CARBONATE RESERVOIR MAPPING

DHI (DIRECT HYDROCARBON INDICATOR)

20 October 2023

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HISTORY OF DHI

1900-1960

Ground work :
Reflection Coefficient
(Zoeppritz) , Reflective Elastic
Moduli, Fluid replacement

1970- Now

DHI, AVO, Seismic
Inversion
(Poisson Reflectivity,
Lamda Mu Rho etc.)

Fawad, M. et. al., 2020-Seismic-fluid detection-a review

SEISMIC WAVE

- The strain energy that propagates in the earth due to the elastic properties of the rocks (Sheriff & Geldart, 1995)

$$V_p = \sqrt{\frac{K + {}^4/_3\mu}{\rho}} = \sqrt{\frac{\lambda + 2\mu}{\rho}}$$

$$V_s = \sqrt{\frac{\mu}{\rho}}$$

- Then Vp and Vs correlation is:

$$V_p = V_s\sqrt{{}^K/_\mu + {}^4/_3}$$

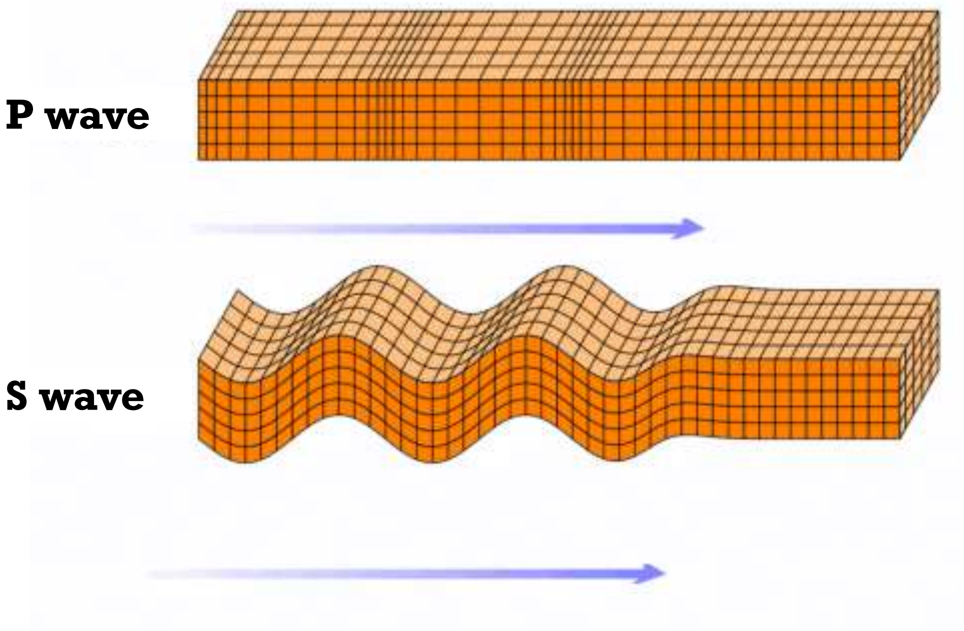


Illustration of P & S Wave propagation through earth body

RC AS A FUNCTION OF THE AVERAGE ANGLE θ

Fluid

Rigidity

$$RC(\theta) \approx \frac{1}{2cos^2\theta}\left[\frac{\Delta V_p}{V_p}\right] - \frac{4V_s^2}{V_p^2} sin^2\theta \left[\frac{\Delta V_s}{V_s}\right] + \frac{1}{2}\left[1 - 4\frac{V_s^2}{V_p^2} sin^2\theta\right]\left[\frac{\Delta\rho}{\rho}\right]$$

$$RC(\theta) \approx A + Bsin^2(\theta) + C\, sin^2(\theta)tan^2(\theta)$$ Simplest form

$$A = \frac{1}{2}\left[\frac{\Delta V_p^2}{V_p} + \frac{\Delta\rho}{\rho}\right]$$; Intercept

$$B = \frac{1}{2}\frac{\Delta V_p}{V_p} - \frac{4V_s^2}{V_p^2}\left[\frac{\Delta V_s}{V_s}\right] - 2\frac{V_s^2}{V_p^2}\left[\frac{\Delta\rho}{\rho}\right]$$, Gradient

$$C = \frac{1}{2}\left[\frac{\Delta V_p}{V_p}\right]$$, Curvature

Framework for AVO gradient and intercept interpretation (Castagna et al., 1998)

WHAT IS DHI IN SEISMIC?

