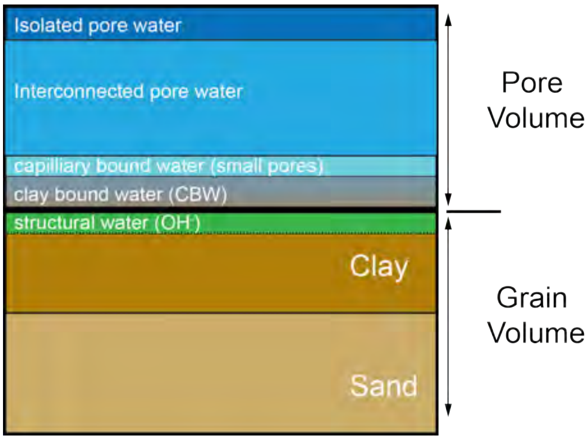
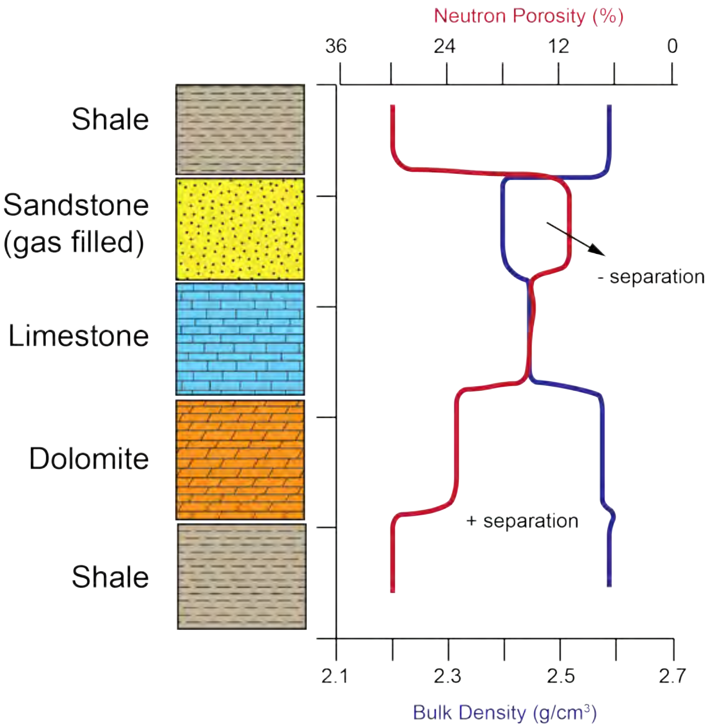
Problem Set Lecture 7: Density and Porosity

1. Neutron Porosity, Lithodensity, Acoustic and Resistivity measurements can all be used to calculate porosity. Using the petrophysical description of porosity (image below) explain what components of the pore space each measurement includes.



2. The image below, taken from the lecture slides, shows the neutron porosity and bulk density of different deeply buried consolidated sediments.



A. Use the litodensity derived bulk density measurements to calculate the ‘density-porosity (ϕ_D)’ of these sediments. Be sure to use appropriate matrix (grain) densities for the different litholgies.

Lithology	ϕ_N	Grain density (g/cm^3)	ϕ_D
Shale			
Sandstone			
Limestone			
Dolomite			

B. How do they compare with the neutron porosity (ϕ_N) measurements?

C. Calculate the best-estimate porosity from the equation:

$$\phi = \sqrt{\frac{\phi_N^2 + \phi_D^2}{2}}$$

3. We often assume a grain density of 2.70 g/cm^3 for shale/clayey sediments when we want to calculate porosity from bulk density.

A. What constituents in the solid fraction can cause this value to be considerably lower?

B. What constituents in the solid fraction can cause this value to be considerably higher?

C. Given a range of grain densities between 2.65 to 2.75 g/cm^3 calculate the porosity for the following measured bulk densities. What is the % error for each measurement if the true grain density is 2.70 g/cm^3

Bulk Density (g/cm^3)	Porosity True	Porosity low	% error	Porosity high	% error
1.4					
1.6					
1.8					
2					
2.2					
2.4					
2.6					

Note: The percent error describes how far the calculated value is from the true value. It is calculated as,

$$Error\ (\%) = \frac{true\ value - calcuated\ value}{true\ value}\ x\ 100$$

4. Given the data in the table below,

Depth (mbsf)	Fractional Porosity
1	0.57
11	0.53
21	0.49
31	0.55
41	0.48
51	0.48
61	0.44
71	0.43
81	0.42
91	0.41
101	0.37
111	0.38
121	0.41
131	0.40
141	0.39
151	0.39

A. Plot the data and calculate an exponential compaction function relating depth and porosity. Show the plot with the curve fit in your answer.

B. What is the predicted porosity of these sediments if they were buried to a depth of 500 m?

C. What is the predicted porosity of these sediments if they were buried to a depth of 2000 m? Does this seem reasonable – why or why not?

