Rock Quality Index (RQI) – Based Predictive Framework for Trapped Saturation in Geologic Pore Systems

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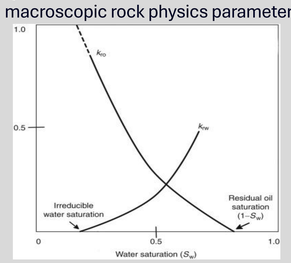
BACKGROUND

Determining depleted hydrocarbon reservoirs and potential reservoirs that require enhanced hydrocarbon recovery project highly depends on accurate prediction of residual or trapped hydrocarbon saturation.

EOR Method	Cost Est. ($/day)	Ref.
Steam Flooding	120 k - 135 k	California Energy Report.
Water Flooding	15 k - 45 k	Leading Texas Energy
CO_2 Flooding	60 k - 100 k	U.S. Energy Information Admin.

Inaccurate prediction of S_{jr} → **Waste of Investment**

S_{jr} is complex to predict due to the interplay between variations in microscopic capillary forces and macroscopic rock physics parameters.



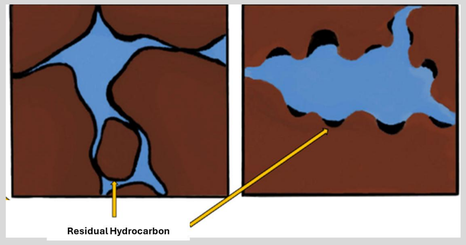


Figure 1 a and b: Saturation trapping in geologic porous media.

OBJECTIVES

1. Provides a simple yet physically reliable way to predict S_{jr} by linking measurable petrophysical indices to the physical mechanisms controlling residual trapping.

2. Show that $S_{jr} = f(S_{ji}, RQI)$ and provide better model for S_{jr} based on the parameters.

3. Postulate physical relationship of Land's C with RQI from Land's trapping equation

$$S_{gr} = \frac{S_{gi}}{1 + C\,S_{gi}}$$

INTRODUCTION

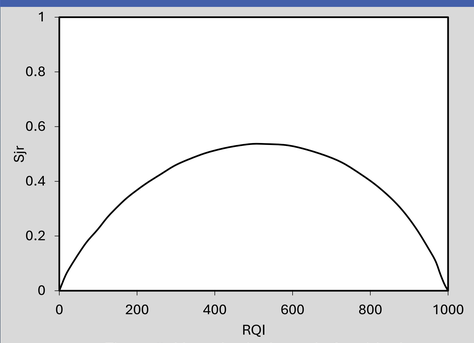


Figure 2: Hypothetical trend of residual saturation of non-wetting phase with RQI.

Equations of interest

$$RQI = \sqrt{\frac{k}{\phi}} \quad \textit{Amaefule et. al. 1993}$$

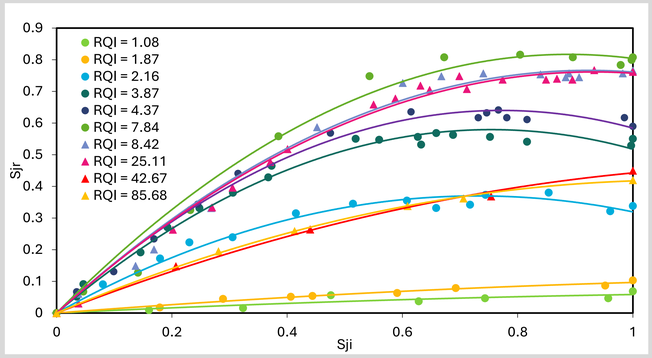
$$S_{gr} = \frac{S_{gi}}{1 + C\,S_{gi}} \quad \textit{Land 1968}$$

