

Interactive comment on “Evolution of structures and hydrothermal alteration in a Palaeoproterozoic metasupracrustal belt: Constraining paired deformation-fluid flow events in a Fe and Cu-Au prospective terrain in northern Sweden” by Joel B. H. Andersson et al.

Jochen Kolb (Referee)

jochen.kolb@kit.edu

Received and published: 1 January 2020

Dear Florian,

please find enclosed my review of the manuscript entitled "Evolution of structures and hydrothermal alteration in a Palaeoproterozoic metasupracrustal belt: Constraining paired deformation-fluid flow events in a Fe and Cu-Au prospective terrain in northern Sweden" by Andersson, Bauer and Lynch. The authors use mapping, structural

C1

analysis, microstructures and mineralogy in order to describe deformation and related hydrothermal alteration systems in their study area. They interpret the structural data and conclude that the structures are best explained by two subsequent deformation stages with different stress field. They try to relate hydrothermal alteration assemblages to the different deformation stages using field observations and microstructural data. The observational data is of very good quality and the structural interpretation is valid. The manuscript is, however, poorly written and the interpretation of the mineralogical and microstructural data needs major improvement. I recommend major revisions of the manuscript before publication. My main concerns are: 1. The wording of the manuscript is poor. The authors are imprecise and don't use the language of our science strictly. They mix up terms and use language that makes understanding of their descriptions difficult or impossible. The entire manuscript needs careful rewording and possibly the care of a native speaker. 2. The authors need to reword the entire manuscript and need to follow the two principles of writing a geology manuscript: (1) old structures or rocks need to be described before their younger counterparts; and (2) data needs to be presented and described first, interpretation follows. 3. The metamorphic and hydrothermal assemblages need to be described in much more detail. What is their relationship to foliations and lineations? The mineralogy of hydrothermal alteration zones depends on P, T, X and physicochemical parameter. This results in the situation that hydrothermal mineral assemblages may not only vary on relative timing in the geological evolution and along a PT path. They also vary with host rock composition, fluid composition, distance from the main fluid conduit etc. This causes in many situations complex hydrothermal alteration patterns and zoning in hydrothermal ore deposits. This is well-described in many similar systems elsewhere in the world. The authors need to be more careful with their petrological data and must observe and interpret with much more detail. It would help the reader, if the authors could add hydrothermal alteration zones to their lithological and structural maps.

Detailed comments: Palaeoproterozoic: The stratigraphic commission has changed the general way of spelling this into Paleoproterozoic (also Archean, etc.). Sulphide:

C2

The now generally accepted spelling of this word in economic geology papers is “sulfide”. Title: Delete “meta” and use supracrustal belt. I personally prefer “greenstone belt”, because often not all of the rocks contained in such a belt are strictly supracrustal (you also describe dykes for example). Mineralization: “Mineralization” is a process not a thing. Check your wording accordingly. Introduction: There is a lot, which is repeated and detailed in later chapters. The introduction should introduce the problem and specify the research questions and the approach. This is only partly true here. Why is the study important? What will the addition to science be? Why is relating hydrothermal alteration to structures important? How is the situation elsewhere in similar terranes with IOCG deposits, Canada, Brazil, Australia (e.g. Tennant Creek, Mount Isa), Mauritania.? Regional Geology: This chapter is poorly worded and poorly structured. The data and observation must be presented before interpretation. A clear stratigraphy is necessary. I suggest preparing a table or a sketch to help the reader. In the text, the nomenclature has to be used strictly and consistently. Methods: No Leapfrog model is shown in this paper – adjust this chapter to the methods used for generation of the data presented in this manuscript. Results: Describe your data from old to young. This is a geology paradigm that makes sense, because old structures are always overprinted by young structures. Don’t shift between scales. Make a description at regional, district, local, outcrop, sample, thin section scale and organise accordingly. Chapter 6.4.1 is needed much earlier in the manuscript. Figures: Correct legend and check for completeness of all legends in all maps. Add legend to the stereographic plots. Page 1 Line 16 ff.: Relationship between alteration assemblages is unclear. Why are there two regional hydrothermal alteration assemblages? What is their relationship? What is the importance of calcite? This needs explanation that is more careful and rewording. Line 20: Avoid the term “brittle-ductile”. This term is derived from geophysical (seismic) investigation of the Earth’s crust and defined as a zone of velocity change of seismic waves. It has no geological meaning. I can show you examples of brittle-ductile behaviour of rocks at 250°C and at 650°C. I suggest avoiding the term, because it does not add any information. Page 2 Line 1: This sen-

