Forum Comment

doi: 10.1130/G39277C.1

Synconvergent exhumation of metamorphic core complexes in the northern North American Cordillera

Félix Gervais
Polytechnic Montreal Civil, 2500 chemin Polytechnique, Montreal, Quebec H3T 1J4, Canada

Stevens et al. (2017) presented a promising study entitled "Synconvergent exhumation of metamorphic core complexes in the northern North America Cordillera." It provided the first 3-D numerical modeling on the formation of metamorphic core complexes (MCCs). Although not referenced in their paper, their model of synconvergent ductile flow over a rigid basement indentor would support the arguments presented by several authors (e.g., Price and Mountjoy; 1970; Mattauer et al.,1983; Johnston et al.,2000; Brown, 2004; Brown and Gibson, 2006; Glombick et al., 2006; Simony and Carr, 2011; Van Rooyen and Carr, 2016). Gervais and Brown (2011) further compiled data from the southern Canadian Cordillera and concluded that a model of sequential synconvergent channel flow above an underthrusting basement ramp, not gravitational collapse, met all distinctive criteria of exhumation modes in collisional orogens compiled from numerical and analogue models. Their conceptual model clearly shows that part of the formation of the Frenchman Cap's MCC is related to ductile flow above a rigid basement ramp (their figure 5-D).

Gervais and Brown (2011) also presented evidence that pressure-temperature-time (*P-T-t*) paths are highly sensitive to model parameters and are thus not able to discriminate between modes of exhumation. For example, isothermal decompression paths were reproduced in numerical models of channel flow orogenic wedge development and diapirism during gravitational collapse. The match between the *T-t* paths derived in their numerical models and those of natural MCCs is, therefore, not a strong argument.

It is not clear how Stevens et al. choose the parameters used in their models. First, the strain rate they used is 3–4 orders of magnitude lower than the commonly accepted 1×10^{-13} to 1×10^{-15} s^{-1} geological range (Baxter and DePaolo, 2004). In addition, in thermomechanical modeling, viscosities of the different rock units are generally calculated from temperature-dependant flow laws derived from deformation experiments on specific rock types. Stevens et al., in contrast, mixed values for the stress exponent n, the activation energy Q and the material parameter A without any justifications. Figure 1 compares viscosities calculated with rheological parameters of the commonly used Maryland diabase (Mackwell et al.,1998) and wet quartzite (Gleason and Tullis, 1995) to those using the preferred parameters of Stevens et al., with the Q value changed from 2.4×10^{-5}, as listed in their table DR3, to 2.4×10^{5} to get realistic results. At a standard geological strain rate of 1×10^{-14} s^{-1}, Stevens' viscous crust would have a viscosity between that of the stiff Maryland diabase and the wet quartzite, whereas at their preferred strain rate of 1×10^{-18} s^{-1}, their modeled crust would be ~1 order of magnitude stiffer than the diabase. Knowing how the diabase and wet quartzite rheological parameters yield contrasting behavior in thermomechanical models, Stevens et al.'s viscosities for mid-crustal viscous rocks appear much too stiff to have the flow behavior presented in their models. In contrast, the plot of viscosities vs temperature shown in their figure DR5 presents much lower viscosities than our calculations, which reproduce results presented in the original publications. It appears that Stevens et al. did not convert the units of the "A" parameter from MPa ns^{-1} into Pa ns^{-1} in their calculations. This is confirmed in Figure 1 (curve-d), which reproduces figure DR5 for n = 2 by using an unconverted value for A (kept in in MPa ns^{-1}) at a strain rate of 1×10^{-18} s^{-1}. The resulting viscosities at supra-solidus temperature (>1023 K) is >2 orders of magnitude lower than the viscosity of partially molten rocks (1×10^{19} Pa·s) used in channel flow models of Beaumont et al. (e.g., Beaumont et al., 2001). Therefore, depending on the way they incorporated the parameters in their models, the resulting viscosity was either too stiff or too soft to yield realistic results.

