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Comment on se-2021-152

Dennis Quandt (Referee)

Referee comment on "Progressive veining during peridotite carbonation: insights from listvenites in Hole BT1B, Samail ophiolite (Oman)" by Manuel D. Menzel et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-152-RC1, 2022

General comments

In this manuscript the authors present detailed petrographic data and element mappings of veins in order to infer the processes of serpentinite carbonation. They establish a model on veining that may be of interest to the vein and serpentinization community. In my opinion this manuscript requires major revisions before it can be considered for publication. My main suggestions for improvements concern (a) the clarification of the descriptive part and (b) some reorganization of the discussion. I also think that (c) more emphasis could be put on the tectonic framework in which the veins formed.

(a) With ca. ten vein types in each host rock lithology (see table 1 and 2) and without a schematic figure illustrating the vein mineralogy, microtextures, and their spatial relationships, this manuscript is difficult to understand. Therefore, I recommend to include a figure that clearly shows the different vein types. This should be part of the results chapter.

(b) In several parts of the discussion, an idea/model/interpretation is presented followed by a description of supporting petrographic observations. In order to enhance the comprehensibility, the observations should be stated in a short phrase and then discussed, not vice versa. Very long phrases should be shortened. Apart from that the manuscript is well written.

(c) In the discussion, veins are interpreted to be associated with tectonic stresses. For this purpose, the regional geological framework could be taken into account in greater detail. Moreover, if there is enough data on listvenites from other settings, listvenite formation/veining in different ophiolites/tectonic settings could be briefly compared. This might be also the basis to test the models presented here.

Specific comments

L. 32: The topic of carbon sequestration is mentioned here; can this idea be picked up again in the discussion/conclusion? Are there implications of your study for carbon sequestration?

L. 42: "Reproducing conditions of listvenite formation at a large scale is experimentally challenging […]" partly repeats L. 37: "[…] experiments have so far not been able to reproduce this reaction […]". Merge them to one phrase.

L. 66: "relative timing" instead of "timing"

L. 74-76: I have the impression that the more recent literature favors a supra-subduction zone over a mid-ocean ridge setting. Is that true? With regard to the general comment (c), a more detailed description might be required.

L. 74-77: As I understand, the term "ophiolite crystallization" here refers to the formation of the mantle rock sequence. However, a complete ophiolitic sequence representing obducted/uplifted oceanic crust may also contain sedimentary rocks on top that did not crystallize. Therefore, consider to change the term "ophiolite crystallization".

L. 91-150: This section partly gives the impression that it is a results chapter. Indeed, the last phrase of this section "In this study, we refine the preliminary vein classification […]" clears this up, but a general phrase in the beginning shortly stating what has been published on this topic would give the section a better structure in my opinion. Also consider to move some general aspects to chapter 2.1.

L. 100-110: Consider to restructure this section as follows: first the old models followed by the new models.

L. 185-onward: In addition to a figure summarizing the vein types, also consider to consistently mention the vein abbreviations as given in Table 1 and 2.

L. 210-376: Results chapter: There are around ten different vein types described in each lithology. It would considerably help to provide a figure that shows a schematic overview of the different vein types. Among others, this should include vein type, mineralogy, host rock, and crosscutting relationships. Also consider if the different vein types can be merged in order to simplify the structure.

L. 249: “surprisingly” sounds subjective.

L. 377-onwards: are the characteristics of drill core samples and fieldwork samples comparable? Any differences that may indicate localized processes etc.?

L. 400: “Incipient carbonate precipitation as ellipsoidal/spheroidal grains in the serpentine matrix […]”; is this carbonate the same as sc0 in Figure 10? If yes, mention sc0 in the main text.

L. 418: Syntaxial veins: an important characteristic of syntaxial veining is growth competition. I could not find that the term “growth competition” was mentioned in the text. Is this because there is no growth competition?

L. 427: Change “[…] steps (4) – (8) may have occurred […]” to “[…] steps IV-VIII may have occurred […]” in order to be consistent.

L. 471-472: “Current models of vein formation treat the host rock as a non-reactive substrate with vein formation due to precipitation from aqueous solution in fluid-filled fractures […]”; this probably represents an important point by which this manuscript stands out from other recent publications on the same/similar topic. If this is the case, also consider to mention the process of “replacement veining” in the last paragraph of the introduction.

L. 482: My understanding is that during antitaxial veining, outward growing mineral fibers are in contact with the host rock (i.e., force or pressure of crystallization). Therefore, I would not expect “significant permeability along the vein-host rock interface” as stated in the text. It is also difficult to compare permeability of different vein types without defining fracture or vein aperture, mineral growth rate etc.

