1. Problem Formulation
MAIN QUESTION OF ROCK PHYSICS

How to Remotely Map Rock Properties and Conditions: Lithology, Porosity, Pressure, Saturation

Rock and fluid prediction away from well control requires understanding of how rock’s bulk and seismic properties are linked to each other and how they vary with geologic age, depth, and location.

Existing
Well

PROSPECT

The main question of remote sensing is:
What reservoir properties may stand behind the seismic amplitude?
**METHODS OF PREDICTION**

Forward Modeling of Seismic Response

Depending on the selected elastic properties of the overburden and reservoir, we model various classes of AVO response.

**Impedance and Poisson’s Ratio**

\[
I_p = \rho_b V_p
\]

\[
PR \equiv \nu = \frac{1}{2} \left( \frac{V_p}{V_s} \right)^2 - 2 \left( \frac{V_p}{V_s} \right)^2 - 1
\]
METHODS OF PREDICTION

Forward Modeling of Seismic Response from Rock Properties

AVO Class I

The AVO response changes with the compaction of shale which may be depth-driven.

Shale compaction with increasing depth

AVO Class II

AVO Class III
METHODS OF PREDICTION

Forward Modeling of Seismic Response versus Fluid

**GP 260**

**AVO Class II**

GAS

The AVO response changes with the pore fluid -- from gas to oil to water.

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**GP 260**

**AVO Class I - II**

OIL

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**GP 260**

**AVO Class I**

WET
METHODS OF PREDICTION -- LAB

Relations between Lithology, Porosity, and Elastic Properties

Laboratory Measurements. Han's (1986) laboratory data set includes over 60 sandstone samples of medium to low porosity and zero to 50% clay content. Shown below is a P-wave velocity versus porosity cross-plot for a subset of these data. The measurements shown below are for room-dry samples at 40 MPa confining pressure and atmospheric pore pressure (air).
METHODS OF PREDICTION -- LAB

Relations between Fluid and Elastic Properties

- Han's (1986) Data
EFFECTS OF OIL PROPERTIES

Oil Reservoir Response Depends on Oil API and GOR

Specify input parameters

Water Salinity (ppm)
45000

Gas Gravity (Specific)
0.65

Oil API
30

GOR
300

Pore Pressure (psi)
5500

Temperature (°F)
200

Specify input parameters

Water Salinity (ppm)
45000

Gas Gravity (Specific)
0.65

Oil API
50

GOR
100

Pore Pressure (psi)
5500

Temperature (°F)
200

Specify input parameters

Water Salinity (ppm)
45000

Gas Gravity (Specific)
0.65

Oil API
20

GOR
200

Pore Pressure (psi)
5500

Temperature (°F)
200

Decreasing GOR
METHODS OF PREDICTION -- WELL

Relations between Lithology, Fluid, and Elastic Properties in Log Data


*Impedance versus Poisson's ratio. Left: at in-situ conditions, right: wet.*
METHODS OF PREDICTION -- WELL

Relations between Lithology, Fluid, Depth, and Elastic Properties in Log Data

Sand/shale gas well offshore South Africa.

Impedance-porosity cross-plots show effects of clay (left) and compaction (right).
Reflection amplitude carries information about elastic contrast in the subsurface. Inversion attempts to translate this information into elastic properties within an interval.

These properties are important because we are interested in absolute values of lithology, fluid, and porosity within intervals.
Log data can be treated as a result of a controlled experiment where various rock properties are measured in the subsurface. Shown below are VSHALE, total porosity, and Ip curves for a Colombian well drilled through Tertiary sand/shale sequence.

The Ip curve mirrors the porosity curve. This means that there is a relation between impedance and porosity.
Impedance-porosity transform can be applied to impedance inversion volume to produce a porosity/lithology volume. Shown below is a La Cira field (Colombia) example.
PRIMER ON ROCK PHYSICS

Finding Transforms and Applying them to Impedance Inversion

Stratigraphy and geology, in general, are important factors to be used to confirm mathematically derived reservoir descriptions.
Caveat of Scale

Thin sub-resolution layers produce smaller amplitude than thick layers. As a result, they produce smaller seismic impedance.

Applying an impedance-porosity transform to seismic impedance will produce a wrong porosity estimate.