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LONG ISLAND, PAPUA NEW GUINEA
ASPECTS OF LANDFORMS AND TEPHROSTRATIGRAPHY

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SUMMARY

Present day geomorphic processes on Long Island include rapid trimming of the coastline and caldera wall by wave action. Deep, rapidly eroding linear gullies cut in the youngest pyroclastic deposits expose numerous sections which allow reconstructions of the island's recent eruptive history.

Deposits from three major Plinian and Peléan pyroclastic eruptions dated at approximately 16,000, 4,000 and 200-300 radiocarbon years bp have been recognised. These phases of cataclysmic activity, probably with associated caldera collapse, were separated by numerous intermittent tephra falls many of which would have been heavy enough to destroy much of the physical environment of the island. Interpretation of the pyroclastic deposits erupted during the period of human occupation provide information about changes in the physical environment.

INTRODUCTION

Although investigations of the volcanology of Long Island extend back to the early 1950's, attention has been focused almost entirely on present activity and petrology to the neglect of the geomorphology and the widespread tephra mantles. The investigations outlined here indicate that the tephrostratigraphy provides the key to the recent history of the central part of the island including the caldera, Lake Wisdom.

Field examination by the three authors was concentrated on the western and northern parts of Long Island. Twenty-four exposures of tephra layers were recorded in some detail and more cursory examinations were made at numerous other sites. These observations together with air photo interpretation indicate that the principal events in the evolution of the present topography of Long Island include the early development of a central volcano, the growth of major and minor satellite eruptive centres, and the occurrence of recent major eruptions which resulted in the formation of the large central caldera and the deposition of extensive and thick pyroclastic deposits. The most important elements of the geomorphology of the island are those relating to the recent phases of major eruption and caldera collapse.

In the present paper significant aspects of the island's geomorphology and the stratigraphy of the pyroclastic deposits emplaced in the Late Quaternary are described and discussed and used to provide some information about aspects of the physical environment during the period of human occupation. An appendix by Blong presents an argument for the date of the latest eruptive activity which devastated the island. An accurate dating of this event is important for the study of biological recolonization of the island.

Records of the Australian Museum, 1982, **Volume 34 Number 7,** 419–426, Figures 1–2.

