Surface wave analysis of Botswana using two-station and ambient noise methods

Introduction

NARS-Botswana is a temporary seismological network of 21 seismometers that is currently installed in Botswana. Its main aim is to explore the subsurface structure and the geodynamical framework of one of the least studied areas in Africa and the world. In this study we use surface wave analysis to obtain insight into the tectonic framework of the study area. Here we present preliminary results for data from 13 NARS-Botswana stations and an additional GSN station (LTBT). Fig.1 shows the stations used here (NARS) in yellow color while we are still waiting for data from (NARS-W) stations in grey color.

The area is characterized by complex tectonics between the Kaapval Craton in the south-east and the Congo Craton in the north-west. It includes mobile fold belts of Paleo-Proterozoic, Paleo- Meso-Proterozoic and Neo-Proterozoic ages, with ophiolites and main faults trending northeast-southwest, and a supposed buried ancient craton called (Maltahohe) in the south-western part (Begg et al., 2009).

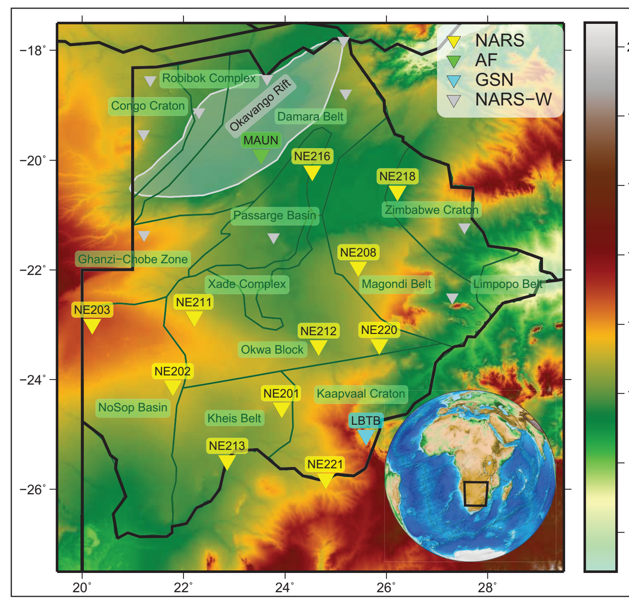
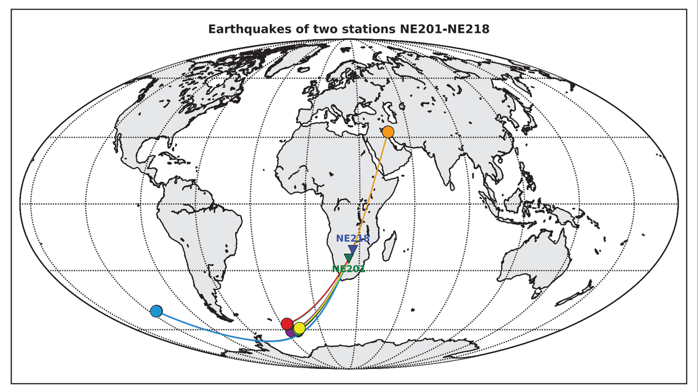


Fig.1 NARS-Botswana network and geological provinces.

Two-station analysis

Interstation phase velocities were obtained from the cross-correlations of the vertical component records of earthquakes within 7 degrees from the interstation azimuth and at epicentral distances from 5 to 120 degrees. The data were corrected for instrument response and decimated to 1 Hz. After visual inspection of the cross-correlations, the phase velocity curves were determined by frequency-time analysis (FTAN; Bensen et al., 2007). Signal to noise ratio (SNR) threshold of 20 was used.

Out of the 78 possible station pairs, 25 showed good dispersion curves. Therefore more data is needed to improve the coverage.



