# MICROSEISMICITY INDUCED BY HYDRAULIC FRACTURING IN SHALES: GEOMECHANICAL MODEL

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## Introduction

We discuss a new interpretation of microseismicity induced by hydraulic fracturing in shale reservoirs. The new geomechanical model explains both source mechanisms and locations of induced events from two stimulated reservoirs – one monitored with a dense surface array and one with two vertical arrays in two boreholes. In both cases we observe shear dip-slip source mechanisms with one vertical and one horizontal plane aligned with location trends. We show that such seismicity can be explained as a shearing along bedding planes caused by aseismic opening of vertical hydraulic fractures.

## Results

We detected and located approximately 300 events with surface array and 100 with borehole arrays. For source mechanism inversion we selected only high quality events with sufficient signal to noise ratio. We inverted P-wave amplitudes to full moment tensor and decomposed it to shear, volumetric and CLVD components. In borehole dataset we inverted general source mechanisms for stronger events and deviatoric source mechanisms for weaker events. We also tested an effect of a presence of noise in the data to evaluate reliability of non-shear components. Consistent picking was applied to obtain the most accurate relative locations in the downhole dataset. Finally, stress field was inverted from source mechanisms.

Observed seismicity from both surface and downhole monitoring of shale stimulations in two very different shale reservoirs is very similar and show consistency with other microseismic monitoring around the world. Locations of induced microseismic events are limited to narrow depth intervals and propagate along distinct trend(s) from injection well(s). These trends are along direction of maximum horizontal stress, i.e. consistent with a direction of fracture propagation. All the source mechanisms are characterized by a small non-shear component which can be explained by noise in the data and/or velocity model uncertainties in the inversion process, i.e. event can be explained as pure shearing on faults without volumetric change. We observe predominantly dip-slip type of events with strike of steeper (almost vertical) plane oriented in direction of fracture propagation. The second possible fault plane is perpendicular, i.e. in horizontal direction. Moreover, there are two groups of dip-slips with opposite polarity. The opposite polarity means we observe opposite movements on neighboring faults.

## Conclusions

In both cases the regional stress field has the maximum regional stress in vertical direction, the maximum horizontal stress parallel to fracture propagation and the minimum horizontal stress perpendicular to the fracture propagation resulting in no regional shear stress on both observed fault planes. Realizing a typical structural weakness of shale in horizontal planes we interpret observed microseismicity as result of a shearing along bedding planes during seismically silent vertical fracture opening.