Plate-Tectonic Evolution and Delayed Partial Melting in Western Papua New Guinea

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Abstract

Late Cainozoic volcanoes in the Papua New Guinea Highlands overlie cratonic crust but yet produce arc-type volcanics. The data from the study of these supposedly anomalous igneous rocks suggest that a mantle magma source which has been chemically modified during subduction and which has passed through rapid and pronounced changes in tectonic setting may later on be the source of magmas produced during a favourable but non-arc tectonic regime.

New data from Papua New Guinea suggest that andesitic and associated arc volcanism may not necessarily be contemporaneous with subduction; Late Cainozoic volcanoes in the Papua New Guinea Highlands overlie the northeastern corner of the Palaeozoic Australian craton (Figure 1) and are of arc-trench character, but evidence of contemporaneous subduction beneath them is lacking.

The Highlands volcanoes rest on a Mesozoic-Tertiary platform-and-trough sequence overlying Late Palaeozoic crust 35 km thick. This part of the northern Australian craton is flanked by an orogenic belt (Figure 1) which contains mid-Cretaceous and Middle Miocene andesitic and dioritic rocks. Volcanism began in the Early Pleistocene-latest Pliocene immediately following Late Pliocene upwarping (Jenkins, 1974) which culminated in the northeast of the Highlands province; weak solfataric and hydrothermal activity is still evident in two centres. Most centres are stratovolcanoes made up dominantly of basaltic rocks which are overlain by andesites; four centres are dominantly andesitic, and one, in the extreme south, is trachytic (Mackenzie, 1976).

Rocks of the Highlands volcanoes range from high-K olivine and quartz tholeiites and trachybasalt through tholeiite to alkali basalt, and from high-K trachyandesite to andesite, and rare dacite and trachyte. They are characterized by high large-ion lithophile element (LILE) contents and fractionated rare earth element (REE) abundances, with L (light) REE enriched relative to H (heavy) REE. In general terms, basalts from volcanoes in the north are richer in SiO_2 and many LILE than those farther south, but there is no regular chemical variation across the province that could be related to an underlying southward-dipping subducted slab (*cf.* Jakeš and White, 1969).

Initial Sr isotope ratios in the Highlands rocks are generally high and are highest in rocks from the more southerly centres; crustal contamination is, however, significant in only one sample. Data on unfractionated basaltic rocks from the most northeasterly centres yield encouraging evidence of a 'pseudo-isochron' (Brooks *et al.*, 1976), corresponding to an age of 103 ± 68 m.y., when plotted on an Rb-Sr isochron diagram. Data from three samples of Middle Miocene basaltic rocks (Page, 1975) also plot on or very near the 'pseudo-isochron'. This suggests isotopic resetting of the mantle beneath the Highlands in the late Mesozoic-early Tertiary; significantly, andesitic volcanic rocks of Albian-Cenomanian age (about 100 m.y.) occur in the orogenic belt immediately north of the Highlands volcanoes.

The following is an internally consistent, though incompletely developed and tested, four-stage model (Figure 2) to account for the Highlands volcanism.

1. Southwestward subduction beneath the northeastern corner of the Australian craton occurred during an

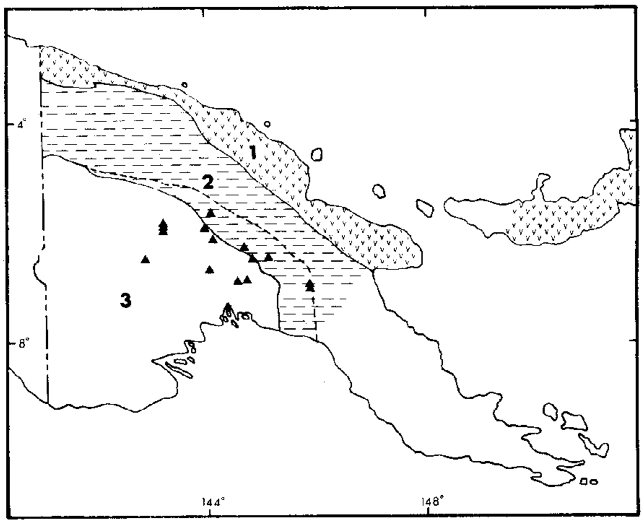

FIGURE 1

Western Papua New Guinea showing Highlands volcanoes (triangles) and generalised tectonic setting: 1, early Tertiary island arc; 2, mobile belt; 3, platform. Broken line is approximate edge of thick Palaeozoic continental crust.

