Universitetet i Stavanger

RE-SIT EXAM IN: PET670 FORMATION EVALUATION AND WELL TESTING
DURATION: 4 HOURS
DATO: 15TH FEBRUARY 2019
"TOOLS" ALLOWED: Simple calculator
EXAM STRUCTURE: This exam consists of two Parts, A and B, on 8 pages, including this one; and Supplements on 2 pages (10 pages total)

Part A: Formation Evaluation

Please provide short and precise answers. You will get zero points for vague, too long, or unreadable answers even if they do contain correct information.
The Supplements with your marks are to be handed in together with the rest of your answers.

---

1. What is logging? (1 p.)
   What do abbreviations WL and LWD mean? (2 p.)
   What is formation volume factor? (2 p.)
2. Describe any one method of determining porosity of a rock sample in the lab. (5 p.)
3. What is capillary pressure? (1 p.)
   If a fluid-fluid interface is in equilibrium, how can one quickly find out which phase is under higher pressure – and what is the direction of the capillary force? (4 p.)
4. How can the location of FWL be found from the pressure vs. depth data? (1 p.)
   What is the capillary pressure curve? Name three methods of obtaining it in the lab. (4 p.)
5. What is the difference between total GR and SGR logs? (1 p.)
   Name three main sources of natural radiation. (3 p.)
   What is the main application of SGR log? (1 p.)
6. What is the principle of formation density logging? (4 p.)
   How is density-derived porosity value affected by gas in the formation? (1 p.)
7. Name the two key processes affecting the fate of neutrons emitted into the formation by the neutron logging tool. (2 p.)
   Does a fast neutron lose much of its original energy if it collides with a lead atom in the formation? With a hydrogen atom? Why? (3 p.)
8. In the context of neutron-density crossplot, what is called positive and negative separation? (2 p.)
   What can the following neutron-density crossplot readings indicate: large positive separation; zero separation; small negative separation? (3 p.)

9. What is V_{sh}, and what can this number be used for? (2 p.)
   Name at least three logs which can be used to estimate V_{sh}. (3 p.)

10. What are resistivity and conductivity – and which units are used for these quantities? (3 p.)
    What is the use of microlog, and what does it mean when ML and MIV readings separate? (2 p.)

11. What are the Hingle plot and the Pickett plott, and what is their main use? (5 p.)

12. Explain what these notations mean: S_{xo}, S_w, R_{xo}, R_{mf}, R_{mc}. Place these notations onto the corresponding empty spaces on Supplement A. Hand in the Supplement together with the rest of your answers. (5 p.)

13. Explain how one can estimate the movable hydrocarbon saturation, $S_o - S_{or}$, from deep and shallow resistivity logs. Explain all the notations, make clear which laws you rely upon and which logs/zones must the measurements be taken from. (5 p.)

To answer Questions 14-15, read the well logs from Supplement B.
Make necessary marks directly on the Supplement sheet
and hand in this sheet together with the rest of your answers.

Clean sandstone has matrix density $\rho_{ma} = 2.65\,\mathrm{g/cm^3}$.

14. Use the logs to perform a lithological analysis. Draw the lithologies in the depth track. Provide a brief explanation. (5 p.)

15. Resistivity log (not shown in the Supplement) indicates the presence of hydrocarbons in the sand zone. Is it possible to find out – based on the density log readings only – if the sand zone contains gas, oil or both? Explain your answer and support it by calculations. (5 p.)

Part B: Well Testing

Well Testing Problem 1 (26 p.)
With data from a 24 hours drawdown in a vertical well producing at 200 STB/D and located nearby a sealing fault, use parameters from Table 1, pressure drawdown data from Table 2 and Fig. 1 and Fig. 2 to answer the questions and carry out the analysis below.

(a) Fig. 1 shows a log-log plot of the drawdown data. Identify flow regimes in the data and indicate the range (start and end). (6 p.)

(b) With Fig. 1 and Fig. 2 as references, carry out a standard semi-log analysis of the drawdown data based on representative data points from Table 2 to compute m, k, $\Delta p_{1\mathrm{hr}}$ and S. (8 p.)

(c) Based on the semi-log plot (Fig. 2), estimate approximate distance to the sealing fault using intersection of straight-lines with slopes characteristic for (hemi-) radial flow regimes. (2 p.)

