

plagioclase intergrown with orthopyroxene (analysis 2, Table 1) was found.

### Water-Fugacity Control

Silicate-phase liquids were determined under H<sub>2</sub>O-saturated and undersaturated conditions from 0.5 to 8 kb in an internally heated pressure vessel (Burnham and others, 1969). The pressure medium was argon, and temperatures were read with three Chromel-Alumel or Pt-Pt10Rh thermocouples. Maximum errors for these runs are estimated at  $\pm 12^\circ\text{C}$  and 0.35 kb but in most cases were less; error brackets in Figures 1 and 2 show estimated errors for each run, which are listed in Tables 2 and 3. A few runs were made at 10 kb in a piston-cylinder apparatus, with errors as shown in Figure 2; techniques of Boettcher and Wyllie (1968) were used.

In H<sub>2</sub>O-saturated runs, approximately 0.1 g of rock was loaded into a Pd50-Ag50 capsule with an excess of H<sub>2</sub>O, and the capsule was welded shut. For H<sub>2</sub>O-undersaturated runs, the oxalic acid technique (described at length by Eggler, 1972a) was used. A fluid phase was always present in the run, which promoted rapid achievement of equilibrium.

One mole of oxalic acid, loaded with rock into the capsule, initially produces 2 moles CO<sub>2</sub> and 2 moles H<sub>2</sub>O at high temperature (Holloway and others, 1968), but H<sub>2</sub>O must then be partitioned between melt and fluid. In the absence of thermodynamic data, it is assumed that H<sub>2</sub>O mixes ideally in the fluid phase ( $f^f_{\text{H}_2\text{O}} = X^f_{\text{H}_2\text{O}} \times f^\circ_{\text{H}_2\text{O}}$ ) and that CO<sub>2</sub> has negligible solubility in the melt. Because  $f^m_{\text{H}_2\text{O}}$  can be related to  $X^m_{\text{H}_2\text{O}}$  (the mole fraction of H<sub>2</sub>O in melt) by the thermodynamic data of Burnham and Davis (1971) on melts in the NaAlSi<sub>3</sub>O<sub>8</sub>-H<sub>2</sub>O system, the amount of oxalic acid to add to the capsule to achieve any amount of H<sub>2</sub>O in the melt can be calculated (Eggler, 1972a).

When a large excess of oxalic acid is used, so that the amount of H<sub>2</sub>O entering the melt is negligible compared to that in the fluid, percent H<sub>2</sub>O in the melt is known no matter what the percent melt in the run, because the fluid contains 50 mole percent H<sub>2</sub>O. Otherwise, the amount of glass must be known to calculate the amount of H<sub>2</sub>O in the melt. Accordingly, modes of critical runs were counted in polished thin section. A few modes were calculated by a least-squares method from probe analyses of

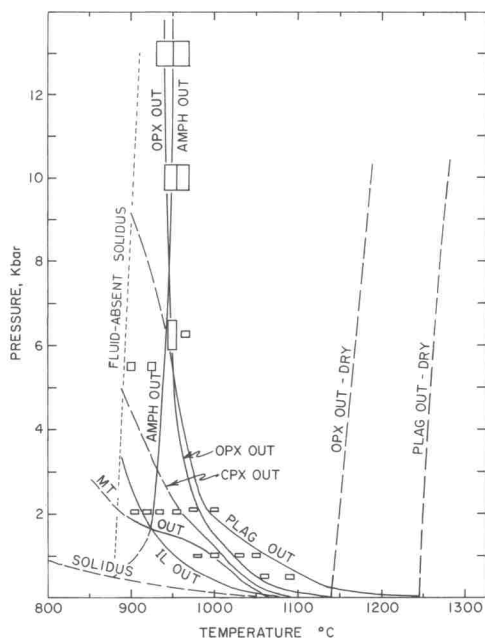


Figure 1. Phase relations for Mount Hood andesite composition at H<sub>2</sub>O-saturated conditions at the QFM buffer. Runs at 10 and 13 kb from Allen and Boettcher (1971); dry liquids extrapolated after Green and Ringwood (1968). Vapor-absent curve inferred.

all phases (see Holloway and Burnham, 1972). Weight percents H<sub>2</sub>O in the melt, listed in Table 3, are believed to be accurate to 0.5 percent.

### Oxygen Buffering

The internally heated pressure vessel was fitted with a 60Pd-40Ag hydrogen membrane (Shaw, 1967) connected to a hydrogen tank and Heise gauge.  $P_{\text{H}_2}$  was maintained at a value to yield an oxygen fugacity, calculated from the  $f^m_{\text{H}_2\text{O}}$  of the run, equal to that of the QFM buffer for the temperature and pressure of the run. The maximum relative error in hydrogen pressure was 6 percent.  $P_{\text{H}_2}$  in runs in the piston-cylinder was close to that of the NNO buffer for pure H<sub>2</sub>O (Eggler, 1972a). Tables 2 and 3 list  $P_{\text{H}_2}$  and  $f_{\text{O}_2}$ .

