Geochemical, Sr-Nd isotopic, and P-T data on a Central Mexican xenolith suite: Evidence for upper mantle and lower crust compositions

P. Schaaf
W. Heinrich

Mineralogisch-Petrographisches Institut, Universität München, Theresienstr. 41, 80333 München, Germany
Institut für Angewandte Geophysik, Petrologie und Lagerstättenforschung, Technische Universität Berlin, EB 310, Straße des 17. Juni 135, 10623 Berlin, Germany.

Introduction

Northeast of San Luis Potosí (Central Mexico, 22°N, 101°W), Quaternary basanites and tuff breccias have sampled a suite of ultramafic upper mantle to lower crustal xenoliths, associated with seven phreatomagmatic maars. Xenolith distribution range from spinel lherzolites (55%), spinel pyroxenites (10%), hornblende pyroxenites (18%) to metaigneous and metapelitic granulites (17%). The SLP volcanic field is located in the back-arc region of two major volcanic belts along the southwestern border of the North American craton (Fig.1): The Oligocene calc-alkaline volcanics from the Sierra Madre Occidental in the east and the late Miocene to recent basaltic to rhyolitic volcanics from the Transmexican Volcanic Belt.

Analysis of the geochemical and Sr-Nd isotopic data together with p-T-conditions of the xenolith profile gives hints for the thermal evolution and composition of the upper mantle segment and lower crust in Central Mexico. The latter is of particular importance because its geotectonic relationships to cratonic North America is still uncertain.

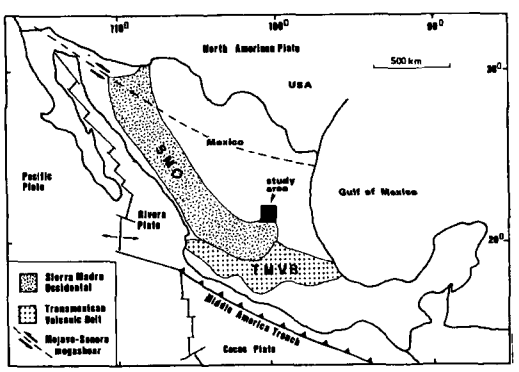

Fig.1: San Luis Potosí field of Quaternary basaltic activity. Simplified volcanic provinces of the Sierra Madre Occidental (SMO) and the Transmexican Volcanic Belt (TMVB)

Results

Spinel lherzolites. Granular and sheared samples mostly have mg values ($Mg/Mg+Fe_{tot.}$) between 0.890 and 0.898, suggesting a fertile character for this mantle segment. Different stages of *REE* depletion are expressed from relatively light $La/Yb_n = 0.4$ to strong La/Yb_n = 0.04 depletion factors. Spinel lherzolite Sr-Nd isotopic data plot within the mantle array in the field of MORBs. Their $^{87}Sr/^{86}Sr$ ratios range from 0.7026 to 0.7031, and ε-Nd values are between +9.6 and +4.2 (Fig.2). Together with the mineralogical and geochemical heterogeneities, the isotopic data suggest different degrees of partial melt extractions.

Spinel pyroxenites Metamorphic textured spinel websterites and magmatic textured spinel pyroxenites reveal similar major and trace element concentrations, characterized by mg values of 0.76 to 0.79. The chondrite-normalized *REE* patterns are light-*REE* enriched (Ce/Yb_n values 0.76 to 0.79), but display strong depletions in La relative to the other *REE*. These rocks show the typical features of high-pressure cumulates of mafic melts induced by partial melting processes. Due to their similar textural equilibrations and p-T gradients towards lower temperatures they are regarded by us as related to the mafic granulite facies xenoliths. $^{87}Sr/^{86}Sr$ ratios are between 0.70337 and 0.70425, ε-Nd values range from +4.0 to +0.9 (Fig.2).

