Marine cycling of particulate trace metals along the rapidly warming western Antarctic Peninsula

Amber L. Annett[1], Robert M. Sherrell [1], Marie Séguret [1], Maria Lagerström[1], Oscar Schofield [1], Hugh Ducklow[2]
[1]Rutgers University, Department of Marine and Coastal Sciences
[2]Columbia University, Lamont-Doherty Earth Observatory

Introduction:

The western Antarctic Peninsula (WAP) is the fastest warming region in the southern hemisphere, and an intensely productive marine system. In contrast to low-productivity offshore waters, shelf waters are rich in iron (Fe), an essential micronutrient for phytoplankton. Fe can be supplied by dust, sea ice, upwelling of waters enriched by interaction with shelf sediments, land runoff, and glacial processes. Many of these are changing as a result of warming. We present three years of particulate trace metal data from surface waters of the Palmer Long Term Ecological Research program, to investigate the sources, cycling and removal of particulate Fe and other biologically active trace elements in this region.

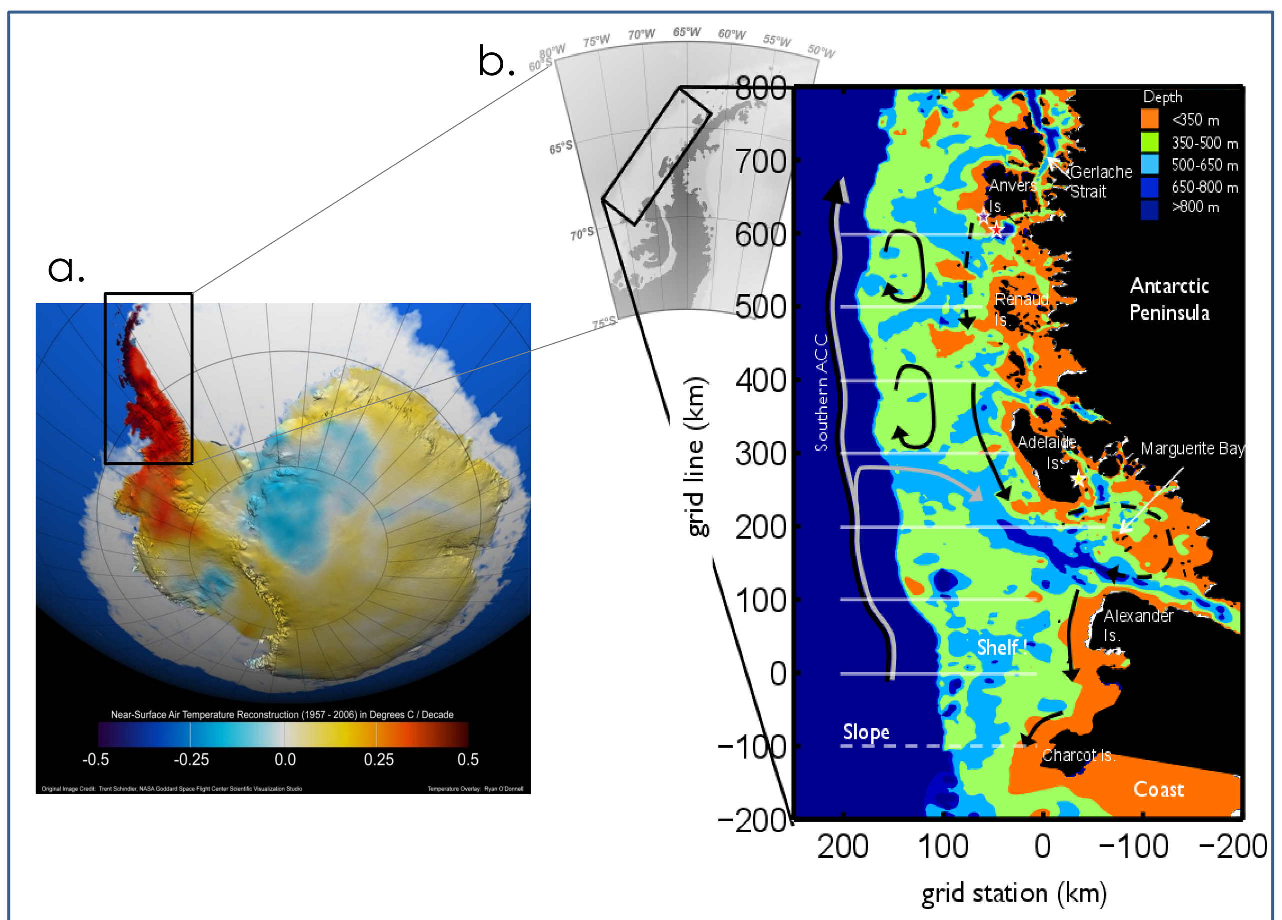

Figure 1: Map of Antarctica showing strong warming in the peninsula region (a) and map of the Palmer-LTER grid area with sampling lines and main current patterns (b; black arrows are surface flow, grey arrows are subsurface currents)

