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The provinciality of Pb isotopes in Pacific Fe-Mn deposits

W. Abouchami
S. J. G. Galer

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

In the late 50's, Chow and Patterson reported the first lead isotopic data from Fe-Mn nodules, and found that '...Atlantic leads were more radiogenic than those of the Pacific', and that '...the Pacific samples show a trend of increasing radiogenic leads from the north-west toward the south-east Pacific'. They further suggested that the distribution of Pb isotopes can be used to trace deep water circulation patterns, a suggestion more recently confirmed by the relationship found by Abouchami and Goldstein (1995) between Pb isotopic variations in Circum-Antarctic Fe-Mn nodules and the present-day pattern of ocean circulation in this region. In the Atlantic, as in the Circum-Antarctic, Pb isotopic compositions of Fe-Mn deposits vary systematically with geographic location and, thus, reflect the deep ocean circulation (Simonetti *et al.*, 1995).

Within this global picture, the 'uniform' Pb isotopic compositions found in Pacific Fe-Mn crusts (von Blankenburg *et al.*, 1996) stand out. These authors argued that Pb isotopes are 'exceedingly well-mixed' in the Pacific, although there seems to be a discrepancy between the short oceanic residence time of Pb in deep waters (~80 yrs) and the residence time of waters in the Pacific (~1000 yrs). Several questions arise, such as the extent to which the 'homogeneity' of Pb isotopes in the Pacific reflect the source homogeneity *vs* mixing processes, and how the mechanisms of mixing in the oceans affect the Pb isotopic distribution. The answers may be important for understanding the oceanic chemistry of Pb and, in particular, the relationship between Pb isotopic variations and mixing processes in the oceans.

We report high precision Pb isotopic data ($2\sigma_{ext.} \leqslant 100$ ppm) obtained using a triple Pb spike (Galer and Abouchami, This volume) together with Nd isotopic compositions on surface scrapings of Fe-Mn deposits from the Pacific ocean basin. Pb isotope ratios display a range of 18.64 and 18.82 for $^{206}Pb/^{204}Pb$, 15.618 to 15.649 for $^{207}Pb/^{204}Pb$ and 38.601 to 38.853 for $^{208}Pb/^{204}Pb$, and these variations are clearly geographically related. As far as $^{206}Pb/^{204}Pb$ ratios are concerned, the least radiogenic ratios are found in the NE Pacific and the most radiogenic in the SW Pacific, in complete agreement with the trend observed by Chow and Patterson (1959). ε_{Nd} values are more radiogenic in the NE Pacific compared to the SW Pacific, as has already been shown in a compilation of the Nd isotopic distribution in Fe-Mn nodules (Albarède and Goldstein, 1992).

By using the Pb triple spike, we are able to fully resolve small variations in $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios as well. In Pb isotope space, two distinct linear arrays are seen, which are clearly related to the geographic distribution of the samples. The first array is defined by samples from the NE and NW, which display relatively constant $^{207}Pb/^{204}Pb$ ratios but increasing $^{206}Pb/^{204}Pb$ ratios from the NW toward the NE Pacific. The second trend is represented by samples from the SW and one sample from the NW Pacific, which overlap the trend defined by Fe-Mn nodules from the Pacific sector of the Circum-Antarctic ocean (Abouchami and Goldstein, 1995). The latter trend reflects binary mixing between Circum-Antarctic Pb and Pacific Pb, showing that the influence of Pb derived from Southern Component Water (SCW) can be traced as far as the equatorial sector of the Pacific. This observation is in full agreement with advection of the Circum-Antarctic Pb signal into the central Pacific, as recently shown by Abouchami *et al.* (1997). In contrast, there is no evidence for such a SCW influence in the NE Pacific sector based upon the data available.

Furthermore, there is also a suggestion of depth variations in $^{206}Pb/^{204}Pb$ ratio, shallow samples having more radiogenic isotopic compositions than deeper samples in a given area. Nd isotopes exhibit the reverse trend and mirror the distribution of Nd isotopes in the water column of the Pacific – that is, deep waters are less radiogenic than surface waters, which reflects the incursion of antarctic waters flowing northward into the Pacific. Thus, like Nd isotopes in seawater, Pb isotopes in Pacific Fe-Mn nodules may exhibit a vertical stratification. In this case, the Pb isotopic signal of deep waters in the Pacific is not acquired directly from surface waters but, rather, is derived from Pb advected horizontally via deep water currents.

We conclude 1) that pre-anthropogenic Pacific ocean lead displays subtle but resolvable variations in all three Pb isotope ratios; 2) Pb isotopes exhibit depth variations similar to those observed for Nd isotopes in Pacific Fe-Mn deposits and seawater; and 3) the contributing sources of Pb are relatively homogeneous in the Pacific compared to those in the Atlantic ocean – however, Pacific Pb is not well-mixed because in contrast to the well-ventilated waters of the Atlantic, circulation in the Pacific is relatively sluggish.

References

Chow, T.J. and Patterson, C.C. (1959) *Geochim. Cosmochim. Acta*, **17**, 21–31.

Abouchami, W. and Goldstein, S.L. (1995) *Geochim. Cosmochim. Acta*, **59**, 1809–20.

Abouchami, W., Goldstein, S.L., Galer, S.J.G., Eisenhauer, A. and Mangini, A. (1997) *Geochim. Cosmochim. Acta*, **61**, 3957–74.

Albarède, F. and Goldstein, S.L. (1992) *Geology*, **20**, 761–3.

Simonetti, A., Abouchami, W., and Goldstein, S.L. (1995) *EOS, Trans. Amer. Geophys. Union, Fall Mtg. Suppl.* **7**, F322.

Von Blankenburg, F., O'Nions, R.K. and Hein, J.R. (1996) *Geochim. Cosmochim. Acta*, **60**, 4957–63.