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Interactive
Comment

Interactive comment on "High temperature indentation creep tests on anhydrite – a promising first look" *by* D. Dorner et al.

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Review of "High temperature indentation creep tests on anhydrite – a promising first look" by Dorner, Roeller and Stoeckhert

General comments: The submitted manuscript highlights the potential of high temperature, atmospheric pressure indentation creep testing for the characterization of rheology of polycrystalline, geological materials. As such it fits well into the special issue it is submitted to. It is an overall well presented, nice study which is easy to follow. It presents new data from carefully conducted experiments, however, - unfortunately – the discussion of why there is a marked discrepancy between expected results (as derived from previous experiments) and data from this study is not sufficiently discussed. The lack of detailed microstructural analysis and/or experiments conducted to variable strain at same conditions hamper any detailed discussion of the microstructural development. While the authors do acknowledge this drawback, even a image of a cut perpendicular to the thinsection view provided would be very useful. The choice of initial experimental sample may have a marked influence on the deformation behaviour and rheology recorded – the pre-existing fabric influence would be expected to be of significance. The latter aspects are unfortunately not discussed in detail. Microstructural analysis is relatively crude, the paper would benefit from some extra petrographic images highlighting the changes in the high strain versus low strain zone. The statement and discussion of lack of additional twinning in high strain zones is not sufficiently supported by the data presented. Using the data (images) provided it is impossible to evaluate if more or less (or even different type of) twinning occurred in the high strain zones.

As a first "look" this study is well-worth putting "out there" for the geological community to see and ponder about, however it is a "first-pass" manuscript/look, tests in different orientation to the foliation and lineation will be essential to a) evaluate how representative obtained data is and b) how pre-existing microstructure influences rheological behaviour. Furthermore, in future detailed quantitative microstructural analysis using EBSD would help to refine the observations and interpretations – best combined with numerical simulations.

Specific remarks: A) Title: Title is 100% appropriate – it is indeed a first look B) Abstract: It should be highlighted that tests were conducted in order to investigate the dislocation regime of anhydrite deformation (as the authors nicely discuss, the chosen conditions is expected to give data for the dislocation creep regime). So, really, it is probably better to say that you aimed to gain information about the dislocation creep regime (activation energy and N value) – and for that the experiments worked. For a first look this is sufficient and good. The last sentence should be omitted. Of course

SED
5, C974–C979, 2014

Interactive Comment

the flow strength is different, Mueller et al. did the experiments at vastly different conditions and reached a different deformation regime (they reported – see their abstract an n value of 1.5-2. (see further comments below)

C) Introduction: Very nice literature review at least for the geological community. It would be good to update the material science community literature review. Especially papers on the combination of indentation tests and numerical simulations should be included here – e.g. Three-dimensional investigation of the texture and microstructure below a nanoindent in a Cu single crystal using 3D EBSD and crystal plasticity finite element simulations N. Zaafarani a, D. Raabe a,*, R.N. Singh b, F. Roters a, S. Zaefferer, Acta Materialia 54 (2006) 1863–1876. For the indentation creep tests, it would be good to not only note the advantages but also disadvantages of these tests. While you can look at strain gradients, since there is overprinting relationships throughout the experiments, for a true evaluation of the microstructural development at different strain rates etc., series of test at same conditions but to different durations would be needed. This is of course possible, but time consuming and again asks for well defined pre-deformation microstructures that are homogeneous.

D) Section Anhydrite: fine nice summary E) Starting material: Why was the plane for the thinsection chosen to be perpendicular to the "normal" thinsection cut parallel to lineation and perpendicular to foliation. I can only assume that the rational was that the anisotropy of deformation would be least in this plane of observation. Please state in text. Nevertheless, it would be very useful to have microstructures presented both parallel and perpendicular to lineation (and the same for the deformed samples. Fig. 2a versus 2b – the foliation seems to be wavy – as the elongation of the grains is at different angles – is that true – please comment.

