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The eastern Rio Grande Rise: a magmatic province

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T45D-0270

Introduction

The Rio Grande Rise and Walvis Ridge are prominent bathymetric features of the South Atlantic. Both likely formed above the Tristan da Cunha mantle plume during the opening of the South Atlantic, when the plume was located beneath or close to the southern Mid-Atlantic spreading ridge (Fig. 1). The western Rio Grande Rise (WRGR) (Fig. 2) formed together with the older parts of the Walvis Ridge between 120-80 Ma. Between 80-60 Ma, the Walvis Ridge (WR) and WRGR were seperated and the easter Rio Grande Rise (ERGR) was formed together with its counterpart on the African Plate.

In the last decade, several wide-angle seismic experiments unraveled the crustal structure of the Walvis Ridge, showing that it is composed of thickened oceanic crust. In contrast, the evolution of the RGR is still debated. The recovery of rock samples of continental character, like granites, quartz sand, and high-grade silica-rich metamorphic rocks, questioned if the RGR is also entirely composed of oceanic crust or if it contains fragments of continental crust.

In 2019, a research expedition was conducted to investigate the crustal structure and composition of the RGR. We present a P-wave velocity profile (Fig. 3) crossing the ERGR in a NNE-SSW direction. We compare the crustal structure of the ERGR to the crustal structure of different parts of the Walvis Ridge and the WRGR.

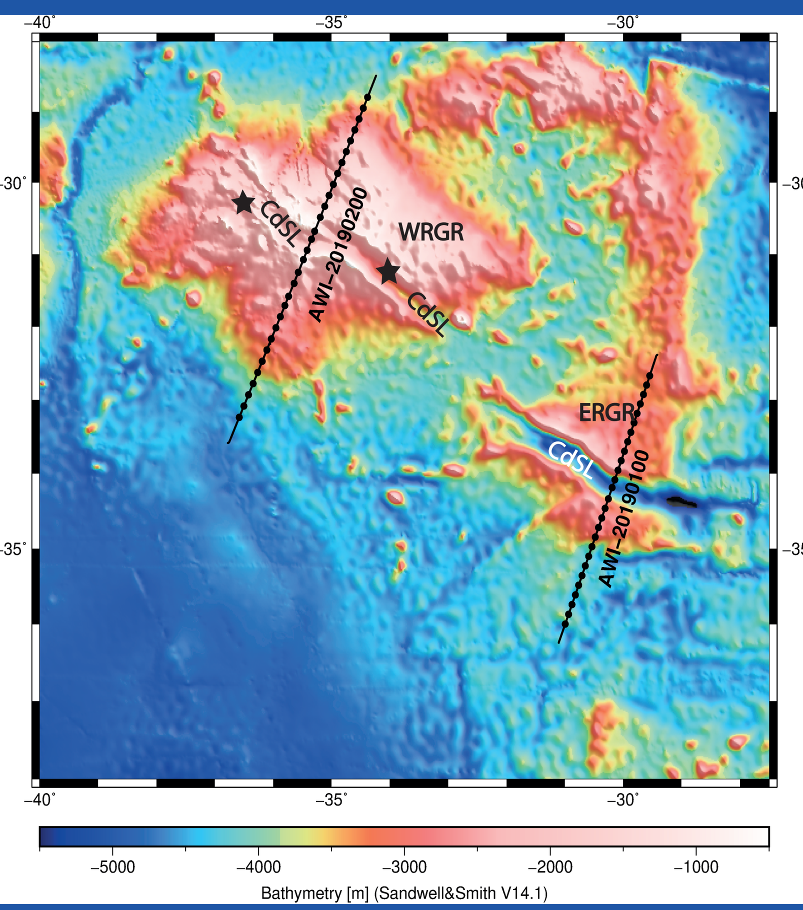


Fig. 2: Bathymetry map showing the locations of seismic refraction profiles AWI-20190100 (eastern Rio Grande Rise) and AWI-20190200 (western Rio Grande Rise)
The deployment positions of the ocean bottom seismometers (OBS) are marked with black circles. The refraction seismic profile is shown as a black line. Both profiles cross the Cruzeiro do Sul Lineament (CdSL). Black stars mark the position of dredged rocks of continental character.

