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Domains of Archean mantle lithosphere deciphered by seismic anisotropy – initial results from the LAPNET array in northern Fennoscandia

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An international LAPNET array (2007–2009, <http://www.oulu.fi/sgo-oty/lapnet>) of the POLENET/LAPNET sub-project of the POLENET-IPY consortium, related to POLENET seismic and geodetic studies in the Arctic regions, consisted of about 60 broadband seismic stations located on the territory of northern Finland and adjacent parts of Sweden, Norway and Russia. We analyze relative P-wave travel-time deviations evaluated for a subset of 90 teleseismic events recorded by the LAPNET array and show examples of lateral variations of shear-wave splitting to demonstrate variability of fabrics of the Archean mantle lithosphere. The initial results clearly demonstrate the Archean mantle lithosphere consists of domains with consistent fabrics reflecting fossil anisotropic structures. 3-D self-consistent anisotropic models with inclined symmetry axes accommodate two independent sets of body-wave anisotropic observations. Individual domains are delimited by boundaries (sutures), where the anisotropic parameters change. The results obtained from the LAPNET array fill a gap in structural studies of the upper mantle beneath northern Fennoscandia.

1 Introduction

The main target of the POLENET/LAPNET sub-project of the POLENET-IPY consortium is to carry out an interdisciplinary research based on a temporary broadband array of seismic stations in the area of northern Finland and adjacent parts of Sweden, Norway and Russia. The international array (see Fig. 1 – list of institutions involved) recorded teleseismic, regional and local events during May 2007–September 2009 for studies that will contribute to the POLENET multidisciplinary research in northern Fennoscandia. Waveforms of seismic phases travelling through the shield are archived for structural studies. Recordings of glacial earthquakes are of particular interest as well (Poutanen and Ivins, 2010; Kozlovskaya et al., 2011).

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The research benefiting from the LAPNET array aims at obtaining a 3-D seismic model of the crust (Silvennoinen et al., 2011) and upper mantle down to 670 km (P- and S-wave velocity tomography models, positions of major boundaries in the crust and the upper mantle, and estimates of seismic anisotropy strength and orientation) in the northern Fennoscandian Shield, particularly beneath the Archean domain of Fennoscandia. The 3-D model can be used to define spatial distribution and depth of the Archean lithosphere for different purposes, e.g., for diamond prospecting. The 3-D model of the crust and the upper mantle will also be used to improve registration and location of local earthquakes and understanding of mechanisms of local seismicity in northern Fennoscandia (e.g., Uski et al., 2006).

Pioneering tomographic studies of the European upper mantle (Aki et al., 1977) provided a rough imaging of the velocity structure. As expected, no distinct regional velocity variations within the upper mantle were detected in the Precambrian region since then, neither on a European scale (Amaru et al., 2008), nor in regional tomography studies based on data of temporary arrays in several regions of Fennoscandia (e.g., Plomerová et al., 2001; Sandoval et al., 2004; Shomali et al., 2006; Eken et al., 2007, 2008). The most significant velocity changes in the upper mantle can be related with lateral changes of depth of the lithosphere-asthenosphere boundary (Calcanile 1991; Cotte et al., 2002; Plomerová et al., 2002, 2008, 2010; Olsson et al., 2007). Studies of fossil anisotropy in most of Fennoscandia (except of its northern part) allowed us to map individual domains of mantle lithosphere with their own consistent fabrics. The domains differ in orientation of symmetry axes, their dips and sometimes also in symmetry of olivine aggregates approximating the structures (Plomerová et al., 2001, 2002, 2006; Vecsey et al., 2007). Retrieved 3-D self-consistent anisotropic models of the mantle lithosphere are delimited by boundaries/transitions which correlate with surface traces of dominant sutures or distinct tectonic faults.

This paper aims at presenting initial results on seismic anisotropy of the mantle lithosphere in northern Fennoscandia, obtained from the LAPNET array body-wave data processed in 3-D. The results are supposed to fill a gap in studies of velocity structure

of the upper mantle beneath Fennoscandia (e.g., Sandoval et al., 2004; Pedersen et al., 2006; Plomerová et al., 2006, 2008; Vecsey et al., 2007; Eken et al., 2010).

2 Data of the POLENET/LAPNET array and methods

The international LAPNET array of the POLENET/LAPNET project consisted of 37 temporary broadband stations and 20 permanent broadband observatories on territory of northern Finland, Sweden, Norway and adjacent rim of Russia (Fig. 1). Most of the stations were located north of the Arctic Circle, which made their servicing a difficult task, especially during the winter time. The array was active in a period from May 2007, when most of French stations were deployed, to September 2009, when temporary stations of the Czech pool were dismantled. Different instrumental equipments were spread over the region in such a way that the stations covered the territory homogeneously as to their spacing of about 70 km, on the average, and also as to the instrument types. The reason was to avoid a potential systematic waveform distortion that could concentrate in a part of the region. Thanks to the intensive work of all the participants on the data pre-processing and archiving, 740 Gb database of continuous recordings was created in the LGIT/J. Fourier University at Grenoble (France), under a guidance of H. Pedersen by summer of 2010. The data is now at stage of additional testing and processing.

In this study we present initial results of P-wave travel-time deviations evaluated for a subset of 90 teleseismic events recorded by the LAPNET array and examples of lateral variations of shear-wave splitting, to demonstrate a variability of the Archean mantle lithosphere fabric. To study P-wave travel-time deviations we picked arrival times on individual recordings simulating the WWSSN response with the use of new semi-automatic software developed by L. Vecsey. The software allows us to measure times of the first extremes correlated across the array and to calculate P-arrival times at individual stations. Applying this software resulted in ~50% decrease of standard deviations of the travel-time residuals in comparison with a manual picking or implementation of other semi-automatic pickers tested (e.g., Rawlinson and Kennett, 2004).

