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From Pleistocene to Present: Obsidian Sources in West New Britain, Papua New Guinea

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ABSTRACT. Artefacts made of obsidian derived from outcrops in the Talasea area of West New Britain, Papua New Guinea, have been found on archaeological sites dating from the late Pleistocene up to the present day and extending over about 8,000 km from west to east of Talasea. The research described here examines the nature of past obsidian exploitation at the Talasea sources and forms part of a larger project on the history of human settlement and resource use in West New Britain. Two aspects of this work are reported here: field studies of the source exposures around Talasea, and the fine-grained discrimination between the sources through PIXE-PIGME ion beam analyses of their chemical compositions.

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In the Bismarck Archipelago of Papua New Guinea obsidian flows of archaeological significance occur in Manus Province on Manus and Lou Islands, and in West New Britain Province around Talasea on the Willaumez Peninsula and at Mopir on Hoskins Peninsula (Fig.1). The obsidians from these areas can be distinguished from each other on the basis of differing chemical compositions (Key, 1969; Smith, 1974; Smith *et al.*, 1977; Duerden *et al.*, 1979, 1980, 1987; Ambrose *et al.*, 1981; Bird & Russell, 1976; Bird *et al.*, 1981a, 1981b, 1988; Fullagar *et al.*, 1989).

Talasea obsidian has been recovered from archaeological sites throughout the western Pacific, extending over about 8,000 km from Sabah in the west (Bellwood & Koon, 1989) to Fiji in the east (Best, 1987). Much of this distribution is associated or contemporary with Lapita pottery (Green, 1979; Kirch & Hunt, 1988). It was also transported, along with obsidian from Mopir (Specht & Hollis, 1982), within New Britain (Specht *et al.*, 1981) and to neighbouring New Ireland (Allen *et al.*, 1989) in the late-terminal Pleistocene between 19 kya and 11 kya. It is only at a much later date, apparently coinciding with the appearance of Lapita pottery in the region, that obsidian from the Manus area appears in New Ireland sites (Allen *et al.*, 1989; Ambrose, 1976; Ambrose & Duerden, 1982; Ambrose *et al.*, 1981;

Downie & White, 1978); on Watom Island (Bird *et al.*, 1981a; Green & Anson, 1987); and southwards in the Solomon Islands (Ambrose, 1976; Ambrose & Green, 1972; Green, 1987) and in Vanuatu (Bird *et al.*, 1981a). At many of these sites, obsidian from two or three of the Bismarck sources is found together in proportions varying between sites and through time within sites (Green, 1987; Green & Anson, 1987; Gosden *et al.*, 1989). The causes underlying these variations in distribution and frequency are not known but may reflect factors such as the realignment of exchange networks.

In addition to this gross differentiation between source areas, there has been some success in the discrimination between obsidians from different volcanic centres on Lou Island in Manus Province and around Talasea (Bird *et al.*, 1981a, 1981b, 1988; Ambrose *et al.*, 1981). While these finer discriminations do not include all possible obsidians from each region, they do indicate that in future it may be possible to assign an archaeological obsidian find not simply to 'Lou' or 'Talasea', but to a specific source flow within the relevant areas (cf. Green, 1987). This adds a new dimension to discussions about variations in the distribution of obsidian from the Bismarck sources, as well as providing a new perspective on extractive behaviour.

An Approach to Studying Source Selectivity

Which mechanisms explain why obsidian from several different West New Britain sources is found in prehistoric sites outside the area? The full answer to this question is likely to be complex, since the possible scenarios are almost limitless. We are conscious of the problem of equifinality, where several different forms of past behaviours could produce identical archaeological expressions. Taking a pragmatic view, however, we can begin to tackle the matter by breaking it up into smaller, more manageable steps, and then devise appropriate methods for studying each step; in other words, build from the bottom up, not from the top down.

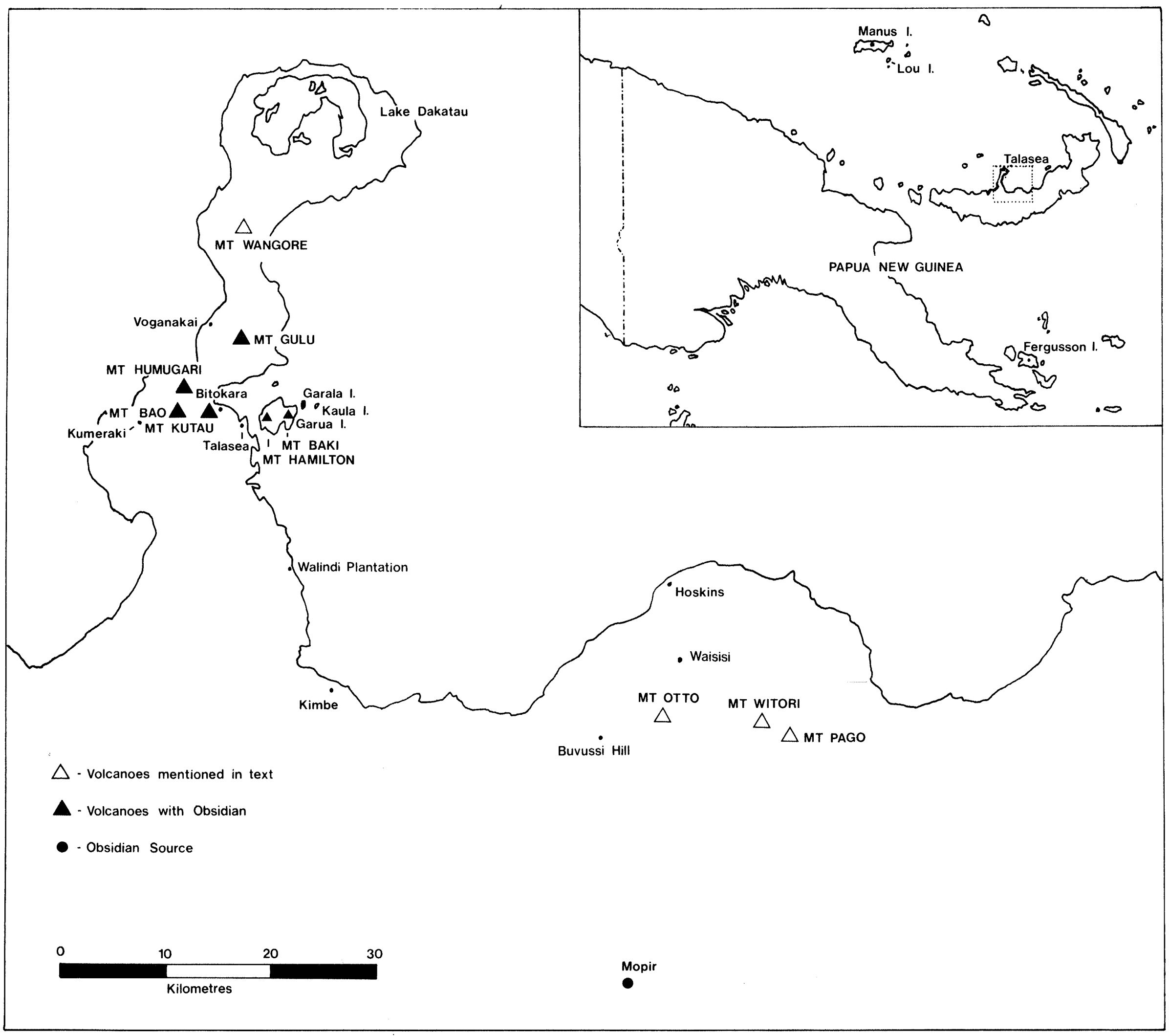

Fig.1. Obsidian source areas and related volcanoes, West New Britain, Papua New Guinea.

