

# **PS Improving the Estimation of Shale Permeability with Process-Based Pore Network Modeling Approach\***

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Search and Discovery Article #42031 (2017)\*\*

Posted March 13, 2017

\*Adapted from poster presentation given at AAPG Eastern Section Meeting, Lexington, Kentucky, September 25-27, 2016

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## **Abstract**

In shale, kerogen and clay make the pore network intricate. For example, in kerogen subspherical pores are connected by cylindrical throats while in clay both pores and throats are triangular or sheet like. To our knowledge, few studies considered the influence of kerogen and clay in reconstructing pore networks. This study uses a process-based modeling approach to reconstruct pore networks of shale. Our process-based approach considers the influence of kerogen and clay on pore morphology and distribution. The estimations of shale permeability based on generated pore networks are improved.

First, analysis of FE-SEM images gives grain size distributions of shale. With the grain size distributions and the process-based method (Bakke and Øren, 1997), this study develops a network A that connects interparticle pores, organic matter (OM) particles and clay agglomerates. With random sphere packing algorithm, this study extracts a network B that connects nanopores in OM particles and a network C that connects pores in clay agglomerates. The pore morphology is set to be different in networks B and C. Then networks B and C are inserted into the selected OM particles and clay agglomerates in network A for the final network D. The pore network D connects interparticle pores, subspherical nanopores and triangular/sheet like pores in clay. Finally, this study applies no-slip permeability equations in the network D and predicts no-slip permeability of shale. The permeability equations are modified according to pore morphology.

This study analyzed FE-SEM images of shales from Sichuan Basin in China and Appalachian basin and then built pore networks. The pore size distributions (PSD) of our pore networks matched well with the PSD defined by the mercury intrusion data. In addition, the resulted permeability estimations are in good agreement with the reported lab measurements. Based on our pore networks, this study further investigated the effect of shale diagenesis on shale permeability. It comes to our knowledge that no process-based approach and networks are exclusively developed for shale. Our process-based modeling considers the influence of kerogen and clay distribution on ultimate pore structure in shale.

### **Reference Cited**

Bakke S., and P. Øren, 1997, 3-D pore scale modelling of heterogeneous sandstone reservoir rocks and flow simulations in the pore networks: SPE 35479.

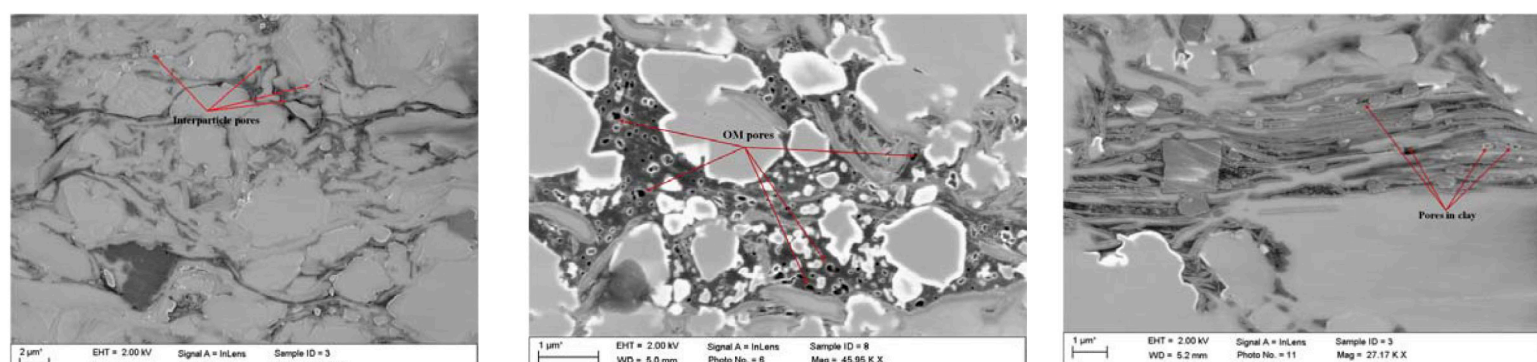
# P12. Improving the Estimation of Shale Permeability with Process-based Pore Network Modeling Approach

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## Conclusions

- An integrated method utilizing 2D SEM images and process-based modeling was developed to reconstruct 3D pore networks in shale matrix.
- No-slip permeability of shale was estimated based on the 3D pore networks.
- High connectivity of organic matter (OM) particles and clay agglomerates leads to higher shale permeability.
- High aspect ratio of pores in clay reduces shale no-slip permeability.