L. 483-484: “[…] fracture permeability created initially by dilatant opening of the vein, which may easily clog due to mineral precipitation […]”; is that also true for slow vein mineral growth rates? See also comment above.

L. 485-490: Are there chemical gradients from vein to host rock that corroborate your interpretation of a reactive interface between vein and host rock, i.e., element depletion in the host rock close to the vein and corresponding element enrichment in the vein minerals indicating reactions?

L. 497-500: Growth zonation in calcites may be also caused by varying growth rates in association with alternating Mn incorporation. Is this model applicable to your observations? Moreover, check if geochemical self-organization (autonomously developed patterns in a closed system without external control) may apply here as a cause for zoning patterns, especially if the patterns are highly oscillatory. The following references may be of interest:

Dromgoole, E. L., & Walter, L. M. (1990). Iron and manganese incorporation into calcite: Effects of growth kinetics, temperature and solution chemistry. Chemical Geology, 81(4), 311-336.

Reeder, R. J., Fagioli, R. O., & Meyers, W. J. (1990). Oscillatory zoning of Mn in solution-grown calcite crystals. Earth-Science Reviews, 29(1-4), 39-46.

Wang, Y., & Merino, E. (1992). Dynamic model of oscillatory zoning of trace elements in calcite: Double layer, inhibition, and self-organization. Geochimica et Cosmochimica Acta, 56(2), 587-596.

L. 501-513: "A more feasible explanation is that the zoned parts of the carbonate veins formed along a preexisting fracture or vein set." I agree, but is there any petrographic evidence supporting this in addition to the later in this section mentioned parallel sets of serpentine veins? Are carbonate and preserved serpentine vein sets characterized by the same orientation? This section also reveals another general issue; often a model or idea is presented, but the observation itself (i.e., the evidence or indication) is described afterwards. In order to increase the comprehensibility of the authors' ideas, the observation should be mentioned first and then discussed. This also applies to other sections (e.g., discussion on crystallization pressure in chapter 5.5). See general comment (b).

L. 515-516: "Listvenites are inferred to form, among other settings, at the base of obducted ophiolites […]"; does this mean that listvenites form when the ophiolite is already obducted, i.e., emplaced on continental crust or uplifted above sea level, respectively?

L. 530: "[…] while the conversion of serpentine to magnesite and quartz is predicted to cause a solid volume expansion of 18 – 22 %"; is there a citation for these numbers?

L. 534-535: What is the "chemical evidence"? Do I understand correctly that the inferred fluid film between vein minerals and wall rock argues against force of crystallization? Was the fluid film consistently existent throughout veining?

L. 538: “On the other hand” implies that the following phrase contradicts the preceding one. But, as I understand, it is an additional argument for leaching.

L. 540-541: “Combined influx of CO_2 and local leaching of silica would thus have resulted in a solid volume decrease at the vein-serpentine interface because magnesite has a higher density than serpentine.”; does this also apply if serpentine did not completely convert into magnesite, i.e., if there are further reaction products. Is there any petrographic support?

L. 557: Can you explain in greater detail how quartz occurrence and expansion are related?

L. 572: “[…] point to an important role of tectonic stress […]”; how does veining fit into the regional tectonic framework? Is there any additional evidence such as vein orientations in accordance with the regional stress regime at the time of formation? How can the absolute timing of vein formation be roughly constrained?

Figure 1: Consider to include sample points in your lithological column.

Figure 2: The zoning of the carbonate vein is difficult to identify in this figure.

Figure 3: Add a scale to a and b.

Figure 5: I miss a legend indicating the Mg and Si concentrations in the maps. Also abbreviations are not explained.

Figure 10: This figure is important for the understanding. Something like this with more focus on the respective vein types would be helpful in the results chapter. Furthermore, can you give more information on the cataclastic and brecciated samples, preferentially in the main text? Give the shape of the fragments and their orientation some indication on the type of fracturing? The abbreviation lc is not defined.

Table 1 and 2: Consider to have the same structure in both tables; first row: serpentinite and listvenite, respectively. Also consider to indicate the origin of the samples, drill core and fieldwork. Clear serpentine = transparent serpentine?

Technical corrections

L. 111: Consider to change “normal to strike-slip faults” to “normal and strike slip faulting”; see also L. 424

L. 137: “Veins per meter” and “veins/m”; check for consistency.

L. 140 and L. 143: “carbonate oxide” and “Carbonate-oxide”; check for consistency.

L. 450: “micron”

L. 517: Consider “fracturing” instead of “fracture”

L. 534-535: “However […]”; word(s) missing/incomplete phrase