There are three key components of a distribution system or network (Torrence, 1986: fig.1): producers, consumers, and the nature of the links between them. At each point, decisions are made that affect the distribution of goods through the system or network. In the context of the Talasea obsidians, such decisions could have determined which sources would ultimately be represented at sites both around Talasea and beyond. Particular obsidians may have had special properties, actual or attributed (e.g., colour, flaking characteristics, ritual associations), that were selected for by the producers and/or the consumers. Where these selections were made by the producers, they could have resulted in a restricted range of source options being available to the consumers. The consumers themselves may have sought obsidian only from certain sources. Furthermore, the way the distribution network or system was integrated could have influenced the degree to which producers were interested in or were able to respond to consumer demands. Individuals at consumption sites may have operated independently and have had special exchange relationships with people who acquired obsidian from a particular place. Alternatively, obsidian may have been pooled within a household or larger group, or organised by one person who controlled its redistribution (cf. Pires-Ferreira & Flannery, 1976). If the distribution mechanisms were poorly integrated, as might occur with a chain of reciprocal down-the-line exchanges, then the resulting distribution pattern might best be described by a random walk model (cf. Renfrew, 1975; Torrence, 1986).

All three aspects of the distribution process need to be examined, but at this stage of the research we choose to focus on only one: the effects of choices made by producers during the initial collection or extraction of obsidian in the Talasea area. Rather than test for all possible explanations for the selection of sources, we focus on one possible set. We hypothesise that people in the Talasea area chose obsidian sources to satisfy their needs with the least investment of energy. It is important to stress that the decision to examine exploitation in terms of a least-cost model is not based on a prior assumption that people in the past were minimising energy expenditure. On the contrary, the advantage of adopting this approach is that, unlike many other possibilities, the hypothesis offers concrete predictions that can be evaluated with archaeological data. Once least-cost considerations are accounted for, we can look more strongly at other possible factors.

To measure energy minimisation, we consider the potential obsidian sources in terms of variables relating to three aspects of exploitation: (1) the functional properties of the obsidian itself; (2) relative cost per unit of useable raw material when collecting or extracting it from a particular form of exposure; and (3) ease of access to potential sources on a local topographic and wider regional scale. Current and planned studies focus on the form of by-products of extraction and production at the sources themselves (cf. Torrence, 1986), the results of which we will compare with independent evidence measuring the degree to which each source was exploited in the past. The results of these studies will be presented elsewhere.

The Talasea Sources

During archaeological fieldwork in the Talasea area in 1988 to 1989, we attempted to locate as many exposures of obsidian as time and mobility would allow in order to collect additional source samples for further inter-source discrimination and for experimental studies of use-wear and use residues. The nature of the exposures and their obsidian were described in terms of a range of variables that evaluate the potential of each occurrence for sustained, low cost exploitation, as well as the gross physical characteristics and flaking properties of each source. These field surveys greatly increased the number of obsidian occurrences reported by Specht (1981). Given the difficulty of systematic surface survey in the tropical environment and problems in visiting the southern and western slopes of one of the major obsidian-producing volcanoes (Mount Bao), our current total of 60 exposures must be regarded as a minimum.

The exposure locations are shown on Figure 2, and Table 1 (see Appendix) provides a summary description of each one. In addition to the extent of each exposure (not shown in Table 1 [see Appendix]), we recorded the density of obsidian within it, recorded the percentage of readily available blocks for five size classes (less than 5 cm, 5-10 cm, 10-20 cm, 20-50 cm, and greater than 50 cm), made an arbitrary assessment of the 'quality' of the obsidian and, finally, recorded any evidence for past exploitation.

Table 1 (see Appendix) presents two variables for an arbitrary assessment of the exploitation of the exposures. 'Extraction' refers to the ease with which useable blocks and flakes could be extracted, and is graded as follows: 'easy' (obsidian probably available in the past as blocks lying on the former ground surfaces), 'moderate' (both now and for most of the past, blocks and flakes probably obtainable only by digging to various depths), and 'hard' (obsidian removable only by percussion from exposed flow margins). 'Quality' summarises source accessibility, block size, density and suitability for flaking. Four categories are used for this criterion: 'not viable', 'low', 'medium' and 'good'.

For a source to be rated as being of 'good quality', it must be easily accessible, easy to moderately easy to extract, abundant, available in large pieces (greater than 15 cm), and perform well in flaking tests.

Previous 'flakeability' tests of Talasea obsidian (Kamminga, 1982), measuring the mechanical properties important for the manufacture and use of obsidian tools, have shown that in general, relative to other flaked stone material from Australia and Papua New Guinea, Talasea obsidian scores highly on resistance to static loading, low on overall toughness, and in the middle of the range on resistance to scratching, compressive strength, tensile strength and elasticity. The test obsidians were relatively isotropic but the homogeneity of blocks of useable size varied according to the amount of tephra and air bubbles included in them. These adversely affected the strength of cores and reduced the predicability of fracture paths but, while lowering flaking quality, did not preclude flaking altogether.

The relative mechanical properties of each source recorded in 1988 to 1989 have not yet been studied in a controlled and detailed way, but flaking tests at each exposure indicate that all but six (Table 1, nos 28, 52, 53, 55, 57 and 60 [see Appendix]) have obsidian yielding a fine conchoidal fracture. The main factors affecting tool production at the remaining 54 exposures are the actual size of the removable blocks, their shape and density. Small blocks obviously limit the size of useable flakes, and core size would have been a major consideration before 3,500 ybp, when stemmed tools and retouched blades reaching more than 20 cm in length were produced around Talasea (cf. Specht *et al.*, 1988). At the other end of the scale, pieces of obsidian with a maximum dimension of about 10 mm are extremely difficult to flake. At two exposures (Table 1, nos 35, 47 [see Appendix]) the obsidian pieces were too small for tool production.

'Exploitation' in Table 1 (see Appendix) refers to evidence for past use of the exposures. 'Present' indicates that there is flaking evidence directly associated with the exposure. 'Present nearby' means that flaking is absent from the immediate vicinity but occurs within a 25 m radius from the exposure. 'Absent' simply means that there is no evidence that a particular exposure was used in the past. In the latter case, flakes distinctive of another exposure may be present nearby.

