ALP 2002 & ALPASS - Active and passive seismic studies targeting the lithosphere of the Eastern Alps

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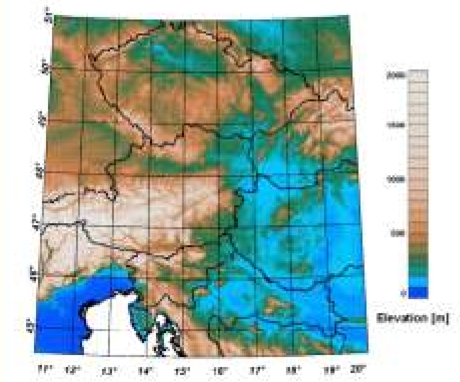
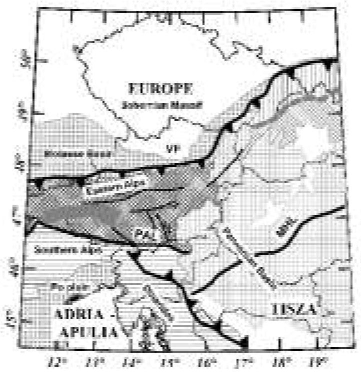
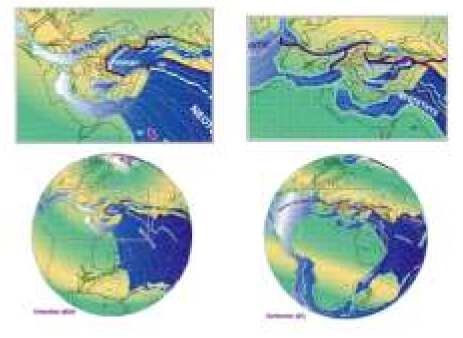
Tectonic and geodynamic setting





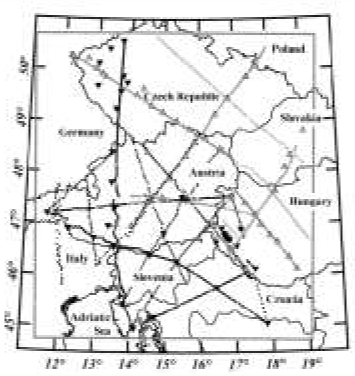
The Alps are the result of a long and ongoing tectonic evolution, initiated coevally with the opening of the Atlantic Ocean in the early Jurassic. Alpine evolution was very complex, involving several stages, and has been better investigated and understood in the western parts of the orogen compared to the eastern segment.
In a regional context, the Eastern Alps are located inbetween the Bohemian Massif, the Carpathians, the Pannonian domain and the Dinarides. Major geodynamic processes involved in the orogeny of the Eastern Alps include the subduction of the Alpine Tethys and the following head-on collision (Late Cretaceous / Early Tertiary) between the European and Adriatic-Apulian plates. In the Miocene, the Eastern Alps were extruded eastwards into the Pannonian domain along major fault systems (PAL, SEMP-Line, Mur-Muerz-Line).



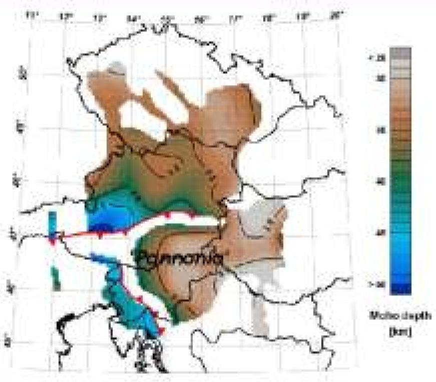
The Alpine Tethys: Spreading (left) in the Late Jurassic and closure (right) in the Late Cretaceous

Seismic investigation with active sources

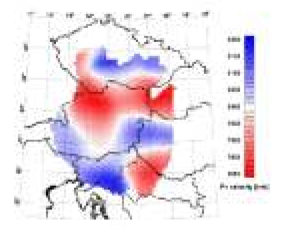
Several refraction lines have been shot in the 70ies. Within the **TRANSALP** campaign a reflection profile from Munich to Verona has been obtained in the late 90ies.. **CELEBRATION 2000** and **ALP 2002** were two large 3D refraction campaigns targeting the Lithosphere of Central Europe. Results of this efforts include a 3D seismic model of the crust and new Moho map of the Eastern Alpine region. A new Moho fragment ("Pannonia"), which is located inbetween Europe, Adria-Apulia and Tisza, could be interpreted.



