Os and Sm/Nd isotopic constraints on ultramafic petrogenesis in the Helvetic basement

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Introduction

Serpentinsed ultramafic rocks are quite abundant in the Aar and Gotthard units (Helvetic basement Central Alps, Switzerland). A complex history of metamorphic events make the understanding of their genesis difficult. Detailed geochemical studies on platinum group (PGE), trace including rare earth elements (*REE*) as well as major elements were performed by Biino and Meisel (1993, 1994). Their conclusions are that the ultramafics are mantle rocks and form part of an ophiolitic sequence, serpentinisation did not effect the element abundances and large scale igneous processes of depletion and/or refertilisation were responsible for the abundance patterns of elements observed today. In this study we applied two isotopic systems (Sm/Nd and Re/Os) with very different geochemical behaviour of the parent/ daughter pair to the studied rocks. Sm/Nd is very sensitive to contamination with continental crust whereas the Re/Os systems makes it possible to see effects only slightly influenced by crustal material. The Re/Os isotopic system can constrain mantle processes even after metamorphism.The idea was to test the above hypothesis which was based on geochemical analyses alone.

Geological setting

The Helvetic basement makes up the external part of the Alps and was exposed through the Cenozoic orogeny. A comprehensive discussion of the evolution of the basement is described by von Raumer *et al.*, (1993), Mercolli *et al.*, (1994) and Abrecht (1994). The Helvetic terrane is a composite basement formed by polymetamorphic rocks containing the ultramafics, Late Ordovician granitoids and a pre-Variscan cover. Samples were taken from lenses ranging up to 100 m in thickness and a few hundred meters in length. The origin of the ultramafic in the transition zone between upper mantle of the lower crust can be deduced from textural relics. They are accompanied by Mg- and Fe-Ti rich metabasalts and metagabbros. The metamorphism reached eclogite facies conditions (Abrecht *et al.*, 1991; Biino, 1994) and occurred during the Caledonian orogeny (Biino *et al.*, 1994 and references therein). The original lithostratigraphic sequence of metasedimentary clastics, mafic and ultramafic rocks, is interpreted by Abrecht *et al.* (1991) as an accretionary prism.

Analytical methods

Analytical procedures will be described in Meisel *et al.* (in prep). In brief osmium was separated from several grams of sample by NiS fusion technique and acid digestion with HF/HCl subsequently distilled and cleaned with an ion exchange bead. The isotopic composition was determined by NTIMS. The description of the Nd procedure will be reported in Nägler and Frei (in prep.).

Results

The deviation of the $^{187}Os/^{188}Os$ ratio are plotted in Fig.1 as γ_{Os} value for T = 0. $\gamma_{Os}(0)$ describes the % deviation of the Os isotopic composition in a sample from present average for carbonaceous chondrites (Walker *et al.*, 1989). After Stille (1987) a major magmatic event occurred in Central Europe during Riphean time, hence the $^{143}Nd/^{144}Nd$ ratios are expressed as ε_{Nd} at T = 0.9 Ga.

The result of this investigation lets us separate several distinct groups of ultramafics characterised by

1. negative γ_{Os}, positive ε_{Nd}, normal mantle Pt/Ir ratio and typical V shape *REE* patterns of harzburgites.
2. high ε_{Nd} values, high positive γ_{Os} typical for depleted mantle rocks and high Pt/Ir ratios.
3. negative c_{Os}, positive ε_{Nd} and light *REE* (*LREE*) enrichments.
4. rocks with an array of positive γ_{Os} and ε_{Nd} values and *LREE* enrichments.

