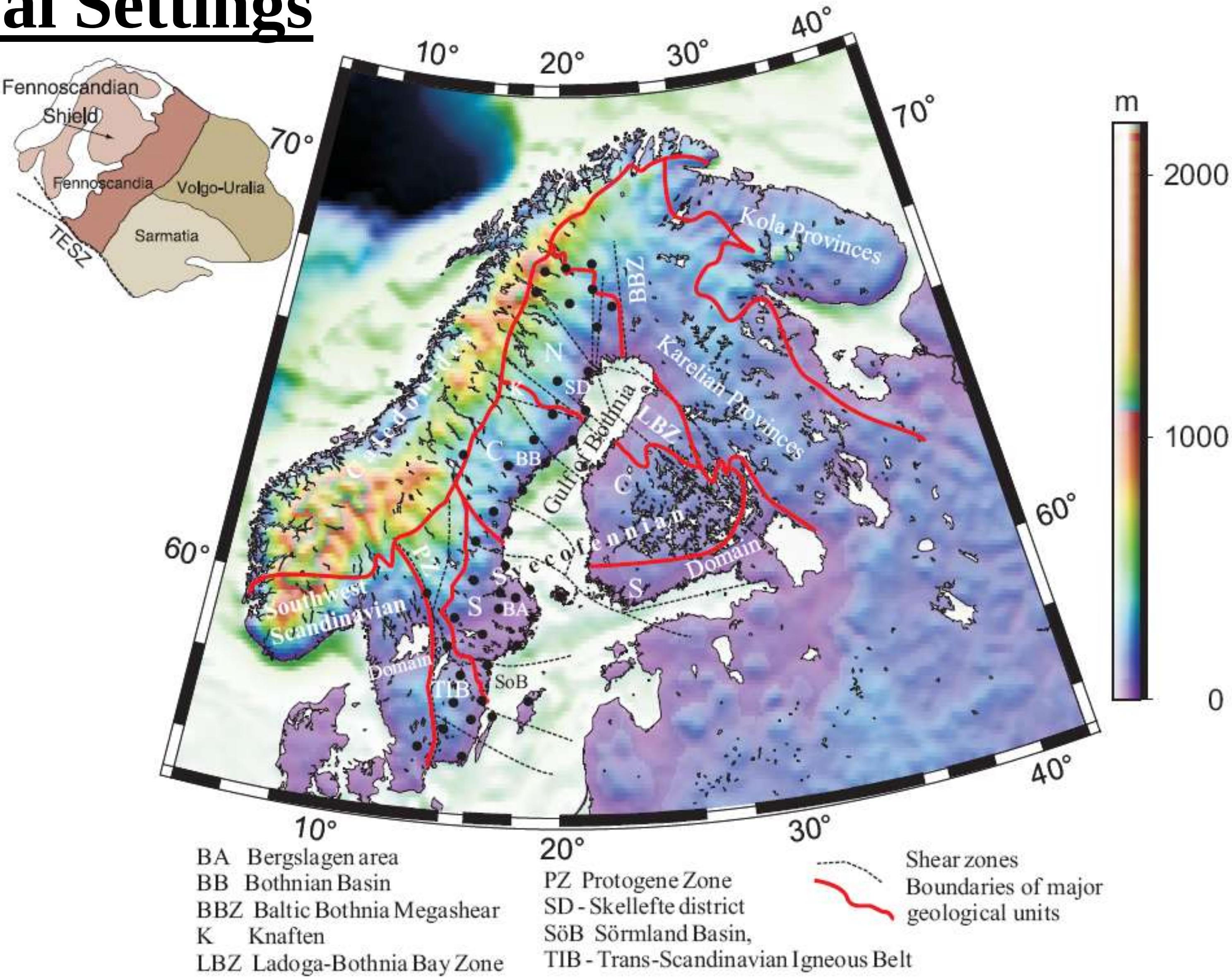
Teleseismic observations from the Baltic Shield Lithosphere beneath Sweden

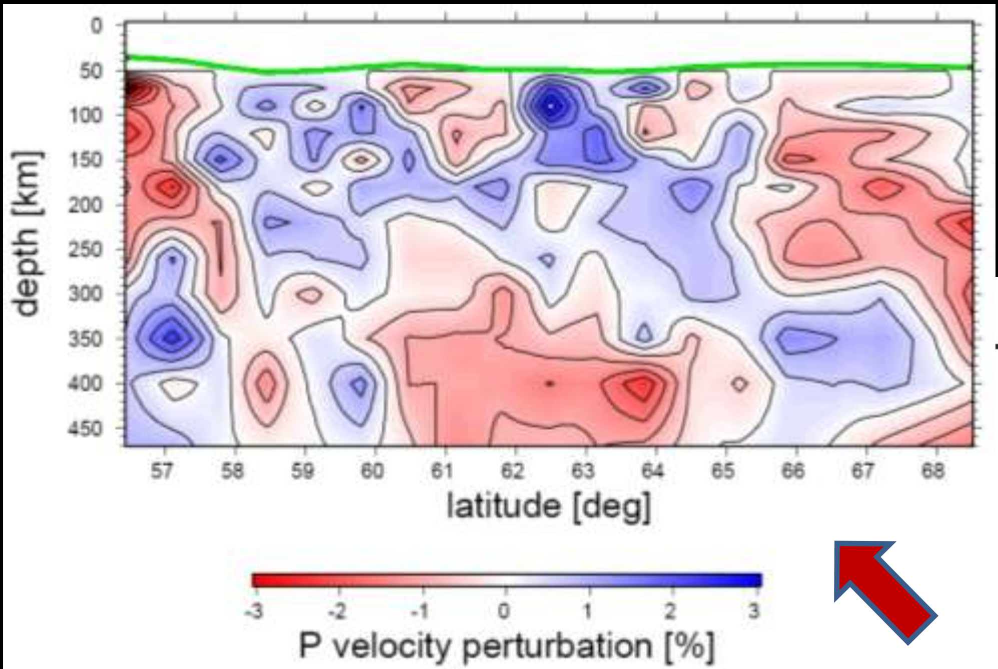
by Roland Roberts

Geological Settings

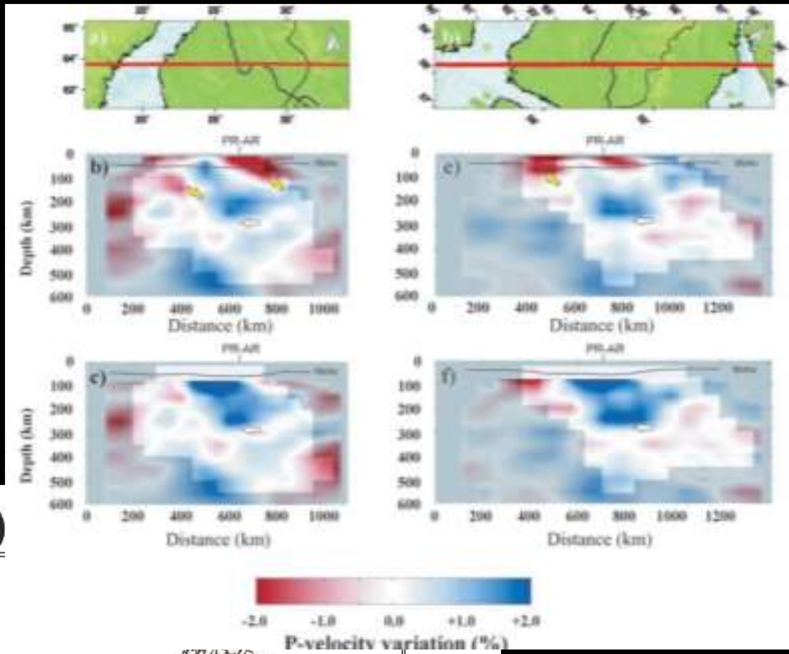


(Fig from Eken et al. 2008b, submitted to *Tectonophysics*)

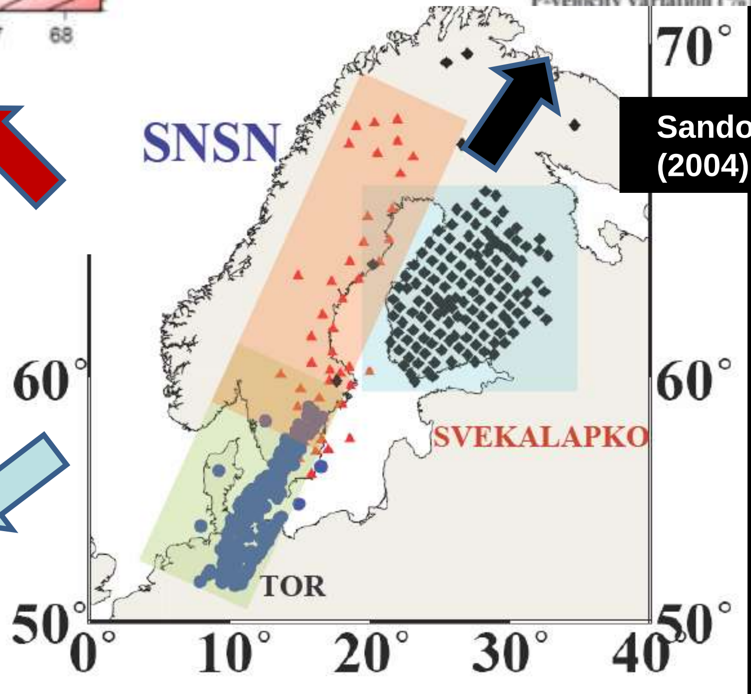
Teleseismic tomography (isotropic)

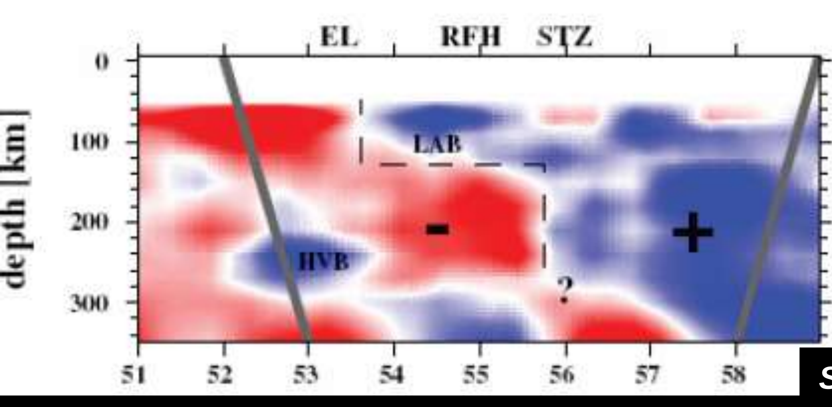


Eken et al. (2007)



