LATE QUATERNARY TEPHRAS AROUND MOUNT HAGEN AND MOUNT GILUWE, PAPUA NEW GUINEA

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ABSTRACT

Nine tephra formations of Late Quaternary age in the area surrounding Mount Hagen and Mount Giluwe, Papua New Guinea, were mapped using marker beds, including palaeosols and distinctive tephra beds. The nine tephras are named and their characteristics and known distribution presented. Other undifferentiated tephra deposits are noted. One tephra formation, Bune Tephra, erupted from south of Mount Giluwe. Most of the others appear to have erupted from sources on the Mount Hagen Range. The youngest, Tomba Tephra, is more than 30,000 years old, and on the basis of isopachs can probably be attributed to a source within the central caldera complex of the Mount Hagen volcano. The antiquity of the tephras suggests that major volcanic activity on Mount Hagen and Mount Giluwe ceased more than 30,000 years ago.

INTRODUCTION

Deposits of volcanic ash, or tephra beds, were recognised and reported by the first geologists to work on cover beds in the Papua New Guinea highlands (e.g., Perry, 1965; Bik, 1967). More recently, we have identified numerous tephras in the course of investigations into the Quaternary histories of the Kaugel Valley (CFP) and the Wahgi Valley (RJB). In an attempt to correlate events in the two valleys, the value of the tephras as marker beds was recognised. Accordingly, joint fieldwork was undertaken to identify and map tephra occurring in the general area between and surrounding the two valleys.

Tephra is a convenient term that may be used to refer to all airborne pyroclastic material including both tephra-fall and tephra-flow deposits (Thorarinsson, 1974). The term is used here to refer to all unconsolidated and airborne pyroclastic deposits irrespective of the size of the material, which ranges up to block size in rare cases, and irrespective of degree of weathering.

Tephras in the study area fall into two groups. One group consists of thin tephra beds (less than about 0.1 m) occurring within peat throughout the area; these tephras, derived from outside the study area, will be described elsewhere by RJB. The other group consists of tephras sufficiently thick to retain their identity within the cover beds around Mount Hagen and Mount Giluwe. This report provides a summary of the upper part of the column of ‘thick’ tephras, and considers characteristics, correlations, and chronology of the tephras. Possible sources are also considered, but our main aim is to present an account of the tephras that will be useful to workers wishing to use them as marker beds in geomorphology and related sciences (see Pullar, 1973). For this reason our descriptions are based on field data, since the usefulness of marker beds is considerably lessened if laboratory analyses are necessary for identification.
AREA AND MAPPING PROCEDURES

Mapping was carried out in the area surrounding Mount Hagen and Mount Giluwe and west to Laiagam and Kandepe, south to Ialibu, and east to include the upper part of the Wahgi Valley (Fig. 1). Within this area the most detailed preliminary mapping was carried out in the Kaugel Valley (Pain, 1973). From this 'core' area we have undertaken mapping within the broader area shown in Figure 1.

