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Modeling geomechanical properties in the montney formation, Alberta, Canada

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ABSTRACT

Recently, unconventional reservoirs have received attention particularly in North America. These reservoirs require hydraulic fracturing to be commercially productive. At this point, it remains unclear as to the influence of geomechanical properties on fracture stimulation and its effective permeability, nature of the fractured zone (whether single extensive fracture or network), and extent of fractured zone. An understanding of the geomechanical properties and their spatial heterogeneity can be used to guide well placement and fracturing job design. In most simulation models, geomechanical properties are assumed to be homogeneous throughout the reservoir. In this study, heterogeneity of geomechanical properties is demonstrated by using geomodeling. A three-dimensional (3D) earth model was built by integrating both petrophysical and geological log data. The model includes dynamic elastic properties and rock strength property distributions in both vertical and horizontal directions within the reservoir and provides an ideal basis to understand hydraulic fracturing and wellbore stability. To determine elastic rock properties, changes in compressional and shear velocity through all the layers of the reservoir rock were taken into consideration. A workflow was developed to constrain well properties to derive realistic rock property values and distributions even in areas where only limited well log information exist. The 3D geomechanical earth model demonstrates that (1) the distribution of rock properties depends on formation lithology and (2) high lateral and vertical resolution can be achieved even in the areas with sparse wellbore information.

1. Introduction

As production from North American conventional hydrocarbon accumulations decline, unconventional low permeability resource development has accelerated due to the ability to hydraulically fracture such reservoirs in a rapid and economic manner. The key challenge faced by these operations is optimal well placement especially in the context of the heterogeneity of the geomechanical properties (e.g. Young's modulus and Poisson's ratio), of the reservoir. At this point, in most fields, there is limited data on geomechanical properties and their spatial distribution.

Passey et al.[1] found that typical parasequences (an upward shoaling package of genetically related beds and bedsets) in a shale gas reservoir resulted in significant variation of petrophysical properties and formation lithology.[1] In addition, organized distribution of platy clay minerals[2] and compliant organic materials [3] can lead to complexity of their mechanical anisotropy. Ahmadov[4] claimed that the maturity of shale and the amount of clay affects mechanical anisotropy. Understanding rock anisotropy and its causes is crucial because it strongly influences the hydraulic fracturing process, well stability, and production.[4]

Here, we report on the mechanical properties of tight siltstone reservoir rocks collected from several wells in the Montney Formation located in Western Alberta, Canada. We present a data set describing the mechanical behavior of Montney rocks, including dynamic elastic properties and their anisotropy within the reservoir. We also discuss these data in the context of three-dimensional (3D) earth models to better understand the spatial distribution of rock geomechanical properties.

1.1. Overview of the montney tight gas reservoir

There are several ways to obtain mechanical properties of underground reservoir rock. One method is from laboratory measurements of core samples. An alternative is to determine mechanical properties indirectly by using sonic well log data, based on the propagation of shear and compressional waves. In general, sound waves propagate through a solid medium in a variety of modes, such as compressional or shear waves or along interfaces as Rayleigh and Stoneley waves.

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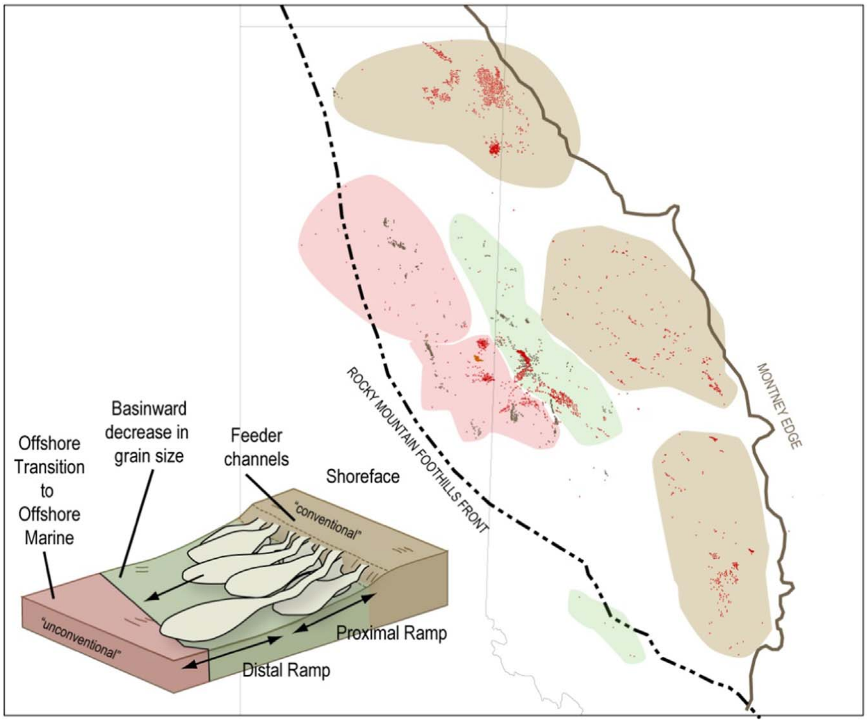

