# The most important is to
# δ

**Presented by**

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# Objectives

**Laboratory estimation of Delta:**

- at different stress level
- for various mixture of sand-clay samples

**Method of estimation:**

- Laboratory transmission wave technique.
- Laboratory Reflection wave technique.

**Setup:**

- A specially designed oedometer (uniaxial strain setup).

# What is Delta

Delta is a moveout parameter which determine the change of seismic velocity /amplitude at an angular wave path compared to the wave velocity /amplitude at a vertical wave path in anisotropic media.

Can be expressed by (Thomsen, 1986):

$$\delta = \frac{(C_{13} + C_{44})^2 - (C_{33} - C_{44})^2}{2C_{33}(C_{33} - C_{44})}$$

$$\mathrm{v}_{S;zx} = \mathrm{v}_{S;zy} = \sqrt{\frac{C_{44}}{\rho}}$$

$$\mathrm{v}_{P;z} = \sqrt{\frac{C_{33}}{\rho}}$$

$C_{13}$ Can be given by, for example, P wave velocity at 45 degree angle with respect to the symmetry axis

# Laboratory Test Technique

# Work Flow

1. Calibration test

2. Design an oedometer setup

3. Measurement of  delta for Sand-clay and their mixtures in oedometer setup

# Actions & Speculations

## Calibration tests

1. Characterize (Cylindrical) a manufactured anisotropic material (only using transmission wave technique)

2. Velocity at various angle were estimated on parallel flat surface to examine the geometrical effect (only using transmission wave technique).

3. Sand and shale core samples having parallel flat surfaces saturated with 3.5 wt% brine will be to estimate the signal strength with specific transducer size (for both transmission and reflection wave techniques).

# Actions & Speculations

## Final tests

Estimate Delta (using transmission and reflection wave techniques) of various lithology (sand-clay) in a specially designed oedometer.

# Materials used for calibration

Peek

Homogeneous and Isotropic material

❑ used to get the system travel time for samples of various size and shape

# Materials used for calibration

Cylindrical

Rectangular

Side view

Top view

Cylindrical

Rectangular

Cross-section view

Bakelite

is manufactured layered medium

❑ used here to estimate delta

# Transmission Wave Technique

# Transmission Wave Technique

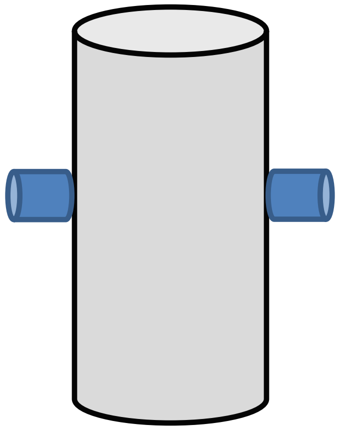
$$v_P(\theta) = v_P(0)\left[1 + \delta \sin^2\theta \cos^2\theta + \varepsilon \sin^4\theta\right]$$

(2nd order effect on travel time)

