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Hydrology and Earth System Sciences Discussions

Interactive comment on "Infiltrative instability near topography with implication for the drainage of soluble rocks" *by* P. Genthon and A. Ormond

Anonymous Referee #2

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The paper presents the study of topography-driven instable infiltration of a reactive fluid in homogeneous soluble porous media. A mathematical model of the problem is constructed and solved in a number of numerical simulations. The authors present model equations and assumptions in a clear manner and the text is well written and easy to follow. Based on modeling results, relevant conclusions are reached regarding the number and geometry of the fingers that form, the relative times necessary for the formation of each one of the fingers, and the parameters that control them. Specific comments follow.

P. 702, line 17-18: In the introduction, and more specifically between the first and second sentence, a more detailed description of infiltrative instability is missing. The first sentence outlines the general environments and conditions for infiltrative instability to

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potentially occur, but does not explain the coupled physical-geochemical phenomenon itself. The description of how the concept 'infiltrative instability' is defined in this work should be provided before a review of previous theoretical and experimental studies is given (second sentence onwards).

P. 705, lines 15-19: Do you assume that density and viscosity remain spatially uniform during mineral dissolution? If so, it should be explicitly stated in the text before equations (4) and (5) are introduced.

P. 705, line 17: Co is referred to throughout the text as 'the initial concentration of the aggressive fluid' (P. 705, line 17) and 'our initial concentration of our active species' (p. 708, line 18). To me, it reads as if Co was the initial condition for the fluid concentration in the entire domain. From section 2.2 it is clear that Co is the concentration at the top boundary. However, I would suggest referring to Co as e.g. 'the concentration of the infiltrating fluid', especially in P. 705, line 17, where the boundary conditions for the problem have not yet been defined.

P. 706, line 18: Is this concentration Co at the top boundary constant over time? The word 'initial' may read here as if the concentration at the top boundary was assumed to be equal to Co only initially. Initial and boundary conditions used for concentrations could also be added to Fig 1.

P. 709, lines 2-4: Regarding time-stepping: is the following the solution sequence implemented: 1) equation (8) is solved, 2) based on permeability and porosity changes, equation (7) is solved, 3) advance time step and go back to step 1) ? In the sentence 'less than 1/10 mesh step is dissolved at each iteration', do you mean 1/10 of the volume of a mesh element?

P. 709, lines 9-18: In Figure 1, I noticed that there are no high-permeability slots in the immediate proximity of the upper right corner of the domain (x = 0 to x = 0.06). Was there any additional constraint imposed near this edge when generating the random slots in this particular realization?

HESSD

5, S486–S489, 2008

P. 709, lines 24-25 and P. 708, line 1: Limitations of the model to simulate flow in the fingers after breakthrough is acknowledged in this section. In addition, in response to a comment by Referee 1, the authors clarify the validity of Darcy's law to simulate infiltrative instability before finger breakthrough occurs (Genthon and Ormond, 2008). It would also be worthwhile to describe the effect that this limitation has on model results after the first finger has developed completely. At that point, I would expect that if described by Darcy's law, the volumetric flow rate in the finger was controlled by the width of the channel and the permeability of the dissolved volume. As a result, flow rates in high permeable fingers (large Rk values) would be larger than in less permeable fingers (for the same channel width). This would enhance hydrodynamic capture by the finger, not only when it was developing (as discussed in P. 711, lines 13-15), but also once the first finger had already developed and other fingers started or continued developing. To me, the latter hydrodynamic capture would somewhat be an artifice of the model. Could the authors comment on this issue and further clarify the physical meaning of the Rk ratio in the context of a fully dissolving porous matrix?

P. 710-711, section 3.2: I could not find in this section a discussion on the conclusion presented in the abstract: 'A sensitivity study shows that a larger permeability contrast between the fingers and the initial undissolved porous medium produces a larger number of fingers' (P. 702, lines 8-10). How was this conclusion reached? For example, large number of fingers forms both in Fig.4b (Rk = 1E5) and in Fig.4d (Rk=100).

P. 717, P. 719, P. 720, P. 721: In Figs. 1 and 5, values along the z-axis increase with depth (i.e. z=depth), while in Figs. 3 and 4, values along the z-axis decrease with depth (i.e. z=elevation). Consistent axis orientations should be used in the figures and consistent references to values along these axes should be made in the text.

Minor corrections

P. 702, line 10, line 11: I suggest spelling out 'Peclet number' and 'Damköhler number' in the abstract instead of using the symbols Pe and Da.

HESSD

5, S486–S489, 2008

P. 702, line 19: The wavelength of which parameter do you refer to?

P. 703, line 11: Correct verb tense: use 'consider' instead of 'considered', in agreement with other verbs in this and previous sentences.

P. 706, lines 19-20: Throughout the text units are given in two different formats: using a forward slash (e.g. m/s) or using negative exponents (e.g. m s-2). A single consistent format should be used for all units in the text.

P. 707, lines 18-22: The first paragraph of section 2.3 is not entirely clear to me. Do you mean that 'both [problems] originate in the sharp interface between non dissolved limestone and voids created by dissolution'? And 'The second one consists in accounting for the permeability jump arising at the interface.'?

P. 708, line 6-7: Already acknowledging the previous correction in this paragraph (Genthon and Ormond, 2008), I would nevertheless suggest avoiding the use of 'former' and 'latter'. Repeating 'fully dissolved volume' and 'non-dissolved volume' will make it easier for the reader.

P. 709, line 9: 'In our first models'

P. 709, line 4: 'an 8-m depth'

P. 709, line 23: It would be convenient to point out that the time lapse given here is dimensionless.

References

Genthon, P., and A. Ormond (2008), Interactive comment on 8220;Infiltrative instability near topography with implication for the drainage of soluble rocks, Hydrol. Earth Syst. Sci. Discuss., 5, S3218211;S323.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 701, 2008.