The procedures adopted during mapping are similar to those used in New Zealand by Vucetich & Pullar (1964, 1969). Within the tephra column, distinctive marker beds, which may be tephra units or palaeosols, are first identified, and then interbedded units may be identified by their stratigraphic position. Ideally each tephra unit should consist of a basal part composed of little-weathered material and an upper part where soil formation took place before the following tephra was deposited leaving a buried palaeosol. In the study area, however, most of the tephras are weathered throughout their thickness, and post-burial change appears to have destroyed most of the buried palaeosols that presumably occurred between many of the units in the tephra column.
<table>
<thead>
<tr>
<th>Tephra name and symbol</th>
<th>Name derivation (Fig. 1)</th>
<th>Type site location (Fig. 1)</th>
<th>Distribution and source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomba Tephra (tm)</td>
<td>Tomba Village (Ramu: SB53-5/AP6956)</td>
<td>CFP 2 km Tamuli Mendi Rd, 8 km west of Tamuli (Wagag: SB54-5/ZU2245)</td>
<td>Widespread, found over whole of study area. Erupted from Mount Hagen.</td>
</tr>
<tr>
<td>Bune Tephra (bn)</td>
<td>Bune locality (Karamui: SB55-9/AP7918)</td>
<td>33.25 km west of Bune (Lake Kutum: SB54-12/ZU3118)</td>
<td>Surrounds southern half of Mount Giluwe. Probably erupted from a source on the southern side of Giluwe.</td>
</tr>
<tr>
<td>Kiripia Tephra (ki)</td>
<td>Kiripia Catholic Mission (Wabag: SB54-8/ZU3140)</td>
<td>CFP2</td>
<td>Kaugel Valley and western and southeastern slopes of Mount Hagen. Source may be on Mount Hagen.</td>
</tr>
<tr>
<td>Kebaga Tephra (kb)</td>
<td>Kebaga Village (Wabag: SB54-8/ZU2945)</td>
<td>CFP2</td>
<td>Kaugel Valley, northern slopes of Mount Giluwe and western and southeastern slopes of Mount Hagen. Source may be on Mount Hagen.</td>
</tr>
<tr>
<td>Balk Tephra (ba)</td>
<td>Balk locality (Ramu: SB55-5/AP8253)</td>
<td>T17, at Keltiga, 6 km west of Mount Hagen town, on the Highlands Highway (Ramu: SB55-5/AP8749)</td>
<td>West and south of Mount Hagen township. May be found to correlate with Kiripia or Kebaga Tephras. Source unknown.</td>
</tr>
<tr>
<td>Ambulai Tephra (am)</td>
<td>Ambulai Stream (Ramu: SB55-5/AP6945)</td>
<td>T17</td>
<td>Kaugel Valley, northern slopes of Mount Giluwe and southern and southeastern slopes of Mount Hagen. May have erupted from Mount Hagen.</td>
</tr>
<tr>
<td>Wanubuga Tephra (wa)</td>
<td>Wanubuga Stream (Wagag: SB54-8, SE part of sheet)</td>
<td>T17</td>
<td>Kaugel Valley, northern slopes of Mount Giluwe, southern and southeastern slopes of Mount Hagen. May have erupted from Mount Hagen.</td>
</tr>
<tr>
<td>Turuk Tephra (tk)</td>
<td>Turuk River (Ramu: SB55-5, SW part of sheet)</td>
<td>T17</td>
<td>A few exposures in the Kaugel Valley and southeast of Mount Hagen. Source unknown.</td>
</tr>
<tr>
<td>Tugoba Tephra (tg)</td>
<td>Tugoba settlement (Ramu: SB55-5/AP8447)</td>
<td>T17</td>
<td>A few exposures in the Kaugel Valley and southeast of Mount Hagen. Source unknown.</td>
</tr>
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</table>

| undifferentiated tephra |

Note: Grid references are from the 1:250,000 topographic map series. An additional reference for T17 is: 1:50,000 Mount Hagen (Special) sheet, AP873 495.
The nature of tephra deposition is such that tephra units can exhibit considerable lateral variation. This variation manifests itself both in initial depositional characteristics following the eruption, and in subsequent weathering changes. Generally, although there are exceptions, tephra decreases in thickness, grainsize, and number of shower beds away from the source. Differential weathering potentially follows from these decreases, and from the variety of weathering environments into which the tephra may be deposited. These variations are clearly discussed by Vucetich & Pullar (1964).

Problems arising from the variations in tephra characteristics can be overcome in the field if sufficient exposures are available. Sites examined should be sufficiently close together to allow recognition of additional tephra units as they enter the column, and loss of units as they lens out. In practice this meant studying as many sites as possible in systematic traverses across the study area (the 'hand-over-hand' mapping of Pullar, 1967). In this way variations in field characteristics could be recognised as they occurred. This method of working is necessary because the same tephra unit may exhibit quite different field characteristics at different points of its range.

In general, mapping was moderately successful, especially in the Kaugel Valley and on the western and southern slopes of Mount Hagen. However, uncertainties arise from a lack of identifiable marker beds in some localities, and long distances between suitable exposures in some parts of the study area. Because of a wide range of weathering and erosion environments, marker beds that are distinct in some places cannot be recognised in others. Moreover, lack of exposures means that coverage of the area is somewhat patchy. Our investigations were limited mainly to road cutting and stream bank exposures, there being few other kinds of exposure in the study area.

Nine tephra formations are named and described in this paper (Table 1). Some of these formations have only local distribution, but most were recognised over much of the study area. As there are few deep exposures, and thickness measurements on deeper tephra are lacking or do not show regular variation, only the uppermost tephra unit is shown on an isopach map.

