CHINA SCHOLARSHIP COUNCIL

Appel à projets Campagne 2022

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Title of the research project : Nitrogen fixation during explosive volcanic eruptions and its implications for the development of life on Earth

Thesis supervisor (HDR) :

Name: MARTIN

Surname: ERWAN

Title: Dr, HDR

email : erwan.martin@sorbonne-universite.fr

Professional adress : ISTeP, tour 46, 46-00, 4ème étage, 4 place Jussieu, 75252 Paris

Research Unit

Name : **ISTeP – Sorbonne Université**

UMR 7198

Doctorate School

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

No PhD student currently supervised by the thesis supervisor

Joint supervisor :

Thesis supervisor (HDR) :

Name: BEKKI

Surname: SLIMANE

Title: Dr, HDR

email : slimane.bekki@sorbonne-universite.fr

Professional adress : LATMOS/IPSL 4 place Jussieu, 75252 Paris

Research Unit

Name : **LATMOS/IPSL – Sorbonne Université**

UMR 8190

Doctorate School

Thesis supervisor's doctorate school (candidate's futur doctoral school) : **ED 129**

2 PhD student currently co-supervised by the thesis supervisor

SORBONNE UNIVERSITÉ

Description of the research project (*ENGLISH*):

Nitrogen (N) is a crucial element for all life on Earth. However, almost all the N is in the very stable form of atmospheric dinitrogen, N_2, which cannot be used, as it is, by living organisms. The process of converting N_2 into biologically assimilable N-bearing molecules (called fixed N: e.g. ammonia, nitrates, nitrites) is called nitrogen fixation. Nowadays, nearly all the N fixation on Earth is achieved through biological and anthropogenic processes. Though marginal in the present-day atmosphere, N fixation must have proceeded through natural abiotic processes on the early Earth (i.e. before the apparition of the N-fixing organisms) in order to allow the development of life. One of the most invoked natural abiotic sources of fixed N is lightning discharges, notably those associated with volcanic activity (Mather et al., 2004; Navarro-Gonzalez et al., 1998). However, up to now, no evidence of substantial amounts of fixed N had ever been found in volcanic records. Our group has very recently discovered very large amounts of nitrate (NO3) in volcanic fallout and pyroclastic flow deposits in arid environments (Aroskay, 2020). It is the first and unique evidence of nitrogen-fixing in volcanic plumes. The concentration of nitrate in the studied volcanic deposits was found to be very strongly correlated with that of volcanic sulphate and chlorine. In addition, the oxygen triple isotopic signature in these nitrates indicated an atmospheric origin, most likely volcanic lightning-produced nitrogen oxides (NOx) oxidized by ozone.
The PhD student will join the Sorbonne University which is ranked among the top 2 universities in France. The work will contribute to a national research project funded by ANR: VOLC-HAL-CLIM (Volcanic Halogens: from Deep Earth to Atmospheric Impacts, https://scanr.enseignementsup-recherche.gouv.fr/project /ANR-18-CE01-0018). It will also contribute to the international programme SSiRC (Stratospheric Sulfur and its Role in Climate) on the stratospheric impact of large volcanic eruptions (http://www.sparc-ssirc.org/). SSiRC is an established SPARC (Stratosphere-Troposphere Processes and their role in Climate) activity, with SPARC being a core project within the World Climate Research Program (WCRP).

Scientific objectives

This major finding opens a wide field of investigations. In this project, we first aim to confirm this discovery by searching for the presence of nitrates in other volcanic deposits, from very ancient to more recent eruptions (pumice/ash fallout, pyroclastic flows) and of different magnitudes (VEI-3 to VEI-8). We also propose to identify unambiguously and quantify the N-fixing processes by analysing the chemical composition of volcanic deposits (in particular the nitrogen and oxygen isotopic composition of volcanic nitrate) and simulating physicochemical processes with numerical models. Finally, we will explore the implications of these processes for the role of explosive volcanic eruptions in the development of life on Earth, notably for the idea of life having started on Earth's surface in volcanic pools fed by eruptions.
Results are expected to be published in high impact scientific journals

Methodology / implication of laboratories / role of the supervisors

The work will involve collecting volcanic samples in different regions of the world and supervised by Erwan Martin. The targeted deposits are (1) ancient super-eruptive deposits (Bishop Tuff ash, and Yellowstone deposits in the Tecopa Basin (Martin and Bindeman, 2009))

and (2) deposits from more moderate and recent explosive eruptions (collaborations with Smithsonian NMHN (USA), UNAM (Mexico), IGPEN (Ecuador) among others).
Volcanic samples will be treated in several laboratories using state-of-the-art ultra-sensitive instrumentation. The extraction and conditioning of nitrates will be done at ISTeP (Paris), in the Erwan Martin laboratory. The Isotopic analysis of nitrates (δ18O, Δ17O, δ15NN) will be carried out at IGE (Grenoble; Albertin et al., 2021), and the associated sulphate isotopic measurements (δ18O, Δ17O, δ34S, Δ33S and Δ36S) at IPGP (Paris; Aroskay et al., 2021), two labs with which the two supervisors collaborate since more than 10 years and will be overall supervised by Erwan Martin. The physico-chemistry modelling (Surl et al., 2021) will be carried out in collaboration with Slimane Bekki at LATMOS.

