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Microseismic Event Location: Optimization Using Azimuth Differences

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1. Summary:

Microseismic events are useful in understanding how horizontal wells are completed, and how much rock volume is stimulated during hydraulic fracturing. Correctly understanding the events' locations will explain how the induced fractures behave in the medium. Traditionally, a microseismic epicenter is located by finding the azimuth from P-wave hodograms, using the difference in arrival times to find the distance, and triangulating from a number of monitor wells. However, the estimations and corrections in this process can create a significant range of error. I propose a method where the difference in azimuth predictions between two microseismic events, recorded at a minimum of three monitor wells, is minimized. My goal is to improve the accuracy of X, Y locations for events in the Granite Wash dataset provided by Devon Energy.

2. Geologic Background & Data:

The Granite Wash was created by the Amarillo and Wichita uplift during the Late Mississippian-Early Pennsylvanian from intense northeast-southwest regional compression. Most of these sediments were deposited in an alluvial fan environment where the sorting and clast size are directly related to proximity of the fan. Many subunits contain hydrocarbons and can be stacked pay zones that are often separated by marine shales or carbonate layers.

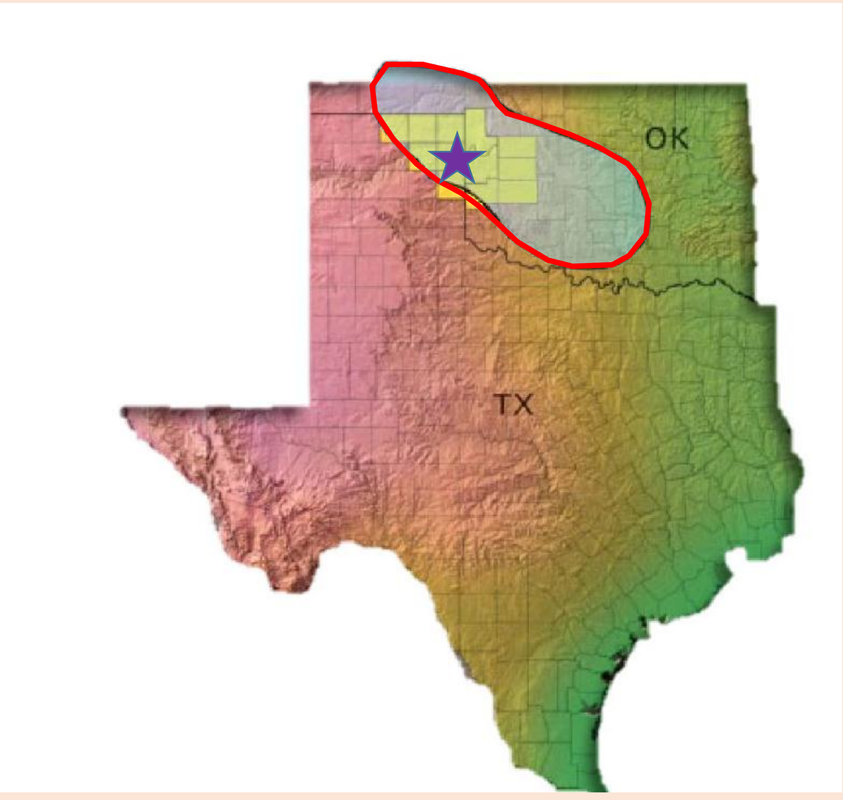


Figure 1: *Map of Anadarko area (red outline) and the study area (purple star). (after LoCricchio, 2012).*

The microseismic data were collected during the hydraulic fracturing of a horizontal well located near Allison, TX, in Wheeler County in 2011. The horizontal well targeted the Cherokee Formation at a depth of approximately 12,500 ft. Three monitor wells provided the data used in this study; each well contained 16 tri-axial geophones; two of the arrays spanned a vertical distance of 740ft, with the third array having a vertical distance of 250ft (Stark, 2015).

