GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

Resolving time dependant stress variations through analysis of microseismicity (M < 0) recorded during hydraulic fracture stimulations

Adam M. Baig[1], Ted Urbancic[1], Eric von Lunen[2]
[1]ESG Canada Inc. [2]NexenCnooc Ltd.

Summary

Hydraulic fracturing of shale reservoirs enhances productivity of reservoirs by propping open fractures in the reservoir. In order to map the extent of the successfully stimulated zones, microseismic monitoring is increasingly used; typical outputs of such monitoring efforts are the geometry of the microseismic event distribution. To relate these event distributions to production decline curves, geomechanical modelling of the injection using these event distributions as a constraint is frequently performed. However, a basic assumtion of such efforts is that the stress regime under which the events are occuring is invariant.

By using multiple-well recordings of microseismic events, the mechanisms of the microseismicity may be determined. These mechanisms are proportional to the strain rate (deformation) that is imparted to the medium at the point of rupture, and as such constrain the stress regime through the treatment. Observations indicate that the stress/strain conditions in the reservoir can be highly variable, implying that microseismicity needs to be coupled to geomechanical models at a more basic level, in that the dynamic stress regime controls both the occurance of these events an the propagation of fluid and proppant in the reservoir.

Introduction

Hydraulic fracturing is a process that involves the injection of fluids above lithostatic pressures to increase permeability of rocks at depth. In the oil and gas industry, the formations that are targeted are typically shale or tight sandstone units. The fracturing process leaves a seismic expression that is responding to a combination of either Coulombic stress transfer on favourably oriented fractures or fluid-induced tensile mechanisms. Both of these end members impose certain constraints on the stress regime, and in general imply that the stress regime during the fracturing process involves significant alteration of the background stresses.

A detailed analysis of microseismic waveforms induced from hydraulic fracturing provides the keys to resolving the dynamics of *in situ* reservoir stresses. Seismic moment tensor inversion (SMTI), for example, on data recorded from numerous azimuths on wellbore-deployed arrays, yields mechanisms that can be used to construct point measures of strain through the stimulations. Furthermore, mechanisms tend to resolve into mixed-mode, shear-tensile mechanisms occurring on fracture planes. The problem of resolving the fracture planes from the mechanisms (each individual mechanism equally admits two solutions for the fracture plane) has been investigated by many authors, and involves determining event clusters and resolving the best-fitting stress orientation (together with stress ratio) on those clusters.

In this study, we examine the behaviour of mechanisms temporally though a number of stages. Previous efforts have focussed on describing the dynamics of mechanisms as the event distributions progress into the reservoir, defining breakout events leading the event cluster that precondition the rock for fluid mobilization later through the stimulation.   Here, we discuss the clustering of the events to define the rotations in stress necessary to activate the different fracture sets to progress the damaged zone further into the reservoir.

Example

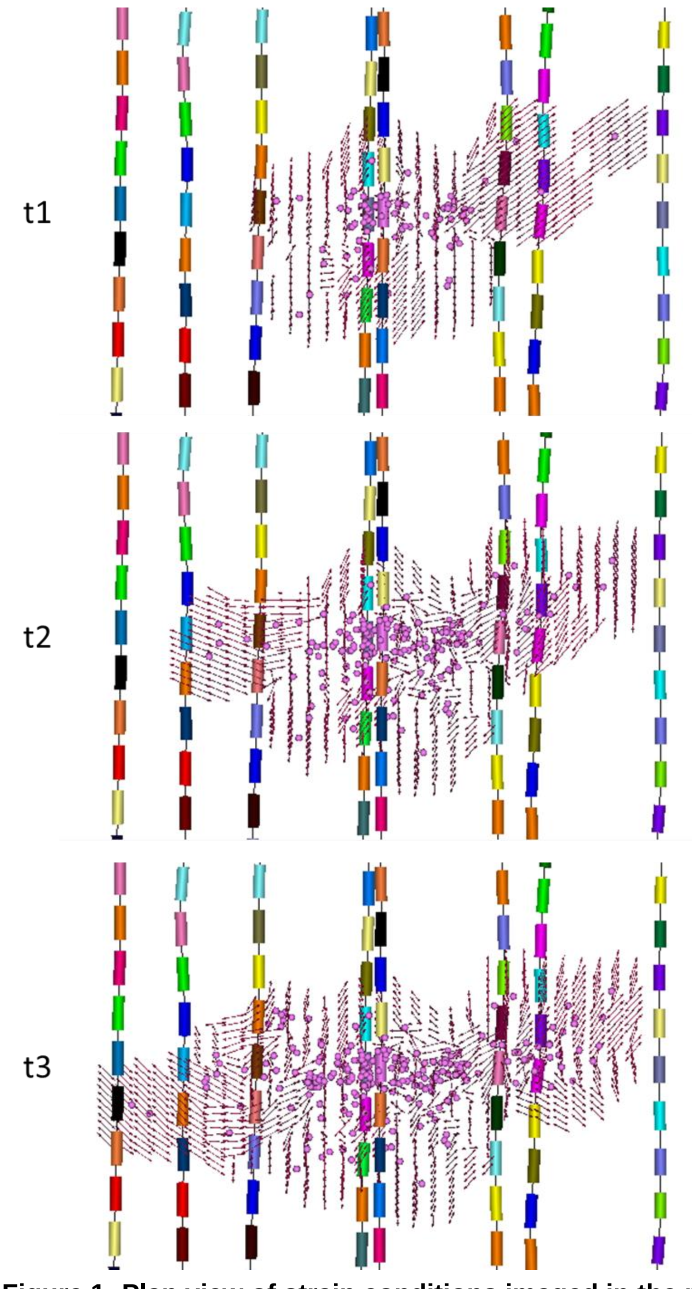

Figure 1: Plan view of strain conditions imaged in the reservoir through deformation state analysis (tensional axis) of microseismic moment tensors during one stage of a multiple-well, zipper-frac pad completion.   The spatial and temporal variability over the three time (t1, t2, t3) steps through the progression of the stage of the strain field implies that the stress regime is highly dynamic though the treatment. In each image, the tensional axis of strain is images as a normalized, two-headed vector, such that vertical axes of strain appear short in plan view, while the horizontal tensional axes appear as long vectors.

In figure 1, we show the temporal progression of the strain field through a stage of a hydraulic fracture zipper-frac completion of a pad in the Horn River Basin in Northeast British Columbia. The variations in the strain field imply a very dynamic stress field is controlling the progression of the fractures and, by extension, the fluids and proppant into the reservoir. We will illustrate this dynamic stress field though the reservoir through clustering events together to solve for the stress orientations in the reservoir.