# 1. Calibration test

## Characterize the Bakelite (Cylindrical)

Use of Peek

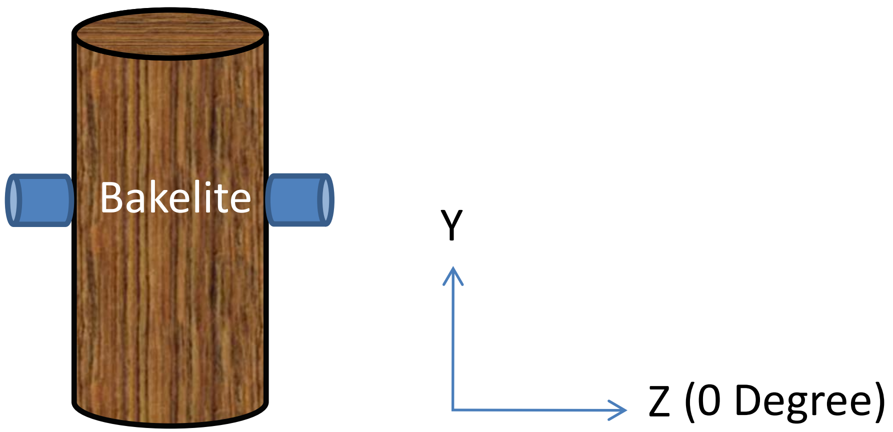


1. Cylindrical peek sample of 38 mm diameter used to estimate system travel time.

2. Travel time measured at each 5°.
3. Group velocity was estimated.

# 1. Calibration test

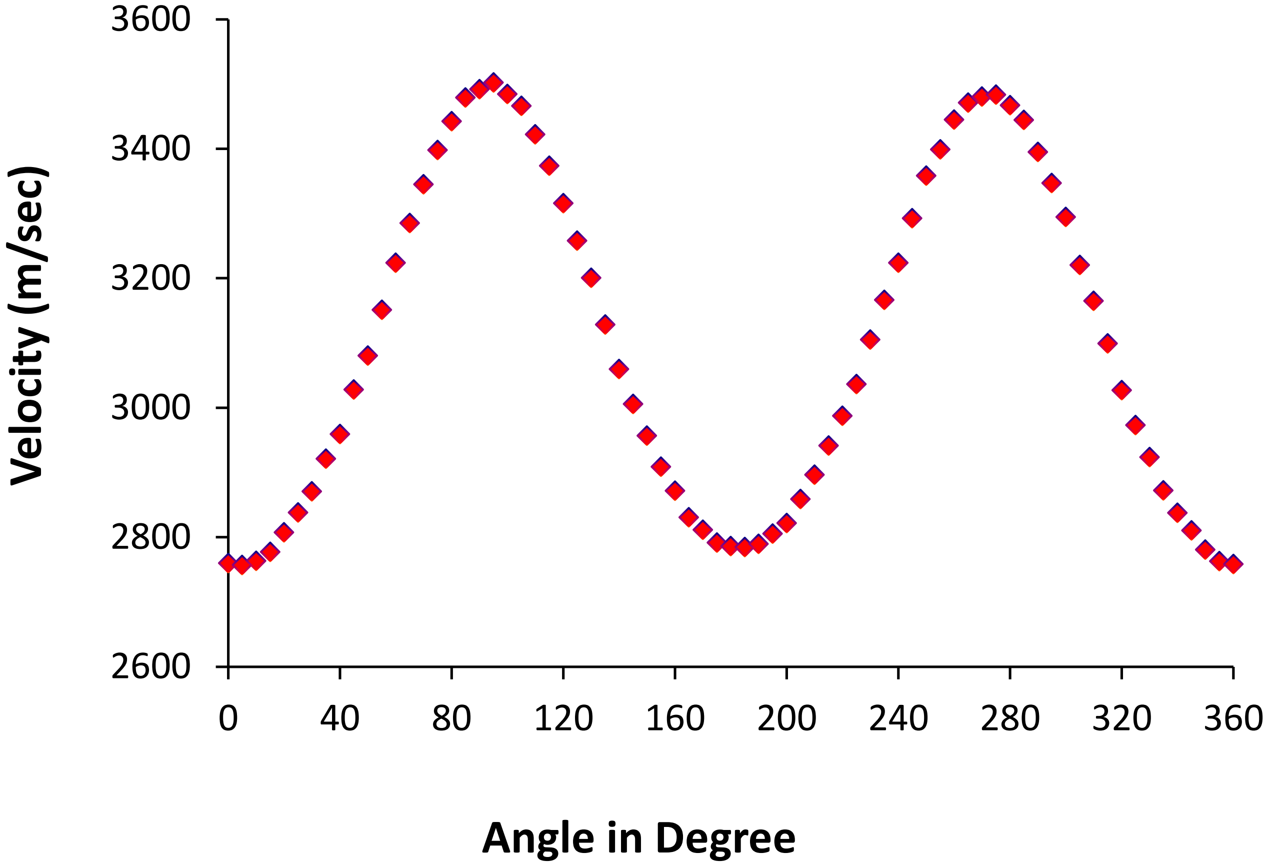
## Characterize the Bakelite (Cylindrical)




1. Diameter of Bakelite is also 38 mm
2. Travel time measured at each 5°.
3. Group velocity was estimated.

# 1. Calibration test

## Velocity as Function of Angle
(Cylindrical Bakelite sample)



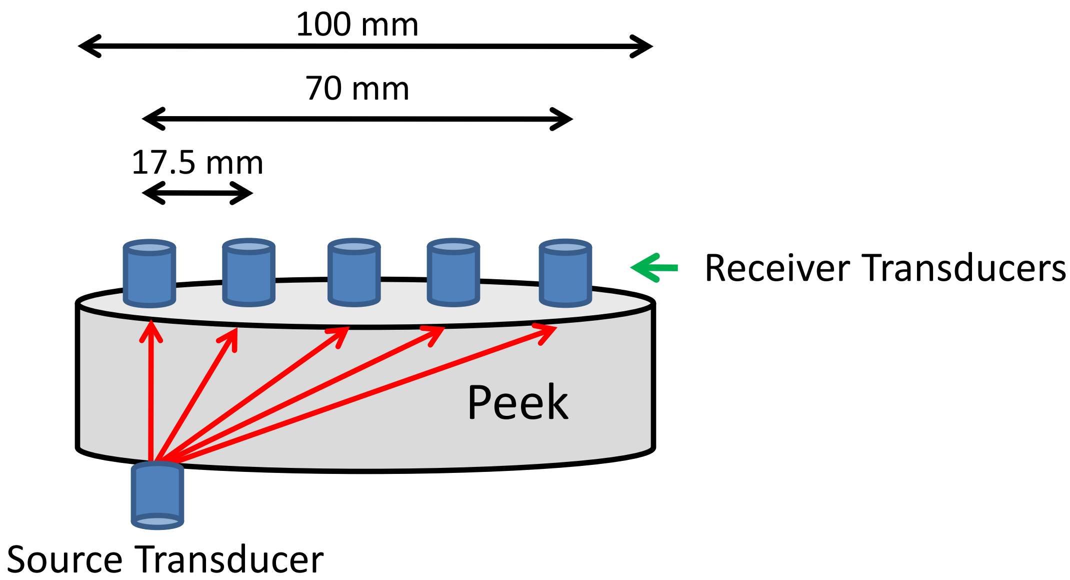

**Estimated delta is +0.22 (Using formula by Thomsen 1986)**

# 1. Calibration test

Investigation of Geometrical effect

# 1. Calibration test

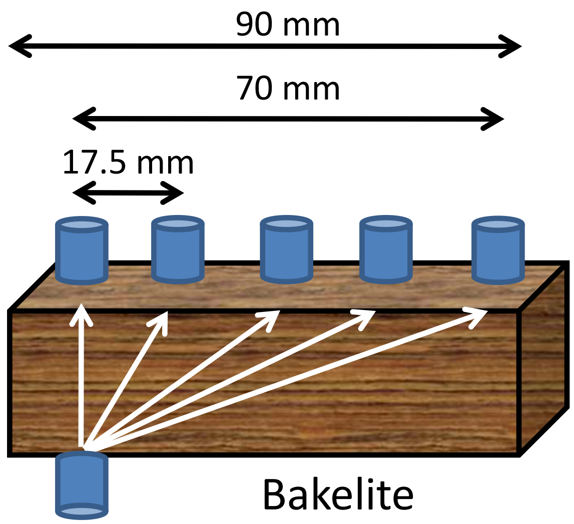
## Measuring on flat surface




Peek sample of flat parallel surfaces (height: 35 mm) used to estimate system travel time at various angle.