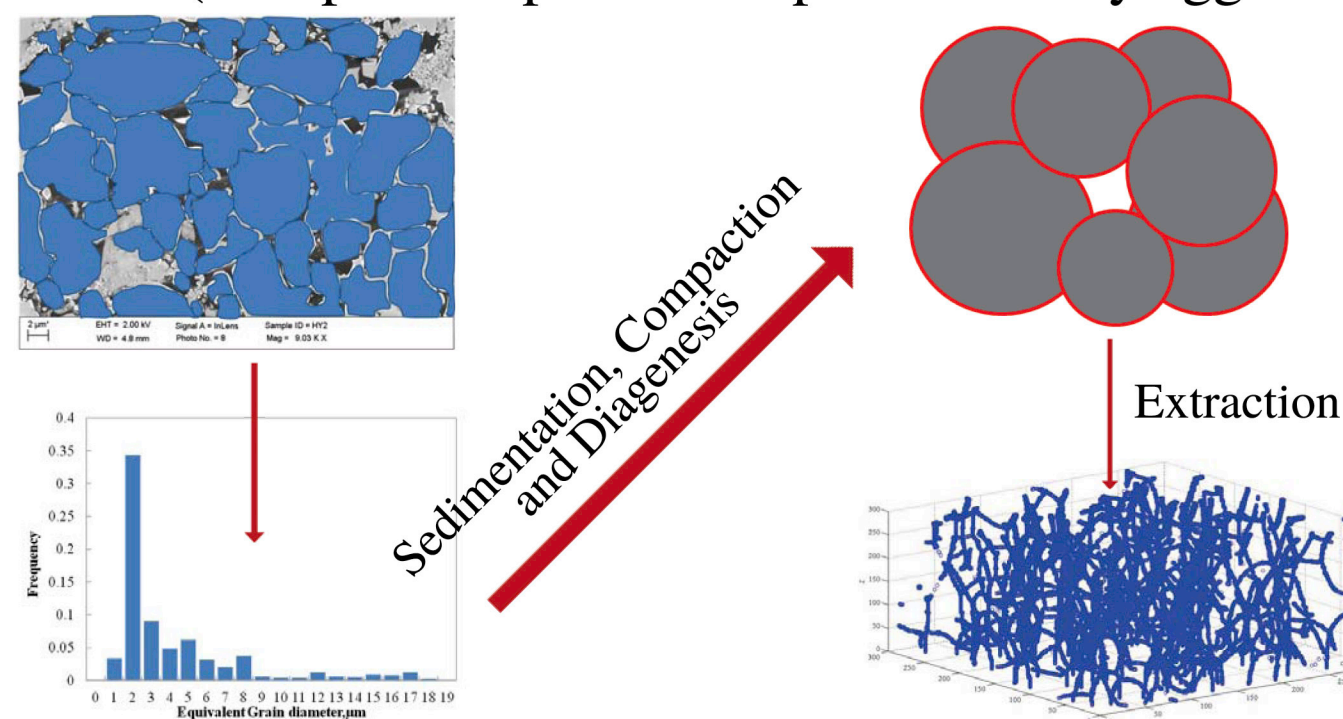
## 1. Introduction



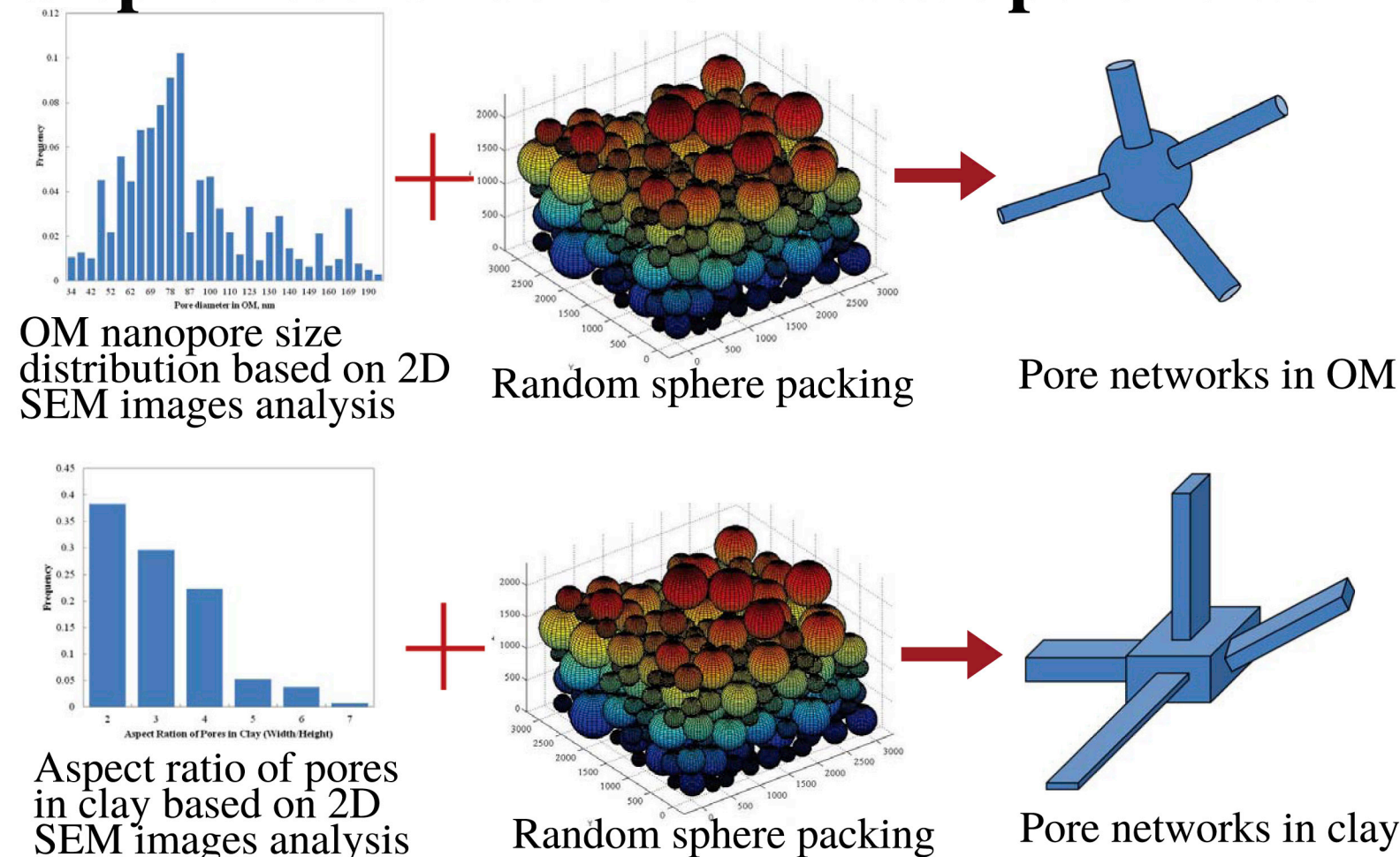
- Interparticle pores: large (~1 μm) and jagged
- OM pores: small (10~100 nm) and rounded
- Pores in clay: Triangular to sheetlike shape

