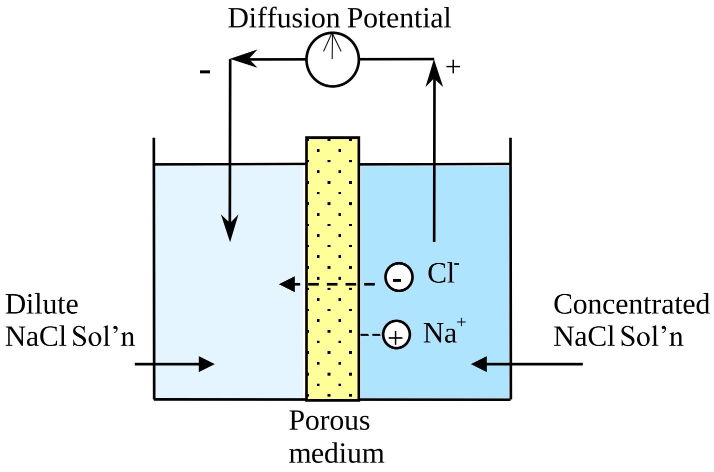
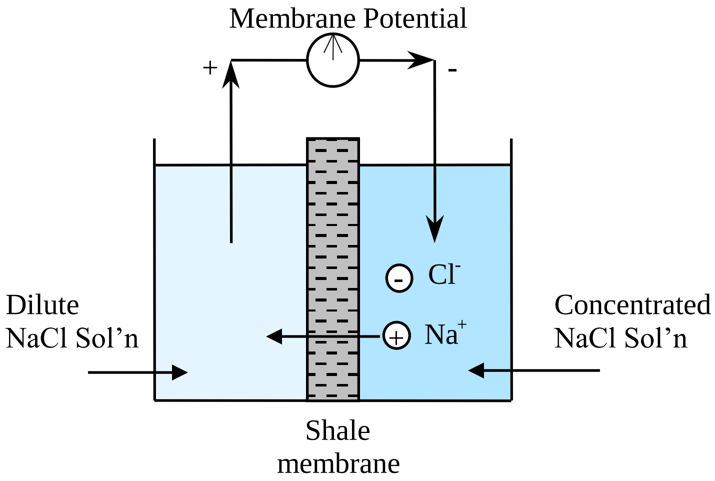
Definition of Potential Cells



