USC University of Southern California

The investigation of an integrative approach for fracture density inversion using AzAVO analysis

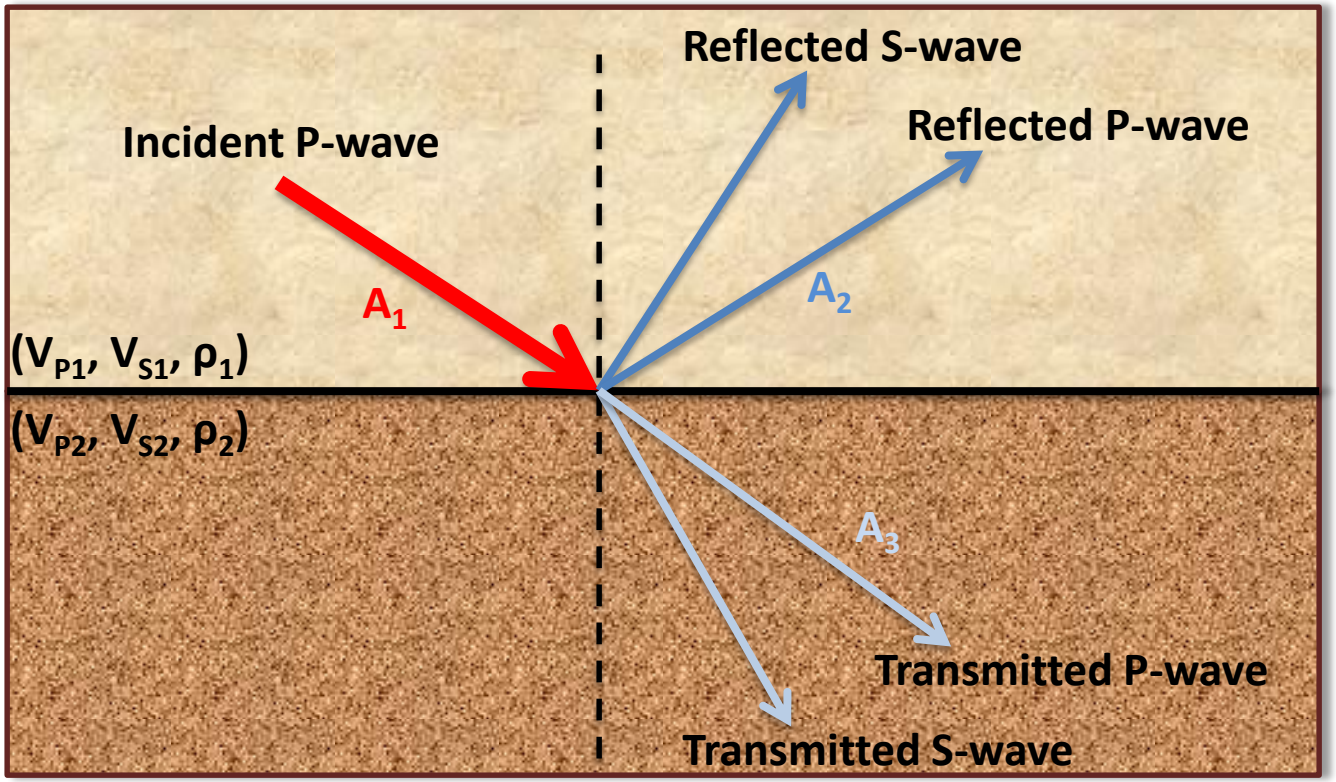
Mahshad Samnejad, and Fred Aminzadeh, University of Southern California

Yong An, Visiting Scholar at USC (from Chinese University of Petroleum)

Outline

1. Introduction
2. Fracture Density Inversion Workflow
3. Rock Physics Model
4. Model AzAVO Response
5. Inverting for Fracture Density
6. Inversion Results
7. Conclusions

