Exercise 5-1

RESISTIVITY DISTRIBUTION

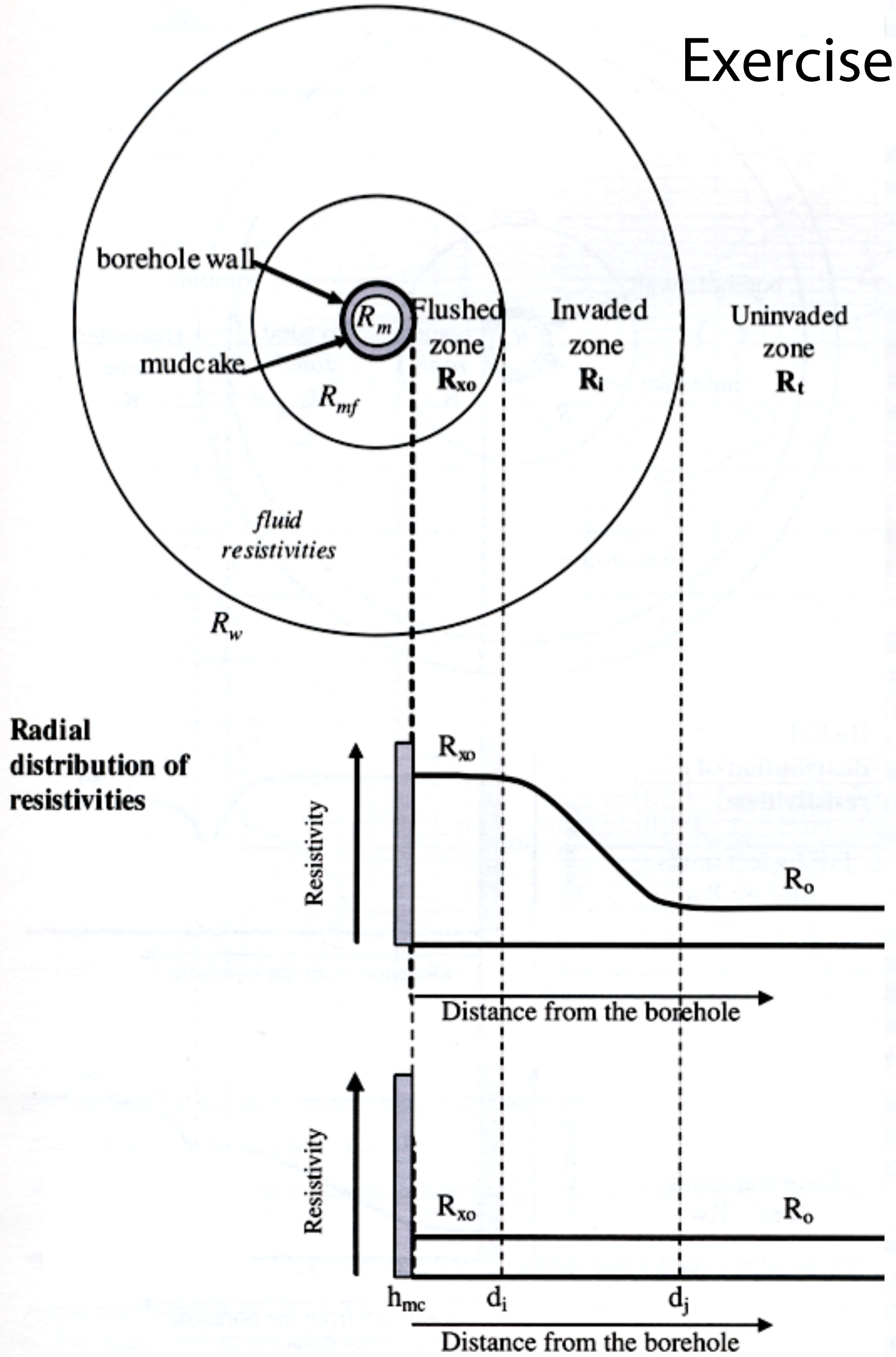
Complex arrangement of water-bearing and HC-bearing zones (see next page).

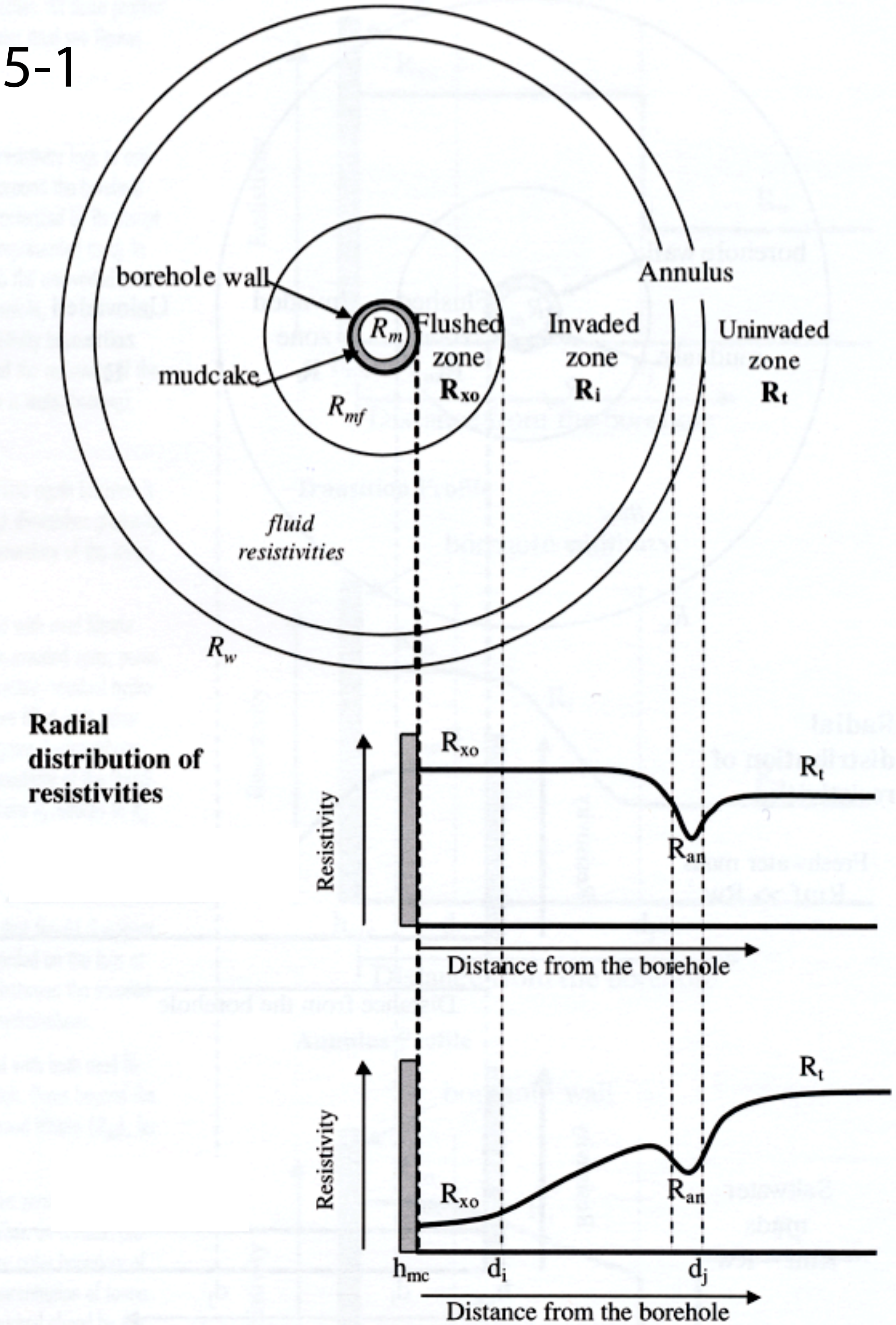
Please explain the given radial distribution of resistivities and describe what you expect to be present:

- freshwater mud,
- saltwater mud,
- water-bearing interval (much more than 60%),
- hydrocarbon-bearing interval (much less than 60% formation water).

Give also the reasons for your interpretation of the specific resistivity transects.

