COMBINED EXERCISE 1

You are provided with a set of logs from a reservoir sequence in the UKCS of the North Sea and a neutron-porosity crossplot.

- The drilling mud was saline water-based and contained no KCl or barite.
- The depth scale is in metres.

Answer the following questions marking the logs with construction lines where appropriate and showing full working for numerical questions.

(a) Identify the main lithologies throughout the log, marking explicitly any fining-up or coarsening-up sequences. Shade the depth scale with the standard colour or pattern for each lithology. (***Hint:*** *You may find carrying out parts (b) and (c) below first help you in this process.*)

(b) Shade the difference between the caliper log and the bit size for:

- Intervals where Caliper<BS and there is mudcake.
- Intervals where Caliper>BS and there is caving.

(c) Shade the intervals of (i) negative separation, and (ii) positive separation on the neutron-density log (track 2).

(d) Comment briefly upon the likely cause of the shape of the gamma ray log in the interval 2635 m and 2645 m.

(e) Why is a similar effect noted on the density log, but not on the neutron or resistivity logs?

(f) Calculate the mud-cake thickness at 2590 m.

(g) Calculate the shale volume (V_{sh}) at 2550 m from the gamma ray log.

(h) Calculate the shale volume (V_{sh}) at 2550 m from the neutron/density separation.

(i) Given that the section between 2560 m and 2609 m is 100% saturated with water (r_f = 1.0 g/cm^3), calculate the porosity at 2590 m.

(j) Repeat the porosity assessment at 2590 m by plotting the appropriate point on the neutron-density crossplot, supplied.

(k) Given that at 2590 m the Archie '*m*' exponent equals 1.86, calculate the resistivity of the water occupying the pores in the rock using the porosity calculated in part (j).

(l) Use the cross-plot method (part (j) above) to calculate the mean porosity in the interval 2505 m to 2531 m.

(m) Given that the water resistivity, R_w, in the interval 2505 m to 2531 m can be assumed to be the same as that calculated in part (k), and that the Archie exponents are m = 1.86

and $n = 2$, use the combined Archie equation to calculate the mean fractional water saturation, S_w, and mean fractional oil saturation, S_o, in the interval.

(n) Given that the reservoir has an area of 5050 acres and that the oil formation volume factor $B_o = 1.45$, calculate the oil in place in Mbbl. to 2 places of decimals.

(o) Given that 30% of this oil is producible, and the mean selling price of Brent crude in 1997 was 19.26 $/bbl., calculate the value of the reserves in the field at that time in millions of dollars.

(p) This was good news for the oil company, and they perforated the interval and completed the well. In order for the well to produce, they committed themselves to an investment of $200,000,000 for a rig to produce the well. The new rig was due to come on-stream on 1st January 1999.

However, by 1998 the mean selling price of Brent crude was 13.52 $/bbl.

Furthermore, additional drilling had confirmed that (i) the earlier values for the reservoir area, reservoir thickness, and porosity were actually only 90% of the original estimates, (ii) the water saturation was 10% higher than originally thought, and (iii) the fraction of producible oil in the reservoir was only 20%.

Additionally, the rig will cost $5000 per day to run in maintenance and salaries.

The current tax regime indicates that the government will take 55% of the value of all oil produced (i.e., 55% of the value of all your revenue from selling the oil).

Reservoir modelling calculations indicate that a steady mean production of 10,000 bbl./day oil will be produced over the lifetime of the field.

The transport costs of getting the oil from the rig to the refinery (laying a pipeline and operating it) will be $0.1 per barrel.

The costs of drilling the initial well, carrying out logging, appraisal of the data, reservoir modelling and administration and management of the field throughout its lifetime must also be taken into account, and come to 50 million dollars for both scenarios.

There is now a decision to be made – what to do! The following questions are relevant, but you may consider other factors as well:

- How much were the reserves worth in 1997, and how much are they worth in 1999?
- How much tax will be paid over the lifetime of the field at 1997 and 1998 costings?
- How much nett revenue will the company have left over at 1997 and 1998 costings?
- How much will this be after rig construction costs and oil transport costs have been taken into account?
- How many days (years) is the field expected to produce for using the 1997 and 1998 data?
- What therefore is the likely rig operating costs over the lifetime of the field using the 1997 and 1998 data?

- Taking all the factors into consideration, what will be the final nett revenue from the field over its lifetime using the 1997 data and then using 1998 data. This is the profit from the field after you have taken into consideration (i) the new estimates for the reservoir parameters, (ii) the revenue lost to tax, (iii) the cost of the rig, (iv) the cost of the transport of the oil, (v) the running costs of the rig, and (vi) the analysis and administration costs.

If it was your decision would you let the field start producing? Give reasons for your decision, backed-up by robust figures to illustrate your point. Remember (i) you have a responsibility to your shareholders and (ii) you have a responsibility to your own pension fund!

