Global variation in Fe-isotopic composition of arc basalts indicate a variably oxidised mantle wedge source?

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We present new Fe-isotope data on >80 mainly basaltic samples from the currently active global network of arcs and use this data to investigate systematic variation in Fe isotopic compositions that may reflect differing oxidation and water content of different arc's mantle wedges. Differences between the melting conditions of different sub-arc mantle wedges may reflect critical tectonic factors such as the rate of subduction. Some models predict that wetter and hence more oxidised mantle wedge peridotite will produce basaltic melts with systematically heavier Fe-isotopic composition.

It established that magmas in subduction-related arc systems have significantly more water than those of from other tectonic settings. Recent XANES studies of melt inclusions using have established good positive correlations between the water content of primitive un-degassed melts and their oxidation state (expressed as $Fe3+/Fe_T$). Global arc magmas have elevated $Fe3+/Fe_T$ values in the range >0.1 to 0.5 (our data set has a mean of ~0.35), compared to MORB with values in the range 0.1-0.2. Studies of peridotite from sub-arc mantle wedges have also revealed elevated oxidation states compared to none arc mantle samples. In spite of the peridotite evidence, the site of the oxidised state of arc magmas remains controversial. Arguments based on redox-sensitive trace element ratios such as V/Sc or Zn/Fe_T imply that oxidation of arc magmas is a process associated with differentiation after the melts have left the mantle wedge source and that the mantle wedge has fO_2 values as reduced as the source of MORB.

Our delta^{57}Fe data span a range from -0.2 to +0.2 ($\pm$0.04), with a mean of +0.05. This is lighter than MORB and BABBs (+0.10). Arc data sets do trend towards heavier values for more fractionated samples. This may reflect a mantle wedge that is more depleted than MORB. Some key relations in our data set include; positive correlations between delta^{57}Fe and Pb- or Sr-isotope ratios, and with $Fe^{3+}+/Fe_T$. There is also a weak correlation between delta^{57}Fe and age of subducting crust (positive). As the trend towards heavier iron in more oxidized samples is not coupled with any correlation with MgO content, this cannot be fractionation driven by olivine or pyroxene.

Our interpretation is that our data reflects difference in the oxidation state of the wedge between different arcs because Fe^{3+} mineral sites have heavier Fe-isotopic and Fe^{3+} is more incompatible during melting. We take the positive correlation with Pb- and Sr-isotopes as a measure of slab input to the wedge, and with slab age to indicate that cold, old slab subduction delivers more oxidation capacity to the wedge.