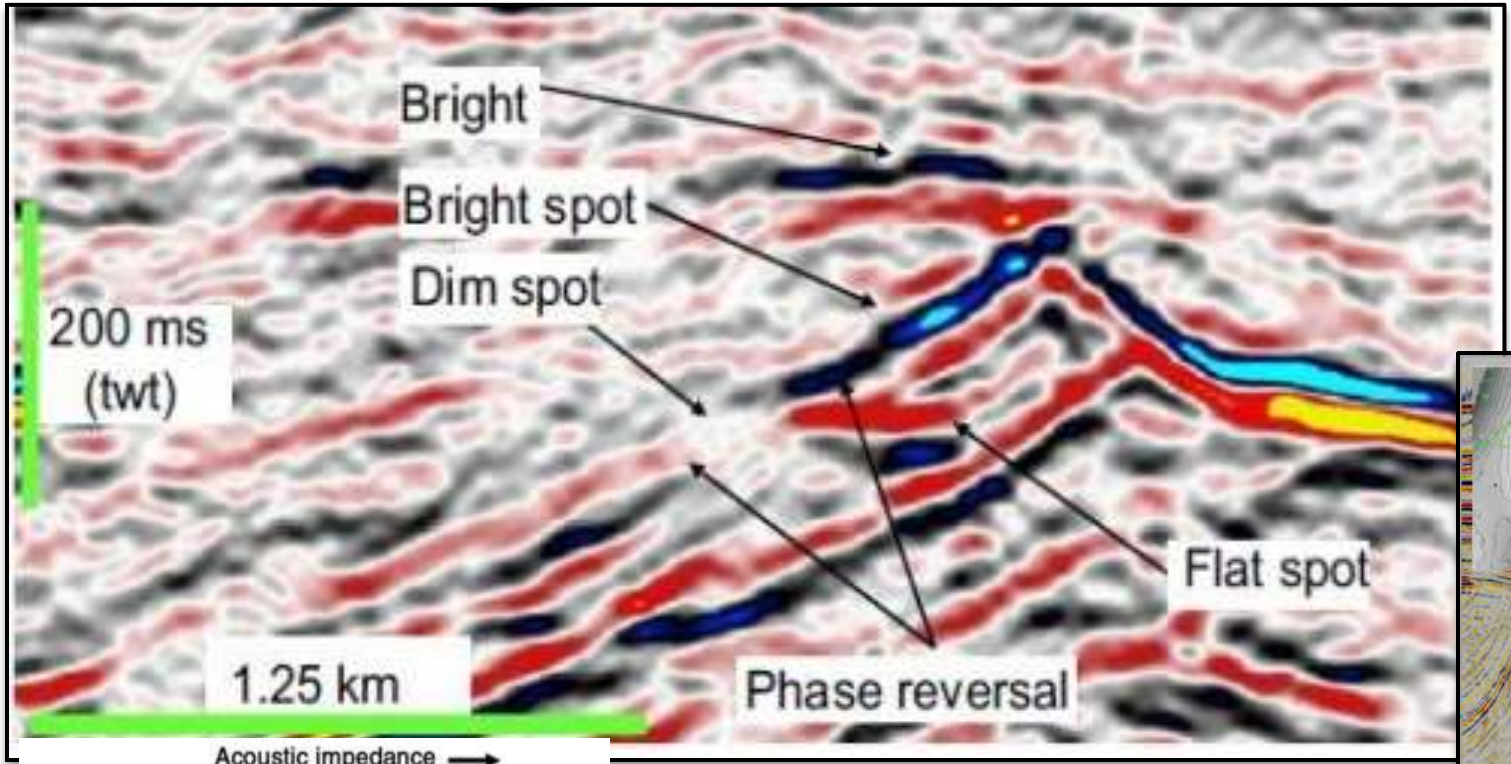
- Is an anomalous seismic attribute value or pattern that could be explained by the presence of hydrocarbons in oil and gas reservoir

