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Crustal Anisotropy from Receiver Functions:

Ground truth from known background geology

Preliminary results

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FWF

- *The project*
- *The site*
- *The network*
- *The technique (isotropy and anisotropy)*
- *Modeling the isotropic structure*
- *The effect of anisotropy*
- *The deep structure*

KTB -- Kontinentales Tiefbohrprogramm der Bundesrepublik Deutschland – or – German Continental Deep Drilling Program

Drilling project from 1987 to 1995

Located 50 km East of Nurnberg, close to the border of CZ, and on the western flank of the Bohemian Massif

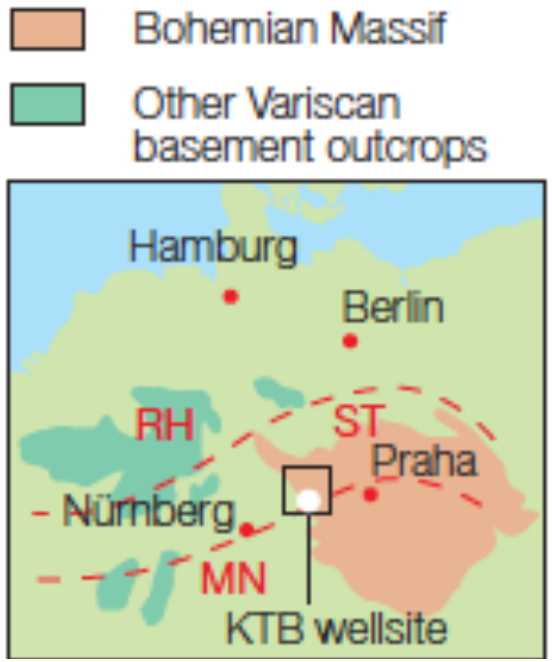
Chosen among 40 sites in Germany

-Suspected to lie at the boundary of Moldanubian and Saxothuringian (MN and ST) units
(continent-continent suture of 320 M.a.)

-It represented a perfect occasion to understand the processes that occur in the deep continental crust, normally inaccessible

-Suspected lower temperature gradient

-Expected max drill depth 10-12 km



9 km (max depth of drill) of metamorphic rocks (gneiss and metabasites) have been drilled under a normal geothermal gradient

Our Project tasks:

•*Compute receiver function out of data recorded at 9 stations installed in the KTB area for 2 years (2012-2014)*

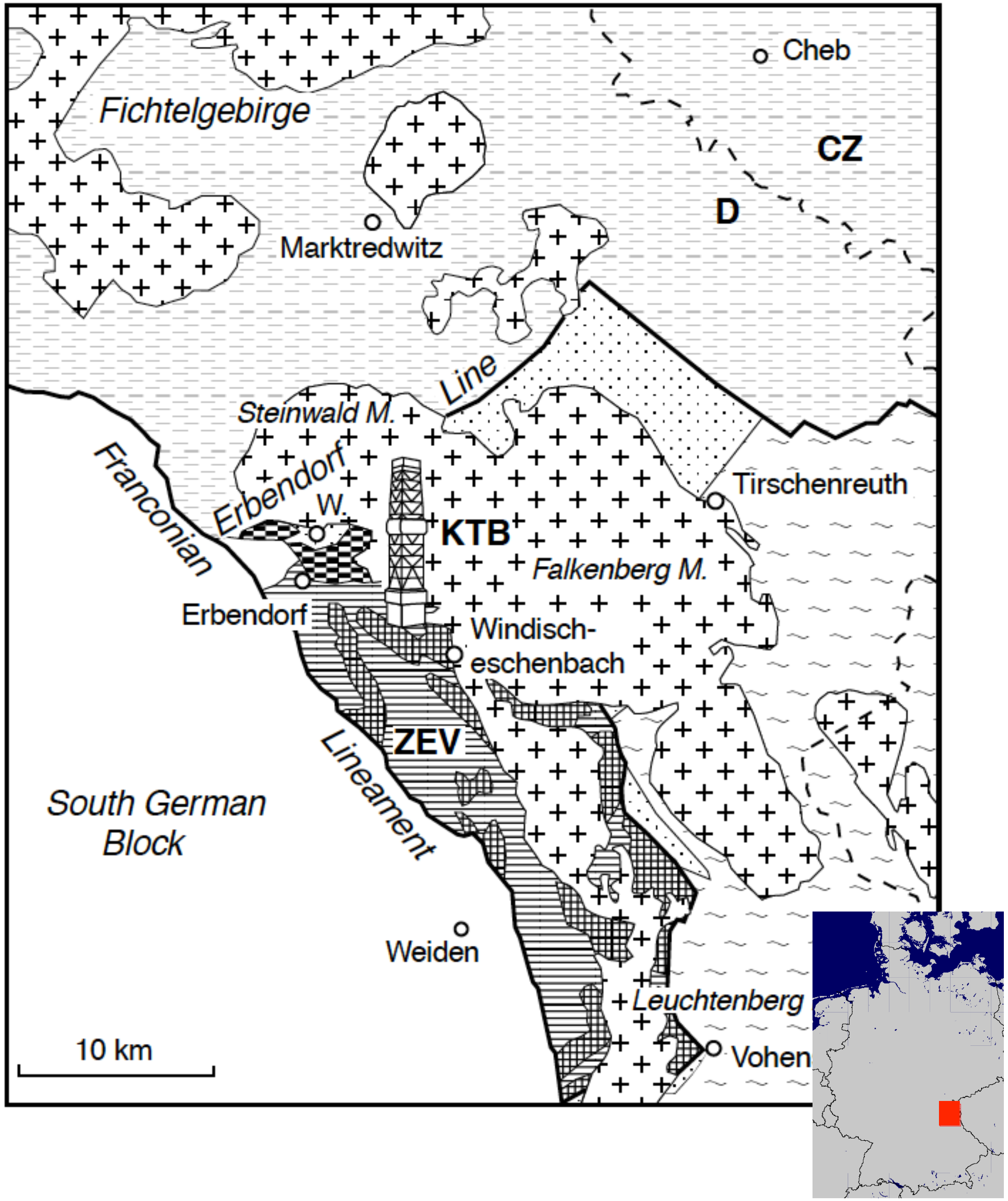
•*Find anisotropic signal on the receiver functions*