Field layout of CELEBRATION 2000 (3rd deployment, grey) and ALP 2002 (black). Triangles represent shots and dots represent geophones.

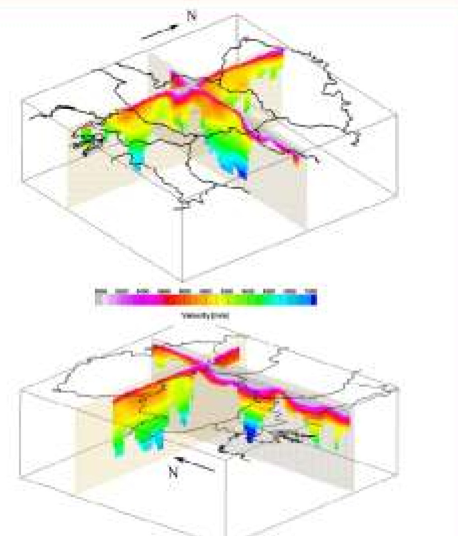


The new Moho map derived from ALP 2002, CELEBRATION 2000 and TRANSALP.



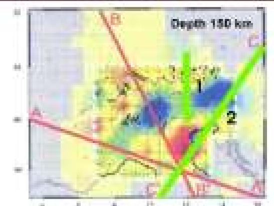
Above:
Moho velocities.

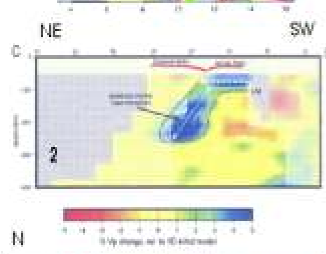
Right:
Vertical slices through the tomographic P-wave velocity model of the crust. The size of the surrounding box is 600 x 660 x 44 km (W-E x N-S x depth).

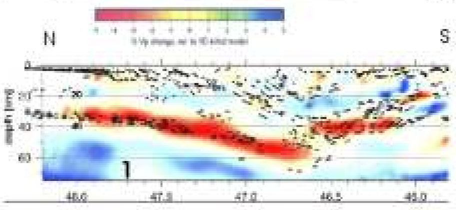


Studies with passive seismic sources

Another outcome of TRANSALP are receiver functions analysis along the profile which correlate well with the reflection data and indicate a subduction of the European domain to the south.
On the other hand, results from a teleseismic study for the whole Alpine region illuminate nothward dipping structures in larger depths.







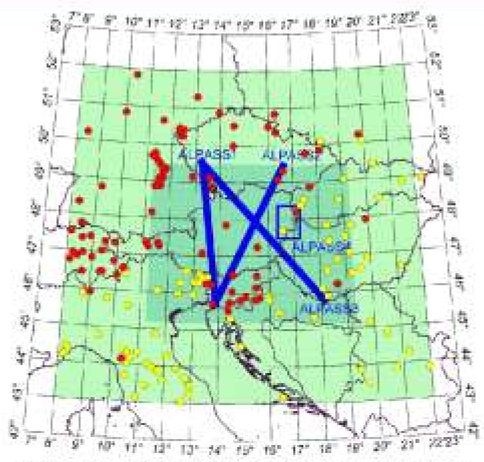
Above:
Working area and a depth slice at 150 km through the teleseimic model of Lippitsch et al.

Middle:
A vertical slice through the model. Location see above.

Below:
Results from receiver function analyses along the TRANSALP profile. The location is also shown in the upper figure. Note the different depth scale in comparison to the

ALPASS

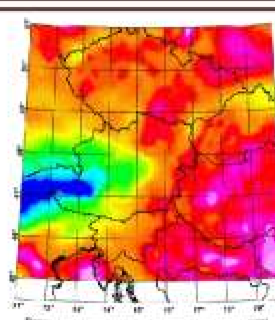
This project utilizies passive seismic data from permanent monitoring services and additional stations which will be deployed along 3 lines. Recording on these lines will start in spring 2005.
The main scientific goals are: Teleseismic images down to the 670 km discontinuity; receiver function analysis to resolve the upper mantle discontinuities and the Moho; evaluation of local earthquakes, relocation and moment tensor solutions in order to delineate active faults and similiar geodynamical relevant zones.

