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Publication details
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Pleistocene colonisation of the Bismarck Archipelago: new evidence from West New Britain

ROBIN TORRENCE, VINCE NEALL, TRUDY DOELMAN, ED RHODES, CHRIS McKEE, HUGH DAVIES, ROBERTO BONETTI, ALESSANDRA GUGLIELMETTI, ALBERTO MANZONI, MASSIMO ODDONE, JEFF PARR, CLELAND WALLACE

Abstract

The geological and archaeological signatures at the site of Kupona na Dari on the Willaumez Peninsula, West New Britain provide important new data about human colonisation of the Bismarck Archipelago. Analyses of the stratigraphy and weathering of paleosols and manuporls, when combined with fission track, radiocarbon, and luminescence dating, indicate that the site was first occupied at about 35-45,000 years ago. During the whole period of occupation, people were exposed to a series of volcanic events which varied in terms of their potential impacts on the local environment. A PIXE-PIGME characterisation study of the obsidian artefacts at the site demonstrates that from the earliest period stone resources were acquired from outcrops located across a relatively large region. When compared with Early-Middle Holocene assemblages from nearby localities, the Pleistocene stone tool technology differs in only a few minor respects. From this analysis we infer that groups were mobile in both periods, but slightly different strategies for the procurement and maintenance of the stone tools were required for the more extensive ranges exploited during the Pleistocene. The inter-disciplinary study of Kupona na Dari concludes that colonisation comprised a long term process of settling into this volcanically active environment. Due to variability in the environments that people encountered, the pattern of colonisation may not have been similar across the entire Bismarck Archipelago.

Background

The Kupona na Dari site, located on the coastal plain about 600 metres from the current shoreline, was identified during an extensive survey of Numundo Plantation (Torrence et al. 1999) (Figures 1, 2). The site consists of a series of interbedded paleosols and tephras preserved as a small, roughly oval, hill (c. 32 x 34 metres) whose top stands about 10 metres above the current high water mark. Many of the
same tephra layers that make up Kupona na Dari are also present in road cuttings in the nearby foothills of the Numundo ridge (Torrence et al. 1999: 44). The consistent mantle bedding of the heavily weathered Pleistocene tephras and the conformable nature of the sequence suggest that this hill may have been a persistent feature at this location—since at least the time represented by the lowest tephras we observed, some 5 metres below the top of the hill (Figure 3). What appears at present to be a rather isolated hill was probably connected to the higher ridges to the west which we suspect are old flows emanating from the remnant caldera preserved as the current Numundo ridge (Figure 2). Since it was located on the farthest promontory or peninsula protruding from the ridge, the hill would have been a relatively prominent place before the emplacement of the Holocene tephras and associated alluviation created the current coastal plain. The site has always been relatively close to the sea. Although the shoreline might have been closer before recent infilling, during the Last Glacial Maximum it was only c. 8 kilometres further away.

At some point during the Late Pleistocene, the hill was eroded to form steeper sides as shown in Figure 3. Some of the erosion probably took place in the relatively long gap in volcanic activity represented by the unconformity between the top of the Pleistocene tephras and the base of the Holocene tephras. This clear break is exhibited by the very large differences in weathering of the stratigraphic layers in these two periods (see below). The early Witori tephras W-K1 and W-K2, which date to c. 5900 and 3600 cal. BP respectively (Torrence et al. 2000; Machida et al. 1996), were eroded off the top of the hill soon after they fell and then piled up around its base, thereby reducing the hillside’s slope angle and buttressing the base with volcanic colluvium. Subsequent tephras W-K3, W-K4, and the W-H series (c. 1800-500 cal. BP) were draped over the hill. There may have been additional periods of erosion during the Pleistocene because our excavations revealed another marked unconformity on the north side (see discussion below). Just over half of the western portion has been removed by modern quarrying, but this ceased in 1999 after artifacts were discovered within the Pleistocene layers (Torrence et al. 1999).
Figure 2: Local setting for Kupona Na Dari showing the location of Early-Middle Holocene assemblages used for comparison. Radius of circle is 2km.

Figure 3: Cross section of the Kupona na Dari hill with stratigraphic units identified by McKee.
The site was first visited in 1998 when the quarrying had just begun, but no artifacts were observed until 1999. As reported in Torrence et al. (1999), obsidian flakes were found stratified under and above a distinctive tephra (Unit C), which is located between 2 and 3 metres below the current ground surface (Figure 3). At the southern end of the section in the soil above this tephra, artifacts were found directly associated with a tight cluster of fire-cracked stones (Figure 4). In 2001 New Britain Palm Oil Ltd. pushed a pile of coconut logs off the top of the hill and onto the sides. They then lent us an excavator and operator who cleared away talus created by the collapse of the original quarry face and carved out four new vertical sections ranging in height from 2-6 metres (Figure 5). Excavation proceeded beneath the level of the current ground surface for about 1.5 metres until it reached a very hard layer of volcanic tuff (Unit A). Running from north to south, the cuttings were labelled II-V, and the sections within them were assigned the same roman numeral. Section IV, located in the tallest, central part of the remnant hill, provides the best preserved sequence. Another area labelled cutting I was excavated into the northern side of the hill at right angles to the quarry face and intersecting with the top of section III. Later, cutting VI was dug out by hand. The steps created by cuttings I and VI provided safe access to the entire profile of the hill. Following basic surveying and a preliminary stratigraphic study of the cleared sections (cf. Figure 3), excavation took place within Squares A, B, and C, as described below.

We begin by describing the site stratigraphy in order to reconstruct the geological history of the site during the time of human occupation. Following this, we apply a range of techniques to provide a chronological framework for these environmental changes and associated human activities. Finally, the results of stone tool analyses are used to reconstruct patterns of human mobility and resource use. A comparison of human behaviour during the Late Pleistocene and Early-Middle Holocene periods within the immediate region helps place the site within the long term context of human colonisation.

Site Stratigraphy

Following initial work in 1999 by Davies (Torrence et al. 1999), McKee and Neall studied the stratigraphy and collected samples of pumice and sediments for further geochemical and pedological analyses. McKee, who visited the site in 2000 and again shortly after the sections had been cleared in 2001, concentrated on the tephras. Following Davies’ original terminology, his basic stratigraphic units (A-H) are demarcated by the flags and drawn lines as shown in Figure 6 (cf. Figure 3). These were used as the strata for luminescence dating. Neall, who arrived at the close of the excavations in 2001, sampled all the units in Section IV and recorded a range of pedogenic variables and anthropogenic features. He made a few new subdivisions within McKee’s stratigraphy, but there were no major differences between the two interpretations. Neall’s interpretation of sections in the archaeological excavations, along with observations made by the archaeologists during excavation, enabled excavated spits to be grouped into stratigraphic units. Artifacts found while studying sections or during soil sampling, both in previous years and during the 2001 field season, were assigned to a stratigraphic unit by the geologist on site at the time. Since the high degree of weathering makes recognition of the units quite difficult, a pedological description is presented in Appendix 1 to aid future researchers in re-locating them at this location.

Geological history

A stratigraphic analysis of the units preserved at this location provides the basis for a reconstruction of the geological history of the coverbeds and, by implication, the history of environmental change in the region during the time that humans occupied Kupona na Dari. Before presenting our results, we define key terms and briefly describe our methodology.

A coverbed is an unconsolidated or weakly consolidated surficial deposit forming a unit that mantles the landscape and rests directly on underlying rock or on other coverbeds. They are usually of Quaternary age and include tephras, loess, alluvium or aeolian sand. Stratigraphic studies at the site have focused on Section IV with additional study of Section VI (using sections from Squares A-C) (Figures 5-8). The history and formation of the layers in each section have been heavily influenced by their particular location within the hill, as for example if one compares Section IV, which was placed in the middle of the hill, with Section VI, which is on the northern flank.

Figure 4: Cluster of fire-cracked stones observed within the quarry face in 1999.
Conclusions about how the coverbeds were formed are based on a visual assessment of the textural changes within the units, the presence of the progressive accumulation of fine-grained materials, whether soil formation was continuous or absent, and the provenance for the sand and silt mineralogy. An important distinction is made between units produced by large plinian and sub-plinian volcanic events and the process known as tephra accretion (Neall 1977). At distal localities during large magnitude eruptions and at proximal localities in small eruptions, dustings of volcanic ash are added to the surface of the soil without wide scale destruction of the vegetative cover. The ash does not fall directly onto the soil surface but is washed off leaves and branches onto the forest floor by the next rains. Over time, these many small additions of tephra build a soil formed from the fine-grained parent materials. Many metres can be accumulated through tephra accretion. It is important to recognize units built up in this way because, compared with the deposits created over a short period in a single eruption, units formed by tephra accretion can represent considerable periods of time and may not necessarily disturb human activities.

Figure 6: Looking east toward quarry face at FABM. Section IV is in the centre. Flags and lines mark units identified by McKee. Luminescence samples were removed from the holes. Section III which has been cut by Squares A and B is at the far left. Square C is in the far distance and slightly to the right of A and B. It cuts through the upper half of the layers represented in the hill. Scale is 1 metre.
Manuports are rounded stones that could not have formed naturally within the airfall tephras and paleosols that make up the stratigraphic sequence at this location. They must therefore have been transported to this hilltop and as such are an important indicator of human activity. They are also useful in interpreting the stratigraphy. Where scattered or isolated stones are found within a coverbed, it is impossible to determine if they are in situ or have fallen into a subsurface pit or tree root hole. The situation is entirely different when they form a horizon at the junction of two units derived from independent processes (e.g. two tephras with different provenances). Firstly, all the stones would be unlikely to travel down the profile at the same rate (i.e. large and small stones would have moved at different speeds, thereby leading to a random spread) and secondly, it would be extremely fortuitous for the stones to become aligned on the same stratigraphic boundary. The presence of lines of manuports at this site, therefore, indicates human activity on a relatively stable landscape.

The coverbeds studied in Sections IV and VI are described below in order from the base up to the top. The descriptions focus on the nature of volcanic activity that formed them and the length of time over which they were formed. Details about the mineralogy and additional information about the type of eruption they represent are presented in Table 1. A summary diagram of the units based on the geological subdivisions identified by McKee and pedological horizons¹ defined by Neall (shown in parentheses below) is presented in Figure 9.

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1. Pedological horizons have been designated according to the soil nomenclature of FAO/UNESCO 1974. The first number refers to each identified parent material. Each capital letter refers to a soil master horizon; in this case all A’s refer to major paleosols (buried soils) and all B’s refer to former subsoils or low organic matter rapidly accumulating soils. The one or two lower case letters refer to the main pedological features of each horizon: p = human presence and influence; b = buried; t = horizon with clay accumulation; w = weathered parent material in situ.
Table 1: Mineralogy, provenance and deposition of the coverbeds at Kupona na Dari
Section IV (stratigraphic thickness = 3.6+ m)

Unit A (14Bw) is a lapilli tuff that shows shower bedding indicative of an airfall origin. Due to its vesicular nature, it may be phreatomagmatic. It was probably deposited over a relatively short time period because it has a very coarse texture and there are no paleosols between the beds. This unit is hard and forms an indurated base to the whole section. The observed lapilli textures suggest Unit A is the result of a plinian eruption. During a hiatus in volcanic activity, represented by the break between this unit and the one above it, people brought stones to this locality (manuports) and deposited them on the relatively stable landscape.

Unit B1 (13Bw) represents a moderately weathered tephra which contains distinctive orange lapilli and may be phreatomagmatic. This unit was formed by tephra accretion over a relatively long time period. Phytoliths are common in the <32 μm fraction. A prominent stone line at the top of the unit indicates another hiatus in volcanic activity.

Unit Lower B (12Bw) lacks orange lapilli in Section IV, although they were seen within this unit in Sections III and VI. The unit seems to represent another period of tephra accretion with a similar provenance to Unit B1.

