# Antimony in mantle-derived rocks: constraints on Earth evolution from moderately siderophile elements

**K.P. Jochum**
**A.W. Hofmann**

*Max-Planck-Institut für Chemie, Postfach 3060, D-55020 Mainz, Germany*

## Introduction

Investigations of moderately siderophile and incompatible elements, such as W, Mo, P, Sn and Sb, are useful to constrain Earth evolution, because these elements have participated in both of the major differentiation processes of the Earth, the segregation of the core and the segregation of the crust. During these processes, their 'doubly incompatible' geochemical properties cause them to be partitioned into metal/sulphide as well as into silicate liquids. However, little is known about some of these elements (e.g. Sb) in mantle-derived rocks, mainly because of analytical difficulties.

## Analytical technique and samples

Spark source mass spectrometry (SSMS) has been used for the determination of Sb (in addition to about 30 trace elements). The agreement of our data for international reference materials with compiled values is better than 15% for most of the samples with no systematic differences apparent (Fig. 1).

A wide variety of samples of differing provenance and tectonic setting were investigated in this study. The rock types include basalts, komatiites and peridotites. Additionally, the CI carbonaceous chondrite Orgueil was analyzed for comparison.

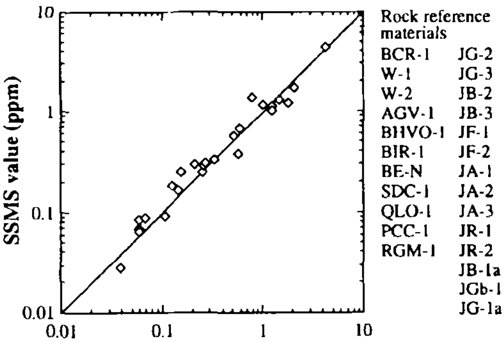


Fig. 1

## Incompatibilty of Sb

When no metal or sulphide phases are present, Sb behaves like an ordinary (lithophile) incompatible element during igneous processes. To determine its relative level of incompatibility, we tested global correlations with other purely lithophile incompatible elements. Fig. 2 suggests a best match of Sb with the light rare earth element Pr. The geochemical behaviour of Sb is consistent with the relationship between incompatibility, ionic charge, and ionic radius.

## Results

Concentration ranges and mean values of Sb and Pr [ppm] as well as Sb/Pr ratios are listed in Table 1.

(1) Oceanic basalts - Mean Sb/Pr ratios are similar in both MORB and OIB. (2) Komatiites and basalts - Most Precambrian rocks (especially those from Kambalda) have high Sb/Pr ratios presumably because of alteration. A large influence of seawater alteration to Sb/Pr ratios was recently found by Jochum and Verma (1993). They showed that Sb in altered MORB samples

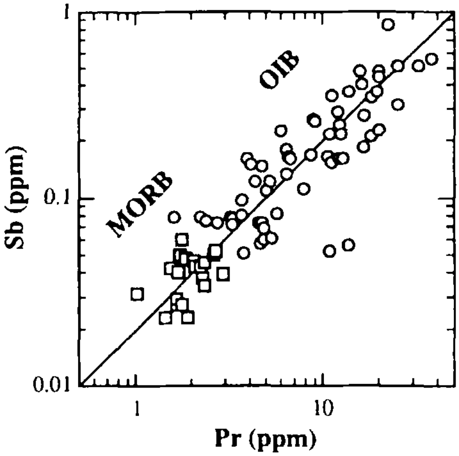


FIG. 2.

TABLE 1.

| | Sb | | Pr | | Sb/Pr |
|---|---|---|---|---|---|
| | range | mean | range | mean | mean |
| MORB | 0.02–0.06 | 0.04 | 1–3 | 2 | 0.02 |
| OIB | 0.05–0.8 | 0.2 | 2–40 | 10 | 0.02 |
| Precambrian komatiites | 0.02–0.4 | 0.2 | 0.3–0.9 | 0.5 | 0.4 |
| Precambrian basalts | 0.04–0.4 | 0.1 | 0.7–6 | 2 | 0.05 |
| Tertiary kom. and bas. | 0.02–0.03 | 0.03 | 0.4–2 | 0.6 | 0.05 |
| Spinel peridotite xenol. | 0.004–0.01 | 0.007 | 0.09–0.3 | 0.2 | 0.03 |
| Continental crust | | 0.2 | | 3.9 | 0.05 |
| CI chondrite (Orgueil) | | 0.14 | | 0.093 | 1.5 |