The data are undoubtedly complex, and no simple typology of exposure potential can convey the full picture. It is already evident that variability is high in almost every dimension, and the potential range of source options for past obsidian workers and consumers was great.

Table 1 (see Appendix) also summarises the depositional contexts of each exposure. The complex volcanic and depositional history of the Talasea area has created a series of different topographic settings, with a wide range of primary and secondary contexts within which the obsidian occurs. The primary contexts include (1) banded rhyolite, (2) blocky rhyolitic flows, and (3) altered rhyolite. The secondary contexts cover (4) pyroclastic flows, and (5) various erosional deposits. Each of these presents different

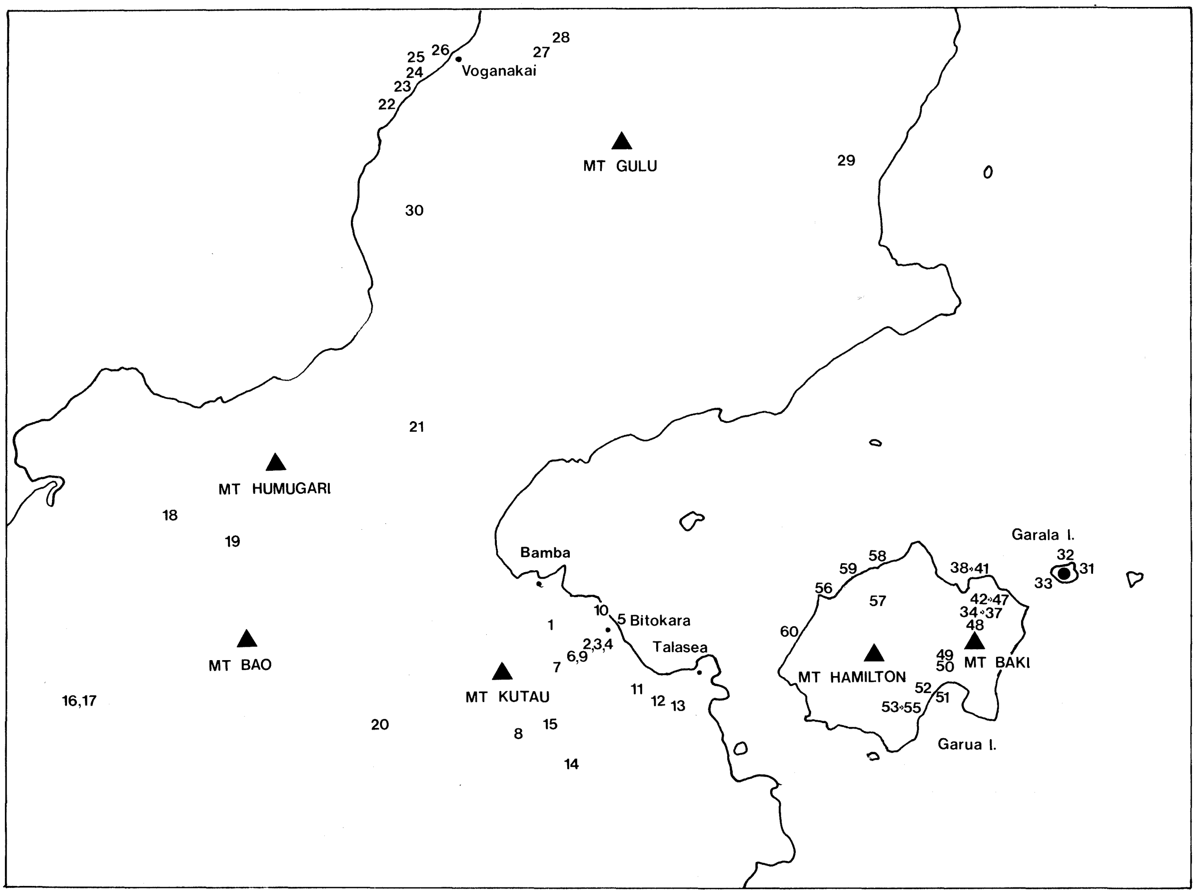

Fig.2. Obsidian source exposures in the Talasea area of West New Britain, Papua New Guinea, listed on Tables 1 and 2 (see Appendix).

possibilities and problems for extracting useable obsidian. Furthermore, we have evidence on Garua Island that people in the past scavenged from the surface and dug shallow pits to obtain worked and unworked obsidian pieces left behind as waste by-products from previous quarrying and manufacturing activities (e.g., source G017, no. 48 on Table 1 [see Appendix]).

Primary Contexts

Banded and altered rhyolitic flows. On the Willaumez Peninsula rhyolitic flows containing bands of obsidian are definitely associated with Mount Kutau, Mount Bao and Mount Gulu. Rhyolitic flows also occur on Garua Island associated with Mount Baki and Mount Hamilton, and on Garala Island. The relative ages of these flows are not known. At the former Talasea airstrip we recorded a possible source of obsidian in gravels whose origin is unknown. Further fieldwork is required to determine whether they have been washed down from an unrecorded source on Mount Humugari, or brought in by wave action from flows at the foot of Mount Kutau.

At least one of the Mount Kutau exposures (Table 1, no.10 [see Appendix]) and several Mount Hamilton rhyolitic flow exposures (Table 1, nos 51-57 [see Appendix]) have been so altered that the rhyolite has lost its original structure and is now very soft and white or yellow in colour. Many flows have also been subjected to considerable faulting.

Rhyolitic flows vary enormously in their potential for exploitation because the width of the obsidian bands can range from tiny 'stringers' of less than one centimetre thickness to massive bands several metres thick. The thinner bands are frequently heavily folded and jointed, thereby reducing the size and affecting the shape of the blocks contained in them (Fig.3). Blocky flows also produce obsidian nodules with a wide range of shapes and sizes. Highly jointed bands are also commonly associated with the formation of cortex, a quality that may reduce the useable size of a block. The cortex varies from a smooth, flat surface, to a moderately rough surface with linear patterns, and to a thick layer with numerous air bubbles. Jointed deposits and some of the blocky flows, however, are relatively easy to exploit, since little effort is needed to prise out the obsidian blocks, especially if the rhyolitic matrix has been altered. Quarrying massive bands of obsidian, on the other hand, would have been extremely difficult, because direct percussion and other forms of force would be required to break the flow edges into useable pieces (Fig.4). Since the rhyolitic flow exposures are so variable, each is assessed on its own merits on Table 1 (see Appendix).

The obsidian from rhyolitic flows varies from exposure

Fig.3. Jointed obsidian flow on Garala Island, Talasea area (exposure 32 on Fig.2 and Tables 1 and 2 [see Appendix]).

to exposure in terms of colour, cortex and the character of phenocrysts, where present. Yet only one set of flows can be distinguished solely in terms of its physical characteristics. Obsidian from Mount Hamilton invariably contains a very high density of small, white phenocrysts. Few Hamilton exposures yield obsidian that produces a conchoidal fracture, and in no cases are fracture patterns regular and predictable. It is not surprising, therefore, that few artefacts with the physical characteristics of the Mount Hamilton flows have been found in the Talasea area. With this sole exception, all other rhyolitic flows produced obsidian with good conchoidal fracturing properties.

