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Poster Presentation EGU 2020–11544 May 5, 2020

Crustal structure of Sri Lanka derived from joint inversion of SWD and RF using a Bayesian approach

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Citation

The content of this presentation is published. For citing, consider:

- **Dreiling et al., 2020**: Dreiling, J., Tilmann, F., Yuan, X., Haberland, C., & Seneviratne, S.W.M. (2020). Crustal structure of Sri Lanka derived from joint inversion of surface wave dispersion and receiver functions using a Bayesian approach. Journal of Geophysical Research: Solid Earth. https://doi.org/10.1029/2019JB018688.

- **Dreiling and Tilmann, 2019**: Dreiling, J., & Tilmann, F. (2019). BayHunter – McMC transdimensional Bayesian inversion of receiver functions and surface wave dispersion. GFZ Data Services. https://doi.org/10.5880/GFZ.2.4.2019.001 and https://github.com/jenndrei/BayHunter.

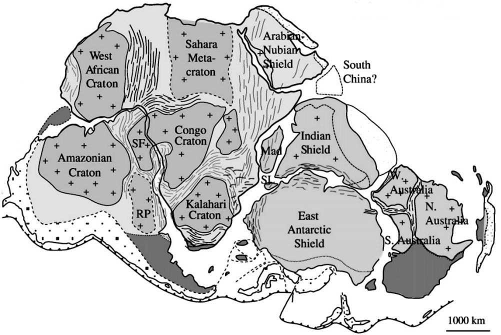
Abstract

We study the crustal structure of Sri Lanka by analyzing data from a temporary seismic network deployed in 2016–2017 to shed light on the amalgamation process from a geophysical perspective. Rayleigh wave phase dispersion curves from ambient noise cross-correlation and receiver functions were jointly inverted using a transdimensional Bayesian approach.

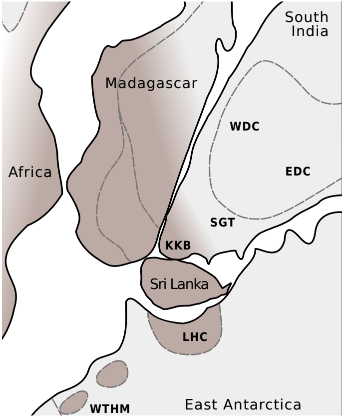
The Moho depths in Sri Lanka range between 30 and 40 km, with the thickest crust (38–40 km) beneath the central Highland Complex (HC). The thinnest crust (30–35 km) is found along the west coast, which experienced crustal thinning associated with the formation of the Mannar Basin. $\mathrm{V_P}/\mathrm{V_S}$ ratios lie within a range of 1.60–1.82 and predominantly favor a felsic to intermediate bulk crustal composition with a significant silica content of the rocks.

A major intra-crustal (18–27 km depth), slightly westward dipping ($\sim$4.3°) interface with high $\mathrm{V_S}$ ($\sim$4 km/s) underneath is prominent in the central HC, continuing into the western Vijayan Complex (VC). The discontinuity might have been part of the respective units prior to the collision and could be an indicator for the proposed tilting of the WC/HC crustal sections. It might also be related to the deep crustal HC/VC thrust contact with the VC as an indenting promontory of high $\mathrm{V_S}$. A low velocity zone in the central HC could have been caused by fluid influx generated by the thrusting process.

Geologic Background
Gondwana's assembly and break-up



(Meert and Lieberman, 2008)



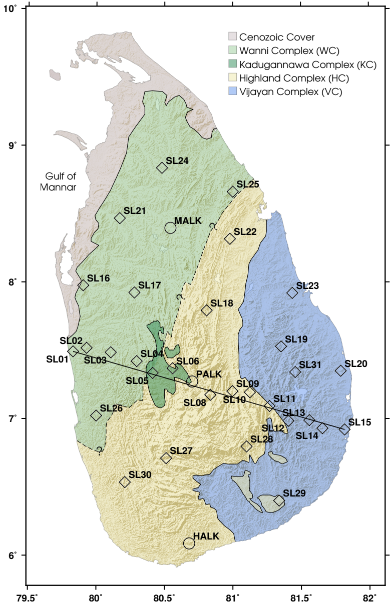
Pan-African Orogeny (PAO)