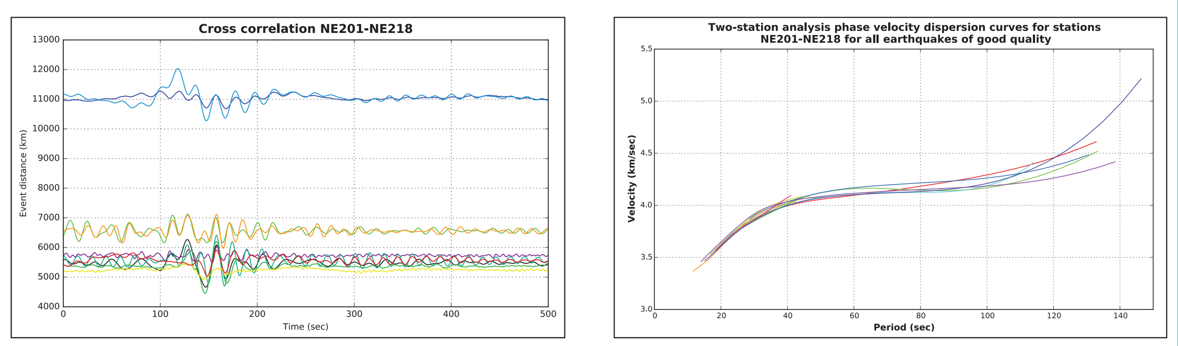


Fig. 2 Example of the two-station analysis for NE201-NE218. The dispersion curves for 10 different earthquakes show good agreement in the period range of 15 to 100 s.

Ambient noise analysis

Rayleigh wave dispersion curves for periods of 3 to 40 seconds were extracted for 3 months of noise data between March and June 2014 using the methodology by Poli et al., (2013).

- 4-hour time windows.
- Exclude windows that contain amplitudes larger than 10 times the standard deviation of the window data.
- Instrument correction.
- Decimation to 1 Hz.
- Spectral whitening.
- Cross-correlation.

We then applied FTAN with a signal to noise ratio (SNR) threshold of 20.

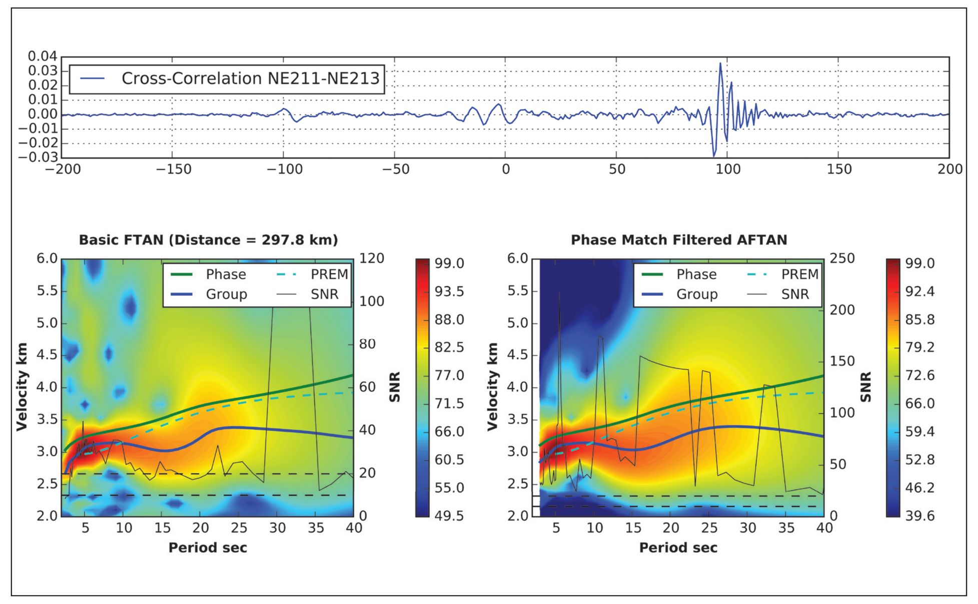


Fig. 4 Frequency-time analysis (FTAN) for NE211-NE213. Left: Basic FTAN result. Right: Cleaned FTAN after applying the phase-matched filter.