•*Compare the RF data-set retrieved at the stations with the 9 km pile of metamorphic rocks (alternating gneiss and metabasites)*

Major questions:

•*To which degree can the structure and anisotropy, previously detected on-site, be retrieved by passive imaging?*

•*Which are the characteristics of the deeper structure, inaccessible by drilling?*



KTB site is located in the northern part of the “Zone Erbendorf-Vohenstrauss” (ZEV)

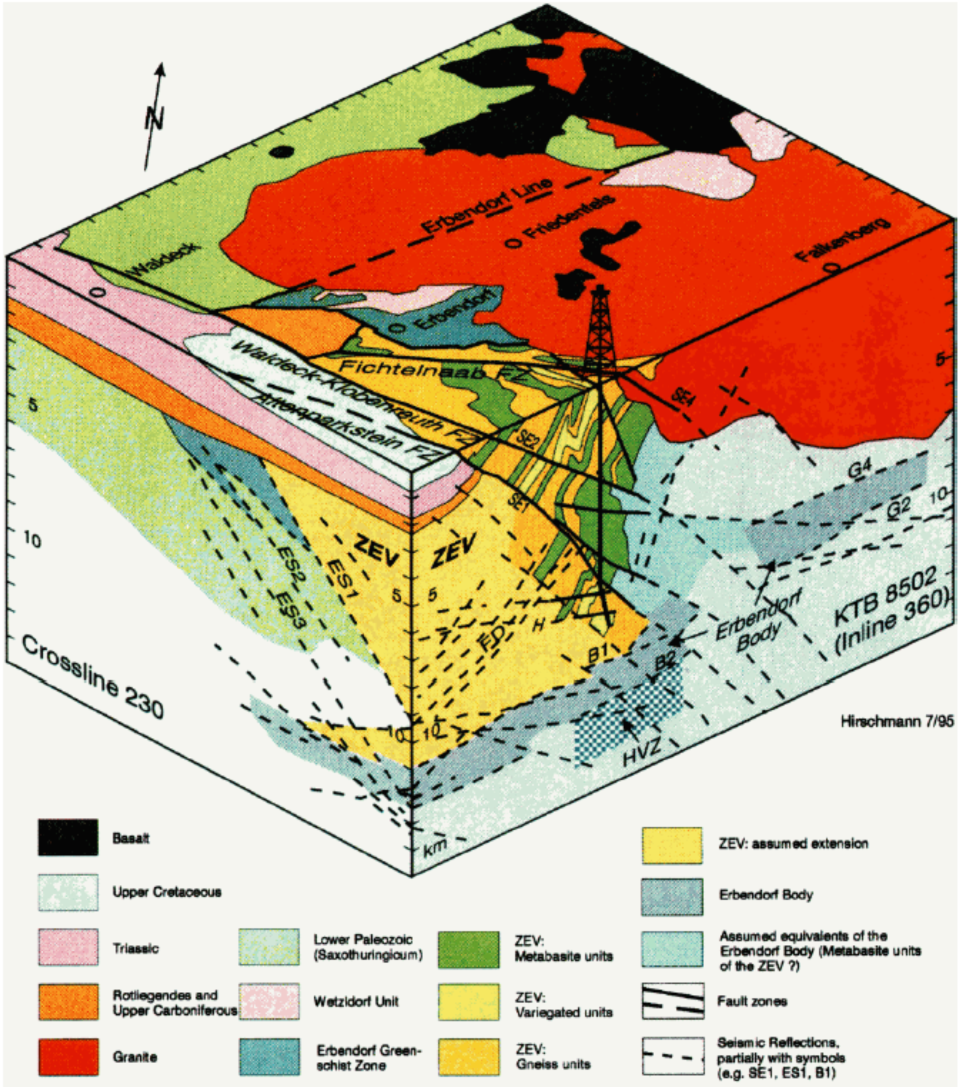
ZEV is a small NW-SE to NNW-SSE trending metamorphic unit

ZEV is composed of paragneiss and metabasic rocks

The Erbendorf line separates the Saxothuringicum from the Moldanubicum units

The Franconian lineament is a NW-SE trending crustal scale fault system that has been repeatedly active

3D reconstruction



Harjes et al, 1997

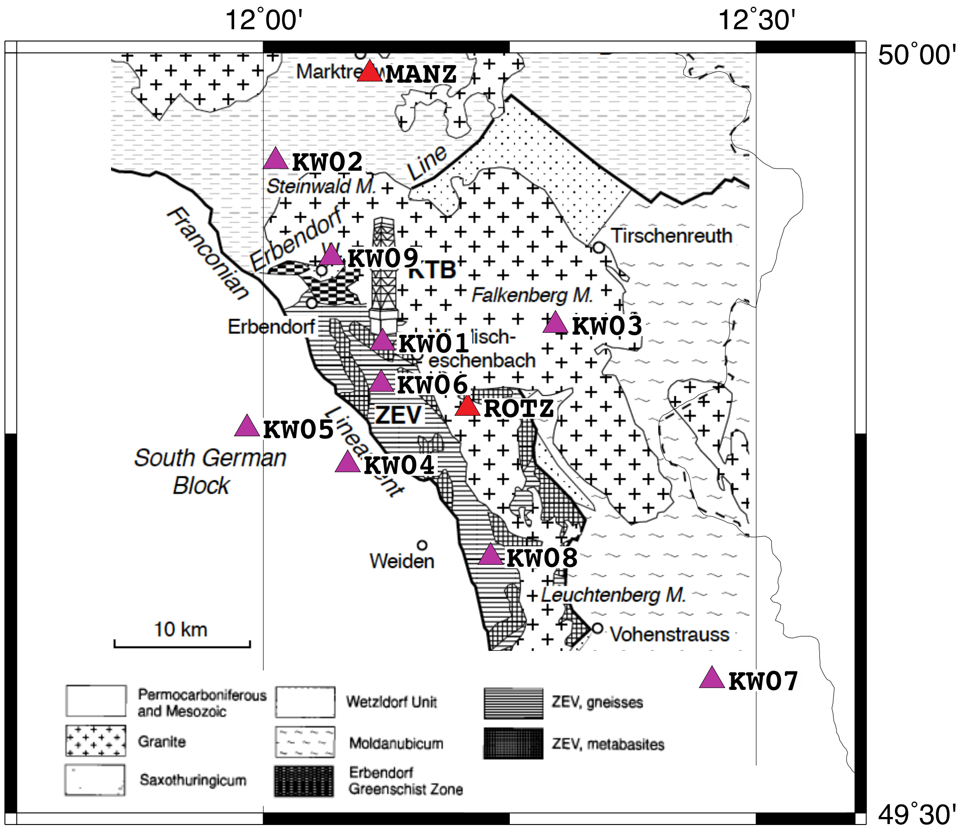
The foliation of the ZEV rocks is generally dipping to the SW.