Unit Upper B (12Apb) represents a long period of relative volcanic quiescence when a soil was able to be formed.

Unit C (11Bw) is one of the key tephra marker beds in the section. It has a loamy sand texture, which contrasts with the high amount of clay in the encompassing units. It would have been deposited as a coarse ash in a single volcanic episode lasting over a relatively short time period. The unit has the potential to be a valuable chronological marker at other Pleistocene sites in the region.

Middle C (10Bw) has a much finer texture than 11Bw. It represents another long period of tephra accretion.

Soil on C (10Apb) again represents a long period of volcanic quiescence during which soil formation extended down into the parent material of Unit C. Between 5 and 15% of the soil is comprised of strongly weathered stone manuports, one of which measured 60 mm across. Many phytoliths occur in the <32 μm fraction.

D1 (9Bw) is clearly a short term airfall eruptive with a few lapilli. Like Unit C, it has potential value as a regional chronostratigraphic marker at late Pleistocene sites in the region.

D2 (8Bw) is another tephra of coarser ash texture which forms discontinuous lithified lumps in the soil (known as 'creamcakes'). It may be phreatomagmatic. It would have been deposited over a relatively short period of time.

D3 (7Apb) is a paleosol formed within the tephra. Its presence indicates a significantly long period of time. One tabular stone manuport 50 mm long was found in this paleosol.

Unit Lower E (6Bw) is of primary volcanic origin comprising 15-35% orange lapilli, and is likely to have been deposited over a short period of time.

Unit Upper E (5Apb) is a paleosol developed within a bed that accumulated by tephra accretion. A horizon containing scattered stone manuports up to 40 mm in size occurs on the upper surface of the unit. Like the other paleosols, this unit represents a considerable period of time in the succession.

Unit F (4Bw) represents a long period of fine tephra accretion. Rare stone manuports up to 70 mm long occur on top of the unit. They reflect a hiatus in soil formation before the next unit was emplaced.

Unit G (3Bt) on first glance appears similar to Unit F but is subtly differentiated by the presence of waxy coatings on the soil aggregates (argillans) and the visual appearance of mafic and creamy weathered coarse ash grains. The whole bed contains <5% of stone manuports between 20 and 50 mm diameter throughout. Our interpretation is that this unit represents a long period of tephra accretion during which there was considerable anthropogenic mixing. There may be a small phreatomagmatic event preserved within it.

Unit H (2Bt) differs from Unit G in colour and structure, but also displays a number of similarities. It also has waxy, chocolate-coloured coatings on the soil aggregates (argillans) and contains rare stone manuports throughout, suggestive of human presence during its formation. Like unit G, it probably also represents a long period of tephra accretion contemporary with human occupation.

Soil on H (2Apb) is a thin (now exhumed) paleosol which developed within the uppermost part of unit H. When the site was visited in 1999 and 2000, it was overlain by the W-K 3 pumice lapilli, but this has since been removed by recent human activities. The paleosol on H at this site therefore represents a longer time interval than the paleosol found beneath W-K 1 elsewhere in the region. The absence of W-K 1 and W-K 2 prior to the deposition of W-K 3 implies removal in the time interval 1700 to 5600 yr BP (Machida et al. 1996). Although erosion by heavy rainfall cannot be discounted, the unusual removal of the Holocene tephras at this location may imply human interference.

Section VI (stratigraphic thickness = 4.1+ m)

As in Section IV, the absence of the W-K 1 and W-K 2 tephras forms an obvious unconformity between the W-K 3 tephra and the Soil on H (2Apb) (Figure 7). The underlying units, H, G, and F, show markedly different properties to
Section IV. In Section VI there are strong suggestions of resorting and human interference. At the top of Squares A and B, Unit H appears to be overthickened and possibly resorted. It may also contain some remobilised material from Unit G. Unit G as it is described in Section IV cannot be positively identified in Section VI. This implies an unconformity under Unit H. Stone manuports are present throughout Unit H. In Square C, Unit F has distinctive black manganese coatings on the soil aggregates (mangans). These do not occur in Section IV and their presence is puzzling. Manganese is mobilized and precipitated by redox reactions suggesting these beds have experienced alternate wetting and drying cycles. This may indicate a change in the climatic regime in terms of moisture since they accumulated.

Moving to the sections for Squares A and B (Figure 8), an unconformity at the top of Unit Upper E is marked by the presence of stone manuports and the absence of most of Units G and F. The nature of this unconformity is of interest. It could represent a storm event, although this seems unlikely for such a low hill on the coastal plain. Human activity at the site is much more likely to have been responsible for the loss of these units from the side of the hill.

Tephra D2 is well preserved and is separated from the Soil on C (10Apb) by a line of fire-cracked stones that must have been sitting on the surface of Soil on C when the tephra fell. The absence of Unit D1 represents an unconformity indicative of an erosion break and a small time interval. It could be related to the fall of the D1 tephra and subsequent erosion, with or without human assistance.

Pedologically the stratigraphic sequence on the side of the hill is unusual in the way the lithologies vary from those in Section IV. There is a strong possibility this may be due to anthropogenic mixing and accompanying downslope processes of thinning at the top combined with accumulation in the colluvial footslope. This implies that one cannot assume an exact correlation in time between the uppermost units, F, G and H, in Sections IV and VI.

Environmental implications for human occupation

It is important to understand the geological history of Kupona Na Dari because the timing and nature of the volcanic activity would have had serious implications for human occupation within this region. Since these units are only exposed by quarrying and excavation at this location and are deeply buried in the surrounding region, we are unable to trace their spatial extent and thereby identify their source volcano. This limits the extent to which one can assess how serious their effects on humans might have been. Despite these difficulties, it is still worthwhile considering the likely effects of the geological events recorded within the stratigraphy at this site.

To begin with, only Units A and C were formed as a consequence of relatively large explosive (plinian) eruptions that might have necessitated abandonment of this location and the wider region, at least on a temporary basis. This is primarily because the tephra would have destroyed the vegetation and possibly fouled the water supply. Unit A is suggestive of a particularly active volcanic period and a nearby source. In contrast, Units D1, D2, and Lower E are comprised of small grained material that represents much smaller volcanic events: D1 was possibly sub-plinian, whereas Lower D2 and Lower E were either local sub-plinian events or these tephras represent materials from a quite distant plinian event. Although these three were not large events, they could still have caused significant damage to the fauna and flora and therefore created serious problems for human occupation. We do not have enough information to predict whether these might have necessitated abandonment of the region. The remaining volcanic units, B1, Middle C, F, G, and H, represent long periods of tephra accretion. These are times when small amounts of fine ash were deposited at frequent intervals. During these periods, life would have been uncomfortable, difficult, and perhaps impossible at times, but human settlement could probably have been possible, at least on an intermittent basis.

Four stone lines were recognized within Section IV at Kupona na Dari. The upper two occur on the surface of two paleosols (5Apb and 10Apb). Their presence indicates the existence of major intervals when tephra accretion was minimal or absent. We interpret these stone lines to be in situ and not derived by downward movement from above. The lower two stone lines, above 13Bw and 14Bw, while not located on obvious paleosols, occur at the boundaries between units which have a different provenance. In these cases insufficient time was available for major soil formation; the presence of the stone manuports may indicate a hiatus in volcanic activity during which people visited the site and deposited the stones. The longest time intervals without volcanic activity in the Kupona na Dari sequence are represented by the paleosol A horizons: Soil on H (2Apb), Upper E (5Apb), D3 (7Apb), Soil on C (10Apb) and Upper B (12Apb). These periods of stability represent the most favourable conditions for human settlement.

The intense anthropogenic activity in Units G and to a lesser extent Unit H, combined with the presence of manuports and artifacts demonstrate that these periods of tephra accretion did not have serious deleterious effects on human activity. Stratigraphic Unit G (3Ap) is exceptional because it has probably been anthropogenically mixed. This horizon is unusual because it is comprised of two strongly contrasting materials: hard brown aggregates surrounded by a friable yellow-brown matrix. It appears that older ashes had been remobilised by gravitational downslope processes. Although many of the other buried soils contained artifacts, these were present only in the upper portions and had become incorporated with little disturbance. In contrast, Unit G seems to have been thoroughly mixed, especially on the side of the hill in Square C. The character of this unit suggests that there may have been some sort of systematic and labour intensive clearance of the top of the hill, perhaps due to gardening or maintenance of the site.

Units G and H show the most intense colours, and the
heaviest textures (clay) in the stratigraphic column, indicating the strongest weathering of all the units. Furthermore, in the subsoil horizons 2Bt (H) and 3Bt (G) there is evidence for downward movement and accumulation of clay in the form of clay skins (argillans) on aggregate surfaces, which was not encountered elsewhere in the stratigraphic section. The intense weathering regime of 2Bt (H) and 3Bt (G) might be a result of a very long period of weathering or it could be related to a shift in climate from a drier and cooler period in the Late Pleistocene to a warmer, wetter period in the early Holocene, as has been suggested by Flenley (1998) for other tropical lowland rain forest regions.

Archaeological excavations

An archaeological sounding of the hill was made using a combination of three 1 x 1 metre squares (labelled A-C). These were placed just above section III within the steps of cuttings I and VI (Figures 5, 6). Contiguous squares A and B were arranged in a roughly east-west direction using section III as their western end. Square C was placed about 20 centimetres further to the east of square B within cutting VI. Square C was excavated to a depth of 2 metres below present ground surface. It preserved the Holocene tephras and the upper units F and H, but Unit G was very poorly represented or missing on this side of the hill (Figure 7). The lower layers of the site were sampled in Squares A and B, although in these squares there was an unconformity between Units H and Upper E and so Units F and G were missing. Square A (excavated to a depth of 1.9 metres below the base of cutting I) began with Unit H, was taken well down into Unit B, and reached patches of Unit A at the base. Unit H comprised the top of Square B (excavated to a depth of 1.4 metres below the base of cutting I), which was terminated about 10 centimetres below Unit C in Unit Upper B. Several manuports, but no artifacts, were recovered during the excavation of Unit B, but 2 artifacts were found in this unit during study and sampling of the quarry face. All in all, the lower units were better sampled by excavation than the upper strata, particularly units E, F and especially G which were poorly represented due to an unconformity on the side of the hill. Despite this problem, the excavations have provided a reasonable sample of the periods of human occupation at this locality.

As noted above, all the strata at the site are composed of very heavily weathered clays derived from the tephras as well as the paleosols formed within them. Due to the extent of weathering, it was sometimes difficult to discriminate between the various geological layers, especially in the upper Units H-F. Arbitrary 10 centimetre spits were used within stratigraphic units which were correlated to nearby sections of the quarry face (e.g. Figure 3). Subsequently, the stratigraphic interpretations made during excavation were revised as necessary following Neall’s analysis of the excavated sections.

The extremely hard, highly weathered, consolidated clays were carefully broken into pieces with a spade or a rock hammer and removed. All the material was placed into a sieve and then further reduced by hand and sorted carefully. A bucket-sized sample was taken from each spit for water sieving off site. The recovery rates from the two methods did not differ significantly, suggesting that sorting through the dry material by hand has provided reliable samples.

Relative dating

Given the depth of the artifact-bearing units below the dated Holocene tephras at Kupona na Dari, it seems a reasonable hypothesis that these date to the Pleistocene period. Dating the site is not a straightforward procedure, however, because the high degree of weathering at this location has removed most of the material required by chronometric methods such as radiocarbon and luminescence dating. We therefore tried a number of ways to obtain a relative age by comparing the Kupona na Dari coverbeds with those from neighbouring Holocene contexts. We analysed the degree and nature of the weathering of the coverbeds and of the manuports derived from different units.

