Some examples of applications of X-ray Circular Magnetic Dichroism in Earth Sciences

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XMCD is an element-, site-, and symmetry-selective technique and allows determination of the site occupancies in iron oxides and oxyhydroxides and the magnetization associated with these ions. A number of unresolved questions related to the distribution of ions on magnetic networks in magnetic minerals of interest in Earth Sciences can be tackled with XMCD. We show three examples of such studies carried out at IMPMC. XMCD spectra of a well characterized synthetic sample of 6-line ferrihydrite, at both K and $L_{2,3}$ energy edges of iron, demonstrate unambiguously the presence of tetrahedrally coordinated Fe(III) in the mineral structure, which was a highly debated question. In a different study, N-type self-reversal magnetization in titanomaghemite from a sample of submarine basalt was identified as a reversal of the tetrahedral and octahedral magnetic subnetworks, because the XMCD spectrum at Fe K-edge of the N-type titanomaghemite at 20 K is a mirror image of the spectrum at 300 K. Finally, XMCD experiments carried out to compare the Fe^{2+}/Fe^{3+} ratio in nanomagnetite chemically produced from lepidocrocite and nanomagnetite biogenically produced by the Fe-reducing bacterium *Shewanella putrefaciens* show that the biogenic nanomagnetite contained a higher amount of Fe^{2+} than the abiogenic nanomagnetite.

The first comprehensive dataset of ^{236}U in the North Atlantic ocean

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Developments in accelerator mass spectrometry (AMS) allow determining very low levels of $^{236}U/^{238}U$ in Ocean waters. As a result, ^{236}U is emerging as a new anthropogenic tracer and its potential in oceanography is currently being explored [1,2]. In this study the first comprehensive dataset of $^{236}U/^{238}U$ in the North Atlantic Ocean is presented. ^{236}U was determined in 90 seawater samples (3 L each), collected during the GEOTRACES cruise GA02 in 2010 along the Northwest Atlantic Ocean. The cruise track was designed to follow the path of the North Atlantic Deep Water (NADW) from its formation region to the relatively deep parts of the western Atlantic Ocean basins. The sources of ^{236}U in the North Atlantic are (i) global fallout and (ii) releases of the European reprocessing plants in La Hague and Sellafield. The results show a broad variation of $^{236}U/^{238}U$ ratios, from $(44\pm15)x10^{-12}$ in the deep western equatorial Atlantic Ocean to $(1477\pm91)x10^{-12}$ in the overflow waters passing Denmark Strait, all ratios being significantly above the theoretical pre-antropogenic level of ocean water. This evidences that the whole transect (from 64ºN to 2ºN) in the North Atlantic Ocean is dominated by anthropogenic ^{236}U. The calculated inventories of ^{236}U increase by a factor of five from the southermost station to the North indicating that besides the fallout derived ^{236}U the water colum in the North Atlantic is already significantly influenced by releases from the European reprocessing plants. Seawater samples from the Arctic Ocean and the South Atlantic Ocean are currently processed, to get a more comprehensive picture of this isotope in the Atlantic Ocean.

[1] Sakaguchi *et al.* (2012). Earth and Planetary Science Letters **333-334**, 165-170. [2] Christl *et al.* (2012). Geochimica and Cosmochimica Acta **77**, 98-107.

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