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Mass transfer from the slab to the mantle and implications for chemical geodynamics in subduction zones

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The fate of subducted mélanges of diverse lithologies as they subduct from deep forearc to sub arc depths is key to understanding mass transfer processes (including volatile cycling) from the slab to the sub-arc mantle. We present the phase equilibria of ultramafic-rich and sediment-rich mélanges at deep forearc to subarc depths to (1) assess if diapirism or dehydration and/or partial melting would be the dominant process of mass transfer, and (2) how these processes affect fractionating Large Ion Lithophile Elements (LILEs) from High Field Strength Elements (HFSEs) to explain the near ubiquitous high LILE/HFSE ratios in arc magmas. We also investigate the potential for development of physico-chemical pathways/channels that may transfer slab signatures to arc magma sources without substantial modification. We find that ultramafic-rich mélanges lose buoyancy at T > 800-1000 °C implying that diapirism can only occur if ascent times are faster than thermal equilibration, under specific conditions of mélange thickness, viscosities and buoyancy. While partial melting may occur due to the heating of a stalled diapir or due to influx of hotter asthenospheric mantle through slab tears, this process would not fractionate LILEs from HFSEs, unless the mélange has high LILE/HFSE ratios to begin with. Otherwise, dehydration appears to be the dominant process of mass transfer (especially to transfer high LILE/HFSE ratios to arc magma sources) given diapirism is highly conditional and slab tears are not as common [1]. Sediment-rich mélanges, on the other hand favor instability formation but lose buoyancy at T >850 °C. Larger diapirs can sustain buoyancy over longer distances from the slab than smaller diapirs [2], and their low degree partial melts could potentially transfer high LILE/HFSE ratio to arc sources. We also find that multiple fluxes of siliceous slab-derived partial melts (as well as silica (solute)-rich slab-derived aqueous fluids) from sediment-rich mélanges to the subarc mantle may create melt-buffered pyroxenite channels behaving as ‘melt enablers’, allowing the transfer of geochemical slab signatures to arc magma sources with substantial modification [3].

[1] Rebaza et al. (2024), EPSL, 647; [2] Rebaza et al. (2024), ESS Open Archive; [3] Rebaza et al. (2023) JPet, 64.