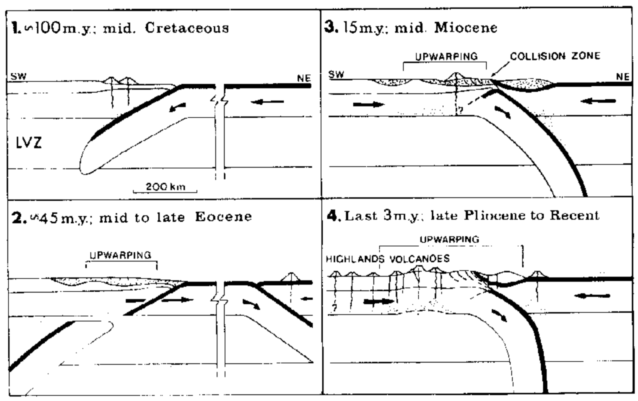

FIGURE 2

Stylised composite SW-NE sections through the Highlands province illustrating tectonic and petrological evolution. Solid black: oceanic crust; dash pattern: Mesozoic-early Tertiary volcanism and sedimentation; stippling: rising slab-derived fluids and chemically modified mantle; arrows: relative plate movements

episode, in and around the Pacific, of greatly accelerated sea-floor spreading and andesitic-dioritic magmatism between 100 and 85 m.y. ago (Larson and Pitman, 1972). Fluids or siliceous melts rich in LILE and in LREE relative to HREE due to equilibration with garnet-bearing (Gill, 1974) subducted oceanic crust rose into and chemically modified the overlying mantle (notably, the lower lithosphere), isotopically reset it, and triggered off limited (mid-Cretaceous?) volcanism.

2. Southwestward subduction ceased, with volcanism, in the Late Cretaceous and was succeeded about 1200 km to the north by northward subduction. The resulting volcanic arc is now represented by the northern coastal ranges of Papua New Guinea. Initiation of northward subduction may have coincided with the Antarctic-Australia split about 55 m.y. ago (Weissel and Hayes, 1971), or with the opening of the Coral Sea about 62 m.y. ago.

3. The Australian continent with its chemically modified lower lithosphere reached the early Tertiary arc-trench system in the Late Oligocene to Early Miocene and, because its buoyancy prevented its being subducted, its northern margin became part of a collision zone. Extensive deformation and uplift in the collision zone during the Middle Miocene were accompanied by andesitic/dioritic and high-K basaltic magmatism.

4. In the Late Pliocene-Early Pleistocene renewed upwarping, culminating in the north of the Highlands province, was followed by the Highlands volcanism. Diapirism from the lower lithosphere, perhaps initiated by build-up of radiogenic heat from K, Th, U, etc in the LILE-enriched source and by gravitational instability, may have caused or enhanced uplift. Alternatively pressure release during upwarping may have initiated diapirism and/or partial melting.

Thus it appears that a mantle magma source region chemically modified during subduction may, probably through rapid and pronounced changes in tectonic setting, be the source of magmas formed during a much later, favourable tectonic regime (*cf.* Johnson *et al.*, 1978).

There are several factors that may complicate this apparently simple concept. One is initial heterogeneity of the lower lithosphere, such as may be the case in the Highlands where Sr isotope ratios are lower in the north, perhaps reflecting depletion by earlier magmatism (volcanic rocks of mobile belt (2), Figure 1). The other is the possible incorporation of LILE-rich upper asthenosphere in the lower lithosphere. as it thickens with age (e.g. Frey and Green, 1974).

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Geomagnetic changes Associated with Thermal Activity on Kadovar Island, Papua New Guinea

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Abstract

Changes in the local magnetic field associated with volcanic thermal activity on Kadovar Island, Papua New Guinea, were measured over a one-year period, 1976/77. The magnetic field changes were highly localised near vents and were quite shallow. They were most likely produced by thermal demagnetisation rather than through piezomagnetic effects.

Introduction

Changes in magnetic field associated with volcanic activity have been reported by investigators in several countries. In particular, Bernstein (1960) and Hurst and Christoffel (1973) have reported changes of several hundred nanotesla (gammas) which they attributed to thermal demagnetisation and remagnetisation of sub-surface rocks.

In late 1976 fumerolic and seismic activity commenced on Kadovar Island. An area of hot ground and dying vegetation surrounding the gas vents appeared in September and rapidly expanded during the following months. Although in recent months the activity appears to have decreased in intensity, it was originally thought that an eruption might be imminent, especially as there had been a series of eruptions at other volcanoes in the Bismarck volcanic arc (Cooke *et al.* 1976).

It was decided to carry out a series of measurements to see whether changes in magnetic field strength would accompany the heating. This paper presents the results of six visits to the island between November 1976 and November 1977.

Kadovar Island

Kadovar is a Quaternary volcanic island, roughly elliptical in shape and measuring approximately 1.3 × 1.5 km. It is one