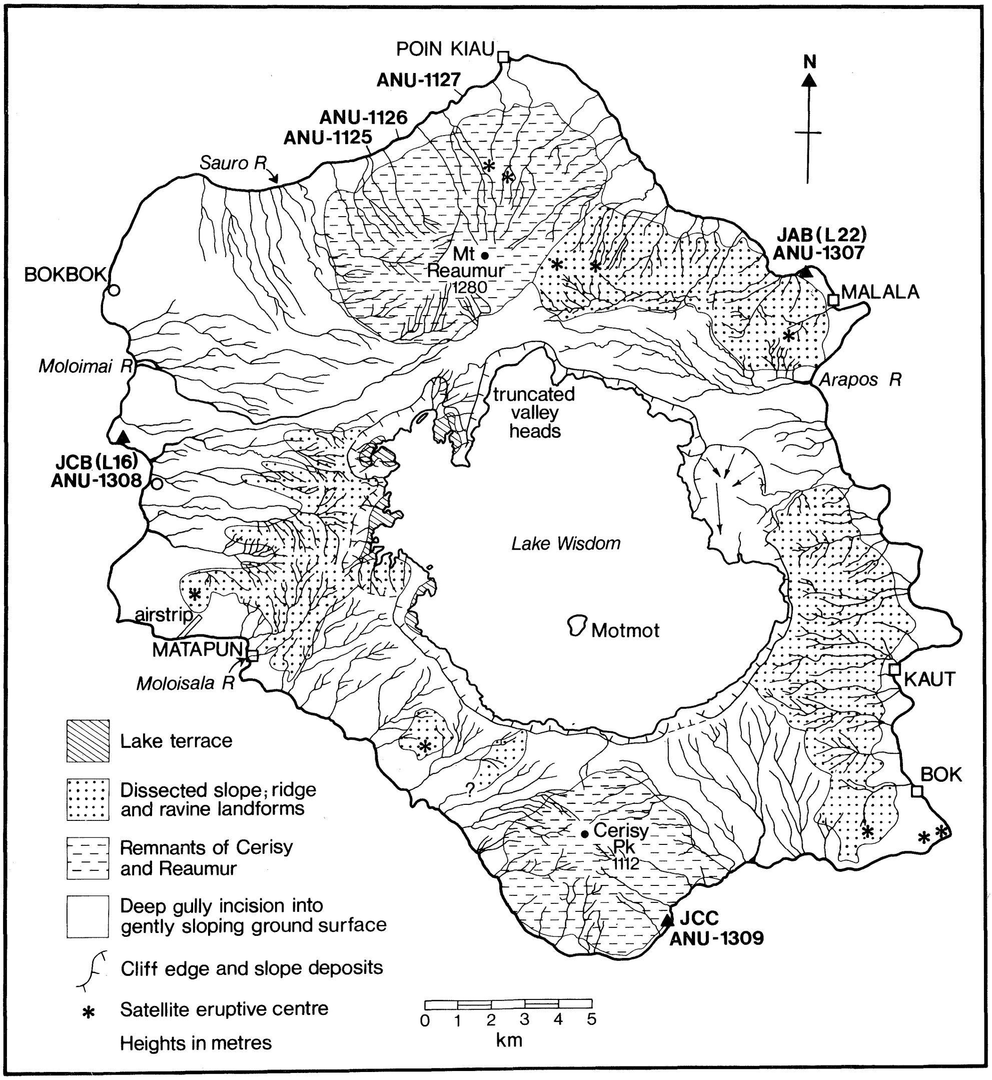

Figure 1. Map of Long Island showing major landforms.

LANDFORMS OF LONG ISLAND

Most of Long Island consists of gentle slopes radiating out from the caldera margins (Fig. 1). These slopes are dissected by numerous gullies which increase in depth inland, in some cases terminating in vertical head-walls up to 30 m high. The steep sidewalls expose unconsolidated pyroclastics and derived sediments, while the broad, normally dry, gully floors often contain a series of gravel bars and inset terraces 2-3 m high. Larger gullies (e.g. the Moloimai River) have braided beds but large scale sediment transport probably occurs on only a few days each year. In some gullies thin lava flows provide resistant bands giving the gully a stepped longitudinal profile.

Most of the coastline is formed in unconsolidated pyroclastic materials and is cliffed and undergoing active retreat due to wave action. Large trees hang precariously over the cliff edge, while cliffs and talus slopes are often notched, with new debris slopes of cliff-fall and windriven material accumulating on the upper beach. In a few places (e.g. north of Biliau and north-west of Malala) older more consolidated pyroclastics provide a more stable coastline as do the lavas outcropping at various sites (e.g. around Cerisy Peak).

Wave action is also eroding the margins of the caldera lake. Motmot, the island in Lake Wisdom, in the past has been rapidly eroded by wind and waves (Ball and Glucksman 1975) since it consisted only of unconsolidated pyroclastics, but lava flows in 1973-74 have reduced this process. To the northern side of the lake, near-vertical cliffs rise about 200 m, and several valley heads have been truncated. This contrasts with the caldera wall around the western embayment of Lake Wisdom which exhibits a well-developed stream network, the lower part of which has been drowned by the lake. The shoreline of this bay is very irregular, and bathymetric surveys by Ball and Glucksman (1978) and McKee show that it is much shallower than the rest of the caldera. A terrace is well preserved here some 10-15 m above present lake level, perhaps indicating a higher lake level. These lines of evidence suggest that the western embayment is older than the rest of the caldera and that more than one phase of caldera collapse has occurred.

On the eastern margin of the caldera a 3 km long section slopes southward and the surrounding scarp indicates that subsidence has occurred. A 400 m wide breach in the scarp allows drainage from the subsided section to the sea; another drainage system to the south leads into Lake Wisdom.

Mt Reaumur (1280 m) and Cerisy Peak (1112 m) are steepsided basaltic volcanoes dissected by radiating streams. Neither shows evidence of activity during the last few thousand years. Several other minor eruptive centres also appear to be extinct.

