16 What makes a disaster? A long-term view of volcanic eruptions and human responses in Papua New Guinea

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VULNERABLE OR RESILIENT?

Modern scholars of natural hazards predict that in developed countries with complex, state-level social organisations, disasters can be mitigated through aid programmes, redistribution of resources, etc., whereas egalitarian societies with smaller social networks have a wide range of responses, but are more likely to fail to adapt and will abandon their homeland (e.g. Chester, 1993: table 8.4). Anthropologists have often painted quite a different picture in which traditional societies are and have been very resilient and adaptable in the face of extreme climatic events. In their view modernisation has often undermined capable traditional means for coping with hazards. They therefore argue that the vulnerability of indigenous groups witnessed in recent disasters is a result of their marginalisation through globalisation and externally forced changes (e.g. Oliver-Smith, 1996: 312–14).

A comparison by Sheets *et al.* (1991; cf. Sheets and McKee, 1994) of the prehistory of the Arenal Valley in Costa Rica with that of El Salvador and Panama substantiates the wider anthropological view that simple societies are quite resilient or even adapted to environmental hazards. Despite the occurrence of ten volcanic eruptions in Costa Rica during a period of 4,000 years, the archaeologists have reconstructed a quite remarkable picture of cultural stability. In contrast, they concluded that a major eruption of Ilopango volcano in El Salvador had disastrous consequences for Mayan civilisation and the Baru volcano severely undermined the prehistoric Bariles chiefdom society in Panama. According to Sheets *et al.* (1991: 446), simpler societies 'appear to be more resilient in the aftermath of explosive eruptions' than more complex societies because the latter are dependent on a built environment and economies characterised by 'occupational specialisation, redistribution, and long distance trade routes'. These conclusions are limited, however, because the authors do not adequately account for differences in the severity of the events they have compared.

One of the problems with trying to develop a general understanding of the impact of extreme events on human societies is that scholars often focus on particular cases which we call 'disasters'. Since a disaster is defined as a situation for which there is a failure to cope, only one possible outcome is considered. Consequently, we know far too little about the whole range of situations, including those in which there is little if any impact. In addition, the focus on the disaster itself has drawn attention away from how societies recover and the very long-term, follow-on effects of the events. The focus only on hazards that have had catastrophic consequences for societies therefore makes it difficult to understand the broader relationships between the nature of extreme climatic events and human responses. Furthermore, this approach has led to an overemphasis on the vulnerability of societies as the most important variable and has ignored differences in the character of the natural events that trigger disasters. I think that this one-sided view combined with the inattention to variability has led to the paucity of theory to explain why disasters take place in particular social contexts and not in others (cf. Oliver-Smith, 1996: 320).

In this chapter I propose that archaeological case studies can make an important contribution to a broader understanding of what does and does not make a disaster. They can also provide data that enable a more careful consideration of the different kinds of consequences that follow from variations in social and environmental contexts. By examining the history of an area which has experienced a number of natural events with differing levels of severity and that have occurred over a relatively long time period, one can compare and contrast the impacts on a range of societies within the same general environmental setting. In this approach the emphasis on 'disaster' as the only outcome is diverted to a more detailed assessment of variation in the nature of the impacts on human groups. I illustrate the value of research of this type by summarising the findings of an archaeological investigation into the effects of a series of volcanic eruptions over at least 6,000 years in the province of West New Britain in Papua New Guinea (Fig. 16.1).

The archaeological case study also raises some important points about the theory and methodology of disaster research. It is shown that problems confronted in the archaeological analysis, particularly in terms of the methods for measuring the severity of events and for monitoring impacts on societies, are as yet not fully developed and need more careful consideration. Second, I argue that we need to look at a wider range of factors when evaluating why some events led to disasters and others did not. Not only are social variables important, as stressed by modern hazard managers and Sheets *et al.* (1991), but more care needs to be taken to understand the impacts on the natural environment and the follow-on effects over the longer term. Finally, the difficult issue of choosing the appropriate temporal and spatial scales both for monitoring impacts and for understanding how societies recover from disasters is discussed. Although solutions are not found for all the limitations identified, the long-term perspective derived from archaeological case studies is clearly shown to provide new insights into how disasters can be defined and monitored.

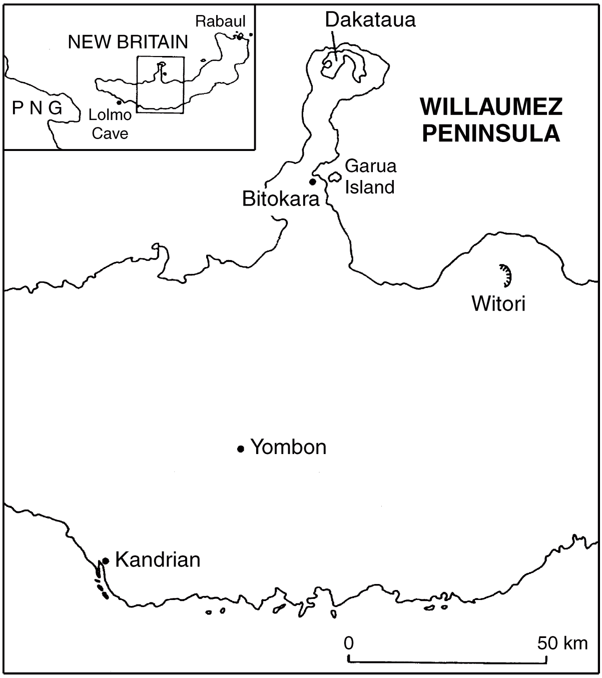

Figure 16.1 Location of volcanoes and relevant archaeological sites in West New Britain

WEST NEW BRITAIN CASE STUDY

A collaborative archaeological research project based in the province of West New Britain in Papua New Guinea (Fig. 16.1) has examined the long-term consequences of disasters from volcanic eruptions on various forms of social and economic organisation. The research illustrates the benefits and limitations of studying the effects of natural disasters on the prehistory of a region. A more detailed presentation of our results is presented in Torrence *et al.* (2000) and Torrence *et al.* (1999) (also cf. Torrence, 1993; Torrence and Webb, 1992; Torrence and Boyd, 1996, 1997). The West New Britain case study is important because it raises a number of issues concerning the relevant variables and scales of analysis that are necessary for understanding why some events become disasters.

