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A new way to quantify the thermal budget around lithospheric-scale shear zones

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Shear zones with kilometre-scale thickness are prominent features of many orogenic belts and tectonic plate boundaries. These zones of high strain and velocity (up to several cm/yr) can undergo significant thermal perturbations related to the balance between three major thermal processes: the diffusion, the advection and the internal production of heat. While heat diffusion tends to smooth the thermal gradients over time, both advection, related to the motion of blocks with different temperature fields, and localized shear heating due to dissipative mechanical work can strongly modify the thermal field.

Metamorphic temperatures zonations in close association with major shear zones then constitute precious records of different thermal states and may be evidences of major thermal perturbations. Understanding how much the three different thermal processes act on the thermal budget in the vicinity of any given thrust zone then becomes crucial. If this becomes possible, primary features of instantaneous thermal field evolution, and consequently, of peak temperatures zonations, can then be correlated to a dominant process among the three previously proposed. To reach that goal, we proceed as follows:

First, we provide a powerful analytical tool allowing to quantify and compare the relative contributions of heat diffusion, heat advection and shear heating to the thermal evolution around any lithospheric-scale shear zone. We consider 11 parameters that control the kinematics, the three-dimensional (3-D) geometry, the initial thermal structure and the average strength of a given shear zone. We show that the number of parameters can then be reduced to three dimensionless parameters which can then be used to quantify the relative contributions of the three thermal processes. Then, in a second step, we validate the dimensional analysis by using 2-D thermo-kinematic numerical models displaying characteristic evolutions of both the instantaneous and peak temperatures for each dominating process.

The applicability of the dimensional analysis to any kind of shear zone (i.e. thrust, normal-slip and strike-slip shear zones) makes it a useful tool that is complementary to previous numerical and analytical studies. Particularly, we demonstrate the difficulty to assign a particular dominant thermal process in the cases of intra-continental thrust zones. A straightforward application dedicated to the inverted thermal metamorphic zonation associated to the Main Central Thrust at the front of the Himalayan belt is displayed as an example.