3. Methods:

I plan to develop a new method where an accurate horizontal location can be determined without the knowledge of the geophones' orientation, perf shot location, or velocity model. This will be accomplished by creating a search algorithm based on a neural network method; gradient descent, simulated annealing, and evolutionary algorithms are potential methods to use on the project. All of my models will assume an isotropic and homogenous medium, although it could be extended to anisotropic heterogeneous media. A simple synthetic model will be created in MatLab where I will minimize the objective function:

$$f(x_1, y_1, x_2, y_2) = \sqrt{\sum_{i=1}^{3} \mathrm{ATAN2}[\sin(\theta_i^m - \theta_i^c), \cos(\theta_i^m - \theta_i^c)]^2}$$

$$\theta_i^c = atan2(\sin\big(atan2(y_1 - y_i^w, x_1 - x_i^w)\big), \cos(atan2(y_2 - y_i^w, x_2 - x_i^w)))$$

where

- x_1, y_1, x_2, y_2 = event's location,
- $y_1 - y_i^w, x_1 - x_i^w$ = monitor well,
- θ_i^m = measured from hodogram, and
- ATAN2 = accounts for signs components

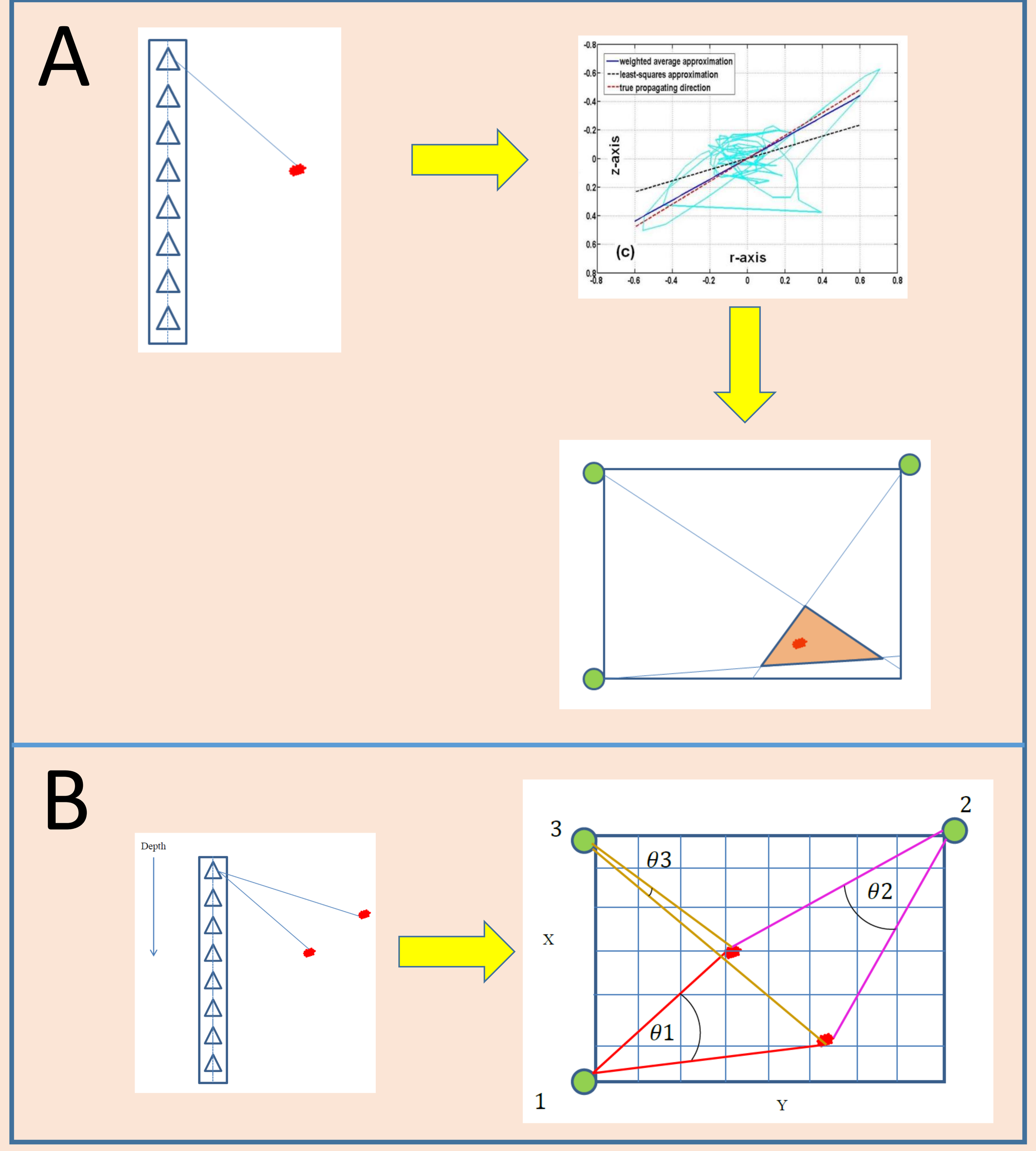
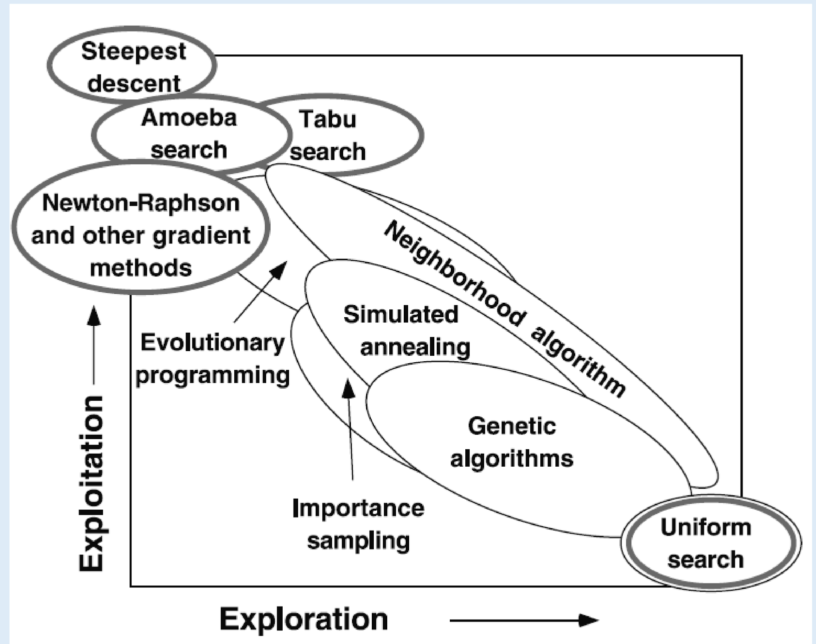


Figure 2: *A) Traditional approach to locating microseismic events, B) the location approach by minimizing the difference in azimuth between events.*

4. Next Steps:



Compute candidate solutions of each event pair in the data set and pick the solution that has the smallest error bars. As an example assume we wish to locate and compute the distribution of event pairs (1,2), (1,3), (1,4), …, (1,*n*).

Other goals:

- Move to simultaneous optimization of 3 or more events
- Use these solutions to orient receivers for events that are only seen on 1 or 2 arrays
- Understand how this analysis can be used to add value to single well jobs

Sambridge, M., Mosegaard, K., 2002, Monte Carlo methods in geophysical inverse problems: Reviews of Geophysics, **40**, 1-25.
LoCricchio, E., 2012, Granite Wash play overview, Anadarko Basin: stratigraphic framework and controls on Pennsylvanian Granite Wash production, Anadarko Basin, Texas and Oklahoma: Presented at the 2012 Annual Convention, AAPG.
Stark, I., 2015, Characterizing focal mechanisms of microseismic events induced by hydraulic fracturing in the Granite Wash: M.S. thesis, University of Oklahoma.

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