Sandoval et al. (2004)

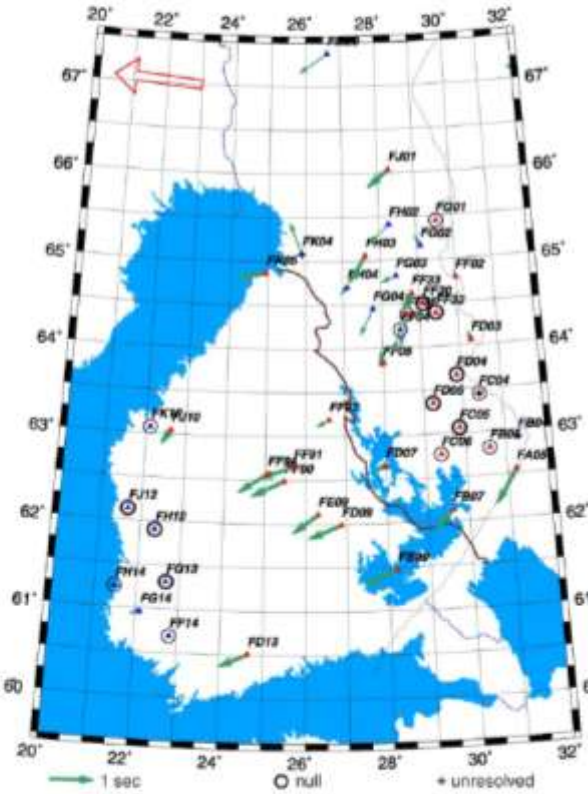




Shomali et al. (2002)

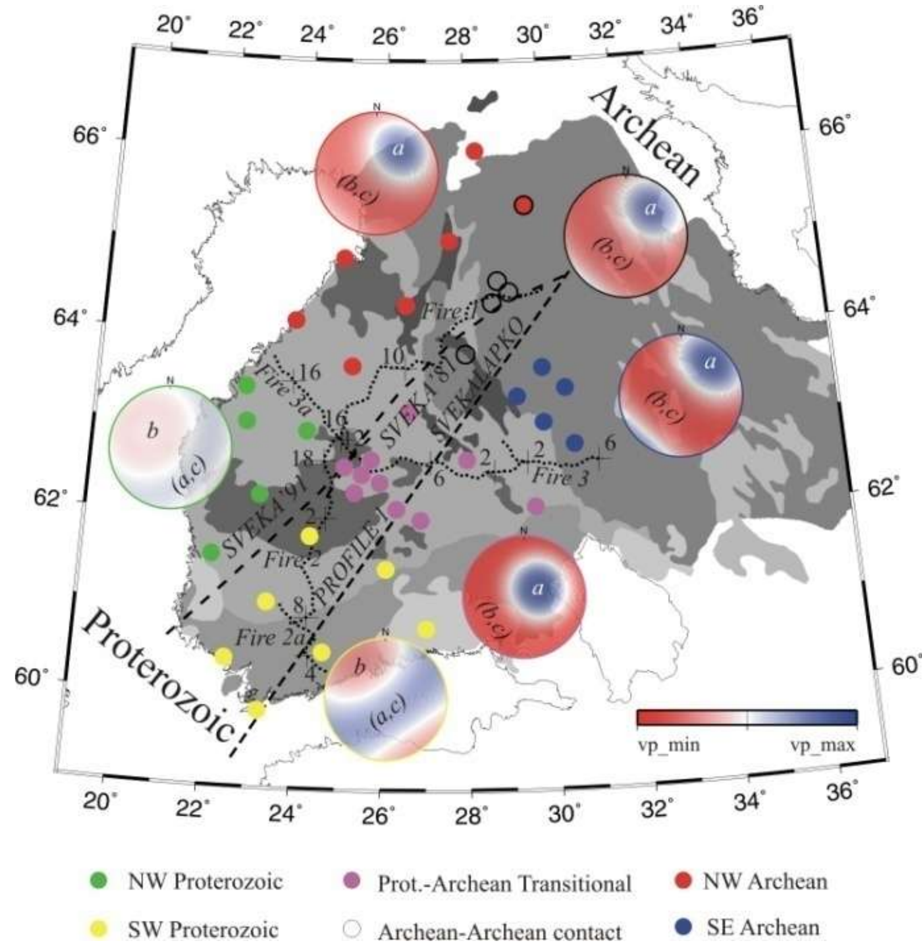
Upper mantle anisotropy beneath central Fennoscandia (south-central Finland, SVEKALAPKO project)

2. From shear waves – SKS splitting



Geographical variations of SKS fast polarizations beneath Finland. There is no uniform model which would fit the whole region.

Joint inversion of SKS splitting parameters and anisotropic part of relative P residuals at 6 different domains.



Vecsey et al. Tectonophysics 2007

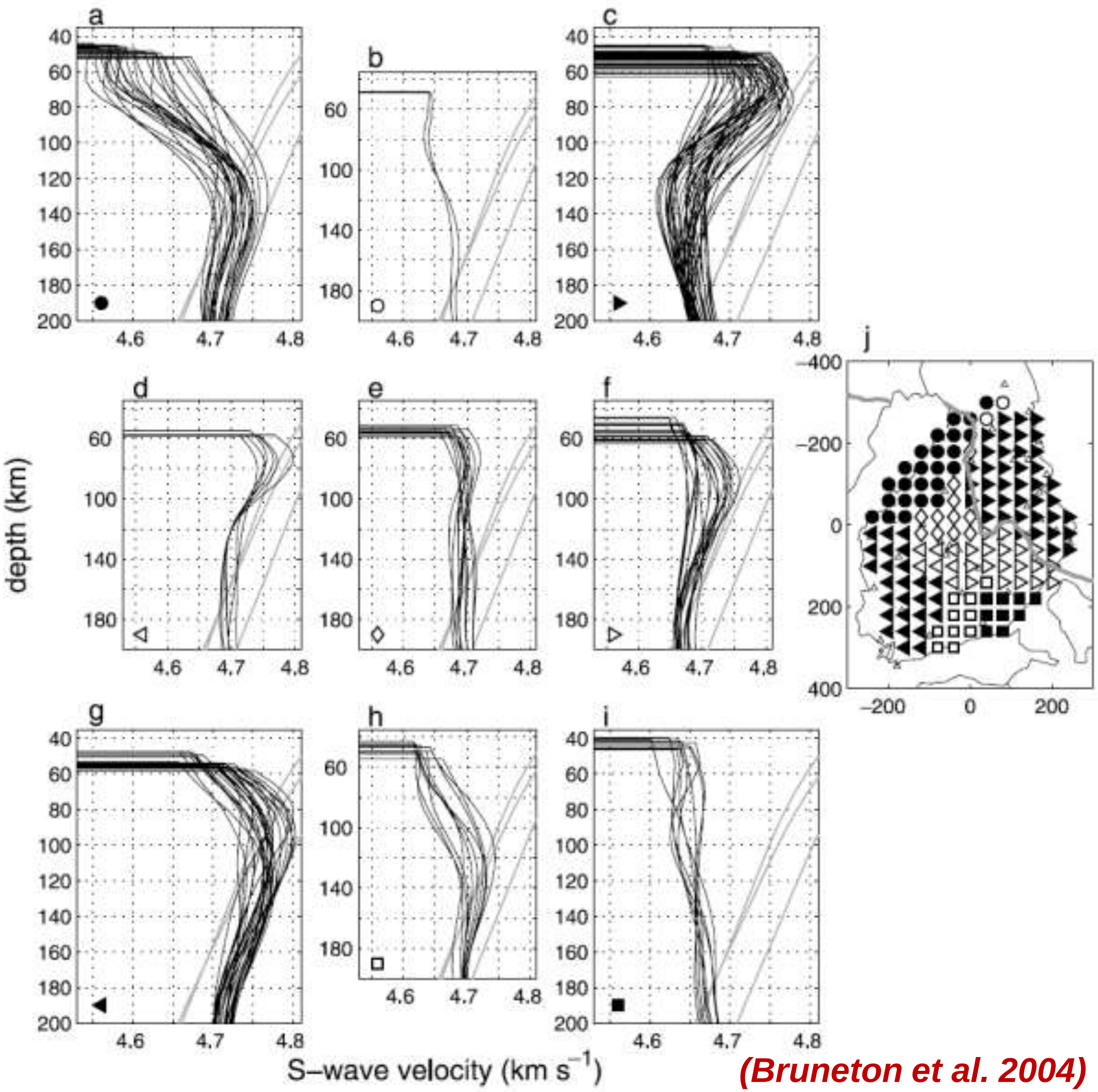
Surface waves analyses (south-central Finland, SVEKALAPKO project)

Inversion of fundamental mode of Rayleigh waves

Classified depth profiles of shear wave velocities forming different families.

Regions derived from surface waves (Bruneton et al. 2004) correlate with those from body waves (Plomerova et al. 2003).

NE azimuth of high velocities in the upper mantle (from surface-wave anisotropy – Pedersen et al., 2007) correlates with ~ NE dipping *a-axes* in Archean lithsophere (joint inversion body waves –Vecsey et al., 2007).