# 1. Calibration test

## Measuring on flat surface

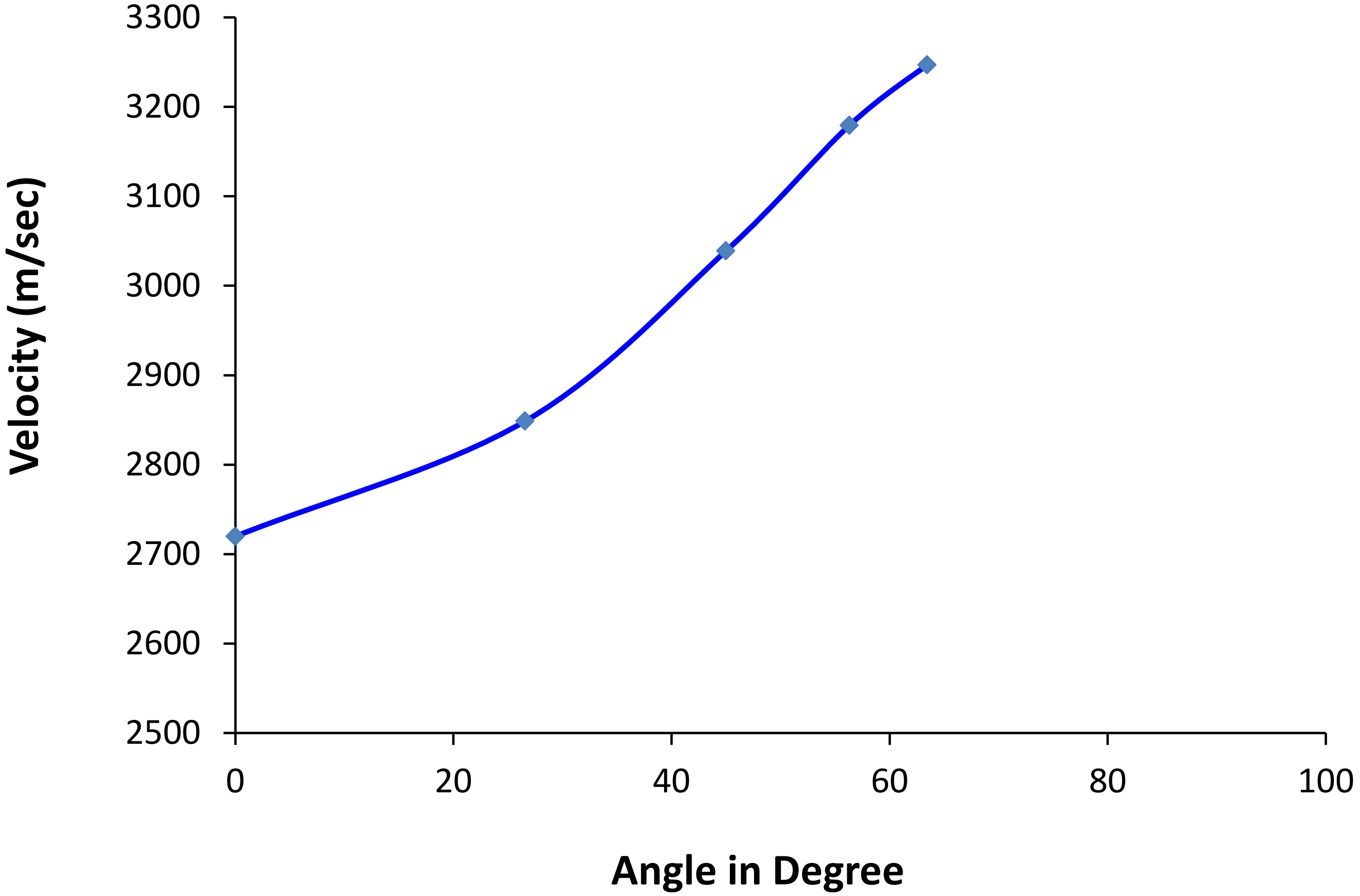



1. Height of Bakelite is also 35 mm
2. Travel time measured at each identical angle (as it was for peek)

# 1. Calibration test

## Velocity as