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Reinventing Source Rocks as Reservoirs

Manika Prasad, Kenechukwu C. Mba, *Colorado School of Mines, CO, USA*

Summary

We have examined organic-rich shales (ORS) to understand the interactions between lithology, kerogen content, and source rock potential. ORS are interesting as source and as hydrocarbon resources. Successful exploration and production programs for ORS need reliable identification of the kerogen content and the maturity through indirect seismic methods. However, the seismic properties of kerogen are poorly understood and so, predictions about maturity and rock-kerogen systems remain a challenge. Assessment of maturity from indirect measurements can be greatly enhanced by establishing and exploiting correlations between physical properties, microstructure, and kerogen content.

In this paper, we show correlations between the impedance microstructure of ORS and their maturity and elastic properties. We have used scanning acoustic microscopy to analyze and map the impedance microstructure in ORS. We quantified textural properties in the images and related these textural properties to maturity and to impedance from acoustic wave propagation measured at centimeter scales. This combined study of acoustic and microstructures of ORS give important insight in changes due to kerogen maturation. We introduce a modified porosity term and find that (i) there is a significant correlation between velocity and modified porosity of all ORS; (ii) Imaging and quantifying microscale impedance texture and contrast in the images allows us to correlate them with ultrasonic measurements on a cm-scale; and (iii) textural heterogeneity, elastic impedance, velocity, and density increase with increasing shale maturity.

In addition to presenting typical acoustic images of ORS and discussing possible methods to predict maturity from impedance, we will also present new data in context with older data in order to expand our knowledge database and to further our understanding of these complex, interesting, and economically important formations. Our work has important bearing on developing successful production and stimulation methodologies.

Results

- Correlation between kerogen content and elastic properties is significantly better if we use porosity-modified kerogen content.
- Porosity – modified kerogen content takes into account the "weakening" effect of the kerogen on the rock frame.
- An inverse correlation exists between stiffness and porosity-modified kerogen content. For example, the C66 stiffness can be predicted from $C^{66} = 30.436e^{-4.94*\text{porosity-modified kerogen}}$, with $R^2 = 0.9$.
- Grain size increases in mature shales.
- Immature shale have a more or less connected kerogen matrix and the higher impedance grains are dispersed in this matrix.
- Mature shale have a larger number of coarse grains. Grains form a framework with kerogen distributed in the pore space.
- The Biot's coefficient is less than 1 and is inversely proportional to maturity, decreasing to below 0.6 for mature ORS.

email: mprasad@mines.edu