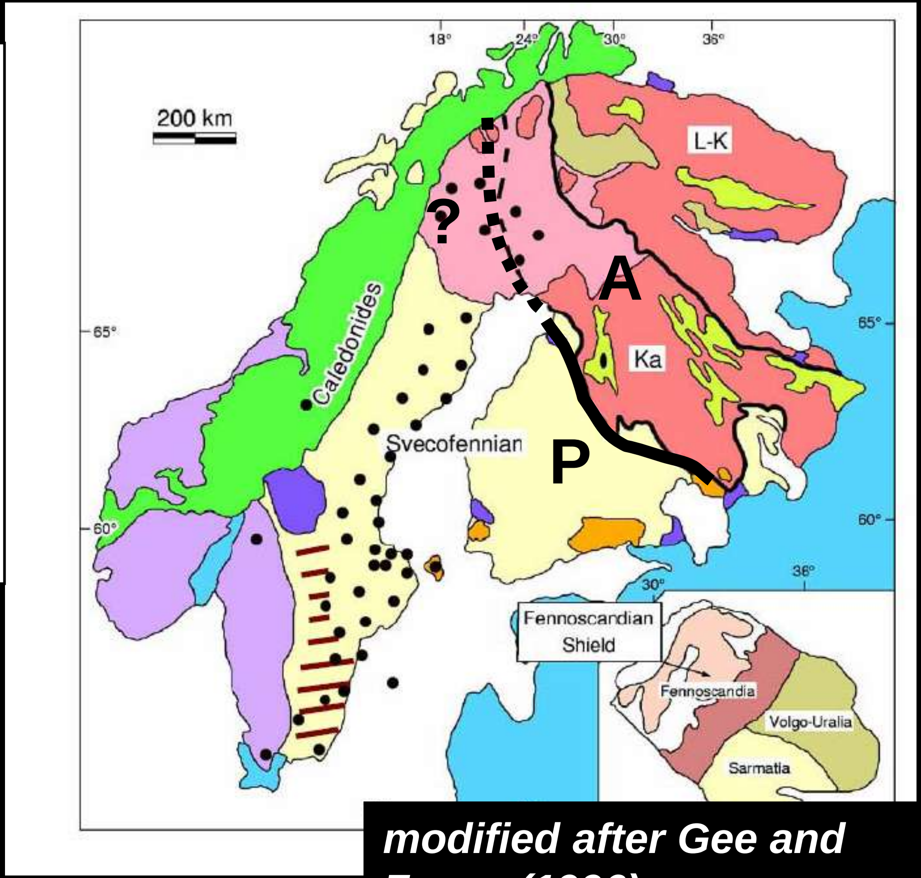


(Bruneton et al. 2004)

- ✓ *Isotropic studies (P tomography) beneath central Fennoscandia did not detect the P/A boundary in the upper mantle.*
- ✓ *Different anisotropic structures modeled for the Proterozoic and Archean parts beneath the SVEKALAPKO array.*

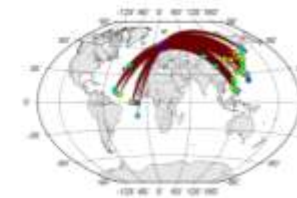
? **What is the upper mantle structure beneath the SNSN network covering the Baltic Shield?**

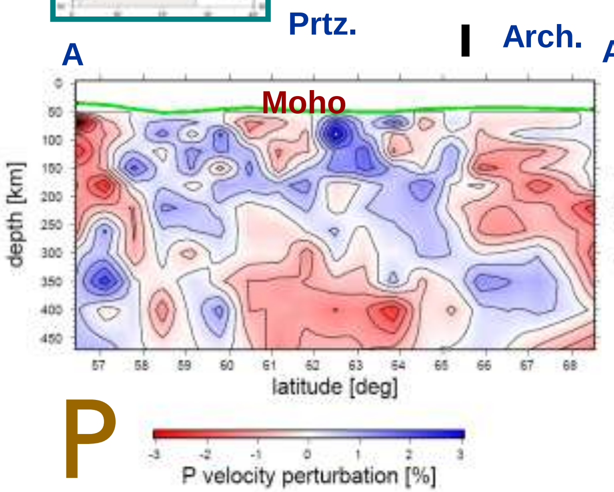
? **Can we follow a continuation of the Proterozoic/Archean boundary in the upper mantle further to the North?**

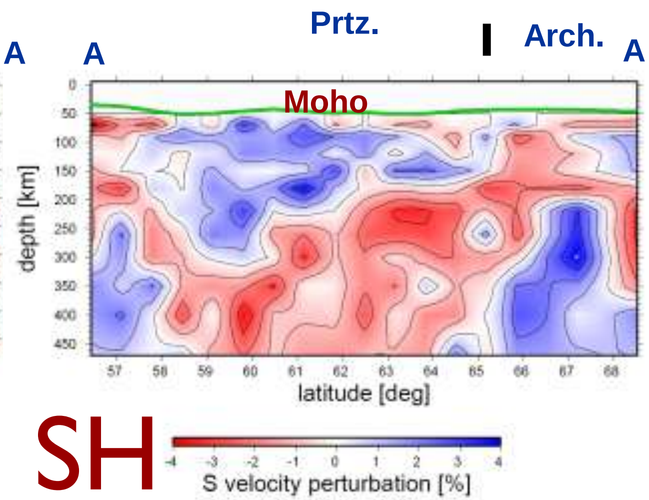


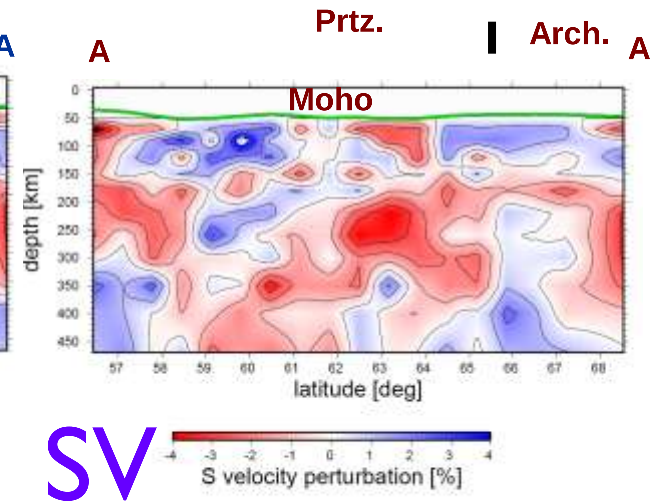
modified after Gee and Zeyen (1996)

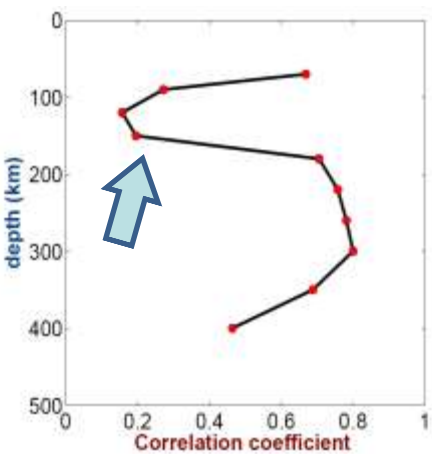
Isotropic velocity tomography efforts (P and S)

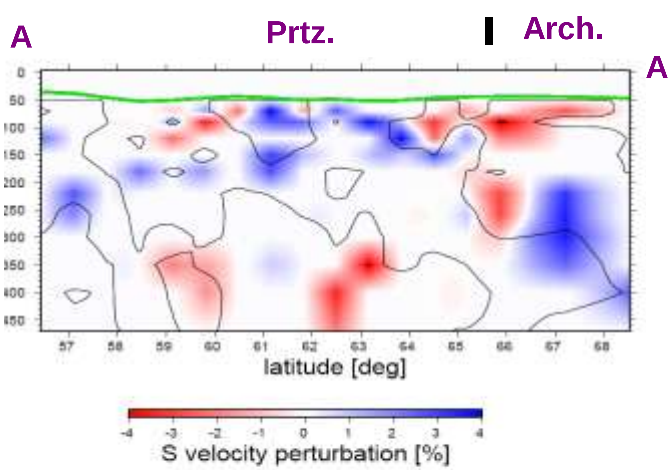












(Eken et al. 2008a)

- ➢P, SH and SV inversions use the same events and stations.
- ➢significant differences between the P and S images, as well as between the SH and SV images down to ~250km.

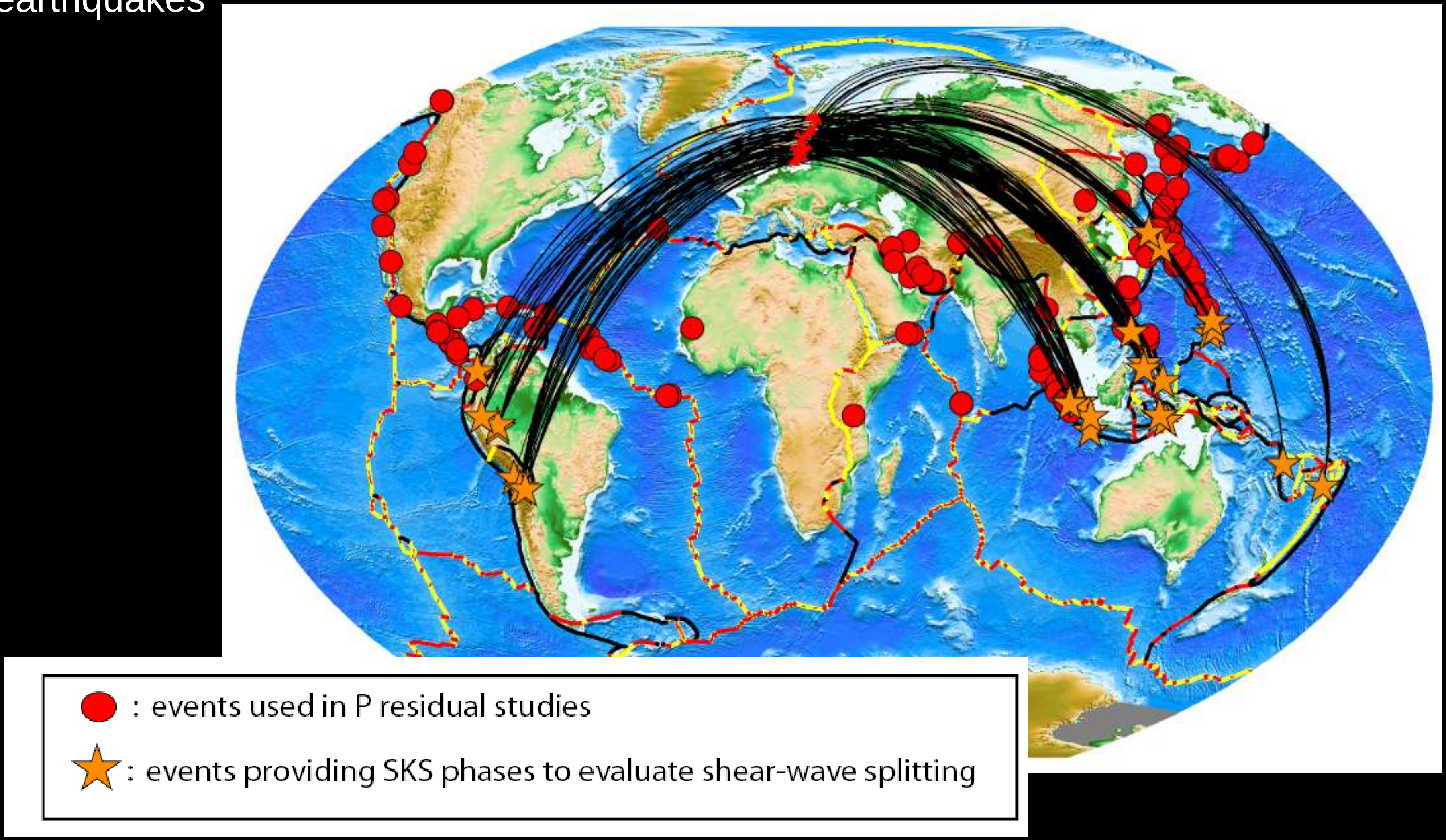
Left: Cell by cell comparison of the S models indicates significant differences along the Archean-Proterozoic contact.