function of angle

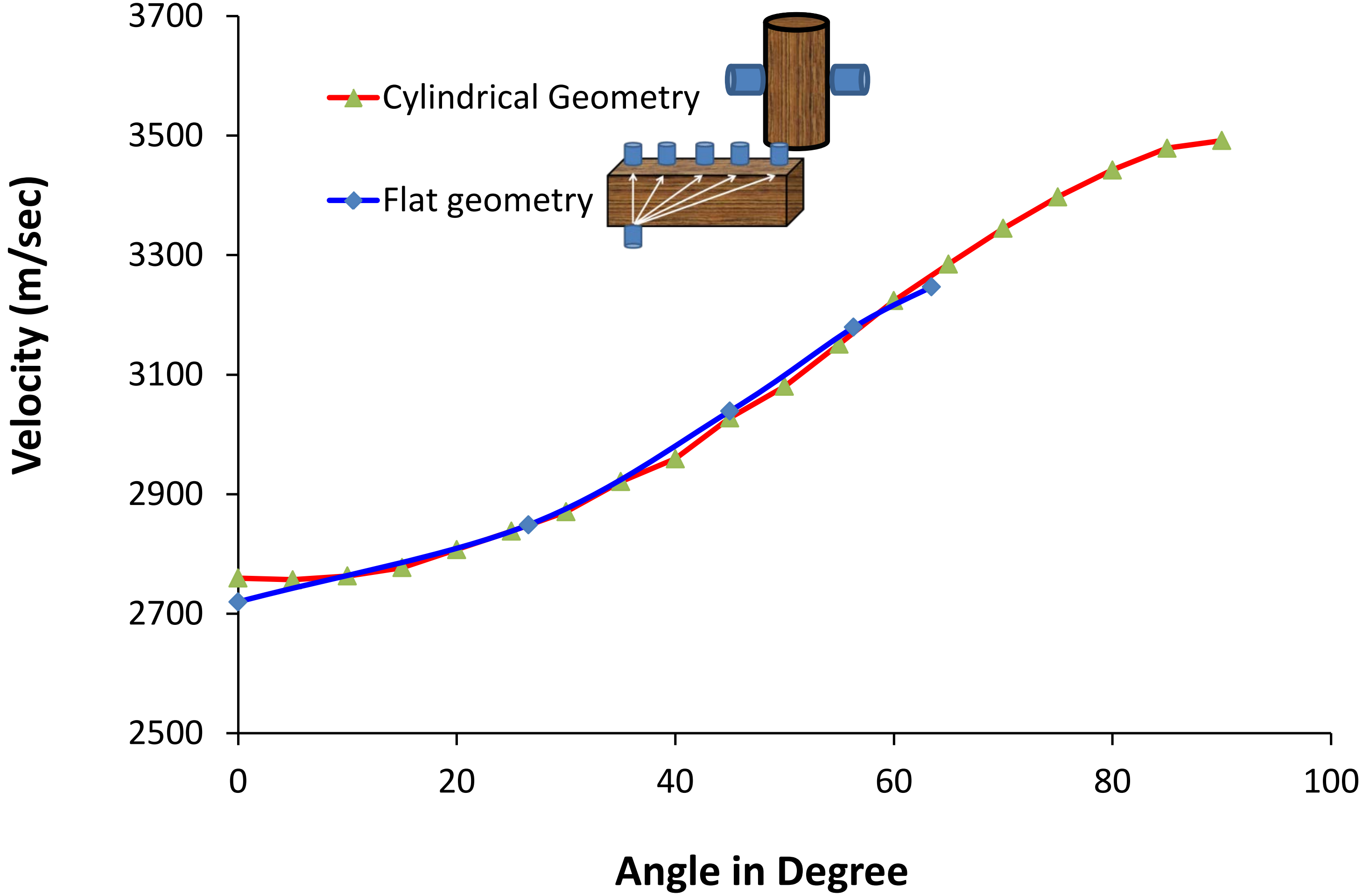
(Flat Bakelite sample)



# 1. Calibration test

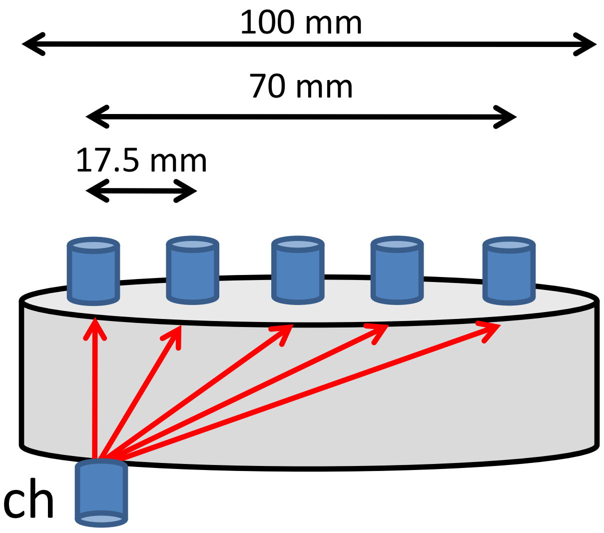
## Velocity as function of angle

(Comparison between cylindrical and flat Bakelite sample)