Exercise 5-1

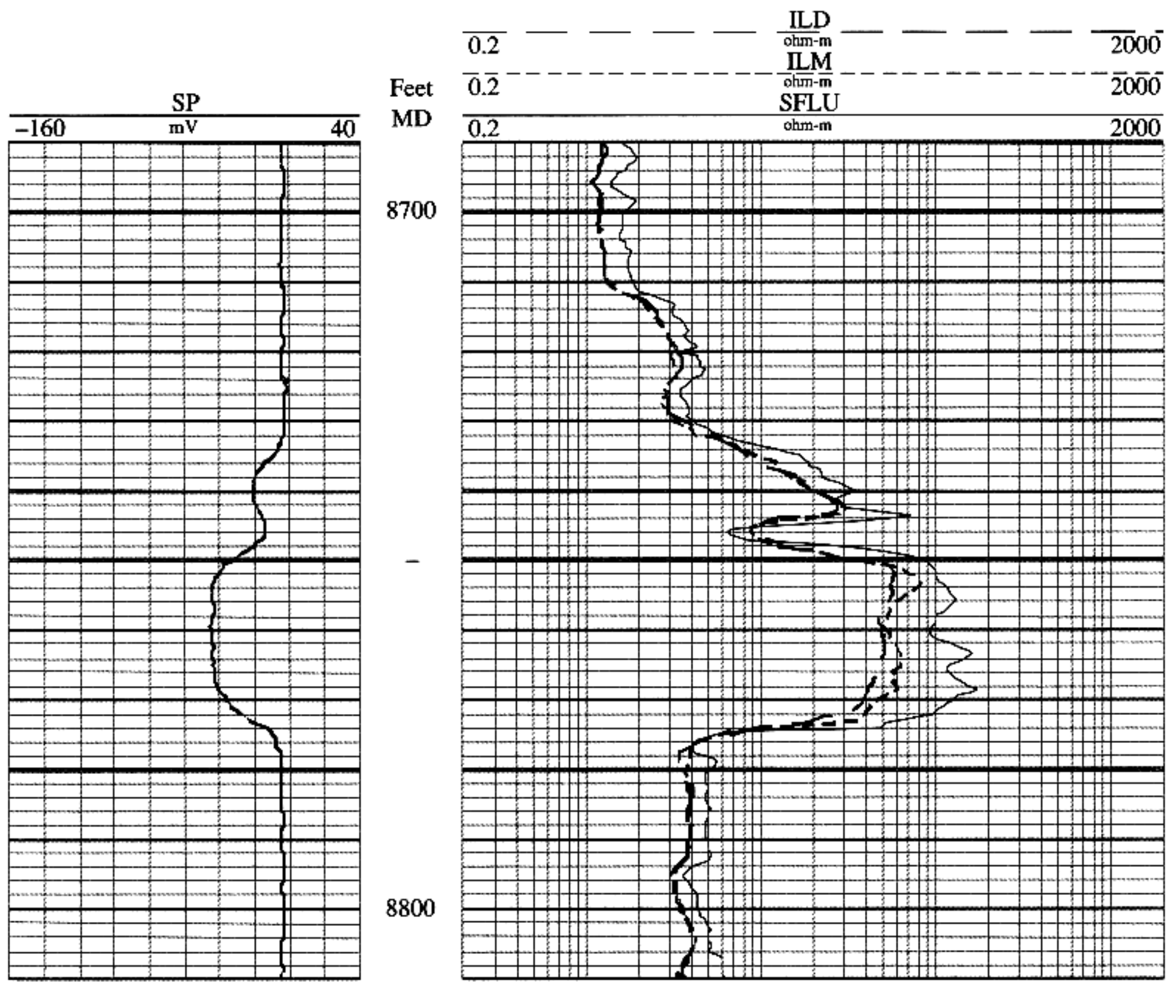

borehole wall
mudcake
Rm
Flushed zone Rxo
Invaded zone Ri
Uninvaded zone Rt
Rmf
fluid resistivities
Rw
Radial distribution of resistivities
Resistivity
Rxo
Ro
Distance from the borehole
Resistivity
Rxo
Ro
hmc
di
dj
Distance from the borehole


Annulus
borehole wall
mudcake
Rm
Flushed zone Rxo
Invaded zone Ri
Uninvaded zone Rt
Rmf
fluid resistivities
Rw
Radial distribution of resistivities
Resistivity
Rxo
Rt
Ran
Distance from the borehole
Resistivity
Rt
Ran
Rxo
hmc
di
dj
Distance from the borehole

Exercise 5-2

SP AND RESISTIVITY

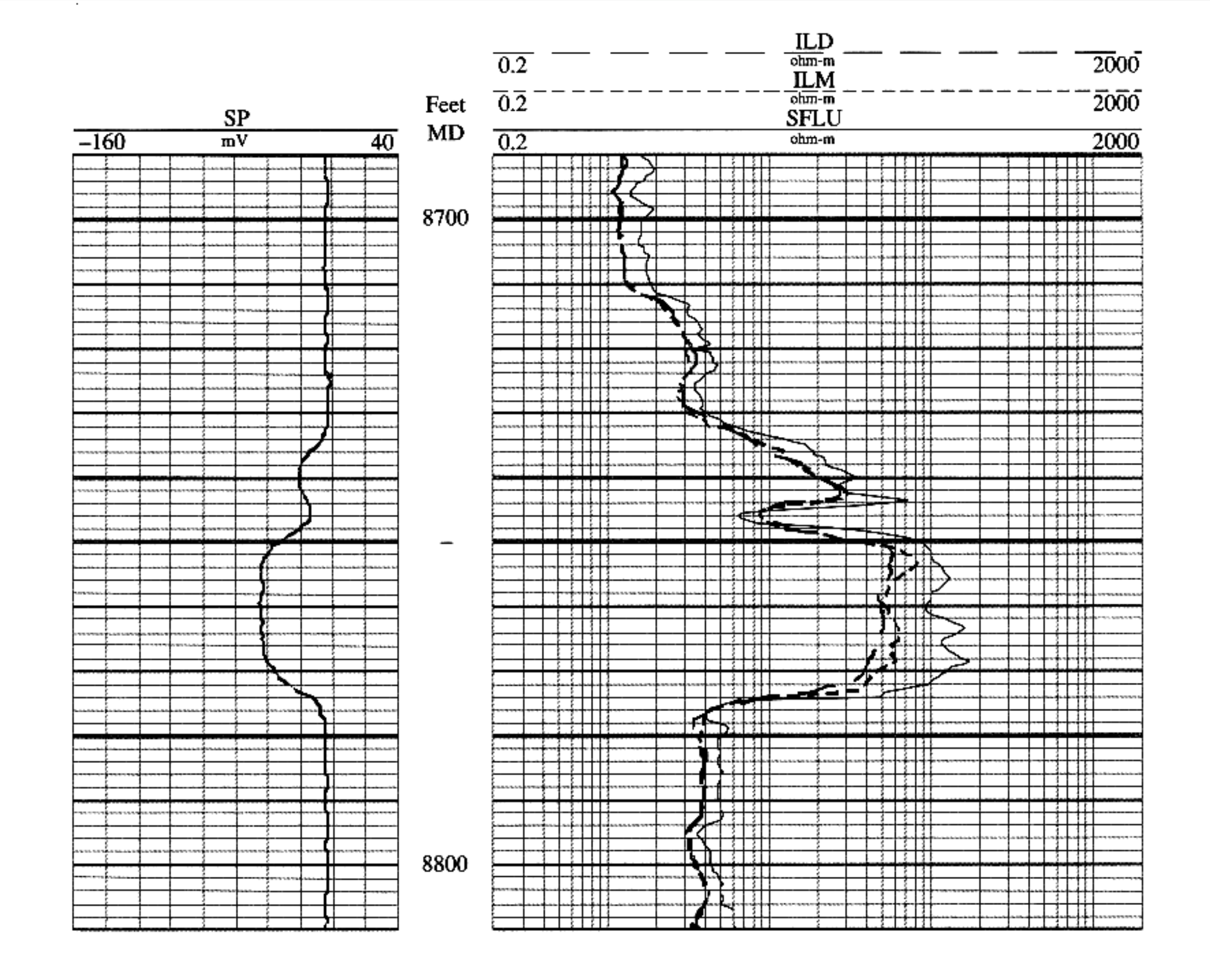
1) Which type of drilling mud do you assume, salt-water based or freshwater based mud?
2) Give the resistivity readings of ILD, ILM and SFLU at 8740 ft and at 8764 ft.



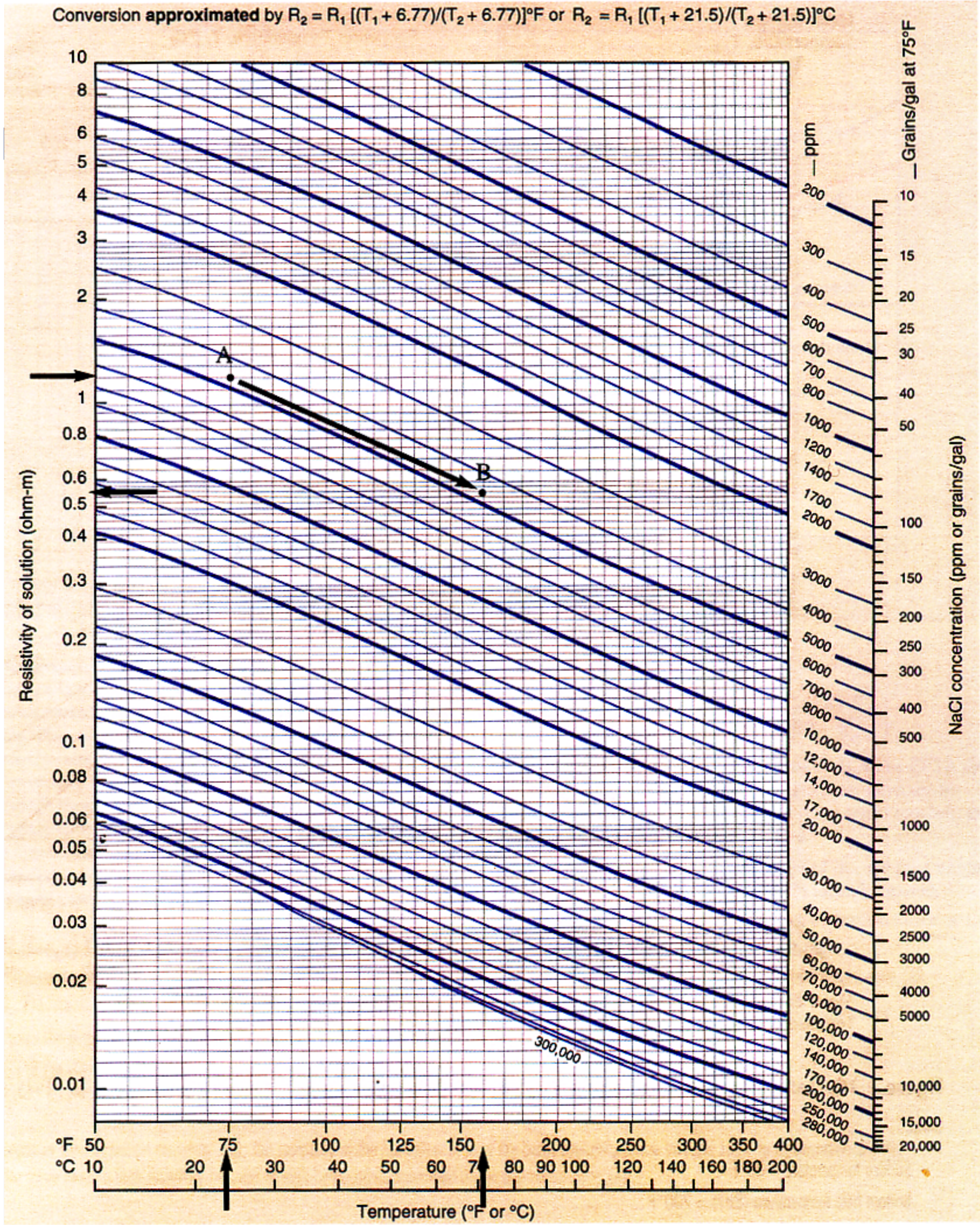
Dual induction log curves through a porous zone, indicated by SP (8748 to 8774 ft).