*(b) from Eveleth et al., Ice melt influence on summertime net community production along the Western Antarctic Peninsula, *submitted 2015*

Iron in the ocean:

Particulate iron is present in three forms in the ocean:

- lithogenic - derived from the earth's crust
- authigenic - minerals formed in the water column
- biogenic - incorporated into living organic matter

Methods:

Surface water samples were collected using a trace-metal clean tow-fish deployed from the ARSV Laurence M. Gould during the austral summers of 2010, 2011 and 2012. Particulate samples were collected on 0.45 µm Supor filters. Particulate matter was digested in HF/HNO3, and trace metals analyzed by ICP-MS at Rutgers University.

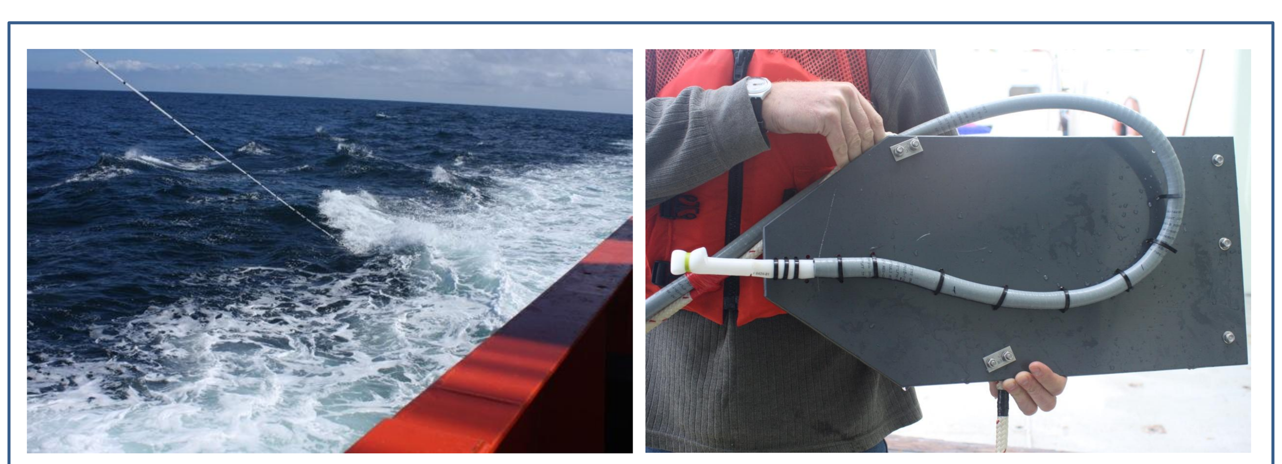

Figure 2: Sampling surface waters using a trace-metal clean towed "fish" system that avoids contamination from the ship.

Summary:

Particulate metal concentrations on the WAP shelf are highly variable, and show strong coastal sources. Authigenic and biogenic phases are particularly important in this region, where Fe-limitation can occur both adjacent to and above the continental shelf.