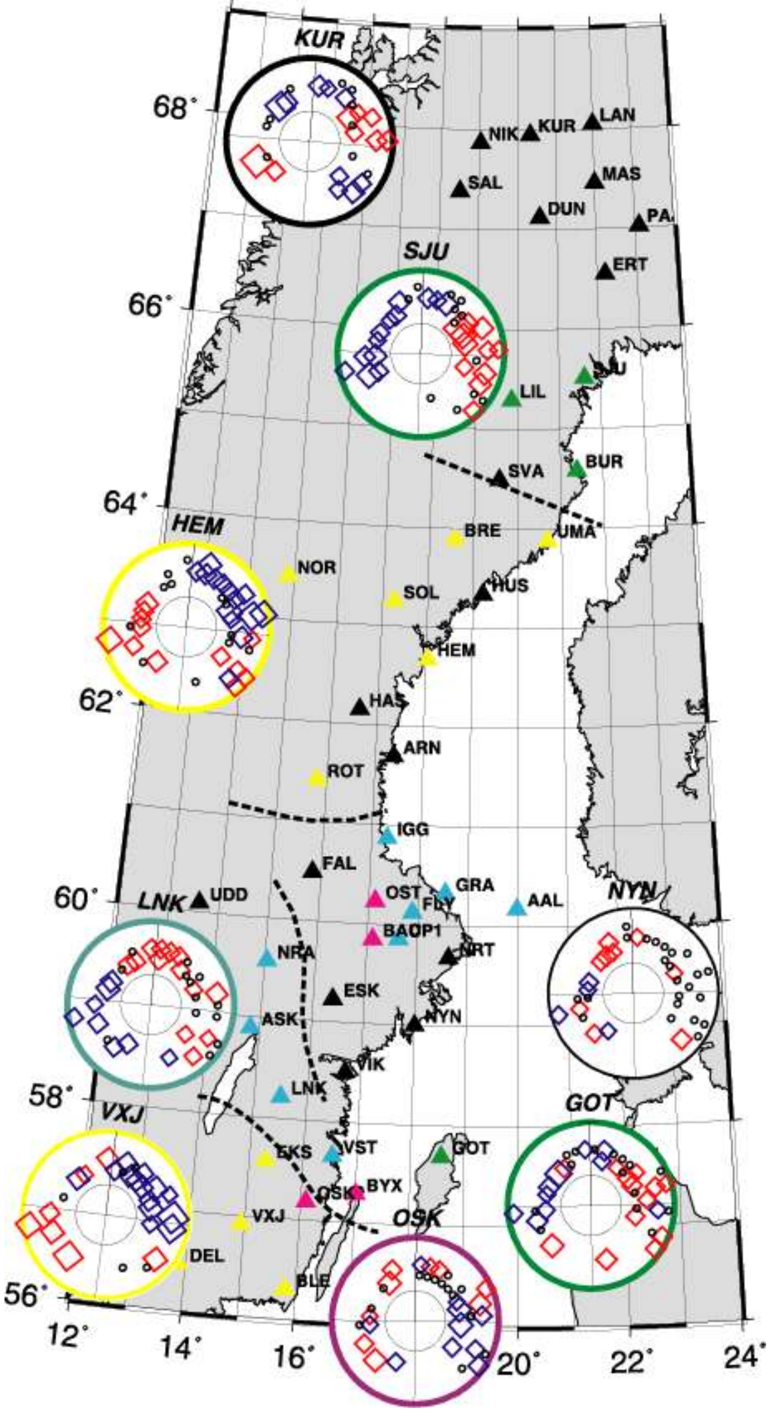
Far Left: Low correlation between SH and SV velocity perturbations down to about 200 km – to the base of the lithosphere?

Data set for studying the seismic anisotropy …

224 high quality waveforms with SKS phase were chosen 25 out of 285 events examined.

P travel time data consists of 4200 high quality picks from 136 teleseismic earthquakes





P-wave anisotropy …

P spheres show azimuth-incidence angle dependent terms of relative travel-time deviations (residuals).

blue diamonds (early arrivals, negative residulas) – high velocity directions

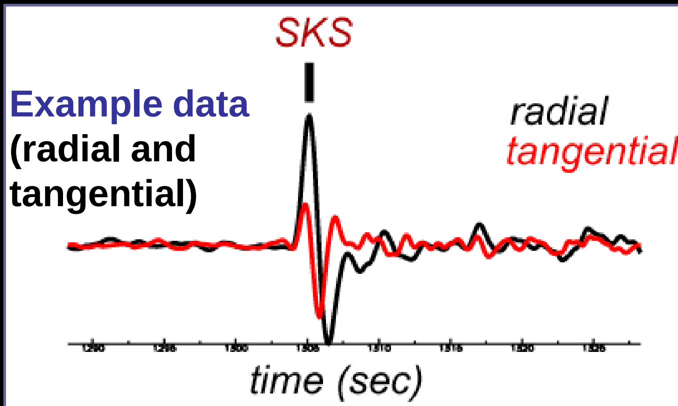
read diamonds (delayed arrivals, positive residuals) – low velocity directions

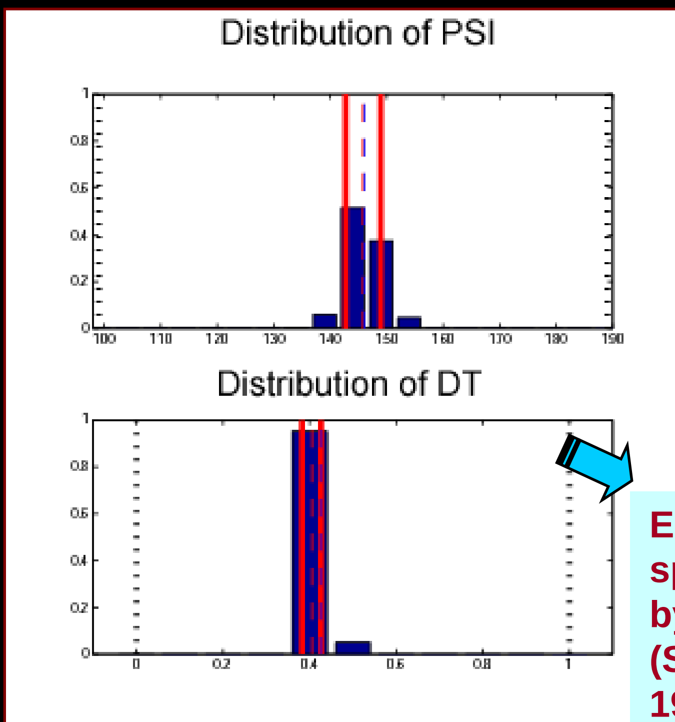
- **All diagrams are calculated from relative residuals *within* the SNSN array and relative to directional means at individual stations.**

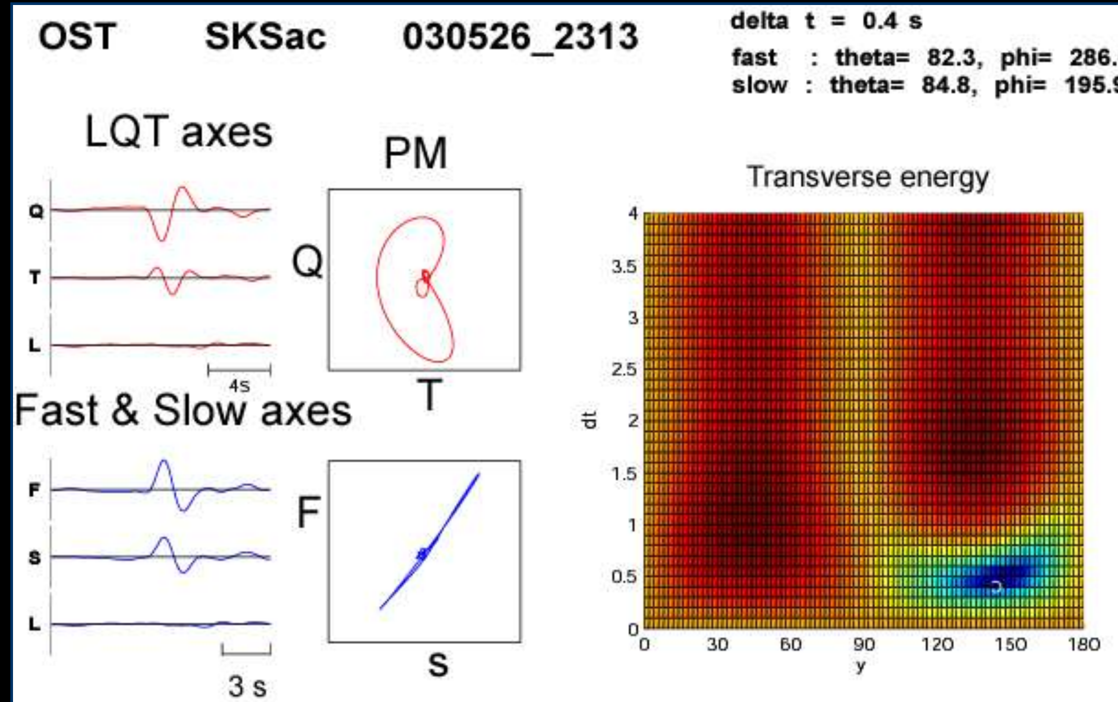
Station with similar pattern form groups – orientations of directions of relatively higher or lower velocities are internally consistent within each group and change at boundaries between the groups.