- stepwise collision of cratons (750–490 Ma) to form Gondwana

Gondwana break-up

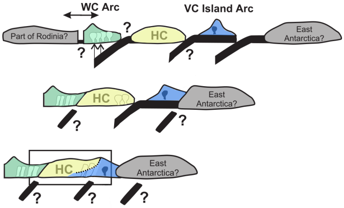
- stepwise break-up between 185–100 Ma

Geologic Background
Gondwana's assembly and break-up



Geology

- Amalgamation during PAO
  (Kehelpannala, 2004)

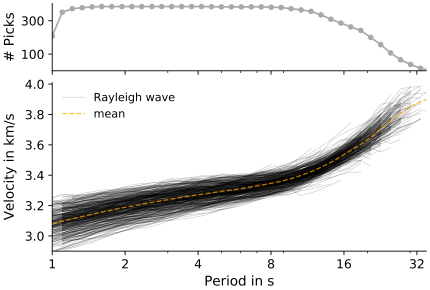


Seismic network

- 33 seismic stations
- continuous seismic data between 2016–2017

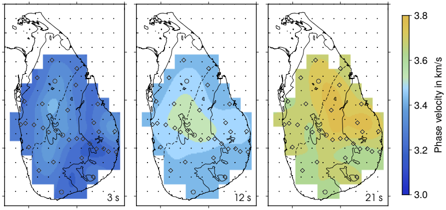
Dispersion measurements

- ambient noise cross-correlation between station pairs
- phase velocities were measured (ZZ, ZR, RZ, RR) and stacked to receive Rayleigh wave dispersion curves



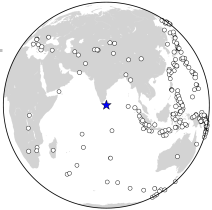
Tomography

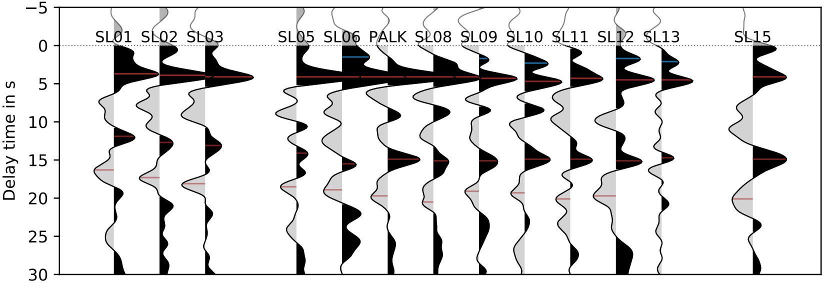
- tomography was performed at 40 discrete periods
- tomographic dispersion curves were assembled at locations of seismic stations



Receiver functions

- events M>5.5, distances 30–90°
- filtering, trimming, downsampling, rotation to LQT, and deconvolution of event traces to compute RFs
- RFs from each station were stacked to a final RF





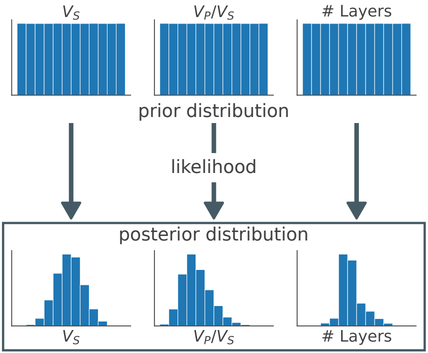
RF stacks along profile (location on map). – Moho phases; – intra-crustal phases

Bayes's theorem

$$p(m|d_{obs})p(d_{obs}) = p(d_{obs}|m)p(m)$$

$$p(m|d_{obs}) \propto p(d_{obs}|m)p(m)$$

posterior $\propto$ likelihood $\cdot$ prior



BayHunter – A Python tool for Bayesian joint inversion. Available on GitHub.

