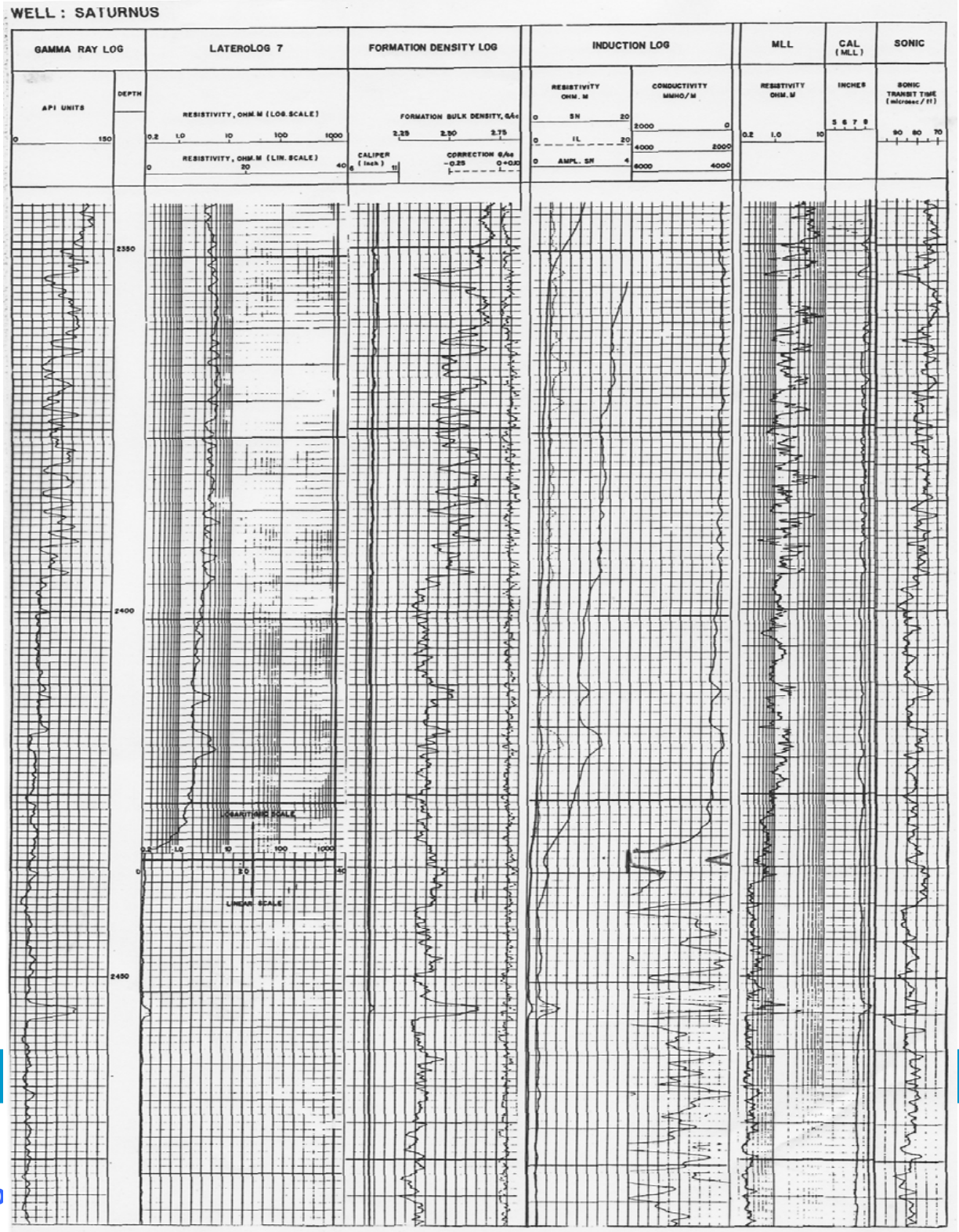
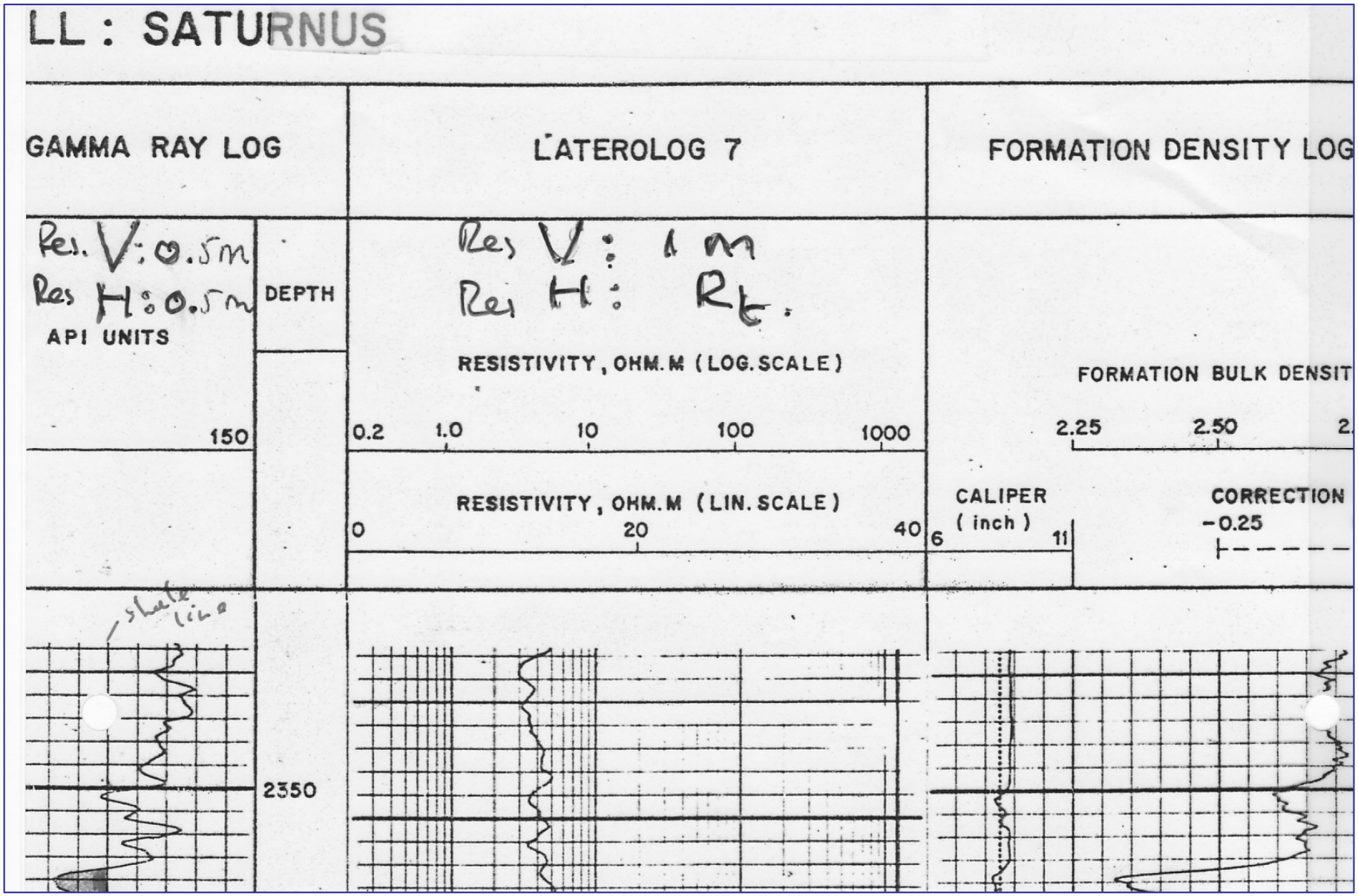
Exercise Saturnus: Log