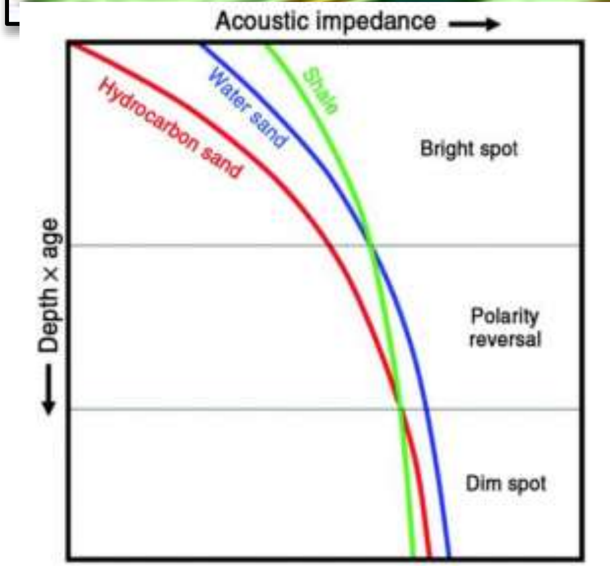
- DHI occur when a change in pore fluids causes a change in the elastic properties of the bulk rock which is seismically detachable (i.e. there is a "fluid effect")

DHI TYPES

Bright spots
Flat spots
Dim spots
Polarity reversals
Gas Chimney
Amplitude versus offset anomaly (AVO)
Frequency Anomaly

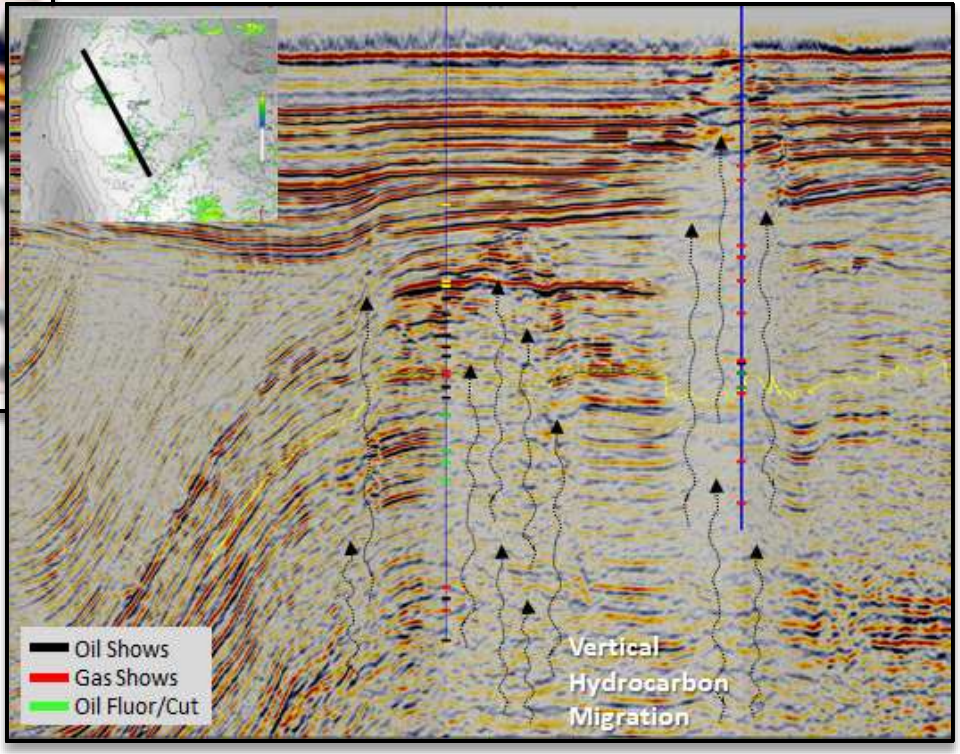
https://wiki.seg.org/wiki/Direct_hydrocarbon_indicators