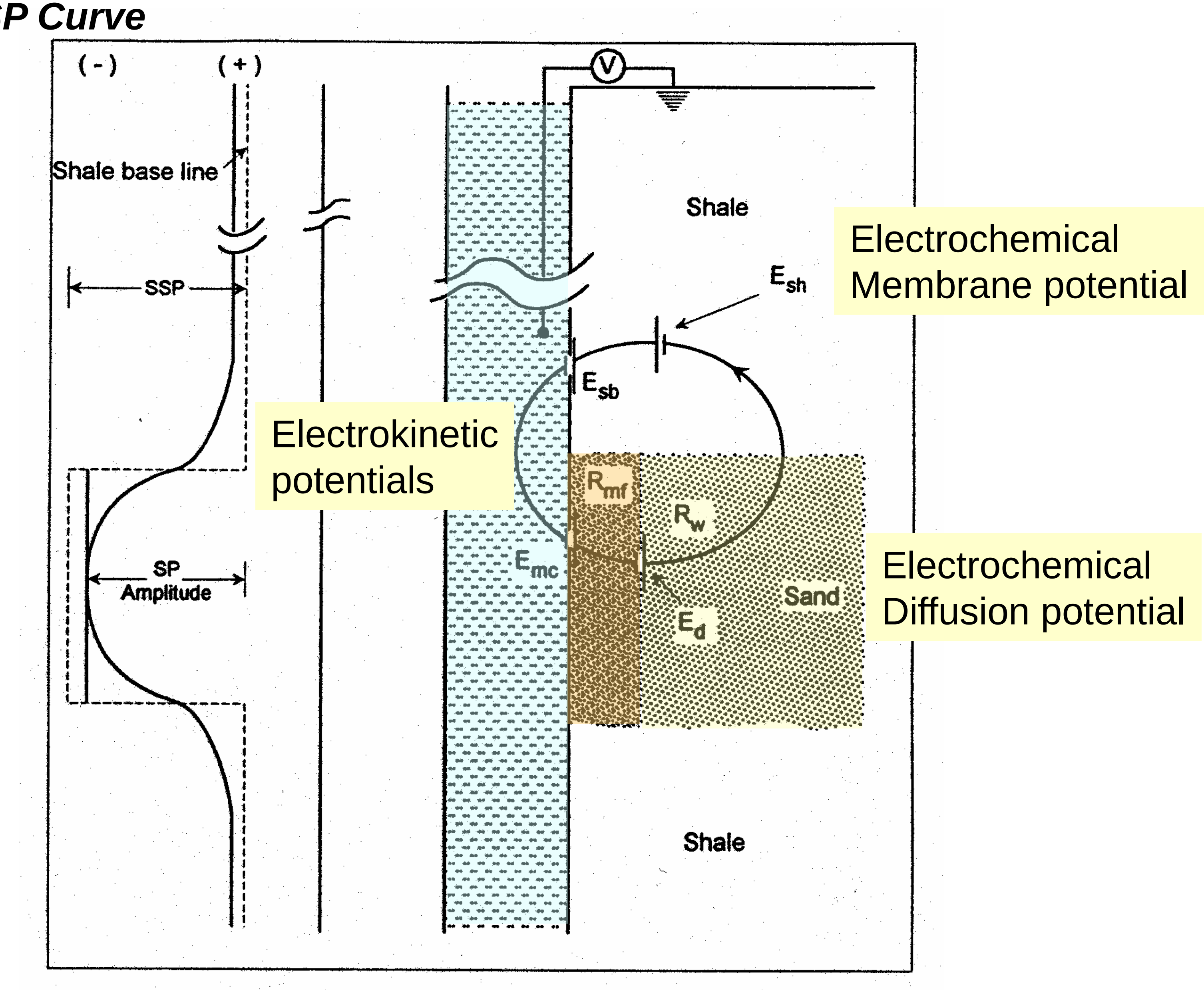


Schematic of diffusion-potential generating cell

Schematic of a membrane-potential generating cell

SP Log

Origin of SP Curve



SP (Spontaneous Potential) Log

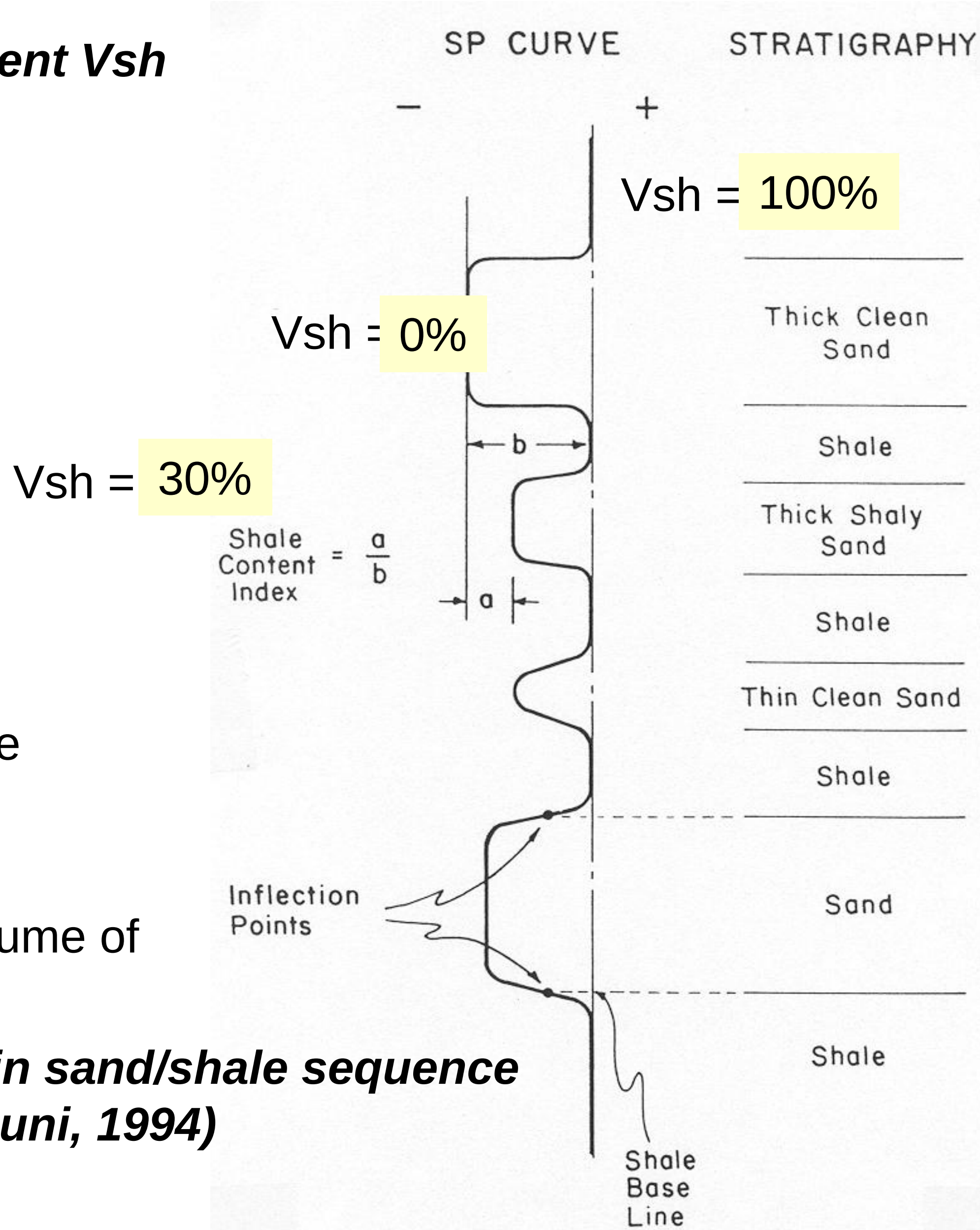
USES

The SP log is used for:

A. Identifying permeable bed boundaries
B. Stratigraphic correlations
C. Determination of formation resistivity factor, F
D. Estimation of shale content (Vsh) for shaly sand formations.
E. Determination of formation water resistivity, Rw
F. All of the above