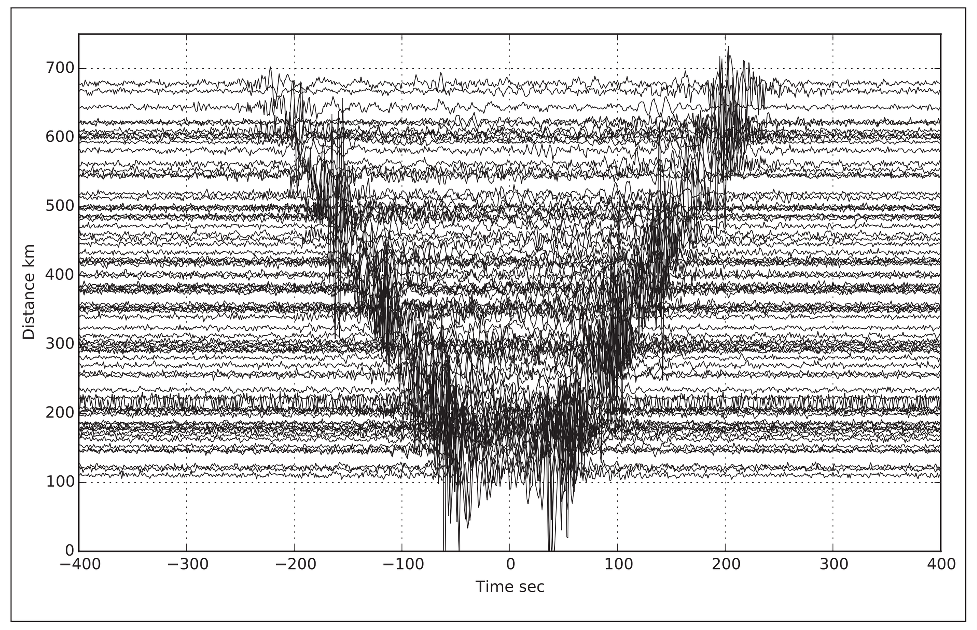


Fig. 3 Three-month cross-correlations filtered between periods of 3—40 sec for all station pairs.

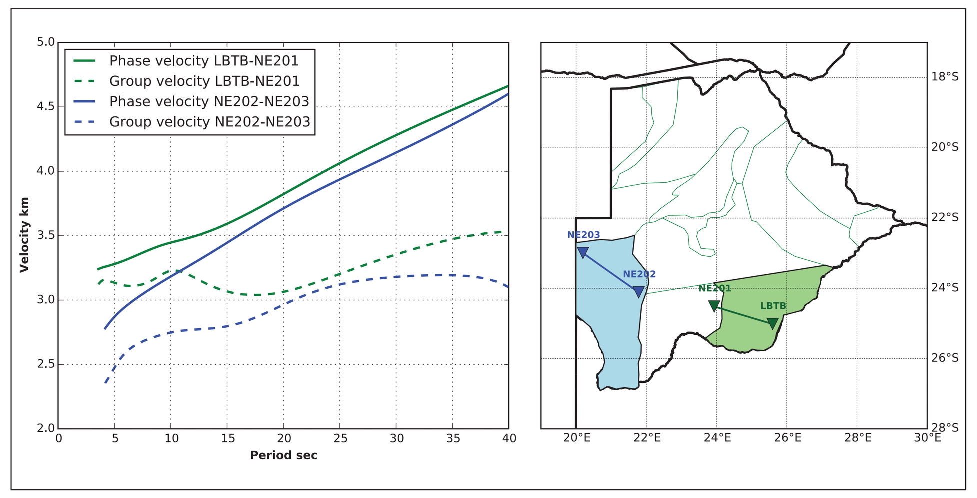


Fig. 5 The dispersion curves show a striking correlation with the tectonic provinces of the study area. The dispersion curves of interstation path LBTB-NE201 within the Kaapvaal Craton shows high velocities at short periods compared to the dispersion curves of NE202-NE203 located within the NoSop Basin that is characterized by a thick layer of the Karoo Sediments group.

Ambient noise surface wave tomography

We inverted the dispersion curves into phase velocity maps for periods 3-40 seconds using the method of Barmin et al. (2001). It is based on minimizing a penalty function based on data misfit, model smoothness, and perturbation from a reference model. Here we show our first results for a 1° x 1° grid with a smoothing distance of 111 km with a weight (α = 100) and path weighted damping (β = 0.4, λ = 1).