Phenocrysts are present in several other rhyolitic flows on Garua Island and near Voganakai village. They differ from the Mount Hamilton variety in being grey, not white. They range in size from 1 to 5 mm, and their density increases in direct relation to their size. Grey phenocrysts are usually indicative of obsidian that is not viable for artefact production, since this kind of obsidian occurs in very thin bands, often simply as rows of droplets in the rhyolite matrix. Some such flows were utilised, however, since artefacts with a low density of small grey phenocrysts are present in small quantities on several archaeological sites in the area.

The obsidian from the Mount Kutau and Mount Bao rhyolitic flows is highly variable in colour and translucency. It is generally banded, grey to grey-green or black in colour. Flakes of this obsidian are frequently not translucent. Obsidian from near Mount Baki on Garua Island and on Garala Island is more likely to be deep black and highly translucent, if not transparent, in thin flakes. Banding is present on Garua at localities G002 and G017 (nos 35 and 36, and 48 on Table 1 [see Appendix]). The physical appearance of obsidian from the various exposures thus varies so greatly that artefacts cannot be assigned to sources solely on the basis of colour or translucency.

Secondary Contexts

Obsidian cobbles suitable for tool production have eroded from rhyolitic flows, and can be found on the ground surface of some hillslopes and beaches (Fig.5), and in some gullies and streambeds. The blocks vary considerably in size and shape, but they are generally very solid and constitute excellent flaking material. Highly rolled and, therefore, very rounded pieces may present problems for artefact production, but in most cases the Talasea obsidian gravels are angular and contain potential flaking platforms. From the point of view of human exploitation, such sources have a considerable advantage over other kinds of occurrence since they do not require a special extractive technology. On the other hand, few surface deposits contain large quantities of

Fig.4. Massive obsidian flow on side of Talasea-Bamba road, below Bitokara Mission (exposure 10 on Fig.2 and Tables 1 and 2 [see Appendix]).

blocks big enough for the production of some kinds of artefact.

On Garua Island obsidian nodules also occur in deposits which appear to result from landslides, possibly caused by volcanic activity or uplift such as is exhibited elsewhere on the island (Table 1, nos 34-37 [see Appendix]). These deposits contain a wide range of material including blocks of banded rhyolite and clusters of large solid nodules. At G002 they range from 15 to 20 cm in diameter up to 45 cm long (Fig.6). Just uphill, at exposure G001 (Table 1, no.34 [see Appendix]), there is some evidence that the deposit has been affected by geothermal activity. As a result, the small tabular pieces of obsidian present here have a very distinctive rough, bubbly cortex. Although the obsidian still fractures well, the small size and tabular shape of the pieces limit the type and size of artefacts that can be produced from them.

A second form of derived context is represented on Mount Gulu by a pyroclastic flow in which obsidian has become incorporated. These pieces range in size from tiny shards to nodules up to 20 cm diameter. The crumbly, soft white matrix would be easy to exploit. The obsidian appears to have been affected by the pyroclastic flow, since many larger pieces have an inner core surrounded by several very thin, highly fractured layers often resembling humanly-modified flakes.

The Effects of Topographic and Regional Setting

Local topographic setting probably had an important effect on the choice of sources, since it would have influenced ease of access to obsidian-bearing deposits. Four major topographic settings may be identified in which obsidian exposures are likely to have been accessible in the past: i) beds and sides of permanent and intermittent water courses, ii) cliff faces, iii) hillslopes, and iv) beaches.

Permanent water courses and gullies formed by intermittent streams are today among the best places to find large quantities of useable obsidian. Not surprisingly, such locations appear to have been those most commonly exploited in the recent past (Specht, 1981). Two factors probably motivated people to choose these locations: a) blocks of obsidian eroded from such contexts are concentrated in a relatively small area and can be obtained with little effort. Whereas surface collecting is possible in active stream beds, it might be necessary to dig down into the beds of dry gullies (as has been ethnographically documented); and b) streams erode volcanic hillslopes and thereby expose sources that might otherwise have been buried or covered with vegetation.

Lambe Gully, near Bitokara Mission, is a good example of a wide, deep intermittent watercourse with exposures of rhyolitic flows and surface scatters of large boulders (exposures 2 to 4, Table 1 [see Appendix]).

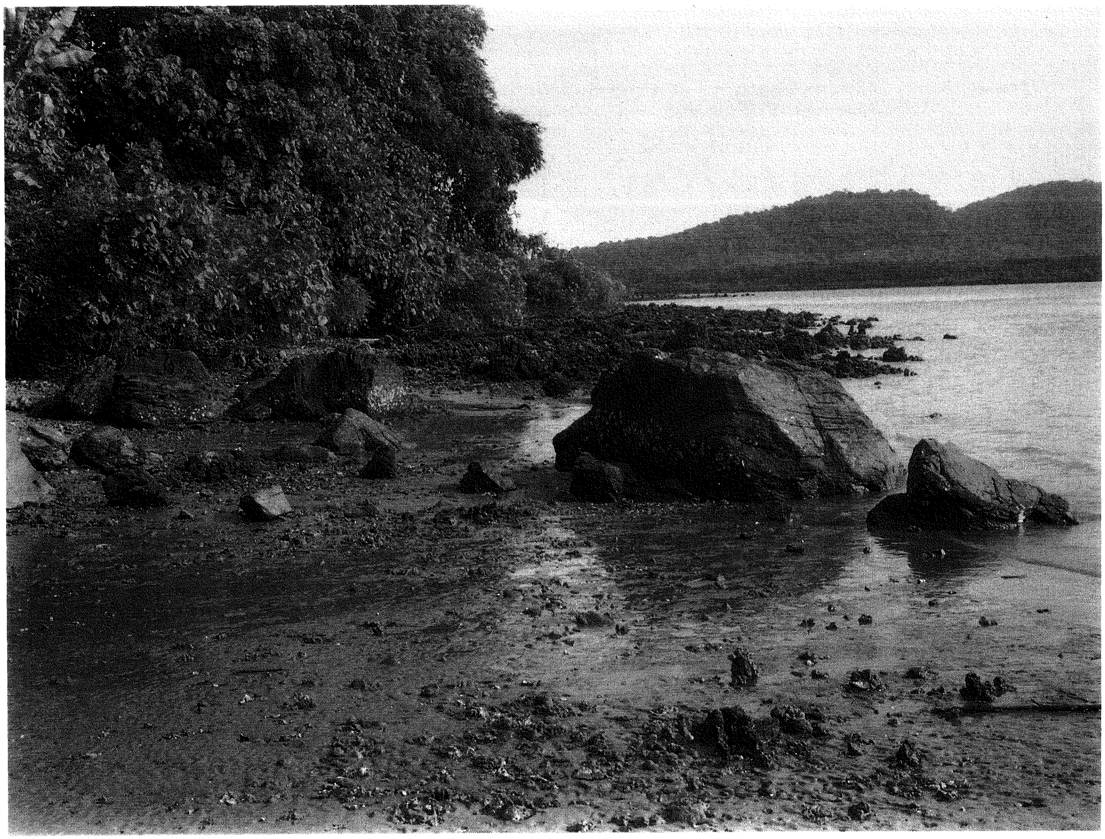

Fig.5. Flow-banded obsidian boulders and small pieces, including worked material, on mud-covered coral platform of Nariri Beach below Bitokara Mission (exposure 5 on Fig.2 and Tables 1 and 2 [see Appendix]).

