doi:10.1130/G32727C.1

Viscous collision in channel explains double domes in metamorphic core complexes

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Rey et al. (2011) propose an appealing numerical model for the development of gneiss domes in an extending crust. They suggest that extension in the upper brittle crust triggers oppositely verging ductile flows in the deep crust, resulting in the rising of two domes of foliation separated by a median high-strain zone (MHSZ). To sustain their model, they compare the modeling results with two natural examples, one of them being the Montagne Noire in the Massif Central (France). However attractive this model, it does not apply for the Montagne Noire, since none of the two main predicted features are present in this area.

We suppose that the schematic cross section of the Montagne Noire (strongly resembling the synthetic cross section proposed by Charles et al. [2009], not to scale, with vertical exaggeration, incorrectly situated on the sketch map, and finally, simply wrong) refers to the eastern part of this structure as a sedimentary basin is represented on the northern flank. In this area, the Montagne Noire has been classically subdivided into two domes, the Espinouse to the north and the Caroux to the south, separated by a pinched syncline that, however, disappears rapidly to the west and flattens to the east. This description could match that suggested by Rey et al. However, the possible existence of a domal structure in the Caroux massif only relies on the presumed equivalence of some meter-thick intercalations of fine-grained gneisses present along both the southern and the northern sides of the massif, interpreted as a refolded sedimentary cover of a gneiss basement, either by horizontal shortening or by diapirism (see Van Den Driessche and Brun, 1992). Yet, such intercalations are present elsewhere in both the Espinouse dome and the Caroux massif and their origin is uncertain (sedimentary, magmatic, or mylonitic) (e.g., Ellenberger, 1967). Hence, the presence of fine-grained gneisses within the Caroux massif is not evidence for a domal structure.

On the other hand, careful structural investigations by Van Den Driessche and Brun (1992) and Brun and Van Den Driessche (1994) have revealed that the apparent dome-shaped foliation pattern in the Caroux massif results in fact from the reworking of thrust-related upright foliations by flat-lying ductile extensional shearing. Rey et al. mention the presence of such flat-lying extensional shearing (termed "décollement" on the cross section of their figure 3), but they ignore its role in the origin of the apparent domal structure. This pattern of ductile deformation in the Caroux massif has been interpreted as resulting from the upward bending of the footwall (the Caroux gneisses) of an extensional system controlled by a detachment fault dipping to the north, along the northern flank of the Espinouse massif (Van Den Driessche and Brun, 1992; Brun and Van Den Driessche, 1994, Brun et al. 1994).

To our knowledge, the structural data provided by Van Den Driessche and Brun (1992) and Brun and Van Den Driessche (1994) in this area have not yet been superceded or invalidated by new data. It is Rey et al.'s right to disagree with such an interpretation of the Montagne Noire tectonics, but they cannot escape these structural data unless they can provide new data.

The second main feature of the Rey et al. model concerns the existence of a MHSZ. In their cross section, this zone is supposed to correspond to the syncline between the two domes. However, this structure corresponds to the extensional detachment of the Caroux massif refolded during the upward bending of the latter. The deformation gradient that exists in this area is related to the extensional shearing and develops upward, toward the contact with the overlying sediments, not in a horizontal direction as described by the Rey et al. model.

Finally, most surprising is the reference to Bouchardon et al. (1979) as the only argument provided by Rey et al. for the existence of the MHSZ in the Montagne Noire. It is a very short paper (two and a half pages) and the abstract just postulates that "For the first time in the Montagne Noire, kyanite-rocks have been identified: stable in the staurolite-garnet-(cordierite) mineralogical association, kyanite is relictual in the (staurolite)-sillimanite-(cordierite-andalusite) association" (p. 1067).

Apart from the fact that this work exclusively deals with the discovery of two outcrops of kyanite in the Caroux massif, it never mentions anything about the strain intensity in this area. This leaves the impression that apart from a first superficial resemblance, the model of Rey et al. is definitively not concerned with the existing geological data in the Montagne Noire.

Reading Rey et al., many metamorphic core complexes show a typical double domes pattern. It is then particularly unfortunate that they chose a natural example that does not match their model. Numerical and physical modeling are invaluable tools to understand deformation processes at crustal or lithospheric scales. But to be fully pertinent, modeling must match at least the major features of the natural examples that it is supposed to reproduce. Eventually, geological data are the only real control on the validity of a model.

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