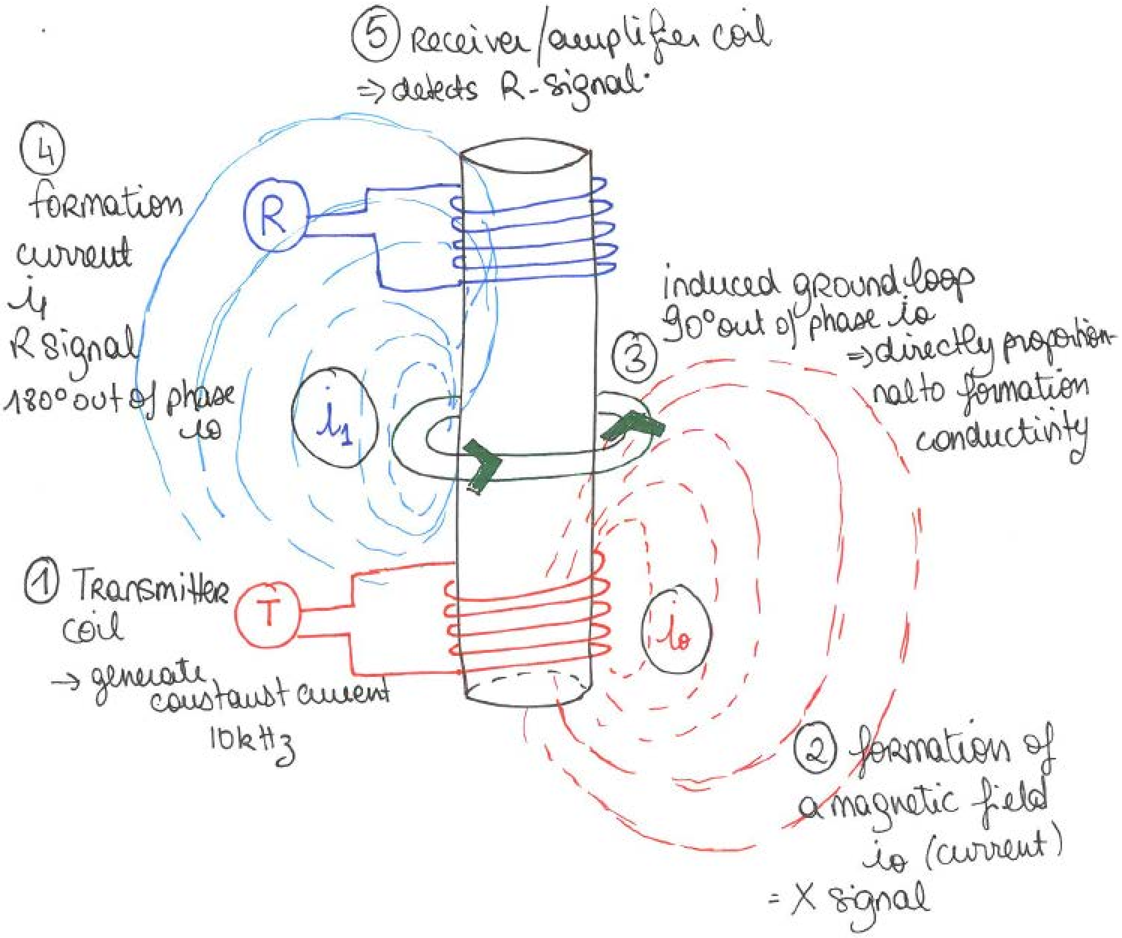
EXAMINATION: PET110 Well logging part **DATE:** 11.05.15

ENGLISH TEXT

Exercise 1 – Induction logs

Use short answers and sketches.