Older tephra underlie those described here but these are exposed only rarely, and in no case could individual units be correlated between two sites. Many of these older tephra have only local distribution. Other deposits underlying and interbedded with the nine tephra described here include lahar deposits, and occasional agglomerates and colluvial deposits.

**DESCRIPTIONS OF TEPHRA FORMATIONS**

Locations of places from which names are derived, together with type sites locations, are given in Table 1, and shown in Figure 1.

**Undifferentiated tephra**

At two sites, T17 at Keltiga and CFP 2 near Tambul, undifferentiated tephra are exposed at the base of the tephra column (Fig. 2). At Tambul these tephra rest on lavas from Mount Giluwe, while at Keltiga they rest on a paleosol formed on a lahar deposit. At each site individual beds may be distinguished, but no correlations are possible on the available data.
Togoba Tephra (tg)

At Keltiga (T17), the type site, Togoba Tephra is highly weathered and consists of 1.5 m of massive yellow-brown to dark yellow-brown clay with numerous grey clay inclusions. It has a firm consistency, and becomes sticky when worked. In the Kaugel Valley this unit is similar in appearance, but is more compacted and there is a slightly coarser layer at its base. This basal layer may be a shower bed, significantly coarser than the rest of the tephra when it was deposited but now weathered to a similar texture.

Togoba Tephra rests on older tephra beds in both the Kaugel Valley and on the southeastern slopes of Mount Hagen. The exposure at site 27, south of Hagen, is much thinner than elsewhere (Fig. 2), suggesting that it may thicken westwards from there. So far, however, it has only been seen in a few deep exposures, insufficient in number to enable any estimates of distribution or source.

Turuk Tephra (tk)

At T17 Turuk Tephra consists of 0.86 m of reddish brown firm massive clay. It contains a few grey clay inclusions, and many dark manganese-rich veins. In the Kaugel Valley this tephra unit is dark yellow-brown without the grey clay inclusions, but containing black manganese inclusions, both as nodules and in channels, similar to those at T17. The main criteria for its identification are the manganese-rich inclusions and its stratigraphic position immediately underlying Wanabugs Tephra.

The lower boundary of Turuk Tephra is diffuse at T17, and also irregular at CFP 2. It is generally darker than the underlying Togoba Tephra and may be recognised on this criterion. At T17 the contact
between reddish brown Turuk Tephra and the markedly contrasting grey sandy Wanabuga Tephra is sharp, unaccompanied, and highlighted by the strong development of hard black and white motled nodules. In other exposures the sharp upper boundary with its distinct colour change persists but is not so marked.

Turuk Tephra is exposed at a few sites in the Kangel Valley and in the area southeast of Mount Hagen. There are no consistent changes in its thickness, which might indicate its sources, over the area studied.

Wanabuga Tephra (wu)

Wanabuga Tephra at Keltiga (T17) is very distinctive. It is 5.20 m thick and consists of four beds. Each is massive and sandy (their dominant characteristics) and generally grey, with inclusions of friable yellowish clay, and white to pink halloysite and manganese nodules. The clay inclusions are concentrated along cracks which extend downwards from the upper boundaries of the sandy beds, while the halloysite and manganese nodules are concentrated along these boundaries (Fig. 3). These characteristics make the Wanabuga Tephra formation a very distinctive unit at T17.

Elsewhere Wanabuga Tephra is also distinctive. At site 27, east of Keltiga and south of Mount Hagen town (Fig. 1), it is 1.70 m thick and comprises two beds. The upper bed retains the grey sandy features of the tephra at T17 and protrudes from the road cutting as a distinct band. The lower bed is more friable and is similar to the central beds at T17. At CFP 2, in the Kangel Valley, Wanabuga Tephra appears to be more strongly weathered than at Keltiga, and has a finer texture and an orange-brown colour. However, it may be recognised by inclusions of grey silt and similar to the deposits at Keltiga and site 27. These inclusions, which have the appearance of "scabrose areas" of little weathered tephra, range from a few centimeters to more than a metre in diameter. Further west on the northern slopes of Mount Giluwe at sites 30 and 71, Wanabuga Tephra retains its grey sandy matrix, the inclusions of friable clay, and the halloysite and manganese nodules which are associated with the contacts between the different beds.