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To study large-scale anisotropy of the upper mantle, we first apply crustal corrections (Grad et al., 2009) and then analyze directional terms of relative residuals at individual stations of the array. We search for similarities and differences in distributions of these azimuth-incidence angle dependent terms determined relative to a station directional mean, which is calculated from station relative residuals (e.g., Babuška and Plomerová, 1992). We plot the directional terms in polar projection of the lower hemisphere to describe the three-dimensionality of the phenomenon and to locate changes in orientation of seismic anisotropy near tectonic boundaries. We relate the phenomenon to fossil anisotropy in the mantle lithosphere (Babuška and Plomerová, 2006, for review).

To confirm the existence of the upper mantle anisotropy beneath the Shield, we analyze splitting parameters of shear waves refracted at the core-mantle boundary (SKS), using the SPLIT software (Vecsey et al., 2008; <http://www.ig.cas.cz/en/personal-pages/ludek-vecsey/split/>). The software enables us to evaluate the shear-wave splitting in 3-D and thus, by inverting the varying splitting parameters (the fast S polarization direction and split delay time δt) along with sensitivity of the P-wave anisotropic parameters on the back-azimuths and angles of propagation within the upper mantle, to infer anisotropic structures with generally oriented (dipping) symmetry axes. At this stage of the research, we invert the P-wave anisotropic parameters separately and analyse jointly the two independent datasets to retrieve preliminary 3-D self-consistent anisotropic models of the mantle lithosphere which fit both types of body waves. We mainly concentrate on a search of boundaries of the Archean mantle lithosphere domains which exhibit a uniform anisotropy. Later on, after accumulating sufficient amount of shear-wave anisotropic parameters, we will invert the body-wave anisotropic parameters jointly to get self-consistent anisotropic models of the Archean part of the Fennoscandian mantle lithosphere.

3 Observed body-wave anisotropy

The northern part of Fennoscandia is well-situated relative to teleseismic earthquake foci. Even the subset of events analyzed up to now provided a good azimuthal coverage of rays at most of the stations. Stations with similar distribution of relatively early and delayed arrival times form groups with their characteristic P-sphere patterns (Fig. 2). The so called “bipolar pattern” (e.g., Babuška and Plomerová, 2006), used for P spheres in which an azimuth (+180) approximately separates the delayed and earlier propagations, is observed at majority of analysed stations. The stations with consistent “bipolar pattern” form three distinct regional groups in the northern and west-central parts of the array. The directional terms of the residuals lie in the interval (−0.5 s, 0.5 s). We associate the pattern with propagation through structures of the mantle lithosphere with opposite orientations of dipping high- and low-velocity directions. We infer the convergently dipping high-velocity directions beneath stations in the northern part of the array (Domains 1 on the east and Domain 3 on the west). In the central part of the array, no pattern dominates in the east (Domain 5), while the high velocities dipping to the NE characterize stations in the west (Domain 4), following thus by about 90° rotated pattern of the stations further to the north (Domain 3), where the high velocities dip to the SE. Only two stations in the southern part of the array (MSF and KU6) exhibit the distinct bipolar pattern similar to that of stations in the NW corner of the array (Domain 3). Further to the southwest, “no P pattern” prevails at most of stations (except of a weak, but not a bipolar pattern at station OUL). In general, the upper mantle, particularly the mantle lithosphere, beneath the Archean part of Fennoscandia exhibits distinct anisotropic characteristics in P-wave propagation in the north, while the mantle beneath the south-eastern part of the LAPNET array does not have a distinct anisotropic pattern. However, detecting no anisotropic signal does not exclude a presence of anisotropy in the upper mantle, but might also reflect a complicated structures resulting in annulling the anisotropic signal observed at the surface (see Fig. 5; Vecsey et al., 2007).

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5 The shear-wave splitting, analogical to the light birefringence in optics, is considered as evidence the waves propagate through an anisotropic medium. Orientation of the fast split shear-wave polarization and the time delay of the split slow-shear wave determine an orientation and intensity of the anisotropy. To model realistic 3-D anisotropic
10 structures of the upper mantle, we need to analyze a large number of shear-wave splitting polarizations and delay times for a large variety of directions of propagations. However, to demonstrate changes of the structure for different provinces we examine geographical variations of the two anisotropic splitting parameters evaluated for an event. Distinct variations of polarization directions, as well as of delay times, were detected
15 across the LAPNET array (Fig. 3). Stations with similar splitting parameters, evaluated for waves with easterly back-azimuths, form groups almost identical with those delimited by a resemblance of the P-sphere patterns, with null (LP51), or, a weak splitting (LP71, LP61) along the domain boundaries (e.g., Plomerová et al., 2001).

4 Modelling the mantle lithosphere domains delimited by body-wave anisotropy

15 It is evident that already at this initial stage of our research, based on the LAPNET data, we can claim that also the Archean mantle lithosphere of northern Fennoscandia consists of several domains with their own fabrics. Both the sharpness of boundaries of the domains mapped according to changes of the anisotropic body-wave parameters, and the correlation between the mantle boundaries and dominant tectonic sutures on the surface, justify us to associate the observed anisotropy with fossil preferred orientation of olivine in the mantle lithosphere. Generally accepted weak asthenosphere flow beneath cratons could hardly produce such abrupt changes observed beneath the shield (Vecsey et al., 2007; Eken et al., 2010). For the first simple estimates of the lithosphere domain fabrics, we invert the P-spheres for the symmetry axes orientation and calculate synthetic shear-wave splitting parameters for a comparison with
20 the observed ones (Fig. 4). Thickness of the mantle lithosphere domains is set to 100 km according to the lithosphere-asthenosphere boundary (LAB) depth estimates

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(Fig. 6) derived for the Archean part of the shield south of the LAPNET array (Vecsey et al., 2007) allows us to consider this tentative model as characterizing the fabrics of the Archean mantle lithosphere east of the complicated contact with the Proterozoic provinces on the west.

