MARIDs and mantle metasomatism

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Introduction

The pressure-temperature conditions of equilibration for Mica-Amphibole-Rutile-Ilmenite-Diopside (MARID) type xenoliths are not accurately known. If MARID-type parageneses occur in the upper mantle their stability must at least be compatible with the array of ambient Pressure-Temperature conditions. Experiments on phlogopite and K-richterite as single phases have shown that these are stable at 50 kbar to 1400°–1500°C (Foley, 1991). In high-pressure melting experiments we have further investigated their stability in several MARID-like assemblages.

Experimental approach

Starting materials for the experiments were natural minerals from a variety of locations. Complete chemical equilibrium among the minerals of the starting mixes is not likely, although Mg-numbers are broadly compatible. This is not a serious drawback, because new crystals form during the experiments. An overview of the starting materials is given below.

Because MARIDs have highly variable modal compositions (Waters, 1987) the bulk composition itself cannot be decisive for the stable mineral assemblage. In our experiments, therefore, the starting mixtures contain equal weight proportions of PHL, K-R and DI - these three minerals making up 100%, 95% or 85% of the mixture; the rest consisting of RU, ILM, or AP. Mg-numbers of our starting materials are relatively high compared to those of common MARIDs. Starting mixtures were sealed in graphite-lined Pt-capsules without special precautions to exclude adhered water. In 15 kbar piston-cylinder experiments, three capsules were run simultaneously in 22mm CaF_2-assemblies, whereas in 50 kbar belt-apparatus experiments a single capsule was run in a CaF_2-assembly (procedures in Brey *et al.*, 1990). After the experiment, capsules were weighed, pierced, and dried at 110°C to determine the volatile contents. Sectioned, polished runs were examined with SEM-EDS to determine the phases present and analysed by microprobe.

mineral	abbrev.	location	rock association	Mg#
Phlogopite	PHL	Palabora, S-Africa	carbonatite	90.3
K-richterite	K-R	Boshof, S-Africa	MARID	91.0
Rutile	RU	Minas Gerais, Brazil		54.3
Ilmenite	ILM	Minas Gerais, Brazil	kimberlite	36.4
Diopside	DI	Inagli, Siberia	dunite	95.8

TABLE 1. Succession of mineral parageneses at 15 kbar

Paragenesis	no-X	AP	RU	ILM
PHL+DI+KR+X[†]	1090°	1090°	1050–1090°	1050–1075°
PHL+DI+KR+X+OL				1090°
L+PHL+DI +X+OL		1125[*]–1175°	1125–1175°	1125°[‡]
L+PHL+DI +OL	1150–1175°			1150°
L +DI +X+OL			1200–1225°	
L +DI +OL	1200–1225°			1200-1225°
L +DI				

[†] X represents the accessory AP, or RU, or ILM in mix
[*] no OL found [‡] newly formed RU in run

TABLE 2. Succession of mineral parageneses at 50 kbar

Paragenesis	no-X		ILM	RU	
PHL+DI+KR+X[†]					
PHL+DI+KR+X	+OL	1300°			
L+PHL+DI+KR[*]+X	+OL		1300°		
L+PHL+DI +X	+OL		1350°	+EN	
L+PHL+DI	+OL			+EN	
L +DI +X	+OL			+EN	1350°
L +DI	+OL	1400–1500°	1500°	+EN	1500°

[†] X represents the accessory RU, or ILM in mix
[*] Kaersutitic amphibole

Results

Despite rapid quench rates (70-80°Cs^{-1}in PC; 230°Cs^{-1} in Belt) quench modification of high-P,T equilibria is a major problem in these experiments. Textural observations combined with phase compositions were used to unravel the true equilibrium phase relations. The Tables present an overview of the succession of parageneses near the solidus.

Because of their high solubility in the melt, the absence of accessory minerals in the runs, or their reappearance as quench phases, provides a very reliable indicator of the solidus. Microprobe analyses indicate that, despite the use of graphite inner capsules, some Fe-losses occurred. In one extreme case, a 15kbar-1125°C run on an ILM-bearing mixture, RU formed. In general it is not expected that the phase equilibria are seriously affected by Fe-loss. In all runs K-R is the first phase to disappear near solidus and enstatite (EN) would be expected to form through incongruent melting. Significant amounts of PHL must therefore participate in the melting reaction since olivine (OL) forms instead. Only in the RU-bearing mixtures at 50 kbar does EN form: the large amount of TiO_2 in the melt probably polymerises the melt structure, thus stabilizing EN (Kushiro, 1975). Precise equilibrium melt compositions cannot be directly measured from the experiments: approximate melt compositions (from area scans) lie on PHL control lines consistent with PHL crystallization upon quenching.

Implications

Solidus temperatures for MARID-type assemblages are marked by squares and tentatively connected with a dashed line in the Figure. The MARID-solidus lies above that of water-saturated peridotite (indicated in Figure; Green, 1973) but hundreds of degrees below that of dry peridotite (Takahashi, 1986). At 50 kbar the solidus position nearly coincides with a typical 'cold' continental geotherm; at 15 kbar it lies at a higher temperature than that of an 'off-axis' oceanic geotherm. It follows that melts from MARID-type assemblages are likely to be mobile as silicate melts in the lower reaches of the continental lithosphere as soon as geothermal conditions are only slightly perturbed. Due to the high degrees of melting, MARID-derived melts are likely to have exceedingly high Mg# (80–90) and will be slightly reactive with respect to mantle EN, and probably very reactive with Al-bearing minerals (garnet, spinel). Such melts are ideal metasomatic agents for the transport of trace elements.

References

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