Introduction

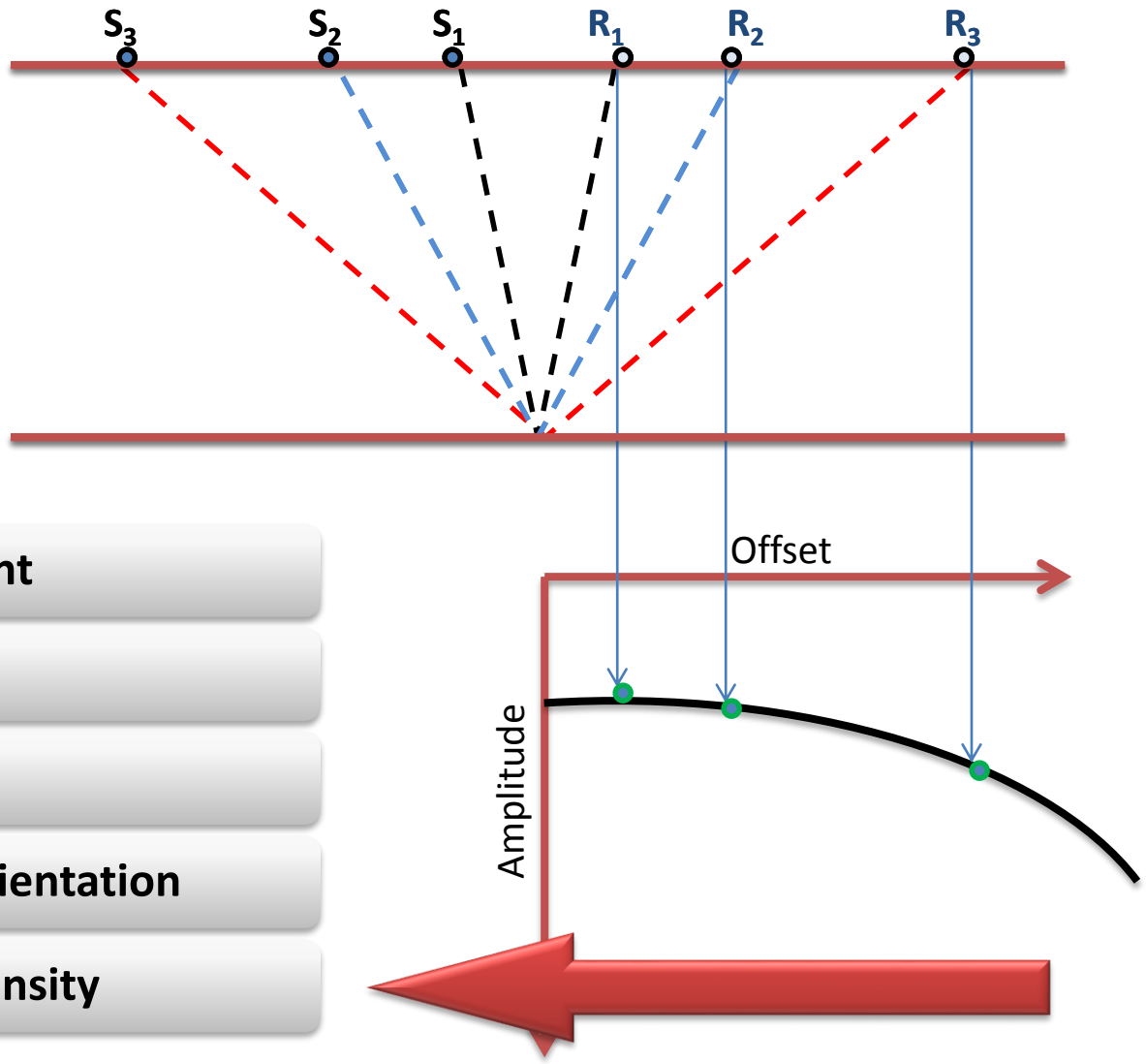


Reflection Coefficient: $R = \frac{A_2}{A_1}$ $T = \frac{A_3}{A_1}$ **(A: Amplitude)**