5. From a laboratory consolidation test, you derive the following data:

Applied Load (kPa)	Void Ratio (e)	Porosity (%)	Bulk Density (g/cm^3)	Equivalent Depth (mbsf)
332	0.81			
498	0.75			
746	0.69			
1120	0.63			
1680	0.56			
2522	0.49			
3784	0.41			

A. Plot the Applied load (effective stress) against the void ratio and derive a compaction function that relates effective stress to void ratio. Include the plot and curve fit in your answer.

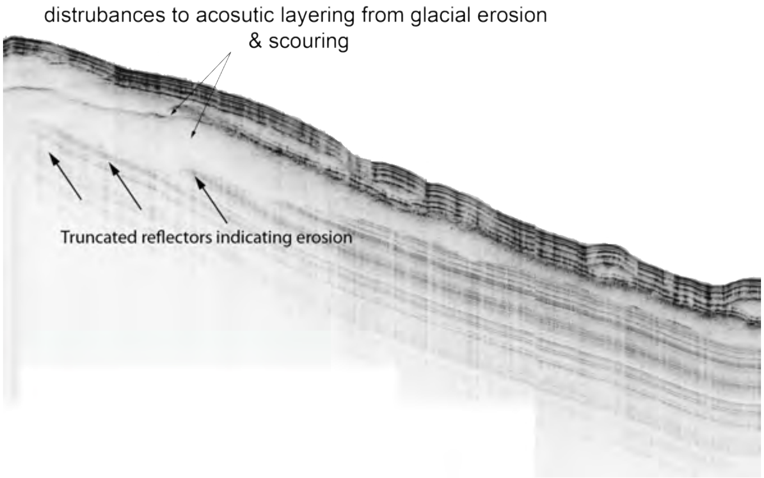
B. What is the predicted compression index and void ratio at the seafloor for these sediments?

C. Calculate the equivalent porosity at each effective stress.

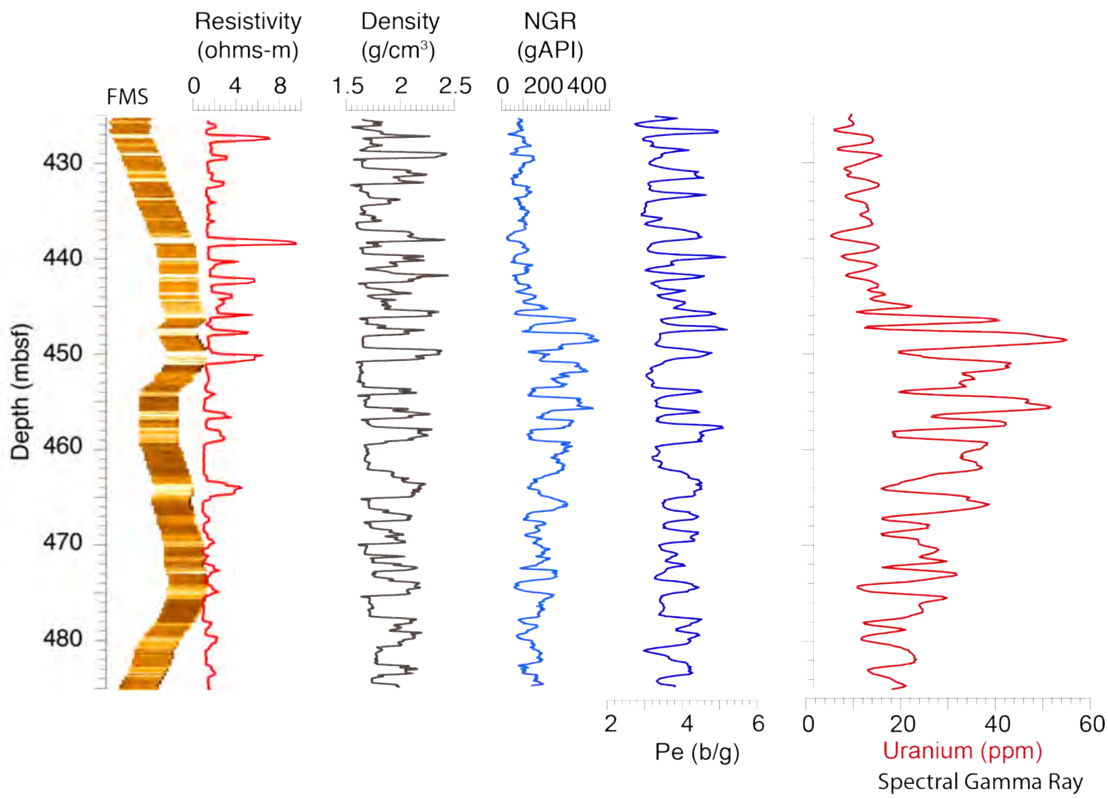
D. Assuming a grain density of 2.70 g/cm3, what is the bulk density at each effective stress level?