# 1. Calibration test

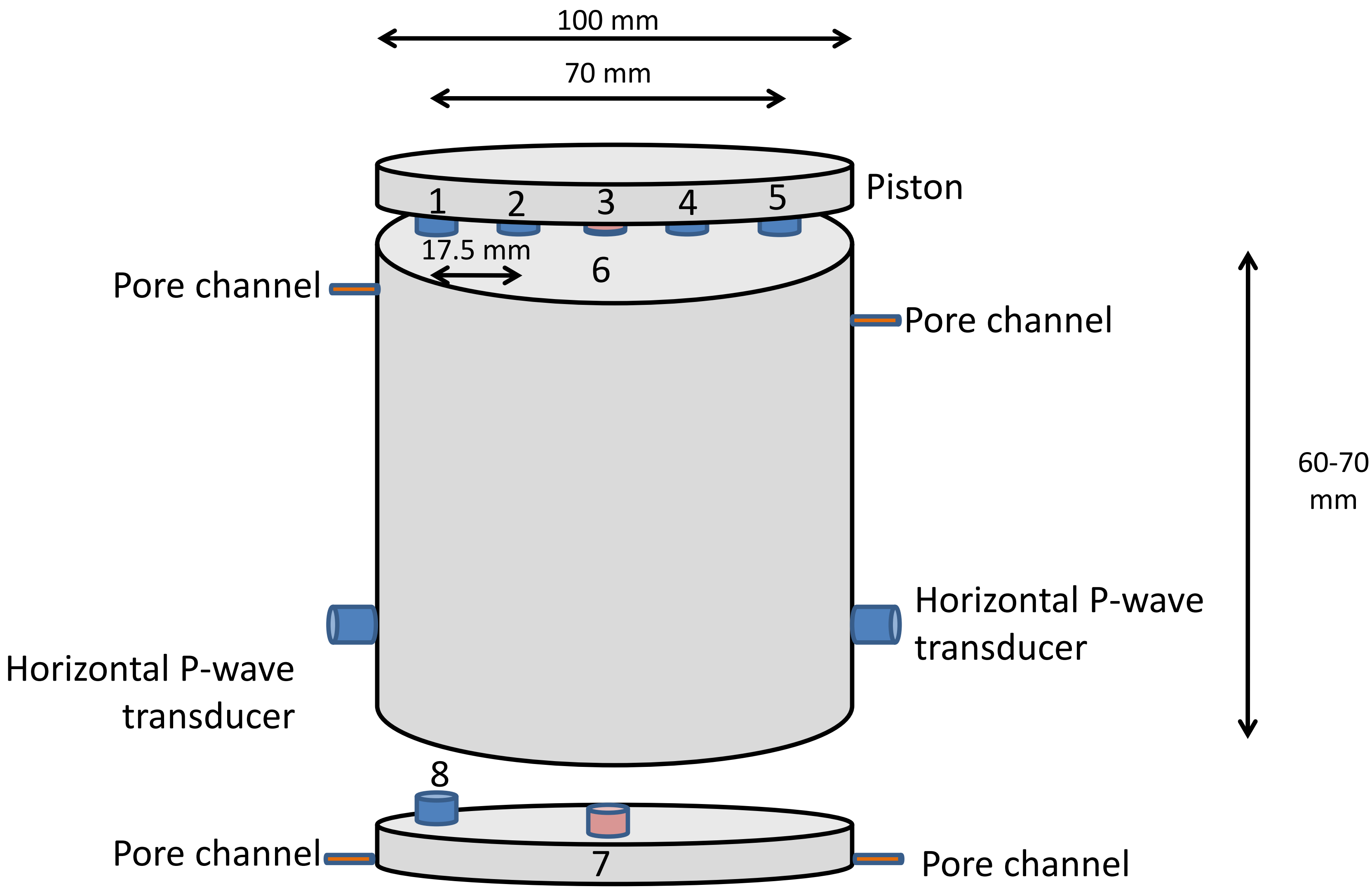
1. Core of Castlegate Sandstone and Pierre Shale with
Diameter: 100mm
Height: 35mm
2. Saturated with 3.5 wt% NaCl brine.




WHY?

1. Quality and strength of signal.
2. Find out:
    a. Radius-length ratio of the sample which may effect on quality of the signal.
    b. Group or phase velocity?
    c. The smallest possible transducer size to achieve optimal signal.

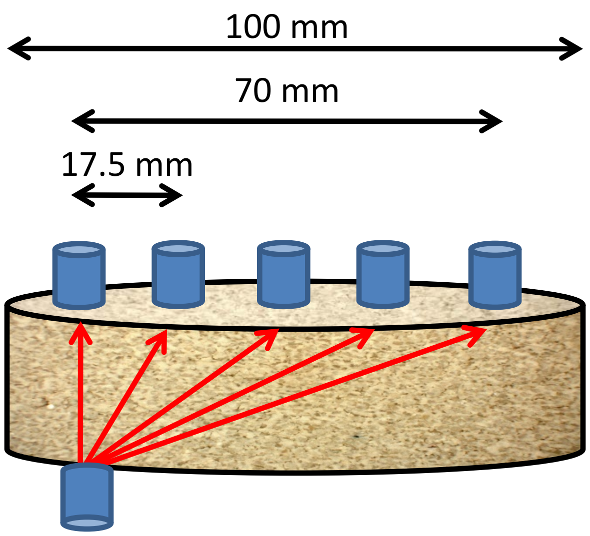
# 2. Design an oedometer setup




1-5: P-wave transducers (Receiver)
8: P-wave transducer (Source)

6 & 7: Vertical S-wave transducers

# Next Step to Achieve DELTA for Various Lithology




Various mixtures of sand-clay

# Reflection method

# Reflection method

$$R_p(\theta_w) \cong R_0 + R_2 \sin^2\theta_w + R_4 \sin^2\theta_w \tan^2\theta_w$$

