Svar Vår 2013

Borehullslogging

OPPGAVE 1

a) Induksjonsloggen

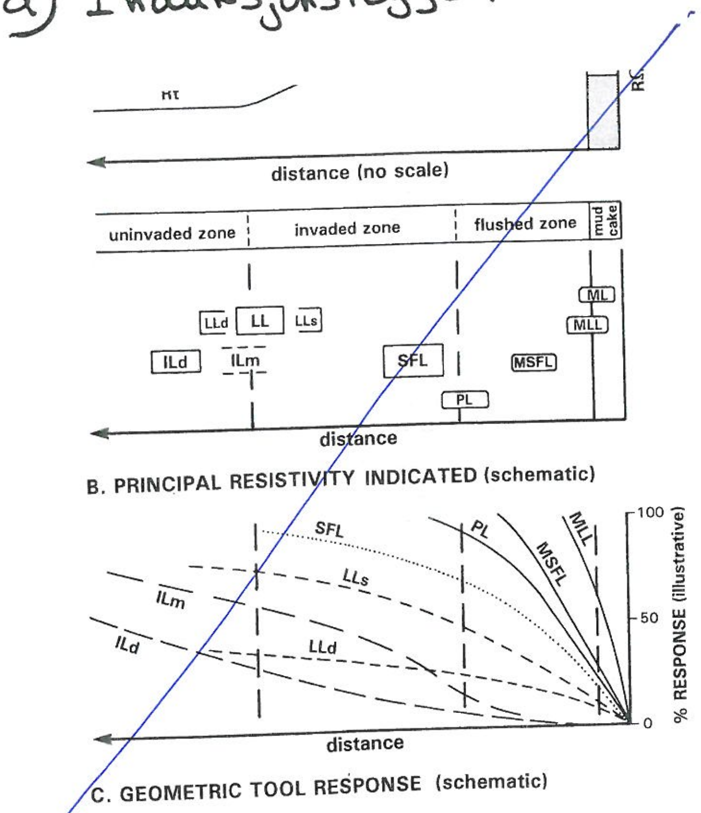


Figure 6.18 The type of resistivity measured by the various tools (after Schlumberger). IL = induction log, deep-medium; LL = laterologs, deep-shallow; SFL = spherically focused log; MSFL = micro-spherically focused log; PL = proximity log; MLL = microlaterolog; ML = microlog.

6.5 Induction tools

Standard tools

The induction tool was introduced to the industry by Henri Doll of Schlumberger in 1949. It was based on the design of a mine detector. A basic induction tool consists of an emitting coil and a receiving coil separated along the length of the tool by an electrically isolated section (mandrel). A constant amplitude sinusoidal current is applied to the transmitter coil. This creates a magnetic field around the tool which in turn induces eddy currents in the formation, flowing in a circular path around the tool (Figure 6.19). The eddy currents create their own magnetic field and induce an alternating current in the receiver coil. The eddy currents are 90° out of phase with the emitter current and the receiver current a further 90°: the emitter and receiver therefore, show a 180° phase shift. This measured current is the so called *R-signal*. There is also a much stronger current caused by a direct coupling of the emitter and receiver coils which is 90° out of phase with the emitting current: this is the *X-signal*.

The standard modern induction tool, such as the Dual Induction of Schlumberger, was introduced in 1963, although the technology had already existed in separate tools for some time. These dual induction tools consisted of emitting and receiving coils along with a series of paired, reverse wound coils, precisely placed to eliminate a)

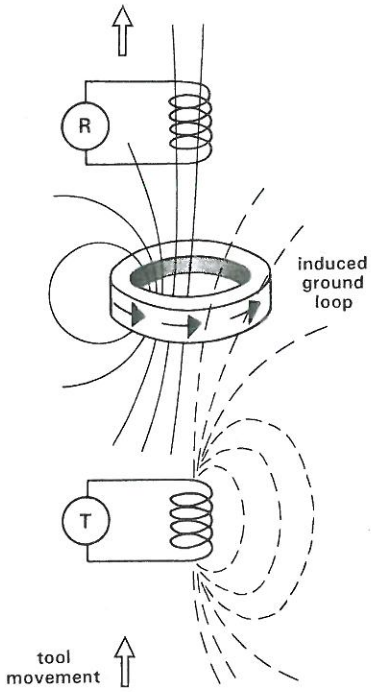


Figure 6.19 The principle of the simple induction tool. The vertical component of the magnetic field from the transmitting coil, T, induces a ground loop in the formation which in turn is detected by the receiver coil, R (re-drawn, modified from Ellis, 1987).

d)

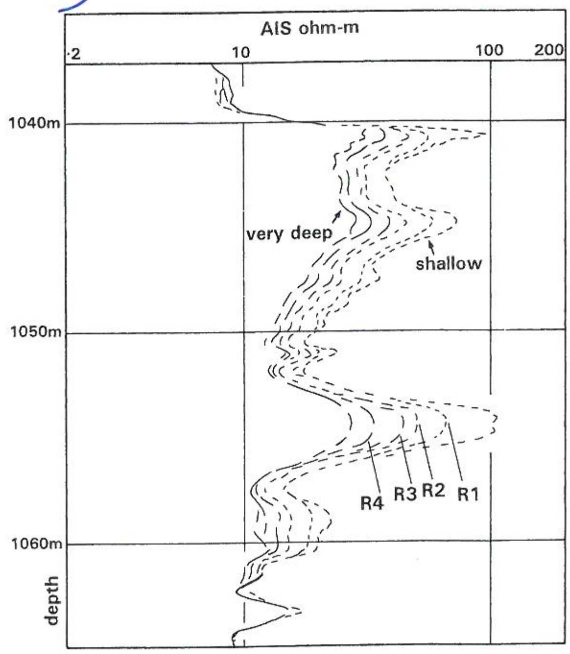


Figure 6.20 Invasion profile indicated by the BPB AIS, array induction tool in a water-filled limestone drilled with oil-based mud. The 4 raw induction tool readings (R1 – R4) have been resolution matched and modelled to give the invasion profile. The results may be presented as a colour image (from Elkington, 1995).

or buck out the unwanted *X*-signal. The typical tool used today, the dual induction (combined with other modules) has been improved but has the same basic construction as the earlier ones. The principal coils are set 1 m (40") apart and it is considered that the induced current comes from the formation between 1 m and 5 m (Western Atlas, 1.6 m) away from the borehole, the exact depth of investigation depending on formation and mud conductivities. The corresponding average depth of investigation for the medium or shallow induction is 80 cm (i.e. detection depth of 50% of the tool signal).