E. Now, assuming an average bulk density of 1.8 g/cm^3 - What burial depths to the applied loads in this consolidation test equate to?

F. Here is an image of glacial erosion on the Lomonosov Ridge, in the central Arctic Ocean. You can see by the truncated reflectors, that the top of the ridge was scraped off, in this case, by a passing tabular iceberg. You estimate that 80 meters of sediment has been eroded. Predict the porosity of sediments below the erosional horizon using the compaction function derived from this consolidation test.

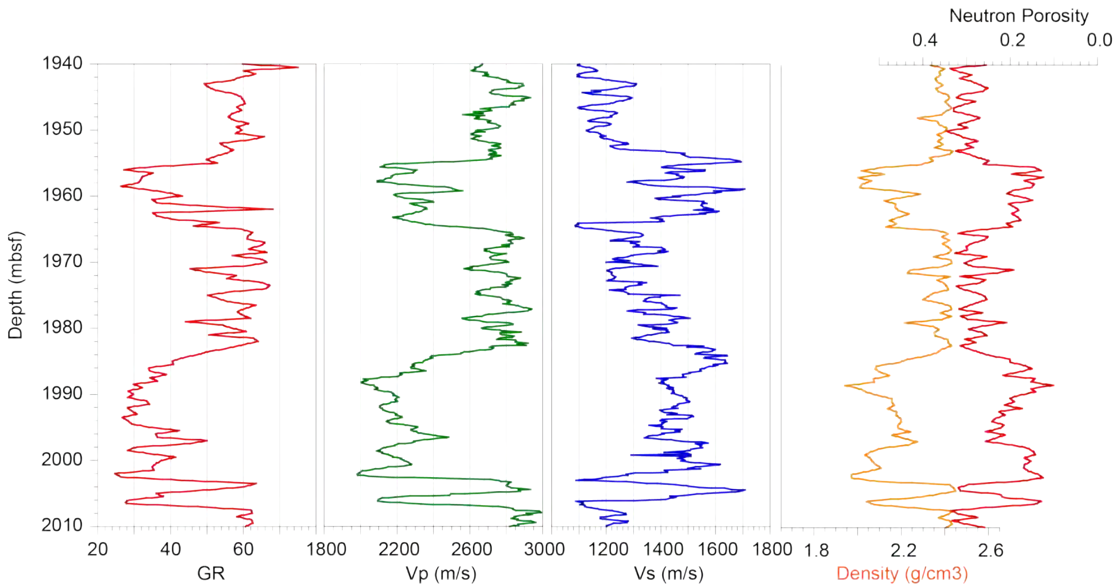


6. In Moment 5 you interpreted a section of logging data from a Cretaceous black shale sequence on Demerara Rise, in the equatorial Atlantic. Below we have added the Photelectric factor log across this same interval. How does it compare with the other lithologic indicators, does it move in phase with changes in other logs? What does it tell us about the lithology of the sediments interbedded with the organic rich black shales?



7. In the above example, the Total organic carbon content of the drilled sediments was measured through the black shale interval. It ranged between 0.72 and 21%. In the absence of coring data, it is possible to estimate the organic carbon content using the lithodensity log. The procedure is outlined in the *source rock evaluation section* (chapter 10 of text). Apply this procedure to estimate the average TOC content of the black shale beds in the example above.

8. In the last Moment we looked at the sound speeds through an interval of a deep reservoir. The Neutron porosity log is added to this measurement suite below. What does it tell us about the pore fluid composition in the sand intervals of the reservoir?



9. Here is tabulated data (Hamilton, 1979) on the porosity-depth relationship for common types of deep-sea sediments. Plot these and

identify which have the higher near-surface porosity, and which are most compressible.

Depth (mbsf)	Density (g/cm^3)	Porosity (%)
Calcareous sediments		
0	1.51	72.0
50	1.60	66.7
100	1.67	62.7
150	1.73	59.0
200	1.78	55.6
300	1.88	49.9
400	1.94	45.8
500	1.98	43.6
Radiolarian ooze		
0	1.17	90.0
50	1.18	88.9
100	1.22	86.0
150	1.28	81.1
200	1.36	74.3
250	1.47	65.5
Diatomaceous ooze		
0	1.24	86.1
50	1.28	83.5
100	1.31	81.2
150	1.34	79.0
200	1.36	77.1
300	1.41	74.0
400	1.43	72.0
500	1.45	71.0
Terrigenous sediment		
0	1.53	72.0
50	1.59	68.2
100	1.66	64.4
150	1.72	60.9
200	1.78	57.4
300	1.90	50.6
400	2.00	44.4
500	2.10	38.9

10. In lecture 1, the following Porosity-Depth relationships for a shale, organic rich shale and sandstone were presented. Describe, in words,

how the porosity of sandy and clayey sediments evolves with burial depth, and comment on the importance of these trends for lithological interpretations from density logs in marine sediments.