TUFFY

Exercise TUFFY:

How to square log readings and define the lithology with the help of various logs.

Objectives:

- Getting acquainted with the relations between FDC-CNL, CNL-SONIC, FDC-SONIC, MID- and M-N plot and their relations to lithology definition.

- In this exercise correlating and squaring of logs is an important purpose for the determination of porosity .

- A comparable evaluation can be made for:
  - . porosity of surrounding rocks around coal seams and ore bodies.
  - . determination of the vertical lithology in fresh water reservoirs.

Well TUFFY-3

The well has encountered two possible reservoir sections, the Sollingen sandstone and the Detfurth. These formations are found in wide areas of Northern-Germany, The Netherlands and the North Sea as:

- Marker seams.
- Potential reservoir sands for oil, gas and water.

Reservoir characteristics:

- BHT = 83°C (at reservoir depth)
- Petrophysical parameters: m = 1.8, n = 2.0.
- The formation water has been assumed to be fully salt saturated (250000 ppm) with the R_w = 0.016 ohm.m at FT.

Production test results:

- Detfurth : 158106 m3/day gas at 50 bar draw down,
- Sollingen: not tested

Mud characteristics

- Mud type: salt water mud
- R_m = 0.076 Ohm.m at 22°C = 105000 ppm = 0.030 Ohm.m at BHT
- R_{mf} = 0.046 Ohm.m at 22 °C = 210000 ppm
- R_{mc} = 0.26 Ohmm at 22 °C

General information

Bit size = 12 1/4 inch

QUESTIONS

Sollingen Sandstone:

- Correlate and square the logs of the Sollingen Sandstone section.

- Correct the resistivities for borehole and invasion effect.

- Determine the lithology, using FDC-CNL, SONIC-CNL, MID- and M-N plot.

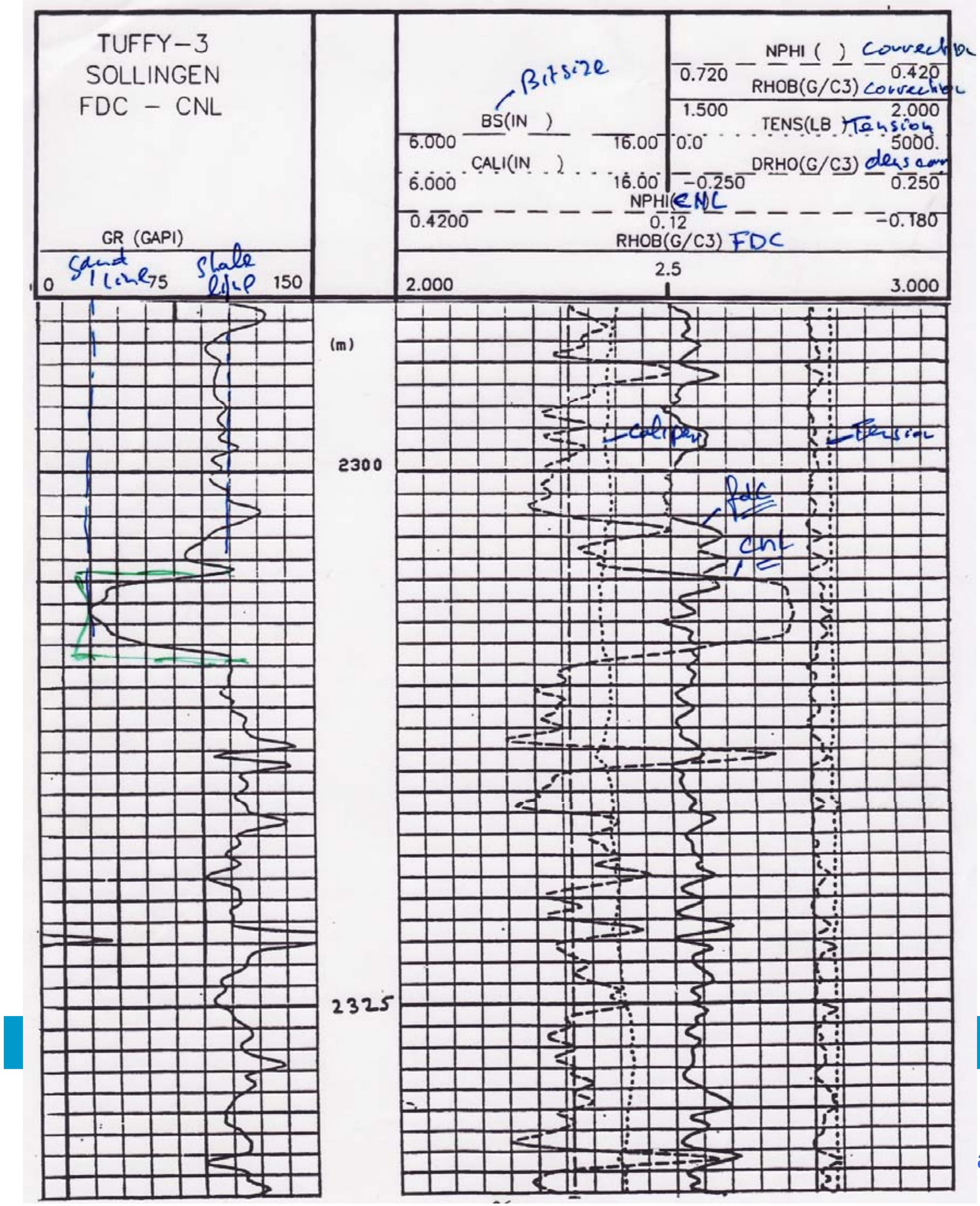
- Explain the position of the plotted points.

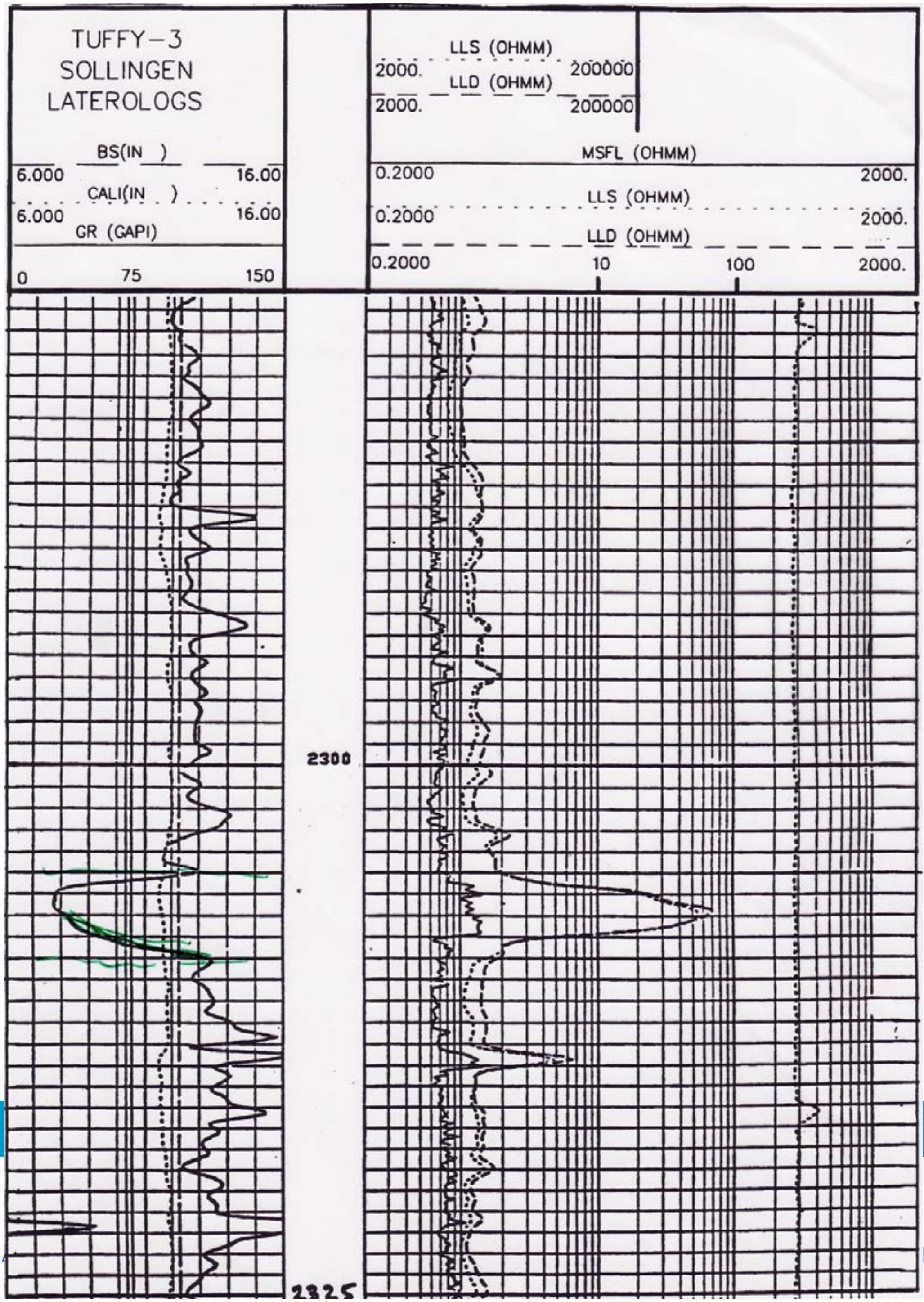
- Calculate Sw using Archie.