Research by Sheets and his colleagues (Sheets *et al.*, 1991; Sheets and McKee, 1994) in the Arenal Valley, Costa Rica, sets the scene for my discussion of volcanic activity in West New Britain, Papua New Guinea. Their work has admirably demonstrated how archaeological studies of disasters can benefit a broader understanding of human and environmental interactions. By examining a very long period of time within a single area, one can compare and contrast the effects of a series of natural events on societies. In case studies of this type some variables can be considered as constant since the groups would have inhabited a roughly similar environment and are likely to have shared cultural traditions. Sheets *et al.* (1991) were unable to link the incidence of volcanic events to major cultural changes and therefore concluded that in this case the societies were extremely resilient.

Although they may be correct, I feel that they have not adequately considered the relatively low severity of the eruptions they have studied. If the impacts of the Arenal eruptions were not very serious, then there would have been no reason for change, regardless of the nature of the society at the time. Indeed, this seems to have been the case. The volume of downwind tephra for the nine eruptions averaged 0.16 km^3 and was never larger than 0.3 km^3 (Melson, 1994: 39) and the stresses on vegetation are assumed to have 'become small at 20 km to 30 km' from the volcano (Sheets, 1994: 325). In contrast, Sheets *et al.* (1991) propose that the Ilopango eruption had a greater impact because complex societies are more susceptible to disasters. However, the Ilopango eruption, with a volume of 30 km^3, was many orders of magnitude larger than the Arenal eruptions. It had a very great environmental impact and destroyed vegetation and human constructions over thousands of square kilometres (Sheets, 1979). It therefore seems likely that the relative scales of the natural hazards discussed by Sheets *et al.* (1991) played at least as much a part in causing the different outcomes as did the variation in the social organisation of the groups affected by the volcanic eruptions.

The West New Britain study has also compared the social and cultural effects of events with varying degrees of severity, although all the eruptions were considerably larger than those of Arenal. As in Costa Rica the fairly egalitarian societies of Papua New Guinea were also very resistant to major change despite facing potentially much more serious catastrophes, but there was nevertheless considerable variability in how these societies responded to the different events. In some cases the volcanic eruptions caused serious human disasters, whereas for others the effects were either less problematic or, when viewed over a long time span, were not disasters at all. Although the data demonstrate that vulnerability is important for understanding disasters, the long-term archaeological studies illustrate that the nature of the triggering factor also causes variation in human responses. This seemingly obvious fact appears to have been overlooked in some studies of disasters. As illustrated below, then, the first step in analysing the impacts of a severe natural event is to assess its severity independent of its effects on cultural processes.

Severity of eruptions

Whereas volcanic eruptions may have had disastrous effects on human populations, they can have enormous benefits for archaeological research. The tephras from these short-lived, specific events provide distinctive marker beds to establish a relative chronology and can often be applied to a very large region (e.g. Machida and Sugiyama, Chapter 17, this volume; Dugmore, 1989; Sheets and Grayson, 1979; Pilcher and Hall, 1996; Sheets *et al.*, 1991; Sheets and McKee, 1994; Zeidler and Isaacson, 1999). Using a combination of stratigraphy, macroscopic properties, refractive indices, and SEM microprobe geochemical analysis, it has been possible to match a number of tephras found in archaeological contexts in West New Britain with their source volcano and specific eruption (Machida *et al.*, 1996; Torrence *et al.*, 2000). We can therefore directly correlate the stratigraphy of sites on the north coast in the Willaumez Peninsula area (e.g. Torrence *et al.*, 1990; Specht *et al.*, 1991; Torrence *et al.*, 1999) with those in the interior (e.g. Yombon) and south coast of the island (e.g. Lolmo cave) up to 100 km away (Gosden *et al.*, 1994; Pavlides, 1993; Pavlides and Gosden, 1994) (Fig. 16.1). In addition, a combination of geological and archaeological research has yielded a relatively large number of radiocarbon assays which can be used to establish fairly accurate dates for many of these eruptions (cf. Torrence *et al.*, 2000; Machida *et al.*, 1996).

To date our research has concentrated on five major eruptions from the two volcanic centres of Witori and Dakataua (Fig. 16.1). Their characteristics are summarised in Tables 16.1–16.3. In the northern part of the Willaumez Peninsula at Garua Island and Bitokara, Witori tephras from W-K1 at 5900 BP, W-K2 at

Table 16.1 Summary of major Holocene volcanic events in West New Britain (based on Machida *et al.*, 1996; Torrence *et al.*, 2000)

Eruption	*Date BP (Cal. years)*	*Volume (km³)*	*Spatial scale (Rank, 1 is highest)*	*Type*
Dakataua volcano				
Dk	1,000	10	4	Phreatomagmatic, plinian, ignimbrite forming
Witori volcano				
W-K4	1,400	6	3	Phreatomagmatic, plinian, ignimbrite forming
W-K3	1,700	6	3	Plinian
W-K2	3,600	30	1	Phreatomagmatic, plinian, ignimbrite forming
W-K1	5,900	10	2	Plinian, ignimbrite forming