(d) With Fig. 1 and Fig. 2 as references and assuming that only late drawdown data after 10 hours of production are available without any knowledge about sealing fault nearby the well, compute m, k, $\Delta p_{1\mathrm{hr}}$ and S. (8 p.)

(e) Comparing the permeability and skin values computed in task (d) and task (b), which ones are closer to correct ones? Can we improve estimation of these parameters based on the results of task (d)? (2 p.)

Well Testing Problem 2 (24 p.)
With data from a 48 hours build-up in a newly fractured well following 12 hour production at 500 STB/D, use parameters from Table 1, pressure build-up data from Table 3 and Fig. 3 to answer the questions and carry out the analysis below.

(a) Fig. 3 shows a log-log plot of the build-up data. Identify flow regimes in the data and indicate the range of each (start and end). (4 p.)

(b) With Fig. 3 as reference, carry out a standard semi-log analysis of the build-up data based on representative data points from Table 3 to compute m, k, $p_{1\mathrm{hr}}$, S and Δp_s. (10 p.)

(c) With Fig. 3 as reference, use representative data points from Table 3 to compute the slope, m', and using the permeability value from the previous task, estimate fracture half-length, x_f. Compared to the computed skin value, what is likely fracture type? (6 p.)

(d) Use semi-log analysis to estimate the formation pressure as extrapolated pressure, p^*. Also, derive an estimate of the pressure drawdown after 48 hours, if the well continued to produce at the initial rate without being shut-in. (4 p.)

Good luck!

Table 1 – Input parameters for Problems 1 and 2

Formation thickness, h	=	300	ft
Porosity, ϕ	=	0.3	
Viscosity, μ	=	0.65	cp
Total compressibility, c_t	=	7.5×10^{-6}	psi^{-1}
Formation volume factor, B	=	1.03	RB/STB
Wellbore radius, r_w	=	0.3	ft

Table 2 – Pressure drawdown data

Elapsed Time (hr)	Pressure (psia)	Elapsed Time (hr)	Pressure (psia)	Elapsed Time (hr)	Pressure (psia)
0.000	4000.000	1.005	3968.930	26.000	3956.024
0.001	3999.176	1.265	3968.258	27.000	3955.836
0.002	3998.402	1.592	3967.567	28.000	3955.656
0.003	3997.667	2.005	3966.846	29.000	3955.481
0.004	3996.968	2.524	3966.086	30.000	3955.312
0.005	3996.277	3.177	3965.281	31.000	3955.148
0.006	3995.452	4.000	3964.428	32.000	3954.990
0.008	3994.477	5.000	3963.555	33.000	3954.836
0.010	3993.340	6.000	3962.809	34.000	3954.686
0.013	3992.034	7.000	3962.157	35.000	3954.540
0.016	3990.563	8.000	3961.577	36.000	3954.398
0.020	3988.942	9.000	3961.055	37.000	3954.261
0.025	3987.201	10.000	3960.581	38.000	3954.126
0.032	3985.387	11.000	3960.146	39.000	3953.995
0.040	3983.557	12.000	3959.744	40.000	3953.867
0.050	3981.774	13.000	3959.371	41.000	3953.742
0.063	3980.096	14.000	3959.023	42.000	3953.620
0.080	3978.565	15.000	3958.696	43.000	3953.501
0.100	3977.201	16.000	3958.389	44.000	3953.385
0.126	3976.002	17.000	3958.098	45.000	3953.271
0.159	3974.950	18.000	3957.823	46.000	3953.159
0.200	3974.016	19.000	3957.561	47.000	3953.050
0.252	3973.172	20.000	3957.312	47.500	3952.996
0.318	3972.390	21.000	3957.074	48.000	3952.943
0.400	3971.654	22.000	3956.847		
0.504	3970.949	23.000	3956.628		
0.634	3970.266	24.000	3956.419		
0.798	3969.596	25.000	3956.218		

