SP C4

Structure and Rheology of the Upper Plate from Seismological Investigations

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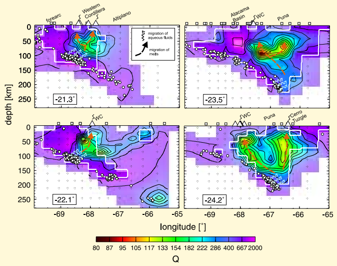
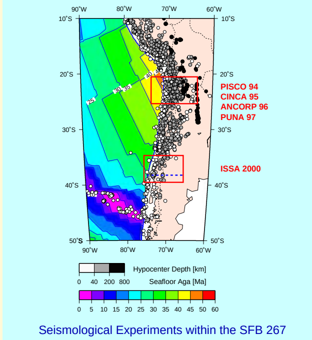
Central Andes

Source Regions and Ascent Paths of Fluids and Melts



It is now widely agreed, that water released from the subducting plate triggers melting in the overlying mantle wedge, providing the source for andesitic volcanism. Yet, the questions of where dehydration occurs, where and how fluids leave the slab, and how they are transported through the mantle wedge are still debated. Here we present Q_p images of the Andean subduction factory.

The intriguing feature in many of the presented Q_p images is that the strong low-Q_p anomalies appear to originate at the distinct earthquake clusters in 100 or 200 km depth. It is very suggestive that these anomalies are due to water fluxed into the mantle wedge by earthquakes, and subsequent triggering of partial melting. The sections suggest that ascend paths of melts are more complicated than often implicitly assumed, and that source depths of melts may vary considerably.

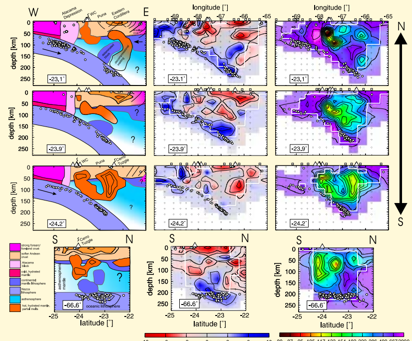


Seismological Experiments within the SFB 267
General hypocenter distribution and age of seafloor

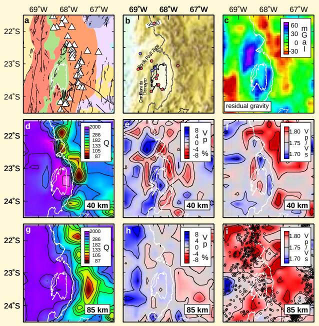
Lithospheric Detachment Beneath the Northern Puna

Lithospheric detachment has been proposed in many locations based on its symptoms. However, the process has never been observed geophysically. Between 23°S and 24°S in the northern Puna, we image a fast, high Q_p body that dips from the base of the easternmost Puna crust 100 km down to the subducted Nazca plate. South of this body the mantle wedge has low velocity and Q, and the Nazca plate thickens by several tens of kilometer above the sharply defined Benioff zone.

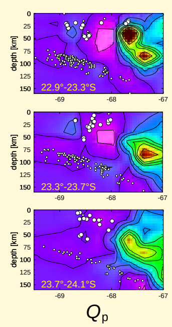
We interpret this fast, high-Q_p body as detaching and probably delaminating South American lithosphere. Further south, at 24°S, where the mantle wedge is characterized by low v_p and low Q_p, and the slab appears to thicken above the Benioff zone, we suggest that detachment has already been completed with the cold continental lithosphere resting atop the subducted Nazca plate.



The Deep Seismic Structure of the Atacama Depression



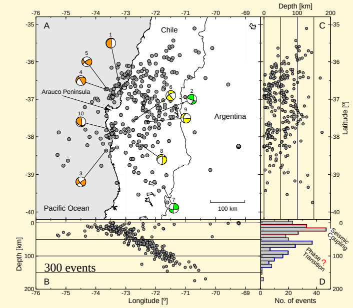
The Atacama basin is a prominent morphological anomaly in the Central Andean forearc. The depression is moulded into the otherwise uninterrupted north-south running topographic slope and active volcanic belt of the Western Andes (a and b). Depth maps of P-wave velocity and attenuation and v_p/v_s ratios through crust and uppermost mantle reveal a rheologically strong (high Q_p and v_p) lithospheric block beneath the basin surrounded by weak regions (low Q_p and v_p) beneath Pre- and Western Cordilleras. The anomalous lithospheric structure appears to bar hot asthenospheric mantle from penetrating deeper into the wedge corner, and hence causes the volcanic front to deviate some 100 km eastwards, away from the trench. The cold block may also influence the thermal structure of the subducted slab causing a reduced Benioff seismicity (i) and less hydration of peridotites in the mantle wedge revealed by reduced v_p/v_s ratios (i). Deformation and uplift seems to be focused at the rheologically weak regions encasing the strong Atacama block that may subside as a whole like a piston in a cylinder. Another confirmation is found from the spatial distribution of local crustal earthquakes. In the cross sections on the right, hypocenters overlaying the Q_p model. Most of the seismicity occurs in a depth of 20-30 km but on the western flank of the Atacama depression they reach down even up to 60 km. On the eastern flank temperatures are too high for stress accumulation.