On morphological grounds the oldest landforms are extensive areas of ridge and ravine topography. These areas with steep slopes and high drainage densities have been so completely dissected that no remnants of the original surface remain. With the exception of a small area on the southwest margin of the caldera and a large one west of Malala these areas of rock outcrop slope generally away from the centre of the island. Field investigations north of Matapun, south and west of Malala and west of Bok indicate that erosional remnants of extinct satellite eruptive centres are present in all three main areas of this landform and that lava flows were abundantly produced by these volcanoes. On the other hand, the indented margin of this landform in the area north of Matapun suggests dissection of the flank of a volcano by radial drainage. Other rock exposures, specifically in the area west of Malala, may also represent the flanks of a central volcano but this is not firmly established.

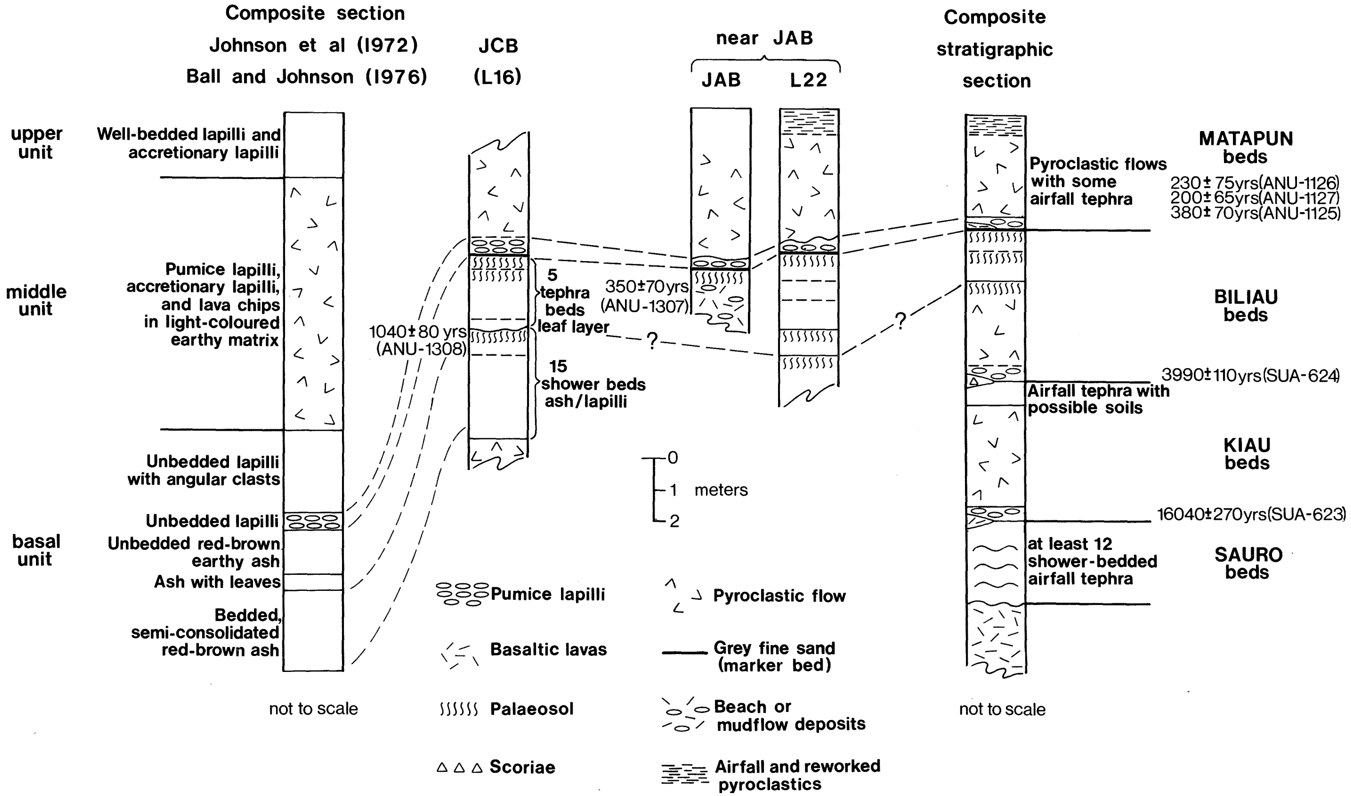

Figure 2. Tephrostratigraphy of Long Island.