$$R_{PP}(\theta, V_P, V_S, \rho)$$

Zoeppritz, 1919

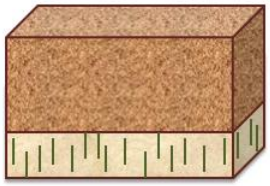
AVO
Amplitude Versus Offset



- Fluid content
- Porosity
- Density
- Fracture Orientation
- Fracture Density

Workflow

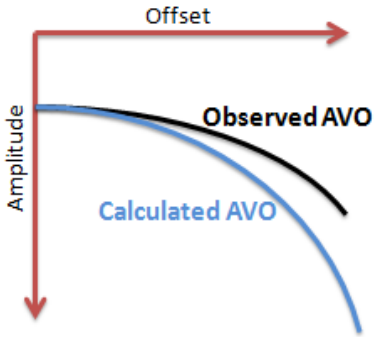
Log, Core, and Geological Information



Rock Layers Physics Model

(V_P, V_S, ρ)

Effective Mechanical Properties Calculation



AVO Response Computation

Rock Physics Model

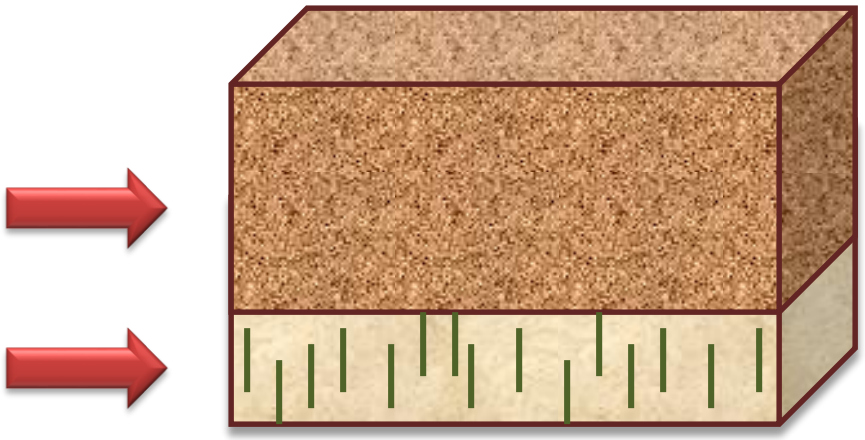
- **Overburden layer:**

Isotropic medium

✓(or use corrected data for layering VTI anisotropy)

✓Known properties from logs and cores

✓(V_P, V_S, ρ)