## 2. Methodology

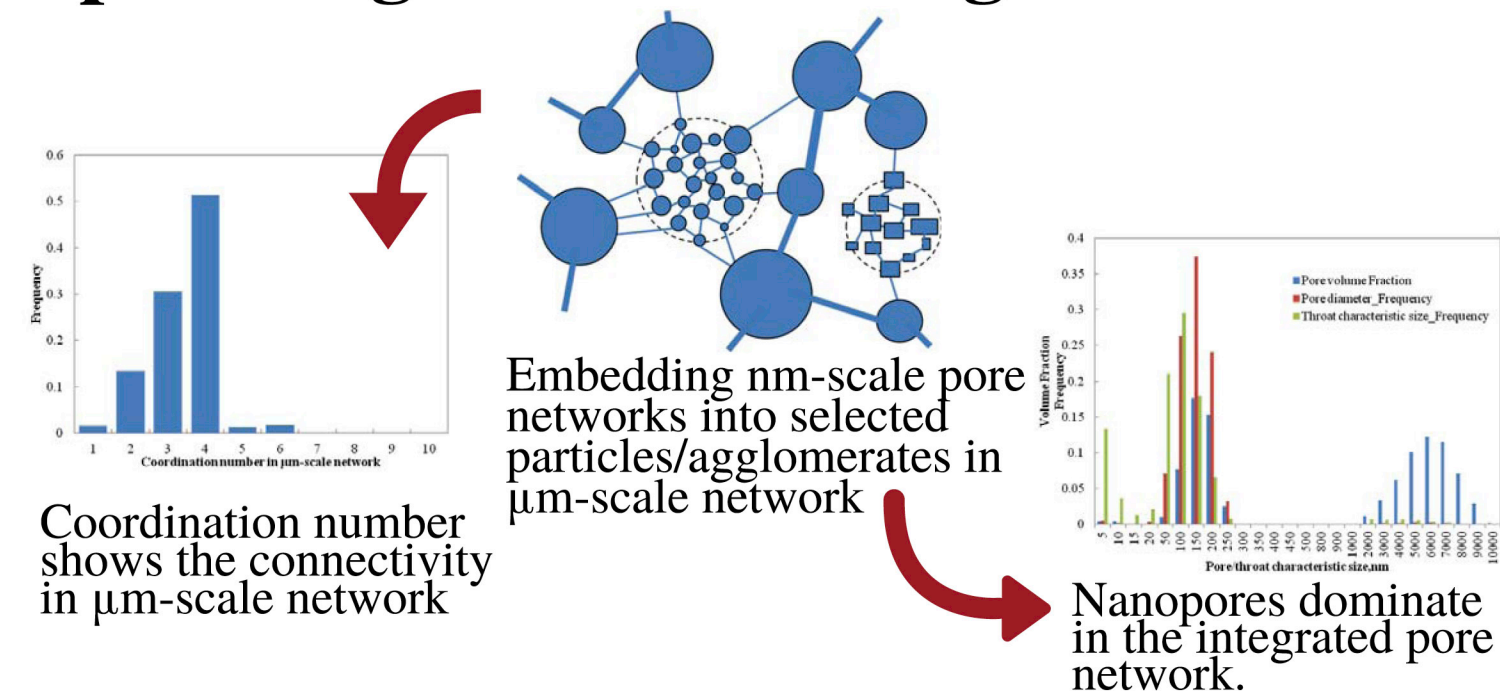
### Step1: Reconstruction of μm-scale network (Interparticle pores-OM particles-Clay agglomerates)



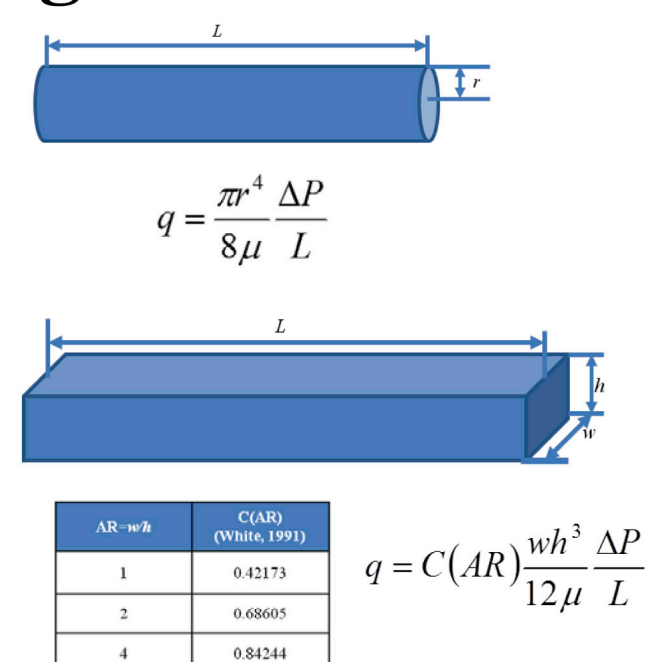
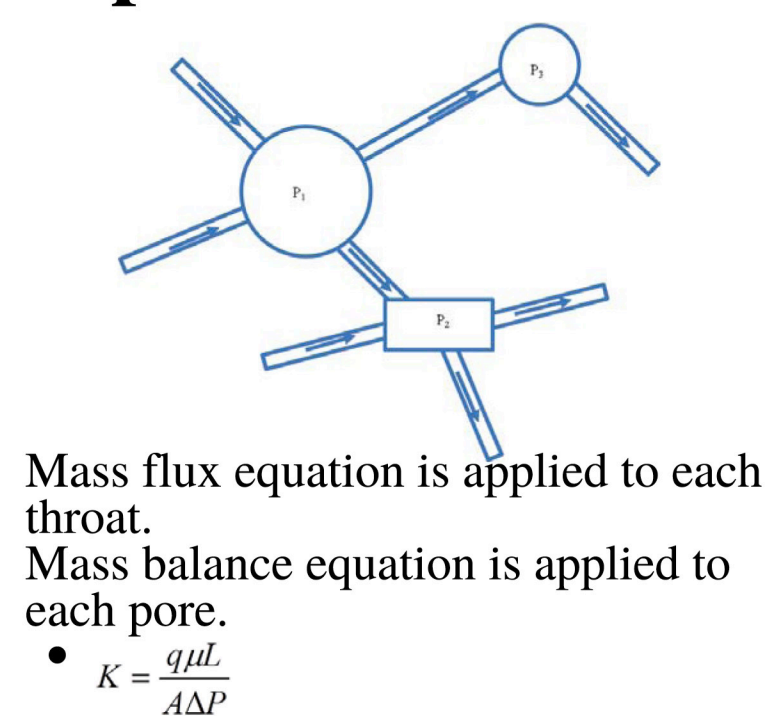
### Step 2: Reconstruction of nm-scale pore network