Seismic reflections SE2 and SE1 were met in the KTB boreholes in the depth intervals 3.2-4 km and 6.8-7.3 km, and represent brittle fault zones of the Franconian Lineament (FL)

SE1 displaces Mesozoic sediments near the surface, as well as the steeply SW dipping, gneiss-metabasite alternation of the ZEV; and also the subhorizontal reflections of the Erbendorf Body (EB) by at least 2-3 km

The boundaries between the different units are partly buried by the granites of the Variscan Oberpfalz pluton

The station network



Bayern net

KTB–IMGW net

KW01

KW02

KW03

KW04

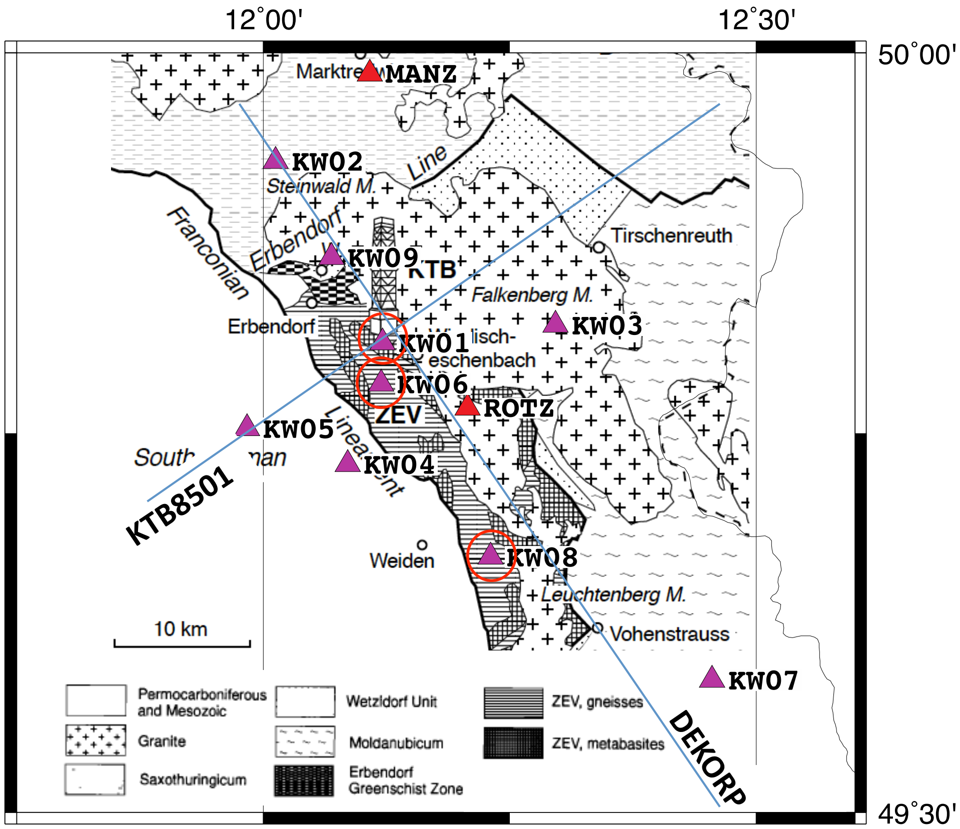
KW05

KW06

KW07

KW08

The station network



▲ Bayern net

▲ KTB–IMGW net

KW01

KW02

KW03

KW04

KW05

KW06

KW07

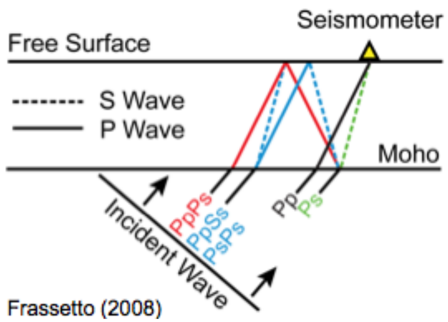
KW08

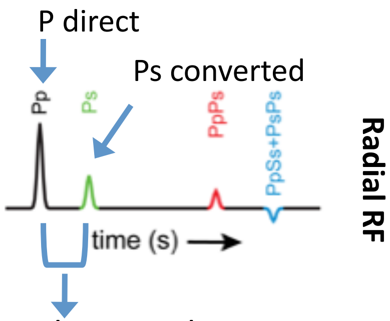
- 3 stations on ZEV
- Alignment of stations along KTB8501 and DEKORP reflection profiles (1985) for comparison with previous investigations
- Recording time: July 2012 to July 2014

Receiver Functions

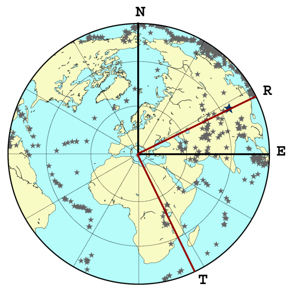
A teleseismic P wave arrives vertically and is converted into an S wave
Allows to detect velocity contrasts at depth