Table 3 – Pressure build-up data

Elapsed Time (hr)	Pressure (psia)	Elapsed Time (hr)	Pressure (psia)	Elapsed Time (hr)	Pressure (psia)
0.0000	5371.712	0.7981	5421.459	24.0000	5487.281
0.0010	5373.592	1.0048	5426.417	25.0000	5487.698
0.0020	5374.370	1.2649	5431.556	26.0000	5488.088
0.0030	5374.966	1.5924	5436.815	27.0000	5488.454
0.0040	5375.467	2.0047	5442.136	28.0000	5488.797
0.0050	5375.924	2.5238	5447.438	29.0000	5489.121
0.0063	5376.436	3.1773	5452.675	30.0000	5489.427
0.0080	5377.011	4.0000	5457.758	31.0000	5489.715
0.0100	5377.654	5.0000	5462.502	32.0000	5489.988
0.0126	5378.376	6.0000	5466.200	33.0000	5490.247
0.0159	5379.184	7.0000	5469.184	34.0000	5490.493
0.0200	5380.090	8.0000	5471.653	35.0000	5490.726
0.0252	5381.106	9.0000	5473.735	36.0000	5490.949
0.0318	5382.243	10.0000	5475.518	37.0000	5491.161
0.0400	5383.517	11.0000	5477.065	38.0000	5491.363
0.0504	5384.943	12.0000	5478.420	39.0000	5491.556
0.0634	5386.539	13.0000	5479.620	40.0000	5491.740
0.0798	5388.326	14.0000	5480.689	41.0000	5491.917
0.1005	5390.325	15.0000	5481.649	42.0000	5492.086
0.1265	5392.560	16.0000	5482.515	43.0000	5492.248
0.1592	5395.060	17.0000	5483.302	44.0000	5492.404
0.2005	5397.850	18.0000	5484.019	45.0000	5492.553
0.2524	5400.957	19.0000	5484.676	46.0000	5492.697
0.3177	5404.398	20.0000	5485.281	47.0000	5492.835
0.4000	5408.182	21.0000	5485.838	48.0000	5492.968
0.5036	5412.302	22.0000	5486.355		
0.6340	5416.739	23.0000	5486.834		

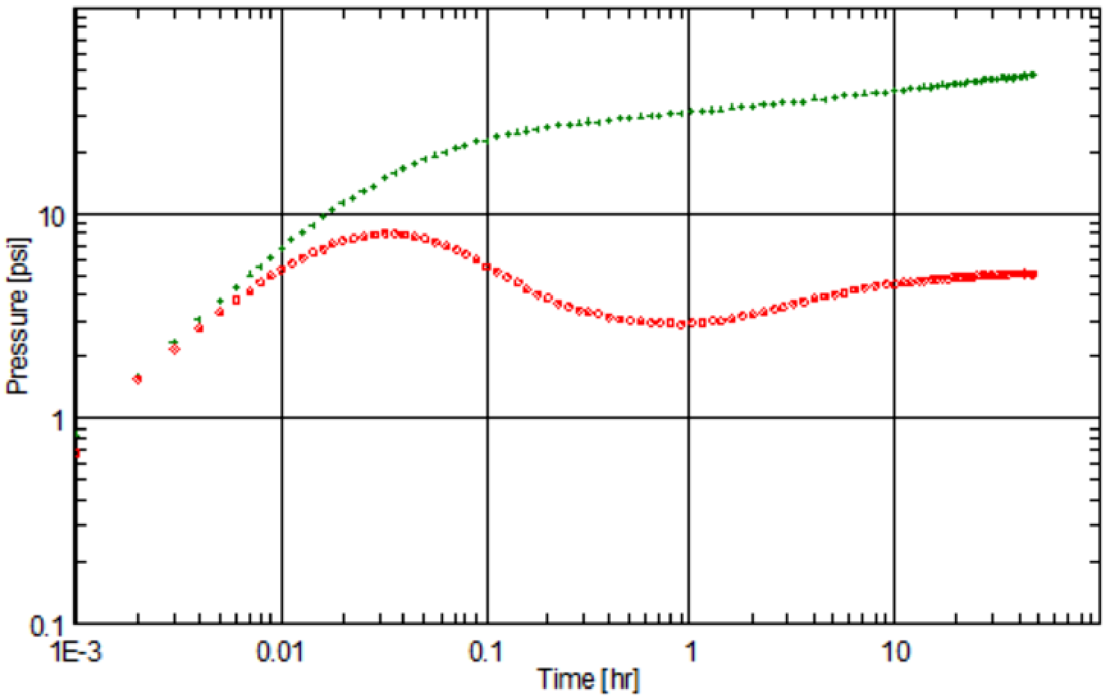


Figure 1: Pressure drawdown (green) and pressure derivative (red) for vertical well near sealing fault (log-log plot).