5 Though the azimuthal coverage of analyzed P waves is adequate to retrieve azimuths ϕ of the symmetry axes in the inversions reliably, angles of axis inclinations θ (measured from vertical) are less well resolved. This is also reflected in small split delay times calculated for the P models in Table 1 δt (calculated delays ~ 0.01 – 0.04 s vs. observed delays ~ 0.8 s), especially at domains, where the shear wave propagates close to the symmetry axis (Domain 1 and 2, cf. with backazimuth in Fig. 3).
10 Vecsey et al. (2011) showed that $\delta t \leq 0.3$ s, i.e., often considered as null splitting due to noise presented in real signals, is evaluated for rays in a cone as broad as 40° centred around the symmetry axis. Therefore, we modified the angles θ (Table 1) to get better fit between the synthetic and observed splitting parameters (Fig. 4). The steeply
15 inclined (a, c) foliations in the northern part of the array and gently inclined lineation in the central part of the array mimic well the observed shear-wave splitting for two teleseismic events with easterly back-azimuths. Such steep fabrics in the shield areas were also inferred from the radial and azimuthal anisotropy of surface waves (Babuška et al., 1998).

20 Sensitivity of different waves on orientations of domain fabrics and their changes strongly depends on wave lengths and on particle motions. The “null” shear-wave splitting (e.g., at station LP51, see Figs. 1 and 3) or significant reduction of split delay times (e.g., at stations LP71, or, LP61) can reflect the sub-vertical propagation of the shear wave close to a steep mantle boundary separating two lithosphere domains with
25 different fabrics, both sampled by the same long-period wave (Fig. 5). Wavelengths of the short-period longitudinal waves propagating in the lithosphere are about $1/4$ of the wavelengths of analyzed shear waves with dominant periods of ~ 8 – 10 s, on average. Therefore, the P-wave travel time deviations are more suitable to locate prominent steep boundaries in the mantle lithosphere (Fig. 5a). Such boundary, indicated beneath

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the NW part of the LAPNET array, can be related to Baltic-Bothnia Megashear Zone which separates the Norrbotten Craton on the west from the Karelian Craton in the east (Korja et al., 2006). On the other hand, in case of a gently dipping contact of two anisotropic blocks (Fig. 5b) the anisotropic signal can disappear on recordings of stations in a broader band around the surface trace of the boundary. This is observed in the P-wave anisotropic signal in the south-eastern part of the LAPNET array (Fig. 2). But some stations in the very east end of the province report the strongest anisotropic signal in the shear waves in its central part suggesting a ray path within the eastern anisotropic block was at least comparable with their wavelength, while a ray path in the western block was shorter for the particular direction of propagation. Surprisingly, the anisotropic model retrieved by the inversion of the P-wave anisotropic parameters in the west (Domain 4, Fig. 4) satisfies the observed splitting in the whole central part of the array between latitudes $\sim 66^\circ$ – 68° N.

We observed a similar distinct decrease of anisotropic signal in a broad zone at stations deployed during the SVEKALAPKO project south of the LAPNET array, which can be considered as the northward continuation of multi-disciplinary studies in Fennoscandia (Hjelt et al., 1996). The contact zone of the Archean-Proterozoic mantle lithosphere south of the LAPNET array appears as a broad zone of decreased anisotropic signal in the P waves and strongly direction-sensitive signal in the shear waves (Plomerová et al., 2006). Vecsey et al. (2007) modelled fabrics of the mantle lithosphere domains by 3-D self-consistent anisotropic structures with different orientations of inclined symmetry axes – the *b*-axis models (in the Proterozoic) and the *a*-axis models (in the Archean).

Location of temporary stations in southern part of the LAPNET (2007–2009) and stations in the northern SVEKALAPKO arrays (1998–1999) overlap, which allows us to compare the anisotropic signals from independent observations (Fig. 6). The P-sphere patterns at stations KU6 and MSF in the south-eastern rim of the LAPNET array are compatible with the patterns evaluated from stations in the north-eastern rim of the SVEKALAPKO array (e.g., FH01 \equiv MFS, FG02, FE03), though the SVEKALAPKO

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array operated for a shorter time (~10 months) and unfortunately, during a period with low teleseismic activity. The “no P-pattern” at the south-western part of the LAPNET stations has its continuation at stations in the central band of the SVEKALAPKO array (e.g., FK05) related to the Proterozoic-Archean transition zone (Plomerová et al., 2006).

Similarly to the situation at the southern end of the LAPNET array, we can compare the initial results obtained from the western part of the LAPNET array with findings of the anisotropy study beneath the Swedish National Seismological Network (SNSN, Eken et al., 2010) westward of the LAPNET array, though the end-of-stations in the north-eastern part of the SNSN did not have comparable amount of data at that time. Stations in this zone, situated most probably above the northern continuation of the Proterozoic-Archean transition in the upper mantle, do not have a clear “bipolar” P pattern, which could reflect fabric of a simple structure with dipping symmetry axis, indicating thus a more complex structure of the mantle lithosphere there.