We retrieve H and Vs of the layer



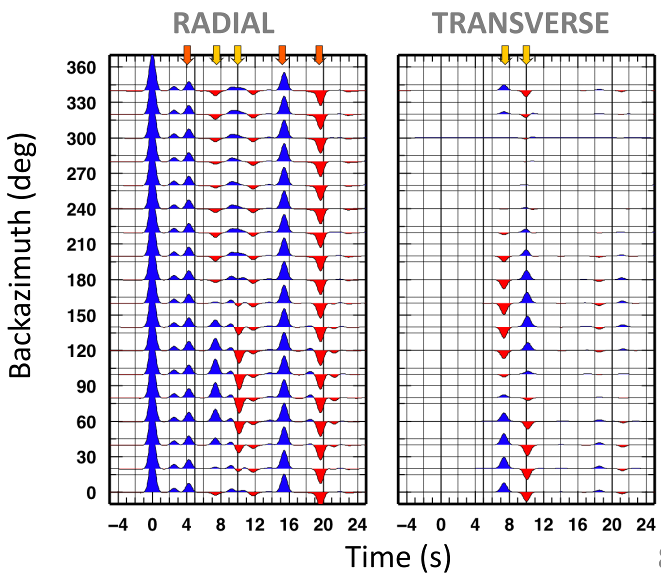


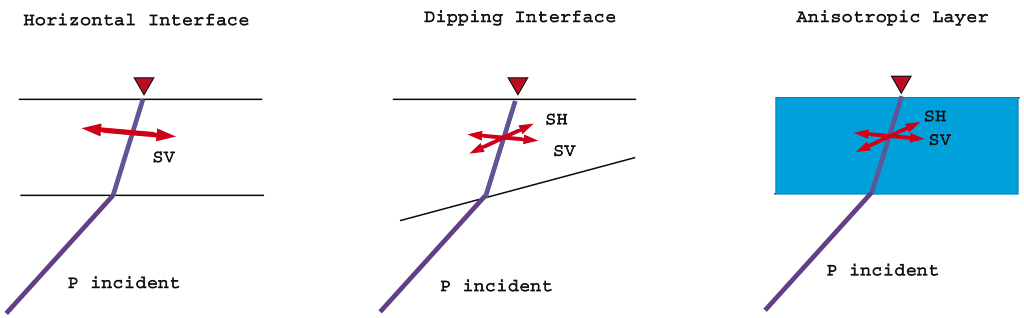
Delay time between P and Ps is proportional to:
- layer thickness (H)
- Vs inside the layer



RF are calculated on **Radial** and **Transverse** directions

BACKAZIMUTHAL SWEEP





When 3D features are present in the subsurface structure, the Ps signal is split in the **Radial** (SV) and **Transverse** (SH) components

Trans-dimensional RF inversion via Monte Carlo sampling

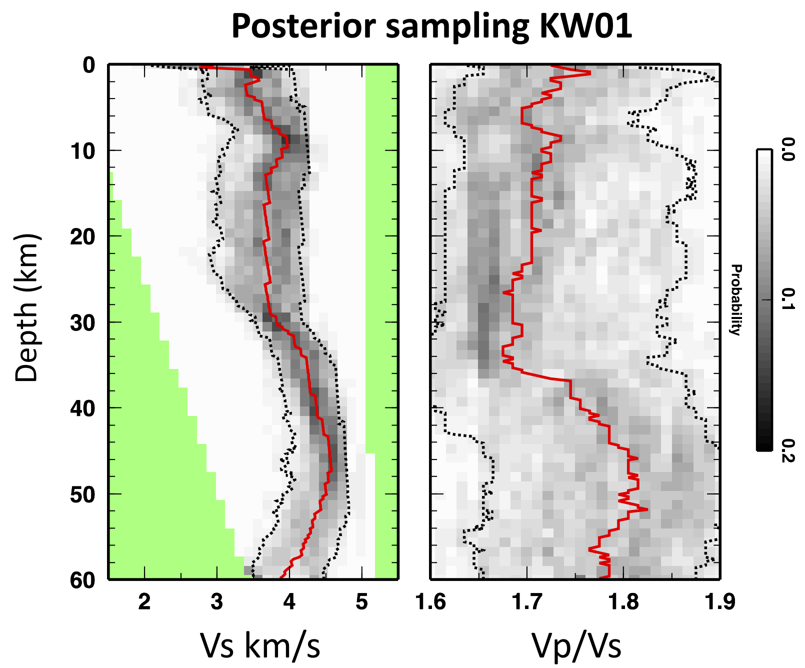
(Piana Agostinetti and Malinverno, 2010)

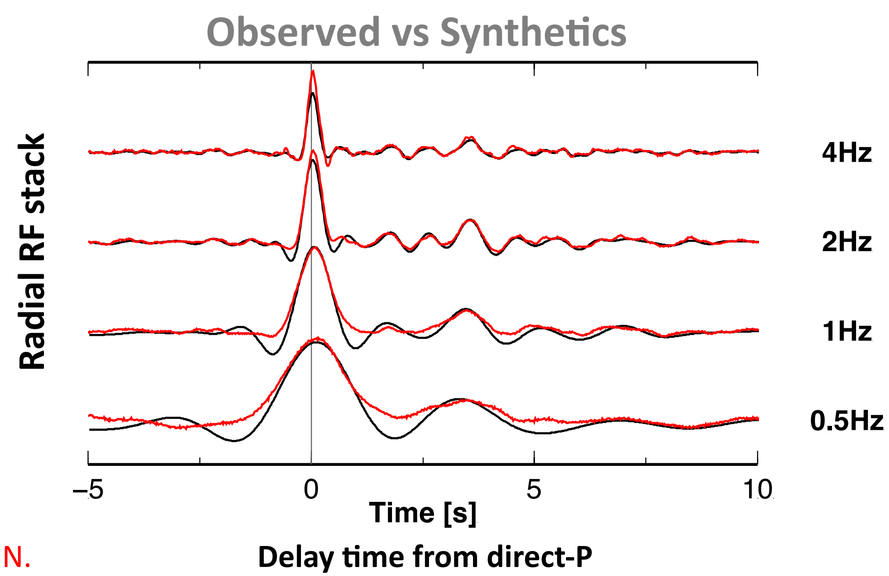
Prior information+observed data=PPD
Trans dimensional=No constraints on number of layers