Recent developments, Array induction tools

Advances have been made in recent years in induction logging. A significant new tool is the array induction. For example the Array Induction Tool (AIS) of BPB, who were the first to introduce such a tool in 1983 (Martin *et al.*, 1984), consists of one emitter coil and four receiver coils. The raw signals are processed mathematically using the laws of electromagnetics, to produce a log value or formation signal. The multiple investigation depths calculated from the tool response can be reconstructed into an invasion profile (Figure 6.20) impossible with 2 value tools, although the shallowest reading is probably not generally into the flushed zone (Head *et al.*, 1992).

A second advance in induction tool design is that modern tools measure both the *R*- and *X*-signals, principally because the *X*-signals are used in subsequent signal processing (*see below*). The modern tools also have the possibility of using different current frequencies. The older tools used a fixed frequency of 40 kHz while modern tools give a choice of 10, 20 and 40 kHz.

The other area of advance in induction logging is in signal processing. Induction tool responses can be very satisfactorily modelled mathematically. This means that the difference between tool derived values and real formation values can be 'modelled out'. It is, effectively, the *'reconstruction of a formation property profile consistent with the measured data'* (Dyos, 1987). This technique, inversion, can be applied in several ways, but essentially consists of predicting realistic formation values from the tool recorded values, by satisfying mathematically, the calculated distortion to the tool signal that the proposed formation would have. This is in fact forward modelling. The Phasor Induction tool of Schlumberger uses signal processing to improve the conventional induction tool measurements using one set of log values to correct the other (Maute, 1992).

The induction tools are important because they provide the only resistivity measurement in wells drilled with oil-based mud. With the older standard tools, signal distortion was common and it was not possible to have a flushed zone resistivity, only a deep reading. Inversion is diminishing signal distortion and with the new array tools a spectrum of resistivities can be presented (Figure 6.20).

7
RESISTIVITY LOGS

7.1 Generalities

The log

Of all the logging tools, those that measure resistivity are archetypal. It was with surface resistivity measurements that Conrad Schlumberger started his company in 1919 and the first log to be run was a resistivity log **(Figure 1.1)**.

Resistivity is an intrinsic property of matter that quantifies its ability to conduct electricity. The higher the resistivity the more difficult it is to pass a current of a particular magnitude. The resistivity log is a measurement of this in subsurface formations. As a downhole measurement, resistivity is distinguished from most, if not all, other properties in that it can be measured in several different ways. This means that resistivity can be measured by LWD tools in both conductive and non-conductive muds during drilling, and by wireline tools post-drilling

Nearly all the minerals and fluids that are encountered in the subsurface have very high resistivities. In fact logging tools are simply not designed to be able to

Opg 1.b)

Induksjonsloggen (særlig ILd) er lite påvirket av dårlig hull fordi den måler motstanden et stykke inn i formasjonen. WL (IL) kjøres midt i hullet

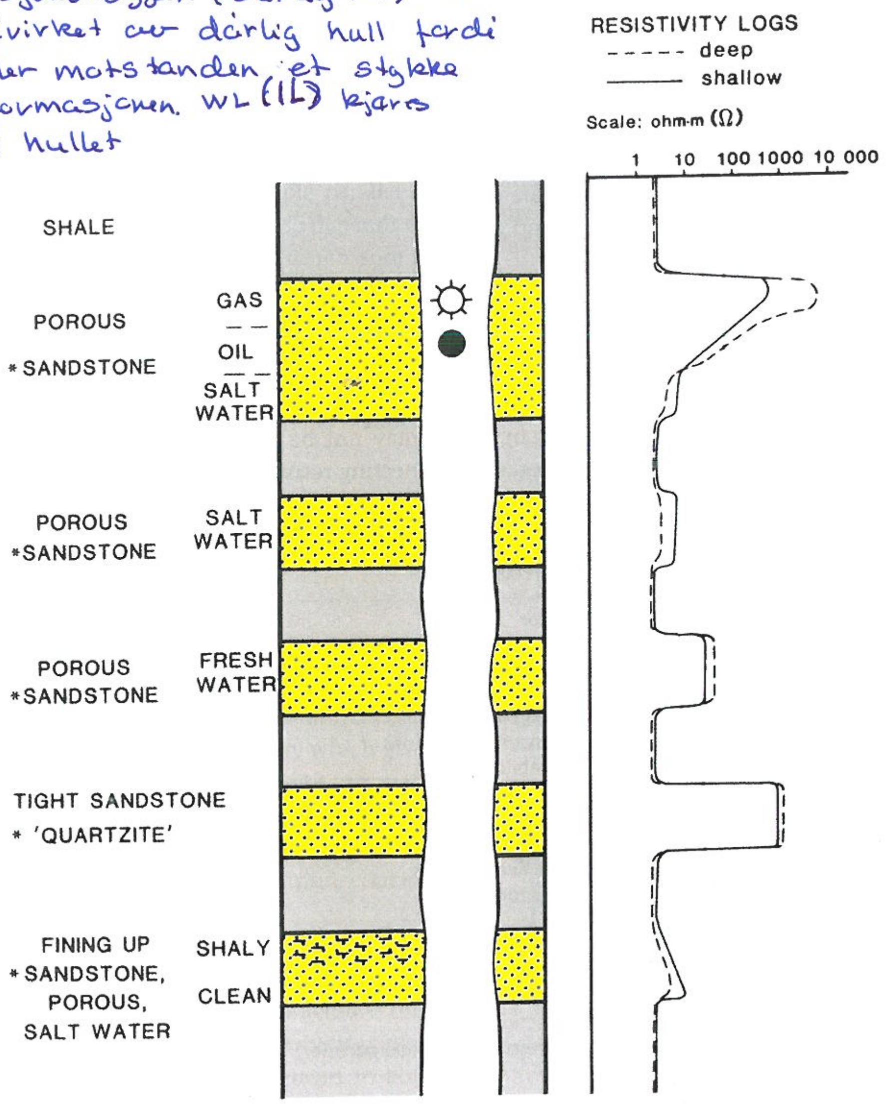
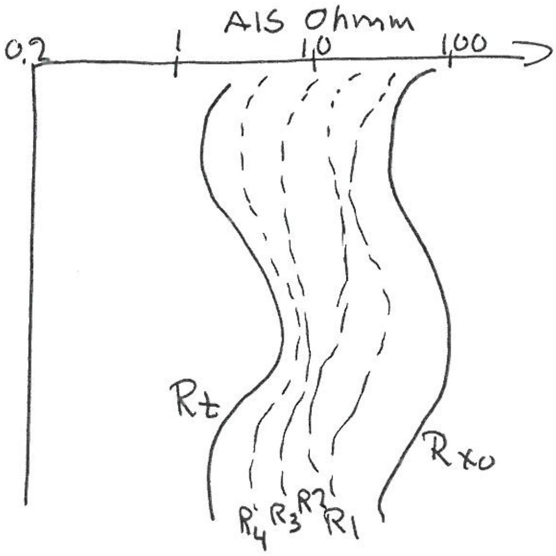