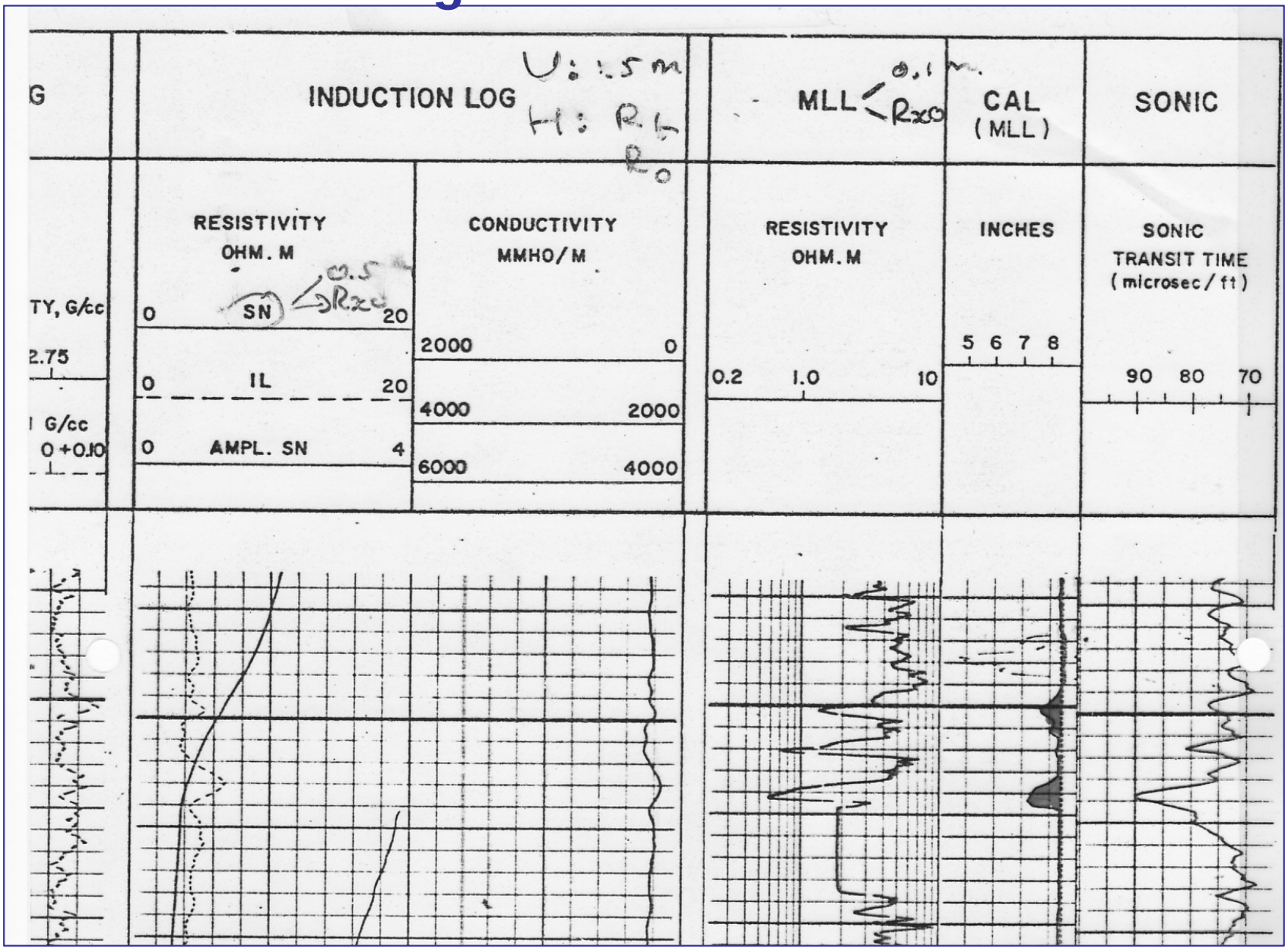


Exercise Saturnus: Log headers. Resolutions and scales



TU Delft

Exercise Saturnus: Log headers. Resolutions and scales