SP Log

Estimation of shale content Vsh



<u>Assumptions</u>

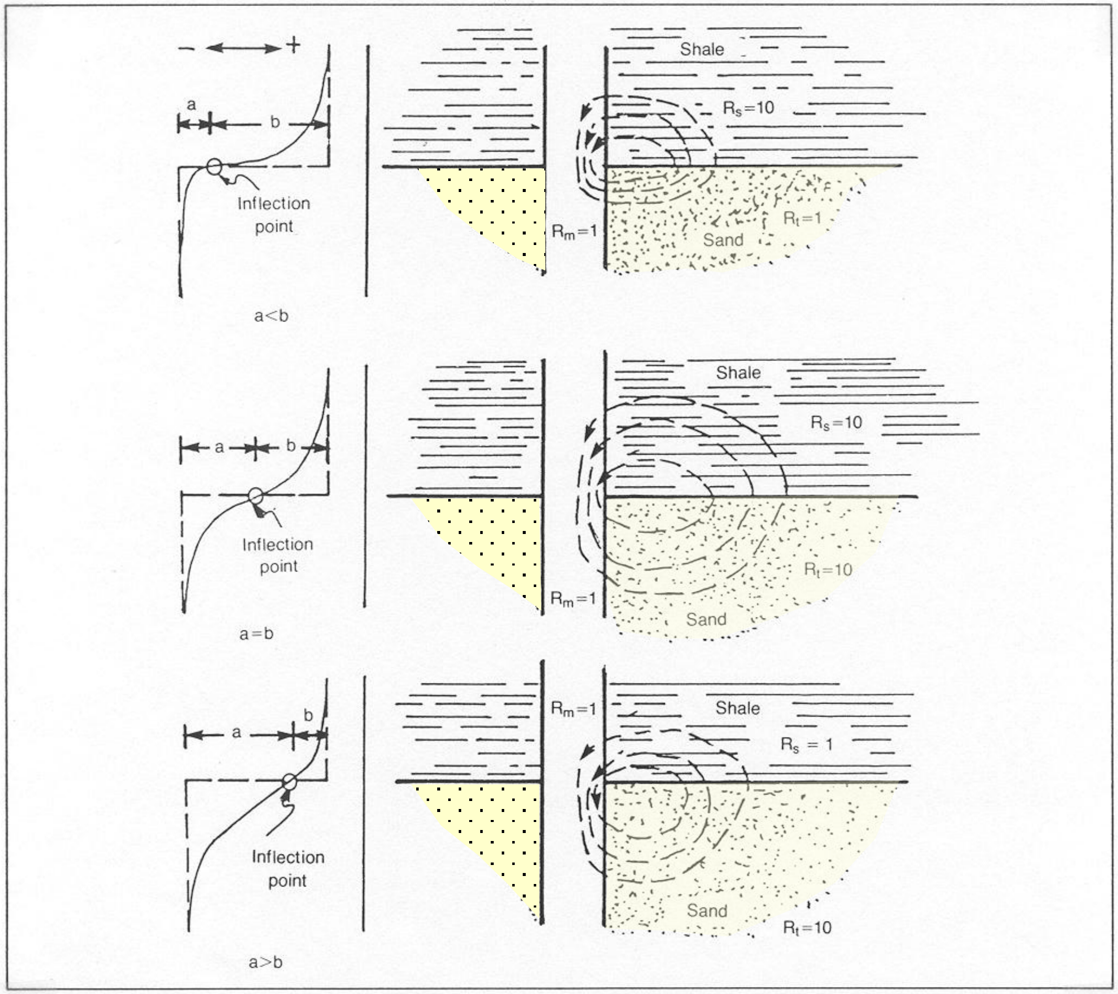
zones of same salinity, shale type....

Typically, overestimates volume of shale

Schematic SP curve in sand/shale sequence (Bassiouni, 1994)

SP Log

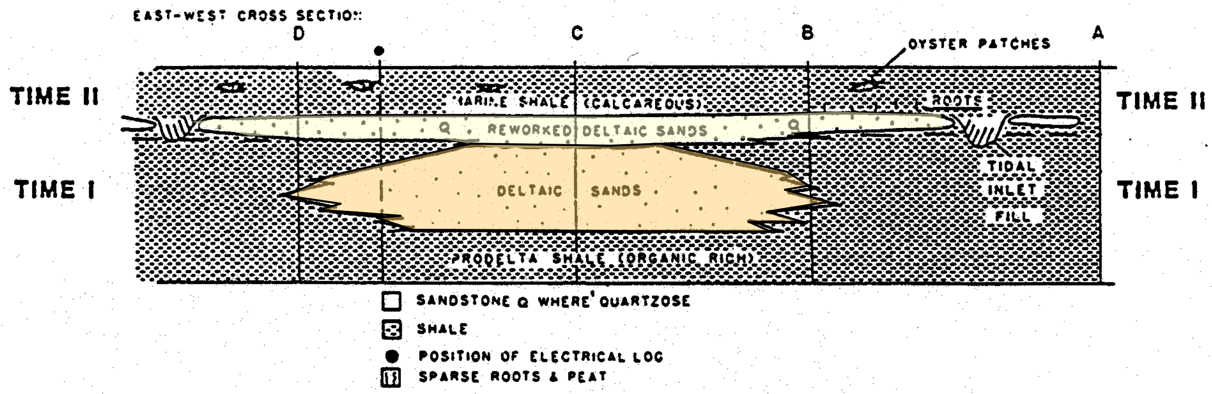
Identification of boundaries (Helander, 1983)



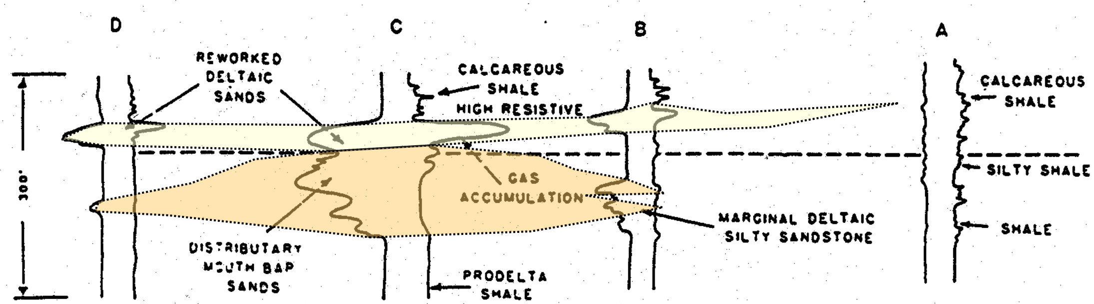
SP shape as a function of current distribution

SP Log

Stratigraphic Correlation



Depositional model for reworked deltaic sands. (A) Plan view setting, (B) Cross section geometry. Note the thickness variations and the differences of areal extent between the lower deltaic sands and the upper reworked sands.



