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# THE PETROLOGY OF LAVA SAMPLES FROM MOUNT VICTORY AND MOUNT YELIA, TERRITORY OF PAPUA AND NEW GUINEA.

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## SUMMARY

The petrography of lava specimens from Mount Victory and Mount Yelia, in northern Papua, are described, and modal analyses of some are given. Although the lavas are of andesitic appearance, the large amount of glass (or felsite) present, and its low refractive index, suggest that they are dacitic in composition. Chemical analyses of two of the lava samples confirm this. The analyses also show that the lavas are calc-alkaline in character. In addition, certain petrographic details suggest that the lavas were formed by magma hybridization. The Mount Victory specimens are compared with lavas from Mount Lamington, and are found to be, petrographically, fairly similar to the Mount Lamington Type II lavas, although chemical analyses of the Mount Lamington lavas differ slightly from those of the Mount Victory specimen.

## INTRODUCTION

The lava samples were submitted by G.A. Taylor for petrographic examination, and were collected from the summits of Mounts Victory and Yelia, on the north coast of Papua, by Mr. Guy Rosenberg of the Division of National Mapping. Prior to the collection of these samples Mount Yelia had not been recognized as a volcano.

Two of the samples were chemically analysed, R.14486 (from Mount Victory) and R.14489 (from Mount Yelia).

The specimens described are : -

| Museum No. | Field No. | Locality |
|---|---|---|
| R.14486 | P.957 | Mount Victory, summit crater, lake area. |
| R.14487 | P.958 | Mount Victory, summit peak, west rim of crater. |
| R.14488 | P.959a) | Mount Yelia, crater, old solfataric area. |
| R.14489 | P.959b) | |
| R.14490 | P.959c) | |
| R.14491 | P.960a) | |
| R.14492 | P.960b) | |
| R.14493 | P.961a) | Mount Yelia, summit peak. |
| R.14494 | P.961b) | |

## PETROGRAPHY

Introduction: In general appearance the lavas seem to be andesitic; no quartz is present as phenocrysts. However, an abundant felsitic matrix in the Mount Victory specimens, and glass in the Mount Yelia specimens leads one to suspect that they are more acid than andesite. This suspicion is confirmed by the two chemical analyses and their norms (see the section on chemistry). On the basis of chemical analysis, the lavas are termed dacite. The specimens from Mount Victory are (augite-) biotite - lamprobolite-dacite; those from Mount Yelia are (augite-) lamprobolite dacite.

The Mount Victory Lavas. In hand specimen R.14486 is pale grey, speckled with black, and is strongly porphyritic. The phenocrysts of plagioclase, amphibole, and biotite range up to 3 mm. across, and are enclosed in an aphanitic groundmass. The phenocrysts are flow-oriented. R.14487 is fairly similar, but is oxidized to a grey-pink colour.

In thin section, R.14486 (T.S.No.10324) is seriate porphyritic; some of the phenocrysts are clustered. The groundmass crystals have an average grain-size of about 0.01 mm.

The phenocrysts consist of plagioclase, lamprobolite, and biotite. Plagioclase forms fresh tabular somewhat embayed crystals showing pronounced oscillatory zoning. The composition ranges from $An_{53}$ at crystal cores to about $An_{38}$ at their margins; some crystals are basified in a zone near their margins with a composition of bytownite. Other plagioclase phenocrysts have a narrow marginal zone in which probable alkali feldspar has exsolved to form minute, irregular intergrowths with the host plagioclase. Lamprobolite phenocrysts are euhedral prisms that are pleochroic with x = straw brown, y = z = dark brown; many crystals have paler coloured margins that may have resulted from either compositional zoning, or bleaching. Commonly, a thin oxidized rim is present. Some crystals are in parallel growth with biotite phenocrysts, without any reaction relations being apparent between the two minerals. Biotite forms euhedral phenocrysts that are pleochroic with x = straw brown, y = z = nearly black.

Some small colourless, granular to prismatic crystals of augite have an average grain-size of 0.2 mm., and rarely exceed 0.4 mm. diameter; they are possibly xenolithic in origin, although the evidence in favour of this is not as strong as in R.14487 (see below). They commonly occur as individual grains, but may form small clusters of granules. In places, augite is partly replaced by lamprobolite.

