Distributions of chemical composition for ancient and current MORB: consequences and perspectives

E. Humler — Laboratoire de Pétrologie, Université de Paris VII, 4 Place Jussieu, 5252 Paris Cedex 05, France

V. Daux — Laboratoire de Géologie des Bassins Sédimentaires, Université de Paris VI, 4 Place Jussieu, 75252 Paris Cedex 05, France

C.H. Langmuir — Lamont Doherty Geological Observatory, Palisades, NY, U.S.A.

We compare the chemical composition, back-tracted depth and crustal thickness of crust formed more than 80 m.y. ago with the zero age crust that is being produced today. Through this comparison, we can evaluate whether the steady state assumption of geophysical depth-age modelling is justified, and whether there have been large scale changes in the distribution of ridge depths with time.

It is important to note that the appropriate comparison is between the isochronous distributions of depth and chemistry. There is not a single depth of ocean ridges today, nor is there a single chemical composition. Therefore the critical question is not whether there is some analogue for some ocean ridge today vs. some ocean ridge in the past, but instead whether there is a statistically significant difference in the distributions of depth and chemistry between the global system of ridges today and that in the Mesozoic.

The twenty years of drilling by the ocean drilling project have provided a significant number of basement samples from older ocean crust. However, these samples are mostly not directly comparable to the zero-age data set of dredged glasses from active ridges, and hence interpretation of their chemical composition requires some care:

(1) many sites are located on bathymetric highs that were created off-axis, or were created by near-ridge hot spots. While these sites may be important for the overall distribution of depths, their chemistry is often anomalous. The data we have considered have been selected in order to avoid a hot spot effect, first by eliminating all holes on shallow crust with La/Sm N greater than 1, and then by eliminating those sites which appear to have come from hot spot margins,

(2) despite the pervasive alteration, some old holes have small amounts of glass for which major element compositions have been determined that are directly comparable to glass compositions for zero age crust. However, when glasses analyses are not available, it is necessary to find proxies for major elements that are relatively unaffected by alteration. Many studies over the years have shown, that for modest degrees of alteration, the high field strengh elements and the *REE* are generally minimally affected by alteration. This is particularly true for ratios among these elements, since any dilution effects by addition of water and alteration minerals will have even less effect on the ratios of unaffected elements than on the absolute concentrations;

(3) there is also the issue of quality of measurement and the fact that most drill core analyses are carried out on whole rocks. The phenocryst content of the whole rock has a major effect on parameters such as Na8.0 and Fe8.0.

These various criteria lead to our selection of sites and data for investigation of this problem. Despite that the elimination of data is far greater than the data we are able to include, the final data set is well distributed around the globe, and include multiple sites on old crust in the Atlantic, Pacific and Indian ocean basins.

Comparison of the chemical and crustal distributions between ancient and current MORB show that the oceanic crust older than 80 m.y. exhibit statistically lower Na8.0, Zr/Y, Sm/Yb N and higher Fe8.0 and crustal thickness (Fig. 1). These systematics suggest that the mantle was hotter in this time period by about 50°C, that the zero age crust was several hundred meters shallower and the crust 1–2 km thicker (Humler *et al*; 1998).

Data from ocean ridges today suggest that there are temperature variations in the upper mantle of as much as 240°C from the hottest to the coldest ridges (Klein and Langmuir, 1987). Within this large amplitude of thermal variation within the earth, there is clearly room for significant temporal changes in the ambient temperature of the upper mantle. The petrological results from the old drillsites suggest that

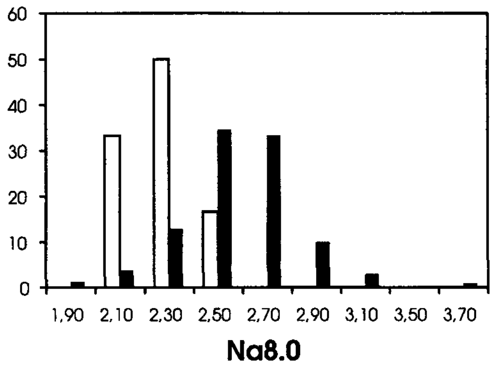

FIG. 1. Chemical distribution of Na8.0 for current and ancient MORBs (normalized to 100%.-black and white areas respectivelly). Old basalts have lower Na8.0 (2.30 $\pm$ 0.15%) and higher Fe8.0 (10.4 $\pm$ 0.35) than current MORBs (2.60+-0.20 and 9.80+-0.60).

the mean temperature of the upper mantle may have been significantly hotter (by about 50°C) than at present. These estimates show that about half of the observed flattening relative to a boundary layer model is due to the change in mantle temperature and crustal composition. A few hundred meters of flattening is all that is required by plate reheating by hot spots or by other mecanisms.

The hotter mantle has important implications for a wide range of associated problems, including sea level change, carbonate compensation depth (through effects on basement depth) and possibly even subduction process. It also accounts easily for the apparent 'thickening of ocean crust with time'.

References

Klein, E. and Langmuir, C.H. (1987) *J. Geophys. Res.*, **92**, 8089–115.

Humler, E., Daux, V. and Langmuir, C.H. (1998) Submitted to *Earth Planet. Sci. Lett.*