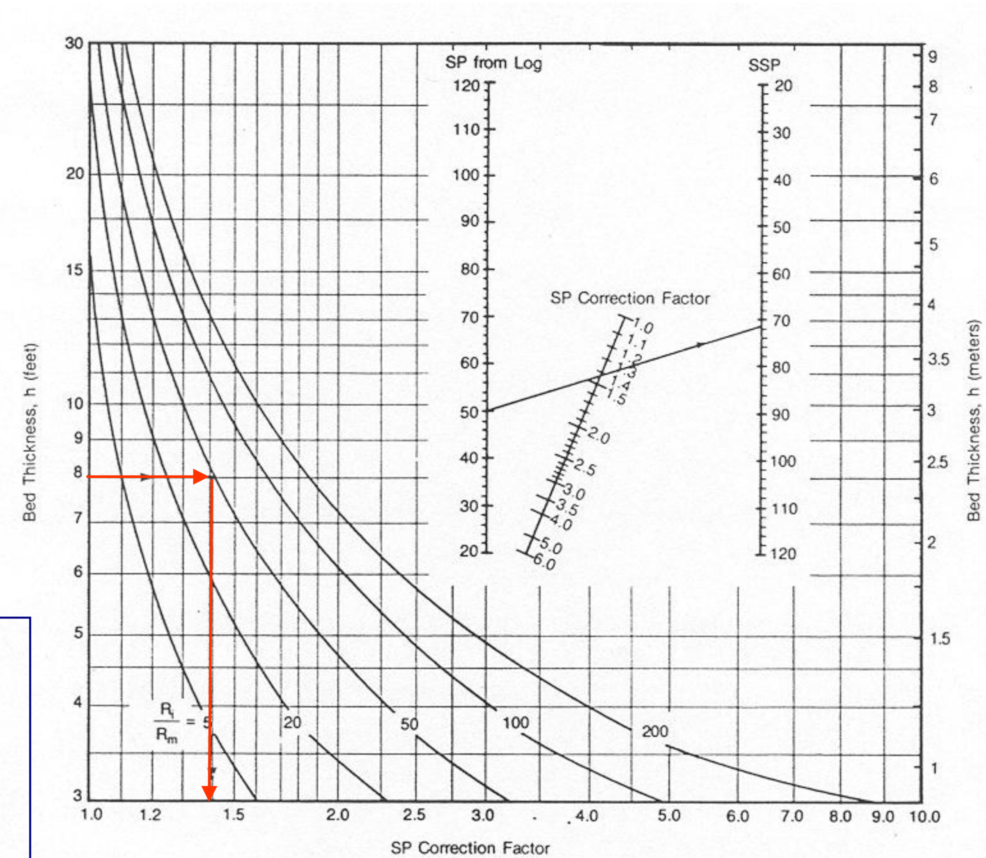
An electric log cross section showing the lateral variation of sandstones in the reworked deltaic setting. This cross section is keyed to the lithologies in above. (After Saxena, 1979)

Procedure to Obtain Rw

- Identify the shale baseline and clean sand lines on the SP log. The difference is SP.
- Calculate the formation temperature
- Convert $(R_{mf})_{Tm}$ => $(R_{mf})_{Tf}$
- If necessary, correct SP for bed thickness and invasion effects. Read bed thickness, h and invaded resistivity, R_i. Obtain SSP.
- If necessary, Convert R_{mf} @ T_f to R_{mfe} @ T_f.
- Calculate R_{we} by:
- Convert R_{we} to R_w.

$$R_{we} = R_{mfe} * 10^{\left(\frac{SSP}{61+0.133T_f}\right)}$$

Bed thickness/invasion correction (Western Atlas, 1992)



$$\text{SP correction factor} = \frac{\left\{4\left(\frac{R_i}{R_m}+2\right)\right\}^{\frac{1}{3.65}} - 1.5}{h - \left\{\left(\frac{R_i}{R_m} + 11\right)/0.65\right\}^{\frac{1}{6.05}} - 0.1} + 0.95$$

for $\frac{R_i}{R_m} > 5$ and $3 < h < 50$, for h in feet.

SSP = SP × SP correction factor

Example:

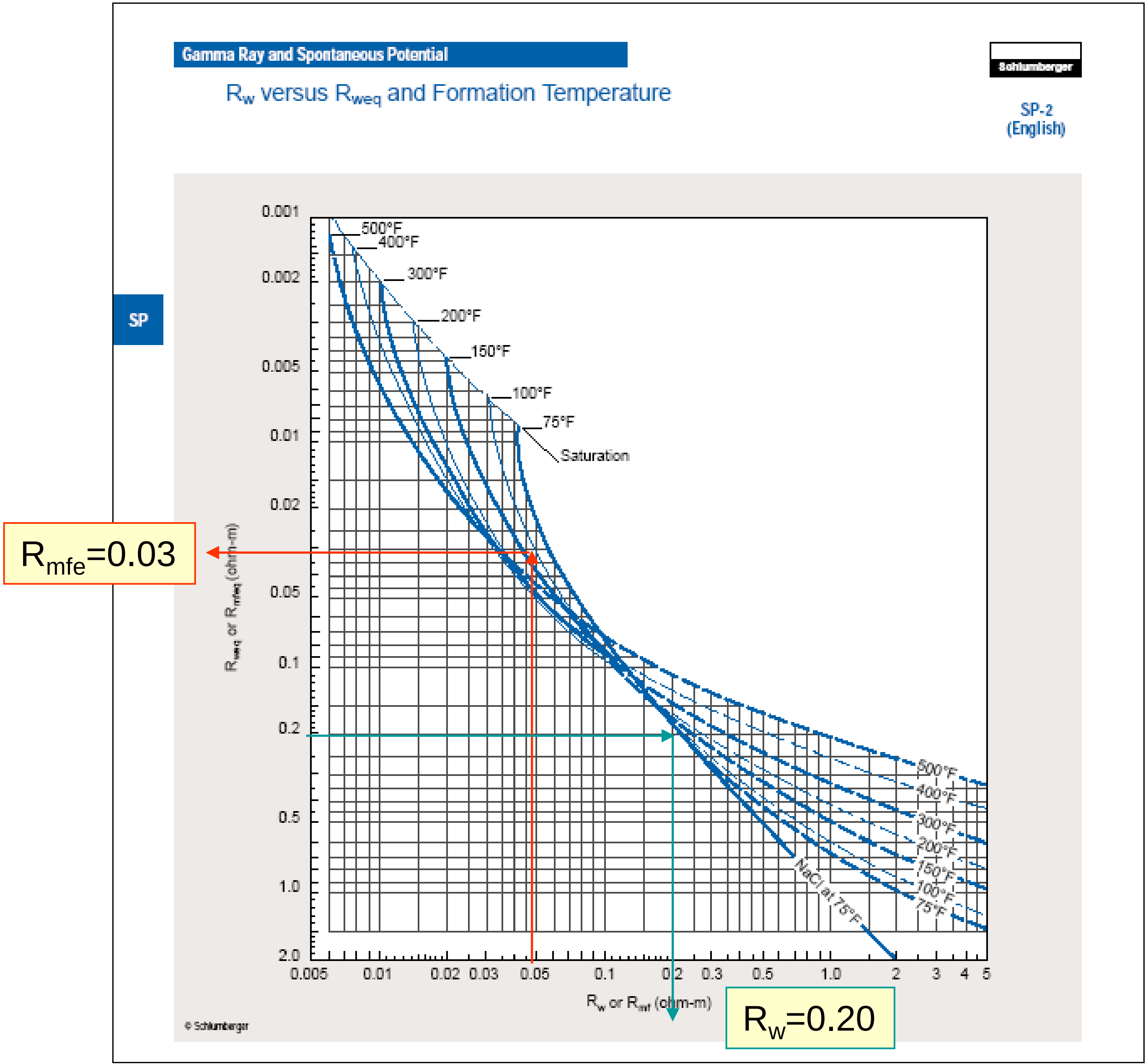
Given: $SP_{(log)}$ = − 50 mV; h = 8 ft; R_i = 35 Ωm; R_m = 0.7Ωm

Solution: Bed thickness = 8 ft; R_i/R_m = 50; SP correction factor = 1.42

Nomograph Solution: SP_{log} = − 50 mV; SP correction factor = 1.42; SSP = − 71 mV

SP Log

Application-Rw



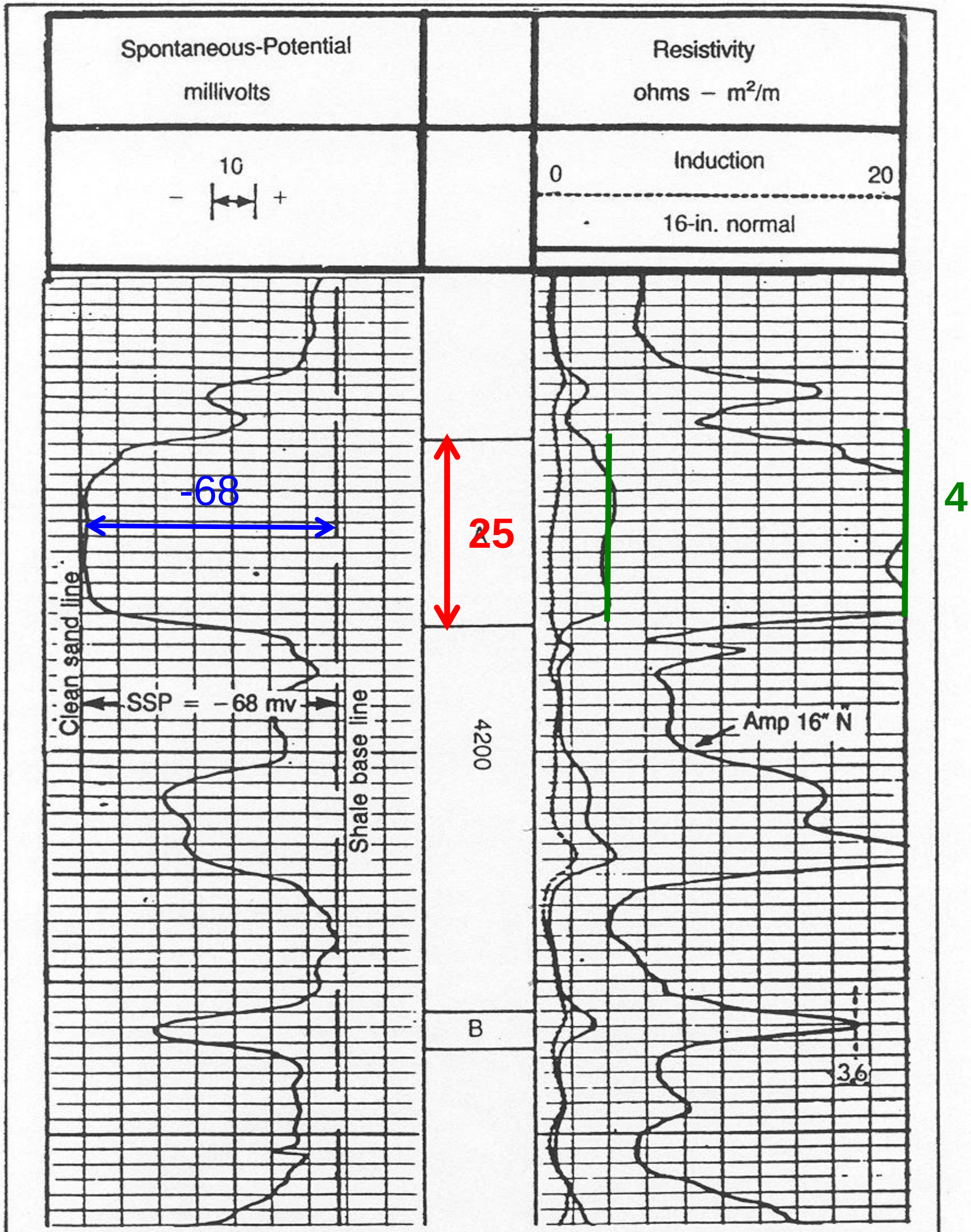
SP Log

Example

SP = -68 mV

Ri = 4 ohmm

H = 25 ft



SP Log

Example

The example is a SP - resistivity log over a series of sands and shales. Referring to the figure, compute Rw for zone A. The following information is given:

TTD= 196 deg F @ TD = 9,400 ft. Gulf Coast well

Rmf = 0.71 @ Tm =68 deg. F Rm = 1.00 @ Tm =68 deg. F

Step 1: Determine the SP value as the difference between the shale baseline and the thick, clean sand line. The shale line is taken as the maximum SP excursion to the right. The sand line is taken as the maximum deflection to the left in the zone of interest.

Step 1: *The shale baseline and clean sand line are drawn on the figure.*

SP = -68 mV is the potential difference.

Step 2: The formation temperature is obtained by linear interpolation between the mean surface temperature and the recorded bottomhole temperature from the log.

SP Log

Example

Step 2: *The formation temperature can be computed by:*

$$T_f = (196 - 75)\frac{4170}{9400} + 75 = 129\,°F$$

Step 3: The R_{mf} and R_m at a measured temperature from the log heading, must be converted to formation temperature.

Step 3: *The Rmf at formation temperature is:*

$$(R_{mf})_f = 0.71\left(\frac{68 + 6.77}{129 + 6.77}\right) = 0.39\,\Omega - m$$

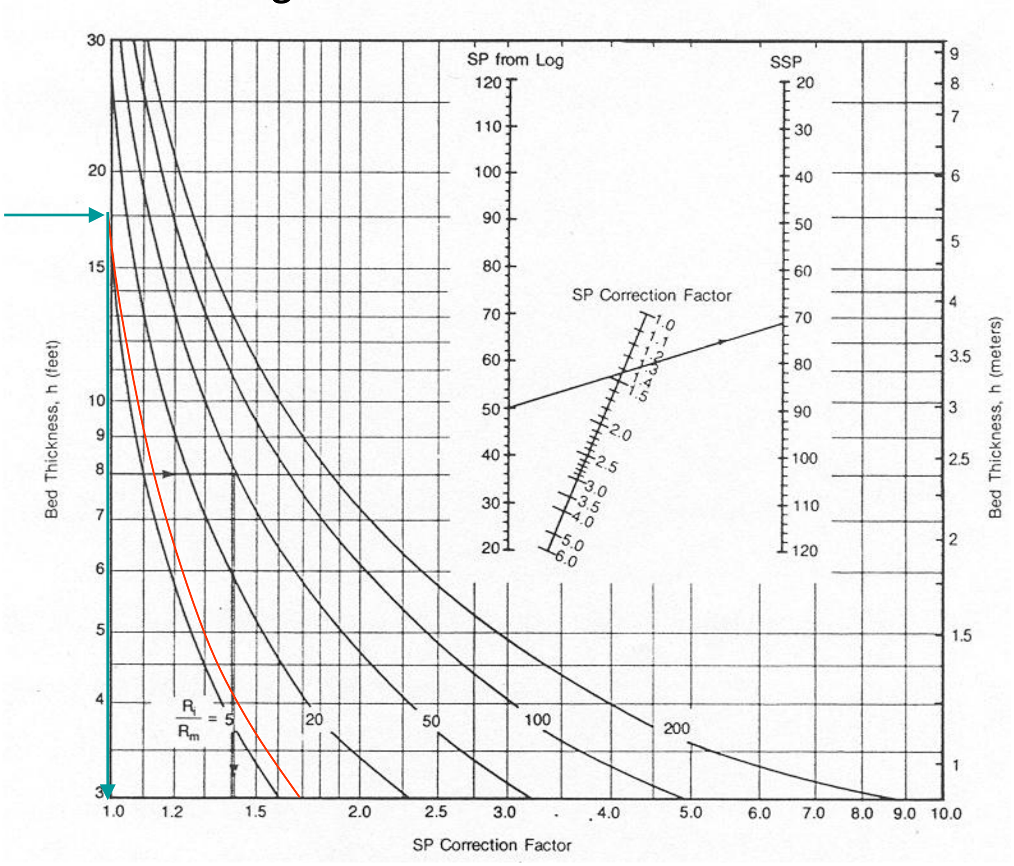
Similarly, Rm = 0.55 ohm-m @ Tf

Step 4: The SP reading must be corrected for bed thickness and resistivity effects. Thin beds and deep invasion reduce the amplitude of the SP to less than the desired SSP. Enter the figure with the bed thickness and invaded-zone resistivity from a short normal, SFL or LL8 and estimate the correction factor.

Example

Step 4: *Bed thickness = 25ft.; Ri, = 4 ohm-m from the 16" short normal; thus Ri/Rm = 7.2 ≈7.5.*

From the figure the correction factor = 1.00.