Fig 1.1

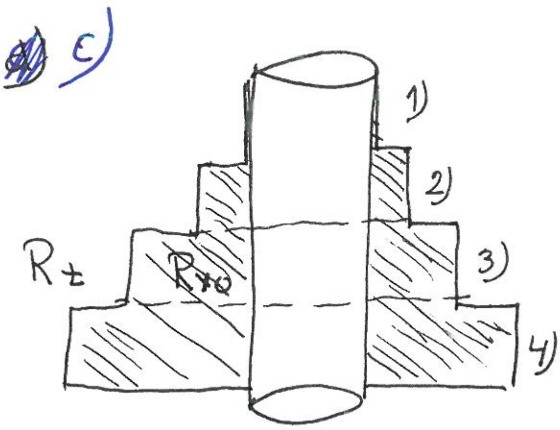
Figure 7.1 The resistivity log: some typical responses. The resistivity log shows the effect of the formation and its contained fluids on the passage of an electric current. *Limestone, dolomite, etc., equally applicable.

d) Array Induction Tool består av sender og av 4 eller flere mottakere. Her får vi kurver med forskjellige inntrengningsdybder og basert på disse kan en beregne R_{xo} og R_t
vi kan også her bruke forskjellige sendefrekvenser 10, 20 og 40 kHz



De nye AIS bruker opptil 10 mottakerkurver og en får en detaljert bestemmelse av invasjonsprofilet og dermed bestemmelse av permeable soner og Net sand

c)



$R_{xo} > R_t$

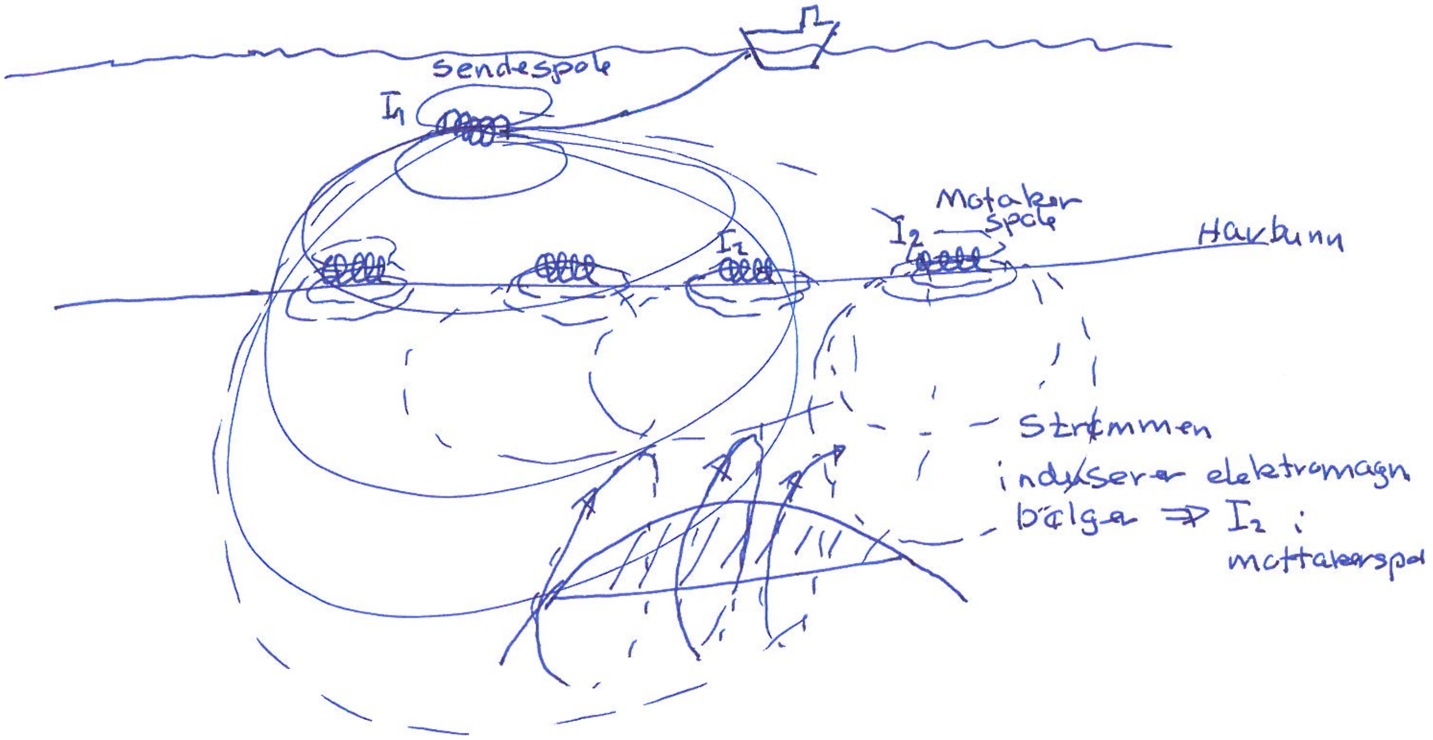
1) $R_{xo} \approx R_{LL8} \approx R_{ILm} \approx R_{ILd} \approx R_t$