The groundmass consists of microlites of plagioclase and euhedra of lamprobolite and biotite enclosed in abundant microcrystalline felsite which, presumably, represents a devitrified glass. In places, the felsite is minutely spherulitic. Small amounts of tridymite fill cavities in the groundmass. Accessory pyrite, opaque iron oxide, and needles of apatite are present.

The result of a modal analysis of the specimen is:- plagioclase: 31%, lamprobolite: 13%, glass (including microlites): 52%, biotite: 3%, augite: 1%, and accessory minerals - trace amounts.

Texturally and, in general, mineralogically, R.14487 (T.S.No.10325) is similar to R.14486. There are, however, some differences. Firstly, there appear to be two types of amphibole phenocryst; one is a red-brown lamprobolite that commonly shows a sub-rounded form and embayed margins. This type may occur in inclusion-like mafic clusters that have interstitial plagioclase - these are possibly xenolithic in origin. The other amphibole forms euhedral phenocrysts that are pleochroic from straw-green to red-brown; these have probably crystallized from the lava. The second difference is that more augite is present, forming single crystals and occurring in granular, inclusion-like clusters; the augite is colourless, and is probably of xenolithic origin. The third important difference is in the presence of a few small, rounded grains of quartz, about 0.5 mm. diameter. These may be phenocrystic, but, from their general appearance, it seems more likely that they are xenocrysts. One quartz grain has a small zircon inclusion. Another noteworthy feature of this specimen is that there appear to be two types of plagioclase present; one forms euhedral crystals with a composition of $An_{38}$, and the other, probably of foreign origin, occurs as embayed crystals that have a composition of about $An_{48}$.

The Mount Yelia Lavas: Except for R.14490, all the specimens are texturally and mineralogically similar to each other; the main difference between R.14490 and the others is in texture. This specimen will be described later.

The chemically analysed specimen, R.14489, is, in hand specimen, a reddish-grey porphyritic rock containing phenocrysts of feldspar and amphibole enclosed by an aphanitic groundmass. In thin section (T.S.No.10327) the lava is seen to be seriate porphyritic; the phenocrysts have an average diameter of 0.5 mm., although some lamprobolite phenocrysts range up to 2.3 mm. long. The vitreous groundmass encloses small flow-oriented microlites that have an average grain-size of 0.05 mm.

The phenocrysts consist of plagioclase, lamprobolite, and of less common augite. Plagioclase forms tabular, somewhat embayed phenocrysts showing oscillatory zoning. The average composition appears to be about $An_{48}$. Some crystals contain fine, marginal intergrowths of (?)exsolved alkali feldspar, together with patchy iron oxide staining. Other crystals are, in places, partly altered to kaolinite. Lamprobolite occurs as prismatic, sometimes intergrown, crystals that are pleochroic with x = pale brown, y= z = very dark brown. Pale green augite is not of common occurrence in this rock. It forms euhedral crystals that occur singly or, in some places, in clusters of intergrown crystals. Some show slight alteration to lamprobolite. The augite in this lava differs from that in the Mount Victory lavas in colour and in habit. In the Mount Yelia specimen it appears to have crystallized from the lava.

The groundmass consists of fine crystals of plagioclase, lamprobolite, and small amounts of augite, enclosed in a colourless vesicular glass that has a refractive index of about 1.496. In places the glass is slightly altered to clay; in other places, slight devitrification to small felsitic spherulites has taken place. Accessory minerals are black iron oxide, apatite, and zircon. Some vesicles contain faintly anisotropic, tridymite showing complex twinning.

A single inclusion was observed to be an embayed grain of quartz surrounded by a reaction rim. The inner zone of the rim, adjacent to the quartz, is formed of glass; the outer zone is formed of fine, elongated pale green diopside crystals that are sub-radially arranged on one side of the inclusion, and parallel to the margin on another side.

A modal analysis of the rock showed the following percentages of minerals:- plagioclase: 31, lamprobolite: 13, glass (including microlites): 51, black iron oxide: 5, and pyroxene: trace amounts.

