Subject offered for a contract starting October 2019

SUBJECT TITTLE:

Geological sources of electromagnetic anomalies and sulfur emission in the Nepal Himalayas

Advisor: **PERRIER, Frédéric, Pr, perrier@ipgp.fr**

Second Supervisor: **GIRAULT, Frédéric, MCF, girault@ipgp.fr**

Host lab/ Team: **IPGP - Physics of Natural Sites (PSN) – UMR7154**

Financing: **Doctoral contract without teaching assignment**

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Presentation of the subject: (1 or 2 pages)

Context:

At large spatial scale, several magneto-telluric (MT) surveys, conducted perpendicular to the Main Himalayan Thrust in the Nepal Himalayas, have revealed mid-crustal conductive regions in the Main Central Thrust (MCT) zone, partially associated with seismic activity. Recently, the high polarizability and frequency-dependent electrical conductivity of black schist in this zone has suggested an important role of this rock-type bearing graphite to the crustal conductivity structure of the MCT zone. At a smaller spatial scale, electrical anomalies have been detected in the vicinity of the numerous hydrothermal systems located in the MCT zone, sometimes associated with sulfur deposits. Besides, these systems exhibit large carbon dioxide (CO_2) emissions, sometimes carrying hydrogen sulfide (H_2S) to the surface. This CO_2, likely produced in the upper crust by metamorphic reactions at more than 5 km depth, has been strongly affected by the 2015 M_w7.8 Gorkha earthquake in Central Nepal. These combined observations suggest that carbon and sulfur, under various forms, could play an essential role during the seismic cycle.

Objectives:

The first objective of the PhD is to map geologically in detail and characterize petrologically the occurrences of black schist in the MCT zone of Central Nepal. If some outcrops are identified, we do not know their spatial extent, their petrography, nor their graphitic content. A combination of X-ray diffraction analysis, scanning electron microscopy and Raman spectroscopy will be used. Special attention will be given to the Syabru-Bensi hydrothermal system, where the association of black schist and CO_2 emission bearing H_2S has already been identified. Then, other occurrences of black schist in the same valley will be investigated, such as at the Upper Sanjen Hydroelectric Project located further north, which has shown CO_2 bearing H_2S emissions from boreholes after the 2015 earthquake. In the following, other locations in Central Nepal will be secondary targets.

The second objective of the PhD is to quantify the amount of H_2S emitted from the ground by the diffuse degassing structures of several hydrothermal systems located in Central Nepal, and to model the CO_2 bearing H_2S discharge at these sites. First measurements of H_2S flux using the accumulation chamber method will be carried out in Syabru-Bensi, together with CO_2 fluxes showing values ranging over five to six orders of magnitude. Then, other hydrothermal systems will be investigated, including some in the same valley. Spatial variations of H_2S flux will give precious information about the spatial extent of such emissions at a given site, its total estimated gaseous H_2S discharge, and likely the location of the reactive front at shallow depth involving hydrothermal water. Temporal variation of H_2S fluxes at selected sites will be assessed using dedicated sensors and compared with available time-series of CO_2 fluxes. The sulfate content of selected hot springs will also be used in order to obtain, together with the total H_2S flux from the ground, a global estimate of sulfur emission from these hydrothermal sites. The effects of a change in transport properties of the upper crust such as permeability will be tested using the CO_2-H_2S diffusive-advective transport model developed.

The third objective of the PhD is to image the subsurface of the diffuse degassing structures and black schist occurrences at selected locations using geophysical sounding techniques. Electrical Resistivity Tomography (ERT), Self-Potential (SP) mapping, and Induced Polarization (IP) tomography will be used. While ERT and IP will image the subsurface up to hundred meters depth and give information about the electrical conductivity (real and imaginary) and chargeability, SP will give the direction of fluid movements and locations of reactive front and alteration processes at play. The use of subsurface geophysical techniques in the near field, such as Time-Domain Electro-Magnetic (TDEM) sounding will also be investigated. Information about the structure at depth of Himalayan hydrothermal systems is generally lacking, hampering a general understanding of the fluid pathways, mineralization, and recharge regions.

The fourth objective of the PhD is to characterize the electromagnetic properties from the studied black schists in the laboratory. Spectral Induced Polarization (SIP) will be measured while varying confining pressure, brine composition, and orientation and type of the black schist. These up-to-date experiments will study the importance of graphite as the main source of polarization and the effects of the orientation of graphitic plates along the natural foliation. The influence of brine containing CO_2 and H_2S on the SIP properties will also be investigated. These experiments will help to enhance both the interpretation of deep crustal geophysical surveys in the region and our understanding of the Himalayan orogeny.

Based on a multidisciplinary approach combining geology, petrology, geochemistry, geophysics and rock mechanics, this PhD work on the tectonic significance of carbon and sulfur release from rocks along an active mega-thrust fault will disentangle the various electromagnetic sources due to seismic activity from purely geological alteration processes. Finally, the used techniques, such as the combination of gas flux measurements and geophysical soundings, and the obtained results, would be valuable assets to more applied concerns in the environment, prospection of mineral resources, and in the industry.