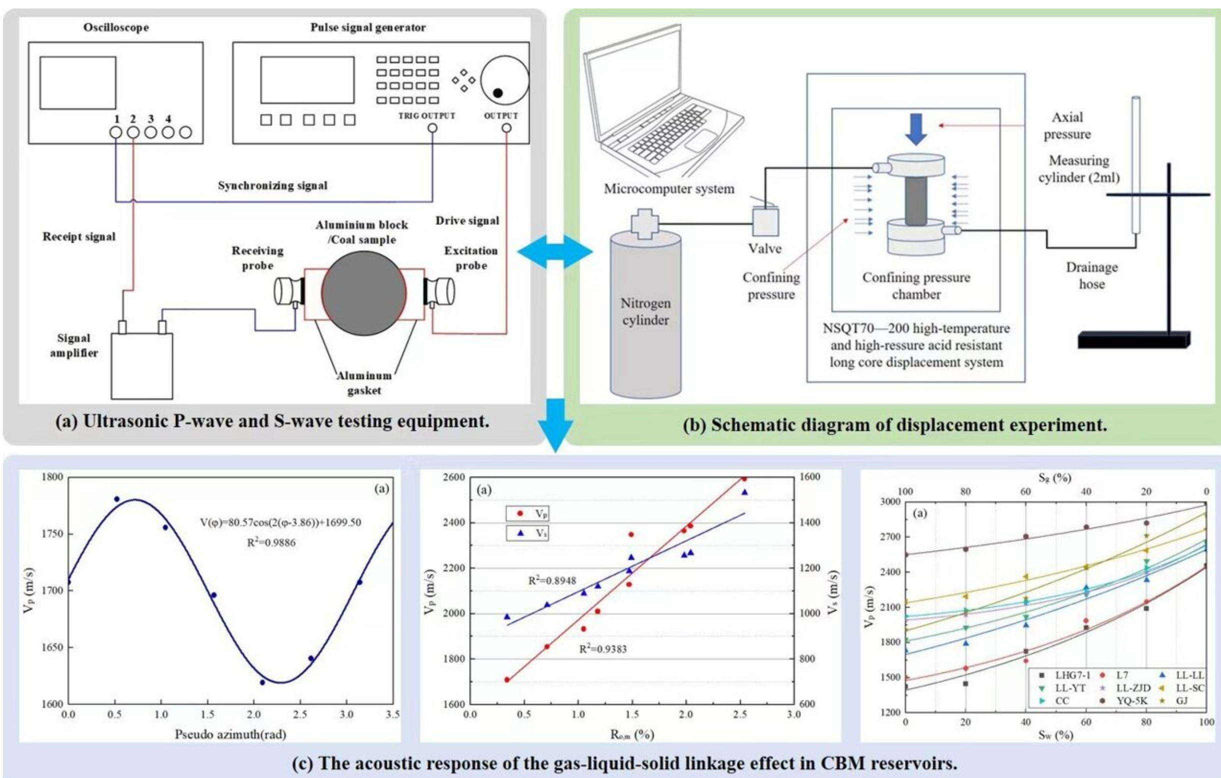
How are the physical characteristics of the coal-fluid system reflected in ultrasound?

April 28 2022



The acoustic characteristic curves of fluid saturation under different coal rank conditions. Credit: Higher Education Press Limited Company

Around the beginning of the 21st century, the world economy entered a new development cycle, and the demand for oil and natural gas resources around the world has skyrocketed. In the face of this huge energy demand, people are beginning to pay more attention to unconventional oil and natural gas resources. Coalbed methane (CBM) is a gas resource associated and symbiotic with coal. CBM is mainly hydrocarbon gas adsorbed on the pore surface of coal matrix and partially freed in pores or dissolved in water. It is, as an associated mineral resource of coal, a clean, high-quality energy and chemical raw material. It is well-known that the burial depth of CBM reservoirs ranges from hundreds of meters to several thousand meters, and its gas-liquid-solid interaction mechanism is complex. So, it is often necessary to obtain the fluid-coal information by means of, for example, acoustic logging. At present, many scholars have carried out the acoustic research on the fluid-coal system. However, there are relatively few studies on the acoustic characteristics of the gas-liquid-solid linkage effect, especially the fluid saturation effect under different coal rank conditions.

A new study, focused on the acoustic characteristics of the gas-liquid-solid linkage effect in CBM reservoirs, has revealed the P-wave and S-wave response of fluid saturation under different coal rank conditions. This work was carried out by the research team of Prof. Dr. Dameng Liu, from the China University of Geosciences (Beijing), and was published online in *Frontiers of Earth Science*.

In this study, typical coal samples with low to high metamorphism were selected from the coal mines in the southern margin of Junggar Basin and in Qinshui Basin. Before the acoustic research, basic experiments including coal industrial analysis, vitrinite reflectance measurement, and maceral analysis were carried out. On this basis, coal ultrasonic P-wave and S-wave testing experiments on dry coal samples and on coal samples containing gas-water with different saturation were carried out. Finally, the influences of coal type and gas-water saturation on acoustic response of CBM formations were analyzed.

The authors noted that for dry coal samples, the acoustic velocity was linear with vitrinite reflectance and density. Meanwhile, the (P-wave velocity Vp)/(S-wave velocity Vs) ratio, relative anisotropy of both Vp and Vs of dry coal samples tended to increase with increasing vitrinite reflectance and density of the coal samples, but the correlation between them was not very strong.

The study also showed that the Vp and Vs of gas-water saturated coal samples increased gradually with increasing water saturation (Sw) and vitrinite reflectance. However, with increasing vitrinite reflectance and density, and Sw increased from 0 to 100%, and the range of Vp and Vs increase was gradually narrowed. For coal samples with similar vitrinite reflectance, the Vp/Vs ratio of tectonic coals was larger than those of primary coals, and the increase rank of Vp and Vs of tectonic coal was also significantly higher when the Sw increased from 0 to 100%.

Additionally, the researchers found that the relative anisotropy of both Vp and Vs increased linearly with the Sw. For coal samples with similar vitrinite reflectance, the relative anisotropy of Vp and Vs and its growth rate of the tectonic coal was larger than that of the primary coal in general at the same Sw. This suggests that the acoustic anisotropy was stronger in the tectonic coal with well-developed pores and fractures. The anisotropy is more markedly influenced by the water saturation Sw.

The analyses of this study on the acoustic characteristics of gas-liquid-solid interactions formed the basis for the geophysical exploration of CBM reservoirs. A clearer understanding of the gas-water distribution characteristics in CBM reservoirs can be obtained when combining these models with those of the previous acoustic works. The study also provides a research basis for in-depth analysis of acoustic geophysical exploration methods under complex fluid conditions in actual reservoirs.

More information: Dameng Liu et al, P-wave and S-wave response of coal rock containing gas-water with different saturation: an experimental perspective, *Frontiers of Earth Science* (2022). DOI: 10.1007/s11707-021-0958-x

Provided by Higher Education Press