and cores throughout the research area indicates the collection of fluvially re-deposited nodules. Transportation of unworked nodules was suggested based on the technological attributes of the artefacts. Size-reduction was assessed as dependent on the distance from the source.

However, the transport processes of obsidian did change over time. The size reduction of cores and artefacts seems to be only valid for the last period of human occupation before European contact. In the earlier periods nodules from fluvial contexts were selected for reduction, but sizes of artefacts did not decrease with the distance to source, even if distances over which raw materials were transported were considerably larger than in the later phases. Additionally, cores were not found in distance zone 3, although angular shatter might indicate a production of flakes on site.

It has been suggested that there are differences in the spatial and temporal distribution of BI-obsidian throughout the research area. Figure 6.71 and Figure 6.72 illustrate the mean maximum length and weight for all debitage separated by site (marked with reference lines are the six large assemblages which define the overall pattern). The clear pattern of size decrease if sites are clustered in distance groups (Figure 4.5) obscures the more complex picture when sites are analysed individually. Although size ranges at individual sites seem to overlap largely in their interquartile ranges, the small sample size of each of these sites has to be considered. Figure 6.73 and Figure 6.74 give the detailed frequency of artefacts of maximum length and weight for each of the marked large assemblages. All except GA-Lebunga show the usual left-skewed distribution pattern of lithic assemblages.

The spatial distribution pattern becomes more complicated if directionality of the transport is considered. Differences between north and south can be seen starting even in assemblages of North Santo compared to, for example the site TI-Kurvot. The differences between these two sites are a combination of directionality and time, as the artefacts in The North Santo sites fall mainly in the earlier time periods, whereas the majority of artefacts from TI-Kurvot were found in time period three. However, artefacts found in Central Vanuatu are generally larger than similar findings in Northern Vanuatu if sites of the same time period are compared (Figure 6.75). The differences in sizes of artefacts, which can not be explained by distance alone, indicate that directionality is a more important explanation for this pattern.

Focusing on the temporal changes in the size distribution of artefacts, Figure 6.76 and Figure 6.77 give the mean length and weight for all debitage separated by time period and distance zone (Figure 6.78 and Figure 6.79 for cores only). It becomes clear that time period three has a different pattern, that is heavily influence by large assemblages. Unfortunately, no artefacts of time periods one and two were found in distance zone 1, so the reduction strategy at the source itself can not be assessed. The size distribution of artefacts separated in time and space give a rather ambiguous pattern. Debitage sizes in time period one seem to increase from distance zone 2 to 3. This pattern is continued in time period two, although it weakens. Cores were only found in the two earlier time periods in distance zone 2, but it seems that core size decreases from time period one to two, which would support the hypothesis of decreasing interconnectivity of communities from the Lapita into the post-Lapita period. Interestingly, artefacts in distance zone 4, which are classified as transported into Vanuatu over very long distances, are not significantly different in their size from artefacts found in distance zone 2. They are, however, significantly smaller than BI-obsidian artefacts found in the same sites.

It should be mentioned that differences in the lithic assemblages are limited to the size of artefacts alone. No changes in the reduction technology to more resource-saving techniques like bipolar or indirect percussion, dependent on the distance from source, was found in the sites. High amounts of flaking failures, seen in the percentage of termination other than feather and in large amounts of angular shatter, is not consistent with a strong emphasis on the efficient, controlled reduction of cores. The evidence for resource maximisation is not very strong. In time periods one and two, neither size measurements, nor reduction techniques indicate an attempt to optimise raw material loss whilst flaking. In time period three, however, size reduction of both artefacts and cores suggests a more intense use of the transported raw material: no associated change in reduction technology nor an increase in the utilisation of flakes were detected.

Three different categories of raw material were found at the sites: BI-obsidian, 'exotic' obsidian (WNB, AD and Fergusson) and different types of non-obsidian rocks (chert, jasper, quartz, etc.). In comparison to BI-obsidian, 'exotic' obsidian is in general more heavily reduced. Usually cores and flakes bear less cortex and the higher percentage of flakes and feather termination indicate more careful handling of the raw material. There is a higher number of bipolar cores suggesting that people attempted to reduce transported raw materials more efficiently. The mean maximum length and mean weight also decrease strongly from the RSC sites to EF-Teouma. This is supported by the high mean number of flake scars on cores. Interestingly, size differences of cores between Vanuatu assemblages and the RSC assemblages are not significant. Therefore, the discard threshold for cores did not change with increasing distance from the source (both, RSC sites and EF-Teouma, are located at a distance of approximately 800 km from the Vanua Lava source) and even the increase of the discard threshold from earlier Lapita assemblages to later ones is replicated across the research area. The mean number of dorsal scars on flakes is not exceptionally high which would usually be increased as the reduction strategy of cores was not standardised.

A third argument against a more intense reduction of cores is the relatively low MNF:core ratio both in EF-Teouma and especially in the Tikopia sites, where the pattern of a high number of cores introduced onto the island seems to be continuous throughout the sequence and is independent of the raw material used. It seems that rather than producing 'usable' artefacts, the possession of this raw material was more important. Therefore, the reduction of cores would only be necessary to increase the overall number of pieces and not the number of 'usable' pieces[5].

The most striking feature of differences between the exotic obsidian and BI-obsidian is the occurrence of 'formal' tools made exclusively from Kutau/Bao material. Three graver and one point were found and discussed in the previous section. A detailed assessment of the social, economic or functional purpose of these artefacts is still pending, but their distribution is restricted to the earliest Lapita-period only and they were not replicated with any other raw material.

In comparison with the remaining 'non-obsidian' raw materials, the size distribution (Figure 6.80 and Figure 6.81) does not follow a clear pattern suggesting that the interpretation of these raw materials as local is correct. In general, the pieces are not larger than BI-obsidian, except at the EF-Arapus and EF-Teouma sites, but there are large overlaps in the interquartile ranges. Reduction intensity of cores might indicate a more intensive utilisation of these raw materials, although the pattern is not unambiguous. Whether the higher numbers of tertiary flakes derive from a pre-processing of the cores somewhere other than the site of discard is not clear.

Additionally, the detailed use-wear analysis of a selected sample of artefacts indicates that utilisation of BI-obsidian was very limited: only about 8% of the selected samples have been identified as utilised tools. Raw materials were used for cutting, scraping, drilling, piercing and carving purposes on a wide variety of materials and, surprisingly, both raw material categories were used in a similar way. Blood residue on surfaces indicate processing of mammal skin and especially for obsidian a use for tattooing activities was suggested. In general, perhaps due to their more durable edges, artefacts made of non-obsidian raw materials were used multi functionally and more intensively.

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[5] A more detailed discussion of the general theory associated concepts of use-value against exchange-value will follow in the next chapter.

Conclusion

This chapter has described the results of a technological analysis of the assemblage. The main focus has been to address questions of spatial and temporal changes in the distribution of BI-obsidian in comparison with obsidian from the Bismarcks and D'Entrecasteaux group and local non-obsidian rocks. The purpose has been to identify resource extraction processes and discuss the hypotheses concerning whether resource maximisation strategies were applied to the reduction of cores.

It has been shown that resource extraction mainly involved the collection of river-rounded nodules from secondary deposition at the source location. It is suggested that the obsidian nodules were most likely transported in an unworked state with no or very little pre-processing. The size reduction of nodules and cores suggests that there was a relationship between size of the nodules and the distance transported. However, this pattern is only valid in time period three, post 1000 BP. In the earlier time periods there is a very ambiguous pattern, with no direct relationship between artefact size and distance.

Additional changes in the distribution of the raw material were observed through time and space. The previous chapter suggested that the transport of BI-obsidian into Central Vanuatu ceased shortly after the end of the Lapita period and never reached South or East Vanuatu. It has been shown that in time period two the transport of the raw material contracted and that the distribution intensified again only in the last period, but that Central Vanuatu was already excluded from the network by this stage. In general this distribution pattern was independent of the utilisation of the raw material. Reduction intensification was not obvious in any of the sites. The common core reduction strategy was free-hand reduction, with only limited formal control of the flaking process. An increase in resource optimisation techniques, like bipolar reduction, correlated with distance was not identified.

If BI-obsidian is compared with the long-distance transported New Britain obsidian in Central Vanuatu, however, an increase in reduction and a more careful handling of New Britain materials is apparent. Bipolar reduction also seems to become more prevalent, although core sizes do not decrease compared with the RSC sites. Formal tools, like 'gravers' or points were only found in very small numbers and were exclusively produced from ‘exotic’ raw materials. The detailed use-wear analysis identified a wide variety of functions for artefacts suggesting that their use was rather opportunistic as has been argued before (Hanslip 2001). These functions might include scarification and use in medical treatment as blood residues were found on the surface of the artefacts.

- Chapter 7 -

7. Exchange and ecology. Conceptualising obsidian distribution

Introduction

In Chapter 2 different approaches to the understanding of exchange systems in the Lapita and post-Lapita periods were discussed. Proposed models range from a generalised exchange system with an egalitarian structure to a specialised network between ranked settlements. In the review of previous models it became apparent that economic theory dominates debates over obsidian distribution, although a discussion of the underlying theoretical assumptions are usually not incorporated into the interpretation of the data. However, the data analysed in Chapters 5 and 6 suggest that economic theory might not be sufficient to explain the changes in social interaction identified in the spatial distribution and production and consumption patterns of the lithic material.

Therefore, in this thesis two different bodies of theory have been applied for the better understanding of the spatial distribution of obsidian and changes in social interaction through time: economic theory and theoretical ecology (Bamforth & Bleed 1997). Although these theories are not mutually exclusive (Bousman 1993, 2005), this chapter will show that they differ in their approach to the archaeological record. Incorporating both bodies of theory this chapter will focus on the controversy as to whether BI-obsidian was distributed as a commodity, following the rules of resource economisation, or as a symbolic object, where social concepts such as gift exchange would have shaped the interaction network. Furthermore, an attempt is made to explain the identified changes in the distribution of the raw material as a correlate of environmental stress. In this context risk minimising strategies of communities might play an important role for the evolution of social interaction networks in the southwest Remote Oceania.

The chapter is structured such as the economic definitions of 'value' and theoretical concepts like 'prestige' and 'trade' will be discussed first. In the second part the concept of risk will be introduced, and it is explained how an alternative approach to the archaeological record results in viable models that can be tested with the available archaeological data.

Economic approaches

The evolution of economic thought in anthropological and archaeological research has been discussed widely (Ericson & Earle 1982; Narotzky 1997; Ortiz 1983; Plattner 1989; Rössler 1999; Sheridan & Bailey 1981; Trigger 1989; Wilk 1996). My main purpose in this section is to give an overview of theoretical concepts, schools and terminology in economic anthropology and archaeology. These provide a useful background for understanding debates about ‘value’.

Theoretical debates in economic anthropology and archaeology are largely derive from the propositions and assumptions that were published by the moral philosopher Adam Smith (1776) in “An Inquiry into the Nature and Causes of the Wealth of Nations”. In this publication, Smith created the image of ‘homo oeconomicus’, an individual who behaves solely according to their *self-interest* and with the aim to *maximise* their share in a free market economy. The individual behaves *rationally* as they focus on the improvement of their own situation or as Smith puts it himself: “[…] it is not to the benevolence of the baker but his self-interest that we owe our bread” (cited from Blaug 1985:60). For Smith this is the *Principle of the invisible Hand* that would produce an optimal result for everyone. Classical economic theory therefore focuses on how the production and distribution of *commodities* in the economic cycle takes place. Exchange is seen as part of the distribution of *commodities* and not as an independent and isolated phenomenon.

The second theoretical school, which was founded partly as a critique and as an improvement of the classical economic approach, was neoclassical microeconomic theory (Wilk 1996). This school is more important for archaeology as it introduced the axiom of *scarce resources and infinite human needs and wants*, which means that the allocation of resources in relation to human needs is the foundation for individual decisions in economic interaction. Furthermore, a direct causation between these two assumptions is presumed. According to Robbins (1968:96), economics is “the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses”. The introduction of these new assumptions was accompanied by a shift of research focus from production and distribution of *commodities* in classical economic theory to the consumption of *goods* in neoclassical theory. The focus on consumption resulted in the neglect of exchange (as part of the distribution of goods) as an important part of the economic cycle. It is important to note that neoclassical theory is not descriptive theory, but prescriptive and normative. It describes how humans 'should' behave if they want their economic decisions to be economically efficient (Schneider 1974:43-44).

Debates about whether the axiom of *scarce resources and infinite human needs and wants* underlies all human economic interaction in both western and non-western societies, or whether this approach is ethnocentric, sparked the long discussion between *Substantivists* and *Formalists* in the mid 20th century. The terms 'formal' and 'substantive' were first defined by the economic historian Karl Polanyi (1957).

> "The substantive meaning of economic derives from man's dependence for his living upon nature and his fellows. It refers to the interchange with his natural and social environment, in so far as this results in supplying him with the means of material want satisfaction.
>
> The formal meaning of economic derives from the logical character of the means-ends relationship, as apparent in such words as 'economical' or 'economizing'. It refers to a definite situation of choice, namely, that between the different uses of means induced by an insufficiency of those means" (Polanyi 1957:243).

According to Polanyi (1957:244-247), the economic system (substantive) is incorporated within a rational economic logic (formal) only in modern Western society (Wilk 1996:6). In non-Western societies, they could be mutually exclusive or the formal meaning, rational decision-making, can be embedded in other social institutions and could operate on different principles from the market as kinship relations or religious institutions. Following Polanyi, all economic systems can be described as being derived from three forms of integration which were abstract patterns of exchange and not a classification of every existing economic systems (Rössler 1999:86):

1. Reciprocity, as a form of symmetrical 'gift' exchange,
2. Redistribution, as a form of movement of commodities to and from a centrum,
3. Market exchange, as "vice versa movements taking place between 'hands' under a market system" (Polanyi 1957:250).

Both, Dalton (1965; 1971) and Sahlins (1972) advanced discussions of the types of reciprocity and types of economy defined by Polanyi. Dalton expanded the substantive approach in his later works (1969:65) in separating economic *organisation* against economic *performance*. As described above, cultural evolutionary models order societies by 'complexity' into bands, tribes, peasants (or agrarian) and modern societies. In Dalton's view, economic *performance* can be described using formalistic tools in all of these societies. However, economic *organisation* into bands and tribes, and to some extent in agrarian societies, can only be analysed through the substantive approach.