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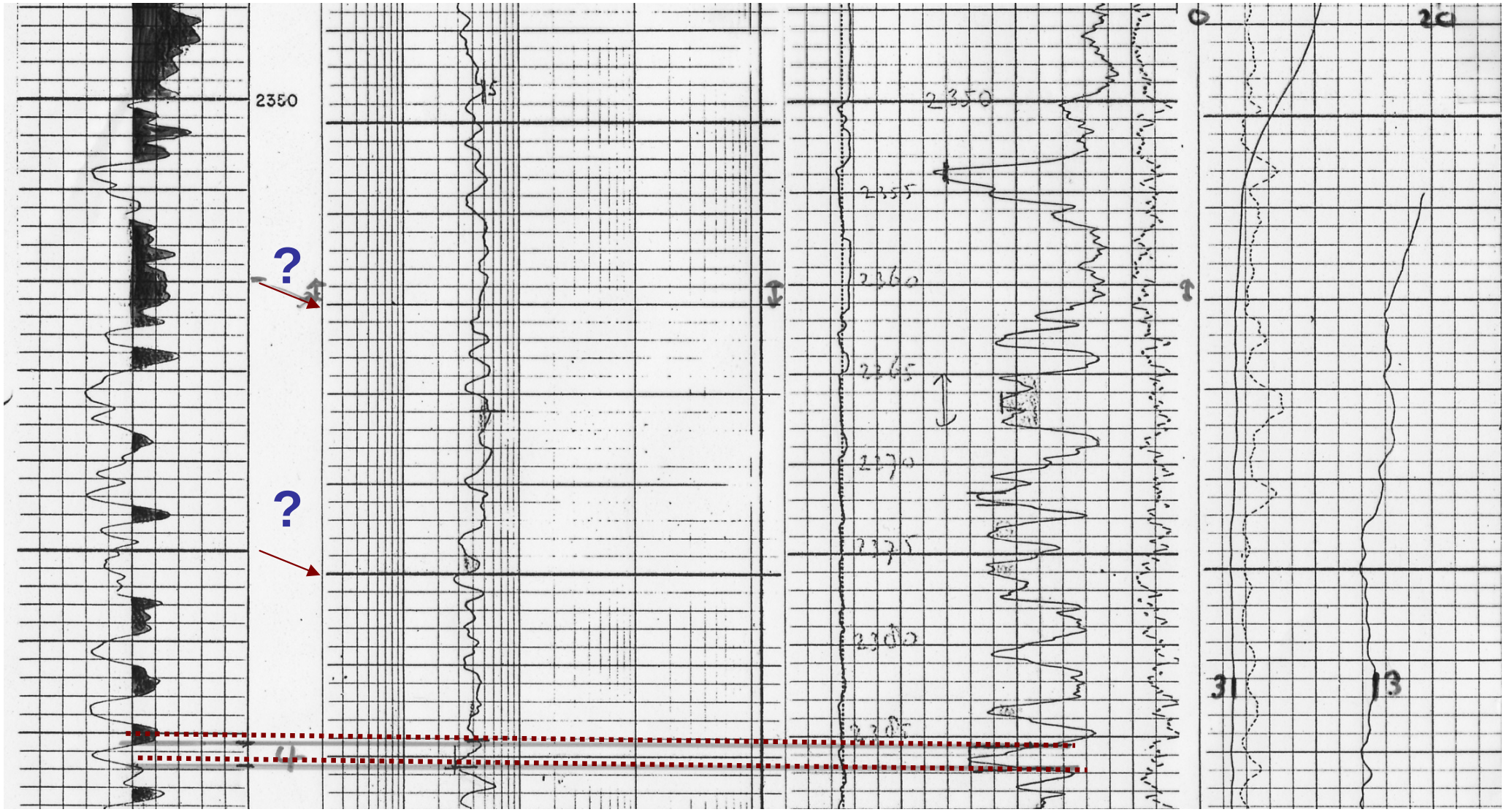
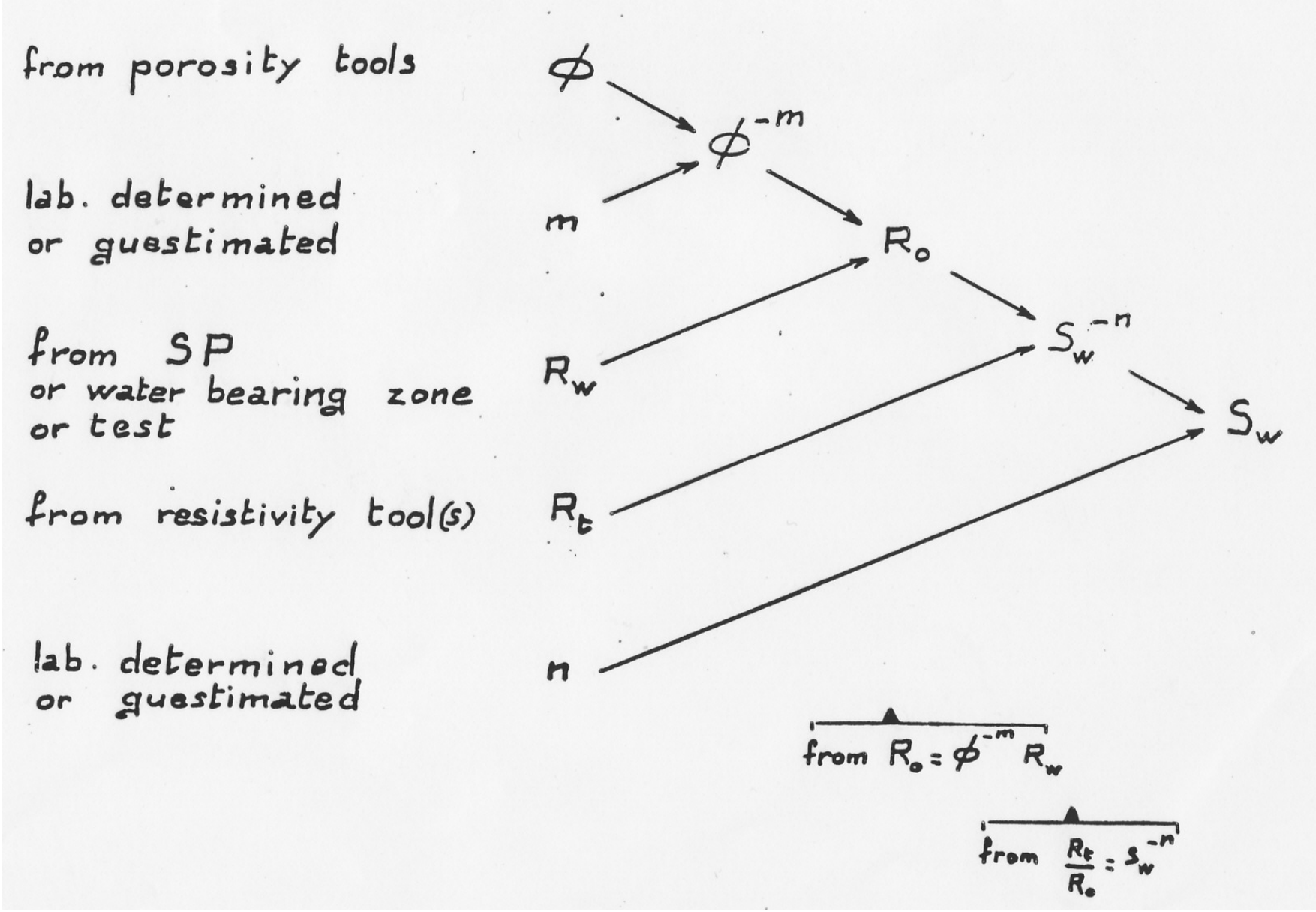
Exercise Saturnus: Vertical aligning



