Upper Mantle Seismic Velocity Estimates around the St. Paul Transform System, Equatorial Atlantic

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Abstract

The equatorial region of the slow-spreading Mid-Atlantic Ridge is characterized by several major transform faults, which are some of the longest on Earth. Among them, the St. Paul Transform system (SPTS) is a complex group of four transform faults, bounding three short intra-transform segments with total offset of 630 km. The northernmost transform is the 200 km-long, 30 km-wide Atoba Ridge, which represents a major topographic feature that rises above sea level at the St. Peter and St. Paul islands (SPSPA). This push-up ridge formed from transpressive stresses along several transform fault step-overs and restraining bends, uplifting mantle rocks at a rate of ~1.5 mm/yr. Moderate-sized earthquakes (>4.0 Mw) have been located by global teleseismic networks along the SPTS and near region. These earthquakes are recorded at large epicentral distances, and include raypaths that travel within the upper mantle (Pn and Sn phases). Pn velocity estimates can help to understand the dynamics of upper mantle structure around of the transform faults. Here, waveforms recorded over ~6 months of 2012 by two autonomous hydrophones moored north and south of SPTS (EA-2 and EA-8), and a seismographic station installed on SPSPA island (ASPSP station) are examined. These data allow us to make Pn velocity estimates from 32 earthquakes that occurred in the SPTS region from 1.5º S to 4.5º N. Pn wave velocities are typically thought to be 8.0–8.2 km/s in upper mantle, however we identify Pn velocities ranging from 7.5 to 9.0 km/s. The slower velocities (7.5-8.0 km/s) are from ray paths oriented parallel to the ridge axis and could be explained by elevated mantle potential temperature and the presence of melt. Ray paths passing through the transform fault system have Pn velocities from 8.1 to 9.0 km/s, indicating that upper mantle conditions are strongly affected by the presence of the crustal fault system. We will also compare our velocity estimates to global shear-wave tomographic models of the upper mantle. Hence it is our goal to show that the availability of autonomous hydrophones and a single island seismic station can be used to make rare estimates of Pn velocities, as well as provide insights into upper mantle structure, in this remote part of the Atlantic Ocean.

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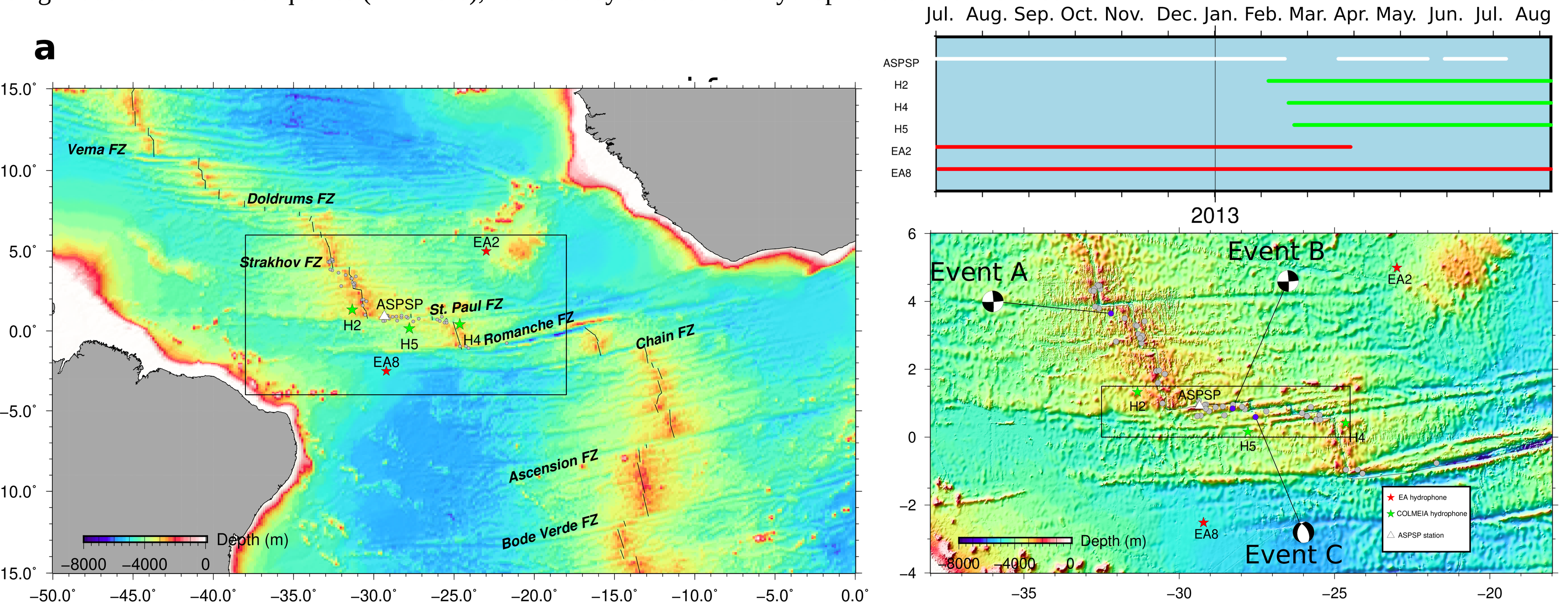
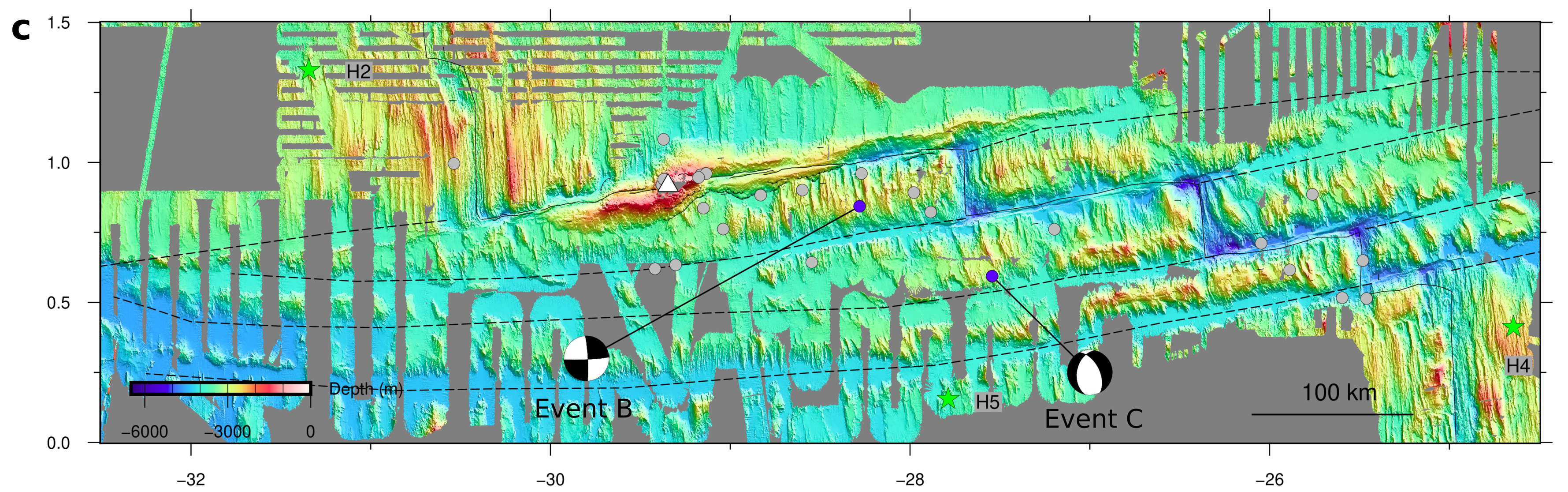
1 Introduction