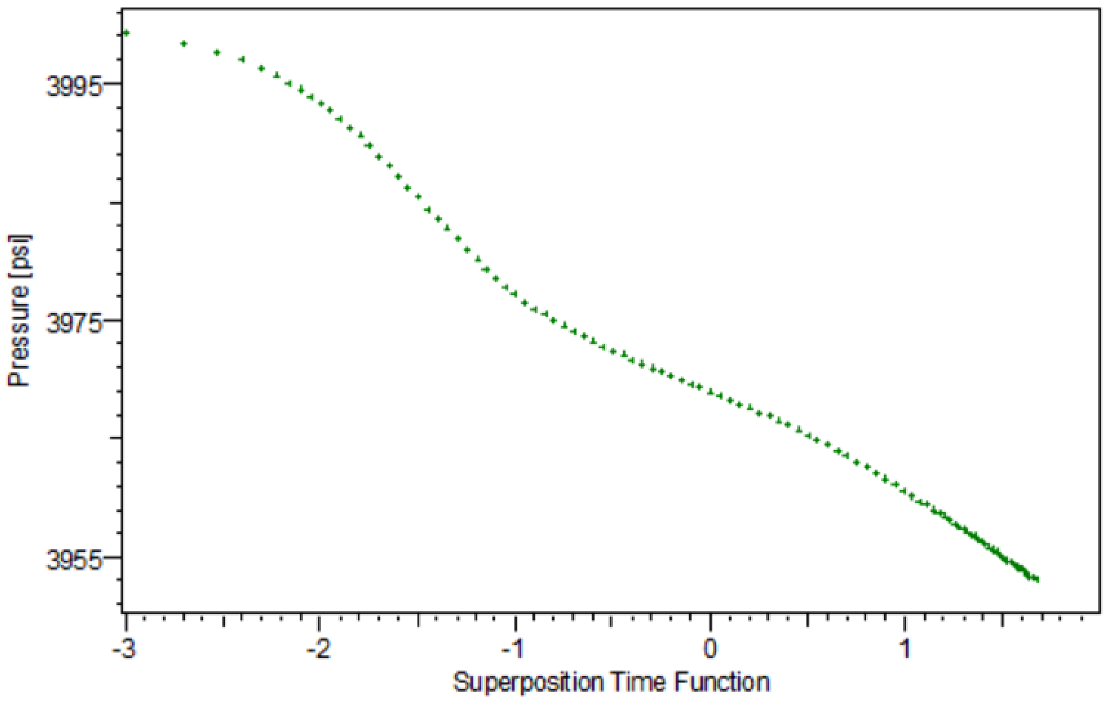


Figure 2: MDH (semi-log) plot for pressure drawdown from Figure 1. Superposition time function: $\log t$.