1. Describe the principles of an induction log using sketches.



X-signal can be detected by receiver coil. It can therefore be eliminated using bucking coils. New tools are also able to measure it (and differentiate from R-Signal)

2. What are the differences between the induction log and laterolog for determining Rt or Ro?

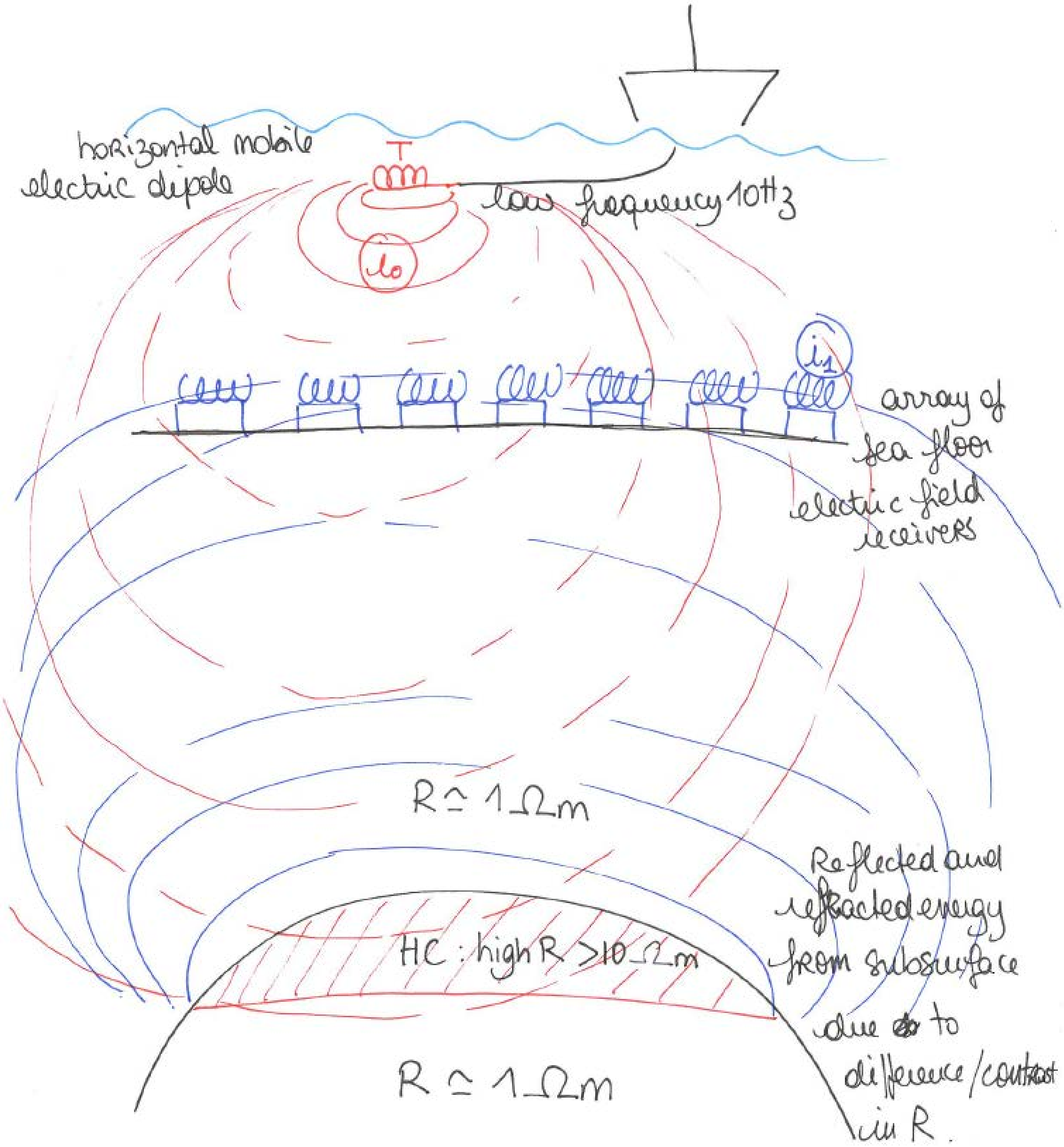
- Induction log measures conductivity: R=1/C so needs to be converted before plotting
- Laterolog measures Resistivity directly
- Laterolog needs Rxo < Rt (only WBM).

3. What are the borehole conditions required to use the induction log (e.g. mud, WL, LWD, etc.)?

- OBM or WBM
- WL and LWD
- Can be used with short diameter holes
- One zone of measurement will not affect the other

4. What is sea bed logging? Describe using sketches.

Sea bed Logging is Electromagnetic Measurement (EM) based on the same principle than induction log. We obtain an image of the subsurface than as to be interpreted (as seismic reflection data too).