Where,

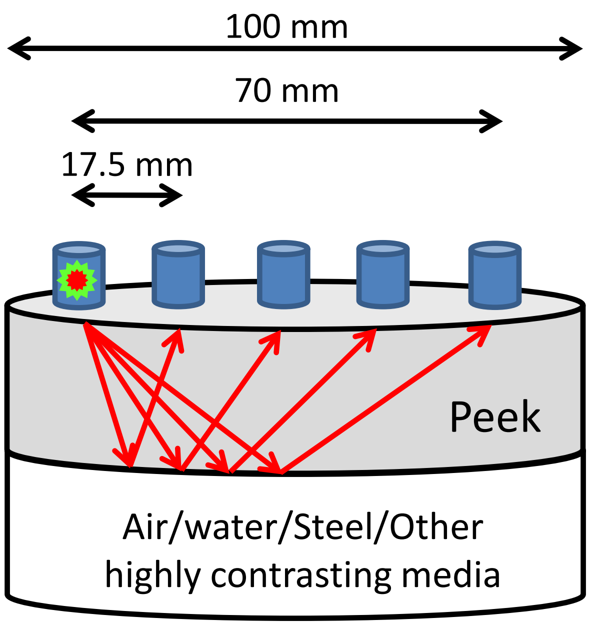
$$R_0 = \frac{\Delta Z_{P0}}{2\overline{Z}_{P0}}$$

$$R_2 = \frac{1}{2}\left[\frac{\Delta V_{P0}}{\overline{V}_{P0}} - \left(\frac{2\overline{V}_{S0}}{\overline{V}_{P0}}\right)^2 \frac{\Delta\mu_0}{\overline{\mu}_0} + \Delta\delta\right]$$

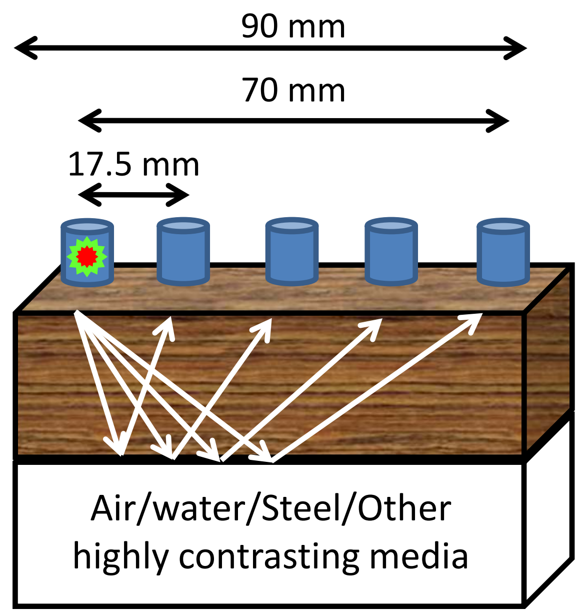
$$R_4 = \frac{1}{2}\left[\frac{\Delta V_{P0}}{\overline{V}_{P0}} + \Delta\varepsilon\right]$$

(1st order effect on wave amplitude)

