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Proposal of Characterization of Hydraulic Fractures and their Correlation to 3D Seismic Data in the Granite Wash

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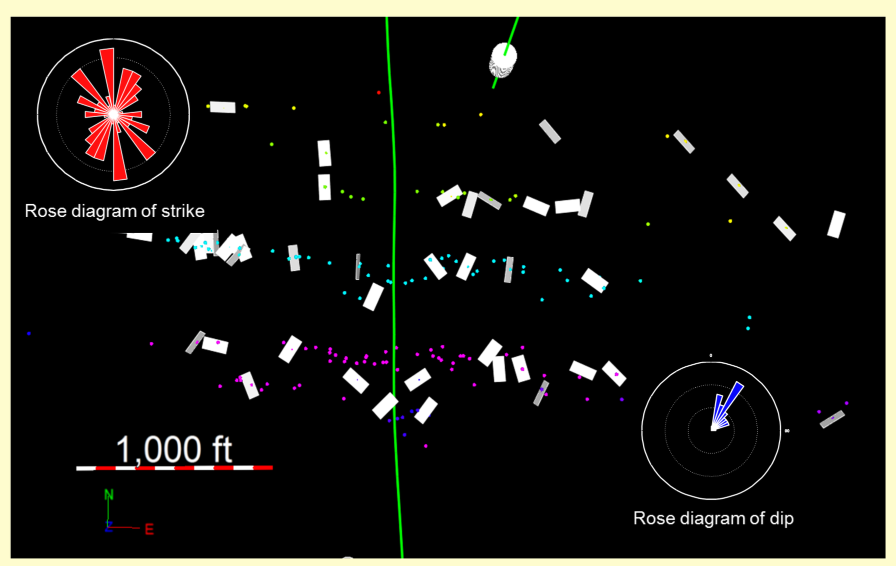
Introduction

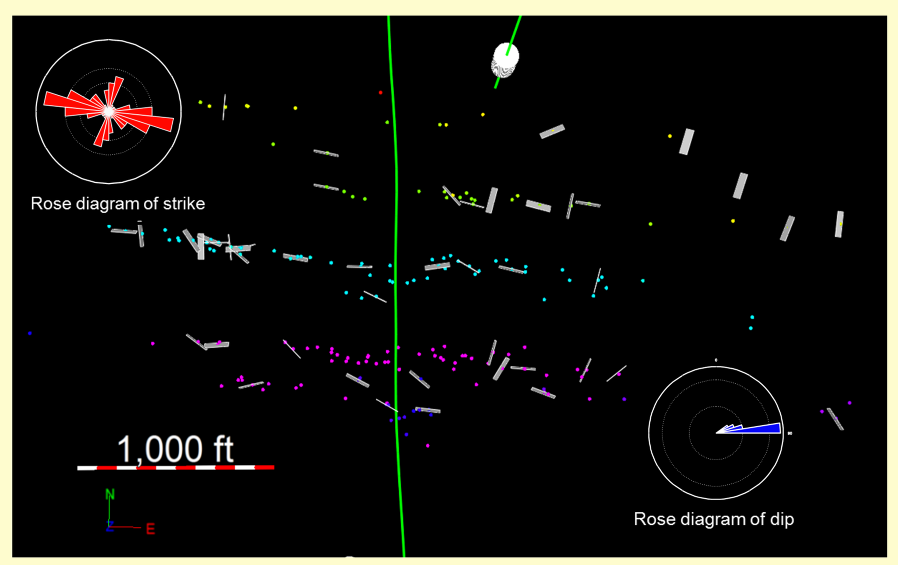
Hydraulic fracturing has been used in oil and gas exploration since the 1940's, but more recently has become the standard in extracting hydrocarbons in low permeability plays. Since then induced fracture characterization has become vital for understanding production efficiency and well planning. This study will build upon previous research conducted on understanding hydraulic fracture growth in the Granite Wash formation of the Anadarko Basin, Texas Panhandle (Long 2014). The geologic complexity of the basin makes the characterization of fracture growth an essential component in planning horizontal and vertical well spacing.