Table 16.2 Average thickness (m) of airfall tephra in archaeological sites

	Locality			
Eruption	*Numundo*	*Garu*	*Garua/Bitokara*	*Yombon*
Dakataua	Absent	Absent	0.75	Absent
W-K3/4			0.20	0.15
W-K4	0.35	0.35		
W-K3	0.50	0.30		
W-K2	1.00	0.80	0.50	0.35
W-K1	0.30	0.40	0.50	0.35

Table 16.3 Comparison between severity of event and cultural response

Severity	*Eruption*	*Abandonment (years)*
1	W-K2	250–800
2	W-K1	1,000–1,600
2	Dakataua	0
3	W-K3	0–300
3	W-K4	

3600 BP, and a mixed layer containing tephras from W-K3 and W-K4 dating to around 1700–1400 BP are well preserved. At Numundo and Garu plantations farther south and nearer the source volcano the full W-K (1–4) sequence plus 2–3 tephras belonging to the later W–H series from Witori is well preserved. These younger tephras are not included in this discussion because they have only recently been recognised in the archaeological record. Although in some cases they may have had significant impacts on human settlement, only a small part of the study area was affected by these eruptions (Torrence *et al.*, 1999). In contrast to the Witori events, tephra from the Dakataua eruption of *c.*1100 BP is restricted to the northern part of the Willaumez Peninsula.

Using a number of indices, including total volume of material ejected (Table 16.1), average depth of tephra in sites in the Willaumez Peninsula and Yombon regions (*c.*80 km to the south) (Table 16.2), and the spatial extent of the tephra (relative ranking with '1' as the largest are given in Table 16.1; cf. isopach maps in Machida *et al.*, 1996; Boyd *et al.*, in press), a relative ranking of the overall severity of these volcanic events can be obtained. These are presented in Table 16.3, where '1' represents the most severe case. The index of severity provides a general measure for comparing the postulated effects of each eruption on the prehistoric human population. In general terms the W-K2 eruption was by far the largest and would have destroyed virtually all the vegetation within most of the eastern two-thirds of West New Britain. The W-K1 event would also have devastated a very large area, although it was emplaced during the wet season and was washed off much of the landscape shortly after the eruption. The highly variable thicknesses for the W-K1 tephra in Table 16.2 reflect the fact that most of the deposits we observed were reworked and redeposited. In contrast, the W-K3 and W-K4 eruptions produced smaller amounts of tephra that would have had more localised effects. The Dakataua eruption produced a great deal of material but its impacts would have been quite restricted in space.

Assessing impacts

The next stage of the analysis is to compare severity (in the West New Britain case using the severity index in Table 16.3) with some measure of how these events affected human settlement. There are several ways to conceptualise the impacts on humans. For example, Sheets *et al.* (1991) compare the timing of cultural changes in terms of phase or period boundaries with the date of eruptions. After both the Ilopango and Baru eruptions, the groups which reoccupied the areas were sufficiently different to warrant the assignment of a new cultural phase, but in the Arenal area the phases are not delimited by a volcanic event. They therefore conclude that the Arenal societies were more resistant to change. Changes in material culture in West New Britain are summarised in Table 16.4. In this case there is one major cultural boundary which is associated with a volcanic eruption and one that is not. The clearest association with material culture change and volcanism is the W-K2 eruption. After this event a very distinctive type of chipped stone tool disappeared and pottery appeared for the first time. In contrast, the other major change in material culture, the disappearance of pottery *c.*2,000 BP, is not associated with a particular eruption but is probably due to internally generated social change (cf. Specht and Gosden, 1997: 190).

One problem with phase boundaries is that they are largely established by the nature of material culture: e.g. presence or absence of key artefact types or styles. These may not adequately reflect changes which took place in cultures like those in West New Britain, for which only a relatively simple repertoire of durable material culture has been preserved in the archaeological record. In evaluating the nature of impacts, one should probably consider a wide range of behaviour. For example, in the West New Britain case settlement and subsistence patterns changed in subtle ways throughout the past 6,000 years (Torrence *et al.*, 2000; Torrence and Stevenson, 2000), but this type of evidence is rarely used to define cultural boundaries.

Another measure of impact is the length of time that a region is abandoned after an extreme natural event. Abandonment is an important measure because it signifies a total failure of the cultural group to adapt to the situation. It is therefore a good reflection of the seriousness of the impact. In many cases the reason why there is a cultural phase boundary after a major environmental event is that people left the area and, after some period of time, a much altered or completely different group brought a new material culture to the area.

When severity of the volcanic eruptions in West New Britain is compared with human impact defined as length of abandonment (Table 16.3), there are some surprising results. The data show that the length of abandonment decreased through time irrespective of the size of the volcanic explosion that caused it. For example, the most severe event, the W-K2 eruption, is not associated with the

Table 16.4 Temporal patterning in material culture in West New Britain

Date BP	*Material culture*
?>5,900–3,600	Stemmed obsidian and chert chipped stone artefacts
3,600–2,000	Lapita style pottery, unretouched obsidian flakes and flake cores, small groundstone axes (extremely rare)
2,000–present	Imported pottery (extremely rare) unretouched obsidian flakes and flake cores, large groundstone axes

longest period of abandonment. Second, although the Dakataua eruption must have been a catastrophic event, since these are the deepest tephra deposits in the northern part of the Willaumez Peninsula, radiocarbon dates from beneath and above the tephra are indistinguisable (Torrence *et al*, 2000: table 2). Viewed from an archaeological perspective, then, Dakataua did not cause a disaster.