Sahlins combined approaches from a substantivist (and structuralist, marxist and neo-evolutionary) perspective with formalist tools. In his critique of the microeconomic assumption of *infinite human needs*, Sahlins gives a detailed description of hunter/gatherer societies as being the "original affluent society" (Sahlins 1972:1-39). According to Sahlins, the concept of scarcity as a principle of economic action does not exist in early hunter/gatherer societies. Instead Sahlins proposes that humans have *limited needs* which are shaped by the subjective and culturally influenced perception of their environment and that natural resources to satisfy these needs are usually more or less adequate. Forces which seriously afflict their economy are mainly the *imminence of diminishing returns,* which imposes high mobility on these societies. Besides his polemic against axioms in neoclassical theory, Sahlins advanced and refined Polanyi's concepts and classifications of reciprocity to include generalised, balanced and negative (Sahlins 1965), and made important comments on the definitions of goods, commodities and gifts (Sahlins 1972:181). More importantly for archaeological research, Sahlins (1963) made a link between different forms of reciprocity and Service's (1962) evolutionary social types: bands, segmentary (or 'big man') societies, chiefdoms and states (cf. Hodder 1982; Renfrew & Bahn 1996; Rössler 1999). A general outcome of the debate between over-socialisation of economic relations with the substantive approach and their under-socialisation of the formalistic approach (Granovetter 1985) was the idea of economic relations being deeply embedded in "all kinds of social institutions". It is widely accepted in anthropological economic theory today that some sort of rationality and least-effort assumptions can also be applied to non-Western, non-Capitalist societies (Wilk 1996:13).

Formalist approaches have been used extensively in archaeological research to understand the organisation of prehistoric exchange. The assumptions of minimising effort and maximising advantage are immanent in the use of fall-off and gravity models (Renfrew 1977) to discriminate amongst possible exchange systems. In the application of these models it was not debated “whether people desire to maximize, but whether accurate predictions could be made by assuming that people desire to maximize utility” (Hodder 1982:202).

Following the substantivist assumption that the economy is embedded in general socio-political institutions, studies of prehistoric exchange have been used to make broader predictions about prehistoric social organisations and cultural formations. In other words, distribution patterns of exchanged objects should reproduce patterns of cultural contexts (Earle 1982:3). This presumption of an evolutionary relationship between the type of exchange and type of society has been criticised by Hodder (1982:201) based on Pryor’s (1977) study, which saw only broad positive correlations between reciprocal exchange, uncertainty of food resources and the complexity of economic institutions. Hodder (1982:201) argued that a direct relationship between exchange and social institutions does not exist. Rather, archaeological research should focus on identifying the social strategies of individuals and how these individuals create exchange systems in their particular social contexts.

Alongside these two main directions in anthropological and archaeological economic theory, neo-Marxist approaches were also developed (Godelier 1966, 1973; Meillassoux 1975). Neo-Marxist theorists were less interested in the ‘economy’ as a fact, but in the distribution of rights in the modes of production, especially concerning “the real role and relative importance of economic relations in the deep logic of the operation of evolution in human societies” (Godelier 1980:257). The emphasis on the embeddedness of economic interaction in social relations, which was similarly formative for the substantivist approach, can therefore also be found in the neo-Marxist theory. As described above, all of these approaches were incorporated into Sahlins’ ideas and were subsequently widely applied in archaeological analysis (Spriggs 1984b; Trigger 1989:340-347).

Recent developments, known as the 'new' institutional economics (North 1990), focus again on institutions and try to understand how they are generated from the behaviour of individuals. Instead of the assumption that entrepreneurs obtain all the information needed to make appropriate economic decisions from market prices alone, this assumes a situation of *bounded rationality* – a limited, local view of the individual's environment (Acheson 1994), and that the acquisition of knowledge is very costly. Since decision makers do not have perfect knowledge, opportunism can, and often does, exist. The fact that those engaged in transactions can have incomplete or distorted information, increases uncertainty, which leads those entering into exchanges to attempt to obtain as much information as possible from others (cf. Geertz 1979). The underlying assumption is that institutions directly affect economic outcomes (distribution and growth), that individuals realise this, and that they attempt to change institutions to serve their ends more effectively, whether these ends be ideological or materialistic (Ensminger 1992; for an application of this approach in archaeological research, see Earle 2002).

The theory of value

It is still much disputed in obsidian research in the Pacific – and different concepts of value for obsidian in Pacific research will be discussed in the next section –, why ancient people choose to transport one particular type of rock over distances up to 6500km.

As described in Rössler (1999:121), it is possible to separate the concept of value for a specific good into four different categories: general value; use value; exchange value and utility. The difference between the use value of an object and its exchange value has been described as a 'paradox' in the classical political economy of Adam Smith. It is common that 'useful' things (like water) have a low price, whereas 'useless' objects (like diamonds) have an exceptionally high price; a paradox which, after Graeber (2005:440; also Rössler 1999:122), goes back to the teachings of Aristotle:

> "The word value, it is to be observed, has two different meanings, and sometimes expresses the utility of some particular object, and sometimes the power of purchasing other goods which the possession of that object conveys. The one may be called 'value in use'; the other, 'value in exchange'. The things which have the greatest value in use have frequently little or no value in exchange; and, on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any value in use; but a very

> great quantity of other goods may frequently be had in exchange for it" (Smith 1776:28).

Different economic schools tried to solve this theoretical problem in different ways. Recently, Graeber (2005:440; also Graeber 2001:23-47) summarised several approaches to the concept of value and its terminological history in different economic schools. The mercantilist school of the 17th and 18th century saw the value of an object as deriving from precious metals. In contrast, the physiocrats of the late 18th century defined agriculture as the ultimate source of value. This school was immediately followed by the political economists of the early 19th century, who defined value as the product of human labour. This line of thought culminated in neoclassical economic theory, where value was only defined by desire to acquire a certain object, and it therefore 'transcended' the physical world altogether.

Neoclassical theory therefore assumes that all human behaviour involves the allocation of resources in pursuit of some kind of scarce good in such a way as to achieve the most product from the least sacrifice. This concept of scarcity, as defining value, is also common in archaeological interpretations of prehistoric Pacific exchange. For example, Kirch (1997:253) proposed that Lapita exchange networks should not be interpreted in functionalist or ecological terms, but that these "networks did have the useful 'function' of moving scarce or discretely distributed resources among communities that were often situated on resource-poor islands". However, in situations where the concept of accumulation of scarce goods for the acquisition of wealth cannot be applied, for example in contests of generosity, maximisation of some sort of value is assumed, be it prestige, honour, fame or religious merit (Graeber 2005:444). This is evident in Kirch's interpretation of the exchange of shell 'valuables' as prestige goods in the Lapita period and thus the possible interpretation of Lapita societies as hierarchically structured (Kirch 1988:113-114).

The second example of archaeological approaches to the source of value of an object is energy expenditure on production and distribution. This can be seen in relation to the classical political economy approach, the *labour embodied theory of value*. Here, the absolute value of an object is defined through the energy or labour invested in its production or acquisition (Ricardo 1819). In these terms, Fredericksen (1994) and

Hanslip (2001) argue for a *low* value of obsidian because of the small amount of energy that flows into the production and curation of 'expedient technologies'.

Both the focus of the neoclassical approach to define the value of goods through individual patterns of consumption as well as the classical approach to define the value of commodities through investment of labour in production and distribution are insufficient for the absolute definition of the term 'value'. Appadurai's (1986:14) economic approach to the 'life history' of commodities showed the flexibility of the terms use value and exchange value depending on the social context in which objects are acquired. Appadurai's proposition was therefore that the process of economic exchange creates value and that this "value is embodied in commodities that are exchanged" (Appadurai 1986:3). Rather than the abstract use of scarcity in neoclassical terms it is social necessity that defines 'rarity' and is central in determining the value of a certain item (Godelier 1977:49; 1980). Similarly, Preucel and Hodder (1996:108-109) criticise models of both prestige goods exchange and world-systems in that local meanings on the peripheries may have transformed the value of goods available in the centre. This is a neo-Marxian critique (cf. Marx cited in Gregory 1982:12).

Recently, Torrence (2005:364-365) has made a proposal of several attributes that explain why obsidian could have been 'valuable' for transport in the Pacific. Torrence determined the social attribute of discrete distribution of obsidian sources in the Pacific to be a particularly good candidate to represent a homeland or a distant place. Additionally, the physical attributes of obsidian, its (a) distinctive glassy appearance (shiny and lustrous), (b) translucency (light passes through and is not only reflected from the surface), and its (c) consistent colour (shiny black, grey, green or red), could have made obsidian desirable to acquire. This concept of 'value' is different from, for example, the neoclassical concept of value, where 'value' is synonymous with 'price' in a market economy and is therefore defined by the concept of 'supply and demand' and the internal processes of market exchange.

Before Pacific exchange is discussed, three different terms for exchange objects and their social meaning must be explained, because as Lazzari (2005:191) puts it, "the anthropological concern about *gift* exchange drew attention to the fact that people exchange things that are not necessary from the point of view of basic subsistence" (my emphasis).

Commodities, goods and gifts

In the last section, two different concepts of the nature of exchange objects were described: Classical political economy defined objects produced for exchange as commodities, but neoclassical theory focused on the consumption of goods. From the anthropological perspective, there is a third category of exchangeable objects: 'Gifts' (Gregory 1982:12).

In anthropological economics, the concept of 'gift' as an exchangeable object is strongly connected with the work of Marcel Mauss (1924). Mauss developed the concept of gift first identified by Morgan (Gregory 1982:17-18), as different from exchange objects in modern western societies. Mauss emphasised that these gifts were not merely economic, but rather the expression of different institutions in an 'organic' connection with each other (the *fait social total*) (Rössler 1999:170). It is important to note that gifts are therefore not the material representations of social relations but rather a symbol of the process of communication in these social relations as gifts have an "indissoluble bond" between the object of exchange and its original owner (Mauss 1924:61). Rather than desiring a good itself, in neoclassical terms, the transactors desire the personal relationship that the exchange of gifts creates. It follows from these definitions of exchange that commodity exchange establishes a relationship between the objects exchanged, whereas gift exchange establishes a relationship between the subjects (Gregory 1982:19).

In Sahlins' definitions of reciprocity, 'gifts' form a separate subclass of exchangeable objects, which should not be confused with the concept of an altruistic gift, or 'pure gift' in Malinowski's terms. Actors engaged in gift exchange can behave out of self-interest, as they try to maximise debt from other transactors (Appadurai 1986; Bourdieu 1977). In this context, gift exchange economy "flourishes in those societies where there is an unstable clan hierarchy" (Gregory 1982:20), and alliances have to be continuously re-negotiated.

According to Sahlins (1972), the distinction between gift exchange and commodity exchange should not be seen as a bipolar opposition, but rather as the extreme points of a continuum, with its key variable of 'kinship distance' defining the extremes. In this context, Appadurai's (1986:18) analysis of the concept of 'keda' in the Kula exchange system refers to the path created through the exchange of these valuables to wealth, power, and reputation for the men who handle them. 'Keda' is thus a polysemic concept, in which the circulation of objects, the making of memories and reputations, and the pursuit of social distinction through strategies of partnership all come together. The most important difference between the exchange of these objects and the exchange of commodities in modern industrial economies is "that the increment being sought in Kula-type systems is in reputation, name, or fame with the critical form of capital for producing this profit being people rather than other factors of production. Pricelessness is a luxury few commodities can afford" (Appadurai 1986:19).

Along these lines, Preucel and Hodder (1996:106) discuss the social reproduction view that assumes objects, for example prestige goods, are material manifestations of social relations, which connect to actors in a relationship of obligation. The cultural commodity view on the other hand assumes that commodities have 'a life of their own' and are able to be exchanged in different social contexts or "spheres of exchange" (for the cultural commodity view, cf. Appadurai 1986; Thomas 1991). In contrast to the classification of forms of exchange, as gift, commodity or barter, this view recognises spheres of exchange which are classifications of different standards of value, such as subsistence goods, prestige goods and rights over humans (Kopytoff 1986). They are hierarchical, culturally defined, and only rarely permeable, so that goods from different spheres cannot be exchanged with each other.

Earle (1997) determined the evolutionary differences between Western Pacific 'big man' societies (but see Spriggs 2008b for a discussion of the concept of 'big man' in relation to colonial impact in the Western Pacific) and Eastern Pacific chiefdoms on the basis of difference in the organisation of exchange in the spheres of 'subsistence economy' (subsistence sphere) and 'political economy' (prestige sphere). Drawing strongly on ethnographic associations, Earle saw the case of intensive inter-island exchange in staple goods as well as prestige goods (seen mainly in the exchange of shell valuables in Mussau) as defining for societies in the Western Pacific from the Lapita colonisation onwards, which in turn limited the opportunity of power accumulation[1]. In contrast, inter-island exchange in the Eastern Pacific was much more limited, although the necessary seafaring technology was accessible and widespread. This lack of external contact led to the development of hierarchies insofar as it enabled persons of power, for example in the chiefdoms of Hawaii, to institutionalise order through the control of the flow of subsistence goods and restrictions in access to prestige goods exchange.

Concepts of value applied to Lapita exchange

Polysemic exchange objects and the social relations generated by their circulation have been the centrepiece of theoretical debates in Pacific anthropology and archaeology for decades (Gregory 1997; Thomas 1991). It is obvious that classifications of exchange in organisation and processes in Polanyi's terms are just starting points for a detailed analysis of the structure of economic systems. In the past, exchange categories such as reciprocity or redistribution and evolutionary concepts of social structures such as 'big man' or chiefdoms were helpful in understanding broad patterns of cultural and economic change. However, according to Aswani and Sheppard (2003:54) recent research has shown that neither of these concepts exists statically, but that they are continuously re-negotiated in changing social contexts.

Formalist, Substantivist and Neo-Marxist concepts of value are explicit or implicit in previously explanations of obsidian distribution in the Pacific and associated interpretations of Lapita social structure. In the following these hypotheses and their underlying theoretical assumption are discussed in detail.

Trade objects / subsistence commodities

An early example is Terrell's (1989:625) proposal that the 'Lapita cultural complex' should be perceived as a prehistoric trade system in which items of material culture, like Lapita pottery, obsidian, stone and shells were circulated. Terrell's model can be summarised as follows:

[1] This model of shell exchange in Lapita times has been disproven in more recent research summarized by Summerhayes (2000).

1. Lapita objects are trade goods. This implies that these objects are specifically made for exchange; they would therefore fall into Appadurai's (1986:16) category of "commodity by destination".

2. These goods are traded between people who are ethnically diverse and therefore do not share the same cultural or economic background (agriculturalists and hunter/gatherers for example). Consequently it would be expected that a close emotional bond between transactors does not exist (Sahlins 1972).

Alienable goods which are bartered by independent transactors are classified as commodities in Gregory's (1982) terms. As a shared identity is presumed not to be necessary for exchange between the transactors, the value of these objects for the individual would be categorised within the sphere of subsistence. In neoclassical terms we therefore have to look for attributes of these objects satisfying human needs, which would make these objects desirable for the individual. However, Appadurai (1986:31) states "demand is […] the economic expression of the political logic of consumption and thus its basis must be sought in that logic. Consumption is eminently social, relational, and active rather than private, atomic, or passive". The basic functionalist approach to the value of obsidian for acquisition, for example, because of its sharp edge, would not explain the choice of communities to import obsidian from one source only (cf. Torrence & Summerhayes 1997).

The definition of obsidian as a subsistence commodity and the focus of obsidian exchange in the Lapita period on only one source imply that the acquisition of this item would have been for the accumulation of wealth. Rather than subsistence products, such as food, for example, obsidian is not needed for subsistence and cannot be defined as utilitarian (Sheppard 1993). It would therefore fall into the category of luxury items. According to Appadurai (1986:38), luxury items are defined as (a) restricted to elites; (b) complex to acquire; (c) produced from high-quality material; (d) requiring specialised knowledge for consumption; and (e) linked to a high degree to body, person and personality. The acquisition of wealth through the accumulation of, – and especially the control of access to – certain luxury items is decisive for the evolution of central power, and characterises many chiefdoms (Earle 1997:231-232).