5. Do we use the induction log to measure the microresistivity Rxo? If not, describe the general functioning and position of the microresistivity tool in the borehole using sketches. Cite three types of microresistivity measurements.

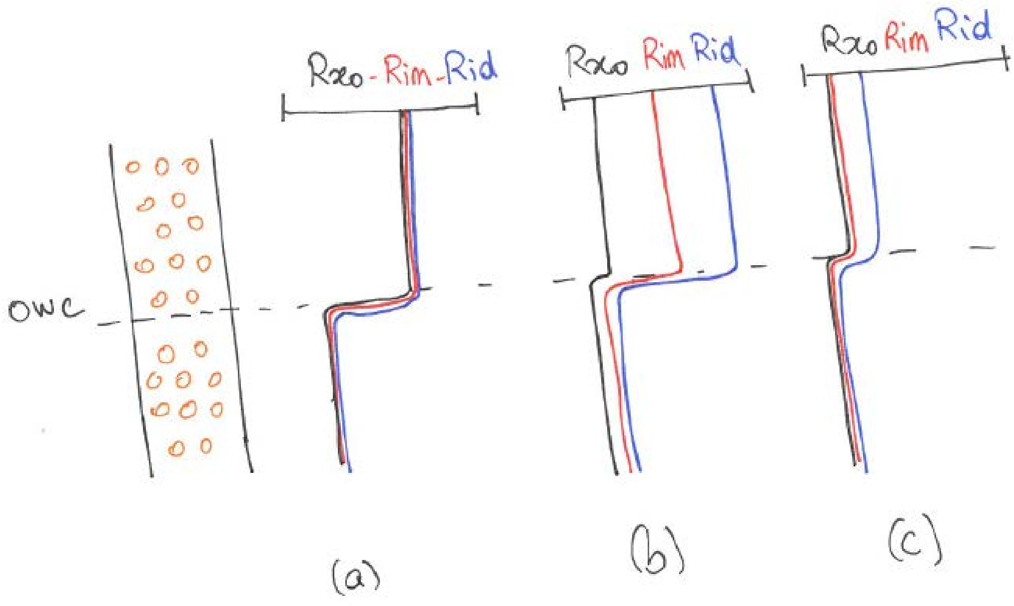
- Microresistivity log is based on laterolog principles using pads positions against the borehole wall. Microresistivity devices:
- Microlaterolog (1 electrode Ao, 2 measuring electrodes and 1 bucking electrode)
- Proximity log (1 electrode Ao, one measuring electrode and one bucking electrode)
- MicroSpherically Focused Log (Two current electrodes Ao and A1, one measuring electrode Mo and 2 monitoring electrodes)

6. What are the advantages of an array induction tool (AIT) in comparison with a dual induction tool?

- Dual induction tool:
    - o 1 transmitter, 1 bucking transmitter and 2 Receivers
        - ⇨ two depths of investigation: deep 1-5m with vertical resolution 2.5m and shallow 0.8-1.5m with vertical resolution 1.5m.
        - ⇨ Correction for mud filtrate invasion

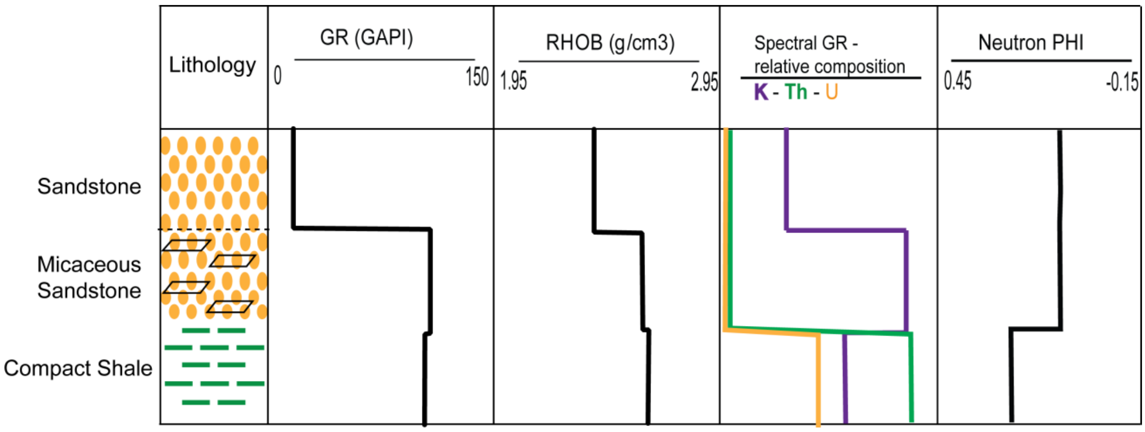
- Array Induction Tool (AIT):
    - o 1 transmitter and 8 Receivers
        - ⇨ 28 raw signals processed mathematically to determine invasion profile
        - ⇨ 5 curves plotted (10", 20", 30", 60" ⇔ 25 cm to 2.3m) to determine correct Rt
        - ⇨ Mud and hole corrections