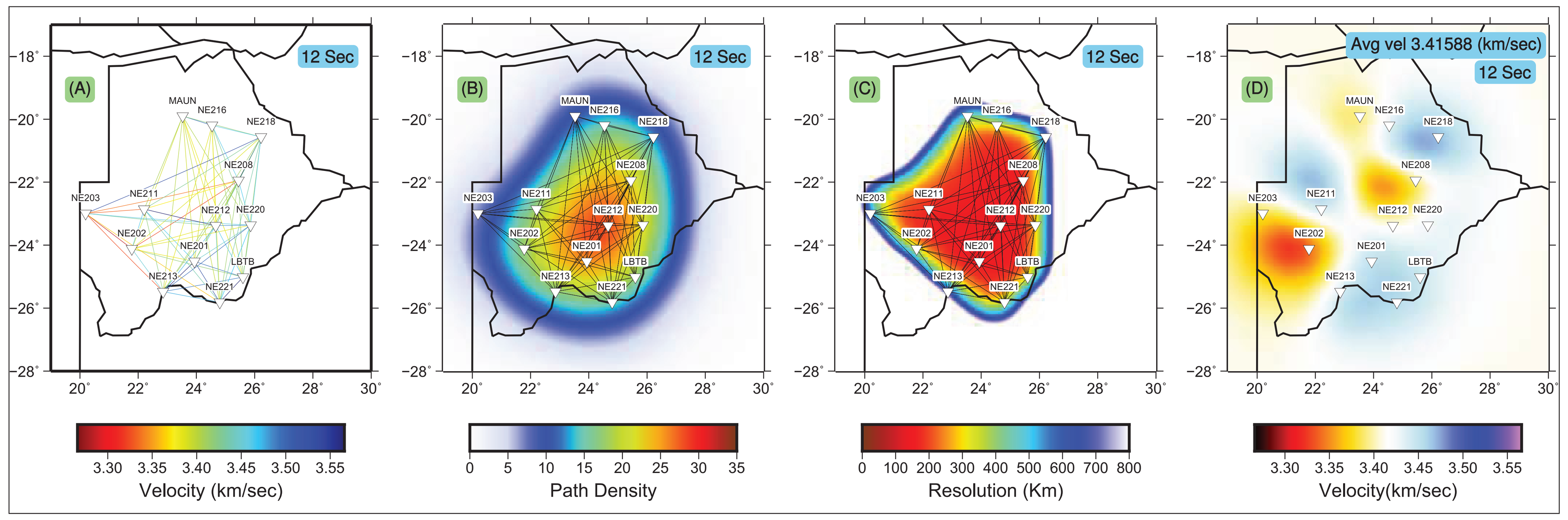


Fig. 6 Example of the inversion of 12 sec period. (A) The interstation path velocities. (B) The path density distribution over the inversion grid. (C) The resolution in km. (D) The inversion results.

Results

In general, the phase velocities showed agreement with the tectonic features:

5-15 sec maps: The most obvious feature is the low-velocity are of the Nosop basin in the southwest. Also, the high-velocity areas of Kaapvaal and Zimbabwe cratons can be identified. Moreover, a low-velocity feature can be recognized from the Damara belt (Okavango rift system) to towards the Passarge basin and Okwa block.

15-30 sec maps: The obvious features are the high-velocity area of the Kaapvaal Craton and the low-velocity area under the Passarge basin and Okwa block. This low-velocity anomaly can be related to the development of the incipient Okavango rift zone. Moreover, a high-velocity feature starts to develop under the Nosop basin. This can be either extension of the Kaapval Craton or a buried ancient craton (Maltahohe) as suggested by Begg et al., (2009).

