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The origin of massive hydrothermal alterations: what drives fluid flow?

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Hydrothermal alterations form when fluids warmer than the host rocks flow through them dissolving and precipitating minerals. These fluids typically flow upwards from deeper geologic units using faults as major conduits. In some cases, hydrothermal alterations affect large (km-scale) rock volumes. One example of such process is the massive high-temperature dolostones that crop out at the Benicàssim outcrop analogue (Maestrat Basin, E Spain). In this area, seismic-scale fault-controlled stratabound dolostone bodies extend over several kilometres away from large-scale faults, replacing Lower Cretaceous limestones. The fluid responsible for such alteration is a seawater-derived brine that interacted with underlying Permian-Triassic and Paleozoic basement rocks. The estimated volume of fluid required to produce the Benicàssim dolomitization is huge, with fluid-rock ratios in the order of several tens to a few hundreds, depending on composition and reaction temperature (Gomez-Rivas et al., 2014). An open key question is what brought this warm fluid (80 – 150 ºC) upwards to a depth of less than 1 km, where the dolomitization reaction took place. The driving forces should have been able not only to provide sufficient fluid volumes at shallow depths but also to heat up the whole host rock, including the non-replaced limestones.

There are two hyphoteses for driving a warm fluid upwards in the Maestrat Basin: (a) rapid release through faults of overpressured solutions in recurrent pulses and (b) thermal convection. We present a series of heat and fluid flow numerical simulations to constrain the dolomitization conditions under these two end-member cases. The results indicate that in a pulsating model the fluid must flow upwards at velocities higher than cm/s to keep their elevated temperature. Otherwise they cool down quickly, and the host rocks cannot be heated. Such velocities can be reached if the fluid flow velocity equals that of fracture propagation, as in mobile hydrofractures (Bons, 2001). The main question is whether fast flow leaves recognizable signs, like hydrofractures of different scales and hydraulic breccias. We estimate fluid pressures reached at the reaction site, and discuss whether they are high enough to break the host rock, according to its petrophysical properties. Thermal convection could have driven pervasive fluid flow at lower flow rates, keeping the fluid warm and allowing time for the rock to react. But this mechanism would have required a shallow and very large intrusion or an anomalous geothermal gradient in order to activate flow by convection. This contribution presents a quantitative analysis of these hypotheses, and discusses their plausibility.

Bons, P.D., 2001. The formation of large quartz veins by rapid ascent of fluids in mobile hydrofractures. Tectonophysics 336, 1-17.

Gomez-Rivas, E., Corbella, M., Martín-Martín, J.D., Stafford, S.L., Teixell, A., Bons, P.D., Griera, A. and Cardellach, E. 2014. Reactivity of dolomitizing fluids and Mg source evaluation of fault-controlled dolomitization at the Benicàssim outcrop analogue (Maestrat Basin, E Spain). Marine and Petroleum Geology, in press.