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Oxidation of the ocean crust: When does it happen?

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Hydrothermal circulation on the ridge flanks is responsible for removing over two thirds of the global hydrothermal heat flux and given the large volumes of fluids involved it has the potential to impart significant geochemical signatures into the ocean crust and oceans. Despite this global significance, two of the key parameters that will influence the heat and geochemical fluxes of ridge flank circulation, the distribution and timing, are poorly constrained. Ridge flank circulation is recorded by the ocean crust through the formation of secondary hydrothermal minerals that form in response to seawater/rock interaction. In the upper oceanic crust this alteration is characterised into secondary minerals formed under either oxidising or reducing conditions, where oxidising conditions suggest relatively open circulation and reducing conditions restricted circulation. These prevailing conditions are intimately linked to fluid pathways and their distribution in the crust and result in variations in the oxidation of the crust from primary values. The oxidation state of whole rock samples combined with the secondary minerals present therefore preserve a record of the prevailing conditions of hydrothermal alteration and can be used to investigate ridge flank fluid/rock reaction.

In this study we use new and literature whole rock Fe^{3+}/Fe_{TOT} ratios from a global sample set of ocean crust sampled by DSDP/ODP/IODP to investigate the timing and distribution of oxidation of the ocean crust. This data set represents the most comprehensive sampling of the ocean crust (0.3 – 170 Ma), and for each site accounts for variation in flow types, alteration type and crustal depth, allowing robust estimates for the overall oxidation state of each crustal site to be made and global trends to be deciphered. The vast majority of the dataset has a range in oxidation state of 18-60% Fe^{3+}/Fe_{TOT}, where 18% represents the general pre-alteration value of the crust, indicating that nearly all samples have undergone fluid/rock reaction and oxidation. The weighted mean oxidation state of the ocean crust does not display a simple linear relationship with crustal age but instead is established early and maintained throughout the progressive aging of the crust. Detailed investigations of key sites demonstrate that although the mean oxidation state does not vary with crustal age, the complexity of hydrothermal alteration does increase with age.