The high density of artefacts found in the gully indicates that it was probably an important source in the past. In addition, in the bed of Malaiol Stream on Garua Island is a series of fluvially-exposed secondary sources which are associated with high densities of flaked debris (exposures 35, 37, 48, Table 1 [see Appendix]). In the past they probably experienced a complex history in various settings, including hillside exposures, deposits buried under waterlain volcanic ashes, and gully exposures. When fully analysed, this unusual locality will allow us to relate the nature of topographic setting to type and extent of exploitation, while holding obsidian quality and form of exposure constant.

Obsidian exposures outcropping as cliffs or on hillslopes could be difficult to find initially on account of the dense vegetation; but once located, they could have been exploited on a regular basis, even when subsequently buried by tephras. Local residents claim, for example, that in the recent past people used to dig for obsidian on the hillslopes of Mount Kutau and Mount Bao. Scree slopes formed below cliffs were also exploited. One such example was uncovered in 1988 by a new road cutting above Bitokara Mission, where the slope immediately below a small flow of obsidian yielded worked and unworked blocks (exposures 6 to 9, Table 1 [see Appendix]). This deposit is currently buried under tephra and soils, though the grey skin formed over some of the flaked surfaces suggests that at some time in the past the scree slope surface was exposed.

Obsidian exposed on beaches is easy to locate. It may occur as boulders from the edges of flows that terminate at the waterline, as parts of flows standing on the beach or the flats in front, or as scatters of boulders and smaller pieces around the mouths of gullies and streams. Although in some cases these exposures may be tidally inundated, their visibility is always high.

Moving beyond local topographic setting, ease of access to sources may also be evaluated on a broader, regional scale. We can propose that there may have been a dichotomy between sources on islands and those on the mainland, or that beach exposures in both areas would have been preferred over inland sources, due to the ease of water transport compared with walking over a ridge-and-ravine topography. Sites from the Lapita pottery period, for example, are commonly, though not exclusively, located on islands and/or in beachside positions. In contrast, at the time of European contact with the Talasea area settlements appear to have been on ridge tops, presumably for defence in warfare, and inland sources were heavily exploited (Specht, 1981).

One of the most important observations made by our fieldwork in the Talasea area is that exposures with obsidian are extremely abundant and are distributed widely around the volcanic centres (Fig.2). Consequently, no one living in the area in the past needed to travel far to reach an adequate source of raw material. Such a widespread distribution may have made it difficult, if

Fig.6. Blocks of obsidian in a landslide/hillslope deposit exposed in the bank of Malaiol stream on Garua Island (exposure 37 on Fig.2 and Tables 1 [see Appendix]).

not impossible, for any one local group to restrict access to obsidian and establish a monopoly of supply (Specht *et al.*, 1988). Beach level exposures on both the mainland and Garua and Garala Islands would have been difficult to police effectively without a great deal of effort, unless a settlement or control post of some kind were established at the exposures. Ignoring for the moment whether particular localities were monopolised, the distribution of useable obsidian in the Talasea area is such that every group living in the area would have had several alternative sources within less than an easy day's walk or short canoe trip. Even where local groups controlled access to exposures, that control may have taken the form of possessing rights of access as much as of denying access to a specific exposure, as appears to have been the case in recent times (Specht, 1981), when no one social group achieved a significant profit from exchanging obsidian to outsiders.

We do not know whether, in the past, all potential obsidian sources were regarded as equally viable and were utilised to the same extent, whether people chose to exploit exposures from a particular geological type or topographical setting, or whether proximity to their settlement or base camp was a major consideration. These are questions that may be illuminated by detailed characterisation studies of relevant assemblages. At this stage, however, it is important to stress that in whatever terms they are measured, the range of options available to past producers and consumers of obsidian in the Talasea area was extremely large.

Impact of an Active Volcanic Landscape

Volcanic activity on the Hoskins and Willaumez Peninsulas must have had a profound effect on human settlement patterns of the Talasea area (cf. the possible impact of volcanism on settlement in the Lakalai area to the south-east of Talasea: Goodenough, 1962), not to mention the choice and exploitation of obsidian sources. There is currently little evidence for much volcanic activity during the late Pleistocene, but during the Holocene the Hoskins-Willaumez region has witnessed eight or more major volcanic events. Russell Blong (Macquarie University, personal communication) has described the event at Mount Witori on the Hoskins Peninsula about 3,500 years ago as among the largest in the world during human history; its tephra blanketed much of central New Britain and would have had a cataclysmic impact on the biota and landscape. The two main airfall tephras documented in our excavation at Bitokara Mission (Specht *et al.*, 1988) have now been observed over a wide area from Garua Island to Walindi, south of Talasea (Fig.1). They probably represent the Witori event and one possibly at Dakataua, north of Talasea, dated to about 1000 to 1400 years ago.

The emplacement of the tephras in the Talasea area had an enormous impact on the landscape, and on access to obsidian exposures in particular. They would have concealed, wholly or partially, most exposures, though it is impossible at this stage to specify how extensive or prolonged this effect was. In some cases, access to the sources might have been restored almost immediately through the erosion of the tephras, but in some cases, such as on scree slopes, the erosion may not have exposed the underlying obsidian. This may have happened, for example, on the slopes of Mount Kutau above Bitokara Mission, where the presence of the scree slope was only revealed in recent times by road-cutting. Some long established and deeply incised watercourses, such as Lambe Gully, were probably altered only marginally by the deposition of tephras, but others may have become permanently silted up. Beach-side exposures on the mainland and the islands might have been modified by silting caused by increased stream loads or local tectonic uplift. The latter process continues today, with the result that the FCH site at Bamba village, where J. Kamminga identified an extensive flaking area with many stemmed tools in 1972, now stands well above the intertidal zone and is almost completely buried by recent silts. Similar factors may help explain why there are so few extensive flaking floors adjacent to high quality beach sources.

In addition to landscape reconstruction, we must also consider the effects of volcanic events on the people exploiting the obsidian. Did the local people survive such events or were they annihilated, to be replaced by people unfamiliar with the area and, hence, likely to exploit different obsidian sources? In the latter case, whereas previous residents might have been able to relocate and excavate sources buried by the tephra falls, the newcomers were probably confined to deposits visible on the surface. One approach to tackling these questions is to trace the specific source of obsidian artefacts on the basis of their chemical composition.