2) $R_{xo} > R_{LL8} > R_{ILm} > R_{ILd} \approx R_t$

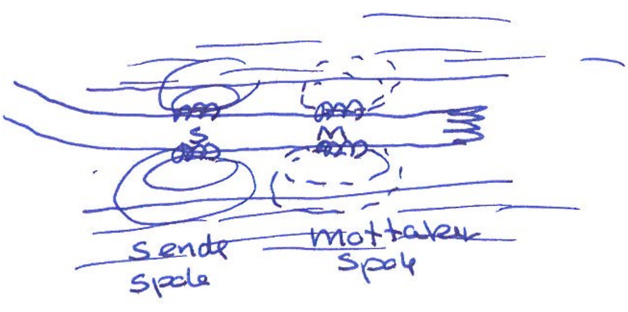
3) $R_{xo} \approx R_{LL8} > R_{ILm} > R_{ILd} > R_t$

4) $R_{xo} \approx R_{LL8} \approx R_{ILm} > R_{ILd} > R_t$

e) Havbunnslogging, Induksjonsloggen, påvisning av HC uten å bore brønn gjennom strukturen



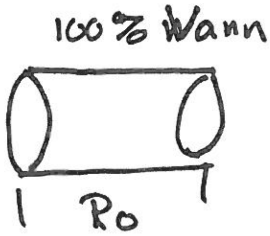
f) Periscope, Induksjonsloggen som brukes ved geostyring i horisontale brønner. Gir avstanden og retningen opp eller ned til motstandskontrasten



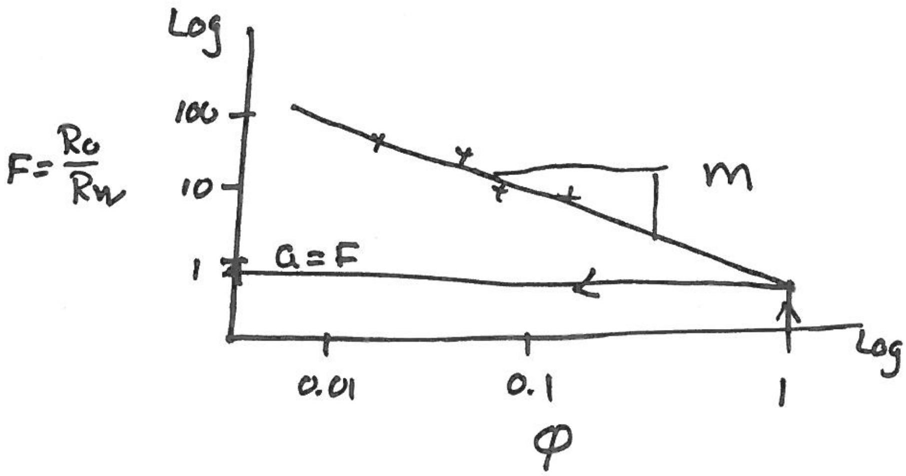
Opgs. 2 a

$F = \frac{a}{\phi^m}$ $S_w = 1 \Rightarrow F = \frac{R_o}{R_w}$

m



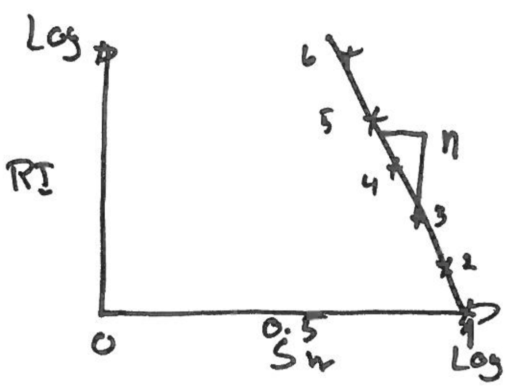
$\log F = -m \log \phi + \log a$

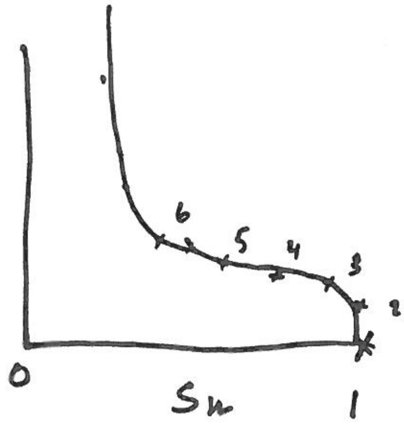


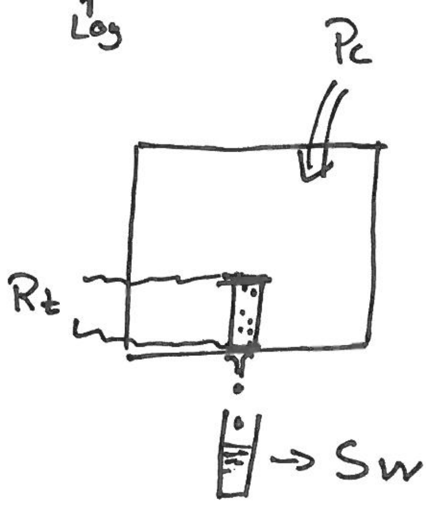
n

$S_w = \left(\frac{F \cdot R_w}{R_t}\right)^{\frac{1}{n}} = \left(\frac{R_o}{R_t}\right)^{\frac{1}{n}}$

