Department of Geosciences
M.S. Thesis Proposal

TITLE: Mapping structural and stratigraphic features using azimuthally dependent seismic attributes.
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Abstract

Natural fractures and faults in the subsurface have an important role in fluid flow and accumulation. Therefore, identifying and mapping fracture and fault systems is important to gain insight in to their geological significance and hydrodynamic control. Conventional processing of seismic data obliterates the azimuthal variations of moveout and amplitude. Nevertheless conventional 3-D surface seismic data acquisition and processing can be utilized in imaging fractures/faults better, by first sorting the data gathered into common azimuth bins, based on the angle between sources and receivers. I will study the effects of azimuthal variations of seismic attributes such as amplitude, time, coherence, dip/reflector azimuth and then analyze and correlate them to fracture/fault orientation and distribution.

Project: Approved as Proposed Approved as Modified Disapproved
Modifications: ____

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(Committee chairman) ________________________

(Department chairman)________________________

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Mapping structural and stratigraphic features using azimuthally dependent seismic attributes.

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Mapping structural and stratigraphic features using azimuthally dependent seismic attributes

Motivation

Is it possible to image and understand faults/fractures better, by seismic attribute analysis on azimuth bins?

Introduction

Natural fractures and faults in the subsurface have an important role in fluid flow and accumulation. Therefore, identifying and mapping fracture and fault systems is important to gain insight in to their geological significance and hydrodynamic control.

Aligned vertical faults and fractures cause azimuthal variations of moveout and amplitude (Chopra et al, 2000). Unfortunately conventional processing of seismic data obliterates the azimuthal variations of moveout and amplitude. Consequently, to better understand the fractured and faulted subsurface, variations in seismic properties of the subsurface along different azimuths need to be brought out. This piece of research aims to address it.

Alford(1986) showed how multicomponent seismic data can be used to estimate fracture density and orientation. Tsvankin et. al., have shown how conventional wide azimuth PP data can also be analyzed for moveout associated with VTI media.

Chopra et. al., and others imply that we can also use azimuthal variation of amplitude and coherence to map fracture density and orientation. Therefore, the normal method of 3-D surface seismic data acquisition can be utilized in imaging them better, by sorting the data gathered in to azimuth bins (Figure1) based on common angle between sources and receivers and analyzing for variation in seismic attributes in those bins.

Methodology

The proposed research entails, the workflow illustrated in Figure 2. This is envisioned in three phases. In the first phase, I will separate the data into common offset/azimuth bins. The data processed would include synthetically generated simple fracture and fault model and actual field data with known set of faulting and/or fractures. This is followed by a velocity model generation for each of the azimuth bins using conventional velocity spectra analysis and normal moveout corrections on them.

In the second phase I will perform a least squares prestack time migration on the azimuth bins. Prestack time migration using each azimuth volume's internally corrected velocities collapses diffraction hyperbolae, moves energy to it's actual location in space and removes the dip-dependence in the velocity field (Lynn, et al., 1996). To minimize the acquisition related noise, which is always manifested in 3-D surveys, but particularly in the lower fold shallow section, I will help Dr. Marfurt in developing and calibrating least squares prestack time migration. This will suppress migration artifacts (i.e., footprint noise) associated with incomplete data, irregular recording gaps, edges of the survey and so forth. Least squares migration can improve the lateral resolution of the subsurface images considerably (Nemeth et. al, 1999).

In the last phase I will evaluate modern seismic attributes analysis as a function of azimuth and offset as a means of fracture delineation. Coherence is a measure of similarity of traces. The amplitude time slices are useful in imaging faults that run perpendicular to strike, but when faults run parallel to strike, the fault lineaments become superimposed on bedding lineaments and therefore, become difficult to image (Bahorich et al, 1995). Coherence can detect faults (Figure 3), as the fault related events such as differential compaction, erosion of an up thrown block, greater formation thickness in a down thrown growth fault block, finite thickness fault zones versus a highly localized fault plane or surfaces etc may give rise to low seismic coherence (Marfurt et al., 1998).

Seismic coherence is also measure of lateral changes in the seismic response caused by variations in stratigraphy, lithology, porosity and the presence of hydrocarbons, besides structure (Figure 4)(Marfurt et al., 1998). Therefore, I would study the effects of azimuthal variations of seismic attributes such as amplitude, time, coherence and dip/azimuth to analyze and correlate them to fracture/fault orientation and distribution. This would involve an integrated structural, stratigraphic interpretation with multiattribute analysis.