Results: Total particulate Iron

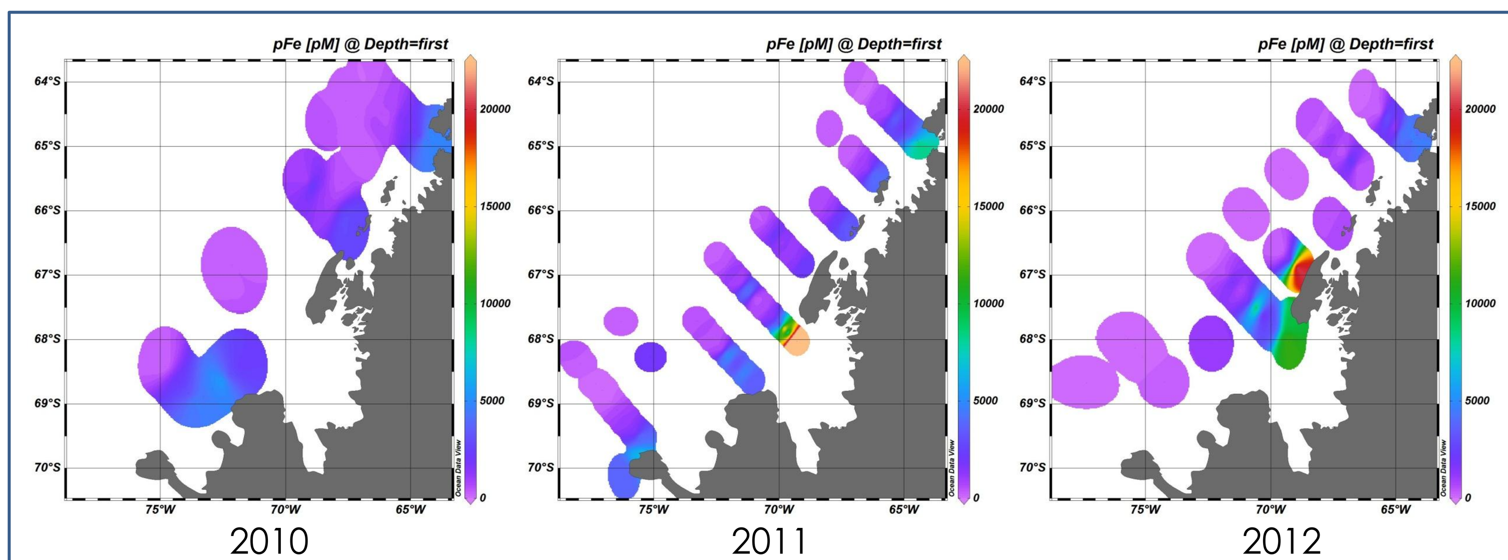

Figure 3: Total particulate iron (Fe) throughout the sampling grid. Maximum concentrations in 2011 reached 42 nM!

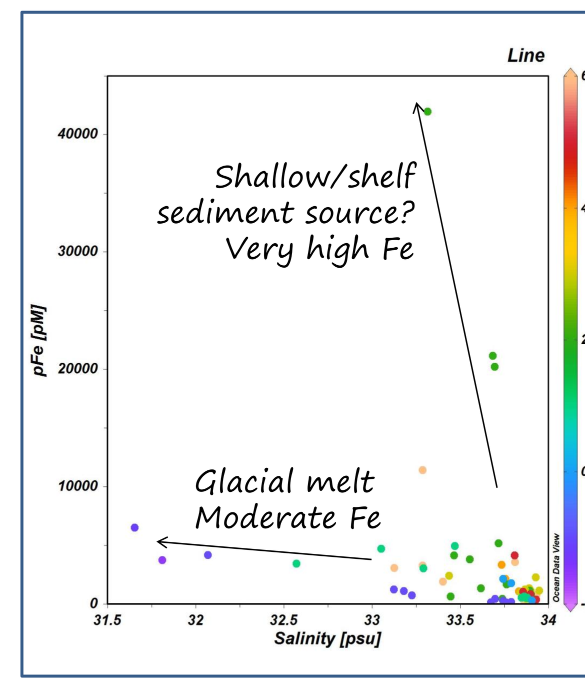

Figure 4: The samples with highest pFe do not have lowest salinity.