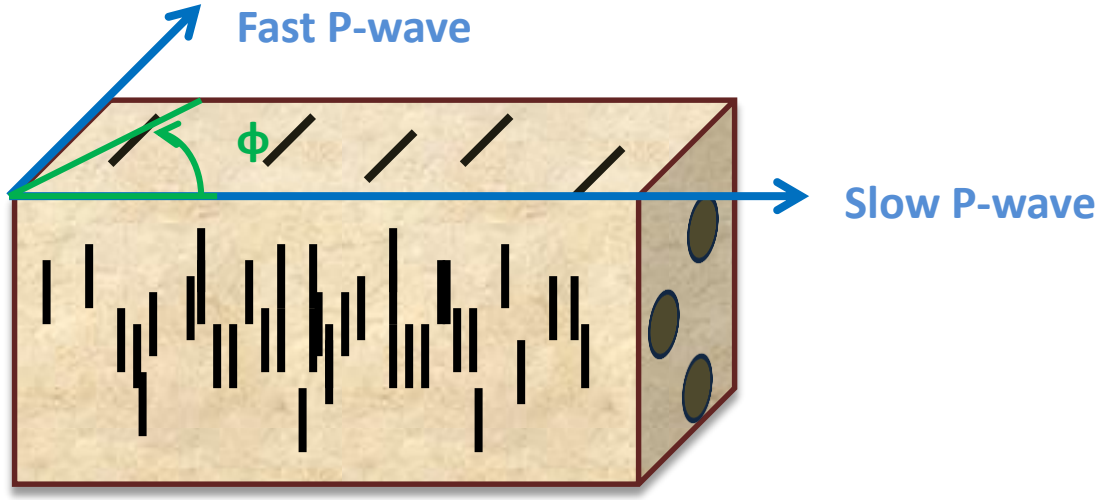


- **Reservoir layer:**

Horizontal Transversely Isotropic medium

- Vertical alignment of fluid-filled fractures
- Need to calculate effective elastic properties for the overall layer

