Sr Isotopic Composition of Mantle Peridotite Xenoliths from the Erzgebirge: Evidence for Ancient Mantle Metasomatism?

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ABSTRACT. Mantle xenoliths brought to the surface by Tertiary volcanism in the Ohře Rift have $^{87}Sr/^{86}Sr$ ratios roughly comparable to those of their host magmas in the Czech Republic and in Poland. In contrast, some xenoliths from volcanic centres along the northern margin of the Ohře Rift Volcanic Field (outside the rift graben) contain highly radiogenic Sr, whereas others have $^{87}Sr/^{86}Sr$ ratios similar to their host rocks and mantle xenoliths reported from the Czech Republic and Poland. Heterogeneous introduction of highly radiogenic Sr into the mantle is the preferred explanation for these observations.

KEY WORDS: mantle xenoliths, peridotite, strontium isotopes, mantle metasomatism.

Introduction

Magmas of the Tertiary volcanic fields in central Europe have brought to the surface abundant and varied fragments of the Earth's upper mantle. The study of these xenoliths has yielded ample evidence for prior depletion and enrichment processes in the mantle below the volcanic fields (e.g., Downes 2001). In many cases, however, the xenoliths are isotopically distinct from their host magmas, i.e., they do not directly represent the source region of the magmas (for example peridotites from SW Poland; Blusztajn and Shimizu 1994).

Extremely high $^{87}Sr/^{86}Sr$ ratios [0.7148–0.7812 (not corrected for age, but such a correction is considered to be minor, see below)] were reported by Pfeiffer et al. (1984) for lherzolithe and harzburgite xenoliths from the northeastern parts of the Eger Graben Volcanic Field (Ohře Rift Volcanic Field *s.l.*) [Geisingberg close to Altenberg; Steinberg close to Ostritz, Saxony]. These volcanic occurrences are not located within the rift, but on the northern, uplifted shoulder of the graben (Altenberg in the Erzgebirge) and to the northeast of the rift, in the Lusatian Block (Steinberg). In the $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$ diagram, the plotted data form a linear array which can be interpreted as an isochron (errorchron) of about 1600 Ma.

The above mentioned ratios reported by Pfeiffer et al. (1984) are in marked contrast to those observed for mantle xenoliths from central Europe in general ($^{87}Sr/^{86}Sr$ = 0.7020–0.7060, see review in Downes, 2001). The xenolith data also differ significantly from the $^{87}Sr/^{86}Sr$ ratios obtained for their host rocks (0.7033–0.7045; Pilot et al. 1984). Vokurka and Bendl (1992), on the other hand, found $^{87}Sr/^{86}Sr$ ratios *in the same range* (0.7032–0.7036) for volcanic rocks and for clinopyroxenes from four lherzolite xenoliths from the Kozakov volcano, located on the Lusatian Fault, again outside the rift proper. In this context, it might be significant that the $^{87}Sr/^{86}Sr$ ratios reported for the mafic volcanics from the NW shoulder of the Ohře Rift (0.7033–0.7045; Pilot et al. 1984) show a wider scatter and extent to higher values than those obtained for mafic volcanics of the Bohemian Massif in general (0.7031–0.7037; reported by Vokurka and Bendl 1992, Wilson et al. 1994).

These contrasting data motivated a new study of Sr isotopic relationships in ultramafic xenoliths from the northern margin of the Ohře Rift Volcanic Field. Its particular aim was to determine whether contrasting data are obtained for whole-rock samples (as provided by Pfeiffer et al. 1984) and mineral separates (as given by Vokurka and Bendl 1992). The present contribution is only a short progress report.

Results

Four samples were selected from the collection of the Geological Survey of Saxony. All samples were analysed as whole-rock samples. For samples RS 11098 and RS12974, also hand-picked clinopyroxene (cpx) and orthopyroxene (opx) separates were analysed. Prior to the analysis, the separates were washed for 15 minutes in concentrated HF diluted 1:1 to remove any contaminants possibly adhering to crystal surfaces.