This study will use P and S-wave arrivals, as well as, first motion direction to calculate fault plane solutions(FPS) for a series of microseismic events. Previous research supports the presence of dip-slip and strike-slip faults in the study area; in this case a larger number of events and the addition of S-wave and amplitude data will be used to further support these results. These different types of faults will be grouped and isolated by location. With the use of a 3D seismic volume, seismic attributes will be used to correlate the different fault types to local structural and stratigraphic features.

Previous Results

Results from previous research (Long 2014), supported the presence of two distinct FPS groups in the Granite Wash, slip-strike and dip-slip events. Each of the two groups, respectively, appeared to be clustered at discrete locations. The fault plane solutions in this study were acquired solely through the use of P-wave first motions.





Left: Shallower Nodal Planes

Right: Steeper Dipping Nodal Planes

Workflow

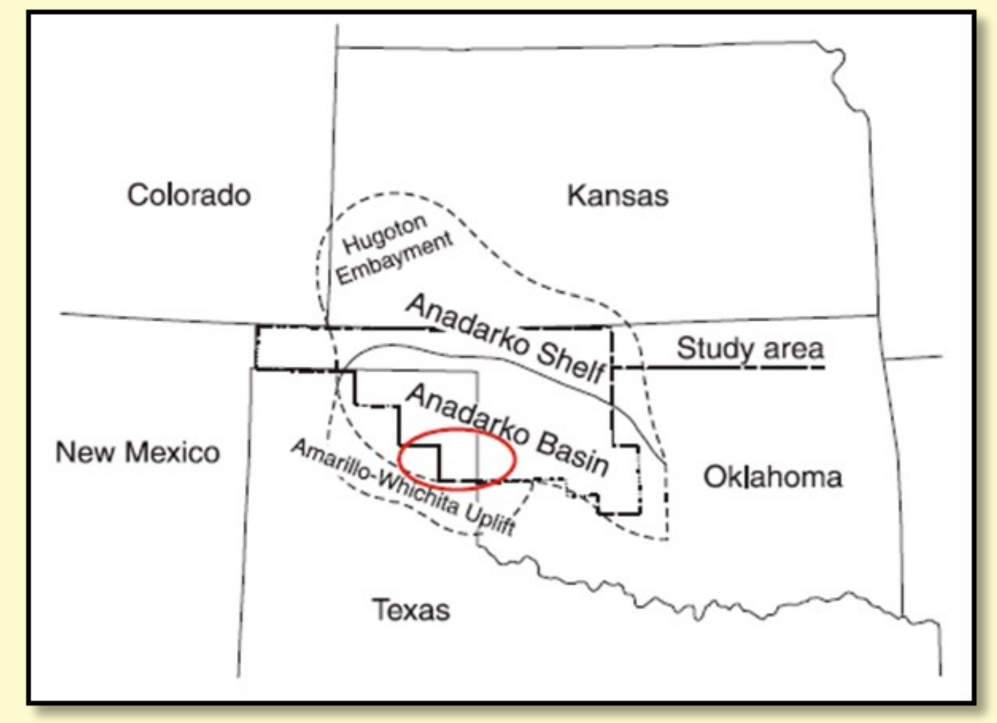
1) Computationally obtain amplitude and first motion data from P-waves and S-waves from 189 microseismic events.
1) Obtain fault plane solutions using amplitude and first motion data.
2) Statistically analyze fault plane solution results.
3) Categorize and locate distinct FPS groups within the data set.
4) Correlate event groups with local geologic structure and stratigraphy through the use of seismic attributes in the 3D volume.