Exercise 5-2

3) Is porous interval filled by water or by hydrocarbons? Reasons for the interpretation, discussing the different zones!
4) Draw a section of the radial distribution of resistivities. Explain the values in terms of invasion and fluid mixing.



Dual induction log curves through a porous zone, indicated by SP (8748 to 8774 ft).



Class exercise 5-3: Fluid resistivities and temperature

Given:

R_m = 1.2 ohm-m at 75° F;

T_f = 160° F.

What is the fluid resistivity at this depth?

Answer: 0.58 ohm-m.

Exercise 5-4

Formation water resistivity

Determine formation water resistivity (R_w) at the porous zone seen on the *SP* log. Use the given charts.

Given:
Surface temperature = 60° F
Total depth = 8007 ft
Bottom hole temperature (BHT) = 135° F
R_{mf} = 0.51 ohm-m at BHT
R_m = 0.91 ohm-m at BHT
Log data (*SP* and resistivities)

Exercise 5-4 (a)

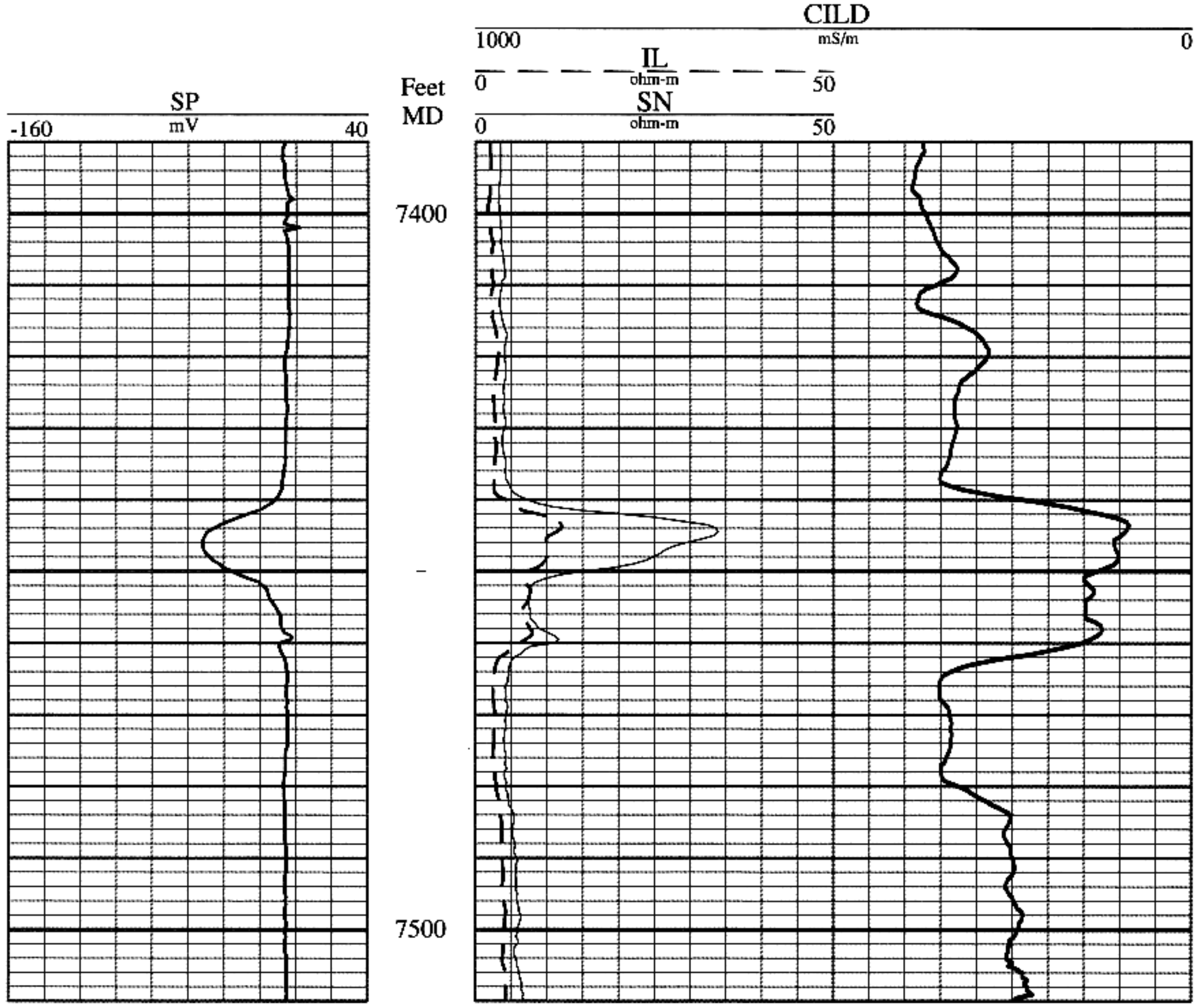


Figure 5-4-A

Exercise 5-4 (b)

Procedure

1. Read from the log, Figure 5-4 (a):

    Formation depth at maximum *SP* deflection;

    SP value at maximum *SP* deflection;

    SP value of shale base line;

    Thickness of porous and permeable bed;

    Short normal (SN) resistivity (normally R_i).

2. Determine T_f, the temperature of the formation. Use Figure 5-4 (d).

3. Correct R_m and R_{mf} to T_f. Use Figure 5-4 (e).

4. Calculate the maximum deflection of the *SP* in relation to the shale base line.

Exercise 5-4 (c)

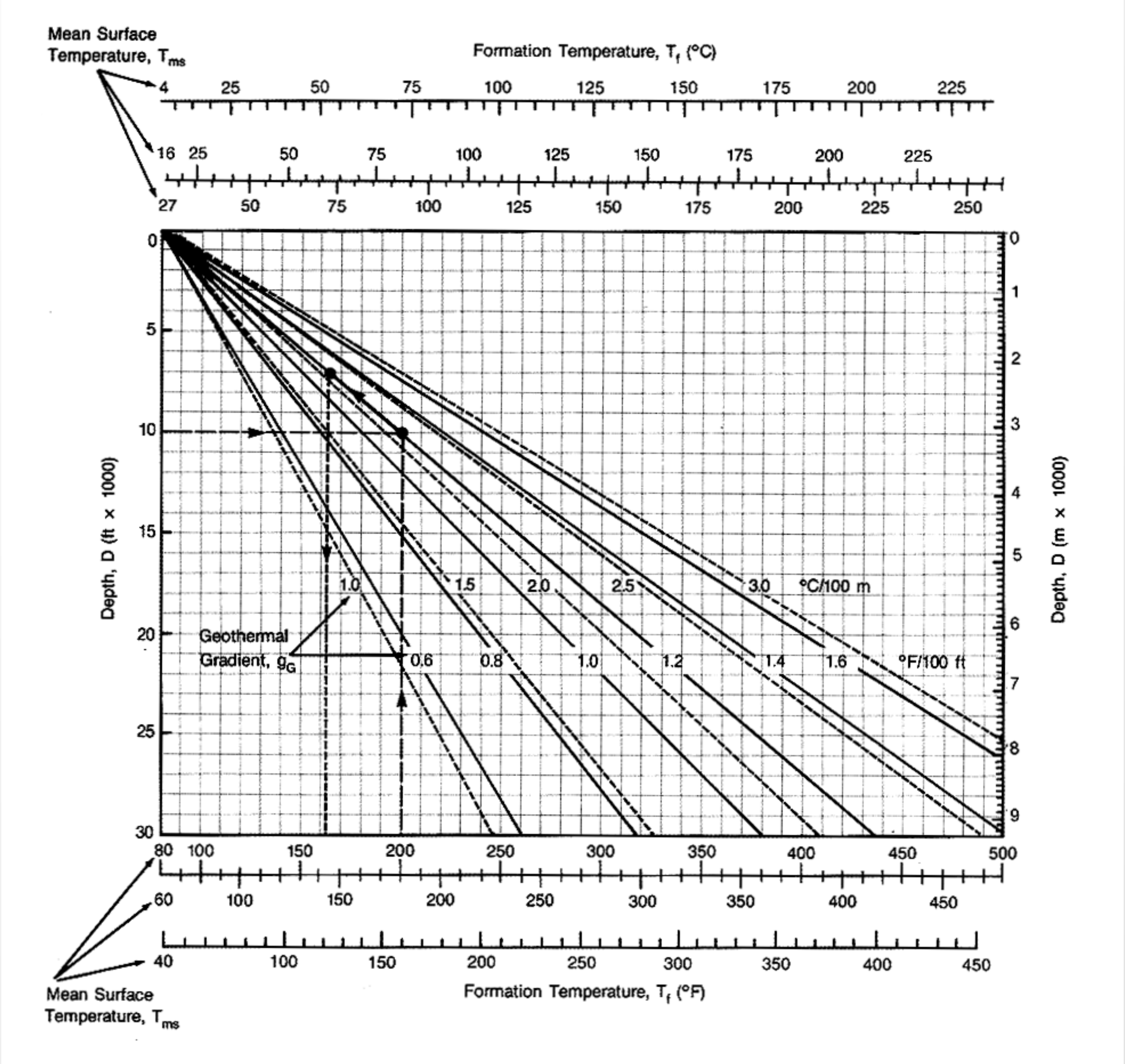
Procedure (cont´d)

5. Because of the thin porous bed, you have to correct the *SP* to *SSP*. First you have to calculate the ratio R_i / R_m (R_i = SN -short normal log- value from log). Use Figure 5-4 (f) for **(a)** bed thickness correction factor, and **(b)** for *SSP* value from *SP*, employing the correction factor. Or calculate: SSP = SP x correction factor.

