Green2Ice PhD 3 offer: CRPG, Université de Lorraine: September 2024 to August 2027

Thesis title: What is the geological and geochemical information stored in the basal part of Greenland ice cores? Implication for the Greenland geology, the processes of debris incorporation in basal ice and the long-term stability of the Greenland Ice Sheet

PhD main advisors: P.-H. Blard (CRPG, Nancy 34%), C. Prud'Homme (CRPG, Nancy 33%), Y. Marrocchi (CRPG, Nancy 33%)

Main host lab: CRPG (CNRS, Université de Lorraine, France)

Collaborations:

F. Fripiat (ULB Brussels – granulometry, samples processing, samples transfer to or from other methods, data interpretation)
J.-L. Tison (ULB Brussels, samples processing, samples transfer to or from other methods, data interpretation)
N. Perdrial (U. Vermont, automatized calculation and statistics from mineral shape maps and composition maps, data interpretation)
A. Svensson and B. Vinther (NBI, Copenhagen, processing of surrounding ice, data interpretation) D. Dahl-Jensen, J.P. Steffensen (NBI, Copenhagen, data interpretation)
M. Gerardin (Georessources, Nancy, clay mineralogy and K-Ar dating of clays)
J. Villeneuve (CRPG, Nancy, SIMS analysis)
M. Protin (CRPG, Nancy, samples saving for further cosmogenic nuclides analysis)
K. Thomsen and T. Freiesleben (DTU Riso, samples exchange for OSL, analysis of U, Th, K for dose rate)
P. Knutz (GEUS Copenhagen, comparison with marine and margin samples)

Our CRPG group seeks a PhD candidate to analyze the geological debris retrieved in the silty-debris rich basal ice of the Greenland ice cores (NEEM, EastGRIP, Camp Century, NewGRIP). The PhD candidate will be part of a large international collaborative group. The candidate's main objective will be to apply a variety of state-of-the-art methodologies to characterize the petrological and geochemical nature of the debris found in ice, to understand their origin and the history of their incorporation into ice. Finally, this work will aim to constrain the succession of events recorded by this rare subglacial material of Greenland, including episodes of deglaciations and sub-ice weathering.

After an initial characterization of the ice core using density estimate, optical description of the macro-features, X-Ray Computed Tomography, debris-rich ice core samples will be processed following an appropriate protocol to optimize the available ice: gas will be first extracted from ice and measured at ULB; ice will be saved for analyzing its cation contents, pH and $\delta^{18}O$ at

the NBI (collaboration with other PIs, Post Docs and PhD of the Green2Ice project at ULB and NBI).

During this initial step, the PhD will collect the geological fraction from the ice by filtering under pressure on 0.20 µm Millipore® (using the filtering pressure system designed at CRPG). Collected dry residues will be weighted to estimate their proportion in ice. Several analyses will then be carried out by the PhD student, following our recent experience on the analysis of basal ice in the NSF project dedicated to Camp Century:

- Petrological and mineralogical description of pebbles and sandy fraction.
- Laser granulometry (Mastersizer 3000® at ULB).
- Qualitative and quantitative analysis of subglacial grain characteristics both at the macro and microscales, notably using SEM high resolution images and geochemical mapping. Identification of typical features and the sequence of successive events (glacial erosion, fluvial transportation, weathering in soils; Mahaney, 2002; Blard et al., 2023, Marschalek et al., 2024), thereby placing relative chronological controls on the successive waxing and waning of the GrIS. Collaboration with N. Perdrial, U. Vermont (USA) for automatized calculation and statistics – method calibration of roundness and circularity metrics of grains from modern sediments and ice debris.
- Clays assemblages will be characterized by X-ray diffraction (Georessources), some of the species being characteristics of weathering in deglaciated conditions (kaolinite). Innovative approach will also be explored, such as $\delta^{18}O$ analysis of these clays, to constrain the origin of the water involved in the weathering reactions forming these clays, and their dating through K-Ar (coll. with M. Gerardin, Georessources).
- The PhD student will also use state-of-the-art facilities of CRPG to determine the geochemical nature, provenance, crystallization age and thermal history of these unique sub-ice rock samples: major and trace elements with SEM, EMP, REE spectra, Sr and Nd isotopes, $^{207}Pb/^{206}Pb$ in feldspars, U/Pb in zircons, (U-Th)/^{4}He thermochronometry.
- Outputs: a global petrological and geochemical GIS map of Greenland.

The petrological and geochemical data obtained by the PhD will not only be used to document and better understand the geology of the Greenland substratum seen for the first time by these unique and rare deep cores. Another outcome of the PhD results will also be to guide the interpretation of the geochronological approaches (in situ cosmogenic isotopes, luminescence dating, collaboration with other scientists, PhDs and PostDoc of Green2Ice) permitting to document the timing and duration of the Greenland ice sheet last deglaciations.

The hired student will have a strong background in geology, geochemistry, and will be able to learn and master a large variety of analytical approaches. Importantly, he/she will need to work in the frame of an international group (Green2Ice project), which will require skills in communication, mobility and ability to synthetize a large combination of observations and data.

Candidates are invited to send their CV and a letter of motivation (2 pages max) to:
pierre-henri.blard@univ-lorraine.fr by June 15th 2024.

Picture of the basal ice section of the NEEM core with silicate debris (picture: M. Protin)