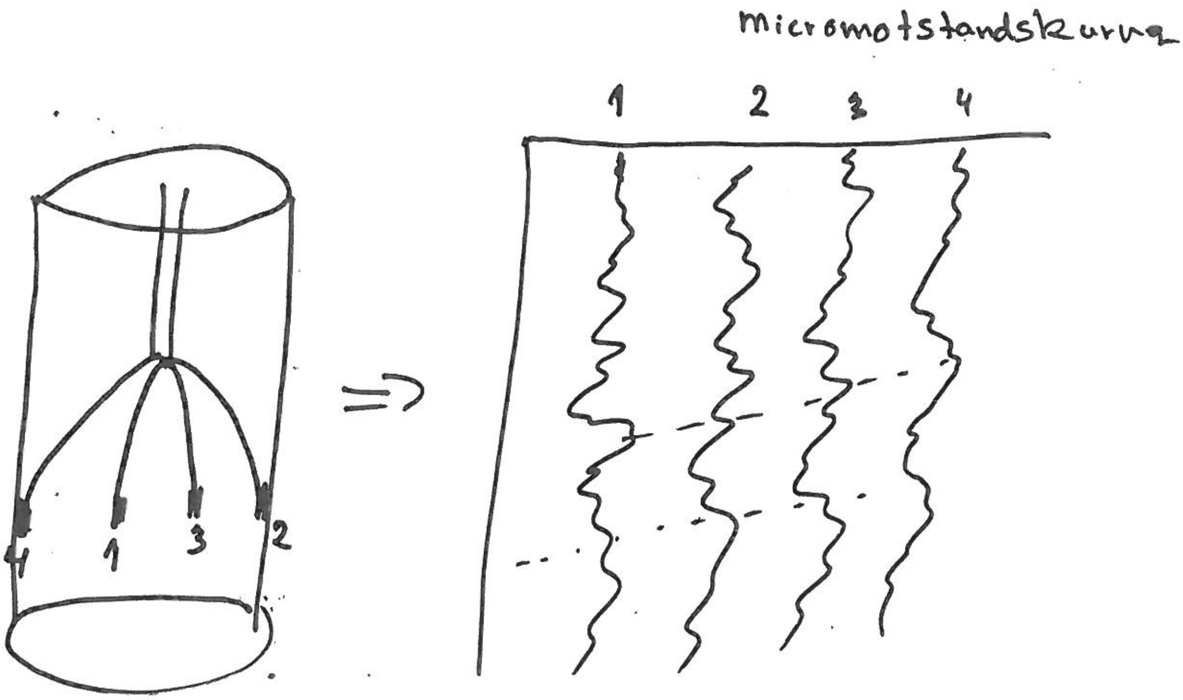
$S_w^n = \frac{R_o}{R_t} = RI$ $-n \log S_w = \log RI$