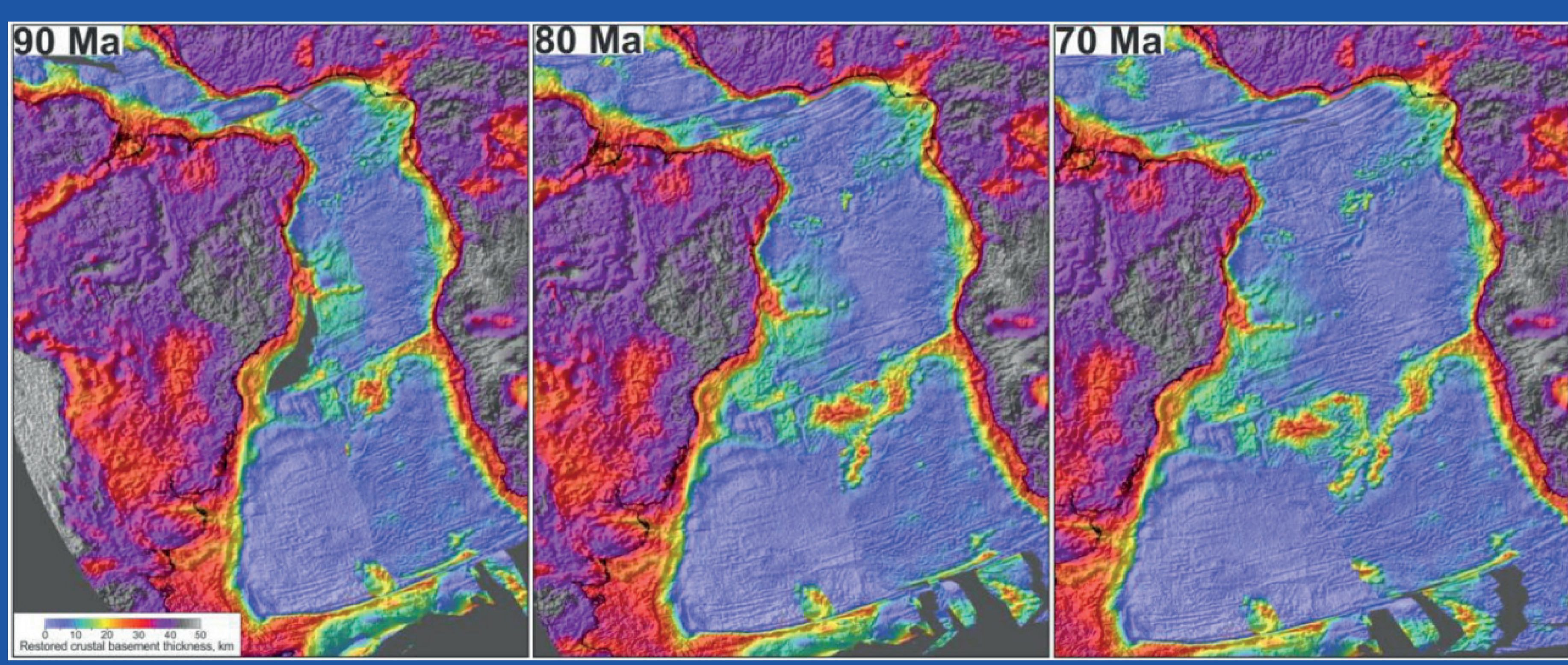


Fig. 1: Plate tectoni reconstruction showing the evolution of the Rio Grande Rise and Walvis Ridge between 70 - 40 Ma, taken from Graça et al. (2019)

