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Magnetotelluric Image of the Fluid Cycle in the Costa Rican Subduction Zone

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Fluids entering the subduction zone are a key factor in the subduction process. They determine the onset of melting, weakening and changes in the dynamics and thermal structure of subduction zones and trigger earthquakes when being released from the subducting plate in a series of metamorphic processes.
However, the amount of water carried into the subduction zone and its distribution are not well constrained by existing data and are subject of vigorous current research in SFB574 (Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters). Electromagnetic methods like magnetotellurics have been used widely to recognize fluid release and melt production through enhanced electrical conductivities.
Here we present an image of the hydration and dehydration cycle down to 120 km depth in one setting derived by an onshore-offshore transect of magnetotelluric soundings in Costa Rica.
An electrically conductive zone in the incoming plate outer rise is associated with sea water penetrating down extensional faults and cracks into the upper mantle possibly causing serpentinization. Along the downward subducting plate distinct conductive anomalies identify fluids from dehydration of sediments, crust and mantle. A conductivity anomaly at a depth of approx. 12 km and at a distance of 65 km from the trench is associated with a first major dehydration reaction of minerally-bound water. This is of importance in the context of mid-slope fluid seeps which are thought to significantly contribute to the recycling of minerally-bound water. The position of the conductivity anomaly correlates with geochemical and seismic evidence stating that mid-slope fluids are originated at >=12 km depth before rising up through deep faults to the seeps. The conductivity anomaly is therefore associated with a fluid accumulation feeding the mid-slope seeps.
Another fluid accumulation is revealed by a conductivity anomaly at 20-30 km depth and a distance of approximately 30 km seaward from the volcanic arc. This lower crustal fluid accumulation could likely be caused by trapping of fluids released due to de-serpentinization processes or due to other mineral dehydration processes. While we are at the moment not able to attribute one specific process causing the anomaly based on electromagnetic data alone, this feature is however of fundamental importance. A comparison with other electromagnetic studies from subduction zones around the world reveal that such a conductivity anomaly is a global feature suggesting the presence of a global fluid sink.
Based on very simplified assumptions we are able derive rough estimates for the amount of water being stored in the overriding plate. Relating seismic evidence as well as petrological results collected in the multi-disciplinary study on the Costa Rican subduction zone we introduce budget estimations for the water cycle in the subduction zone.