TU Delft

Exercise Saturnus: Help table 1 & 2



Exercise Saturnus: Help table 1 & 2

By definition: $F = R_o / R_w$

Experimentally: $F = \phi^{-m}$

$$\boxed{\phi^{-m} = R_o / R_w} \qquad (1)$$

in which:
- F = formation resistivity factor
- R_o = formation resistivity at 100% water saturation
- R_w = resistivity of (saturating) formation water
- ϕ = porosity (Fraction of void space in bulk volume)
- m = cementation factor

By definition: $I = R_t / R_o$

Experimentally: $I = S_w^{-n}$

$$\boxed{S_w^{-n} = R_t / R_o} \qquad (2)$$

in which:
- I = resistivity index
- R_t = formation resistivity when oil is present ($S_w < 100\%$)
- S_w = water saturation (Fraction of porosity)
- n = saturation exponent.

These are the two basic equations (ARCHIE).

Elimination of R_o between (1) and (2) gives:

$$R_t = \phi^{-m} \cdot S_w^{-n} \cdot R_w$$

ϕ, R_t, R_w, m, n are required to calculate S_w

$$S_w^{n} = R_w \cdot \phi^{-m} \cdot R_t^{-1}$$

Exercise Saturnus

Questions:

1) Porosity calibration.
Using the core data given above, construct the lines relating bulk density and porosity in the gas bearing and in the water bearing zones (Fig. 1).

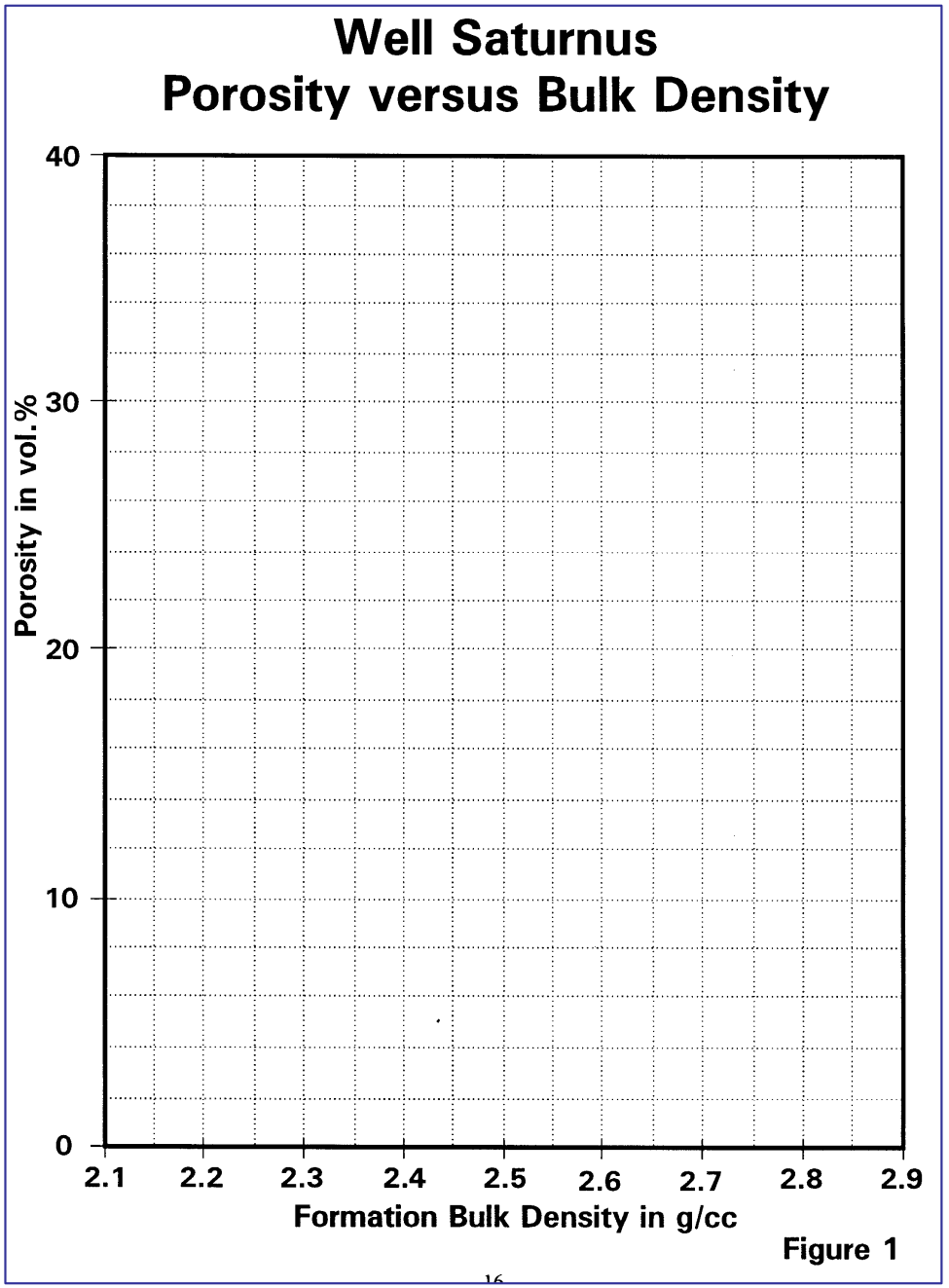


Figure 1

Exercise Saturnus

2) Water bearing section.
In table 1, the Induction log readings of several water bearing intervals are listed.

