

Solid Earth, Review

High-Resolution Analysis of the Physicochemical Characteristics of Sandstone Media at the Lithofacies Scale

The potential paper is well written, valid and original. Indeed, models that combine spatial representation of physical and chemical parameters contrast large parts of literature on sandstone aquifers and reservoirs that focus on facies and permeability upscaling.

I strongly support the publication of this paper in *Solid Earth*. However, revisions and reply to general and specific comments are needed and there is my availability to review the paper a second time in case of request of the editors.

General comments

The authors should consider literature on the physiochemical properties of sandstone media more widely in the introduction and discussion. I recognize that the paper is original, but the authors should clarify better the reason in the introduction. As expressed above, models that combine spatial representation of chemical and physical parameters contrasts large part of literature on sandstone that largely focuses on 3D representation of the physical properties in three dimensions. Other papers exclusively treat the chemical properties of sandstone aquifers. Although the paper is generally well written I can see problems in the organization of the conclusions.

Please, refer to the comments below that aim to support resolution of problems and bring the impact out of your research.

Specific comments

1.0 Introduction

Lines 29-30 Add papers that treat upscaling and spatial properties of sandstone with regards to permeability issues related to nuclear waste repositories and hydrocarbon reservoirs.

- Kiryukhin, A.V., Kaymin, E.P. and Zakharova, E.V., 2008. Using TOUGHREACT to model laboratory tests on the interaction of NaNO₃-NaOH fluids with sandstone rock at a deep radionuclide repository site. *Nuclear technology*, 164(2), pp.196-206.

- Medici, G., West, L.J. and Mountney, N.P., 2016. Characterizing flow pathways in a sandstone aquifer: tectonic vs sedimentary heterogeneities. *Journal of contaminant hydrology*, 194, pp.36-58.
- Medici, G., West, L.J., Mountney, N.P. and Welch, M., 2019. Permeability of rock discontinuities and faults in the Triassic Sherwood Sandstone Group (UK): insights for management of fluvio-aeolian aquifers worldwide. *Hydrogeology Journal*, 27(8), pp.2835-2855.

Lines 32-34 Again, I suggest updated literature on the topic for low porosity layers that reduce flow at the scale of the pumping tests in sandstone.

- Hamdi, Hamidreza, Philippe Ruelland, Pierre Bergey, and Patrick WM Corbett. "Using geological well testing for improving the selection of appropriate reservoir models." *Petroleum Geoscience* 20, no. 4 (2014): 353-368.
- Medici, G., West, L.J. and Mountney, N.P., 2019. Sedimentary flow heterogeneities in the Triassic UK Sherwood Sandstone Group: Insights for hydrocarbon exploration. *Geological Journal*, 54(3), pp.1361-1378.
- Jackson, M.D., Muggeridge, A.H., Yoshida, S. and Johnson, H.D., 2003. Upscaling permeability measurements within complex heterolithic tidal sandstones. *Mathematical Geology*, 35(5), pp.499-520.
- Tellam, J.H. and Barker, R.D., 2006. Towards prediction of saturated-zone pollutant movement in groundwaters in fractured permeable-matrix aquifers: the case of the UK Permo-Triassic sandstones. *Geological Society, London, Special Publications*, 263(1), pp.1-48.
- Tidwell, V.C. and Wilson, J.L., 1997. Laboratory method for investigating permeability upscaling. *Water Resources Research*, 33(7), pp.1607-1616.

Lines 25-68 Overall very good introduction. I suggest to add two or three sentences to explain not only which is your observation scale but also where it lies. Your outputs lie between the core plug and pumping test scale. Hence, your research contributes to bridge the gap between the two scales. See below relevant publications on the upscaling properties of sandstone aquifers/reservoirs.

- Corbett, P.W., Hamdi, H. and Gurav, H., 2012. Layered fluvial reservoirs with internal fluid cross flow: a well-connected family of well test pressure transient responses. *Petroleum Geoscience*, 18(2), pp.219-229.

- Medici, G., West, L.J. and Mountney, N.P., 2018. Characterization of a fluvial aquifer at a range of depths and scales: the Triassic St Bees Sandstone Formation, Cumbria, UK. *Hydrogeology journal*, 26(2), pp.565-591.

- Zheng, S.Y., Corbett, P.W., Ryseth, A. and Stewart, G., 2000. Uncertainty in well test and core permeability analysis: a case study in fluvial channel reservoirs, northern North Sea, Norway. *AAPG bulletin*, 84(12), pp.1929-1954.

2. Measurement campaign

Line 109 "Hassler cell permeameter". I understand that you provide a reference. But, I think the manuscript would benefit of a sentence that explains the basic principal of your permeameter.

Lines 182-183 I leave to the authors the decision to state typical ranges of flow anisotropies (K_h/K_v) at the centimetre-meter scale in sandstones providing general references. Typical flow anisotropies are ~10-500 in sandstone aquifers with lower value in channelized sandstone of fluvial and deltaic origin.

3. Results

Lines 238-239 I suggest described by Fongngern et al. (2018).

Lines 306-307 Possible adding a short explanation on the reason why inverse distance and kriging provide comparable results? I guess the geometry that needs to be interpolated is relatively simple.

Lines 316-323 Realistic values of intrinsic permeability but very low. Please, justify your outputs with reference to the rock-type/lithofacies. The reason of this low permeability should be the sheet-like sandstone nature of the geological material tested. It's well known that sheet like sandstone are not very conductive for the fluids.

I'm inviting the author to make more evident in the paper the relation between sedimentology and intrinsic permeability.

4. Discussion

Line 379 If the authors want to enlarge bibliography on sandstone mineralogy and diagenesis. I suggest the following papers:

- Ixer, R.A., Turner, P. and Waugh, B., 1979. Authigenic iron and titanium oxides in Triassic red beds:(St. Bees Sandstone), Cumbria, northern England. *Geological Journal*, 14(2), pp.179-192.

- Van Keer, I., Muchez, P.H. and Viaene, W., 1998. Clay mineralogical variations and evolutions in sandstone sequences near a coal seam and shales in the Westphalian of the Campine Basin (NE Belgium). *Clay Minerals*, 33(1), pp.159-169.

Line 380 I invite the authors to avoid the use of “because” in a scientific paper. Aside from minor issues the manuscript is very well written.

5 Conclusions

Lines 400-401 I agree on the use of bulletin points. I suggest adding one or two sentences to introduce your four points. This passage from standard text to bulletin points sound chunky to the readers.

Lines 417-419 Future work is introduced here in an abrupt way. Also, better avoiding new topics in the conclusions. It's fine to introduce future research scenarios. But, in this case, the topic needs to be analysed in the discussion section.

Figures and tables

All figures and tables of publishable quality. I remind the authors to comment on the low intrinsic permeabilities (see Fig. 14) of the studied deposits.

Fig. 6 Make this image larger.

Fig. 7 Figures on axes larger.

Overall, very good contribution to the petro-hydraulic properties of porous sandstone.

My best wishes,

Giacomo Medici