Use of ultrasonic data to generate pseudo logs for the verification of rock integrity

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Introduction

Rock integrity is associated to rock structure, in turn influencing elastic waves velocities.

Comparing log elastic wave velocities to the velocities of the intact rock under the same environmental and stress conditions can then provide information on rock integrity at depth.

Methodology

Main steps of the proposed methodology:

1. **Velocity-Stress-Porosity (V.S.P.)** relationship is calibrated on the basis of ultrasonic measurements on laboratory samples at increasing stresses;

2. the formation stress state is estimated by solving an inversion process based on break-out and tensile failures evidences;

3. the **V.S.P.** relationship is applied to porosity logs to generate pseudo logs of velocities, which are finally compared to the measured V_P and V_S logs

Hypotheses

V.S.P. calibration:

- ultrasonic and log measurements in the low frequency range (Biot's theory, 1956)

Stress state inversion:

- rock strength is known;

- the vertical direction is a principal stress direction and the well is vertical.

Bibliography

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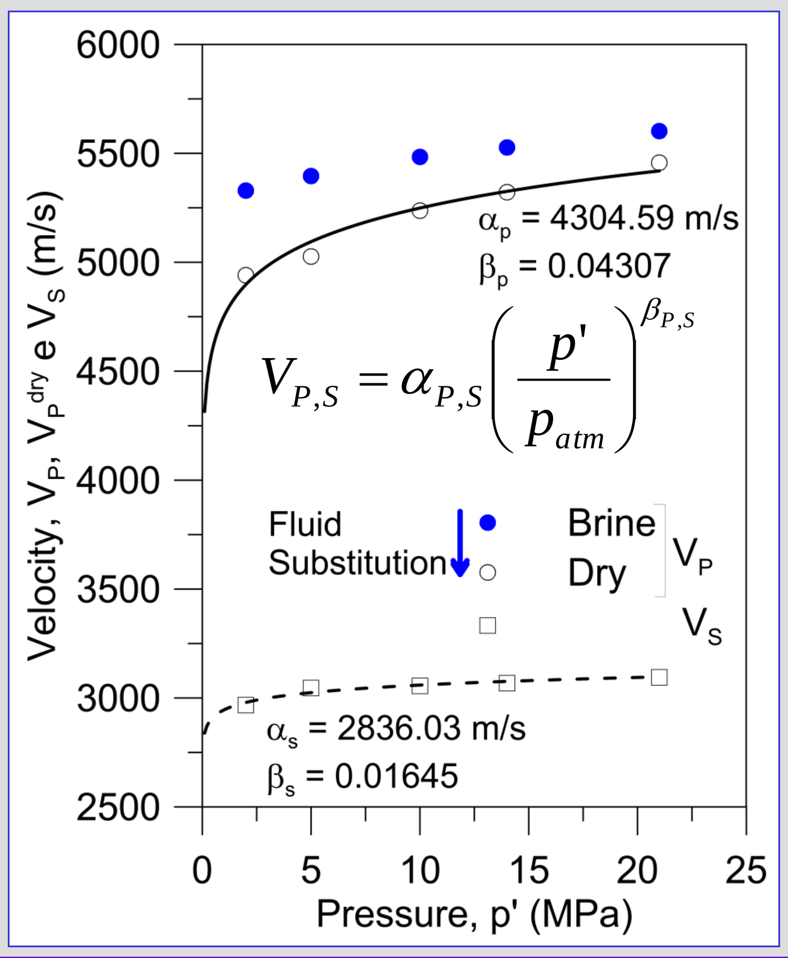
V.S.P. calibration

Elastic wave velocities are related to stress state and void ratio: $V_{P,S} = \alpha_{P,S}\left(\frac{p'}{p_{atm}}\right)^{\beta_{P,S}}$