At approximately what value of the price of Brent crude does the field become a nett loss to the company?

HELPFUL EQUATIONS

Shale Volume from the gamma ray log:

$$V_{sh} = \frac{GR_{\log} - GR_{sand}}{GR_{shale} - GR_{sand}}$$

Shale Volume by neutron /density separation:

$$V_{sh} = \frac{Separation\ at\ given\ depth - Separation\ for\ sand}{Separation\ for\ shale - Separation\ for\ sand}$$

Porosity from the density log:

$$f_D = \frac{r_{ma} - r_b}{r_{ma} - r_w}$$

Porosity from the sonic log:

$$f_S = \frac{\Delta t_{ma} - \Delta t_b}{\Delta t_{ma} - \Delta t_w}$$

Archie's First Law:

$$R_t = R_w f^{-m} \quad \text{therefore} \quad R_w = R_t f^{m}$$

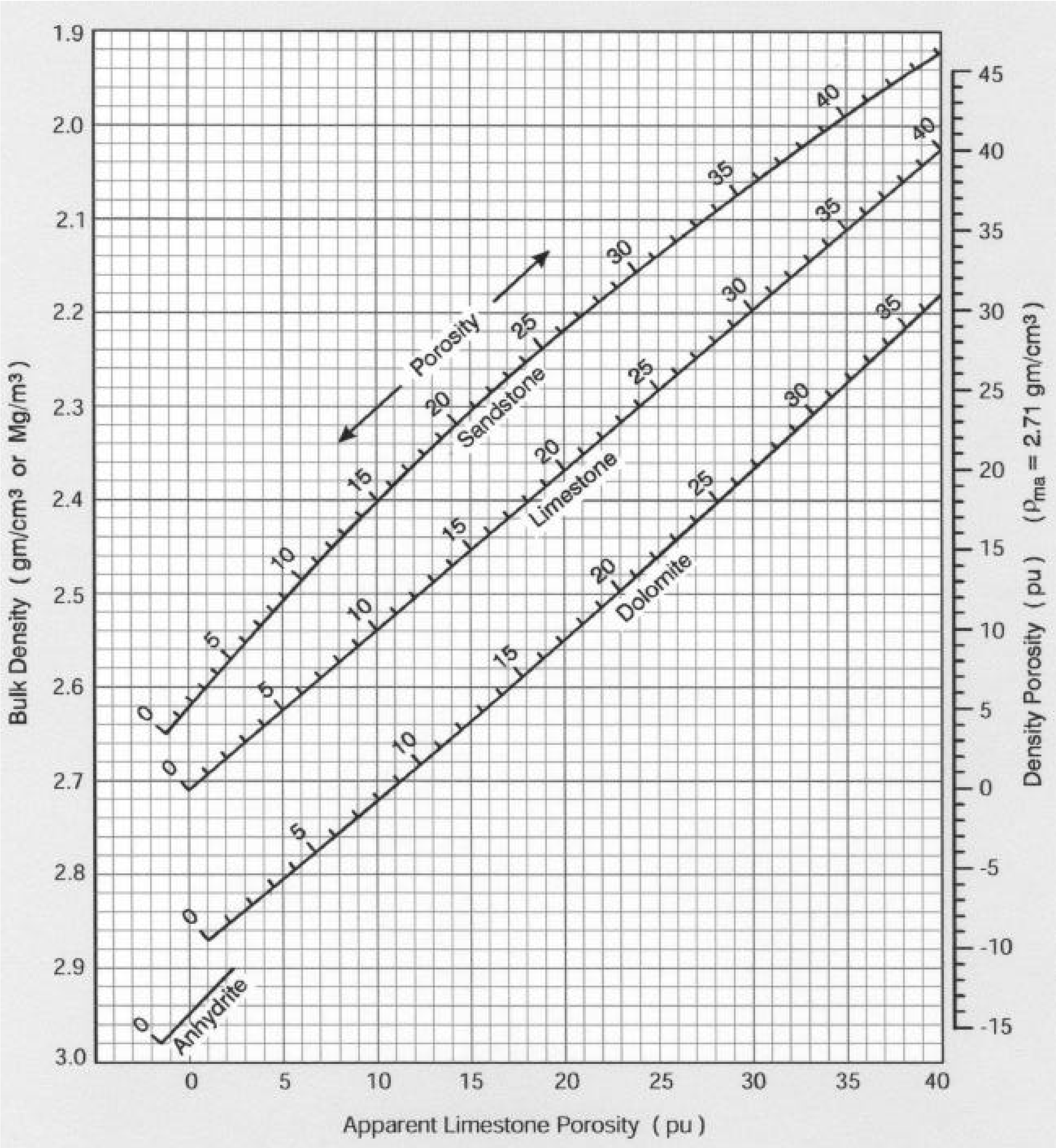
Archie's Combined Law:

$$R_t = R_w f^{-m} S_w^{-n} \quad \text{therefore} \quad S_w = \sqrt[n]{\frac{R_w}{R_t\ f^{m}}}$$