Four transform faults and three intra-transform ridge segments make up the St Paul transform system (SPTS), located in the equatorial Atlantic ocean. Rocks on the St and St Paul Islets are brought to the surface by transpression, resulting in exposures of serpentinized and mylonitized peridotites. It is thought that the nature of the underlying mantle may explain this extraordinary uplift (Maia et al., 2016), however observations of lower crust and mantle seismic properties are difficult due to the remote location. Here, we present estimates of upper mantle Pn velocity, obtained using moderate-sized earthquakes (>Mw 3.6), recorded by autonomous hydrophones and a broad band.





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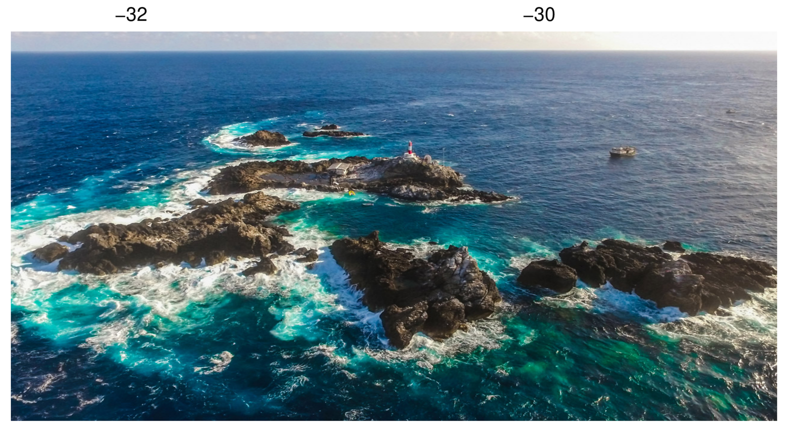
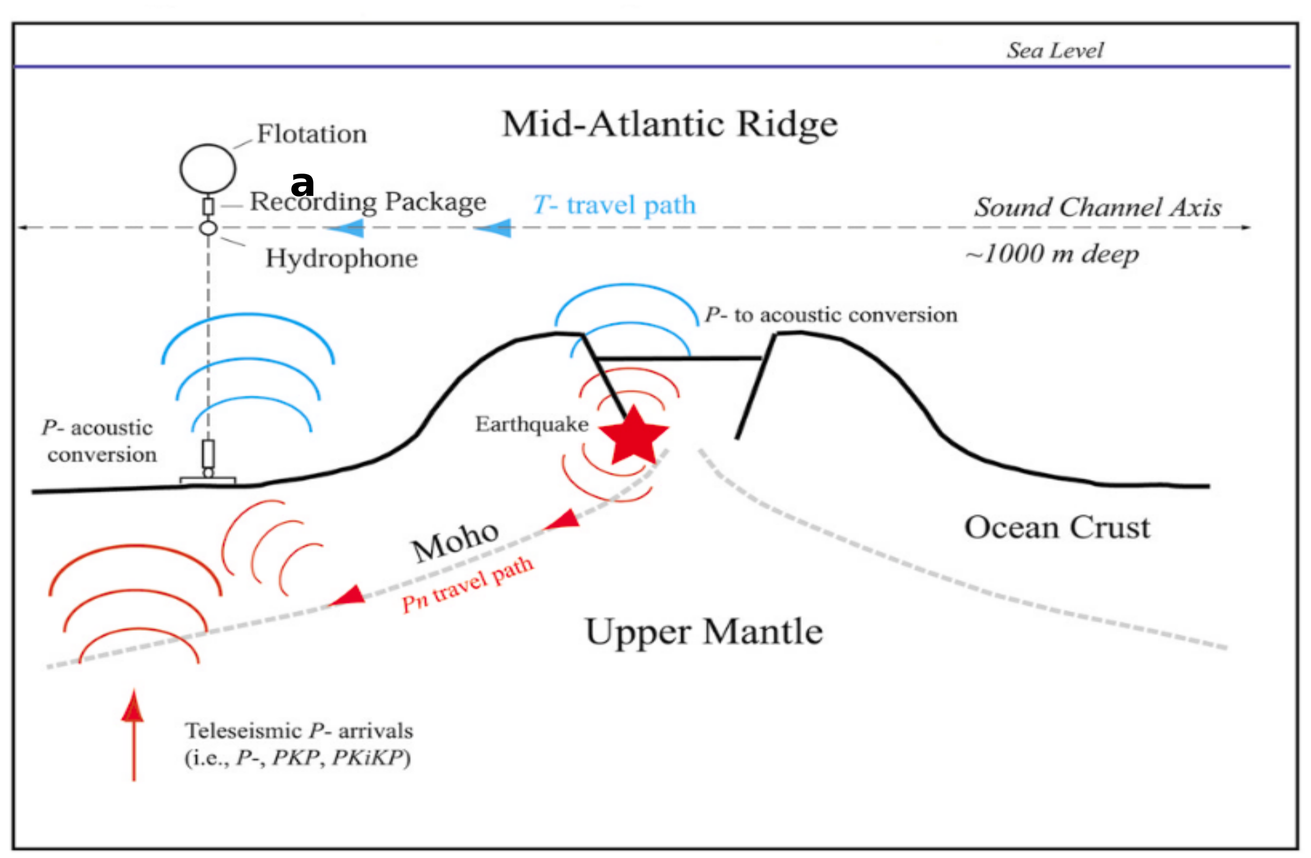


Objectives

Our first objective is to estimate upper mantle Pn velocity in the St Paul transform system and surrounding mid-Atlantic Ridge segments. We aim to use these estimates to examine how variations in upper mantle velocity might influence uplift of the SPTS, and the relationship between Pn, transform fault processes and crustal structure.

2 Data Acquisition

Data were recorded by a single seismographic station (ASPSP) on St. Peter and St. Paul Islet (de Melo & do Nasciemento., 2018); two autonomous hydrophones (EA2 and EA8) were deployed in 2011-2015 as part of the EA array (Smith et al., 2012), and three more (H2, H4 and H5) were deployed during COLMEIA experiment in 2013 (Maia et al., 2013).