P-wave velocity model AWI-20190100

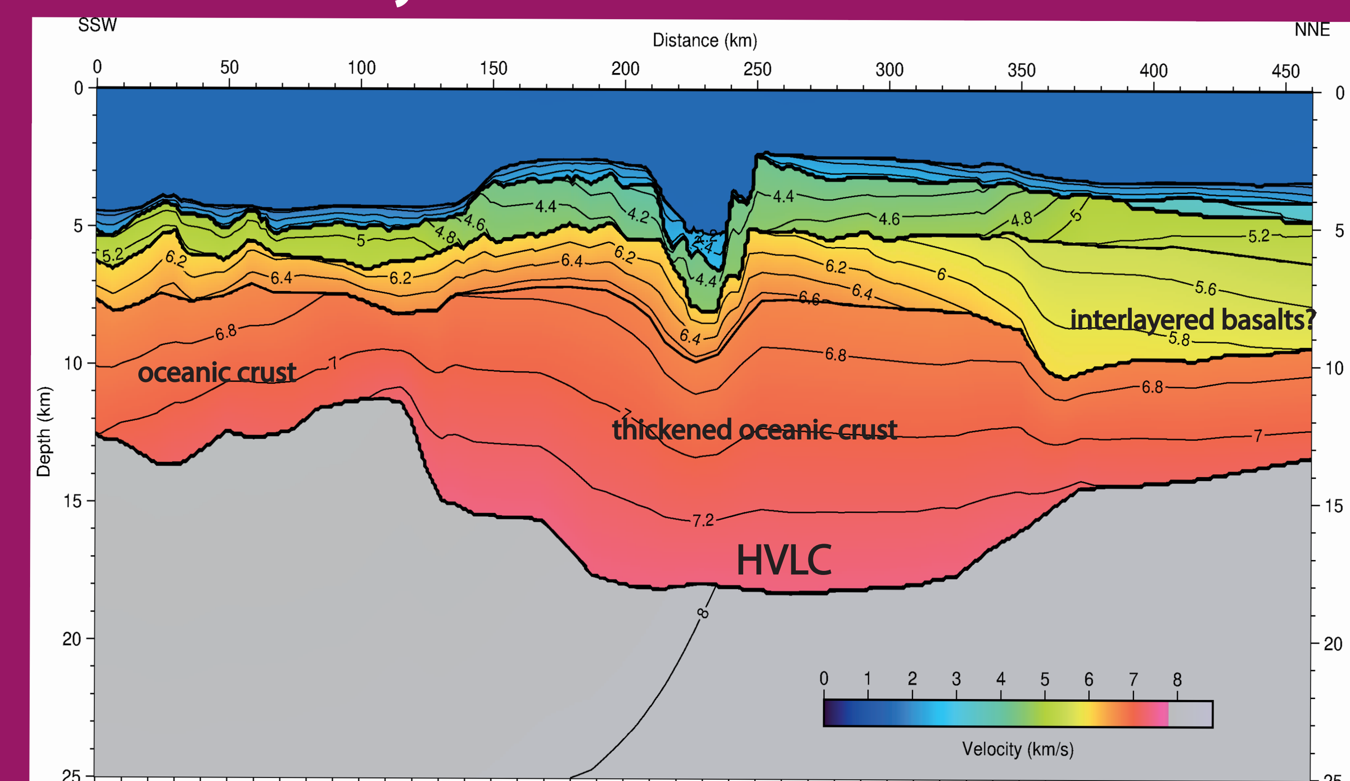


Fig. 4: P-wave velocity model 20190100, derived by forward modelling
Thick black lines mark the boundaries of the velocity layer. The ray coverage and computed travel times are shown in Figs. 5 and 6.