https://wiki.seg.org/wiki/Direct_hydrocarbon_indicators

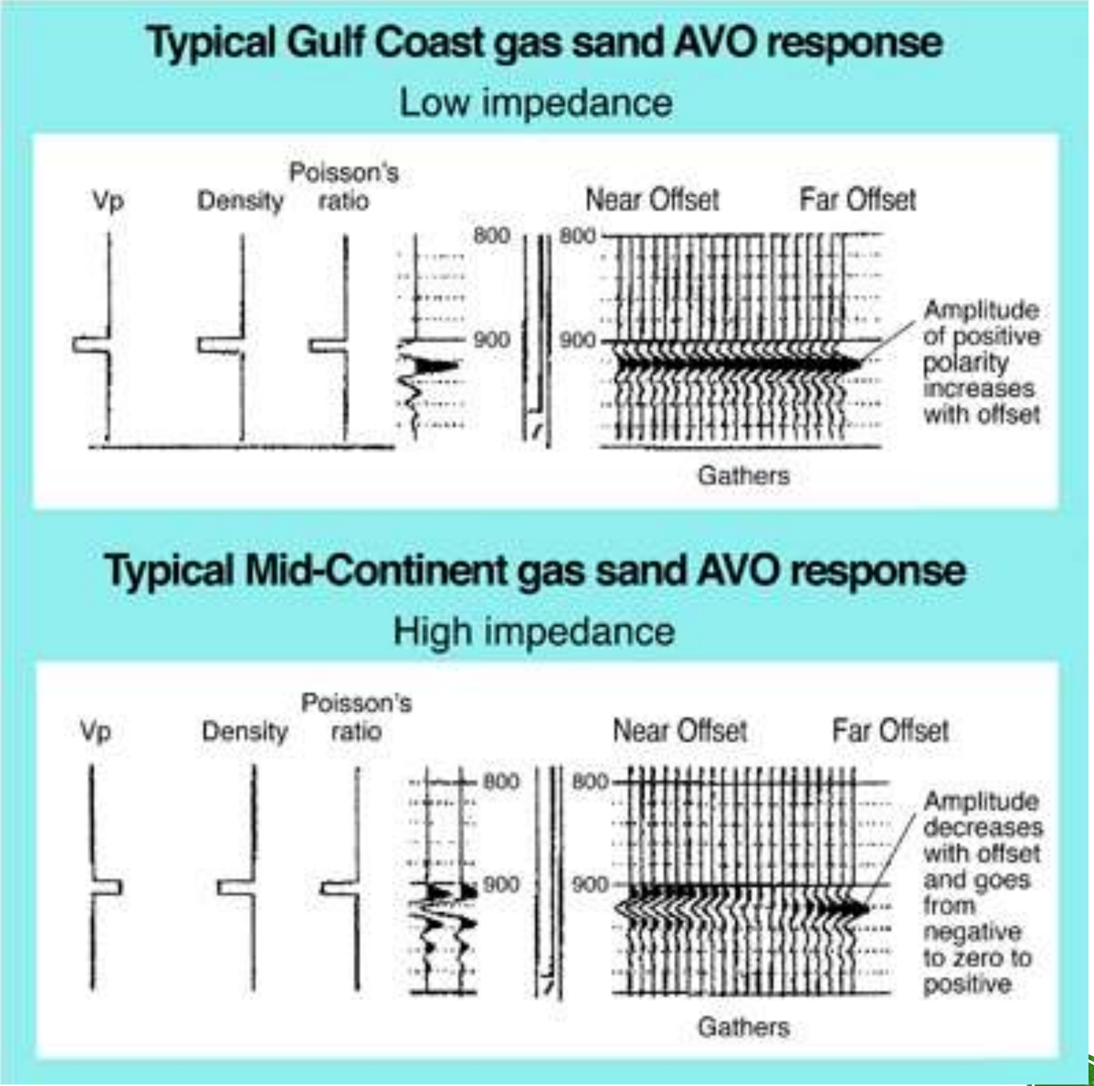
Gas Chimney



https://dgbes.com/chimney_atlas/images/purpose.png

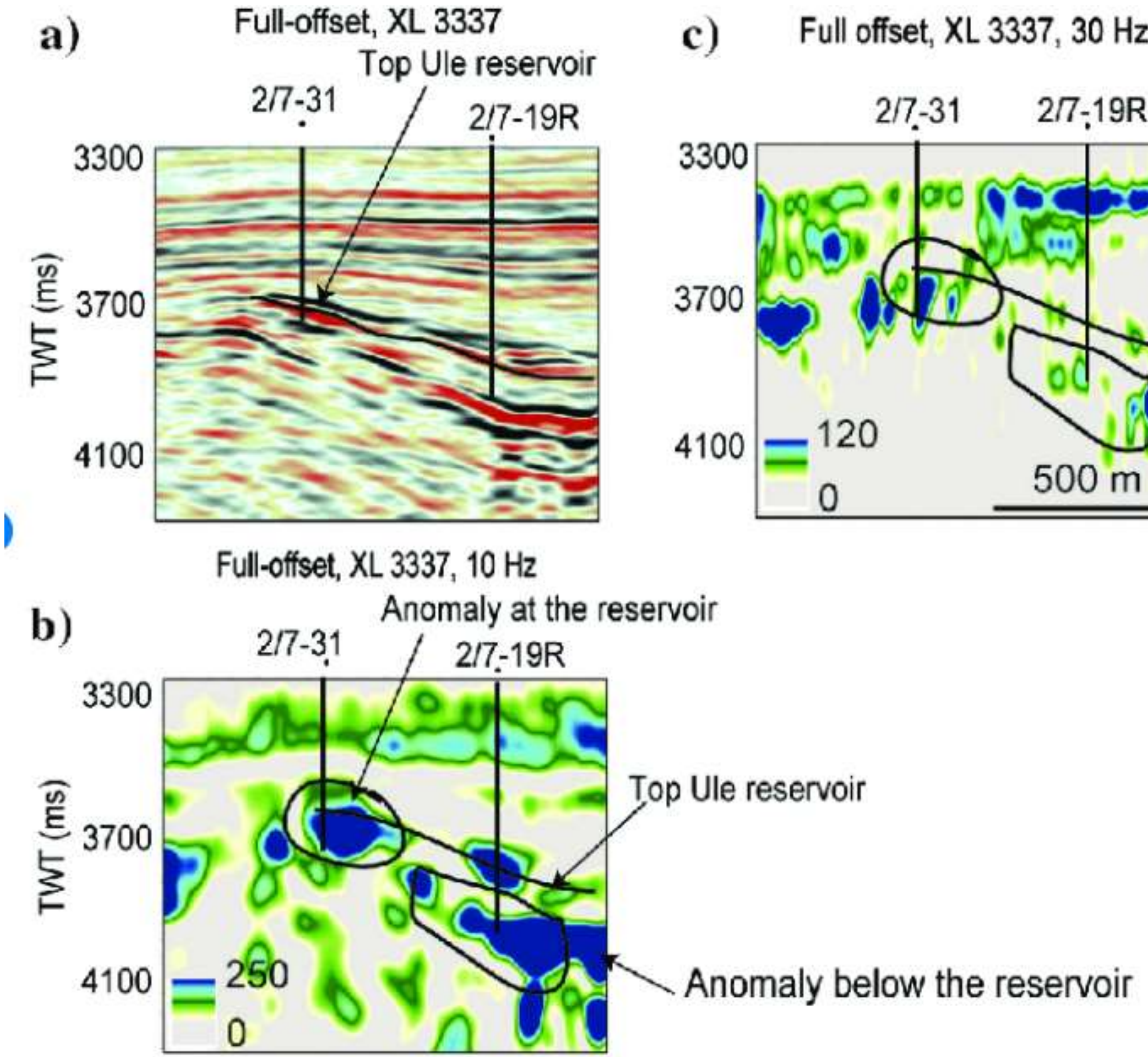
AVO (Amplitude Versus Offset)

Variation in seismic reflection amplitude with change in distance between shot point and receiver that indicates differences in lithology and fluid content in rocks above and below the reflector.



https://glossary.oilfield.slb.com/en/terms/a/amplitude_variation_with_offset

Low Frequency Anomaly



(Ahmad, et all. 2017)

DHI'S PITFALLS

1. PROBLEM IN IN DIFFERENTIATING THE WELLS WITH GAS BUILDUPS AND WELLS WITH LOW-SATURATION GAS (FIZZ GAS), WHICH ARE CONSIDER DRY HOLES.

- DRY HOLES ARE OFTEN INTERPRETED AS FALSE POSITIVES; WHICH ARE OFTEN FOUND IN TIGHT RESERVOIRS AND THICK WET SANDS

- LOW-SATURATION GAS PHENOMENON IS OFTEN RELATED TO A BREAK IN A RESERVOIR SEAL AND IS DUE TO RESIDUAL GAS THAT ASSEMBLE A HIGH AMPLITUDE EFFECT SIMILAR TO A COMMERCIAL SATURATION

2. ROCKS WITH LOW IMPEDANCE COULD MISTAKEN FOR HYDROCARBONS, SUCH AS COAL BEDS, LOW DENSITY SHALE, ASH, MUD VOLCANO, ETC.