The data for W-K3 and W-K4 are harder to interpret since these tephras have been mixed together in a relatively thin stratum on Garua Island and at Yombon and the dates for these eruptions (1700 BP, 1400 BP), particularly W-K4, are based on very few radiocarbon determinations (Machida *et al.*, 1996). Nevertheless, the eruptions seem to have had minimal effect over much of West New Britain. Sites appear to have been abandoned at Yombon several hundred years before W-K3 and were not occupied until shortly after W-K4 (Torrence *et al.*, 2000). On Garua Island there is a change in land use beginning about 2000 BP such that artefacts were deposited in fewer places than previously and after 1600 BP only two hilltops have evidence of use. Although parts of the island may have been abandoned, the site of FSZ continued to be actively used until the Dakataua eruption. Furthermore, at FSZ the W-K3 and W-K4 mixed tephras found elsewhere have been removed by human activities. Seemingly, then, W-K3 and W-K4 were not disasters on Garua Island.

It seems likely that the people who left Garua resettled on the nearby mainland since Bitokara is reoccupied about the same time as people left Garua and use of this place expands greatly after the time of the W-K4 event (Fig. 16.1). A larger set of chronometric dates is needed to be completely certain that the changes in settlement in the interior at Yombon and on the Willaumez Peninsula were not causally related to the W-K3 and W-K4 events. It seems more likely, however, that the population movements reflect the expected pattern for people using a low-intensity system of shifting cultivation (Torrence and Stevenson, 2000).

A very different pattern of impacts has been recorded at Numundo and Garu plantations further to the south and nearer the source volcano (Fig. 16.1). The results of limited test pitting indicate that this region was abandoned after the W-K3 eruption and, with the exception of very rare sparse artefact scatters, there is no evidence of reoccupation before the W-K4 eruption approximately 300 years later. In other words, the impact of the W-K3 eruption was as almost as severe in these areas as was the considerably larger W-K2 event. What is also interesting is that there is no evidence in the form of a noticeable increase in number of places used or density of artefacts that the people fleeing this disaster at Numundo and Garu sought refuge in the interior or further up the peninsula, where the impact appears to have been minimal. In contrast, after the W-K4 eruption there was a significant increase in the number of people and the intensity of land use at Numundo and Garu. Unfortunately, we do not have dates to assess exactly when the reoccupation after the W-K4 event occurred. This is important because the considerable intensity of land use recorded at Numundo and Garu may indicate the presence of refugees from the Dakataua eruption, which would have caused serious problems for these populations (Torrence *et al.*, 1999).

INTERPRETING IMPACTS

The brief summary of the Witori and Dakataua events demonstrates that there is no simple, direct relationship between the severity of the volcanic eruptions and the cultural responses in West New Britain. If we accept Sheet *et al.*'s (1991) findings, then the explanation for variation in responses should be accounted for by differences in social organisation. The data discussed below illustrate that the situation is much more complex. In my view one needs to take a more comprehensive look and consider a much broader range of factors that would have affected the way human groups were able to respond to the volcanic eruption. To begin with, environmental damage needs to be assessed. In the following discussion I consider gross changes in topography and physiography as well as damage to vegetation and processes of forest regeneration. Second, in order to assess cultural vulnerability, variation in economic and social organisation is considered.

Landscape changes

Volcanic eruptions can cause a total alteration of the landscape, especially near the source. Away from the centre of activity the major changes in topography are caused by airfall tephra. The emplacement of tephra up to 50 cm thick over a landscape will significantly alter the overall topography (i.e. by smoothing over rough surfaces, decreasing slopes, infilling valleys, changing of drainage patterns etc.), which has implications for human settlement, especially when combined with the erosional processes that follow (Boyd and Torrence, 1996). In addition to impacts on raw material extraction (Torrence *et al.*, 1996) and subsistence patterns, these changes can markedly affect the social and sacred landscapes so that, for example, 'special' places, trails and territorial markers are no longer recognisable and/or lose their meaning. The main changes in behaviour due to landscape alteration that we have traced relate to the creation of beaches and in places an extensive coastal plain (cf. Gosden and Webb, 1994). On Garua Island the emplacement of the W-K2 tephra created a new strip of land surrounding parts of the island and subsequent settlement focused on the new coastal plain before moving into the uplands (Torrence and Boyd, 1997; Torrence and Stevenson, 2000).

At Numundo Plantation changes in coastal topography had more profound effects on settlement. From our very preliminary survey work, we can track the evolution of the current coastal plain during the past 6,000 years from shallow water to dry land as a result of infilling from the Witori W-K1–4 airfall tephras and deposition of additional tephras eroded from the surrounding hillsides. As the plain filled in, the number of ecozones (e.g. shallow water, reef, mangroves, swamp, lakes, etc.) expanded after W-K2 and then declined after W-K3. As a consequence, the intensity of human use shifted from dispersed over the whole area (pre-W-K2), to concentrated near the coast (post-W-K2), and then to a mixed use of foothills for settlement and coastal plain for agriculture (post-W-K4). It seems likely that the long abandonment period after the W-K3 eruption in this region may have resulted from the destruction of many of the productive shallow-water swamps and mangroves. In contrast, one factor in the marked increase in intensity of land use after W-K4 might have been the expansion of dry, low-lying areas suitable for agriculture as a consequence of the emplacement of the tephra (cf. Torrence *et al.*, 1999).