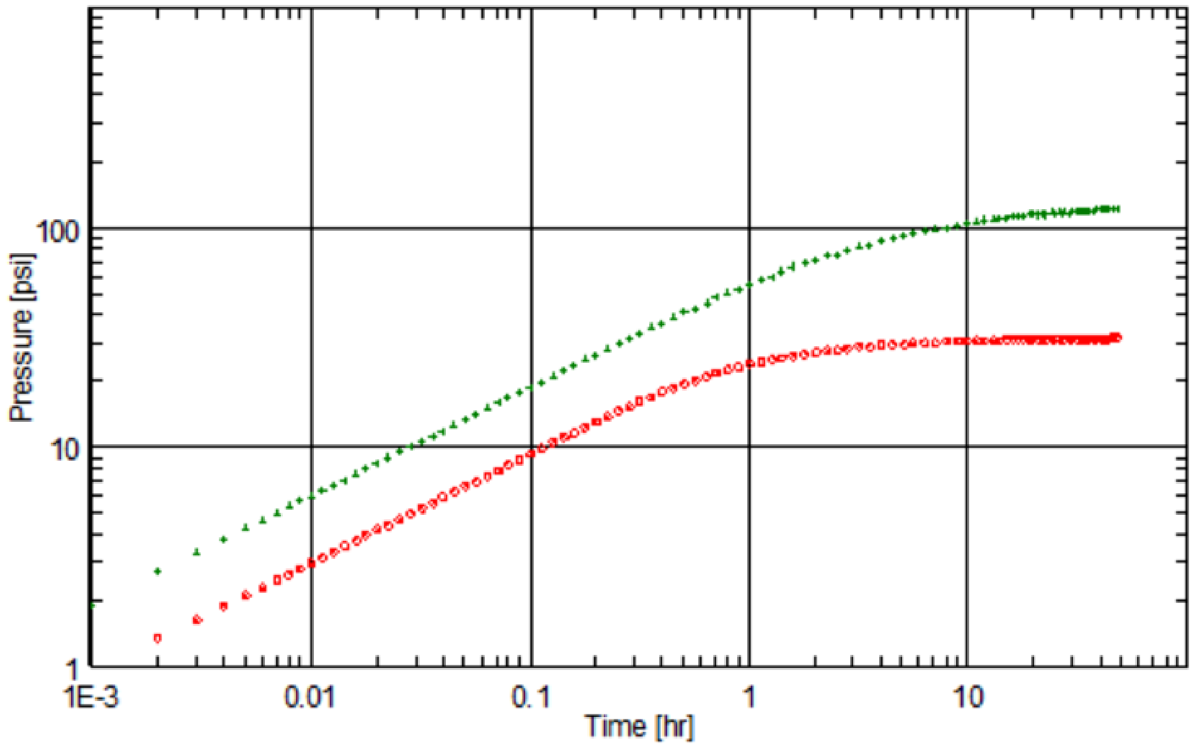


Figure 3: Pressure build-up (green) and pressure derivative (red) for fractured well.

STANDARD EQUATIONS WELL TESTING

$$p_D = \frac{kh}{18.66qB\mu}\Delta p$$ (SI units, oil; field units: 18.66 → 141.2)

$$t_D = \frac{0.000355k}{\phi\mu c_t r_w^2}t$$ (SI units, oil and gas; field units: 0.000355 → 0.000264)

$$m = \frac{21.49qB\mu}{kh}$$ (SI units; field units: 21.49 → 162.6)

$$p_{wf}(t) = p_i - m\left(\log t + \log\frac{k}{\phi\mu c_t r_w^2} - 3.098 + \frac{S}{1.151}\right)$$ (SI units, DD data; field units: 3.098 → 3.228)

$$S = 1.151\left(\frac{p_i - p_{1hr}}{m} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.098\right)$$ (SI units, DD data; field units: 3.098 → 3.228)

$$p_{ws}(\Delta t) = p_{wf,s} + m\left(\log\frac{\Delta t}{t+\Delta t} + \log t + \log\frac{k}{\phi\mu c_t r_w^2} - 3.098 + \frac{S}{1.151}\right)$$ (SI units, BU data; field units: 3.098 → 3.228)

$$S = 1.151\left(\frac{p_{1hr} - p_{wf,s}}{m} - \log\frac{t}{t+1} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.098\right)$$ (SI units, BU data; field units: 3.098 → 3.228)

$$\Delta p_S = \frac{m}{1.151}S$$

$$r_{inv} = 0.0286\sqrt{\frac{kt}{\phi\mu c_t}}$$ (SI units; field units: 0.0286 → 0.0246)

$$d = 0.0141\sqrt{\frac{kt}{\phi\mu c_t}}$$ (SI units; field units: 0.0141 → 0.0122)

Fractured wells:

$$m' = \frac{0.624qB}{hx_f}\sqrt{\frac{\mu}{k\phi c_t}}$$ (SI units; field units: 0.624 → 4.064)

$$S = \ln\frac{2r_w}{x_f}$$ (fracture with infinite conductivity)

$$S = \ln\frac{er_w}{x_f} = \ln\frac{2.718r_w}{x_f}$$ (fracture with uniform flux)

Gas tests:

$$q_{sc} = C\left(\bar{p}^2 - p_{wf}^2\right)^n$$ (simplified deliverability, p^2 formulation)

