

INTERACTION OF METASOMATIC FLUIDS AND BASALTIC MELT WITH MANTLE XENOLITHS

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Introduction

For the genesis of basaltic magmas three processes are under discussion:
 partial melting of primitive mantle rocks
 differentiation processes accompanied by crystal settling and
 partial melting of depleted mantle rocks, preceded by metasomatic processes.

Experimental petrology and almost the whole spectrum of geochemical methods have been applied to support the different hypotheses. Xenoliths of mantle rocks, transported by fast ascending magmas, i.e. kimberlites and basalts, are the favoured reference materials. They are also the basis of the results presented in this paper.

Source and relevance of samples

Cenozoic basalts of the Federal Republic of Germany are host rocks of peridotitic xenoliths from harzburgitic to lherzolitic composition. Their average composition is representative for continental spinel peridotitic xenoliths worldwide; they represent depleted mantle rocks (OEHM, SCHNEIDER, WEDEPOHL, 1983). Certain major and trace element compositions and Sr-isotope data of xenoliths indicate a metasomatic overprint preceding magma generation (WEDEPOHL, MENGEL, OEHM, 1984; MENGEL, KRAMM, WEDEPOHL, GOHN, 1985; HARTMANN, 1986).

The topic of this paper is

- to develop a model of the metasomatic process,
- to trace and localize it from the very first detectable chemical influence to the beginning of melting and magma separation in the xenoliths and
- to distinguish these features from reactions caused by the basaltic liquid, carrying the xenoliths to the surface.



Fig. 1: Reaction rims around cpx (A) and melt (B), migrating along grain boundaries and mineral cracks.

Table 1: Average composition of glass, opx and rims of fluid inclusion tracks in opx
(Microprobe analyses)

	A glass (n=66)	B opx core (n=3)	C opx fluid inclusion tracks (n=2)
SiO ₂	60.2	55.20	57.77
TiO ₂	1.6	0.02	0.06
Al ₂ O	18.7	3.54	4.31
ΣFeO	1.8	5.60	5.16
MnO	0.02	0.12	0.10
MgO	1.3	33.56	27.99
CaO	1.4	1.06	2.28
Na ₂ O	4.5 *	0.13	1.52
K ₂ O	6.7	0.00	0.23
P ₂ O ₅	n.d.	< 0.01	< 0.02
SO ₃	n.d.	0.01	0.08
Cr ₂ O ₃	0.03	0.61	0.51
Total	96.25	99.86	100.03

A: Average composition of glass from reaction rims, reaction domains and migration conduits.

* minimum value due to losses by evaporation during electron bombardment

B: orthopyroxene (core)

C: Fingerprints from metasomatic fluids in fluid inclusion tracks of orthopyroxene (opx)
Si, Al, Ca, Na, K, S contributed from the fluid phase

In the pathways of the degassed fluid inclusions the first fingerprints of a metasomatic fluid can be proven (Table 1). In a very small area around the open degassing pipes in an orthopyroxene Si, Al, Ca, K and Na are enriched, the latter by a factor of 10.

All the clinopyroxenes have reaction rims as shown in Fig. 1. The grain boundaries are corroded, some of the small cavities are filled with potassium- and sodium-rich glasses.

At grain boundary junctions reaction domains occur. Orthopyroxene, clinopyroxene and spinel are involved in solution processes. The matrix of these domains is also potassium-rich glass.

Starting from reaction rims or -domains, the melt migrates along grain boundaries and cracks, finally forming a tiny network, demonstrating the mobility of even very small amounts of melt. Minerals precipitated from this melt are:

Olivine - Clinopyroxene - Cr-rich Spinel - (Orthopyroxene) - Plagioclase (with K, Fe, Cr, Ti) - Apatite - Armalcolite - Picroilmenite - Calcite (from immiscible carbonate melt droplets) - Aegerine - Alkalihornblende (?) and secondary: - Smectite

The average composition of glass from reaction rims, reaction domains and migration channels (66 microprobe analyses) is given in Tab. 1. Whereas the content of K is comparatively constant, the variation of sodium is high, reflecting the interaction of the fluid phase with clinopyroxene and the crystallization of sodium-bearing minerals like clinopyroxene, aegerine and plagioclase from the melt.

The origin of glass in the xenoliths

These observations may not reflect a single-step process because during the rapid ascent the temperature of the xenoliths was raised to the temperature of the surrounding basalt magma. The observed melting may be caused only by this increase in temperature, but the structural relation in the involved microenvironments shows that a preceding metasomatic process in the mantle produced the extraordinary composition in these particular volumes. The concentration of Si, Al, K and Na cannot be contributed from the existing minerals, that are involved in these reactions, as a series of analyses of the minerals and their grain boundaries shows. They have to be transported by a metasomatic fluid phase.

In our case it can be proven, that minute amounts of isolated melt can not be directly related to preexisting crystals of phlogopite or amphiboles. Even if the secondary precipitated minerals and the change of composition of the involved veins of cpx, opx and spinel are recalculated the model doesn't fit.

Phlogopite and amphibole, as phases, formed by an early metasomatic process and melted because of the increased temperature induced by the surrounding basalt, is an insufficient picture, because in almost all samples, containing phlogopite this is in contact with melt, and it seems to be stable in these melt.

From these observations it is postulated that a fluid phase, transporting Si, Al, K and Na released primary melting and crystallization processes in depleted mantle environment under upper mantle conditions.

Experiments on the partial dissolution of peridotitic mineral associations under mantle conditions (SCHNEIDER and EGGLE, 1984) show appreciable dissolution of matter from the preexisting minerals in H_2O and $H_2O + CO_2$ as fluid phase (up to 11.8 weight % solute in fluid). Si, Al, Na and K are enriched in the solution, whereas there is a decrease of Fe, Mg and Ca compared to the composition of the peridotitic starting material. In our investigation all elements show exactly the same trend as predicted from the dissolution experiments.

The contact of the basaltic melt caused different reactions, including melting of peridotite minerals. Olivine becomes enriched in the fayalitic component. Spinel is gradually changed to magnetite, and the basaltic melt in contact with melt from the xenoliths is of different character. All that proves the differences in composition and oxygen fugacities of the melts.

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