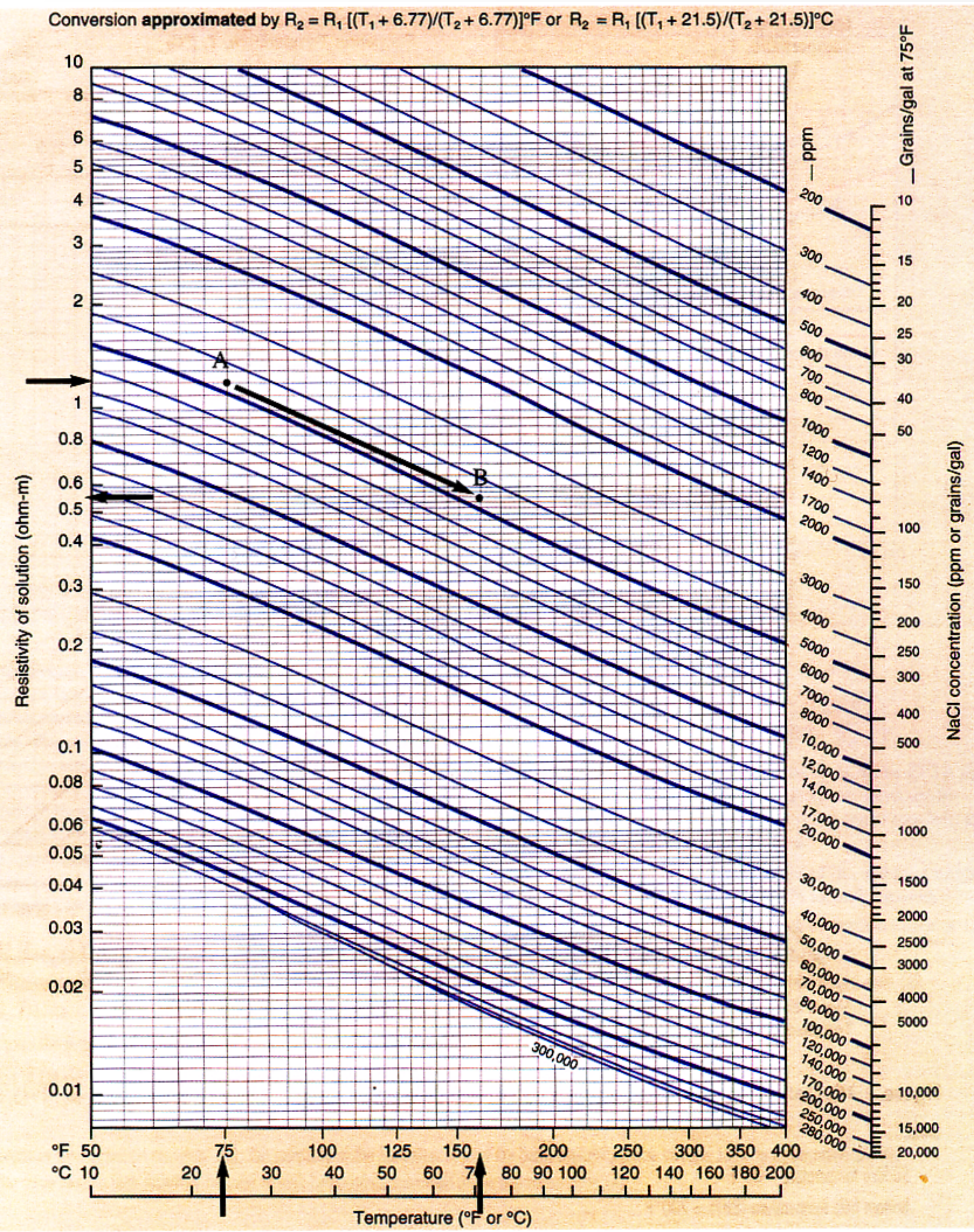
6. Determine the ratio R_{mf} / R_{we} ($R_{we} = R_w$ equivalent), considering T_f (see point 2). Use Figure 5-4 (g). From the result determine R_{we}: to do this, divide the corrected value for R_{mf} by the ratio R_{mf} / R_{we}.

7. Correct R_{we} to R_w. Use Figure 5-4 (h). This chart can also be used to calculate the R_{mf} at the formation temperature from the value obtained at the surface.

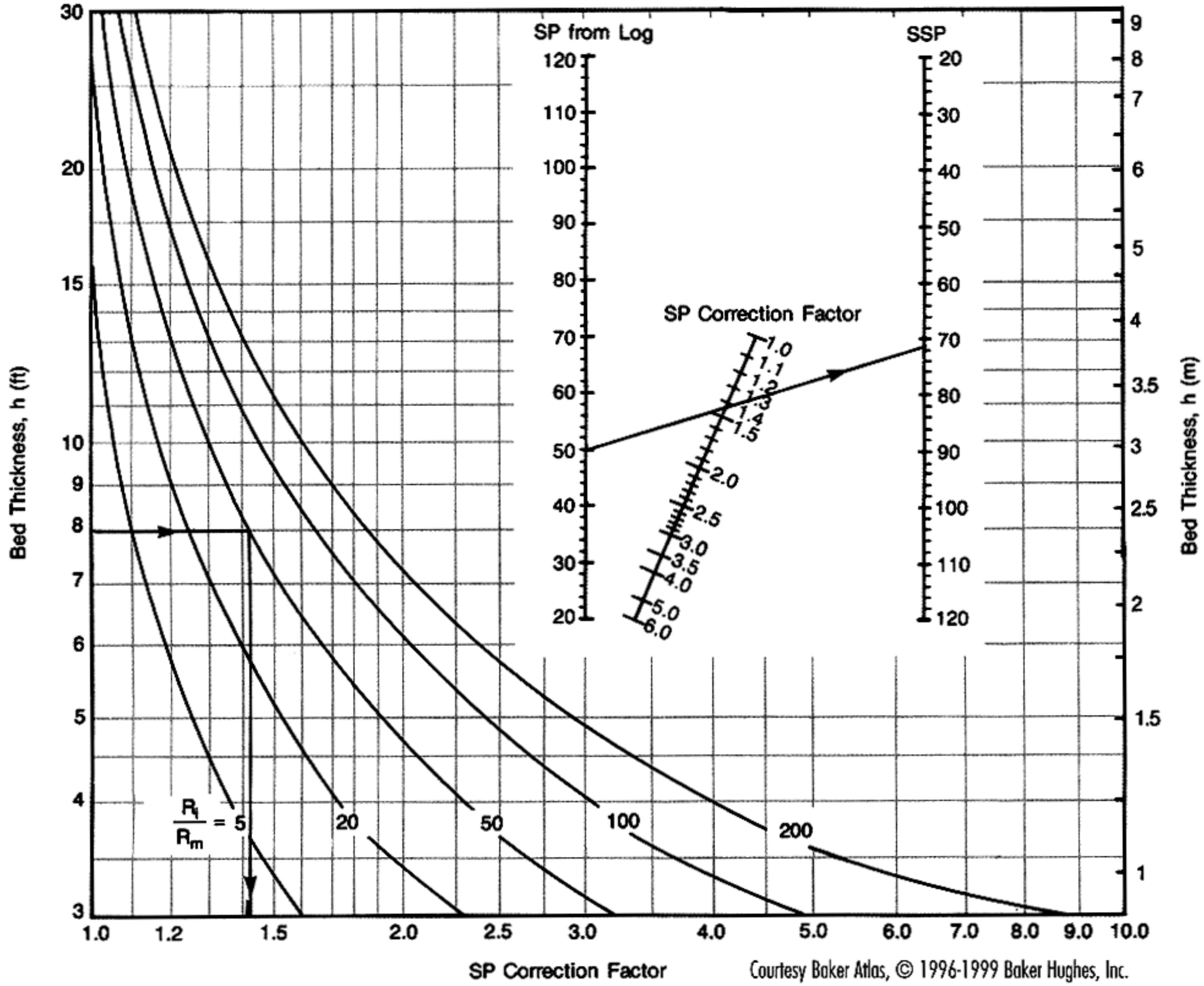
Exercise 5-4 (d)