Fig. 1. Montney Formation Gas Production and basin Types in Northwestern Alberta and Northeast British Columbia[9].

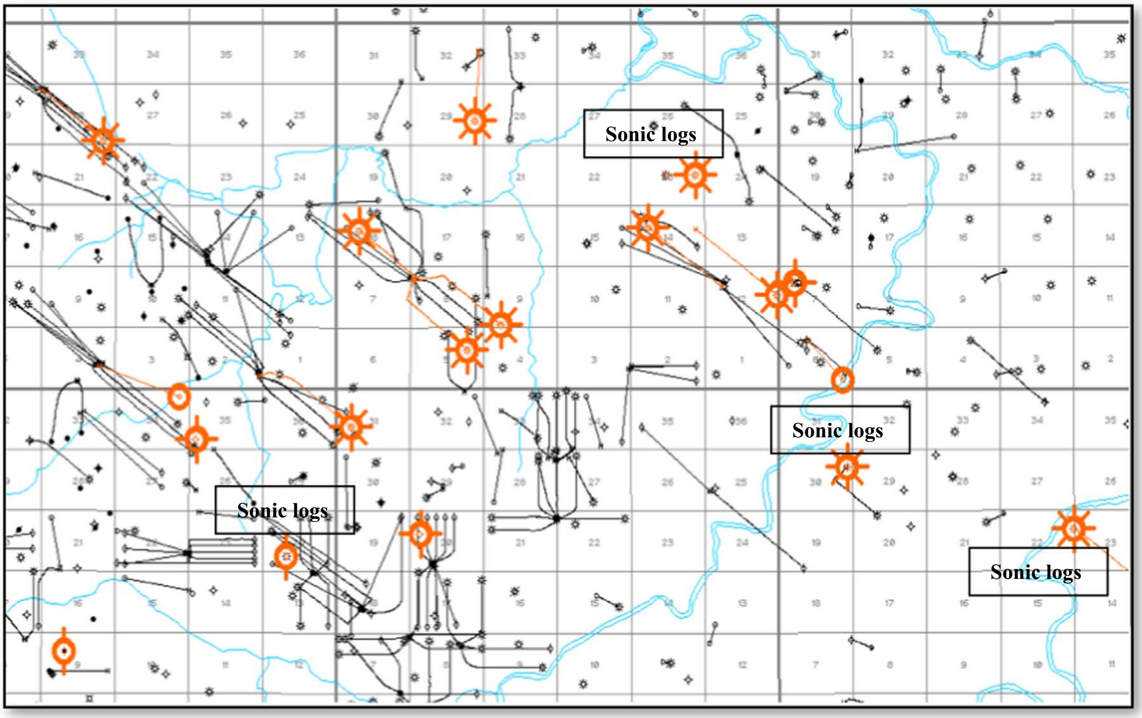

Fig. 2. Wells used in this study. The wells highlighted in red by the radial spokes had *GR* and *RHOB* log data. Wells with sonic log data are also highlighted.

Acoustic wave velocity (the velocity of the sound wave measured across the receiver array is the speed of sound through the formation directly opposite the receivers) can be used to characterize materials. For instance, a compressional sound wave travels through steel at 57 µs/ft (187 µs/m), through zero porosity sandstone at 55.5 µs/ft (182 µs/m) and through zero porosity limestone at 155 µs/ft (155 µs/m). The change in acoustic wave velocity is related to the properties or volume of fluid in the rock pore space which depends on the porosity [5] as well as grain and pore network geometries, wave frequency.

In 1821, shale gas had been produced from a natural penetration in the fractured Devonian shale in the Appalachian Mountains.[6] In the early 1980s several operators started production of gas from the Barnett shale in Texas and by the end of 1990s, production started to ramp up through the use of horizontal drilling combined with multi-stage hydraulic fracturing. In 1997, by using water with chemical additives as a fracturing fluid, productivity was further raised while decreasing well cost.[7] Now, production from new shale gas resources is growing around the world.