Melt-rock interaction in the oceanic lithosphere

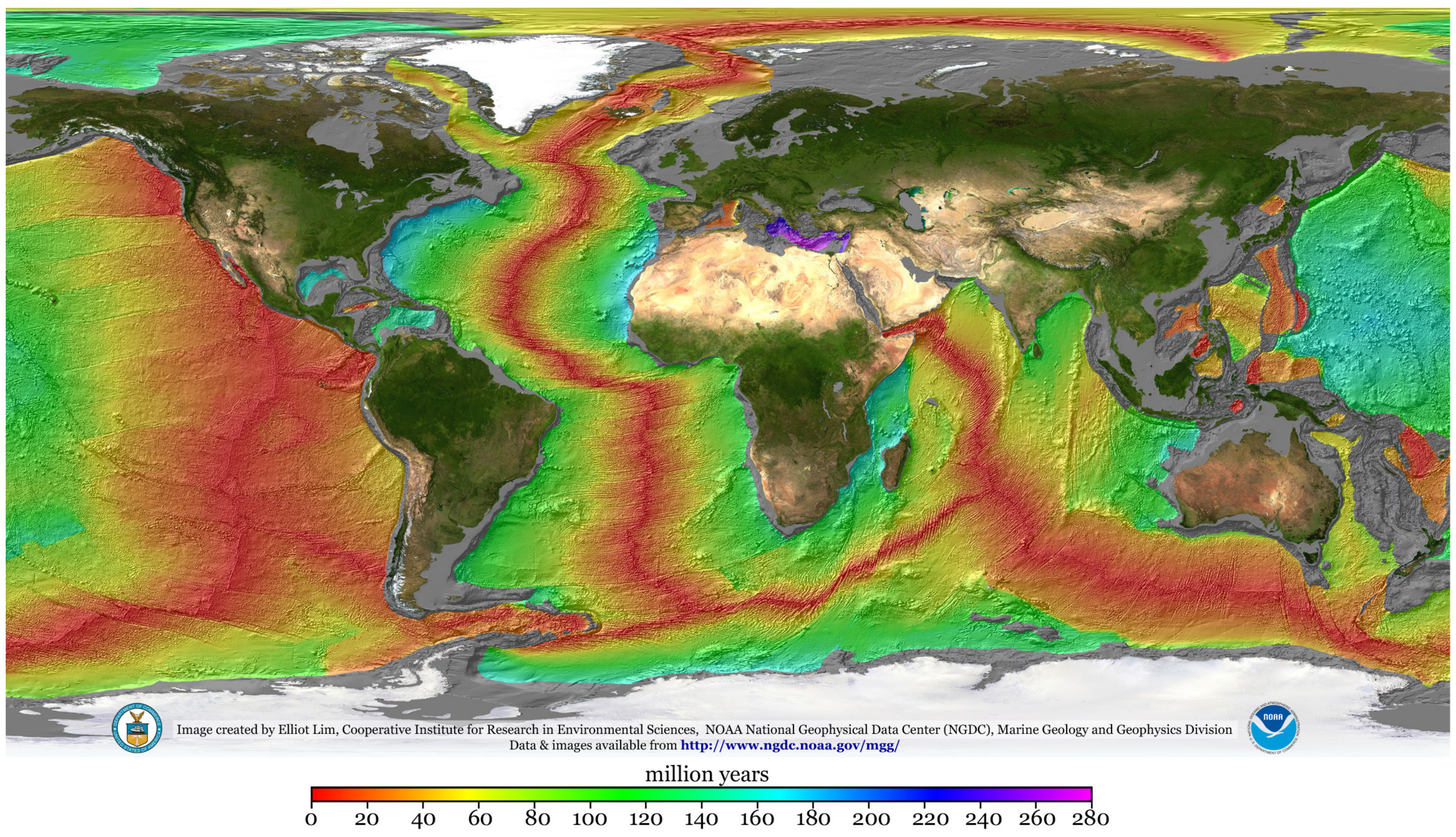
Case study of the Bay of Islands Ophiolite, Newfoundland