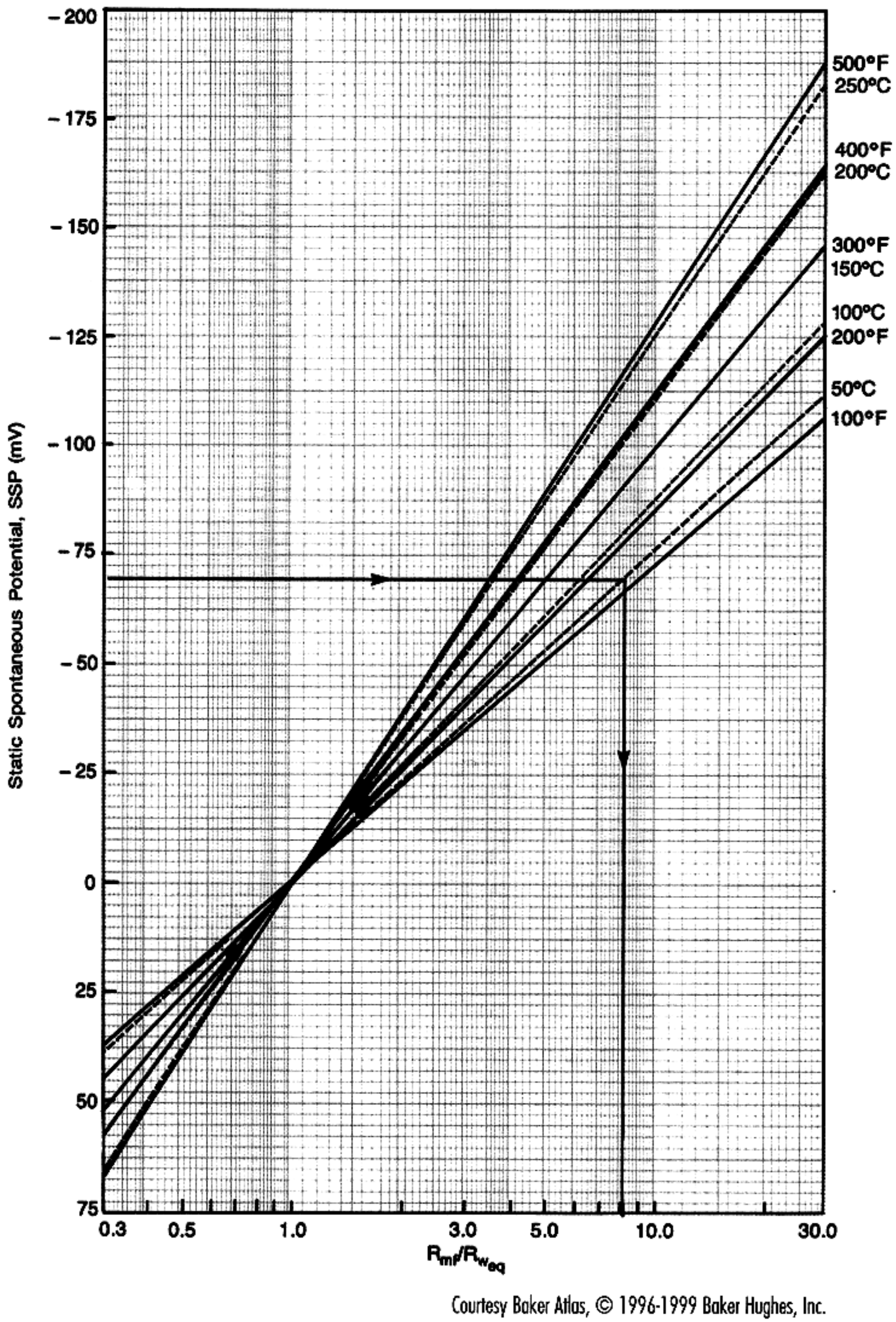
5.4 (e) Fluid resistivities and temperature calculation



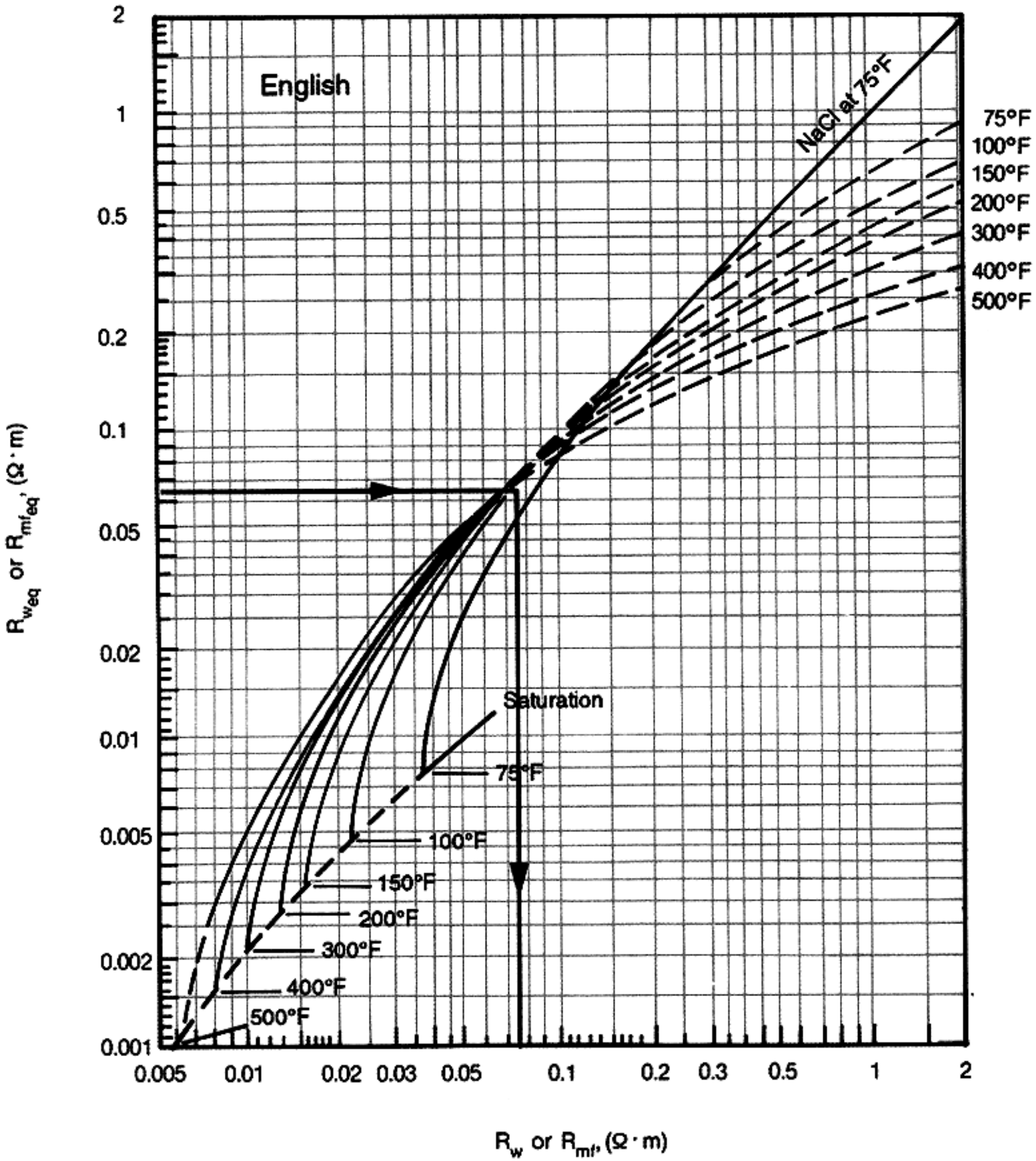
Exercise 5-4 (f)



Exercise 5-4 (g)



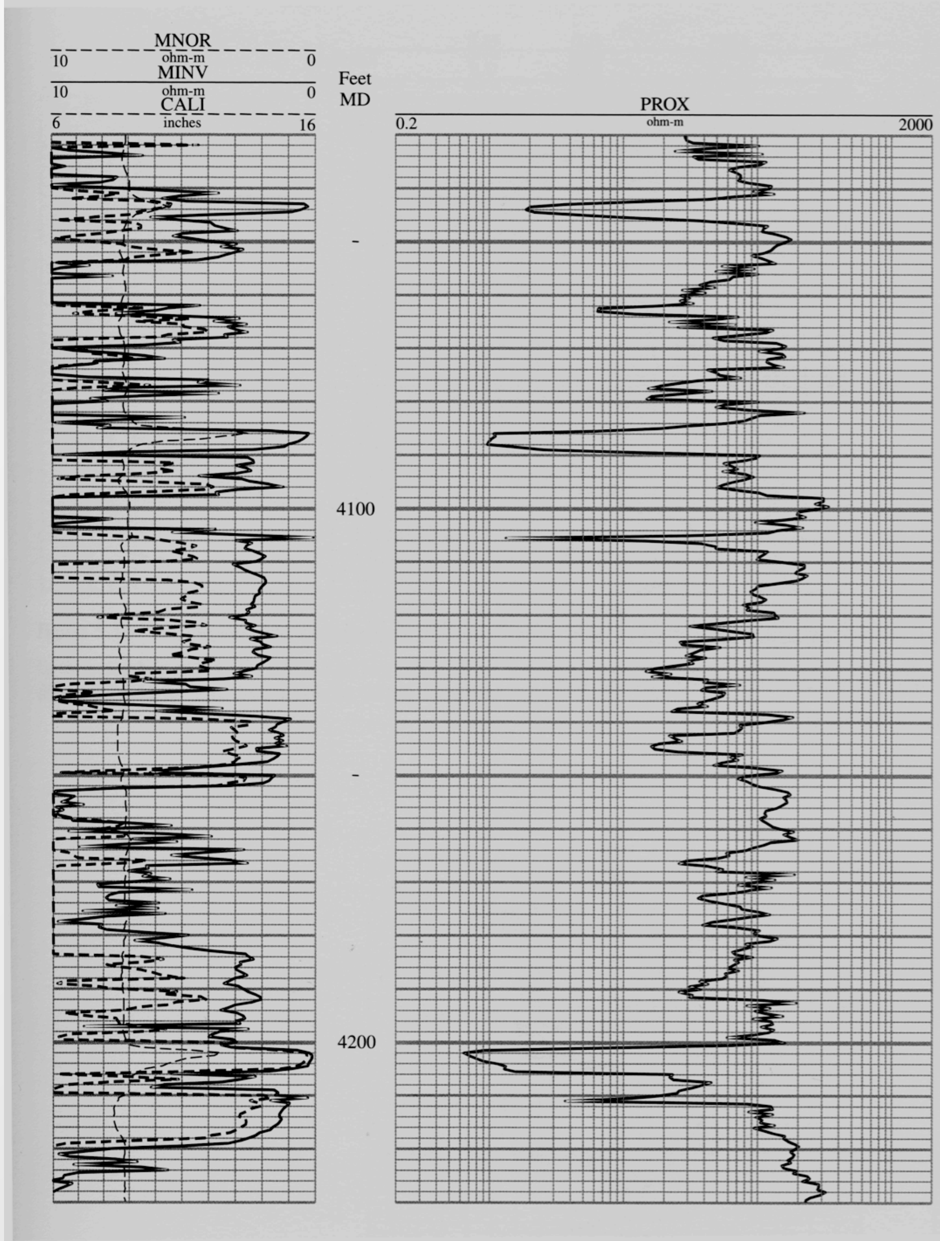
Exercise 5-4 (h)



Exercise 5-5: resistivities in the flushed zone

Exercise: Examine the log curves at 4144 ft., read and explain the readings of the different logs in terms of permeability.

