Geophysical Research Abstracts
Vol. 20, EGU2018-13931, 2018
EGU General Assembly 2018

Multi-scale geological and geophysical characterization of Miocene continental carbonates (Samos Island, Greece): How to combine and compare field study and laboratory experiments?

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In case of subsurface characterization of continental carbonates, linking seismic, sonic logs and ultrasonic measurements on samples is challenging. Indeed, one of the main issue to tackle is the high petrophysical heterogeneity and the different factors that drive this heterogeneity in these continental carbonates. This work focuses on Miocene continental carbonates of the East Aegean (Samos Island) which present small continental basins with lacustrine and palustrine carbonate deposits.

One of the main goal of this work is to link the macro- and microstructure of these carbonates (controlled by sedimentology and diagenesis) with elastic wave velocities and petrophysical properties. What are the petrographic, acoustic and petrophysical signatures of these continental carbonates? How to characterize the different scales of petrophysical heterogeneities from sample scale to field scale? What are the main factors which control the propagation of elastic waves at these different scales?

To answer these questions, different approaches will be presented. Indeed, the combination of geological descriptions and geophysical measurements at field and lab scales is essential to understand the geophysical signature of carbonates. At the field scale, we carried out a seismic-refraction campaign to obtain wave velocities at a decametric scale. A photogrammetric campaign also provided a 3D overview of the studied outcrop and a visual estimation of the heterogeneities at the outcrop scale (stratification, fractures...). At an intermediate scale, we acquired sonic and gamma-ray measurements on outcrop along a sedimentary log. Following these measurements, a high resolution sampling was performed in order to compare outcrop and plug data. At the plug scale, a petrographic description (conventional microscopy and cathodoluminescence) allows to describe microfacies and determine the impact of diagenesis on microstructure. In order to define elastic and reservoir properties at the sample scale, ultrasonic P-wave and S-wave velocities, porosity and permeability were measured on plugs.

Each scale of investigation exhibits different controlling factors of elasticity. Seismic data are primary controlled by lithology contrasts (limestone versus marls) and structural setting (stratification, fracturation). At the intermediate scale, the stacking of different facies and the diagenetic overprint seems to control sonic changes. At the plug scale, microstructure changes appear to be the first controlling factor of elasticity. Indeed, variations of sedimentology control the primary fabric of carbonate rocks and early diagenetic modifications could sharply modify this fabric and lead to huge modifications of microstructure. As an example, for the same primary fabric, an early dissolution phase leads to a decrease of P-wave velocities; while a recrystallization episode induces an increase of this property. Finally, the integration of field study and laboratory experiments is the key to define the geological factors which govern the geological properties at different scales.