Solid Earth Discuss., 7, C58–C63, 2015
www.solid-earth-discuss.net/7/C58/2015/

Solid Earth
Discussions

Interactive comment on "Brittle–viscous deformation of vein quartz under fluid-rich low greenschist facies conditions" *by* H. J. Kjøll et al.

L. F. G. Morales (Referee)

morales@gfz-potsdam.de

Received and published: 24 February 2015

This paper presents the results of a detailed microstructural study couple with EBSD crystallographic orientation measurements in a quartz vein embedded in a phyllonitic matrix from a shear zone in the Repparfjord Tectonic Window in northern Norway. The vein was deformed at low greenschist conditions, and in this mechanical context, , the quartz vein acts as a rigid body in a weak matrix. The authors demonstrated that deformation in the quartz vein is accommodated by two different mechanisms. The first, less effective, is the deformation accommodation by dislocation glide along the basal plane, which is orientated parallel to the flow plane of the studied sample and easily activated in the observed conditions. Nevertheless in the prevailed conditions this mechanism is inneficient, and in due to the hardening, increase fluid pressure and

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

increase on the rheological contrast between matrix and the vein, the quartz crystals fracture along specific crystallographic planes, forming domainal fractures. These are immediatially sealed by nucleation of new grain from fluids that penetrate the fractures, and later by grain boundary migration. The paper is very interesting, very well written, easy to follow, the figures are clear and informative (although very small in my printed copy) and it will certainly attract a lot of interest and is a great contribution to Solid Earth discussions. Before the publication however, the authors may want to consider the minor comments below:

1) One of the points that attracted my attention was the discussion regarding the crystallographic-controlled fracturing process on the quartz crystals. The authors have used concepts of "surface energy" to explain why the fractures developed preferentially parallel to one of the symmetrically related prismatic {m} or rhomb {r}. Although this is a valid argument, I wonder if the authors gave a thought on the possibility that the fracturing process can also be explained by the anisotropic elastic behavior of quartz (in terms of Young's modulus or stiffness surface)? I am adding a figure with the quartz single crystal Young's modulus calculated from the elastic constant of quartz of McSkimin (1965) – also attached, the scale is in GPa. From this picture it is very clear that the prismatic planes {m} and {a} are less rigid (in red), then for example, the basal plane. But this becomes more interesting if you look at the rhomb planes. In this case, the {r} planes (in blue) are much more rigid than the {z} planes, which are symmetrically related but clearly have a very different elastic behavior. In fact, the {z} planes are almost as weak as the prismatic planes. So, you can go further in your interpretation about the parallelism between the fractures and the crystal planes and point out that based on the above, it is more likely that you have {z} planes parallel to the subsidiary fractures (rather then {r} planes) and even quantify theoretical stresses to do so. I suggest that you perform by yourself this calculation based on your orientation data, this can be done on MTEX, and essentially you have to combine your data with the elastic constant I am attaching here (you just have to change the scale to GPa, as the values here are given in Mbar). If you get for example the orientations of the "old" grains in

the Fig. 6 (which is essentially a single crystal) and perform this calculation, you will have a plot of the Young's modulus for that crystal in that particular orientation. You can even do that for the whole aggregate if you want, although in this case I don't think it will make sense; Note that Young's modulus may also explain the development of Dauphiné twinning,

2) The second point is the discussion about dynamic recrystallization. The authors clearly show the high angle grain boundaries in the new grains, particularly in the Domains 1, 2 and 4, and interpret these observations are result from solution-precipitation during the fracture healing, which I definitely agree. Nevertheless the presence of a large amount of subgrains in the Domain 3 suggests that the initial steps of dynamic recrystallization by subgrain rotation took place in this domain (although no new grains are yet developed). The authors also have used a misorientation of 10° to separate "low" to "high" angle grain boundaries, which is below the standard 15° normally used, but in their map the only "clear" individual grain (center-left of the map in Fig. 8) has a misorientation slightly above 10°. So this grain could also be a grain resulting from progressive SGRR. This is very interesting because this is the only domain where viscous flow was more active, and the only place where subgrain rotation would be active in these conditions. In addition, the fact that you have clear subgrains also imply that dislocation climb was active in this portion. So, I think the authors should not complete discard dynamic recrystallization (as implied in the text) and tell that it is possibly present only in domain 3 in initial steps and has a minor effect;

3) On the pole figures, the authors had chosen to plot 10000 random points extracted from the orientation map. This is not the best choice in the pole figures of the new grains, mainly because if you have 10000 points selected at random in the whole map, and 70% of your map is made of "old grains" (like the map on the Fig. 6), you will have many points that belong to the old grains, mixed with the points of the new grains. I recommend that the authors make new plots for the new grains, using "one point per grain" measurements, and clearly separated by grain sizes. If you still see grains with

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

the same orientation as the host in the finer grained portion, then the nucleation and growth of the new crystals along the fractures might be crystallographically controlled by the old grains. On MTEX you can do that somethin like below (extracted from one of my scripts, the grain size separation is not shown here)

```
% Calculate and plot figures - one point per grain

grains_atg_10 = calcGrains(ebsd_atg,’angle’,10*degree);

oppg_atg_10=get(grains_atg_10,’meanOrientation’);

odf_oppg_atg=calcODF(oppg_atg_10,’halfwidth’,8*degree);

figure(’position’,[400 400 1600 1600])

plotpdf(odf_oppg_atg,

[Miller(1,0,0),Miller(0,1,0),Miller(0,0,1)],’antipodal’,’silent’,’contourf’)

colorbar

savefigure(’987-X_antigorite_pole_figures_OPPG.eps’)
```

Minor comments included:

Pg. 220, line 4 – The camera is a Nordif UF-1000, correct?