Note: The Induction log is usually less suitable than the Laterolog in salt saturated mud due to the strong borehole effect when Rt >> Rm. Here, the tool was set at zero in the borehole opposite a non conductive formation. Thus the borehole effect is cancelled out, at least for a particular borehole size. Small variations in the borehole size may be neglected, especially since the contrast between Rt and Rm is small. Furthermore the resistivities opposite the water bearing layers are too low to be read accurately from the Laterolog. The conductivity curve from the Induction log was used instead to determine the resistivities.

Questions
- Read the formation bulk densities for the intervals selected in table 1. Translate these into porosity using figure 1.
- Plot resistivity versus bulk density ρ_b in Fig. 2, assuming m = 2. Add a porosity scale to the ρ_b - axis. Then, determine the value of Rw .
- Read the Microlaterolog resistivities. Compare these values with those given by the Induction log. Which conclusion can you draw?
- Above we assumed m = 2. Considering now the invaded zone and the corresponding resistivities (RMLL and Rmf); calculate for each interval the value of m. What average m do you obtain?
- Would a value of m different from 2 appreciably affect the final result of the evaluation?

Exercise Saturnus

Table 1: Water bearing section.

Bed	Interval (m)	D_b	C	R	ϕ_{FDC}	R_{MLL}	m
N/	Depth GR - FDC		mmho/m	ohm.m	%	ohm.m	
13	2433.2 - 2434.8		2500				
14	2440.3 - 2441.8		4000				
15	2449.3 - 2450.8		3600				
16	2451.2 - 2452.5		2300				
17	2448.4 - 2460.0		3200				
18	2465.8 - 2467.2		2000				
19	2473.0 - 2474.0		4700				
20	2474.0 - 2476.3		2600				
21	2477.4 - 2478.0		4700				
22	2479.0 - 2480.0		3100				

Exercise Saturnus
Figure 2

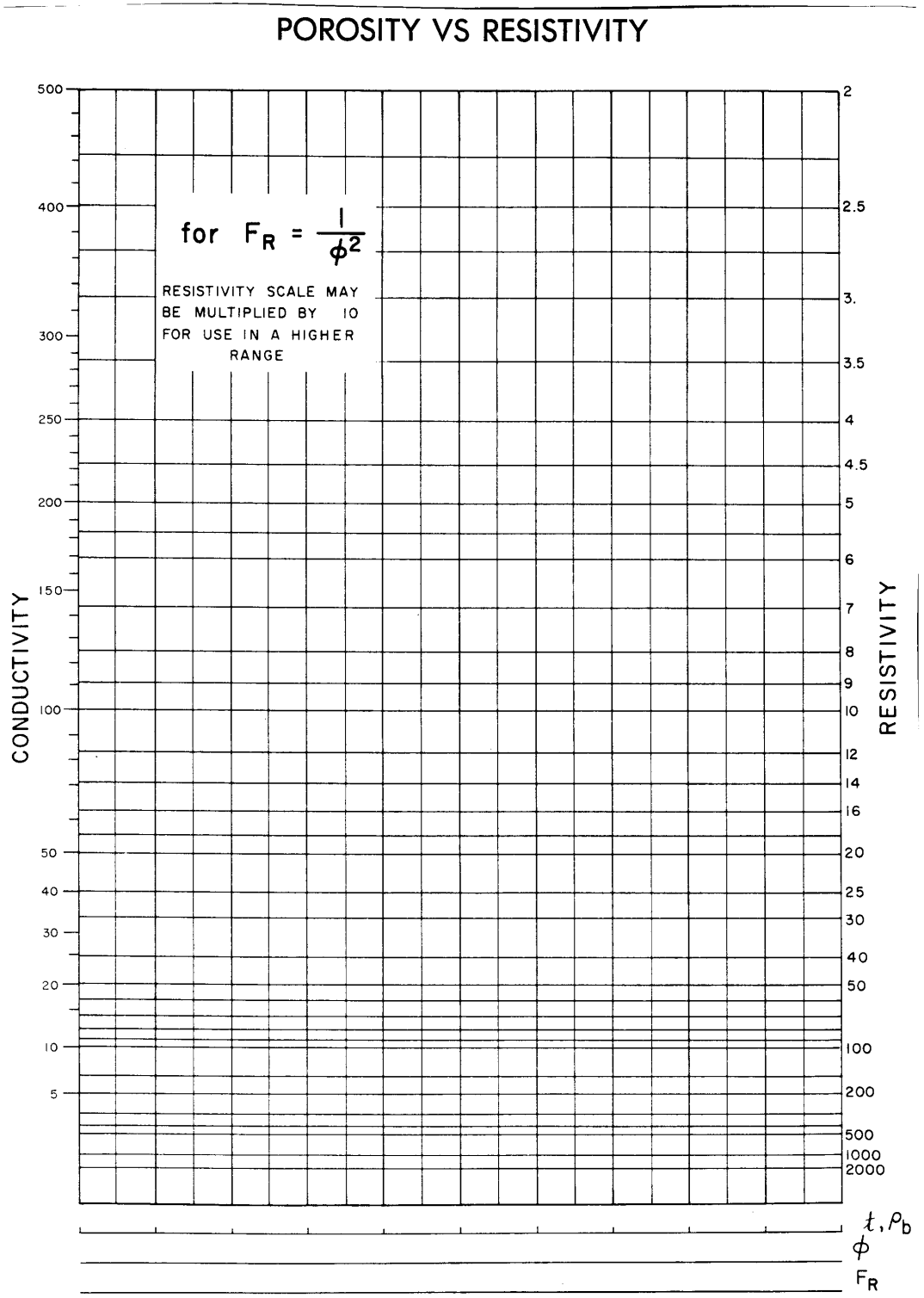


figure 2

Exercise Saturnus

3) Gas bearing section

Now resistivities can be read accurately from the Laterolog on its logarithmic scale.

Questions.

- Read the resistivity of beds 1 to 12 (Table 2).
- Convert bulk densities into porosity values.
- Plot resistivity versus porosity on the m = 2 grid paper (Figure 3).
- Construct the iso-saturation lines (Sw = 90%, 80%, 70%, etc.).
- Determine graphically the water saturation of each interval and complete Table 2.

Exercise Saturnus

Table 2: Gas bearing section.