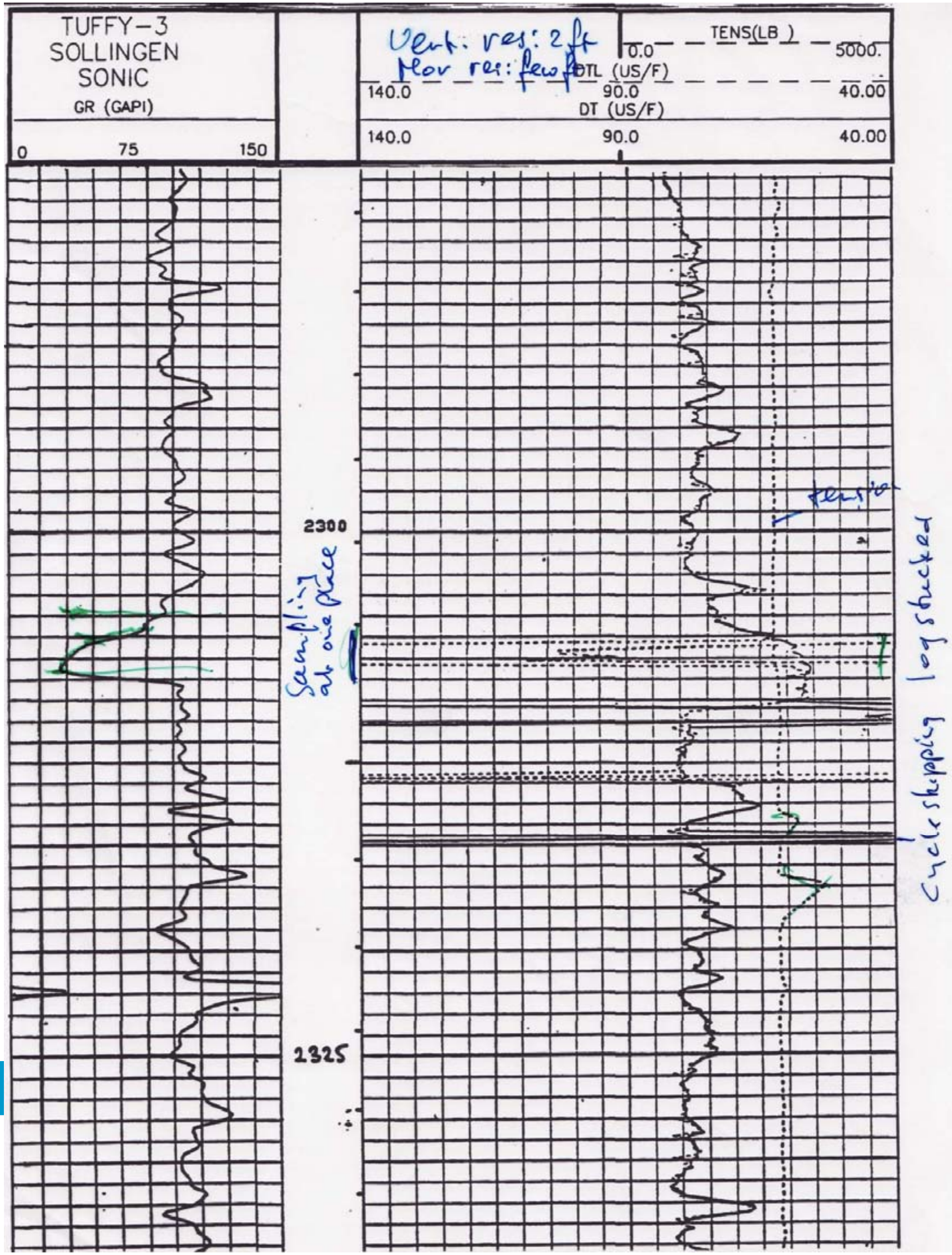
- What would be the effect when the pores are filled with salt water and how can it be observed?

Table 1, Tuffy-3

Layer	Depth	Density	Neutron	RLLd	Sonic	RLLd	θ	Shc
No.	(m)	(g/cc)	(p.u.)	(ohm.m)	(:s/ft)	(ohm.m)		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								


TUFFY-3
SOLLINGEN
FDC - CNL
GR (GAPI)
0
75
150
sand line
shale line
(m)
2300
2325
BS(IN)
Bitsize
6.000
16.00
CALI(IN)
6.000
16.00
0.4200
NPHI CNL
0.12
RHOB(G/C3) FDC
2.000
2.5
3.000
-0.180
NPHI ( ) correction
0.720
0.420
RHOB(G/C3) correction
1.500
2.000
TENS(LB) Tension
0.0
5000.
DRHO(G/C3) dens corr
-0.250
0.250
caliper
tension
FDC
CNL


TUFFY-3
SOLLINGEN
LATEROLOGS
BS(IN)
6.000
16.00
CALI(IN)
6.000
16.00
GR (GAPI)
0
75
150
LLS (OHMM)
2000.
200000
LLD (OHMM)
2000.
200000
MSFL (OHMM)
0.2000
2000.
LLS (OHMM)
0.2000
2000.
LLD (OHMM)
0.2000
10
100
2000.
2300
2325

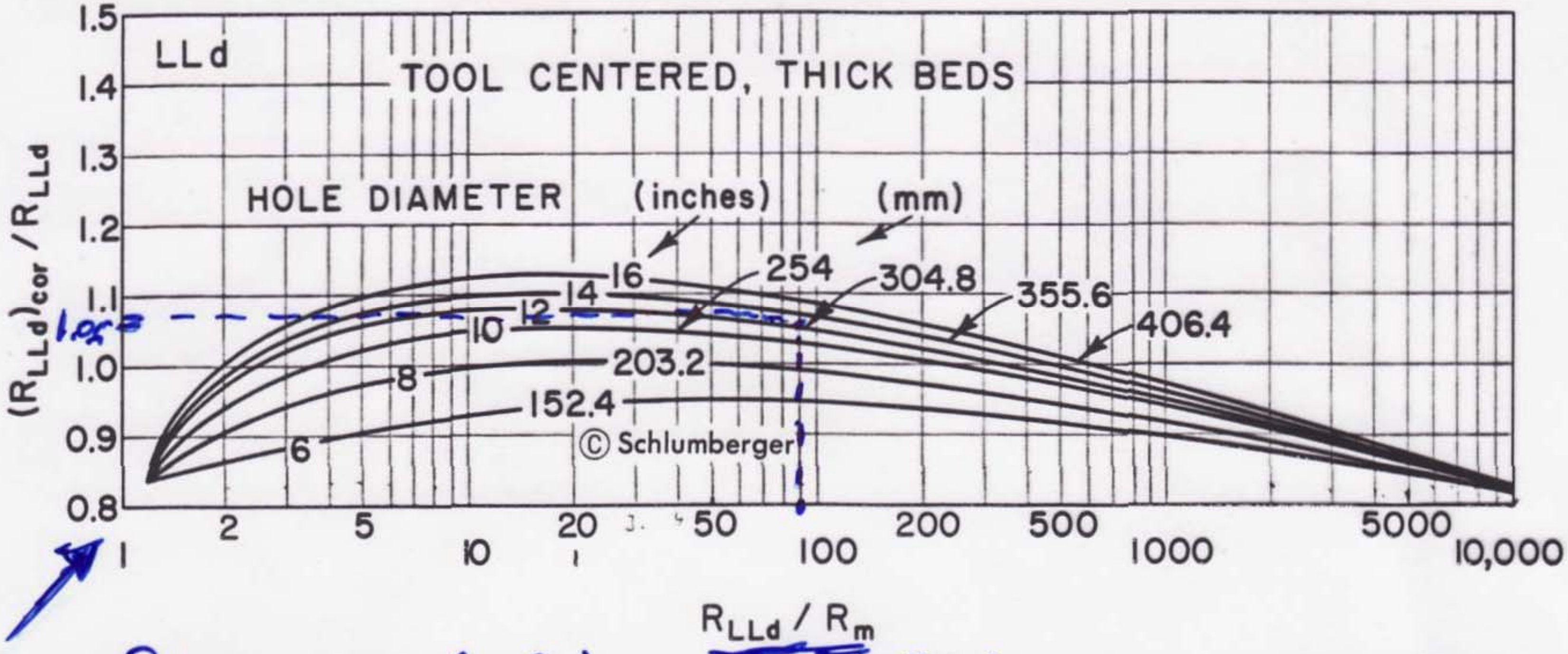

TUFFY-3
SOLLINGEN
SONIC
GR (GAPI)
0 75 150
Vert. res: 2 ft
Hor res: few ft
TENS(LB)
0.0 5000.
DTL (US/F)
140.0 90.0 40.00
DT (US/F)
140.0 90.0 40.00
tension
2300
Sampling at one place
log stucked
cycle skipping
2325

