Calibrating seismic fracture prediction using borehole image logs, application to the Mississippian Limestone

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Introduction

The Mississippian Limestone reservoir is located in northern Oklahoma and southern Kansas. Drilling activity has increased in the reservoir over the past decade with horizontal drilling and hydraulic fracturing. Hydrocarbon storage cannot be directly attributed to matrix porosity, especially outside of the tripolite chert. Almost all hydrocarbon reservoirs in sedimentary rock contain fractures, with the majority of them sufficiently fractured enough to be considered fractured reservoirs (Nelson, R. A. 2001). Natural fractures in the Mississippian Lime contribute both to hydrocarbon storage and permeability. The goal of my work is to find a 3D seismic “proxy” to predict the presence of natural fractures away from the well bore. I will determine which seismic inversion and attribute products to use by correlating linear and nonlinear combinations of attributes with fracture intensity measured six horizontal borehole image logs that lie within the bounds of a seismic survey. I will start with the simplest method of multiple-variable nonlinear regression. Five of the six borehole images will be used in the generation of the fracture prediction model, in order to quality control the results of the fracture prediction model with the blind borehole image log not used in its generation.

I will then evaluate other methods including neural networks and proximal support vector machines (Zhang et al., 2015). The resulting fracture prediction model can then be utilized as an input for a previously generated geostatistical model using traditional well log and seismic data (Lindsey, 2015). The fracture intensity component could potentially provide an explanation for why production levels in some areas do confirm expectations based solely on matrix porosity. In addition, if fracture aperture and geometry can be predicted through core, borehole image logs, and outcrop; the fracture intensity model can then be used to generate a discrete fracture network model. The workflow for creating a fracture intensity model is not only applicable to the Mississippian Limestone reservoir, but is applicable to any fractured reservoir that has borehole image logs and seismic data available.

Geologic Background

The Mississippian ranges in age from 320 to 360 million years ago (Figure 1). The study area was on the shelf margin of the Anadarko Basin (Figure 2) (Lane and DeKeyser, 1980). Oil sourced from the Woodford shale migrated into the Mississippian Limestone reservoir and was sealed by the overlying impermeable Pennsylvanian shales (Figure 3). During the early Pennsylvanian, the Mississippian carbonates were exposed and eroded. Much of the reserves lie in porous carbonates where porosity truncates against the Mississippian Pennsylvanian unconformity (Figure 4). The Mississippian reservoir is comprised of tripolite chert, porous limestone, cherty limestone, and cherty dolomitic limestone. Matrix porosity typically ranges from 5% to 20%; however, porosity can range from 20% to 30% in the tripolite. Permeability ranges from .001 to about 1 mD (Matson, 2015). The carbonate component of the Mississippian is a naturally fractured, providing hydrocarbon storage.

Hypothesis

• Through the use of surrounding attributes, I will be able to predict the fracture intensity in the blind well
• The suite of surface seismic attributes used to predict the fracture intensity in the blind well can be used as fracture intensity proxy in undrilled portions of the survey
• A combination of porosity and fracture intensity will better correlate to well production than porosity by itself
• The strike of structural deformation measured by curvature and coherence and azimuthal anisotropy will be correlated to the orientation of natural fractures seen in image logs
• Simple linear correlation techniques will fail; rather I will need to introduce concepts of thresholds (e.g. minimum levels of deformation orbrittleness) to correlate attributes to fractures in the wells.
• The additional input of fracture intensity into a previously constructed geostatistical model in the same location will give better insight into the reservoir.

References:


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