Specimens R.14488 (T.S.No.10326), R.14491(T.S.No. 10329) and R.14492 (T.S.No.10330) are all texturally and mineralogically similar to R.14489. The glass in R.14488 has a refractive index of about 1.495; in the other specimens it is partly oxidized. In R.14488, some of the cavities contain tridymite that has complex twinning, and which has a refractive index of about 1.485. Specimen R.14491 contains two inclusions of quartz. One is embayed, and is surrounded by a reaction corona of felted to radially arranged fine, acicular clinopyroxene prisms. The other is attached to and partly encloses a plagioclase phenocryst; on this one, no reaction rim is present.

Specimens R.14493 (T.S. No.10331) and R.14494 (T.S. No.10332) are texturally similar to the other Mount Yelia lavas. However, strong alteration has taken place. In R.14493, plagioclase amphibole, and the glass re almost completely replaced by clay minerals. Augite, however is unaltered. Although the whole of R.14494 is altered to clay minerals, pseudomorphed amphibole crystals can be recognized because they are rimmed by hydrated iron oxide dust.

Specimen R.14490 is, mineralogically, similar to the other Mount Yelia lavas; in texture, and in the percentages of minerals present, however, it is different. A modal analysis of the rock showed the following percentages of minerals present: plagioclase: 29, lamprobolite: 33, glass (including microlites): 30, black iron oxide: 7, and clinopyroxene: trace amounts.

The rock is moderately porphyritic , and contains phenocrysts of lambrobolite and less common plagioclase, ranging up to 3 mm. in size. The phenocrysts are contained in a groundmass formed of tabular, randomly oriented plagioclase crystals, prismatic lamprobolite and colourless augite, all enclosed by vesicular glass. The groundmass crystals are fairly equigranular, and have an average grain-size of 0.3 mm. The glass has a refractive index of about 1.493, and encloses minute plagioclase microlites; it is partly ferruginized around many of the vesicles.

The crystal cores, of tabular plagioclase crystals are mostly replaced by clay minerals ; crystal margins are usually quite fresh. Plagioclase composition is about $An_{55}$ at crystal cores, zoned very sharply near crystal margins to $An_{47}$, and to $An_{37}$ at the margins.

<u>Summary of Petrography</u>: The Mount Victory lavas are rocks of andesitic appearance but which are of dacitic composition. In these rocks this is indicated by the presence of large amount (52%) of residual devitrified glass. Plagioclase phenocrysts tend to be embayed, and many have rarified zones on their margins. Some xenocrystic plagioclase is apparently present in one specimen, and small xenoliths and xenocrysts of clinopyroxene occur in both rocks. Some

small, probable xenocrysts of quartz are present in one specimen; these are not surrounded by reaction rims. The characteristic ferro-magnesian content of the Mount Victory lavas is biotite-lamprobolite.

The Mount Yelia lavas are probable andesitic rocks of dacitic composition (Rittman - 1960, p.102 - would term these rocks "hyaloandesite") with a ferro-magnesian content of augite-lamprobolite. Otherwise they are fairly similar to the Mount Victory lavas. The glass in the Mount Yelia lavas is fresh, and most of the rocks contain about 50%; its refractive index was measured in some specimens, and found to range between about 1.493 and 1.496, indicating a silica content of, roughly speaking, 72% (W.O. George, in Williams, Tumer and Gilbert - 1954). Considering the acid nature of the glass, and of the rock as a whole, some of the quartz inclusions in the Mt. Yelia lavas show apparently anomalous reaction relationships in that they are surrounded by a corona of fine-grained clinopyroxene; another quartz inclusion, however, has no such corona. The significance of this will be discussed later.

One of the Mount Yelia specimens is significantly different from the others in texture and in the relative proportions of minerals present; it appears to be more basic in character; its content of glass is 20% less than in the other specimens, with a refractive index that is apparently the same.

## CHEMISTRY

The chemical analyses and C.I.P.W. norms of two of the lava specimens are shown in Tables 1 and 2. Referring, firstly, to the analyses, it will be seen that the Mount Yelia and Mount Victory lava samples analysed are fairly similar to each other. The main differences are in total iron oxide - the Mount Yelia sample is slightly richer in iron and is slightly poorer in magnesia; it is slightly less rich in the alkalies.