Terrell sees his proposal of Lapita as trade goods mainly as a critique of two concepts of the 'Lapita cultural complex'. First, Lapita was not an ethnically defined group of people "hermetically-sealed off from biological, cultural, and linguistic contact" (Terrell

1989:625), and secondly, the concept of Austronesian languages developing in isolation (Terrell 2004a; Terrell *et al.* 1997). In his publications, he focused on the interconnectiveness of Lapita exchange systems and on their ability to fuel social interaction. However, the implication of Lapita as a trade good that interconnected distant ethnically diverse communities with each other has economic implications for example implying Lapita was a ranked society with single individuals accumulating wealth, which still has to be proven.

Prestige objects / 'primitive valuables'

The second approach to Lapita exchange is Kirch's (1988; 1990; 1991; 1997) proposal for a hierarchical structure of Lapita society based on the exchange of prestige goods and primitive valuables. Based on Dalton's (1977) classification, Appadurai summarises the concept of primitive valuables as a "class of things" which represent an intersection between 'pure' gifts and 'pure' commerce. With the gift, they share (a) a certain insensitivity to supply and demand; (b) a high coding in terms of etiquette and appropriateness; and (c) a tendency to follow socially set paths. With pure barter, their exchange shares (a) the spirit of calculation; (b) an openness to self-interest; and (c) a preference for transaction with relative strangers (Appadurai 1986:25).

Kirch focuses on two categories of items: shell 'valuables' and obsidian artefacts. The value of obsidian is defined through the geographical extension of the Lapita exchange network. His is therefore an economic approach, both classical and neo-classical at the same time, which implies scarcity of resource and energy invested in transport of raw material as determining value. The value of shell valuables is identified through the association with the ethnographic record, where the acquisition and exchange of these items are related to institutions of power and status (Appadurai 1986; Aswani & Sheppard 2003; Munn 1983; Thomas 1991). However, rather than the assumption of both classes of items as trade goods for the sole acquisition of material wealth, social structures are emphasised. This implies that the transactors in exchange share social institutions and cultural background, and exchange of prestige items and primitive valuables are necessary for accumulation of social status in hierarchical communities, or as Earle (1997:233) describes it: "wealth was a medium both to fashion external networks of kinship and allies forming interaction spheres and to compete locally for status in political hierarchies”. Kirch’s interpretation of shell valuables adopts Appadurai’s (1986:24-25) characterisation of primitive valuables, which incorporates several features: (a) the powers of acquisition that they represent are highly specific; (b) their distribution is controlled in various ways; (c) patron-client relationships evolve out of this control; (d) their main function is to provide the necessary condition for entry to high-status positions, for maintaining rank, or for combining attacks on status; and (e) the social systems in which they appear are designed to prevent competition which could question established hierarchies.

The difficulty of assessing value of these objects was pointed out by Aswani and Sheppard (2003:64-66) in their analysis of colonial and pre-colonial exchange of shell rings in the Western Solomons. Value was emic, ascribed not only by the acquisition of the artefacts for displaying social status, in Appadurai’s terms ‘exchange makes value’, but similar types of shell rings were also classified according to specific physical attributes like size, quality of the material and colour (Aswani & Sheppard 2003:66). This ascription of value because of certain physical attributes is similar to Torrence’s (2005) proposal for intrinsic values of obsidian as described in the beginning of this chapter. Furthermore, it is difficult to apply the classical economic assumption of value as invested energy or labour, as only the highest-ranking artefacts were made solely by craft specialists. Lower-ranking shell rings made for barter, the production of which most possibly demanded a similar input of work hours, were manufactured by commoners and slaves (Aswani & Sheppard 2003:65).

In Kirch’s interpretation of Far or Early Western Lapita societies as being hierarchical, the focus is on the role of shell valuables rather than on the exchange of obsidian. Initially, the spatial distribution of obsidian in the Western Pacific was employed as a proxy for the spatial extension of the unified generalised Lapita exchange system in which shell valuables could have been circulating (Kirch 1988). However, in the current version of this model, the Lapita exchange system is seen as a series of interconnected local exchange networks in which objects were exchanged (Green & Kirch 1997; Kirch 1991). This change to the interpretation of the spatial organisation of the Lapita network has no impact on the interpretation of the modes of exchange. This is because the focus on the import of prestige items shifts from shell valuables in Far Western Lapita to its transformation to long-distance exchanged obsidian in the West, South and East Lapita provinces (Kirch 1997:246-255). Archaeological evidence for this model includes, according to Kirch (1988:112), (a) the irregular distribution pattern of some classes of valuable; (b) the occurrence of specialised sites for the manufacture of shell valuables, compared to sites which “manufactured only one or two classes or no valuables at all”; and (c) that sites with a high amount of shell valuables were not necessarily manufacturing centres. Additionally, sites with a high amount of shell manufacturing debris are regularly located on resource-poor islands, but they commonly display the import of several exotic items. There is evidence of highly irregular distribution of shell valuables and shell manufacturing debris, together with the extensive transport of exotic material throughout the islands of the Far Western Lapita province. This is seen as supportive of the ethnographically founded association of shell valuables with prestige goods. A possible transformation of this system in west Remote Oceania tempted Kirch to make the assumption of a very complex exchange system in the Lapita period between hierarchically ranked communities.

Social relations / gifts

As described in Chapter 2, the concept of obsidian exchange for maintaining ‘ties’ between distant communities in the Lapita period was first proposed by Green (1987:246). However, similar to Kirch’s proposal of long-distance transported obsidian as a prestige good, this raw material was seen as having value as a luxury and status-maintaining item with social and ideological significance. Distant communities preferred to import it, rather than depend on a slightly inferior and less prestigious replacement from a non-homeland community much closer geographically (Green 1987:246; also Specht 2002).

In this section the first part of Green’s proposal, the importance of the social component of maintaining ‘ties’ with distant communities, will be discussed as being separate from the evaluation of the items as prestige goods. Value in these terms is not defined through classic economic analysis or neoclassical economic assumptions, but through the focus on how the material flow underwrites or initiates social relations. In Sahlins’ (1972:186) terms, “if friends make gifts, gifts make friends”. It has been described above how social actors are able to move between different exchange ‘modalities’ and standards of valuation depending on the social and exchange contexts in which they are situated (Aswani & Sheppard 2003:54). Items of exchange could therefore change their ascribed value over time and could acquire and lose value as they move in and out of different spheres of exchange (Preucel & Hodder 1996:106).

The previous two models focused on the use of external exchange and the acquisition of prestige goods for competition of social power internally. However, in Chapter 2 it was mentioned that Sheppard (1993:135) describes the discard of obsidian in the Reef Santa Cruz (RSC) sites in a non-utilitarian way "according to another set of commodity (utilitarian) values". It is therefore theoretically unclear if long-distance transported obsidian artefacts can been seen as identical to prestige goods, for example the shell valuables in the Far Western Lapita province. Sheppard (1993) proposed instead a model of artefacts moving through changing spheres of value (cf. Bourdieu 1977; Thomas 1991). This is a proposal which has been echoed by several authors (e.g. Green 1996; Specht 2002; Torrence & Doelman 2008; Torrence & Summerhayes 1997), and is related to the proposal by White et al. (White 1996b; White *et al.* 2006) that closed trading networks could always 'leak' particular raw materials from one network to another, resulting in a seeming mixing of different exchange networks. Similarly, Strathern (1992:175; cf. also Godelier 1977) argues that gift exchange was often accompanied by trade, or that traded items were essential for gift exchange (see also, Harris 1968:563-564, for an early critique on Malinowski's interpretation of the Kula-exchange system as focussed solely on gift exchange).

In Sheppard's view (1993:135), the value of obsidian was rather a concrete symbol of exchange and not the item of exchange itself. Its value can therefore not be measured through utility, energy investment or scarcity, but is defined through its ability to make social relationships visible (see above Mauss' critique of this 'gift' classification of value). This is an observation which correlates to the analysis of exchange pattern by Strathern (1987; 1988; 1992) in Papua New Guinea. Furthermore, and this is directly related to the process of colonisation of Remote Oceania, economic relationships would have integrated a low density population within a social network (Earle 1997:228). These social connections therefore could have been used in re-creating known social worlds in an unknown territory, and might be seen as forms of risk management, an approach that is discussed in more detail below[2].

Defining testable models

Renfrew's 'modes of exchange' are still used widely in archaeological research and will be adapted in this work to analyse processes involved in the spatial distribution of obsidian (1975; also Renfrew & Bahn 1996). Renfrew separated ten different modes of exchange, ranging from 'direct access' to 'Port of Trade' (Figure 7.1). In this work two of these models, down-the-line/prestige-chain and central place redistribution, are selected as most likely to explain obsidian distribution in the Western Pacific. In addition, one additional model was selected based on the proposed continuous interaction model through trade-networks of Terrell and Welsch (1997; also Terrell 1989).

Down-the-line exchange has been previously associated with obsidian in the Pacific as this mode is active in non-market societies for the exchange of commodities and prestige goods. Although defined primarily in terms of spatial distribution, Renfrew's modes of exchange imply social values of certain items: for example in his variant of the down-the-line model, the prestige-chain model. Hodder (1974; 1978b; 1978a) and Torrence (1986) used and developed these models as theoretical frameworks. However, as summarised by Hodder (1982), they assume a need for exchange but do not explain why it occurs.

Renfrew correlates the different exchange modes with an evolutionary framework of economic development and growth. Based on a concept of efficiency of economic interaction, he states that home-based reciprocal exchange (and connected to it, down-the-line exchange) is seen as inefficient. Societies with long distance exchange and stratified social structures tend to favour redistribution (similarly, regional diversity favours redistribution). This emergence of more complex exchange mechanisms results in increasingly segmented societies, where the process of exchange is less embedded in social relations (Renfrew 1975:44). Central-place-redistribution was therefore identified

[2] Graeber (2005:451) described this approach in his theory of action as the value of items deriving only from the action they represent, but notes that the actors see them as valuables in themselves.

as the second model to be tested against the archaeological data. This model is especially important as Kirch (1988) suggested for the Lapita period a hierarchical social structure. Similarly, the Lapita sites in the Reef Santa Cruz islands have been interpreted as important central places (Green 1976; Green & Kirch 1997) in the colonisation of southwest Remote Oceania.

Down-the-line: Commodity and Prestige good exchange

The down-the-line trade model was introduced into archaeological research by Renfrew (1975). Down-the-line exchange is, in his terms, reduplicated home-base or boundary reciprocity, so that the commodity travels across successive territories through successive exchanges. Since its introduction, this model has found widespread acceptance in archaeological research in general and it has also been applied to explain the spatial distribution pattern of obsidian in Lapita and post-Lapita times: e.g. “where materials are passed along through a series of transactions, often gaining commodity value as they progress along the chain” (Kirch 1997:247).

As a predictive economic model, it shows how exchanged material goods should be distributed, if a commodity is available only at a highly localised source or sources for the material and if highly organised directional exchange is absent. If these premisses are fulfilled, frequencies or quantities of commodities in the down-the-line model show a general pattern of decrease with increasing distance, which Renfrew calls the *law of monotonic decrement* (Renfrew 1977:76, Figure 4). The fall off curve in this model can be separated into a linear attenuation in the ‘supply zone’, where communities could have had direct access to the source of raw material, and exponential fall-off outside of this ‘supply zone’ in the ‘contact zone’ (Figure 7.2A). Spatial extensions of these different zones are not necessarily the same in every environment, as the distance between points has to be considered in comparison of traversing terrain. Effective distance may indeed be regarded as a measure of the energy required in moving goods between two points, and it depends on the transport technology available. Renfrew (1975) saw marine trade as virtually excluding a down-the-line exchange mode. He also stated however, that rivers or sea, and indeed deserts, may be regarded as easy channels of communication depending on the transport available (Renfrew 1975:45). This notion is adapted in Sheppard’s interpretation of the RSC sites as in direct contact with the source area and would situate these sites within the 'supply zone', even if they are located in a distance of approximately 2000km from the West New Britain source area.

A variant to the classic down-the-line model is the prestige chain exchange model. Similar to the down-the-line model, it assumes transport of a commodity through a number of independent exchange transactions. Resulting from the same premisse, but influenced by several different factors (Renfrew 1977:77), the fall off curve of high value or prestige goods has a less accentuated slope than the classical down-the-line model: these artefacts travel in higher numbers for longer distances (Figure 7.2B).

Apart from the predictive capacity of this model for the spatial distribution of material goods, it is important to note that Renfrew saw these distribution patterns as an indication of the transmission of information, as "the traded material itself, at its place of receipt, and independent of the means by which it reached that place, may convey meaning. […] From the standpoint of the receiver it is a message" (Renfrew 1975:22, 24). Therefore the situation of exchange has multiple connotations, as not only the trade item is exchanged but also information and social relations.

Hodder (1974; 1978a; also Hodder & Orton 1976:101) advanced these mathematical models in a series of publications with the special focus of identifying equifinality[3]. He also identified a striking correlation between spatial distribution patterns and the social value of an item using regression analyses (summarised in Torrence 1986:118-119). Hodder used a mathematical formula[4] which describes the form and steepness of the fall-off curve outside the 'supply zone'. Torrence (1986:131-134) could successfully demonstrate this correlation in her application of these hypotheses to 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 a low value of α (0.1 – 0.6) shows that items were distributed only over short distances; a high value of α (0.9 – 2.5)

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[3] Both Hodder (1978a:162) and Torrence (1986:119) discuss the problem of equifinality (similar patterning derived from free-lance trading, middlemen trading or prestige-chain exchange, and marketing of a very expensive item) in the application of predictive models for distance decay analysis. They argue that this problem is not solvable with the models themselves, but that additional techniques – Torrence (1986:119) mentions spatial autocorrelation and trend surface analysis – have to be employed.

[4] The regression analysis used here is: Log $Y = a - bX^{\alpha} + e$ (Hodder & Orton 1976:101), where a and b are unknown constants. '*a*' representing *Y*, when *X*=0; '*b*' describes the reverse proportionality of *X* and *Y*; and '*e*' is the "standard error of the estimate" (cited in Hodder & Orton 1976:101).

indicates long distance transportation. However, when α=0 direct access of home-bound reciprocity is assumed (see Torrence 2004:116-117, for a discussion of these models).

Central place distribution: Redistribution and market exchange

The second model to be tested with the data is the central place redistribution model. The concept of a central place is not only derived from a larger accumulation of people in one place, but more from a centrality of exchange activity (Renfrew 1977:85). In this model a directional exchange between different sites in a hierarchical spatial and social structure is assumed (cf. Kirch 1988, for the discussion of central places in Lapita contexts). In non-market societies this is interpreted as a network of social obligations between a dominant centre and dependent periphery (Hodder & Orton 1976:146), which could correlate with a "hierarchy of central persons", defined through the individual accumulation of wealth and prestige (Renfrew 1975:24). Seen in terms of economic efficiency, the institution of the central redistribution agency minimises transport costs as it maximises economic output. According to Renfrew it, is a prerequisite for the evolution of complex civilisation (Renfrew 1975:10, 11).