Mean Elastodynamic Properties
Hudson's model

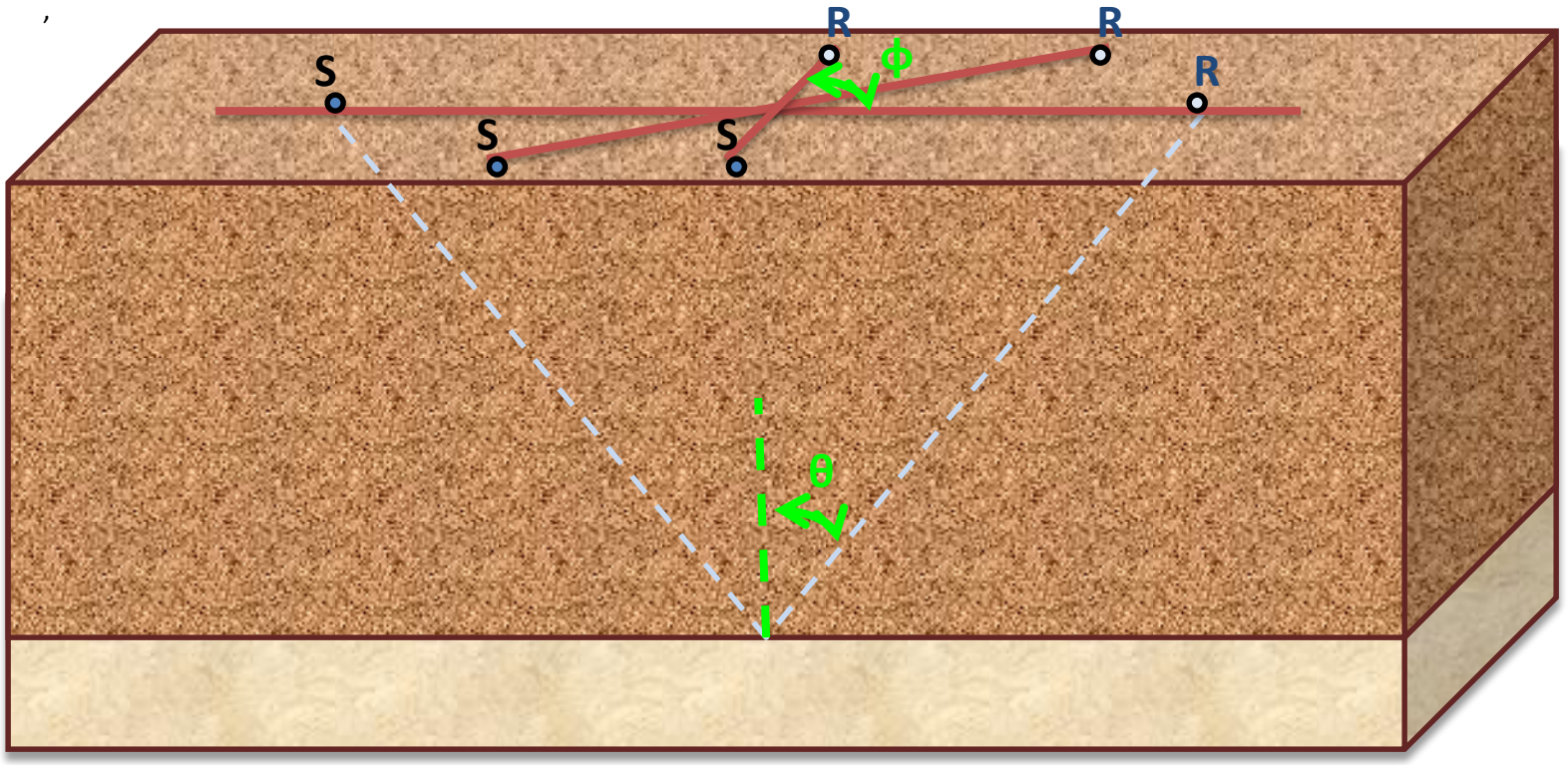


Overall Vp

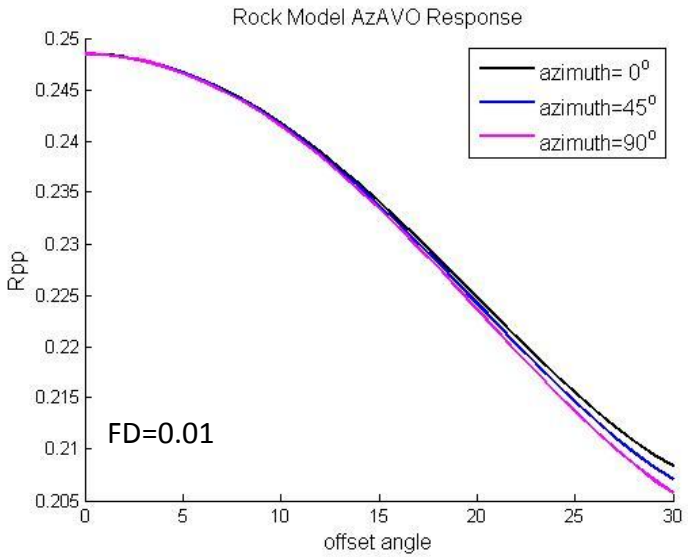
- **Rock mechanical properties** — Uncracked Rock Vp
- **Wave Travel Direction** — Azimuth with respect to fracture alignment
- **Fracture Density** — Volume of crack in unit volume of rock
- **Fractures shape** — Assumed as circular inclusions

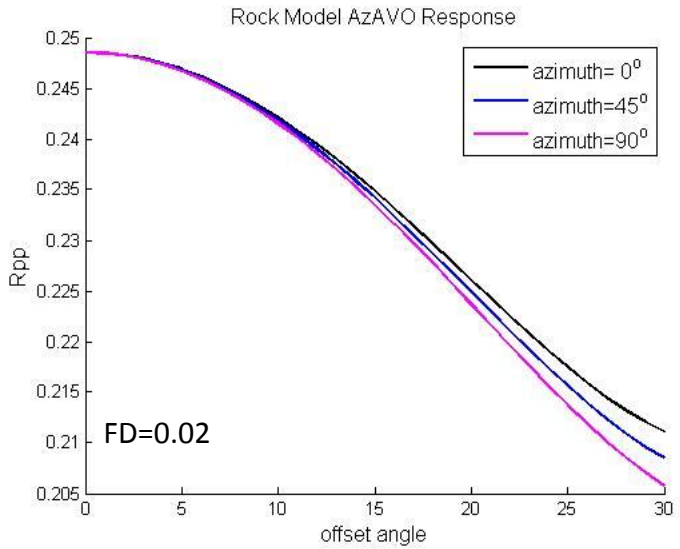
AzAVO Response Computation
Ruger and Tsvankin