This particular log package includes a proximity log to read R_{xo}, a microlog to determine permeable zones, and a caliper to determine the size of the borehole.

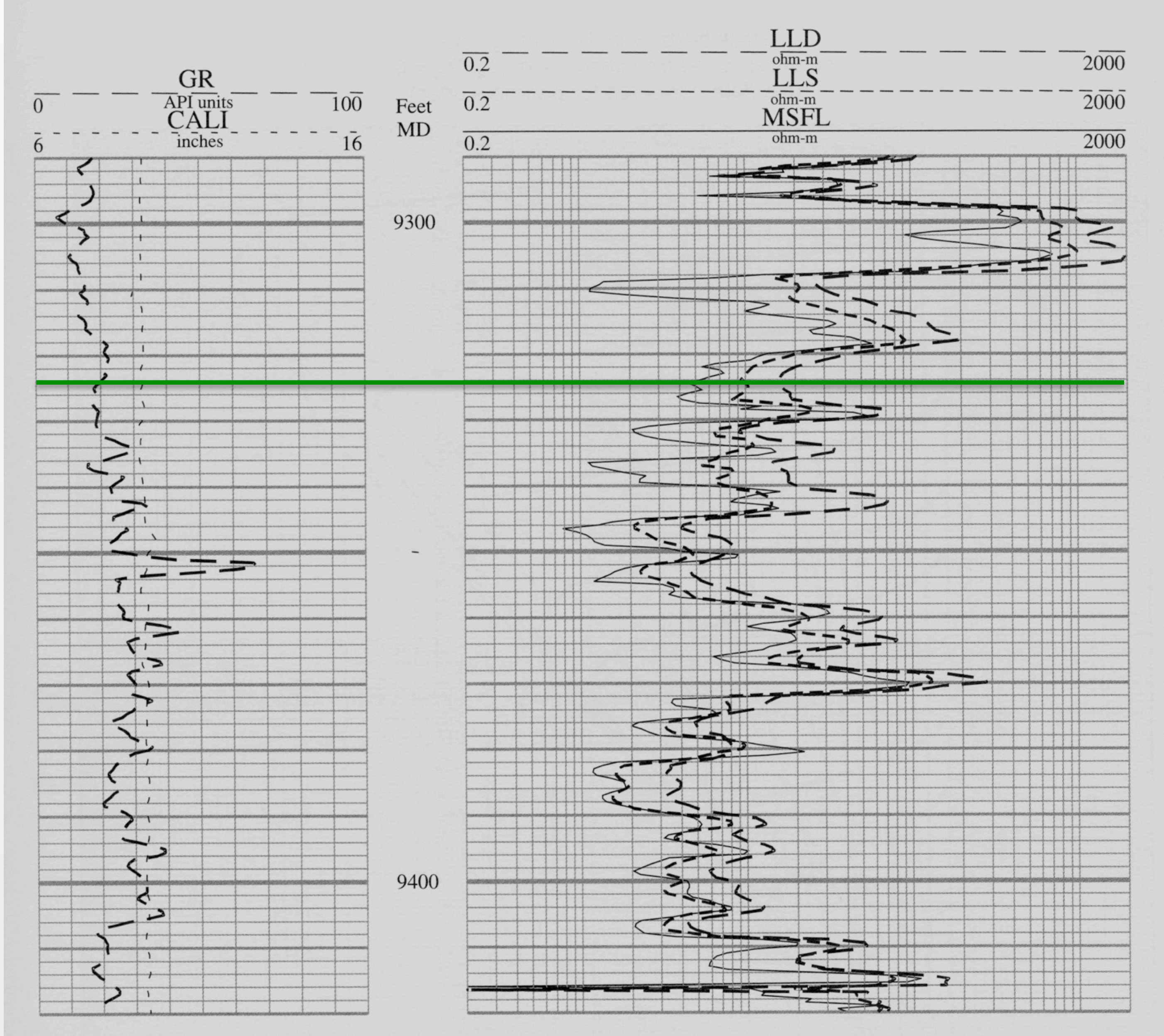


Exercise 5-6: Dual Laterolog + MSFL

Example of Dual Laterolog + MSFL: $R_{mf} \sim R_w$.

Scale is four times logarithmic.

Question: Read deep resistivity, invaded and flushed zone resistivities from the log at 9324 ft. Correct values and explain. What is the diameter of invasion?



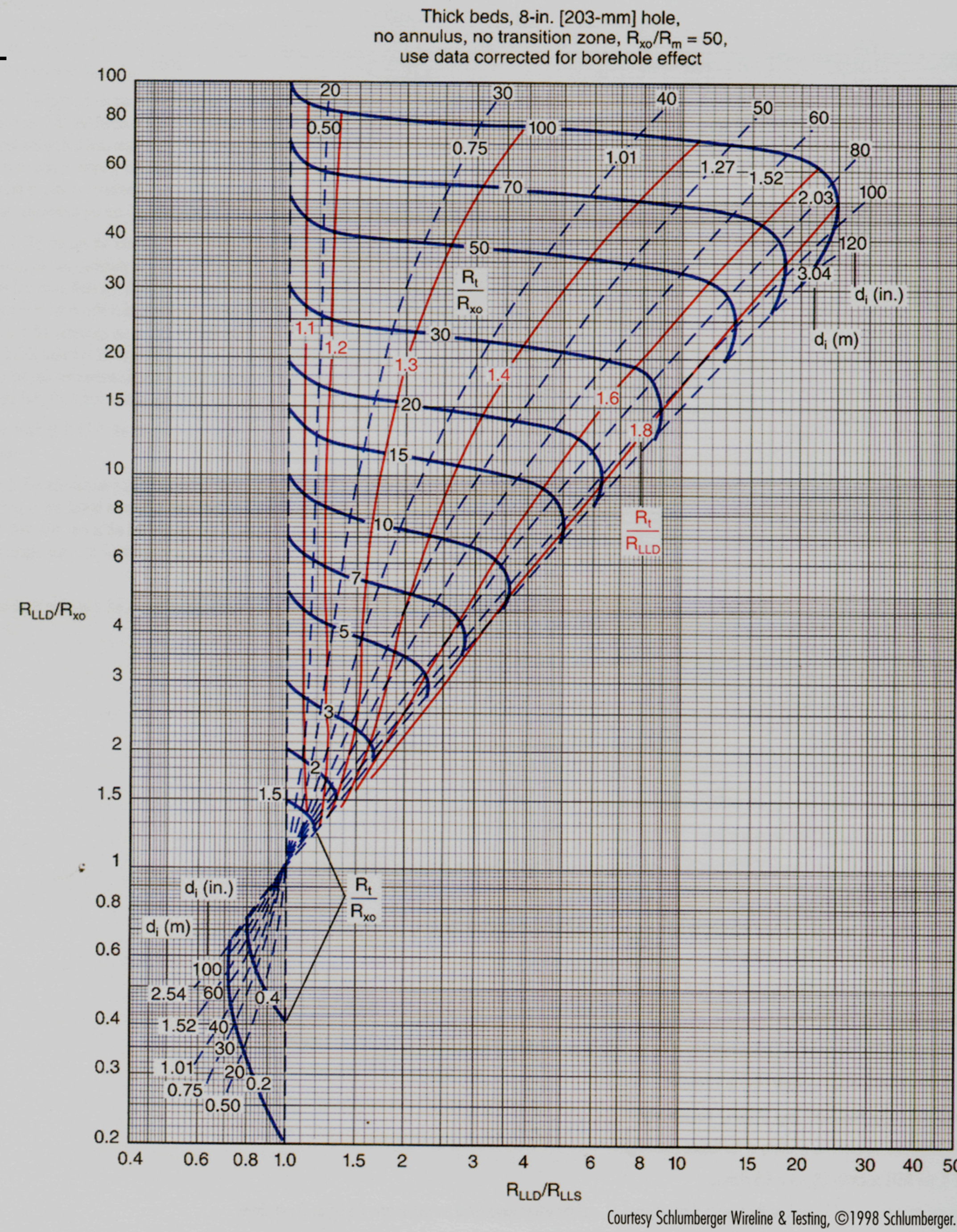
Exercise 5-6: Dual Laterolog + MSFL

Dual laterolog - R_{xo} tornado chart for correcting logged resistivities to R_t.

Blue dashed lines, upper part of diagram: scale from 20 to 120 gives d_i (diameter of invasion) in inches; scale from 0.5 to 3.04 gives d_i in meters.

Blue solid lines: R_t / R_{xo}; scale values increase from bottom to top and range from 0.2 to 100.

Red lines: R_t / R_{LLD}, ranging from 1.1 to 1.8.