luation

DUAL LATEROLOG* CORRECTION CHARTS

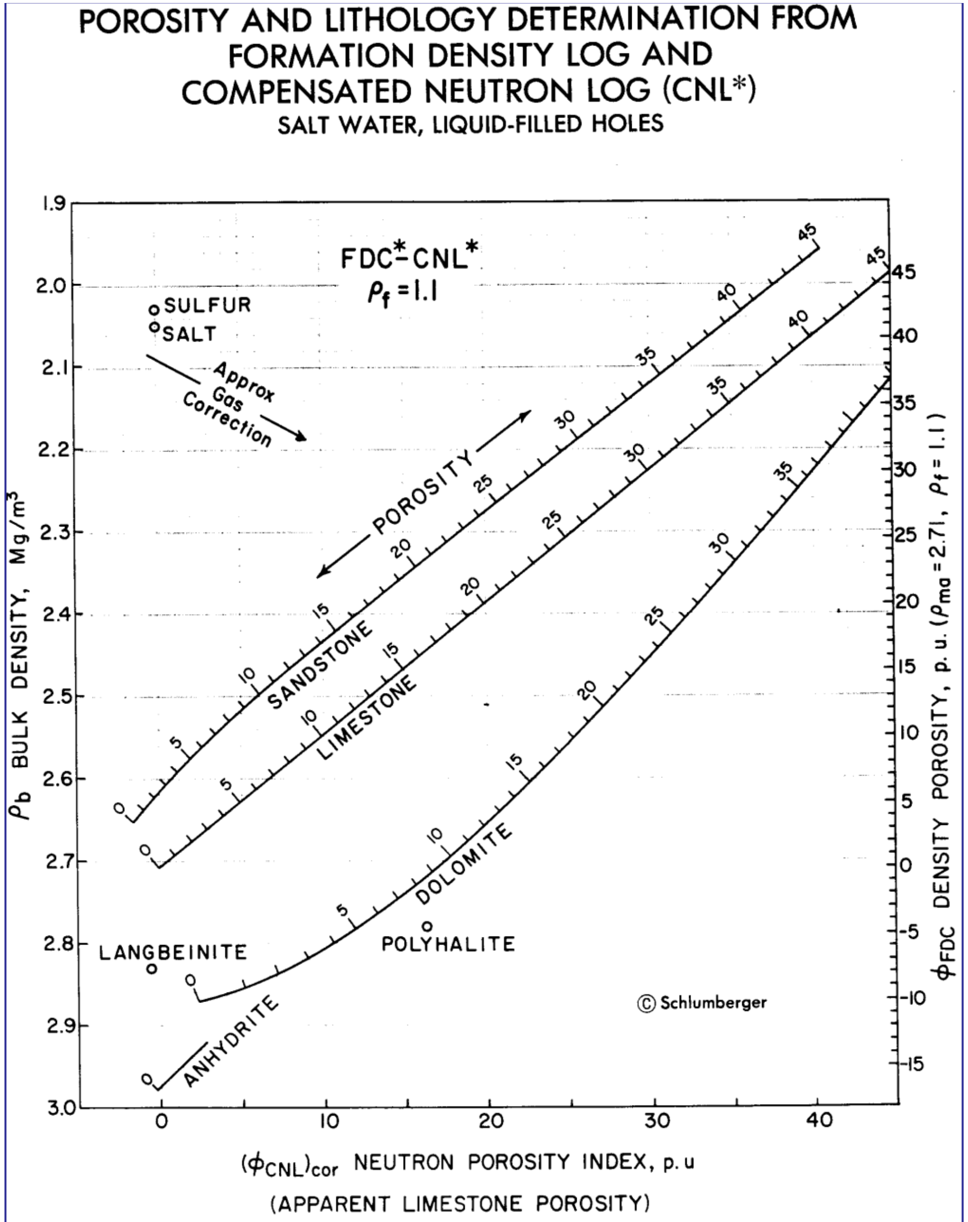
SONDE CENTERED

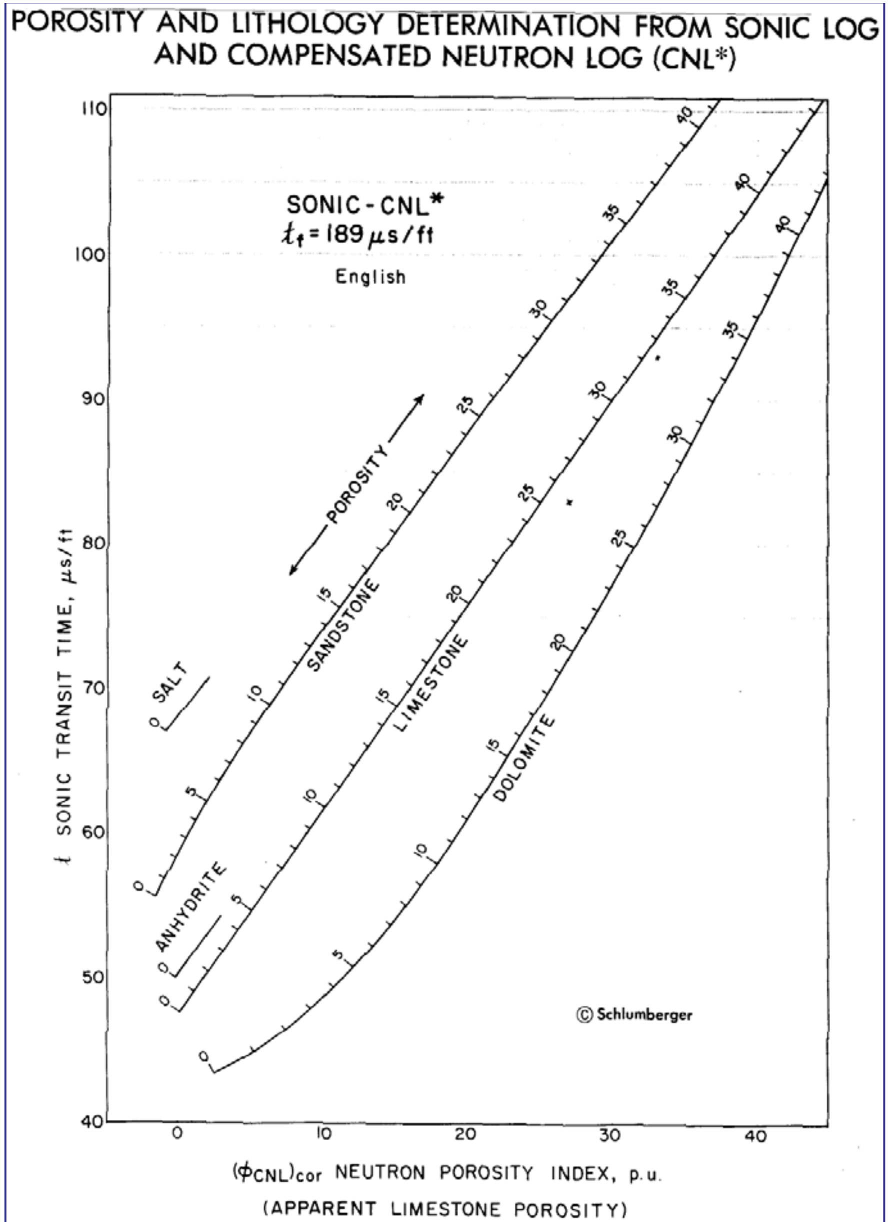
DEEP LATEROLOG* BOREHOLE CORRECTION



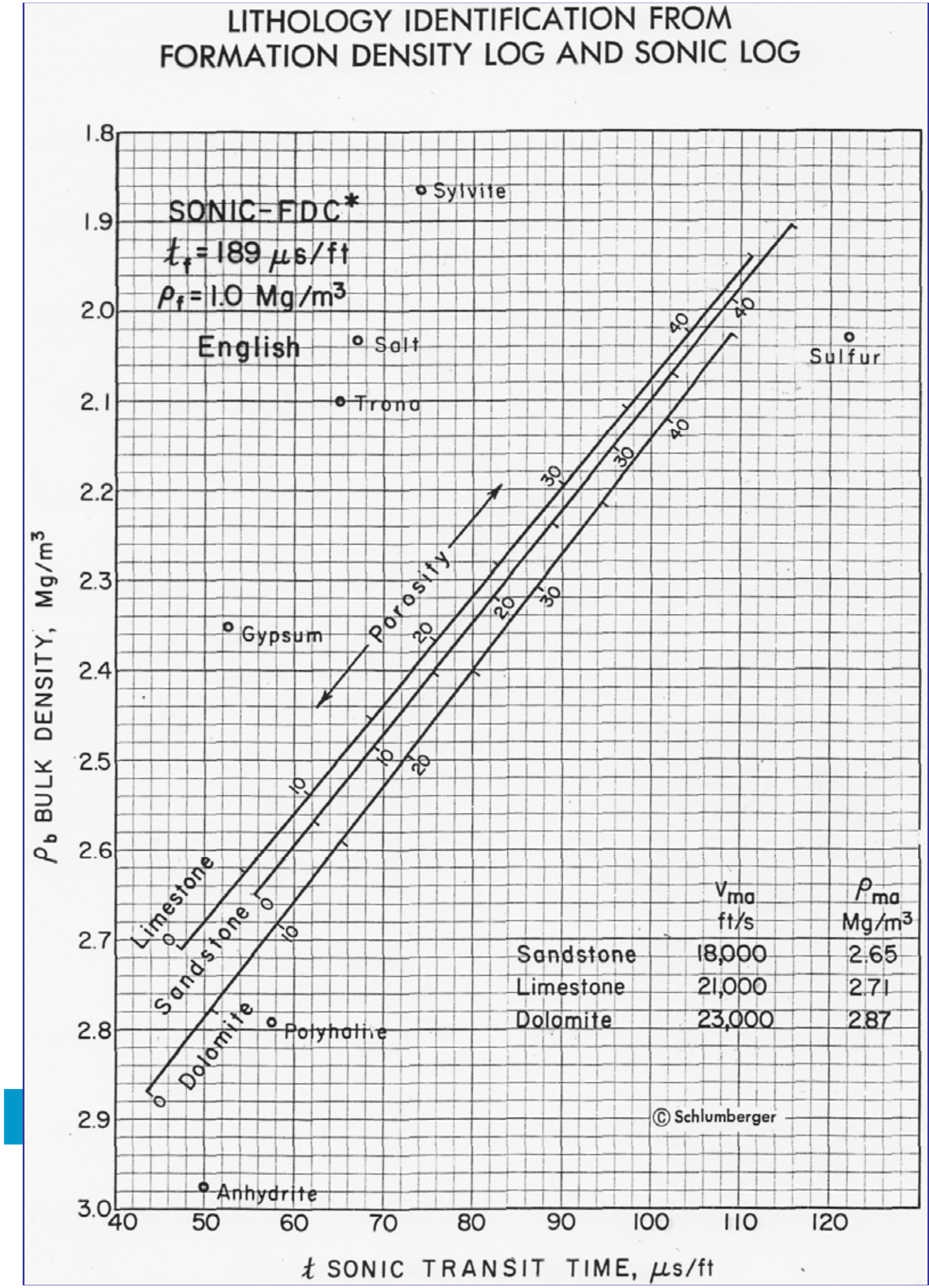
$R_m = 0.076\ (22°C) \Rightarrow$ naar 83°C brengen $= 0.03\ \Omega m$