# 1. Calibration test




To achieve system travel time



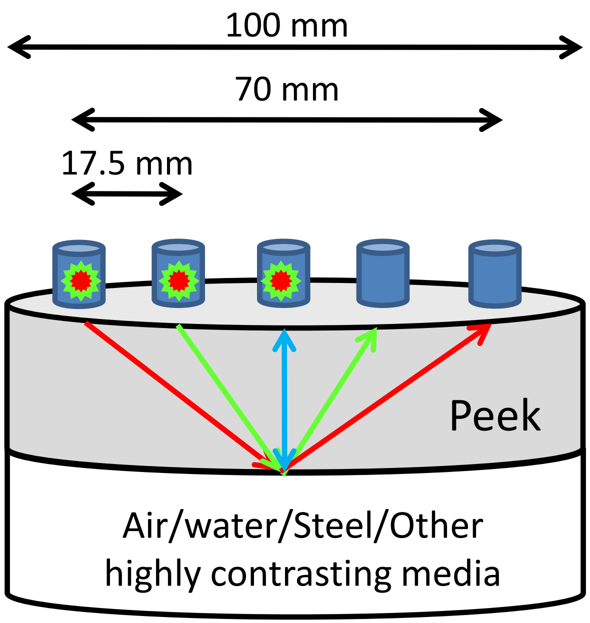

To achieve Delta

Source

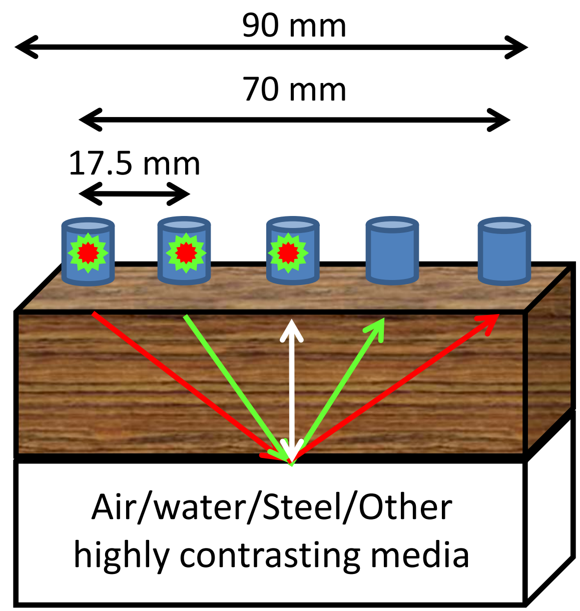
Reflection wave Technique

OR

# 1. Calibration test



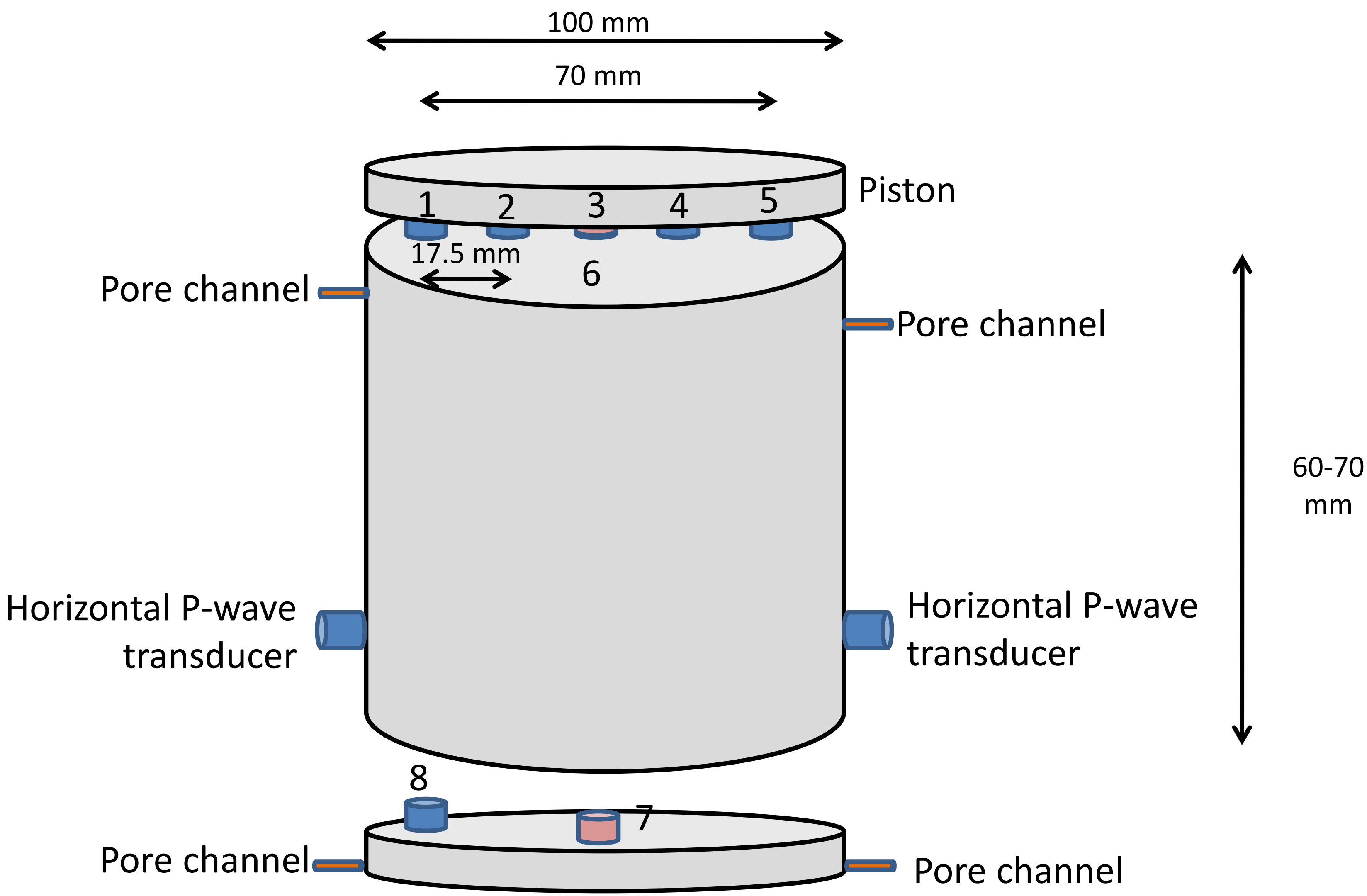

To achieve system travel time




To achieve  Delta

Source