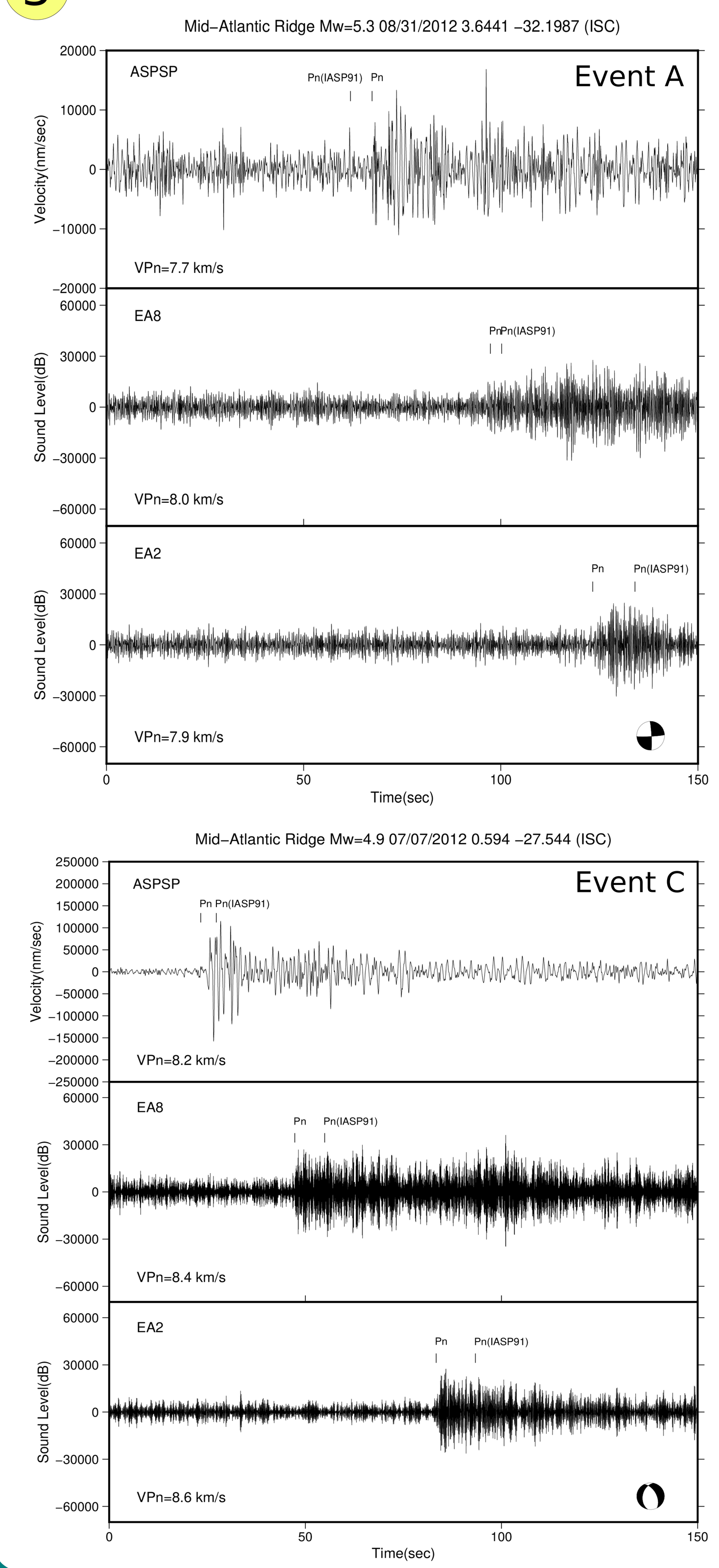


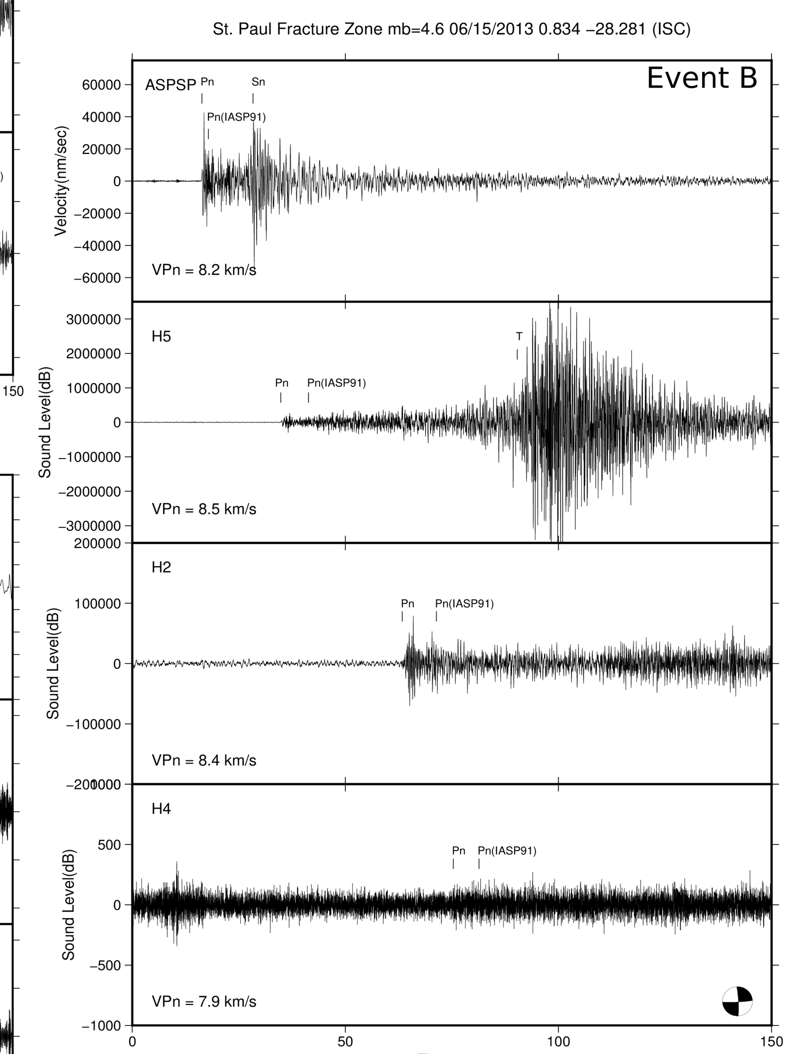
Analysis

Waveform data were bandpass filtered at 6-20 Hz, and Pn arrivals were identified with the aid of predicted arrival times from the IASP91 global model. Pn arrivals were then then picked manually for each station. Event origin times and locations were taken from the ISC catalog, giving a travel time to each station. An additional delay was added to account for the length of the mooring cable, using a constant water velocity from the global ocean sound speed model (GDEM). **(a)** The diagram present a scheme of seismic/acoustic propagation paths of the P waves (obtained in Dziak et al., 2004).