$$C = \frac{1}{S_{grmax}} - 1 \quad \textit{Land 1968}$$

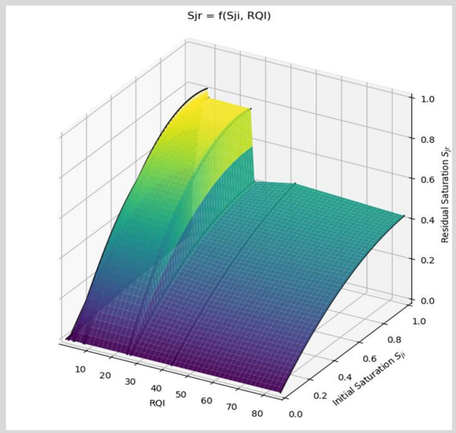
METHODS

Experimental data of k, ϕ, S_{jr}, S_{ji} ⇒ **Flow Unit Validation Analysis** ⇒ **Simultaneuously fit $RQI - S_{ji}$ path and S_{jr}** ⇒ **Predict S_{jr}**

RESULTS



Figures 3: Comparison of dependence of S_{jr} on RQI and S_{ji}.

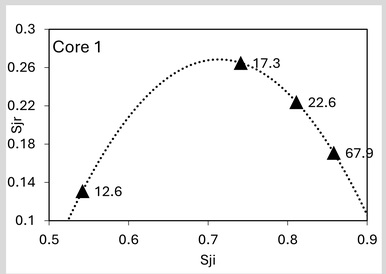


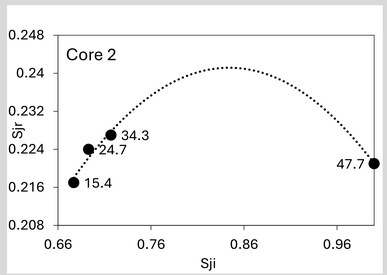
Figures 4: Surface plot depicting further decrease in S_{jr} with increase in S_{ji} at a certain RQI threshold.

Final Equation

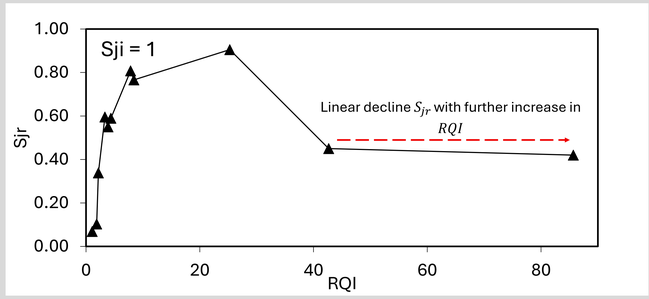
$$S_{jr} = \frac{a\,S_{ji}RQI}{1 + b\,S_{ji}^{c} + d\,RQI^{2}}$$

$$\ldots.(a, b, c, d \geq 0)$$

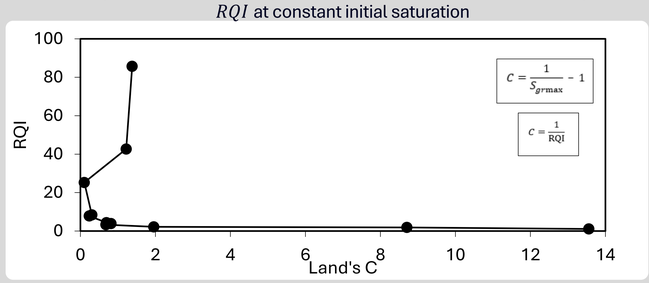




Figures 5a and 5b: Illustrating relationship using different formation cores.



Figures 6: Trend showing non-wetting phase relationship with High RQI at constant initial saturation



Figures 7: Illustrating that Land's C is dependent on RQI. Literature reveals that C is dependent on rock type, curvature, wettability, pore structure.

CONCLUSION

- It is accurate to argue that several petrophysical parameters influences S_{jr} prediction. However, most of these parameters are not easy or cheap to measure.
- The idea of this study is to show an affordable means to accurately estimate S_{jr} with easily measurable static and dynamic petrophysical data.
- S_{jr} has been excellently shown to be a function of S_{ji} and pore structure define as RQI.
- Unlike existing saturation trapping equations, this is the first to capture a clearly defined influence of pore structure.

REFERENCES

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