Because of its distinctive character and sharp contact with the underlying Turuk Tephra, Wanabuga Tephra was used as a marker bed in mapping tephra formations around Mounts Hagen and Giluwe. Its upper boundary is marked by a blocky paleosol which shows clearly as a dark band at Keltiga (Fig. 1) and on the northern slopes of Giluwe. At CFP 2, where the road cutting is older and has weathered, the paleosol also has a fretted appearance where individual soil blocks have fallen out. The contact between Wanabuga Tephra and underlying tephra beds (generally Ambulai Tephra) is sharp and easily recognised by the contrast between the sandy grey Wanabuga Tephra and the yellowish clay of the overlying material.

Wanabuga Tephra has been found on the northern slopes of Mount Giluwe, in the Kangel Valley, and on the southern and southeastern slopes of Mount Hagen, as far east as Mount Hagen town. Its distribution and thickness (Fig. 2) indicate that it may have erupted from the southern part of the Mount Hagen Range.

Ambulai Tephra (nm)

At the type site (T17) Ambulai Tephra consists of 1.10 m of yellow-brown very friable silt grey clay with abundant pinkish-brown veins of silt material infilling channels and cracks. The unit has a prismatic structure which breaks down to medium to fine (5-20 mm) blocks in the upper part. Within the Kangel Valley the formation is still very friable but contains fine white clay inclusions instead of the pinkish-brown silty clay, and exhibits a coarse basal layer about 0.1 m thick. These characteristics persist to the most westerly of the exposures examined. East of the type site the formation thins out rapidly and becomes less distinct. However, it may still be recognised at site 27 (Fig. 2). In most places its very friable nature and its position immediately overlying Wanabuga Tephra allow it to be readily identified.

The lower boundary of Ambulai Tephra, where it rests on Wanabuga Tephra, has been described above; it is quite distinct. The upper boundary of the formation is marked by a blocky paleosol. At Keltiga this paleosol is weakly developed (Fig. 3), but in the Kangel Valley the paleosol is distinct and is the uppermost of the only two paleosols readily identified in the tephra column.
Ambulai Tephra is found on the northern slopes of Mount Giluwe, in the Kaugel Valley, and on the southern and southeastern slopes of Mount Hagen as far east as Mount Hagen town (Figs 2 and 4). Like Wanabuga Tephra, it may have erupted from Mount Hagen.

Balk Tephra (ba)

At 117, the type site, 0.8 m of bright yellow-brown clay with a coarse blocky structure is exposed; the clay is firm in the section but on working becomes very friable. Balk Tephra may be recognised easily by these characteristics over its restricted distribution. It rests on the palaeosol formed on Ambulai Tephra and so may also be identified from its stratigraphic position. The upper boundary, with
Correlation section C–D from Wapenamanda to Bune (cf. Fig. 1). Beds within Bune Tephra are numbered. The asterisk indicates the type site for Bune Tephra (site 53). For tephra symbols refer to Table 1. Note the decrease in thickness of Tomba Tephra both north and south of site 86.

Tomba Tephra, another distinctive marker bed, may also be used to identify Balk Tephra. Both upper and lower boundaries are distinct to sharp.

Balk Tephra is locally distributed south and west of Mount Hagen town. As it occurs in the same stratigraphic position as Kebaga and Kiripia Tephras, it may on further work be found to correlate with either or both of these units. At present, however, it is regarded as a distinct unit. Its source is unknown.

Kebaga Tephra (kb)

At the type site (CFP 2) Kebaga Tephra consists of 0.5 m of light brown massive sandy clay, sticky when wet, with abundant fine black manganese-rich veins and a discontinuous sandy basal layer. At sites 96 and 92 (Fig. 41 the unit consists of light brown sandy tephra with numerous graded shower beds.

Kebaga Tephra may be recognised by its light brown colour which distinguishes it from the darker tephras which bracket it in the tephra column, and from its stratigraphic position as the second unit up from Wambuga Tephra where the latter unit is exposed.