Pg. 220, line 1-9 – Please add details about the post-processing steps of your data, principally in terms of confidence index. The sample is tilted 70° from the horizontal, so it is 20° to the electron beam;

Pg. 227 – line 13 – “drag folds” appear here for the first time..

Pg. 227 – line 25 – considering that the authors do not present any TEM image showing dislocation entanglement, I would remove that from here and just keep “strain hardening and localized embrittlement” because maybe other hardening processes may had taken place? Or add a “most probably”;

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

Pg. 235, conclusions 1 – you have to emphasize the fractures parallel to prismatic and rhomb planes rather than to basal plane, which is almost absent;

Pole figures in general – the correct representation of the quartz c-axis is [c], which means one single axes, rather than <c>, meaning a group of symmetrically related c-axes, which is not the case for quartz.

Quartz elastic constant to calculate Young's modulus

a-Quartz McSkimin et al 1965 J.Appl.Phys.v.36p.1624-1632

alpha quartz Trigonal SG P3221 25°C d=2.648 g/cm3

4.9134 4.9134 5.4052 90.000 90.000 120.000 2

.8680 .0704 .1191 -.1804 .0000 .0000

.0704 .8680 .1191 .1804 .0000 .0000

.1191 .1191 1.0575 .0000 .0000 .0000

-.1804 .1804 .0000 .5820 .0000 .0000

.0000 .0000 .0000 .0000 .5820 -.1804

.0000 .0000 .0000 .0000 -.1804 .3988

Luiz F. G. Morales Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ Sektion 3.2, Geomechanik und Rheologie Telegrafenberg, 14473 Potsdam Deutschland (Germany)

Interactive comment on Solid Earth Discuss., 7, 213, 2015.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

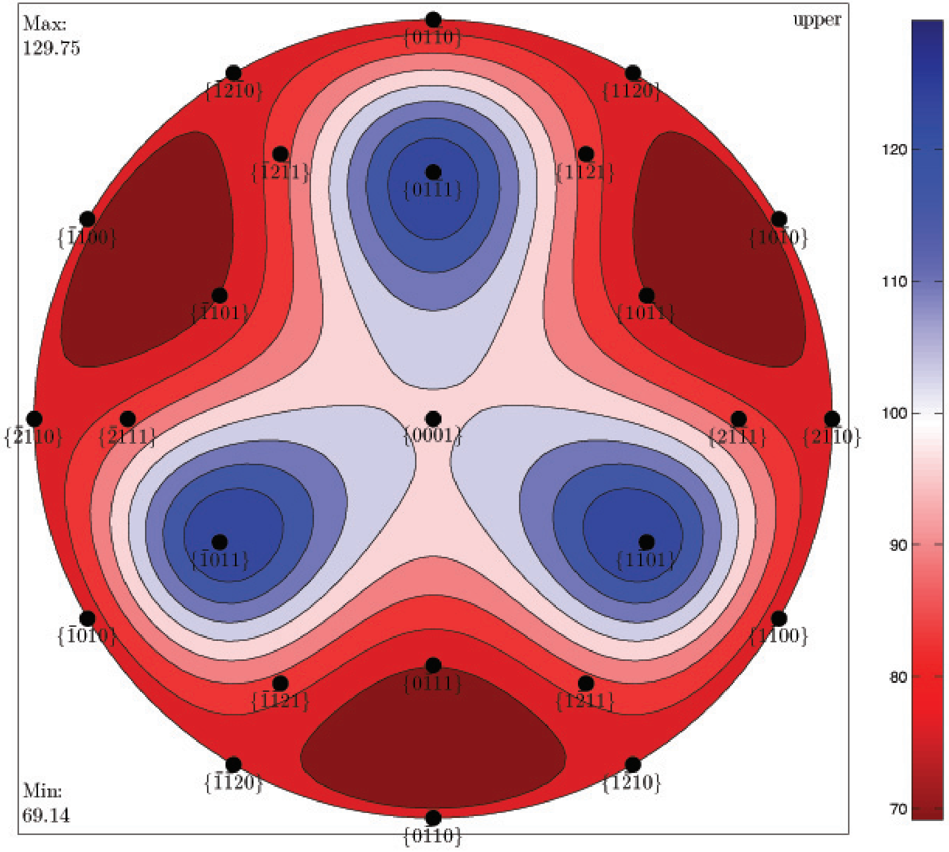
Max:
129.75
upper
{$0\bar{1}10$}
{$\bar{1}2\bar{1}0$}
{$11\bar{2}0$}
{$\bar{1}2\bar{1}1$}
{$0\bar{1}11$}
{$11\bar{2}1$}
{$\bar{1}100$}
{$10\bar{1}0$}
{$\bar{1}101$}
{$10\bar{1}1$}
{$\bar{2}110$}
{$\bar{2}111$}
{0001}
{$2\bar{1}\bar{1}1$}
{$2\bar{1}\bar{1}0$}
{$\bar{1}011$}
{$1\bar{1}01$}
{$\bar{1}010$}
{$1\bar{1}00$}
{$01\bar{1}1$}
{$\bar{1}\bar{1}21$}
{$1\bar{2}11$}
{$\bar{1}\bar{1}20$}
{$1\bar{2}10$}
{$01\bar{1}0$}
Min:
69.14
120
110
100
90
80
70

Fig. 1.