CHINA SCHOLARSHIP COUNCIL

Appel à projets
Campagne 2022
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Title of the research project :

Impact of thermal, compositional and structural inheritance on early post orogenic continental break up in the South China Sea.

Thesis supervisor (HDR) :

Name : Laetitia Surname : Le Pourhiet

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Research Unit

Name : Institut des sciences de la Terrre Paris

Code (ex. UMR xxxx) :UMR 7193

Doctorate School

Thesis supervisor's doctorate school (candidate's futur doctoral school) : ED 398 GRNE

PhD student currently supervised by the thesis supervisor (number, year of the first inscription) :

1 student started in sept 2018 finishing March 2022

Joint supervisor :

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Title : Professor

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Research Unit

Name : INSTITUT TERRE & ENVIRONNEMENT DE STRASBOURG (ITES)

Code (ex. UMR xxxx) : UMR 7063

École doctorale

Joint supervisor's doctorate school : ED413

Or, if non SU : Studentswill be Attached to SU

PhD student currently supervised by the joint supervisor (number, year of the first inscription) :
2 students / one started 2018 defending on 12/10/2021,one which started 1/9/2021

Description of the project

Impact of thermal, compositional and structural inheritance on early post orogenic continental break up in the South China Sea.

Drilling in the frame of the International Ocean Discovery Program (IODP) in the South China Sea (SCS) together with the analysis of high-resolution seismic reflection and refraction seismic data provide observational evidence to established the finite deformation and related stratigraphic and magmatic record which can constrain "when", "where" and "how" continental break-up occurred or failed. Thus, the SCS is at present one of the rare examples where rift processes can be tested by data sets, which makes it one of the best laboratories to test and calibrate numerical modelling approaches.

The latest results from the SCS show that numerical and physics based conceptual models of passive margin formation and continental break-up developed for magma rich and magma poor Atlantic-type continental break-up systems cannot capture/explain the observations made in the SCS. In particular, they do not explain the accommodation of sediments developed above well imaged metamorphic core complexes like the Liwan Sag (Zhang et al., 2019,2021) nor the presence of transitional continental crust starved with melt drilled at IODP Sites 184, 349 and 367 before the onset of steady state seafloor spreading that is marked by Penrose type oceanic crust drilled at IODP Site 368 in the SCS . Part of the explanation for this failure lie on the specific geodynamic context of the continental break-up in the SCS. While Atlantic type margins typically form long time after orogenic collapse far from active subduction zone, the SCS forms in an early post orogenic setting surrounded by subduction zones, similar to some basins in the Mediterranean or Caribbean.

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Numerical models have been developed to proposed physics-based conceptual models of post orogenic collapse. These models often include the formation of continental metamorphic core complexes. Yet, none of these simulations have been pushed to the stage of continental break-up, almost none of them account for erosion and sedimentation, and no attention has been paid to the rate of subsidence, predicted by these simulations during ongoing extension. Most of these past studies focused on the tectono-metamorphic evolution of deep crustal units exhumed along detachment structures of failed wide continental rifts such as the Basin and Ranges, the Mediterranean area (see Labrousse et al. 2015 for review, Le Pourhiet et al. 2012 for 3D simulations). or in exhumed/uplifed and exposed Orogenic systems (e.g. Caledonides, Wiest et al 2019 or Northern Cordillera USA see Teyssier and Whitney 2002 for review) where syn-tectonic sediments are either rarely preserved or if preserved, were not linked to the extensional evolution New physics-based conceptual models are needed to really understand the dynamics of continental break-up in the early post orogenic context such as the SCS which may be more common than previously assumed (e.g. early evolution of the breakup along the borders of Pangea).

High quality seismic images from the SCS, do not only allow to map deep structures that are very similar to well established conceptual models developed for exhumed rocks, but they also give access to sedimentation and rates thanks to drilling calibration. The occurrence of metamorphic core complex is known to be limited to geological provinces with a lower crust which viscosity is lower than 1e19 Pa.s on a thickness of 15 km (Block and royden, 1990). But this value is only an upper bound. Lowering the value of viscosity in the simulation does not really affect the final geometry/structures of the crust, only the rate at which the structures might form but these rates are not so well calibrated by thermo-chronology (e.g. Huet al. 2011). Using the sedimentary units from the Liwan Sag and the NW SCS basin as a precise tape recorder, together with new numerical simulations, we therefore have a unique opportunity to calibrate precisely the viscosity of the lower crust at the onset of continental rifting.

In a second step, once the lower crust has been carefully calibrated both in the arc and in the forearc region, we will run longer term numerical simulations aiming at characterizing the timing and the role of crustal and mantle melt during continental break-up in post orogenic setting. The simulations will be calibrated by comparing existing Wheeler diagrams of the sedimentary record in the ocean-continent transition with synthetic ones produced as a back product of the numerical simulations.

Finally, the SCS provides several example of V-shape oceanic basins, some that propagated and some that failed to do so. Several hypotheses have been proposed to explain the failure and the variation in propagation rates with time but none of them have carefully been calibrated to data (Le Pourhiet et al. 2018, Savva et al. 2014). Building on the knowledge from 2D modelling and on the data available at the tip of the different propagators (failed and succeeded ones), we will finally put together 3D simulations to evaluate the respective role of boundary conditions and inheritance from the crust and the mantle in the success or failure of the different propagators.