Bed	Interval (m)	ρ_b	R_{LL}	φ_{FDC}	S_w
N/			ohm.m	%	
1	2366.0-2367.0	2.47			
2	2371.6-2372.2	2.43			
3	2383.0-2384.1	2.45			
4	2385.4-2386.9	2.42			
5	2392.5-2394.2	2.51			
6	2398.6-2399.8	2.33			
7	2403.0-2405.5	2.38			
8	2413.0-2415.5	2.40			
9	2417.0-2418.5	2.42			
10	2420.0-2421.5	2.40			
11	2425.8-2427.5	2.38			
12	2429.1-2430.0	2.39			

Exercise Saturnus
Figure 3

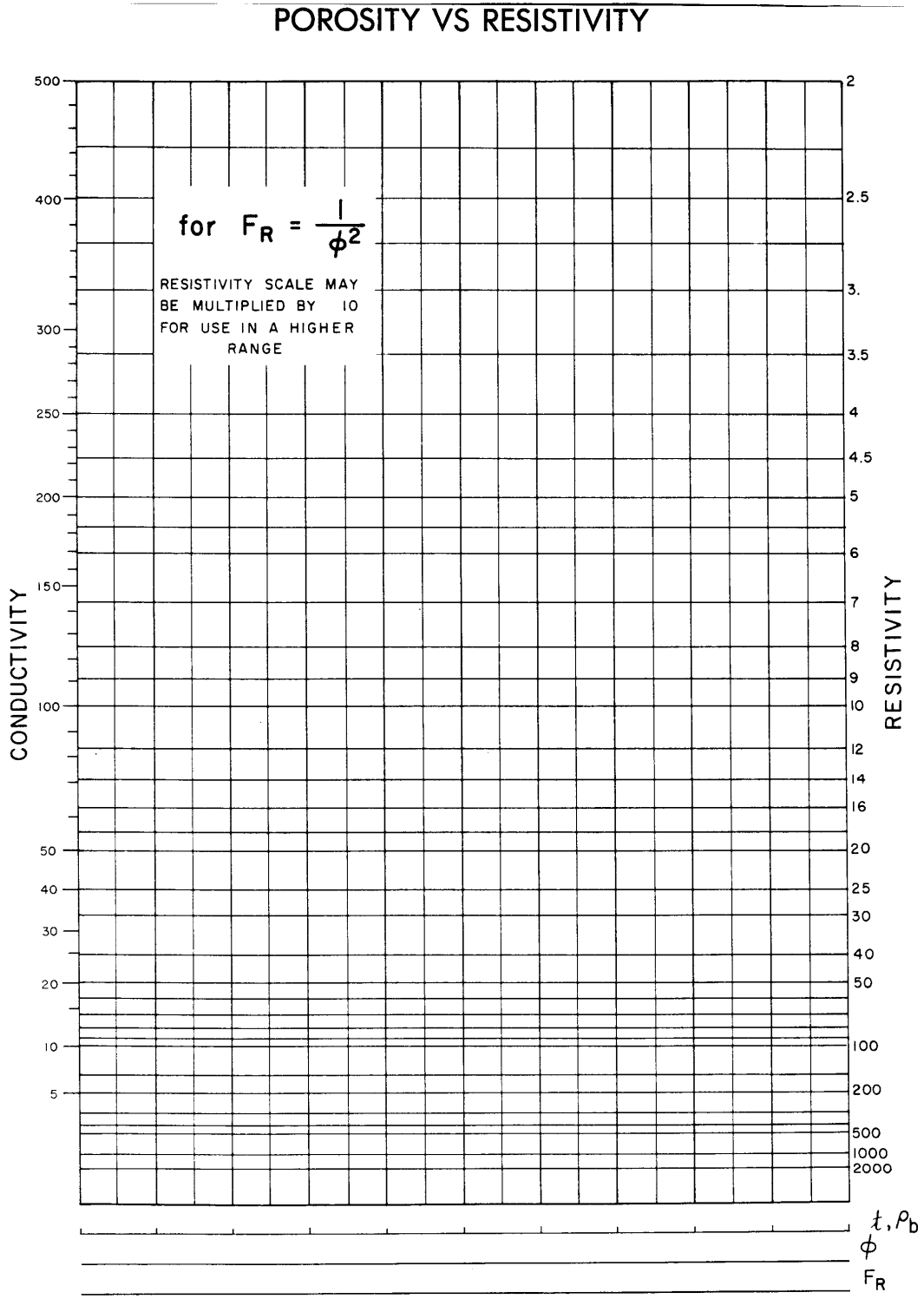
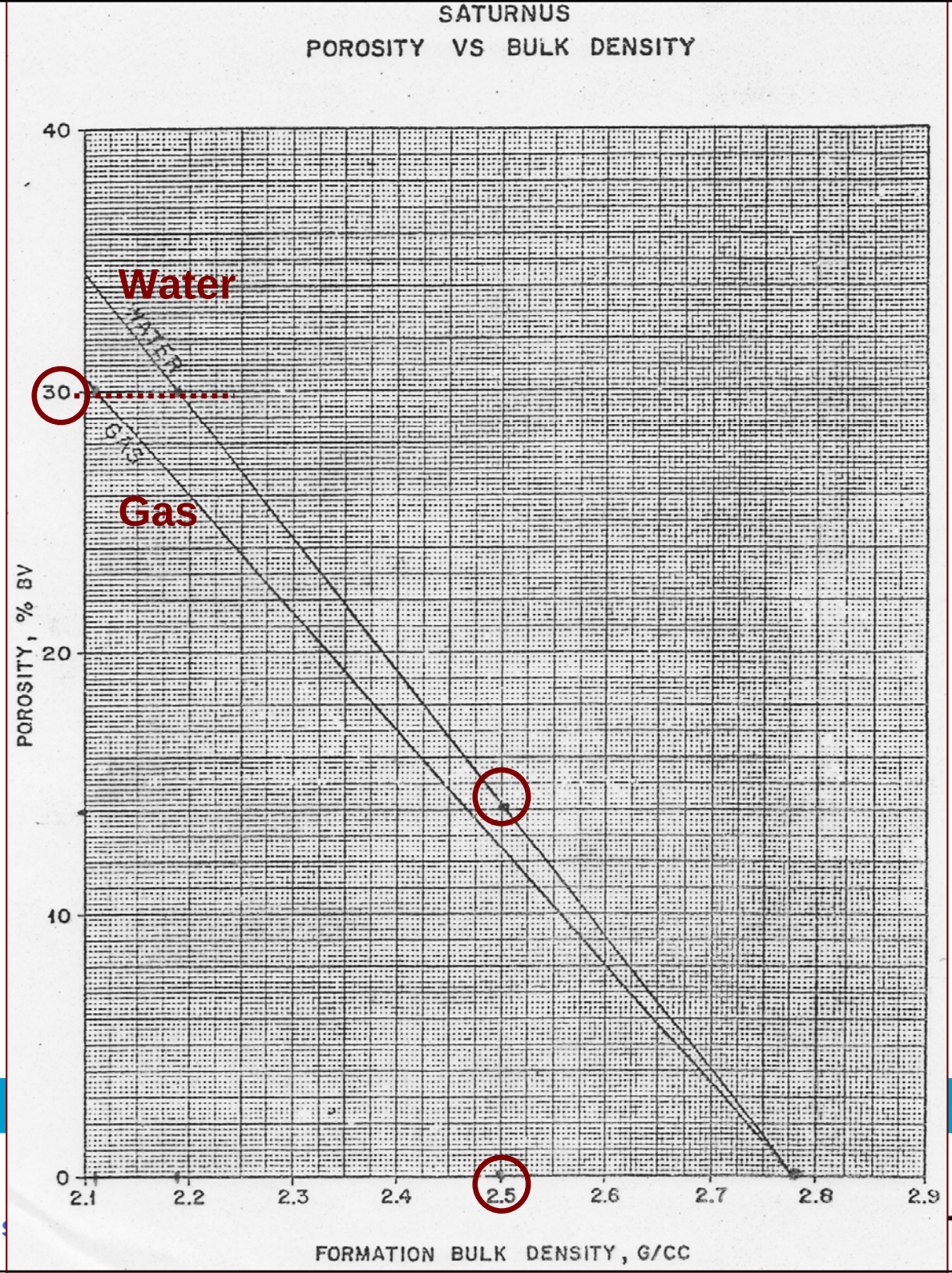