Regeneration

The speed and nature of forest regeneration should be critical in determining the potential for human recolonisation of an area after a volcanic eruption. The length of time for complete regeneration depends on the extent of destruction, which in turn is caused by the chemical composition, physical properties (e.g. grain size, porosity) and depth of the tephra. Airfall tephra with depths up to 50 cm, as in the case of the W-K1, W-K2 and Dakataua events, would have totally annihilated the ground cover and stripped most, if not all, of the canopy of its leaves and branches (Blong, 1984: 316–25). A recent case study of the 1994 Rabaul eruption found that in depths less than 20 cm, trees were defoliated but many plants were able to regenerate from suckers and roots, whereas tephra greater than 50 cm caused severe problems. Replanting was also difficult in areas of thick tephra deposits because of 'calcium, phosphorous and potassium deficiencies, high salt concentrations in the tephra, low nutrient holding capacity, and absence of a balanced soil ecology' (Lentfer *et al.*, in press). In places where the tephra fall was 1–15 cm there was good recovery of gardens once the rains had come. In some cases the regrowth was extremely lush because of the added nutrients derived from the decayed plant matter buried under the ash (*ibid.*).

On the whole, one can predict that the length of time for recovery would be directly correlated with the severity index I have used to compare the West New Britain eruptions, since it was calculated in terms of both the depth and areal extent of the tephra. Spatial extent of the destruction is critical because recolonisation of vegetation depends on sea, water and animal transport of plant propagules. Given the history of recolonisation on Krakatau – such that a rainforest currently stands on islands where all living matter had been completely obliterated in 1883 (Thornton, 1996), one would expect that 100 years would have been adequate for full forest cover even after the most severe eruptions, although the inland regions might have required a bit longer because of the increased distance from seed banks.

Although tropical forests can regenerate quite quickly, the types and variety of species present may vary widely because succession has a very significant random element to it. For example, Krakatau may be totally reforested today, but the number of species is quite low compared to before the eruption and, due to the vagaries of history, a very different suite of both animal and plant species has recolonised the various island remnants of the original caldera (Thornton, 1996). In contrast, in their study of revegetation on Vulcan volcano at Rabaul, Lentfer *et al.* (in press) found that the composition of the early plant colonisers was very similar to that recorded for Krakatau, suggesting some measure of determinism in the early stages of the regeneration process. Research on how vegetation recovery took place in West New Britain has recently been initiated using the analysis of phytoliths (Boyd *et al.*, 1998), starch grains (Therin *et al.*, 1999) and pollen (Torrence *et al.*, 1999).

Species composition would have been extremely important to hunter-gatherers or forest managers (i.e. low-intensity, shifting agriculturalists). If, as a consequence of random events, the post-eruption forest contained a larger number of fruit or nut trees or tubers, then it might have lent itself to intensive culling and/or management and permitted higher population densities than previously. Obviously the reverse is also true. Furthermore, food plants tend to be more common in the early stages of forest succession, and some sources of food such as fruits and nuts are much easier to harvest before the full canopy develops. Returning sooner, rather than later, in the sequence of forest succession could therefore have had advantages in terms of harvesting or managing of wild plant resources.

Part of the observed temporal trend in the length of abandonment may therefore have been caused by differences in the way reforestation occurred, but it is difficult to argue that the extremely long periods of abandonment after the first two eruptions, 1,000 and 250 years respectively, can be satisfactorily explained by environmental factors alone. Furthermore, the human response to these environmental factors would not have been direct, but would have been mediated by cultural factors. For example, at a very simple level it is quite clear that societies practising agriculture could have recolonised the region at different speeds and in different ways than would be the pattern with hunter-gatherers.

Subsistence and settlement

The resilience of the various societies in the face of the volcanic eruptions and their ability to recolonise at different speeds would have depended at least in part on the patterns of subsistence and settlement which they practised. Archaeological research in the province has revealed that despite the punctuated environmental record, the nature of subsistence and settlement changed in a directional manner. A gradual shift through time from a focus on the production of multi-purpose, retouched, chipped stone artefacts ('stemmed tools') to the production and use of expediently manufactured, unretouched flakes has been proposed as the result of a decrease in mobility (Torrence *et al.*, 2000; Torrence, 1992, 1994; Fullagar, 1992; Kealhofer *et al.*, 1999). Data on changes in the distribution of artefacts across space on Garua Island (Torrence *et al.*, 2000) and Yombon (Pavlides, 1999) from dispersed to clustered appear to indicate there was a gradual reduction in mobility through time, paralleling the shifts in technological organisation of stone tools. Studies of starch grain assemblages recovered from sites on Garua Island and at Bitokara have also been interpreted to indicate a higher degree of sedentism through time (Therin *et al.*, 1999). I have proposed that these changes in lithics and settlement patterns are part of a more general process involving a gradual intensification in the management of plant resources through time (Torrence, 1992, 1994; Torrence *et al.*, 2000).

If, for whatever reasons, people were increasingly managing their resources so as to get higher returns per unit area, it seems likely that they would have been able to colonise a new region more quickly. Along similar lines, if they were gardening tubers and could clear the ash from their plants or had an alternative source of new tubers, then they could return permanently within a year after an eruption – if the ash was less than 50 cm – and rather more slowly in worse-affected areas which require the addition of nutrients and the restoration of particular soil properties (cf. Lentfer *et al.*, in press). It therefore seems likely that the linear change in subsistence pattern, which is inferred from the lithics and settlement data, took place independently of the history of eruptions but was critical in accounting for the temporal trend toward increasingly rapid recolonisation.