Parameters

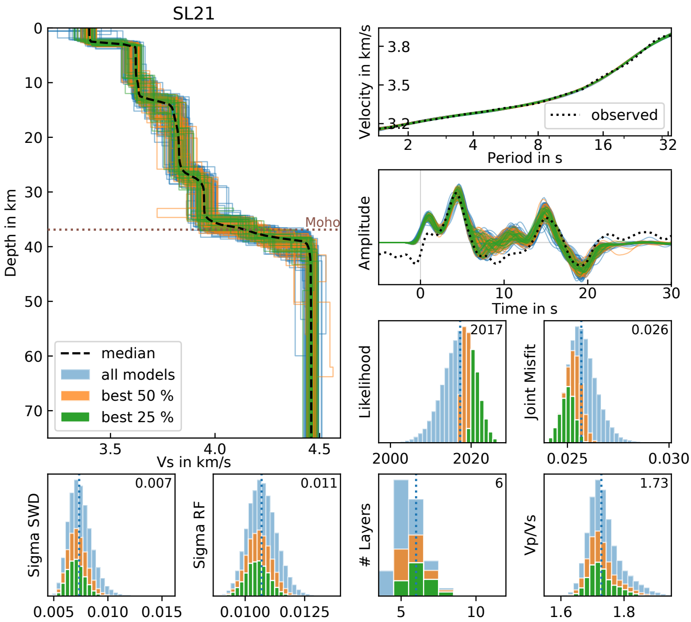
- $\mathrm{V_S}$-depth structure
- crustal $\mathrm{V_P}/\mathrm{V_S}$
- data noise (σ)
- number of layers

Parameter space

- exploration based on Bayes's theorem
- Markov chain Monte Carlo sampling
- two sampling phases

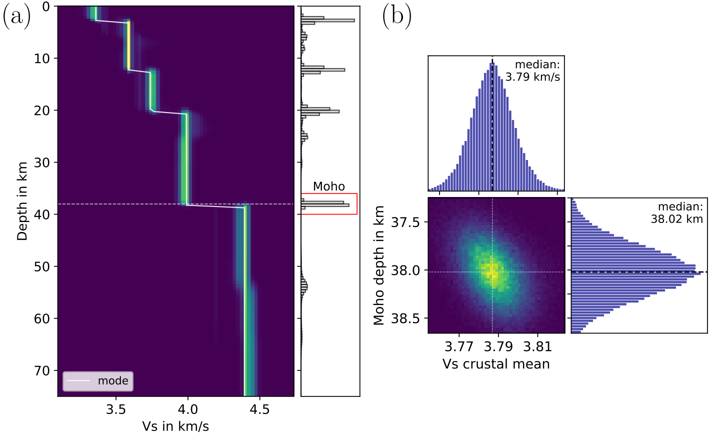
Bayesian Inversion Results

Posterior distribution (100,000 models) for SL21



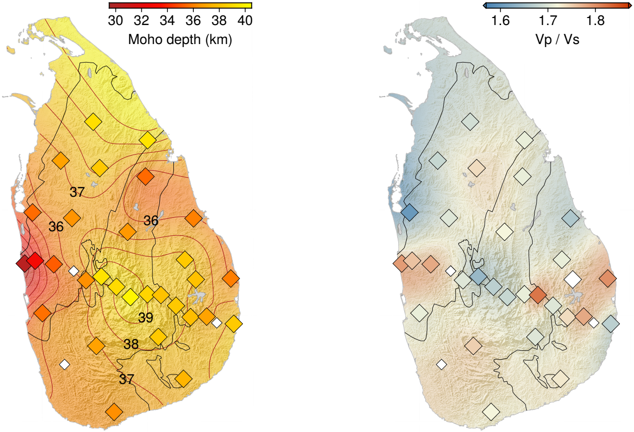
Bayesian Inversion Results

Estimation of Moho depth for SL10



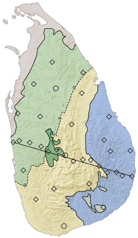
Observations

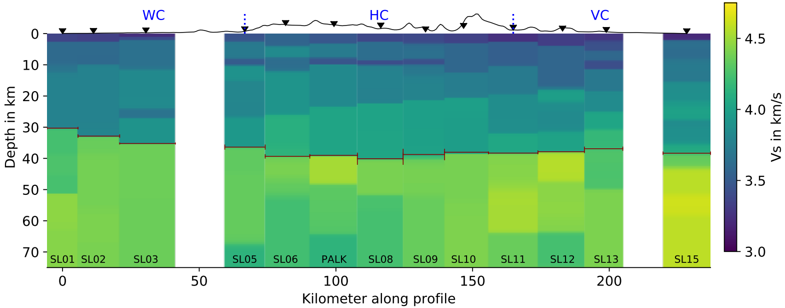
- Moho interface depth between 30 and 40 km
- V_P/V_S between 1.60 and 1.82 (felsic/intermediate)