Analyses of the paleosols

As noted previously, five prominent paleosols (buried soils) were identified in Section IV beneath the W-K 3 pumice (2Apb, 5Apb, 7Apb, 10Apb, and 12Apb). The fact that each represents a prolonged period of weathering implies considerable periods of landscape stability at these times. In order to gain some insight into the history and relative age of the parent materials and paleosols, they were compared with samples taken from the nearby site of FAAH (Figure 2), where there is a sequence of interbedded tephras and paleosols that correlates with the well-dated Holocene teprostratigraphy for this region (Machida et al. 1996). The results of this comparison help place the Kupona na Dari site within a relative time sequence for this region.

It is worth noting that the weathering of the tephras would not be predicted to conform to a simple linear model because they are derived from different provenances with varying compositions and differing grain sizes. Although one might expect a general progression from the production of allophane to the formation of halloysite and eventually under long weathering to gibbsite and/or kaolinite, these are broad trends expected of material from a single lithology. Such is not the case for the tephras that formed the basis of the stratigraphy at Kupona Na Dari.

Initially we determined the quantities of carbon and nitrogen. When they were on the surface and supporting vegetation, the paleosols would have contained significant amounts of carbon (>5%) and nitrogen (>0.4%). Since these elements are gradually lost over time after the soil is buried by tephra, the amount still preserved in the paleosol provides a relative indication of age. As seen in Table 2, the values of carbon remaining in the paleosols is miniscule, the
highest being 0.23% C in 5Apb. This amount of carbon in a sample is insufficient for radiocarbon dating. Nitrogen shows similar trends. These small amounts of carbon and nitrogen indicate that a significant time period has elapsed since these paleosols were first buried.

A second analysis focused on the relative proportions of minerals in the clay fraction of the paleosols. When soils undergo weathering the nature of the clay minerals within them changes. The percentages of glass and amorphous materials are useful variables because their abundance decreases during the process of weathering. The results for the paleosols at FAAH range from 25-48% (mean 41%) (Table 2). In contrast, for the paleosols and their parent materials at Kupona na Dari, halloysite levels vary between 66 and 93% (average 75%). The one exception is the lowermost unit in this study (13Bw), which contained 30% kaolinite, a product found in the most advanced stages of volcanic soil weathering, together with 41% halloysite. These figures demonstrate the considerably greater degree of weathering of the beds at Kupona na Dari, compared with the much younger FAAH site. Little significance can be placed on the presence of quartz, feldspar, vermiculite, smectite and mica-vermiculite in the clay fractions because of their minor proportions (<8%).

Taken together, the various studies of weathering of the coverbeds support the hypothesis that the paleosols at the Kupona na Dari site are considerably older than 6,000 years BP, as exemplified by the younger paleosols from FAAH, and are likely to be at least as old as late Pleistocene in age.

**Manuport weathering**

Manuports, in the form of unworked, rounded stones, which at this site are mainly composed of andesite, are relatively common within the buried soils at Kupona na Dari and at Holocene age sites excavated in this region (Torrence 2001a). At Kupona na Dari they often occur on old land surfaces formed in relatively stable periods between the volcanic events that created the major stratigraphic units at the site, but they are often also distributed throughout tephra accretion deposits, because they were discarded as the deposit built up slowly. Only on rare occasions are they clustered into discrete groups (see below and Figures 4, 10). As discussed in a later section, we interpret the manuports to have been used in the preparation of food.

<table>
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<th>Soil horizon</th>
<th>Geological unit</th>
<th>Quartz %</th>
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<th>Halloysite %</th>
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<tr>
<td>FAAH XVII</td>
<td>Paleosol on redeposited W-K 1</td>
<td>0</td>
<td>4</td>
<td>50</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>46</td>
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<tr>
<td>FAAH XVII</td>
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<td>0</td>
<td>2</td>
<td>50</td>
<td>0</td>
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<td>0</td>
<td>48</td>
<td>n.d.</td>
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<td>H</td>
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<td>0</td>
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<td>0.2</td>
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<tr>
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<td>3Bt</td>
<td>G</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
<td>29</td>
<td>0.005</td>
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</tr>
</tbody>
</table>

Table 2: Clay mineralogy and elemental values for paleosols sampled at Kupona na Dari and FAAH
Many of the stones show evidence of strong weathering, some to the point where they crumbled during excavation. Our initial impression was that the Kupona na Dari manuports were much more highly weathered than those recovered from Holocene-aged deposits at other sites. This would support an age well into the Pleistocene for these deposits. It also seemed likely that an attempt to quantify the differences between the weathering within contexts of different ages might provide an indication of a relative age for the Kupona na Dari deposits.

For this reason, Neall conducted an analysis of various weathering parameters for manuports derived from Holocene contexts (FAAH Trench XVII; FACC Trench XVIII; FACQ Trench XXI; FACP Trench XIX; FACQ Trench XXI; FACP Trench XVIII and present-day soil) and from the strata at Kupona na Dari. The variables used in the study are listed in Table 3. The analysis was restricted to a single lithology: andesite. One manuport was selected from each excavated spit, so this sometimes meant there were multiple samples for a single stratigraphic unit. Using the Holocene tephra sequence for the Witori volcano (Machida et al. 1996; Torrence et al. 2000), an age could be assigned to the samples derived from the Holocene sites. The oldest levels from these are buried by the W-K1 tephra which has been dated by radiocarbon to be c. 5,900 cal. BP (Torrence et al. 2000).

In order to explore whether there is a statistical relationship between the degree of weathering of the manuports and age, without knowing the precise ages of the beds at Kupona na Dari, we tested the plausibility of two different scenarios. First, assuming the oldest Unit A at Kupona na Dari was 20,000 B.P., the units were arranged in a sequence along an x-axis from 6,000 (top) to 20,000 (base). Second, assuming the oldest bed A was 40,000 years old, a relative age from 6,000 (youngest) to 40,000 (oldest) was assigned for each bed >6,000 years old. It is worth noting that it would not be accurate to plot the data in relation to depth of deposit, since the thickness of the tephras that make up the sequence is not proportional to their age.

The thickness of weathering rinds and the depth of exfoliation produced the most useful results when compared to the analytical time lines plotted on the x-axis. The results, which are plotted in Figure 10, show that weathering increases with depth in the sequence and is therefore a function of time. Variation in the degree of weathering of stones belonging to the same stratigraphic unit is probably due to the fact that the stones had been weathered to

---

**EXTERNAL EXAMINATION**

1. Exfoliation (Present/Absent)
2. Exfoliation – if Present – (maximum depth)
3. Description of outer surface
4. Specific Gravity of Sample – estimated in field – (low/medium/high)

**INTERNAL EXAMINATION** (Sample broken open and examined with binocular microscope)

1. Weathering rind (Present/Absent)
2. Weathering Rind – if Present – (maximum thickness)
3. Ease of fracturing – (very hard/hard/brittle/soft)
4. Type of lithology – (subtle differences in andesite lithologies, including any vesicularity)
5. Iron or manganese staining – (Present/Absent)
6. Iron or manganese staining – if Present – (extent: weak/moderate/strong)

Table 3: Variables used in weathering study of andesitic manuports.
differing degrees before they were collected and brought back to the site. A second important observation is that there is a major difference in the thickness of exfoliation and weathering rinds in the units dating less than c. 6,000 years.

Assuming a straight line relationship to relative age with a maximum of 20,000 years, the weathering rind data (Figure 10) show a significant positive correlation \( r = 0.57, p = 0.0002 \). This correlation remains the same if a maximum of 40,000 years is used. Making a similar assumption for the exfoliation data, there is also a significant positive correlation \( r = 0.67, p < 0.0001 \), for the 20,000 year maximum; \( r = 0.68 \) for the 40,000 year maximum. These results indicate that should a sufficiently precise age be determined from the >6,000 year old succession, these data offer a predictive capability. One could relate a weathering rind or exfoliation thickness to a specific >6,000 year age and then extrapolate relative ages into real ages for the other data.

The differential degree of weathering on the manuports from the Holocene-aged sites and Kupona na Dari are also important because it is consistent with there being a major difference in age between the weathered units A to H at Kupona na Dari and the Holocene sequences nearby. The results indicate the presence of a major disconformity between the Holocene coverbeds above and what must be weathered Pleistocene tephras below.

### Fission track dating

A characterisation study of a sample of obsidian artifacts from Kupona na Dari was made using PIXE-PIGME analysis with the same machine conditions as in previous studies (e.g. Summerhayes et al. 1998). It yielded surprising results. As shown in Table 4, the two most popular sources in the oldest units B-F are Mopir and Gulu, although Baki occurs in the lowest sampled unit. Secondly, and most importantly, the Kutau/Bao source is only present in the uppermost units F and H. Since Kutau/Bao obsidian dominates most assemblages from New Britain, this result is very unusual, but this pattern might be caused by the date when the obsidian sources became available for use.

We therefore applied the Fission Track Dating (FTD) method (Durrani and Bull 1987; Bonetti et al. 1998) to 10 samples which represent all 4 of the major obsidian chemical groups in West New Britain that are known to have been used widely in the past. The locations of known geological outcrops for each of the various chemical groups of obsidian are shown in Figure 1. Detailed descriptions of the outcrops are presented in Torrence et al. (1992) and Fullagar et al. (1991). A detailed description of the techniques used is presented in Appendix 2.

The results of fission track dating of all the obsidian chemical groups known in West New Britain are shown in Table 5. The so-called ‘apparent’ ages are reported in the last column. These have not been corrected for a possible temperature-induced fading effect (Durrani and Bull 1987) because we calculated the amount of fading by comparing the induced and spontaneous fission track diameters and found that it was negligible. The amount of fading for all samples was within the experimental uncertainties. In contrast to the very old samples from Australia analysed previously (Bonetti et al. 1998), the ‘apparent’ ages coincide with the ‘corrected’ ages for these relatively young samples from West New Britain.

Since the samples were analysed at different times as the project developed, the deviations in the results between samples from the same chemical group could be due to inconsistencies in the methodology. To check for this, tracks from all the earlier samples were recounted by the person who did the most recent analyses and Bonetti also recounted the entire set. In addition, a third person repeated

### Table 4: PIXE-PIGME analysis of obsidian source use

<table>
<thead>
<tr>
<th>Period</th>
<th>Unit</th>
<th>Baki</th>
<th>Gulu</th>
<th>Mopir</th>
<th>Kutau/Bao</th>
<th>WNB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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<td>FABM</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>17</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td></td>
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<td>Holocene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Results of fission track dating of obsidian sources in West New Britain

\[ \rho_s, \rho_i \text{ represent the spontaneous and induced track densities, respectively (the latter normalized to a neutron fluence of } 10^{10} \text{ n/cm}^2). \]

\[ \text{Ages are calculated by means of the following constants: } \lambda = 1.551 \times 10^{-6} \text{ a}^{-1}; \]

\[ \eta = 137.88, \sigma = 580.2 \text{ b; } \lambda_0 = 7.03 \times 10^{17} \text{ a}^{-1}. \]

1. Detailed information on locations and descriptions of outcrops is presented in Torrence et al. (1992: Figure 2, Table 1) and Fullagar et al. (1991).

2. Date previously published in Bonetti et al. (1998).
all the calculations. We can therefore be certain that the current dates are as accurate as is possible with the methods used.

As shown in Table 5, the ages often exhibit a rather large uncertainty. This is clearly due to the very young age of these obsidian outcrops relative to the very long spontaneous fission half life of $^{238}$U ($9.9 \times 10^{16}$ a; where a = years). The very small spontaneous fission track densities can be considered near the limit of what can be determined using the Fission Track Dating method.

In a previous study, the Baki and Kutau/Bao flows were dated by FTD at around 26-30,000 years, with the Baki flow the older of the two (Bonetti et al. 1998: 281). The new determinations, however, suggest that the Kutau/Bao source may be substantially younger, although the large standard deviations create uncertainty on this point. The fission track dates make it very clear that Mopir was formed long before the arrival of humans. This helps explain why it is present both at Kupona na Dari and in Pleistocene-aged contexts in New Ireland (e.g. Summerhayes and Allen 1993; Rosenfeld 1997:221).