The existence of directional trade and central places will fundamentally change the distribution pattern of a raw material (Renfrew 1975:49, Figure 12; 1977:86, Figure 5). Rather than a simple exponential fall off curve of monotonic decrement from the border of the 'supply zone' onwards, central place redistribution (Figure 7.2C) shows an asymmetry in the fall-off around the central place (a "double peaking" in Hodder & Orton 1976:149 terms), of course only based on the "necessary assumption that the quantity recovered at any location bears some regular relationship to the quantity passing through it" (Renfrew 1975:48). In these cases, not only the total quantity of one commodity will be found at these sites, but also the frequency[5] of the commodity will be higher, and could be disproportionally larger than the population at the central place.

Random interaction and continuous exchange / maximal interconnected network / concentric drop off from obsidian source

[5] In terms of the occurrence of artefacts on different sites.

Greenhill and Gray (2005:34) criticised the approach of Terrell and Welsch (1997) to Austronesian dispersal, because it suggests at its most extreme a maximally interconnected network. Exchange of goods in the context of a continuous maximal interconnected network is here interpreted as showing a semi-random pattern. The large number of 'uncoordinated events' could produce a quantifiable fall off curve, which Renfrew (1977:76, 79-80, Figure 3) describes as a Gaussian fall-off curve concentrically distributed from a single source. Depending on the number of events, the concentration is spatially close to the centre. If the number of events becomes larger, the distribution would therefore be more widely dispersed.

Ecological approaches

The majority of hypotheses about exchange systems in the Western Pacific focus on structural aspects in the role of exchange systems, for example, in the development of social hierarchies, or define these systems as some kind of 'trade' (cf. Terrell 1989). In contrast to these approaches, ecological theories concentrate on the adaptation of individuals and societies to environmental forces. Hypotheses about risk minimising strategies can form a powerful conceptual framework explaining social interaction in the context of environmental constraints.

Steward (1955) formally coined the term cultural ecology (CE), and conceived it as a methodology for examining the relationships between human groups and their environments, rather than a factual body of data governing the nature of those relationships (Yesner 2008:40): As Murphy puts it:

> "Social Institutions, customary practices and the like were treated as part of an objective universe, as positive entities that could be counted and measured, as part of an irreducible reality. More importantly, these components of the social and cultural universe has a natural order; the parts were related one to another, and the work of science was to discover these relations as they existed in both space and time" (Murphy 1977:16-17).

Despite its clear focus on the material base of society, Steward did not consider the theory to be a form of economic determinism. Rather, cultural ecology placed emphasis on the study of behaviour patterns, demography and subsistence, and on the performance of work (Murphy 1977:24). The materialistic and positivistic approach of CE has since undergone many changes. However, its formal assumption - that each organism affects and in turn is affected by its environment (Lewis 1989:946, cited in Casimir 1993:215) is still in use (e.g. Tschauner 1996; Yesner 2008). It is important to note that the early attempts of processual archaeology to test hypotheses developed from general ecological factors was quickly corrected in favour of identifying the nature of ecological processes in the patterning of subsistence settlement (Yesner 2008:42). This critique of the processual approach to ethnographic analogies is seen in Ambrose (1978) as described above. Although these linkages were correlative rather than explanatory, they recognised the importance of ecology as an organising framework for the distribution of population intensities, technologies and other traits amongst indigenous groups (Yesner 2008:40).

Modelling environmental factors in Pacific research

Since mounting evidence shows that environmental factors could have played a major role in the evolution and spread of cultures in the Western Pacific (Allen 2006; Anderson 2003; Anderson *et al.* 2006; Clark 2003; Torrence 2002; Torrence *et al.* 2000; for a contrasting view, see Lilley 2004; 2008) an ecological approach is highly relevant. Most prominent in the discussion of natural causes for the spread of cultures and especially the explanation of changes in the spatial distribution of different varieties of obsidian (Ambrose, Bird *et al.* 1981) are a series of volcanic eruptions in West New Britain covering large parts of the island (Grattan & Torrence 2008a; Lentfer & Torrence 2007; Petrie & Torrence 2008; Torrence 2002; Torrence *et al.* 2000; Torrence & Doelman 2008). Petrie and Torrence (2008:729, 743) see a "tantalising close" correlation between the emergence and decline of Lapita and two eruptions of Mt. Witori in West New Britain. However, the authors caution against using this correlation simply as an actual causation of events. Similarly, Lilley (2000:189) argued against a causative link between these two events and Lapita, because volcanic eruptions might only accelerate processes already emerging. Therefore, volcanism or other geological phenomena do not cause cultural change in "any but the most proximal sense" (Lilley 2004:94; 2008).

Focusing less on short-term natural disaster for causative factors of cultural change, a series of scholars have become increasingly interested in long-term climatic changes in the Pacific (Allen 2006; Anderson *et al.* 2006; Field 2004; Hunt & Lipo 2001; Nunn

1999, 2007). These approaches concentrate on fluctuations in wind-directions, sea-levels, sea-surface temperatures and rainfall patterns in the Holocene, causing vegetational change and having an impact on the predictability of, for example, food resources. These hypotheses have made significant contributions to the understanding of causation of colonisation and culture change.

Human Behavioural Ecology (HBE)

Evolutionary ecology - the study of how evolutionary adaptive designs perform in ecological contexts - together with basic concepts of CE define the theoretical framework of human behavioural ecology (HBE, Winterhalder & Smith 2000); or as Bentley et al. (2008:117) puts it: "human behavioral ecology is evolutionary ecology applied to human behavior". Different from the selectionist approach of Evolutionary Archaeology (Lyman & O'Brien 1998, 2001; Smith 1983; Smith & Winterhalder 1992; for a summary see Clarkson 2004:26-30), HBE emphasises that human culture and behaviour are forms of "phenotypic plasticity" (Bentley *et al.* 2008:117-118) that allow humans to adapt to different social environmental and ecological conditions. Called the *Phenotypic Gambit*, this axiom rests on the assumption that human behaviour is less influenced by past evolutionary processes and the transmission of cultural units, but is more dependent on current levels of fitness for adaptive strategies (Bentley *et al.* 2008:118). This behavioural flexibility is the adaptation rather than the specific behaviours at any given moment (Shennan 2002). Therefore, HBE emphasises the effects of human agency in cultural evolution, which make it possible for culture to change more rapidly than simply through biological evolution (Bentley *et al.* 2008).

Optimal Foraging Theory (OFT) predicts that, all things being equal, humans consistently weigh the benefits versus costs of their future actions, tending to make decisions that maximise a particular variable, or currency. Since the costs and benefits of different foraging options are difficult or impossible to quantify in increments of fitness, proxy currencies (presumed correlates of fitness) are employed (Smith 1983:626). Currencies include energy, information, time, technology, risk – all of which can be used as the currency to be maximised (or minimised in the case of risk).

OFT in Pacific research

Recently, Kennett et al. (2006) used OFT modelling to investigate the role of food production in the process of human dispersal into Oceania. Based on a critique of biogeographical models (Keegan & Diamond 1987), which according to Kennett et al. (2006:268) do not analyse reasons initiating migration, and the recognition of push and pull factors in Mobile Founding Migrant (MFM) models, they proposed a hypothesis of rapid dispersals in the unstable phase of the MFM model through opportunistic foraging behaviour. Keegan et al. (2006:268) describe their approach as a multivariable model in the conceptual framework of 'ideal free distribution' (IFD), which assumes that individuals will concentrate in patches in proportion with the amount of resources, population density dependent (Brown 1964, see below), available in each patch (Fretwell 1972) and the sustainability of each patch. Once a patch is depleted or over-exhausted, a population dispersal is initiated to the next suitable patch (Kennett *et al.* 2006:270, Figure 12.3).

As described in Chapter 2, the MFM model represents a series of pulse and pause stages, from a stable population increase during pause periods to unstable phases with higher mobility during pulse stages. These phases of higher mobility are initiated through (a) increased population, (b) patch depletion through soil degradation and erosion, and (c) increased territoriality and warfare. The model of Kennett et al. (2006:283-285) correlates well with the archaeological data and explains the long pause between the initial colonisation of Near Oceania and the Lapita period, and between the Lapita period and the final expansion into Eastern Polynesia. The driving force for the colonisation would, therefore, be increased population growth through "intensive maritime foraging coupled with low-level food production that intensified through the interval" of sedentariness in the Pleistocene until Lapita and through intensified agricultural systems in the late Holocene until about 1200 BP (Kennett *et al.* 2006:284).

Theory of Risk and Uncertainty

Risk research is a wide scientific field that can be subdivided, according to Cashdan, into areas of risk assessment, decision analysis, risk perception and behavioural responses (Cashdan 1985:455; 1990b). In archaeological and anthropological applications, especially in HBE models, the term 'risk' has been differentiated between the definitions: *effects of stochastic variation in the outcome associated with some* *behaviour* (Torrence 1989:59; see also Winterhalder *et al.* 1999:302) and, in a more economic perspective, *the probability of loss* (Wiessner 1982a:172). Most of the recent applications of risk in archaeological and anthropological research take unpredictable resource variability as the source for 'risk' (Bamforth & Bleed 1997:114).

The concept of 'uncertainty', an individual's lack of knowledge (Cashdan 1990b:2) about their environment in a particular situation, is also important. Uncertainty therefore, focuses on the process of an individual's decision making in a particular situation in which the underlying probabilities are not fully known. 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 1990:48). However, if risk is seen as unpredictable variation in some ecological or economic variable both terms are used synonymously (Cashdan 1990b:2). Risk therefore results from stochastic variation in variables such as the frequency, predictability or duration of resource availability (Clarkson 2007), or the spatial structure (extent or homogeneity) of resources (Halstead & O'Shea 1989:3).

'Coping with risk' modelling has found wide application in theoretical ecology. Responses to risk in human societies may include: (a) mobility, either in residential or logistical mobility (Clarkson 2007; Winterhalder 1996); (b) storage, either food stuffs or social obligations (Cashdan 1985; Halstead & O'Shea 1982; Wiessner 1982b); (c) resource intensification (Bird & O'Connell 2006); (d) resource diversification (Winterhalder *et al.* 1999); (e) group foraging (Bliege Bird *et al.* 2002); (f) technological adaptation and innovation (Bamforth & Bleed 1997; Clarkson 2007; Hiscock 1994; Torrence 1983, 1989, 2001); and (g) exchange, either through reciprocity or trade (Cashdan 1985, 1990a; Torrence & Doelman 2008; Wiessner 1982b; Winterhalder 1997).

Risk management strategies in theoretical ecology

The adoption of risk into HBE derives from the recognition of the empirical shortcomings of the marginal-value theorem (in classical economy named the *law of diminishing returns*), in predicting movement amongst patches (Stephens 1990; Stephens & Charnov 1982). Although risk-minimising approaches generally concentrate more on ecological conditions than evolutionary causes, Winterhalder (1999:302) suggests that because of the "taxonomic ubiquity of risk-sensitive tactics", that an assessment of risk in decision-making processes is a common evolutionary phenomenon. Winterhalder et al. (1999) formulated two general principles of risk-sensitive behaviour. Based on empirical observation of animal behaviour in different situations, they came to the conclusion that organisms tend to act risk-averse when the average expected return of foraging is above the survival requirements or if the variance within occurs in the expected amount of returns. They act risk-prone, when returns are below the survival requirements or if the variance occurs in the delay of the returns[6].

Responses to risk can therefore be generalised in spreading variance in consumption (exposure to risk):

1. across individuals; through sharing or pooling,
2. over space; through mobility, field scattering and hoarding,
3. through economic activity types; by diversification, and
4. over time; through storage (Winterhalder *et al.* 1999:339).

Risk management strategies can therefore be seen in relation to abundance and the predictability of resources (Bamforth & Bleed 1997), and in relation to prevention of loss or minimising variance in the outcome of an event. It is important to note that abundance of resources cannot be described as an absolute property of environments, but more as the ratio between the number of possible resources and the population density of a certain area (Brown 1964). Thus, the critical consideration is not the frequency of resources, but the amount of competition for those resources.

Risk reduction and reciprocal exchange

Theoretical modelling of risk reduction and reciprocal exchange is still in its early stage of development. Sharing of resources may have the appearance of generosity, but can also be interpreted as one of self-interest. Winterhalder (1996:47) defines reciprocal cooperation in terms of mutual agreement that if individual A acts to the benefit of individual B at some cost to A at certain point in time, A can expect that B will reciprocate sometime in the future. The individual benefit is greater than the cost,

[6] Which means that the outcome of returns are known, but it is unclear when the returns can be accessed.

providing mutual benefit for the two-way interaction. Such transfers take several forms, including tolerated theft, reciprocity and 'by-product cooperation' (Winterhalder 1997). However, the nature of, and extent to which human groups engage in such transfers are variable (Kelly 1995:161-164).

Commercial trade as a specific form of reciprocal cooperation is not well understood in the HBE framework of risk reduction. Kaplan and Hill (1985) argue for trade opportunities in the context of disproportionate production gains and resulting reproductive advantages in the form of higher offspring survival rates and more mating opportunities. Reciprocal cooperation is most prominent in situations where the uncertainty of an individual forager about resource outcome is high. By exchanging a portion of their yield on a successful day, an individual increases the probability of receiving a portion of another's yield when unsuccessful. As the probability of such events increases, so do the benefits of reciprocal transfers. Where yields are relatively stable and predictable, the risk of individual shortfalls will be relatively low. Though resource transfers may still occur under such circumstances, they are more likely to be guided by the willing loss of excess yield than by the desire to mitigate the significance of subsequent resource shortfalls (see Bliege Bird *et al.* 2002).

Another factor influencing the development of reciprocal cooperation is the spatial structure of resources. If individuals within a group experience synchronous surpluses and shortfalls of resources, risk cannot be reduced by intra-group exchange. Under such circumstances, members of a group are better served by developing and maintaining exchange relationships with individuals in other groups which have complementary or at least asynchronic phases of resource abundance. However, when all participants in a regional exchange system undergo synchronous periods of resource depression, collapse of the system becomes possible (Cashdan 1985; Wiessner 1982a) – for example during periods of catastrophic environmental changes and natural disasters (Petrie & Torrence 2008; Torrence 2002; Torrence *et al.* 2000). Winterhalder (1986:387, Figure 6) summarised these factors and their effects in a four-part model by using intra-forager variance and inter-forager correlation as the primary determinants. As discussed above, risk-minimising reciprocity systems are only expected when individual forager returns are highly variable.

One of the best known ethnographic examples of between-group reciprocal cooperation is that of *hxaro*, practiced by Kalahari San groups, and described in detail by Wiessner (1982b; 2002). *Hxaro* involves the development of social networks through the regular giving of gifts, including functional and decorative items[7]. These gifts not only provide a direct means of redistributing goods, but also a pretext for population movements under conditions of local resource scarcity (Kelly 1995:180). Wiessner (1982b; 2002; also Cashdan 1985; 1990b) has suggested that exchange of people and goods within and between groups is a key mechanism for coping with risk among foragers in marginal, variable, and unpredictable subsistence contexts. Exchanges between these groups do not fall off directly with distance, but are often more intense with distant groups who have complementary resources rather with adjacent group who have similar ones (Wiessner 1982a:175).