30.000.000 models extracted for the posterior sampling

Joint inversion of RF at different frequency cut-off for absolute S-velocity profile
(ISOTROPIC, 1D)

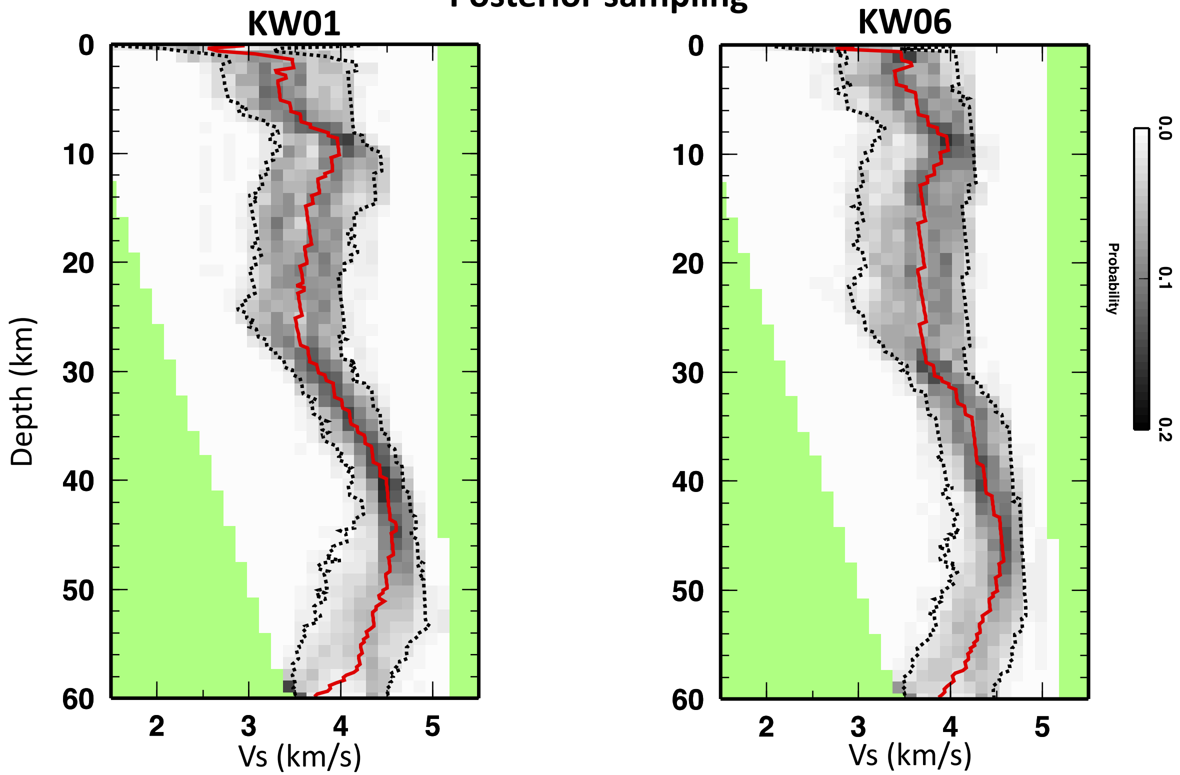
Frequency cut off at 4Hz→ vertical resolution < 500m
(for shallow layers)





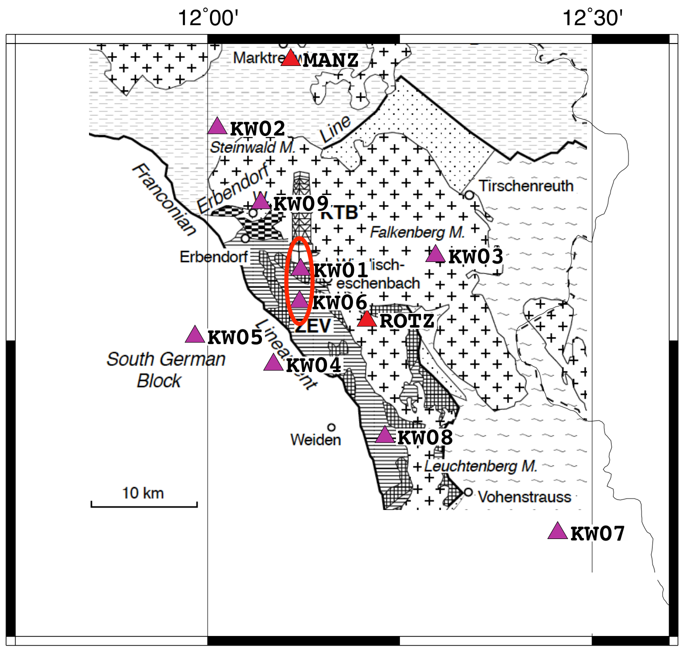
For questions on the inversion technique go to Poster **NS43A-3854**, N. Piana Agostinetti, Thursday, 01:40 PM - 06:00 PM