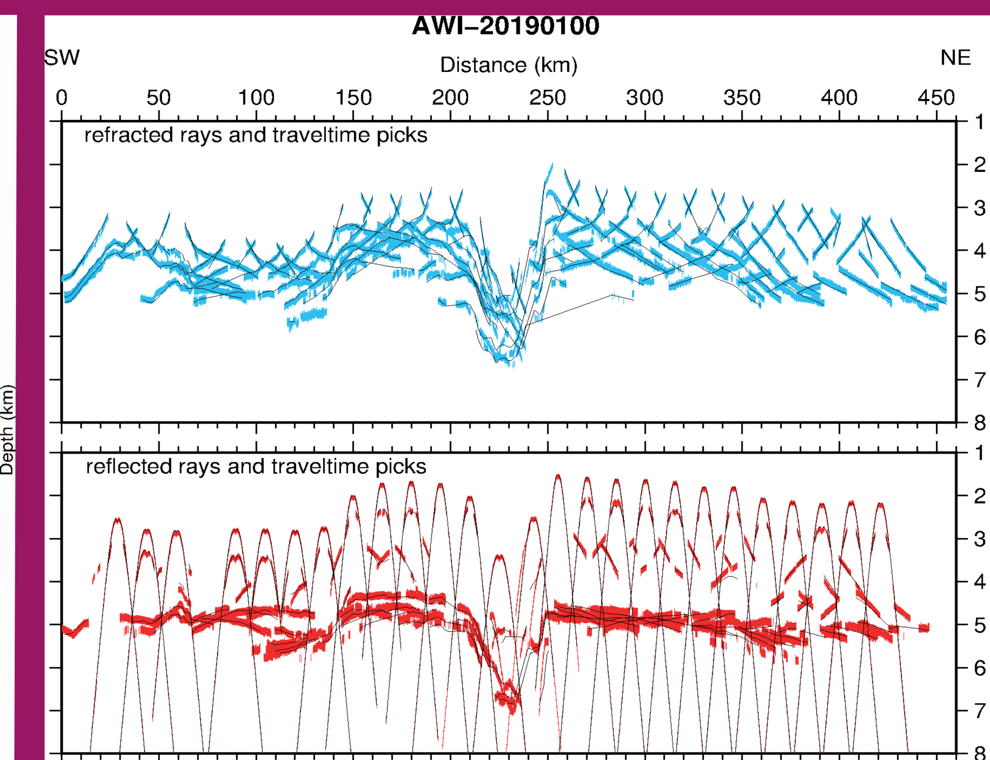


Fig. 5: Ray coverage of P-wave velocity profile AWI-20190100.
The ray paths of the refracted waves are shown as blue, refracted reflected waves as red lines. Black lines mark the boundaries between the velocity layers.

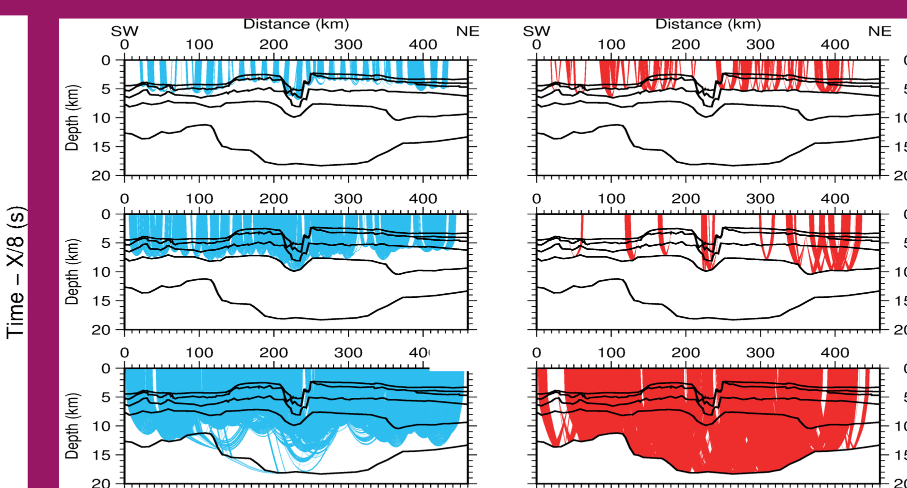
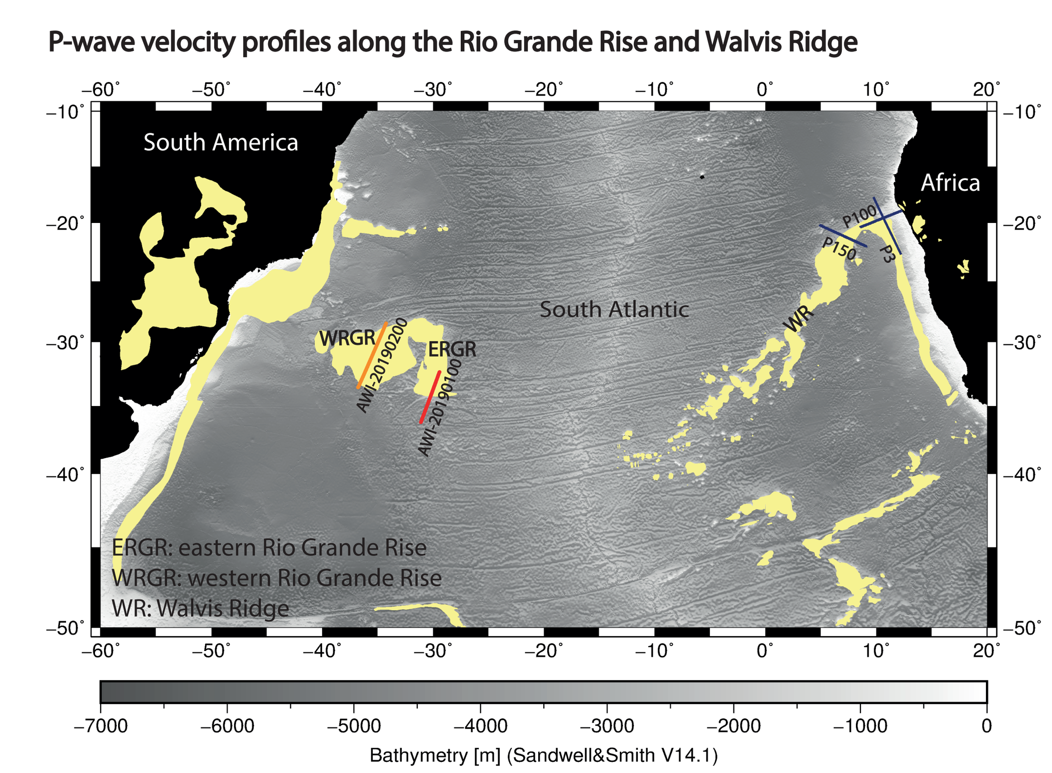