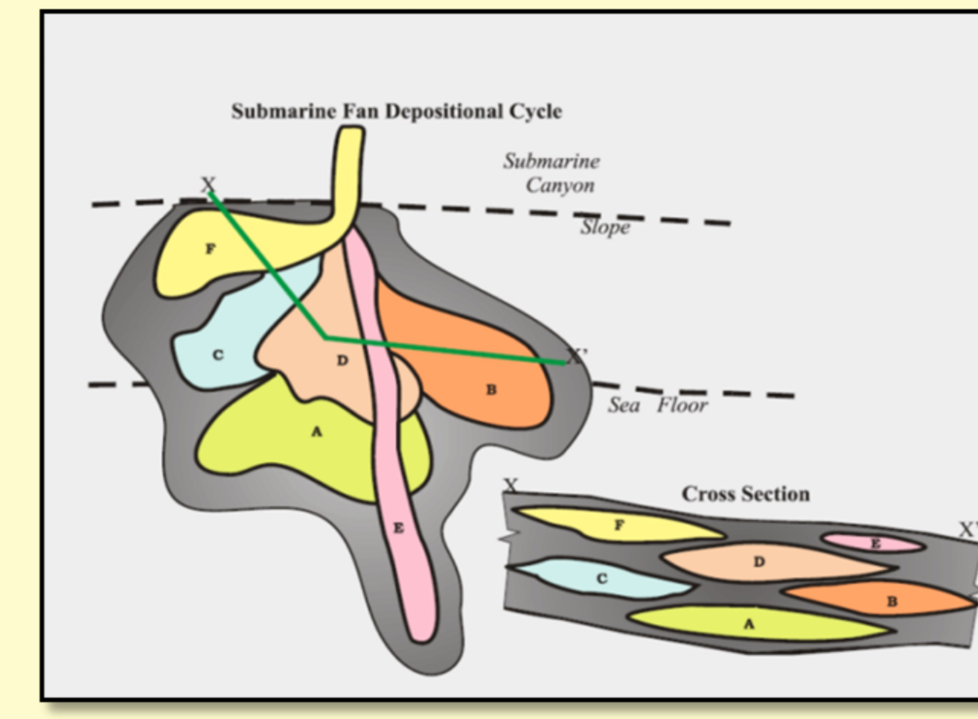
Geology of the Granite Wash

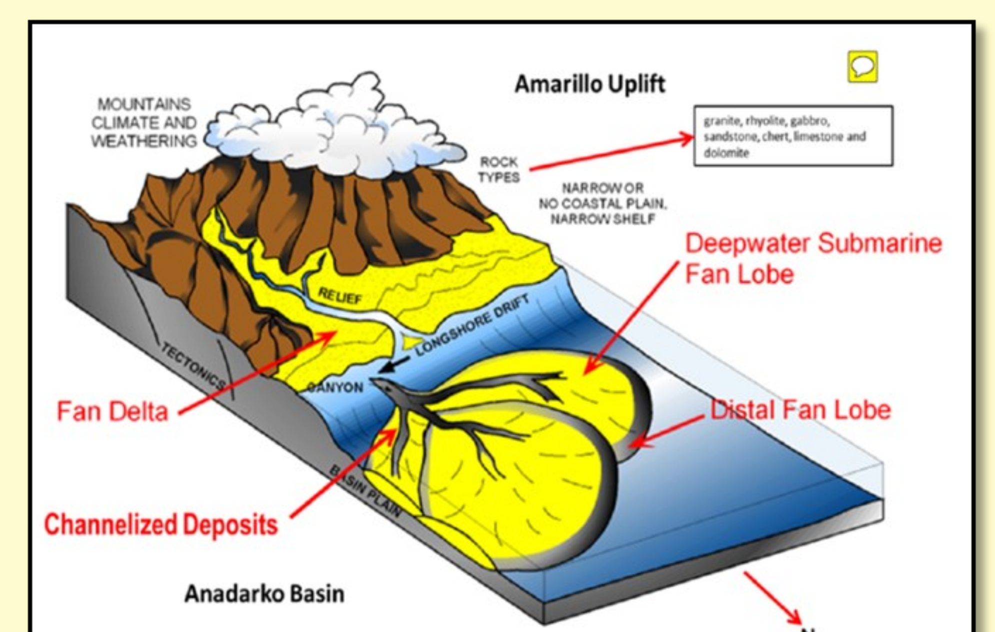
During the Pennsylvanian period, tectonic activity in southwestern Oklahoma caused the Wichita uplift. Sediments of various lithologies were eroded and deposited in the Amarillo Basin to the northeast. The deposition of these sediments occurred as a series of alluvial fans, turbidite and debris flows and fan deltas. The nature of the deposition of these sediments led to a high level of geologic complexity in the Granite Wash, characterized by layers of variable thickness and lateral continuity.