It will be noted that most of the iron oxide in R.14489 is present as ferric oxide; in the claculation of the norm, this has resulted in the presence of hematite (He), and in a much larger amount of quartz (Qz) being present than in R.14486. If the iron had been less oxidized, then some would have been available to form diopside (Di), thus using more of the silica molecular proportions, and making less available for quartz.

The reason for the oxidation in R.14489 is probably due to weathering subsequent to the formation of the lava. This sample is the least oxidised of the Mount Yelia lavas, but, even so, in hand specimen it has a reddish-grey colour probably due to weathering.

The petrography suggests that the rocks, although of andesitic aspect, are probably more acid . This is confirmed by the chemical analyses. Nockolds (1954, p.1019, analysis II) average for 49 chemical analyses of andesite shows a silica percentage of 54.20; in the norm of this average, only 5.7% of quartz is present. This can be compared with 62.7% and 61.5% of silica in the two rocks under discussion, and the 14.40% of normative quartz in R.14486. The closest comparable analysis in Nockolds' (op.cit.) tables is VI on p.1015, the average for dacite and dacite-obsidian.

TABLE 1: Chemical Analyses

| | R.14486 | R.14489 |
|---|---|---|
| $SiO_2$ | 62.7 | 61.5 |
| $TiO_2$ | 0.67 | 0.68 |
| $Al_2O_3$ | 16.1 | 15.7 |
| $Fe_2O_3$ | 2.25 | 4.55 |
| FeO | 2.20 | 1.54 |
| MnO | 0.08 | 0.09 |
| MgO | 3.15 | 2.25 |
| CaO | 5.05 | 5.10 |
| $Na_2O$ | 4.25 | 3.40 |
| $K_2O$ | 2.50 | 2.00 |
| $P_2O_5$ | 0.31 | 0.20 |
| $H_2O-$ | 0.07 | 0.40 |
| $H_2O+$ | 0.54 | 1.80 |
| $CO_2$ | 0.18 | 0.89 |
| | 100.05 | 100.10 |

TABLE 2: C.I.P.W. Norms

| | | R.14486 | R.14489 |
|---|---|---|---|
| $Q_3$ | | 14.40 | 20.81 |
| $O_2$ | | 15.01 | 11.90 |
| Ab | | 36.15 | 28.82 |
| An | | 17.24 | 21.68 |
| Di | WO | 1.97 | 1.16 |
| | En | 1.50 | 1.00 |
| | Fs | 0.26 | - |
| Hg | En | 6.40 | 4.60 |
| | Fg | 0.92 | - |
| Mt | | 3.25 | 3.02 |
| He | | - | 2.56 |
| Il | | 1.37 | 1.37 |
| Ap | | 0.67 | 0.34 |
| Cc | | 0.40 | - |

R.14486: Mount Victory: biotite- Lamprobolite dacite from the summit crater, lake area.

R.14489: Mount Yelia : (augite-) lamprobolite dacite from old solfataric area.

Analyst: C.R. Edmond, A.M.D.L.

## DISCUSSION

Chemically, the Mount Victory and Mount Yelia lavas are calc-alkaline. This is shown by their positions on the FMA diagram, Figure I. Specimen R.14486 falls within the field occupied by the Mount Lamington lavas (Taylor, 1958, p.82); but R.14486 is apparently far more iron rich, though how much of the iron oxide was introduced by weathering is not known. Also on the diagram, for purposes of comparison, are Tilley's (1950) typical tholeiite trend, the position of the Mount Lamington lavas, and the area of calc-alkaline rocks.