7. We have run three resistivity logs: Rxo-Rim-Rid in a well using salt water based mud. Draw the response of each of these logs to a vertical column of sand with oil and water zones for three situations:
    a. No invasion
    b. Moderate mud filtrate invasion
    c. Very deep mud filtrate invasion



Exercise 2

1. Draw the log responses to the lithology column on Figure 2.1.
    a. Which other log(s) could you use to interpret the micaceous sand? Draw on Figure 2.1



b. How would you compute the porosity in the micaceous sand?

To compute the porosity in micaceous sand, we need to know first the quantity of mica relatively to the quantity of quartz. For that we can use the method of MN and MP triangular plots.

Once we know the quantity, we can compute the porosity using density log:

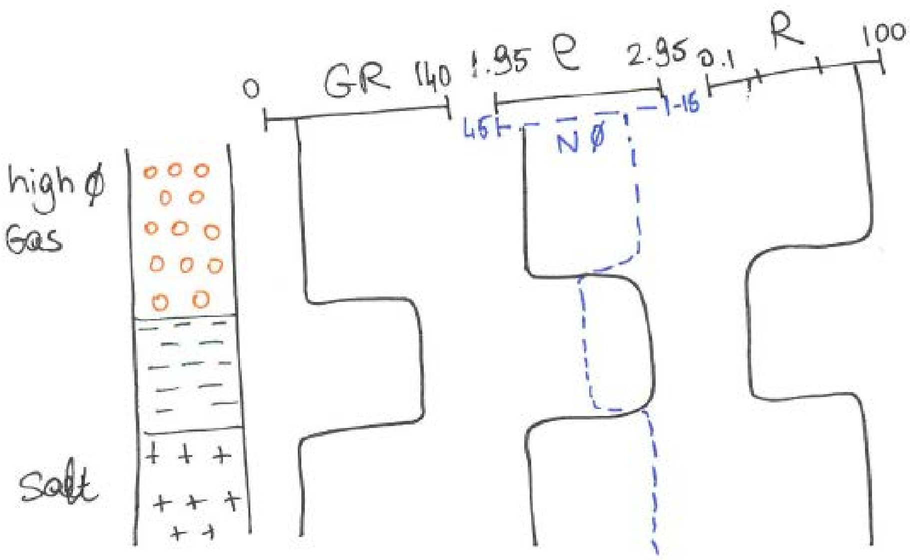
$$\emptyset_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

$$\emptyset_D = \frac{(percentage\,.\,\rho_{Qz} + percentage\,.\,\rho_{mica}) - \rho_b}{(percentage\,.\,\rho_{Qz} + percentage\,.\,\rho_{mica}) - \rho_f}$$

