Variable time lags between fluid addition and mantle melting in subduction zones

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The large excesses in ^{238}U and ^{226}Ra measured in some arc magmas are taken as evidence for addition of slab-fluids to the mantle wedge shortly (hundreds to thousands of years) before eruption, suggesting a direct spatial and causal relationship between fluid fluxing and mantle melting beneath the arcs. A large proportion of arc magmas are, however, in or close to ^{238}U-^{230}Th equilibrium. This is generally interpreted as resulting either from aging of the magmas in the crust or buffering of the young slab-fluid U-series signal by an older sediment component in secular equilibrium. Alternatively this may indicate that significant time lags (>350 kyr) between slab-fluid addition and mantle melting are common.

Our work on Volcan de Colima, Mexico, demonstrate that arc magmas in ^{238}U-^{230}Th equilibrium can have large ^{231}Pa and ^{226}Ra excesses, a situation likely to apply to most arc magmas in or near ^{238}U-^{230}Th equilibrium, which rules out aging of the magmas in the crust as the cause of equilibrium. Arc Volcanoes in or near ^{238}U-^{230}Th equilibrium include magmas showing limited geochemical evidence for sediment addition to the mantle wedge and magmas with significant contributions from sediments. Quantitative metasomatism and melting models further indicate that addition of sediment melts to a depleted mantle wedge cannot compensate the ^{238}U excesses induced by recent addition of fluids derived from the altered oceanic crust. Addition of sediment melts cannot account for the characteristically high proportion of arc magmas in ^{238}U-^{230}Th equilibrium in the event of systematic addition of slab-fluids to the mantle wedge shortly before melting and eruption. Melting of sources that have returned to secular equilibrium after metasomatism by the slab-derived components appears to be a common situation in arc setting. The absence of U-Th fractionation during melting most certainly depicts higher fO_2 of arc sources compared to MORB sources that yield magmas with ^{230}Th excesses.

Overall, the global U-Th array is best explained in terms of the time lag between metasomatism and melting varying from less than few hundred years to more than 350 kyr for magmas in or near U-Th secular equilibrium. This implies that in some cases mantle melting has a close temporal and spatial relationship to fluid fluxing, while in other cases significant delays occur potentially allowing downward transport of the hydrated mantle to the loci of melting beneath the arc.