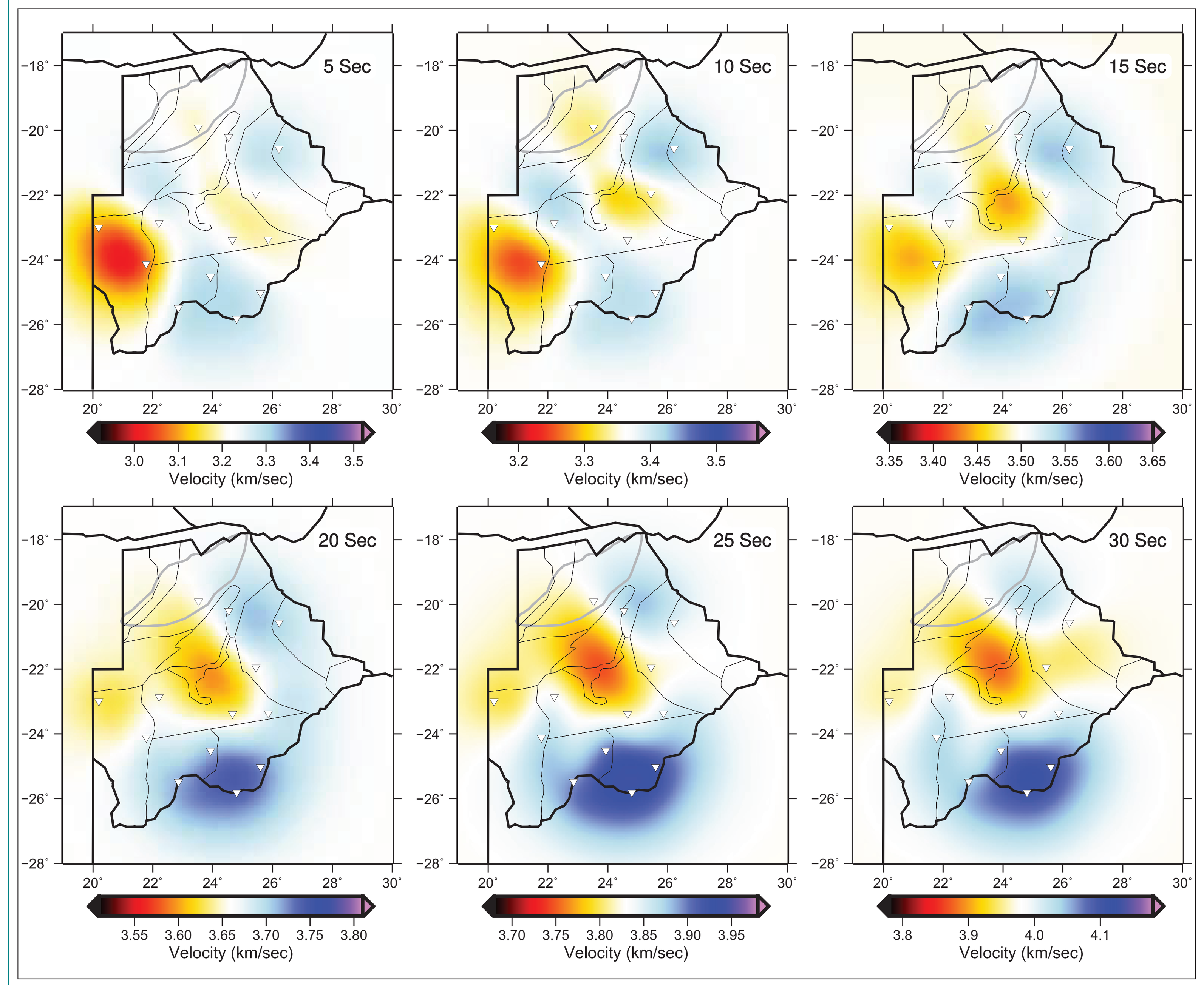


Fig.7 the phase velocity maps of periods 5, 10, 20, 25, and 30 sec results overlaid with the geological provinces.

Conclusions

- The estimated phase velocity maps showed **a good agreement with the tectonic provinces** in the study area.
- **A low-velocity anomaly** has been found underneath Damara belt, Passarge basin, and Okwa block, which may be related to the development of **the incipient Okavango rift system**.
- **High-velocities** have been detected at periods 20-30 sec in the south-west underneath the Nosop Basin which can be related to **a buried craton**.

Future work: By next year, more data will be available to improve the data coverage and the quality of the measurements of the two-station (period 15-100 sec) and noise (period 5-30 sec) analyses. The phase velocity maps will then be inverted for a 3D tomographic shear-wave velocity model to image the subsurface structure of the study area.

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References

Begg, G. C., Griffin, W. L., Natapov, L. M., O'reilly, S. Y., Grand, S. P., O'neill, C. J., Hronsky, J. M. A., Djomani, Y. P., Swain, C. J., Deen, T. & Bowden, P., 2009. The lithospheric architecture of Africa: Seismic tomography, mantle petrology, and tectonic evolution. Geosphere, 5, 23-50.

Barmin, M. P., Ritzwoller, M. H., and Levshin, A. L., 2001. A fast and reliable method for surface wave tomography, Pure appl. Geophys., 158, 1351—1375.

Bensen, G. D., Ritzwoller, M.H., Barmin, M.P., Levshin, A.L., Lin, F., Moschetti, M.P., Shapiro, N.M., and Yang, Y., 2006. Processing seismic ambient noise data to obtain reliable broad-band surface wave dispersion measurements, Geophys. J. Int., 169, 1239—1260.

Knopoff, L., 1972. Observation and inversion of surface-wave dispersion, Tectonophysics, 13, 497—519.

Poli, P., Pedersen, H.A., Campillo, M. & the POLENET/LAPNET Working Group, 2013. Noise directivity and group velocity tomography in a region with small velocity contrasts: the northern Baltic Shield, Geophys. J. Int., 192, 413—424.

For more information

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