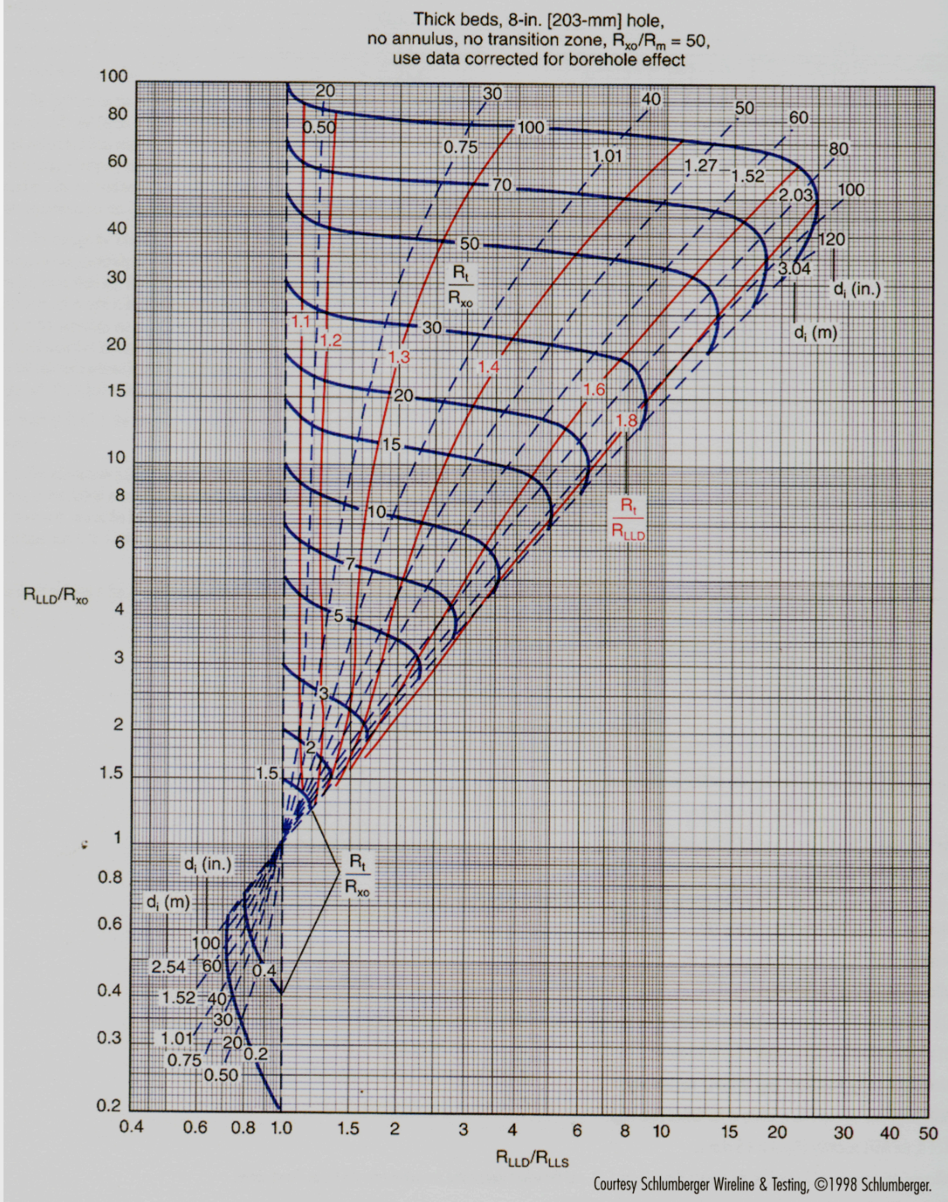
Procedure exercise 5-6: Dual Laterolog + MSFL

- Calculate first $R_{LLD} / R_{MSFL} = R_{LLD} / R_{xo}$
- Calculate then R_{LLD} / R_{LLS}

Correct the readings for R_t and R_{xo} from the log at 9324 ft. :

- Find R_{LLD} / R_{xo} on vertical axis.
- Find R_{LLD} / R_{LLS} on horizontal axis.
- Determine intersection point and read the ratio values of R_t/R_{LLD} and R_t/R_{xo} . Note these in a table for calculation (see formulas below).
- d_i: the value is picked by following the dashed, blue lines to the scale at the top.

$$R_{t\ corr.} = \frac{R_t}{R_{LLD}} \times R_{LLD} \qquad R_{xo\ corr.} = \frac{R_{t\ corr.}}{R_t / R_{xo}}$$



Procedure: exercise 5-6: Dual Laterolog+ MSFL

LLD (long-dashed line) = xx ohm-m; LLS (short-dashed line = yy ohm-m; MSFL (solid line) = …. ohm-m.

R_t / R_{LLD}	d_i	R_t / R_{xo}	$R_{t\ corr.}$	$R_{xo\ corr.}$
xx	yy	zz	aa	bb

Calculations

$$R_{t\ corr.} = \frac{R_t}{R_{LLD}} \times R_{LLD}$$

$$R_{xo\ corr.} = \frac{R_{t\ corr.}}{R_t / R_{xo}}$$

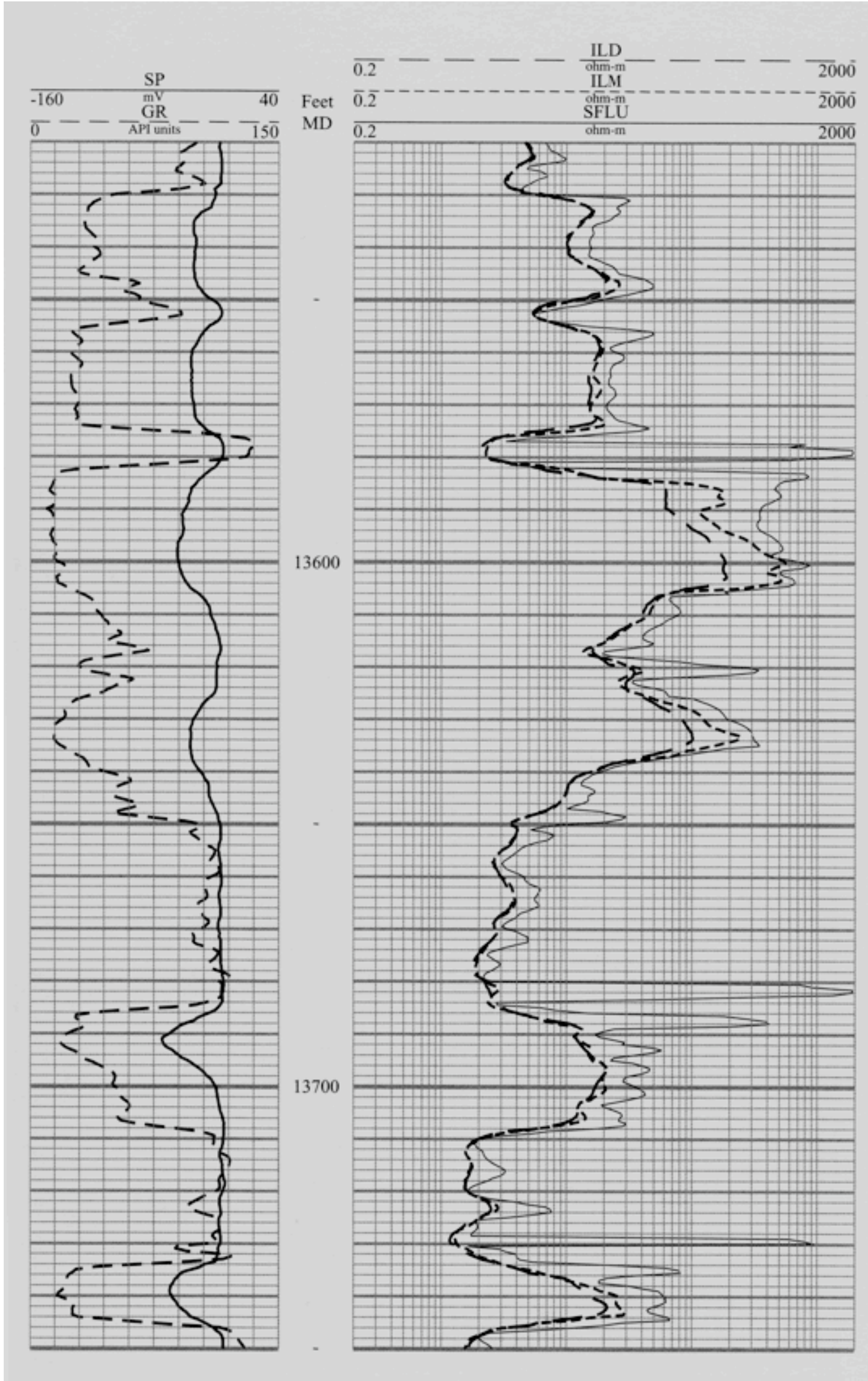
When the deep laterolog reading is corrected for invasion via the tornado-chart, the resulting estimate of true formation resistivity is always greater than the deep laterolog reading.

Class exercise: Dual Induction Log

Read all logs at 13591 ft. and correct for true resistivities.

Deep induction log resistivity: The dashed ILD curve measures the deep resistivity of the formation, or close to true resistivity (R_t). At the depth of 13,591 ft, the deep resistivity (ILD) is 70 ohm-m.