Posterior sampling

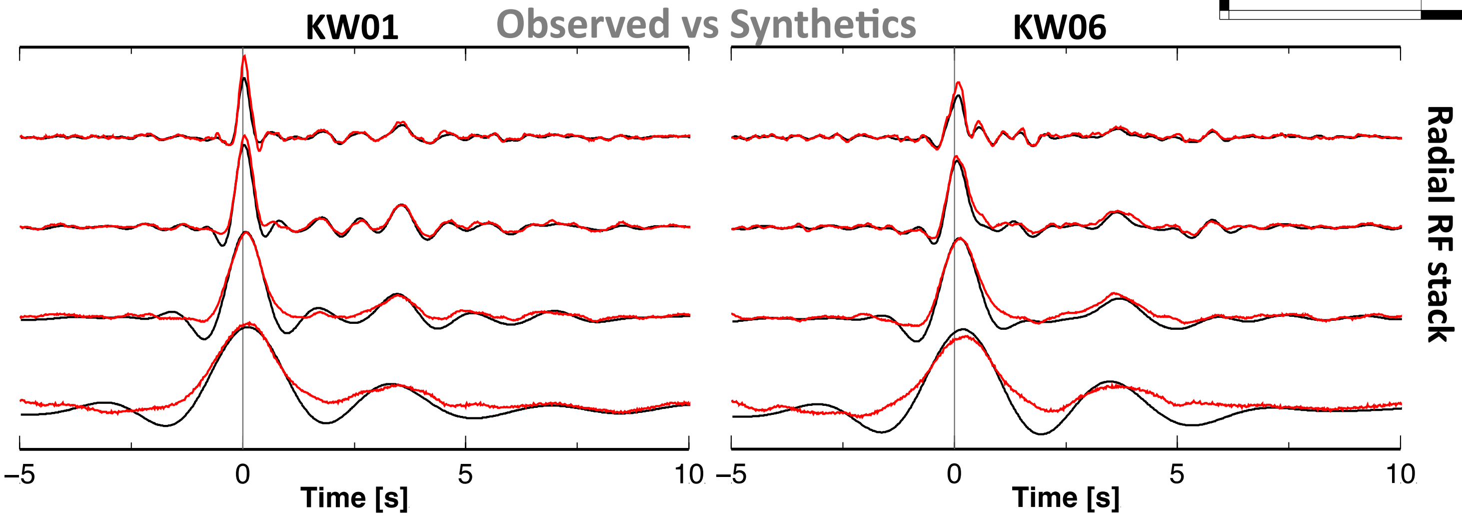


Vs models for the central stations located on ZEV

Posterior probability function (grey shading)
Posterior mean model (red curve)



Observed vs Synthetics

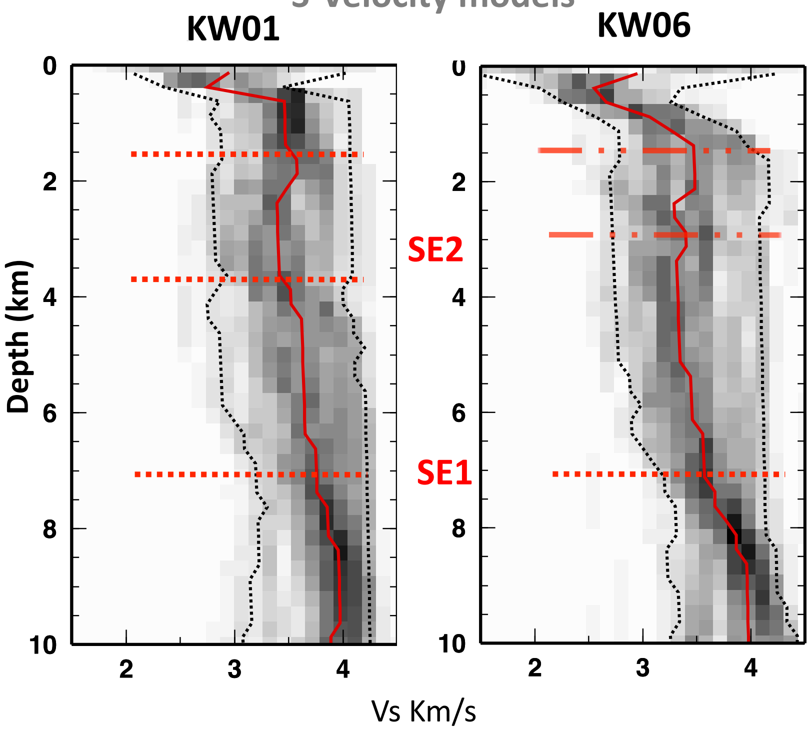


Very similar Vs models for these stations located ~3km apart

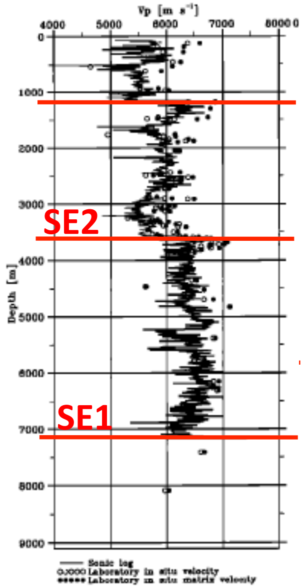
Very good fit between observed (black) and synthetic (red) stacked radial

ZOOM in the SHALLOW STRUCTURE
10 km max depth

S-Velocity models

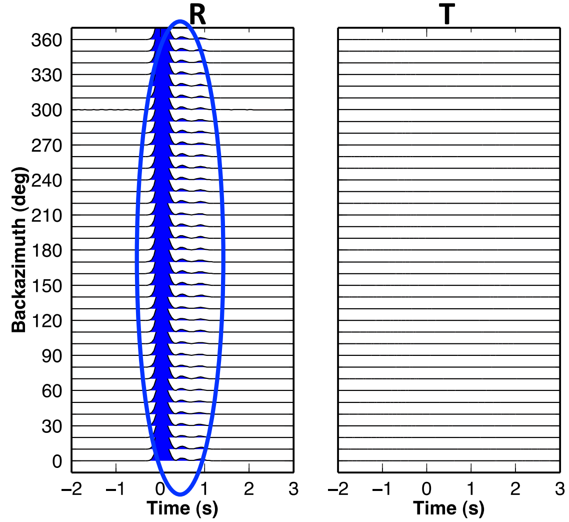


P-Velocity (sonic log)

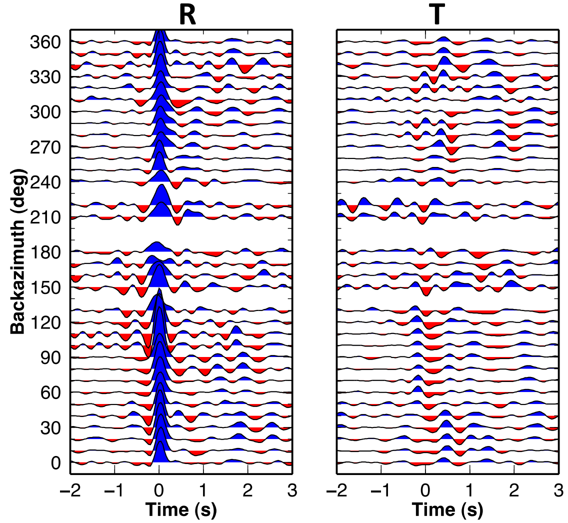


(Berckhemer et al., 1997)

