Pore Throat Dimensions, "Apparent Cross-sectional Area", and Electrical Resistivity in Low Porosity Carbonates

Jan H. Norbisrath, Gregor P. Eberli, and Ralf J. Weger

Project Objectives

- Expand the Verwer et al. (2011) resistivity data set into lower porosity rocks to better assess the control by pore throat dimensions on the resistivity of carbonates.
- Evaluate the effect of the "apparent cross-sectional area" on the electrical resistivity

Project Purpose

Previous studies by Verwer et al. (2011) have shown that the electrical resistivity and Archie's cementation factor, *m,* in carbonates are mainly controlled by the fluid filled pore structure. Their most arresting finding is that samples with simple, large pore structures and high permeability tend to have higher resistivity than samples with similar porosity but small, complex pore structures dominated by small pores and lower permeability (Figure 1). Verwer et al. (2011) hypothesize that this trend is related to the "apparent cross-sectional area", which rises with the increasing number of pore throats in microporous, low permeability carbonates. In this study, we test this hypothesis by assessing the complex relationships between the electrical resistivity and the pore structures in both low porosity rocks and highly microporous rocks.

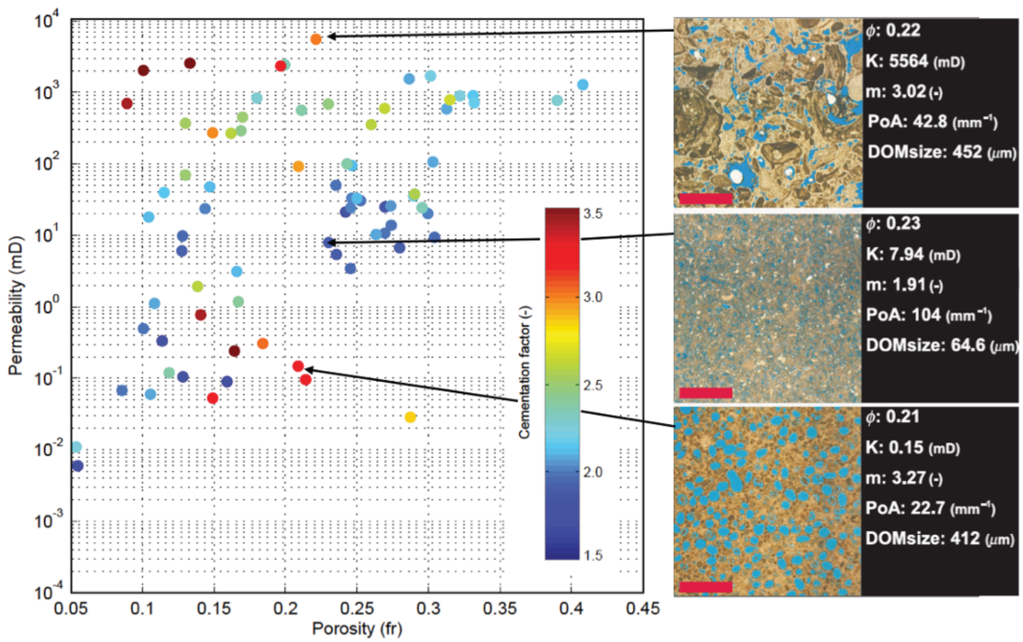

Figure 1: Porosity-permeability cross plot with cementation factor superimposed in color. Samples with high permeabilities have a higher cementation factor for a given porosity, as exemplified by the top two examples on the right. Oomoldic samples are the exception to the general trend (example on the lower right) (modified from Verwer et al. 2011)

Scope of Work

By expanding the data set into the realm of low porosity (< 10%) and dominantly microporous samples, we will try to specifically assess the controls of pore throat diameter and number on the electrical resistivity of carbonates.

Initial laboratory measurements of low porosity core plugs (1-10% porosity) will be compared to quantitative geometric parameters of the rock using the Digital Image Analysis (DIA) method on thin sections. Because in some samples the porosity is mostly microporous, the pore geometries cannot be captured with DIA analysis. To quantify the full spectrum of the pore throat diameters in these samples, Mercury Injection Capillary Pressure (MICP) analyses will be conducted. This information will be used to calculate the "apparent cross-sectional area" of the pore throats, which is assumed to be the most influential factor on electrical conductivity in the rock. The outcome of this project will be a better understanding of the relationship between pore throat dimensions/number and the electrical resistivity of carbonates, particularly those with lower porosities. Moreover, the impact of high microporosities on resistivity will be defined in more detail.

Project Description

1. Perform MICP (Mercury Injection Capillary Pressure) analysis on a broad range of samples from different origins with porosities ranging between 1 and 15%.
2. Measure electrical resistivity, formation factor, and permeability of these samples.
3. Evaluate scatter in resistivity measurements as a function of the apparent cross-sectional area and other physical properties, such as permeability.

Key Deliverables

In combination with the data set described in Verwer et al. (2011), this study will provide a comprehensive data set that correlates resistivity to porosity, permeability, and pore structure, size, and number (using MICP and DIA). The results will help to further improve the inversion of carbonate pore structure from down hole log resistivity data and thereby improve the calculation of water saturation in carbonate reservoirs, eventually leading to improved oil estimates.

References

Archie, G.E., 1942, The electrical resistivity log as an aid in determining some reservoir characteristics: Petroleum Transactions of AIME (Am. Inst. Min. Metall. Eng.), v. 146, p. 54-62.

Verwer, K., Eberli, G.P. and Weger, R.J., 2011, Effect of pore structure on electrical resistivity in carbonates: AAPG Bulletin, v. 95/2, p1-16.