$RLL = 26\ \Omega m \rightarrow 26/0.03 \approx 90 \rightarrow 12.¼'' \rightarrow 1.05 \quad RLL_{corr} = \frac{RLL}{1.05} = 25.2\ \Omega m$


POROSITY AND LITHOLOGY DETERMINATION FROM FORMATION DENSITY LOG AND COMPENSATED NEUTRON LOG (CNL*)
SALT WATER, LIQUID-FILLED HOLES
FDC*-CNL*
ρ_f = 1.1
SULFUR
SALT
Approx Gas Correction
POROSITY
SANDSTONE
LIMESTONE
DOLOMITE
ANHYDRITE
LANGBEINITE
POLYHALITE
© Schlumberger
ρ_b BULK DENSITY, Mg/m³
ϕ_{FDC} DENSITY POROSITY, p. u. (ρ_{ma} = 2.71, ρ_f = 1.1)
$(\phi_{CNL})_{cor}$ NEUTRON POROSITY INDEX, p. u
(APPARENT LIMESTONE POROSITY)


POROSITY AND LITHOLOGY DETERMINATION FROM SONIC LOG AND COMPENSATED NEUTRON LOG (CNL*)
SONIC-CNL*
t_f = 189 µs/ft
English
POROSITY
SALT
SANDSTONE
LIMESTONE
DOLOMITE
ANHYDRITE
© Schlumberger
t SONIC TRANSIT TIME, µs/ft
$(\phi_{CNL})_{cor}$ NEUTRON POROSITY INDEX, p.u.
(APPARENT LIMESTONE POROSITY)

TU Delft


LITHOLOGY IDENTIFICATION FROM
FORMATION DENSITY LOG AND SONIC LOG
SONIC-FDC*
t_f = 189 μs/ft
ρ_f = 1.0 Mg/m³
English
Sylvite
Salt
Sulfur
Trona
Gypsum
Porosity
Limestone
Sandstone
Dolomite
Polyhalite
Anhydrite
V_{ma} ft/s
ρ_{ma} Mg/m³
Sandstone 18,000 2.65
Limestone 21,000 2.71
Dolomite 23,000 2.87
© Schlumberger
ρ_b BULK DENSITY, Mg/m³
t SONIC TRANSIT TIME, μs/ft

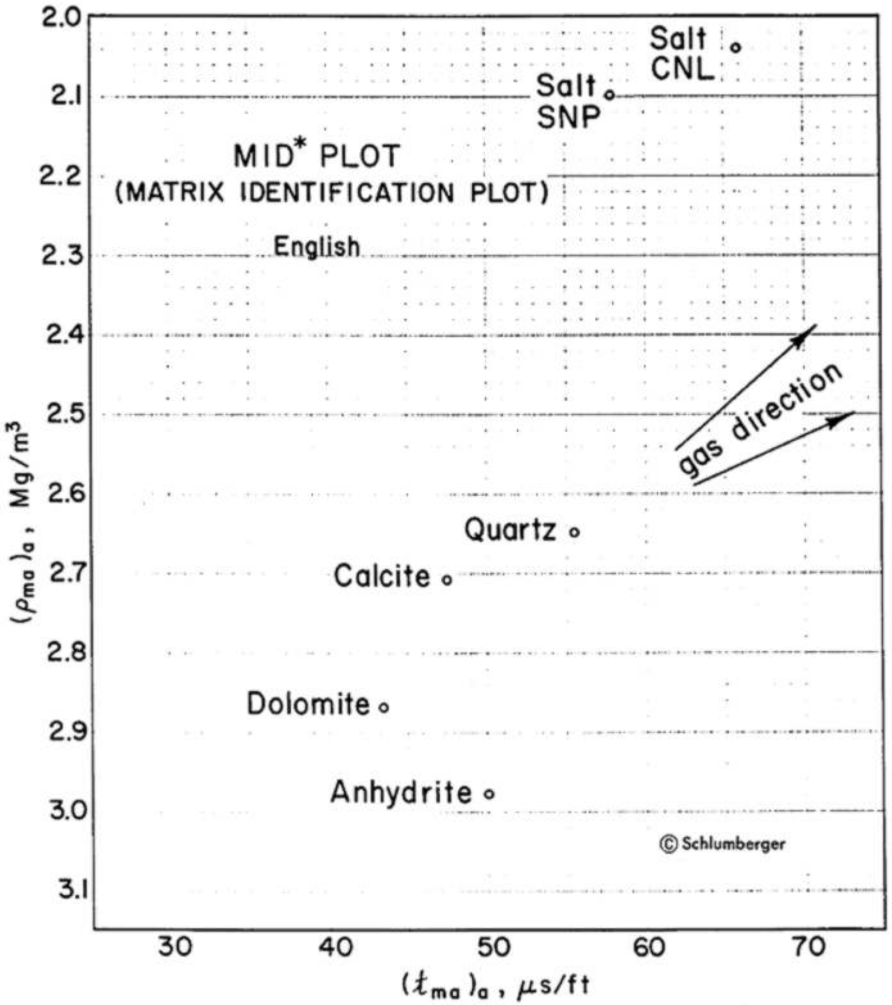
HOW TO USE THE MID PLOT*[8]

Select the $(t_{ma})_a$ and $(\rho_{ma})_a$ charts for your Neutron-log type, borehole-fluid salinity, and measuring system (English or metric).

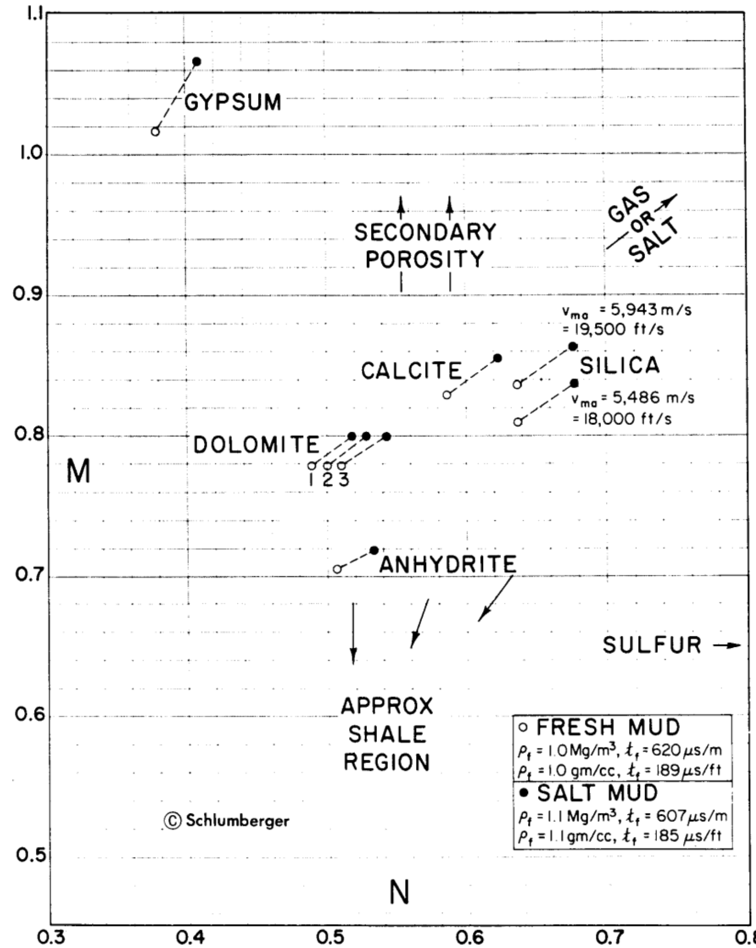
Tabulate t, and ρ_b, and ϕ_N (limestone) by depths for each chosen station and the resultant $(t_{ma})_a$ and $(\rho_{ma})_a$ from the appropriate chart. Plot the points on the MID-Plot grid. The plot will generally form a pattern which identifies the major reservoir rock by its proximity to the labeled points on the plot.

