Pb, U and Th behaviour during alteration of the oceanic crust

C. Verati
J. Lancelot

Laboratoire de Géochimie Isotopique, UM2- CNRS UMR 5567,
Place E. Bataillon, 34095 MONTPELLIER cedex 05 - France

Studies of magmatic rocks from deep-sea holes are primordial in order to quantify the effects of hydrothermal alteration and off-axis alterations on element redistribution within the oceanic crust. Defining geochemical characteristics of the altered oceanic crust is a key parameter to understand (1) magmatic processes occurring in the subduction zones and (2) the altered oceanic crust recycling within the mantle.

Sample descriptions

We report Pb, U and Th contents of 62 rock samples from the Hole 504B, the deepest drill hole in the ocean crust, penetrating to 2111 meters below seafloor (mbsf), over the course of seven drilling legs.

Hole 504B is located in 5.9 m.y.-old crust, 201 km south of the Costa Rica Rift, the easternmost segment of the Galapagos Spreading Center (GSC) in the eastern equatorial Pacific. Rocks underwent various alteration types (Alt *et al.*, 1996): (1) oxidising alteration at low temperatures (<100°C) in the upper volcanic section (UVS), (2) anoxic alteration at low temperature (<150°C) in the lower volcanic section (LVS), (3) the mineralised zone comprising a stockwork, (4) greenschist facies conditions in the upper dikes (UD), (5) higher alteration temperatures approaching amphibolite facies conditions in the lower dikes (LD) and (6) the UVS, LVS, MZ and UD finally underwent off-axis alteration (zeolite facies).

Analytical procedures

In ultraclean room, 100 to 200 mg of powdered basaltic samples were digested with a HF-HNO_3 mixture at a temperature of 60°C. After evaporation to dryness, the sample is taken into solution in $HClO_4$+HNO_3 over a day. After evaporation of this mixture, the sample is taken into solution in HCl(6N) over a day. This solution is evaporated. Afterwards, the sample is taken into solution in 1 cc HNO_3(13N) + 4 cc H_2O. This final solution is diluted with water until the content is around 1 g of rock/l. We used routinely tridistilled reagents to minimize the blank. Total blanks were measured in the final dilute solution: 1–2 ppb for Pb and under the detection limit for U and Th. Pb, U and Th contents are precise respectively within 6%, 7% and 5%. The contents were analysed with ICP-MS, and were corrected of blanks for Pb.

Results and discussion

Lead. Pb contents are very heterogeneous (<10 ppb to 43 ppm) and depend on the degree of alteration varying with depth. Preferential leached zones (losses of 70% of the initial Pb) are located in the lower dike complex, which corresponds to the zone of maximal interaction between the upward hydrothermal fluids and the rocks. The transition zone between the volcanic section and the dikes is a preferential layer for Pb reprecipitation, especially in the mineralised zone (stockwork) where Pb concentrated in secondary sulphides. In the volcanic section, Pb was moderately reprecipitated (Ce/Pb<25) or leached (Ce/Pb>25).

TABLE 1. Pb, U and Th mean contents of each alteration zones along the 504B borehole (this study) and of end-members (compilation after Chen *et al.*, 1986; Chen, 1987; White, 1993; Kramers and Tolstikhin, 1997)

	Pb	U	Th
Deep seawater	2 ppt	3 ppb	0.7 ppt
Hydrothermal fluids	34–90 ppb	0.1–3 ppb	0.1–8 ppt
Unaltered oceanic crust (MORB)	0.5 ppm	0.08 ppm	0.2 ppm
504B (ppm)			
Upper Volcanic Section	0.98	0.12	0.33
Lower Volcanic Section	0.41	0.11	0.07
Mineralised Zone	3.40	0.04	0.03
Upper Dykes	0.35	<0.01	0.02
Lower Dykes	0.06	<0.01	0.03

Uranium.40% of the contents are under the detection limit (10 ppb), especially in the dike complex. But, significant U enrichments occur in the volcanic section. This U enrichments can not be related to primary heterogeneity of the mantle source. U was intensively leached by ascending hydrothermal fluids through the dike complex, and was preferentially reprecipitated within the pillow-lavas and the basaltic flows under anoxic conditions at low temperatures.

Thorium. Th contents are relatively constant through the altered oceanic crust, but are below typical N-MORB contents. The monotonous behaviour of the contents suggests that Th was relatively immobile during the alteration processes. Th contents thus would represent predominant magma type related to an extremely depleted source, as previously demonstrated with other geochemical data on the 504B rocks (Bach *et al.*, 1996). The occasionally Th enrichments in the volcanic section would be related to primary heterogeneity in the mantle source (high Th contents are strictly correlated with high La/Yb).

This study demonstrates that Pb, U and Th have very different behaviour during the alteration processes of the oceanic crust. Hydrothermal alteration and off-axis alterations thus induce U/Pb, Th/Pb and U/Th fractionation whose values will depend on the considered lithologic unit.

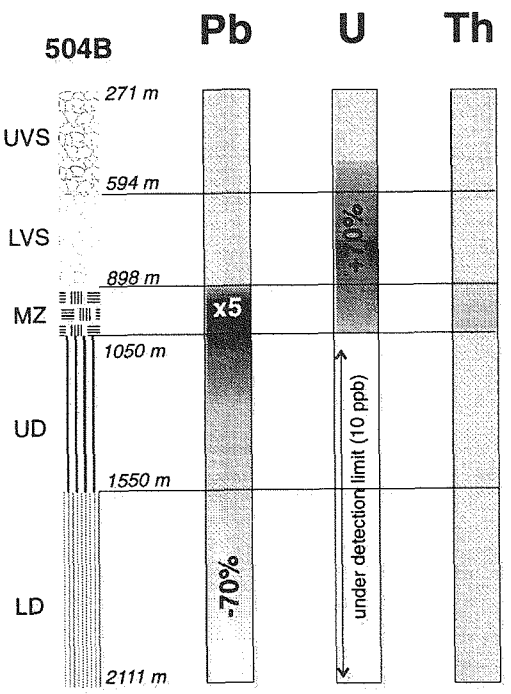

FIG. 1. Pb, U and Th content variations within the altered oceanic crust. UVS: upper volcanic section; LVS: lower volcanic section; MZ: mineralised zone; UD: upper dykes; LD: lower dykes.

References

Alt, J.C., Laverne, C., Vanko, D., Tartarotti, P., Teagle, D.A.H., Bach, W., Zuleger, E., Erzinger, J. and Honnorez, J. (1996) *Proceedings of the ODP, Scientific Results*, **148**, 417–34.

Bach, W., Erzinger, J., Alt, J.C. and Teagle, D.A.H. (1996) *Proceedings of the ODP, Scientific Results*, **148**, 39–55.

Chen, J.H. (1987) *J. of Geophys. Res.*, **92**, 11411–15.

Chen, J.H., Wasserburg, G.J., Von Damm, K.L. and Edmond, J.L., (1986) *Geochim. Cosmochim. Acta*, **50**, 2467–79.

Kramers, J.D. and Tolstikhin, I.N. (1997) *Chem. Geol.*, **139**, 75–110.

White, W.M. (1993) *Earth Planet. Sci. Lett.*, **115**, 211–26.