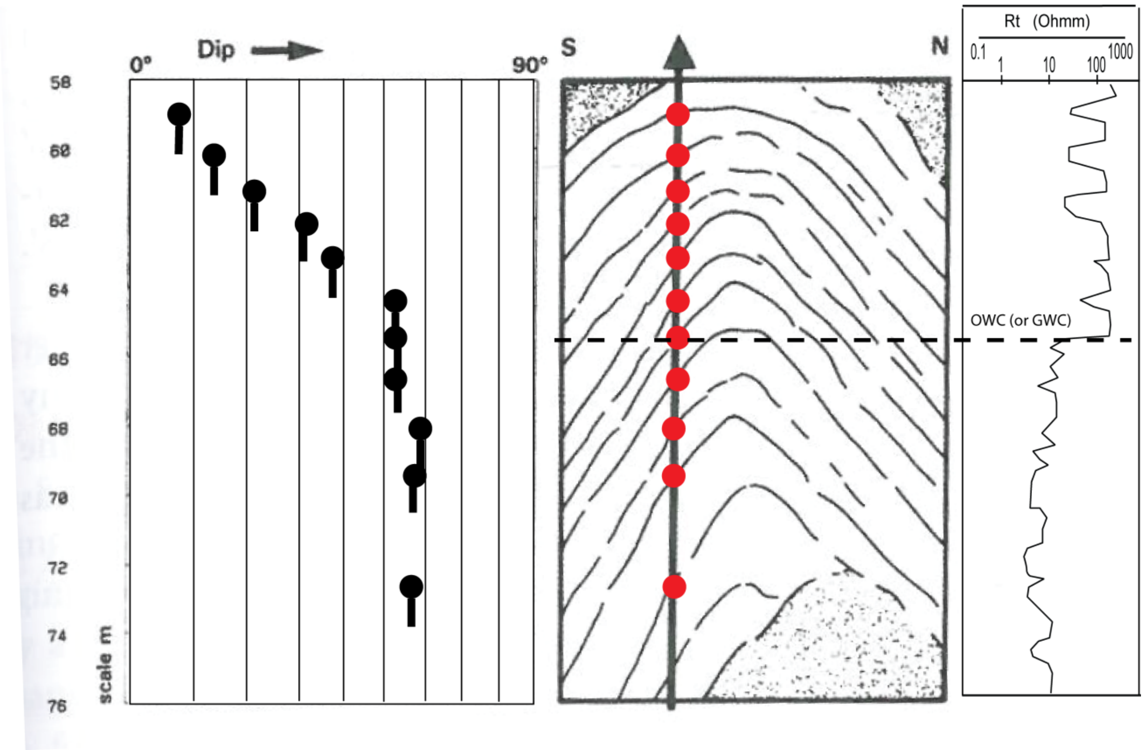
Or we can read the porosity from the Density/Neutron crossplot, using the percentages from plot MP.

2. Describe how salt can create problems in log interpretation, as it can easily be misinterpreted. You can use sketches to illustrate.

Salt can be misinterpreted with a porous sand zone filled with gas. In order to differentiate them, the sonic log could be used under certain conditions, core or cutting data also. The evaluation of the fluids in the well using pressure could also determine if it can be gas or not as salt is a sealing barrier.



3. Figure 2.2 shows a cross section of geological structure with a well.
   a. Put the tadpoles corresponding to the dots on the layers crossing the well in the tadpole plot of Figure 2.2.



   b. What is the name of this geological structure?

This structure is an anticline (2D cross section, the well is drilled on one side)

   c. If you had been given only the tadpole plots, would you be able to interpret the same structure? Explain why.

No, because the tadpoles plot gives only really local information: the dip and azimuth of the layers around the borehole. The top of the anticline is too far from the well to be detected by the dipmeter and therefore without extra information we cannot interpret the dipmeter plot as an anticline

   d. The lithology is an alternation of sand and shale. Can the structure be a reservoir? If yes, put the fluid contact using the resistivity track on Figure 2.2.

The anticline can be a reservoir, with the fluid stored at the top of it. Usually this is sealed by shale.

   e. Can you determine the fluid's nature with only the resistivity log? Which other log(s) should you use?

To determine if the fluid is oil or gas, we should use a combination of Density and Neutron logs (look for gas effect) or pressure data.

Exercise 3 – Well evaluation

From the well 17/12-4 from the Bream oil field on the Sele high the following wireline logs are given

- Gamma log
- Caliper log
- Neutron log
- Sonic log
- Resistivity log

1: Mark the lithology in the depth track for the log interval.