3 Regional Earthquakes

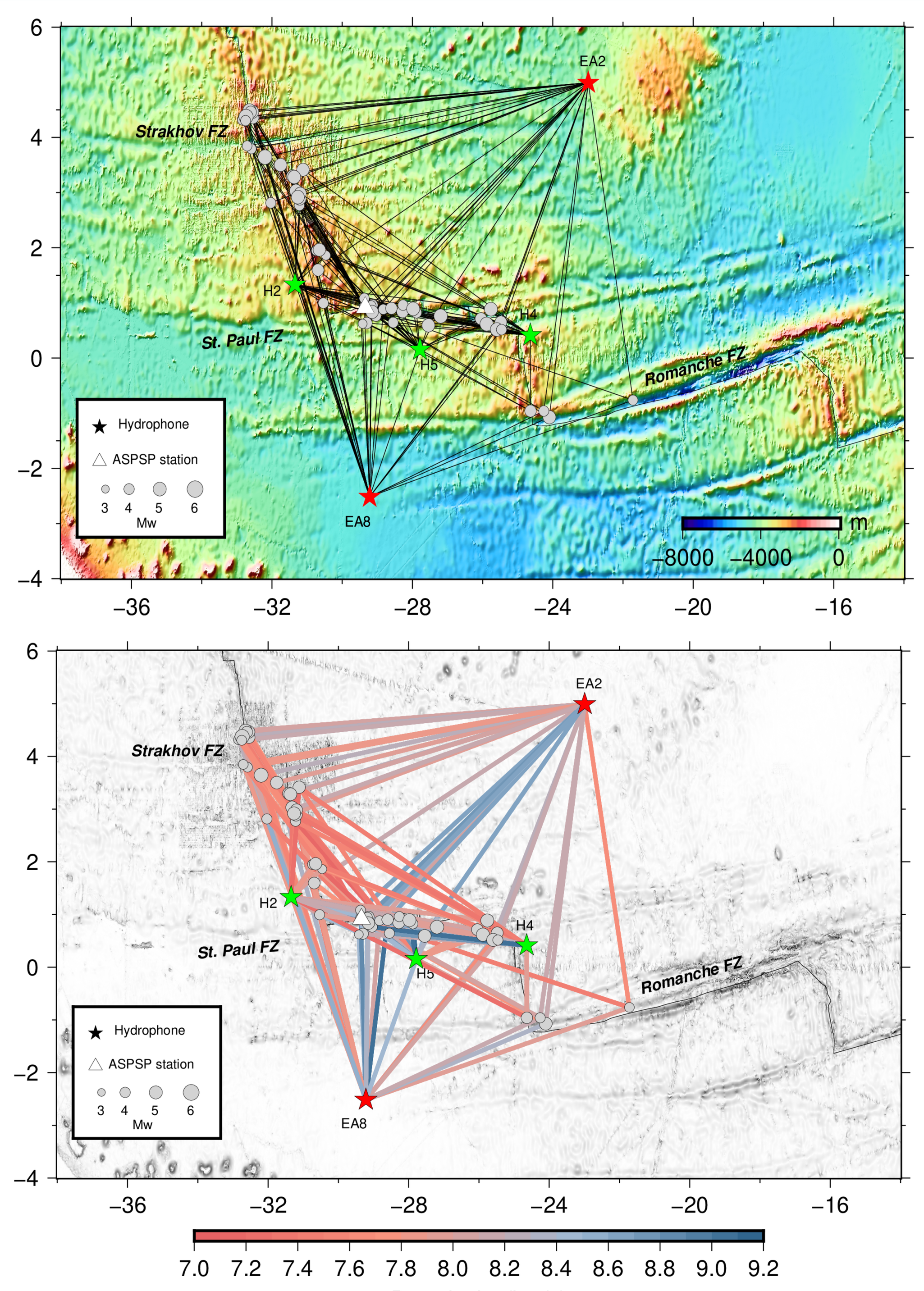
Waveforms from 54 regional earthquakes were used, (Mw 3.5-5.4) over the time interval shown in 1a. Plots below and right show predicted Pn arrivals (IASP91), observed Pn arrivals, moment tensors (ISC), and resulting Pn velocity estimates for three example events in **(a)**, **(b)** and **(c)** records.