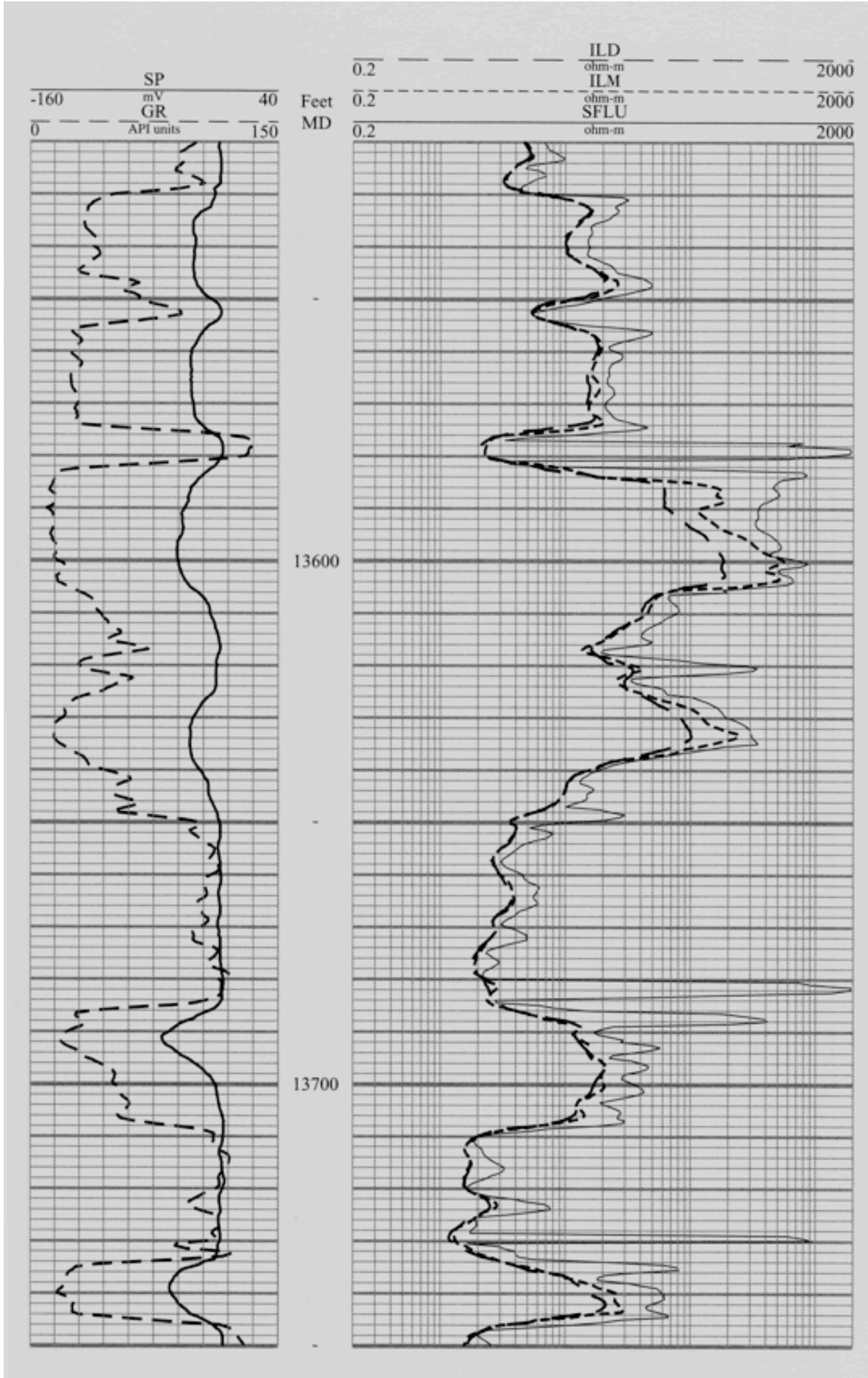
Medium induction log resistivity: The dotted ILM curve measures the medium resistivity of the formation or resistivity of the invaded zone (R_i). At 13,591 ft, the medium resistivity (ILM) is 105 ohm-m.



Class exercise: Dual Induction Log

Spherically focused log resistivity:
The solid SFLU curve measures the shallow resistivity of the formation or resistivity of the flushed zone (R_{xo}). At 13,591 ft, the resistivity of the flushed zone is 320 ohm-m.

The ratios SFLU/ILD and ILM/ILD are needed for work on the tornado chart, useful for correcting the values.



Class exercise: Dual Induction Log

$ILD = R_{ILD} = 70$ ohm-m;

$ILM = R_{ILM} = 105$ ohm-m;

$SFLU = R_{SFL} = 320$ ohm-m

$R_{SFL} / R_{ILD} = 4.6$

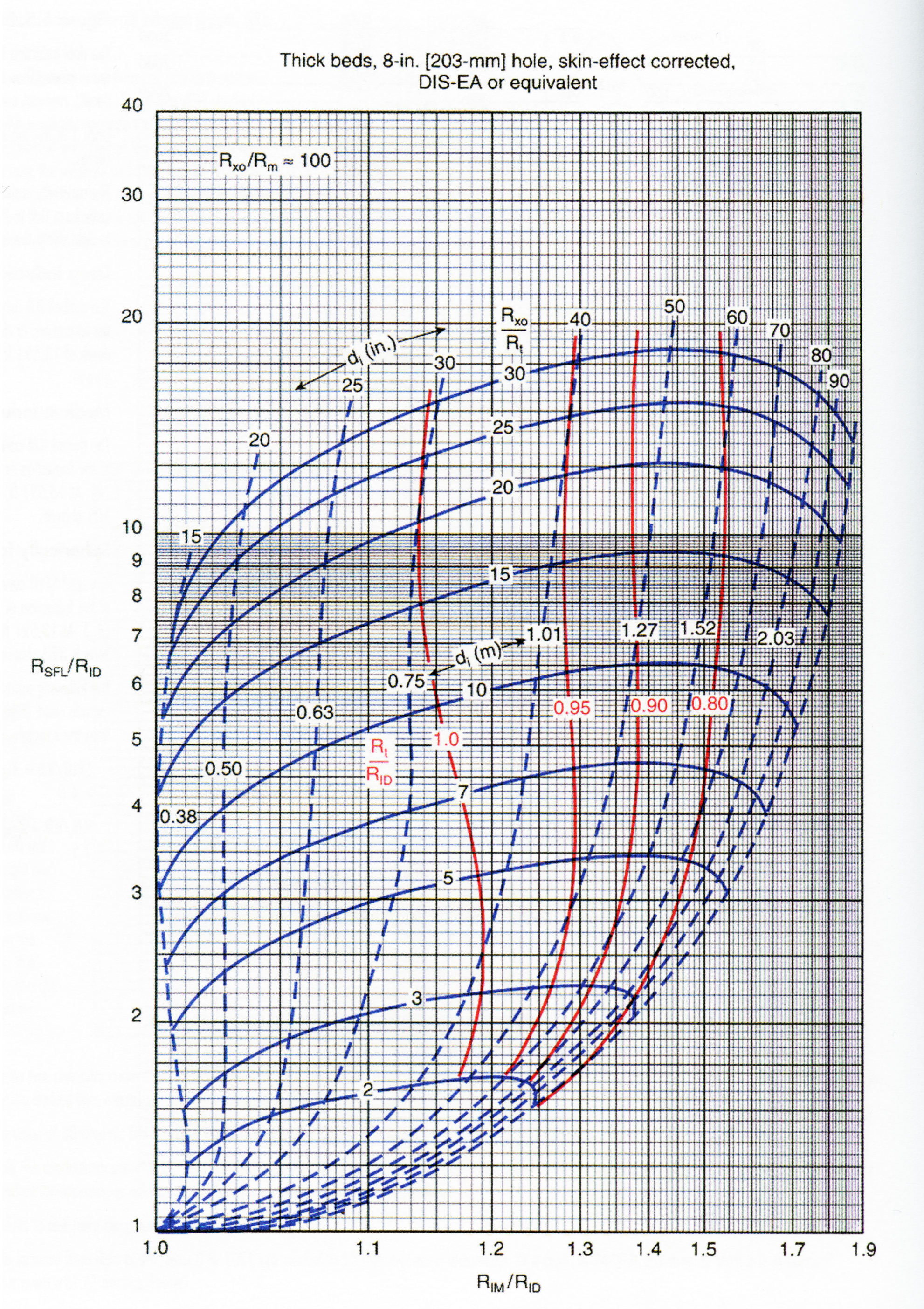
$R_{ILM} / R_{ILD} = 1.5$

$$R_t(\text{corrected}) = \frac{R_t}{R_{ILD}} \times R_{ILD}$$

equ. A

$$R_{xo}(\text{corrected}) = \frac{R_{xo}}{R_t} \times R_t(\text{corrected})$$

equ. B



Courtesy Schlumberger Wireline & Testing, ©1998 Schlumberger.

Class exercise: Dual Induction Log

Procedure:

1. Plot the R_{SFL}/R_{ILD} ratio (= 4.6) on the vertical axis (labeled R_{SFL}/R_{ID}), and the R_{ILM}/R_{ILD} ratio (= 1.5) on the horizontal axis (labeled R_{IM}/R_{ID}). Plot the intersection of these two values on the tornado chart, and pick the following values:

2. Relation of R_t/R_{ILD} is represented by the solid red lines (also labeled in red). They range from 1.0 to 0.8, decreasing from left to right. The R_t/R_{ILD} value falls on the 0.80 line.

3. Diameter of invasion around the borehole: d_j is picked by following the dashed, blue lines upwards to the appropriate scale. The black labelled d_j scale increase from left to right. It is in inches across the top of the tornado chart and in meters through the middle part of the chart. In our example, d_j is between the 60-inch and 70-inch lines; it is about 68 inches.

Class exercise: Dual Induction Log

4. Ratio R_{xo}/R_t represents the resistivity of the flushed zone over the true resistivity of the formation (corrected R_t). This ratio, derived from the chart, is needed for later calculations.

   The scale is represented by the heavy, blue, solid lines, and the black labeled scale values are shown as whole numbers midway across the lines. In this example, the plotted sample falls on the line with a value of 7.0.

5. Finally, with the values taken from the chart and from the log, we calculate corrected values for R_t *and* R_{xo}.
   (A) R_t correct*ed* = 0.80 x 70 = 56 ohm-m
   (B) R_{xo} (corrected) = 7 x 56 = 392 ohm-m

6. When the deep induction log reading is corrected for invasion via the tornado chart, the resulting estimate of true formation resistivity is always less than the deep induction reading.