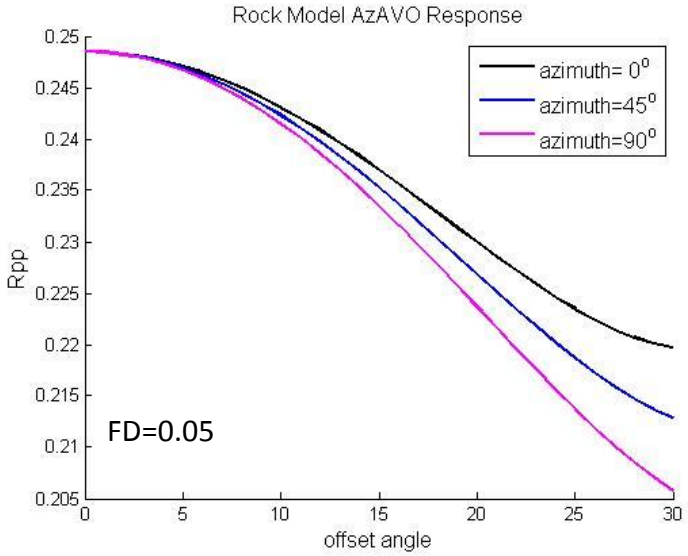
$R_{PP}(\theta, \phi, V_P, V_S, \rho)$

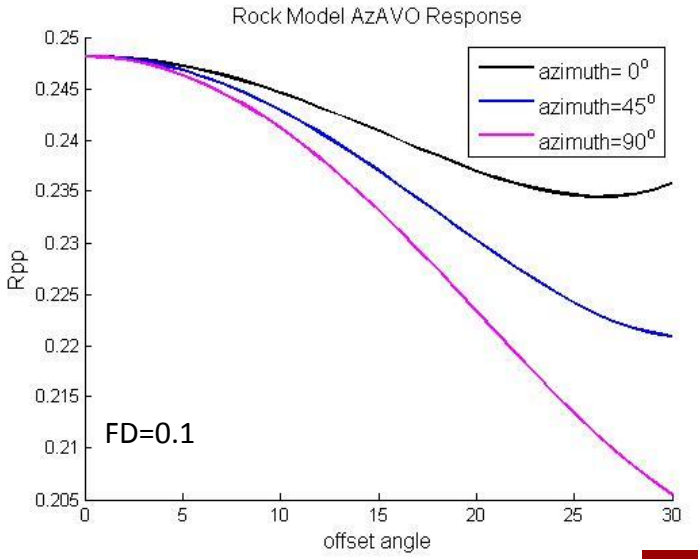


Effect of Fracture Density on AVO Response









Inverting for Fracture Density

$F(r) = R_{cal}$

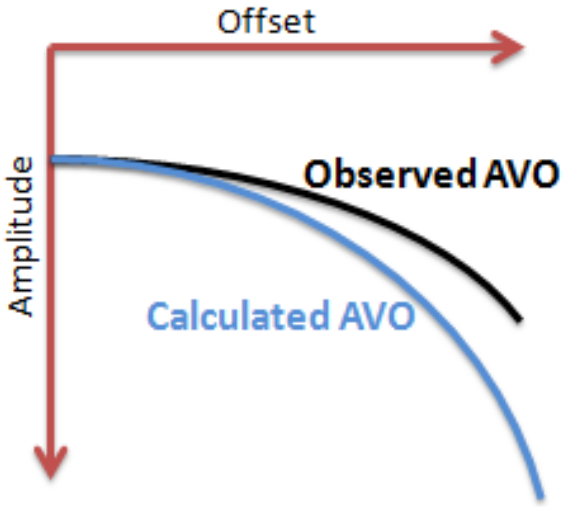
$\min (R_{cal} - R_{obs}) \rightarrow r=?$