Observations

- central low velocity zone at ∼10 km depth
- mid-crustal interface dipping between 18 and 27 km
- Moho interface depth between 30 and 40 km

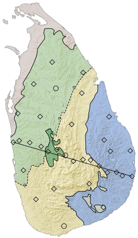


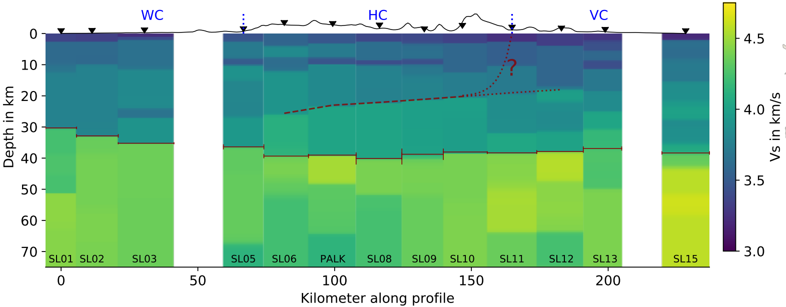


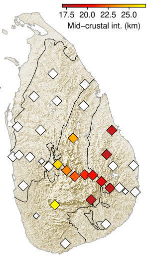
Bayesian Inversion Results
for Sri Lanka

Interpretations

- low velocity zone might represent a different rock composition through fluid influx
- mid-crustal feature in HC might represent a tilted crustal section or the HC/VC thrust contact





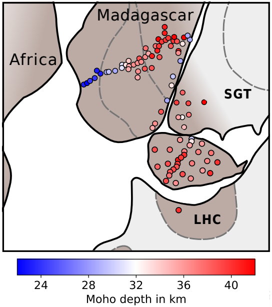


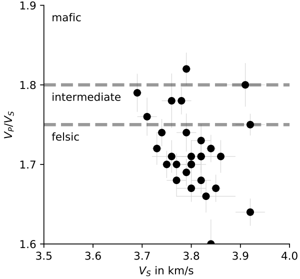
Bayesian Inversion Results
in context of Gondwana deformation

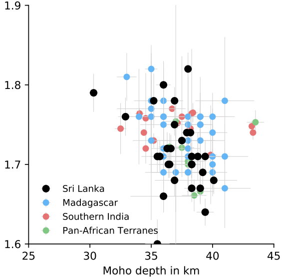
Comparison to Pan-African terranes

- Moho depths: 32–40 km
- felsic/intermediate bulk crustal composition
- upper crustal LVZ in some terranes

→ similarities hint toward strong crustal unification during Pan-African Orogeny







Conclusion and Summary

Crustal structure of Sri Lanka

- felsic/intermediate bulk crustal composition
- upper crustal LVZ indicates a different rock composition
- mid-crustal interface represents an inherited structure in the HC or the HC/VC thrust contact
- Moho discontinuity shows mostly isostatically compensated crust

Comparison to other Pan-African terranes

- seismic similarities due to region spanning unification during PAO
- differences through autochtone terrane compositions, positions within the orogen, and individual reworking processes after PAO

References

- **Dreiling et al., 2020**: Dreiling, J., Tilmann, F., Yuan, X., Haberland, C., & Seneviratne, S.W.M. (2020). Crustal structure of Sri Lanka derived from joint inversion of surface wave dispersion and receiver functions using a Bayesian approach. Journal of Geophysical Research: Solid Earth. https://doi.org/10.1029/2019JB018688.
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- **Dreiling and Tilmann, 2019**: Dreiling, J., & Tilmann, F. (2019). BayHunter – McMC transdimensional Bayesian inversion of receiver functions and surface wave dispersion. GFZ Data Services. https://doi.org/10.5880/GFZ.2.4.2019.001 and https://github.com/jenndrei/BayHunter.

Figures are taken from:

- **Meert and Lieberman, 2008**: Meert, J. G. and Lieberman, B. S. (2008). The Neoproterozoic assembly of Gondwana and its relationship to the Ediacaran–Cambrian radiation. Gondwana Research.
- **Kehelpannala, 2004**: Kehelpannala, K. (2004). Arc accretion around Sri Lanka during the assembly of Gondwana. Gondwana Research.