DOCTORAT ECOLOGIE
BRETAGNE GEOSCIENCES
LOIRE AGRONOMIE ALIMENTATION

PhD PROPOSAL FOR THE DOCTORAL SCHOOL

« Ecologie, Géosciences, Agronomie, ALimentation »

GENERAL INFORMATION

Thesis title: Climate-erosion-tectonic interactions in a "hyper-active" context: modelling the impact of river incision on the mechanical behaviour of the continental crust
Acronym: Hyperinteractif
Disciplinary field 1: Geosciences **Disciplinary field 2:** Select an element
Three keywords: Tectonics, Erosion, Modelling
Research unit : Geosciences Rennes
Name of the thesis director HDR (Habilitation thesis to supervise research) required: Steer Philippe **Email address of the thesis director:** philippe.steer@univ-rennes1.fr **Name of the thesis co-director (if applicable): HDR (Habilitation thesis to supervise research) required:** Yamato Philippe **Email address of the thesis co-director (if applicable):** philippe.yamato@univ-rennes1.fr **Name of the thesis co-supervisor 1 (if applicable):** Guillaume Benjamin **Email address of the thesis co-supervisor 1 (if applicable):** benjamin.guillaume@univ-rennes1.fr
Thesis grant (funding origin and amount): Doctoral School Contract by Université Rennes 1
Contact(s) (mailing address and E-mail): PhD supervisors : Philippe Steer (philippe.steer@univ-rennes1.fr / 0223234265), Philippe Yamato (philippe.yamato@univ-rennes1.fr / 0223236095) et Benjamin Guillaume (benjamin.guillaume@univ-rennes1.fr / 0223235183). Géosciences Rennes, Université de Rennes 1, Campus Beaulieu, Adresse : 263 Avenue Général Leclerc, 35042 Rennes
Recruitment process: Recruitment process depends on thesis funding. To select the corresponding recruitment process, please visit the EGAAL website here. This information is needed for proposal publication. ☒ **Doctoral school contest** ☐ **Interview** ☐ **Other (indicate) :**

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All sections must be filled. Once filled, please save the proposal form in pdf format using the following naming: Supervisor Name_Unit_Subject Acronym_EN.pdf

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SCIENTIFIC DESCRIPTION OF THE PhD PROJECT

Socio-economic and scientific context : (10 lines)

The surface of the Earth represents the interface between the outer and inner envelopes of the Earth. The evolution of this surface is thus controlled by tectonic processes, erosion and climate and involves interactions between these processes that can promote natural hazards (e.g. earthquakes, floods, landslides). The main goal of this PhD thesis is to better understand these interaction mechanisms through a numerical modelling approach applied to regions associated with extreme tectonic, erosion and climatic dynamics. The PhD student will benefit from a dynamic research environment within Geosciences Rennes (Unité Mixte de Recherches under the supervision of the University of Rennes 1 and the CNRS). He will be associated with ambitious research projects (ERC FEASIBLe, ANR Topo-Extreme, IUF Yamato) and will benefit from the unique international skills of the researchers and teams associated with his supervision on numerical modelling and climate-erosion-tectonic interactions.

Assumptions and questions (8 lines)

The topography of mountain ranges results from a competition, integrated in time and space, between tectonic surrection and erosion processes, modulated by climate. Tectonic surrection allows for an increase in the relief and slopes of the topography, which catalyzes erosion rates, reflecting the "action" of tectonics on erosion. Numerous studies suggest that, in turn, erosion impacts on tectonic processes particularly through the isostatic response and changes in stress state that it generates. These "feedbacks" result from erosion-induced topographic unloading and associated deformation. The deep valleys of the Himalayan syntaxes represent exceptional and "hyper-active" targets to study these interactions because their rates of erosion and surrection are among the fastest observed on Earth.