Social organisation

Although Sheets *et al.* (1991) were correct to recognise the importance of social organisation as a factor in how disasters are caused and managed, in the case of West New Britain, their prediction that complex social organisations are less sensitive to environmental perturbation than simpler societies fails to explain the observed pattern. Throughout the time period considered the social groups appear to have been relatively egalitarian societies. There is little evidence for major changes in the complexity of the social organisations in this region during prehistory, although the nature and role of prestige goods were not stable. Social differences are nevertheless implicated in the long-term trend toward smaller periods of abandonment after the volcanic eruptions because the nature and speed of recolonisation cannot be explained solely by the severity of the event in terms of damage to the environment.

The most important social implication for understanding variation in the nature of recolonisation is that it cannot be understood as a purely local process. After an extreme event people need social ties that allow them to take refuge elsewhere, even if only temporarily. If not, they will perish. Part of the variation in recolonisation witnessed in the West New Britain data must be due to the presence or absence of and/or differences in the social linkages between the victims and their neighbours or with more distant people with whom they could shelter. Where they could have sheltered and for how long would have depended on the nature of their social ties with groups outside the affected area, whether the immigrants could have been incorporated within the social practices and land tenure arrangements of their allies, and the potential of the resources in these places to support increased population. Whereas finding temporary refuges might have been relatively easy, maintaining a satisfactory existence away from the homeland on a very long-term basis might not have been possible.

In all the cases that we have monitored in West New Britain, the thickness of the tephra was such that sources of food would have been destroyed and fresh water would also have been badly affected. If the event occurred in the dry season, as was the case in the Rabaul 1994 eruption, people might have had to wait as long as six months for rains leading to natural regeneration or the revitalisation of gardens (cf. Lentfer *et al.*, in press). For the W-K1, W-K2 and Dakataua events throughout the region and for W-K3 and W-K4 at Numundo and Garu, the environmental damage would have been so extensive that people could not have recolonised for some years even if they were able to replant their gardens.

Survival in these cases would have been completely contingent on having social relations elsewhere. Since the spatial scale of the eruptions differed, however, the scale and nature of the social linkages required to enable safe refuges would have varied. So, for example, groups surviving the W-K1 or W-K2 disaster would have needed friends and relations at much greater distances than those experiencing the impacts of the less spatially extensive Dakataua, W-K3 or W-K4 eruptions. It seems very likely that the much longer times for reoccupation after W-K1 and W-K2 indicate that local groups were not able to seek refuge and did not survive. In contrast, the rapid resettlement after Dakataua implies that the original residents may have been responsible for the recolonisation.

It is difficult to obtain accurate comparisons toward the length of social ties at various times in the prehistory of West New Britain given current data. Obsidian from the Bismarck Archipelago outcrops has been recovered from sites located in many areas of Melanesia and dating to all the periods we have studied (e.g. White, 1996). After the W-K2 eruption, obsidian is found over a larger area than in previous periods. This pattern suggests the presence of wider cultural links. At this same time people were decorating their pottery with motifs that are also shared over a very large region extending as far as Tonga and Samoa (e.g. Summerhayes, 2000). The wider regional social ties could help explain the shorter length of depopulation when compared to the W-K1 eruption. Kirch (1988) has suggested that the fairly rapid speed of the colonisation throughout Near Oceania of people bearing the Lapita decorated pottery was facilitated by social links between communities such as are reflected in the distribution of obsidian from West New Britain. From about 2,000 years ago onward, obsidian movement is more restricted in space, but there is an expansion into newer areas, such as the Papua New Guinea Highlands region (White, 1996: 201). Clearly, there was a re-orientation in the location of social links, but currently we are unable to assess precisely how these data relate to differences in the length and strength of social networks. Although we can infer that variations in the social make-up of the societies involved must have greatly affected rates of recolonisation in West New Britain, it is difficult to accurately monitor these differences with current archaeological data, although this should be pursued in future work.

We also need to invoke social differences in explaining the long-term trend for a reduction in the length of abandonment because the ability to bud off from a larger social group or to organise a mass movement of people is an explicitly social process. Relatively rapid recolonisation of an area which has been totally decimated would also have required means for buffering failures, such as ways to secure links with people remaining behind and/or efficient means for redistributing resources. Small groups with fewer social ties are likely to have been less successful at supporting themselves at an early stage of natural regeneration, but could have recolonised later in the succession when food supplies were more abundant.

In summary, understanding the impacts of the various eruptions requires a great deal of geological, environmental and archaeological data. At this stage much of this is not yet available in adequate detail to assess fully the relative importance of the environmental changes brought by the volcanic events in West New Britain versus the vulnerability of the societies, as monitored by their economic and social organisation. Nevertheless, the case study demonstrates the importance of considering a wide number of factors rather than concentrating solely on the vulnerability of the societies themselves. Furthermore, given the small amount of variation in the social organisations present in the study region, it is obvious that the severity of the event was a critical variable. Finally, a number of methodological problems have been faced in trying to sort out the various impacts, and these deserve more serious discussion.

METHODOLOGICAL ISSUES

The most serious methodological issues identified by the West New Britain case study are limitations in the way impacts are assessed by archeologists and problems with selecting appropriate spatial and temporal scales for monitoring the effects of the eruptions. For the West New Britain case study I have used length of abandonment as a rough measure of the impact of volcanic events on the contemporary human societies. As a first stage, this is a reasonable way to compare disasters occurring in the same area, but detailed comparison between regions in other parts of the world would be more difficult because potential rates of recovery are necessarily linked to local environmental conditions. This measure is also limited because the character and speed of landscape recovery is unlikely to be identical after different events due to landscape changes caused by lavas and airfall tephras and the stochastic nature of forest regeneration.