Results: Lithogenic metals

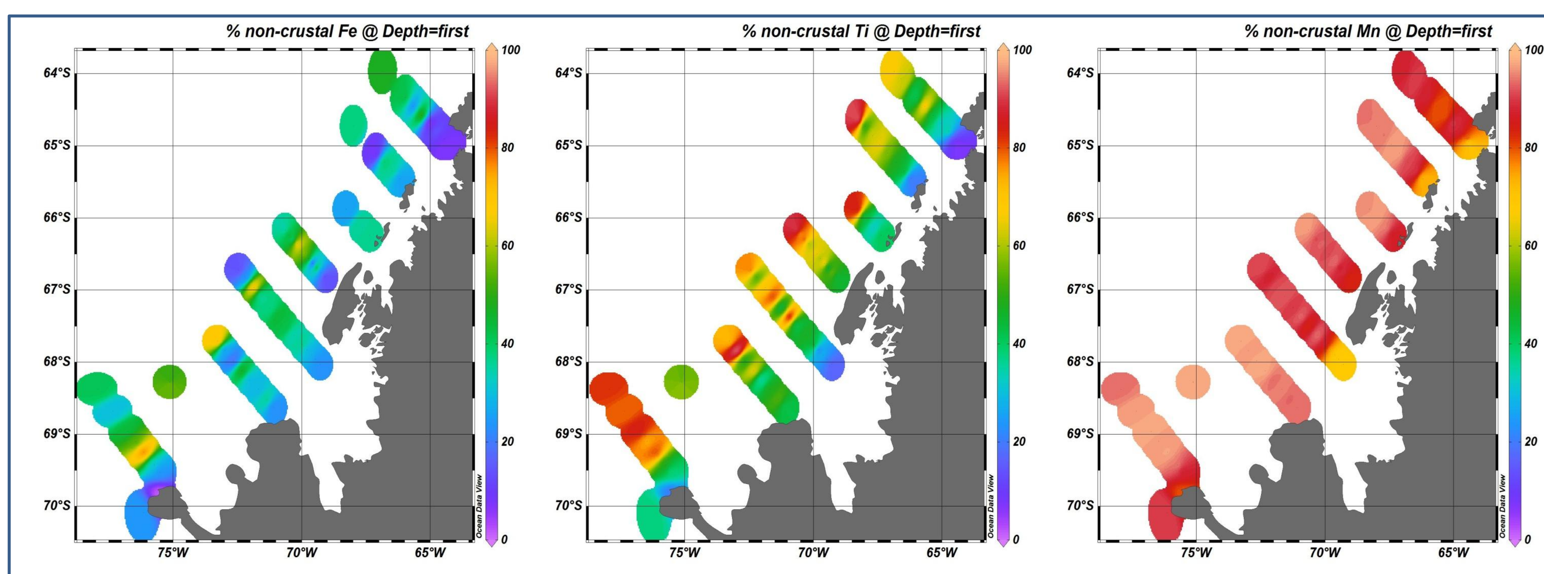

Figure 5: Percentage of non-crustal metals (Fe, Ti and Mn) in surface waters of the sampling grid. Scales are the same for all metals.

Many elements that are typically dominated by the lithogenic phase show very high non-crustal proportions along the WAP (Fig 5).

A comparison of factor analysis between particulate metals in the North Atlantic and WAP waters shows much less variance captured by component 1 for Fe, Al, Ti, Th, Pb, V and Y (Fig 6).

