Improved Estimation of Water Saturation in a Lower-Paleozoic European Organic-Rich Shale Gas Formation*

Yifu Han1 and Siddharth Misra2

Search and Discovery Article #42154 (2017)**
 Posted November 20, 2017

*Adapted from poster presentation given at AAPG 2017 Mid-Continent Section Meeting, Oklahoma City, Oklahoma, September 30 – October 3, 2017
**Datapages © 2017 Serial rights given by author. For all other rights contact author directly.

1Mewbourne College of Earth and Energy, University of Oklahoma, Norman, OK (misra@ou.edu)
2Mewbourne College of Earth and Energy, University of Oklahoma, Norman, OK

Abstract

Unconventional resources or organic-rich shale formation generally exhibits high clay content, significant variations in lithology, rock texture, total organic carbon, accompanied by high connate water salinity, presence of disseminated pyrite grains, and low values of porosity. Subsurface electromagnetic (EM) measurements, namely galvanic resistivity, EM induction, EM propagation, and dielectric dispersion, exhibit frequency dependence due to the interfacial polarization (IP) of clay, grain surfaces, and conductive minerals. These petrophysical attributes adversely affect the log-derived water saturation estimates. The conventional subsurface EM measurement interpretation methods generate inaccurate saturation estimates in clay- and pyrite-bearing shales primarily because multifrequency conductivity and permittivity logs are interpreted separately using empirical models at a single frequency. In this work we propose an inversion-based method to process and interpret broadband EM dispersion logs. In clay and pyrite rich formation, the recently published clay and pyrite dispersion model (PS) is coupled into the inversion scheme to process logs, which takes clay and pyrite IP effects into account.

References Cited


Improved Estimation of Water Saturation in a Lower-Paleozoic European Organic-Rich Shale Gas Formation

Yifu Han and Siddharth Misra

Mewbourne College of Earth and Energy, The University of Oklahoma

Summary

Unconventional resources or organic-rich shale formation generally exhibits high clay content, significant variations in lithology, rock texture, total organic carbon, accompanied by high connate water salinity, presence of disseminated pyrite grains, and low values of porosity. Subsurface electromagnetic (EM) measurements, namely galvanic resistivity, EM induction, EM propagation, and dielectric dispersion, exhibit frequency dependence due to the interfacial polarization (IP) of clay, grain surfaces, and conductive minerals. These petrophysical attributes adversely affect the log-derived water saturation estimates. The conventional subsurface EM measurement interpretation methods generate inaccurate saturation estimates in clay- and pyrite-bearing shales primarily because multifrequency conductivity and permittivity logs are interpreted separately using empirical models at a single frequency. In this work we propose an inversion-based method to process and interpret broadband EM dispersion logs. In clay and pyrite rich formation, the recently published clay and pyrite dispersion model (PS) is coupled into the inversion scheme to process logs, which takes clay and pyrite IP effects into account.

Introduction

Figure 1. Downhole EM tools (Hzeem et al., 2008).

Figure 2. Frequency dispersion conductivity and permittivity logs (Wang and Poppitt, 2013).

Figure 3. The alteration in electromagnetic (Mistra et al., 2016).

Figure 4. The characteristics of EM dispersion of sedimentary rock as a function of frequency (Wang and Poppitt, 2013).

Figure 5. Modified inversion scheme to process logs, which takes clay and pyrite IP effects into account.

Table 1. Assumed petrophysical properties of the synthetic layer used for this study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturation</td>
<td>0.30</td>
</tr>
<tr>
<td>Porosity</td>
<td>0.01</td>
</tr>
<tr>
<td>Conductivity</td>
<td>0.01</td>
</tr>
<tr>
<td>Permittivity</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Figure 6. Convergence of modified LMA estimates of PS-model parameters.

Figure 7. Comparison of measured and modeled broadband dispersion data.

Conclusions

Improved water saturation estimates were obtained in one shale gas well in an European Lower Paleozoic formation. This mandates application of the newly proposed inversion scheme on multifrequency permittivity and conductivity logs, generally obtained by running EM induction, propagation, and dielectric dispersion tools in a single well. The proposed method ensures consistent estimation of water saturation and certain petrophysical parameters irrespective of the EM log-acquisition frequency which is extremely beneficial for shales rich in clay and pyrite.