HETEROGENEITY OF THE SUB-OCEANIC DEPLETED MANTLE

[1]DOSSO, L., [2]BOUGAULT, H., and [3]VLASTELIC, I. [1]UMR6538-CNRS, [1,2]IFREMER, BP70, 29280, Plouzané, France;
[3]now at Max Planck Institut für Chemie, Abteilung Geochemie, Postfach 3060, D-55020, Mainz, Germany.

Summary
From the examples of the north mid-atlantic ridge and the pacific-antarctic ridge studies, the geochemical properties of the sub-oceanic depleted mantle are reviewed and the heterogeneous character of the « normal mid-ocean ridge basalts » (N-MORB) source is emphasized.

The north mid-atlantic ridge (10-45°N)
The recently published studies of the mid-atlantic ridge basalts north and south of the Azores (Yu, Fontignie et al. 1997) (Dosso, Bougault et al. 1999) contribute to illustrate the trace element and isotopic geochemical variations of the mantle source regions from 10 to 70°N (Figure 1a). There is a long wavelength enrichment in incompatible elements and isotopes associated with the Azores hot spot which extends to the north at least up to 45°N and to the south, to Hayes fracture zone near 33°N when looking at the incompatible element ratios, and to Kane fracture zone near 22°N when looking at the Sr isotope ratios (Figure 1). This strong asymetry in the surface expression of the Azores mantle plume is supported by the interpretation of along track geophysical data and by the upper mantle thermal structure as previously inferred from seismic tomography and geoid models as discussed in (Goslin 1999).
Superimposed on these gradients are local spikes of enrichment. The most prominent are (1) the 14°N anomaly which is clearly associated with a topographic anomaly and has been tentatively interpreted as an embryonic mantle plume (Bougault, Dmitriev et al. 1988) (Dosso, Bougault et al. 1993) and (2) the Oceanographer anomaly spike which is reflected rather modestly in the morphology of the ridge axis but is not obviously related to a plume. Its rather unique isotopic characteristics (low $^{206}Pb/^{204}Pb$ ratios with high $^{87}Sr/^{86}Sr$ and low $^{143}Nd/^{144}Nd$) could be attributed to the involvement of subcontinental material –the presence of subcontinental material has been called upon to explain the existence of old zircons from drilled gabbros near the Kane fracture zone (Pilot, Werner et al. 1998)- but the samples do not contain the negative Nb-Ta anomalies usually associated with the presence of continental material in the mantle source (3) the 42-43°N double anomaly which might be related to surface expression of the Azores mantle plume (Dosso, Bollinger et al. 2000).
South of the Azores hot spot, all Sr-Nd-Pb isotopic systems give apparent ages in the range of 100 to 300 ma. Irrespective of the interpretation of these ages (Dosso, Bougault et al. 1999), it is interesting to note that in Sr mantle isochron diagrams, separate correlations are obtained for 10-24°N and 31-38°N samples. Depleted sources with low Rb/Sr and La/Sm -$(Nb/Zr)_N$- ratios have $^{87}Sr/^{86}Sr$ which vary between 0.70215 and 0.7029. To the north of the Azores hot spot, such correlation is not apparent but incompatible element depleted basalts have $^{87}Sr/^{86}Sr$ which can still reach 0.7031.

The pacific-antarctic ridge (56-66°S)
It is widely believed that Pacific ridges are formed from a single fairly well mixed reservoir, source of N-MORBs, and extending from the Australian-Antarctic discordance to the Juan de Fuca ridge. In support of this idea, axial bathymetry, major/trace elements and isotopes suggest that the pacific-antarctic ridge (56-66°S) is devoid of any hotspot influence (Figure 1b) (Vlastelic, Dosso et al. 2000). The depleted mantle source in the area, south of the Easter microplate has an average $^{87}Sr/^{86}Sr$ of 0.7025. However a recent Sr-Nd-Pb compilation of all Pacific MORB samples (except those coming from segments associated with known hotspots –the Galapagos spreading centre, the east rift of Easter microplate and the segment near the Hollister-Louisville hotspot system) reveal different isotopic signatures north and south of the Easter microplate (25°S) (Vlastelic, Aslanian et al. 1999). In particular, the depleted mantle north of 25°S has on average higher Sr (0.70257±0.00026, n=300), higher Nd and lower Pb isotopic ratios than the southern ones (0.70248±0.00008, n=92). This evidence of two different « depleted » mantle domains in the pacific is further strengthened, as illustrated in Figure 2, by the observation of different average depths of the ridge axes north (2850m) and south (2450m) of the 25°S boundary. This difference is attributed to differences in the thermal structure of the uppermost mantle on either side of the 25°S boundary.

Trace element characteristics
The well known depletion, of Ta-Nb (compared to La) observed in depleted MORBs varies as a function of the degree of depletion of the basalts as measured by the La/Sm ratio.
The Nb/Ta ratio of depleted MORBs is constant in first approximation but decreases as the degree of depletion of the basalt increases (Niu and Batiza 1997).

Conclusions
The recent studies of the north mid-atlantic ridge and the pacific-antarctic ridge point out to a variety of « depleted » N-MORB sources with, in particular, different $^{87}Sr/^{86}Sr$ ratios from 0.70215 to 0.7031. This variation in the depleted end-member MORB component cannot be attributed only to plume-depleted mantle interactions. The notion of passive heterogeneities in the upper mantle probably needs to be accounted for and, in some cases, be put in relation with discontinuities in plate tectonic motions or with intraplate deformation.

