westwards relative to Antarctica the volcanic foci remained relatively stationary. It is proposed that the line traced by the volcanic foci that are at present operating in the Auckland area lie to the east of the line traced by the volcanic focus that lies beneath the Egmont area. The relatively small volumes of nephelinitic magma from which the volcanic rocks of the Auckland domain were derived is considered to have been generated at a depth of the order of 75km beneath a relatively thick plate of lithosphere. The magma responsible for the generation of the volcanic rocks of the Egmont domain is believed to have initially formed at even greater depths than the Auckland volcanic focus. This magma was initially silica and potash rich but after reacting with the phases present in the overlying upper-mantle this initial magma changed in composition; and this process has resulted in the evolution of a suite of magmas that consist mainly of andesites, benmoreites and tristanites.

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THE ORIGIN OF MAGMAS AT CONVERGENT PLATE BOUNDARIES

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The dominant lava types produced by volcanism in young island arcs are basalts close to silica-saturation, basaltic andesites and andesites. These lavas are often referred to two associations — the island arc tholeiitic association, found in volcanoes ~80 - 150 km above the Benioff Zone, and the calc-alkaline association, in volcanoes ~ 100 - 250 km above the Benioff Zone. The major possible source materials for primary magmas of the two associations are former oceanic crust (in the form of eclogite) in the subducted lithosphere slab, and the overlying wedge of peridotitic mantle (Figs. 1 and 2).

Complementary experimental studies of the crystallization of tholeiitic basalts (Nicholls and Ringwood, 1973) and the partial melting of the pyrolite model mantle composition (Green, 1973), both under high water pressures, have indicated that basaltic to basaltic andesite magmas of the island arc tholeiitic association may be produced by partial melting of hydrous peridotitic mantle to depths of ~ 80 km.

Both the nature and origin of primary magmas of the calc-alkaline association are under debate. Studies of the crystallization of andesites at high pressures (T.H. Green, 1972; Stern, 1974) have indicated that andesitic magmas (~60% SiO_2) may be produced by partial melting of eclogite in the former oceanic crust at depths of ~ 100 km.

Liquids with 55-60% SiO_2 have also been produced by experimental melting of hydrous peridotitic assemblages, the estimated maximum depths for the corresponding equilibrium partial melting process in the mantle ranging from ~ 40 km. (Nicholls, 1974) to > 60 km. (Mysen and Boettcher, 1975). These results show that, if partial melting of peridotitic mantle is the major process in the formation of andesites, then partial melting and magma separation must take place in the shallow portions of the mantle wedge beneath volcanoes of the calc-alkaline association, rather than immediately above the Benioff Zone. However, experimental liquids with 55-60% SiO_2 are much more magnesian than natural andesite lavas, suggesting that the latter have a more complex history, almost certainly involving processes of crystal fractionation.

Further consideration of geochemical data and experimental phase relationships for island-arc magma types has allowed the formulation of a model which attempts to explain spatial variation in the geochemistry of island-arc volcanic rocks (Ringwood, 1974; Nicholls and Ringwood, 1973). At shallow Benioff Zone depths (80-100 km) dehydration of the basaltic crustal component of downgoing oceanic lithosphere causes the introduction of water into the overlying mantle wedge

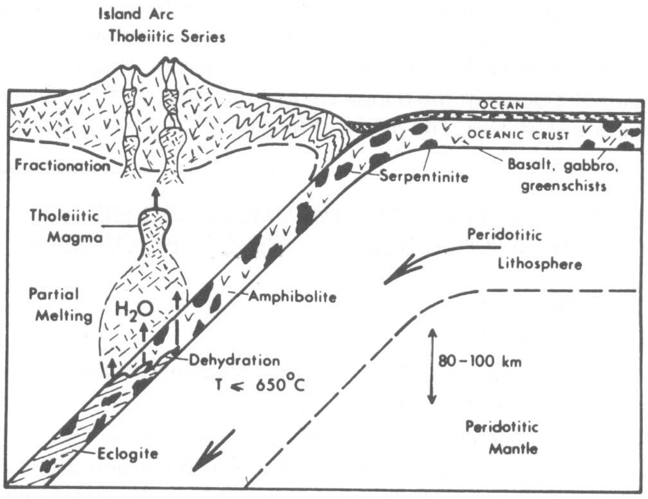

Figure 1
Petrogenetic model of tholeiitic volcanism in island arcs (modified from Ringwood, 1974).

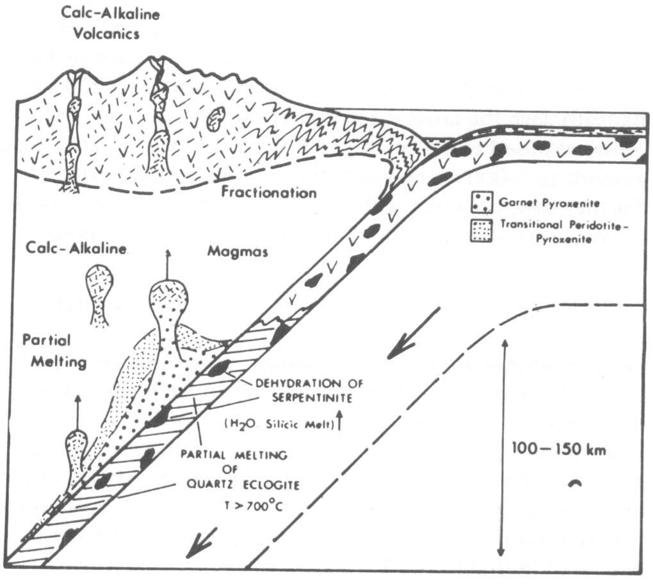

Figure 2
Petrogenetic model of calc-alkaline (andesitic) volcanism in island arcs (modified from Ringwood 1974).

