Subito! E-Newsletter #6: December 2018

Introduction

Welcome to the 6th SUBITOP E-Newsletter! SUBITOP is slowly coming to an end by entering the last and decisive final year. In this newsletter we would like to show SUBITOP contributions to GeoMod, report from our last training fieldtrip to the Betics and briefly present the first published SUBITOP paper by Boris Gailleton. Congratulations and well done Boris!

1 Betics field trip

Almost finished! The last SUBITOP workshop took place in October 2018. The field course, led by Frédéric Gueydan, focused on field observations of different units (External Zones, Alboran domain and Ronda Peridotites) in the Western Betics. Our base-camp was in Ardales, a lovely town surrounded by enviable natural spots in the core of Andalucía which is also one of the most interesting geological settings in the Mediterranean. An external participant, joining the 15 SUBITOP ESRs, was Jason Williams from ICTJA Barcelona who is a postdoctoral researcher actively working on the Betics. Western Betics is a complex region which, with a wide set of data, can be explained through several models. The aim of the trip was to make field observations and encourage discussions about the models that could explain these field evidences. We focused on studying the deformation of the External zones in contact with the Alboran domain, the deformation in the Alboran Domain, and its relation with the Ronda Peridotites. First, we pointed our attention towards the deformation in the Alboran Domain. We walked over the exhumed lithosphere of the Alboran domain and started our journey at the surface of the crust. As the day advanced, we entered deeper and deeper into the lithosphere until, eventually, the Moho. As we walked all along the lithosphere, we had a chance to see the P-T evolution of the exhumed lithosphere, from low metamorphism up to the mylonitic facies. We then turned our attention to the deformation between the external-internal zones, and the deformation related to the intersection of both units. It indicated that the Alboran-Domain was affected by a process such as westwards slab-rollback. This means that at some moment before, it was somewhere closer to the Eastern-Betics. Finally, we briefly studied an outcrop of the Ronda Peridotites in the Alboran Domain. Their history remains a controversial but some field evidences and literature data suggest that the back-arc extension due to the westward propagation of the Alboran-domain could be a potential explanation for the exhumation of these peridotites. There are some uncertainties about the process which could explain the setting of the Western Betics and the exhumation of the Ronda Peridotites. There many models which could explain all this history (that is the beauty of the Betics).

Figure 1: SUBITOP ESRs discussing an outcrop.

One of the models that was discussed suggests that at some point during the westwards motion of the Alboran Domain, a switch from continental extension (with sub-continental mantle exhumation) to a rift inversion (by thrusting) occurred, allowing the outcropping of the Ronda Peridotites.

Figure 2: A fantastic view across the study area.

2 GeoMod 2018, Barcelona

More than half of the SUBITOP ESRs attended GeoMod 2018 in Barcelona and presented their work: KB, Ajay, Jessica, Arthur, Ehsan, Antoine and Nico. Jessica, Ajay and Arthur were asked to give a talk on their current work, based on their abstracts which we would like to share with all readers.

Figure 3: All participants at GeoMod 2018 in Barcelona

2.1 Jessica: Lithosphere weakening mechanisms influence on subduction zones migration

Figure 4: Jessica during her talk

Retreating subduction zones (e.g. Caribbean (figure 1.), Scotia or Gibraltar) are migrating via fracturing that occurs at the edges of the down-going slab (at the so-called STEP faults). Fracturing allows for slab propagation and can be seen at the conjugate fractures propagation in a thin sheet (the lithosphere). This kind of propagation has been widely studied in material sciences, such as in elasto-plastic media or metals. The fracturing path appears to be highly dependent on the material's rheology and on its response to stresses. We perform 3D simulations of retreating slabs over several million years focusing on slab migration patterns. We vary the weakening mechanism, by varying the use of strain weakening in our models. Our simulations show very different outcomes depending on the use of strain weakening. When it is allowed, very localized STEP faults form spontaneously and allow for slab retreat via converging fracturing paths that lead to a narrowing of the slab. When it is not allowed, we observe a much wider partition of stresses on the plate, leading to divergent fracture propagation and a widening of the slab. Current work is dedicated to understanding these numerical results by adapting fracture propagation results from material sciences, in order to explain what mechanisms, cause the convergence or divergence of fracturing paths during slab retreat.