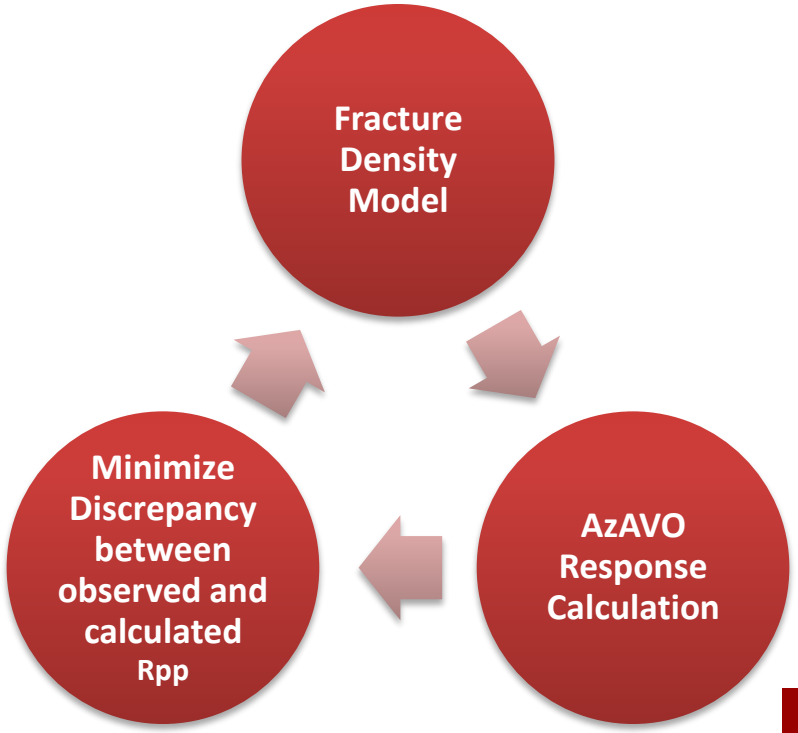
r: Fractured Rock Model
F: AVO calculation Forward Model
R_{cal}: Calculated Reflection Coefficient
R_{obs}: Observed Reflection Coefficient

For each input "r" model, the AzAVO response is written as:

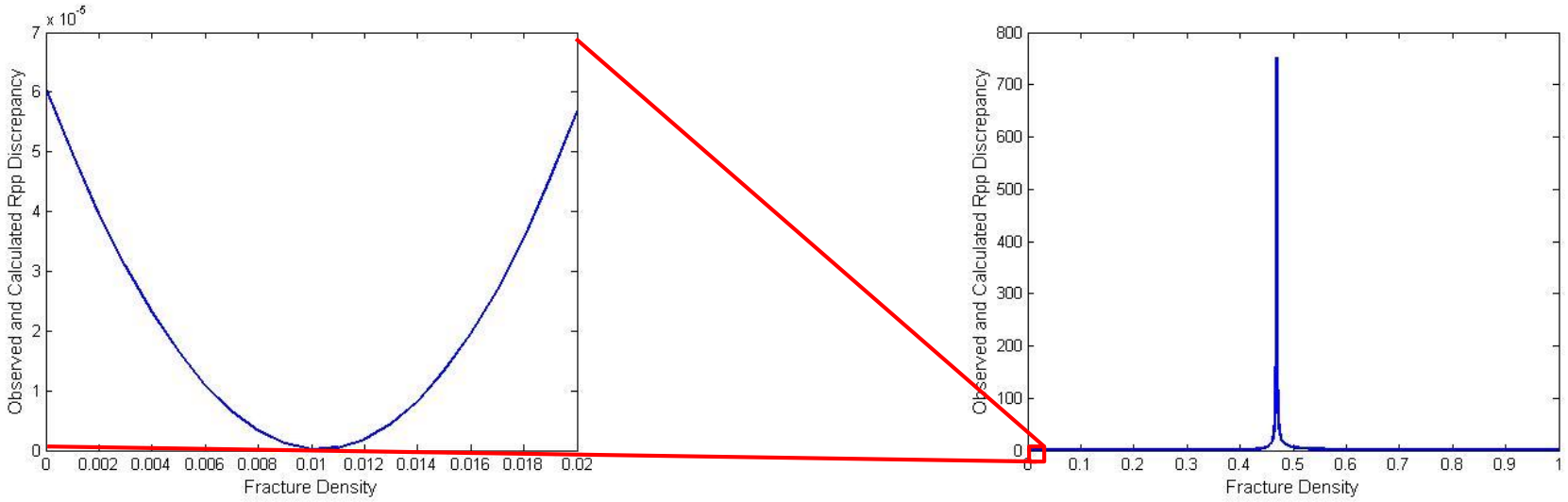
$$\begin{bmatrix} R_{11} & \cdots & R_{1n} \\ \vdots & \ddots & \vdots \\ R_{m1} & \cdots & R_{mn} \end{bmatrix}$$