Cashdan (1985:455), summarised these approaches under the concept ‘reciprocity as insurance’, as part of the economic theory of risk minimisation. In this theoretical framework, insurance is defined as a tool for reducing risk by sharing costs. Therefore, the risk itself is not reduced, but the outcome of resource variability or loss is distributed over a larger number of individuals / communities. The spatial extension of risk reducing exchange networks is according to Cashdan (1985:457-458) directly dependent on: (a) residential mobility of the exchanging groups; (b) the nature of the risk itself, for example variability in resources due to climatic change; and (c) the relative costs and benefits of reciprocity compared to alternative means of risk reduction, for example storage. The more a group becomes sedentary and the more the resource variability becomes predictable, the smaller the geographic extent of their reciprocal exchange system will be and the more they will rely on storage, rather than reciprocal exchange.

Defining testable models

Null hypotheses deriving from OFT models provide useful heuristic tools (Keene 1983) to test assumptions about the prevalence of certain variables, for example, emic

[7] Two interesting by-products for the analysis of material culture in the archaeological record are that in the situation of *hxaro*, artefacts in relation to the exchange network were rarely buried with the person owning the artefact, but are passed on to remaining *hxaro* partners by children with a request for return so that the *hxaro* network will not be broken (Wiessner 1982b:74).

structures against etic constraints. Assessing risk reducing strategies in lithic technology in the Pacific has significant limitations, as previous research has shown that with the beginning of the Lapita period simple reduction techniques became prevalent in archaeological assemblages (Allen & Bell 1988; Halsey 1995; Hanslip 2001; Sheppard 1993; Specht *et al.* 1988; Torrence 1992). However, as has been discussed earlier, technological strategies are just one of a multitude of options individuals and groups can use in coping with risk. Concentrating on the spatial distribution of material culture through time, rather than on technology, two models will be tested, which incorporate different types of value for obsidian (defined in the economic section of this chapter) in connection to environmental constraints.

Environmental unpredictability response – commercial trade

Risk management strategies and their impact on trade relationships between communities, in contrast to the wide variety of approaches to reciprocity (see below), have received little attention from evolutionary ecologists (Winterhalder 1996:51, in contrast with the wide variety of approaches to reciprocity (see below)). In the context of HBE, Kaplan and Hill (1985; Kaplan *et al.* 1990) examined processes of food sharing in the setting of small-scale societies. In their research they defined trade as exchange of fitness-proximate currencies (correlates of fitness) (Smith 1985), and stated that these forms of exchange can occur immediately or be time-delayed, but tend to occur more often immediately (Kaplan and Hill 1985:226-227). This matches the economic definition of trade as a relationship between objects that are exchanged, rather than establishing a relationship between subjects exchanging goods.

Kaplan and Hill summarised their results in a general model (Figure 7.3) of resource acquisition patterns (Kaplan & Hill 1985:239). Dependent on the means and variances of food resources in correlation to their spatial structure, they distinguished situations when either balanced reciprocity or trade are preferential. Therefore, balanced reciprocity occurs in situations where variance is high but the means are equal (in this situation balanced reciprocity reduces short term variance in resource supply). In contrast, trade should occur where variance is low and means are unequal. Matching Harris' (1979; 1980) assumption that balanced reciprocity and trade do not evolve in an abundant environment where foragers are not in danger of overexploiting food resources (and therefore do not need mechanisms to restrict intensifications of resource exploitation), Kaplan and Hill's model predicts no exchange in situations of low variance and equal means. In the case of high variance and substantial unequal means, both balanced reciprocity and trade may occur.

In the 'commercial trade' model put forward in this thesis, variance in food resources is substituted by the risk of resource failure. Based on this assumption, we would expect a decrease in trade in situations of unpredictable resources output correlated with an even distribution of resources. This means that in situations of unpredictable resource output the costs of acquiring information about the status of produced goods in the exchange partner's patch and the transport of the exchange goods are higher than the benefits of trading. In a risk-averse society (Winterhalder *et al.* 1999) this would result in a declining amount of commercial trade over time. Transferred to obsidian exchange in a 'gift' economy, which means that obsidian is seen as a transfer of symbols of obligations in Wiessner's (1982a) terms and not as items of commercial value, it is expected that the number of exchange items will proportionally decrease.

Environmental unpredictability response – delayed reciprocity and gift giving

The theoretical concept of 'delayed reciprocity' differs fundamentally from the concept of 'commercial trade'. Rather than a focus on the exchange of resource surplus for the acquisition of wealth or prestige (power), delayed reciprocity concentrates on the development of social networks of obligations (Gregory 1997). These relationships can be seen in the context of establishing social networks which support individuals or communities in times of crises. In the context of risk management strategies in case studies described by Cashdan and Wiessner (Cashdan 1985; Wiessner 1982a, 1982b, 2002), these social networks can be seen as 'insurances' to reduce the effects of resource shortages through forms of social storage (Halstead & O'Shea 1982). As described in Kaplan and Hill's model, balanced reciprocity is intimately connected with high resource variance and more or less spatially-equal distribution of resources (see also Winterhalder 1990; 1996:51-52). Risk therefore adds to the general benefits of food sharing (Kaplan & Hill 1985) by increasing the marginal value of food that unpredictably becomes scarce.

Building a model to test with the collected data, we first assume a general risk-averse behaviour in human societies (Winterhalder *et al.* 1999:338). Secondly, if reciprocal exchange is seen as an 'insurance' against variance of resource output we should see an increase in reciprocal exchange during phases of environmental unpredictability and a decrease of reciprocal exchange in phases of environmental stability. Thirdly, as Winterhalder et al. (1999) described in their review of different generalised models of risk-sensitive behaviour, risk-averse behaviour should only shift to risk-prone behaviour if mean resource yields fall below minimum survival requirements (see also Fitzhugh 2001). Again, if obsidian is seen as a symbol of obligations in a social network we would expect an increase in the number of exchanged items during periods of increased resource variability.

Conclusion

This chapter summarises the theoretical framework of analysing lithic exchange in the Western Pacific. Whereas previous research, interpretations and hypotheses on exchange in the Pacific used different theoretical approaches (and usually preferred economic explanations for exchange), archaeologists were only rarely explicit about the assumptions and the theoretical framework they were using[8]. In this thesis alternative models derived from economic and neo-Darwinian theory are described. These models are on the one hand microeconomic, as in the case of down-the-line, central-place exchange, and random interaction models, and on the other hand environmental-adaptation models, as is the case of risk management strategies in correlation to environmental unpredictability. Although in this chapter the two approaches - Economy and Ecology / Risk - are separated in different sections, it should not cloud the recognition that in a holistic perspective these two aspects of human society are of course mutually inclusive (Bousman 1993, 2005).

Understanding the exchange of goods based on economic processes alone has been identified as not being sufficient to explain the spatial distribution of material culture. Rather, the complex networks have to be acknowledged in which inter-communication between distant groups are stressed. This is already recognised in the recent literature on

[8] Exceptions are, for example: Aswani & Sheppard 2003; Kirch 1997; Terrell 2004b; Terrell & Welsch 1997; Torrence 2005.

lithic exchange in southwest Remote Oceania (Irwin & Holdaway 1996; Kirch 1997; Sheppard 1993; Specht 2002), where the social aspects of interaction in connection to obsidian distribution are emphasised rather than an actual 'trade'. This leaves behind the model of 'trade' especially in the context of the minor ‘utility value’ of obsidian as a tool and its debatable ‘exchange value’ as a prestige good in relation to 'expedient technologies'. Instead the focus has shifted to the social ties which were established through contact (Spriggs 2001; 2004; 2007).

- Chapter 8 -

8. Discussion

Introduction

In Chapters 5 and 6 the results of two bodies of data investigated in this thesis, geochemistry and technological analysis of flaked lithic assemblages, were presented. Chapter 7 discussed the underlying theoretical assumptions for obsidian exchange with particular focus on the value of obsidian. Based on the evaluation of the concept of 'value' and a critique of economic theory, alternative hypotheses were proposed concentrating on the function of obsidian distribution in the management of risk in unpredictable environments. Five different models were described which incorporate these theoretical considerations: (a) down-the-line exchange; (b) central place distribution; (c) random, continuous interaction; (d) response to environmental constraints with a trade network; and (e) response to environmental constraints with reciprocity.

This chapter addresses the four research questions posed in Chapter 1. First, potential processes of interaction and exchange active over time are considered. Secondly, it will be discussed how spatial and temporal distribution patterns evident in the data set might be explained through the five general models described in Chapter 7. Thirdly, a more detailed assessment of previous models of obsidian exchange and social interaction described in Chapter 2 is conducted. Finally, it is discussed what implications obsidian exchange might have had for the understanding of social interaction in Pacific history.

Assessing research questions and modelling spatial and temporal distribution of the lithic assemblages

Question 1: Are the same processes of interaction and exchange active through time or can we detect differences? And are these differences or similarities raw material dependent?

The sites analysed in this thesis cover the complete time period of human occupation of the islands of Vanuatu from the initial colonisation during Lapita times until the period of contact with European explorers. Here a general outline of the changes and continuities between the different time periods defined in Chapter 6 will be given. It was noted in Chapter 5 that the spatial distribution of raw materials changed over time. It is necessary to distinguish the different time periods from each other as the strong increase in artefact numbers in the latest occupation period overshadows more subtle changes in the earlier periods which generally had smaller assemblage sizes.

The most striking continuity between the different time periods was the lack of change in reduction technology. Only freehand and bipolar reduction of cores were employed and neither raw material scarcity nor abundance, geographical distance of transport nor occupation time had an impact on technology or artefact use. In general, the high amount of flaking failure in all sites throughout the research area is not consistent with a strong emphasis on the efficient, controlled reduction of cores. In contrast, there are indications, albeit not very strong, that 'exotic' obsidian material transported into sites in Central Vanuatu was reduced a little more carefully; to be seen through higher amounts of feather termination and a higher flake to shatter ratio.

A second continuity was the apparent transport of BI-obsidian in the form of unworked nodules and, similarly, the exploitation of the same secondary deposits of the sources through time. No increase or concentration of artefacts or nodules with un-rolled cortex can be detected. All distance zones throughout the research area showed artefacts and cores with cortex, although the amount of cortex on cores was reduced depending on distance to the source. In contrast, the amount of cortex on debitage only decreased between transported and non-transported material, and not proportional to the distance transported. There was indeed a slight increase in the amount of cortex on debitage in distance zone 3 compared with distance zone 2. Interestingly, Tikopia shows a high amount of cortex on flakes, together with a lower amount of cortex on cores. This might indicate a stronger decortication in the Tikopia sites, which can be interpreted as a more intense reduction of cores. However, this increase in reduction intensity did not result in a more careful reduction of cores, as high percentages of flaking failures and angular shatter were also detected.

The third continuity is the use of 'non-obsidian' raw materials throughout the whole sequence in almost similar numbers. It has been noted that the decrease of artefacts in time period three derives from the analysis of a smaller number of assemblages in this time period and might therefore be biased.

A fourth constant over time was the contact between the Banks Islands and islands to the North. Although there is a marked decrease in artefact numbers in time period two (especially after 2000 BP until 750 BP in the Sinapupu phase of Tikopia), contact never halted completely. The time periods defined here are too broad to detect a hiatus in the transport of BI-obsidian, as for example suggested by Garling (2007) for Bismarck Archipelago obsidian during the occupation history of the Tanga Islands, New Ireland Province, PNG. In general, there is a sequence of far-reaching contact in the Lapita period, a slow decline in the immediately post-Lapita period and a faster decline after 2000 BP until about 1000 BP. This is followed by a sharp increase in contact from about 1000 BP throughout the North of the research area. A discussion of possible processes involved in this change will follow in the next sections.

There were also discontinuities between the time periods. The most striking between the Lapita and post-Lapita periods is the occurrence of 'exotic' obsidian in sites only in the earliest phase of colonisation. No obsidian from outside Vanuatu has been detected in any of the post-Lapita sites so far. This very distinctive distribution pattern leads to the assumption that the transport of this material was in direct social and economic relation to the colonisation process (Kirch 1988). Once the colonisation process was completed, the particular social or economic functions ascribed to the transportation of obsidian were not necessary for continued settlement of the islands.

A second discontinuity between earlier and later assemblages has already been mentioned: the size of assemblages. There was a marked increase in assemblage size over time not only in Tikopia, but also in other sites throughout the northern part of the research area, for example in TI-Kurvot, Pakea and ML-Lequesdewen. The transition between time periods two and three is not well understood, but generally it is seen as a period of social and political disruption (Spriggs 1997:187). It has been associated with the evolution of new societal structures and saw the advent of Polynesian influence on Tikopia and elsewhere.

The third discontinuity was the disruption of raw material transport to the islands of Central Vanuatu simultaneously with the end of Lapita and the occurrence of independent trajectories in pottery decoration after 2800 BP (Bedford 2006b). Although this disruption of contact with Central Vanuatu is not abrupt, as there might be BI-obsidian artefacts in post-Lapita Layers on Epi and maybe a pitchstone connection between sites in northern Efate and Mota Lava in the Banks group, these contacts probably end no later than 2400 BP. However, further research on Epi is needed to resolve the ambiguous results in the geochemical analysis.

The fourth discontinuity was a significant change in the process of transportation. Only in the latest period is there an unambiguous correlation between size decline of artefacts and cores and an increase of geographical distance from the source. The previous two time periods do not show a distance-decay pattern in their size distributions. Whether this size decrease in time period three derives from an intensification of reduction, or from size constraints to the transported nodules has been discussed. The latter hypothesis was suggested because no reduction intensity measured by an increase in mean number of dorsal scars on flakes and flake scars on cores was apparent. Also the amount of cortex on flakes decreases only in a comparison of transported material with material reduced at the sources themselves and not between sites in distance zones 2 and 3.

Question 2: How was the spatial distribution of obsidian in Vanuatu organised?

Several problems concerning the distribution of the raw materials have to be considered. First and foremost, Renfrew's models outlined in Chapter 7 were not developed in an island context so that the distances raw materials travelled in canoes cannot automatically be compared with transport over land by human labour (see Torrence 1986:122, for discussion). Although this issue is acknowledged, it is believed that the distance zones applied in Chapter 5 are defined on a broad enough basis to detect distance-decay characteristics. Secondly, consumption patterns of obsidian raw materials are only one possible way to quantify lithic assemblages. Several propositions applied in Pacific lithics research have been discussed in the methods section in Chapter 6. Most importantly, post-depositional breakage of artefacts was taken into account by applying MNF to core ratios. Accordingly, Specht (2002) concludes in his assessment of previous work that the mean weight of artefacts is the most powerful, and most applicable, measurement for inter-site comparison. Thirdly, the main focus of this work is not the analysis of patterns in terms of utilisation but rather the exploitation mechanisms of the resource, the distribution pattern of raw material and the usage of resources in the production of artefacts. Therefore, functional studies of artefacts were only considered in passing and it was decided to concentrate on reduction strategies in relation to resource maximisation processes.

