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

Water-Fugacity Control

Silicate-phase liquidi were determined under H_2O–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 $\pm 12°C$ 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 10kb in a piston-cylinder apparatus, with errors as shown in Figure 2; techniques of Boettcher and Wyllie (1968) were used.

In H_2O–saturated runs, approximately 0.1 g of rock was loaded into a Pd50–Ag50 capsule with an excess of H_2O, and the capsule was welded shut. For H_2O-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_2 and 2 moles H_2O at high temperature (Holloway and others, 1968), but H_2O must then be partitioned between melt and fluid. In the absence of thermodynamic data, it is assumed that H_2O mixes ideally in the fluid phase ($f^{fl}_{H_2O} = X^{fl}_{H_2O} \times f°_{H_2O}$) and that CO_2 has negligible solubility in the melt. Because $f^m_{H_2O}$ can be related to $X^m_{H_2O}$ (the mole fraction of H_2O in melt) by the thermodynamic data of Burnham and Davis (1971) on melts in the $NaAlSi_3O_8$–H_2O system, the amount of oxalic acid to add to the capsule to achieve any amount of H_2O in the melt can be calculated (Eggler, 1972a).

When a large excess of oxalic acid is used, so that the amount of H_2O entering the melt is negligible compared to that in the fluid, percent H_2O in the melt is known no matter what the percent melt in the run, because the fluid contains 50 mole percent H_2O. Otherwise, the amount of glass must be known to calculate the amount of H_2O 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
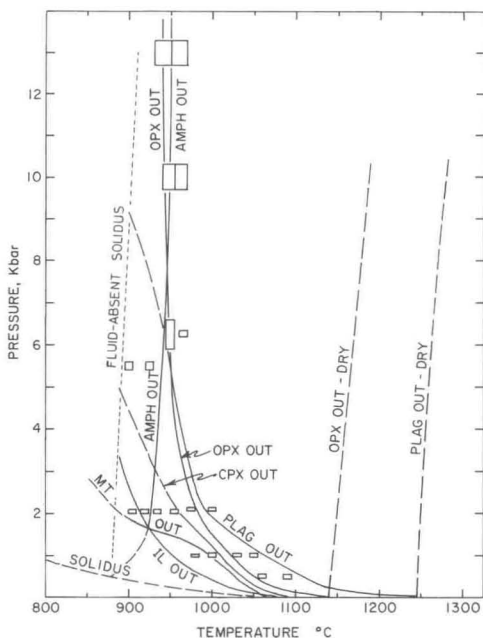

Figure 1. Phase relations for Mount Hood andesite composition at H_2O–saturated conditions at the QFM buffer. Runs at 10 and 13 kb from Allen and Boettcher (1971); dry liquidi extrapolated after Green and Ringwood (1968). Vapor-absent curve inferred.

all phases (see Holloway and Burnham, 1972). Weight percents H_2O 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_{H_2} was maintained at a value to yield an oxygen fugacity, calculated from the $f^m_{H_2O}$ 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_{H_2} in runs in the piston-cylinder was close to that of the NNO buffer for pure H_2O (Eggler, 1972a). Tables 2 and 3 list P_{H_2} and f_{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 $\pm 3°C$ or less. Oxygen
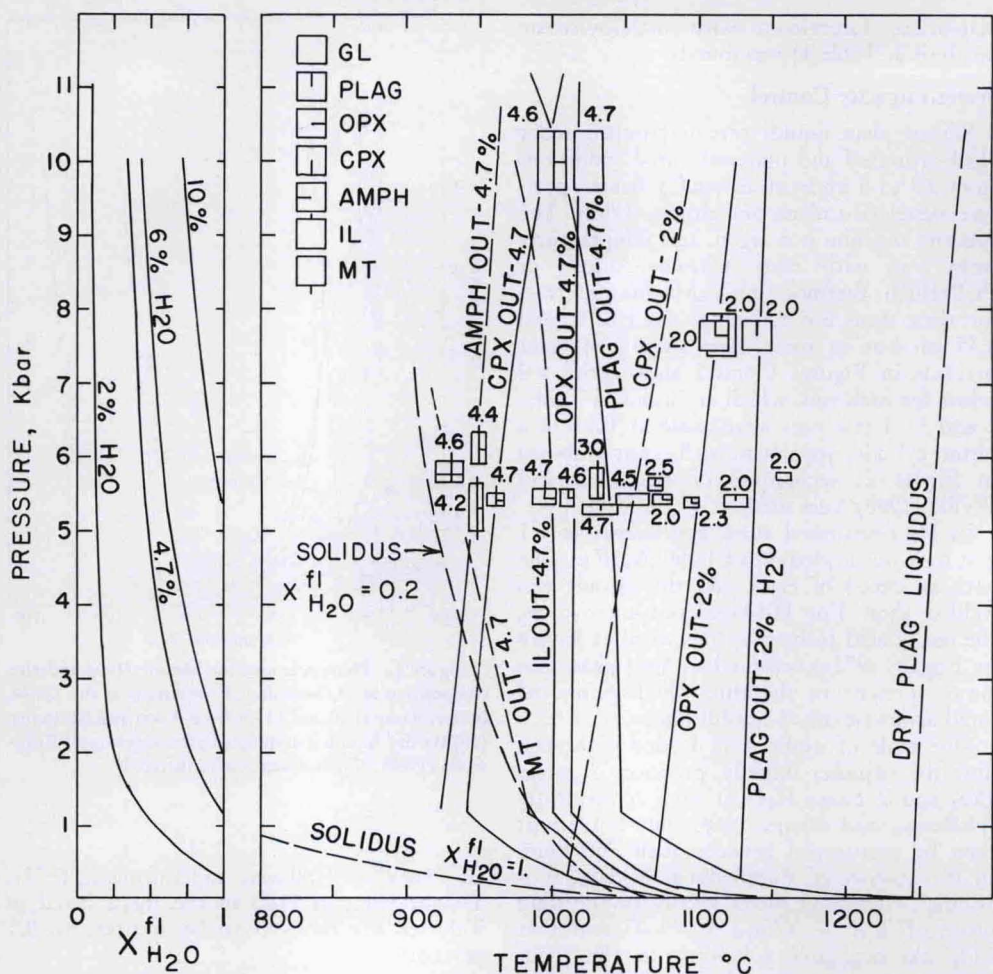
Figure 2. Phase relations at H_2O–undersaturated conditions. Numbers near run boxes indicate wt percent H_2O in melt of the run. Liquidi are drawn for H_2O contents in melt of 2.0 and 4.7 percent. Graph at left relates wt percent H_2O in melt to $X^{fl}_{H_2O}$ at 1,000° C.

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° and 1,200°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 ×1,500. Probe analyses were performed on ARL–AMX and EMX instruments by techniques described previously (Eggler, 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