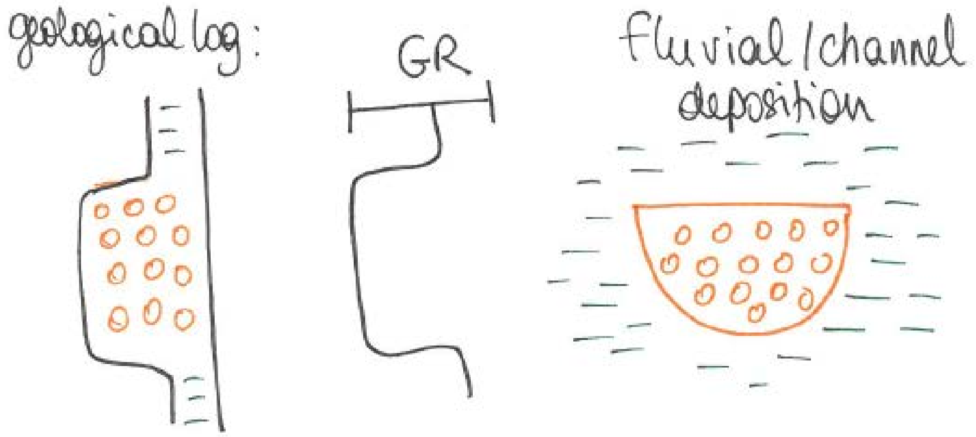
2. Mark directly on the logs oil or water for the entire sand zone.

3. Describe the vertical communication for the whole interval and the oil/water contact(s).

There is no good communication in this well. Many layers of shale are sealing thorough the sequence. We can find oil/water and again oil/water a bit deeper

4. Describe the sedimentology for the Bryne formation. Which log(s) do you use? Illustrate the depositional environment with a sketch.

We use mainly Gamma Ray log to determine the sedimentology: fluvial with uniform deposition.



5. Mark the Net Sand zones for the whole interval. What is the definition of Net Sand?

Net Sand is producible sand with Ø >10% and Vcl<40%

6. Determine the porosity Ø using 3 techniques and the water saturation Sw at 2310.

	Density (g/cm3)	Neutron Porosity	Sonic (μs/ft)	Resisitivity (Ohmm)
Oil zone 2310m	2.17	0.22	85	200
Water zone 2350m	2.20	0.18	85	0.3

ρ_{qz} = 2.65 g/cm^3 ρ_{fl} = 2.65 g/cm^3

Δtqz = 55 μs/ft Δtfl = 189 μs/ft

Porosity computation from three methods:

Oil zone

- Porosity from density

$$\emptyset_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

$$\emptyset_D = \frac{2.65 - 2.17}{2.65 - 1.00}$$

$$\boldsymbol{\emptyset_D = 0.29}$$

- Porosity from sonic

$$\emptyset_s = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

$$\emptyset_s = \frac{85 - 55}{189 - 55}$$

$$\boldsymbol{\emptyset_s = 0.22}$$

- Porosity from density and neutron logs using chart

$$\emptyset = \mathbf{0.275}$$

There are uncertainties in the porosity computation, we will use porosity from density log from now on.

