Geomechanical facies classification in carbonate rocks of the Barra Velha Formation for improved reservoir management

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Abstract

Uniaxial compressive strength (UCS) is the maximum axial compressive stress that a rock sample can withstand before failing and it is a key mechanical strength parameter for geomechanical modeling in hydrocarbon wells, as it is used in assessing well stability, selecting oil recovery techniques, and designing stimulation techniques to ensure reservoir management and production optimization. Additionally, UCS can be estimated from empirical correlations among rock strength and geophysical and petrophysical data, which in turn generates a continuous log that can be used for the classification of different mechanical strength facies along the reservoir, which can serve as input for predicting models in data-sparse wells using data science. Mechanical strength is mainly controlled by porosity, mineralogy, fractures, in-situ stress state, and sedimentary facies. Carbonate rocks have low to intermediate mechanical strength, and this behavior is directly related to sedimentary facies, which show a wide variety of composition, texture, and porosities. The aim of this work is to classify the carbonate rocks of the Barra Velha formation, the main reservoir in Pre-salt, Brazil, into geomechanical facies and establish a relationship among mechanical strength, sedimentary facies, and flow units. A database of the Buzios field composed of conventional logs, well tests, nuclear magnetic resonance data, mineral spectroscopy, and high-resolution photos of thin sections was used. To achieve the proposed objective, the Dunham's classification for carbonate sedimentary facies from high-resolution photo of thin sections descriptions was used, followed by the estimation of dynamic geomechanical models, such as in-situ stresses, and UCS using correlations from the literature, continuing with Bayesian classification for the definition of geomechanical facies starting from a priori model created with UCS ranges, then 4 attributes were selected with the highest accuracy in defining the posteriori facies model, and flow units were taken from pre-existing works for the same study area. Five geomechanical facies were defined, whose strength varies from very low, low, intermediate to high, the attributes that defined these facies with greater accuracy (around 86%) were porosity total from nuclear magnetic resonance, calcareous and quartz mineral content, and the difference between horizontal stresses. The very low strength facies presented the best flow conditions (Flow units 4 and 3) that also corresponded to Grainstone (with oolites) sedimentary facies with intergranular type porosity and mainly calcite cement. On the other hand, the high strength facies encompassed the worst flow conditions (Flow unit 1) with predominance of dolomite and quartz cement, without apparent porosity dominated by microcrystalline rock and Grainstone (with dendrites). The weakest facies comprised the flow units with the best oil production indices, however, the low strength 2 facies, despite having low mechanical strength, was classified as a flow barrier, as it is mainly composed of clay.