TEPHROSTRATIGRAPHY AND ERUPTIVE HISTORY

This section is concerned mainly with the unconsolidated pyroclastic deposits formed during the latter part of the eruptive history of the Long Island volcanic complex. The general tephrostratigraphy, based on field observations on the western and northern sides of the island, is illustrated and compared with the earlier work of Johnson *et al.* (1972) and Ball and Johnson (1976) in Figure 2. This interpretation revises the threefold division of Johnson *et al.* (1972). Substantive details for this revision are presented in Pain *et al.* (in press). Correlations are also drawn with the stratigraphy at or near two archaeological sites, JAB and JCB.

Sauro beds: these are best exposed in the middle and upper reaches of the Sauro river valley southwest of Poin Kiau. At least twelve shower bedded airfall tephras occur.

Kiau beds: minor basaltic lava flows occur at some localities, but the Sauro beds are usually overlain by the basal lapilli member of the Kiau beds, which in turn is overlain by pyroclastic flow deposits. A series of airfall tephras with possible intervening soils completes the sequence. Charcoal from the outer rings of a tree trunk lying on the basal pumice lapilli of the Kiau beds in the headward end of Moloisala River near Matapun provides a ^{14}C age of 16,040 ± 270 years bp (SUA-623).

Biliau beds: these represent a depositional sequence identical to that of the Kiau beds. A charcoaled log from the basal lapilli of the Biliau beds exposed on the coast northwest of Malala yielded a ^{14}C age of 3990 ± 110 years bp (SUA-624).

The pyroclastic flow unit of the Biliau beds is overlain by airfall tephras with at least three palaeosols of which two are well-developed. Charcoal in the lowermost palaeosol at the JCB archaeological site gave a ^{14}C age of 1040 ± 80 years bp (ANU-1308), while a soil formed directly under the basal unit of the Matapun beds at archaeological site JAB contains charcoal dated at 350 ± 70 years bp (ANU-1307). The palaeosols and ^{14}C dates indicate that intermittent eruptive activity continued for a considerable period after the catastrophic emplacement of the pyroclastic flow unit.

Matapun beds: the base of these beds is marked by a 1-2 cm thick layer of grey fine sand overlain by up to two metres of pumice lapilli. As with the Biliau and Kiau beds, most of this sequence is composed of pyroclastic flow deposits, in some sections up to 10 m thick (equivalent to the 'middle unit' of Johnson *et al.* (1972)). In some localities several flow units can be recognised with basal sequences of gently undulating cross bedded deposits of pumice lapilli and lava fragments. Other sections contain numerous carbonised logs, oriented generally away from the caldera with a dip slightly greater than that of the present ground surface. Three samples of carbonized wood collected by Hughes from this unit have been dated 230 ± 75 years bp (ANU-1126), 200 ± 65 years bp (ANU-1127), and 380 ± 70 years bp (ANU-1125). At the top of the Matapun beds minor airfall tephras occur, often exhibiting a platy structure. Many exposures have been extensively reworked by fluvial action and mudflows.

DISCUSSION

The Matapun eruptive sequence began with the emplacement of an airfall pumice lapilli unit, continued with a series of pyroclastic flows, and concluded with the deposition of a thin, fine-grained airfall tephra. Such an eruptive sequence is similar to the classic eruptions of Vesuvius in AD 79 and Santorini in Minoan times (Lirer *et al.* 1973; Bond and Sparks 1976). As Sparks and Wilson (1976) have demonstrated, the occurrence of an initial airfall (Plinian) phase followed by the production of ignimbrites or pyroclastic flows (Peléan phase) is explained by a model involving gravitational collapse of the eruptive column.

The Matapun ignimbrite sequence was preceded by two similar eruptive phases which emplaced the Kiau and Biliau basal lapilli and subsequent ignimbrites. These two phases were each followed by intermittent eruptive activity and soil formation.

The recognition of three periods of emplacement of massive quantities of ignimbrites suggests the possibility of three phases of caldera collapse, as it seems unlikely that large scale evacuation of the magma chamber can occur without collapse. This lends some additional credence to the geomorphic evidence for more than one phase of collapse, and to the suggestion of Ball and Johnson (1976) that the abundance of volcaniclastic materials in the lower visible part of the caldera wall may indicate a series of subsidence events.