2.2 Arthur: The interplay between slab's morphology and kinematic and surface topography

Figure 5: Arthur during his talk.

To first order, seismic tomography shows that slabs morphologies vary from sinking straight into the lower mantle to lie flat at the upper-lower mantle discontinuity (e.g., Lay, 1994; Li et al., 2008), or even to get thicker in the shallow lower mantle (e.g., Lee and King, 2011). The apparent thickening of the slab might be linked to the folding behaviour of the slab when it starts to interact with the upper-lower mantle discontinuity at 660 km depth (Ribe, 2003; Běhounková and Čížková, 2008). Indeed, it has long been realized that this discontinuity coincides with an endothermic phase transition (Ringwood, 1975; Christensen, 1995; Faccenda and Zilio, 2017) and to be likely site of a viscosity contrast at 660 km depth (Hager, 1984, Goes et al., 2017). Both parameters enhance the resisting force and hamper the slab to sink into the lower mantle. As a result, slabs can be either flattened at the transition zone or folds before to sink in the deep part of the mantle. Previous findings show that periodic slab folding behaviour can explain a variety of puzzling geological and geophysical observations such as (1) periodic variations of the oceanic plate velocity (Cogne and Humler, 2004); (2) trench retreat and advance episodes (Billen and Arredondo, 2018) and (3) the scattered distribution of slab dip angle in the upper mantle (Jarrad, 1986; Cerpa et al., 2015). Most of the previous studies have tried to constrain slab morphology and kinematics, by imposing mantle phase transition at 660 km depth, viscosity contrast between the upper/lower mantle discontinuity and plates rheology. Nevertheless, those models ignored how these deep slab dynamics might generate topographic variations of the upper plate throughout subduction evolution. Unravelling the complex interplay between folding slab at depth and the upper plate topography is carried out by using a 2D self-consistent single-sided subducting numerical model. Using the geodynamical modelling code CITCOM, we study the temporal evolution of the slab and the related mantle convection features with the long wavelength surface and dynamic topography of the upper plate. Our models are set up with upper mantle phase transitions which cover a plausible range of olivine phases transformations and upper/lower mantle viscosity contrast. Our models reproduce both slabs laying down at the transition zone and sinking straight into the lower mantle, and, more interestingly, slab folding morphology. We are working on the relationships between slab's folding morphology (Fig.1) and kinematics including the resulting dynamic topography. We highlight that the uplift of the upper plate occurs when the slab sinks without trench retreat or during trench advance phase coupled with steep slab dip angle. In contrast, subsidence of the upper plate occurs under a relatively shallow slab dip angle along with a high trench retreat motion.

2.3 Ajay: New improvements on LitMod package: A tool for integrated geophysical-petrological modelling of the crust and upper mantle

LitMod is a combined geophysical-petrological 2D forward modelling tool developed ten years ago at ICTJA-CSIC to study the thermal, compositional, density and seismological structure of lithosphere and sublithosphere domains by combining data from petrology, mineral physics and geophysical observables within a self-consistent framework (Afonso et al., 2008). Here, we present a set of improvements on the different modules of the current version of the LitMod package focused on the graphic user interface (GUI), the average composition of the upper mantle, and the incorporation of anomalous sublithospheric bodies in terms of composition, temperature and seismic velocities.

Figure 6: Ajay during his talk

A new GUI has been developed under Python programming language (Rossum et al., 1995; Hunter et al., 2007) to gain versatility and compatibility with the different operating systems and platforms. We tested several changes in the sublithospheric mantle composition (DMM, Workman Stanley, 2005 instead PUM, McDonough Sun 1995) and in the attenuation parameters (grain size and period) to fit the calculated seismic velocities with those from the ak135 global reference model (Kennett et al., 1991). None of these changes produce significant variations in the calculated velocity values below 200 km depth and hence, the calculated synthetic tomography from LitMod shows a red shift below this depth. The most interesting improvement is the possibility to incorporate sublithospheric bodies with different chemical compositions, and either anomalous velocities (Vp or Vs) or temperatures, which can be imposed from independent studies for each target region. To this end we increased the range of temperatures up to 2200oC in calculating the mineral assemblages and we incorporated anelasticity in calculating the bulk rock seismic velocities and their partial derivatives, such that we can translate temperature anomalies into seismic velocities and vice-versa. Additionally, this new tool permits to calculate coupled-uncoupled elevation to estimate the effects of density anomalies on topography giving an upper bound for dynamic topography under isostatic equilibrium.