Example

Step 5: The mud filtrate resistivity (Rmf) at formation temperature calculated from Step 3, must be corrected to Rmfe, for use in the SSP equation. The term equivalent is a result of two assumptions in formulating the SSP equation:

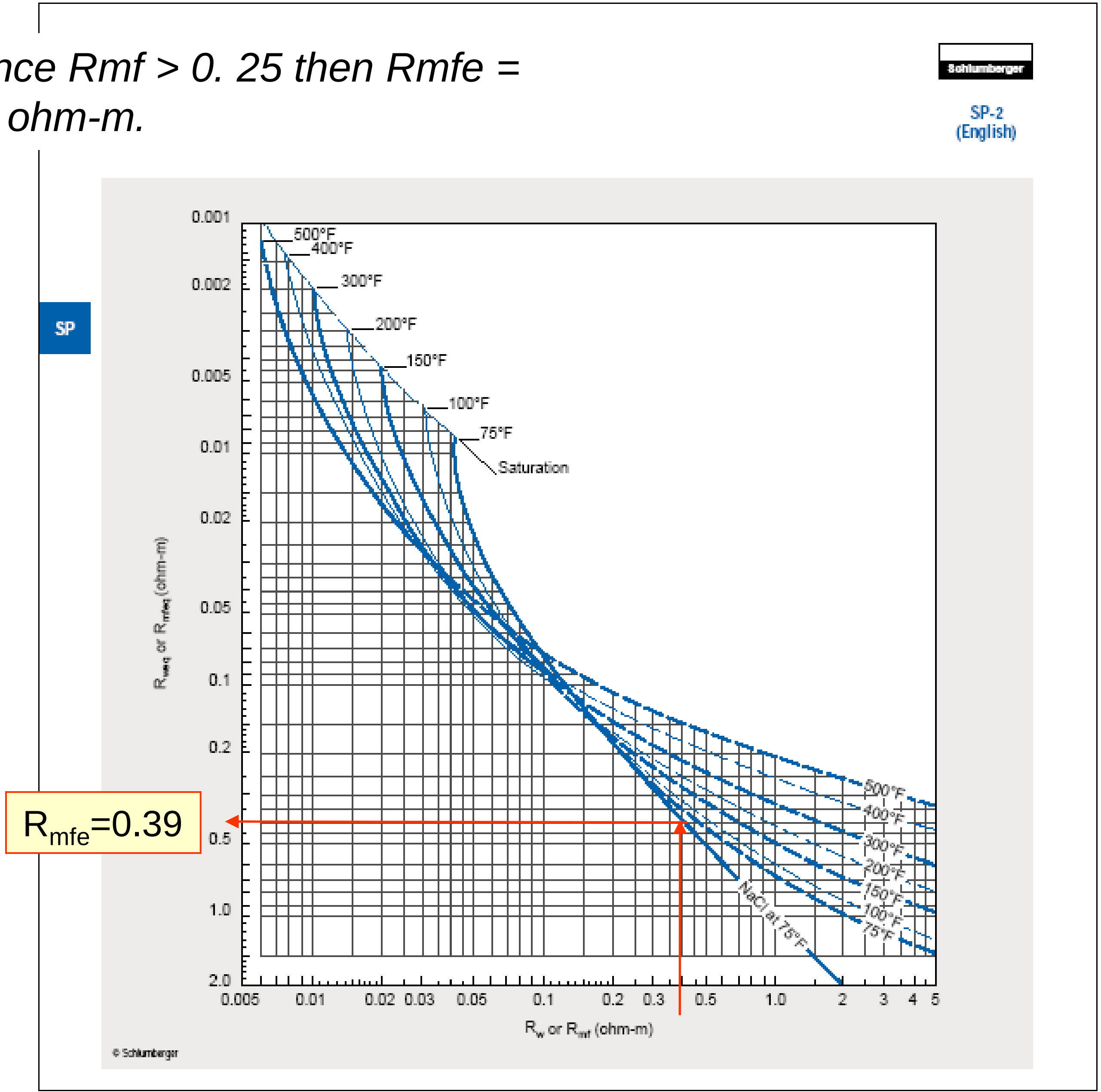
(1) formation water and mud filtrate are NaCl solutions, and

(2) activity ratios can be replaced by resistivity ratios.

Use the figure to convert from Rmf $\rightarrow$ Rmfe and from Rwe $\rightarrow$ Rw

(Do not use the dashed lines, they are for gyp-based muds).

Step 5: *Since Rmf > 0. 25 then Rmfe = Rmf= 0.39 ohm-m.*



Example

Step 6: Calculate Rwe by using:

$$R_{we} = R_{mfe} * 10^{\left(\frac{SSP}{61+0.133T}\right)}$$

Step 6: *Calculate the equivalent formation water resistivity.*

$$R_{we} = 0.39 * 10^{\left(\frac{-68}{61+0.133(129)}\right)} = 0.052\ \Omega - m$$

Step 7: Use the equivalence conversion chart to convert Rwe to Rw.