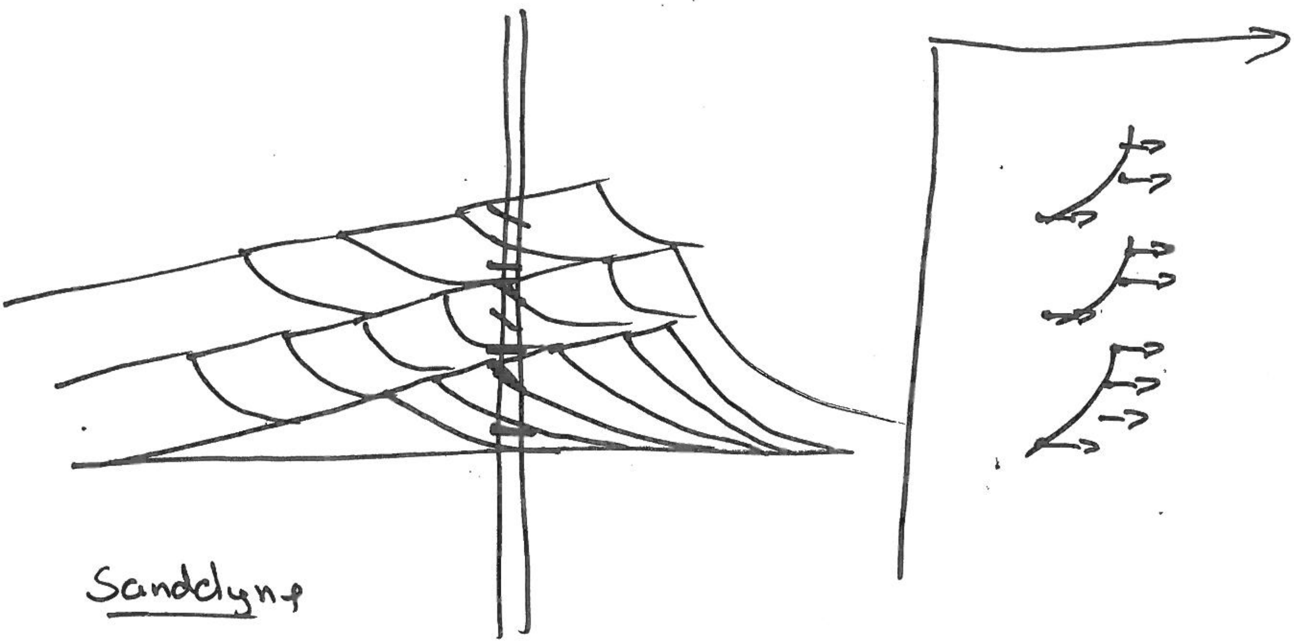




2b



Vindavsetning



Sanddyne

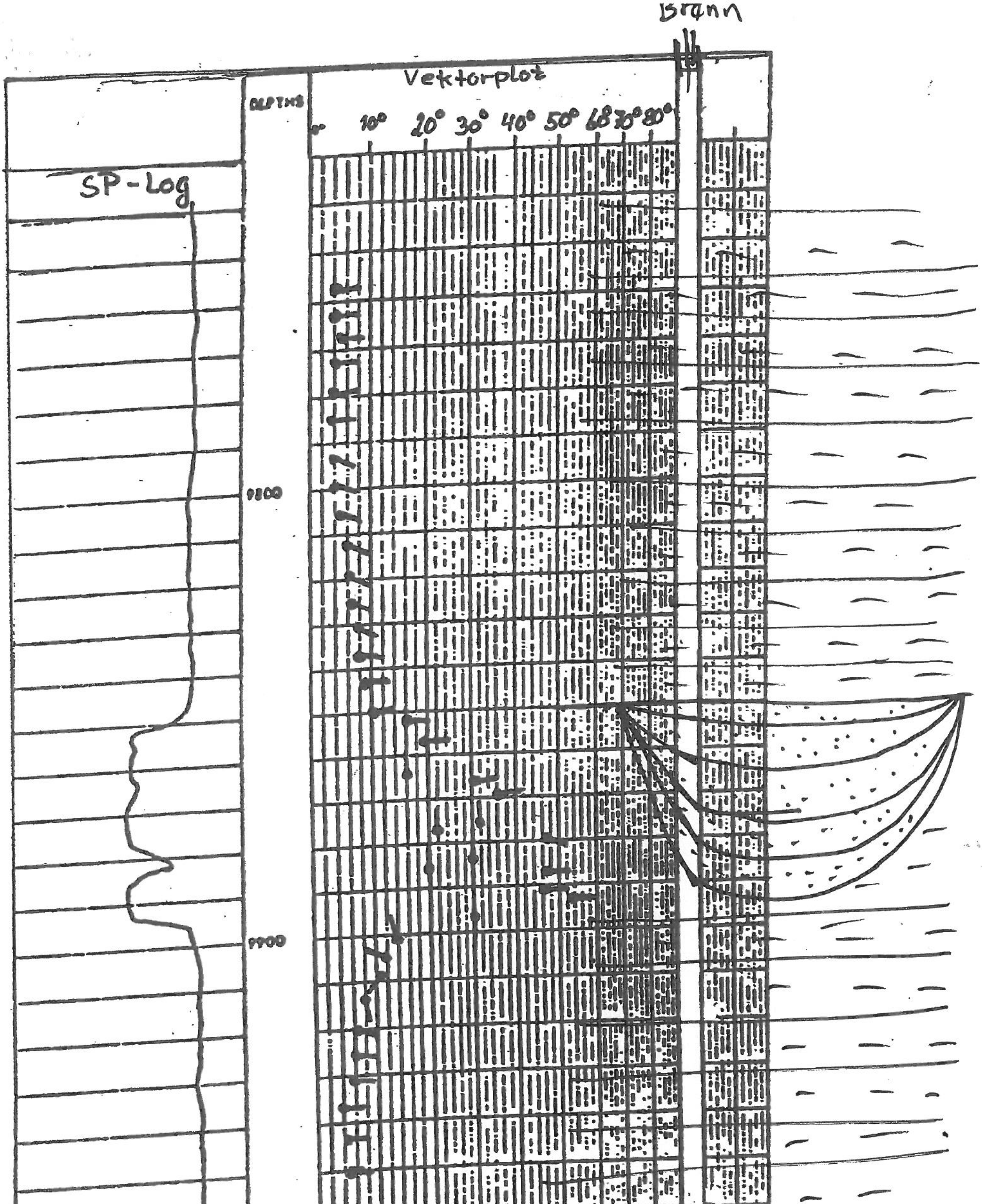
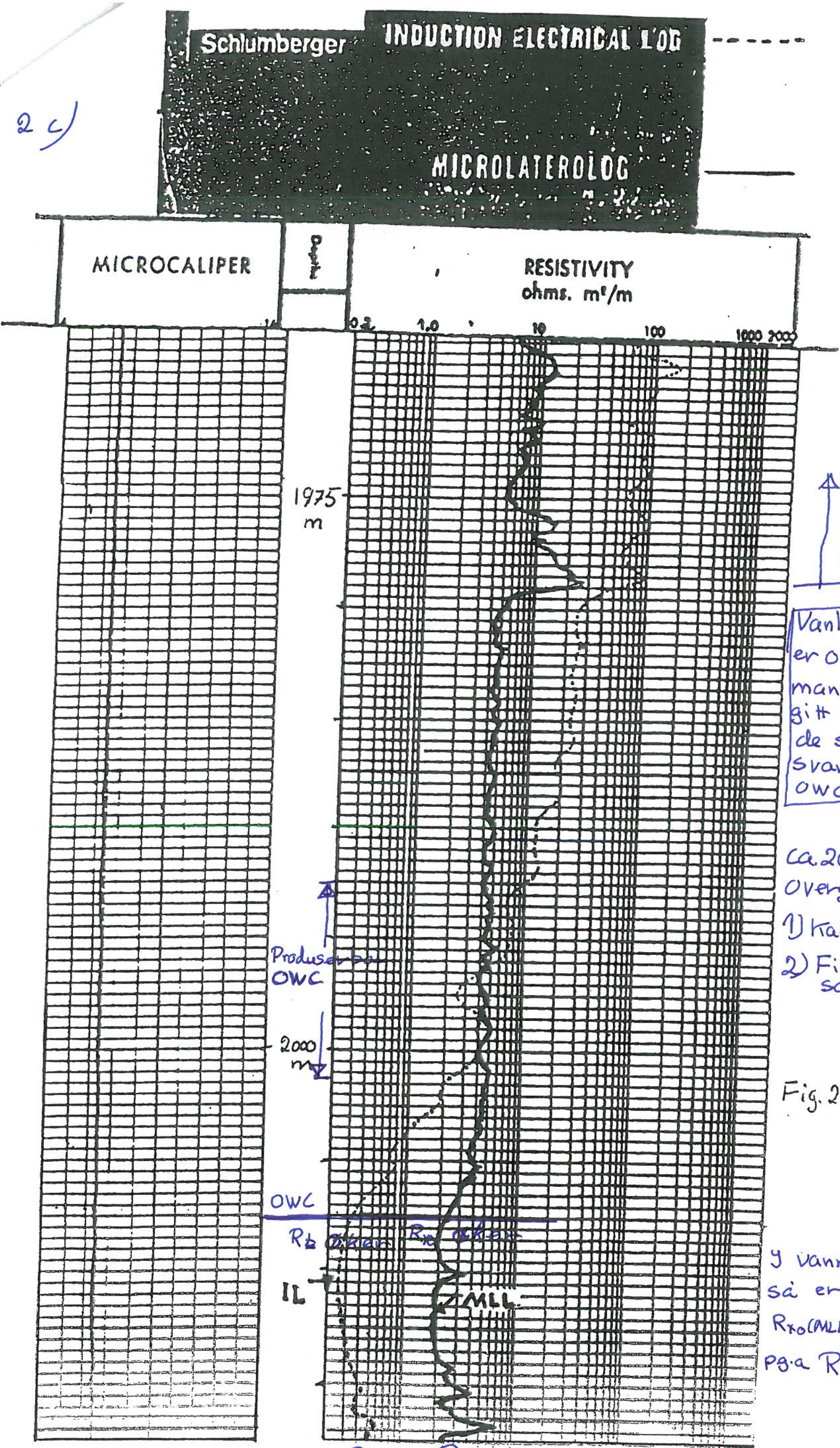