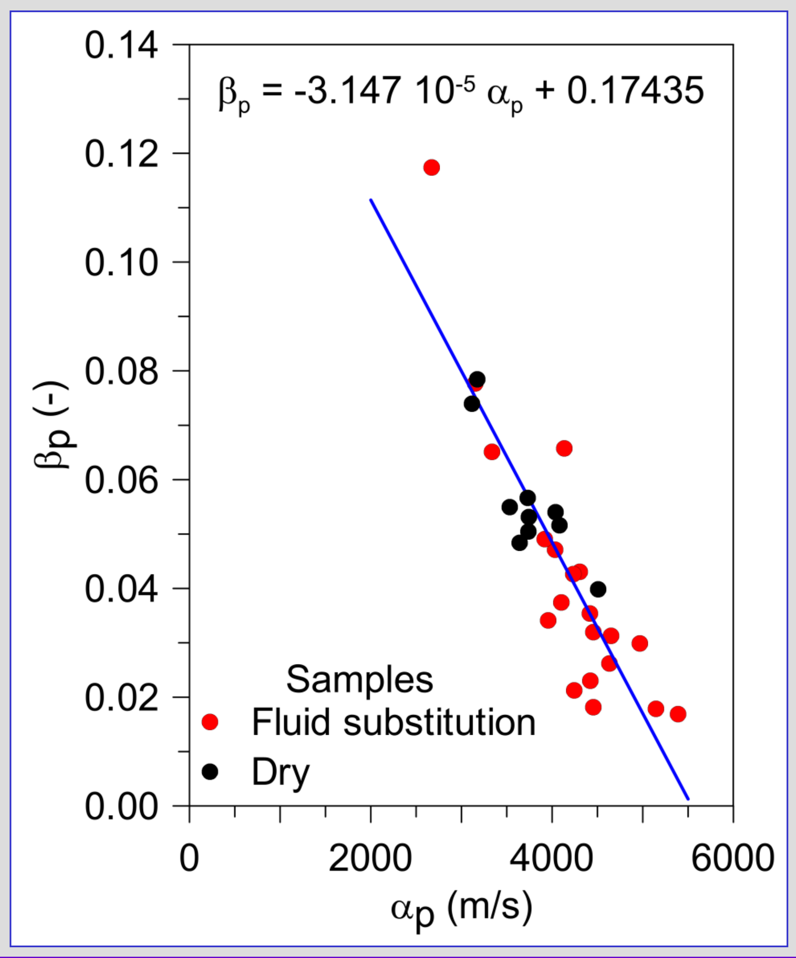
α & β material parameters

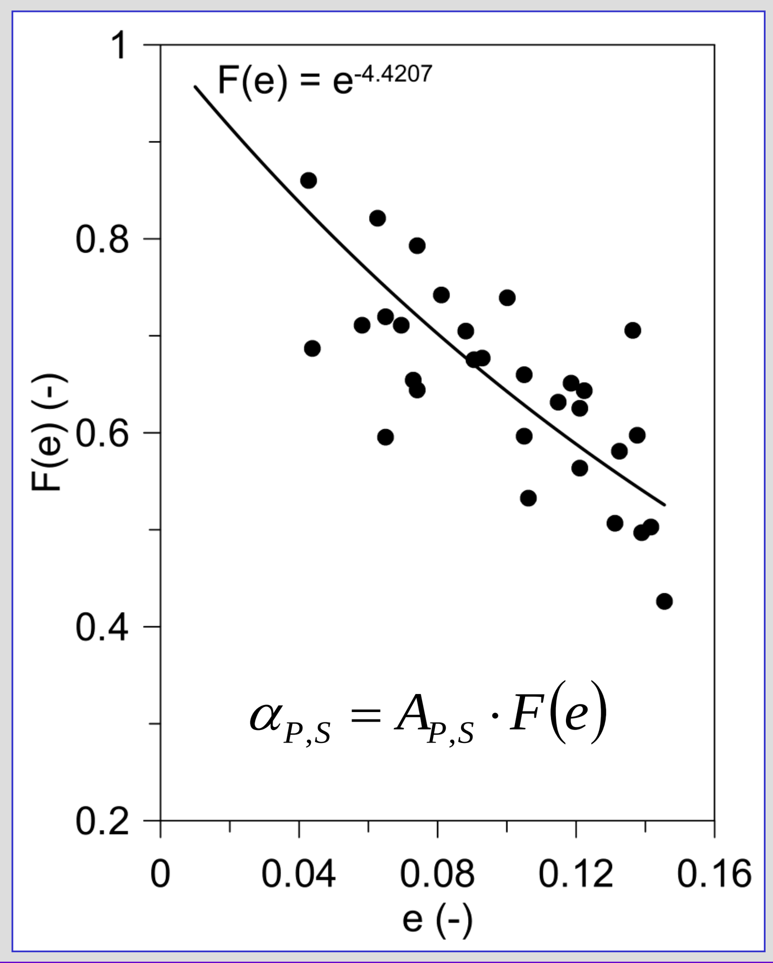
Decomposition of α
mineralogy component: A
structural component: F(e)