Samples RS11098, RS11104 and RS11105 from **Ahornberg** (south of Seiffen, Erzgebirge) yielded $^{87}Sr/^{86}Sr$ ratios in a narrow range of 0.70356–0.70376 (present-day ratios; Table 1). Their Sr isotopic compositions thus lie in the same range as those of mafic volcanics and clinopyroxenes from mantle xenoliths studied by Vokurka and Bendl (1992). The cpx separate of sample RS11098 yielded $^{87}Sr/^{86}Sr$ ratio of 0.70367 (Table 1). $^{87}Sr/^{86}Sr$ ratio of 0.70528 was determined for the opx, which – due to its low Sr contents – does not affect the whole-rock Sr isotopic composition. Even though this value is subject to large error due to the low Sr concentration in opx (<2 ppm), this high $^{87}Sr/^{86}Sr$ ratio may indicate that even in samples with low $^{87}Sr/^{86}Sr$ ratio for whole rocks and cpx, some anomalously radiogenic Sr may be present.

In contrast, sample RS12974 from **Horkenberg** (northeast of Schirgiswalde within the Lusatian Block) yielded a whole-rock $^{87}Sr/^{86}Sr$ ratio of 0.70734, which is not as high as the ratios reported by Pfeiffer et al. (1984), but *distinctly higher* than *any other ratio* so far reported for mantle peridotites from western and central Europe (see review by Downes 2001). Highly radiogenic Sr appears to reside – surprisingly – in opx, which yielded $^{87}Sr/^{86}Sr$ ratio of 0.70745 (a repeated analysis of a new concentrate yielded $^{87}Sr/^{86}Sr$ = 0.70730), whereas the cpx separate yielded $^{87}Sr/^{86}Sr$ ratio of 0.70429. It is not clear whether the radiogenic Sr actually resides in the opx crystal or in tiny inclusions, which are observed in some grains. Although cpx

Sample	RS 11098	RS 11104	RS 11105	RS 12974
Locality	**Ahornberg**	**Ahornberg**	**Ahornberg**	**Horkenberg**
Lithology	**harzburgite**	**harzburgite**	**harzburgite**	**lherzolite**
SiO_2 (wt.%)	40.57	43.54	44.33	40.81
TiO_2	0.10	0.02	0.03	0.01
Al_2O_3	1.19	1.14	1.50	1.19
FeO	8.79	7.48	7.47	7.72
MnO	0.14	0.12	0.12	0.12
MgO	43.20	47.80	45.80	43.67
CaO	1.25	0.81	0.98	3.10
Na_2O	<0.02	<0.02	<0.02	<0.02
K_2O	0.02	<0.02	<0.02	<0.02
P_2O_5	0.02	<0.02	<0.02	<0.02
LOI	4.27	0.00	0.00	1.99
Total	99.55	100.91	100.23	98.61
Sr (ppm)	21.00	20.00	26.00	129.00
Ni (ppm)	3100.00	3400.00	3400.00	3500.00
Cr (ppm)	2600.00	3300.00	4000.00	4100.00
$^{87}Sr/^{86}Sr$ (wr)	0.70376	0.70373	0.70356	0.70734
Sr (cpx)	95.80	n.a.	n.a.	476.90
Rb (cpx)	0.70	n.a.	n.a.	1.30
$^{87}Sr/^{86}Sr$ (cpx)	0.70367	n.a.	n.a.	0.70429
Sr (opx)	1.70	n.a.	n.a.	145.6*
Rb (opx)	0.80	n.a.	n.a.	1.2*
$^{87}Sr/^{86}Sr$ (opx)	0.70528	n.a.	n.a.	0.70745*

Tab. 1. Chemical composition and Sr isotopic composition of the analysed xenoliths. Major and trace elements were determined by XRF. Sr isotopes were determined using standard procedures and have 2σ error of ±0.00005 on average. Sr and Rb concentrations of mineral separates were determined by isotope dilution. Whole-rock samples were run as unspiked samples. A value of 0.71029 was obtained for NBS SRM987 during the course of the study.
*a repeated analysis on a new concentrate yielded 117 ppm Sr, 1.2 ppm Rb and $^{87}Sr/^{86}Sr$ = 0.70730.
n.a. – not analysed

contains about 477 ppm Sr and opx only 146 ppm Sr (this Sr content is very high for opx!), the whole-rock $^{87}Sr/^{86}Sr$ ratio is dominated by opx due to the relatively low content of cpx in the sample.