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(Fig. 1). Subsequent melting of hydrous peridotitic mantle yields basaltic magmas of the "island-arc tholeiitic" suite, as developed for example in the Tonga-Kermadec section of the S.W. Pacific arcs.

At greater depths (100 - 250 km) the former oceanic crust, now transformed to eclogite, undergoes partial melting, producing hydrous rhyodacite-rhyolite liquids rich in K and related trace elements (Fig. 2). The peridotitic mantle overlying the Benioff Zone is modified toward pyroxenitic compositions by reaction with these liquids. Subsequent partial melting of this modified mantle produces magmas of basaltic to basaltic andesite compositions, richer in K than those associated with the island-arc tholeiitic series. Intermediate pressure fractionation of these magmas, involving mainly olivine, calcic clinopyroxene and amphibole, allows evolution toward andesitic magmas. Superimposed lower pressure fractionation processes yield a wide range of "calc-alkaline", "high-K calc-alkaline" and "shoshonitic" lavas, such as those developed in several of the S.W. Pacific arcs.

Rocks of a "high-K alkaline" suite, dominated by strongly silica-undersaturated leucite basanites, tephrites and phonolites, are relatively rare in island arcs, where they are usually associated with Benioff Zone depths of 250-400 km. Good examples occur in the Sunda arc of Indonesia, particularly in the island of Java. The origin of magmas of this suite, and associated sodic alkaline suites, may not be related primarily to the dehydration or melting of subducted oceanic crust, but may reflect the tapping of the mantle low velocity zone behind the main volcanic arc during tensional faulting associated with the formation of interarc basins on sialic crust.

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GEOCHEMISTRY OF THE VOLCANIC ROCKS OF THE SUNDA ISLAND ARC OF INDONESIA

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The Sunda arc represents the collision zone between the India and Asia (or China) plates. The Sunda volcanic arc extends from north of Sumatra, along the southwestern coast of Sumatra, through Java, Bali, Lombok, Sumbawa, Flores and the Lesser Sunda Islands, after which it becomes known as the Banda arc. There are a variety of tectonic environments represented along the arc. In Sumatra the crust is ∿40 km thick and Palaeozoic granites show it to be relatively old. The Benioff zone as defined by the location of earthquake foci extends only to relatively shallow depths of ∿200 km. Beneath Java the crust is somewhat thinner, younger; the oldest exposed rocks being ? Mesozoic, and the Benioff zone extends to ∿600km beneath the Java Sea to the north. Further east, the crust is thinner (∿15 km), oceanic in velocity structure and again the Benioff zone extends to great depths.

There are three major volcanic associations represented along the arc.

(1) **The normal island arc association** is the most abundant and widespread, being found along the entire length of the arc. Rocks of this association range in composition from those showing affinities with the island arc tholeiitic suite closest to the trench, over Benioff zone depths of 100-150 km, through a spectrum of calc-alkaline to high-K calc-alkaline varieties more distant from the trench, over Benioff zone depths of 200-250 km. This latter group are sometimes referred to as "shoshonites". Chemically, rocks of this suite have low concentrations of TiO_2, high Al_2O_3, low MgO and a variable, but generally low alkali content. The predominantly basaltic rocks of the island arc tholeiitic suite are geochemically primitive whereas the calc-alkaline rocks are more evolved. The rocks of this association exhibit consistent spatial, geochemical variations normal to the arc; the best defined being that of K which shows an increasing abundance relative to SiO_2 with increasing depth to the Benioff zone. The "incompatible" trace elements such as Rb, Sr, Ba, U, Th, Zr and Hb all behave sympathetically with K and there is a suggestion that $^{87}Sr/^{86}Sr$ ratios increase regularly in the series from the tholeiitic rocks (∿0.7043) to the high-K calc-alkaline rocks (∿0.7050). Elements such as Ni, Co and Cr are characteristically depleted in all the rocks of this association, although they are somewhat more abundant in the tholeiitic rocks.

(2) Rocks of the **high-K alkaline association** are much less common and are predominantly leucite basanites and their derivatives. Volcanoes erupting these lavas are generally found over Benioff zone depths >300 km and at present there are only two or three active volcanoes of this type, although there are several more extinct. Chemically, these rocks again have low TiO_2, a characteristic feature of island arc rocks, MgO is much higher than in the normal island arc association and total alkalis are much more abundant, largely reflecting the high K_2O contents. Rocks of this association are highly enriched in the "incompatible" trace elements and are also moderately enriched in the siderophile trace elements. $^{87}Sr/^{86}Sr$ ratios are relatively low (∿0.7043). Thus, despite being geochemically primitive in terms of Mg/Fe ratios and $^{87}Sr/^{86}Sr$ ratios, rocks of this association are also enriched in K and related trace elements.

(3) The third major association is represented by the **rhyolitic tuffs and ignimbrites** which are widespread in

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