F) Creep rig & Experimental procedur, Mechanical data: fine, nice G) Microfabrics: The main problem with this section is that the microstructural description is not supported sufficiently by the photomicrographs provided. At least one extra figure with close-up micrographs and arrows pointing to specific features is needed. The statement that no additional twinning occurs in not supported by the material provided – can you quantify this (could be done with EBSD or visually combined with ImageJ?! Such data would be needed to be able to discuss the implications of the lack of extra twinning in the discussion. Extra data that can be easily provided and presented: a) it seems there is some systematics in the angle of the cones/shearzones to the indentor for different temperatures (as would be expected (ie different rock properties at different temperature – angle of shear plane should change). Please quantify and put into the discussion as an extra paragraph (nice result . . .). Could be done as an extra table in addition in drawing in the outline of the passive cone on the relevant micrograph. b) Thinsection photomicrograph of thinsction cut parallel to lineation (fine if it is only a half sample – does it show a different shear plane angle (see above) than the thinsection perpendicular to lineation – this would be expected and points to another interesting feature of such experiments! c) Grain size of wake versus shear zone: It is stated that there is no grain size increase (pg. 12 line 23), This is very hard to evaluate with the data you provide, more micrographs or quantitative data would be needed

G) Discussion: Microfabrics rewrite – supplement with discussion of extra data provided as outlined in "E" (above) -> angle of shear plane, anisotropy in the sample (from micrographs of thinsections cut pararllel to lineations, grain size data Future work (line 7-8, pg. 13) -> refer to experimental and numerical study (as provided above and references therein -> there is quite a bit of numerical literature out there in the material science community. Paragraph pg. 13, line 23ff: Without extra data on the twinning, this discussion is not possible. Delete, if not new data is provided, otherwise rewrite in view of new data. - Discussion: Deformation regime: fine. - Discussion: Extraplolation to natural strain rates . . . The comparison with Mueller et al. data as done at the moment is not valid in the first place – as the deformation regimes are clearly different (n=1.5-2 (dominantly diffusion or dissolution –percipitation creep) and N=3.9 dislocation creep. Therefore, it is expected that the flow stress is significantly different- for dislocation creep it should be significantly higher. Please modify discussion of this part accordingly taking the n value into account!! The statement: The unexpectedly high flow stress – (line 27 page 15) is not necessarily true. As far as the literature goes, there is no (as far as I know) experiments you can compare your data with directly. The obvious weakness of the anhydrite in natural examples (pag. 16 line 3 ff) is still a valid discussion point, here the water weakening discussion from the previous pg. (pg. 15) can be moved. The comparison with wet quartz is interesting and should be kept. Nice! One reason for high flow stress could be the fact that the sample was pre-deformed – effect of work hardening – please include in discussion

H) Potential of indentation creep method: - If you provide the thinsection cut parallel to lineation, you can make a case it is possible to study the anisotropy of rocks especially the effects of pre-existing fabric I) Summary and Conclusion Remove line 25-26 pg. 17 unless data is provided for twinning Adjust discussion of higher stress etc. to comments given and resultant modifications.

Add advantage and disadvantage of developing, heterogeneous deformation (note is both an advantage and disadvantage) – needs definitely strain sample series with homogeneous (reproducible) starting material Add possibility of easy testing (angle of shear plane) of anisotropy of deformed rocks (different angle of shear plane depending on preexisting deformation features) (this can only be put in if you provide the relevant data and it shows something valuable.

Technical corrections Pg. 6: 3. Experimental : Should be titled: Experimental Set-up Pg. 8 Experimental procedure: Delete the last part of the last sentence of this paragraph, you do not show any images taken in the SEM Pg. 10: Make new section: Test performed Move the first paragraph of Results section Pg. 16 line 23: "Evaluation of mechanical data. . . Fig. 2: Add XYZ framework in figure Fig. 3: Add XYZ framework in figure, if you after revisions show a thinseciton view parallel to lineation – please put this plane of thinsection also into the figure. Thanks. Fig.5: Add deformation temperatures , the calculated strain rates and stress for each line. Fig. 9 combine with Fig. 11: Draw on photomicrographs, lines outlining the different areas as depicted in Fig 9c. IN the close-up (currently Fig. 11) the wake can be seen very nicely. Fig. 10:

SED

5, C974–C979, 2014

Draw in the outline of the passive cone Fig. 13: Put in n values for curves – to make clear that different deformation regimes are compared (for anhydrite)

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SED
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