Fig. 6: travel time picks and computed travel times
The vertical length of the travel time picks (blue: refractions, red: reflections) represents the assigned uncertainties, which increase with depth. The computed travel times are shown as black lines.

P-wave velocity profiles along the Rio Grande Rise and Walvis Ridge



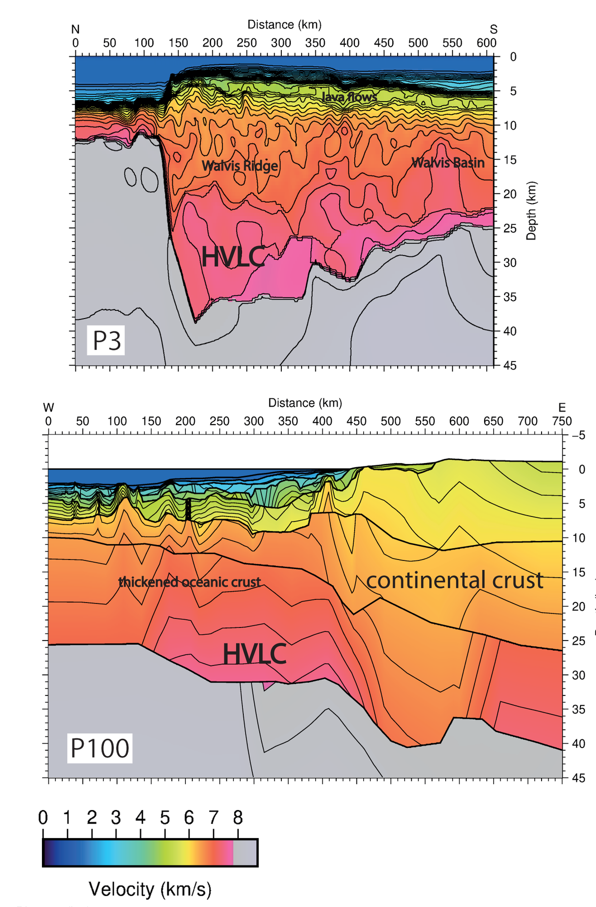
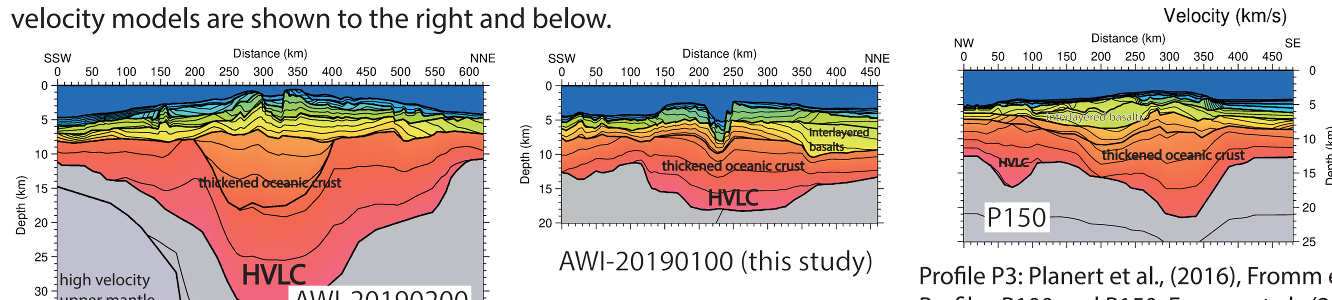


