ISOTOPIC AND CHEMICAL COMPOSITION OF MEGA- AND PHENOCRYSTS: EVIDENCE FOR THE PETROGENESIS OF THE HEGAU VOLCANIC PROVINCE

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The Miocene Hegau volcanic field in southern Germany situated 60 - 70 km east of the Rhinegraben, is part of the Tertiary-Quaternary extension-related magmatic province of western and central Europe. Magmatism in the European continental rift zone exhibits a strong bimodality. The erupted magmas in the Hegau comprise silica-poor, Ni- and Cr-rich olivine-melilitites, the intermediate deckentuff-series and phonolites.

The petrogenesis of fractionated alkaline melts (trachytes, phonolites, alkali-rhyolites) within continental riftzones is still controversial (e.g. WILSON and DOWNES 1991, WEDEPOHL et al. 1994). In some riftzones the evolution of the lavas can be related to processes of low pressure fractional crystallization, in others more complex models have to be involved. To shed light on the petrogenesis of the Hegau volcanic field as an example for European rift zone volcanism we determined the bulk rock and mineral chemistry of the volcanics and the isotopic composition of hornblende and clinopyroxene mega- and phenocrysts.

High concentrations of Ni (300 - 500 ppm), Cr (700 - 1500 ppm), Mg-numbers above 0.72 and strongly fractionated REE patterns (La/Yb 37) as well as the isotopic composition demonstrate the primitive character of the olivine melilitic magmas and render them likely candidates for primary melt compositions. Chemically the deckentuff magmas form a differentiation trend with the olivine melilitites which does not extend to the phonolites.

The phonolites have Mg-numbers below 0.30 and Ni and Cr contents below detection limit. Compared to olivine melilitites they are enriched in the incompatible elements U, Th, Pb, Cs, Ba, Ga, Hf, Zr and HREE, but depleted in LREE (La - Dy).

Comparison of the chemical composition of amph and cpx-megacrysts with experimentally determined amph and cpx compositions (BREY and GREEN 1977, KELLER 1978) in olivine

melilititic systems led to an estimated pressure of crystallization of ~2.5 GPa for the megacrysts in the olivine melilitites and ~2.0 GPa in the deckentuffs. The amph and cpx-megacrysts as well as the phenocrysts show a strong differentiation trend with increasing of Al, Fe, Ti and Na and decreasing Si, Mg and Cr (Fig. 1).

Differences in megacryst and phenocryst compositions (the megacrysts show generally higher concentrations of Si, Al and Na and lower concentrations of Ca and Ti) are due to the difference in crystallizing pressure. Isotopically the megacrysts appear to be in equilibrium with the phenocrysts (Fig. 2).