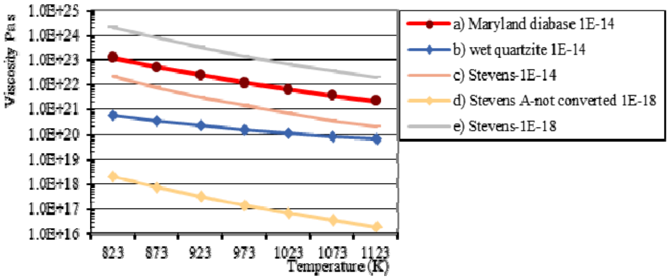

Figure 1. Plot of viscosities versus temperature for different strain rates (in s^{-1}). See text for details.

I am sure that Stevens et al. will correct these errors and present more robust results from their highly promising 3-D numerical models. In their new models, I would be very interested to see the effect of a basement geometry reflecting the geometry of a rifted cratonic margin with a basement ramp spanning the entire width of the model, but with two basement promontories separated by lateral ramps. Inasmuch as the flow velocity in a viscous channel is proportional to the cube of the channel's thickness, flow should be faster in the jog between the two lateral ramps (as argued by Hynes, 2002). It should thus be expected that "MCCs" formed this way be located foreland-ward over basement jogs and not over the promontories as in Stevens et al..

REFERENCES CITED

Baxter, E.F., and DePaolo, D.J., 2004, Can metamorphic reactions proceed faster than bulk strain?: Contributions to Mineralogy and Petrology, v. 146, p. 657–670, doi:10.1007/s00410-003-0525-3.

Beaumont, C.J., Jamieson, R.A., Nguyen, M.H., and Lee, B., 2001, Himalayan tectonics explained by extrusion of a low-viscosity crustal channel coupled to focused surface denudation: Nature, v. 414, p. 738–742, doi:10.1038/414738a.

Brown, R.L., 2004, Thrust-belt accretion and hinterland underplating of orogenic wedges; An example from the Canadian Cordillera: American Association of Petroleum Geologists Memoir, v. 82, p. 51–64.

Brown, R.L., and Gibson, H.D., 2006. An argument for channel flow in the southern Canadian Cordillera and comparison with Himalayan tectonics, in Law, R.D., et al., eds., Channel Flow, Ductile Extrusion and Exhumation in Continental Collision Zones: Geological Society of London Special Publications, v. 268, p. 543–559.

Gervais, F., and Brown, R.L., 2011, Testing modes of exhumation in collisional orogens: Synconvergent channel flow in the southeastern Canadian Cordillera: Lithosphere, v. 3, p. 55–75, doi:10.1130/L98.1.

Gleason, G.C., and Tullis, J., 1995, A flow law for dislocation creep of quartz aggregates determined with the molten salt cell: Tectonophysics, v. 247, p. 1–23, doi:10.1016/0040-1951(95)00011-B.

Glombick, P., Thompson, R.I., Erdmer, P., and Daughtry, K.L., 2006, A reappraisal of the tectonic significance of early Tertiary low-angle shear zones exposed in the Vernon map area (82 L), Shuswap metamorphic complex, southeastern Canadian Cordillera: Canadian Journal of Earth Sciences, v. 43, p. 245–268, doi:10.1139/e05-101.

Hynes, A., 2002, Encouraging the extrusion of deep-crustal rocks in collisional zones: Mineralogical Magazine, v. 66, p. 5–24, doi:10.1180/0026461026610013.

Johnston, D.H., Williams, P.F., Brown, R.L., Crowley, J.L., and Carr, S.D., 2000, Northeastward extrusion and extensional exhumation of crystalline rocks of the Monashee Complex, southeastern Canadian Cordillera: Journal of Structural Geology, v. 22, p. 603–625, doi:10.1016/S0191-8141(99)00185-6.

Stevens, L.M., Bendick, R., and Baldwin, J.A., 2017, Synconvergent exhumation of metamorphic core complexes in the northern North American Cordillera: Geology, v. 45, 495-498, doi:10.1130/G38802.1.