Brønn
SP-Log
DEPTHS
Vektorplot
0°
10°
20°
30°
40°
50°
60°
70°
80°
9800
9900

Fig. 2.1

2 c)



↑ økende motstand f.eks pga. grovere sand

Vanligvis så er OWC = FWL man har også gitt poeng for de som har svart produserbar OWC

ca. 20 m Overgangssone

1) Kalkstein el.

2) Finkornig sand

Fig. 2.2

I vannsone så er R_{xo}(MLL) > R_t (IL pga. $R_{mf} > R_w$

R_{xo} - bare liten økning fra vann til olje

Brønn 3/6-1

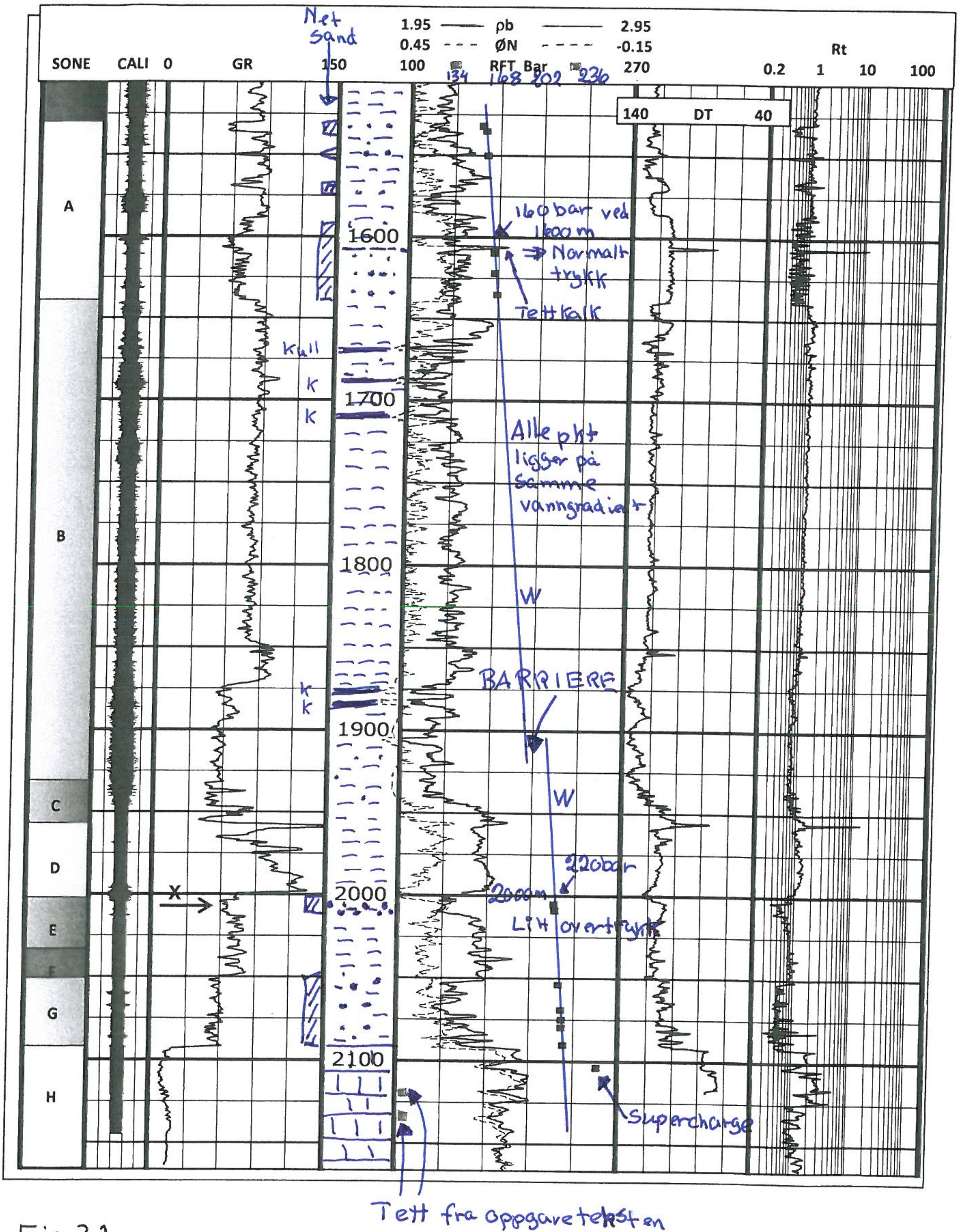


Fig. 3.1

Oppgave 3

a) Loggkvalitet

~~Fra~~ Caliperloggen viser en del utvasking og dermed dårlig kvalitet. Særlig tetthetsloggen og nøytronloggen er påvirket av dårlig hull.