The presence of secondary porosity in the form of vugs or fractures produces displacements parallel to the Sonic-sensitive axis.

The presence of gas will displace points as shown on the basic MID Plot. Identification of shaliness is best done by plotting some shale points to establish the shale trend lines.



M-N PLOT* FOR MINERAL IDENTIFICATION[7]



This crossplot may be used to help identify mineral mixtures from Sonic, Density, and Neutron logs. (The Neutron log used in the above chart is the CNL*.) Except in gas-bearing formations, M and N are practically independent of porosity. They are defined as:

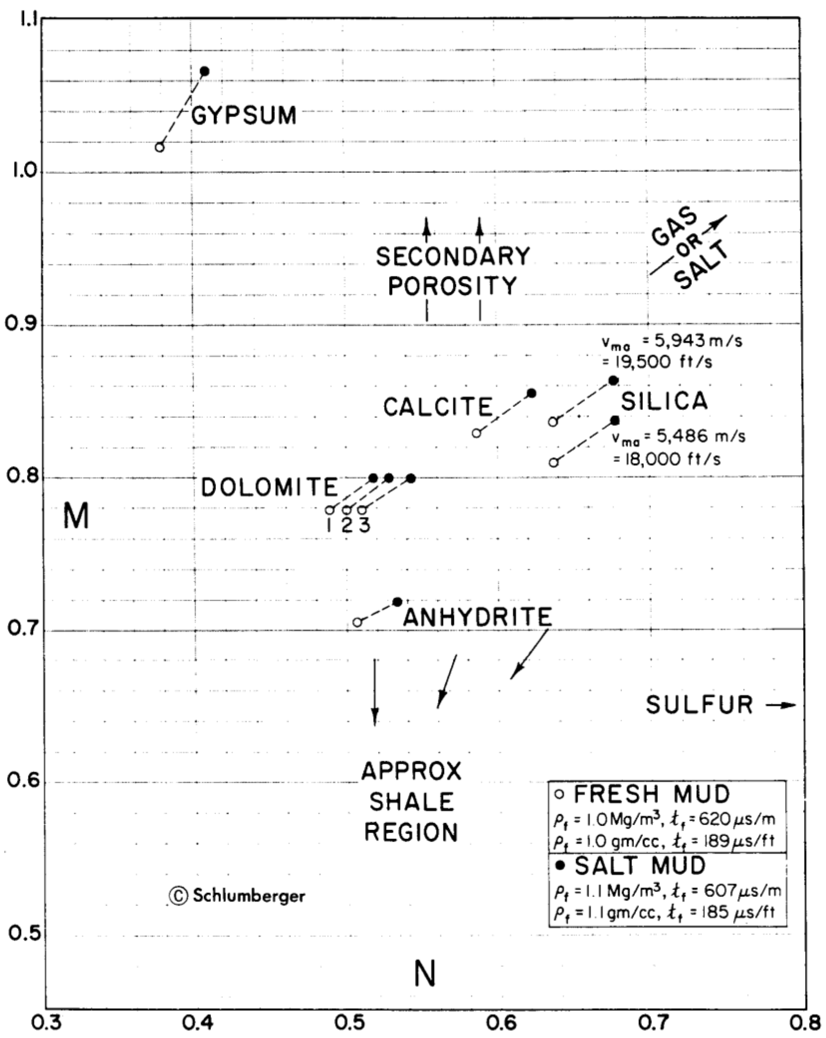
$$M = \frac{t_f - t}{\rho_b - \rho_f} \times 0.01 \text{ (English)}; \quad M = \frac{t_f - t}{\rho_b - \rho_f} \times 0.003 \text{ (Metric)}; \quad N = \frac{(\phi_N)_f - \phi_N}{\rho_b - \rho_f} \text{ (Either)}$$

Points for binary mixtures plot along a line connecting the two mineral points. Ternary mixtures plot within the triangle defined by the three constituent minerals. The effect of gas, shaliness, secondary porosity, etc. is to shift data points in the directions shown by the arrows.

The dolomite lines are divided as to porosity as follows:

1) ϕ = 5.5 to 30 p.u. 2) ϕ = 1.5 to 5.5 p.u. and ϕ > 30 p.u. 3) ϕ = 0 to 1.5 p.u.

M-N PLOT* FOR MINERAL IDENTIFICATION[7]