The patterns are in a good agreement with those found in previous studies in the region (Plomerova *et al.* 2001; 2002; Babuska and Plomerova, 2004).

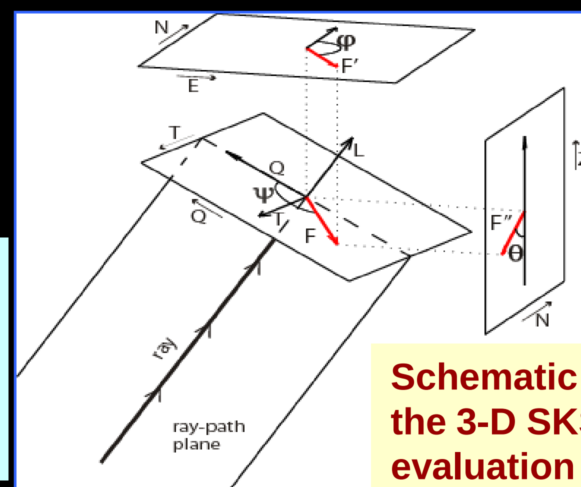
Evaluation of shear wave splitting …





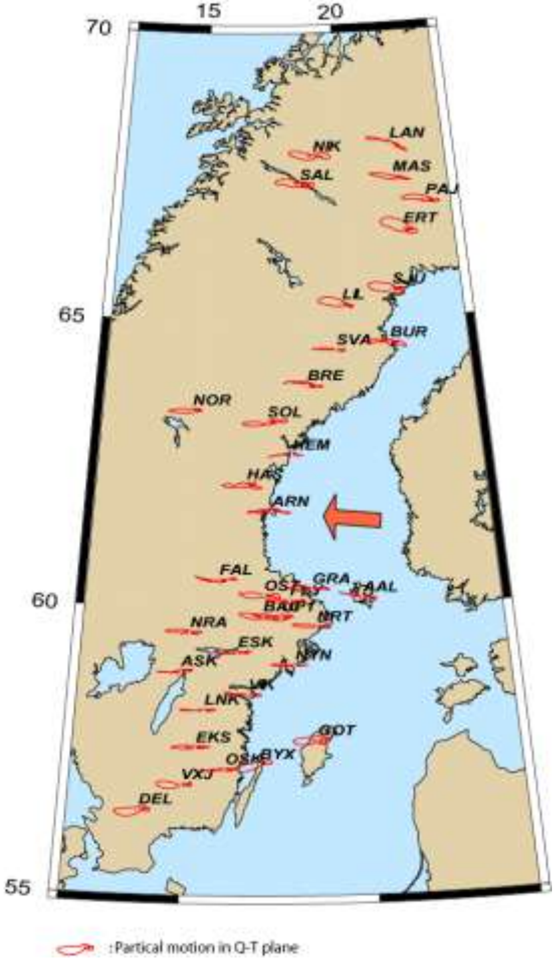


Error estimation of splitting parameters by bootstrap method (Sandvol & Hearn, 1994)



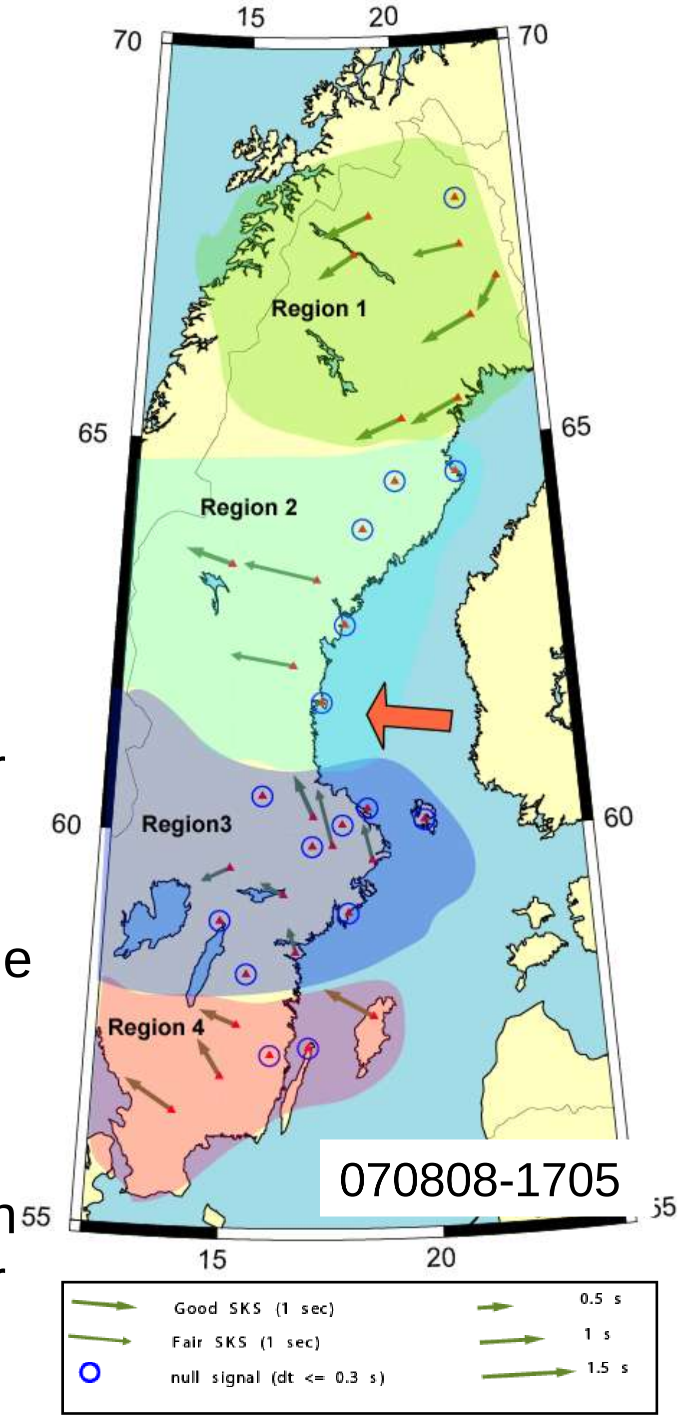
Schematic illustration of the 3-D SKS splitting evaluation (Sileny and Plomerova, 1996)

An example of lateral variation …



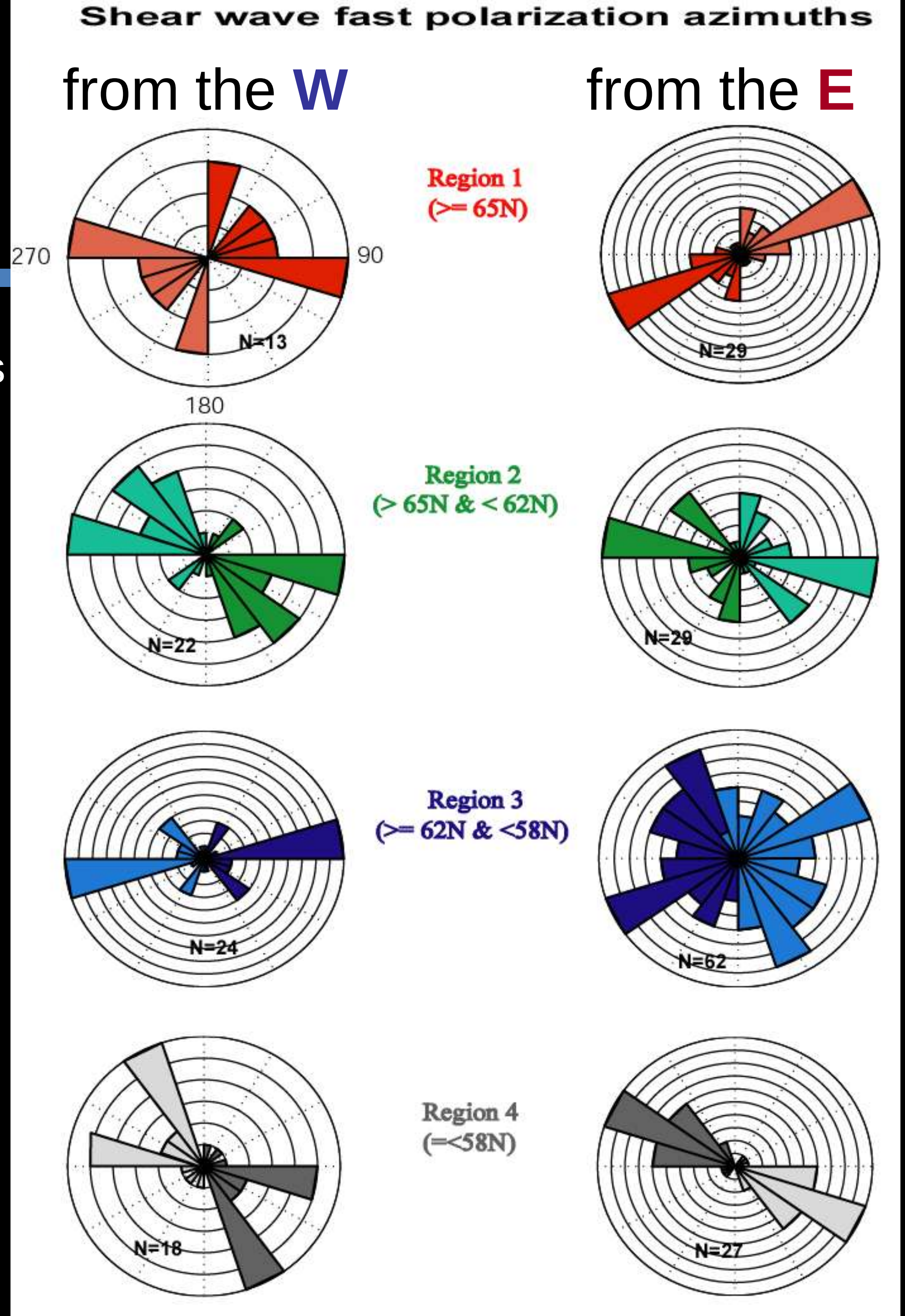
✓ **Examples of lateral variations** of the **particle motions** and **evaluated splittings** of **SKS** wave approaching the SNSN array from **eastern** backazimuth.

