Hydrol. Earth Syst. Sci. Discuss., 5, S583–S587, 2008
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Hydrology and Earth System Sciences Discussions

HESSD

5, S583–S587, 2008

Interactive Comment

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

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Received and published: 3 July 2008

We would like firstly to acknowledge your comments that help to clarify the results (and limitations) of the paper. All comments will be addressed here. However, specific sections will be devoted to 3 comments that could raise some doubts on the validity of our results.

1) Are the non dimensional equations correct? The comment of referee 3 is : "I suppose v' and C' are the dimensionless velocity and concentration. However, v' doesn't seem to be dimensionless. By using the definition of v0 and P', it can be deduced that: v' = v/(v0h), that means, it has dimension of 1/length".

Clearly working with a wrong adimensionalisation produces wrong results. However, if all variables are non dimensional and if there are no error in deriving the equations, it cannot be obtained in any case that V' has dimension of 1/length. Firstly, let us check that the velocity and pressure units are truly pressure and velocity. We use rho*g*k0/mu as velocity unit, which can easily been seen as a velocity (ms-1), and rho*g*h as the pressure unit, which can also be seen as a pressure (Pas). If the gradient in the Darcy equation is non dimensionalized using the 1/h unit, equation (4) is readily obtained, where V' and P' are nondimensional variables. However, if the gradient is dimensional, one obtains that V' has the unit of V0*h, which is clearly inconsistent. We suspect that some confusion may occur due to use the same notation for the dimensional and the non dimensional gradient (nabla), and we propose to write in the revised paper the non dimensional nabla operator as nabla'. This will also answer to the second part of the comment pertaining to equation (5), as the (nabla) and (nabla**2) were non dimensionalized with the 1/h and 1/h2 units.

2) How do the results of the paper depend on the initial permeability distribution? Even, referee 3 has some doubts if an homogeneous initial permeability will allow the infiltrative instability to develop. We would like to answer in two step:

Does the infiltrative instability develop in an homogeneous infinite medium? The answer is yes in our reference case, characterized by Da infinite and Pe=300, since we are in the domain of strong instability (see by example, Ortoleva et al., 1987 or Steefel and Lasaga, 1990). In a numerical model, instability sets on with small truncation errors in computation, and in real geological cases, an homogeneous porous medium never exists. However, in the cases with Pe= 30 and especially on the upstream side of figures 4a and 4c, the instability is weaker and the initial high permeability zones help the onset of the instability, which we propose to emphasize with a comment in the revised version of the paper.

Why are the initial high permeability slots introduced in our models? This is a consequence of the topographic jump at the left side of our models. If these slots are not introduced, we observe that dissolution is only located near surface and results in water flowing from the surface toward the topographic jump. This is runoff, rather than infiltration instability. The distribution of the random slots has been deduced from the intrinsic random function of our Fortran compiler. We have however carefully checked that this distribution has little influence on the final drainage pattern. We have used different random function of different Fortran compilers, regularly spaced slots, or distributions offset by half of our modeling box. This is explained in lines 15-20 of page 710. As noted by referee 2 in his comment relative to p. 709 lines 9-18, there is no permeable slot near the right border of our model, in order to prevent fast superficial dissolution near this corner.

3) Once a finger reaches the right boundary of the models, its growth is stopped. What is the influence on the fingering process (comment of referee 2 on page 709) as function of the Rk parameter (permeability ratio between the fully dissolved and non dissolved zones)?

In the case of pure carbonated rock, only the highest possible value of Rk applies to model the fully dissolved medium. Then equation (1) implies that the pressure is almost constant in the finger and equal to the atmospheric pressure. This constant pressure condition characterizes a void volume connected to atmospheric pressure and is not an artifice of the model. Consequently, the capture effect on developing fingers is not an artifice of the model. However, if a finger is no more allowed to evolve, it cannot split and generate secondary instabilities, which could possibly arise for example at the bottom of the second finger of figure 3 and drain the base of the modeling box. The sensitivity study on Rk is introduced in reference to incompletely soluble material. Then the capture effect of a fully developed finger on developing fingers is weaker. It results that several fingers are able to develop simultaneously, a result outlined in the paper.

Specific comments by referee 2 are now addressed:

P 702, line 17-18 : the revised version will include a description of the infiltration instability.

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P 705, line 15-19 : We will emphasize that density and viscosity are constant in the model and that therefore the results only apply to low solubility rock (and not to evaporites, for example)

P 705, line 17 and p. 706, line 18. C0 is the concentration at the top boundary. Due to instantaneous dissolution, the concentration of active species has to be zero in the non dissolved rock. This will be clarified in the revised version of the paper.

P 709 lines 2-4. Yes for the time stepping and for the 1/10 mesh volume. However, equation (8) and (9) are solved together and not only equation (8).

P 709, lines 9-18 : see 2)

P 709 line 24-25 : see 3)

P 710-711 section 3.2 : Maybe, it was insufficiently outlined, but, as a large permeability ratio enhances capture phenomena, it does not allow the simultaneous development of several fingers. This is best seen on figure 4b, where only one finger is able to develop up to y= 0.6, where in the same area 4 fingers where able to develop up to y=0.6 in figure 4d.

"The runs of Figs. 4a and 4b are characterized by the largest permeability contrast (Rk=1E5) and thus by enhanced hydrodynamic capture of reactive fluid that prevents the simultaneous development of neighbour fingers, an effect that has been previously noted by Ormond and Ortoleva (2000). This is best evidenced in Fig. 4b where the finger at x=0.95 develops on almost half the cliff height before it is stopped by the progression of an horizontal channel that originates from the first finger"

However, this effect is less visible on figures 4a and 4c, since only wide finger could develop at low Pe, an effect which should be outlined in the revised version.

P 717 ... Inconsistent Y axis orientations in different figures. This will be corrected. Thank you !

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Interactive Comment

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Interactive Discussion

Discussion Paper

Answers to specific comments from referee 3

Comment 1. See 2)

Comment 2. Equation 2 is improperly written: the first term should be multiplied and not divided by the porosity. Since this term is shown to be negligible, there is no influence on the results of the paper. The referee is warmly thanked for having noted this error.

Comment 3. See 1)

Comment 4. Once again, thank you to have noted this inconstancy. Equation (8) holds when 100% of the soluble matrix has been dissolved (which only correspond to phi = 1 only if there the whole rock volume is soluble) and (9) when there is still some matrix to dissolve. The relationship between porosity and C arises since there cannot be any porous matrix to dissolve where C is larger than zero. This is a consequence of the instantaneous dissolution rate. This has to be clarified in the revised version.

Comment 5. See 2)

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