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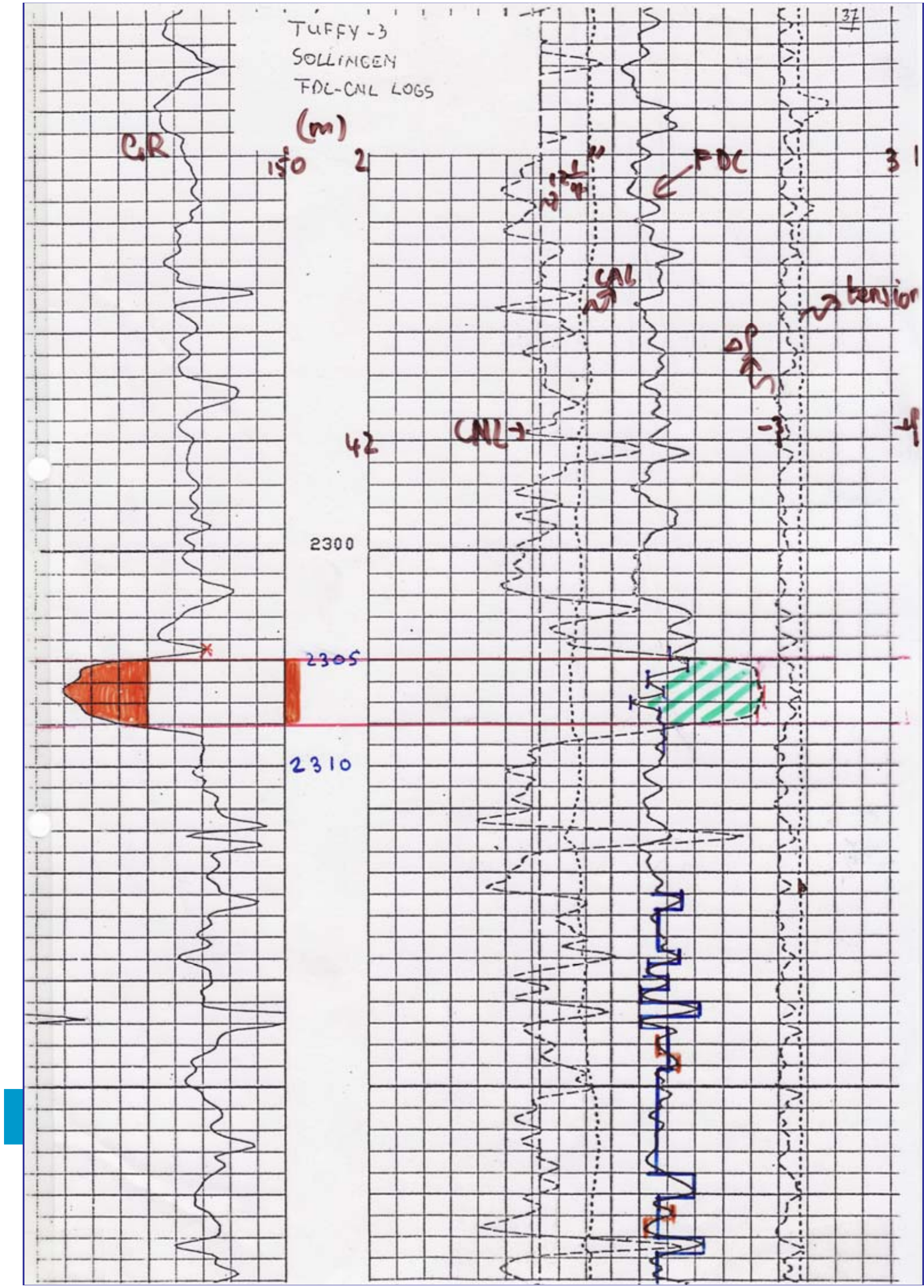
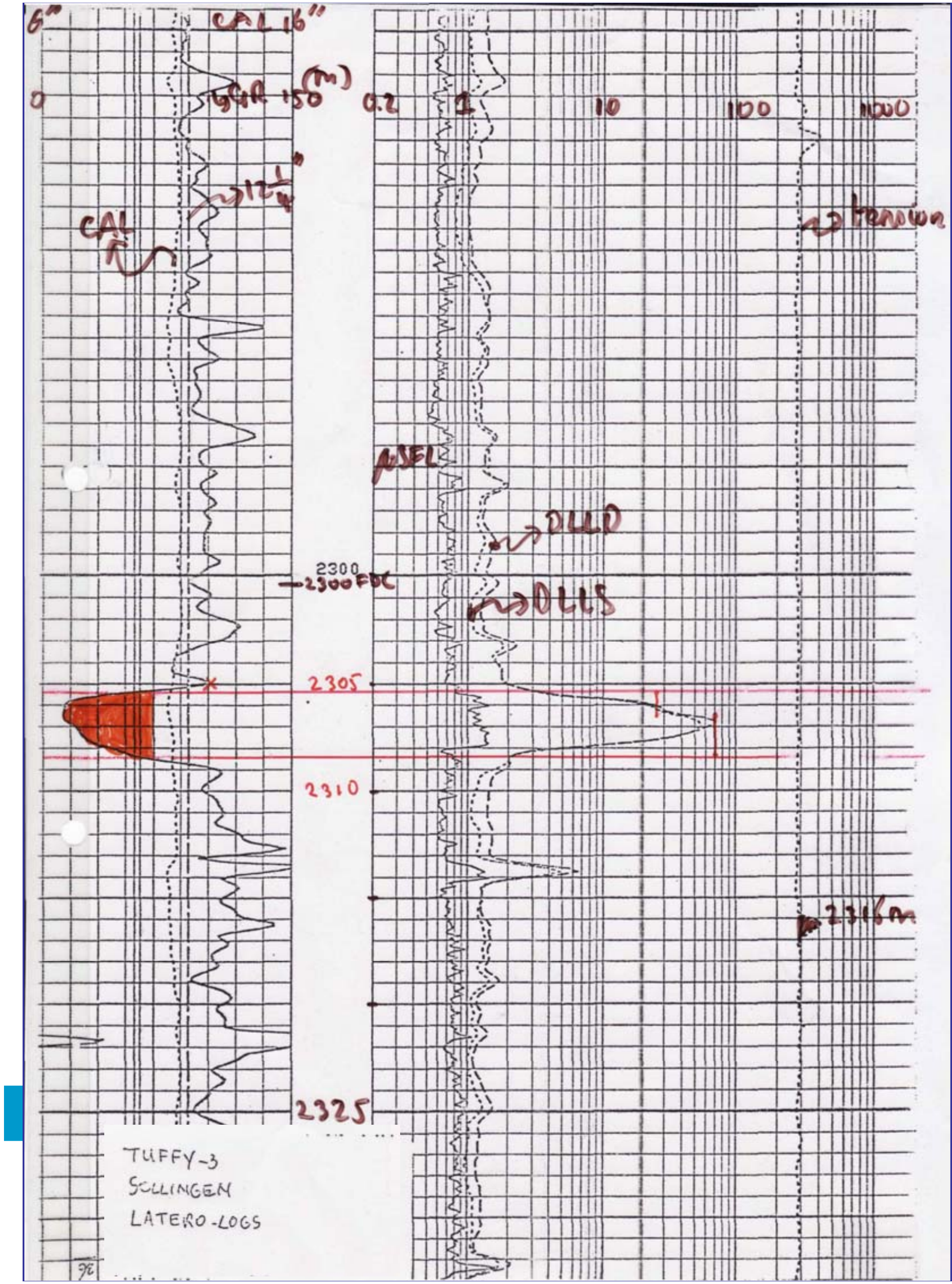
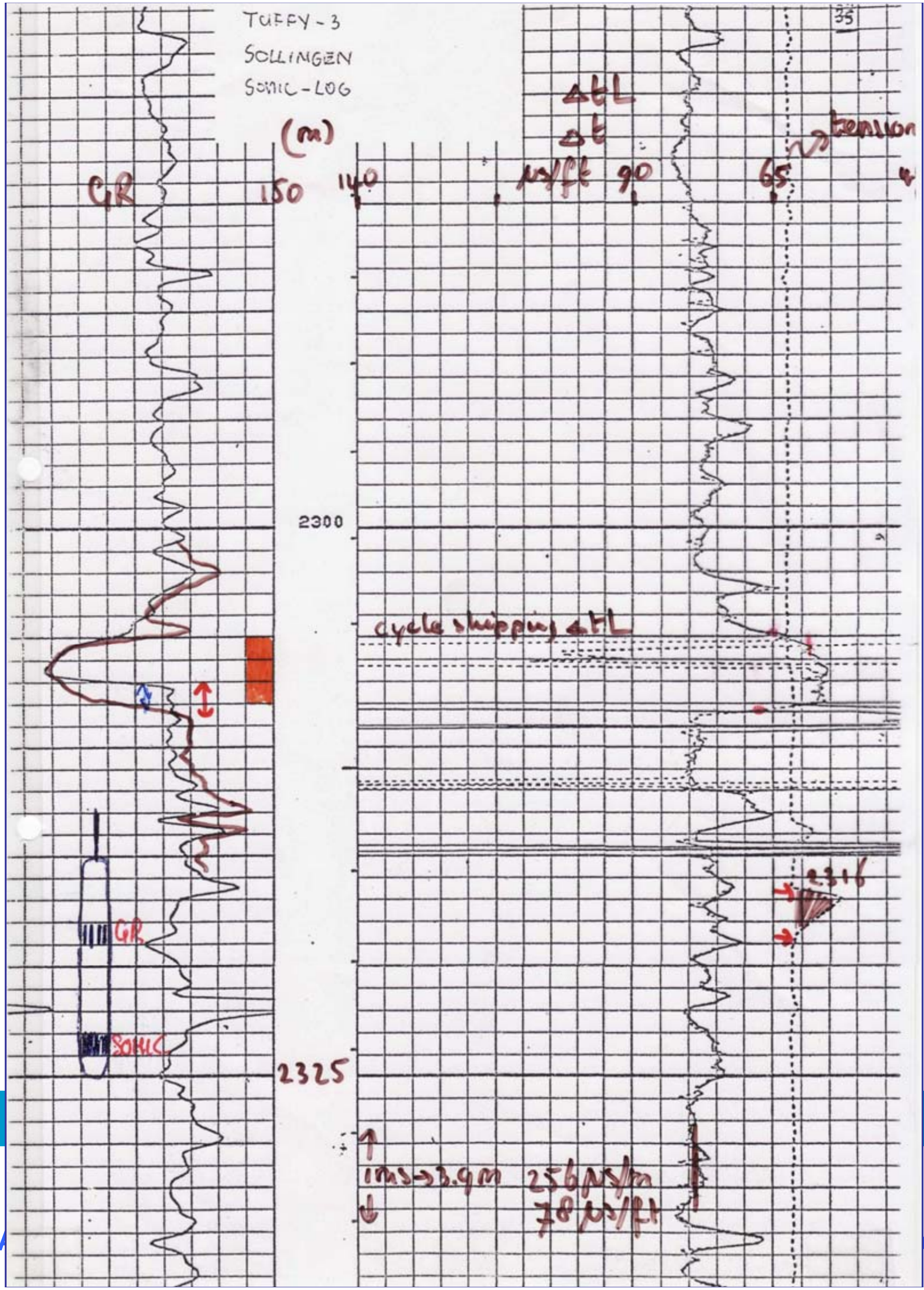
ANSWERS


TUFFY-3
SOLLINGEN
FDC-CNL LOGS
(m)
GR
150
2
FDC
3
CAL
tension
CNL
42
2300
2305
2310



6"
CAL 16"
0
GR 150 (m)
0.2
1
10
100
1000
12¼"
CAL
tension
MSFL
DLLD
2300
2300 FDC
DLLS
2305
2310
2316m
2325
TUFFY-3
SOLLINGEN
LATERO-LOGS


TUFFY-3
SOLLINGEN
SONIC-LOG
(m)
ΔtL
Δt
tension
GR
150
140
μs/ft
90
65
2300
cycle skipping ΔtL
2316
GR
SONIC
2325
1ms→3.9m 256μs/m
78μs/ft

Answers Tuffy (Sollingen)

Sollingen Sst.
Squared and multiplexed log-values.

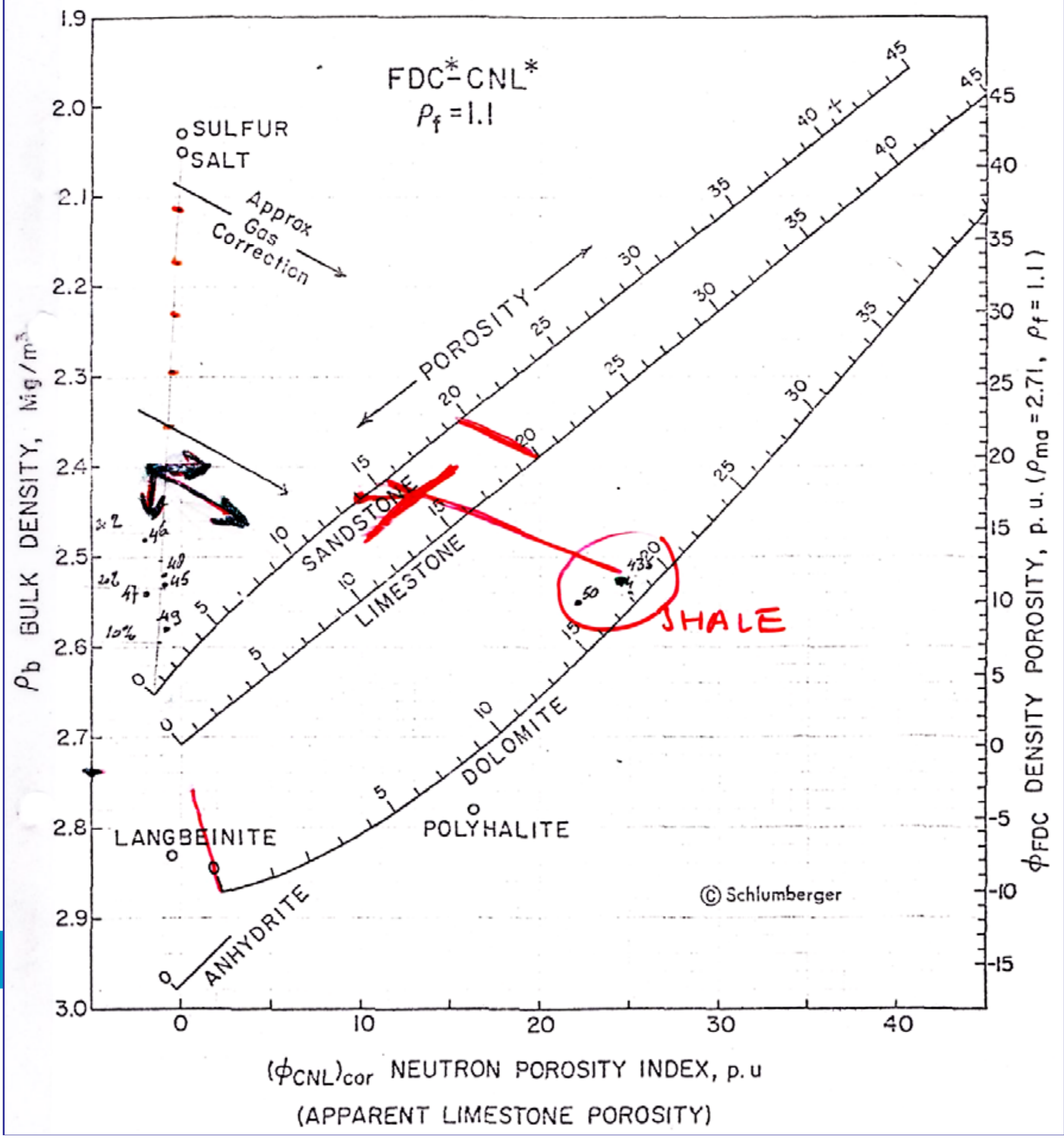
	Layer	Depth m.	FDC gr/cc	CNL p.u.	R1ld ohmm	dt musec/ft
1	50	2304.4	2.55	22	1.8	75
2	49	2305.0	2.58	-1	26.0	58
3	48	2305.5	2.52	-1	26.0	57
4	47	2306.2	2.54	-2	70.0	55
5	46	2306.8	2.48	-2	70.0	57
6	45	2307.2	2.53	-1	70.0	57
7	44	2308.0	2.54	25	1.8	78
8	43	2309.5	2.51	26	1.8	80