Taking these issues into account, the data analysis gave a good indication of the mechanisms most likely to be influencing the spatial distribution of artefacts. Three different models, defined in Chapter 7, will be evaluated which focus on the processes of raw material transportation: down-the-line, central place distribution and random interaction. These models use economic theory as a conceptual framework and the value of the raw material will also be assessed on this basis. Additionally, two further models also discussed in Chapter 7 will be examined, which concentrate not on the mode of transportation, but on giving an alternative explanation for the spatial distribution of BI-obsidian: the relation to environmental factors and the management of risk.

Model 1: Down-the-line / prestige chain exchange

The down-the-line exchange model has been successfully applied for the prediction of spatial distribution patterns of artefacts in situations where a commodity is available only at a highly-localised source and when highly-organised directional exchange is absent. In these cases, the distribution of a raw material follows a pattern of linear attenuation in the supply zone where communities could have had direct access to the source, and a fall-off in the quantity of a raw material outside of this zone, where the commodity travels across successive territories, through successive exchanges. This model predicts an exponential pattern of raw material distribution for a low value commodity, if other factors like special social meanings of the raw material or economic competition between different raw materials can be excluded. The resulting lack of precision of this model in explaining concepts of value not originating in economic theory, for example Mauss' concept of the 'gift', was discussed in Chapter 7. Evaluation of the social status of an item, however, has been incorporated into these models by Hodder (1974; 1978a; Hodder & Orton 1976) and Torrence (1986) in the mathematical calculation of the steepness of the fall-off curve. The transition from a strong exponential decrease in the contact zone in the classical down-the-line model to a less accentuated fall-off in the prestige-chain model can be related to the increase in social value of an exchanged item.

In the previous section, it was noted that there were significant differences in artefact distribution between raw materials and time periods throughout the research area. Therefore evidence supporting or rejecting this model will be presented for BI-obsidian and 'exotic' obsidian separated by time period. However, it also has to be noted that, in general, the attributes analysed gave an ambiguous pattern so that it might not be possible to definitively support or reject particular models.

BI-Obsidian

As has already been discussed several indicators can be considered for raw material abundance at a site. In this case some of these indicators gave contradicting results. When total number of artefacts is compared, there is a clear pattern of distance decay in time periods one and two. Unfortunately, no sites are known at the source itself during this time period, but the large numbers of artefacts found in ML-Lequesdewen might give an indication of assemblage size in close vicinity to and also perhaps within the supply zone of the source. In total, 109 artefacts were found at this site. The numbers drop significantly the further away the site is located. At the Makue site on Aore possibly only 22 artefacts were found and the EF-Teouma site showed only 9 artefacts. Also in the RSC sites only 13 artefacts were found in Lapita-aged sites (Doherty 2007:304, Table 6.3) and perhaps only 19 artefacts in the Tikopia sites, but with unclear age brackets.

A second indicator for down-the-line exchange is the ratio of obsidian to other raw materials (Figure 6.15, Figure 6.24 and Figure 6.40). There is a clear drop in the ratio from distance zones 2 to 3, which would also support the notion of the distance zone 2 sites, at least in the North, being in the supply-zone of both sources. Core size and weight cannot be assessed for distance zone 3 as no cores were found in this zone. In time period two, however, there is a marked decrease in core size and weight between distance zones 2 and 3. This pattern of decreased core size and weight is even stronger in time period three. One additional argument for down-the-line exchange in the latest period is the mean amount of cortex on cores. There is a dramatic decrease from 33.8% in distance zone 1 and 36% in distance zone 2 to 7.8% in distance zone 3.

The debitage found at the sites gives a slightly different picture. In time periods one and two the artefact size actually increases in Central Vanuatu (distance zone 3). In time period one mean artefact length is larger than the mean length of artefacts in distance zone 1 in time period three, similar to the mean weight of all debitage. Figure 6.68 shows that the percentage of tertiary flakes increases from distance zones 1 to 2 and 3, but that the differences between distance zones 2 and 3 are not significant.

This pattern of spatial distribution changes in time period three. Rather than an exponential fall-off in mean debitage size and weight, the distance-decay appears to be linear (Figure 6.76 and Figure 6.77). An assessment of the total numbers of artefacts found throughout the research area and the average number of artefacts per cubic metre is indeed difficult. The total numbers of artefacts found at the sites shows the same pattern as the percentage of tertiary flakes at the sites. It seems that there is no significant distance-decay in the total numbers between distance zones 2 and 3 if the excavated area is considered. Similarly, dorsal cortex on flakes does decrease with distance from source, but it seems that the distribution is highly distorted by artefact numbers at different sites. Large assemblages like TI-Kurvot and ML-Lequesdewen show similar amounts of dorsal cortex to Tikopia or EF-Teouma in Central Vanuatu. Additionally, the occurrence of flakes with >90% dorsal cortex suggests that unworked nodules were transported, rather than cores which were reduced in different distance-dependent stages. Reduction intensity measured from the mean number of dorsal scars does not increase with the distance from source. However, that might suggest this attribute is not a good indicator of reduction intensity for Lapita and post-Lapita reduction technology.

There does not seem to be a strong indicator for down-the-line exchange of BI-obsidian in the research area from the technological analysis of the assemblages. An exponential decrease in size and weight can only be detected in the total amount of artefacts found in sites and the mean amount of cortex on cores in the earlier time periods. By contrast, in the earlier time periods artefact size and weight increase with distance to source. In time period three there is a strong indication of distance-decay in the assemblages, but linear rather than exponential. This leads to the suggestion that in time period three, direct access or, more likely home-based reciprocity (Torrence 2004:116-117) was the most likely process of exchange rather than down-the-line (Torrence 1986:119-120, Table 5).

This suggestion can be tested through correlation of curve estimates of mean weight of debitage, mean maximum length of debitage, mean amount of dorsal cortex, percentage of tertiary flakes and mean amount of cortex on cores (Figures 8.1 - 8.5). In general, best-fit estimates for quadratic and cubic curves are higher than linear ones, especially for the 'tertiary flakes' and 'mean amount of dorsal cortex' attributes. However, both curve estimates are heavily influenced by the larger amounts of cortex on flakes in TI-Kurvot than in ML-Lequesdewen. Additionally, due to the small sample number of only four sites in the dataset, cubic curves will always score higher in the correlation, because they have two points of inversion rather than only one or none in the case of linear curves. Considering these issues, the high scores of correlation from the linear curve (r = 0.899, 0.876, 0.817) in the remaining three attributes support the linear distribution model.

Furthermore, Table 8.1 gives the Pearson's r-values for different regression correlations using the formula described in Chapter 7[1]. In general, α-values of zero score highest (r > .954) in the correlation of distance-decay characteristics and they are the only α-values which were statistically significant in the evaluation of all attributes. Additionally, if other α-values score highly in the correlation then they are usually low (α < 0.6). According to Torrence (1986:118) and Hodder (1978a:174) this also suggests low social/economic value for this raw material.

[1] As a reminder: The regression analysis used here is: Log $Y = a - bX^{\alpha} + e$.

WNB-obsidian

West New Britain obsidian shows a different spatial distribution pattern. It has been previously discussed in detail that 'exotic' obsidian raw material was only transported into Vanuatu during the initial colonisation phase and that transport ceased with the end of the Lapita period. Therefore, the discussion of the down-the-line model for these raw materials is limited to time period one.

In his review of the current data on the spatial distribution of WNB obsidian, Specht (2002) used the attribute 'mean weight of artefacts' for the interpretation of possible modes of exchange during Lapita times. He concludes from the weight distribution that in general there was no difference between the five distance zones defined in his work. The focus of this section is the evaluation of his hypothesis in 'distance zone 5'. In distance zone five, five sites from two island groups (SE Solomons and New Caledonia) were included. The three large RSC assemblages were the comparison dataset for the analysis of the 'exotic' raw materials throughout this thesis. The additional artefacts from two sites from New Caledonia are discussed in Sand and Sheppard (2000). The mean weight noted in Specht (2002:40, Table 2) for the WKO013/13a site on New Caledonia gives a slightly distorted picture, as one of the artefacts is a 'graver' with a weight of 2.3g (Sand & Sheppard 2000:239, Table 1). These artefacts are significantly larger than other debitage. In this case, the assemblage only consists of two pieces with the other piece representing a small flake (Gifford & Shutler Jr. 1956:67, 136, Plate 11-l). Therefore, the mean weight of 0.3g for the KVO003 site on New Caledonia is considered to be more representative for WNB assemblages on New Caledonia.

It was noted in Chapter 6 that there are indications that cores transported to the sites (especially in TI-Kurvot and Tikopia sites) were already decorticated, because, although they had in general similar sizes to the RSC cores, they were significantly lighter and carried less cortex. Additionally, there is a decrease in the mean maximum length and mean weight of debitage from the early RSC sites (19.6mm / 2.4g, respectively 18.6mm / 1.9g) to both the large assemblages of Makue (16.6mm / 0.9g, Galipaud & Swete-Kelly 2007a:159, Table 2) and EF-Teouma (16.0mm / 1.1g). The evidence for intensified reduction in the Vanuatu sites is unclear. Bipolar reduction is more prevalent and cores carry more flake scars on the surface. In contrast, flakes have lower mean numbers of dorsal scars and the MNF:core ratio is rather low.

From this evidence it seems that the down-the-line model has merit in explaining the distribution patterns (Figure 8.6 and Figure 8.7). The curve estimates displayed in Figure 8.7 show the highest correlation (r = 0.959, respectively r = .970) with a cubic curve. The main characteristic of cubic curves is the two points of inversion as described above, compared to quadratic or logarithmic curves which have just one. Sheppard (1993:129) suggests, based on the large amounts of WNB-obsidian found in early RSC sites, a direct contact with the supply zone, a result which is supported by comparison with Halsey's (1995:82) analysis of the Makekur assemblage from the Arawe Islands, West New Britain. The best-fit estimate displays the first point of inversion close to the RSC sites, supporting this hypothesis. The significantly smaller amount of obsidian artefacts found in Vanuatu and the decrease in mean weight of artefacts would support the hypothesis that WNB-obsidian transported into Vanuatu had its origin not directly at the source, but at the RSC sites. The second point of inversion is assumed to be somewhere more distant than the EF-Teouma site. In the context of the down-the-line model the very high flake:core ratios in the RSC sites could be explained by the removal of cores from the assemblages for further transport. Therefore, a multi-staged transport system which as an essential part of the colonising strategy of the Lapita dispersal (Kirch 1988:104) is supported by the evidence. Whether this transport system can be interpreted as an "exchange" system, with a backflow of goods from the newly-established settlements will be discussed in the next section.

Model 2: Central Place distribution

The model of an occurrence of central places in the distribution of artefacts is difficult to assess. In general there are clear differences in the number of excavated artefacts between sites, especially in Central Vanuatu. To start in the latest time period: for BI-obsidian it has already been established that direct access to the sources seem to best explain the physical attributes of artefacts in different sites in the three distance zones. There is no spike in the distance-decay characteristic, which could be interpreted as a redistribution centre for BI-obsidian exchange.

The almost complete breakdown of contact in time period two, in total only 68 BI-obsidian artefacts were detected in all excavated sites, makes any assessment of differences in the spatial distribution of artefacts very difficult. In general, there is little support from the lithic assemblages that certain sites were importing more obsidian for redistribution.

Time period one shows a different pattern. The occurrence of different assemblage sizes, especially in the SANMA, MALAMPA and SHEFA provinces with the two large assemblages of Makue and EF-Teouma and a series of smaller assemblages from Malakula and Mota Lava suggest that there were differences in the settlement structure. Interestingly, outside of the direct supply zone in the Banks Islands group – ML-Lequesdewen has an exceptionally large assemblage, but with insecure age brackets – BI-obsidian is more abundant in sites with large WNB assemblages. Additionally, the single artefact found in Vao, Malakula, is a large angular shatter (max. length 22mm, weight 2.8g) with a high amount of unworked surface. Therefore, this artefact distribution has to be considered in the context of the colonisation of a previously uninhabited area. Rather than showing a central place redistribution strategy, which then would also suggest a socially stratified society (as discussed in Chapter 7), this could also be interpreted in relation to the MFM model as 'filling up' an area after a patchy initial colonisation of only certain islands by a small founder population. This hypothesis is supported by the slightly younger ages of the smaller assemblages: for example 2900 BP in ML-Lequesdewen and Vao, Malakula.

Model 3: Random interaction

A random interaction model is described by Renfrew (1977:79-80) as having a Gaussian fall-off distribution concentrically organised around a single source. The distance zones used in this work were defined to assess whether a random interaction model is a viable hypothesis. The high directionality in the transport of BI-obsidian does not support this model. It has been shown that differences in the assemblage sizes, and additionally several physical attributes of debitage, can be detected in sites located north (TI-Kurvot) and south (The North Santo sites) of the source in distance zone 2. Furthermore, contact to the south discontinues after about 2400 BP, whereas the contact continues to the north and intensifies in the latest time period. In addition, the fall off in artefact distribution does not follow a Gaussian curve, as shown by the artefact numbers from EF-Teouma compared to the North Santo sites in time period one and the distribution of mean length and weight of all debitage.

Assessing social value of BI- and WNB-obsidian in the context of economic models

BI-obsidian

No strong indicators for resource maximisation techniques were found at any site throughout the research area. On the contrary, especially in the earlier two time periods, all physical attributes show an increase, for example mean size or weight of debitage; or are rather insensitive to distance-decay, such as platform-thickness. Only in the latest time period is a linear decrease in the mean size and weight of artefacts apparent, which is interpreted as all sites being located within the supply zone with direct contact to the source area. In the context of economic theory the simple procurement technique and the lack of further exchange of this raw material has to be interpreted as obsidian having a low value, which would also be supported by the less strongly controlled reduction of the material. However, once again the question of the virtue of economic models for the assessment of the value of BI-obsidian raw material has to be raised and therefore two alternative models will be discussed in the next section.

WNB-obsidian

In Chapter 7, it was noted that the social value of a commodity can be evaluated by the shape of the fall off curve in a down-the-line exchange system. It has also been shown that a down-the-line exchange system (ignoring for a moment whether there was an exchange system in existence at all) can be assumed, with the RSC sites defining the boundary of the supply zone and the sites in Central Vanuatu being representative of sites in the contact zone. The regression analysis on the mean weight of debitage, mean maximum length and mean maximum thickness of artefacts[2] in the two large assemblages of SANMA and SHEFA provinces and site KVO003 in New Caledonia showed the highest correlation with low values of α (Table 8.2). The most significant correlations ($\delta < 0.01$) are between $0.4 < \alpha < 0.6$. Interestingly, mean maximum length

[2] These attributes are the only ones which were available at the time of writing (cf. Galipaud & Swete-Kelly 2007a; Sand & Sheppard 2000; Sheppard 1993; Specht 2002).

and thickness show a high correlation with $\alpha = 0$ (both significance at $\delta < 0.01$), suggesting direct access or home-based reciprocity. In general, low values for α imply that obsidian was not a highly valued commodity (already suggested by Specht *et al.* 1988), questioning the idea of obsidian transport because of some sort of status deriving from the possession thereof (Specht 2002:44).