C3

tence is misleading as is the referencing. The two papers do not describe the situation in Norbotten as your wording indicates. It is unclear to me, how metamorphic rocks with only restricted porosity (and generally no permeability) can focus fluid flow. Fluid follows the hydraulic gradient and can only migrate through permeable rock. Line 3 ff.: This is repeated from the previous page. Reword and avoid repetition. Line 12: There is a problem here and also elsewhere in the text with the terminology. You define “Svekokarelian” as an orogeny. Here you use it as a stratigraphic term. This is confusing for the reader and needs to be avoided. In the regional geology chapter, a description of stratigraphy (old to young) and metamorphism and deformation (if information is available) is needed. The terminology needs to be clearly defined (if helpful with a table) and strictly used in the entire manuscript. Page 4 Line 25 ff.: What was used to constrain the PT conditions? The method or mineral assemblage needs to be stated. Otherwise, the reader cannot evaluate the quality of the data himself. Is it the metamorphic peak that is recorded? What is the approximate timing of metamorphism? You state that PT conditions raised from greenschist to amphibolite facies regionally, but then outline granulite facies conditions. What is true? Line 30 ff.: You say that the deformation is polyphase, but you only describe one stage of deformation in the text. Page 10 Line 6: This needs much more explanation. How does dip-slip relate to compressional deformation? Generally, compressional deformation is related to folding, strike-slip and reverse shearing and not normal (dip-slip) deformation. Line 10 ff.: You need to organize. E.g. you describe brittle and ductile deformation of feldspar, then describe many other things and then describe ductile deformation of quartz. See above; organize the structural description according to scale, either from small-scale to regional-scale or vice versa. The quartz fabrics (D1/D2 similar, low-T) contradict the feldspar fabrics (D1 >450°C, D2 low-T) – why? Page 12 Line 15 ff.: This remains unclear. If scapolite forms porphyroblasts, then it at least postdates D1 (otherwise, it must be porphyroclastic). If the veins are deformed by D2, then they predate D2. Which time constraints do you have between D1 and D2 to say that the veins postdate the scapolite porphyroblasts? Why is scapolite not formed at the same time? Page

C4

13 Line 4 ff.: This is very confusing. You jump in your description from early to young and vice versa. The reader is unable to follow this. The important message is, which hydrothermal alteration assemblage(!) is temporally related to which structural fabric and to which stage in the metamorphic PT evolution (prograde, peak, retrograde). You also need to distinguish between hydrothermal alteration and metamorphic mineral assemblages. They form via completely different processes. This needs careful rewording. Page 14 Line 20 ff.: What about the feldspar microstructures described above? What do they indicate? What about the mineral assemblages? Which PT conditions do they indicate? This needs much more discussion and integration of microstructural and petrological data. Likely much better PT constrains are possible by such an integration. Page 15 Line 5: Relatively low P and upper crustal conditions are also true for D1 deformation. This does not add any information and is a very vague and imprecise statement. See also comment above. Line 6 ff.: This needs more discussion. It remains completely unclear, why you add information from other localities and which relevance that may have. You first need to constrain PT conditions and relative timing of deformation, metamorphic and hydrothermal stages in your study area before you can compare those to other (similar or connected) areas. Readers, who are not familiar with the regional geology, will be confused and cannot decide on the relevance of the data presented here for comparison. Line 13 ff.: This part suffers from bad wording and poor organization. Please reword and discuss from old (L1) to young (L2). The mineral species that define the stretching lineation may help in constraining relative timing and PT conditions. Page 16 Line 20 ff.: Why are you presenting this? There is a lot of speculation and the reader gets no idea, what the relevance of this is: delete. Line 26 ff.: I am confused: Why do D2 shear bands indicate D1 deformation? Page 17 Line 2 ff.: What is the timing of metamorphism? The epidote-amphibolite facies in pillow basalts can be very early in the evolution and may represent seafloor metasomatism. Alternatively, a similar mineral assemblage can form during regional metamorphism. This needs more discussion of evidence of relative timing. Page 19 Line 4: If the scapolite is really porphyroblastic everywhere, then it must (by definition)

C5

be post-tectonic. You say that the scapolite porphyroblasts occur in low-strain areas, which may mean that scapolite growth postdates D1 here but is pre-, syn- or post-D1 in the high-strain zones. This needs more discussion and more precise investigation of the relative timing. Furthermore, you contradict yourself with the interpretation of the absolute age data. You say that D1 is 1.88-1.86 Ga, that scapolite alteration is syn- to late-D1 and that scapolite formed (together with titanite) at 1.9 Ga. This is 20-40 m.y. earlier than D1 and not syn- to late-D1. Moreover, you do not provide the precision of the geochronological data, which makes further evaluation by the reader impossible. Is scapolite formed during seafloor alteration at 1.9 Ga? Line 10 ff.: The discussion about Cl/Br geochemistry and fluid source remains unclear. If you have two generations of scapolite, what will whole rock data tell you? Why do you consider an evaporitic source, when the data contradicts this? This needs much more discussion, if this is important for the conclusions of this work. I am not sure, where this will lead to?? You don't really have shown constrains on the relative timing of scapolite alteration. This makes it really difficult to follow. Line 17 ff.: If you would follow the geological principle of describing the oldest features first, your text would be much easier to follow. You get not all possible information out of your data. There is much more on P-T-D-X relationships in your data that needs to be presented and discussed. The important part is that hydrothermal alteration assemblages are controlled by complex P-T-X relationships. The mineral presence in the hydrothermal alteration assemblages depends not only on fluid composition, but also on host rock composition and fluid rock ratio. Thus, it is very common in hydrothermally altered regions to find different hydrothermal alteration assemblages in different host rocks that formed at the same time or to find zoning of hydrothermal alteration assemblages depending on the distance from the main hydrothermal fluid conduit (e.g. a shear zone or a pluton). All this needs to be worked out from your data and displayed in maps and discussed accordingly.

Kind regards Jochen Kolb

Please also note the supplement to this comment:

C6

<https://www.solid-earth-discuss.net/se-2019-150/se-2019-150-RC2-supplement.pdf>

Interactive comment on Solid Earth Discuss., <https://doi.org/10.5194/se-2019-150>, 2019.