R. Tilhac, G. Gonnet, N. Berthelot, H. Henry, J. Bédard

romain.tilhac@umontpellier.fr

Beneath mid-ocean ridges, upwelling mantle partially melts to produce basaltic magmas, leaving behind residual peridotites. This process builds new oceanic lithosphere and constitutes one of the major heat and mass transfers on Earth. As such, the oceanic lithosphere offers unique—but complex—insights into our planet's dynamic interior.

For decades, petrologists and geochemists have emphasized the importance of decompression melting and the contribution of subducted, recycled materials in the mantle source. While these early works have shaped our understanding of basalt genesis, they often overlook the lithosphere's role as a reactive filter. Field observations from fossil oceanic lithosphere tectonically emplaced on land (*i.e.* **ophiolites**) document complex spatio-temporal evolution with multiple stages of magmatic intrusion and melt-rock interaction across varying tectonic contexts. Reconciling these observations with prevailing conceptual views remains a key challenge. To address it, this work aims to place quantitative constraints to field observations by combining analytical data and numerical simulations.



The global mid-ocean ridge system is a nearly continuous mountain chain spanning >60,000 km—the longest on Earth. New oceanic lithosphere (**in red**) forms along these ridges, causing the planet's most important volcanic activity (>75% of all magmas). As the ocean floor spreads driven by mantle convection, the lithosphere cools, densifies and eventually sinks into the mantle during subduction—one of the most striking expressions of plate tectonics.

Typical views of mantle outcrops from the Bay of Islands Ophiolite Complex (BOIC). Red Rocky Gulch, Lewis Hills massif (Credits: Cabox).

The Bay of Islands Ophiolite Complex (BOIC) is among the world's best preserved ophiolites and an iconic locality for early magma chamber models. However, the ophiolite has remained relatively underexplored in light of modern analytical and numerical techniques because of its difficult access.

This work led by R. Tilhac (CNRS, Géosciences Montpellier) is based on a collaboration with H. Henry (GET, Toulouse) and J. Bédard (Geol. Survey of Canada), following the latter's initiative to revive the study of this ophiolite with logistical support from the Geol. Survey of Newfoundland. It focusses on the ophiolite's **North Arm Massif** where evidence of boninitic underplating documents polystaged evolution of the crust-mantle transition zone. The interest of this work is (**1**) to leverage the peculiar signature (*e.g.*, Ti-poor) of the magmas involved to geochemically track the consequences of their migration, and (**2**) to benefit from lateral variations in the extent of preservation of the original (*i.e.* tholeiitic) lithosphere. It represents a unique opportunity to get insights into tectono-magmatic processes normally hidden deep beneath the ocean floor.

Project 1 - G. Gonnet (M1 AWARE-Earth / Géosciences Montpellier)

