

Interactive comment on “Rheological transitions in the middle crust: insights from Cordilleran metamorphic core complexes” by Frances J. Cooper et al.

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Received and published: 17 January 2017

Reviewer comment 1: This is an interesting manuscript, and the figures in case studies are nice. But it suffers from several major problems that make it inappropriate to be published as an original research article. I listed three major issues that may help the authors: 1) The fundamental problem is that most of the ideas and concepts have been published by the same authors previously, e.g., Cooper et al. (2010), Platt and Behr (2014), and Behr and Platt (2011), etc. I do not think the new contribution in the paper warrant a new research article. If the authors believe so, they should write a clear statement in the manuscript about what is new, and how it compares to their papers in the past.

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Response 1: While we agree that many of the ideas and pictures have been published previously, this paper makes three important new contributions:

- (1) Although we proposed the Localized-Distributed Transition (LDT) in Cooper et al. (2010b) based on work in the northern Snake Range, we were unable to see and map the transition there. Therefore, one of the main contributions in this paper is to document the existence of the LDT in the Whipple Mountains, and to show why it can be difficult to find and document it in other metamorphic core complexes, using the northern Snake Range and Ruby Mountains-East Humboldt Range as examples.
- (2) Our paper provides a prediction of and mechanical explanation for the geometry of the detachment, as summarized in Figure 3 and Section 2.
- (3) We document that in each of these three metamorphic core complexes, the brittle detachment is late Tertiary (late Oligocene-middle Miocene) in age. Previous suggestions that the detachments initiated in the early Tertiary were based on a misinterpretation of Ar-Ar cooling age “chrontours”.

In order to emphasise these new contributions presented in the paper, we have added a few sentences to the end of the abstract and the Introduction (page 3, lines 25–33) as follows:

“Using field observations, microstructural analyses, and thermobarometric data, we (i) document the exhumation of footwall rocks from the middle crust to the surface in each core complex as they pass through different rheological transitions; (ii) document the exhumed LDT in the Whipple Mountains, show why it is not easily identified in the northern Snake Range, and has not been exhumed in the Ruby Mountains–East Humboldt Range; (iii) present a prediction of, and a mechanical explanation for, the geometry of the detachments in these three core complexes and many like them; and (iv) show that the detachments in all three core complexes formed during the Miocene, and post-date early phases of extension and exhumation in the exhumed mid-crustal metamorphic rocks.”

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Reviewer comment 2: 2) The two major questions the authors pledge to address in the manuscript does not get addressed by the contribution from the manuscript, but get partially answered by a synthesis of previously published papers. In addition, the three case studies are more of a synthesis rather than original research. I think the authors should specifically state and focus on the contributions from this manuscript, and on how the new contributions help to answer the questions.

Response 2: Again, we have directly addressed this point in the new text at end of the abstract and the Introduction (page 3, lines 25–33), which emphasizes the new contributions in this paper.

Reviewer comment 3: 3) The definition of LDT need to be refined and be more specific. I do not see how this definition help us to understand the rheology of the middle crust. It essentially says that below an localised narrow shear zone there exists a zone with more distributed deformation. The thickness of the zone is essentially unknown, or at least not specified by the authors. One can understand that it is really not easy to specify a thickness. But on the other hand, one can also argue that such a vague concept does not help us to understand the rheology at all. There are no standards proposed to specify what is localised and what is distributed deformation. LDT also has dynamic effects inherent in its name itself, but the authors seldom mention it. The author make a great deal of the relationship between depth and LDT. It causes major problems since depth itself says little about the lithology, temperature, strain rate, and stress. The authors may need to add some discussions about the dynamic history and/or some discussions about the geothermal gradient. A loosely defined geothermal gradient and almost no touch on dynamic history during exhumation cannot support the strong depth restriction specified in the manuscript which the authors make a great deal of.

Response 3: The definition of the LDT is in fact quite specific: it is a boundary below which there is no evidence for strain localization. We have added this definition in the text. It is directly related to rheology: strain localization in our view is primarily a

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consequence of a switch to deformation mechanisms that produce higher strain-rates than classic climb-assisted dislocation creep, which is the "default" mechanism for the ductile deformation of crystalline materials. These mechanisms, which are primarily grain-size sensitive creep mechanisms, are discussed and quantified in the text (Section 3 and Figures 3 and 4). The upward transition from climb-assisted dislocation creep to grain-size sensitive creep is primarily controlled by grain-size, which is related to stress through dynamic recrystallization. The stress is related to the strength of the rocks, which is strongly temperature sensitive. Apart from in subduction zones and regions of active magmatism, temperature is a function of depth, and we have assumed a fairly standard geothermal gradient of 22–25°C/km: we have modified the text to make this clear. This leads to the classic depth-stress relationship, which we have discussed in some depth in our earlier papers (e.g., Behr and Platt, 2011, 2014; Platt and Behr, 2011b). Our mechanical discussion, centred around Figures 3 and 4, is therefore framed in terms of temperature and depth.

In principle, the zone of distributed deformation below the LDT forms a semi-infinite half space, but in practice it will be limited by the boundary with higher strength lower crustal or upper mantle rocks, as we point out in the text (section 2.1).

Interactive comment on Solid Earth Discuss., doi:10.5194/se-2016-135, 2016.