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Metamorphic sole genesis at the base of ophiolite nappes: Insights from numerical models

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Obduction emplaces oceanic lithosphere on top of continental lithosphere. Although a number of studies have focused on this enigmatic process, the initial stages of obduction remain poorly understood. Field, petrological, and geochronological data reveal that during the first stages of the obduction (i.e., during the first 1-2 Myrs) a HT-LP metamorphic sole ($\sim$700-800 $^{\circ}$C and $\sim$1 GPa) is systematically welded at the base of ophiolite nappes. However, the reason why such welding of the ophiolite soles occurs at these particular P-T conditions, and only at the onset of obduction, is still an open issue.

The aim of this study is to explore the conditions required to explain the genesis of metamorphic soles. For this, we employ two-dimensional numerical modelling, constrained by the wealth of available data from the Oman ophiolite. We first present a thermo-kinematic model in which the velocity field is prescribed in order to simulate obduction initiation. The heat advection-diffusion equation is solved at each time step. The model is intentionally kept simple in order to control each parameter (e.g., convergence rate, dip angle, thermal age) and to test its influence on the resulting P-T conditions obtained through time along the obduction interface. Results show that the key factor allowing the formation of metamorphic soles is the age of the oceanic lithosphere involved.

Moreover, we speculate that the reason why metamorphic soles are always welded at the same P-T conditions is due to the fact that, at these particular conditions, strength jumps occur within the oceanic lithosphere. These jumps lead to changes in strain localisation and allow the spalling of oceanic crust and its juxtaposition to the ophiolite nappe. This hypothesis is further tested using thermo-mechanical models in which the obduction initiates dynamically (only initial and boundary conditions are prescribed). The interplay between the temperature evolution and the mechanical behaviour is then discussed.