Water and carbon fluxes in subduction zones.

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Stable isotopes of hydrogen, oxygen and carbon can give very strong constraints on water and carbon fluxes at subduction zones and particularly on the proportion of subducted carbon and water outgassed back to ocean-atmosphere and crust through subduction-zone magmatism.

It has long been shown that the original carbonate-organic matter sedimentary mixture gradually equilibrates and that only very extreme Corg/Ccarb ratios give rise to δ^{13}C significantly different from –4â/PDB, the value corresponding to the average subducted Corg/Ccarb of $\sim$15%. Furthermore, the subducted carbon species are very stable under subducted slab conditions and unlikely to participate significantly to subduction zone volcanic fluids. Wether they do or not their isotope composition will lie close to the upper mantle value of –4 â/PDB, expressing that upper mantle δ^{13}C is in stationary state (outgassed and subducted fluxes have the same δ^{13}C at –4â).

The main δ^{13}C variations in subduction volcanism then stem from deep magma outgassing, due to the fact that the gas-magma fractionation δ^{13}C is high (+3 to +4â), the initial magma carbon concentration is high ($\sim$4000ppm) and the solubility (Cppm = O.137 P_{kBars} exp(0.03 P_{kBars})) rather small : $\sim$0,15 to 1ppm/bar in the 0-30 Kbars range. Thus at a depth of 40km ($\sim$11 kilobars) the solubility is around 2000ppm. The magma has already lost half of its carbon, its residual δ^{13}C has moved from –4 to -7 and that of the escaping CO_2 from $\sim$0 to –3â.

The δ^{13}C is thus mainly a tracer of the degree of outgassing of the primary magma source, hence of its depth.

The two other stable isotope tracers , hydrogen and oxygen have the following significance : hydrogen behaves in a way rather similarly to carbon, with a primary δD rather constant at –30 –40â/SMOW reflecting its subducted slab's origin, and negative

departures from that value reflecting the degree of water outgassing. The difference with carbon is that water is much more soluble than CO2. That difference, however is somewhat corrected by the fact that the primary water concentrations are very variable and can be very high (up to 15%).

Oxygen isotopes reflect the proportion of upper oceanic slab extract contribution to magma generation in the mantle wedge, hence also the original water content of this magma, from $\sim$0.5-1% for δ^{18}O around 5.5â/SMOW to 12-15% for δ^{18}O of 8.5-9â.

The combined δD and δ^{18}O then give indications on the outgassing path (slow and at equilibrium/ fast and linked to distillation effects, two-stage evolution etcÖ).

Associated to the estimates of subduction magma production (plutonic and volcanic) the isotopic data allow to estimate the aerial volcanic fluxes of water and carbon dioxide (expressed as a C flux) respectively to 1.2 10^{14} g/year and $\sim 10^{13}$g/year and the corresponding plutonic fluxes to the crust to 10^{15}g/year and 1.2 10^{14} g /year.

It thus appears that the residual water flux subducted to the mantle is essentially equal to the water flux outgassed at ridges.($\sim 10^{14}$ g/year). For carbon the flux subducted to the mantle, resulting from sediment and oceanic crust subduction is decoupled from the outgassed flux, whose origin is to be found in the upperlying wedge.