Recognition of sharply bounded domains in the Archean mantle lithosphere is the most significant finding of this initial study of body-wave anisotropy beneath the LAPNET array. Although we need to process more data to model structures of the domains reliably in 3-D, particularly inclinations of the symmetry axes, the location of their boundaries delimited independently from the P- and S-wave anisotropy is convincing. Abrupt changes of the observed body-wave anisotropy, often related to distinct tectonic sutures, allows us to associate it with fossil structure of the mantle lithosphere and not with anisotropy reflecting an olivine orientation due to the present-day flow and/or local circulations in the sub-lithospheric mantle, which is, on top of that, generally considered to be very small beneath cratons (Montagner, 1998; Pedersen et al., 2006; Assumpção et al., 2011).

In our previous studies, we modelled the domain-like structures of continental lithosphere in different European provinces, mostly of Proterozoic and younger ages (Plomerová and Babuška, 2010 for review). Vecsey et al. (2007) modelled dipping fabrics in the Archean provinces in south-eastern Finland. Also study of surface-wave

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polarization anisotropy suggests steeply inclined fabrics beneath Archean cratons, in general (Babuška et al., 1998). As one of possible mechanisms how such fabric could be formed, Babuška and Plomerová (1989) proposed a scenario based on cycles of oceanic lithosphere subductions, accretions of micro-continent fragments and a gradual stabilization of the lithosphere-asthenosphere boundary by a mantle flow after a detachment of lower parts of subducting slabs. Such plausible scenario can work in the modern plate-tectonic style. We also have to seek for explanations of the fossil fabrics observed in the Archean provinces, i.e., a fabric created at early-stage of plate tectonics or in pre-plate tectonic style (Condie and Benn, 2006). At any case, the early lithosphere formed in dynamic conditions, far from simple cooling which should produce a sub-horizontal layered structure of the lithosphere (Plomerová and Babuška, 2010).

5 Conclusions

Similarly to what we found in other continental regions, the mantle lithosphere of northern Fennoscandia consists of several blocks with differently oriented fabrics. We detected anisotropic signal at stations of the LAPNET array – both in the P-wave travel-time deviations and shear-wave splitting. The anisotropic parameters change across the array and stations with similar characteristics form groups. The geographical variations of seismic-wave anisotropy delimit individual domains of the mantle lithosphere, each having a consistent fabric. The domains are sharply bounded both in the Proterozoic and Archean provinces and can be modelled in 3-D by peridotite aggregates with dipping lineation a or foliation (a, c). These findings allow us to interpret the domains as micro-plate fragments retaining fossil fabrics in the mantle lithosphere, reflecting thus an olivine LPO created before the micro-plates assembled, and formed in dynamic conditions far from simple cooling processes which would result in horizontally layered structures. Studies of fossil anisotropy preserved in the mantle lithosphere contribute both to mapping the lithosphere-asthenosphere boundary and deciphering the boundaries of individual blocks building the continental lithosphere.

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5 References

Aki, K., Christoffersson, A., and Husebye, E. S.: Determination of 3-dimensional seismic structure of lithosphere, *J. Geophys. Res.*, **82**, 277–296, 1977.

Amaru, M. L., Spakman, W., Villasenor, A., Sandoval, S., and Kissling, E.: A new absolute arrival time data set for Europe, *Geophys. J. Int.*, **173**, 465–472, 2008.

10 Assumpção, M., Guarido, M., van der Lee, S., and Dourado, J. C.: Upper-mantle seismic anisotropy from SKS splitting in the South American stable platform: A test of asthenospheric flow models beneath the lithosphere, *Lithosphere*, **3**, 173–180; doi:10.1130/L99.1, 2011.

Babuška, V. and Plomerová, J.: Seismic anisotropy of the subcrustal lithosphere in Europe: another clue to recognition of accreted terranes?, in: *Deep structure and past kinematics of accreted terranes*, edited by: Hillhouse, J. W., *Geophys. Monograph*, **50**, IUGG Vol. 5, Washington DC, 209–217, 1989.

15 Babuška, V. and Plomerová, J.: The lithosphere in central Europe – seismological and petrological aspects, *Tectonophysics*, **207**, 141–163, 1992.

Babuška, V. and Plomerová, J.: European mantle lithosphere assembled from rigid microplates with inherited seismic anisotropy, *Phys. Earth. Planet. Inter.*, **158**, 264–280, 2006.

20 Babuška, V., Montagner, J.-P., Plomerová, J., and Girardin, N.: Age-dependent large-scale fabric of the mantle lithosphere as derived from surface-wave velocity anisotropy, *Pure and Appl. Geophys.*, **151**, 257–280, 1998.

Babuška, V., Plomerová, J., and Šílený, J.: Models of seismic anisotropy in deep continental lithosphere, *Phys. Earth Planet. Interior*, **78**, 167–191, 1993.

25 Calcagnile, G.: Deep structure of Fennoscandia from fundamental and higher mode dispersion of Rayleigh waves, *Tectonophysics*, **195**, 139–149, 1991.

Condie, K. C. and Benn, K.: Archean Geodynamics: Similar to or different from modern geodynamics? In: *Archean Geodynamics and Environments*, edited by: Benn, K., Mareschal, J.-C., Condie, K. C., *AGU Geophysical Monograph* **164**, Washington, DC, 206, 47–60, 2006.

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Cotte, N., Pedersen, H. A., and TOR Working Group: Sharp contrast in lithospheric structure across the Sorgenfrei-Tornquist Zone as inferred by Rayleigh wave analysis of TOR1 project data, *Tectonophysics*, 360, 75–88, 2002.