figure 3

Exercise Saturnus

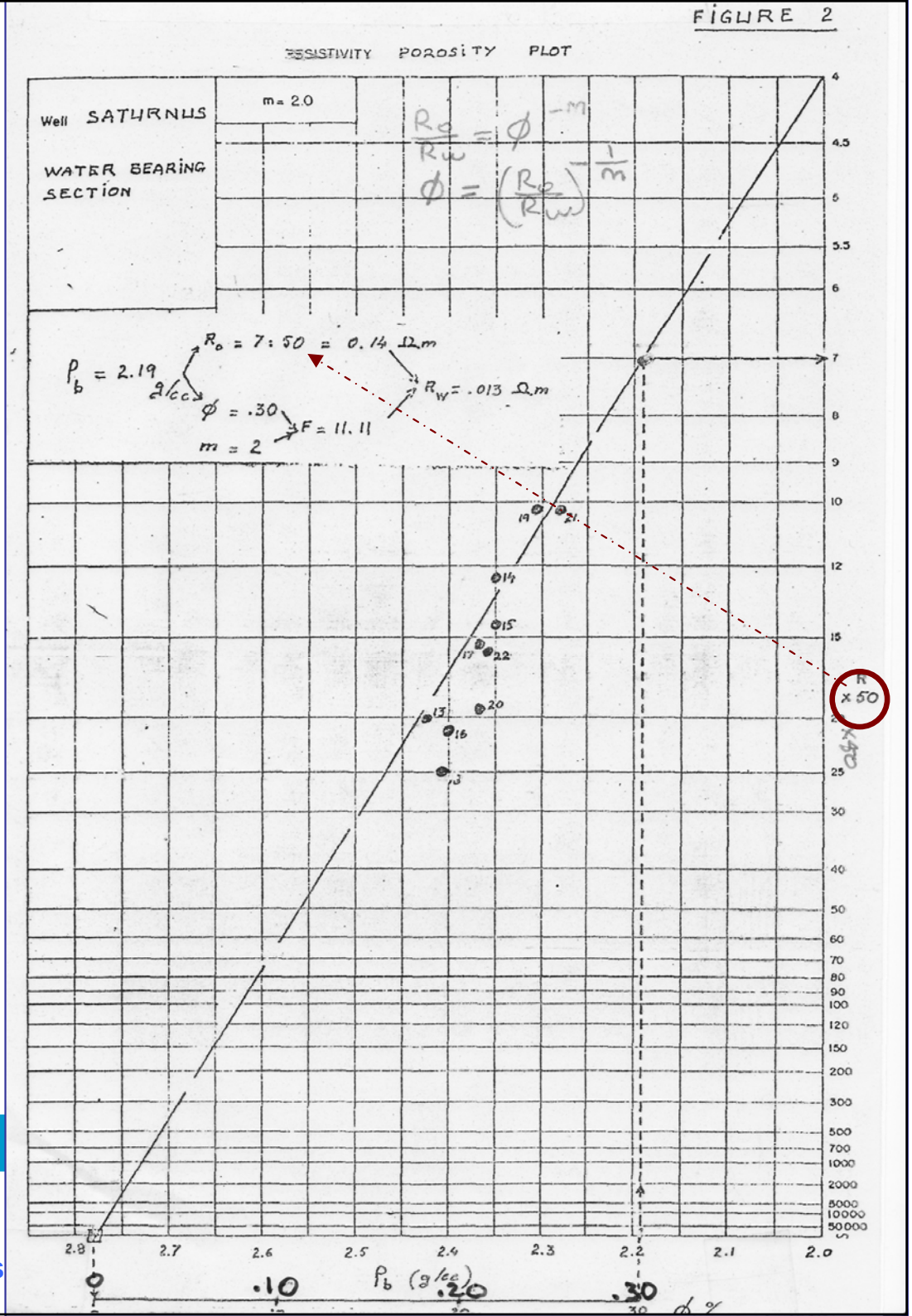
Figure 1



Exercise Saturnus
Figure 2

$Ro/Rw = \phi^{-m}$,
Ro = 0.14 Ωm, and,
$\phi = 0.30$

Then:
For m = 2 then Rw = 0.013 Ωm
For m = 1.7 then Rw = 0.018 Ωm



Exercise Saturnus: Table 1

$\frac{R_o}{R_w} = \phi^{-m}$

WATER BEARING SECTION

(One possible programme for the calculation of m is given on the following page)