An alternative measure of impact is the degree to which the trajectory of cultural change parallels that of disasters. So, for example, Sheets *et al.* (1991) consider the chronological relationship between cultural phase boundaries and volcanic eruptions. The prehistory of West New Britain illustrates a difficulty with using this approach on its own. In the case of the W-K1 event there was no appreciable change in the artefact assemblages before and after the eruption, but a very large area appears to have been abandoned for 1,000 years afterwards. Obviously, the *local* population was seriously affected by this event. On the other hand, the *wider region*, which was the source of the populations who recolonised the affected area, probably did not face a disaster and maintained the same technological system outside the affected region. The opposite took place after the W-K2 eruption. Major cultural changes took place outside West New Britain during the time the area was abandoned and so the colonisers brought with them a very different set of material culture items. Whether the impact of people fleeing the region and taking refuge elsewhere had a role to play in the development of these new cultural items or the process was completely external to the volcanic eruptions cannot be determined solely from a study of West New Britain itself, but is a research topic worth pursuing.

Although each provides a gross index of how volcanic events have affected populations, neither the cultural phase nor length of abandonment approach to monitoring cultural responses is completely satisfactory, mainly because each focuses on very large-scale changes and glosses over the complexity in the data. New approaches to assessing impacts are needed that examine a wider range of effects.

Possibly the most important methodological issue to be faced when assessing the nature of disasters is choosing the spatial scale of analysis. First, one needs a way to determine the size of the area directly affected by the volcanic eruption. For this one could use a simple measure such as depth of tephra. The second difficulty is locating the areas which suffered indirect effects. Surrounding populations could have been affected because they provided food and shelter for refugees and may have made adjustments to enable settlement of refugees on a long-term basis. Even further afield, other areas may have suffered because trading links with an affected area were disrupted. In addition, some places may even have benefited through loss of competition or disruption of trading networks (cf. Sheets, 1979).

A second methodological issue is the selection of the spatial scale for analysis. The West New Britain study shows that spatial scales are particularly important when trying to understand the process of recolonisation. In the case of the W-K1 and W-K2 eruptions, when the region was abandoned for many generations, the recolonising population must have comprised a different group of people from the former inhabitants and one that may have had tenuous connections to this area. The case for population replacement is less clear for recolonisation after the W-K3 and W-K4 events, but the timing and nature of reoccupation must nevertheless have been determined by the social organisation, subsistence and settlement patterns of the populations in the surrounding regions. If these had reached the culturally determined carrying capacity, then the refugee population may have been encouraged to return more quickly than if there had been opportunities for them to be incorporated and so on. A number of scenarios can be imagined, but all involve consideration of the region (of unknown size and different for each event) outside the affected area.

Since the prehistory of West New Britain can be assumed to have comprised a set of recolonisations by different populations, most likely coming from different sources, the pattern provided by the archaeological data for a gradual decrease in the length of abandonment and an increase in the intensification of land use is very puzzling. One would not have expected a punctuated history of disasters to be correlated with stability or a slow, gradual cultural change. In particular, the continuity in lithic technology before and after the W-K1 disaster is remarkable. How is it that people returned 1,000 years later to the same lithic sources, made distinctive tools that were the same as before, and generally took up almost where they left off? In contrast, abrupt changes, such as the arrival of pottery after the W-K2 event, are quite predictable since the populations may have been quite different. To understand these puzzles, one would have to look outside West New Britain to the regions where the colonisers originated.

Even without the benefit of having studied a large enough region, some general predictions to guide future research can be derived from considering the process of recolonisation in West New Britain on an appropriately large spatial scale. First, I expect that in the period from *c.*6,000 to around 5,000 BP, when the affected area appears to have remained abandoned, other regions did not experience population stress. Either local solutions were found to cope with rising populations, e.g. subsistence intensification took place, or population size was relatively stable and there was no stimulus for moving out and colonising new territory. Furthermore, social and ideological factors may not have encouraged movement into the empty region.

The timing of repopulation *c.*3,300 BP, several hundred years after the W-K2 event, must also be explained by processes operating outside of West New Britain. Finally, recolonisation after the Dakataua event appears to have been so rapid that, apart from the fact that this was a more localised catastrophe, the process must have differed markedly from previous episodes of recolonisation.

Although in theory one could describe the attributes of the relevant region that should be studied, in practice it is difficult to define adequately the nature and level of the indirect effects to be studied and to predict exactly where the spatial boundaries of the affected area would have been. Furthermore, as in the case of the West New Britain eruptions, where the region that was indirectly affected would probably lie outside the island itself, the size of the appropriate study area would be beyond the capabilities of a single research project.

In addition to selecting the best spatial scale of analysis, the choice of which chronological scales to study is very important and is also not straightforward. One of the advantages of archaeological research is that it enables one to track the follow-on effects of a extreme natural hazard over the period anywhere from a few decades to a millennium, depending on the chronological resolution that is possible (cf. Sheets, 1979: 558; Grayson and Sheets, 1979). Immediately after a disaster people are usually forced to abandon a region, creating a very major short-term impact on their lives. The effect, however, may not be a long-lasting one and the population may return, clean up the mess, and carry on. Archaeology, which operates over scales rarely less than several generations, may not be able to monitor adequately the very short-term effects and may be tempted to conclude that the event had no impact. On the other hand, a group may return quickly but be forced to adopt new patterns of behaviour in order to adapt to its altered environment. Alternatively, groups may have to leave their homes for a very long time period, in which case the people who recolonise the region may bring many new cultural practices with them. In both these cases the one-off natural event had very major long-term effects, but these occurred at different time scales. From a methodological point of view, it is therefore quite important to analyse the impact of these short-term events over a number of chronological scales. This point is well demonstrated by the wide range of temporal impacts witnessed in prehistoric West New Britain.