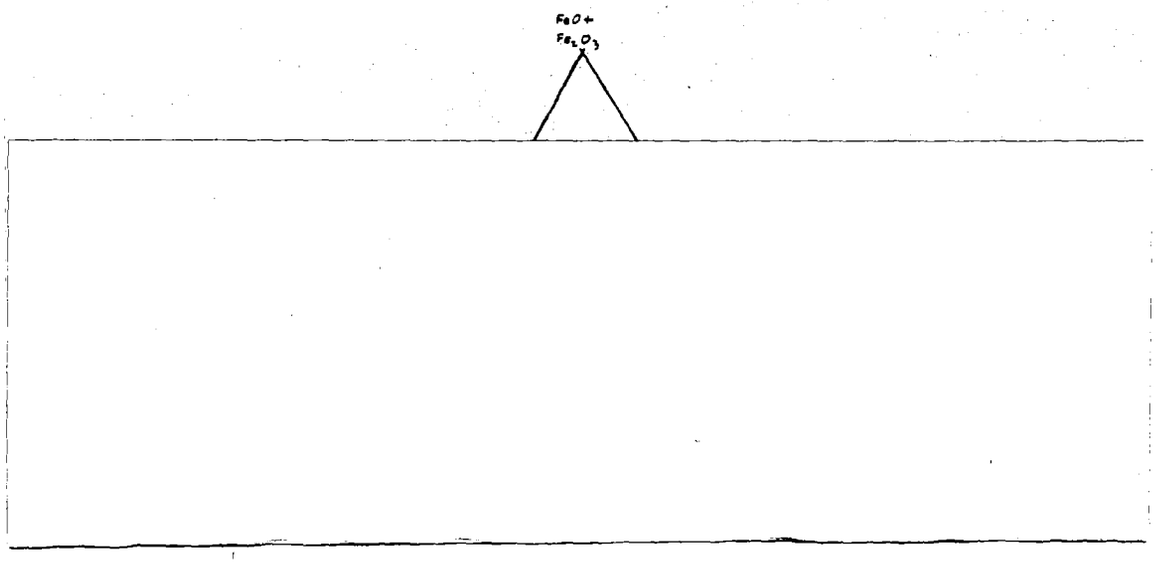


Figure I. F.M.A. (Total iron oxide, magnesian, and total alkalies) diagram. The cross indicates R.14486, and the black circle, R.14489. The unbroken line represents Tilley's (1950) tholeiite trend; the area enclosed by the dashed line, calc-alkaline rocks; the area enclosed by the chain dashed line, Mount Lamington lavas.

This area has been compiled by the writer from several occurrences of calc-alkaline rocks, i.e., Williams(1935) Thayer (1937), Larsen (1948), Oliver (1961), Morgan (1963), and Drewes, et al. (1961).

Calc-alkaline rocks are thought by many geologists to result from hybridization - e.g., Larsen, et al. (1938) Tilley (op.cit ), McDougal (1960), and this idea may explain one or two of the anomalous features noted in the specimens under consideration. Some of the quartz inclusions in the Mount Yelia lava samples contain reaction coronas which are exactly similar to those occurring on quartz inclusions in sub-silicic rocks (see, for example, figure 5, Morgan,1961). And yet the Mount Yelia lavas are acid. The reason for the presence of these reaction rims is hard to explain unless one supposes that the rock enclosing the quartz is a hybrid, and that the quartz grains were originally enclosed by a far more basic rock prior to hybridization. This is an interesting problem which, unfortunately, cannot be solved here.