$R_w = 0{,}013$

Bed N°	Interval (m) (depth GR-FDC)	ρ_b	C_t mmhos/m	R_t ohm.m	ϕ_{FDC} %	R_{MLL} ohm.m	m R_w=0.013	m R_{mf} 0.026
13	2433.2-2434.8	2.425	2500	0.40	18.0	0.45	1.95	1.66
14	2440.3-2441.8	2.35	4000	0.25	21.7	0.3.	1.92	1.62
15	2449.3-2450.8	2.35	3600	0.28	21.7	0.35	1.96	1.72
16	2451.2-2452.5	2.40	2300	0.43	19.25	0.50	2.09	1.78
17	2458.4-2460.0	2.37	3200	0.31	20.7	0.31	1.90	1.59
18	2465.8-2467.2	2.41	2000	0.50	18.7	0.50	2.05	1.74
19	2473.0-2474.0	2.31	4700	0.21	23.9	0.25	1.89	1.59
20	2474.0-2476.3	2.37	2600	0.38	20.7	0.4	2.01	1.75
21	2477.4-2478.0	2.28	4700	0.21	25.3	0.23	1.97	1.57
22	2479.0-2480.0	2.36	3100	0.32	21.3	0.45	2.10	1.83

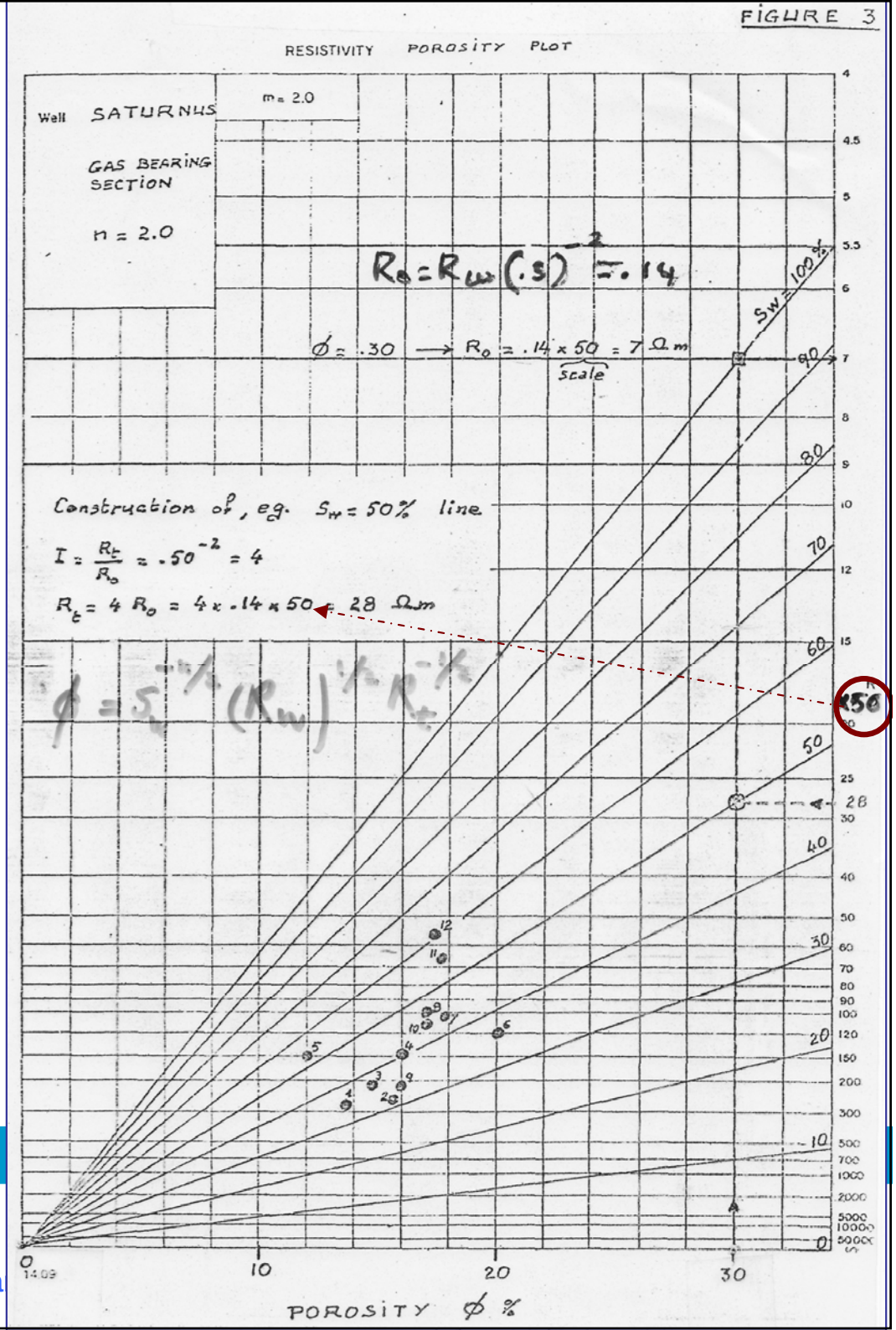
R_{IND} → average: 1.98 (sd.08

R_{MLL} → $\bar{m} = 1.69 = 1.70$

$\frac{R_o}{R_w} = \phi^{-m} \simeq \frac{R_{xo}}{R_{mf}}$

Exercise Saturnus

Combined Archie I & II to calculate Sw



Exercise Saturnus: Table 2

GAS BEARING SECTION

Procedure for the construction of isosaturation lines is given above.

Bed N°	Interval (m)	ρ_b	R_{LL} ohm.m	ϕ_{FDC} %	S_w %
1	2366.0-2367.0	2.47	5.4	13.8	35
2	2371.6-2372.2	2.43	5.0	15.7	32
3	2383.0-2384.1	2.45	4.2	14.7	37
4	2385.4-2386.9	2.42	2.9	16.0	40
5	2392.5-2394.2	2.51	3.0	12.0	53
6	2398.6-2399.8	2.33	2.4	20.1	36
7	2403.0-2405.5	2.38	2.1	17.8	44
8	2413.0-2415.5	2.40	2.0	17.0	47
9	2417.0-2418.5	2.42	4.3	16.0	34
10	2420.0-2421.5	2.40	2.2	17.0	44
11	2425.8-2427.5	2.38	1.3	17.8	55
12	2429.1-2430.0	2.39	1.1	17.4	60