The question still remains as to why this raw material was transported over such long distances? As was discussed in Chapter 7 that the basis of Renfrew's models in a neoclassical economics framework might not be appropriate for the assessment of the value of this raw material. Alternative ideas of value like the "lifeline to a homeland approach" (Kirch 1988) have also been discussed, and in this context the importance of social contacts in a potential hostile environment have been emphasised (Torrence 2005). In line with the hypothesis of the re-creation (Green & Kirch 1997) or replication (Specht 2002) of an ancestral society, I would like to advocate the idea that the value of this raw material derives from the idea of a common origin. However, rather than re-creating social worlds, I would suggest that the founding communities used obsidian as a marker of group affiliation in an unknown territory. This hypothesis is based on three indicators: First, it is unclear from the archaeological record whether an exchange system for WNB obsidian existed at all in Remote Oceania. Secondly, if the re-creation of social worlds was the main focus of obsidian transportation, the breakdown of any kind of long distance transport into Remote Oceania with the end of Lapita would be hard to explain. Thirdly, it is unlikely that a secondary migration caused this breakdown, as obsidian exchange in the Bismarck Archipelago was apparently not impacted by any social disruptions which might occurred in this area at this time. Although the predominance of particular obsidian varieties changed over time, transportation of the raw material throughout the Archipelago did continue (Summerhayes 2009).

Model 4: Environmental unpredictability response – commercial trade

It has already been discussed how the previous three models concentrate on economic explanations for the spatial distribution pattern of artefacts. Social value of a raw material has been assessed through steepness of the fall-off curve in the down-the-line exchange model. However, all three models have been rejected for the latest time period and a direct contact to the source area was proposed as a viable hypothesis for the mode of transportation.

Regional environmental factors have already been considered by others in model-building, especially in the assessment of the importance of social networks in the colonisation phase (Ambrose, Bird *et al.* 1981; Anderson *et al.* 2006; Field 2004; Grattan & Torrence 2008b; Torrence & Grattan 2002). The two models presented in this section take economic factors into consideration, but assume the variability of food resources as a proxy for the assessment of the reason for obsidian transportation. Chapter 7 gave the theoretical background on which human decision making might have been based in Human Behavioural Ecology. The importance of risk management was suggested as fundamental quality for the evolution of cultures in unpredictable environments.

Chapters 3 and 7 introduced palaeoclimate modelling for the evaluation of the predictability of food resources throughout the time of human colonisation of Remote Oceania. In this context the importance of ENSO variability during the last 3500 years was emphasised. Correlating human dispersal into Remote Oceania with the number of ENSO events (Figure 8.8), it becomes clear that the Lapita expansion occurred in a time of high ENSO variability (Anderson *et al.* 2006). The time period of about 2500 - 1000 BP shows relatively stable environmental conditions which were superseded by the transition of the 'Medieval Warm Period' to the 'Little Ice Age' at around 800 700 BP, showing extremely high ENSO variability. The data show that transportation of obsidian raw material was not continuous throughout time. We can see a contraction of the amount and the extent of obsidian raw material transportation after initial colonisation, with an almost complete break-down in interaction during the post-Lapita phase, especially to the south, until about 1000 BP. At that point in time interaction intensifies markedly to the north with large amounts of obsidian transported throughout the Banks Islands group, Torres Islands and the Southeast Solomons.

The models introduced by Kaplan and Hill (1985) and outlined in Chapter 7 identify an increase in trade when resources were unevenly distributed spatially, but with a predictable resource outcome. In the context of this model two assumptions are made: (a) the amount of artefacts is considered as proportional to the intensity of contact and

(b) it is assumed that food resources are evenly distributed between the islands in the contact zone of BI-obsidian transportation. Therefore, during phases of environmental stability, food resources would be evenly distributed with a low variance in the outcome. In phases of environmental turmoil, these food resources would still be evenly distributed, but with a high variance.

Considering the two assumptions, there is a marked decline in contact measured in the amount of obsidian transported in phases of high environmental stability and an increase in contact when resources become more unpredictable, such as after 1000 BP If obsidian were to be a trade item, its distribution should be the complete opposite of the identified pattern: an increase in trade during times of predictable resource surplus and a decrease in times of increasing resource variability when the produced yield might be stored. Alternatively, conceptualising a cost/benefit strategy in the theoretical framework of optimisation of risk, the costs of acquiring information about resource outcomes produced by your trading partner might be higher than the potential gain of trading food resources. Therefore, it seems reasonable to assume that obsidian was not a trade item, but that its value derived from other factors. This concept of trade and gift will be further discussed in the following sections.

Model 5: Environmental unpredictability response – delayed reciprocity and gift giving

It has been noted several times now in the discussion of the social value of obsidian, that rather than being important for the acquisition of wealth and power (trade item or prestige good), other factors might be more important for the explanation of the spatial distribution of obsidian in Remote Oceania. Sheppard (1993) argues for the RSC case that the actual acquisition of WNB-obsidian did not define its value, but instead the process of exchange, for which obsidian would be just a symbol and not the item of exchange itself. Starting from this approach to the archaeological data the concept of delayed reciprocity has been discussed in Chapter 7 as one important quality to reduce risk in an unpredictable environment. As noted in that chapter, Wiessner (1982b) discussed the *hxaro* exchange network of the San in the Kalahari where gift giving is seen as essential for the development of long-term relationships in the form of social obligations. These long-term commitments form an 'insurance' at times of increasing resource variability.

This conceptualisation of risk reduction can also been seen in Kaplan and Hill's model of human behavioural response to spatial resource distribution, when evenly distributed resources and high variance in resource outcome also stimulate the development of balanced reciprocity. Considering the low value for obsidian based on economic models discussed in the previous sections, ideas of obsidian as a symbol of connection or as a token of obligation have merit. If obsidian is interpreted as a token or a symbol in Sheppard's terms for a network of social obligations – and therefore being not a trade item itself but being part of a trade system (cf. Harris 1968) – an increase of contact would be expected in times of high resource variance, with little exchange or no exchange at all (Harris 1980) in times of predictable resource outcomes. The distribution pattern would therefore be the complete opposite to the pattern assumed for trade networks.

Unfortunately, no statistical correlations can be given for this model in relation to the data collected in this work. Further research on the detailed palaeo-environmental data is needed to verify the hypothesis suggested here. However, the interesting correlation between a more intense communication between communities during periods of environmental stress, and the interpretation of obsidian not based on its economic value (use-value or exchange-value), but as a symbol of a connection between communities in the most general term, certainly needs to be considered in future research.

Question 3. Can established models of West New Britain and Admiralty Islands obsidian exchange organisation in the Pacific be adapted to explain the spatial distribution of BI-obsidian?

Different models for the evaluation of obsidian distribution in the archaeological record during the Lapita period were developed in the past. Broadly classified into two different categories, one group concentrates on explaining the archaeological record with different systems of exchange (generalised single, non specialist; localised, specialised; multiple and specialist) and the other uses mobility and human dispersal (mobility and embedded procurement; 'Coloniser and trader') as explanatory frameworks. For the post-Lapita period, however, explicit models for obsidian distribution are rare, especially in Remote Oceania.

As mentioned several times above, it is unclear whether the distribution of obsidian during the Lapita period actually represents an exchange system. Here it has been argued that the 'Coloniser' model (Irwin & Holdaway 1996; Specht 2002) best describes the distribution pattern of WNB-obsidian, with obsidian not being important as an exchange good, but rather as an indicator for group affiliation. In this general hypothesis of the reason for obsidian transportation, the process of down-the-line distribution has to be associated with a first colonisation pulse reaching the Southeast Solomon Islands and from thence further expansion into Vanuatu with no direct contact to the original WNB homeland. Of course, this lack of an exchange system of WNB-obsidian in Lapita times does not imply that the Lapita people did not have exchange networks at all. It simply implies that any existing exchange networks were not important for the distribution of WNB-obsidian in southwest Remote Oceania.

The Mobile Founding Migrant (MFM) model assumes the very fast expansion of the Lapita dispersal into Remote Oceania as a result of an unstable environmental and social situation. It has been described how the expansion took place in a time period of high ENSO variability with probably high variance in food resources and changing weather patterns (including changing wind directions as discussed by Anderson *et al.* 2006). Interestingly, the WK-2 eruption occurs near the beginning, recently re-dated to c.3340 BP (Petrie & Torrence 2008). This might also have had an impact as an important 'push'-factor for colonisation. The limited number of artefacts and the highly ambiguous pattern of physical attributes measured in the earliest time period for BI-obsidian artefacts might also be best explained in the framework of a highly mobile colonising population and embedded procurement of raw material. That colonisation was conducted through a series of waves is suggested by the slightly younger ages of RF-6 among the RSC sites and the appearance of AD-obsidian in Tikopia, which might be associated with the dominance of AD-obsidian in middle and late Lapita assemblages on Mussau, Anir and the Duke of York Islands (Summerhayes 2003b, 2003a; 2004b; 2009) and Nissan and Buka as well in the northern Solomon Islands (Wickler 1990, 2001).

In the post-Lapita period the reason for the significant decrease in the amount of transported Bi-obsidian becomes clearer, if Pawley's (1981) model of increasing isolation and focus on intensification of settlement structures of each island in separation is considered. Similar to Fredericksen's (1994) research on the AD-obsidian distribution, the current project finds little evidence for Allen's (1984) and Kirch's (1988) models for the continuing evolution of Lapita exchange systems into the early post-Lapita phase. A continuity of exchange systems from Lapita into the post-Lapita phase is not clearly identified during time period two. Although the temporal resolution of the current research is very low, ideas of a series of contracting systems or the spatial splitting of an existing exchange system into several more localised ones can be rejected. Whether the concentration on one obsidian resource, evidenced through the ratio of Gaua to Vanua Lava material during time periods two and three (Table 6.15), suggests an increase in specialisation is unclear. Similarly unclear is whether this pattern could also be interpreted as a mimicking of the specialised exchange networks detected by Torrence and Summerhayes in the Willaumez Peninsula. Nor is this focus on one particular source accompanied by a more specialised technology, nor by the evolution of more complex exchange systems. This is because the identified acquisition mode is direct access or direct home-based reciprocity.

Question 4. What implications does obsidian exchange have for the understanding of social interaction in Pacific history?

Time period one:

This work has attempted to track social interaction through changes in the distribution of one specific item of Pacific islands' material culture: obsidian (Figure 8.8). It has been shown that the long-distance transportation of West New Britain obsidian into Vanuatu was limited to the colonisation phase only and was therefore a very short-lived phenomenon which ceased directly with the end of the initial burst of human dispersal. In the discussion of social interaction in the aftermath of this colonisation period over the long time span of more than 2600 years, it must be considered that this initial colonisation phase was an exceptional and most likely singular event that might have contributed only marginally to the evolution of the cultural diversity which exists in the Western Pacific today.

It seems that the necessity of carrying or acquiring an item marking an unified ethnic identity stopped once islands were found and inhabited, which then provided the means to nurture a founding community sustainably. Intensification of settlement and agriculture accompanied this process. It should be mentioned here that this cessation of obsidian transportation might not simultaneously disrupt all interaction networks between distant communities, as the transportation of obsidian might not be part of trade networks that distributed other items, for example food. This hypothesis fits well with Anderson's (2003) model of human dispersal during phases of high social instability and the OFT model of patch use put forward by Kennett et al. (2006). Small highly-mobile groups would therefore settle highly productive patches first. These patches are only abandoned when the resource outcome of an inhabited patch is less than the predicted outcome of a new patch. Kennett et al. associate this pattern with the Lapita dispersal where an initial burst of colonisation is followed by a steady increase in population density, "filling up" adjacent patches, and the intensification of agriculture. This process can also be seen in the distribution of WNB-obsidian in Vanuatu: two large sites, EF-Teouma and Makue which are both relatively early sites, have higher amounts of WNB-obsidian, with other sites of slightly younger age having significantly less obsidian, for example those just off Malakula and on Mota Lava.

Bedford (2007) argues for a regional differentiation in Vanuatu starting in the dentate-stamped pottery phase and more "dramatically' in the post-Lapita phase. It also seems that the dentate-stamped phase lasted longer in the north of the archipelago than in the south. This correlates well with the lithic data suggesting contracting networks directly after the end of the initial burst of colonisation. Contact with late Lapita sites on Tikopia, which showed import of AD-obsidian in this phase, suggests that the breakdown of interaction was not uniform. However, it seems that the actual migration of people into the region was also a short-lived phenomenon, which was restricted to an initial burst of colonisation.

Time period two:

Following this 'unique' event of human colonisation, any type of obsidian transportation was completely disrupted in Central Vanuatu. Additionally, no evidence has been found in the lithic record that exchange networks spread in the post-Lapita phase from Vanuatu to the islands of Fiji (Best 2002; Burley 2005). To the contrary, the interaction networks were significantly reduced and underwent a rather strong contraction. If obsidian distribution is interpreted as a proxy for the intensity of interaction, then there seems to be a significant decrease in communication between the early colonising communities (cf. Sheppard & Walter 2006:67, for a similar interpretation of southeast Solomons' cultural history). Most probably associated with a time of stable environmental conditions these founding communities concentrated on the intensification of each separate settlement rather than continuing a costly interaction network. However, contact between these different groups in the north of Vanuatu and the southeast of the Solomons never entirely stopped. A similar phenomenon can also be detected in the emergence of new highly-regionalised networks in central and southern Vanuatu, based on the ceramic sequences. It seems that the concept of complete isolation might not be a useful heuristic to explain the origin of cultural diversity.

From the lithic perspective these times of increasing separation can be interpreted as the background for an emerging cultural diversification. Identifying Lapita as an ‘ethnic identity’ (Chiu & Sand 2007) with shared norms and values (Green 2002), similarities in the post-Lapita ceramic record would derive more from a common origin than from continuous interaction networks. The intensification of agriculture in a most likely highly-predictable (low risk) and abundant environment can be correlated with the ‘pause phase’ of Green’s (2003) and Anderson’s (2003) models of Lapita dispersal. It therefore has to be assumed that contracting networks and relative isolation were important factors in the emergence of cultural diversity. Contrary to Terrell’s (1989) assumption of continuous interaction networks throughout the area of human dispersal, there is no indication for far-reaching ‘trade’ networks in obsidian in post-Lapita times.

Low inter-island communication was suggested from the beginnings of modern Pacific research as having a high impact on the emergence of cultural diversity. However, instead of seeing these islands as isolates in Goodenough’s (1957) terms, low-level contact continued between islands in Vanuatu and the southern Solomons on a highly selective basis. One factor in defining Pacific islands as isolates is the geographical distance which had to be overcome. This assumption is not supported by the lithic evidence. On the contrary, the distribution of BI-obsidian seems to indicate that distance played only a minor role in maintaining interaction. For example, no BI-obsidian was found at later sites in North Santo although these sites are located at relatively closer distances to obsidian sources (and Santo is visible from some islands of the Banks group) than contemporary sites on Tikopia. Unfortunately, the archaeological record analysed in this work does not unambiguously suggest alternative factors for this highly selective communication between islands.