from each ultrasonic test



relationship between α & β

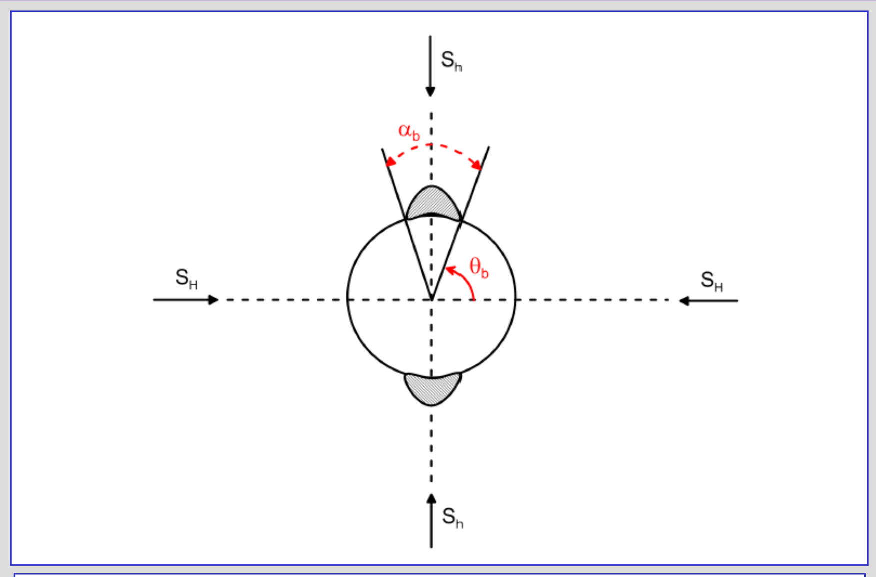




Determination of the stress state

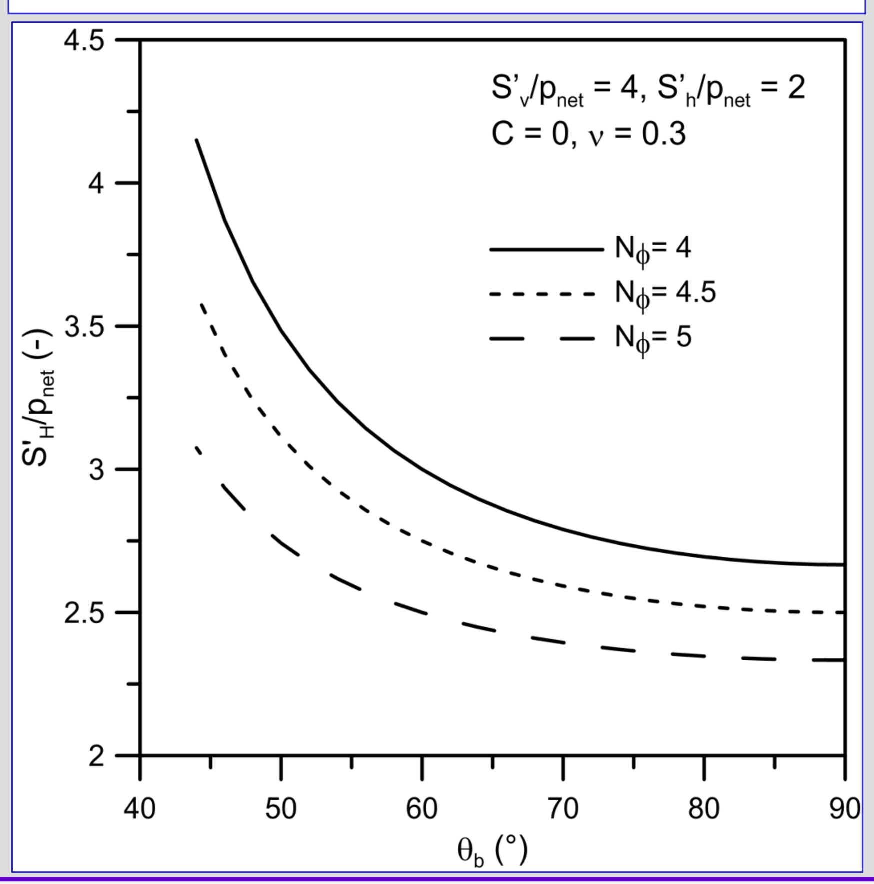
- S'_v (vertical effective stress) from density logs
- S'_h (min horizontal effective stress) from mini-frac tests
- p_{net} = mud pressure – hydrocarbon pressure

Limits on S'_H (max horizontal effective stress) estimated from breakout and tensile failures during borehole excavations