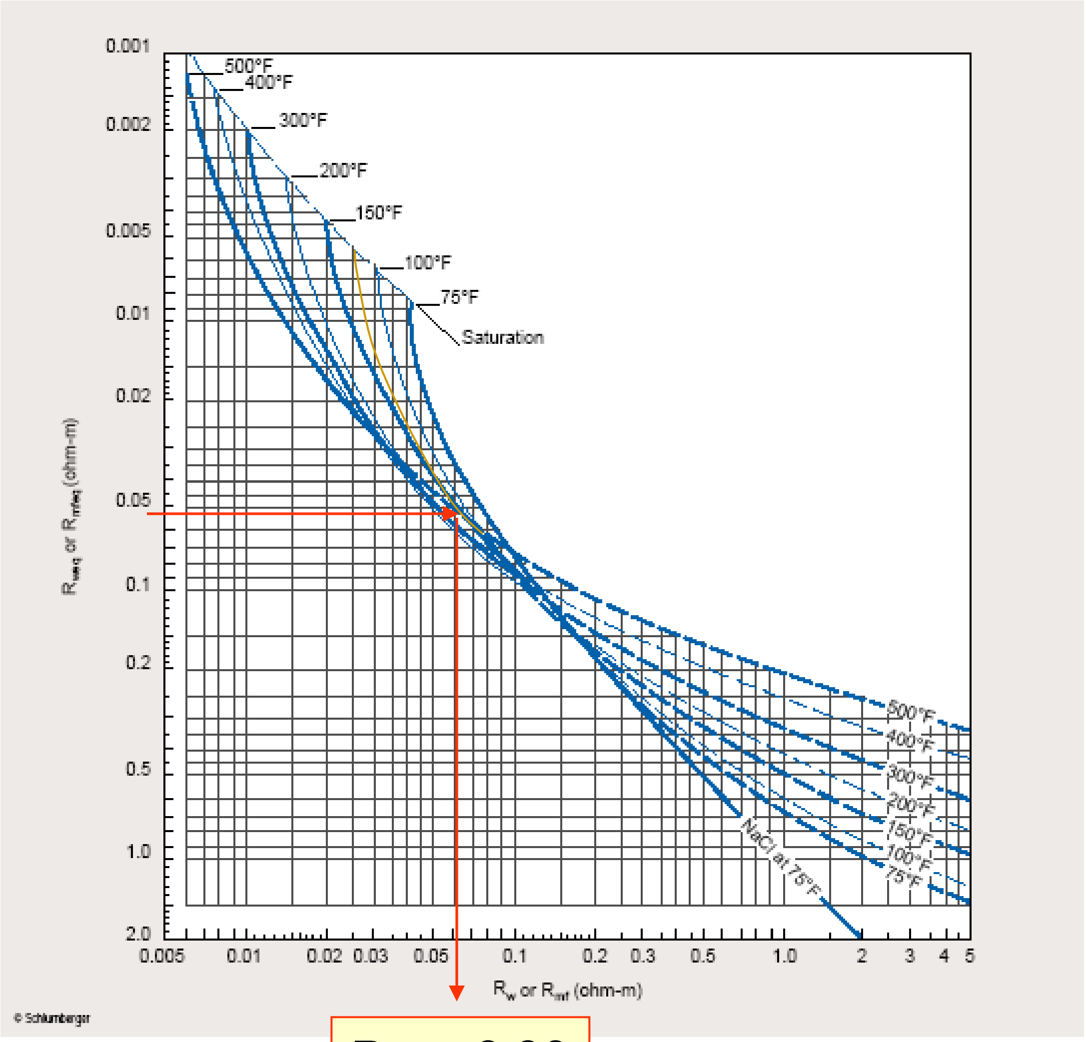
SP Log

Application-Rw

Example

Step 7:

Rw = 0. 060 ohm-m

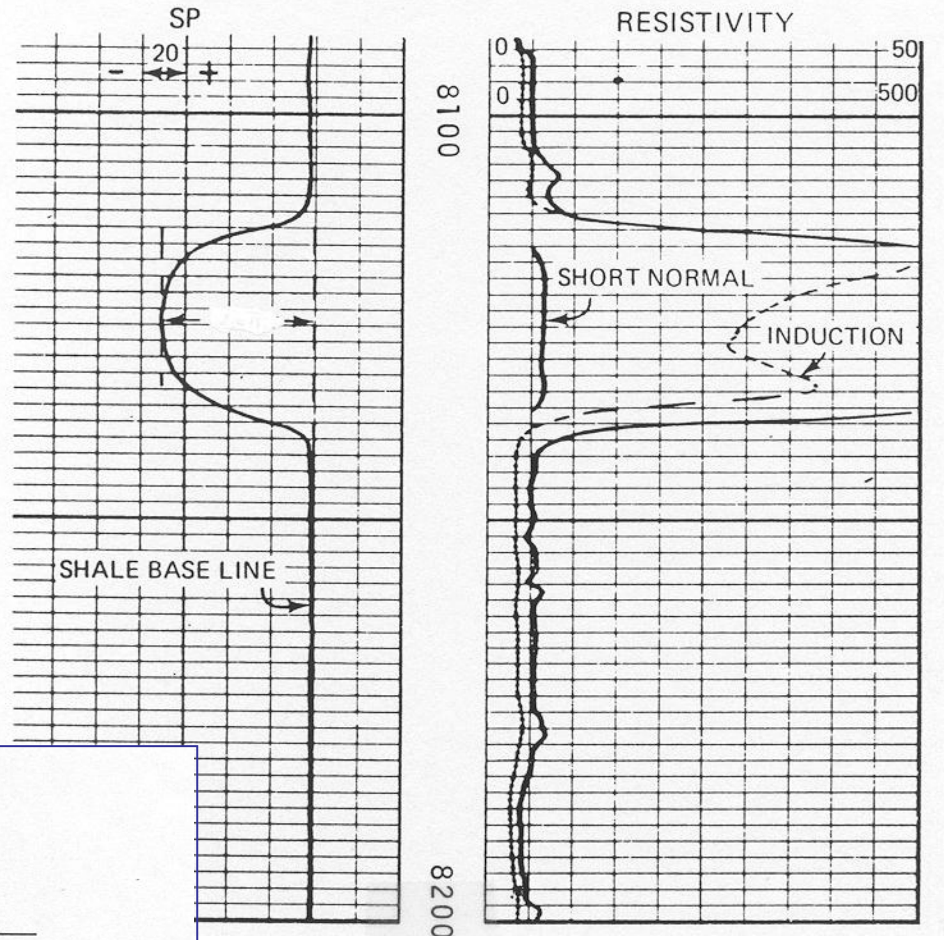


Rw = 0.06

SP Log

Exercise

Well Log Heading Data: Formation – Morrow sandstone
R_{mf} = 2.0 @ 70°F surface temp. = 60°
R_m = 2.5 @ 70 TD temp. 164 TD = 10500



SP ALGORITHM

1. T_{TD} ________ TD ________ T_o ________ T_f ________
2. R_{mf} = _____ @ _____F R_m = _____ @ _____F R_{mf} @ T_f = ________
   R_m @ T_f = ________
3. SP from log ________mV.
4. Bed thickness ________ft.
5. SP correction R_i ______ R_i/R_m ______ correction factor ______
   SSP = ____ * ____ = _____
   c.f. SP
6. R_{mfe} = ______
7. R_{we} = ______
8. R_w = ______