Method

pTatin2 and 3d are open source codes (https://bitbucket.org/ptatin/, May et al. 2015) which solves mechanical and thermal conservation equations together with surface processes. The candidate with learn how to use (and modify) them on supercomputing facilities available both at the lab and nationally. In order to calibrate the simulations, the candidate will need to develop new output such as synthetic wheeler diagram for sedimentations.

References other than advisors

Block, L., & Royden, L. H. (1990). Core complex geometries and regional scale flow in the lower crust. *Tectonics*, *9*(4), 557-567.
Savva, D., Pubellier, M., Franke, D., Chamot-Rooke, N., Meresse, F., Steuer, S., & Auxietre, J. L. (2014). Different expressions of rifting on the South China Sea margins. *Marine and Petroleum Geology*, *58*, 579-598.
Barckhausen, U., Engels, M., Franke, D., Ladage, S., & Pubellier, M. (2014). Evolution of the South China Sea: Revised ages for breakup and seafloor spreading. *Marine and Petroleum Geology*, *58*, 599-611.
Wiest, J. D., Osmundsen, P. T., Jacobs, J., & Fossen, H. (2019). Deep crustal flow within postorogenic metamorphic core complexes: insights from the southern Western Gneiss Region of Norway. *Tectonics*, *38*(12), 4267-4289.
Teyssier, C., & Whitney, D. L. (2002). Gneiss domes and orogeny. *Geology*, *30*(12), 1139-1142.

The candidates are expected to have a background in quantitative tectonics (stress strain rheology) possibly modelling with demonstrated skills in basic programming (python or matlab), previous experience with C language is a plus but it is not mandatory.

Principal advisor :
PR Laetitia Le Pourhiet Sorbonne University develops and use thermo-mechanical codes designed for tectonic applications for more than 20 years. Together with her former students, she has published many papers on continental metamorphic core complexes in 2 and 3D as well as several contributions to continental break-up propagation in 3D. She will form and assist the successful candidate in the development of new simulations.

Some References related to the project.

Le Pourhiet, L., Chamot-Rooke, N., Delescluse, M., May, D. A., Watremez, L., & Pubellier, M. (2018). Continental break-up of the South China Sea stalled by far-field compression. *Nature Geoscience*, *11*(8), 605-609.
Le Pourhiet, L., Huet, B., May, D. A., Labrousse, L., & Jolivet, L. (2012). Kinematic interpretation of the 3D shapes of metamorphic core complexes. *Geochemistry, Geophysics, Geosystems*, *13*(9).
Huet, B., Le Pourhiet, L., Labrousse, L., Burov, E., & Jolivet, L. (2011). Post-orogenic extension and metamorphic core complexes in a heterogeneous crust: the role of crustal layering inherited from collision. Application to the Cyclades (Aegean domain). *Geophysical Journal International*, *184*(2), 611-625.
May, D. A., Brown, J., & Le Pourhiet, L. (2015). A scalable, matrix-free multigrid preconditioner for finite element discretizations of heterogeneous Stokes flow. *Computer Methods in Applied Mechanics and Engineering*, *290*, 496-523.
Labrousse, L., Huet, B., Le Pourhiet, L., Jolivet, L., & Burov, E. (2016). Rheological implications of extensional detachments: Mediterranean and numerical insights. *Earth-Science Reviews*, *161*, 233-258.

Co-advisor :
PR Gianreto Manatschal Strasbourg University
has developed together with his former students a lot the recent concepts in the analysis of passive margins formation. He is a specialist in seismic data interpretation and its comparison with fossil analogues. He will provide the successful candidate with the data necessary to calibrate the simulation. This thesis will also benefit from his continuous collaboration with China and in particular with Dr Cumei Zhang from Guangzhou Institute of oceanology.

Some References related to the project.

Zhang, C., Sun, Z., Manatschal, G., Pang, X., Li, S., Sauter, D., ... & Zhao, M. (2021). Ocean-continent transition architecture and breakup mechanism at the mid-northern South China Sea. *Earth-Science Reviews*, 103620.
Luo, P., Manatschal, G., Ren, J., Zhao, Z., Wang, H., & Tong, D. (2021). Tectono-Magmatic and stratigraphic evolution of final rifting and breakup: Evidence from the tip of the southwestern propagator in the south China sea. *Marine and Petroleum Geology*, *129*, 105079.
Zhang, C., Sun, Z., Manatschal, G., Pang, X., Qiu, N., Su, M., ... & Zhao, Y. (2021). Syn-rift magmatic characteristics and evolution at a sediment-rich margin: Insights from high-resolution seismic data from the South China Sea. *Gondwana Research*, *91*, 81-96.
Zhang, C., Su, M., Pang, X., Zheng, J., Liu, B., Sun, Z., & Manatschal, G.(2019). Tectono−sedimentary analysis ofthe hyperextended Liwan sag basin
(midnorthern margin of the South China Sea). Tectonics, 38. https://doi.org/10.1029/2018TC005063