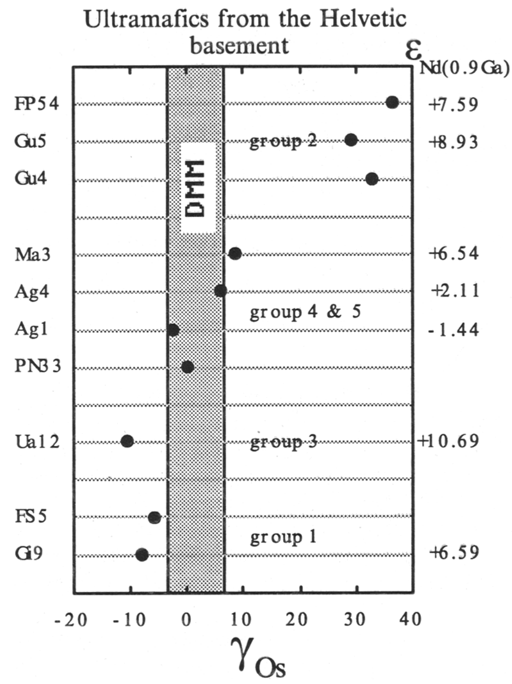

FIG. 1. Isotopic data of all samples analysed. DMM is the depleted MORB mantle.

5. negative ε_{Nd} values and slightly positive γ_{Os}.

The results support the distinction of group 2 rocks from the rest of the ultramafics. Their high γ_{Os} is a prominent feature which is also expressed by the PGE ratios. The other groups are distinct also in other geochemical features. Group 3 and 4 show light REE enrichment but are further split into two separate groups based on the isotopic data.

Calculation of the rhenium depletion age (T_{RD}) after Walker *et al.* (1989) for the samples from group 1 and 3 give *ca.* 2 Ga. A model age (T_{DM}) for Nd for one sample from group 1 gives an age of *ca.* 1.4 Ga.

Discussion

Both isotopic systems support the observation seen in the geochemical analysis. The isotopic measurements introduced parameters which help us to constrain their petrogenesis.

The sample from the first group is the most primitive one. It has the characteristics of a harzburgite (*REE*, major elements). The old T_{DM} and T_{RD} ages imply a long term isolation from the convecting mantle of group 1. All the other groups must have underwent processes of enrichments and differentiation after their formation.

Samples from group 2 analysed in this work have cumulitic layering (former chromitite) within the ultramafic lenses. They are fractionated and thus must have gone through a liquidus phase. Plume-derived systems of HIMU character cause high γ_{Os} values (Hauri and Hart, 1993). This process could explain the high percentage of melting of mantle material with a subsequent formation of cumulates.

The group 3 sample shows the same T_{RD} age as group 1 indicating the same origin. An addition of *LREE* to group 3 at a later stage without changes of the Os isotopic composition occurred. The difference between group 3 to 4 are the positive γ_{Os} values of the latter. Contamination by crustal material to increase the *LREE* abundances is not consistent with the isotopic data. Percolation of depleted ultramafics (group 1) with a basaltic melt to different extent can explain the isotopic variations. This process must have occurred in the mantle and is consistent with the conclusion based on geochemical analysis. Platinum and Palladium (PPGE) as well as the *LREE* and Sc enrichment is coupled with an increase in the γ_{Os} value.

Sample Ag1 from group 5 is associated geologically with Ag4. An overprinting of the isotopic system through a late metasomatic process is consistent with petrological and geochemical observations.

Conclusions

By integrating all the information from this and former investigations we propose the following scenario:

A formation of a depleted and isolated part of the mantle before 1 Ga. A later stage mantle plume caused drastic changes in the Re/Os- and partly in the Sm/Nd-systems at approx. 0.9 Ga. An increase in γ_{Os} as well as an enrichment in the *LREE* leading to lower present day ε_{Nd} were the consequences. PPGE were also added to the system of depleted harzburgites. This mantle plume could have caused the breakup of the Proterozoic Supercontinent (Piper, 1982) which was followed by a formation of an oceanic crust. In a final step, metasomatic changes in the *REE* as observed in group 3 and 5 are postulated. These changes might have occurred during the formation of the accretionary wedge while subducted.