Eken, T., Plomerová, J., Roberts, R., Vecsey, L., Babuška, V., Shomali, H., and Bodvarsson, R.: Seismic anisotropy of the mantle lithosphere beneath the Swedish National Seismological Network (SNSN), *Tectonophysics*, 480, 241–258, 2010.

Eken, T., Shomali, H., Roberts, R., and Bodvarsson, R.: Upper mantle structure of the Baltic Shield below the Swedish National Seismological Networks (SNSN) resolved by teleseismic tomography, *Geophys. J. Int.*, 169, 617–630, 2007.

Eken, T., Shomali, Z. H., Roberts, R., Hieronymus, Ch. F., and Bodvarsson, R.: S and P velocity heterogeneities within the upper mantle below the Baltic Shield, *Tectonophysics*, 462, 109–124, 2008.

Grad, M., Tiira, T., and ESC Working Group: The Moho depth map of the European Plate, *Geophys. J. Int.*, 176, 279–292, 2009.

Hjelt, S.-E., Daly, S., and SVEKALAPKO colleagues: SVEKALAPKO – evolution of Palaeoproterozoic and Archean lithosphere, edited by: Gee, D. G., and Zeyen, H. J., *Lithosphere Dynamics, Origin and Evolution of Continents*, Uppsala University, 57–67, 1996.

Korja, A., Lahtinen, R., and Nironen, M.: The Svekofennian orogen: a collage of microcontinents and island arcs, edited by: Gee, D. G. and Stephenson, R. A., *European Lithosphere Dynamics*, Geol. Soc. London, Memoirs, 32, 561–578, 2006.

Kozlovskaya, E. and the POLENET/LAPNET Working Group: Analysis of glacial seismic events from Greenland recorded by the POLENET/LAPNET experiment during the IPY 2007–2009, EGU General Assembly, Vienna, Austria, 3–8 April 2011, *Geophysical Research Abstracts*, 13, EGU2011-8322, 2011.

Montagner, J.-P.: Where can seismic anisotropy be detected in the Earth's mantle?, in: *Boundary Layers*, *Pure Appl. Geophys.*, 151, 223–256, 1998.

Olsson, S.: Analyses of seismic wave conversion in the crust and upper mantle beneath the Baltic Shield, *Digital Comprehensive Summaries of Uppsala Dissertations from of Science and Technology* 319, Acta-Universitatis-Upsaliensis-Uppsala, ISBN: 978-91-554-6919-1, 2007.

Pedersen, H. A., Bruneton, M., Maupin, V., and SVEKALAPKO STWG: Lithospheric and sublithospheric anisotropy beneath the Baltic Shield from surface wave array analysis, *Earth Planet. Sci. Lett.*, 244, 590–605, 2006.

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- Poutanen, M. and Ivins, E. R.: Upper mantle dynamics and quaternary climate in cratonic areas (DynaQlim)-Understanding the glacial isostatic adjustment, *J. Geodyn.*, 50, 2–7, 2010.
- Plomerová, J. and Babuška, V.: Long memory of mantle lithosphere fabric - European LAB constrained from seismic anisotropy, *Lithos*, 120, 131–143, 2010.
- 5 Plomerová, J., Arvidsson, R., Babuška, V., Granet, M., Kulhánek, O., Poupinet, G., and Šílený, J.: An array study of lithospheric structure across the Protogine zone, Varmland, south-central Sweden – signs of a paleocontinental collision, *Tectonophysics*, 332, 1–21, 2001.
- Plomerová, J., Babuška, V., Vecsey, L., Kouba, D., and TOR Working Group: Seismic anisotropy of the lithosphere around the Trans-European Suture Zone (TESZ) based on teleseismic body-wave data of the TOR experiment, *Tectonophysics*, 360, 89–114, 2002.
- 10 Plomerová, J., Babuška, V., Vecsey, L., Kozlovskaya, E., Raita, T., and SSTWG: Proterozoic-Archean boundary in the upper mantle of eastern Fennoscandia as seen by seismic anisotropy, *J. Geodyn.*, 41, 400–410, doi:10.1016/j.jog.2005.10.008, 2006.
- Plomerová, J., Babuška, V., Kozlovskaya, E., Vecsey L., and Hyvonen, L. T.: Seismic anisotropy – a key to resolve fabrics of mantle lithosphere of Fennoscandia, *Tectonophysics*, 462, 125–136, 2008.
- 15 Rawlinson, N. and Kennett, B. L. N.: Rapid estimation of relative and absolute delay times across a network by adaptive stacking, *Geophys. J. Int.*, 157, 332–340, doi:10.1111/j.1365-246X.2004.02188.x, 2004.
- 20 Sandoval, S., Kisling, E., Ansorge, J., and SVEKALAKO Seismic Tomography working Group: High-resolution body wave tomography beneath the SVEKALAPKO array – II. Anomalous upper mantle structure beneath the central Baltic Shield, *Geophys. J. Int.*, 157, 200–214, 2004.
- Shomali, Z. H., Roberts, R. G., Pedersen, L. B., and the TOR Working Group: Lithospheric structure of the Tornquist Zone resolved by nonlinear P and S teleseismic tomography along the TOR array, *Tectonophysics*, 416, 133–149, 2006.
- 25 Silvenoinenn, H., Kozlovskaya, E., Kissling, E., Janik, T., and the POLENET/LAPNET Working Group: Compilation of initial 3-D crustal model northern Fennoscandian shield, *Geophysical Research Abstracts*, 13, EGU2011-9968, 2011.
- 30 Uski, M., Tiira, T., Korja, A., and Elo, S.: The 2003 earthquake swarm in Anjalankoski, south-eastern Finland, *Tectonophysics*, 422, 55–69, 2006.
- Vecsey, L., Plomerová, J., and Babuška, V.: Shear-wave splitting measurements – problems and solutions, *Tectonophysics*, 462, 178–196, doi:10.1016/j.tecto.2008.01.021, 2008.

