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Influence of Pressure and Temperature on Elastic Wave Propagation in Brazilian Pre-salt Carbonate

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Introduction

Including heat and mass transport phenomenon studies in rocks is essential for understanding fluid flow and wave propagation processes in geological, physical, and petrophysical studies of reservoir rocks, especially Brazilian pre-salt carbonates. During hydrocarbon production, variations in effective stress, resulting from changes in pore pressure, can induce fracturing and deformation within the reservoir. Likewise, the fluid injection used to increase the oil recovery causes local temperature variations and, consequently, a reservoir deformation due to rock expansion and contraction altering the mechanical properties of the rock. Also, the pore fluids are affected by pressure and temperature, with temperature more significantly impacted by the kinetic molecular and the volumetric fluid expansion properties. In this context, the present study aims to investigate the effects of confining pressure, pore pressure, and temperature on the propagation of P- and S-wave elastic velocities in a brine saturated sample from the Barra Velha Formation, Santos Basin, Brazil.

Method

The methodology involves measurements of the P- and S-waves transit time using a triaxial rock physics system and a standard sample of 1.5” in diameter, capable of inducing temperatures of 23, 40, 65, 80, and 100°C, which were subject to the confining pressures from 5 to 63 MPa, and pore pressures ranging from 0 to 53 MPa. The elastic wave velocities (Vp and Vs) were calculated for each case based on the wave time traveling in a transmission test at sample length. The pressure pore was evaluated at maximum confining pressure by the load and unload pore pressure cycles, and Vp and Vs were measured during the tests (an effective pressure of ~10-42 MPa). In addition, we performed compressibility and velocity experiments to evaluate the properties of the applied brine fluid, a Brazilian Formation Water (BFW), such as volume reduction at the maximum confining pressure (~60MPa) and the P-wave transit time and velocity.

Results and Conclusions

The measurement results were analyzed through the crossplots of the properties of interest, especially about the elastic velocities (Vp and Vs) under method conditions of saturation, temperature, confining pressure, and pore pressure. Therefore, we observed an increase of Vp and Vs with rising confining pressure, supposedly caused by the closure of microfractures and porosity reduction, which improves the rock's stiffness and decreases the elastic wave travel time. However, an increment of pore pressure causes the opposite effect, reducing the effective pressure by promoting an expansion in porosity and a delay in elastic wave velocities.

The temperature increment (23°C to 100°C) displayed a significative reduction of the measured velocities, observed around 5%, at the same pressure conditions, attributed to the thermal expansion of the rock matrix and the pore fluid that may cause a slight growth of porosity, decrease density, and reduce the mechanical strength. Also, checking the registered waveforms, we noticed a delay in wave transit time and amplitude reduction with temperature increasing, corroborating temperature effect analyses.