The fission track dates from the obsidian sources on the Willaumez Peninsula are quite variable and therefore demand careful analysis. To begin with, there are two very different dates for samples from the Gulu chemical group. This is quite surprising because the chemical composition of these samples as determined by PIXE-PIGME is quite homogeneous (Torrence et al. 1992; Bird et al. 1997). Sample 433, which has an older determination, was collected from within a pyroclastic flow located on the eastern side of the peninsula. This location is completely separated from the other two samples, 1576 and 1577, which were derived from a rhyolitic flow. It therefore seems likely that despite the similarity in composition of the magmas, the two Gulu sources were formed at very different times. The older outcrop was stratified under a number of undated layers of tephra exposed within a modern quarry, but it may have been accessible during the time of early human colonisation of the region.

The Baki samples produced a similar pattern: the 1573 sample collected on Garua Island returned a much younger age than sample 381 which was obtained from an outcrop on the adjacent Garala Island. It has already been noted that the Baki source is somewhat variable in chemical composition, but the differences are continuous rather than discrete. Samples with variable compositions have been collected from the same outcrop. Previously, the variation was proposed as due to the origin of the obsidian within an ash-flow deposit that contained zones of welded tuff (Bird et al. 1997: 64-66). While it is possible for obsidians of different chemistry to appear as a consequence of magma mixing (Hughes and Smith 1993: 85), it is much more likely for obsidians of different chemistry and ages to be derived from older material of a volcanic edifice, e.g. a glassy volcanic dome, which has been reincorporated into a younger flow. Alternately, it may be that the flows on Garala are actually much older than the Garua outcrops despite having similar compositions.

Considering all the dates now available, it is possible that the Gulu and Baki obsidians recovered from Kupona na Dari were derived solely from the older flows. If that is the case, then these archaeological levels may pre-date the formation of the younger Gulu, Baki and, significantly, the Kutau/Bao flows. This possibility particularly applies to the Kutau/Bao obsidian which has the youngest dates.

We know that the Kutau/Bao outcrops had formed by c. 20,000 BP since obsidian artifacts sourced to this chemical group have been recovered from contexts dated by radiocarbon at Matenbek, Matenkupum (Summerhayes and Allen 1993: 147), and Buang Merabak (Rosenfeld 1997: 221). Compared with the abundance of Mopir obsidian, the relative scarcity of Kutau/Bao obsidian at these sites, nevertheless suggests that the source had not been heavily exploited, perhaps because it had not been in existence very long. Gulu obsidian is present in Pleistocene levels at Matenbek, whereas Baki is not (Summerhayes and Allen 1993), although this is not unusual because the Baki source is only rarely found outside the Willaumez Peninsula at any date (Summerhayes et al. 1998; Torrence and Summerhayes 1997).

Combining the results from the fission track dating with the information that the Kutau/Bao source is absent at Kupona na Dari until Unit F, we propose that the lower levels of the site, lacking Kutau/Bao obsidian, pre-date 20,000 and could be very much older. In contrast, the upper units F and H, which contain Kutau/Bao obsidian, possibly post-date 20,000 BP.

In future work it would be useful to date the actual artifacts recovered from the early levels from Kupona na Dari using the Fission Track Dating method to see if they were obtained from the very much older Baki and Gulu outcrops. If not, then this would help set upper limits on the potential age of these deposits. Since this is a destructive technique, this decision cannot be made lightly and not until definitive use-wear and technological studies have been completed. The younger dates (21-39,000 for Baki and 17-30,000 for Gulu at one standard deviation) would also fit neatly within the currently known dates for human colonisation of this region. Secondly, further geological analysis of the various obsidian outcrops to better understand the history and method of their formation is highly desirable since this information would help us better understand the physical geography of the Willaumez Peninsula during the period of early human settlement.

**Radiocarbon dating**

Due to the high degree of weathering at the site, organic preservation is very poor. Material appropriate for radiocarbon dating was not recovered during excavation, despite careful searching and wet sieving. Proxy methods for dating human activity on the site were therefore sought through the extraction of microscopic carbon and phytoliths from soil samples. The results are presented in Table 6. A problem with these methods is the possibility of
contamination, particularly through root activity or from the roots themselves. Coconut roots had penetrated almost the entire depth of the site in Section IV. Root disturbance was particularly obvious within Square C where modern roots were frequently encountered. Roots were less common in Squares A and B but they were nevertheless present.

In the first attempt at extracting organic material for dating, Carol Lenter processed 0.4 kg of soil by disaggregating with calgon, flotation in sodium polytungstate, centrifuging and then decanting the floating fraction. This then required treatment with hydrochloric acid and hydrogen peroxide to remove modern contaminants. The organic residue was sent to Beta Analytic but the sample was too small for AMS dating. To use radiocarbon dating of soils would involve such a large quantity of material that it would be difficult to be sure what was being recovered and dated. In a second attempt humic colloids were extracted from a bulk soil sample from Unit D. This procedure produced a date of 8380 ± 120 (Table 6). Given the depth of the sample in the sequence and the number of volcanic events separating it from the Holocene tephras, this date was considered too young and probably contaminated by modern humic acids.

A further attempt at radiocarbon dating was conducted by Jeff Parr who carried out a dating programme of the coverbeds from a number of contexts including other Holocene sites in the region (Parr 2003). In this case phytoliths and charcoal were extracted by microwave digestion (Parr 2002) from units H and F within the upper sequence at the site. Samples were then taken by Parr to the ANTARES target preparation laboratory ANSTO, Sydney. There he pretreated the extracted phytoliths with chromic acid (0.4M K2Cr2O7 and 2M H2SO4) at 80°C for 2 hours and at room temperature for a further 16 hours. Following crushing in a sterilised Retsch centrifugal ball mill for 4 hours, samples were washed in HCl and allowed to dry for 15 hrs. Charcoal samples were prepared by Parr using the standard laboratory pretreatment procedures (Bird and Gröcke 1997; Hua et al. 2001; Jacobsen et al. 1997). They were then combusted by Alan Williams of ANSTO at 900°C and subjected to graphitisation (Jacobsen et al. 1997). Finally, accelerated mass spectrometry was conducted by Ugo Zoppi.

The results presented in Table 6 are generally too young. The youngest age of 1050 ± 30 on charcoal extracted from the soil at the top of Unit H is too young because the soil is stratified underneath the W-K3 tephra which is reasonably well dated to around 1800 radiocarbon years (Machida et al. 1996: 71). The date on phytoliths of 5060 ± 100 from the base of unit H is also somewhat younger than expected given that Unit H is similar to units elsewhere in the region that are stratified under W-K1, which dates to at least 5200 radiocarbon years (Torrence et al. 2000: 229). In contrast, we have no stratigraphic grounds for rejecting the date of 7550 ± 100 on phytoliths from Unit F, although given the luminescence dates discussed below it may also be too young.

We conclude that overall the results of radiocarbon dating of organic material preserved in the coverbeds has been disappointing, although the two dates on phytoliths may be indicative of late Holocene ages for the upper units at the site. Within the lower units at the site, the preservation of phytoliths and organic carbon was not good enough to produce enough material for reliable dating using radiocarbon methods.

### Luminescence dating

Optically stimulated luminescence dating was conducted at Kupona na Dari on samples from units A, E and H in section IV. The E and H samples were taken near the base of the unit in order to focus on the tephras rather than the paleosols and to date the oldest event. Rhodes measured the gamma dose rate directly at the sample locations, although the Unit A sample whose result is reported here was collected in 2000 and submitted for preliminary testing prior to the fieldwork. All samples were measured using the SAR protocol (Murray and Wintle 2000; Banerjee et al. 2001). Beta dose rate values were calculated using both NAA and in situ NaI measurements. A value of 30 ± 5% water content was assumed for all samples, estimated from the measured in situ water content values. The results are summarised in Table 7.

The Unit A (OxL-1421) sample, which is based only on rare sand-sized quartz, produced very widely divergent $D_e$ values, with two being very much higher. They were used to calculate the estimated age of 36,000 ± 3,900 years before 2000AD. The presence of many lower values, however, means that the reliability of this age estimate is questionable.

Sand-sized quartz was found to be rare in the remaining samples, but Units E and H did provide some aliquots with potentially meaningful results: 39,800 ± 5,200 (OxL-1426) and 23,200 ± 6,100 years (OxL-1427) respectively (Table 7). Both fine-grained quartz and fine-grained polymineralic grains were separated for each sample. However, only sample OxL-1428 from Unit E had significant OSL or IRSL signals for one fine-grained quartz aliquot and one fine-grained polymineralic aliquot. Combining the rather low precision and disparate results for these fine-grained aliquots from Unit E gives an age estimate at an apparent age of 38,000 ± 10,400 years.

Despite the rather low precision of the dates, the results are reasonably consistent with the stratigraphy. The central
date for Unit E is older than the lower stratified unit A but the dates overlap at one standard deviation. It is encouraging that the two results based on different sample types from the single Unit E produced comparable results. In addition, Unit H, which is well separated in terms of volcanic history from Unit E, has returned a considerably younger date as would be expected. It is worth noting that the most reliable age, for Unit E, comes from several layers above the major concentration of artifacts which occurs in Unit C (see below). There is therefore a possibility that the real age of Unit E is earlier than other sites reported in the region so far, possibly older than 40,000 years.

On the other hand, one must interpret the age estimates with caution because the radioactivity and radiogenic isotope concentrations are very low, making the dose rate difficult to measure accurately. Secondly, the very wet conditions of this tropical setting are difficult to estimate accurately and this means the samples are susceptible to systematic over or under estimation of age if the assumed water content is inaccurate. Thirdly, there is a very low concentration of quartz in the samples. Further work with these samples and expansion to other units may produce more accurate results, but using luminescence dating on samples of this type is always going to be problematic.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Depth (m)</th>
<th>Code</th>
<th>D$_E$ (Gy)</th>
<th>Dose rate (mGy/a)</th>
<th>Age (years before 2000 AD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.5</td>
<td>OxL-1421</td>
<td>9.49 ± 0.95</td>
<td>0.28 ± 0.01</td>
<td>36,000 ± 1,900</td>
</tr>
<tr>
<td>E</td>
<td>2.3</td>
<td>OxL-1426</td>
<td>10.0 ± 1.5</td>
<td>0.26 ± 0.01</td>
<td>39,800 ± 5,200</td>
</tr>
<tr>
<td>E</td>
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<td>OxL-1428</td>
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<td>38,000 ± 10,400</td>
</tr>
<tr>
<td>H</td>
<td>0.9</td>
<td>OxL-1427</td>
<td>6.9 ± 1.7</td>
<td>0.30 ± 0.03</td>
<td>23,200 ± 6,100</td>
</tr>
</tbody>
</table>

Table 7: Results from optically stimulated luminescence dating

Summary of dating

In summary, the luminescence dates (c. 38-39,000 and 23,000 years ago) are consistent with expectations based on the local stratigraphy of the site and the high degree of weathering of the volcanic tephras and soils. They also make good sense in terms of fission track dating of the obsidian sources and the timing of the occurrence of artifacts sourced to the Baki, Gulu and Kutau/Bao outcrops. The dates are also comparable with the early radiocarbon dates for Pleistocene occupation elsewhere in New Britain (Pavlides and Gosden 1994) and in the Bismarck Archipelago (Leavesley et al. 2002; Allen 2000; Spriggs 1997). In contrast, the radiocarbon determinations for units H and F are very much younger and may be subject to contamination. There is a problem, however, when comparing the various types of dates because at present there is no reliable way to convert radiocarbon years of this antiquity into calendar years, as is the case for the luminescence and fission track dates.