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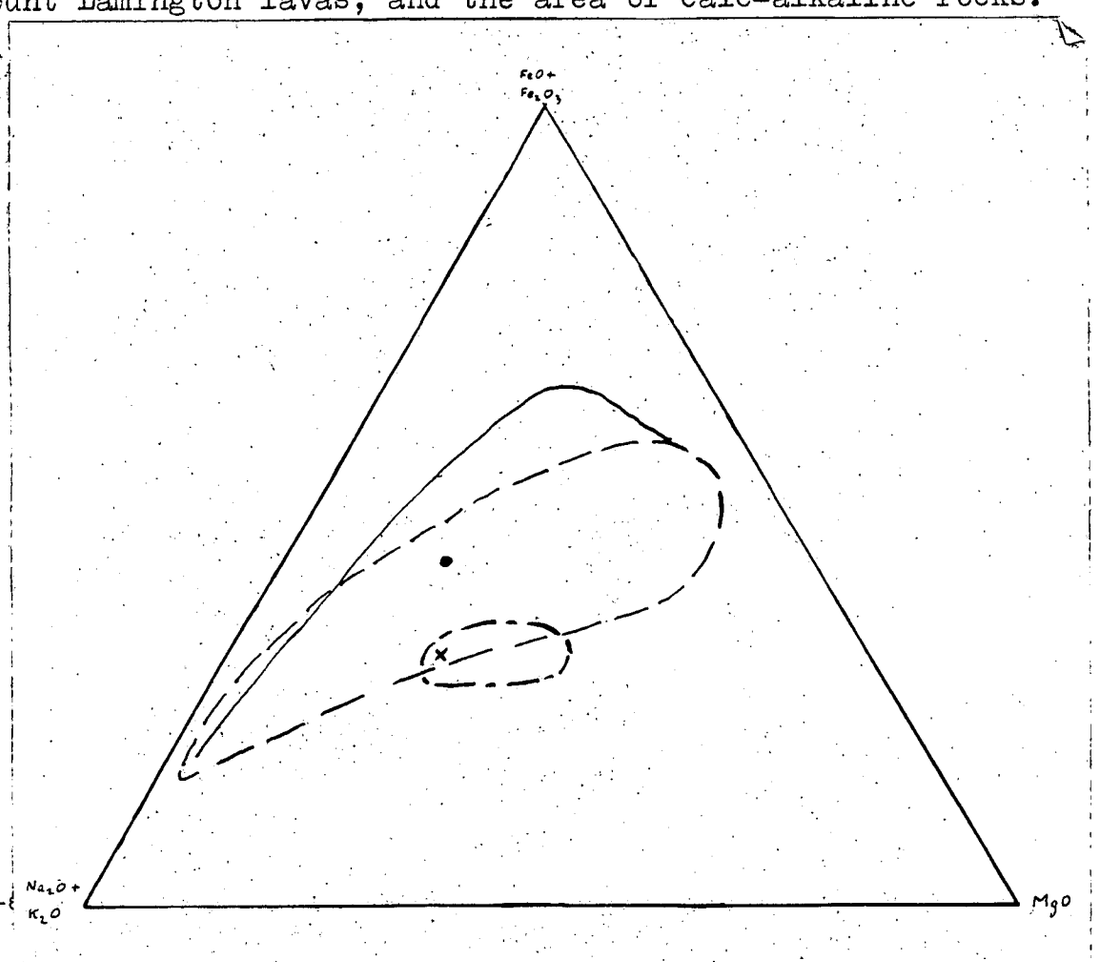


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Additional evidence in favour of hybridization is seen in the barified rims on some of the plagioclase phenocrysts in one of the Mount Victory lavas. Also, one of the Mount Yelia rocks has a plagioclase "phenocryst" to which is attached, and which is partly enclosed by a grain of quartz; in this case, no reaction corona is present on the quartz, although the grain is adjacent to the lava matrix. One of the Mount Victory specimens has two types of plagioclase phenocryst; one has a composition of $An_{38}$ and forms euhedral crystals, and the other has a composition of $An_{48}$, and occurs as embayed crystals. The embayed crystals are, presumably, foreign to the rock.

## COMPARISON WITH MOUNT LAMINGTON LAVAS

When the specimens were submitted, it was mentioned that the Mount Victory lava "bears a striking similarity to the Mount Lamington lavas." The writer has made a brief examination of thin sections of the Mount Lamington rocks, and considers that in general, the Mount Victory specimens are most similar to the Type II lavas (Taylor, 1958, pp.69-81 and 110-117) of Mount Lamington. There are several differences of detail - for example, more pyroxene is present, the groundmass of the Mount Lamington lavas are more crystalline; also,no anhydrite was detected in the Mount Victory lavas.

In Table 3A, the analysis of the Mount Victory lava is listed with analyses of Type II lavas from Mount Lamington. Some differences can be seen. The Mount Lamington lavas contain less silica and potash, and are slightly richer in total iron oxide, magnesia, lime, and phosphate than the Mount Victory specimen. Titania is remarkably high in the Mount Lamington lavas. However, in the FMA diagram of Figure I it will be seen that R.14486 plots in the same general field as the Mount Lamington lavas.

The writer has calculated the CIPW norms of the Mount Lamington lavas; these are shown, with the norm of R.14486, in Table 3B. It will be seen that they range from quartz-bearing andesite (No.13) to dacite rocks (No.12). In all but two of the Mt. Lamington lavas, hematite (He) is present in the norm. This is due not so much to the ozidation of iron, but to the high $TiO_2$ content of the lavas - in some specimens, the amount of ilmenite (Il) is more than twice that of the Mount Victory lava. The higher phosphate content in the Mount Lamington lavas is also made obvious by the amount of apatite (Ap) in the norms.

