Problem Set Lecture 4: Resistivity

1. What factors influence the resistivity of sediments?

2. What additional influence needs to be considered when measuring resistivity in a borehole?

3. Two main types of resistivity tools are used, leterlogs and induction tools. What is the basic difference in how these tools measure resistivity, and what considerations determine which tool is bet suited to a given environment?

4. Draw a typical fluid invasion profile for a borehole showing R_t, R_i, and R_{xo}. Show the distance from the borehole wall (in cm) that the common resistivity tools measure: Laterlogs (deep and shallow), Spherically focused log, induction log (deep, medium) and the microlog.

5. A section of sandstone reservoir was logged and found to have a porosity of 18%. The water resistivity is estimated to be 0.2 ohm-m, and R_t was measured to be 10 ohm-m. Using the practical Archie equation, what is the water saturation? If the pore spaces are occupied by only brine and oil, what is the hydrocarbon saturation?

6. If the sandstone reservoir is 150 m thick, 1.5 km wide, and 0.6 km long, what is the volume (m^3) of oil that it contains?

7. You need to calculate porosity for a section of a borehole where you have high-resolution FMS resistivity measurements. To do this, you first need to determine the formation factor for these sediments, which are shales, so the Practical Archie equation (and other models developed for sand reservoirs) will not work. Fortunately, there exist a few laboratory measurements of porosity and resistivity from the same lithologic unit.

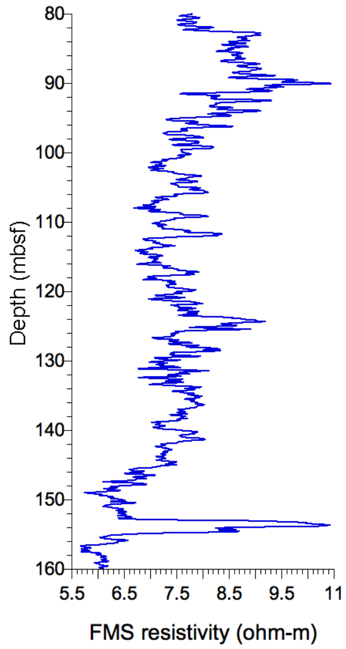
   A. Using the simple definition of the formation factor ($F=R_o/R_w$), calculate *F* for the different laboratory samples. The pore fluid is 100% seawater (salinity 35 ppt) and all measurements were made at room temperature (20°C). Use the Schlumberger look-up table to find R_w.

Porosity	Resistivity (ohm-m)	Formation Factor (F)
0.804	0.460	
0.759	0.463	
0.728	0.550	
0.714	0.561	
0.646	0.609	
0.627	0.733	
0.604	0.709	
0.587	0.772	
0.555	0.884	
0.522	0.889	
0.510	0.797	
0.496	0.945	
0.491	0.932	
0.484	0.955	
0.479	0.996	
0.450	1.215	
0.372	1.508	

B. Plot the data, with the F as the dependent variable and ϕ as the independent variable.

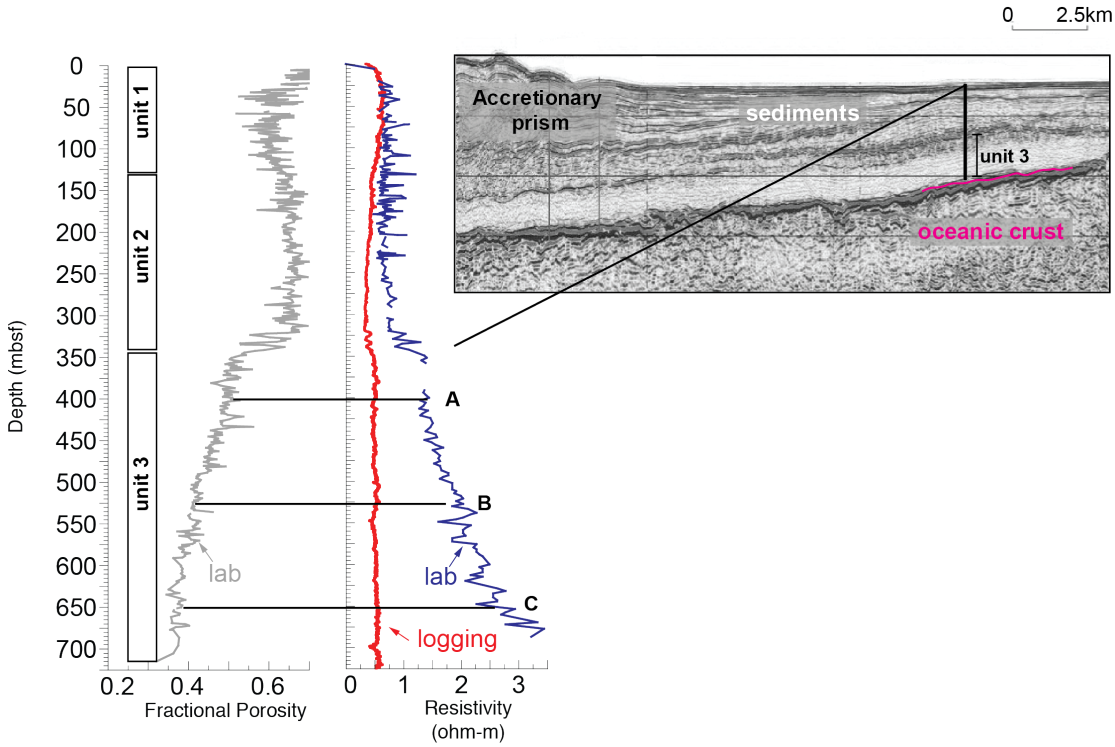
C. Use a power-law regression to determine the constants '*a*' and '*m*' for this sediment type. Remember that these exponents relate porosity to the formation factor ($F = a/\phi^m = a\phi^{-m}$).