Novelty of the study

Previous research, with the exception of the work done by Chopra et al and azimuthal velocity analysis by Tsvankin et al, little has been published . But this thesis attempts to get further along the road by combining many such techniques to reconcile azimuthal variations in seismic attributes due to fracture and fault systems to their orientation and distribution.

Conclusions

The proposed work tries to address effective imaging of the complex carbonate geology encountered in the fields, such as found in west Texas. Such areas include structural features such as major fault and fracture systems, minor faults, subtle stratigraphic changes etc. The aim is to effectively image fractures/faults by separating the seismic data cube into sub volumes of azimuth bins and utilize these for seismic attribute analysis. Coherence and coherence derived dip/azimuth as seismic attributes are effective tools in structural and stratigraphic interpretation.

To achieve the goal of the project, I would implement the workflow. The developed algorithms would be calibrated on actual 3-D data set in addition to the calibration on Golden's physical model.

The thesis aims to develop a methodology for mapping and interpretation to reconcile azimuthal variations in seismic attributes due to fracture and fault systems to their orientation and distribution

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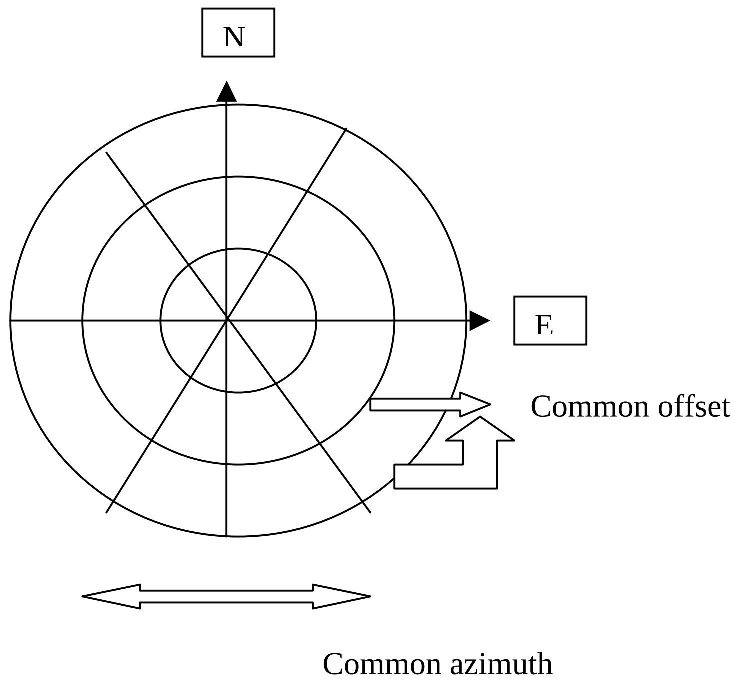


Fig 1. Representation of azimuth bin distribution in to four quadrants based on common offsets and azimuths.