If we accept the various lines of argument presented so far, then Kupona na Dari may have been occupied for the first time by somewhere around 35-45,000 years ago and is therefore likely to represent the period of earliest colonisation of the Bismarck Archipelago. Dating the most recent end of the sequence is more difficult. The artifacts recovered from the paleosol 2Apb could have been deposited at any time after the 23,000 BP date for the tephra but before c. 1,800 BP, the date of the overlying volcanic tephra (Machida et al. 1996). It therefore seems safe to analyse the uppermost Unit H apart from the lower units. One might also distinguish a 'middle' period comprising Unit F. The presence of Kutau/Bao obsidian indicates that Unit F may fall within the later Pleistocene period (c. 10-20,000 BP) which is currently seen as a distinctive phase by a number of scholars (e.g. Allen 2000; Spriggs 1997; Kirch 2000), although the luminescence date suggests it could be slightly older. For the purposes of analysis, then, it makes sense to discriminate 3 potential phases at Kupona na Dari: (1) earliest colonisation (Units B, C, D, E); (2) 'settling in' during the late Pleistocene (Unit F); and (3) fully established regional groups in very late Pleistocene and/or early Holocene (Units G, H).

Having established that Kupona Na Dari represents the time of early colonisation of the Willaumez Peninsula, we can now turn to the archaeological record. We begin by focusing on stone resource use, site structure, and lithic technology at Kupona na Dari. Next, in order to place Pleistocene land use in the Willaumez Peninsula within a larger temporal context, we contrast data on stone artifacts from Kupona na Dari with early Holocene lithic assemblages from neighbouring localities.

Stone resource use

Kirch (2000: 76-77) provides an excellent description of previously published Pleistocene lithic assemblages.

The lithic technology of the pre-20,000 B.P. period in the Bismarcks consists almost exclusively of simple flake and core tools of expedient or amorphous shapes. These were made of locally available rocks, primarily fine-grained igneous or sedimentary types. There is no indication at this earliest period of the transport or exchange of stone resources over long distances.

As he notes, the key attributes are the simple flake technology and the absence of nonlocal resources, in particular obsidian, which was transported over large distances only after 20,000 years ago. It is worth noting that this summary is based on a very small sample size since there are very few detailed published studies of lithic technology for Pleistocene sites in this region: Pamwak (Fredericksen 1997: 220); Panakiwuk (Marshall and Allen 1991); Buang Merabak (Leavesley and Allen 1998); and Yomboon (Pavlides 1999). Allen (1993:146) states that the chipped stone artifacts from the Pleistocene sites in this region 'appear to show a good deal of inter-site variability.
which seems to reflect the different local raw material resources more than cultural continuities in terms of their manufacture and use. For example, Balof, Panakiwuk and Buan Merabak have smaller artifacts and show more care in flaking than Matenkapum possibly because, as Allen et al. (1989: 554), Spriggs (1997: 59) and Leaveseley and Allen (1998: 73) hypothesise, good quality raw material was less accessible since local sources became exhausted through time. In contrast, recent data from inland New Britain have altered the overall picture. Even at the earliest date for human occupation in this region, chert was procured directly from primary outcrops rather than from secondary sources such as the river cobbles widely used elsewhere. Secondly, the admittedly very small assemblage (29) excavated by Pavlides contains a formal tool in the form of an ovoid unifacial scraper and a number of other retouched flakes (Pavlides 2004; 1999: 213-226; Pavlides and Gosden 1994: 609). The differences in lithic technology expressed at the Yombon sites may be signalling variations between the activities in open contexts versus the rock shelters studied in New Ireland. As another open site, it is therefore worth considering how Kupona na Dari fits into this pattern.

Since there are no sources of flakeable material in the immediate vicinity, all the chipped stone was brought to the site from some considerable distance. Already this is potentially quite an important difference from all the other known Pleistocene sites in the Bismarck Archipelago. Of the 191 stone artifacts recovered from the excavations or sections at Kupona na Dari, all except 5 (3 chert and 2 chaledony) were made from imported obsidian. Artifacts still retaining cortex (outer surface) were very rare at the site (Table 8), but of these the majority were struck from water-rolled cobbles, rather than freshly quarried material. This is the same pattern for the other well studied Pleistocene sites in New Britain and New Ireland. Reasonably fresh, rough cortex typical of pieces extracted from outcrops was, however, present on 2 obsidian artifacts from Unit C and 1 from Unit F.

The PIXE-PIGME analyses of obsidian artifacts summarised in Table 4 show that even from the initial occupation (Units B, C) a broad range of sources was exploited. All the four most widely used chemical groups of West New Britain obsidian are represented within the Pleistocene sequence. In the earliest period obsidian from sources both to the north (Baki, Gulu) and to the southeast (Mopir) (Figure 1) was transported to this single location. Torrence et al. (1996: 216, fig. 2) argued that it is likely that the Mopir and Gulu obsidian flows were easily accessible from the coast until well into the Holocene, even when the sea level was lower. In contrast, the Baki outcrops may have been landlocked by at least three kilometres from the coast from at least the late Pleistocene until the middle Holocene. The presence of Baki in the earliest unit may therefore indicate that people explored beyond the beach not long after reaching the area.

Straight line distances between FABM and the major outcrops are as follows (cf. Figure 1): Mopir (39 km); Baki (23 km); Gulu (32 km); Kutau/Bao (23 km to Bitokara Mission). Even if the primary mode of transport was by boat, as seems likely (cf. Allen 2000), they imply one and more likely two days travel roundtrip, especially if by canoe. Furthermore, the distances over which stone resources were transported are significant when compared to other Pleistocene sites where only localised raw material appears to have been utilised, although, admittedly, it is much more difficult to pinpoint their exact sources. In addition, the wide range of sources represented at Kupona na Dari suggests that people had been in the region long enough to become familiar with a variety of resources distributed across a wide area. It is therefore doubtful that they were just passing through on their way somewhere else since they left behind obsidian that had been acquired from sources in several different directions.

The characterisation study supports previous conclusions that early colonisers were good explorers and could adapt easily to new, local resources (Allen 2000: 150; Gosden

<table>
<thead>
<tr>
<th>Site</th>
<th>Unit</th>
<th>0%</th>
<th>1-25%</th>
<th>26-50%</th>
<th>51-99%</th>
<th>100%</th>
<th>Total</th>
<th>Rough</th>
<th>Shiny</th>
<th>Water-rolled</th>
</tr>
</thead>
<tbody>
<tr>
<td>FABM</td>
<td>Early</td>
<td>101</td>
<td>10</td>
<td>1</td>
<td></td>
<td></td>
<td>112</td>
<td>2</td>
<td>9</td>
<td></td>
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<tr>
<td></td>
<td>%</td>
<td>90.2</td>
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<td>0.9</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>22</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
<td>27</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>81.5</td>
<td>11.1</td>
<td>3.7</td>
<td>3.7</td>
<td></td>
<td>52</td>
<td>4</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late</td>
<td>49</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 chert</td>
<td>2 chaledony</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>94.2</td>
<td>1.9</td>
<td>3.9</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>Total</td>
<td>282</td>
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<td>13</td>
<td>13</td>
<td>5</td>
<td>354</td>
<td>13</td>
<td>54</td>
<td>5 (1 chert)</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>79.7</td>
<td>11.6</td>
<td>3.7</td>
<td>3.7</td>
<td>1.4</td>
<td></td>
<td>4</td>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 8: Amount and type of cortex on chipped stone artifacts. At FABM the periods are comprised as follows: Early (Units B, C, D, E); Middle (Units F); Late (Units G, H). Rough cortex is derived from primary outcrops. Shiny cortex is probably derived from primary outcrops but may also indicate the reuse of flakes.
In contrast to other sites, however, resources were brought back to Kupona na Dari from a number of reasonably distant places, either direct to the site, which acted as a central place or base camp, or as part of a mobility pattern that involved transporting raw material or curated artifacts over quite a large range before arriving at Kupona na Dari. Although obsidian was transported much greater distances after 20,000 BP (Summerhayes and Allen 1993), Kupona na Dari provides the earliest evidence for transport well beyond the sources before that period. The selection of raw materials from a number of relatively distant sources demonstrates that even from the earliest period, people in the Willaumez Peninsula organised their use of stone so as to extend its usefulness across a sizeable region. Such a strategy could have reduced risks faced by colonisers moving into unfamiliar territory (cf. Hiscock 1994).

This general picture is supported by the other raw materials present at the site, although they date to the post 20,000 period when transport of resources might be expected, based on previous findings from New Ireland (e.g. Allen 2000; Allen and Gosden 1996; Gosden 1995; Summerhayes and Allen 1993). Chert and chalcedony artifacts recovered in the excavations or during soil sampling are derived from the later units F-H. Although these raw materials have also been recovered from the early Holocene assemblages in the local region, they are similarly rare at that time. Three of the non-obsidian artifacts with cortex are water-rolled, which points to river cobbles as the most likely sources. These raw materials are not found currently within the coastal plain near the site; we suspect they were obtained from gravel beds within rivers that drain the inland. Potential locations are currently located at least as far away from Kupona na Dari as are the Willaumez Peninsula obsidian sources.

**Site Structure**

Gosden and Robertson (1991: 24) have proposed that differences in land use can be inferred by studying the intensity of site use, the range of activities carried out at a site, the nature of cleaning up on the site. They linked changes in site structure between the earlier and later periods of the Pleistocene at Matenkupkum to decreases in mobility. Since the excavations at Kupona na Dari only comprise 3 square metres and not all periods were represented in each one, it is not possible to duplicate the Gosden and Robertson study. Still, the framework they have proposed is useful for investigating changes in behaviour at the site.

Table 9 shows how the total sample of 191 chipped stone artifacts is distributed among the stratigraphic units at Kupona na Dari. They linked changes in site structure between the earlier and later periods of the Pleistocene at Matenkupkum to decreases in mobility. Since the excavations at Kupona na Dari only comprise 3 square metres and not all periods were represented in each one, it is not possible to duplicate the Gosden and Robertson study. Still, the framework they have proposed is useful for investigating changes in behaviour at the site.

Table 9 shows how the total sample of 191 chipped stone artifacts is distributed among the stratigraphic units in the excavated squares as well as within the sections that were studied or sampled in the course of stratigraphic analyses or luminescence dating. Table 10 presents the data in terms of weights and numbers of artifacts per cubic volume of excavated sediments (calculated by mean depth of spit multiplied by area). There are serious problems with using density since it is dependent on the mechanism and timing of formation for the deposits in which the artifacts are located, so these can only be very general ‘ballpark’ figures. The numbers and relative density of artifacts for the earliest period is certainly much greater than for the open sites at

<table>
<thead>
<tr>
<th>Stratigraphic unit</th>
<th>Excavated Squares (m³)</th>
<th>Section IV</th>
<th>Other Sections</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>A B C</td>
<td>1 1 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>39 29</td>
<td>13 5 86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>2 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>16</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>25</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>11 20 15</td>
<td>3 49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>50 65 40 28 8 191</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Distribution of artifacts in the stratigraphic units at Kupona na Dari.

<table>
<thead>
<tr>
<th>Site</th>
<th>Unit</th>
<th>Weight (g)</th>
<th>Volume</th>
<th>Wt/m³</th>
<th>Number</th>
<th>Number/m³</th>
<th>Mean Wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>FABM</td>
<td>C</td>
<td>217.0</td>
<td>0.796</td>
<td>272.6</td>
<td>68</td>
<td>85.4</td>
<td>3.2</td>
</tr>
<tr>
<td>E</td>
<td>25.3</td>
<td>0.210</td>
<td>120.5</td>
<td>16</td>
<td>76.2</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>73.4</td>
<td>0.593</td>
<td>123.7</td>
<td>25</td>
<td>42.2</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>H/G</td>
<td>48.1</td>
<td>0.208</td>
<td>231.3</td>
<td>3</td>
<td>14.4</td>
<td>16.0</td>
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<tr>
<td>H</td>
<td>115.1</td>
<td>0.678</td>
<td>169.8</td>
<td>43</td>
<td>63.4</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>242.3</td>
<td>1.006</td>
<td>240.8</td>
<td>84</td>
<td>83.5</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>73.4</td>
<td>0.593</td>
<td>123.7</td>
<td>25</td>
<td>42.2</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>163.2</td>
<td>0.886</td>
<td>184.2</td>
<td>46</td>
<td>51.9</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>575.6</td>
<td>3.250</td>
<td>177.1</td>
<td>354</td>
<td>108.9</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 10: Relative density and mean weight of artifacts from excavated contexts. Early (Units B, C, D, E), Middle (Unit F), Late (Units G, H).
Yombon, but is less than reported for the rock shelter at Matenekupkum (Gosden and Robertson 1991; Gosden 1995: 813). One problem with comparisons is that all the stone at Kupona na Dari has been imported from a considerable distance, whereas only local raw materials were used at the other contemporary sites.