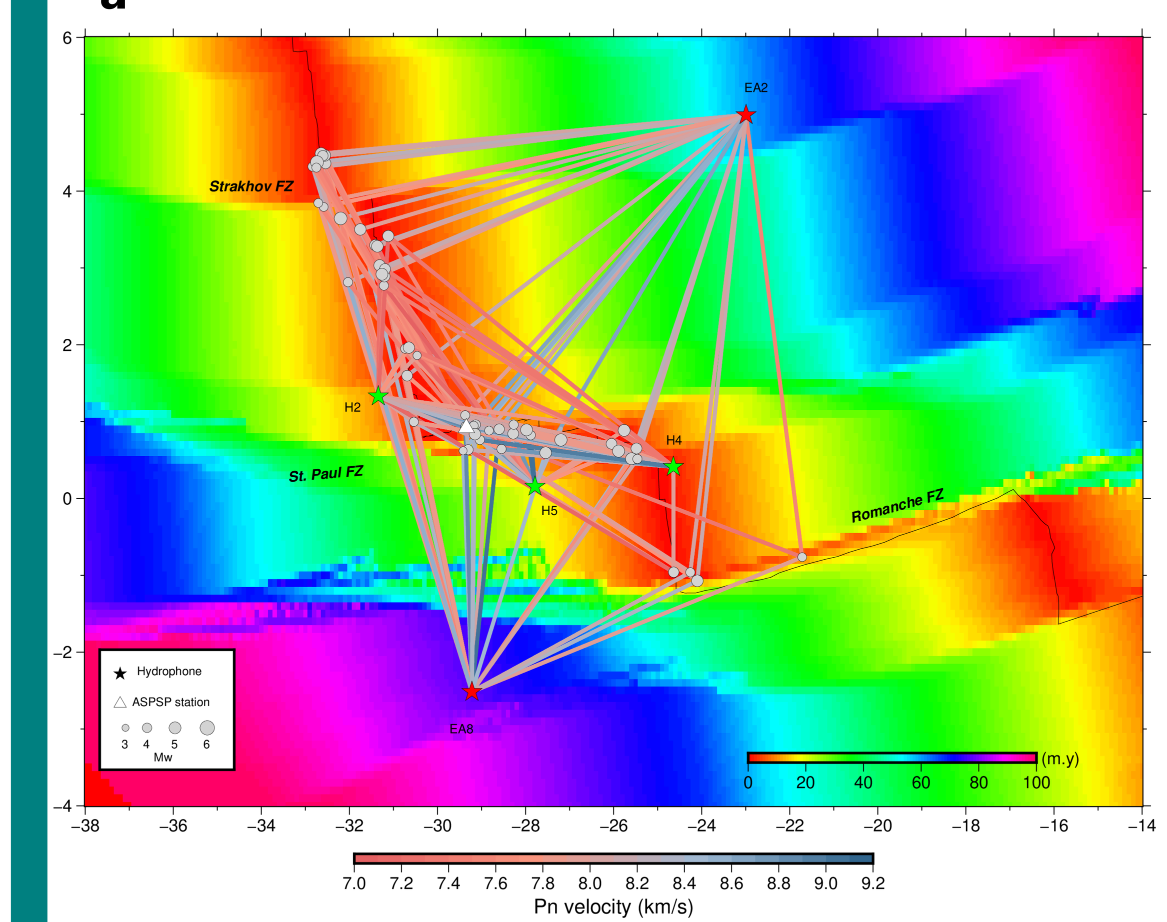
4 Raypaths and Pn velocity

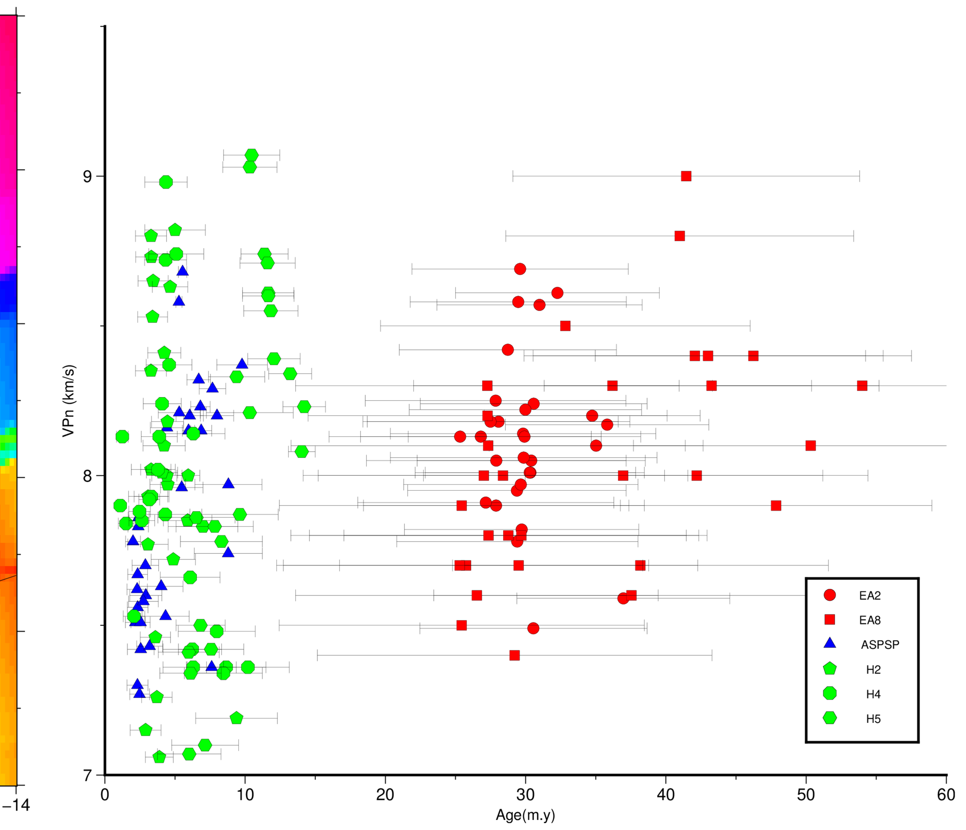
A total of 186 raypaths were analysed along the work. 90 of them belong to the 30 earthquakes occurred in 2012, being it from EA2 and EA8 hydrophone together ASPSP station. We obtained the total of 96 raypaths in 2013, which they were from the three COLMEIA hydrophone together of the ASPSP station records. The epicentral distances shown a range from 60.5 km until 1094.9 km, and arrival times range between 14 and 139.5 seconds. It was calculated using the epicenter coordinates of ISC catalogue to events with magnitude above 4.0. In 2013 events list, four of them with magnitudes 3.5-3.6 ML occurred in St. Paul Transform System were add to ISC catalogue using the ASPSP station (de Melo et al., 2019, submitted).



