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The importance of slab-mantle coupling at 80 km depth in subduction zones

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Subduction zones are complicated regions with fluid flow, earthquakes, melting and metamorphism, and ductile deformation, all interacting. One of the major controls on these processes is temperature. Thermal modeling suggests that the temperature of subduction zones is largely determined by the balance between cooling due to inflow of cold lithosphere and heating due to the flow of hot mantle towards the slab due to induced convection in the wedge mantle. Understanding this flow in the mantle wedge has been a major topic of research in the geodynamics of subduction zones.

Direct evidence for solid-state flow in the mantle wedge is provided by heat flow patterns across convergent margins. Few margins are very well characterized and the arc region is associated with local heat sources such as magmatic intrusions that are a cause of large scatter in the data. Nevertheless, the available data suggest mantle convection occurs at depths greater than around 70 to 90 km irrespective of the age of the slab.

Flow in the mantle wedge is thought to be restricted to regions where there is strong coupling between the downgoing slab and overlying mantle. Shallow levels in subduction zones are more weakly coupled. As a result of the decoupling, the corner of the wedge mantle undergoes cooling and hydration to form a cold nose.

Thermal modeling predicts a kink should exist in the thermal structure along the subduction boundary corresponding to the depth at which strong coupling between the mantle and slab become effective. The study of subduction-type metamorphism provides information on the P-T conditions close to the subduction boundary and can potentially be used to identify this type of kink in the thermal structure and, hence, to constrain the depth of strong coupling in ancient subduction settings. The Sanbagawa belt is a rare example of where this has been proposed and suggests induced flow at a depth of around 65 km.

The available evidence suggests the depth of coupling is roughly the same in all subduction zones. This common depth of coupling can help explain the common depth to the slab beneath volcanic arcs. The mechanism responsible for a change from weak to strong coupling is, however, not well known. Dehydration of antigorite and other weak hydrous phases may play a role. However, the temperature at the onset of the thermal kink is different for different subduction zones and so such a mechanism cannot explain the common depth.

The Sanbagawa belt preserves a series of peridotite bodies derived from the mantle wedge, which have experienced metamorphism at depths from 30 to greater than 100 km. The boundaries of these bodies are, therefore, fossil examples of the subduction boundary. This area is ideal for studying the controls on the coupling.

Keywords: subduction zone, wedge mantle, coupling, slab