Cooking Stones

Support for the conclusion that the site was used on a number of different occasions during the earliest period of occupation is provided by the presence of large numbers of fire-cracked rocks, particularly within Unit C. Since the hill is formed by airfall tephras, all the stones recovered within the excavation must have been brought to the site from somewhere else. Since many of them are slightly rounded, they must have been collected from surface contexts rather than extracted from outcrops. The majority are andesite and could easily have been obtained from nearby hills or alluvial fans. Many of the stones look as if they had been cracked or fractured through heating. None resemble hammerstones, which is not surprising since even freshly quarried andesite is relatively soft. As discussed above, all are weathered and some were poorly preserved. The highest density of stones was found in Units G and C.

As noted above, when the site was first discovered, a small cluster or pile of stones was observed in the quarry section within Unit C (Figure 4). When some of the stones were carefully removed, we found some obsidian artefacts mixed within them. Another very dense cluster of stones with obsidian artifacts scattered among them was excavated within Unit C in Squares A and B, as shown in Figures 8, 11, 12.

We hypothesise that many, if not all, of the stones in Unit C and in the other units had been used in the preparation of food, although we did not detect the presence of deliberately constructed pits for this purpose. Presumably food was cooked within layers of heated stones placed directly on the ground surface, as is still done in many parts of Papua New Guinea today. In many instances pits are not constructed. When the cooking was complete, the ‘oven’ was partially or completely dismantled and the stones were dispersed to varying degrees or removed to a safe place for future use. The clusters of stones and artifacts which we uncovered in Unit C may also represent piles of waste material cleared up

Figure 11: View of layers and cooking stones preserved in the section of Squares A and B. The main group of stones is sealed between Units D2 and C (lighter bands). Note the presence of two stones located below Unit C and within paleosol Unit Upper B, the lowest level where artifacts occur at the site. One stone is in the section and another is in situ within Square A. The scale is divided into 50 cm bands.
Lithic Technology

Although the sample of artifacts recovered from Kupona na Dari is quite small, it can nevertheless provide important information about the nature of lithic technology and, by inference, about land use patterns during the Pleistocene colonisation of the region. Unfortunately, when viewed under high powered microscopy, the surfaces of the obsidian artifacts are so pitted and eroded that Fullagar (personal communication) concluded that use wear analysis might be extremely limited. Some starch granules were observed by him, but a residue study was not attempted. We therefore turn to an analysis of the technology of manufacture of the artifacts.

With the possible exception of the Yombon sites (Pavlides 2004; 1999; Pavlides and Gosden 1994) and Pamwak, (Fredericksen et al. 1993), the manufacture of stone artifacts at Pleistocene sites in the Bismarck Archipelago can be characterised as highly expedient. For comparison with Kupona na Dari, we focus on Buang Merabak and Yombon because the assemblages are well described and date to the earliest period of colonisation. In New Ireland, local river cobbles were reduced in a rather unsystematic manner creating few if any systematic cores (e.g. Leavesley and Allen 1998: 73), whereas at Yombon, cobbles were collected from secondary contexts, apparently moved short distances, flaked, and discarded expediently. Although water-rolled surfaces of obsidian also dominate the type of cortex present at Kupona na Dari, material extracted directly from outcrops was also used, as evidenced by the presence of unweathered, rough, brown cortex. The most important difference is the very high percentage of artifacts bearing cortex at Buang Merabak (30% units 5 and 6; 26.2% unit 4; 33% unit 3) (Leavesley and Allen 1998:72) and Yombon (38%) (Pavlides 1999: 216) when compared to Kupona na Dari: 9.8% early period; 18.5% middle period; 5.8% late period, (Table 8). The Kupona na Dari assemblage exhibits a pattern of behaviour in which the uselife of the artifacts may have been deliberately extended further than at the other Pleistocene sites. Prior to their discard at the site, obsidian nodules were reduced either at the raw material source or at one or more other localities along the way.

Allen (personal communication) has made the tantalising suggestion that the size or nature of the raw material source may have created a need for reduction of obsidian nodules at the source when compared to the raw material worked in New Ireland. What if the obsidian nodules were too large to carry easily (in comparison to smaller New Ireland river cobbles), or if extraction from the obsidian outcrops required a certain amount of flaking that removed cortex? This would explain why the obsidian artifacts at Kupona na Dari had so little original cortex. Although an interesting hypothesis, it is difficult to test. Currently, it would be no problem to acquire many small cobbles from most of the outcrops visited and described by Torrence et al. (1992), but the situation during the Pleistocene may have been quite different, especially if the Willaumez Peninsula flows were relatively young and fresh. Nevertheless, the presence of

from other areas of the site. It is possible that these were deliberately placed at the edges of the hill as part of rubbish disposal or were piled up carefully and kept for reuse, but more complete excavation is required to test for evidence of systematic use of space or maintenance activities.

If our interpretation is correct, then the cooking stones were utilised by the first colonists in the region. Possibly these fire-cracked stones do not occur in other Pleistocene sites until much later (e.g. Spriggs et al. 2003: 56 report a stone-lined oven at c. 10,000 BP), because cooking with stones normally took place on open sites and much less often in rock shelters. It is therefore significant that Pavlides (1999: 215) reports 7 fire-cracked stones from 2 Pleistocene contexts in the Yombon region. The rock shelters may have been used for very short-term occupations or completely different purposes than the open-air locations. The high density of cooking stones at Kupona na Dari, particularly within Unit C, may indicate that this location was occupied over a relatively long time period or re-used on many occasions. It is worth noting that high densities of cooking stones have also been found in Holocene excavations in the region, particularly at locations near the coast or the Kulu River (cf. Torrence 2001a; 2002).

The relatively high concentrations of cooking stones in the lowest levels at the site and the possibility that they were deliberately placed in certain areas address several of the Gosden and Robertson (1991) criteria. To fully evaluate these propositions about site structure, a much larger portion of the site needs to be excavated.

Figure 12 Plan view of the surface of one spit in Unit C within Square A showing the distribution of obsidian artifacts scattered among a high density of fire-cracked stones.
Table 11: Assemblage composition at Kupona na Dari (FABM) and neighbouring Holocene contexts.

At FABM the periods are comprised as follows: Early (Units B, C, D, E); Middle (Unit F); Late (Units G, H).

Like all the other Pleistocene sites, simple flakes were the primary products at Kupona na Dari (Figure 13). Rakes completely dominate the assemblage whereas cores are quite rare (Table 12). A significant difference from the general pattern at other Bismarck Archipelago Pleistocene sites is that flakes, rather than cobbles, are the primary source of cores at this site (Table 12). Flakes were initially struck from cobbles, transported to Kupona na Dari, and then used as cores to produce additional smaller flakes. This strategy minimised the amount of material that needed to be transported. The flakes also economised on time and energy because they could be used as a tool as well as a producer of extra flakes (Figure 13). The movement of flakes which were later transformed into cores illustrates a degree of foresight and planning not exhibited in other sites in the pre-20,000 year old phase of the Pleistocene.

The percentage of retouch and/or use wear can provide a measure of the intensity with which the raw material was used. Pavlides (2003; 1999:217) recovered nine 'tools' which comprised 31% of the studied assemblages, however, this category includes artifacts with retouch, edge damage, and any other form of use wear (Pavlides, personal communication). Retouch is absent at Pamwak prior to 10,000 BP (Fredericksen 1997: 220) and also prior to 20,000 BP (units 5 and 6) at Buang Merabak, although it is present in small amounts in the late period: 2.4% for unit 4, and 1.1%

In contrast, the levels of retouch were much higher at Kupona na Dari than at other contemporary sites: 5.4% of the early and 7.7% of the late assemblages (Table 13). Furthermore, of the complete artifacts with modified edges, 45.5% and 50% respectively had retouch on two or more edges (Table 14; Figure 14). The majority of the retouch is direct and unifacial. A unique retouched artifact was recovered from the Soil on H (2Apb) in Section IV during soil sampling. It is the distal end of a blade bearing two overlapping layers of steep, unifacial, direct retouch along the whole length of both margins (Figure 14). It resembles retouched tips on Type I stemmed tools from Garua Island (Rath 2000; Rath and Torrence 2003). If it does date to the Pleistocene, it provides a remarkable case of continuity. It seems more likely that, as elsewhere at Numundo Plantation, the uppermost paleosol on Pleistocene-aged clays comprised the land surface on which artifacts dated to the early Holocene were deposited.

Since the properties of ‘edge damage’ and ‘use wear’ are defined differently in the various studies, comparisons are difficult. Leavesley and Allen (1998: 69) included use wear which was observed under a low power microscope. It is perhaps not surprising, then, that they reported very much higher amounts (30% for units 5 and 6; 14.6% for unit 4 and 21.2% for unit 3) than the incidence of macroscopic edge damage that was monitored at Kupona na Dari (10.7% for the early period decreasing to 3.8% for the late period: Table 13). It may be that a similar proportion of the artifacts had been used in the various Pleistocene assemblages, but at Kupona na Dari more investment was made in preparing the edges in advance of use or in repairing them by using retouch. One possible explanation for the differences between Pleistocene-aged sites is that if people desired tools for heavy tasks such as scraping, the very fragile and sharp edges of obsidian would have needed treatment beforehand, whereas the harder materials selected elsewhere would have required very little adjustment prior to their use. A further possibility is that the Kupona na Dari assemblages represent a more carefully planned and/or more intensive use of raw material.

In summary, the Kupona na Dari lithic assemblage shares some characteristics with contemporary sites, but it is also unique in several key attributes that relate to raw material exploitation. In addition, tool manufacture and use appear to have been planned in advance and then executed in stages. At this site all the raw material was acquired from beyond the local neighbourhood. Flake cores were prepared, possibly at the obsidian source. They were then moved to other locations where they were used and/or additional flakes were removed and some of these cores were discarded. The degree of retouch is also relatively high. The planning and careful use of raw materials may have been a necessity given the scarcity of suitable stone in the

<table>
<thead>
<tr>
<th>Site</th>
<th>Unit</th>
<th>1 modified edge</th>
<th>≥2 modified edges</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FABM</td>
<td>Early</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
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<td>54.5</td>
<td>45.5</td>
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<td>Late</td>
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<td>%</td>
<td>50</td>
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<tr>
<td>Region</td>
<td>Holocene</td>
<td>18</td>
<td>3</td>
<td>21</td>
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<tr>
<td>%</td>
<td>85.7</td>
<td>14.3</td>
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Table 14: Number of modified edges (with retouch and/or edge damage) on complete artifacts only. Early (Units B, C, D, E); Middle (Unit F); Late (Units G, H).

![Figure 14: Kupona na Dari obsidian retouched blade, possibly the tip of a stemmed tool, from the Soil on H (2Apb).](image-url)
immediate vicinity, a different situation from similarly dated sites in the region. On the other hand, the Yombon assemblage demonstrates that staged production also took place in a setting where raw material was abundant. It therefore seems plausible that the nature of the lithic technology at Kupona na Dari was conditioned by the pattern of land use in this region. When compared with rock shelter excavations in New Ireland, the data from Kupona na Dari suggest that early colonisers in various parts of the Bismarck Archipelago may each have had slightly different approaches to the procurement, manufacture and use of lithic raw material. Although obsidian has different properties than the tougher stones used elsewhere, it is not clear that this was the primary reason for the variations we observe among the Pleistocene technologies. It is just as likely that varying patterns of land use were responsible for the range in approach to stone procurement and use as observed in the archaeological record.