Computation of water saturation

- Formation factor in oil zone

$$F\_oil = \frac{0.62}{0.29^{2.15}} = 8.82$$

- Water zone
  - Porosity from density

$$\emptyset_D = \frac{2.65 - 2.20}{2.65 - 1.00} = 0.27$$

  - Formation factor

$$F\_wat = \frac{0.62}{0.27^{2.15}} = 10.35$$

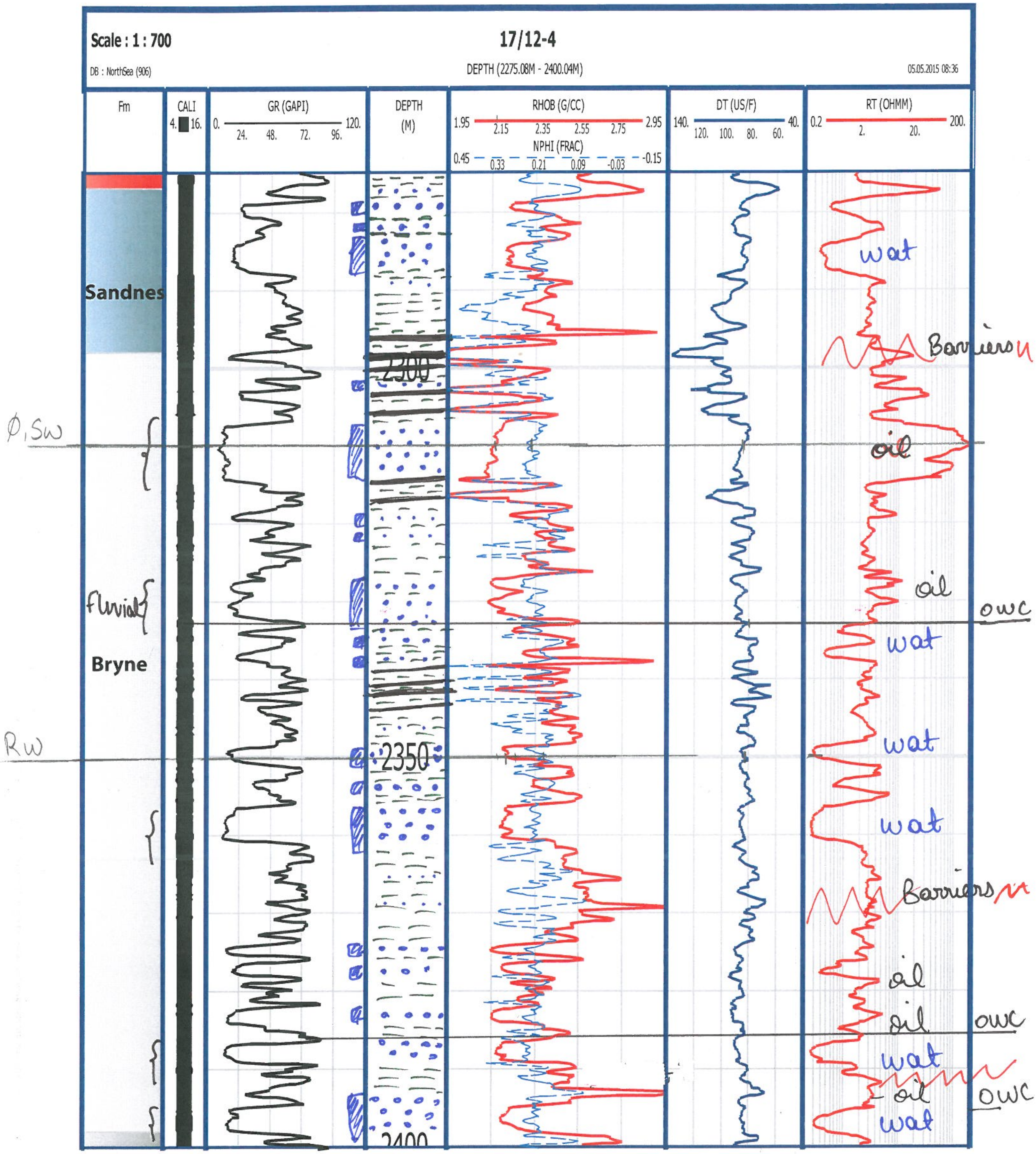
  - Rw

$$Rw = \frac{Ro}{F} = \frac{0.3}{10.35} = \ 0.0289$$

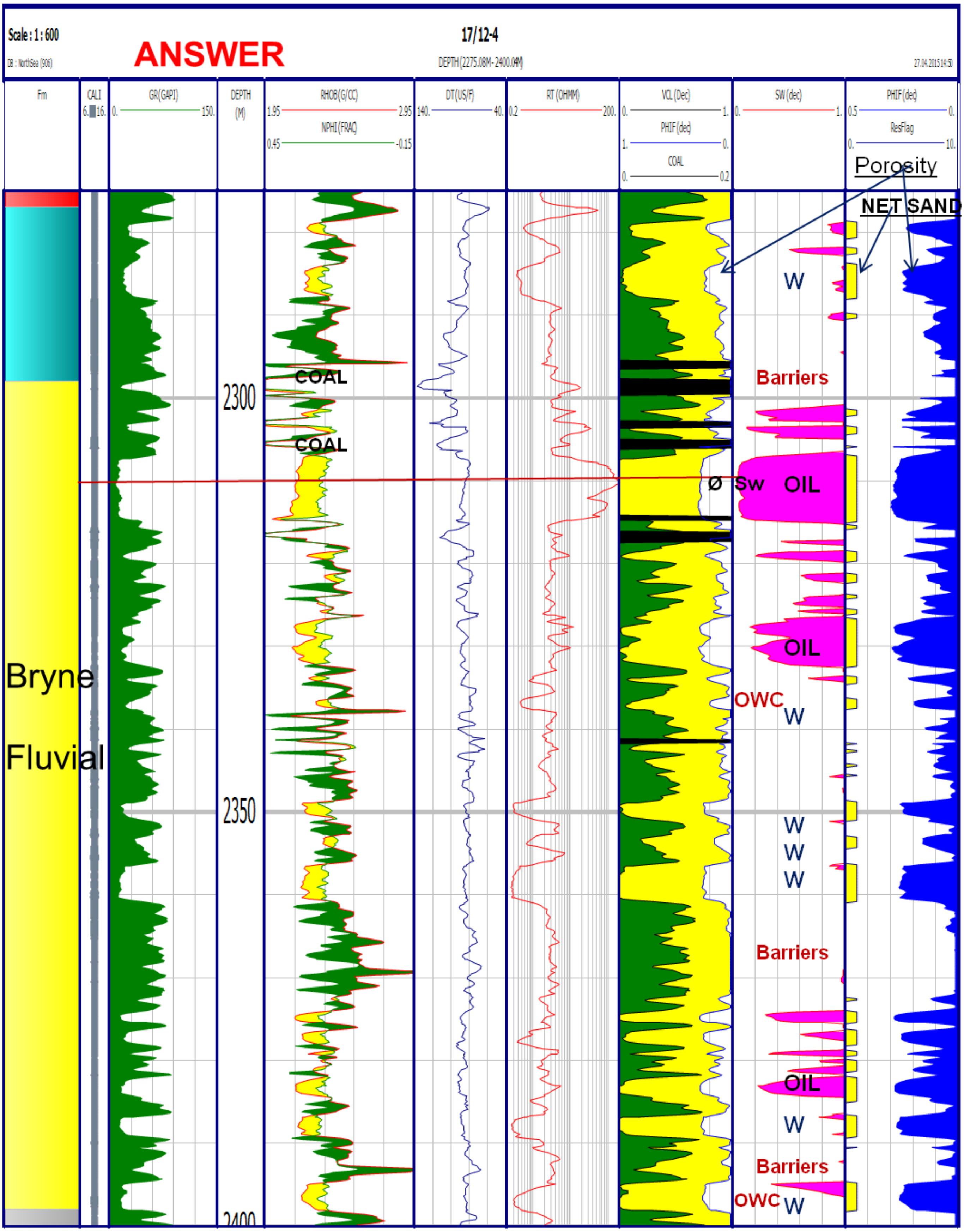
- Water saturation in oil zone

$$Sw = \sqrt[2]{\frac{F\_oil \times Rw}{Rt}} = \sqrt[2]{\frac{8.82 \times 0.0289}{200}} = \mathbf{0.0357} = \boldsymbol{Sw}$$

Really high S_{HC} due to the lack of communication within the reservoir.



Net Sand
sandstone
coal
shale



Scale : 1 : 600
DB : NorthSea (906)
ANSWER
17/12-4
DEPTH (2275.08M - 2400.04M)
27.04.2015 14:53
Fm
CALI
6. 16.
GR(GAPI)
0. 150.
DEPTH (M)
RHOB(G/CC)
1.95 2.95
NPHI(FRAC)
0.45 -0.15
DT(US/F)
140. 40.
RT (OHMM)
0.2 200.
VCL (Dec)
0. 1.
PHIF (dec)
1. 0.
COAL
0. 0.2
SW (dec)
0. 1.
PHIF (dec)
0.5 0.
ResFlag
0. 10.
Porosity
NET SAND
W
Barriers
COAL
COAL
2300
Ø Sw OIL
OIL
OWC W
Bryne
Fluvial
2350
W
W
W
Barriers
OIL
W
Barriers
OWC W
2400