- Shear wave split – prove existence of seismic anisotropy within the upper mantle
- Splitting parameters change at the boundaries of anisotropic domains
- Domains correlate well with zoning according to bipolar patterns of P spheres

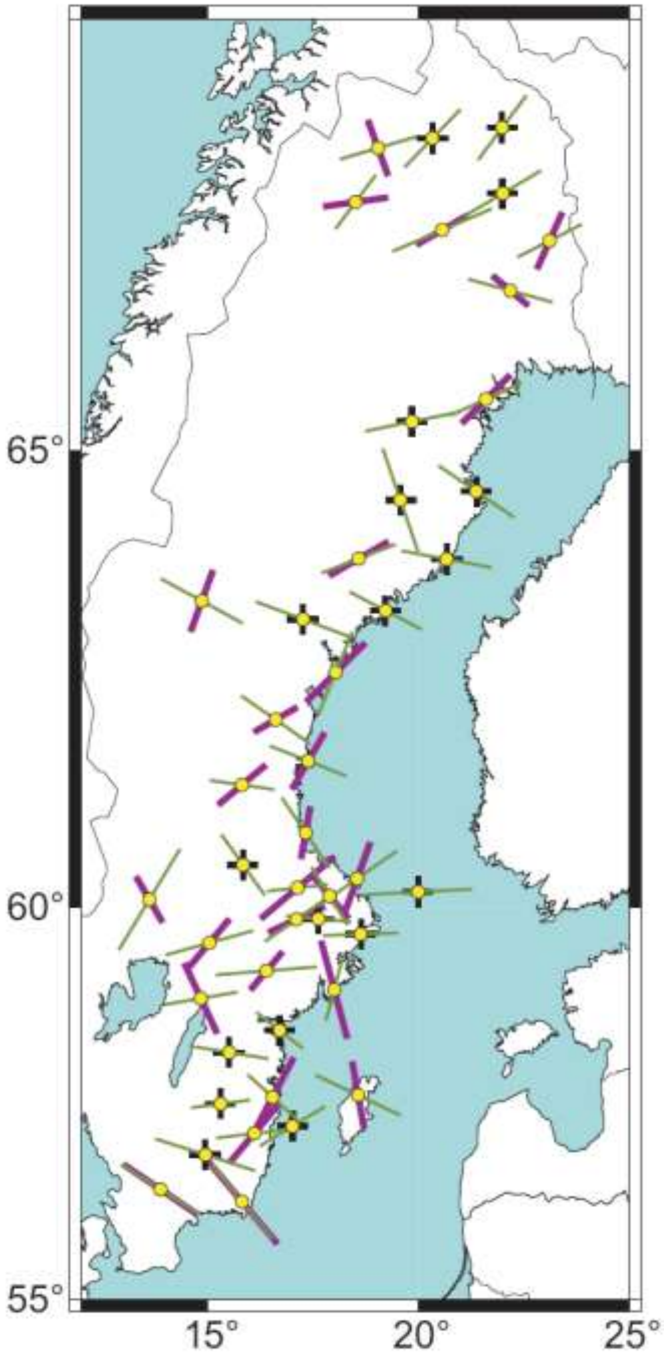


Shear wave fast polarization azimuths …

- Shear wave fast polarization azimuths vary with the backazimuths of SKS waves approaching stations ....
- Fast S polarization azimuths are different for the waves arriving from opposite directions ...
- ✓ Simple one-layer models with horizonal symmetry axes do not fit data
- ✓ Alternatively, models with inclined symetry axes, similar to what results from inversion of P residual spheres, can explain the upper mantle anisotropy beneath the Baltic Shield (SNSN)



Shear-wave splitting from SKS and P410-to-S converted phases

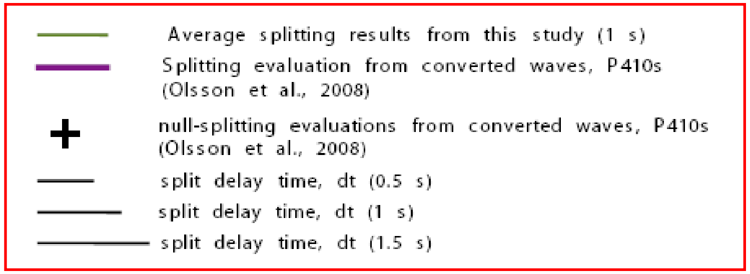


Green – Average Fast S polarizations azimuths in 0-180deg. range (***this study***).
Purple – Fast P410s fast S polarizations azimuths
(*Olsson et al., 2008*)

- **Two independent data sets with**
  - **- different frequency contents**
  - **- different ray paths**

✓ **Average difference in azimuths ~ 30º**
✓ **Average difference in delay times ~ 0.3 s**

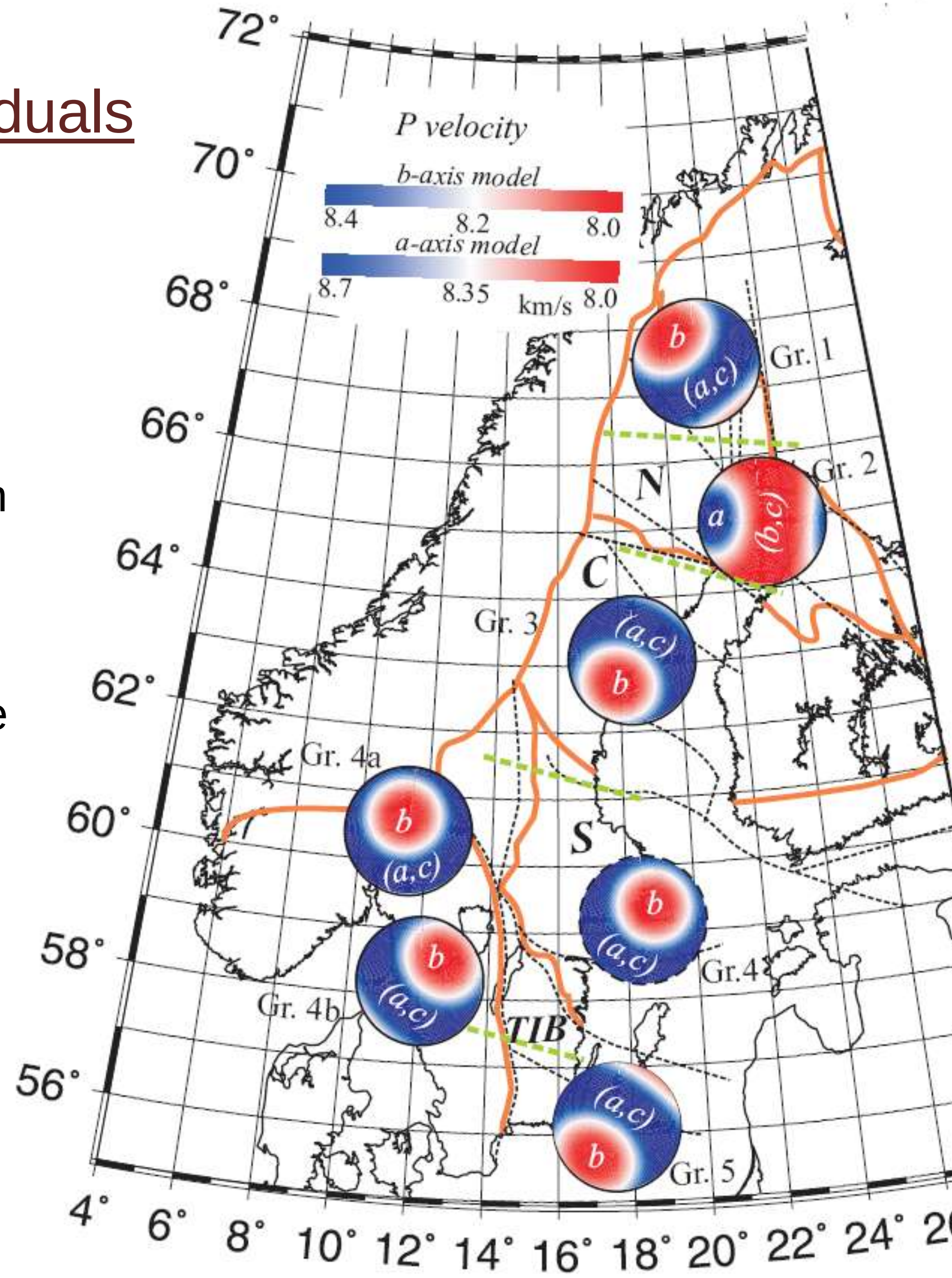
Source of splitting for P410s phases is located above the depth of conversion (410 km)