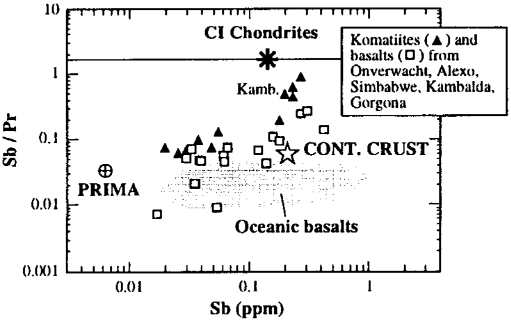


FIG. 3

can be enriched by a factor of 2000 compared to fresh glasses. Antimony concentrations in Tertiary komatiites and basalts from Gorgona Island are low; however, most Sb/Pr ratios are also higher than those of MORB. (3) Spinel peridotite xenoliths - Antimony concentrations from different locations are very low. The nodule SC-1, which is 'primitive' with respect to its major element and compatible trace-element chemistry (Jagoutz *et al.*, 1979) has a Sb concentration of 6 ppb and a Sb/Pr ratio of 0.022. (4) CI chondrite - Our values for Orgueil are in excellent agreement with the mean CI chondritic abundances of Anders and Grevesse (1989). (5) Continental crust - The estimate of Taylor and McLennan (1985) is rather uncertain.

### Earth evolution

We assume that the primitive mantle has been differentiated into different mantle reservoirs and continental crust. Fig. 3 shows that the mantle derived oceanic basalts have similar Sb/Pr ratios of about 0.02 which may be different from the Sb/Pr ratio of the bulk continental crust (0.05). Investigations by Sims *et al.* (1990) also indicate that crustal-derived materials are enriched in Sb to Ce (an element of similar incompatibility as Pr) compared to oceanic basalts. Noll *et al.* (1992) explained this enrichment by the transport of Sb from the subducting slab to the arc magma source region by hydrothermal fluids. This is supported by correlations of Sb with B. A similar enrichment in crustal material has been previously observed for Pb (Hofmann *et al.*, 1986) and As (Noll *et al.*, 1992).

From these data we calculate a Sb/Pr ratio of 0.03 for the primitive mantle (PRIMA). Assuming Pr = 0.24 ppm for PRIMA, we obtain Sb = 7 ppb for the bulk silicate Earth. A PRIMA composition can also be estimated from the chemistry of fertile spinel peridotite xenoliths. Our analyses of spinel peridotite xenoliths (Tab. 1) give Sb concentrations which agree with the estimate derived from oceanic basalts. Antimony is depleted in the PRIMA relative to CI chondritic abundances by a factor of 50 (Fig. 3). This depletion is due to both volatility and siderophility. The volatility corrected depletion factor of 8 for Sb is similar to other moderately siderophile elements (5–20) and in agreement with heterogeneous accretion.

### References

Anders, E. and Grevesse, N. (1989) *Geochim. Cosmochim. Acta*, **53**, 197–214.

Hofmann, A.W. *et al* (1986) *Earth Planet. Sci. Lett.*, **79**, 33–45.

Jagoutz, E. *et al* (1979) *Proc. 10th Lunar Planet. Sci. Conf.*, 2031–50.

Jochum,K.P. and Verma, S.P. (1993) *Terra Abstr. Suppl. No. 7 to Terra Nova*, **5**, 342.

Noll Jr., P.D., Newsom, H.E., Leeman, W.P. and Garcia, S.R. (1992) *EOS*, **73**, 342-3.

Sims, K.W.W., Newsom, H.E. and Gladney, E.S. (1990) In *Origin of the Earth* (Newsom,H.E. and Jones, J.H., eds.), Oxford Univ. Press, 291–317.

Taylor, S.R. and McLennan, S.M. (1985) *The Continental Crust: Its Composition and Evolution*, Blackwell.