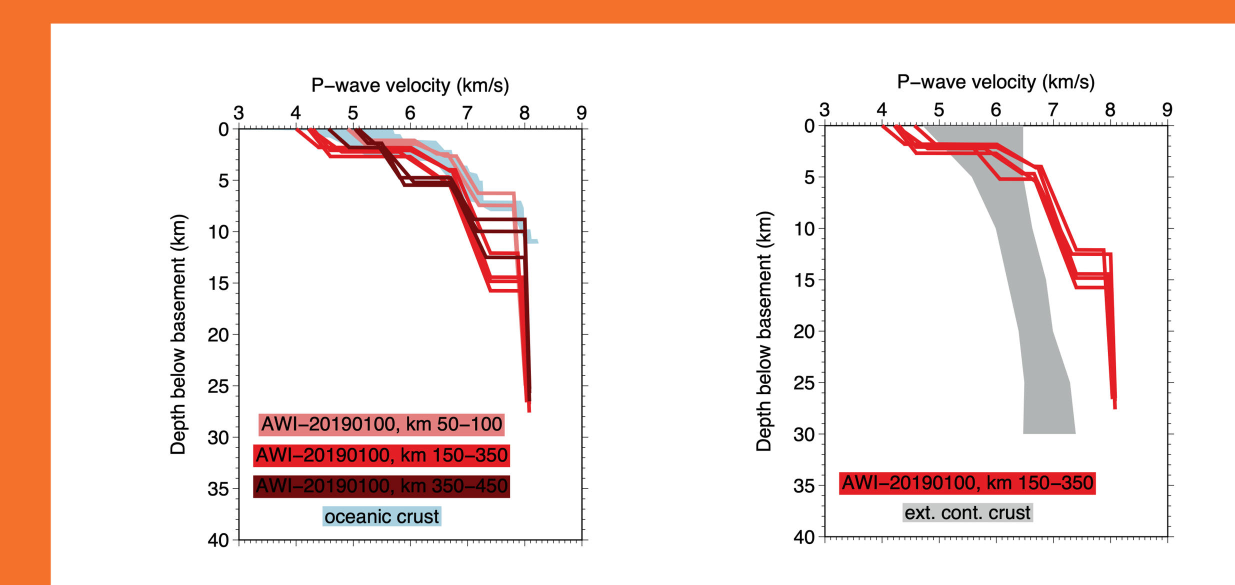
Fig. 3: Bathymetric map of the South Atlantic, showing the main bathymetric structures
Magmatic features are colored yellow (after Coffin et al., 2006) Colored lines mark the position of wide-angle seismic profiles along the RGR and WR. The corresponding P-wave velocity models are shown to the right and below.



Profile P3: Planert et al., (2016), Fromm et al., (2015)
Profiles P100 and P150: Fromm et al., (2015, 2017)
Profiles AWI-20190100/200: Unpublished