3 Paper: A segmentation approach for the reproducible extraction and quantification of knickpoints from river long profiles, by Boris Gailleton et al.

Figure 7: Our first paper hero, Boris!

A segmentation approach for the reproducible extraction and quantification of knickpoints from river long profiles Upland landscapes are shaped by competition between erosion and mountain building processes. Geomorphologist have been developing methods to unravel tectonics and landscape evolution based on the shape of the topography, which has the advantage to provide a spatially continuous record of these events. Following the rise of available global Digital Elevation Models (DEMs) of the last decades, many methods have been developed to quantify and extract morphometrics from these DEMs. Our manuscript, developed through the Subitop ITN framework, aims to provide a new objective and open source algorithm to extract one of these morphometric. We are focusing on the river network, as it is the main engine of erosion in active landscapes. Several observations have been highlighting the importance of quantifying the shape of rivers in geomorphological studies: for instance river incision is scaled to its slope and its discharge; harder lithologies are eroded by steeper reaches; or shift in surface processes can be traced in river profiles. In other words, changes in river steepness are key features to understand landscape evolution. In this contribution we specifically developed an algorithm to extract the discrete points where the river network adapt its steepness, called a knickpoint. Many studies are using knickpoint location to unravel landscape evolution, however in most of the time these feature are manually selected, making results hardly reproducible. The aim of our algorithm is to provide an objective and reproducible method to extract changes in channel steepness, using a wide range of statistical tools and signal processing filters to isolate the knickpoint locations. Knickpoints are sorted into categories: increase of steepness, decrease of steepness and vertical step (ie waterfall). We then test our algorithm against field dataset on two active and complex landscapes: Santa Cruz Island (CA, USA) and Quadrilátero Ferrífero (Minas Gerais, Brazil) and discuss its performance and how to adapt the algorithm to each specific field site. We finally test our algorithm against the existing ones achieving the same goal of reproducibility and discuss the pro and cons of each. The discussion paper is still under open review on ESURF and the code is available in the open source research software LSDTopoTools.

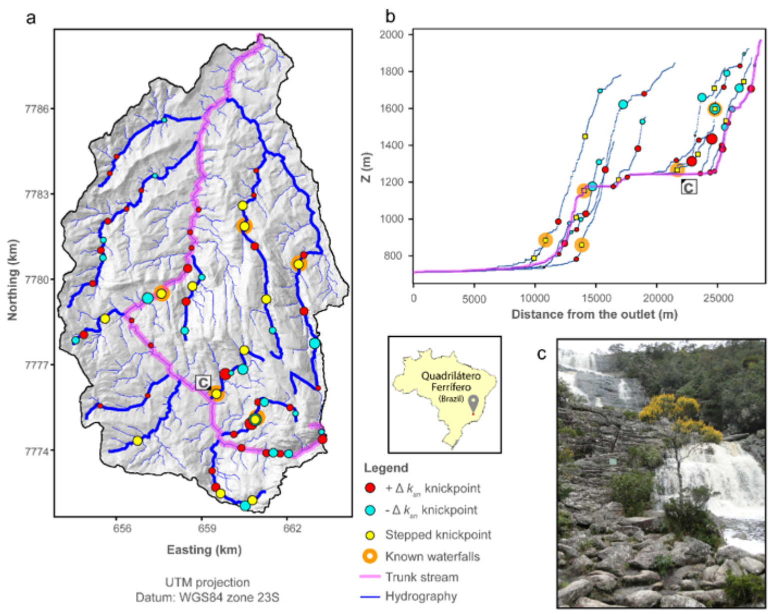

Figure 8: Illustration of knickpoint extraction in the Brazilian field site.

4 Upcoming events

- **AGU Fall Meeting 2018:** 10-14 December 2018 in Washingten D.C., USA
- **EGU abstract submission deadline:** 10 January 2018
- **EGU GA 2019:** 8-12 April 2019 in Vienna, Austria.
- **TopoEurope/Subitop Conference:** "Linking shallow and deep processes in subduction systems"m, 5-10 May 2019, Granada, Spain

Newsletter by Ehsan Kosari, Carlos Fernandez Garcia,Kittiphon Boonma, Nicholas Schliffke, in collaboration with other ESRs.