Runs were made at 1 atm in 50Pd-50Ag envelopes in vertical quench furnaces wound with platinum and kanthal wire. Temperatures were controlled to  $\pm 3^\circ\text{C}$  or less. Oxygen

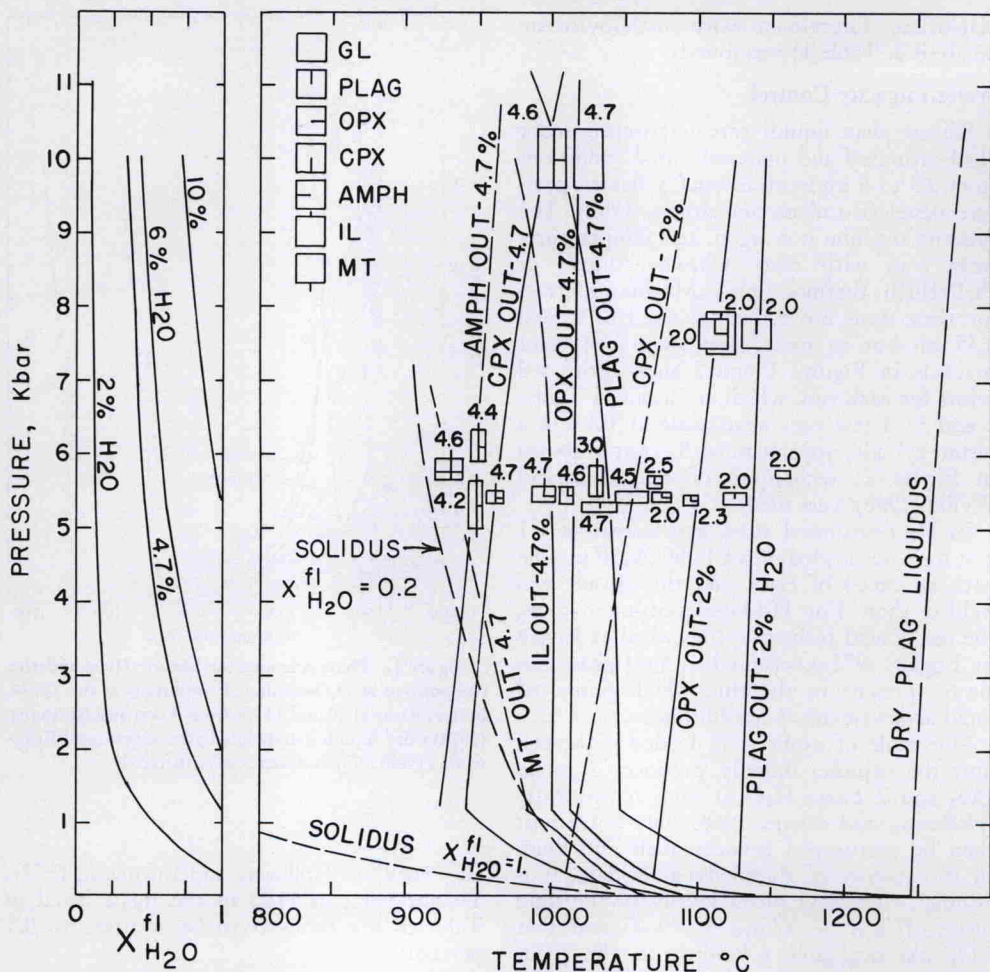


Figure 2. Phase relations at  $H_2O$ -undersaturated conditions. Numbers near run boxes indicate wt percent  $H_2O$  in melt of the run. Liquidi are drawn for

$H_2O$  contents in melt of 2.0 and 4.7 percent. Graph at left relates wt percent  $H_2O$  in melt to  $X^{fl}_{H_2O}$  at  $1,000^\circ C$ .

fugacities were controlled by standard  $CO_2$ - $H_2$  gas-mixing techniques (Darken and Gurry, 1945). Both temperature and  $f_{O_2}$  were checked by determining the NNO reaction at  $1,100^\circ$  and  $1,200^\circ C$ .

#### Phase Identification and Analysis

All runs were crushed and examined in immersion oils. Opaque phases were identified in polished section under oil and magnified  $\times 1,500$ . Probe analyses were performed on ARL-AMX and EMX instruments by techniques described previously (Egglar, 1972a).

## EXPERIMENTAL RESULTS

### Phase Relations

Runs at 1 atm appear in  $f_{O_2}$ - $T$  projection in Figure 3. While silicate liquidi are apparently little affected by  $f_{O_2}$ , stability of the oxides, ilmenite and magnetite, is increased by higher  $f_{O_2}$ . Ilmenite is a rhombohedral phase which is a solid solution of ilmenite ( $FeTiO_3$ ) and hematite ( $Fe_2O_3$ ). Magnetite is a spinel phase which is a solid solution of magnetite ( $Fe_3O_4$ ) and ulvospinel ( $Fe_2TiO_4$ ). Perhaps surprisingly, ilmenite crystallizes at a higher temperature