Hornblende pyroxenites In relation to the spinel pyroxenites, the hornblende-rich pyroxenites are more evolved (mg values = 0.59-0.67). Their *LREE* are typically enriched (La/Yb_n = 3.96-5.84 and *HREE* concentrations are 6 to 8 times chondritic. In conjunction with their Sr and Nd isotopic

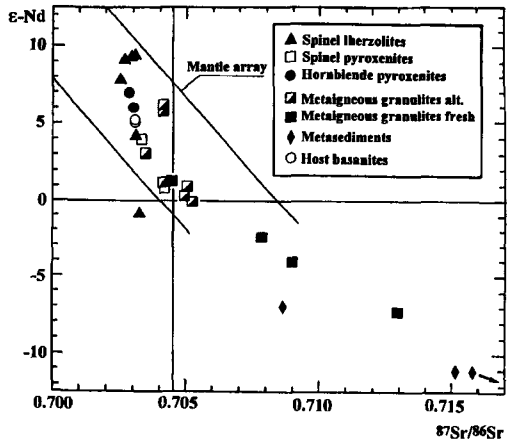

Fig.2: Present-day Nd and Sr isotope compositions of the SLP xenolith suite. Altered and fresh metaigneous xenoliths are plotted with different symbols (see text).

signatures ($^{87}Sr/^{86}Sr$ = 0.70288-0.70303; ε-Nd = +6.1 to +7.0), these xenoliths represent high-pressure cumulates genetically linked to the host basanites ($^{87}Sr/^{86}$ = 0.70309; ε-Nd = +5.7; Fig.2). Mineral chemistry in all ultramafic rock types of the xenolith suite reveals distinct disequilibrium features reflecting partial re-equilibrium stages towards lower temperatures estimated to be from 1,050 to 850°C at 9 to 15 kbar at depths not far from the Moho, which is located below Central Mexico at about 30 km.

Metaigneous granulites CIPW-normative mineralogy indicates that the magmatic precursors of these granulites range from grabbronoritic/gabbroic to tonalitic compositions. Felsic compositions were not observed in the whole xenolith suite.

Mafic xenoliths consist of plagioclase ± clinopyroxene ± orthopyroxene ± garnet ± amphibole ± rutile ± scapolite and display a considerable geochemical variability (SiO_2 < 52 wt%; mg values = 0.63-0.57). They represent both mafic cumulates and fractionated melts up to more evolved rocks with accumulation of plagioclase. $^{87}Sr/^{86}Sr$ ratios are from 0.7035 to 0.7053, ε-Nd values between 0 and +6.2 (Fig.2). Nd (T_{DM}) model ages range from 1.1 to 1.6 Ga.

Intermediate xenoliths are garnet-free and quartz-bearing (SiO_2 > 52 wt%; mg values about 0.52) and consist of rocks from quartz-dioritic to tonalitic compositions. Some of them display similar *REE* pattern to the gabbroic suite but with higher *LREE*-concentrations, due to some crystal–liquid fractionation processes. $^{87}Sr/^{86}Sr$ ratios are between 0.7079 and 0.7128, ε-Nd values range from −7.3 to −2.4 (Fig.2) and Nd model ages lie between 1.8 and 2.3 Ga. All samples show similar Ca-Al-zoning patterns documented in orthopyroxene, clinopyroxene and plagioclase which are, along with the presence of coronas around garnet, interpreted as representing partial reequilibrium stages from 940 ± 60°C and 7-11 kbar down to lower temperatures and pressures. There is no indication of a secondary heating event in these xenoliths.

Conclusions

Sm-Nd isotopic compositions of the spinel lherzolites indicate a heterogeneous composition of the upper mante segment benaeth SLP. The estimated mantle temperatures are higher than those predicted by low heat-flow measurements at the SLP flield, indicating, that the surface heat flow has not equilibrated to elevated temperatures at depht. This supports a young perturbation event beneath the SLP area and connects the onset of uplift and cooling of the SLP mantle segment with the back-arc extensional regime of the Quaternary volcanic cycle of the Transmexican Volcanic Belt.

When looking at the granulite facies xenoliths, we can see clearly the migration of the p-T gradient towards lower temperatures implying, that there is no secondary heating event detectable in our samples from the SLP lower crustal xenolith suite. Sm-Nd isotopic data can not provide information of granulite facies metamorphism. A Sm-Nd 6 point WR isochron of 4 metaigneous xenoliths and 2 spinel pyroxenites, yields an age value of 1248±69 Ma (1σ) with an initial ε-Nd value of +2.3. The xenoliths forming the isochron are 'fresh' (without secondary amphiboles) and garnet-free, whereas the altered granulites (containing secondary amphiboles and secondary amphiboles in the coronas around garnet) plot significantly above the isochron, due to the introduction of external fluids. The age value can be interpreted as the time of the crystallization of the magmatic precursors of the granulites and by that way adds an middle Proterozoic age value to the puzzle of basement rocks in Central Mexico.