Holocene Comparisons

Since it is reasonable to assume that populations had fully settled into the Willaumez Peninsula by the Holocene period, one would expect Pleistocene colonisers to have had a different pattern of land use. A comparison between the two periods could therefore help us better understand the process of colonisation. Following this line of argument, we selected excavated samples of Holocene stone tools derived from the same geographic setting as Kupona na Dari (although of course the local area was not exactly the same due to sea level change and additional emplacements of volcanic tephras). Artifacts were selected from eight test pits (designated by roman numerals) from four areas given PNG site codes. The one metre square test pits are within a 2 kilometre radius of Kupona na Dari and are also situated on small hills on or near the coastal plain (Figure 2). In stratigraphic terms the artifacts were found in levels just below the W-K1 (5900 cal. BP) or W-K2 (3600 cal. BP) tephras (cf. Torrence et al. 2000). In many cases the W-K1 tephra has not been preserved and so material derived from under the W-K1 tephra could include Early as well as Middle Holocene assemblages. The sample sizes are shown in Table 15. AMS determinations obtained from these contexts are presented in Table 16. It should be stressed that on the basis of tephrochronological studies in the region (Machida et al. 1996; Torrence et al. 2000) the small assemblages recovered from under the W-K1 tephra will be earlier than the radiocarbon ages in Table 16, but material suitable for dating was not recovered from these contexts.

As shown in Tables 8-14, there are surprisingly few obvious differences between the Holocene and Pleistocene assemblages we studied. The lithic technology during both periods was focused around the manufacture of variously sized and shaped flakes, which form the largest component of all the assemblages (Table 11). Pleistocene knapping may have been less careful or accurate as indicated by the higher proportions of shatter, but differences in the representation of the various kinds of debitage are relatively minor. Secondly, it is interesting that flakes rather than nodules
were the basic core form in both periods (Table 12). In this way both technologies minimised the quantity of raw material that was transported because flake cores can also carry out many of the same tasks as the flakes they produce.

Thirdly, in both periods people mainly produced simple flake tools and applied very little retouch, although the proportion that was retouched was slightly higher during the Pleistocene (Table 13). Retouched artifacts known as stemmed tools are characteristic of the Holocene in this region (Araho et al. 2002; Torrence 2003), but these forms are relatively rare and were not recovered from excavated contexts in the local catchment of Kupona na Dari. A retouched flake discovered in the soil on Unit H (2Apb) is possibly the tip of a stemmed tool made on a prismatic blade, known as Type I (Figure 14; Araho et al. 2002; Rath 2000; Rath and Torrence 2003). As discussed previously this context may belong to the Holocene rather than the Pleistocene period.

Part of the explanation for the similarities in the Pleistocene and Holocene stone tool assemblages is that both these societies experienced little short-term subsistence risk. Consequently, they mainly utilised generalised tools made up of only a few components, regardless of whether they were exploiting wild or domesticated resources (Torrence 2001b). This strategy results in simple flake technologies, such as those used throughout prehistory in this region.

Despite the similarities, the admittedly small variations between the basic flake assemblages of the Pleistocene and Holocene periods in the study area may signify differences in land use. To begin with, raw material procurement in the Early-Middle Holocene was not the same as during the period of colonisation. Whereas all potential obsidian sources in West New Britain were exploited during the Pleistocene, the Early-Middle Holocene consumers concentrated on the Willaumez Peninsula outcrops (Baki, Gulu, Kutau/Bao) and focused almost entirely on the Kutau/Bao sources (Torrence 2004). One possible explanation for this change is that the scale of landscape use decreased through time, with groups settling down into smaller regions than were exploited when people first arrived. This might mean that people made special purpose trips to very specific obsidian sources.

A second possibility is that the focus on Kutao/Bao obsidian during the Early-Middle Holocene may also indicate the importance of ownership, territoriality, social networks and exchange ties at this time, as previously proposed (Torrence 2004; Torrence and Summerhayes 1997; Torrence et al. 1996: 219-20; Summerhayes et al. 1998:153). These aspects of behaviour may not have been emphasized to the same extent during the Pleistocene, possibly because population levels were considerably lower and/or obsidian was obtained through embedded procurement rather than through scheduled trips. Along these lines, it is interesting that the Pleistocene consumers focused mainly on water-rolled obsidian cobbles as a source of raw material. These could be collected from a wide range of secondary contexts. In contrast, during the later period, obsidian was mostly removed directly from the outcrops, as indicated by the presence of rough and shiny cortex (Table 8). The difference in source material may be related to the importance of ownership and exchange which led to a more systematic use of particular outcrops. On the other hand, other factors, including volume of use or availability of cobbles of an appropriate size may have also conditioned the selection of cobbles during the Pleistocene. If present, the development of regular exchange networks designed to provision people with useful raw materials, combined with the possibility that ownership was involved could indicate that people had a fairly stable relationship with regard to the regions that they occupied and used.

Other aspects of the Pleistocene and Holocene lithic assemblages suggest there were differences in the scale of landscape use and by inference in the nature of the mobility patterns. It is noteworthy that the Pleistocene assemblages have a much lower percentage of artifacts with cortex than the Holocene examples in our sample (Table 8). In addition, a slightly larger percentage of the flakes were retouched (Table 13) and the intensity of use as measured by the number of edges on complete artifacts with retouch or macroscopic edge damage is also higher in the Pleistocene assemblages (Table 14).

The relatively higher intensity of raw material use in the Pleistocene suggests that early colonisers visited the stone sources less frequently than did the Holocene inhabitants, possibly because they were exploiting a much larger range and found it difficult to return frequently. In contrast, since the mean weight of the artifacts discarded at Kupona na Dari is much larger than at the Holocene sites (Table 10) and the larger proportion of shatter indicates less care taken with knapping (Table 11), minimising raw material consumption as such was clearly not the major aim of the Pleistocene lithic technology. The creation of a lithic technology that employed multi-purpose artifacts (flakes) as both cores and tools and applied retouch to create effective edges suggests that prolonging the use life of the tool kit was more important during the Pleistocene than was conservation of raw material.

The type of lithic technology exhibited during the Pleistocene in the Willaumez Peninsula makes sense during a period in which people invested more effort in planning ahead and making sure that they were supplied with necessary tools and raw materials. In other words, this was a time when people were more concerned to avoid the risk of failing to have tools at hand. Such behaviour would make sense as part of a strategy when people were exploring a new landscape and/or when populations levels were low and so support mechanisms were scarce. It also makes sense in a region where lithic raw materials were widely dispersed or within land use patterns that kept people away from the sources for relatively long periods of time. It therefore seems likely that although groups were relatively mobile in both the Pleistocene and the Holocene, the early colonisers covered more space either on a daily or longer term basis. It must be stressed, however, that lithic technologies utilised within the Pleistocene and the Holocene are not
qualitatively different but represent varying positions along a single continuum.

Finally, if the density of artifacts recovered from these sites is a meaningful measure, the intensity of landscape use also differed through time. The number of artifacts recovered per cubic metre of excavated deposit (but not the weight) is considerably higher during the early and middle Holocene period than at Kupona na Dari (Table 10). These data may monitor a change in the later period to higher population densities, more intense use of the region, or a more expedient use of raw materials. Any or all of these possibilities, however, suggest a more locally oriented land use pattern during the Holocene than in the Pleistocene.

Comparisons with other regions

In a number of important and stimulating papers separately and together, Gosden (1993; 1995) and Allen (1995; 2000; 2003; Allen and Gosden 1996) have reconstructed changes in land use during the early colonisation of near Oceania, largely on the basis of material derived from excavations of rock shelters in New Ireland. In their model the first phase of settlement is characterised by high mobility fuelled by effective maritime transport. They propose that at this time people moved fairly frequently among rich patches of resources. In the second phase, beginning about 20,000 years BP, a decrease in mobility coupled with the transport of resources back to home bases is inferred. Although the Allen and Gosden reconstruction emphasises marine resources (although cf. Allen 2003), Spriggs (1997: 37-8) has made the important point that the knowledge and skills required for the effective exploitation of plant resources may also have been crucial in effectively exploiting new areas.

The Gosden and Allen scenario of change from higher to lower mobility combined with different strategies for provisioning is quite convincing both from a theoretical and an empirical point of view. It is worth stressing, however, that their synthesis is based on the excavation of small samples from very few sites, the large majority of which are rock shelters and many of which have not been fully published. The model is also heavily biased by data obtained from sites on New Ireland where the relatively stable nature of the coastline has contributed to the preservation of appropriately aged deposits.

It is perhaps not surprising, then, that when one moves beyond the pioneering excavations of rock shelters in New Ireland to open contexts at Yombon and Kupona na Dari in New Britain, the nature of tool manufacture and use are different, possibly indicating variability in the nature of colonisation. Although Yombon and Kupona na Dari share some similarities in the preparation of cores or tools at the source prior to their transport elsewhere, there appear to be differences in the use of local as opposed to non-local raw materials and the degree to which the assemblage was focused on portability and extended use life of the core tools. The problem is that the Yombon assemblage was found close to the quarry, whereas Kupona na Dari is located at a considerable distance from the sources. Also the very small size of the Yombon assemblage limits the inferences that can be made. Nevertheless, the fact that people have already found the Yombon chert sources by 35,000 BP indicates that they were highly flexible in terms of their subsistence patterns and well adapted to both tropical forest and coastal resources. We infer that they were also highly mobile.

Only Kupona na Dari has produced evidence for the importation of resources from a reasonable distance prior to 20,000 BP and the exploitation of a large area (at least 70 kilometres across) as signified by the sources of the imported obsidian. In addition, other deviations from late Pleistocene sites in the Bismarck Archipelago in stone tool technology cannot be easily accounted for by the same strategies of tool reduction being applied to different raw materials, as proposed by some authors (e.g. Allen 1993: 146; Spriggs 1997: 59). It seems more likely that varying strategies were implemented, probably because the makers were trying to achieve different results, particularly in terms of their time and energy scheduling.

A second bias that reflects the heavy dependence on sites in New Ireland is an implicit assumption that the Pleistocene landscape was relatively constant, with the exception of variations in sea level. Models based on New Ireland, however, may not be appropriate for understanding how humans coped with highly unstable volcanic islands such as Manus and New Britain. Changes in the use of obsidian at Pamwak in Manus and elsewhere in the Bismarck Archipelago demonstrate that volcanic activity can have major impacts on human patterns of resource use and possibly of social strategies to cope with variations in raw materials (e.g. Ambrose et al. 1981; Torrence et al. 1996; Fredericksen 1997). Although most of these well documented changes occurred at the end of the Pleistocene and within the Holocene, they provide examples for the types of landscape instability that people in certain areas might have faced during the early period of colonisation. As presented earlier in this paper, the geological history of Kupona na Dari and the fission track dates for the obsidian demonstrate that during the Pleistocene populations experienced major volcanic events relatively frequently and also co-habited with the smaller dustings that led to thick tephra accretions. Clearly the Willaumez Peninsula has long been a region punctuated by severe natural disasters as well as less radical but nevertheless significant volcanic agents of landscape change.

The extensive nature of land use fuelled by high mobility which can be inferred from the lithic assemblage at Kupona na Dari conforms to the Gosden and Allen colonisation model. This strategy makes good sense during the early stages of occupation within an unfamiliar landscape. On the other hand, the analysis of the Kupona na Dari stone tools demonstrates that, as at Yombon, these groups had different strategies for managing their lithic resources than those exhibited in the New Ireland assemblages. Variations between New Ireland and New Britain could be due to the
impacts on the widely spaced resources that we hypothesise they were exploiting. It is quite likely that the relatively frequent events and the long periods of tephra accumulation lowered the productivity of the rainforest. If so, a sensible response would have been to expand the size of the area which was exploited. In fact, the combination of mobility and careful planning were probably quite important in ensuring success in an unstable environment punctuated by volcanic events.