Vecsey, L., Plomerová, J., Eken, T., and Babuška, V.: Role of seismic anisotropy in isotropic tomographic models of the upper mantle, Geophysical Research Abstracts, Vol. 13, EGU2011-3164, 2011.

5 Vecsey, L., Plomerová, J., Kozlovskaya, E., and Babuška, V.: Shear-wave splitting as a diagnostic of varying upper mantle structure beneath south-eastern Fennoscandia, Tectonophysics, 438, 57–77, 2007.

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3, 655–678, 2011

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Table 1. Anisotropic models retrieved by the P-sphere inversion, along with modifications of inclination angle to fit the shear-wave splitting.

Region	P-model	Original inversion				Modified	
		θ°	ϕ°	H(km)	$v_p(\text{km s}^{-1})$	θ°	ϕ°
Domain 1	<i>b</i> -axis	25	80	100	8.1	80	80
Domain 2	<i>b</i> -axis	30	105	100	8.1	80	105
Domain 3	<i>b</i> -axis	60	275	100	8.3	60	280
Domain 4	<i>a</i> -axis	15	55	100	8.5	70	55

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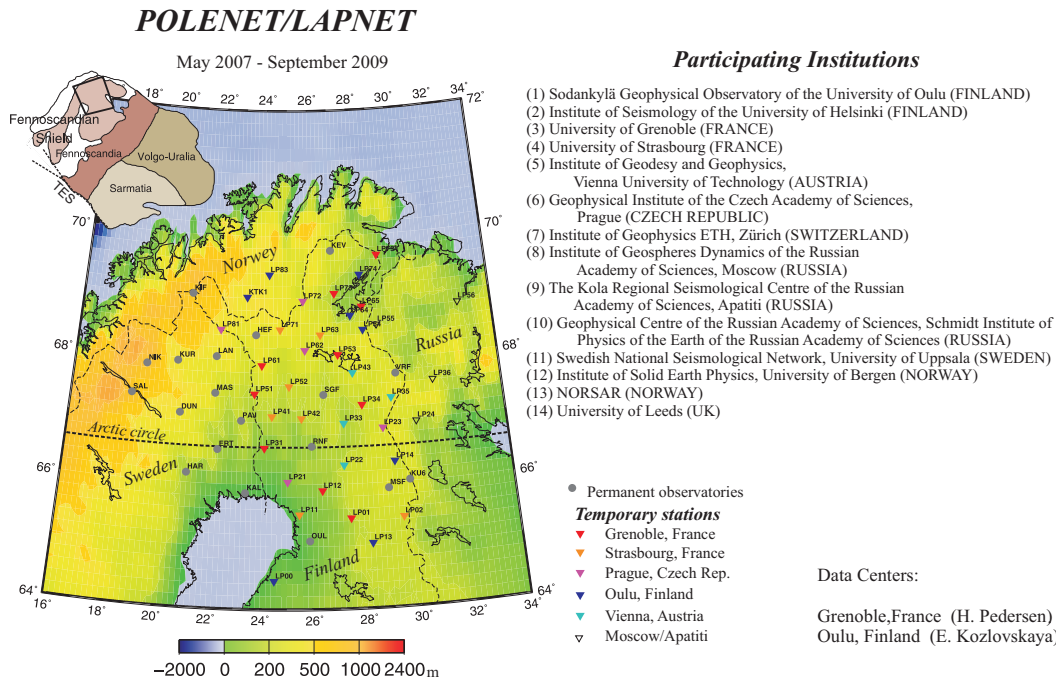


Fig. 1. POLENET/LAPNET network of broad-band seismological stations.

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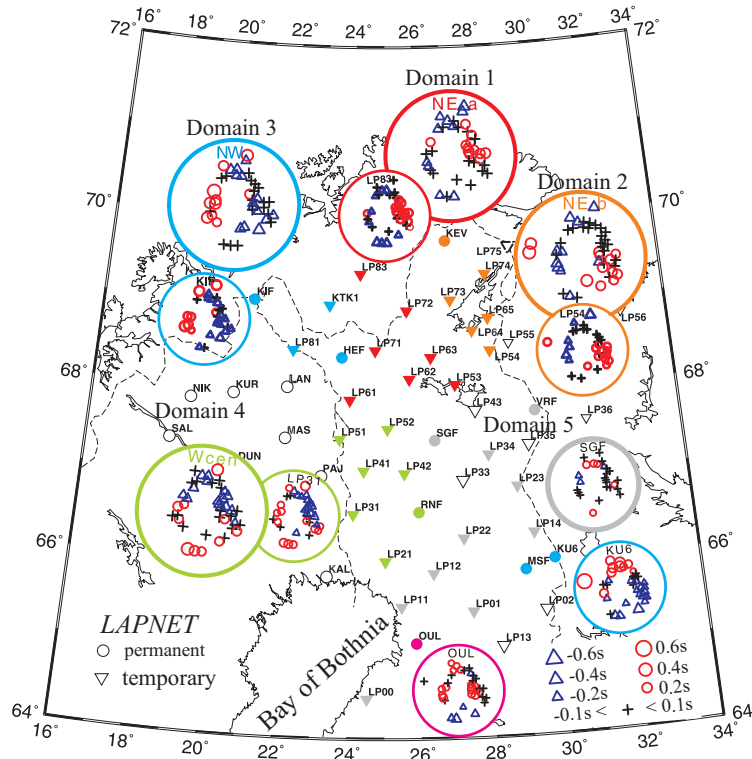


Fig. 2. Stations clustered into domains according to similarity of distribution of early and delayed travel times relative to a directional mean at each station, calculated from relative residuals. The P spheres show smoothed azimuth-incidence angle dependent terms for representatives of each group and those calculated from all stations included in each group (marked by different colours).

