Subject offered for a contract starting october 2015

SUBJECT TITTLE: Interpreting Continental Break-up from Surface Observations

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For more information go to http://ed560.ipgp.fr, section: Offres de these (PhD offer), You must apply on the Doctoral School website

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Project summary

Rifting of continental lithosphere is a fundamental process that controls the evolution of continents and the birth of ocean basins. Continental rift basins are also a major deposit for hydrocarbons – a key natural resource. Despite the fundamental place of rifts in our planet's geology and their economic importance, we still do not fully understand how they form. Evidence of how continents break apart is left behind in the igneous rocks, through geochemical analysis, and in the sedimentary accumulations, as a record of past tectonics and surface topography. Observational evidence of the structure of the upper mantle in active rifts can be gained through geophysical and seismic studies. The over-all aim of the project is to utilise these observations to interpret how the physics of continental break-up is translated into geological observations.

Continental rifting, which is often associated with the production of significant amounts of melt and their intrusion into the crust and involves the entire mantle-lithosphere system through heat transfer and stretching. The association between thermal plumes and break-up is clear along the coastline of the Atlantic Ocean, with three distinctive volcanic provinces that erupted as the ocean basin formed. However, we do not know if break-up causes the volcanism or if the volcanism causes break-up. The East African Rift zone is the most distinctive actively rifting region on our planet. Within the rift valley there are active volcanic systems, evidence of large amounts of melt and perhaps a deep source of hot mantle that is responsible for this volcanism and the current break-up. <u>The research challenge is to build the tools to quantitatively interrogate numerical models against observations of igneous chemistry, mantle seismology and crustal tectonics</u>. The central gap in our understanding is how precisely thermal plumes and lithosphere interact and, importantly, how change in melt production and lithosphere strength is recorded within the seismological and geochemical observations. Numerical models of rift evolution have typically focused on making a qualitative comparison to rift evolution. <u>In the East African Rift we have the quality of geochemical, seismological and tectonic datasets to quantitatively understand how a young rift zone forms</u>. The results of this work will then have implications for our understanding of the thermal history of rift basins and importantly hydrocarbon maturation as the basin eventually becomes subareal and deposits accumulate.

PhD project objectives

*0 Develop the methods to allow for full waveform propagation through 2-D and 3-D geodynamic model space. We want to know how the seismic wave is effected by melt to better understand the structure of the lithosphere-asthenosphere during active rifting.

*1 Propagate seismic waves through the 3-D rift model to explore how alignment of flow and the presence of partial melt impacts the seismic observations.

*2 Use the model to explore the interaction between deep mantle flow and rifting. Make comparisons with the model and evidence from studies of seismic tomography, receiver function analysis and seismic anistropy across Afar and Ethiopia.

Key questions using seismology probe the lithosphere-asthenosphere during active rifting:

(1) How much melt is retained within the mantle and how does this melt impact the bulk structure of the upper mantle? Melt retention will be effected by the compaction of mantle rock and the amount of melt being generated. Melt retention may be significantly enhanced if there is more melt produced by for example the inclusion of pyroxenite. How melt retention effects the seismic wave in combination with solid mantle changes will then impact what structures are observable. We will create forward models of wave propagation through the forward model of continental break-up to fully explore how processes are transformed into observations (Figure 1).

(2) What is the role of seismic anisotropy due to melt geometry and the 3-D nature of mantle flow? How melt is stored in the mantle may effect the attenuation of seismic waves (e.g. *Jackson et al., JGR, 2004; McCarthy & Takei, JGR, 2011*). The attenuation may be frequency dependent and also a function of how the melt is stored within the mantle. This attenuation may be responsible for the very low shear wave velocities found from surface wave tomography. The very low velocities may also be due to ray paths being altered by the necking of the lithosphere within the rift zone. Furthermore, a strong impedance contrast at 60 to 50 km depth may be required to reconcile the receiver functions, which cannot be captured in the latest forward models (*Rychert et al., Nat. Geo. 2012*). Working along with the expertise in computation seismology at IPGP, we will develop the methods to convert the forward models to seismic structure and explore how seismic wave propagation is impacted by the predicted upper mantle properties.

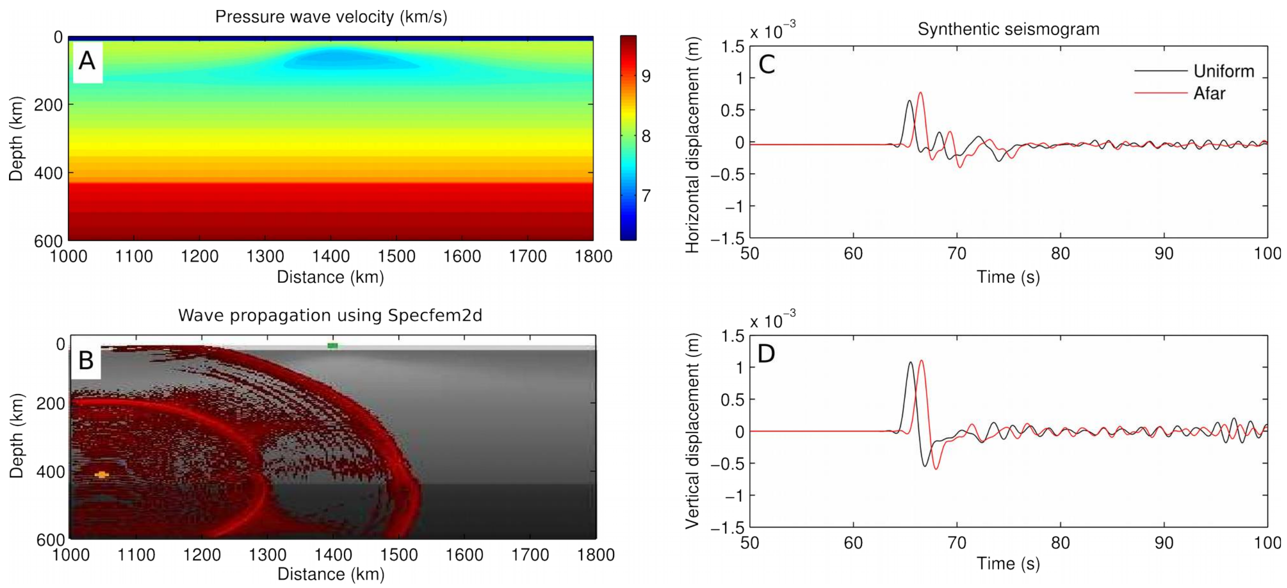

***Figure 1**: Example of the propagation of a seismic wave through the 2-D model domain.(A) Pressure wave velocity from the geodynamic model presented in Figure 2. (B) Snapshot of the propagation of a seismic wave through the model domain using the software SPECFEM2D. (C) and (D) displacement recorded at the model receiver (green square in part B), red line is for the model displayed in parts A and B, black line is for a reference model of constant lithosphere thickness.*