PERMEABILITY CORRELATIONS FOR CARBONATE & OTHER ROCKS


Presentation rev. 3

Otis P. Armstrong, PE
The form: $k \text{ (md)} = 10\phi^{1.5}(1/Sw-c - 1)^{1.9}$
(if $k$ calc > 200, use 1, not 10)

It is presented to improve description of potentially productive zones of carbonates.

Equations that do not use the form: $(1/Sw-c - 1)$ cannot accurately describe $k$ at both low & high $Swc$, i.e. at $Swc=1$, $k$ must equal zero.

Following Graphs are comparisons:
Error w/ opa eqn is 10x’s less than Sch97 and 20x’s less Timur
Only 2 false negatives and 3 false positives at 1md cut point
MOBILE HC VALUE

Provided, a min k can be established, mobile HC factor is simply a mapping of the Bulk Volume Water Term, BVW. More correct K forms, with \((1/Swc - 1)^n\) are just more complex. Below is a simple derivation & recall \((N^a)(N^{-b})=N^{(a-b)}\) but \(((N^a)^b)=N^{(a*b)}\):

\[Sw-c = BVW/ \phi\] in Timor’s equation gives:

\[K_{min} = \left\{92.6(\phi)^{2.2}/(Sw-c)\right\}^2 \Rightarrow \phi_{min} = \left\{\sqrt{K_{min} \times BVW/92.6}\right\}^{0.313}\]

and using these terms in the movable HC formula:

\[\phi(S_{wc}^{0.2} - S_{wc})7760 = 7760\{\phi(\phi \ S_{wc}/\phi)^{0.2} - BVW\} = BBL/AcFt = 7760\{\phi^{0.8}(BVW)^{0.2} - BVW\} \Rightarrow K_{min} \text{ RULE: } 7760\left\{\sqrt{K_{min} /92.6}\right\}^{0.25}(BVW)^{0.513} - BVW\]

Other forms give similar results, but with limited range:

\[\text{Max Swc RULE: } (BBL/ AcFt)_{mo} = 7760(BVW)[(S_{wc})^{-0.8} - 1]\]

\[\phi_{min} \text{ RULE: } (BBL/ AcFt)_{mo} = 7760\{[\phi_{min}^{0.8} ]BVW^{0.2} - BVW\}\]
At each BVW, a MINIMUM mobility of BBL/AcFt is defined using a parametric of Porosity or Connate Water or k.
Plot of Core Data as BVW & Mobility Ratio: BBL/AcFt Minimum Proposed at 0.2md line or $780BVW^{0.44}$
Increased mobility ~ increased chance depo is economical 90% of all USA crb prdn from depo >130bbl/ acft. US data shows: prospecting in low $\phi$ Siluran & older rocks; success rates 2-4x’s higher if dolomites are tested compared to developing simular age & $\phi$ limestone rocks.
2nd $\phi$ & Vug Carbs: => bimodal pores

In logging terms: movable HC is:

$$\text{BBL/ AcFt} = 7760[\sqrt{a}] * [\sqrt{\frac{Rmf}{Rxo}} - \sqrt{\frac{Rw}{Rt}}]$$

at irreducible $\text{H2O} = 7760\{\sqrt{\frac{Rw}{aRt}}\} \left(\frac{S_{wc}}{S_{wc} - 1}\right)^{-0.8}$$

Where $a$ is term to make $F = (a/\phi^2)$, typically $a=1$ in carb.
Summary

- Typical conditions, production < 900 & > 130 bbl/ac-ft.
- Mobile HC expressed as BBL/Acft is a handy way to evaluate deposit, provided lithology is understood.
- The closer values are to litho-minimums, the less the chances of economic HC extraction.
- Low mobility values also indicate low permeability, w/o bimodal pores.
- Higher values indicate higher effective porosity.
- Watch for chalk & silt porosity types as they have higher min’s.
- Rocks with < 140 bbl/AcFt = cap rocks unless Vug or coarse ss porosity types.
- USA prdn data show Vug type more often dolomite, more brittle & dolomites more often in Siluran & older formations.
Upper Ordovician Zone, Clean Carbonate, Western Latvia

movable HC
36 wells W. Latvia
bbl/acft bbl/acft
200 235 max
94 131 avg
60 90 std
36 n
IX LS clean

Indication in 36 wells: this zone is a Cap Rock, typically <140 & does not contribute to oil flow, remove this zone in Htests.
<table>
<thead>
<tr>
<th>Horner Analysis</th>
<th>Danish</th>
<th>OPA/core</th>
</tr>
</thead>
<tbody>
<tr>
<td>t, m</td>
<td>10</td>
<td>0.62</td>
</tr>
<tr>
<td>por %</td>
<td>11</td>
<td>17.4</td>
</tr>
<tr>
<td>k, md</td>
<td>2.5</td>
<td>40.5</td>
</tr>
</tbody>
</table>

Horner gives md-m
Geol. Factors = thickness
cores show ~1m sucrosic LS

Indications are: oil flow is from thin lower sucrosic LS/Dolo
Thanks for hearing my considerations. A more detailed Discussion is available by email request.

‘otis-a@oiljetpump.com’