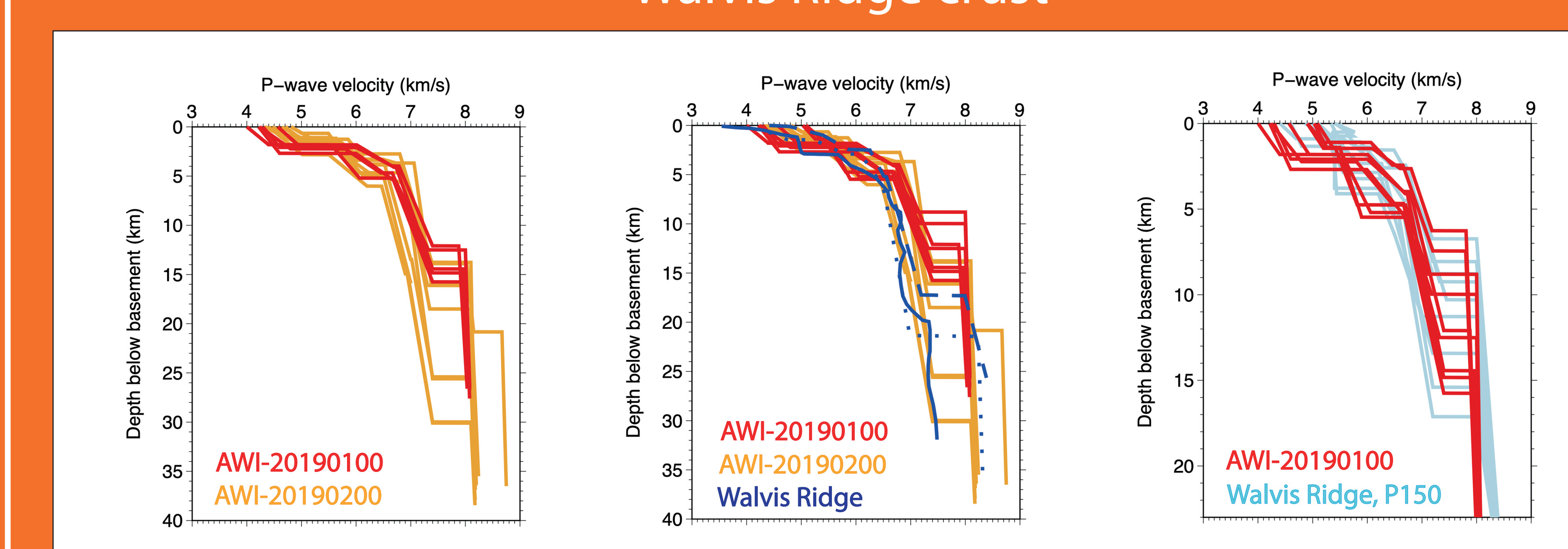
Comparison of ERGR crust with other crustal models

Oceanic crust and extended continental crust



Comparison of velocity-depth profiles along AWI-20190100 (red lines) with typical Atlantic oceanic crust after White et al., (1992) (blue, left panel) and with extended continental crust (grey, right panel) after Christensen and Mooney (1995). P-wave velocities of ERGR lie within the range for oceanic crust and outside the range of continental crust.

Walvis Ridge crust



Comparison of velocity-depth profiles along AWI-20190100 (red lines) with the Western Rio Grande Rise and Walvis Ridge.
Left panel: Crustal structure of WRGR (orange) and ERGR (red) are comparable. Lower crust of ERGR is only half as thick as lower crust of WRGR, but the P-wave velocities are in good agreement. Lower crust of WRGR and ERGR are both characterized by a high velocity lower crust (HVLC).
Mid panel: Comparison of velocity-depth profiles along AWI-20190100 and 3 profiles crossing the Walvis Ridge (P100: dotted line, P150: dashed blue line, P3: solid line, for locations see Fig. 3). Best fit of velocity-depth functions: ERGR with profile P150 (dashed blue line)
Right Panel: Comparison of velocity-depth profiles along AWI-20190100 (red lines) and P150 (blue lines, Walvis Ridge, for locations see Fig. 3)

Research Questions

1) What is the crustal structure of the eastern Rio Grande Rise?
2) Are there indications for a microcontinent within the plateau?
3) How does the crust compare to the Walvis Ridge and the western Rio Grande Rise?

Preliminary Results

- Crust of ERGR up to 15 km thick, half as thick as WRGR
- Lower crust characterized by high velocity lower crust (HVLC), typical for Large Igneous Provinces (LIPS)
- CdSL graben in ERGR deeper than in WRGR
- Crustal structure typical for Oceanic Plateaus (LIPs) & submarine ridges
- Crust of ERGR comparable to crust of Walvis Ridge > typical crustal structure of LIPs
- No indications for a detached microcontinent !

Acknowledgements
We thank captain and crew of RV Maria S. Merian for their support during the research cruise. We also thank the AWI DEPAS Pool for providing the OBS and OBH systems for the project. This work is funded by the DFG and AWI.

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