Dual Water Model (DW) @model

One of the saturation from resistivity models.

The dual-water model accounts for the fact that different shales have different shale-bound water saturation $s_{wb} = \frac{V_{wb}}{V_t}$:

$$\phi_t = \phi_e + \phi_t s_{wb}$$

so that formation water saturation s_w is related to total water saturation $s_{wt} = \frac{V_{wb}+V_w}{V_t}$ as:

$$s_w = \frac{s_{wt} - s_{wb}}{1 - s_{wb}}$$

Rock volume V is a sum of rock matrix volume V_m and total pore volume V_t :

$$V = V_m + V_t = (1 - \phi_t)V + \phi_t V$$

where

$$\phi_t = \frac{V_t}{V}$$

Total pore volume V_t is a sum of shale-bound water V_{wb} and free fluid volume V_e (water and hydrocarbons):

$$V_t = \phi_t V = V_e + V_{wb} = \phi_e V + s_{wb} V_t$$

where

$$V_e = V_t(1 - s_{wb})$$

and therefore:

$$\phi_e = \phi_t(1 - s_{wb})$$

Total volume of water is a sum of shale-bound water V_{wb} and free water V_{wf} :

$$V_{wt} = V_{wb} + V_{wf}$$

and relates to V_t as:

$$s_{wt} V_t = s_{wb} V_t + s_w V_e = s_{wb} V_t + s_w V_t (1 - s_{wb})$$

or

$$s_{wt} = s_{wb} + s_w (1 - s_{wb})$$

which gives an explicit formula for formation water saturation:

$$s_w = \frac{s_{wt} - s_{wb}}{1 - s_{wb}}$$

Formation resistivity R_t is given by the following correlation:

$$\frac{1}{R_t} = \phi_t^m s_{wt}^n \left[\frac{1}{R_w} + \frac{s_{wb}}{s_{wt}} \left(\frac{1}{R_{wb}} - \frac{1}{R_w} \right) \right] \quad \Rightarrow \quad s_w = \frac{s_{wt} - s_{wb}}{1 - s_{wb}}$$

where

$s_{wb} = \frac{V_{wb}}{V_t}$	shale-bound water saturation
$s_{wt} = \frac{V_{wb}+V_w}{V_t}$	total water saturation (shal-bound water and free-water)

R_{wb}	specific electrical resisitvity of shale-bound water

In simple case when all shales have the same properties, the shale-bound water saturation can be expressed through the shaliness as:

(1) $$s_{wb} = \zeta_{wb} V_{sh}$$

s_w	formation water saturation	
s_{wb}	bound water saturation	
ϕ_e	effective porosity	
V_{sh}	shaliness	
R_t	total measured resistivity from OH logs	
R_w	formation water resistivity	
R_{sh}	wet clay resistivity	
A	dimensionless constant, characterising the rock matrix contribution to the total electrical resistivity	0.5 ÷ 1, default value is 1 for sandstones and 0.9 for limestones
m	formation matrix cementation exponent	1.5 ÷ 2.5, default value is 2
n	formation matrix water-saturation exponent	1.5 ÷ 2.5, default value is 2

In some practical cases, the clay resisitvity R_{sh} can be expressed as:

(2) $$\frac{1}{R_{sh}} = B \cdot Q_V$$

where

B	conductance per cat-ion (mho · cm^2/meq)
Q_V	Cation Exchange Capacity (meq/ml)

and both can be measured in laboratory.

The other model parameters still need calibration on core data.

See Also

Petroleum Industry / Upstream / Subsurface E&P Disciplines / Petrophysics

Well & Reservoir Surveillance / Well logging / Reservoir Data Logs (RDL) / Formation Resistivity Log @model