

## ***Interactive comment on “Variability of the groundwater sulfate concentration in fractured rock slopes: a tool to identify active unstable areas” by S. Binet et al.***

**S. Binet et al.**

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Answer to referee 1:

Thank you for your comments. You will find here, for each point, a remind of your questions following by my answers. (the text “” is a citation from the corrected manuscript)

-It is not clear whether or when an open or closed system is assumed in the phreeqc calculations. In case of an open system do you fix the pCO<sub>2</sub> at the atmospheric value(10-3.5 atm) or soil value (10-0.7 atm)? Assumptions should be clearly mentioned (e.g., in chapter 4.1).

First of all, a mistake was found in the text, according to our model assumptions,  $\text{PCO}_2$  in soil is 10–1.7 atm. “Dissolved ions in spring water are considered originating from rocks and gases. The necessary quantities of minerals and gases to be dissolved in the soil water to obtain the spring water composition were obtained from inverse modeling with PHREEQC, by specifying the measured concentration of major ions (Ca, Mg, K, Na,  $\text{SO}_4$ , Cl,  $\text{NO}_3$ , alkalinity), pH, temperature (fixed to 8 °C for all conditions) of both, the soil and the target spring water. The minerals considered for dissolution in the water are halite (for Cl), quartz, plagioclase, phlogopite, Kmica and pyrite. Minerals considered potentially precipitating dependent on the calculated saturation index were calcite, dolomite, ferrihydrite, gibbsite. The model considers  $\text{CO}_2$  and  $\text{O}_2$  as two dissolved phases. The calculated amount of consumed gas will open the discussion about open / close reservoir conditions.”

- On page 5429, line 3-7, you conclude that respiration processes did not occur, as  $\text{pCO}_2$  values were not disturbed compared to atmospheric values. However, in chapter 4.1 you say that in the soil  $\text{pCO}_2$  values of 10–0.7 atm are measured, which indicate that respiration is important (at least in the soil). Could you explain this apparent contradiction?

“respiration processes observed in soil, did not occur in the open fractures as such processes are known to disturb the groundwater  $\text{pCO}_2$  values compared to the atmospheric pressure. This indicates that the organic matter of soil water was effectively outfiltered and/or entirely respired in soil before flowing through the fractures.”

- In chapter 5.2, line 14-16, you give some threshold values, which are, in principle, for the studied sites. I think it would be interesting to discuss whether this can be applied to other sites and on what it could depend (e.g., pyrite content or grain size of the fracture filling).

“This ratio is established from 2 different alpine valleys (Tinee and Rosone). Extrapolate this ratio for other slopes means that the water /rock interaction surfaces and that the

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weathering state in the stable areas are similar. Such hypothesis can be tested using a well know stable area before testing the potentially unstable zones”.

- In the last paragraph of section 5.2 time scales of rock deformation and transport are discussed. However, there also is a time scale for pyrite dissolution. If the dissolution rate is changed, it will take some time for sulfate to reach a new steady state concentration, even in the deformation area. I think this dissolution time scale can be important. At least it should be discussed.

“If the dissolution rate is changed, it will take some time for sulfate to reach a new steady state concentration. No experimental data is available about the refreshed rates of pyrite. The Figure 4 suggests that the changes in transport delay and in the dissolution rates take from 1 to 6 month to reach the spring”.

Technical Corrections - The English should be improved. I attached a pdf file with some (suggestions for) corrections. done

- Page 5421, line 3 and page 5422, line 15. The verb "evolve" is used, whereas I think "vary" or "range" is meant. For me, "evolve" refers to a change in time.

New sentence: “In all these sites the water flows from soil to the Gneiss rock”

- Page 5424, line 22 and page 5429, line 2 and 9. I don't know what you mean with the word "script" in this context. A script is something written down. Please, use another word.

Ok , new sentence is “in the model assumptions”

- Page 5428, line 15. According to equation 1, 3.75 moles of oxygen oxidizes two in C2176stead of one mole of sulfur.

Ok - Page 5429, line 1. pCO<sub>2</sub> values are superior not inferior to atmospheric pCO<sub>2</sub> values (10<sup>-3.32</sup> > 10<sup>-3.5</sup> and 10<sup>-2.7</sup> > 10<sup>-3.5</sup>). Ok - Page 5429, line 14. What do you mean when you say that something explains "more than 90%"? If it refers

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to some error analysis, explain it. If it just means that it explains something well, give a more qualitative description.

Ok, 90% in delete and remplaced by “ Albite, anorthite and phlogopite well explain the water chemistry acquisition”. In the model, I had a sentence: “ The calculation uncertainty is fixed to15% because the model is a simplification using only 5 minerals to describe the gneiss rock.”

- Page 5432, line 25. I do not understand the expression "to bring clouds about". Please use another expression.

Ok, the chapter was rewritten. - Table 1. The stoichiometric coefficients of anorthite and pyrite are wrong. Please, correct them.

Ok - Caption of figure 1. The description of map A, B and C do not seem to coincide with the figure.

Ok label was wrong

- Caption of figure 5. This caption says that water is oversaturated with respect to calcite, whereas the text says it is saturated.

Ok, the water is saturated with respect to calcite, because calcite can precipitate.

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