# 2. Design an oedometer setup

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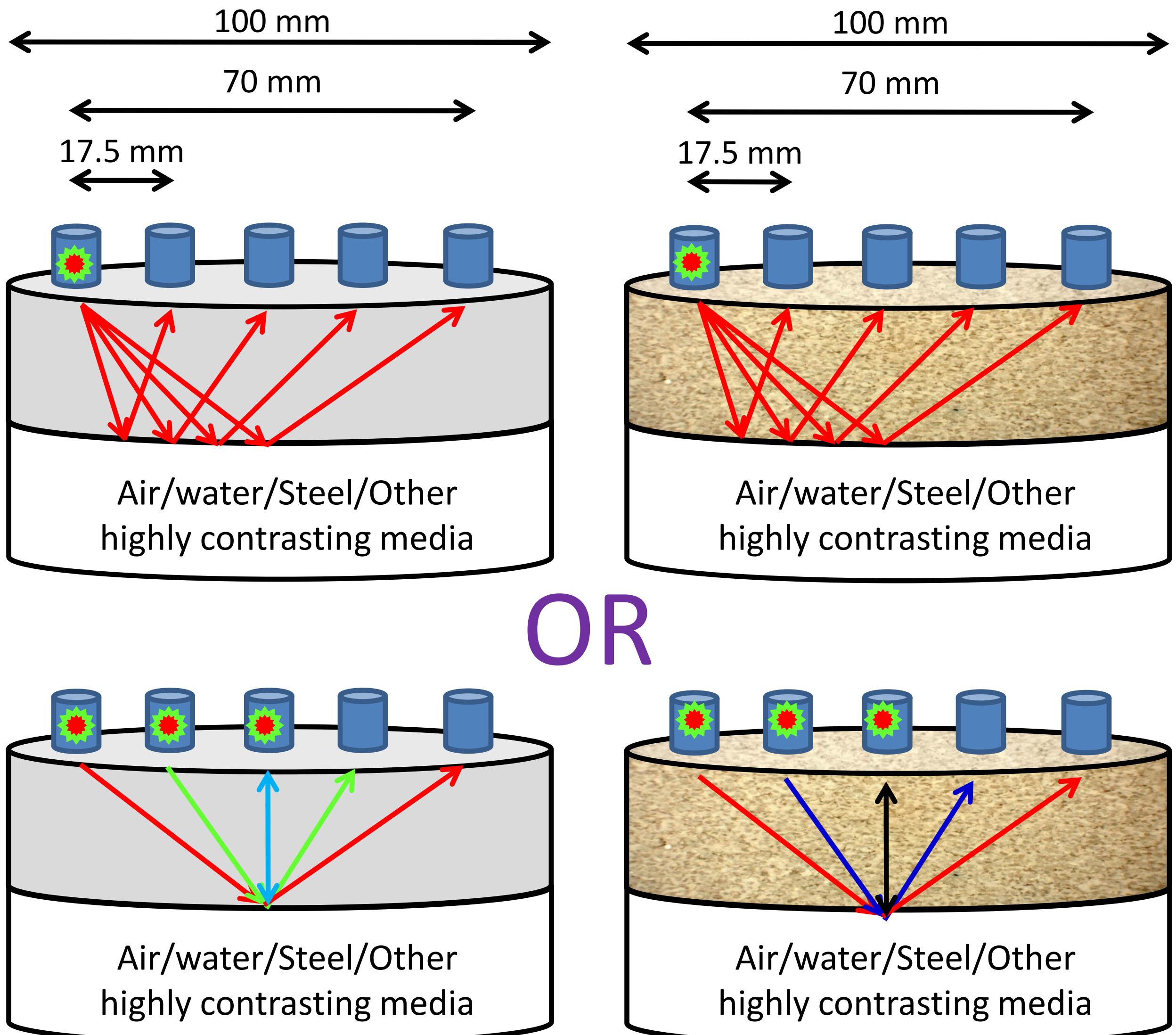
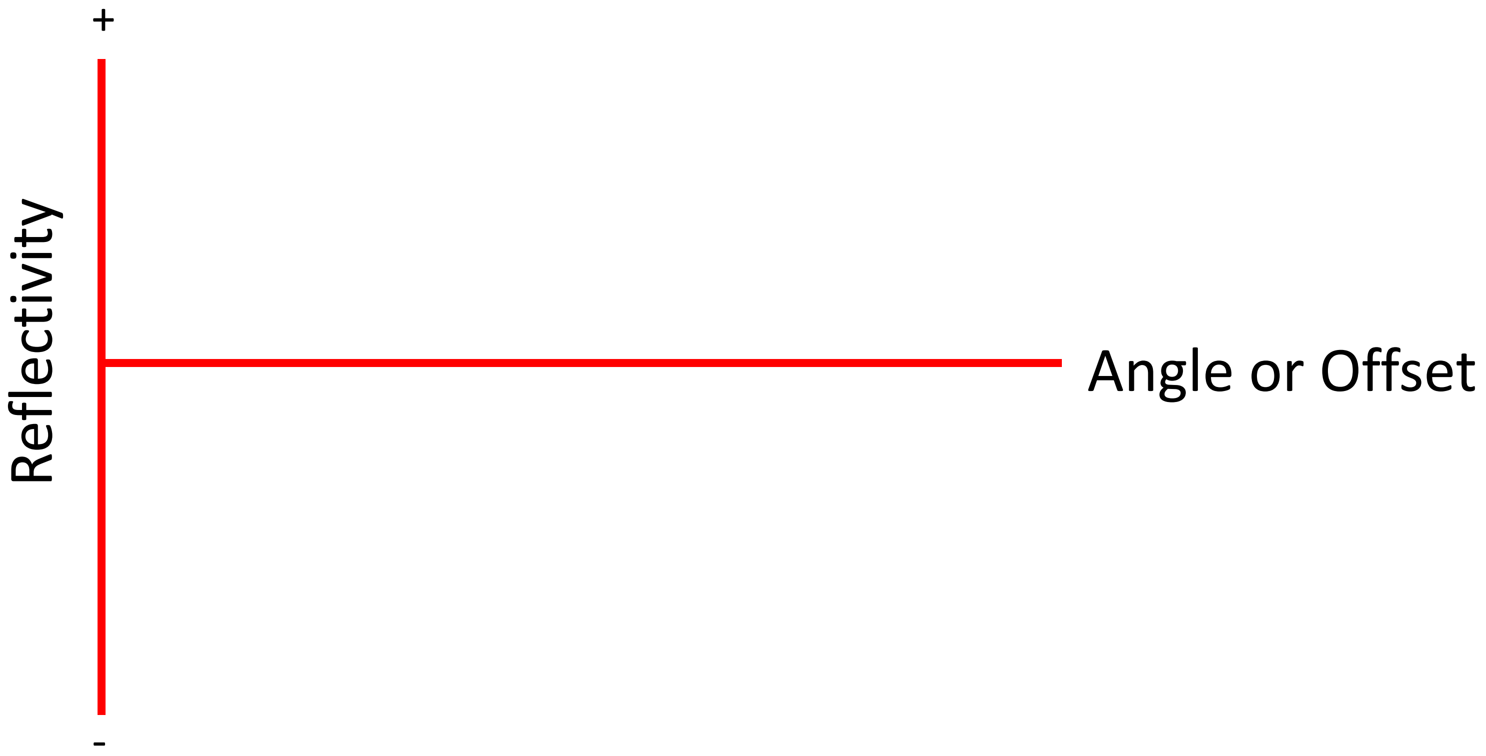
# Next Step to Achieve DELTA for Various Lithology






**What this will tells us?**

1. We can compare Isotropic and Anisotropic AVO.
2. ***Is there any other mathod to evalute? I am still searching…..***

Delta is nothing but