Mineralogy and Proposed P – T Paths of Basaltic Lavas from Rabaul Caldera, Papua New Guinea

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Abstract. Rabaul caldera is a large volcanic depression at the north-east tip of New Britain, Papua New Guinea. The lavas range in composition from basalt to rhyolite and have a calc-alkaline affinity but also display features typical of tholeiites, including moderate absolute iron enrichment in flows cropping out around the caldera. The basalts contain phenocrysts of plagioclase and clinopyroxene with less abundant olivine and titanomagnetite. In the basaltic andesites olivine is rare, while orthopyroxene and titanomagnetite are common along with plagioclase and clinopyroxene. Orthopyroxene is also found mantling olivine in some of the basalts while in both rock types pigeonitic augite is a fairly common constituent of the groundmass. Plagioclase in both basalt and basaltic andesite often exhibits sieve texture and analysis of the glass blebs show them to be of similar composition to the bulk rock. Phenocrystic clinopyroxene is a diopsidic augite in both basalt and basaltic andesite. Al$_2$O$_3$ content of the clinopyroxene is moderately high (~4%) and often shows considerable variation in any one grain. Calculations show that the microphenocrysts probably crystallised near the surface, while phenocrysts crystallised at around 7 kb (21 km). Neither the basalts nor the basaltic andesites would have been in equilibrium at any geologically reasonable P and T with quartz eclogite. Equilibration between mantle peridotite and a typical Rabaul basaltic liquid could have occurred around 35 kb and 1270 °C. A basaltic andesite liquid yields a temperature of 1263 °C and a pressure of 28 kb for equilibration with mantle peridotite.

Partial melting of sufficient volumes of mantle peridotite at these P's and T's requires about 15% H$_2$O, but there is no evidence that these magmas ever contained large amounts of water. It is proposed that the Rabaul magmas were initially generated by partial melting of subducted lithosphere and subsequently modified by minor partial melting as they passed through the overlying mantle peridotite.

Introduction

Rabaul caldera, situated at the northeast tip of New Britain, lies at the eastern end of the New Guinea–New Britain volcanic arc. The caldera is the result of
two closely spaced periods of construction and collapse, each collapse being
accompanied by the eruption of dacitic pumice ash-flows. Presently, volcanic
activity is confined to small cones within the caldera. The geology and petrology
of Rabaul caldera is described elsewhere (Heming, 1974) and the mineralogy
and geochemistry of the ash-flows is treated by Heming and Carmichael (1973).

Basalt and basaltic andesite lavas of the caldera display a mild absolute iron
enrichment trend and contain occasional groundmass pigeonite while the basalts
display a reaction relationship between olivine and liquid. Their trace element
geochemistry has strong similarities to calc-alkalic series (Jakeš and Gill, 1970),
especially in the high abundance of Rb, Ba and Sr and moderate to low K/Rb
(529–282) and high Rb/Sr (0.03–0.05). In some other respects however, particularly
Ti/Zr and the relative abundance of Ti, Zr and Sr, the Rabaul rocks have close
affinities to low-potash tholeiites (Pearce and Cann, 1973). The potassium to
sodium ratios vary from 0.25 to 0.52 and overlap the range displayed by the
lavas of Tonga which lie between 0.25-0.40 (Ewart et al., 1973). Yet in strong
contrast to the flat rare-earth element pattern displayed by low-potassium
tholeiites and island arc tholeiites the Rabaul rocks are all enriched in light
rare-earth elements (Σ LaEu/Gd–Lu=2.32–1.13) (Heming and Rankin,
unpub. data). The lack of an iron enrichment trend in the lavas of some parasitic
cones suggests that this effect is some artifice of the magma chamber below the
caldera. This, combined with the generally alkalic character of the suite and the
high alumina contents of the basalts suggest a calc-alkalic affinity. Basalt and
basaltic andesite constitute about 53% of the volume of lava erupted, andesite
30%, dacite 15% and rhyolite about 2%. The chemical variation from basalt
to rhyolite can be readily explained by crystal fractionation of the observed
phenocryst phases (Heming, 1974).

In this paper, the mineralogy of the basalts, basaltic andesites and andesites is
described and P–T paths for the lavas are calculated.

Mineralogy

Feldspar

Zoned plagioclase is a ubiquitous phenocryst and groundmass mineral in basic
and intermediate lavas from Rabaul; however, a potassium feldspar is absent
from the series. Analyses of feldspar are shown in Figure 1. In both the basalts
and basaltic andesites the composition ranges from An₉₅ to An₄₀, with a slightly
more restricted range in the groundmass plagioclase (An₈₀ to An₄₅). Plagioclase
compositions in the andesites and dacites also cover a considerable range (An₈₅
to An₃₅) but most lie between An₈₀ and An₄₀. Rarely, xenocrysts of anorthite
are found in coarse-grained clots in the andesites. Groundmass feldspar is rela-
tively rare in the more siliceous rocks, most rocks of andesite and dacite composi-
tion having a glassy base. When a groundmass feldspar is present it is usually
less sodic than the coexisting phenocrysts.

The range of compositional zoning in individual plagioclase crystals from