Conclusions

The results of this preliminary study confirm that anomalously radiogenic Sr resides locally in the sub-lithospheric mantle below the NW shoulder of the Ohře Rift in the area of the Erzgebirge (Krušné hory Mountains). The fact that the high Sr isotope ratio was also found in acid-washed, hand-picked opx separates shows that the highly radiogenic Sr was not introduced in the course of a post-emplacement alteration process. However, the ultimate origin of the highly radiogenic Sr cannot be discussed with the data now available.

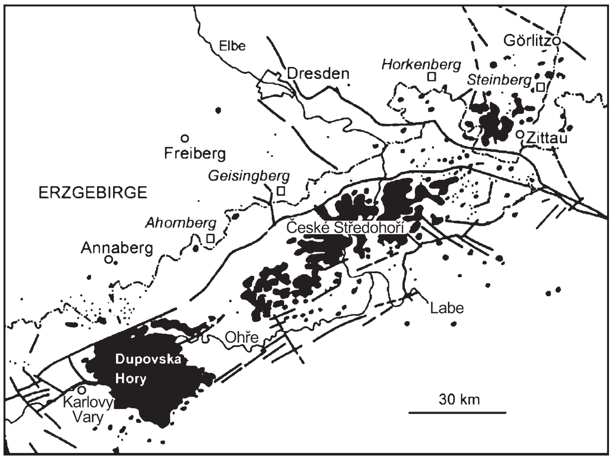

Fig. 1. A map of the Ohre (Eger) Rift showing the distribution of volcanic rocks (black) and sample locations Ahornberg and Horkenberg (this study) and Geisingberg and Steinberg (Pilot et al. 1984).

The presence of highly radiogenic Sr in mantle peridotite xenoliths from the northern margin of the Ohře Rift Volcanic Field is most probably unrelated to the Tertiary magmatic episode, as the volcanics produced during this episode are characterized by rather low $^{87}Sr/^{86}Sr$ ratios (e.g., Vokurka and Bendl 1992; Wilson et al. 1994). Also, some clinopyroxene separates analysed by Vokurka and Bendl (1992) as well as our peridotite xenolith samples from the Ahornberg do not show elevated $^{87}Sr/^{86}Sr$ values. Hence, it can be assumed that the presence of highly radiogenic Sr in some peridotite xenoliths reflects an *old* enrichment event.

This enrichment event may have involved heterogeneous introduction of Rb and Sr which finally resulted in the evolution of the errorchron observed by Pilot et al. (1984). Alternatively, the linear array may reflect two(?-)component mixing. Both interpretations face the problem that – based on the data of Pfeiffer et al. (1984) – in the former case the initial $^{87}Sr/^{86}Sr$ ratio is high (>0.7100), whereas in the second model both components have $^{87}Sr/^{86}Sr$ ratios >0.7100. However, the discovery of samples with $^{87}Sr/^{86}Sr$ of ca. 0.7037 and a sample with $^{87}Sr/^{86}Sr$ 0.7073 (this study) indicates that such high initial values may not be required, i.e. the linear array may be an artefact of sample selection.

Kramer and Seifert (2000) found amphibole and phlogopite in peridotite xenoliths from several volcanoes in the Erzgebirge and Lusatian Block, suggesting modal mantle metasomatism, which may be related to either the Tertiary magmatic episode or to an old 'event' that led to the introduction of highly radiogenic Sr into the mantle. The samples investigated do not contain hydrous phases (only some serpentine is present on fractures in olivine). Hence it is not clear whether the presence of highly radiogenic Sr is related to the metasomatic event that is indicated by the hydrous minerals.

The ultimate origin of radiogenic Sr may lie in the crust. This is particularly indicated by the extremely high values reported by Pilot et al. (1984). In this context, it is perhaps significant that

Willner et al. (2002) recently suggested that in the Erzgebirge, i.e., in the area, where highly radiogenic Sr is found in mantle peridotites, delamination and detachment of the sublithospheric mantle occurred in the Devonian, leading to the penetration of crustal rocks to a depth exceeding 160 km. Clearly, more detailed mineralogical and isotopic studies on a larger sample set are necessary to address these problems.

Acknowledgements

I thank M. Lapp and A. Friebe of the Geological Survey of Saxony for providing the samples and A. Braun and S. Mühlberg for technical assistance. M. Tichomirowa generously allowed me to work in the isotope lab.

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