

TABLE 3. RESULTS OF EXPERIMENTAL RUNS AT H₂O-UNDERSATURATED CONDITIONS

P (kb)	T (°C)	P _{H₂} (b)	Conditions of run			H ₂ O in melt (wt %)	m f _{H₂O} (b)	-log f _{O₂} (b)	Phases present [†]
			Time (hrs)	Oxalic acid (wt %)	Est. % glass (wt)				
5.75	1,158	18.0	4	7.3	100	2.0	987	8.83	gl
5.43	1,125	19.5	10	7.7	99.8	2.0	891	9.41	gl, pl(tr.)
5.40	1,095	18.4	14	7.7	80	2.3	1,121	9.57	gl, pl, opx(sa)
5.62	1,070	26.2	25	7.7	74.5*	2.5	1,340	10.08	gl, pl, opx
5.45	1,070	46.8	22	30.6	100	4.3	2,657	9.99	gl
5.45	1,075	10.0	21	5.7	71.6*	2.0	882	9.53	gl, pl, opx
5.43	1,055	49.1	7	40.0	100	4.5	2,753	10.22	gl
5.30	1,034	49.1	12.5	47.3	93	4.7	2,790	10.52	gl, pl
5.43	1,010	40.7	30	41.2	85	4.6	2,770	10.73	gl, pl, opx(sa)
5.65	1,030	10.5	23	5.7	36.4*	3.0	1,720	9.66	gl, opx, pl, cpx(sa), il
5.47	995	42.0	24	35.9	70	4.7	2,844	10.98	gl, opx, pl, il
5.43	970	17.8	24	5.5	20.1*	3.7	2,033	12.38	gl, opx, pl, il, cpx(sa)
5.41	960	43.8	22.5	33.6	60	4.7	2,735	11.63	gl, opx, cpx(tr.), pl, il
5.31	968	27.6	24	9.3	30	4.0	2,200	11.28	gl, opx, cpx, pl, il
6.12	950	40.0	24	20.0	38.7*	4.4	2,906	11.67	gl, opx, cpx(sa), pl, il
5.31	948	27.6	24	8.7	19.5*	4.2	2,313	11.58	gl, opx, cpx, pl, mt, il
5.80	930	51.0	25	33.4	60	4.6	2,910	12.23	gl, cpx, opx, pl, il, hb
7.65	1,140	22.7	6	7.4	99.5	2.0	1,340	9.00	gl, pl(sa)
7.65	1,115	22.7	6	7.3	97	2.0	1,331	9.33	gl, pl
7.65	1,110	22.7	6	7.5	95	2.0	1,331	9.40	gl, pl, opx(sa)
10.0	1,025	86.6	7	26.2	100	4.7	6,100	10.48	gl
10.0	1,000	86.1	6	24.0	95	4.6	5,970	10.88	gl, cpx, opx, pl(sa)

*Percent glass determined by point count, or from calculated mode.

[†]gl = glass, pl = plagioclase, opx = orthopyroxene, cpx = clinopyroxene, il = ilmenite-hematite solid solution, mt = magnetite-ulvospinel solid solution, tr. = trace, sa = small amount.

final andesite melt, because a phase, once in equilibrium with a melt, cannot disappear except by reaction or by the placement of the melt, once separated, in a different regime of intensive parameters. Osborn (1969) has argued the latter case, that magnetite would be more stable at high pressure than at low and therefore could be important at high pressure in deriving an andesite melt but absent in a lava erupted at low pressure. Such a lack of magnetite in andesite is common (Carmichael and Nicholls, 1967). A model system at high pressure (Eggler, 1971) and the present study provide no evidence of a pressure effect on magnetite stability.

Role of Oxide Phases

For the Mount Hood andesite composition, the iron-oxide phase first appearing is ilmenite, not magnetite, as in the model systems. In a mass-balance calculation designed to produce

average andesite from tholeiite by subtraction of olivine, clinopyroxene, plagioclase, and iron-titanium oxide, the substitution of ilmenite for magnetite is of little consequence, for only 2 to 2.5 wt percent oxide need be subtracted, and either ilmenite or titaniferous magnetite serves equally well. However, the fractionation model typified by the systems FeO-Fe₂O₃-SiO₂-MgO (Osborn, 1959) and CaO-MgO-FeO-Fe₂O₃-SiO₂ (Presnall, 1966) is critically dependent on the presence of magnetite, rather than ilmenite. The crucial step in obtaining a silica-enrichment trend and suppressing an iron-enrichment trend is maintenance of the Fe₂O₃/FeO ratio of the melt, by external buffering of f_{O₂}, even as precipitation of magnetite threatens to lower that ratio. A lower Fe₂O₃/FeO ratio allows fractionating liquids to crystallize more Mg-, Fe-rich silicates, subtraction of which lowers the Mg/Fe ratio of the liquid. These relations