b) 1) Basert på motstandsloggen sammen med de andre loggene så er det kun vann i denne brønnen. Den høye motstanden i kalksonen nederst skyldes lav porøsitet. 2) Trykkplottet viser at alle punktene ligger på en vanngradient (1 bar / 10 m)

c) Punkt X $\rho_b = 2.15$

Der er lite variasjon i GR ned til 2100 m. Trykkpunktene viser permeable/sand soner $V_{cl} < 0.3$

Punkt X (fra $\rho_b - \varphi_N$)
Er sand med noe leire. $V_{cl} = 0.2$ ρ_{cL}

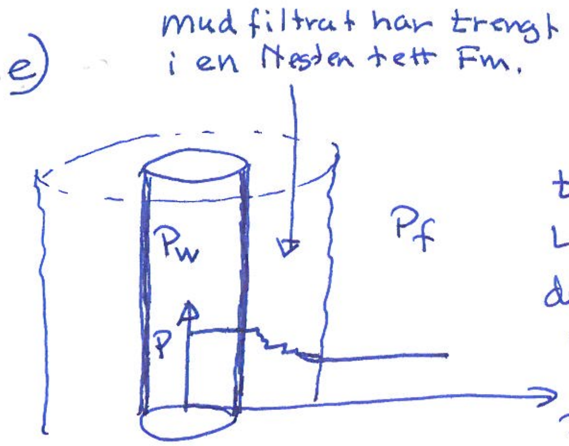
$$\varphi = \varphi_{Dc} = \varphi_D - V_{cl} \cdot \varphi_{Dcl} = \frac{2.65 - 2.15}{2.65 - 1} - 0.2 \cdot \frac{2.65 - 2.35}{2.65 - 1} =$$

$$= 0.30 - 0.2 \cdot 0.18 = \underline{\underline{0.26}}$$

d) Plaseringen av trykkpunktene er basert på råloggene GR, ρ_b, φ_N, DT og R_t. Der hvor det er permeable soner sand/kalk prøver en å ta et trykkpunkt. Trykkpunkter gir også permeabilitet fra trykkoppbygging (build up). Vi tar også trykkpunkter i sand/leire for å se om disse sonene er tette.

Trykkpunktene dekker godt de sikre og de usikre permeable sonene og vi trenger ikke ta flere trykkpunkter

Øvre del normalt trykk, Nedre del litt overtrykk (p.g.a barriere imellom) e)

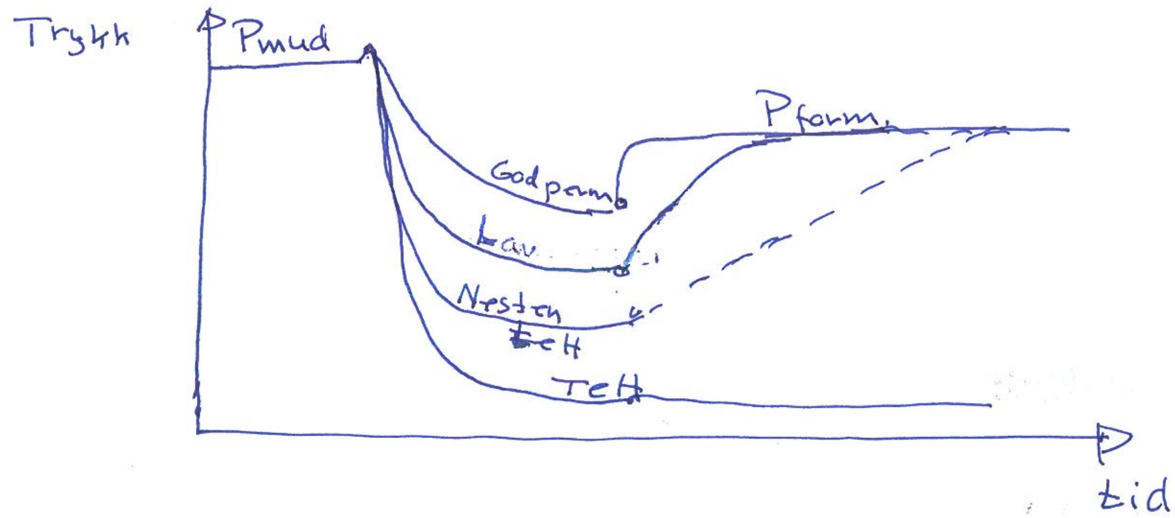


I nokså tette formasjoner vil trykket i innvadert sone ofte være litt høyere enn formasjonstrykket (P_f) derfor blir det trykket en måler bli litt høyere.

Punkter i toppen av kalksonen viser supercharge

Der er trykkbarriere mellom øvre og nedre sone fra trykkplott

f) Råkurve til trykkmåling



g) Fra råkurven til trykkmålingen f) er Net Sand = God perm til Nesten tett formasjon ($k \approx 0.05$mD)

Avkutningsverdi Net Sand (sandsten) $\phi \approx 0.10$ $V_{cl} \approx 0.4$

Sone H viser 2 trykkpunkter tett kalksten og et trykkpunkt nesten tett (supercharge)

ρ_b ved trykkpunktene er 2.36 g/cc Nesten tett og 2.40 på for tett

$$\phi_b = \frac{2.72 - 2.36}{2.72 - 1} = 0.21$$

Nett Sand

$$\phi_b = \frac{2.72 - 2.40}{2.72 - 1} = 0.19$$

Tett

Avkutningsverdi i kalken er $\phi = 0.20$