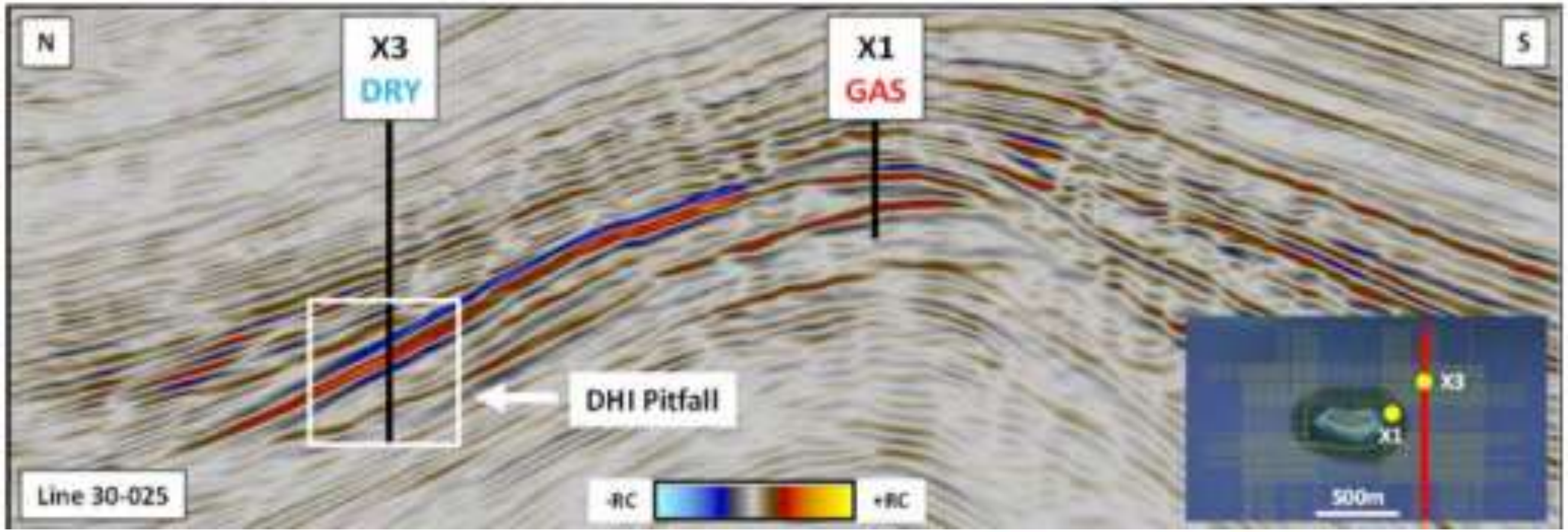
DHI'S PITFALLS

3. FLAT REFLECTIONS MAY BE CAUSED BY UNUSUAL LITHOLOGY VARIATIONS RATHER THAN FLUID CONTACTS

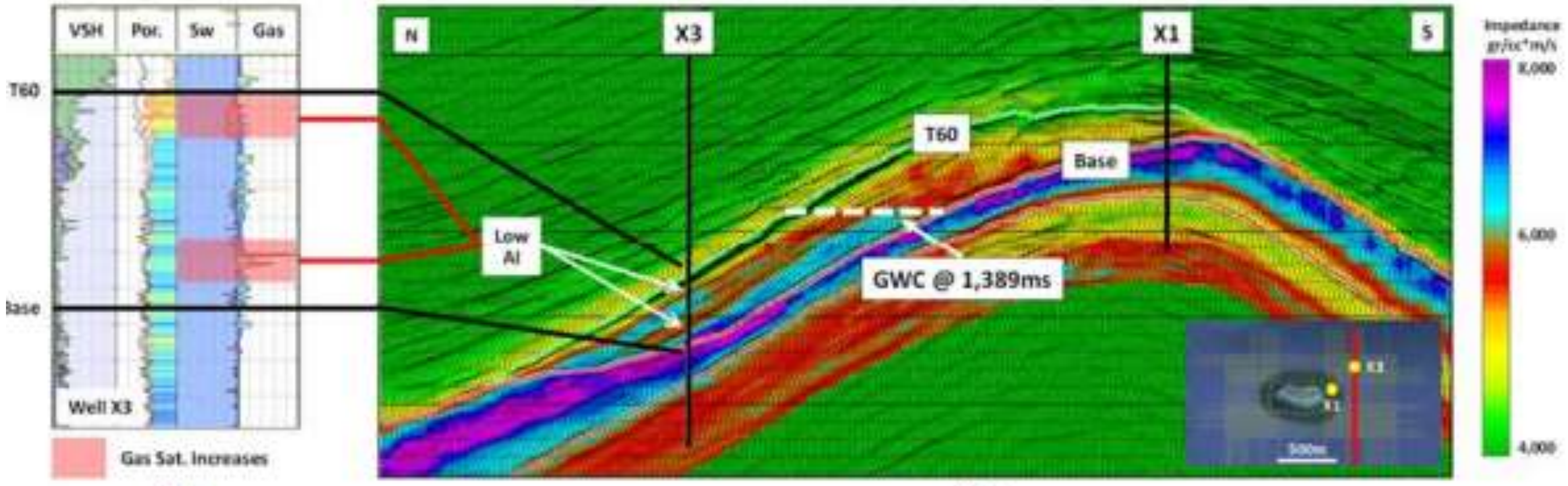
4. POLARITY OF THE DATA COULD BE INCORRECT, CAUSING BRIGHT AMPLITUDE IN A HIGH IMPEDANCE ZONE

5. SUPERPOSITION OF SEISMIC REFLECTIONS AND TUNING EFFECTS.

6. SIGNAL CONTAMINATION DUE TO NOISE.



Low gas saturation that decreases the compressional velocity (Vp) is predicted to be the main reason behind the DHI pitfall.



(a) (b)

Figure 8. (a) Well X3 log section shows that there is two zone where the gas saturation slightly increase, and (b) Model-based inversion section. Green-yellow (low AI) and blue-purple (High AI).