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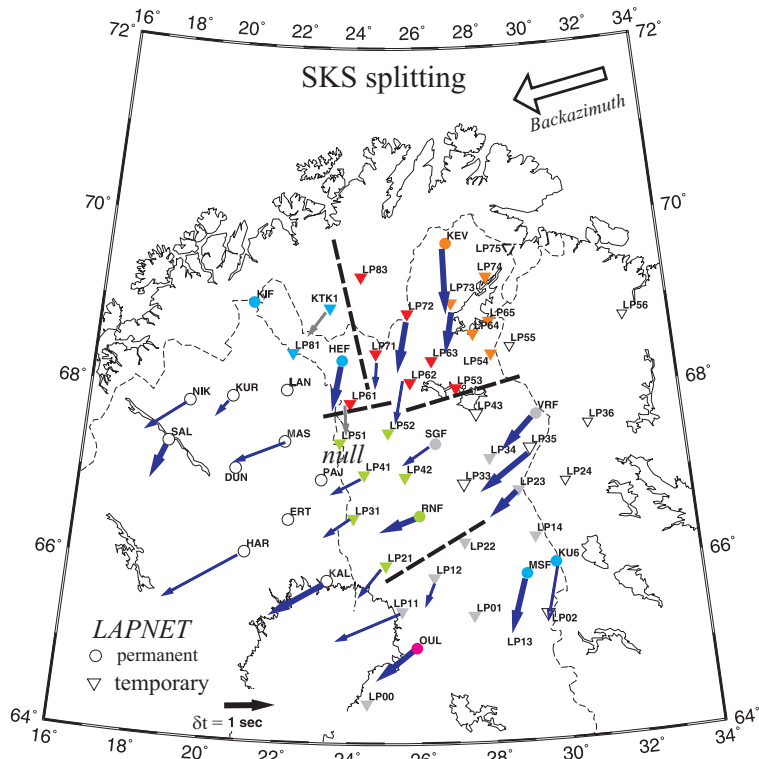
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2008/08/04 20:45:14.0 5.91S 130.19E, depth 173km, Mw 6.1, BANDA SEA

Fig. 3. Geographical variations of fast shear-wave polarizations and split delay times for an event occurred on 2008/08/04 at 20:45:14.0 with epicentre in Banda Sea -5.91°S , 130.19°E . Stations with similar fast S polarizations and split delay times form groups like those determined from P-spheres (stations in the same colours as in Fig. 2). Anisotropic signal of shear wave decreases or disappears (null split) at stations close to boundaries (schematically marked by dashed lines). Good, firm and poor splitting measurements are marked by thick, thin and empty-head arrows, respectively.

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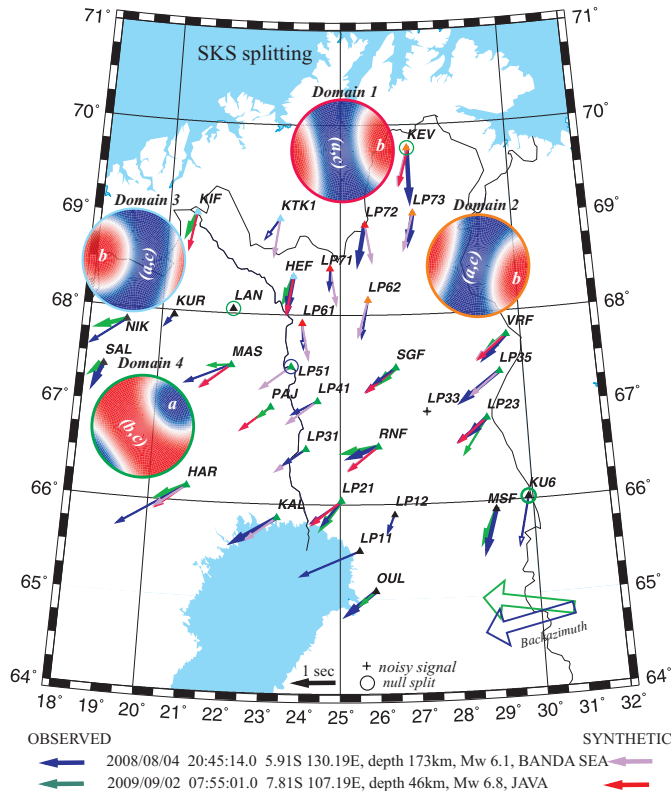


Fig. 4. Observed and synthetic shear-wave splitting for two events with easterly back-azimuths modelled according to results of the P-sphere inversions with modified inclination of symmetry axes (see Table 1). Stations (triangles) are coloured according to the anisotropic model used. Anisotropic aggregates with divergently dipping high-velocity (a, c) foliations (the b -axis models) approximate the lithosphere fabric beneath the northern part of the LAPNET array, whereas in the central part a model with steeply dipping lineation a (the a -axis model) fit the observed shear-wave splitting and P-wave anisotropic parameters (in its western part).