5 Crustal Age and Pn velocity

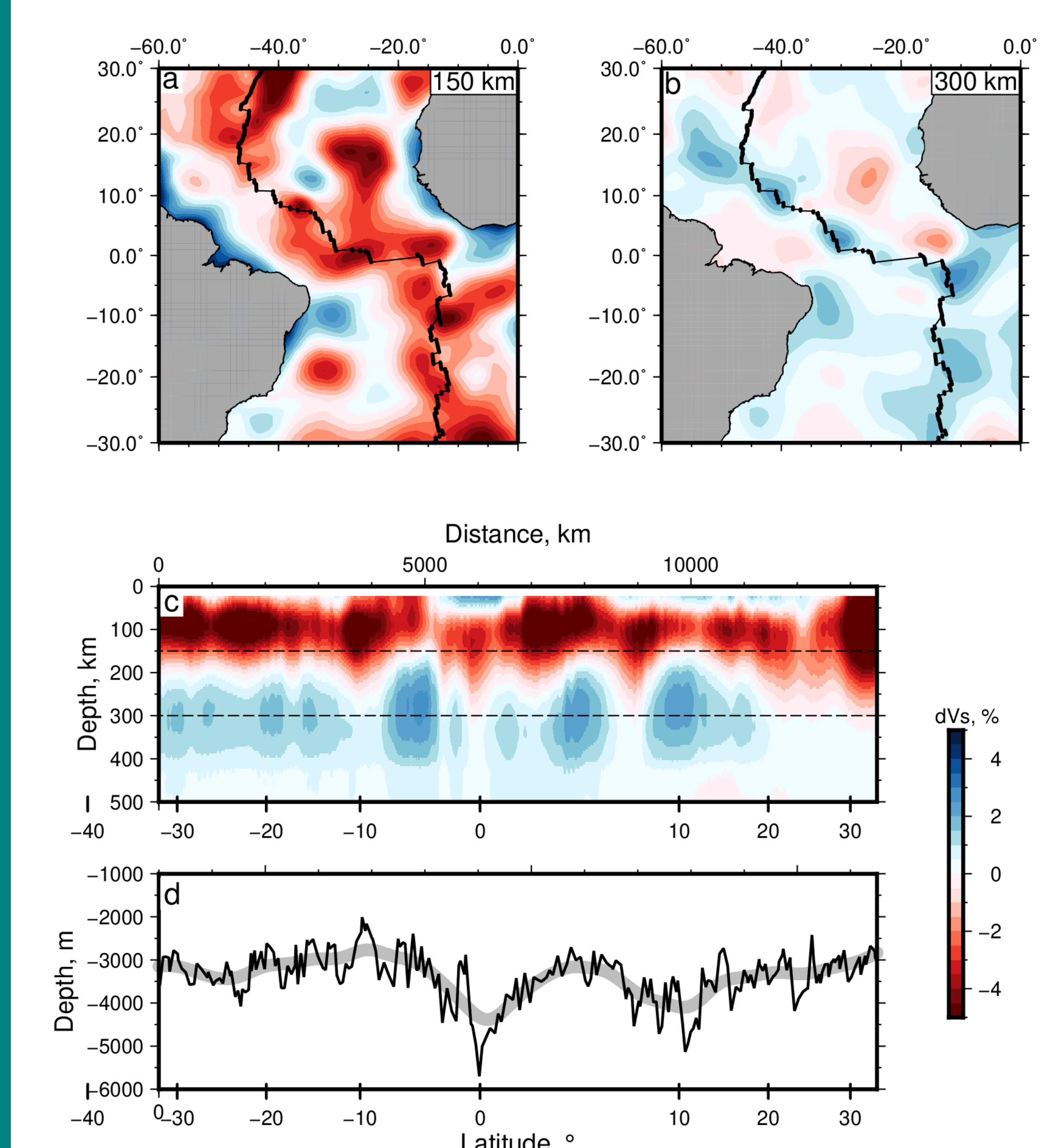
We explore the relationship between Pn velocity and oceanic crustal age. Our raypaths cross a range of crustal ages until 15 m.y with Pn values reaching since 7.2 until 9.2 km/s, and crustal ages 25-55 m.y shown a Pn velocity range of 7.4-8.7 km/s **(a)**. However, there is weak evidence for a systematic relationship between age and Pn velocity **(b)**.