The main steps of the thesis and scientific procedure (10-12 lines)

The objective of this thesis is to model and constrain the existing couplings between surface processes and the mechanical behavior of the continental crust at depth, particularly in the valleys of the Himalayan syntaxes. More specifically, the aim is (1) to study the impact of river erosion rates on the location and rate of deformation and the changes of pressure and temperature at depth inducing metamorphic reactions, (2) to determine the role of periodic fluctuations in erosion rates (e.g., climatic cycles) or extreme erosion events (e.g., capture of a catchment, landslides) and (3) to study the respective roles of erosion and lateral tectonic compression on the evolution of the shape of the valley and the coupling between erosion and deformation. The role of topography on deformation will also be considered through the prism of so-called topographic stresses, associated fractures and faults, and their impact on erosion and deformation rates. More broadly, this thesis will further investigate the coupling between erosion and crustal deformation, including elastic, brittle and viscous deformations, and will also address time-scale transfer issues (e.g. short-term effects of river incision vs. long-term effects of crustal creep).

Methodological and technical approaches considered (4-6 lines)

To address these issues, the PhD student will perform numerical models in order test different erosion laws and study their effects in different tectonic contexts. The natural targets chosen to constrain the models are the Nanga Parbat (West-Himalayan syntaxis) and the Namche Barwa (East-Himalayan syntaxis) where structural and thermochronological data show that the incision of both the Indus and Tsangpo rivers are closely associated with the formation of metamorphic domes (aneurysm phenomenon). The PhD student will use a 2D thermo-mechanical numerical model, based on the finite difference method, including a free surface, and allowing to take into account complex rheologies (visco-elasto-plastic). He will have to implement new functionalities in the code (e.g., erosion laws) necessary to tackle the issues relative to this work. The results of the models will be confronted with existing field data including erosion, thermochronological, metamorphic, structural and geological data, in the broadest sense. Depending on the candidate's skills, field work may be organized to acquire new data.

Scientific and technical skills required by the candidate

Initial training in Earth sciences with a good level and a strong taste for physics (especially mechanics), or in physics with additional training in Earth sciences. The candidate will demonstrate skills in numerical modeling and

will have an interest in tectonics and landscape dynamics.

THESIS SUPERVISION[1]

Unit name: Géosciences Rennes	**Team name:** DIMENV
Unit director name: Olivier Dauteuil	**Team director name:** Yves Méheust
Mailing address of the unit director: olivier.dauteuil@univ-rennes1.fr	**Mailing address of the team director:** yves.meheust@univ-rennes1.fr

Thesis director

Surname, first name: Steer Philippe

Position: Associate Professor

Obtained date of the HDR (Habilitation thesis to supervise research): 2020

Employer: Université Rennes 1

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 40%

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 50%

Number of current thesis supervisions/co-supervisions: 1

Thesis co-director

Surname, first name: Yamato Philippe

Position: Professor

Obtained date of the HDR (Habilitation thesis to supervise research): 2014

Employer: Université Rennes 1

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 30 %

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 50%

Number of current thesis supervisions/co-supervisions: 1

Thesis co-supervisor 1 (if applicable)

Surname, first name: Guillaume Benjamin

Position: Associate Professor

[1] **In EGAAL Doctoral School, if only one scientist in thesis supervision = 100% of supervision rate; if 2 people involved in thesis supervision = from 50% to 70% of supervision rate for the director; if 3 people involved in thesis supervision = 40% / 30% / 30% of supervision rate distribution among supervisors.**

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Habilitation thesis to supervise research ☐ yes ☒ no If yes, date diploma received:

Employer: Université Rennes 1

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 30

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 0

Number of current thesis supervisions/co-supervisions: 0

Professional status of previous PhD students supervised by both director and co-supervisors (from 5 years)

Please provide the following information for each PhD students supervised

Surname, first name: Croissant Thomas

Date of PhD beginning and PhD defence: 2013-2016

Thesis supervision: Dimitri Lague and Philippe Steer

Professional status and location: Post-doc, Durham University

Contract profile (post-doc, fixed-term, permanent): post-doc

List of publications from the thesis work:

- Croissant, T., Lague, D., Steer, P., & Davy, P. (2017). Rapid post-seismic landslide evacuation boosted by dynamic river width. Nature Geoscience, 10(9), 680-684.
- Croissant, T., Steer, P., Lague, D., Davy, P., Jeandet, L., & Hilton, R. G. (2019). Seismic cycles, earthquakes, landslides and sediment fluxes: Linking tectonics to surface processes using a reduced-complexity model. Geomorphology, 339, 87-103.
- Croissant, T., Lague, D., Davy, P., Davies, T., & Steer, P. (2017). A precipiton-based approach to model hydro-sedimentary hazards induced by large sediment supplies in alluvial fans. Earth Surface Processes and Landforms, 42(13), 2054-2067.
- Croissant, T., Lague, D., Davy, P., Davies, T., & Steer, P. (2017). A precipiton-based approach to model hydro-sedimentary hazards induced by large sediment supplies in alluvial fans. Earth Surface Processes and Landforms, 42(13), 2054-2067.
- Davy, P., Croissant, T., & Lague, D. (2017). A precipiton method to calculate river hydrodynamics, with applications to flood prediction, landscape evolution models, and braiding instabilities. Journal of geophysical research: earth surface, 122(8), 1491-1512.

Surname, first name: Jeandet Louise

Date of PhD beginning and PhD defence: 2015-2018

Thesis supervision: Dimitri Lague and Philippe Steer

Professional status and location: Post-doc, Paris Sorbonne University

Contract profile (post-doc, fixed-term, permanent): post-doc

List of publications from the thesis work:

- Steer, P., Jeandet, L., Cubas, N., Marc, O., Meunier, P., Simoes, M., ... & Hovius, N. (2020). Earthquake statistics changed by typhoon-driven erosion. Scientific reports, 10(1), 1-11.
- Jeandet, L., Steer, P., Lague, D., & Davy, P. (2019). Coulomb mechanics and relief constraints explain landslide size distribution. Geophysical Research Letters, 46(8), 4258-4266.

- Jeandet Ribes, L., Cubas, N., Bhat, H. S., & Steer, P. (2020). The Impact of Large Erosional Events and Transient Normal Stress Changes on the Seismicity of Faults. Geophysical Research Letters, 47(22), e2020GL087631.

Surname, first name: Bernard Maxime

Date of PhD beginning and PhD defence: 2017-2020

Thesis supervision: Kerry Gallagher and Philippe Steer

Professional status and location: Post-doc, GFZ Potsdam

Contract profile (post-doc, fixed-term, permanent): post-doc

List of publications from the thesis work:

- Bernard, M., Steer, P., Gallagher, K., & Lundbek Egholm, D. (2020). Modelling the effects of ice transport and sediment sources on the form of detrital thermochronological age probability distributions from glacial settings. Earth Surface Dynamics, 8(4), 931-953.
- Bernard, M., Steer, P., Gallagher, K., & Lundbek Egholm, D. (in review). The impact of lithology on fjord morphology, Geophysical Research Letters.

Surname, first name: Hertgen Solenn

Date of PhD beginning and PhD defence: 2015-2018

Thesis supervision: Philippe Yamato and Benjamin Guillaume

Professional status and location: ATER, Université de Franche-comté

Contract profile (post-doc, fixed-term, permanent): ATER

List of publications from the thesis work:

- Angiboust S., Yamato P., Hertgen S., Hyppolito T., Bebout G.E. and Morales L., (2017) "Fluid pathways and high pressure metasomatism in a subducted continental slice (Mt. Emilius klippe, W. Alps)", Journal of Metamorphic Geology, doi:10.1111/jmg.12241
- Hertgen S., Yamato P., Morales L. and Angiboust S.(2017) "Evidence for brittle deformation events at eclogite-facies P-T conditions (example of the Mt. Emilius klippe, Western Alps). Tectonophysics, doi: 10.1016/j.tecto.2017.03.028
- Guillaume B., Hertgen S., Martinod J., and Cerpa N (2018) "Slab dip, surface tectonics: How and when do they change following an acceleration/slow down of the overriding plate?" Tectonophysics, 726, doi: 10.1016/j.tecto.2018.01.030
- Hertgen S., Yamato P., Guillaume B., Magni V., Schliffke N., and van Hunen J. (2020), "Influence of the thickness of the overriding plate on convergence zone dynamics", Geochemistry Geophysics Geosystems, doi:10.1029/2019GC008678