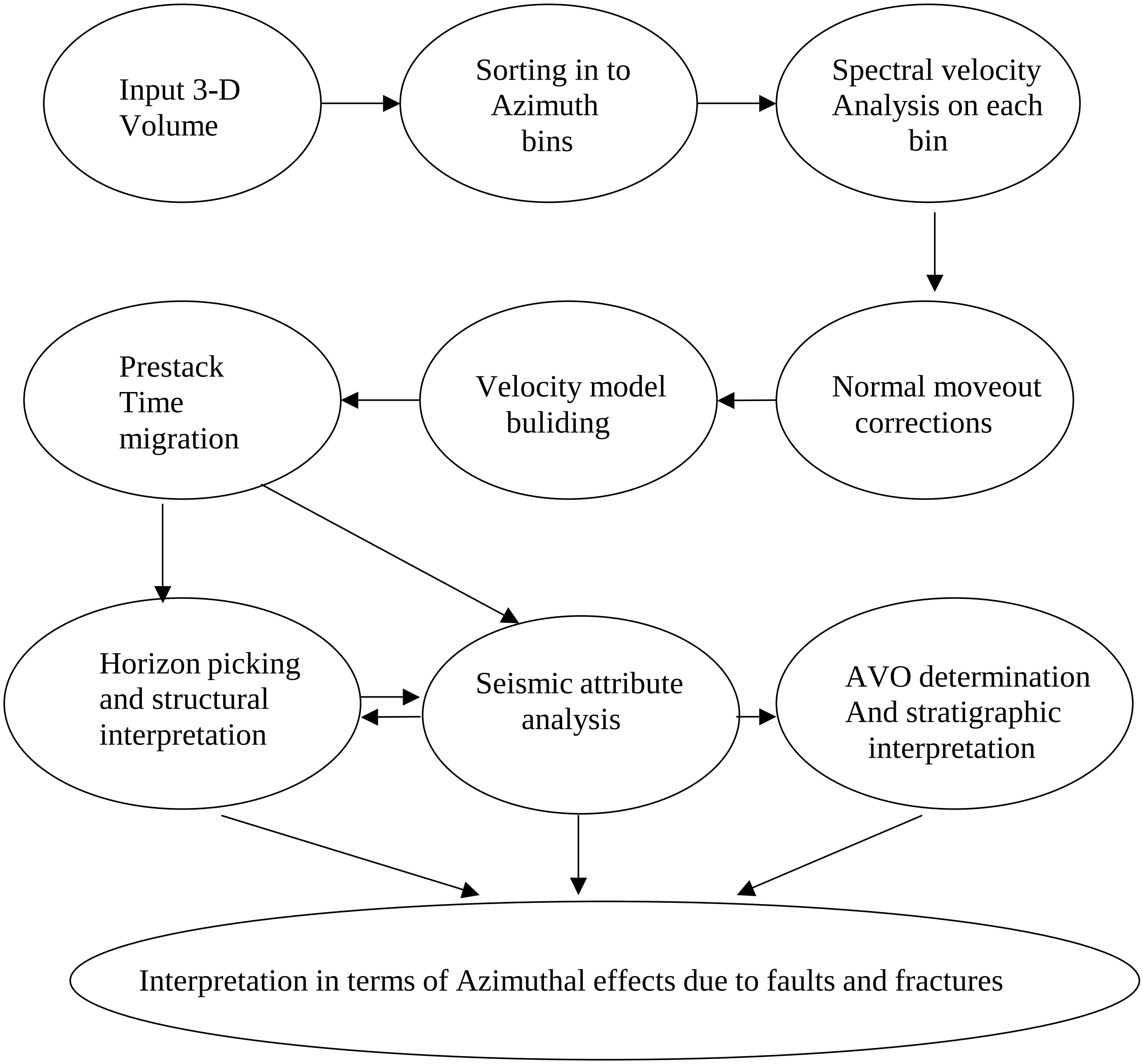
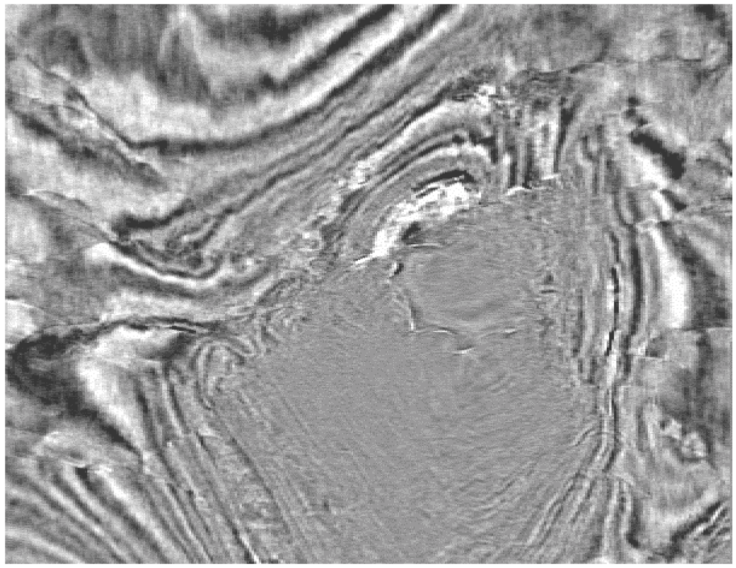
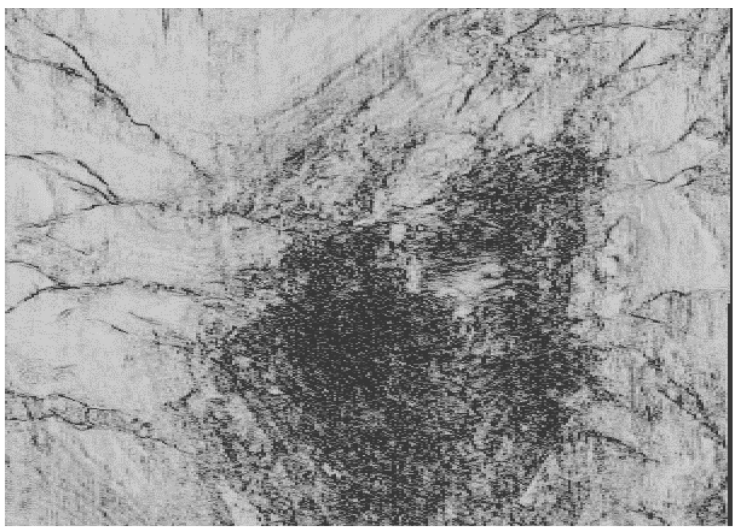


Fig. 2. Workflow illustrating the proposed methodology.