Southern Andes

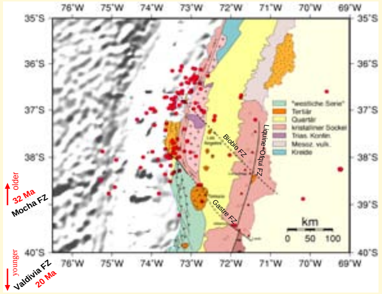
Distribution of Seismicity

The depth-frequency-distribution of the local earthquakes obtained by the ISSA 2000 network reaches its maximum at 25 km depth (lower left corner of right hand figure). In the Northern Andes, the majority of the earthquakes is located at 100 km depth. In a younger and therefore hotter subducted oceanic crust, the blueschist to eclogite transformation, and also the induced seismicity takes place at lower depths. This reaction has a lower limit of approx. 500°C and 1.3 GPa (40-50 km). The oceanic lithosphere north of the Mocha fracture zone was formed 32 Ma ago. South of the Valdivia fracture zone, it was generated within 20 Ma (see geological map below). The change in seismicity from north to south reflects this situation. Seismicity in the younger oceanic crust is vanishing.



Crustal Seismicity

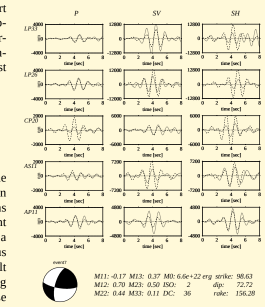
The distribution of seismic release in the upper plate (depth < 40km) shows a clear concentration of active deformation in the forearc of the active margin system. The Main Cordillera with the prominent Liquine-Ofqui intra-arc discontinuity and the Longitudinal valley instead show only scarce seismicity (see figure below. Red dots mark epicenters in the depth range 0 - 40 km). The main area of seismic release along the coast is identic with the axis of actual major uplift and the postulated center of basal accretion and antiformal stacking at depth. Regional centers of seismic release south and north of the Arauco peninsula can be correlated with prominent fault zones: the Gastre fault zone (S) and Bio-Bio fault zone (N).



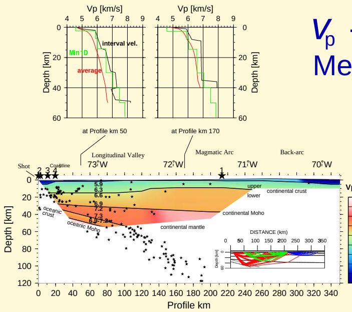
Geological field observations show the active character of the faults, whereas their seismically active part seems restricted to the fore-arc zone. Striking is the observation that these two faults limit a zone with apparently no seismicity corresponding to the Arauco peninsula and Nahuelbuta Range, that however show highest uplift and topography in the forearc.

Moment Tensor - Inversion

The figure on the right illustrates the solution of the moment tensor inversion and the comparison between synthetic (dashed lines) and observed seismograms (solid lines). The earthquake (No. 7 in the upper right figure) is located east of the seismic coupling zone in a depth of 133 km. The solution consists of an enormous high non-double couple part (100% - DC). This result can indicate a complex source mechanism including dehydration processes, which are postulated for these regions.



V_p - Velocity Models Derived from Wide-Angle Measurements and from Local Earthquake Data



The velocity model at 39°S as derived from wide-angle and seismic refraction data of the ISSA 2000 transsect. The velocity model consists of five layers. The lower boundary of the oceanic crust is constrained by a pronounced Moho-reflection in the data measured for the shots 2, 3, and 4. All earthquake hypocenters south of 37°S detected by the ISSA network were projected perpendicularly onto to velocity model (small black stars in the velocity model). The calculated Minimum-1D model derived from this earthquakes is also plotted into the V(z) diagrams (green trace). It shows a remarkable coincidence with the velocity structure derived from the refraction profile and fits well to the velocity model in the forearc.

The next step will be the calculation of v_p-, v_p/v_s- and Q_p models. Especially Q_p- tomography based on local earthquake data has turned out to be a powerful tool for imaging subduction related features above the Wadati-Benioff zone. Our current knowledge of this area in the Central Andes mainly rests upon the results from the seismological experiments, carried out within the SFB 267.