Answers Tuffy (Sollingen)

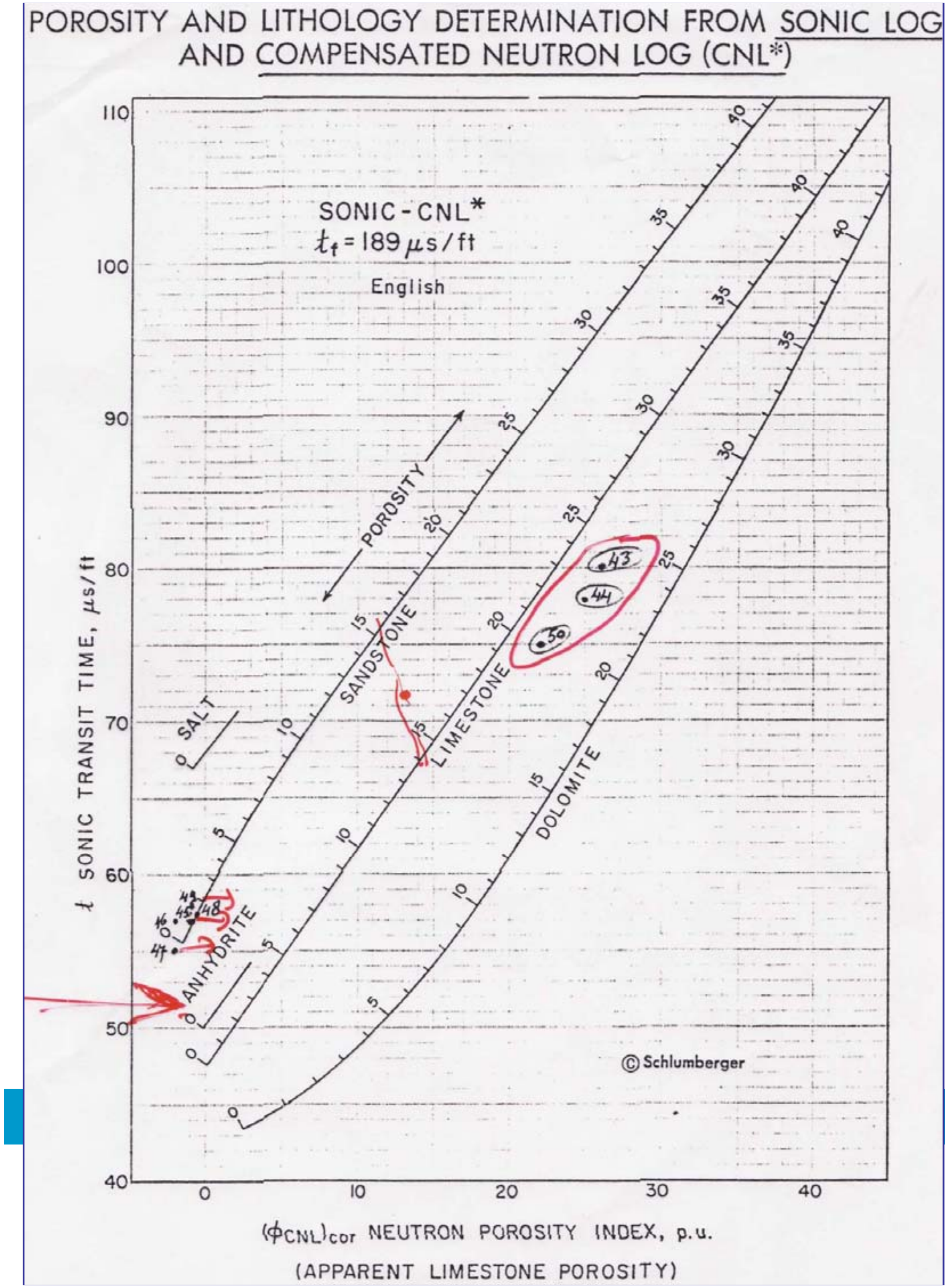
	Layer	R11dcorr	Phi FDC-CNL	ShC
2	49	~~25.2~~ 27.3	0.04	0.54
3	48	~~25.2~~ 27.3	0.065	0.71
4	47	63	0.05	0.76
5	46	63	0.07	0.83
6	45	63	0.06	0.80
7	44	1.9	0.07	0.00

POROSITY AND LITHOLOGY DETERMINATION FROM FORMATION DENSITY LOG AND COMPENSATED NEUTRON LOG (CNL*)