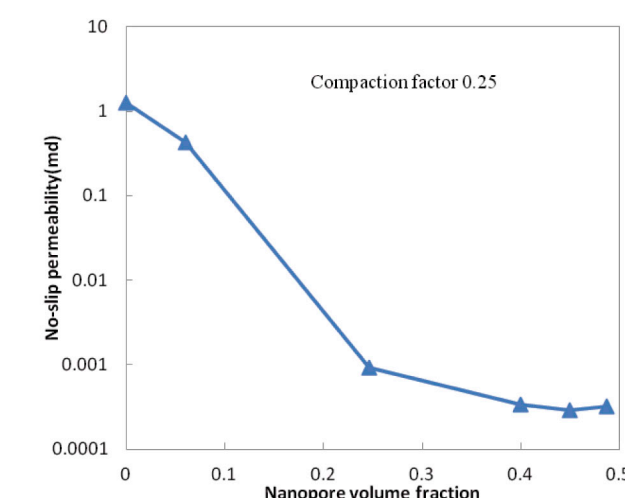
### Step3: Integrated network generation



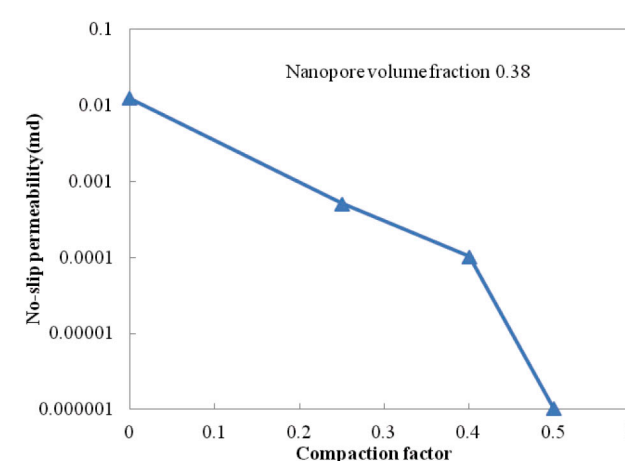
### Step4: Gas flow modeling



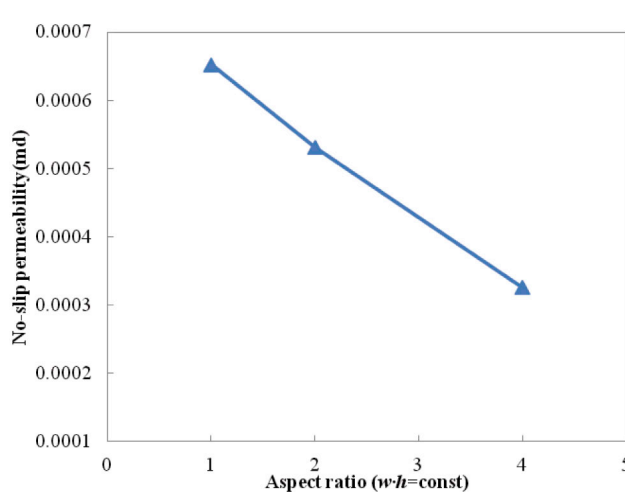
## 3. Results



When nanopore volume fraction reaches 0.4, nm-scale pore networks dominate the flow path.



Large compaction factor leads to low connectivity between OM particles and clay agglomerates.



When all nanopores are sheetlike, higher aspect ratio reduces shale no-slip permeability.

## Acknowledgements

Authors acknowledge Yanchang Petroleum Group for the permission of publishing the experimental data.

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