TABLE 3: Comparison of Mount Victory and Mount Lamington Type II Lavas.

A. Analyses

| | R.14486 | 8 | 10 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.7 | 59.85 | 58.45 | 60.26 | 56.92 | 59.72 | 60.32 |
| $TiO_2$ | 0.67 | 1.61 | 1.14 | 1.46 | 1.22 | 1.04 | 0.87 |
| $Al_2O_3$ | 16.1 | 16.29 | 16.24 | 15.78 | 16.05 | 16.19 | 17.51 |
| $Fe_2O_3$ | 2.25 | 2.83 | 3.17 | 2.62 | 2.67 | 3.67 | 2.72 |
| FeO | 2.20 | 2.05 | 2.30 | 2.36 | 3.12 | 1.58 | 2.02 |
| MnO | 0.08 | 0.14 | 0.12 | 0.11 | 0.12 | 0.10 | 0.11 |
| MgO | 3.15 | 3.58 | 4.05 | 3.54 | 4.96 | 3.42 | 3.24 |
| CaO | 5.05 | 6.21 | 6.71 | 6.04 | 6.93 | 6.04 | 5.70 |
| $Na_2O$ | 4.25 | 4.19 | 4.09 | 4.02 | 3.88 | 4.23 | 4.33 |
| $K_2O$ | 2.50 | 2.36 | 2.39 | 2.31 | 2.21 | 2.33 | 2.30 |
| $P_2O_5$ | 0.31 | 0.99 | 0.81 | 0.86 | 1.11 | 1.54 | 0.76 |
| $H_2O-$ | 0.07 | 0.06 | 0.01 | 0.03 | 0.07 | 0.07 | 0.21 |
| $H_2O+$ | 0.54 | Tr. | Tr | 0.12 | 0.11 | Tr. | Tr. |
| $CO_2$ | 0.18 | nil | nil | N.D. | N.D. | N.D. | nil |
| $SO_3$ | N.D. | 0.21 | 0.13 | 0.18 | 0.14 | 0.21 | 0.17 |
| Cl | N.D. | 0.14 | 0.15 | 0.10 | 0.11 | 0.13 | 0.15 |
| | 100.05 | 100.51 | 99.76 | 99.79 | 99.62 | 100.27 | 100.41 |

B. Norms

| | | R.14486 | 8 | 10 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|
| $Q_3$ | | 14.40 | 12.33 | 9.24 | 13.62 | 7.86 | 12.54 | 11.40 |
| Or | | 15.01 | 13.90 | 14.46 | 13.59 | 13.02 | 14.15 | 14.15 |
| Ab | | 36.15 | 35.63 | 34.58 | 34.00 | 33.01 | 35.63 | 36.68 |
| Au | | 17.24 | 18.63 | 18.63 | 18.32 | 20.02 | 18.35 | 21.41 |
| Di | Wo | 1.97 | 2.44 | 3.83 | 2.55 | 2.78 | 1.04 | 0.93 |
| | En | 1.50 | 2.10 | 3.30 | 2.20 | 2.20 | 0.90 | 0.78 |
| | Fs | 0.26 | – | – | – | 0.26 | – | 0.03 |
| Hg | En | 6.40 | 5.20 | 6.80 | 6.70 | 10.20 | 7.60 | 7.32 |
| | Fs | 0.92 | – | – | – | 1.06 | – | 0.25 |
| Mt | | 3.25 | 2.55 | 4.41 | 3.48 | 3.94 | 2.32 | 3.94 |
| He | | – | 1.12 | 0.16 | 0.16 | – | 2.08 | – |
| Il | | 1.37 | 3.04 | 2.13 | 2.89 | 2.28 | 1.98 | 1.67 |
| Ap | | 0.67 | 2.35 | 2.02 | 2.02 | 2.69 | 3.36 | 1.68 |
| Cc | | 0.40 | – | – | – | – | – | – |

R.14486 Mount Victory: quoted from Table 1 Analyst: C.R. Edmond, A.M.D.L., Adelaide.
8 to 15 Mount Lamington: Type II lavas: quoted from Taylor (1958), Table II, p.82.
Analyst: A.W. Dye & Co. Sydney.

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