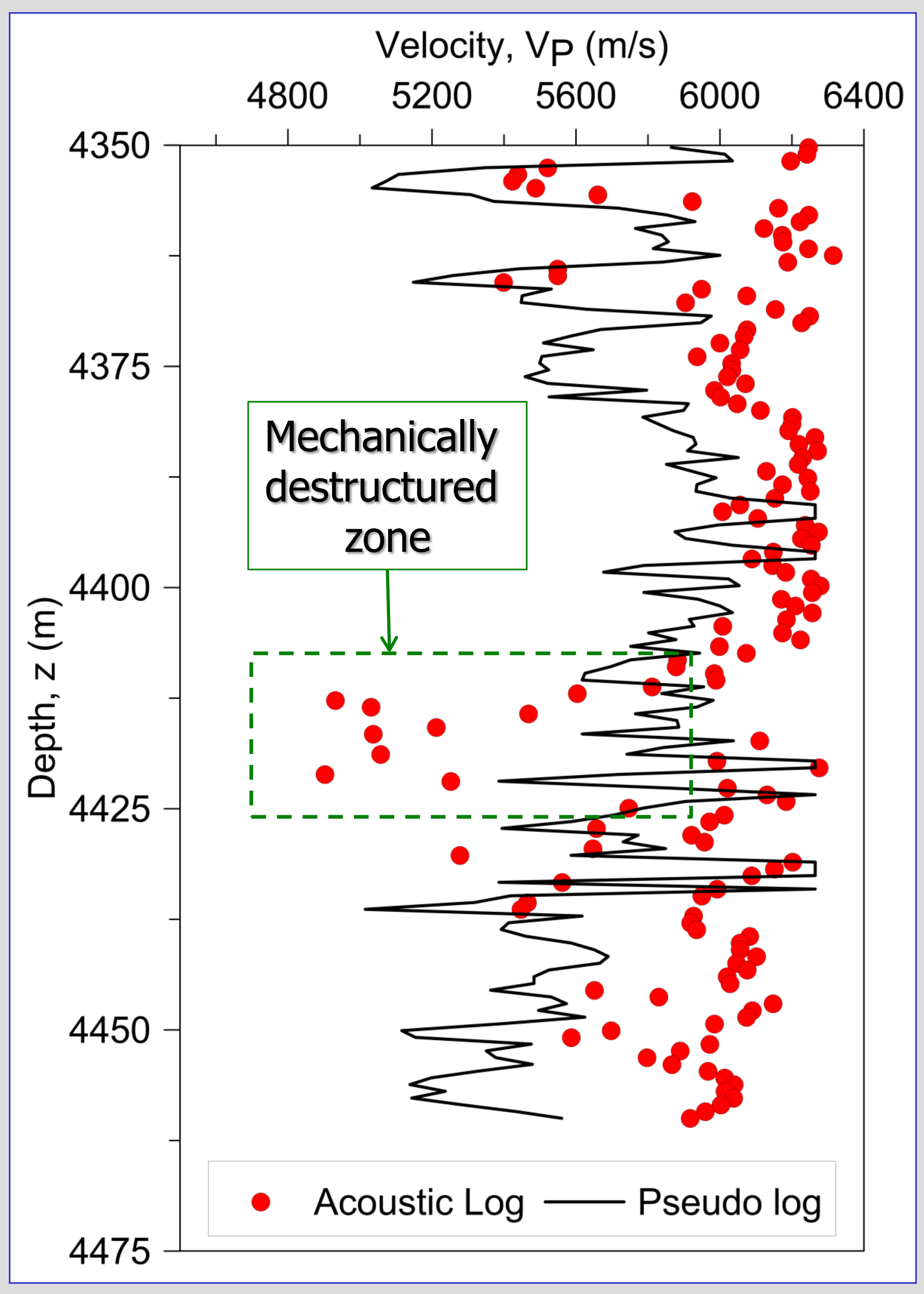
Example: estimation of a lower bound of S'_H from the amplitude α_b of the breakout failure obtained from caliper data, under the assumptions:

- the amplitude of the breakout coincides with the amplitude of the yielded zone if the material is elastic-perfectly plastic
- Mohr-Coulomb yield surface $\sigma'_1 = C + N_\phi \sigma'_3$



Results

- the fabric component F(e) depends on the structural state;
- comparison between the measured and the pseudo V_P and V_S logs help to assess the structural state of the rock;
- local destructuration leads to lower velocities than those predicted through the pseudo log.



Further Information

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