Kebaga Tephra rests conformably on Ambulai Tephra in the Kaugel Valley and on the southern slopes of Mount Hagen. On the western slopes of Mount Hagen it rests on undifferentiated tephras, here the contact may be conformable, or it may be an erosional unconformity. Its upper boundary is almost everywhere conformable with Kiripia Tephra, which is missing only at the far western edges of the mapped distribution of Kiripia Tephra. Near Mendi, Kebaga Tephra is overlain conformably by Bune Tephra (Figs. 2 and 4).

Kebaga Tephra occurs on the northern slopes of Mount Gilaue, in the Kaugel Valley, and on the western and southern slopes of Mount Hagen. The thickest exposures (up to 2.50 m) are on the western slopes of Mount Hagen, suggesting a source in that vicinity.

Kiripia Tephra (ki)

At the type site (CFP 2) Kiripia Tephra consists of 0.9 m of massive yellow brown, sticky to slightly friable, sandy clay (designated KAU 7 in Pain, 1973). On the western slopes of Mount Hagen it is composed of up to 2 m of yellow-brown sandy tephra with numerous shower beds. The main internal
Criterion for its recognition is the abundance of white clay nodules throughout the unit. However, it is most readily recognised by its stratigraphic position immediately underlying the easily recognisable Tomba and Bune Tephra.

Kirupa Tephra has conformable contacts with both underlying and overlying units. At all exposures examined it is overlain by Kebaga Tephra, and at all but one site it is overlain by Tomba Tephra. At site 31 (Fig. 2) it is overlain conformably by a lahar deposit which is in turn overlain by Tomba Tephra. Its stratigraphic position is thus clear.

This tephra is found on the western and southern slopes of Mount Hagen and in the Kanigel Valley. It is thickest near Mount Hagen and thins rapidly west from the Kanigel Valley (Figs. 2 and 4) and is therefore thought to have eroded from somewhere on the Mount Hagen Range.

Bune Tephra (tn)

The following is a description of Bune Tephra at the type site:

<table>
<thead>
<tr>
<th>Bed</th>
<th>cm</th>
<th>Tephra</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>145</td>
<td>Tomba Tephra</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>greenish-grey loamy sand</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>reddish clay</td>
</tr>
<tr>
<td>4</td>
<td>51</td>
<td>yellow-brown and bluish-grey graded shower beds</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>grey olive fine sandy and clayey beds</td>
</tr>
<tr>
<td>6</td>
<td>240</td>
<td>grey olive to white sandy clay massive tephra</td>
</tr>
</tbody>
</table>

At other sections where the base of Bune Tephra is exposed, bed 5 in the above description is seen to be the lowermost. Beds 2, 3, and 4 are distinctive and form useful marker beds for correlation of Bune Tephra away from the type locality. This is particularly useful where Bune Tephra and Tomba Tephra are both present, since they have similar characteristics. Bed 2 is more persistent than the others and is the best marker bed; it is present in nearly every exposure of Bune Tephra examined. Thus the presence of one or more of beds 2, 3, and 4 is the main criterion for the recognition of Bune Tephra.

Where the lower boundary of Bune Tephra is exposed it rests on undifferentiated deposits including tephra and lahar materials; some contacts are conformable while others are disconformable. The upper contact with Tomba Tephra is conformable in all areas. Where these tephras are similar the upper boundary of Bune Tephra is defined as the contact between bed 1 and the coarse sandy basal layer of the overlying Tomba Tephra.

Bune Tephra surrounds the southern half of Mount Giluwe, from site 70 north of Mendi to site 63 south of Kirupa (Figs. 1, 2, 4, 5). It has also been tentatively recognised at other sites in the Kanigel Valley (e.g., CFP 126, Figs. 1 & 4). Because of this distribution, and because the thickest exposures and contact beds are found on the southern slopes of Mount Giluwe, it is thought to have eroded from a source in that area.

Tomba Tephra (tm)

At the type site (CFP 2) Tomba Tephra is 2.0 m thick and consists of two beds, both yellow-brown loamy sand, which contain numerous sand grains giving the unit a porphyritic appearance. The upper bed has a coarse sandy basal layer 1 mm thick and a grey olive to light yellow brown colour; (2) the presence of two or more beds with coarse basal layers; and (4) the presence of distinctive clay channel-filling veins that are the result of post-depositional pedological alteration. The sand fraction is dominated by feldspars; heavy minerals are 90% green hornblende with minor amounts of biotite, zircon, and apatite. Allophane in the matrix and gibbsite in the channel fillings and nodules are the main clay minerals (Parfitt, 1975).

