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Titre et résumé de la thèse – Title and abstract of the thesis

Non-traditional stable isotope fractionation (Fe, Li, Ge) during subduction zone metamorphism and geochronology of metamorphic minerals

Devolatilisation reactions occurring during subduction zone metamorphism (SZM) of the hydrothermally altered oceanic lithosphere may be source of significant fluid-mediated mass transfer to the overlying mantle wedge. During seafloor hydrothermal alteration and SZM, the oceanic lithosphere undergoes petrological and geochemical transformations. Element mobility and recycling processes may be evaluated using geochemical tracers (trace elements, stable isotopes). Besides, radiogenic isotopes can help placing age and time constraints on metamorphic reactions. Accessory minerals (zircon, allanite, titanite or monazite) contain variable U, Th and Pb contents, and can be dated with the U–Pb or Th–Pb methods. They often display different generations formed under various pressure and temperature conditions and, thus, are useful to reconstruct the metamorphic history of subducted rocks.

The first part of this study investigates Fe, Ge and Li non-traditional stable isotopes as geochemical tracers of fluid–rock interactions during hydrothermal alteration and SZM in Variscan rocks from 1) the Ile de Groix high-pressure/low-temperature (HP–LT) terrane (Brittany, France) and 2) the Limousin ophiolite (French Massif Central). Iron and Ge stable isotopes can fractionate during magmatic processes and during low-temperature hydrothermal alteration. It is recognised that Fe and Ge mobility and isotope fractionation depend on the physico-chemical parameters of fluid–rock interactions. The metabasites of the Ile de Groix (blueschists, eclogites and retrograde greenschists) derive from a basaltic protolith with a Fe isotope composition heavier than mid-ocean ridge basalts (MORB), even if Fe isotopes may also have fractionated towards heavier values during hydrothermal alteration and Fe oxidation prior to subduction. The large stability field of Fe-rich minerals (garnet, epidote, amphiboles and omphacite) allow whole rock Fe and δ^{56}Fe compositions to be preserved during SZM, and prevent Fe release in fluids. The data anticipate that fluid-induced metasomatism of the mantle wedge might only weakly affect mantle Fe isotope composition under sub-solidus conditions, although melting of the heavy-Fe metabasites at deeper level might produce mantle Fe isotope heterogeneities. By contrast, the HP–LT metabasites of the Ile de Groix have Ge isotopic compositions similar to MORB. While there is no evidence of Ge isotope fractionation during hydrothermal alteration and prograde metamorphism, Ge isotopes can fractionate towards heavier values during intensive fluid–rock interactions related to the late stages of retrograde metamorphism. Migration of fluids along the crust–mantle interface may trigger Ge isotope fractionation in the mantle wedge, even if δ^{74}Ge variations are too small to generate bulk mantle Ge isotopic heterogeneities through fluid-induced metasomatism or partial melting.

Contrary to Fe and Ge, Li is a light and highly mobile element in fluids. Its two isotopes can fractionate significantly by chemical diffusion or kinetic fractionation. Variations in Li elemental and isotopic compositions of serpentinites and amphibolites from the Limousin ophiolite reflect changes in fluid composition and temperature conditions during seafloor hydrothermal alteration. On the other hand, blueschists and eclogites from the Ile de Groix have high Li abundances compared to fresh and altered MORB, indicating Li enrichment during interaction with sediment-derived fluids in addition to hydrothermal alteration. However, the low δ^{7}Li of whole rocks, glaucophane and omphacite result from subsequent fluid-induced kinetic Li isotope fractionation under prograde and peak HP–LT conditions. Thus, Li behaviour and isotope fractionation in subduction zones strongly differ from heavier Fe and Ge.

The second part of this study examines the behaviour of U–Th–Pb isotopes during in-situ dating of metamorphic minerals. Because accessory minerals can be chemically zoned, protocols were developed for in-situ U–Pb and Th–Pb geochronology by laser ablation inductively-coupled plasma mass spectrometry (LA-ICPMS). However, laser-induced elemental fractionation and matrix effects are common problems during LA-ICPMS analysis. This study compares the ablation behaviour of a series of allanite, titanite and zircon reference materials and discusses the effects of laser ablation on data accuracy and precision. Matrix effects occurring during laser ablation may be responsible for systematic errors on ages, if non-matrix-matched standardisation is employed. However, matrix effects related to elemental fractionation during laser ablation could affect age accuracy and precision even with a matrix-matched standardisation, if laser fluence and repetition rate are increased.

Titre et résumé de la leçon d'essai – Title and abstract of the inaugural lecture

Le diamant : un minéral précieux pour la connaissance des processus internes de la Terre

De tout temps le diamant a fasciné les différentes civilisations humaines grâce à ses propriétés remarquables, en particulier son éclat et sa dureté. En plus de son emploi comme gemme, le diamant est un matériau couramment utilisé dans l'industrie. Les conditions particulières de formation du diamant en profondeur et sa remontée en surface en font un minéral de grand intérêt pour l'étude des processus internes de la Terre. Cette leçon d'essai commencera par une introduction des propriétés physiques, chimiques et cristallographiques du diamant. La seconde partie présentera les processus géologiques responsables de la formation du diamant et des gisements diamantifères. La dernière partie se concentrera sur les informations que peuvent apporter les diamants sur la composition du manteau terrestre et sur le cycle du carbone.