Characterisation of Talasea Sources

Several analytical techniques have been applied to the characterisation of Melanesian obsidians, but proton-induced x-ray emission (PIXE) spectrometry and proton-induced gamma-ray emission (PIGME) have emerged as particularly important and powerful tools (Bird *et al.*, 1981a). Catalogues of element concentrations have been presented by Bird *et al.* (1981b) and Duerden *et al.* (1987) using 13 elements, and by Bird *et al.* (1988) using 14 elements (cf. Fullagar *et al.*, 1989). While all of the major Melanesian sources and some subsources have been distinguished through these techniques, the range of variability at any source or subsource remains to be thoroughly explored. For West New Britain, results to date have suggested four source/subsource groupings: Pilu-Voganakai, Kutau-Bao, Garala, and Mopir (on Hoskins Peninsula). Here we present the results of further analyses of 53 samples from 26 exposures within the Talasea area, together with one sample from the Waisisi site and 18 from one Mopir exposure (Table 2 [see Appendix]). This represents a total of 72 samples from 28 localities, using 11 elements to produce nine ratios:

Al/Na, F/Na, Mn/Fe, Zr/Fe, Y/Zr, K/Fe, Ca/Fe, Rb/Fe, and Sr/Fe.

The use of ratios of element concentrations for statistical cluster analysis of obsidian samples is a common procedure provided that they are independent variables. Two detectors were used in the present

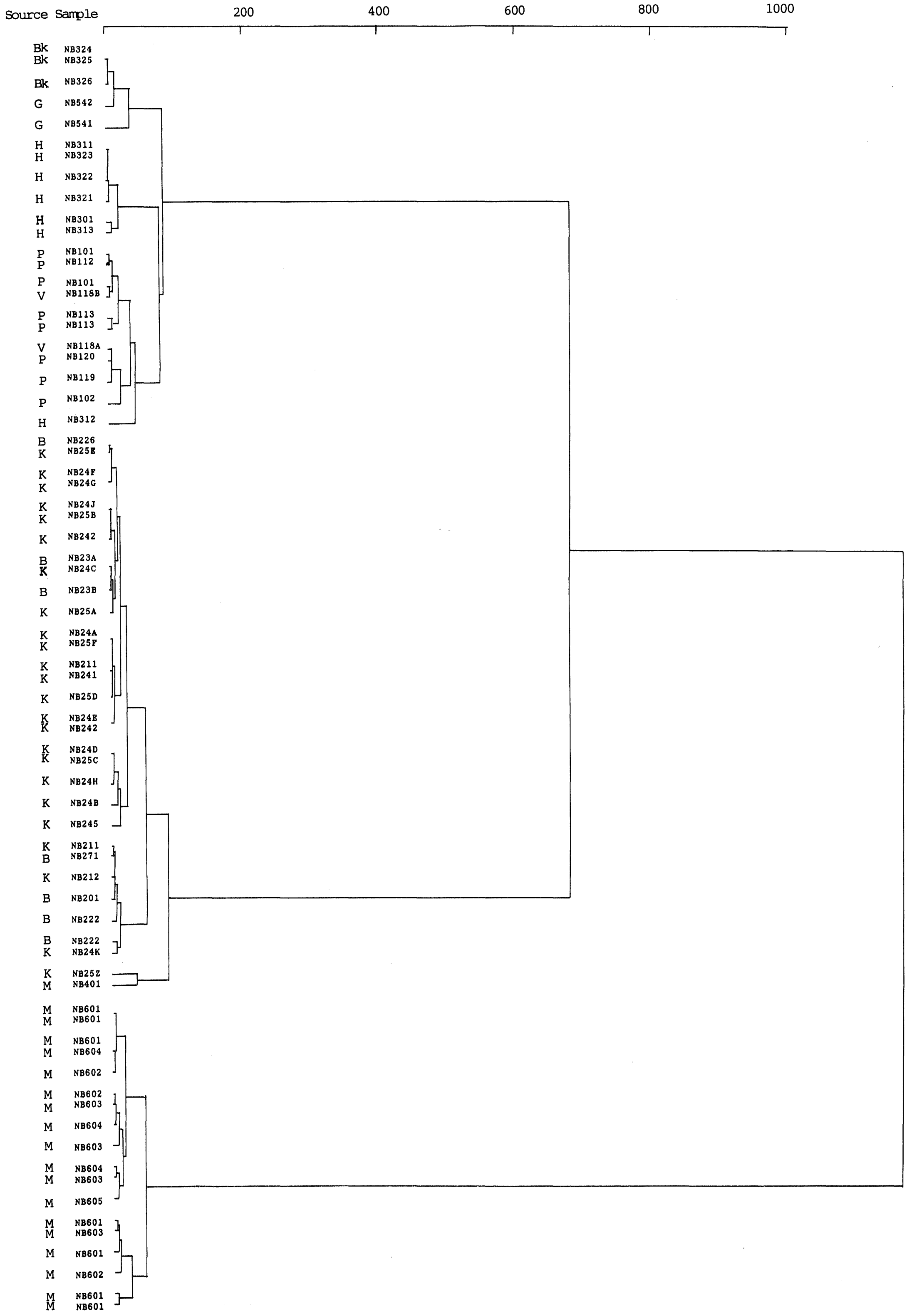

Fig.7. Dendrogram of results of PIGME-PIXE analyses of obsidian source exposures around Talasea and Mopir, and of artefacts from Waisisi. The dendrogram shows the sequence of nearest-neighbours in nine parameter space for the 72 samples listed on Table 2 (see Appendix).

measurements, and the calculation of ratios is equivalent to the use of Na and Fe measurements to normalise the efficiency of each detector in each run. This removes small correlated instrumental variations in the measured parameters, and provides an improved data set for use in the investigation of compositional clustering. This is confirmed when a correspondence analysis carried out with 11 element concentrations is compared with the one using nine ratios presented here. It would be unsatisfactory to calculate a larger number of ratios which would then no longer be independent parameters.

Several statistical techniques have been applied to these data to test for discrimination between sub-sources within the Talasea area. A dendrogram that displays the sequence of nearest neighbours in nine-parameter space is shown in Figure 7 for the 72 samples described above. Three well-separated clusters are labelled with the names of the source locations which each contains. The distance between clusters is indicated by the length of the linking horizontal lines. Some minor clustering is observed within the three main groups, but these remain to be further substantiated.

A second illustration of the clustering is shown in Figure 8 which is produced by a correspondence analysis of the same 72 sample data set. This is a procedure that plots samples which are most distinct as well as the parameters responsible for the distinctions along the horizontal axis and less significant distinctions along the vertical axis. This is done in such a way that more than 80 to 90% of the variance of the data set is accounted for. The same three major clusters are observed again with some minor grouping within them. The work is still in progress and results must be treated as preliminary, but several important points have already emerged.

