Upscaling of reservoir properties

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Summary (Arial 12pt bold or Calibri 12pt bold)

This work describes a method of scaling up reservoir properties based on similarity of transport phenomena equations. The properties are porosity, permeability, formation resistivity factor, specific heat capacity and thermal conductivity. For each property equivalent electrical curcuit is constructed and system of linear equations is obtained. Due to sparce nature of the matrix of system conjugate gradient method is used as one of the fastest.

Results for scaling up reservoir properties has been obtained for different sets of data (experimental and artifical). Experimental and model-by-model ways of vaildation of the proposed model have been described and is a subject of the future work.

Introduction

Conventional and unconventional reservoir simulations require numerous amounts of data regarding reservoir properties. There are two major (several) scale levels at which we can measure these properties directly or indirectly: core laboratory scale (in terms of centimeters) and logging tools scale (in terms of decimeters). But for commercial reservoir simulators these properties must (should) be provided at a higher scale level (in terms of meters) to satisfy grid block size. So there is a huge gap between what data is available and what we actually need for simulation.

In this work, we try to scale up the key reservoir properties: porosity, permeability, formation resistivity factor, specific heat capacity and thermal conductivity.

Theory and/or Method

The theoretical approach is both simple and powerful. It is based on similarity of equations of mass flow through porous media (Darcy's law), conductive heat transfer through porous media (Fourier's law) and electrical conductivity (Ohm's law).

Darcy's law:

$$u = -(k/\mu)\nabla P$$

where u is the flow velocity, k is the absolute permeability, μ is the dynamic viscosity of fluid and ∇P is the pressure gradient.

Fourier's law:

$$q = -k_{th}\nabla T$$

where q is the heat flux, k_{th} is the thermal conductivity and ∇T is the temperature gradient.

Ohm's law:

$$J = -\sigma \nabla \Phi$$

where J is the current density, σ is the electrical conductivity and $\nabla\Phi$ is the charge density gradient.

For scaling up certain reservoir property we created equivalent electrical circuit consisting of resistors with appropriate electrical resistivity. Then we use Kirchhoff's circuit laws to construct a matrix for system of linear equations that describes the circuit. Finally, we use the conjugate gradient method to solve the system for total resistivity and convert it back to corresponding reservoir property.

Examples

As an example of the application of the above approach we use 10x10x10 cubic lattice with randomly assigned reservoir properties from an experimentally obtained distributions (porosity, permeability, etc.).

For a given porosity vs permeability distribution (green dots) we can see resulting scaled up porosity vs permeability distribution (blue dots) on Figure 1.

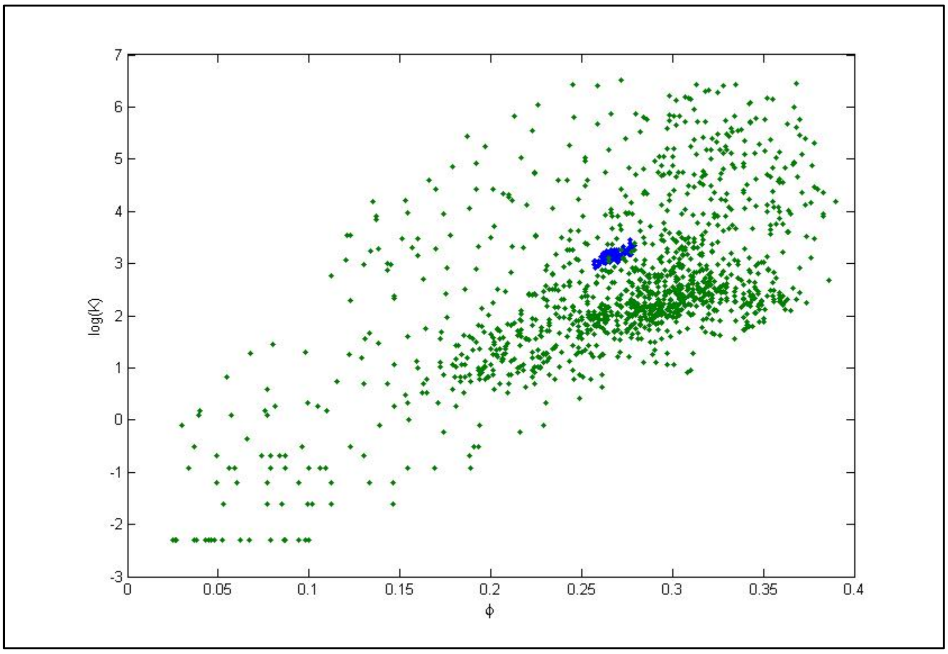

Figure 1 – Porosity vs permeability distributions (original and scaled up)

Conclusions

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References

1. Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2007). *Transport Phenomena* (изд. Revised Second Edition). John Wiley & Sons, Inc.
2. Clayton, R. P. (2001). *Fundamentals of electric circuit analysis.* John Wiley & Sons, Inc.
3. Dake, L. P. (1978). *Fundamentals of Reservoir Engineering.* ELSEVIER SCIENCE B.V.
4. Kantzas, A. (1985). *Computer Simulation of Relative Permeability Properties of Porous Media (Master's thesis).* Waterloo, Ontario.
5. Hestenes, M. R., & Stiefel, E. (1952). Methods of Conjugate Gradients for Solving Linear Systems. *Journal of Research of the National Bureau of Standards*, 409-436.