Numerical modelling of continental collision, oceanic subduction and related geodynamical processes

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Collisional and subduction zones are sites on the Earth surface where two continents collide or an oceanic plate descends into the mantle, respectively. Apart from these gross scale phenomena, a wide variety of other small scale geological processes take place at the same time. The study of these processes is crucial for the understanding of the subduction/collision history and for the interpretation of geophysical data that, in turn, gives information about the present-day structure of these areas.

In recent years, coupled petrological-thermomechanical numerical models have been used to study processes occurring at collision/subduction settings.

We use I2VIS code with visco-plastic rheologies (Gerya and Yuen, 2003) to model subduction zones characterized by an early oceanic subduction followed by continental collision. Collision between two continents includes mountain chains building, continental crust recycling in the mantle and exhumation of HP-UHP metamorphic rocks. In case of plate decoupling, asthenospheric mantle wedges between the continents triggering the retreating and delamination of the converging continental plate.

In order to investigate hydration and subsequent dehydration of the slab, we also performed 2D numerical models of a spontaneously bending oceanic plate using I2ELVIS code that account for visco-elasto-plastic rheologies (Gerya and Yuen, 2007). At the outer rise, bending-related slab faulting occurs and provides a pathway for water percolation in the slab. Faults generally deep trenchward, but antithetic faults are also common. As the slab subducts, serpentinized faults acquire a vertical position; on the other hand, pressure and temperature increase so that hydrous phases become unstable and elevated pore fluid pressure build up allowing to brittle deformation at big depths. Results are consistent with intermediate-depth earthquakes distribution and confirm the now well accepted theory that dehydration of the slab as the main trigger mechanism for earthquakes with deep hypocenters. We also found that the anisotropy measured above subduction zones seems to be related to the spatial distribution of the serpentinized faults in the slab.

Slab melt metasomatism as recorded in cpx and opx in mantle xenoliths from Cerro del Fraile (Argentina)

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Ultramafic xenoliths found in Quaternary lava flows and diatreme breccias at Cerro del Fraile, 25 km east of the main AVZ (Austral Volcanic Zone, Patagonia), represent fragments of the mantle wedge above the subducting slab and provide valuable material for studying the nature of metasomatizing melt in suprasubduction setting. They mainly consist of lherzolites, with minor harzburgites and plagioclase-bearing orthopyroxenites. One composite sample is characterized by dunitic domains cut by orthopyroxenite veins. Host basalts are basaltic-trachyandesite, with mg# varying between 46.4 and 53.1. Compositionally they are very similar to the Nb-enriched arc basalts found in several volcanic arcs worldwide.

Based on major and trace element features two groups of clinopyroxenes and orthopyroxenes can be distinguished in the lherzolites, and another group in the orthopyroxenite. Primary cpx and cpx in melt patches in peridotites have higher mg# than cpx in pyroxenites. Analogously mg# of opx in the peridotitic matrix range from 88.0 to 91.4 while opx in pyroxenites have lower and more variable mg#. Secondary cpx presents higher LREE, Th, U, Zr, Hf, and Sr contents than primary cpx. Analogously Group2 opx has higher LREE, Th, U and Sr contents than Group1 opx. Opx of pyroxenites are very different, with flat REE patterns at about chondritic values and Sr and Ti contents higher than those of peridotites' opx. Ti content in both primary and secondary peridotitic minerals are always very low (Ti in opx<450 ppm, Ti in cpx<1100 ppm).

These geochemical characteristics are consistent with interaction and hybridization with a Si-Na-rich melt, deriving from the melting of the subducting Antarctic plate. Slab melt metasomatism produced both Na and LREE enrichment in pyroxenes and positive Zr-Hf anomalies in cpx. The melts reacted with peridotites and reached the Moho, where they resided and fractionated orthopyroxenites. Successively the asthenospheric upwelling caused the mixing between OIB-like material and the already subduction-contaminated mantle wedge resulting in the formation of Nb-enriched trachybasalts that brought the xenoliths to the surface.