D. Examine the plot of FMS resistivity, and calculate the maximum and minimum porosity in this interval of the borehole. The resistivity of the mud filtrate is 2.0 ohm-m.



E. As porosity decreases, does resistivity increase or decrease? Explain why.

8. During a drilling expedition to the Nankai Trough, where the Philippine Plate is subducting beneath Japan, you compare laboratory measurements of resistivity and porosity with LWD resistivity measurements. The laboratory data appear to make sense, showing a predictable correlation between resistivity and porosity, but the LWD resistivity measurements do not increase as you go deeper into the section (*see figure below*). You know that the drilling site is located on young (7 Ma) oceanic crust, and expect relatively high heat flow and in-situ temperatures. You want to test whether the high geothermal gradient is causing the in-situ resistivity measurements to remain constant.



A. Calculate the predicted heat flow from the underlying oceanic crust.

B. The average laboratory thermal conductivity of the sediments is 1.46 w/mK. What should the temperature gradient be?

C. Unit 3 is composed of sediments with a similar composition. Calcuate the formation factor at the three points given in the table below. Laboratory porosity and resistivity data indicate that:

$$F = \frac{1.58}{\phi^{2.17}}$$

Position	Depth (mbsf)	Frac. Porosity	F	R_{Lab} (ohm-m)	R_{LWD} (ohm-m)	Rw	T (°C)
A	400	0.50		1.09	0.502		
B	525	0.42		1.33	0.536		
C	650	0.38		1.71	0.549		

D. Calculate the resistivity of formation water (R_w) based on the basic definition of F where;

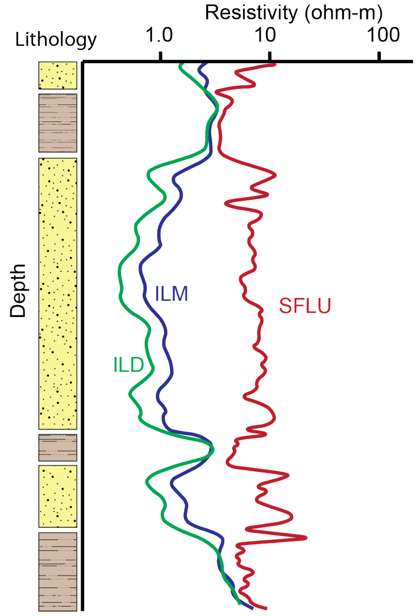
$$F = \frac{R_o}{R_W}$$

E. Using the Schlumberger look-up table, calculate the temperature of the formation water assuming a salinity of 35 ppt.

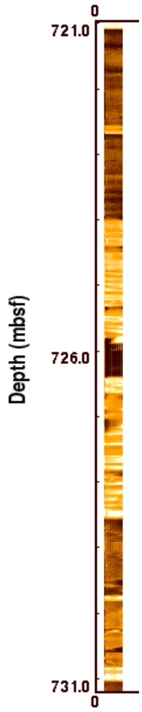
F. What is the geothermal gradient derived from the resistivity-based temperature estimates?

G. How does it compare with the predicted geothermal gradient? Are high in-situ temperatures responsible for the constant downhole LWD resistivity measurements? What other factors should be investigated?

9. What do the acronyms stand for on the resistivity profile below? Explain why the resistivity profiles become offset in the sandstone intervals.



10. Identify the resistive and conductive layers in the FMS image to the right. If the sediment mineral composition is not changing, and the pore water composition remains constant. What may be causing the change in resistivity?



Resistivity of NaCl Solutions

Conversion **approximated** by $R_2 = R_1 [(T_1 + 6.77)/(T_2 + 6.77)]$°F or $R_2 = R_1 [(T_1 + 21.5)/(T_2 + 21.5)]$°C