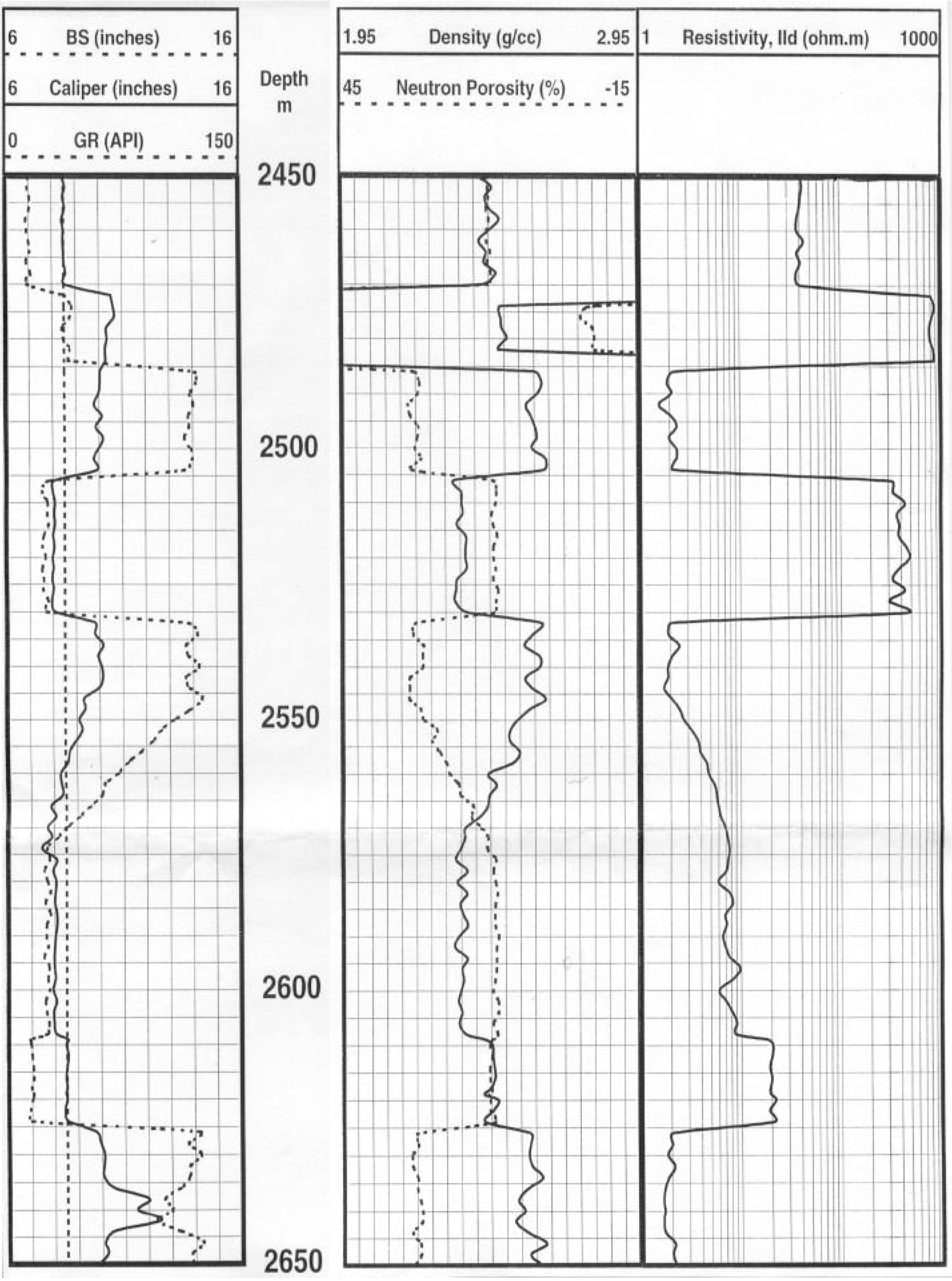
Stock Tank Oil In Place:

$$STOOIP = \frac{25453\ A\ hf\ \ (1 - S_w)}{B_o}$$

where: reservoir area, A is measured in acres, and reservoir zone thickness, *h*, is measured in metres.



Neutron-Density-Porosity-Lithology Cross-plot for a fluid density of 1.0 g/cm^3. (Courtesy of Reeves Wireline Ltd.)


6 BS (inches) 16
6 Caliper (inches) 16
0 GR (API) 150
Depth m
2450
2500
2550
2600
2650
1.95 Density (g/cc) 2.95
45 Neutron Porosity (%) -15
1 Resistivity, lld (ohm.m) 1000