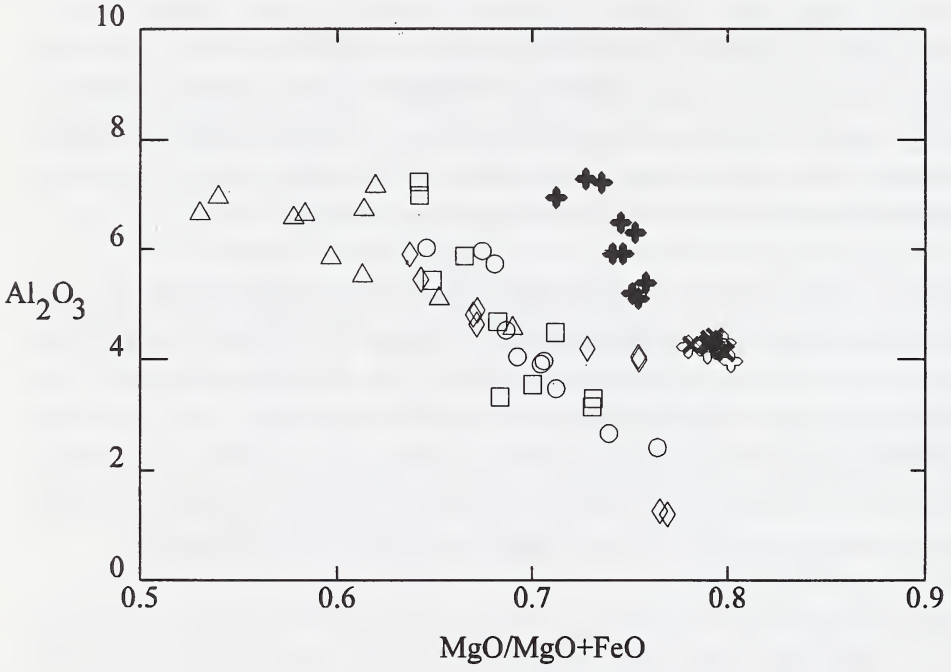

Fig. 1: Al_2O_3 (wt.%) vs. Mg-Number. The filled symbols represent megacrysts, the open symbols phenocrysts. A fractionation trend towards Al-rich compositions is apparent.

The genesis of deckentuffs can be explained with a model involving fractional crystallization of ol, cpx, amph from an olivine melilititic magma. However, there are isotopic differences between the deckentuffmagmas and the olivine melilitites (higher $^{143}Nd/^{144}Nd$) which may be explained by contamination in a heterogeneous mantle.

The phonolites have high and variable $^{87}Sr/^{86}Sr$ ratios (Fig.2) which points to contamination by young felsic crust. Thus, the phonolites may have developed by fractional crystallization of magnetite, apatite ± perovskite from a highly differentiated deckentuff magma at shallow crustal levels. Magma mixing with phonolite is indicated in some deckentuff localities by pyroxenes with aegirine cores and Ti-augite rims, by two populations of groundmass spinels (Mn-rich and Mn-poor) and by elevated Sr-Isotopes. The petrogenesis of the Hegau volcanics thus involves partial melting at depths corresponding to about 2.7 GPa, fractional crystallization and contamination within the mantle, and fractional crystallization, contamination and magma mixing at crustal levels.

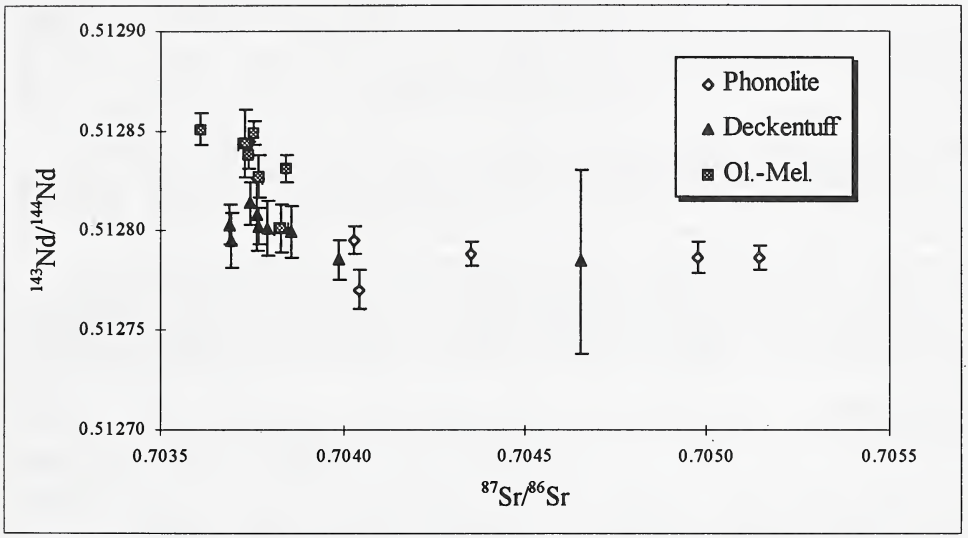

Fig. 2: Variations in $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ of volcanic rocks from the Hegau.

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