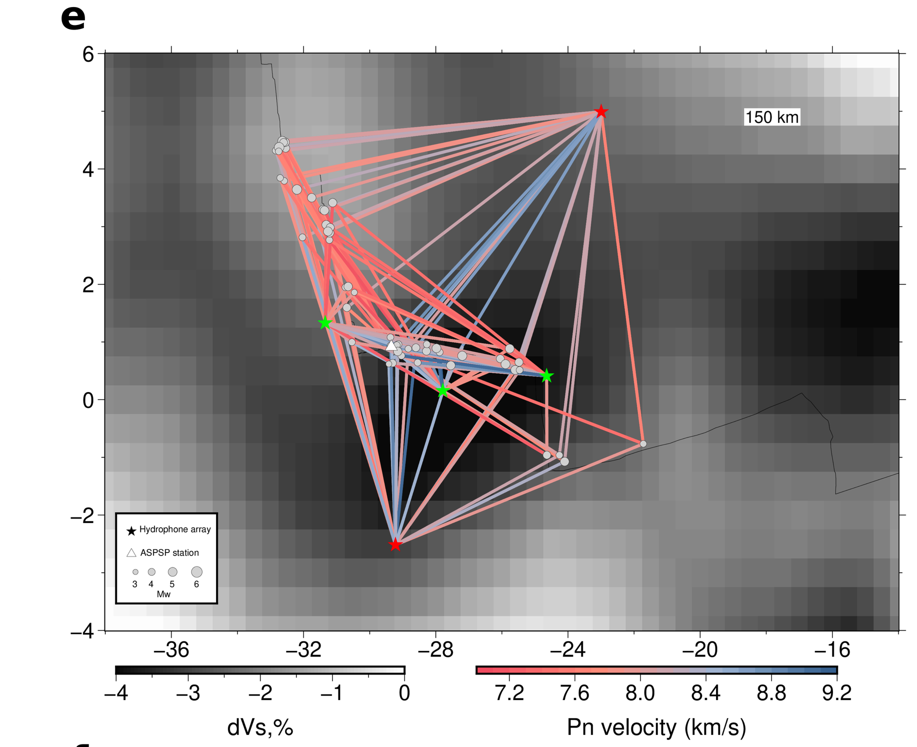


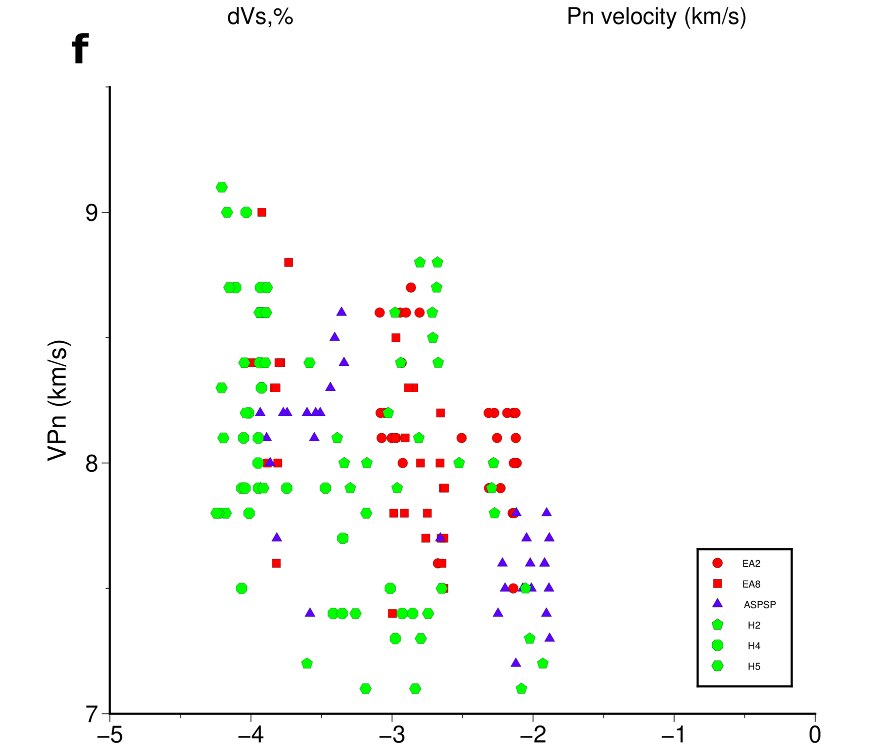


6 Sub-Plate Velocities

We compare our Pn velocity estimates with a global shear wave velocity model (Schaeffer & Lebedev, 2013), to investigate whether our high Pn velocity estimates have any relation to deeper mantle properties. However, we find that the Pn velocities measured there is no clear relationship with dVs **(f)**.







7 Conclusions

- Autonomous hydrophones can be used to measure Pn velocity of earthquakes occurred along the ocean faults and spreading ridges
- Pn wave present high velocities along the St. Paul Transform System, Equatorial Atlantic
- Crustal age shown weak relationship with Pn velocities and dVs of global tomography are not correlated

Selected References

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