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Study on the Effect of Pressure in Crack Density of Carbonate Rocks

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Summary

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Abstract

Rocks in the Earth's crust contain different type of pores including cracks. This characteristic significantly affect the propagation of elastic waves in Earth. By extending the classic Biot's poroelasticity theory from porous media to rocks with cracks, previous authors added crack density and pore aspect ratio as two important parameters to the original approach. In this new approach, the crack density and aspect ratio can be obtained by inverting the velocity versus effective pressure data of dry and fluid-saturated rocks measured in the lab. Previous authors showed that this technique works well in different type of rocks. However, the carbonate rocks used in those previous papers are limited to commercial limestones (mainly grainstones according to Dunham's classification). Therefore, there is a need to test this theoretical approach into different type of carbonate rocks as they are very complex. The present paper focuses in the estimation of crack parameters of a set of carbonate rock samples from the Arab formation in the Middle East. This set of samples includes different carbonate rocks: limestones with different textures, going from mudstones to grainstones, and some dolstones. Overall, we have 3 mudstone samples, 3 wackestone samples, 3 pack-mudstone samples, 5 pack-grainstone samples, 5 grainstone samples and 2 dolostone samples. Our preliminary results show that most of the simulations predict well the acoustic velocity (Vp and Vs) variation with pressure.

Simulations were performed in the samples that estimate the crack density and average pore aspect ratio. The Crack density is defined for penny-shaped cracks:$\varepsilon = NR^3/V$ where V is the rock volume containing N-number of penny-shaped cracks, and R is the radius of penny-shaped cracks. The experimental data of samples of Vp, Vs, and porosity were provided. In general, we found that the model and the experiments corroborate that the increase in velocity with effective pressure is the result of the closure of the cracks. In other words, the crack density and the inverse pore aspect ratio of the rock samples decrease with the increase of confining pressure. As in previous studies, the inversion examples show in overall the validity of the numerical technique for estimating crack parameters from lab velocity data. Consequently, this modified theory seems to have a broader application scope in the measurement of rock properties of Earth's crust, including carbonates from the Jurassic, using seismic or acoustic waves. Further studies are needed and planned to explain and to refine the simulations of the exceptions found here.

We found in particular that the higher the bulk modulus of the solid grain, the higher the crack density. In fact, for bulk modulus of the solid grain higher than 150 GPa, the crack density is higher than 0.1, and for bulk modulus of the solid grain lower than 80 GPa, the crack density is lower than 0.0825. In addition, the average maximum crack density found in these samples is: 0.14 for dolostones, 0.12 for grainstones, 0.15 for pack-grainstones, 0.108 for wackestones, 0.10725 for mudstones, and 0.137 for pack-mudstone. In other words, the crack density of wackestones and mudstones are the lowest compared to the other carbonate lithology. A potential explanation for this could be that mudstones and wackestones are mud-supported rocks, so these two rock types could be more ductile than the rest that are grain supported leading to less crack density . In further studies, we plan to add more samples and to include image analysis to detect and quantify the actual crack density, and then better understand our results and applicability of the numerical technique used here.