

An Endangered Geochemical Paradigm? The Relationship of Melts to Sources

Albrecht W. Hofmann (hofmann@mpch-mainz.mpg.de)

Max-Planck-Institut f. Chemie, Postfach 3060, Mainz, 55020, Germany

Much of the conventional interpretation of mantle derived melts rests on the assumption that chemical and isotopic compositions of basalts can be "inverted" to characterize the composition of the respective mantle sources (Hofmann, 1997). Traditionally, isotopic parameters have been ranked as most reliable in this respect, followed by highly-incompatible trace element ratios, REE patterns, and "spidergrams." This has been backed up by inverse modeling using simple melting models with equilibrium partitioning, and forward models, which allow more complex processes to be explored.

All along, some have questioned this approach on various grounds, including the applicability of local equilibrium during melting, the effect of wall rock contamination, and other modifications of the "primary" melt compositions by fractional crystallization. Also, chemical and isotopic data consistent with binary mixing processes have led to an emphasis on the role of mixing melts derived from different sources. Nevertheless, these complications have not been viewed by most geochemists as serious threats to the basic paradigm, which says that lava compositions can be used to infer important aspects of the composition of the mantle.

Recently, analyses of melt inclusions in phenocrysts from basaltic lavas have opened a Pandora's Box of compositional complexity that far exceeds anything seen in ordinary lava compositions (Sobolev and Shimizu, 1993). Initially, it was thought that the entire range of compositions can be produced by progressive fractional melting and subsequent crystallization processes. However, recent observations also require source heterogeneities preserved in individual hand specimens, and even in individual phenocrysts (Sobolev et al., 2000). How can we hope to interpret the bulk composition of a lava sample from one oceanic island, when we find in its interior a variability and range of compositions similar to that of all oceanic island basalts?

Another endangered piece of conventional wisdom is the notion that Mg-rich melts are necessarily more "primitive" than less Mg-rich melts. There is at least one basalt province (Iceland) where Mg-number correlates significantly with Nd isotope ratios (Chauvel and Hemond, 2000). This shows that high-Mg lavas and lower-Mg lavas are derived from different sources. In addition, it is known that melts formed from eclogite will have lower Mg and higher Si contents than those formed from lherzolites. Thus, the notion that all primary melts formed in the mantle must be in equilibrium with mantle olivine is no longer a dogma.

Finally, new experiments have yielded diffusion coefficients of REE in clinopyroxene that are so low that crystal-melt disequilibrium may persist for geologically significant periods of time (Van Orman, 1999). Consequently, the isotopic composition of the melt is not necessarily identical to that of the bulk source.

Will conventional mantle geochemistry survive? Many of the old arguments favoring conventional wisdom have not gone away. For example, oceanic basalts can be mapped using isotopes and trace elements, revealing regional geochemical trends and discontinuities on scales of 10 to 10,000 kilometers, and we can characterize certain OIB provinces by distinct isotopic "flavors." This suggests that the local source heterogeneities are effectively averaged in the erupted lavas, so that the lava composition is approximately representative of the average composition of the source on at least a kilometer scale.

But what if these mixing processes produce biased rather than representative characterizations of mantle source (Phipps Morgan and Morgan, 1998)? Biased melt compositions might still be mappable but provide a distorted image of mantle geochemistry. One possible test of this is to see if the average isotopic composition of plume-generated volcanic rocks changes systematically as a function of the variation of the specific tectonic setting in which the lavas erupt. For example, plumes located close spreading centers (Iceland, Galapagos Islands, the Ninetyeast Ridge 43 Ma ago, Emperor Ridge 80 Ma ago; see Regelous et al., this Conference) produce at least some MORB-like basalts. Are these basalts actually derived from the plume source, or has the MORB source invaded the plume melting region? We cannot be sure whether the effect is caused by non-plume material being tapped, or whether the more depleted components are actually part of the plume but melt in significant amounts only at shallow levels when there is no lithospheric lid above the plume. At present, there appears to be no decisive test to resolve the dilemma.

- Chauvel C & Hemond C, *Geochem. Geophys. Geosystems*, **1**, (2000).
Hofmann AW, *Nature*, **385**, 219-229, (1997).
Phipps Morgan J & Morgan WJ, *Earth Planet. Sci. Lett.*, **170**, 215-239, (1998).
Sobolev AV & Shimizu N, *Nature*, **363**, 151-154, (1993).
Sobolev AV, Hofmann AW & Nikogosian IK, *Nature*, **404**, 986-990, (2000).
Van Orman JA, Koga KT & Grove TL, *EOS Tans. AGU Suppl.*, **80**, F1113, (1999).