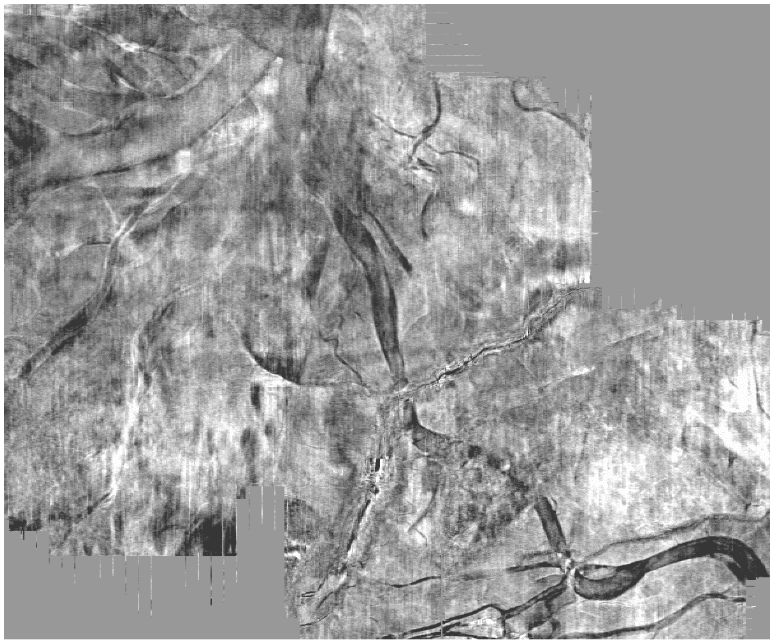
a)

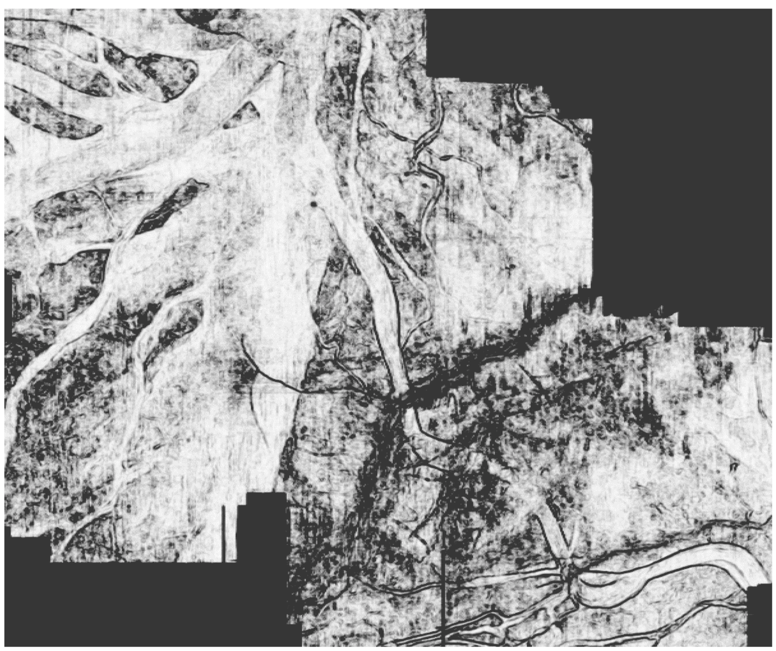


b)

Fig.3. Time slice trough a seismic data volume at a) t= 1200ms and b) coherence at t=1200ms . Data courtesy of Geco-Prakla.(Marfurt et al.,1998).

a)





b)

Fig.4. a**)** Seismic data exacted along an interpreted Pleistocene horizon showing the Plaeo-Missippi distributary Channels. Data courtesy of Geco-Prakla. b) Sensitivity of coherency images of stratigraphic features corresponding to seismic data in a) to vertical integration window, w. Analysis window a=b= 30m. (Marfurt et al., 1998).