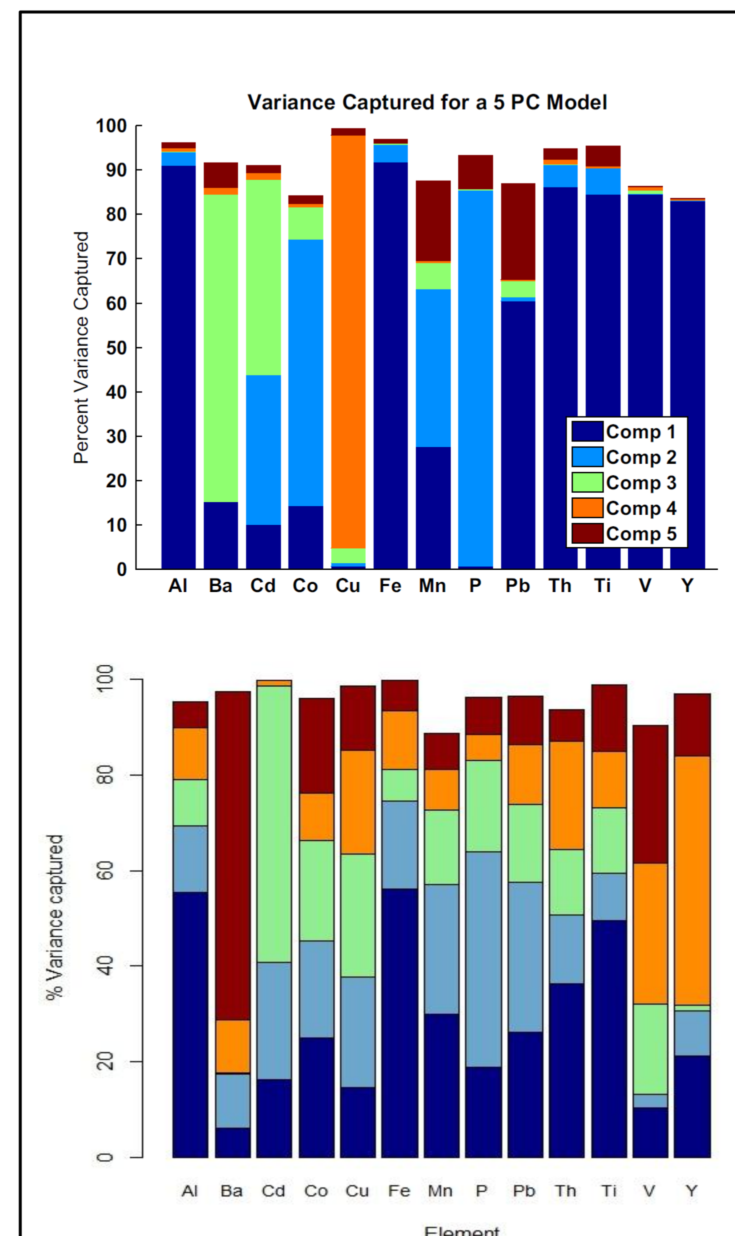

Figure 6: Factor analysis for key metals from two different marine environments. Top: North Atlantic, from Ohnemus and Lam (2015). Component 1 is dominant for Al, Fe, Pb, Th, Ti, V and Y, and therefore probably corresponds to the lithogenic phase. Component 1 is a main factor for some WAP metals (Al, Fe, Ti; bottom) but is less dominant in this area and does not capture much variance of the other lithogenic metals.

*Ohnemus & Lam (2015) . Deep Sea Research II, 116: 283-302 doi: 10.1016/j.dsr2.2014.11.019

