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Mineralogical composition of the clay fraction and its impact on porosity and permeability in siliciclastic rocks

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Introduction

In siliciclastic reservoirs, permeability and porosity are fundamental properties, as they determine fluid storage and transmission capacity. These properties are strongly influenced by the mineralogical composition, particularly the clay fraction, which may contribute to rock cementation and porosity filling. Understanding the interactions between the mineralogy of the clay fraction and these properties is crucial for evaluating reservoir quality and optimizing its exploitation. This research investigates the mineralogical composition of the clay fraction and its relationships with porosity and permeability of standard siliciclastic reservoir samples, utilizing commercial analog plug samples from different formations.

Method and/or Theory

Twenty-three sandstones (Kokurek core samples) were analyzed in cylindrical plug format. The samples were characterized by X-ray diffraction (XRD) and X-ray fluorescence (XRF) to obtain an overall view of the rock composition. Porosity and permeability data were obtained in the laboratory. The clay fraction was separated for grain sizes smaller than 2 µm and characterized by XRD and XRF, identifying the clay minerals present.

Results and Conclusions

The samples exhibited clay content between 2% and 15% relative to the total mineralogy, with porosity ranging from 6.1% to 29.6% and permeability between 0.03 mD and 4628 mD. The results indicate no effect of clay minerals on porosity, but on permeability. The permeability of the analyzed rocks is influenced by the amount and type of clay minerals. Samples with higher clay content (> 8 %) tend to exhibit low permeability (< 10^2 mD). For example, Sister Gray Berea, Upper Gray Berea, and Bandera Gray samples, which have clay content of 6.1%, 5.9% and 13.9% respectively, have permeability as low as 20 mD. Clay minerals significantly reduce fluid flow by obstructing the pores. However, the type of clay mineral also influences permeability in distinct ways. Kaolinite, present in all samples, according to literature, forms large, non-expansive particles. Even at higher proportions, its impact on permeability was reduced, as observed in the Bentheimer sample (~2500 mD). However, when Illite is present in higher proportions than kaolinite, samples tend to exhibit low permeabilities, indicating that illite has the potential to substantially restrict pore connectivity. The presence of small amounts of chlorite may result in pore obstruction by filling intergranular spaces and forming compact layers. On the other hand, samples with small amounts of smectite showed higher permeability, indicating that, even in low proportions, this mineral may have a reduced impact on permeability. In addition to composition, the distribution of clay minerals in the rock matrix also significantly affects permeability. The results suggest that not only the content, but also the type and combination of clay minerals may play a significant role in reservoir rocks.