Electrical resistivity, Archie's Law and Pore Space Geometry in Carbonates

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Project Purpose

The electrical resistivity in fluid-filled sedimentary rocks is largely controlled by its pore space geometry, as the electric current is conducted predominantly through the pore fluid. Yet, in carbonates, the variation in electrical resistivity and the cementation factor for a given porosity are poorly understood. Many studies have recognized that acoustic velocity and permeability in carbonate rocks is dependent upon pore geometry. In this study we aim to explore the complex relationship between the shape and size of pores and pore throats and the flow of the electric charge. It is postulated that the carbonate pore structure exerts a strong control on the electrical resistivity.

Scope of Work

Initial laboratory measurements of electrical resistivity in relation to quantitative geometric parameters derived from digital image analysis of thin sections yielded unexpected but strong correlation with the geometrical parameter m of Archie's law (Archie, 1942) that is derived from resistivity properties of the rock. For example, samples with a highly intricate pore network have a low formation resistivity factor and, thus, a low cementation factor for a given porosity. Furthermore, some samples with a high cementation factor had an unexpected high permeability. To corroborate these results and consolidate the initial trends, we aim to expand the data set with a sample set containing a variety of different textures and pore types.

Key Deliverables

This project will provide an overview of the factors controlling electrical resistivity in carbonate rocks. In addition, we will assess the influence of both the complicated textures and pore types on the electrical resistivity-porosity and porosity-permeability relationships.

Project Description

The project will utilize the following workflow:

1. Electrical resistivity, formation factor, and porosity were measured on 33 1" and 1.5" core plug samples. Four-electrode resistivity was measured as a function of frequency, stress, and temperature.
2. Perform CSL digital image analysis on thin sections to assess pore structure (Weger et al., 2009).
3. Evaluate scatter in resistivity measurements as a function of the carbonate pore structure and other physical properties such as permeability.
4. Test obtained relationships within Archie's Law and generalize the obtained results.

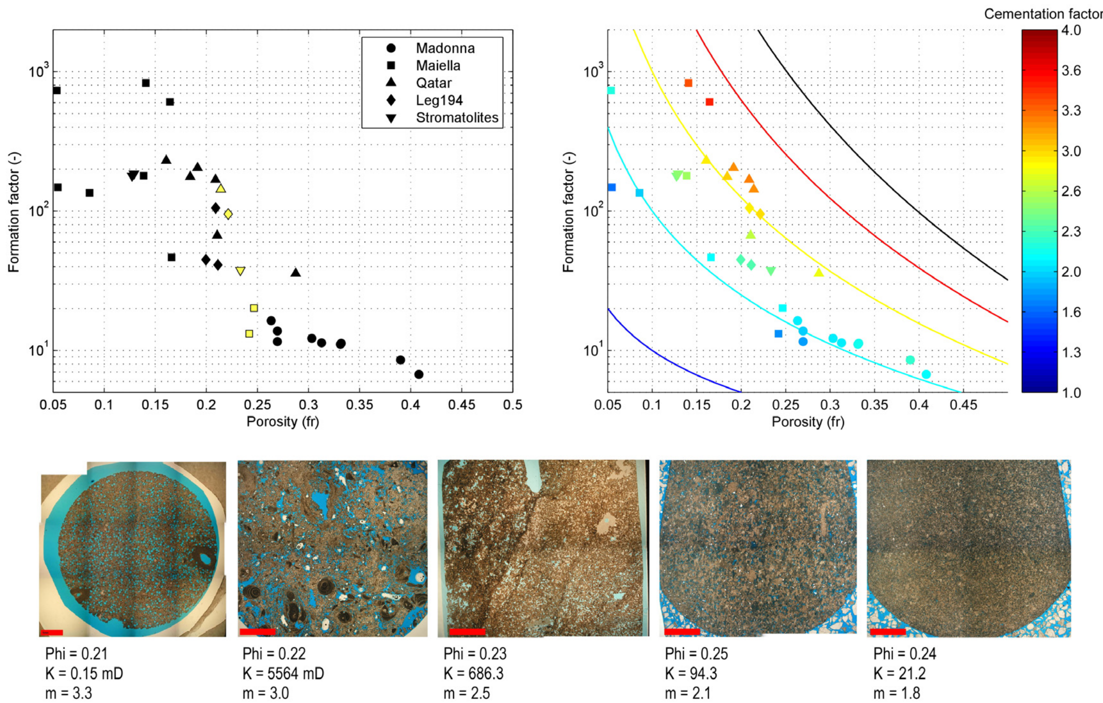

Figure 1. Cross plot of porosity vs. formation factor (left) and porosity vs. formation factor with the cementation factor (m) superimposed. Also shown are lines of equal m (right). Resistivity decreases with increasing porosity. The formation factor shows a variation of one order of magnitude for a given porosity. The cementation factor ranges from 1.75 to 3.5 in the data set. Porosity, gas permeability, cementation factor, and corresponding photomicrographs are shown (yellow symbols).

Expected results

The project aims to elucidate the effect of the carbonate pore structure on electrical resistivity in carbonates. The previously documented strong correlation of quantitative geometric parameters derived from DIA of thin sections to the geometrical parameter *m* of Archie's law that is derived from resistivity properties of the rock will be consolidated and generalized. The connection potentially allows pore structure and permeability to be inferred from down hole log information as long as the fluid characteristics are known. In addition, if the initial results hold up, it will have drastic implications for the calculations of water saturation (S_w) from resistivity logs.

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.

Weger, R.J., Eberli, G.P., Baechle, G.T., Massaferro, J.L., and Sun, Y.-F., 2009, Quantification of pore structure and its effect on sonic velocity and permeability in carbonates: AAPG Bulletin, no. 10, v. 93, p. 1297-1317.