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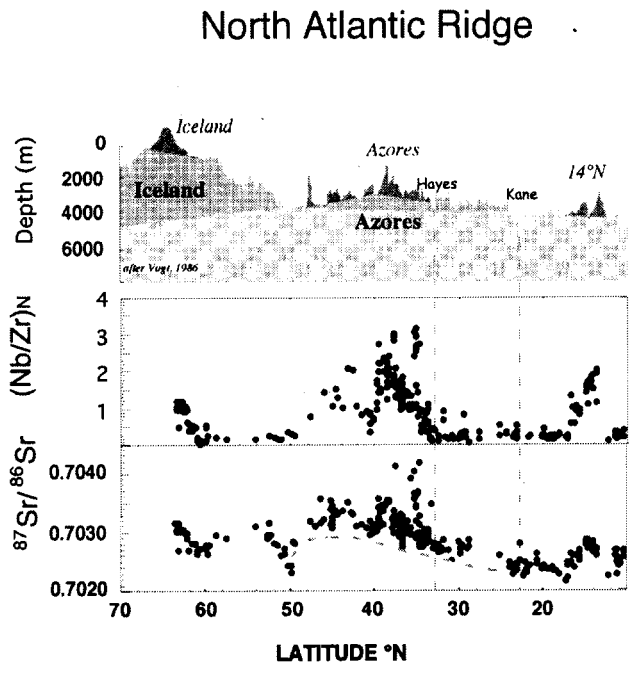

Figure 1a. Geochemical morphology of the north mid-atlantic ridge, influenced by hot spots. Between Hayes and Kane fracture zones depleted samples with (Nb/Zr)N<1 have Sr isotopic ratios above 0.7025.

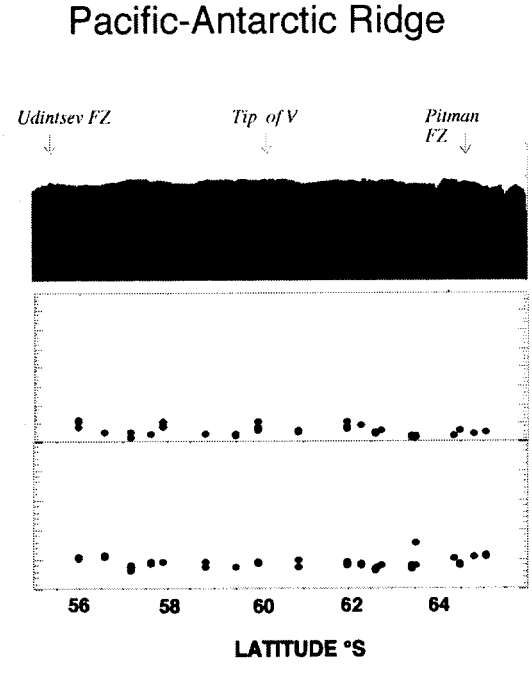

Figure 1b. Geochemical characteristics of the pacific antarctic ridge (56-66°S) suggesting an overall depleted and homogeneous mantle source. Note that the latitude scale is different from figure 1a.

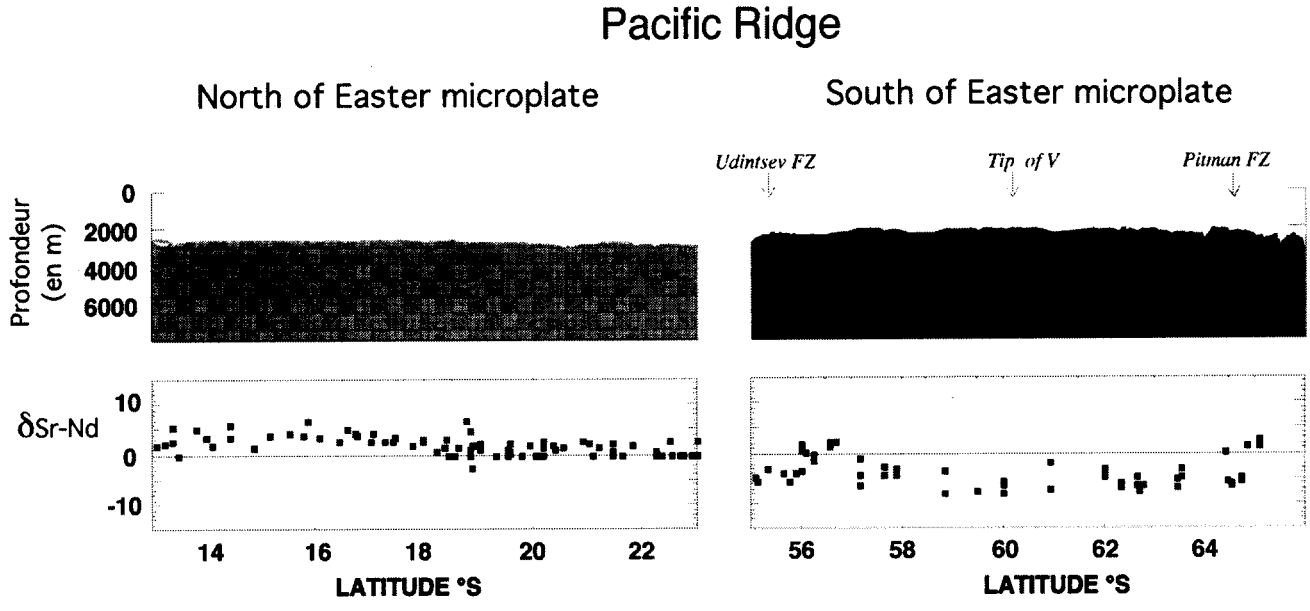

Figure 2 illustrating the bathymetric and geochemical comparison of two sections of Pacific ridge to the north and the south of the Easter microplate limit. The geochemical parameter δSr-Nd defines the position of the isotopic composition of the analyzed sample in a Sr-Nd, relative to a reference line as defined in Vlastelic (1999). *Note the regular decrease of δSr-Nd towards 25°S.*