SYNTHETIC RF



OBSERVED at KW01



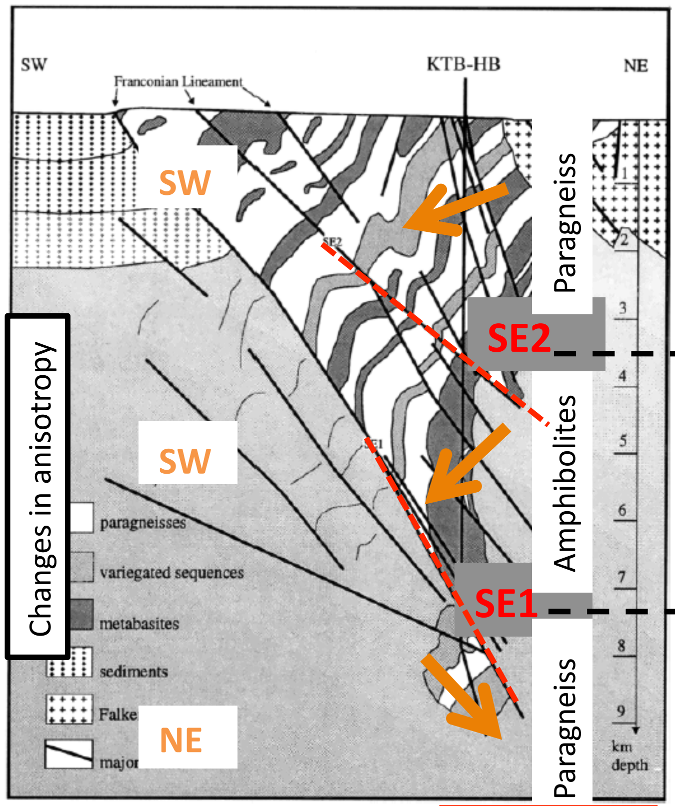
Depth (km)	Vs (km/s)	Vp	
0.5	2.5	5.8	(high crack density)
1.5	3.5	5.5	(alternating gneiss and amphibolites)
2.1	3.75	6.4	
3.6	3.5	6.0	
7.3	3.75	6.5	
10	3.9	6.7	

Good correspondence between the models and the sonic log

…but the isotropic model cannot fit the signal on the transverse component

EFFECT of DIPPING INTERFACES and INCLINED ANISOTROPY

Geological Model → **Geophysical Model** → **Predicted Receiver functions**



Trend of anisotropy

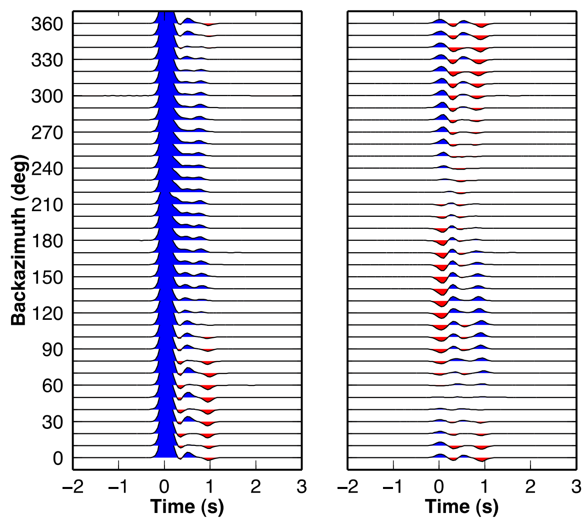
faults
Strike 140°
Dip to NE

Depth profile can be subdivided into 3 major sections according to a lithological subdivision, and a structural subdivision

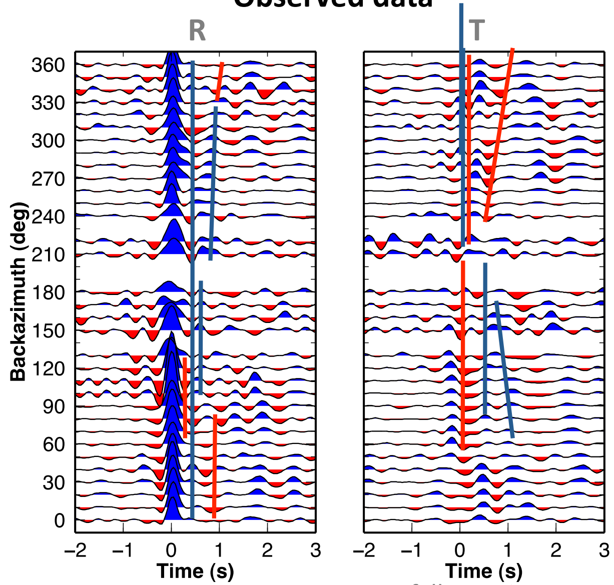
- (S_H ~N150°)Principal stress is // to fault system and foliation planes
- cracks open // to foliation
- Anisotropy is perpendicular to cracks

- Depth interval characterized by one lithology and several fractures oriented as SE1 and SE2
- Anisotropy is perpendicular to the fractures planes

- Depth interval characterized by alternating rock layers
- Anisotropy is perpendicular to the layering (foliation planes)