Most of the island's coastline and more than half of the interior comprises one landform unit, the surface of which is the result of the emplacement and subsequent reworking of the Matapun beds. These created a new landsurface over the island, with the partial exception of Cerisy, Reaumur and other older remnants. Much of the exposed Matapun ignimbrites is underlain by the older Kiau and Biliau ignimbrites. Numerous exposures in present-day gullies indicate that these earlier landscapes were also dissected by a series of valleys similar to those existing today, and evidently on the same drainage lines. Although the surfaces are similar in form, the present ground surface along the coast and lower flanks of the island is 5-30 + m higher than prior to the deposition of the Matapun beds. These beds have also significantly extended the area of the island, at least on the western and northern sides; each previous ignimbrite eruption may have similarly extended the island's area, followed by rapid erosional retreat. Only in very limited areas, such as at the JCB, JCC and JAB archaeological sites and areas of lava flows around Cerisy Peak and south of Malala, do deposits older than the Matapun beds outcrop on the coast.

Archaeological sites JCB and JAB show that Long Island was inhabited, though not necessarily continuously, for possibly 700 years from about 1,000 years ago. During this time several major tephra falls occurred. At the JCB site individual tephras range up to 27 cm in compacted thickness. The initial airfall deposits could have been as much as 50 cm thick. Evidence from eruptions elsewhere for which historical documents are available indicate that tephra falls of as little as 10-15 cm uncompacted thickness are sufficient to cause the collapse of houses, the destruction of crops and forest, and the death of wild, feral and domesticated animals (Blong, in press). Thus, even intermittent tephra falls between the ignimbrite eruptions could have destroyed much if not all of the biota of Long Island. Its inhabitants, therefore, may have been forced to evacuate the island on several occasions. During the ignimbrite eruptions the destruction of life and habitat would have been virtually complete, not only because of the high temperatures of the ignimbrites, but also because of the thickness of the new deposits.

Recognition that the same eruptive sequence of ignimbrite eruptions, followed by intermittent tephra falls, has occurred three times since the older volcanoes of Cerisy and Reaumur ceased activity, suggests that the Long Island centre will continue with limited intermittent activity involving mainly tephra falls with long intervals of soil formation before again entering a phase of cataclysmic (Plinian and Peléan) activity.

APPENDIX 1: (R. J. Blong)

The three radiocarbon dates on the Matapun beds (ANU-1125, ANU-1126, and ANU-1127) are expressed, as are all radiocarbon dates, in terms of radiocarbon years.

Such recent dates, however, require correction before they can be expressed in calendar years.

The pooled mean of the three dates can be obtained using the expression.

$$PM(3) = \frac{Ab^2c^2 + Ba^2c^2 + Ca^2b^2}{a^2b^2 + b^2c^2 + a^2c^2} \pm \left(\frac{a^2b^2c^2}{a^2b^2 + b^2c^2 + a^2c^2}\right)^{1/2}$$

where A ± a, B ± b, and C ± c represent the three radiometric ages (Polach, 1976).

In the present case A ± a = 380 ± 70
B ± b = 230 ± 75
C ± c = 200 ± 65

Substituting in the above equation the pooled mean of the three dates become 270 ± 40. This single estimate can now be converted from radiocarbon years to calendar years using calibrations derived from tree ring corrections. For the present exercise the following curves and corrections were used:

		Year AD
Damon, Long and Wallick (1972):	270 ± 40 becomes 305 ± 66	= 1580-1710
Ralph, Michael and Han (1973):	340-420 yrs BP	= 1530-1610
Clark (1975):	300-380 yrs BP	= 1570-1650
Stuiver (1978):	270-350 yrs BP	= 1600-1680

The midpoints of the estimates derived from the four calibration curves are respectively 1645, 1570, 1610, and 1640. On the basis of these age estimates we can state with some confidence that the last catastrophic eruption of Long Island and the emplacement of the Matapun beds occurred during the first half of the 17th century. A more detailed analysis by Blong (in prep.) rejects ANU -1125 on the grounds that the age estimate is substantially older than those provided by ANU -1126 and ANU -1127, pools the data with other ^{14}C dates from other sources and concludes that the radiocarbon evidence indicates that the eruption occurred between 1630 and 1670 A.D. The arguments presented have been summarised in Pain *et al.* (in press).

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