SALT WATER, LIQUID-FILLED HOLES

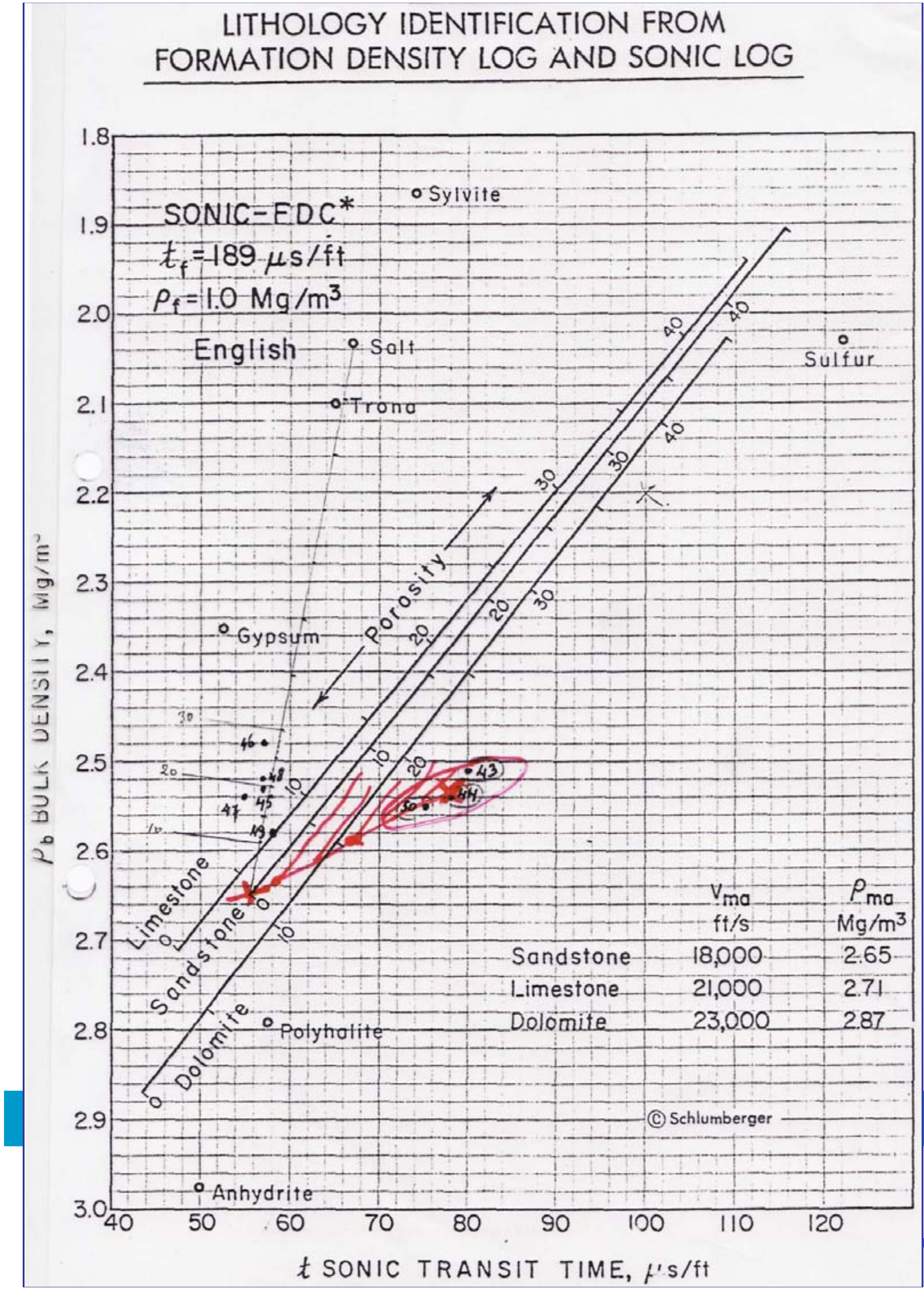


tion

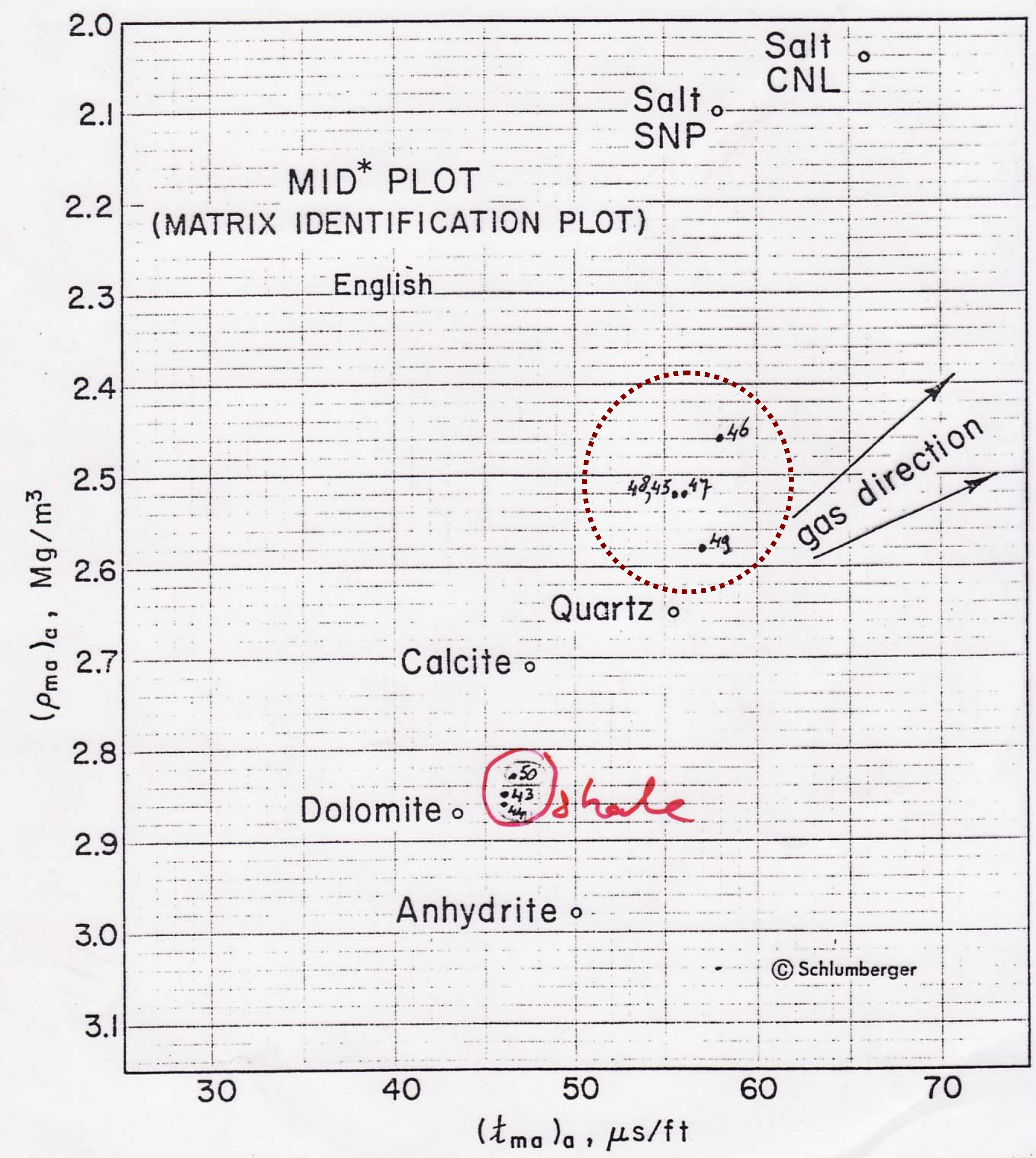


POROSITY AND LITHOLOGY DETERMINATION FROM SONIC LOG AND COMPENSATED NEUTRON LOG (CNL*)
SONIC - CNL*
t_f = 189 μs/ft
English
POROSITY
SANDSTONE
LIMESTONE
DOLOMITE
SALT
ANHYDRITE
© Schlumberger
t SONIC TRANSIT TIME, μs/ft
(ϕ_{CNL})cor NEUTRON POROSITY INDEX, p.u.
(APPARENT LIMESTONE POROSITY)

evaluation



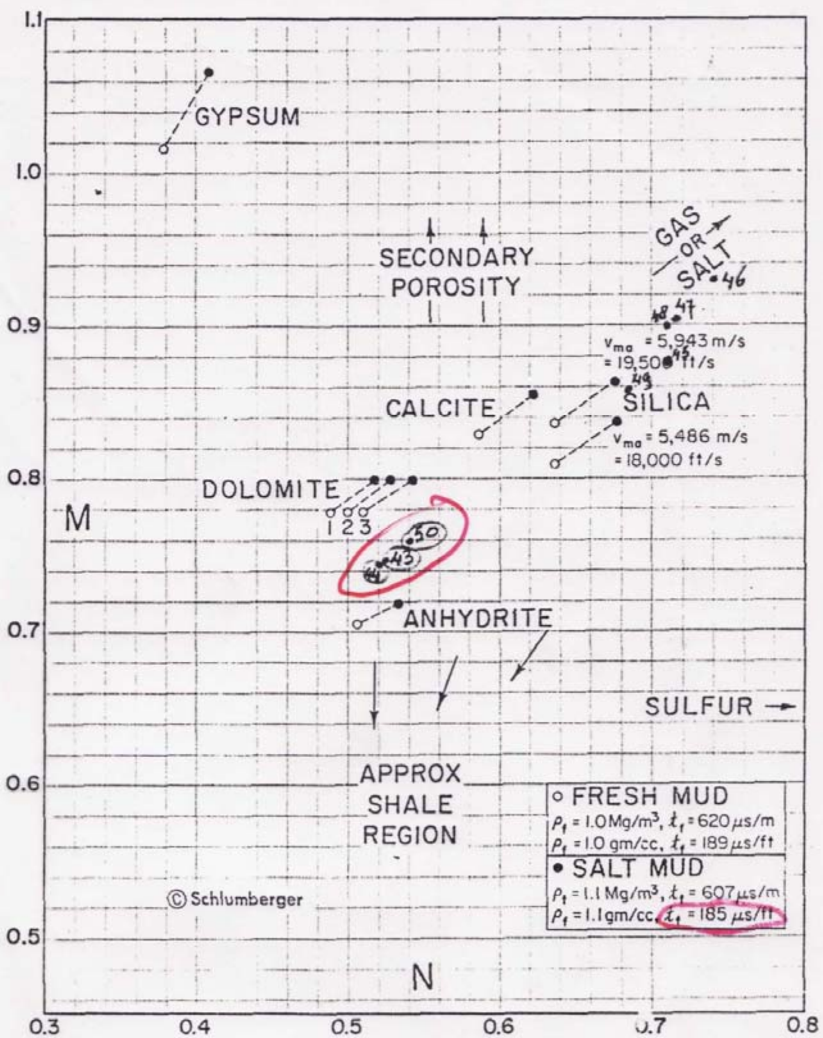
LITHOLOGY IDENTIFICATION FROM FORMATION DENSITY LOG AND SONIC LOG
SONIC-FDC*
t_f = 189 µs/ft
ρ_f = 1.0 Mg/m³
English
Sylvite
Salt
Trona
Sulfur
Gypsum
Polyhalite
Anhydrite
Porosity
Limestone
Sandstone
Dolomite
V_{ma} ft/s
ρ_{ma} Mg/m³
Sandstone 18,000 2.65
Limestone 21,000 2.71
Dolomite 23,000 2.87
© Schlumberger
ρ_b BULK DENSITY, Mg/m³
t SONIC TRANSIT TIME, µs/ft



MID* PLOT
(MATRIX IDENTIFICATION PLOT)
English
Salt CNL
Salt SNP
Quartz
Calcite
Dolomite
Anhydrite
shale
gas direction
46
48,43
47
49
50
43
44
© Schlumberger
$(\rho_{ma})_a$, Mg/m^3
$(t_{ma})_a$, μs/ft
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
30
40
50
60
70

TU Delft

M-N PLOT* FOR MINERAL IDENTIFICATION[7]



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