1. On the basis of the nine element ratios, it does not seem possible to distinguish between obsidian exposures from the Kutau and Bao subsources. Some individual exposures have a high degree of variability. For example, samples from different heights in the same flow exposure in Lambe Gully (a Kutau sub-source) are less like each other than they are like samples from the Bao source. This needs more detailed examination, perhaps using more elements.

2. The exposures on Garua Island separate into two distinct subsources that can be equated with the Mount Baki and Mount Hamilton source volcanoes.

3. The two exposures on Garala Island, represented by only one sample each, are widely separated. Since the nearest subsource is Baki on Garua Island, it is possible that Garala and Baki overlap in composition.

4. Sample no. 14 on Table 2 (see Appendix) is thought to be associated with a Kutau flow because of its spatial proximity to this volcano. Its composition, however, seems to be distinct from other Kutau samples and is closer to those from Mopir. There is thus a hint that there may be some overlap between Mopir and some Talasea subsources.

5. It seems unlikely that the various exposures at Voganakai will be distinguishable from each other. They seem to form a distinct subsource separate from

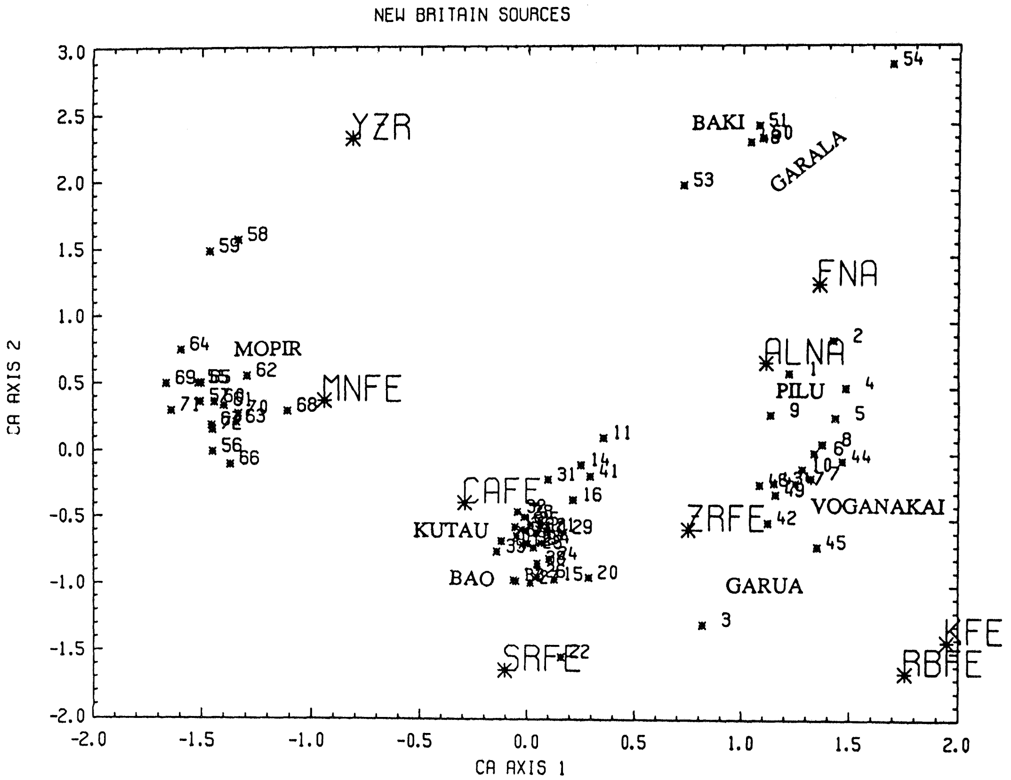

Fig.8. Correspondence analysis plot of the 72 samples on Table 2 (see Appendix).

others in the Talasea area.

In summary, these results generally support those of earlier studies that suggest at least three source groups can be distinguished for the Talasea area (e.g., Bird *et al.*, 1981; Fullagar *et al.*, 1989). The preliminary results further suggest that with more source sampling we may be able to distinguish between Baki and Hamilton on Garua Island, and possibly between Baki and Garala. This would yield a total of five distinct subsources in the Talasea area.

Prospects

An evaluation of Green's (1987) proposal for variations through time in the use of Talasea subsources, and an analysis of the causes underlying these variations, remains a long way down the line. The three avenues of investigation described above - source descriptions, landscape reconstructions, and chemical characterisation of source compositions - offer some hope of success. Systematic examination of Mount Humugari and Mount Gulu areas and the southern slopes of Mount Bao may reveal additional exposures. With these exceptions, the description of obsidian exposures extant in the Talasea area is now reasonably comprehensive. Some of the relevant variables have been identified for evaluating whether energy minimisation played a role in source selection. Once patterns of past source selection have been identified and we have adequate data on the geological and geomorphological characteristics of the obsidian sources, we should be able to evaluate whether source selection was based on a desire to minimise energy expenditure. The detailed chemical characterisation of Talasea obsidians will be extended with additional samples from Talasea and Mopir. This expanded database, hopefully, will aid the identification of source-specific characteristics that will in turn permit the matching of archaeological items to specific subsources.

We have also identified past landscapes at three different periods. They are represented by soil horizons below and interbedded between two distinctive tephras described as layers 5 and 8/9 in Specht *et al.* (1988). These are found over a large portion of the Talasea area, and as far south as Walindi Plantation (Fig.1). At this stage we are only just beginning to establish the ages of these horizons and to reconstruct the human and physical environment of each period. It is already evident that Holocene volcanic activity has played a major role in shaping the availability of obsidian exposures, and the effects of this activity on other aspects of human existence are likely to have been profound.

The results of this research will form the basis for a better understanding of the complex relationships between human social behaviours and physical environment on the north coast of New Britain, and will also contribute to the study of the interplay between local adaptation and regional interaction within the island world of Near Oceania.

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APPENDIX

Table 1. Assessment of all Talasea area obsidian exposures recorded between 1973 and 1988.

