

An important corollary of this model is that it provides a mechanism for the transport of water from the hydrosphere into the mantle (Ringwood, 1969). Water plays a significant role in the derivation and crystallization of magmas (Burnham, 1967; Brown and Fyfe, 1970). Hence it is of critical importance to investigate the effect of water on the crystallization and fractionation of calc-alkaline magmas at high pressures. Preliminary reconnaissance hydrous experiments at high pressure on high-alumina quartz tholeiite, basaltic andesite, andesite and dacite have been reported (Green and Ringwood, 1967, 1968). This work demonstrated

- (1) the key role of amphibole at low-moderate pressures,
- (2) a change in liquidus phase in dacite-rhyodacite compositions from quartz (anhydrous) to garnet (hydrous),
- (3) in the presence of water, the andesite liquidus no longer falls in a pronounced thermal valley between more basic and more acid compositions (Green and Ringwood, 1968; Fig. 8).

The present study investigates in detail the crystallization and fractionation of a calc-alkaline andesite under high-pressure hydrous conditions with known quantities of water present. It has the aim of determining the control water exerts on the temperature of melting and the nature of potential magmas produced in the subduction zone.

Choice of Composition

Recent geochemical work on Fiji (Gill, 1970) has provided the background for the choice of composition. Gill suggested that Fiji represents the development of an island arc passing through several geochemically distinct cycles of igneous activity. These cycles of activity may be summarized as follows—

- (a) island arc tholeiitic series—first period of eruption,
- (b) calc-alkaline series—second period of eruption,
- (c) shoshonitic series—third period of eruption.

A typical calc-alkaline andesite from the second period of eruption was chosen¹. Slightly more mafic and more silicic members occur in this period of eruption. Thus the experimental work undertaken may be applied to test the possible links, through crystal fractionation processes, between the rock types of this calc-alkaline series, and also to determine the likely depth at which these processes occurred.

Experimental

The natural andesite was crushed, melted and quenched to a glass. This glass was subsequently checked for homogeneity by optical examination in immersion oils, and by electron microprobe analysis of fragments. The oxidation state, iron content and alkali element content were determined by chemical analysis (E. Kiss, A.N.U. analyst). The resulting composition obtained for the glass is given in Table 1, together with an analysis of the original sample (Gill, 1970). There is excellent agreement between the two analyses.

The high pressure experimental technique using a piston-cylinder apparatus is similar to that described by D. H. Green and Ringwood (1967) for anhydrous runs and by Essene *et al.* (1970) for hydrous runs. In the latter, 2, 5, or 10% by weight of H₂O was added with

¹ Mr. J. Gill, Australian National University kindly provided a sample of specimen 68-66 (Gill, 1970).

Table 1. Comparison of analysis of andesite 68-66 (Gill, 1970) with glass prepared for this experimental work

	68-66	Glass	Glass (recalculated to 100%, values based on chemical analyses)
SiO ₂	59.39	60.27 ^a	60.24
TiO ₂	0.68	0.67 ^a	0.69
Al ₂ O ₃	16.73	16.95 ^a	16.98
Fe ₂ O ₃	3.66	0.87 ^b	0.88
FeO	2.61	5.28 ^b	5.35
MnO	0.13	0.13 ^c	0.13
MgO	3.08	3.30 ^a	3.14
CaO	7.12	7.34 ^a	7.22
Na ₂ O	3.97	3.91 ^b	3.91
K ₂ O	1.27	1.26 ^b	1.26
P ₂ O ₅	0.20	0.20 ^c	0.20
Loss	0.55		
	99.39	100.18	100.00

Norms

q	13.9	11.4	11.3
or	7.5	7.2	7.5
ab	33.6	33.0	33.1
an	24.1	25.1	25.0
di	7.9	8.2	8.0
hy	4.8	12.0	12.1
mt	5.3	1.3	1.3
il	1.3	1.5	1.3
ap	0.4	0.4	0.4

^a Denotes content determined by electron microprobe analysis of glass fragments.

^b Denotes content determined by chemical analysis (E. Kiss, A. N. U. analyst).

^c Denotes content not determined; presumed same as analyzed in natural rock.

the aid of a microsyringe. A pressure correction of -10% to the nominal pressure was applied (Green *et al.*, 1966). For runs at temperatures less than 1100° C Ag-Pd capsules were used. Generally run times were between 12-24 hours for temperatures less than 950° C and from 6-12 hours at 950-1100° C. For temperatures above 1100° C Pt capsules were used and run times reduced to 1-4 hours (< 1300° C) or to less than 1 hour (> 1300° C).

At the conclusion of a run, the sample was examined optically and by X-ray diffraction. When crystal size was adequate, quantitative analyses of minerals present were obtained using an electron microprobe (A.R.L., EMX model) following the methods outlined by Sweatman and Long (1969) and Lovering and Ware (1970). The principal fractionation trends for differing pressures and water content were then determined, using these analyses.

Results

The results for the crystallization of the andesite glass from 9-36 kb for anhydrous conditions and 2, 5, and 10% by weight of water added are summarized in Figs. 1-4.