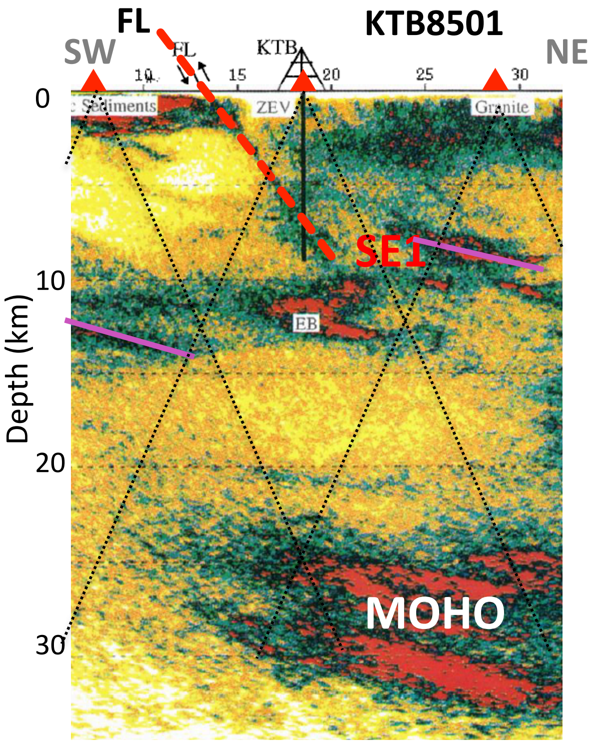
Observed data



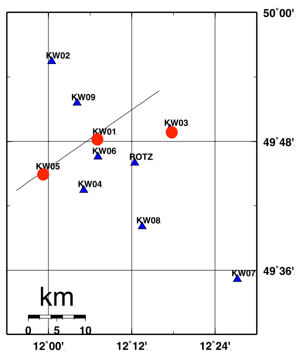
Background figure from Emmermann and Lauterjung (1997)

AGU fall meeting 2014

For larger delay times we can explore the deeper structures and compare them with previous results from active seismic investigations

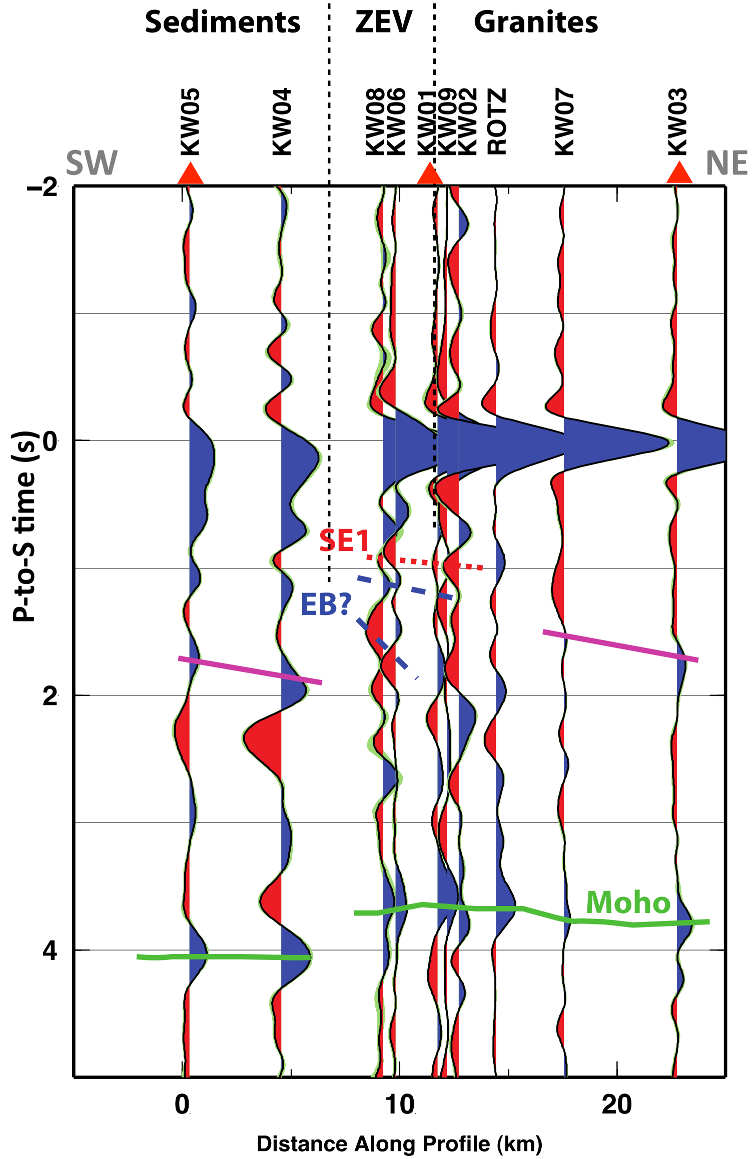


Emmermann and Lauterjung (1997)



Features apparent in the wide angle profile:

- •Different reflectivity between sediments and granites
- •SE1
- •Erbendorf body (EB)
- •2 zones of high reflectivity dislocated by the SE1
- •Moho



Single station Radial RF stack-along KTB8501

Features apparent in the receiver functions:

- •Differentiate between sediments, ZEV and granites:
  - •Typical broadening of P-direct pulse for sediments
  - •Below ZEV we recognize the stratification
  - •No stratification in the granitic body
- •Follow SE1 below ZEV and granites
- •Identify top and Bottom (?) of Erbendorf Body (EB)
- •Similarity of the positive jumps at 1.5-2 s with the 2 zones of high reflectivity seen in KTB8501
- •Reconstruct Moho geometry (shallower below ZEV)

Conclusions

•KTB represents a unique chance for testing passive techniques by knowledge of in-situ structures

•We run a passive seismic experiment for 2 years in the KTB area

•Retrieve the receiver functions for the 9 stations deployed

•From the stack of the Radial component of the RF we retrieve a S-wave velocity model that shows good correspondence to the P-velocities from sonic logs

•We compute synthetic RF including the effect of dipping layers and of anisotropy from on site observations and get a qualitative comparison with the data

•Can we obtain a quantitative comparison?

Thank you for your attention!

Contact: irene.bianchi@univie.ac.at

DI33A-4296 Slab Detachment Under the Eastern Alps Seen By Seismic Anisotropy
Wednesday, December 17, 2014, 01:40 PM - 06:00 PM , Moscone South-Poster Hall

DI33A-4295 Anisotropic Structure of the Upper Mantle in the Carpathian-Pannonian Region: From SKS Splitting data and Xenolith Constraints
Wednesday, December 17, 2014, 01:40 PM - 06:00 PM , Moscone South-Poster Hall