Quantitative relationship between the elastic properties and kerogen content in organic-rich shale

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Introduction

kerogen represents more than 80% of the organic matter (Tissot1984), which is the most significant natural matter to generate oil and gas. In addition to many other factors influencing the properties of shale gas, kerogen is of particular importance not only because it is indicative of gas-production potential, but also because of its unique velocity, density, and resistivity characteristics (Zhu, 2011). Despite the significant influence on the physical properties of shale, however, the effects of kerogen contents on the elastic properties are inherently complex. It is difficult to quantitatively discriminate on a real shale sample, which makes the topic still far from being elucidated. An effective approach to overcome such problem is to work with well-controlled synthetic shale, where it is possible to accurately quantify desired factors and investigate their effect separately. In this sense, based on the hot-pressing technique, we built a physical model called artificial organic rich shale (Xie, 2016), and the similarities to natural shale have been demonstrated based on comprehensive experimental measurement in many perspectives. With AORS, the kerogen content can be accurately quantified, then to investigate its effect on the physical properties of framework separately.

Methodology

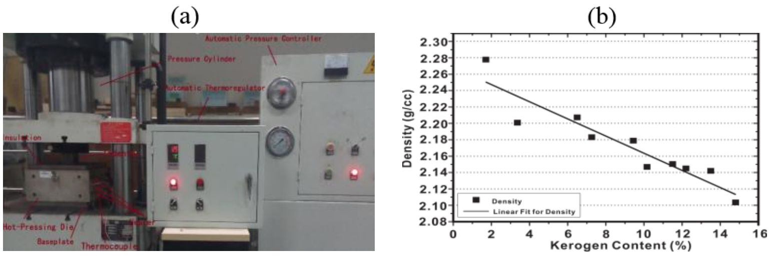

Figure.1 (a) picture of Hot-pressing system, (b) Density versus KC for 10 AORS samples

A total of 10 AORS full block samples were manufactured with different weight percentages of kerogen (1.71% to 14.80%) by the hot-pressing system (Fig.1a). In order to assess the influence of kerogen content (KC) on the elastic properties in the elevated confining pressure (0, 2, 5, 10, 15, 20, 25, 30, 35, 40, 50, 60MPa), ultrasonic velocities of P−wave (V_P) and S−wave (V_{SH} & V_{SV}) were tested with 0.5 MHz transducers in the cylinder samples which were horizontal cored from the block samples. The density was measured by using the standard weighing method. Fig.1b showed the crossplot of density versus kerogen content for 10 AORS samples. The densities tended to be linearly decreasing with the increasing KC in the range of 1.71% to 14.8%, and the fitting coefficient is 0.85.

Results

Yin (1992) provided a detailed error analysis of ultrasonic pulse transmission technique, which helped our measurements yield approximated 0.7% and 1.2% in the corresponding relatively error for the Vp and Vs estimation, respectively. Although there are outliers that are likely due to sample heterogeneity, the velocities for both P-wave and S-wave velocities tend to decrease with the increasing KC in each step of the loading CP (Fig.2a, 2b), so did the P-wave and S-wave impedance (Fig.2c, 2d), V_P switched to be more sensitive to the CP than those of Vs during the pressure loading process when the CP are greater than 2MPa. Fig.3 showed the crossplot that V_P /V_S ratio versus acoustic impedance (P−wave & S−wave) color coded by various KC in different CP, in which different color represented different KC, different markers denoted different CP. V_P /V_S ratio and AI (V_P & V_S impedance) trend upper with the increasing CP for the AORS with same KC. We divided the crossplot into multiple zones with different colored ellipse, in which the markers are characterized as same colors (same KC). In this sense, the plotted template among AI, CP and V_P /V_S can be acted as good indicator to distinguish different KC.

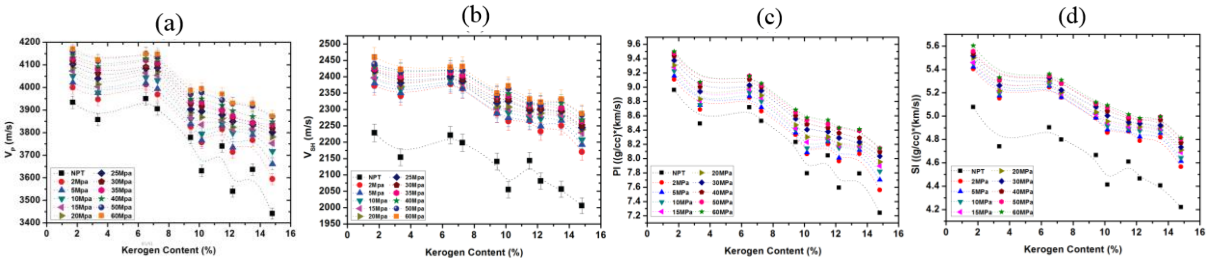

Figure 2: Relationship between KC (Wt %) and (a)Vp, (b) V_{SH},(c) PI, (d) SI for the AORS in varied CP.

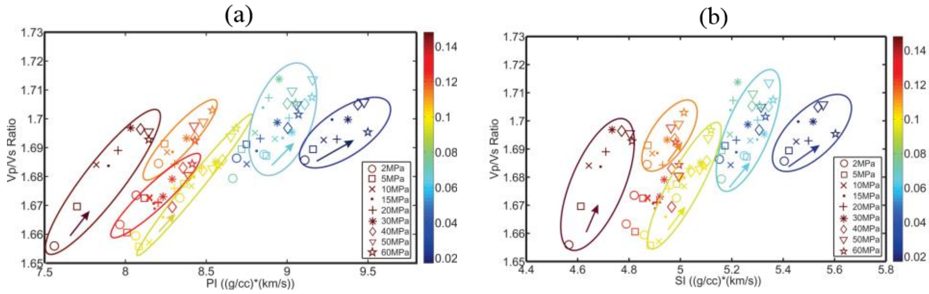

Figure 3: Crossplot that Vp/Vs ratio versus (a) P-wave impedance (PI), (b) S-wave impedance (SI) color coded by different kerogen content in the condition of elevated CP.

Conclusions

A set of 10 artificial organic rich shale were manufactured in which only the proportion of organic material was varied from about 1.71% to 14.80% by weight. The bulk density of these composites decreased linearly with KC, V_P and V_S generally decrease with organic content in each step of pressurized procedure, so did the acoustic impedance. P-wave velocities switched to be more sensitive to the CP than those of V_P and V_S during the pressure loading process when the CP are greater than 2MPa. Templet that V_P /V_S ratio versus acoustic impedance color coded by KC in different CP may be a potential tool to predict the KC.

Acknowledgements

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