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Earth and Planetary Science Letters 239 (2005) 286–308
EPSL
www.elsevier.com/locate/epsl

Re–Os and S systematics of spinel peridotite xenoliths from east central China: Evidence for contrasting effects of melt percolation

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Received 31 March 2005; received in revised form 29 August 2005; accepted 3 September 2005
Available online 19 October 2005
Editor: K. Farley

Abstract

Os isotopic compositions and Re and Os concentrations were determined for Cenozoic basalt-borne ultramafic xenoliths from the Subei Basin of east central China. Re–Os analyses were coupled with whole rock major and trace element and S abundance determinations, and with characterization of rock textures, modal phase proportions and sulfide petrography. The two main sampling areas, Lianshan and Panshishan, separated by only 6 km, have similar textures and major and moderately incompatible lithophile trace element compositions. The Os isotopic ratios of these two areas plot on the same trends relating $^{187}Os/^{188}Os$ to indices of melt extraction such as whole rock Yb content. These Os isotopic systematics suggest that both areas were affected by an early Proterozoic (~1.8 Ga) melt extraction event. Thus the two areas apparently shared the same long term lithospheric history. Nevertheless, the sulfide abundances and whole rock S, Os and Re concentrations are strikingly lower in Lianshan than in Panshishan, and the two localities have different incompatible lithophile trace element signatures. These differences resulted from contrasting melt percolation styles between the two areas. Lianshan was affected by extensive percolation of sulfur undersaturated melts that removed Re, Os and S, while Panshishan experienced interaction with low degree or highly evolved melts that added Re, Cu and S, but had no affect on Os abundances. The lack of correlation between $^{187}Os/^{188}Os$ and $^{187}Re/^{188}Os$, compared with the good correlation between $^{187}Os/^{188}Os$ and Yb, indicates that the perturbation of the Re and Os concentrations was fairly recent, and perhaps related to Mesozoic or Cenozoic lithospheric thinning in eastern China.

The Lianshan Os concentrations are typical of those of off-cratonic mantle xenoliths, while the Panshishan Os concentrations are closer to those of orogenic peridotites. This suggests that the low Os concentrations, and by extension, the low concentrations of all of the highly siderophile elements (HSE) typically observed in ultramafic mantle xenoliths, may result from recent melt percolation processes, probably directly or indirectly related to the magmatism that brought the xenoliths to the surface. Thus ultramafic xenoliths may not provide reliable estimates of the HSE contents of the upper mantle, and variations in HSE abundances between xenolith localities should not be used to define global scale processes. Os and other HSE abundances may prove to be sensitive indicators of melt percolation, and may provide information about the degree of sulfur saturation of the melts. Despite the

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doi:10.1016/j.epsl.2005.09.010

loss of Os during recent percolation, the Os isotopic ratios of most samples are nearly unmodified by this process, confirming the utility of this system for dating ancient melt extraction events.

Keywords: peridotites; osmium; Os isotopes; sulfur; chalcophile elements; mantle xenoliths

1. Introduction

During Earth accretion, the highly siderophile elements (Ru, Rh, Pd, Re, Os, Ir, Pt, Au) were almost completely segregated into the core. The small quantities of these elements present in the silicate earth are thought to be derived from meteoritic material added after core formation [1]. Recent analytical improvements have permitted the HSE contents of mantle-derived rocks to be determined with greater precision, allowing variations in HSE abundances between localities to be established with confidence. It has been shown that the HSE abundances of peridotite xenoliths carried by alkali basalts are more variable and usually lower than those of peridotites exposed in orogenic massifs. These regional differences potentially reflect spatial variations in the late meteoritic veneer delivered to the earth and moon [2], or in core–mantle interaction and mantle differentiation. However, recent studies [3–5] show that HSE abundances can be greatly altered by small scale processes such as melt percolation. The effects of these local processes must be understood before global scale processes can be considered.

Osmium is particularly well suited for addressing this problem. Os behaves compatibly during partial melting, so Os abundances in mantle peridotites are much less affected than incompatible HSE (Re, Au, Pd, Pt) abundances by melt extraction. Thus partial melting leaves peridotite residues with low and variable Re/Os ratios. As ^{187}Re is the radioactive parent of ^{187}Os, this fractionation leads with time to Os isotopic variations that correlate with the degree of ancient melt extraction. Because peridotites have high Os concentrations, their Os isotopic compositions are relatively resistant to modification during metasomatism, and reflect the long-term lithospheric history of these rocks. On the other hand, variations in Os abundances may result from superimposed recent processes [6,7]. Thus the Re–Os system provides an excellent tool for determining whether the low and highly variable HSE contents of peridotite xenoliths are of ancient or recent origin.

We present results of an Os isotopic study of two ultramafic xenolith suites from eastern central China. Re–Os analyses were coupled with whole rock major and trace element analyses and characterization of the rock textures. CO_2 contents and FeO/Fe_2O_3 ratios were determined to explore possible relationships between extent of alteration and Os and Re concentrations. As sulfides are normally the major hosts of Os and other HSE in mantle rocks, the sulfides were examined and sulfur concentrations were determined.

2. Geologic and tectonic setting

The xenoliths were collected from Neogene alkali basalts of the Subei basin, located east of the Tanlu fault zone in east central China (Fig. 1a). Seismic refraction data indicate that this Eocene fault-depression basin is underlain by about 30 km of continental crust [8,9]. This region is marked by the Triassic collision of the Yangtze (South China) block with the dominantly Archean North China block (NCB). While the Yangtze block is mainly Proterozoic, evidence for Archean crust has been found in its western part [10], and 2500 Ma zircons have been found in East Anhui province [11]. West of the Tanlu fault, the collision zone is defined by the ultrahigh pressure (UHP) Dabieshan metamorphic belt, but the location of the suture east of the fault is debated. The similarity between the Sulu and the Dabieshan UHP belts may imply (e.g. [12]) that the suture lies beneath or slightly north of the Sulu terrain [13]. In this case the mantle lithosphere beneath the Subei basin would belong to the Yangtze block. However, Li [14] proposed that the upper crust of the Yangtze block was detached and thrust to the north, while the lower crust and mantle lithosphere were subducted, with the suture located near the lattitude of Nanjing. If this model, which has some support from isotopic data [15], is correct, the uppermost mantle lithosphere beneath much of the Subei basin is actually part of the NCB, despite the association of the upper crust with the Yangtze block. The samples studied here come from just north of the proposed subsurface suture. Thus while a Yangtze lithospheric provenance seems more likely, a NCB provenance cannot be excluded.

Geophysical and geochemical data argue that large thicknesses of mantle lithosphere have been removed from beneath eastern China (reviews in [16–18]). The timing and lateral and vertical extent of, as well as the mechanisms and tectonic driving forces responsible