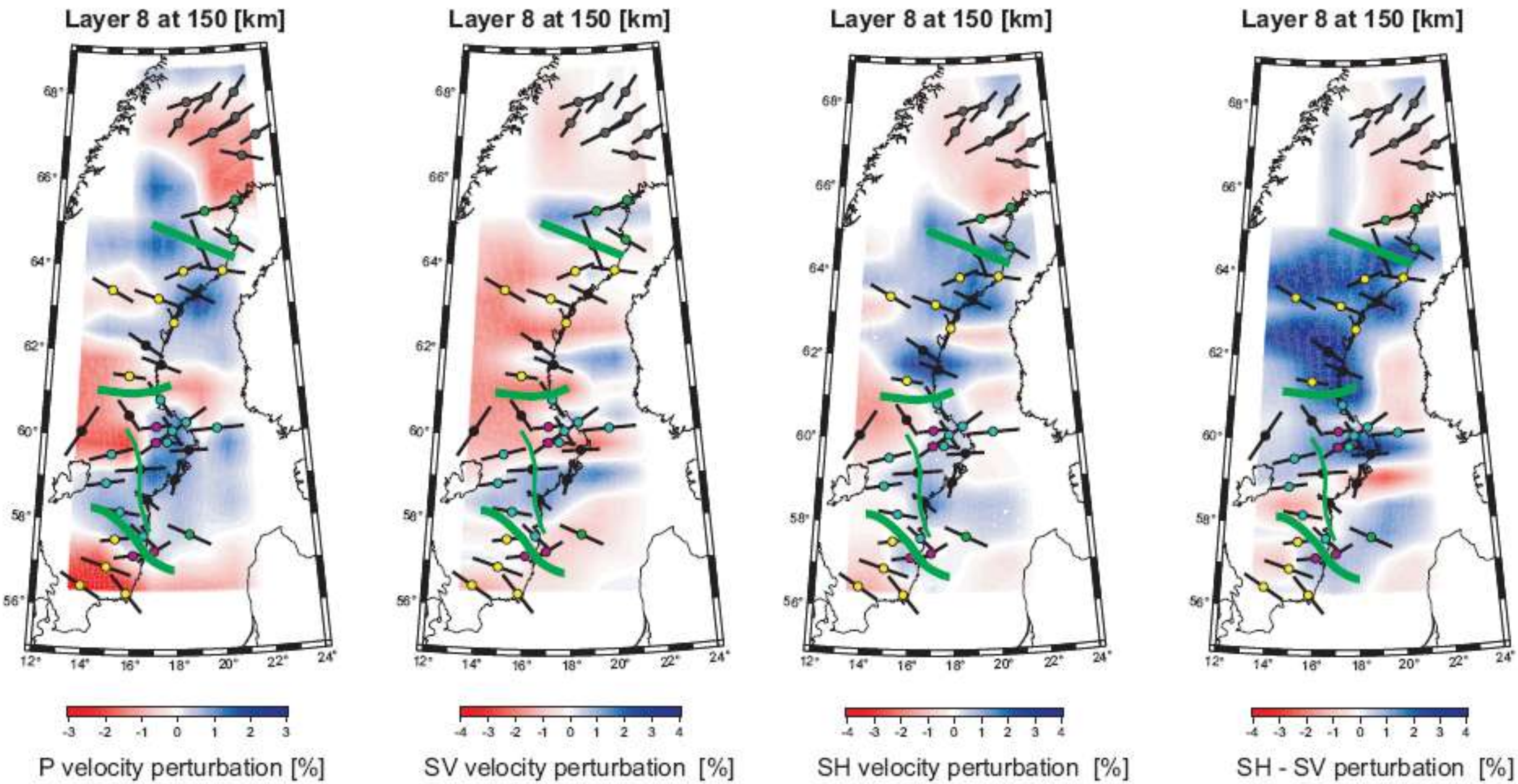
Joint inversion of body-waves anisotropic parameters (P residuals and SKS splitting)

Models with plunging symmetry axes, both with the ‘fast’ and ‘slow’ b axes – mimic well the observed anisotropic signals.

Either the high-velocity foliation (a,c) in the b-axis models or lineation *a* in the a-axis models were resolved after joint inversion



SKS splitting co-located with tomography



Conclusions …

- ✓ The structure of the upper mantle beneath the Sweden is anisotropic;

- ✓ The dominant part of seismic anisotropy can be associated with fabric of the mantle lithosphere;

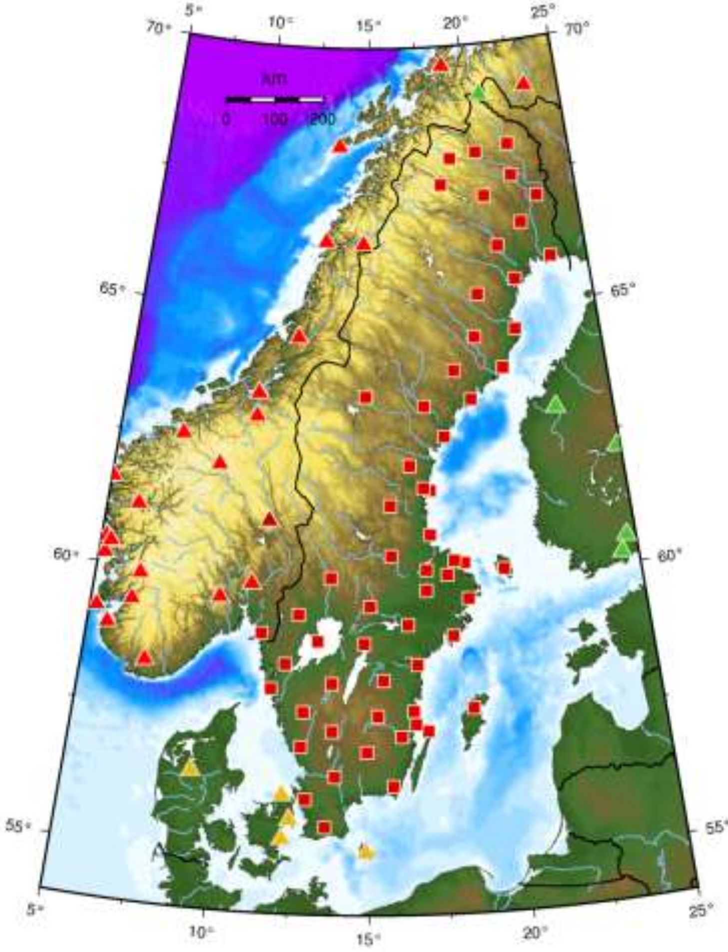
- ✓ The mantle lithosphere consist of several domains with their own fabric which can be approximated by 3D self-consistent anisotropic models with plunging symmetry axes;

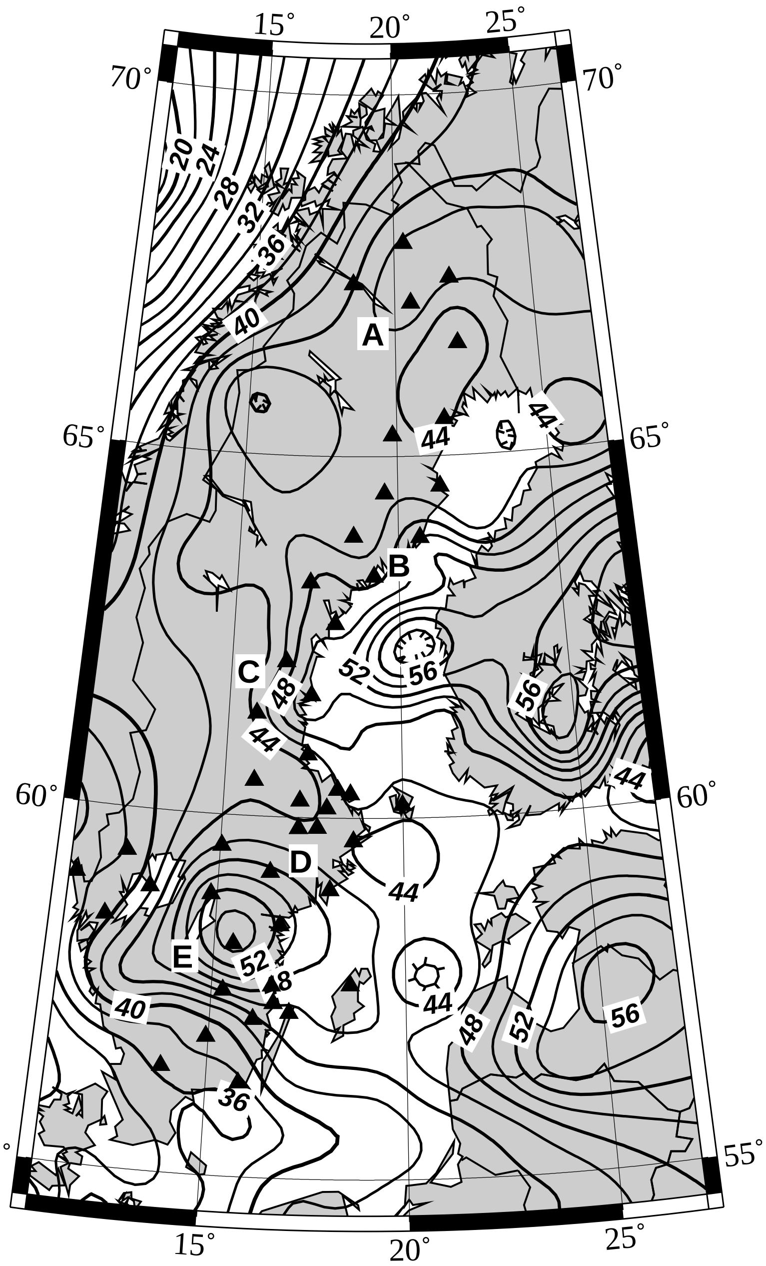
- ✓ The domains in the Proterozoic part of Fennoscandia seem to be sharply bounded by sutures cutting the whole lithosphere;

- ✓ Surface projections of the boundaries of the mantle lithosphere domains correlate well with boundaries of main crustal terranes;

- ✓ The domain boundaries correlate also with large-scale structures revealed in seismic tomography, i.e. the boundaries often correspond to both a change in bulk velocity and a change in anisotropic fabric.