The origin of the name "Granite Wash" is due to eroded granite being the primary sediment in the basin, but also refers to the entire spectrum of lithologies found in the formation including boulder-sized conglomerates, arkose sandstones, carbonates, and shales.

The diagenesis of sandstones in the basin caused the formation of authegenic minerals such as calcite, kaolinite, feldspars, quartz, and chlorite which are the main cause of the low porosity and permeability found in many parts of the Granite Wash (Dutton, 1984). Therefore hydraulic fracturing has greatly increased the hydrocarbon production of the formation and thus its popularity as a resource play in recent years.







Upper Left: map view of the study area. Red circle shows where the Granite Wash is located in relation to the Anadarko Basin. Ingram 2006.

Upper Right: Map view and plan view of a depositional model of geometry of different lithologies within the formation. Crawford 2013.

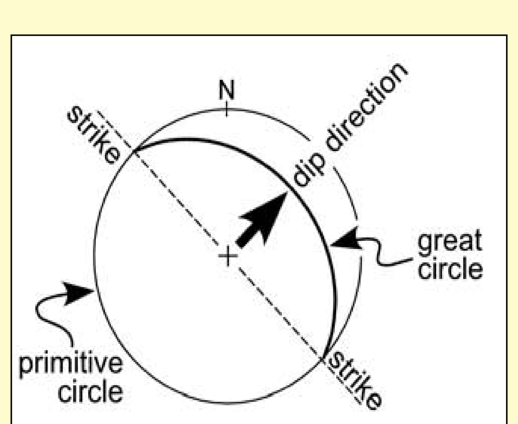
Lower Left: Depiction of the depositional processes that created the Granite Wash. Crawford 2013.

Fault Plane Solutions Overview

P-wave and S-wave first motions and amplitudes recorded by seismograms can provide useful information in identifying the nature of slip of a fault plane. When waves leave the focus of a fault or fracture, the wave will leave as compression on one side of the fault plane and leave as compression in the opposite direction on the other side of the fault plane. After the first motion is recorded as up or down at a variety of geophone locations, the fault plane strike and dip can be determined. Amplitudes of the events will be analyzed using the radiation patterns of the P and S-waves. The inclusion of amplitude data will serve to further constrain the calculated fault plane solutions. There are always two possible fault plane solutions called *nodal planes.*

A focal mechanism solution, or "beach ball diagram" is a graphical representation of the fault plane based on wave first motions and amplitudes. The diagrams consists of a stereographic projection consisting of two white quadrants and two black quadrants, black representing compression and white representing dilation. The circle arcs represent the two nodal planes.

A)



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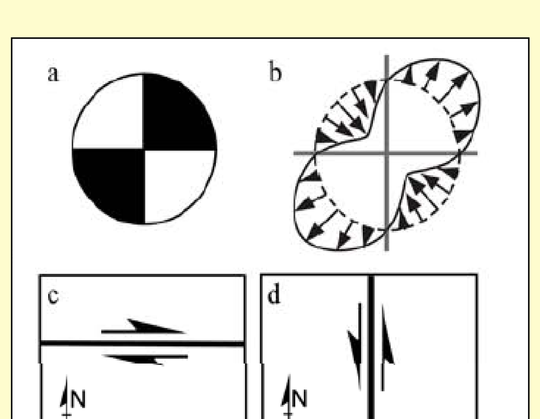

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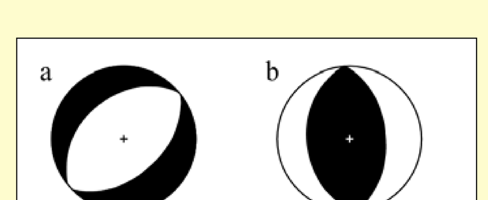