(Rowi, V et al, 2018)
DHI pitfall assessment in prospecting pliocene globigerina biogenic gas play in "X structure", Madura Strait, East Java Basin

HOW RISKING OUR DHI INTERPRETATION ?

Identified the DHI → Calibrated into well data information

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Used statistical to analyze the distribution and percentage the correlation on each DHI

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Ranking and Risking

Example of DHI's Risking

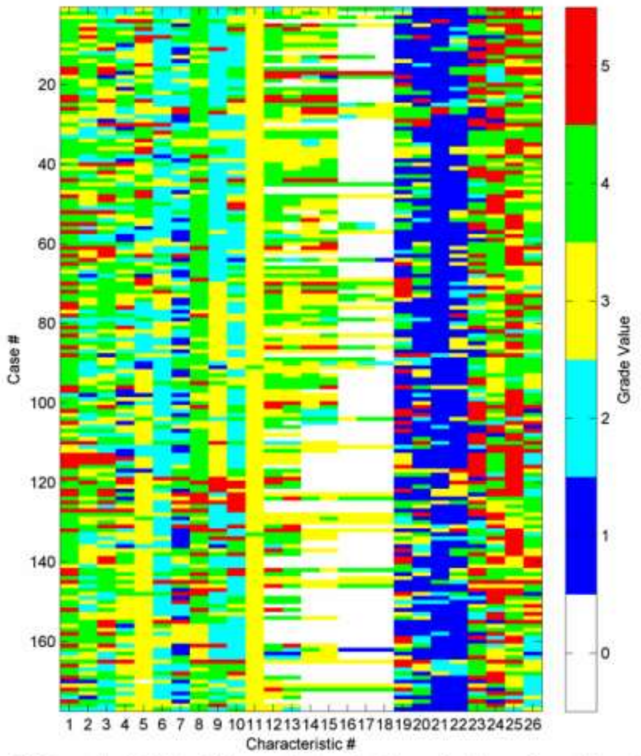

Figure 1.7: A matrix including all characteristics and values colored according to the grades.

(Sansal, A., 2014-contribution of seismic amplitude anomaly information in prospect risk analysis)

THANK YOU

Q&A