Additional figures





15°
20°
25°
70°
70°
20
24
28
32
36
40
A
44
44
65°
65°
B
C
48
52
56
56
44
44
60°
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D
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E
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48
40
44
48
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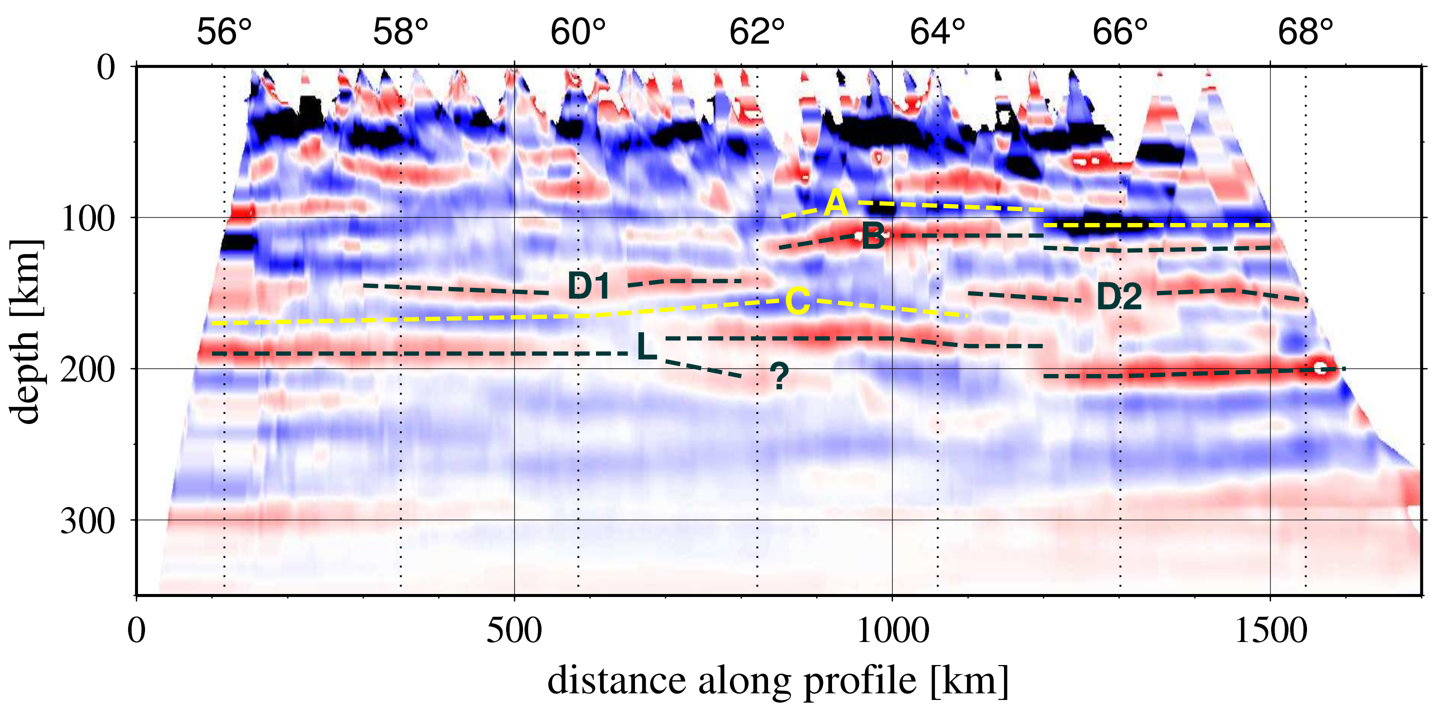
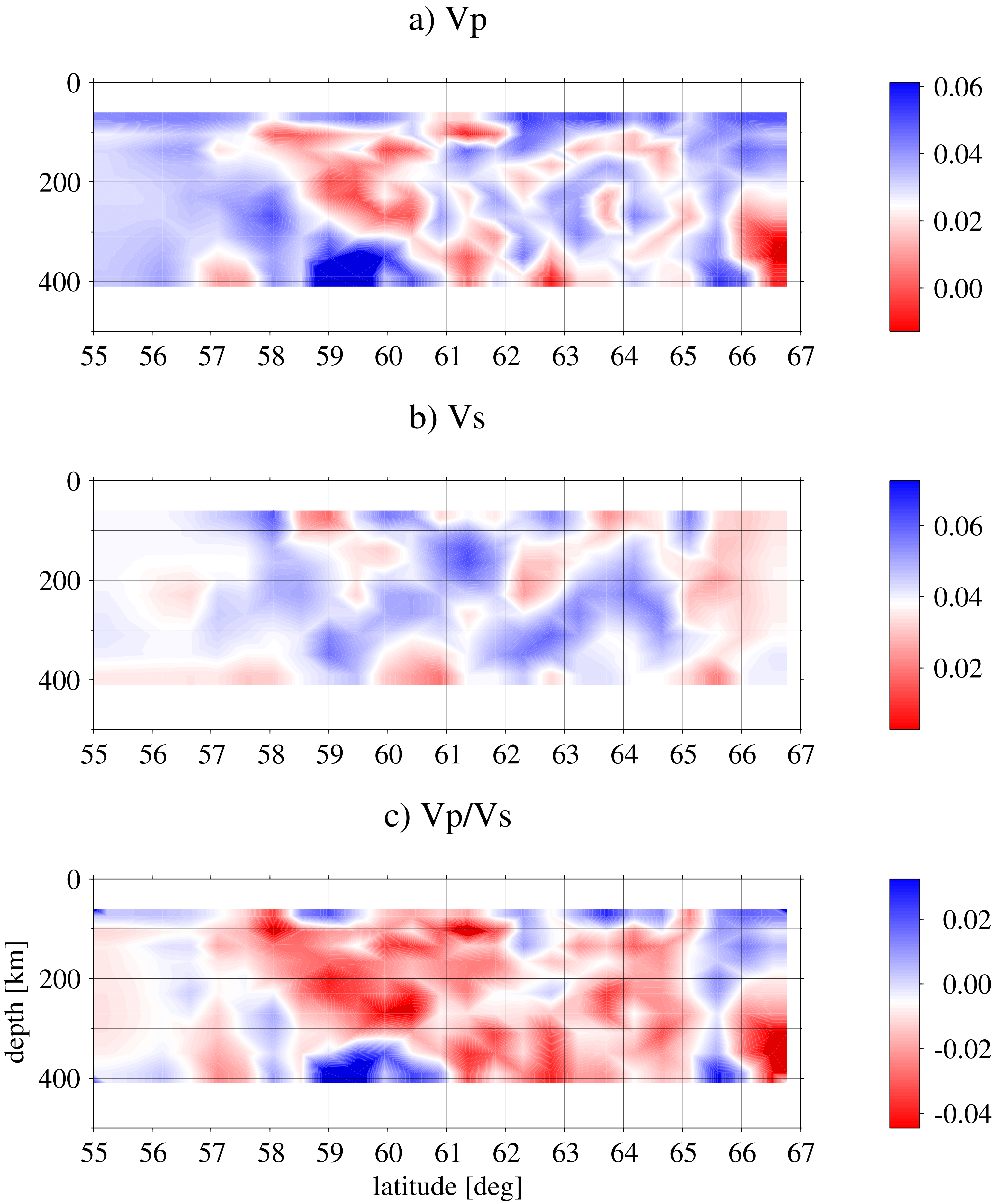
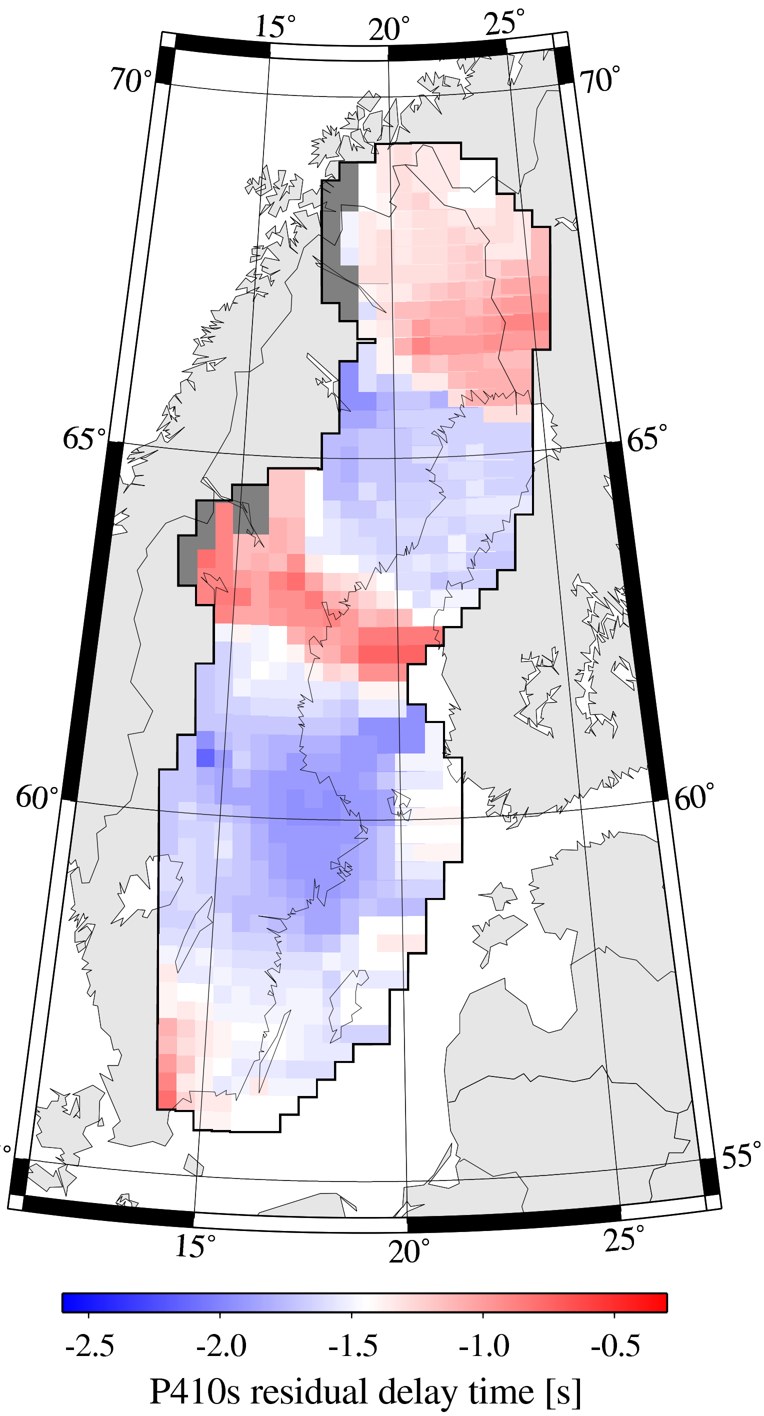
56
36
55°
55°
15°
20°
25°



56°
58°
60°
62°
64°
66°
68°
0
100
200
300
depth [km]
A
B
C
D1
D2
L
?
0
500
1000
1500
distance along profile [km]


a) Vp
b) Vs
c) Vp/Vs
depth [km]
latitude [deg]
0
200
400
55
56
57
58
59
60
61
62
63
64
65
66
67
0.06
0.04
0.02
0.00
-0.02
-0.04


15°
20°
25°
70°
70°
65°
65°
60°
60°
55°
55°
15°
20°
25°
-2.5
-2.0
-1.5
-1.0
-0.5
P410s residual delay time [s]