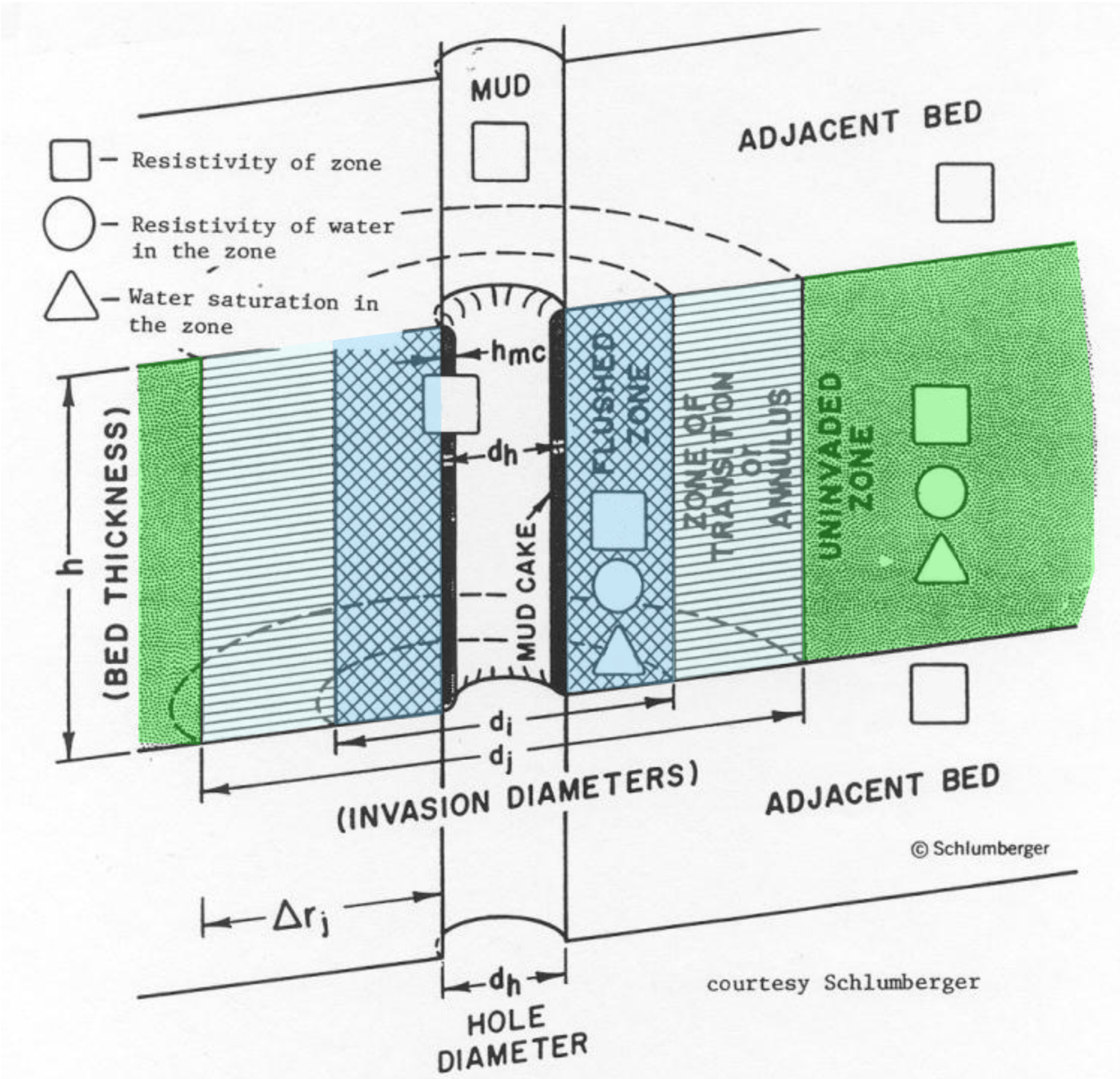
$$\bar{p}^2 - p_{wf}^2 = aq_{sc} + bq_{sc}^2$$ (LIT based deliverability, p^2 formulation)

$$AOF = \frac{1}{2b}\left(-a + \sqrt{a^2 + 4b\bar{p}^2}\right)$$ (LIT based AOF, p^2 formulation)

This sheet is to be handed in together with your answers.