Formal exchange systems for the distribution of obsidian cannot be detected in either the Lapita or the early post-Lapita phase. The socio-political transformations (Friedman 1981; cited in Spriggs 1997:156) resulting from changes in prestige-good exchange systems are rendered suspect in light of a non-existent exchange system. Long distance transportation of obsidian was not directly superseded by intensification of a short distance exchange network, but rather by a long hiatus of very limited inter-island communication. Intensification of communication only increased in the latest phase (after 1000 BP) when environmental constraints may have amplified resource failure and local communities could have used external contacts to reduce risk in these unstable times.

Time period three:

During the third time period after 1000 BP, a sharp increase in obsidian distribution can be detected. This increase did not spatially extend existing networks, as no obsidian is found in Central Vanuatu, but rather intensified existing communication between islands. These communication networks did not result in development of more complex exchange networks – at least not for obsidian – as direct access or home-bound reciprocity was identified as the “exchange” mode for the distribution of BI-obsidian. It has also been argued that as a reaction to increasing resource variability, delayed reciprocity networks developed in which obsidian most likely represented symbols of obligations rather than ‘trade’ goods themselves. The origins of cultural diversity were detected in a previous phase of low inter-island communication. However, the intensification of cultural diversity and the ‘socio-political transformations’ which resulted in the evolution of complex exchange networks for pigs, shell valuables and other commodities, particular in the northern parts of Vanuatu (Bedford & Spriggs

2008; Huffman 1996), most likely occurred during this latest phase of human occupation.

McElreath et al. (2003) discuss increasing social interaction as not involuntarily resulting in a levelling of cultural differences (cf. Boyd & Richerson 1985, 2005). In this context it is important to note that the migration of large numbers of people would seriously affect the distribution of cultural markers in societies. The distribution of BI-obsidian could therefore be interpreted as representing higher mobility during times of environmental stress. This might indicate a return to the successful adaptations of the Lapita phase. This mobility, however, has to be considered in relation to migration. Whereas an adaptive strategy is suggested in the Lapita phase migration, it seems that there was a shift away from residential mobility to the mobility of interaction and the flow of items in this later phase.

Conclusion

This chapter has discussed the results of the data set presented in Chapters 5 and 6 in relation to the models proposed in Chapter 7. The model of down-the-line transportation is identified as statistically the most probable for explaining the spatial distribution of WNB obsidian from the RSC sites to areas further out in the Pacific and that other sites in Remote Oceania did not have direct contact with the founding population in West New Britain. However, whether this model also describes an exchange system and not just a directionality in the coloniser mode is unclear. It has been suggested as an alternative to the 'exchange' interpretation that obsidian in the context of colonisation should rather be identified as an ethnic marker, describing a common ancestry.

BI-obsidian on the other hand, might have been obtained through embedded procurement in the earlier two time periods, as the size distribution follows no clear patterns of distance decay. Whether colonisers 're-created' social worlds in the newly inhabited islands is therefore unclear. The evidence does not support the notion of a specialised exchange system as identified by Torrence and Summerhayes (1997) in the Willaumez Peninsula as existing in Vanuatu during initial colonisation.

For the latest time period, when interaction between groups intensified, direct access or home-based reciprocity is argued to best explain the data. Specialised trading of raw material might be suggested by the increased distribution of Vanua Lava obsidian as compared with Gaua obsidian. As the reduction and utilisation of the raw material does not increase significantly, it is suggested that the distribution of BI-obsidian can be explained through an ‘insurance’ based interaction network, in which social obligations were identified through certain symbols, of which obsidian might have been one. These networks of social obligations became more important during times of environmental stress as a risk reducing strategy.

- Chapter 9 -

9. Conclusion

In the context of the research questions formulated in Chapter 1 and previous research outlined in Chapter 2, this project has provided substantial new data, ideas and interpretations for the understanding of interaction networks in southwest Remote Oceania in the past. The thesis has concentrated on the evaluation of one specific part of the archaeological record and attempted to present ideas on the evolution of cultural history from this perspective only. Four different aspects of obsidian extraction, distribution and utilisation were examined: (a) the geochemistry of the sources; (b) the spatial distribution of artefacts; (c) processes of artefact transportation; and (d) the value of obsidian.

Geochemistry of the two Northern Vanuatu sources

Previous work suggested that more than the two known sources in Northern Vanuatu existed, and that therefore artefacts which showed geochemical similarities with the Banks Islands sources but were not a close match, could possibly originate from there. This research has shown that the two known sources were the only sources of obsidian existing in Vanuatu, and these sources have a low internal variation and can readily be distinguished from other sources in the Western Pacific.

Both sources were geologically examined, and pyroclastic flows were identified as the most probable origin of the volcanic deposits. This suggests that no localised obsidian outcrop existed but rather that the source location had a significant spatial extent. In relation to this finding the extraction of mainly secondary deposits becomes more likely than the existence of localised quarries, where mining activities could result in high quality nodules. At both source locations obsidian nodules were readily available in an eroded state in riverbeds or accessible with the removal of only small amounts of loose soil.

However, although the two BI-obsidian sources were the only ones utilised in the past, pitchstone outcrops were also exploited, although only to a small extent. One pitchstone source from the island of Tongoa was analysed, but no artefacts originating from there were found. Other pitchstone varieties were used in small numbers at the sites of EF-Arapus, TI-Kurvot and ML-Lequesdewen, and on Epi, but no sources for this material were identified. They most likely derive from small localised sources on several islands throughout the Archipelago. One interesting connection was found, however, as a pitchstone artefact from the EF-Arapus site showed good correlation with one artefact from ML-Lequesdewen, suggesting a continued contact of people from the Banks group with Central Vanuatu in the immediately post-Lapita phase.

Spatial distribution of artefacts

The network of inter-communication suggested by the transportation of obsidian raw material throughout the research area had its widest spatial extension during Lapita times. During time period one, BI-obsidian was found at several sites in the south-eastern Solomons and was also transported to early Lapita sites in Vanuatu. This widespread distribution of BI-obsidian was only short lived. Transportation into Central Vanuatu stopped with the end of Lapita, with only very limited evidence suggesting some transportation in the early post-Lapita phase in islands further north.

During the long period of settlement intensification during the post-Lapita phase obsidian distribution almost came to a complete halt. It has been shown that the artefacts found in eastern Fiji did not originate from Vanuatu, but rather from a small, still unknown source somewhere in west Fiji. There is therefore no physical evidence for contact between Fiji and Vanuatu during post-Lapita times. Whether any contact existed at all during this time cannot be securely assessed based on the lithic evidence alone. Evidence other than the ‘obsidian-connection’ is needed to verify any putative contacts.

It is important to note that obsidian transportation away from the two islands of origin never completely halted. Small numbers of artefacts were found on other islands throughout prehistory, but only after ~1000 AD did the contact between islands increase significantly again. Large assemblages of artefacts were found in Mota Lava, the Torres Islands, Pakea and Tikopia. However, no artefacts were found south of the Banks Islands group in this phase, suggesting that at the time of intensification the communication networks to the south of the islands were already disrupted.

Much speculation has been made as to the reasons why this intensification occurred so suddenly at that time. In this research the correlation between environmental constraints and intensification, rather than purely economic explanations of increased social stratification, has been put forward. It has been suggested that hierarchies were not the reason for intensification of communication, but rather the consequence of intensified communication. The intensification of communication became necessary as the time of very predictable food resources ended with the end of the 'Medieval Warm Period' and changed into an era of *very unpredictable* climates with a high variance in food resources. Obsidian was therefore not the cause of interaction, but rather a symbol for the process.

Processes of artefact transportation

Different processes of exchange have been evaluated for artefact transportation. The basis for an assessment of the spatial distribution of raw materials is Renfrew's (1977) ten modes of reciprocity. It has been ascertained that different modes of exchange existed for different raw materials. Exotic raw materials like the long-distance transported obsidian of West New Britain, West Fergusson and Admiralty Islands weren treated differently from Banks Islands and other local non-obsidian rocks.

For the long-distance transported material of Kutau/Bao, down-the-line relaying has been identified as the most likely process of transportation. Based on a detailed analysis of average weight of artefacts in Specht's (2002) distance zone five, evidence of Sheppard's (1993) interpretation of the RSC sites as being in the supply zone of WNB raw material was found. In addition, sites at greater geographical distances to the source were not connected to the homeland itself, but rather to these first sites of early colonisation. Support for this hypothesis can also be found in other physical attributes of artefacts discussed in this thesis, for example (a) less cortex on artefacts, (b) more bipolar reduction of cores and (c) more flakes with feather termination.

The terms reciprocity and exchange are deliberately avoided in this study as it is unclear whether an exchange system existed at all or whether transportation was directly connected to colonisation. In the context of colonisation it has been suggested that obsidian was a symbol of ethnic identity, defining group affiliation in a new-found territory. This interpretation is slightly modified from Kirch's hypothesis of a 'connection to an ancestral homeland', where obsidian exchange is interpreted as an 'insurance' in a unpredictable environment.

During time period one, Banks Islands raw materials were also transported throughout the archipelago. The physical attributes of the artefacts found, however, do not unambiguously support one specific mode of exchange. It has therefore been suggested that embedded procurement of raw materials was the most likely mode of transportation, where people collected material during other activities not specially related to raw material procurement. These processes of acquisition changed in the latest phase of the cultural sequence. The intensification of communication between different islands did not cause the emergence of complex exchange systems for obsidian, but instead direct access or home-based reciprocity was identified. The more intensified reduction of cores at sites on Tikopia, resulting in an overall size decrease of artefacts, cannot be clearly identified with a resource maximisation strategy as different physical attributes, such as (a) amount of cortex, (b) flake termination, or (c) amount of flaking failures, do not decrease or increase proportionally. As a reason of this unusual pattern of artefact utilisation, the embeddedness of obsidian in an interaction network has been proposed, in which the acquisition of obsidian was needed as a token of social obligations rather than as a simple trade good.

Value of obsidian

One of the main questions about obsidian distribution in the Western Pacific is why people made an effort to transport certain obsidian varieties over very long distances and then discarded them without elaborate 'utilisation'. Comparing the function of BI-obsidian with non-obsidian rocks of most likely local origin, it seems that these artefacts were mainly used for the same purposes. The only specialised tool type – made solely from WNB obsidian – is the 'graver' which was found in several assemblages throughout Remote Oceania. They are found only in very small numbers, except in the RSC sites; incidentally giving further support to the hypothesis of the origin of Vanuatu's earliest colonisers in these islands.

It was shown in Chapter 7, that the question of value of obsidian through acquisition/utilisation might derive from a biased perspective on the basis of economic theory. Rather than identifying obsidian as a commodity, the acquisition of which could result in power or prestige, the alternative concept of gift giving has been discussed in detail. The assessment of the social value of an object in the theoretical framework of Renfrew's modes of exchange was advanced through statistical analysis of regression curves by Hodder (1978a) and Torrence (1986). Their work suggests that obsidian most likely only had a low value. Purely economic models might therefore not be suited to explain the spatial distribution of this raw material.

As an alternative to the ascription of value to obsidian, the importance of symbols for group affiliation or ethnic markers has to be considered for the Lapita phase. In consideration of risk management as a basic human characteristic, the easy identification of group affiliation in the very unpredictable situation of colonising new territories should not be underestimated. Therefore, obsidian has to be evaluated in its embeddedness in other networks of communication. If obsidian were a symbol, it might have been an easy medium of communication.

The approach to obsidian as a symbol of communication was re-invented or might have persisted throughout the long period of sparse interaction in the post-Lapita period in which different groups on separate islands developed their own expressions of cultural identity. This cultural diversification intensified when environmental change made food resources unpredictable again and interaction networks re-emerged. The evolution of the multitude of cultures we can see today in southwest Remote Oceania therefore has a long history starting in early post-Lapita times. Obsidian distribution was not a cause of it but rather a by-product, as a symbol of social obligation embedded in trading networks which most possibly only developed in the 600-odd years before European explorers appeared in the Archipelago.

Future perspectives

Much work remains to be done. In concluding this thesis, six points of interest for future research can be identified:

1. There is a good understanding of the general geochemistry of the two Vanuatu sources, but the remaining sources in the Western Pacific still need further research with LA-ICPMS. LA-ICPMS has proven to be a quick, reliable and very accurate technique for the geochemical analysis of obsidian. But although it

is widely applied now in archaeological research the database for Pacific obsidian sources is far from complete. More source samples with a secure allocation to different outcrops need to be analysed.

2. For a more detailed understanding of the extraction processes at the two Vanuatu sources further research and surveys are needed, especially focussing on earlier deposits near the source areas themselves. The present work has shown that BI-obsidian was utilised in large amounts in the Banks group itself and in smaller amounts outside it. However, sites with a well-preserved stratigraphy in these source locations were not found during the 2006 fieldwork season. Only deposits from the latest time period have been excavated. For the crucial time period of the early and mid post-Lapita phase c. 2700 BP until about 1000 BP, but to test the ideas further, it would be beneficial to enlarge the sample of sites.

3. In relation to the incomplete database of obsidian sources in the Pacific, the exact location of the volcanic glass outcrop in Fiji where the Lakeba artefacts originate from has still to be identified. Additionally, not much has been said here about the spatial distribution of material from the Tongan sources as this was not the focus of the thesis. However, local connections between sites in the general area of central Remote Oceania need further research. Hypotheses that focus on internal archipelago-based cultural processes are likely to have greater explanatory potential for understanding post-Lapita societies than those that emphasise the significance of long distance interaction and migration between the islands of the Western and Central Pacific.

4. More work concentrating on the technological attributes of stone artefacts can clarify issues this research has raised. Additional studies could include flaking properties and fracture mechanics. Considering the dominance of Vanua Lava material in the latest deposits, the experimental evaluation of flaking properties, as already mentioned by Smith et al. (1977), could perhaps rule out functional considerations for the choice of raw material transported. Additionally, size constraints suggested by the physical attributes of flakes were not assessed experimentally in this study. Although it has been evidenced in this work that

functional aspects of raw materials were not a major factor in raw material procurement, experimental data could further help evaluate this proposition.

5. In relation to functional aspects of artefacts, more research on use of artefacts needs to be done. The long history of successful research on use-wear and residue analysis in the Pacific (Barton *et al.* 1998; Fullagar 1992, 1993; Fullagar *et al.* 1989; Fullagar *et al.* 1998; Kononenko 2007), most recently continued with Nina Kononenko's PhD thesis (Kononenko 2008), has proven that functional approaches to artefacts are necessary to determine utilisation patterns of different raw materials. Use wear or rather the lack of it in the examined assemblages gives evidence of the underlying reasons for the spatial distribution of artefacts. Functional questions were not the focus of this thesis but especially in consideration of the long distance transportation of certain raw materials, much more research is needed to test in detail the model of the value of obsidian as a symbol of interaction and not as a tool specifically acquired for certain uses.

6. Finally, the consideration of environmental change tentatively proposed in this work as having a major impact on the emergence of social networks of interaction needs to be the focus of further research. This alternative model for the evolution of cultural diversification in the Western Pacific does not yet have the detailed foundation necessary to make far-reaching interpretations viable. As Allen (2006) states, the time has come now to move away from simple correlations towards a detailed exploration of processes linking environmental parameters with cultural change.

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