Forum Reply

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The origin of contractional structures in extensional gneiss domes

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We are grateful to Wolfgang Franke for his Comment (Franke, 2017) and for the opportunity to discuss some interesting issues regarding the evolution of the Variscides and how our numerical experiments might inform the connection between structures observed in the field and larger-scale tectonic processes.

In the first section of his Comment, Franke expresses his concern that the transition between deeper contractional and shallower extensional domains is too sharp in our numerical experiments (Rey et al., 2017) compared to what he observes in the field. He claims that his model of transpressional pull-apart (Franke et al., 2011) better explains the strain gradient observed in the Montagne Noire dome of the French Massif Central. First, we note that in cross section, the strong steeply dipping fabric and the strong shallow fabric in the dome are less than a kilometer apart (e.g., Roger et al., 2015, their figure 2B; Rabin et al., 2015, their figure 8A; Trap et al., 2017). Second, in our numerical experiments, the strain gradient in the transition zone between the two strain regimes depends on the duration of extension, and/or the imposed velocity boundary conditions. Therefore, this strain gradient on its own is not diagnostic of transpression.

In the second point of his Comment, Franke notes that in the forelands of the Variscan orogen, high-temperature metamorphism and partial melting were coeval with synorogenic sedimentation that continued until ca. 320 Ma. According to Franke, this observation precludes crustal thickening as a cause for partial melting and therefore invalidates the model of gravitational collapse put forward to explain gneiss domes in the Variscan forelands (e.g., Echtler and Malavieille, 1990; Van Den Driessche and Brun, 1992). Franke proposes an anorogenic heat source, possibly a mantle plume, to explain partial melting of the deep crust.

First, we stress that the conclusions of our paper remain valid as long as a weak, partially molten lower crust decouples the upper crust from the lithospheric mantle. How partial melting is achieved, via crustal thickening or other means, doesn't affect our conclusions. Second, the presence of enclaves of eclogite (~1.4 GPa, 725 °C) dated at 315 Ma in the Montagne Noire gneiss dome (Whitney et al., 2015), with evidence of earlier amphibolite facies conditions, suggests that burial to 50–55 km was followed by rapid exhumation. Here, it is interesting to note the similarities with the Himalayas, where eclogites as young at 14 Ma have been reported (e.g., Wang et al., 2016) in mid-Miocene migmatite-bearing gneiss domes (e.g., Cottle et al., 2009) <100 km from the foreland. In the Himalayas as well, partial melting of the crust occurred <20 m.y. after crustal thickening. Nevertheless, Franke is right to emphasize that before ca. 320 Ma, the southern edge of the Variscan orogen was at or below sea level. However, instead of ruling out crustal thickening and invoking a mantle plume for which there is little volcanic evidence, one may consider that, at the southern edge of the Variscan orogen, the onset of crustal thickening occurred below sea level until 320 Ma when a change of plate motion led to collapse, and the formation and denudation of the Montagne Noire gneiss dome between ca. 315 and ca. 300 Ma in a dextral pull-apart setting (e.g., Doublier et al., 2015).

REFERENCES CITED

Cottle, J.M., Jessup, M.J., Newell, D.L., Horstwood, S.A., Noble, S.R., Parrish, R.R., Waters, D.J., and Searle, M.P., 2009, Geochronology of granulitized eclogite from the Ama Drime Massif: implications for the tectonic evolution of the South Tibetan Himalaya: Tectonics, v. 28, p. 1–25, doi:10.1029/2008TC002256.

Doublier, M.P., Potel, S., and Wemmer, K., 2015, The tectono-metamorphic evolution of the very low-grade hanging wall constrains two stage gneiss dome formation in the Montagne Noire example (S-France): Journal of Metamorphic Geology, v. 33, p. 71–89, doi:10.1111/jmg.12111.

Echtler, H., and Malavieille, J., 1990, Extensional tectonics, basement uplift and Stephano-Permian Collapse basin in a late Variscan metamorphic core complex (Montagne Noire, Southern Massif-Central): Tectonophysics, v. 177, p. 125–138, doi:10.1016/00401951(90)90277-F.

Franke, W., Doublier, M.P., Klama, K., Potel, S., and Wemmer, K., 2011, Hot metamorphic core complex in a cold foreland: International Journal of Earth Sciences, v. 100, p. 753–785, doi:10.1007/s00531-010-0512-7.

Franke, W., 2017, The origin of contractional structures in extensional gneiss domes: Comment: Geology, v. 45, doi:10.1130/G39092C.1.

Rabin, M., Trap, P., Carry, N., Fréville, K., Cenki-Tok, B., Lobjoie, C., Goncalves, P., and Marquer, D., 2015, Strain Partitioning along the anatectic front in the Variscan Montagne Noire massif (southern French Massif Central): Tectonics, v. 34, p. 1709–1735, doi:10.1002/2014TC003790.

Rey, P.F., Mondy, L., Duclaux, G., Teyssier, C., Whitney, D.L., Bocher, M., and Prigent, C., 2017, The origin of contractional structures in extensional gneiss domes: Geology, v. 45, p. 263–266, doi:10.1130/G38595.1.

Roger, F., Teyssier, C., Respaut, J.-P., Rey, P.F., Jolivet, M., Whitney, D.L., Paquette, J.-L., and Brunel, M., 2015, Timing of formation and exhumation of the Montagne Noire double dome, French Massif Central: Tectonophysics, v. 640, p. 53–69, doi:10.1016/j.tecto.2014.12.002.

Trap, P., Roger, F., Cenki-Tok, B., Paquette, J.L., 2017, Timing and duration of partial melting and magmatism in the Variscan Montagne Noire gneiss dome (French Massif Central): International Journal of Earth Sciences, v. 106, p. 453–476.

Van Den Driessche, J., and Brun, J.-P., 1992, Tectonic evolution of the Montagne Noire (French Massif Central): A model of extensional gneiss dome: Geodinamica Acta, v. 5, p. 85–97, doi:10.1080/09853111.1992.11105221.

Wang, Y., Zhang, L., Zhang, J., and Wei, C., 2016, The youngest eclogite in central Himalaya: P-T path, U-Pb zircon age and its tectonic implication: Gondwana Research, v. 41, p. 188–206, doi:10.1016/j.gr.2015.10.013.

Whitney, D.L., Roger, F., Teyssier, C., Rey, P.F., and Respaut, J.-P., 2015, Syn-collapse eclogite metamorphism and exhumation of the deep crust in a migmatite dome: The *P-T-t* record of the youngest Variscan eclogite (Montagne Noire, French Massif Central): Earth and Planetary Science Letters, v. 430, p. 224–234, doi:10.1016/j.epsl.2015.08.026.