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Electrical conductivity of the serpentinised mantle and fluid flow in subduction zones

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Water is recycled to the Earth's interior at subduction zones. In the mantle wedge above the subducted slab, electromagnetic profiles reveal high electrical-conductivity bodies. In hot areas (> 700°C), water released by dehydration of the slab induces melting of the mantle under volcanic arcs. Melting can explain the observed high conductivities. In the cold (<700°C) melt-free forearc mantle wedge, fluid water migrates and causes serpentinisation detected as low seismic wave velocities in the mantle wedge.

Serpentinisation is caused by the release of large amounts of hydrous fluids in the cold mantle above the dehydrating subducting plate. Low seismic velocities in the wedge give a time-integrated image of extensive hydration and serpentinisation within the stability of serpentine below 700°C. High conductivities in electromagnetic profiles may provide "instantaneous" images of fluid circulation. For example, high electrical conductivities up to 1 S.m-1 have been observed in the hydrated wedge of the hot Ryukyu and Kyushu subductions, while moderate conductivities are observed in the cold Pacific subduction beneath N-E Japan. These differences can reflect the actual concentrations of fluids provided the conductivity contrast is high between the fluid and serpentinised rocks. Here we show with complex impedance measurements that serpentinites have low electrical conductivities (< 10-4 S.m-1) similar to those of dry mantle minerals below 700°C. Thus, electrical conductivity is only sensitive to the fluid content and salinity in the hydrated mantle wedge, not to serpentinisation. A small fraction (ca. 1% in volume) of connective high-salinity fluids accounts for the highest observed conductivities. In the hydrated mantle wedge, the low-salinity fluids ($\leq$ 0.1 m) released by slab dehydration evolve towards high-salinity ($\geq$ 1 m) fluids during progressive serpentinisation. These fluids can mix with arc magmas at depths and account for high-chlorine melt inclusions in arc lavas.

The process of mantle wedge serpentinisation takes place within a few tens of million years depending on the thermal state and efficiency of fluid release and flow. Thus, high electrical conductivity areas in the cold wedge will form over similar timescales. Such a state is observed for some hot subduction zones, but not for cold subduction, probably reflecting less fluid-rock interaction in the cold wedge of the latter. This conclusion also is supported by the observation from seismic properties in hot subduction zones of extensive shallow serpentinisation, whereas serpentinisation is restricted to greater depths in cold subduction zones.