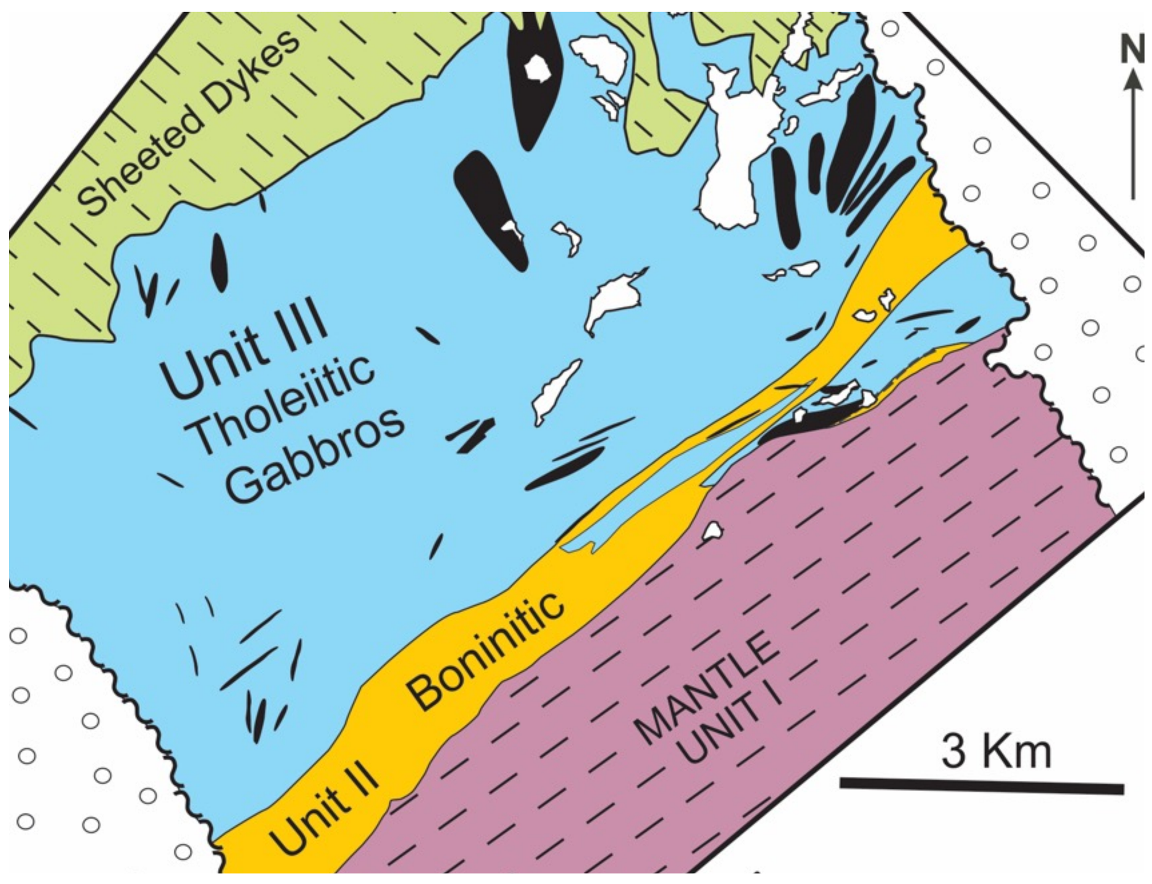
Petro-geochemical characterization of primitive boninitic cumulates

The formation of magmatic harzburgites is a puzzling expression of boninitic underplating in BOIC. While harzburgites are typically interpreted as residual mantle rocks after partial melting, field evidence here indicates that they crystallized as cumulates within dykes and sills. The presence of reaction rims, clusters and trails of pyroxenes further suggests that fragments of the variably reacted host rocks were detached and entrained by magmatic flow. This project aims to provide a complete petro-geochemical characterization of these cumulates to better understand their formation in light of thermodynamic modeling.

Project 2 - N. Berthelot (M2 UBO / Géosciences Montpellier)

Geospeedometric study of gabbroic assimilation by boninitic melts

Plagioclase peridotites are a pervasive product of the partial assimilation of tholeitic gabbros by primitive boninitic melts. In BOIC, these exceptionally fresh rocks preserve sodic plagioclase (*i.e.* anorthite content = 45-75 %) inherited from their tholeitic protolith alongside Mg-rich olivine (forsterite content = 90 %) derived from the assimilating melts. This assemblage suggests that chemical equilibrium was not fully attained during assimilation. This project aims to measure chemical zoning profiles within minerals, fit them to diffusion models and derive kinetic constraints (*i.e.* geospeedometry) on the assimilation process.



Simplified geological map of the North Arm Massif. The area of interest (**in yellow**) shows tholeitic gabbros variably preserved during boninitic underplating.

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