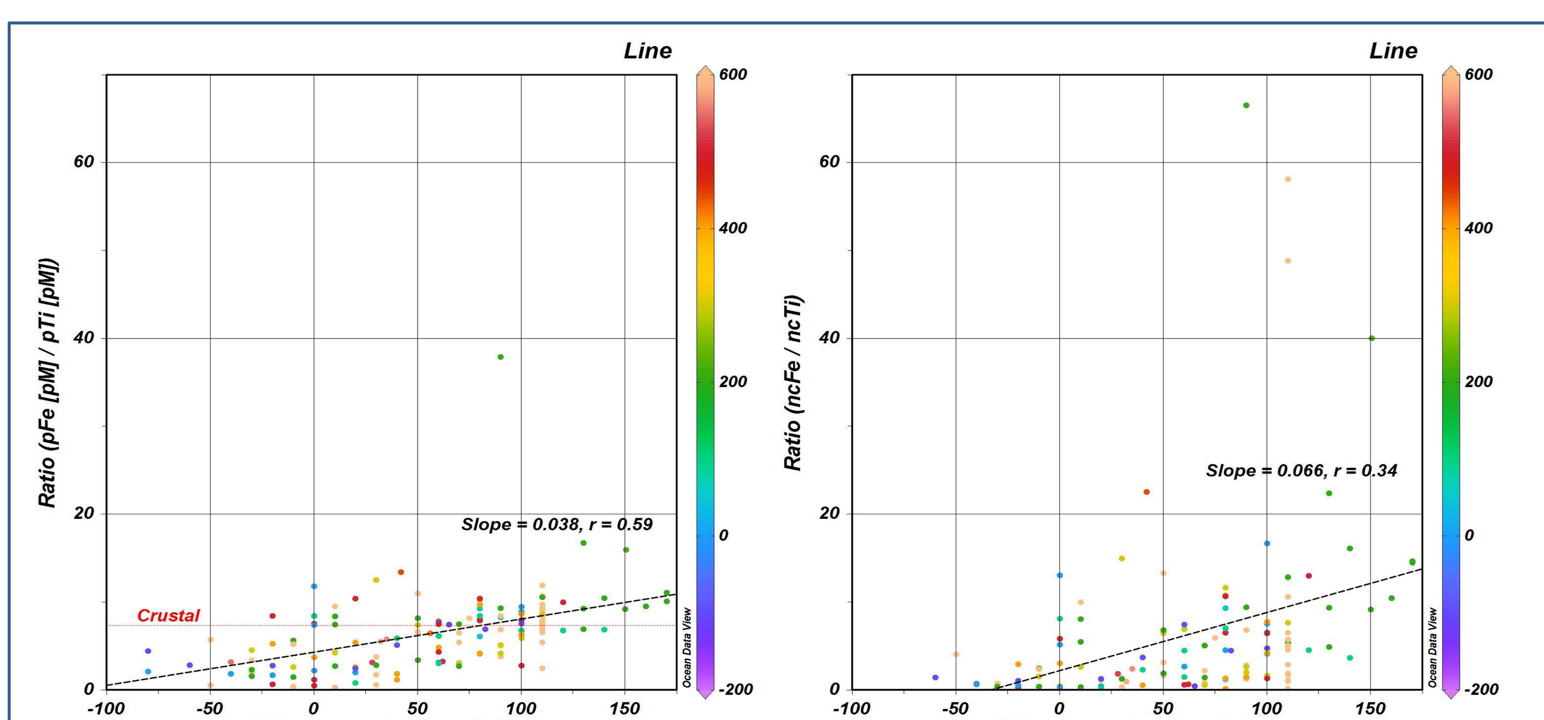

Figure 7: Fe:Ti ratios in bulk (left) and non-crustal (right) particulate matter versus distance from the shelf break (positive values are inshore). The slope is steeper for the non-crustal fraction.

Ratios of Fe:Ti show a decrease away from the coastline, which is more pronounced in the non-crustal fraction. We suggest that this is due to higher Fe:Ti ratios in authigenic particles relative to biogenic particles, and that the authigenic phase makes up a decreasing proportion of particulate matter with increasing distance from shore. In shallower, near-shore environments, scavenging of glacially-sourced metals and resuspension of sediments is expected to deliver more authigenic particles than in more open-ocean settings.

Results: Biogenic

Biogenic metal ratios show much higher Fe supply in 2011 than 2010. Several stations have high Cu:P and/or Zn:P in 2010, even above the shelf, that imply Fe-limitation (Fig 8).

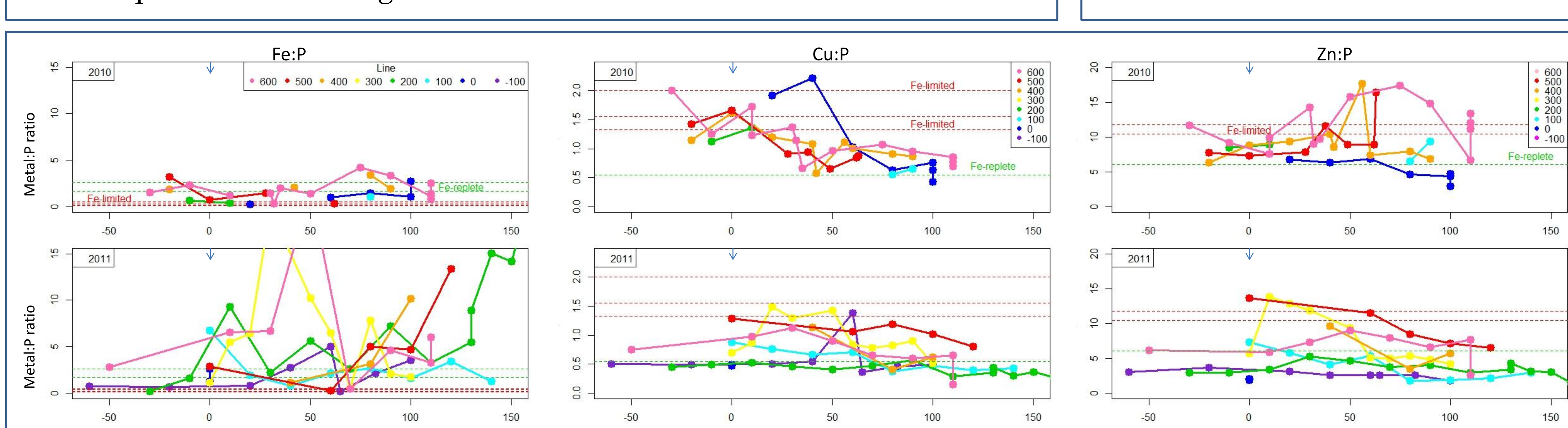

Figure 8: Selected metal:P ratios of the non-crustal particulate fraction in 2010 and 2011. Arrow denotes shelf break.