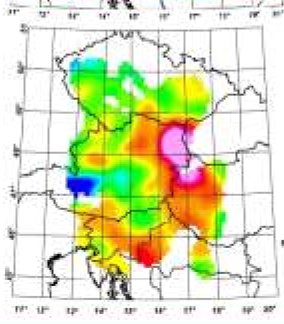


Field layout of ALPASS. Red and yellow circles denote permament seismic stations. The three blue lines represent dense observations with temporal stations. The rectangle is an area of special interest where also a dense 3D network is planned.

Features from other data sets

The use of Bouguer anomalies for the interpreation of deeper structures is problematic due to the strongly variing crustal structure. Therefore the effect of the upper layers and the Moho geometry has been minimzed by the following procedure: The uppermost 10 km have been removed using a Vp-density relationship. For the remaining crust down to the Moho, a constant gradient / starting velocity model has been seeked which minimizes the correlation between the residual gravity and the Moho depths (expressed in two-way traveltime).
The residual field should show density variations in the lower crust and the upper mantle only. Positive residuals (higher densities) can be correlated with the "Dinaridic" subduction and a high-velocity lower crust beneath the Vienna Basin which is also visible in the seismic model.
The main feature in the magnetic map (total intensity) is the "Berchtesgadener Anomaly" which origin is still unclear in detail. This zone and its eastward continuation correlates strongly with the strike-slip faults along which the extrusion took place.
In comparison to the Southern Alps and Dinarides, the seismicity in the Eastern Alps is weak despite their sophisticated structure. Earthquakes mainly occur in the uppermost crust along active strike-slip faults. The stress field exposes mainly both compressional and strike-slip behaviour, reflecting the collision and subsequent extrusion.
Heat flow measurements are very sparse and therefore, do not allow the interpreation of large structures.



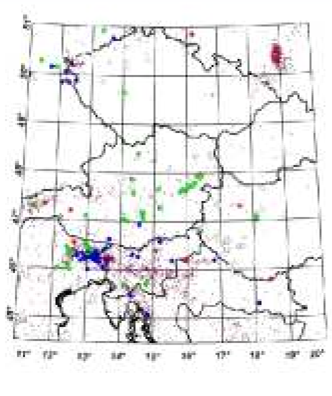


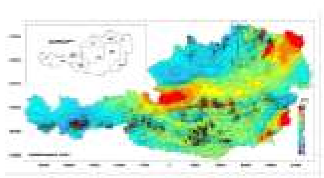
Left above:
Bouguer anomaly map, reference datum WGS84

Left below:
Residual bouguer anomaly (see text)

Right above:
Earthquake distribution after USGS (purple coloured dots, Magnitude > 1, 1973-2000)
Circles: stress data from the CASMO-project (blue: dominantly reverse fault; red: dominantly normal fault; green: strike-slip fault; white: unknown tectonic regime)

Right below:
Aeromagnetic map of Austria (total magnetic intensity)





Key questions in the Eastern Alpine region

The studies targeting the crust and Moho indicate a subduction to the south, while deeper structures point towards the opposite direction. Perhaps the upper structures resemble the late cretaceous subduction of the Alpine Tethys, while the deeper structures reveal images of earlier processes.
Juxtaposed with this problem is the question for an exact outline of the Alpine Tethys suture resp. the boundaries between Variscian and Alpidic Europe. The Pannonian microplate and its relation to the other plate fragments in the area is just another hint for a series of complex geodynamic processes which took place in the Eastern Alps.
The qualitative concept of extrusion tectonics is widely agreed on. However, the quantitative consequences are not absolutely clear. Both brittle and ductile behaviour of crust and mantle seems possible.

Benefits from ALP 2002 and ALPASS to EuroArray

The newest models of the crust and Moho provide excellent "surface corrections" for studies targeting the deeper lithosphere (e.g., teleseismic tomography). Knowledge of the sophisticated structures of the Eastern Alps provided by these and earlier studies is an important basis for further research.
Well-trained researchers and a broad scientific understanding of geodynamic processes will be necessary for dealing with data from EuroArray. Both will be an additional outcome of the current studies.

Contributions of EuroArray to problems in the Eastern Alpine region

As outlined above, the geodynamic history of the Eastern Alpine region seems to be very complex and is far from being thoroughly understood. Deep seated structures in the lithopshere may provide additional information on early processes associated with the orogeny. Especially the collection of MT data would be a valuable contribution since only very sparse studies concerning resistivity have been conducted so far.
The integration into a broad international community could push the interest in geodynamical research and the understanding of the processes involved among austrian geoscientists.

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