Please write your candidate number in the corresponding field.

Candidate number: ______________________

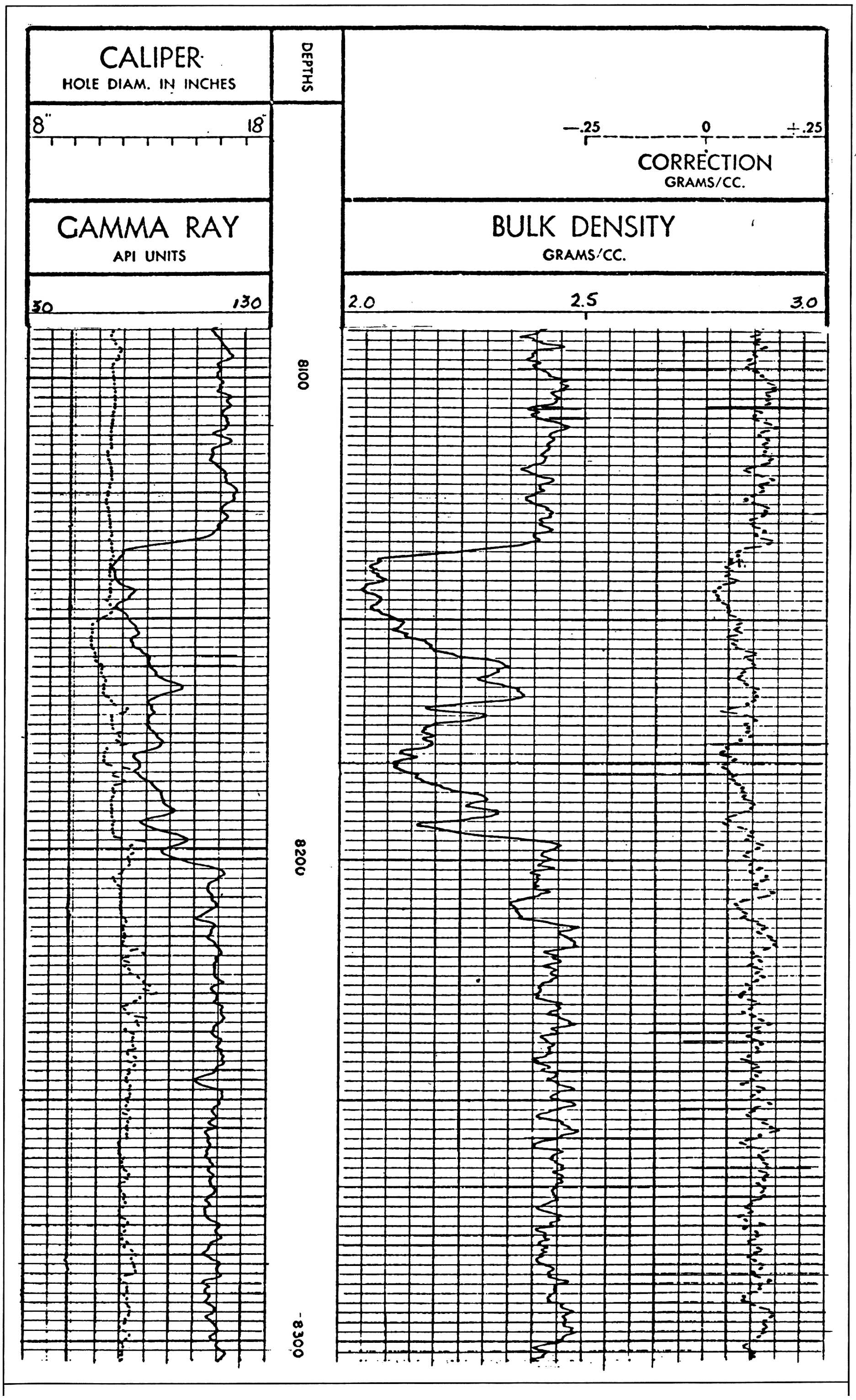


Supplement A: Borehole environment

This sheet is to be handed in together with your answers.

Please write your candidate number in the corresponding field.

Candidate number: ______________________



Supplement B: Log reading exercise