Hydrol. Earth Syst. Sci. Discuss., 5, S1540–S1543, 2008
www.hydrol-earth-syst-sci-discuss.net/5/S1540/2008/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Thermal conductivity of unsaturated clay-rocks" *by* D. Jougnot and A. Revil

Anonymous Referee #2

Received and published: 21 October 2008

This paper extends the thermal conductivity model of Revil (2000) to account for variable saturation. The new model is unique in that its functional form allows for a connection between thermal conductivity and electrical conductivity. Effective thermal conductivity is modeled using the same Archie exponents used to model electrical conductivity. The proposed approach is rather clever and appears to be a new and original contribution. Tests are conducted using published data, and it is shown that the new model adequately describes the dependence of thermal conductivity on the degree of saturation. Thus, the approach appears to have merit. The paper is well written, it is organized in a logical manner, and the derivation of the new model is presented in sufficient detail.

Although my overall assessment of this work is rather positive, I have several concerns regarding the results and conclusions of this work. Those concerns are:

1. After noting that the values of m are quite low relative to the value reported by Revil et al. (2005), the authors state that the presence of micro-cracks caused a decrease in m. This statement needs to be reworded. While it is not unreasonable to conclude that micro-cracks *may* have caused a decrease in m, additional evidence would be required to establish a clear cause and effect. Also, it is not clear why the m value from Revil et al. (2005) is used as benchmark to assess whether or not the optimized m values are of the correct magnitude. This value is for water-saturated argillite. It seems entirely possible that values of m obtained using the new model (with variable saturation) might differ from the m value for a saturated sample. Why is this not considered as a possible explanation for the "low" values? Can this be ruled out? Insofar as the data in Figure 3 include values of thermal conductivity at saturation, I encourage the authors to consider using this subset of the data to estimate m values using approach of Revil et al. (2005). This would allow for an assessment of the effect of micro-cracks on the parameter m that is independent of the new model.

2. In the Conclusions the authors suppose that m = 2 could be used for undisturbed argillites. No basis for this supposition is presented. The authors argue that the m values between 1.37 and 1.52 for the argillite samples are low due to the presence of micro-cracks, but they present to no evidence to support the supposition that this parameter would increase to the particular value of m = 2 for undisturbed (i.e., no micro-cracks) argillites.

3. In light of the previous comment, and the fact that a value of n is reported for damaged (i.e., *disturbed*) argillites only, it is premature to conclude that the thermal conductivity of *undisturbed* formations can be obtained by non-intrusive imaging. The experimental results do not support this conclusion. Additional testing is needed to verify that the approach has merit.

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Following are additional comments that address relatively minor issues:

Page 2411, line 5: Should Gruesco et al. (2007) be Gruesco et al. (2006) instead? See also page 2413, line 26.

Page 2412, line 1: A word (or words) is missing from this sentence.

Page 2412, lines 15-18: It is indicated here that effective thermal conductivity can be estimated from the water phase saturation and the thermal conductivity of the solids. I suggest modifying this sentence to indicate that porosity and the conductivity of the brine are also required to estimate the effective thermal conductivity.

Page 2412, line 18: It is indicated here that the conductivity of the solids is determined using a mixture approach. This may be a source of potential confusion inasmuch as two different approaches were employed to obtain the conductivity of the solids. The mixture approach was used for the glass bead data, but λ_s was obtained via optimization for the argillite data. I recommend rewriting this sentence to clarify that two different approaches were employed.

Page 2419: The number for sixth sample is given as EST 2538 in Table 1, whereas it is given as EST 2528 in Fig. 3 and in the text (see page 2415, line 14).

Page 2420: It is not clear what the value λ_s = 0.0044 $WK^{-1}m^{-1}$ represents in Figure 1. The text indicates that λ_s was fixed at a value of 0.80 $WK^{-1}m^{-1}$. Furthermore, the value λ_s = 0.0044 W $K^{-1}m^{-1}$ does not appear to be realistic for glass beads.

References cited:

Revil, A.: Thermal conductivity of unconsolidated sediments with geophysical applications, J. Geophys. Res., 105(B7), 16749-16768, 2000.

Revil A., Leroy, P., and Titov, K.: Characterization of transport properties of argillaceous sediments. Application to the Callovo-Oxfordian Argillite, J. Geophys. Res., 110, B06202, doi:10.1029/2004JB003442, 2005.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 2409, 2008.

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