FIG.2	EXPOSURE NAME	DEPOSITIONAL CONTEXT	TOPOGRAPHY	EXTRACTION	QUALITY	EXPLOITATION
	KUTAU					
1	Babenavuavua	banded rhyolite	cliff, stream	moderate	good	present
2	Lambe gully, 4	banded rhyolite	stream, gully	moderate	good	present
3	Lambe gully, 5	banded rhyolite	stream, gully	moderate	good	present
4	Lambe gully, 6	banded rhyolite	stream, gully	moderate	medium	present
5	Nariri beach	cobbles and boulders	beach	easy	low-good	present
6	T1/H/II	cobbles	hillslope road cutting	moderate	good	present
7	T1/H/III	banded rhyolite	hillslope road cutting	moderate	low-medium	present
8	T5	cobbles and boulders	hillslope road cutting	moderate	medium	present nearby
9	T1/H/1a,b (Whudi)	cobbles	hillslope road cutting	easy	good	present
10	Talasea-Bamba road	altered rhyolite	hillslope road cutting	moderate	medium	present nearby
11	Talasea Admin.	tephra matrix	hillslope	moderate	medium	present nearby
12	Talasea Hospital	banded rhyolite	hillslope road cutting	moderate-hard	medium	present nearby
13	Talasea	banded rhyolite	hillslope	no data	no data	present nearby
14	Murukina	cobbles	hillslope road cutting	moderate	good	present
15	Kao	cobbles and boulders	hillslope road cutting	moderate	good	present
	BAO					
16	Kelepu	tephra matrix	stream, gully	moderate	good	present, pit
17	Mount Bao	tephra matrix	hillslope road cutting	moderate	good	present nearby
18	Gulemono	cobbles	stream, gully	moderate	good	present
19	Vakava	banded rhyolite, boulders	cliff	moderate-hard	low	present
20	Matanavoko	cobbles	stream, gully	moderate	good	present
21	Talasea airstrip	cobbles	buried stream bed, gravel pit	easy	good	possible flakes
	GULU					
22	V001 (Pilu beach)	banded rhyolite and boulders	beach	hard	medium	present
23	V002 (Pilu boulder)	banded rhyolite and boulders	beach	moderate	low	present nearby
24	V003	banded rhyolite	beach	moderate	medium	present nearby
25	V004	cobbles	beach	easy	low	present
26	V005 (Voko e Balive)	banded rhyolite and boulders	beach	hard	good	present
27	V006 (Gulu ne Doli)	tephra matrix	stream, gully	moderate	medium	present nearby
28	V007 (Ketouma)	altered rhyolite,tephra matrix	cliff	moderate	not viable	absent
29	V008	pyroclastic flow	hillslope (scoria pit)	easy	good	present nearby
30	V009	tephra matrix ?pyroclastic flow	hillslope road cutting	easy	low	present nearby

Table 1 (cont'd).

	GARALA					
31	Garala, Area A	banded rhyolite, boulders + cobbles	beach	moderate	medium-good	present
32	Garala, Area B	banded rhyolite, boulders + cobbles	beach	moderate	medium-good	present
33	Garala, Area D	cobbles and boulders	beach	moderate	low	present
	BAKI					
34	G001 (Garua 6)	landslide/hillslope (thermal alteration?)	stream, gully road cutting	moderate	low-medium	present
35	G002 A	banded rhyolite	stream, gully	moderate	not viable	absent
36	G002 B	landslide/hillslope	stream, hillslope	easy	medium	present
37	G002 C	landslide/hillslope	stream, hillslope	easy	low-medium	present
38	G003 A	banded rhyolite	beach, cliff	hard	low-medium	present nearby
39	G003 B	blocky rhyolitic flow	cliff	moderate	medium	present nearby
40	G004	blocky rhyolitic flow, banded rhyolite	cliff, hillslope	hard	low	absent
41	G005	boulders, blocky rhyolitic flow	beach	hard	medium	present
42	G006	cobbles	hillslope road cutting	easy	medium-good	present nearby
43	G007	blocky rhyolitic flow	hillslope road cutting	hard	medium	absent
44	G008 A	blocky rhyolitic flow	cliff, hillslope	hard	medium	absent
45	G008 B	blocky rhyolitic flow	cliff	easy	high	present
46	G016 A	banded rhyolite, blocky rhyolitic flow	cliff, hillslope	moderate	good	present nearby
47	G016 B	probably banded rhyolite	hillslope	hard	not viable	absent
48	G017	blocky rhyolitic flow	stream, gully	easy	medium-good	present, pit
	HAMILTON					
49	G009	banded rhyolite	hillslope	moderate	low	absent
50	G010	banded rhyolite	stream, gully	easy	low	absent
51	G011	altered banded rhyolite	beach	hard	low	possible flakes
52	G012	altered banded rhyolite	cliff, hillslope	hard	not viable	absent
53	G013	altered banded rhyolite	stream, gully, cliff	easy-moderate	not viable	absent
54	G014	altered banded rhyolite	stream, gully, cliff	moderate	low	absent
55	G015	altered banded rhyolite	stream, gully, hillslope	easy-moderate	not viable	absent
56	G018	banded rhyolite	beach	easy-moderate	low	absent
57	G019	altered banded rhyolite	cliff, hillslope	easy	not viable	absent
58	Garua 4	banded rhyolite	stream, gully	hard	low	possible flakes
59	Garua 5	boulders	beach	hard	low	possible flakes
60	Garua, west beach	banded rhyolite	beach	hard	not viable	absent

Table 2. Catalogue of PIGME-PIXE analyses of selected obsidian source exposures around Talasea and at Mopir, together with archaeological artefacts from the Waisisi site (no. 52 on Fig.4).

FIG.2	EXPOSURE NAME	PRESENT EXPOSURE TYPE	FLAKING EVIDENCE	PIGME PIXE No.	FIG.4
	KUTAU				
1	Babenavuavua	overlooking gully	present	NB24A, NB24B	21,22
2	Lambe gully, 4	gully wall	present	NB24C, NB24D	23,24
3	Lambe gully, 5	gully wall	present	NB24E, NB24F, NB24G	26,27,25
4	Lambe gully, 6	gully wall	present	NB24H, NB24I	28,29
5	Nariri beach	coast	present	NB24J, NB24K	20,30,31
6	T1/H/II	road outcrop, gutter	present	NB25E	33
7	T1/H/III	road outcrop, gutter	present	NB25F	34
8	T5	road outcrop	present nearby	NB25A	36
9	T1/H/1a,b (Whudi)	road outcrop, eroded gutter	present	NB25C, NB25D	32,38
10	Talasea-Bamba	road road cutting, coast	present nearby	NB212, NB242	14,39,40
13	Talasea	hillslope	present nearby	NB211	12,13
14	Murukina	road outcrop	present	NB25Z	35
15	Kao	road outcrop	present	NB25B	37
	BAO				
16	Kelepu	gully	present	NB222, NB226	15,16,17
18	Gulemono	gully side and base	present	NB271	41
19	Vakava	cliff	present	NB23A, NB23B	18,19
20	Matanavoko	above and below ground surface	present	NB201	11
	GULU				
22	Pilu beach	coast	present	NB101, NB102, NB119, NB120	1,2,3,9,10
23	Pilu boulder	coast	present nearby	NB112, NB113	4,5,6
26	Voko e Balive	coast	present	NB118A, NB118B	7,8
	GARALA				
31	Garala	coast	present	NB542	53
33	Garala, Area D	coast	present	NB541	54
	BAKI				
34	Garua 6	road outcrop, cutting, stream bed	present	NB323-NB326 inclusive	48,49,50,51
	HAMILTON				
58	Garua 4	gully	possible flakes	NB311-NB313 inclusive	43,44,45
59	Garua 5	coast	possible flakes	NB321, NB322	46,47
60	Garua, west beach	coast	absent	NB301	41
	MOPIR				
	Waisisi	buried archaeological soil	present	NB401	52
	Mopir	gully side and base	present	NB601-NB604 inclusive	55-72 incl.

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