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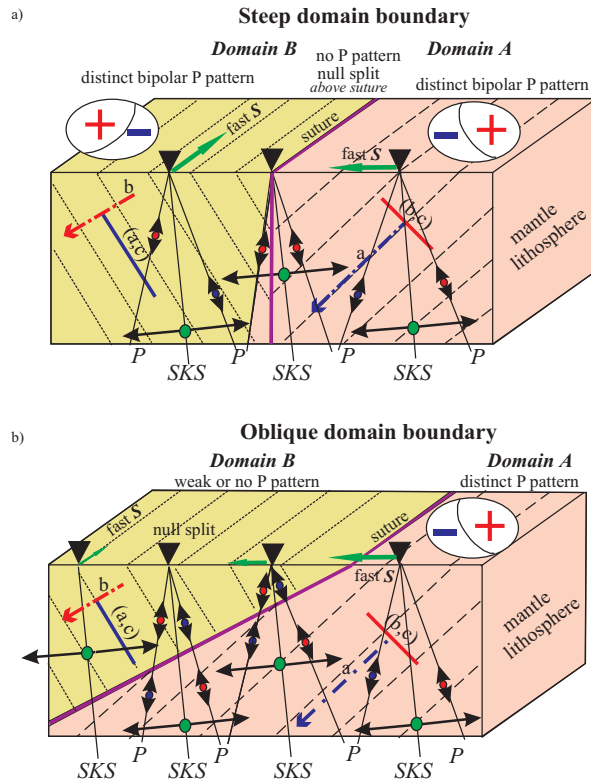


Fig. 5. Schematic fast shear-waves (long arrows perpendicular to rays) and their polarizations (green arrows) along with distribution of early (blue) and delayed (red) P-wave (short longitudinal arrows along rays) arrivals and their projection into the P spheres (schematic bipolar pattern shown) within two blocks with different orientation of anisotropy. Domain B is characterized by olivine aggregate with hexagonal symmetry b (the b -axis model) and dipping high-velocity foliation (a, c). Domain A is approximated by hexagonal aggregate with dipping lineation a (the a -axis model). Anisotropic signal in shear waves propagating along a near vertical suture disappears (null splitting), or, decreases significantly, because the waves sample both structures. If the waves travel across an inclined suture we can detect anisotropic signal reflecting a structure, which is consistent in a volume at least comparable with the shear wavelength. The steep suture is marked by an abrupt change in the P-sphere pattern, while the oblique suture is reflected as a broader transition with no or weak anisotropic P pattern.

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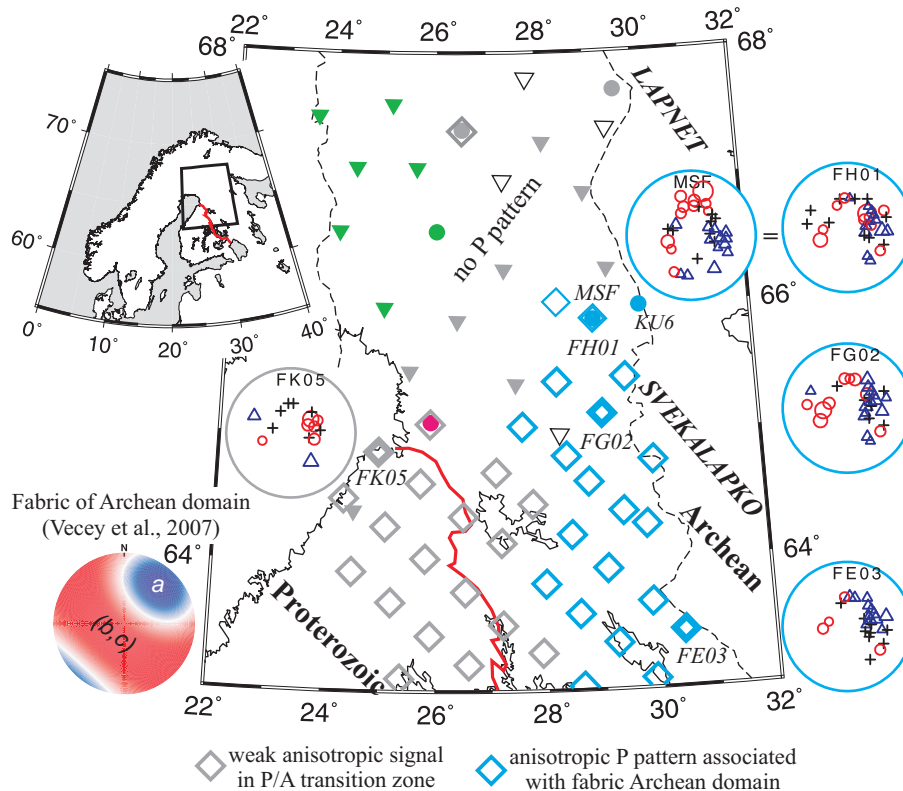


Fig. 6. Linkage of the P-sphere patterns in the southern part of the LAPNET array overlapping with the northern part of the SVEKALAPKO array. No P-pattern identified in the south-eastern part of the LAPNET array (full grey triangles and circles) concurs with the weak anisotropic signal at stations above the Proterozoic/Archean (P/A) transition zone in the upper mantle evaluated from the SVEKALAPKO data (Plomerová et al., 2006). Examples of the P-spheres for stations FH01, FG02 and FE03 of the SVEKALAPKO array in the Archean domain of Karelia (blue diamonds) show high degree of resemblance with the two south-easternmost stations of LAPNET (MSF and KU6).

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