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Geomechanics Field and Laboratory Characterization of Woodford Shale: The Next Gas Play

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Abstract

Woodford shale is emerging as one of the major gas formations in the US Midwest. Despite its tremendous potential, existing data on the Woodford shale geomechanics characterization are limited at best. In this work, a well in the Woodford shale formation, 200 feet deep, was cored and logged in Oklahoma, USA. The resulting retrieved preserved cores were lab tested using standard acoustic techniques and triaxial testing for shale mechanical and poromechanical characterization in terms of compressibility, strength, pore pressure coefficient, Young's modulus, Poisson's ratio, etc. In addition, shale mechanical parameters alteration when in contact with drilling muds and fracturing fluids were measured using Brazilian tests and the innovative Inclined Direct Shear Testing Device (IDSTD™). Finally, mechanical Woodford shale parameters were also measured and correlated with field log results, using samples a tiny as drill cuttings (a few millimeters in size) with the newly emerging nano-indentation rock characterization techniques developed in the GeoGenome™ Industry Consortium. This newly developed methodology for rock testing and shale chracterization, part of the nanotechnology wave, showed excellent results when compared with shale acoustic laboratory measurements and log data and results.

Despite a relatively high quartz content as shown by XRD and Elemental Capture Spectroscopy (ECS) log results, the Woodford shale does exhibit clear transversely isotropic mechanical characteristics, from Young's moduli to Poisson's ratios and other mechanical parameters. Moreover, IDSTD™ and Brazilian tensile tests on the preserved Woodford samples exposed to different drilling and hydraulic fracturing fluids showed that fluid effects play an important role on both compressive strength and tensile strength of the shale despite the fact that the Woodford clay content mainly composes of illite and chlorite.

The mechanical and poromechanical properties of Woodford shale were measured at four different scales, from field well logs to standard rock testing to the penny-size samples of IDSTD™ and down to drill cuttings scales using the nano-indentation. Furthermore, the innovative nano-indentation techniques for rock testing have allowed the construction of a GeoGenome™ simulation model which can estimate and determine macroscopic rock properties based on porosity, packing density, and mineralogy. The simulated moduli and parameters using this model showed excellent agreement when compared to both lab and field log results.

Introduction

Woodford shale formation, deposited during the lower Mississippian and upper Devonian period in anaerobic marine environment, is found throughout the central part of US Midwest. The formation has long been known to be one of the major source rocks of the region and is recently emerging as one of the major gas plays with publicly announced rate up to 10 MMCFD and estimated reserve from 2.0 to 3.0 BCF per well.[1] The relatively low permeability of this formation, estimated to be 45 nD by pressure pulse decay method, makes hydraulic fracturing a vital process for the production from the formation. However, strangely enough, the mechanical and poromechanical properties of the formation which are essential for drilling as well as fracturing operations are little known. Moreover, the environment sensitive and reactive shale samples used for mechanical characterization on some previous studies attempting to characterize this shale gas play were collected from a ditch on an outcrop which makes these studies not comprehensive in terms of field and laboratory experimental preserved shale sample quantity and quality.[2]

Standard Testing

In this geomechanics comprehensive study, 200 ft of well-preserved shale were cored from a well in the Woodford formation located at the Northern flank of the Arbuckle uplift (Pontatoc County, Oklahoma). The preserved cores were mechanically characterized through comprehensive standard lab measurements including Ultrasonic Pulse Velocity (UPV), triaxial tests, and tensile split tests (Brazilian tests) which allow obtaining important poromechanical parameters such as Young's modulus, Poisson's ratio, Pore Pressure Coefficient, compressive strength, and tensile strength, in addition to measurements of shale failure parameters such as cohesion and friction angle.