m= number of source-receiver pairs
n= number of azimuth bins

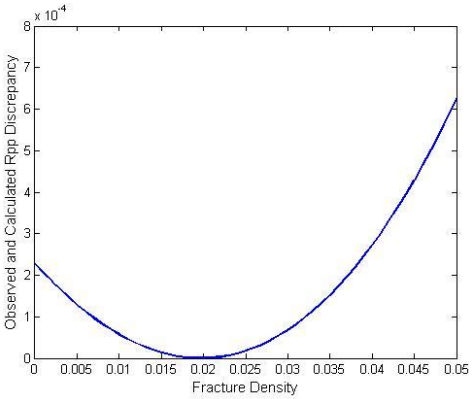




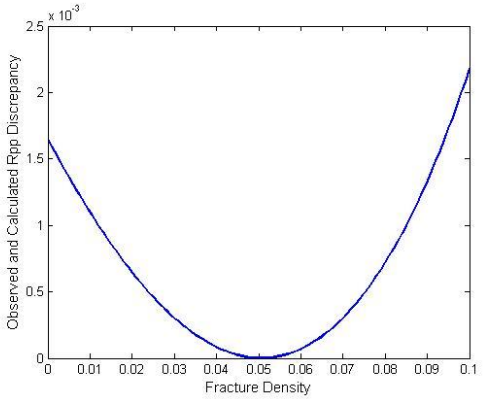
Inversion Results



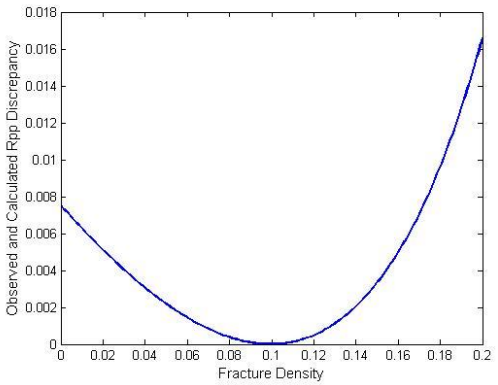
FD=0.0107



FD=0.0197



FD=0.0503



FD=0.1002

Sources of Error

Any amplitude data acquisition is accompanied by measurement errors

- **Noisy amplitude data is available**

A simplified rock model does not fully represent real fracture set structural complications

- **Single fracture set rocks cannot be fully described with a few parameters**
- **Multiple fracture set rocks require more geological insight due to complications in reversing the superposition procedure**
- **Random orientation of fractures does not exhibit a preferred direction of anisotropy, and responses like an isotropic medium**

Modeled AVO responses do not include any frequency dependence

No consideration for the properties of the fluid filling the fractures is included

Conclusions

1. A workflow is developed for fracture density inversion from AzAVO data.

2. Seismic wave reflection in the interface of reservoir rock and overburden is modeled with simplified log data assumptions.

3. The effect of fracture density on the AVO response of the rock is investigated.

4. Synthetic Reflection Coefficient data having added random noise is used to invert for fracture density.

5. Good agreement is obtained between the calculated inverted fracture density and the assumed fracture density.

6. Future work can be done for the investigation of the effect of other parameters, such as fluid content, major fracture set dip, and multiple fracture sets, on AVO response.

Acknowledgement

- USC Reservoir Monitoring Consortium (RMC)
- Fluor Foundation

USC

Thank You