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Brittle failure at high-pressure conditions: the key role of reaction-induced volume changes

Philippe Yamato[1,2], Thibault Duretz[1,3], Marie Baïsset[4], and Cindy Luisier[1,3]
[1]Univ Rennes, CNRS, Géosciences Rennes - UMR 6118, F-35000 Rennes, France
[2]Institut Universitaire de France, Paris, France
[3]Institüt für Geowissenschaften, Goethe Universität, 60438 Frankfurt am Main, Germany
[4]Institut des Sciences de la Terre de Paris, Université Pierre et Marie Curie, 75005 Paris, France

Metamorphic reactions can lead to drastic changes in rocks mechanical properties. Indeed, during such transformations, the nucleation of new phases with different strength, grain size and/or density compared to the primary phases is enhanced, and transient processes due to the ongoing reaction are then activated.

Eclogitization of lower crustal rocks during continental subduction constitutes an emblematic transformation illustrating these processes. In such tectonic context, it has been shown that eclogitization seems to be closely associated with the occurrence of seismogenic events. However, the mechanisms that trigger brittle failure in such high pressure environments remain highly debated. Indeed, whether the change in density or the change in rheology can lead to embrittlement is still enigmatic.

By using 2D compressible mechanical numerical models we studied the impact of the strong negative volume change of the eclogitization reaction on the rocks rheological behaviour. We show that eclogitization-induced density change occurring out of equilibrium can, by itself, generates sufficient shear stress to fail the rocks at high-pressure conditions.

Rupture initiation at depth in continental subduction zones could therefore be explained by volume changes, even without considering the modifications of the rheological properties induced by the transformation. Our results also indicate that the negative volume change associated with brittle failure can enhance the propagation of the eclogitization process by a runaway mechanism as long as the reaction is not limited by the lack of reactants.