Surname, first name: Poh Jonathan

Date of PhD beginning and PhD defence: 2016-2019

Thesis supervision: Philippe Yamato, Patrick Ledru, and Thibault Duretz

Professional status and location: Post-doc, School of Civil and Environmental Engineering, Nanyang Technological University, Singapore

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Contract profile (post-doc, fixed-term, permanent): post-doc

List of publications from the thesis work:

- Poh J., Yamato P., Duretz T., Gapais D., and Ledru P. (2020), "Precambrian deformation belts in compressive tectonic regimes: A numerical perspective", Tectonophysics, doi:10.1016/j.tecto.2020.228350
- Poh J., Yamato P., Duretz T., Gapais D., and Ledru P. "The transition from ancient to modern-style tectonics: insights from lithosphere dynamics modelling in compressional regimes", Gondwana Research (accepted after minor revisions).
- Poh J., Eldursi K., Yamato P., Ledru P., Chi G., and Benedicto A. « Role of hydrothermal circulation above inherited basement structures in relation to unconformity-related uranium mineralisation » (submitted to Journal of Structural Geology).

Surname, first name: Fernandez-Garcia Carlos

Date of PhD beginning and PhD defence: 2016-2019

Thesis supervision: Benjamin Guillaume, and Jean-Pierre Brun

Professional status and location: Engineer in sub-surface geophysics, Granada, Spain

Contract profile (post-doc, fixed-term, permanent): fixed-term

List of publications from the thesis work:

- Fernandez-Garcia, C., Guillaume, B., Brun, J.-P., (2019), 3D slab breakoff in laboratory experiments, Tectonophysics, 773, doi:10.1016/j.tecto.2019.228223.
- Santos-Bueno, N., Fernández-García, C., et al. (2019), Focal Mechanisms for Subcrustal Earthquakes Beneath the Gibraltar Arc, Geophysical Research Letters, 46, doi:10.1029/ 2018GL081587.

Five main recent publications of the supervisors on thesis subject:

- Porkoláb, K., Duretz, T., **Yamato, P.** et al. Extrusion of subducted crust explains the emplacement of far-travelled ophiolites. Nature Communications 12, 1499 (2021).
- **Steer, P.,** Jeandet, L., Cubas, N., Marc, O., Meunier, P., Simoes, M., ... & Hovius, N. (2020). Earthquake statistics changed by typhoon-driven erosion. Scientific reports, 10(1), 1-11.
- Jeandet Ribes, L., Cubas, N., Bhat, H. S., & **Steer, P.** (2020). The Impact of Large Erosional Events and Transient Normal Stress Changes on the Seismicity of Faults. Geophysical Research Letters, 47(22), e2020GL087631.
- Cerpa, N. G., **Guillaume, B.**, & Martinod, J. (2018). The interplay between overriding plate kinematics, slab dip and tectonics. Geophysical Journal International, 215(3), 1789-1802.
- Collignon, M., **Yamato, P.**, Castelltort, S., & Kaus, B. J. (2016). Modeling of wind gap formation and development of sedimentary basins during fold growth: application to the Zagros Fold Belt, Iran. Earth Surface Processes and Landforms, 41(11), 1521-1535.
- **Steer, P.**, Simoes, M., Cattin, R., & Shyu, J. B. H. (2014). Erosion influences the seismicity of active thrust faults. Nature communications, 5(1), 1-7.

THESIS FUNDING

Origin(s) of the thesis funding: Doctoral School Contract by Université Rennes 1

Gross monthly salary: 1770 €

Thesis funding state : Non acquired

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Funding beginning date/Funding ending date: 01/10/2021 / 3 years

Date: 17/03/2021

Name, signature of unit director: Olivier Dauteuil

Olivier DAUTEUIL
Directeur de Géosciences
Rennes UMR6118

Name, signature of team director: Yves Méheust

Name, signature of thesis project director: Philippe Steer