With the exception of the W-K3 and W-K4 eruptions as experienced on Garua Island, all the volcanic events in West New Britain that we have studied must have had catastrophic *immediate* impacts, but there was considerable variation in the way societies were affected when considered at other time scales. In terms of as little as several generations the Dakataua eruption seems to have made very little difference to population levels in the Willaumez Peninsula. In contrast, over the very *long term* of several centuries, the W-K2 event made quite a significant impact on the prehistory of the region. Finally, when viewed over several centuries, the W-K1 event caused a complete depopulation of a large region, but considered a millennium later, it seems to have had very little effect on the cultural practices in the affected area.

Although archaeological data are generally amenable to the study of long-term processes, one of the most serious problems is getting good enough chronological control to adequately assess the nature and scale of impacts. I have argued previously that studies of volcanic disasters are much aided by the presence of airfall tephras that can be linked to single events. Although sourced tephras are invaluable for establishing a *relative chronology* over sometimes large regions, their presence does not solve the need for accurate, *short-term dates*. For example, material underlying a dated tephra may have no relevant chronological association with it because it might have been abandoned some considerable time before the eruption. If one wants to relate the buried material directly to the eruption, then independent chronometric control is required. Similarly, monitoring the nature and rates of recolonisation requires excellent chronological control. The history of recolonisation in West New Britain presented in Table 16.3 is only based on a limited sample of radiocarbon dates (Torrence *et al.*, 2000) and so the patterns which we have detected could be inaccurate. Another difficulty archaeologists face is determining whether a population remained or left the area for relatively short periods that may nevertheless have been significant for cultural processes, e.g. several generations, but are too small to be detected given the limitations of radiocarbon dating.

Archaeologists need to think hard about what types of questions concerning the impacts of natural hazards can be answered satisfactorily given the limitations of their data. As a first step, we should continue to develop better means for measuring impacts than are commonly used at present. Second, examining impacts on a range of spatial and temporal scales is very important for understanding the wide range of processes that result when an area experiences a severe climatic event. Finally, we must accept that there are major difficulties in assessing the degree of short-term impacts on human societies and in tracing indirect effects over very large regions, particularly if they are as poorly researched as is the case in Papua New Guinea.

IMPORTANCE OF DISASTER STUDIES

Since the analysis of disasters can make a significant contribution to theories about human social and cultural change, it is important to overcome the methodological difficulties raised above. For example, the long-term history of recolonisation in

West New Britain, which is characterised by a series of short-term events that had a variety of impacts on cultural process, has far-reaching implications for current theories of culture change. First, the lack of correlation between the severity of volcanic events and the impact on societies as measured by the length of abandonment illustrates the importance of historical contingencies and stochastic elements in long-term cultural processes. Second, environmental factors, such as ecological succession and forest regeneration, are unlikely to fully explain the patterns observed – especially the exceedingly long periods of abandonment in the early periods and the gradual trend toward increasingly intensified systems of land management. Third, the pattern of subsistence intensification within West New Britain must be explained largely in terms of complex interactions between social processes operating outside the region and the environment of the affected region. The decrease in the length of abandonment over time might be assumed to represent some form of long-term 'adaptation' to volcanic disasters, but this explanation is untenable since the changes in culture reflected in the archaeological record took place outside the region directly affected by the volcanic events and were then reintroduced into the affected area. If there was any form of adaptation to the volcanic history of West New Britain, then it took place within the wider region which experienced indirect effects of the eruptions. Researching this hypothesis demands further research aimed at identifying the homelands of the people who recolonised the region and a comparison of the cultural history of these regions with that of West New Britain.

Disaster research also has a significant role to play in archaeology because it focuses on the fundamental interactions between externally generated environmental factors and the way these are perceived and manipulated by human groups. I have argued that although the study of disasters provides an excellent opportunity for archaeologists to seriously examine important questions concerning the cause, speed and direction of culture change, there are a number of methodological issues concerning the measurement of impact and spatial and chronological scales that require further study.

Considering the question raised in the title of this chapter – what makes a disaster? – the data from West New Britain illustrate that an answer can be framed on several levels. First, the severity of the natural hazard is very important. Smaller eruptions had less impact on societies than did the larger ones. Second, the impacts are felt at differing spatial scales depending on the social ties of the group affected and the nature of social process in the region where people took refuge. Third, disasters need to be defined at different time scales. A disaster may have occurred over a short time period when a region was abandoned immediately following the event, but the picture over the long term may have been more complex since various areas were abandoned for different lengths of time. If the group returned after a short time interval, then it might not be considered to be as large a disaster as if the region were depopulated for many generations. Evaluating when and how serious a disaster was is not a simple procedure. For example, in the West New Britain case major changes in material culture took place with recolonisation after the W-K2 event but not after the other eruptions. In contrast, there do not appear to have been any major changes once people returned after the W-K1 disaster. Furthermore, the slow, gradual intensification in land use which took place over about 6,000 years may have had little to do with the catastrophic events, since subsistence and settlement patterns were established by social systems that were introduced into the region through colonisation, often long after the volcanic eruptions. As yet we do not have an adequate framework for distinguishing impacts that occur at different temporal scales to allow us to make adequate comparisons of different natural hazards.

Finally, the value of focusing on disasters as a way of developing new theories of cultural change is highlighted by the study. Without the emphasis on searching for the impacts of volcanic eruptions, the punctuated history of abandonment and reoccupation is likely to have been overlooked in favour of the gradual changes in lithic technology and settlement which would probably have been assumed to have been internally generated. We now know, however, that changes in material culture, subsistence and economic systems were at least in part a consequence of processes occurring elsewhere. These new insights are very important because they have led to a number of new hypotheses that will guide further research.

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