Conclusions

Our multi-disciplinary research on the geological and archaeological history of the Kupona na Dari site makes an important contribution to understanding when and how the Bismarck Archipelago was first colonised by human groups. The original proposal that the presence of numerous layers of tephra overlying the earliest artifacts and the advanced state of the weathering indicate a very old age for the site (Torrence et al. 1999) has been confirmed by additional detailed stratigraphic and geochemical studies of the sediments and manuports within them. Luminescence dating has provided useful age determinations that, if correct, suggest that human activity at the site is as early as other Pleistocene sites currently known from New Britain (Pavlides and Gosden 1994) and within the range of the oldest dates for human presence in New Ireland (cf. Allen 2000; Leavesley et al. 2002). These dates are given support by the relatively young fission track dates for the formation of the Kutao/Bao obsidian and its absence in the lowest levels. A future priority is to obtain direct fission track dates on artifacts to confirm that they were derived from the older of the Gulu and Baki outcrops.

Our proposals for the multiple sources of colonisers within the Bismarck Archipelago and about the nature of land use in the Willaumez Peninsula need to be tested further through additional research and fieldwork. The problem of how to obtain reliable and precise chronometric dates from heavily weathered contexts in our region appears to be intractable at present. New methodologies are required. The potential of fission track dating of the obsidian sources and artifacts has not yet been fully exploited and could be enhanced with additional geological fieldwork. If humans arrived on the Willaumez Peninsula before some of the sources had been emplaced, then they experienced major landscape instability and change. Due to ongoing volcanic activity, some regions may have been dangerous and/or devoid of useful plant and animal resources. To interpret the archaeological record, we need to know more about the risks that the new colonisers faced.

Although the discovery of this important site was fortuitous, we now know from other sections and soundings in the local area that there is some potential for further investigation of human land use patterns during the Pleistocene in this region. Further research in these deposits would be quite difficult due to the large overburden of Holocene and Pleistocene tephras and the problems of
chronometric dating. Nevertheless, the opportunity to extend our knowledge about how early human populations coped with, settled into, and ultimately profoundly altered the wide range of environments they encountered within the Bismark Archipelago should make the effort worthwhile.

**Acknowledgments**

Fieldwork was funded by the Australian Research Council, Pacific Biological Foundation and New Britain Palm Oil, Ltd. and supported by the National Research Institute (PNG), PNG National Museum and Art Gallery, University of Papua New Guinea, Mahonia Na Dari Research Station, Walindi Resort, West New Britain Provincial Cultural Centre, Australian Museum. Torrence was supported by an Australian Research Council Senior Research Fellowship. Funds for the PIXE-PIGME analyses were provided by grants from AINSE. We are also grateful to the following for their assistance during the fieldwork: Nick Thompson, Mike Hoare, NBPOL staff at Numundo Plantation and especially Bob Wilson. Peter White’s surveying skills were essential for tracking the stratigraphy across the sections and preparing the site maps and sections for publication. Special thanks to our hard working excavators: Sarah Bryne; Cosmos Coroncos; Vincent Kewibu; Ken Mulvaney; Daniel Perceval; Jim Specht; and Peter White. Glenn Summerhayes and Ivo Orlic converted the PIXE-PIGME results into obsidian source attributions. Michele Fullagar gave advice on use wear analysis. Carol Lentfer conducted the clay mineralogical analyses. Richard D’Ath handled the PIXE-PIGME data. Bukitude, R. 1998. Fission track dating of obsidian source: an example of an intact source. *Radiation Measurements* 33: 105-107.

**References**


Appendix I

Kupona na Dari Soil Profile (described in moist conditions)

2Apb 0-6 cm (Buried soil on H)
greyish brown clay loam; sandy, plastic, very friable; moderately developed 0-50 mm blocky structure; < 0.1%, > 1 mm vesicular pores; few 1-2 mm horizontal and vertical roots; indistinct, smooth boundary because of pods of younger pumiceous tephra from above.

2Bt 6-77 cm (Dark brown H)
strong brown at base and very dusky red (2.5YR 2.5/4) at top; clay; < 5% sub-rounded coarse fragments up to 70 mm; very sticky, very plastic, very firm; strongly developed 10-100 mm blocky breaking to crumb structure; thin waxy chocolate coloured argillans on larger aggregates and in voids and root channels; > 2%, 1-5 mm tubular pores; few 1-10 mm vertical and horizontal, fine and coarse roots; gradational, smooth boundary with large lenses and vertical channels up to 15 cm across of younger pumiceous tephra from above extending down into this horizon; rare sub-rounded stones up to 70 cm.

3Bt 77-107 cm (G)
dark reddish brown (5YR 3/4) aggregates surrounded by yellow-brown matrix; clay; < 5% rounded 20-50 mm-sized anthropogenic stones; very sticky, plastic, firm; moderately to strongly developed 20-100 mm columnar breaking to 10-20 mm blocky structure; thin waxy argillans, more especially in voids and channels; many more mafic and creamy weathered sand grains than in horizon above; < 0.1%, 2-5 mm tubular pores; few < 1 mm vertical roots; diffuse, gradational boundary.

4Bw 107-167 cm (F)
dark reddish brown (5YR 3/3-3/4) clay; very sticky, very plastic and friable; strongly developed > 100 mm columnar and blocky breaking to strongly developed 10-20 mm nutty structure; distinct, patchy and unusual mangan coatings 0.1-0.5 mm thickness (10-50%); 0.1-0.5%, 1-5 mm tubular pores; few 1 to > 5 mm horizontal roots; indistinct, smooth boundary but few rounded weathered stones up to 40 mm diameter forming a stone line at base.

5Apb 167-173 cm (Upper E)
dark reddish brown (5YR 3/3) with olive and dark yellow brown (anthropogenic) roots: clay; very sticky, very plastic and friable; strongly developed 20-100 mm blocky breaking to strongly developed 10-20 mm nutty (60%) and crumb (40%) structure; 0.5-2%, < 1 mm sized pores; few 1-20 mm vertical and horizontal roots; distinct, smooth boundary.

6Bw 173-178 cm (Lower E)
dark reddish brown (5YR 3/4) to reddish brown (5YR 4/4), clay with detectable sand; 15-35% rounded 5-10 mm orange lapilli; very sticky, very plastic and friable; strongly developed 10-20 mm nutty breaking to moderately developed 1-2 mm nutty, crumb and granular structure; 0.5-2%, < 1 mm sized pores; few < 1 mm vertical roots; distinct, smooth boundary but horizon discontinuous because pumice lapilli are preserved in discontinuous pockets; immediately beneath on lower contact was an obsidian artifact.

7Apb 178-190 cm (D3)
dark reddish brown (5YR 3/3-3/4) clay (one tabular stone in upper part 50 mm long with 5 mm weathering rind and grey centre); very sticky, very plastic and firm; strongly developed 20-50 mm blocky breaking to strongly developed 2-10 mm nutty (80%) and crumb (20%) structure; > 2%, < 1 mm tubular pores; few 1-2 mm vertical roots; distinct and smooth basal contact.

8Bw 190-197 cm (D2)
light yellow-brown sandy loam; discontinuous compacted ash forming coarse fragments (‘cream cakes’); very strong; massive breaking to single grain; 0.5-2%, < 1 mm tubular pores; few < 1 mm vertical roots; sharp, discontinuous but wavy boundary.

9Bw 197-205 cm (D1)
yellow-brown, loam (one lapillus observed); friable; moderately developed 10-20 mm blocky breaking to 2-5 mm nutty and crumb structure; 0.5-2%, < 1 mm pore size; few < 1 mm vertical roots; distinct and smooth boundary.

10Apb 205-226 cm (Soil on C)
very dusky red (2.5YR 2.5/4) to dark reddish brown (5YR 3/4) clay; 5-15% sub-rounded, strongly weathered coarse fragments (one spherical to ovate stone up to 60 mm across, most < 20 mm); very sticky, very plastic and friable; strongly developed 20-100 mm blocky breaking to strongly developed 10-20 mm nutty (80%) and granular (20%) structure; 0.5-2%, 1-2 mm tubular pores; many < 2 mm vertical roots; gradational, smooth boundary.

10Bw 226-244 cm (Middle C)
dark reddish brown (5YR 3/3-3/4) clay; very sticky, very plastic and friable; strongly developed 20-100 mm blocky breaking to moderately developed 10-20 mm nutty (70%) and crumb (30%) structure; 0.5-2%, < 1-2 mm tubular pores; few < 1 mm vertical roots; distinct and smooth boundary.

11Bw 244-261 cm (Tephra C)
brown to dark brown (7.5YR 4/4) loamy sand; abundant (>75%), sub-rounded to sub-angular coarse fragments; friable; weakly developed 20-50 mm blocky structure breaking to single grains; > 2%, 1-2 mm interstitial pores; very few 2-5 mm horizontal roots; distinct, smooth boundary with a thin manganese placic horizon.

12Apb 261-284 cm (Upper B)
dark reddish brown (5YR 3/4 ) clay; very sticky, very plastic, friable; strongly developed 20-50 mm blocky breaking to strongly developed 10-20 mm nutty (80%) and crumb (20%) structure; >2%, 1-2 mm tubular pores; few 1-2 and >5 mm vertical roots; smooth boundary.
Appendix 2

Methods used for Fission Track Dating

The FTD method relies on the property of vitreous (and other dielectric) materials to register the interaction with heavily ionizing particles such as fission fragments via a damage of their structure, thus causing the formation of the so-called latent track. Samples to be dated usually contain uranium impurities of the order of a few ppm and it is this element which undergoes spontaneous fission. The FTD method is based on the well known age equation of radioactive decay:

\[ N_s = \frac{\lambda_f}{\lambda} N_{^{238}U} (e^{\lambda t} - 1) \]

where \( N_s \) is the number of \(^{238}\)U decays by spontaneous fission, \( \lambda_f \), \( \lambda \) are the (known) spontaneous fission and total decay constants of \(^{238}\)U, and \( N_{^{238}U} \) represents the number of \(^{238}\)U atoms present in the sample.

To find out \( t \), the age of the sample, one must therefore determine \( N_s \) and \( N_{^{238}U} \). According to the FTD method, \( N_s \) is obtained by counting the number of spontaneous fission tracks accumulated in the life span of the sample per unit area. This is achieved by obtaining thin and sufficiently transparent slices from the samples, mounting them in epoxy resin, carefully polishing and etching them in a strong acid reagent, such as a 20% solution of HF, and finally observing the etched tracks with an optical microscope. Similarly, \( N_{^{238}U} \) is deduced by counting the number of induced fission tracks per unit area obtained in the sample once this is bombarded with a known thermal neutron fluence at a nuclear reactor.

The analysis used the TRIGA Mark II Reactor of the LENA laboratory of the University of Pavia, Italy. The neutron fluence, \( \phi \), was equal to $1.38 \times 10^{13}$ n/cm$^2$.

By using the above approach, \( N_{^{238}U} \) is given by the following relation:

\[ N_{^{238}U} = \frac{N_i \eta}{\sigma \phi} \]

where \( N_i \) represents the number of induced fission tracks, \( \eta \) is the \(^{238}\)U/\(^{235}\)U isotopic ratio, \( \sigma \) is the thermal neutron fission cross section and \( \phi \) is the neutron fluence.

So the age of the samples is obtained by the following relation:

\[ T = \frac{1}{\lambda} \ln \left( \frac{1 + \frac{\lambda_f}{\lambda} \eta_0 \rho_s}{\lambda_f \eta_0 \rho_i} \right) \]

where \( \rho_s \) and \( \rho_i \) are the spontaneous and induced fission track densities.