The above characteristics describe Tomba Tephra adequately over most of its range. As noted the number of beds is greater where the formation is thickest; 7 members occur at Tomba (site 78) and 8 at site 66, north of Tomba (Figs. 1, 4). The basal layers of various beds range from lapilli to blocks at different sites. At T17, where Tomba Tephra is farther away from source, it consists of 0.90 m of light
Tomba Tephra conformably overlies older tephra beds at many sites; where it does it exhibits mantle bedding. On valley floors (e.g. Kaugel Valley) it disconformably overlies lake beds or colluvial and alluvial deposits. In most places the base is defined by marked changes in colour and texture. Bune Tephra is distinguished from it by the presence of the reddish clay bed 2. In most exposures Tomba Tephra is the uppermost formation and occurs at the present land surface. On fans, foot-slopes, and the valley floor of the Kaugel Valley it may be overlain by the Kaugel Drumliten (Pain, 1975). Elsewhere in similar situations it may be overlain by other colluvial deposits.

Tomba Tephra has been mapped over more than 3000 km² surrounding Mount Giluwe and west and south of Mount Hagen. It has also been tentatively recognised in the Magurima, Numbi, Wage, and Kundep valleys to the west, and also at Kuk, east of Mount Hagen. It is thickest near Tomba, and thins out with distance from this locality (Fig. 5). The number of beds is also greatest, and the unit thinnest, near Tomba (see Pain, 1973). These features, together with the isopachs (Fig. 5), indicate a source on the southern part of Mount Hagen, the most likely area being the caldera complex discussed by Mackenzie (1973).
DISTRIBUTION AND CORRELATION

The distributions of the various tephra formations are not known in their entirety, largely because of the lack of suitable exposures over large parts of the study area. However, other factors also play a part. East of Mount Hagen town and south of Togoba deep exposures of tephra were examined, but none of the tephras could be correlated with those described in this paper. More detailed field examination of sites close together may lead to such correlations, but additional work is required on trace element compositions of the kind carried out by Westgate and his colleagues in Canada (e.g. Smith & Westgate, 1969) and Kohn (1970) in New Zealand.

Detailed investigations of trace element compositions of Bune and Tomba Tephras may also help resolve the problem of distinguishing them in the areas where they overlap. From the field evidence it is clear that they are very similar in appearance, and that Bune Tephra appears to underlie Tomba Tephra; at least the distinctive marker beds within the former formation lie below the base of Tomba Tephra. However, part of the upper member of Bune Tephra may be interbedded with Tomba Tephra, and for tephrochronological purposes they may be regarded as being coeval.

Examination of the isopach map (Fig. 5) indicates that distributions of Tomba and Bune Tephras are influenced by the presence of Mount Giluwe. A lobe of Tomba Tephra extends down the Kaugel Valley and around the eastern side of Mount Giluwe towards Bune. The few sites examined in the northwest of the study area suggest that the major lobe of Tomba Tephra passed north of Mount Giluwe. Tomba Tephra has not been identified between Bune and Mendi on the south and southwest of Giluwe, suggesting that the mountain exercised a 'shadow' effect on the deposition of the tephra. Similarly, Bune Tephra does not occur on the northern slopes of Mount Giluwe (Fig. 5).

SOURCES

Only Tomba Tephra can definitely be assigned a source area, on the basis of the isopach map (Fig. 5) and an increasing size of material and number of beds. Bune Tephra was almost certainly erupted from a source south of the summit area of Mount Giluwe, while Wanabuga, Ambulai, Kebaga, and Kiripia Tephras probably came from sources on the Mount Hagen Range, Togoba, Turuk, and Balk Tephras give no indication of their likely sources.

Eruptive sources that were probably active during the period when the tephras were deposited include: the three major volcanic centres of Mounts Hagen, Giluwe, and Talba, as well as the Sugarloaf Plateau, and minor centres (in terms of size of cone) at Malia, on the southern slopes of Mount Hagen; Terek, near the confluence of the Kaugel and Nebilyer Rivers; Kraidung, north of Mount Hagen town; one in the Wabao-Wapenamanda Valley; and cones along a fault which runs across the southern foothills of Mount Giluwe (Fig. 1).