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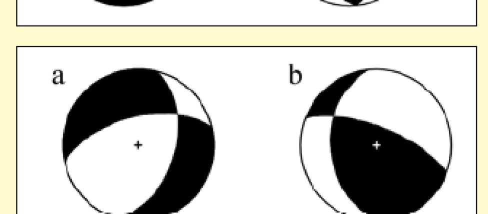

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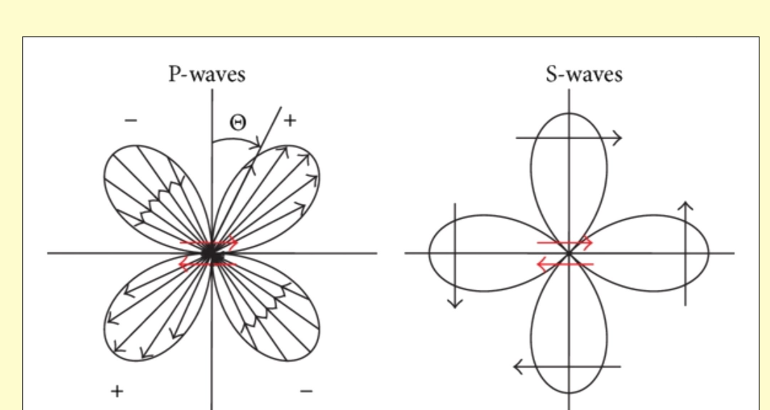
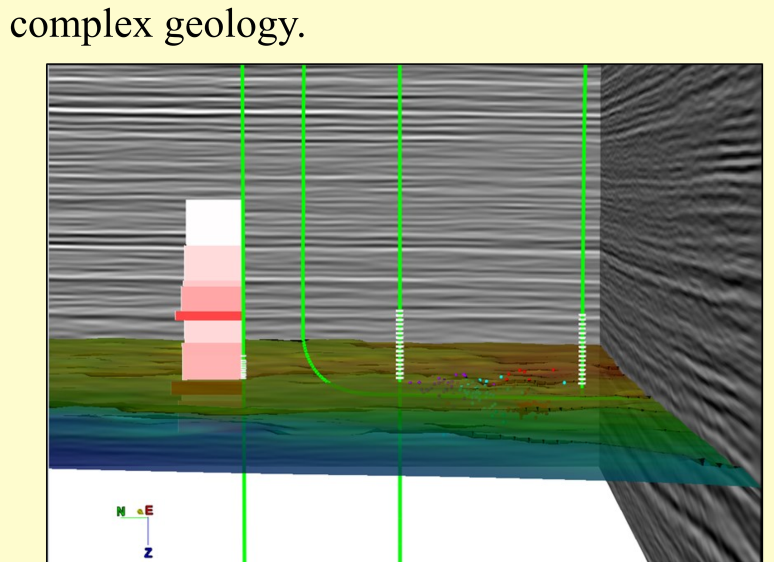


A) depiction of how fault plane geometry is determined from a focal mechanism solution (Cronin 2010)
B) depiction of how a strike-slip fault plane would look like on an FMS. Arrows show compression/dilatation, and the two nodal planes (Cronin 2010)
C) examples of both a) normal fault and b) reverse fault FMS's (Cronin 2010)
D) examples of both a) oblique normal and b) oblique reverse fault FMS's (Cronin 2010)
E) Diagrams of radiation patterns of the radial displacement component of P-waves (left) and of the transverse displacement component of S-waves (right) (Aki and Richards 2002)

Research Goals

The ultimate goal of this research is to characterize hydraulic fractures in the Granite Wash and to correlate them to structural and stratigraphic geology. Further knowledge of the behavior fractures in a given geologic setting will be beneficial in future well planning in the area and may also prove valuable in other, similar, areas of complex geology.



View of Cherokee Horizon, well locations and previous event locations in 3D seismic volume. (Long 2014)

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