References from the supervisors and their team linked to this project

- Albertin S., et al., 2021, Nitrogen isotopes ($\delta^{15}N$) and first quantification of oxygen isotope anomalies ($\Delta^{17}O$, $\delta^{18}O$) in atmospheric nitrogen dioxide, Atmospheric Chemistry and Physics, 21 (13), pp.10477-10497.

- Aroskay A. (2020) Thèse Doctorat, Sorbonne Université

- Aroskay A., et al., 2021, Multi O- and S-isotopes as tracers of black crusts formation under volcanic and non-volcanic atmospheric conditions in Sicily (Italy), Science of the Total Environment, 750, pp.142283.

- Surl L., et al., Observation and modelling of ozone-destructive halogen chemistry in a passively degassing volcanic plume, Atmospheric Chemistry and Physics, European Geosciences Union, 2021, 21 (16), pp.12413-12441.

- Martin, E.; Bindeman, I., 2009, Mass-independent isotopic signatures of volcanic sulfate from three supereruption ash deposits in Lake Tecopa, California, Earth Planet. Sci. Lett. 2009, 282, 102–114.

- Aroskay A., MartinE., Bekki S., Montana G., Randazzo L., Cartigny P., Chabas A., Verney-Carron A. (2021). Multi O- and S-isotopes as tracers of black crusts formation under volcanic and non-volcanic atmospheric conditions in Sicily (Italy). Sciences of the Total Environnment. 750, 142283.

- Galeazzo T., Bekki S., Martin E., Savarino J., Arnold S. (2018). Photochemical box-modelling of volcanic SO_2 oxidation : isotopic constraints. Atmospheric chemistry and physics. Atmos. Chem. Phys. 18, 17909-17931.

- Martin E. (2018) Volcanic plume impact on the atmosphere and climate: O- and S-isotope insight into sulfate aerosol formation. MDPI Geosciences. 8, 198

- Martin E., Bekki, S., Ninin, C. & Bindeman I. (2014). Volcanic sulfate formation in the troposphere. Journal of Geophysical Research. Atmos., 119, 12660–12673.

- Le Gendre E., Martin E, Villemant B, Cartigny P, Assayag N. (2017) A simple and reliable anion exchange resin method for sulfate extraction and purification suitable for O- and S- isotope measurements. Rapid Communications in Mass Spectrometry, 31, 1-8. Doi: 10.1002/rcm.7771

- Martin E. & Bindeman I. (2009). Mass-independent isotopic signatures of volcanic sulfate from three supereruption ash deposits in Lake Tecopa, California. Earth and Planetary Science Letters, 282, 102-114

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CALENDRIER DE LA CAMPAGNE

26 juillet

Lancement de la campagne
Diffusion de l'appel à projets par les écoles doctorales auprès de leurs encadrantes et encadrants.

Jusqu'au 17 septembre

Les chercheurs/enseignants-chercheurs et chercheuses/enseignantes-chercheuses de Sorbonne Université soumeXent des proposiBons de projets de recherche doctoraux à leur directeur et directrice d'école doctorale (en uBlisant le formulaire joint) et à l'adresse suivante : hBps://inscripKons.sorbonne-universite.fr/lime25/index.php/344242?lang=fr

Jusqu'au 24 septembre

Les écoles doctorales valident le cas échéant les projets et noBfie le collège doctoral de leur décision à l'adresse suivante : **csc-su@listes.upmc.fr**

1er octobre

Mise en ligne des projets validés sur le site web de Sorbonne Université et ouverture des candidatures
hBps://www.sorbonne-universite.fr
Les candidats chinois prennent contact avec les porteurs et porteuses de projets et leur envoient un dossier de candidature.
Les candidates et les candidats déposent leur dossier à l'adresse suivante :
hBps://inscripKons.sorbonne-universite.fr/lime25/index.php/383154?newtest=Y&lang=fr

31 janvier

Fermeture des candidatures
Les porteurs et porteuses de projet ont transmis la candidature retenue après audiBon des candidates et candidats à leur école doctorale

Jusqu'au 21 février

Après examen, les écoles doctorales envoient les leXres de pré-admission signées et tamponnées des candidats et candidates retenues au collège doctoral

28 février

Le collège doctoral envoie les leXres de pré-admission aux candidates et candidats

Jusqu'au 31 mars

Les candidates et candidats retenus par Sorbonne Université candidate sur le site internet du CSC

31 mai

Diffusion des résultats par le CSC auprès de SU
Envoi résultats aux candidates et candidats ainsi qu'aux porteurs et porteuses de projet