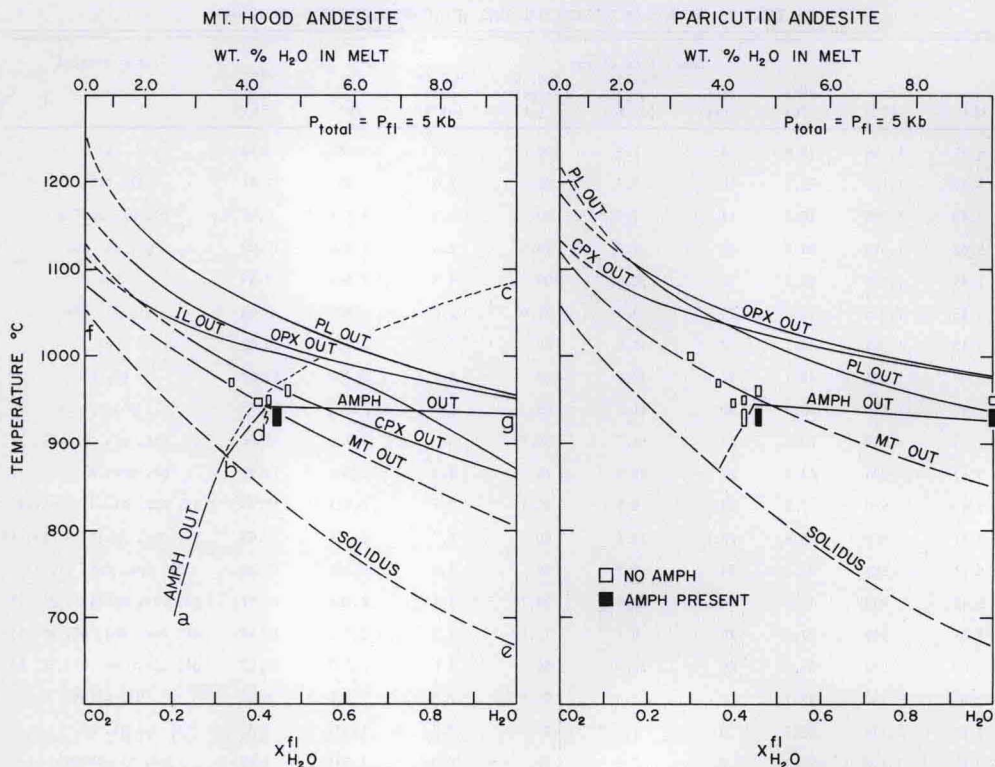


Figure 4. T - X sections at 5 kb for Mount Hood andesite and Paricutin andesite (Eggler, 1972a). Liquidi dashed where approximately located; run boxes

hold precisely because magnetite has a higher $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio than silicate melt; f_{O_2} buffering maintains the magnetite stability field. Precipitation of ilmenite with a low $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio would change the phase relations entirely.

Furthermore, melting studies of basalts (Holloway and Burnham, 1972; Yoder and Tilley, 1962) show magnetite or magnesioferite, not ilmenite, as the nearer liquidus phase. If basalts are the fractionation parents of andesites, it is curious that a typical andesite contains ilmenite as the highest melting oxide phase.

Most important, we note that neither ilmenite nor magnetite is stable near the silicate liquidus at any of the conditions investigated (Figs. 1, 2, and 3) and thus could not have played a role in fractionation. There is, of course, a possibility that higher f_{O_2} , possibly combined with depression of the plagioclase liquidus by a few percent H_2O , could produce suitable conditions for Fe-Ti

show experimental determination of amphibole stability. Amphibole dehydration curve (abc) inferred; short dashed where metastable.

oxide stability at the liquidus. The following sections examine that possibility.

Magnitude of Oxygen Fugacities

Perhaps the most reliable indicator of oxygen fugacity in natural magmas is the composition of coexisting magnetite-ilmenite pairs (Buddington and Lindsley, 1964). Some values obtained from this geobarometer-thermometer on basalts and calcalkaline rocks are presented in Figure 5, including one from the andesite studied. Unfortunately, many of these values probably do not represent near-liquidus conditions. We shall argue below, however, that f_{O_2} varies in a melt-crystal system along lines subparallel to the buffers shown, so that the range of f_{O_2} in subalkaline and calcalkaline systems lies between the dashed lines. It appears that at higher, magmatic temperatures, f_{O_2} values are below NNO.

A second f_{O_2} indicator, comparison of the $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio of a rock with $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios of experimentally produced melts, is