The minor cones all have local tephra deposits associated with them; these are left undifferentiated in this report. The presence of these local deposits and the small size of the cones does not preclude the possibility that some of them produced
tephras with a regional distribution. So far, however, no such tephras have been distinguished. The major tephras with regional distribution seem to have erupted from major volcanic centres, which in practice means Mount Hagen, since so far only one tephra can be attributed to Giluwe and none to Ialibu. Malia, a small parasitic cone on the southeastern slopes of Mount Hagen, seems likely as a source for some tephra deposits, but no definite formation can be attributed to this source. *

**CHRONOLOGY OF ERUPTIVE EVENTS**

At present there are few reliable absolute dates on Quaternary volcanic materials in the highlands apart from $^{14}C$ dates for young tephras found in swamps in the Gumants Valley (Blong, in prep.). Five $^{14}C$ dates relating to Tomba Tephra are reported in Pain (1973):

<table>
<thead>
<tr>
<th>ANU</th>
<th>806</th>
<th>28,410 ± 1500 yr B.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANU</td>
<td>753</td>
<td>34,530 ± 2360 yr B.P.</td>
</tr>
<tr>
<td>ANU</td>
<td>194</td>
<td>31,470 ± 900 yr B.P.</td>
</tr>
<tr>
<td>ANU</td>
<td>752</td>
<td>31,900 ± 1300 yr B.P.</td>
</tr>
<tr>
<td>ANU</td>
<td>254</td>
<td>34,000 ± 1500 yr B.P.</td>
</tr>
</tbody>
</table>

When considered with a range of two standard deviations these dates cannot be separated statistically and thus an age of between 30,000 and 31,000 years B.P. can be assumed on this evidence for Tomba Tephra. However, a recently collected sample has given a dated of greater than 50,000 years B.P. for cellulose from wood collected at Kuk. This, together with doubts about the accuracy of the original dates because of contamination of samples with younger material before collection, suggests that Tomba Tephra may well be older than 50,000 years B.P.

$\text{Ages } \geq 50,000 \text{ yr}$

The dominance of Mount Hagen in terms of tephra production appears at first sight to be surprising, since it is generally though to be the oldest of the Quaternary volcanoes in the highlands area on the basis of degree of dissection (see, e.g. Bain et al., 1970). However, the few available radiometric dates do not support this age relationship. Page & Johnson (1974) report K-Ar ages of 204,000 and 218,000 ± 10,000 years B.P. for samples from Mount Hagen, whereas the only date so far available from Mount Giluwe is about 300,000 B.P. (Dr E. Löffler, pers. comm.).

Tephrochronological evidence presented here indicates that the last paroxysmal eruptions of tephra in the area were from Mount Hagen (Tomba Tephra) and Mount Giluwe (Bune Tephra), and that sources on the two stratovolcanes were in eruption at approximately the same time prior to 50,000 years ago.

**CONCLUSIONS**

Of the more than 15 tephra formations indentified throughout the study area, only nine are sufficiently well exposed to allow them to be characterised and named. Of these nine, Tomba Tephra is the youngest, with an age greater than 40,000 years B.P. and probably greater than 50,000 years B.P. This formation was produced by Mount Hagen, as were at least four of the other named tephras. Of the *

* In a distribution map of Late Cenozoic eruptive centres in central Papua New Guinea but outside of this area of study, see Fig. 1 in Mackenzie (this volume). Ed.
remaining four tephra formations, three come from unknown sources and the fourth, Bune Tephra, comes from the southern side of Mount Giluwe.

The tephra formations discussed in this paper may be identified on the basis of various kinds of criteria. Internal characteristics are important in some cases, particularly with regard to the important marker beds, Wanabuga Tephra, various beds of Bune Tephra, and Tomba Tephra. Other tephra formations are more easily recognised by their stratigraphic position in relation to distinctive marker beds.

The ages of the named tephras, ranging from greater than 30,000 years B.P. to perhaps several hundred thousand years B.P., indicate the considerable antiquity of the last stages of volcanism of Mount Hagen and Mount Giluwe. This paper provides a basis for further work on tephrostratigraphy and tephrochronology in the area; when undertaken, such work will help to elucidate the Quaternary geomorphic history of the Papua New Guinea highlands.

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