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Crystallization of Calc-Alkaline Andesite under Controlled High-Pressure Hydrous Conditions

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Abstract. A series of experimental runs has been conducted on a glass prepared from a natural island arc calc-alkaline andesite from Fiji. The crystallization sequence was determined for the pressure interval 9–36 kb under anhydrous conditions and with 2, 5, and 10% by weight of water carefully added.

Addition of water markedly lowers the liquidus, depresses the appearance of quartz and plagioclase in the crystallization sequence, and greatly enlarges the field of garnet-clinopyroxene crystallization above 25 kb. Amphibole crystallizes in hydrous runs up to 25 kb.

Electron microprobe analyses of critical phases allows calculation of controls on crystal fractionation trends. For hydrous conditions at 5–15 kb amphibole-clinopyroxene dominate fractionation and a moderate decrease in Mg/Fe and a slight increase in K/Na occurs. At 15–25 kb garnet also affects the fractionation and a moderate decrease in Mg/Fe and an increase in K/Na results. Above 25 kb garnet-clinopyroxene control the fractionation and there is a slight decrease in Mg/Fe but a significant increase in K/Na and a pronounced silica enrichment.

In terms of major element chemistry, the derivation of the Fijian dacites in the second period of eruption may be satisfactorily explained by the fractionation of hydrous andesite at pressures > 25 kb. Alternatively the dacites may result from lower degrees of melting of the down-going hydrous lithosphere. Similarly other members of this eruptive period may be derived according to a model of eclogite-controlled fractional melting or crystallization. Models involving amphibole fractionation at lower pressures are less satisfactory for explaining compositions in the Fijian second period of eruption, but in other environments models including amphibole-controlled fractionation may form part of a continuum of melting processes in subduction zones.

Introduction

In recent years the concept of the new global tectonics has focussed attention on orogenic belts and island arc areas as zones of collision and consumption of the lithosphere. These zones are the sites of extensive magmatic activity involving addition of large volumes of material to the crust. In particular the calc-alkaline igneous rock series and the newly defined island arc tholeiitic series constitute the bulk of this activity (Jakes and Gill, 1970; Gill, 1970). Recent syntheses of models linking high pressure experimental results on fractionation of members of the calc-alkaline igneous rock suite (Green and Ringwood, 1968, 1969) with new geochemical results (Taylor, 1969; Taylor *et al.*, 1969) and discussions of subduction zones and island arc tectonics (Raleigh and Lee, 1969) have all concluded that a 2-stage model for the development of calc-alkaline rocks from the mantle is in best accord with the experimental and observational results. In the first stage basalts are erupted at the mid-ocean ridges, then are carried into the subduction zones of the continental margins or island arc areas, and finally undergo melting in the second stage to produce calc-alkaline magmas.