Exam PET500 - PART 1: Reservoir Geology (50% Exam)

Part I. Petroleum Geology and Sedimentology

1. List three types of continental margins and different sedimentary basins under each continental margin.
2. Definition: What is sedimentary facies?
3. Name the following five depositional systems $(A - E)$ in a passive margin (Figure 1).

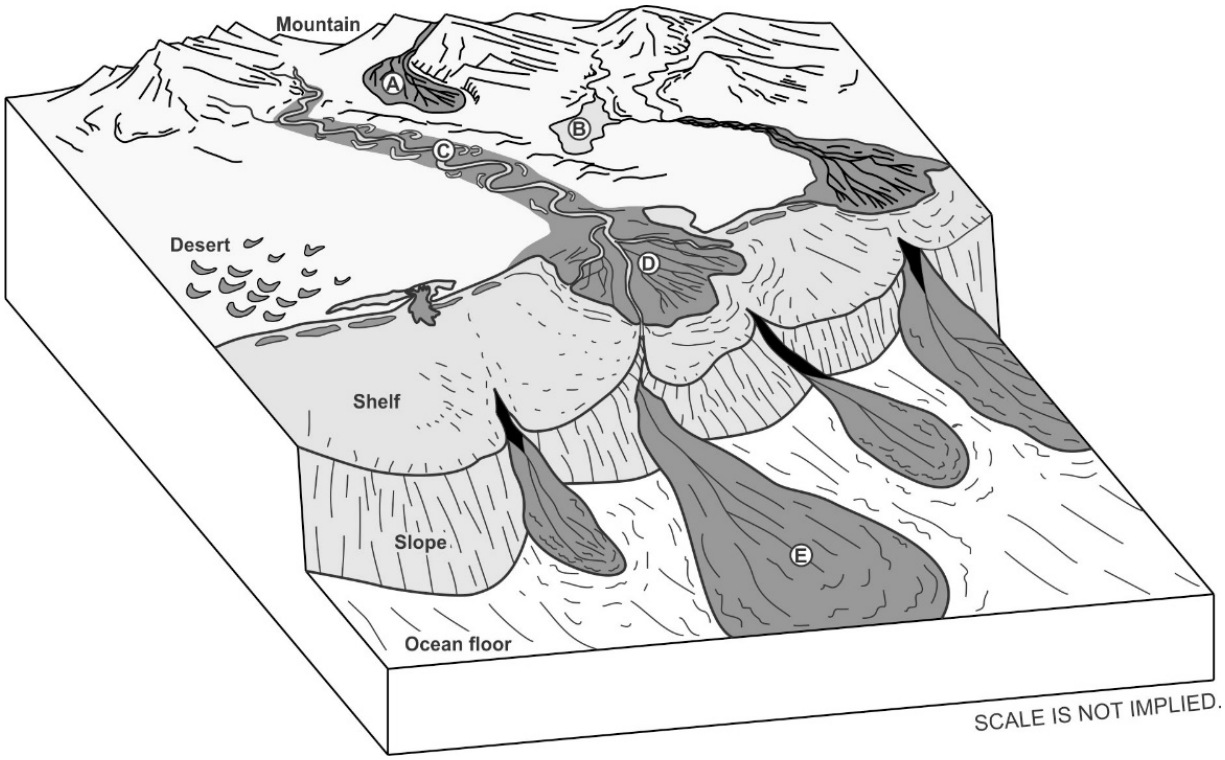

Figure 1. Depositional model in a passive margin

4. List at least five environmental requirements for carbonate sedimentation.
5. Definition: What is diagenesis of sedimentary rocks?

   Briefly define four diagenetic processes of sedimentary rocks.

   Explain how porosity changes under each diagenesis.
6. Table 1 shows the geochemical analysis of three source rock samples. By using the $\mathrm{HI} - \mathrm{T_{max}}$ cross plot (Figure 2), determine the kerogen type of each source rock and explain expected organic components and predominant hydrocarbon potential.

   Hint: Answers should follow the format of: *Rock sample: Kerogen type; Expected organic components; Predominant hydrocarbon potential*.

Table 1. Geochemical analysis of three rock samples

Rock sample	Tmax (ºC)	Hydrogen Index
A	465	35
B	435	690
C	450	320

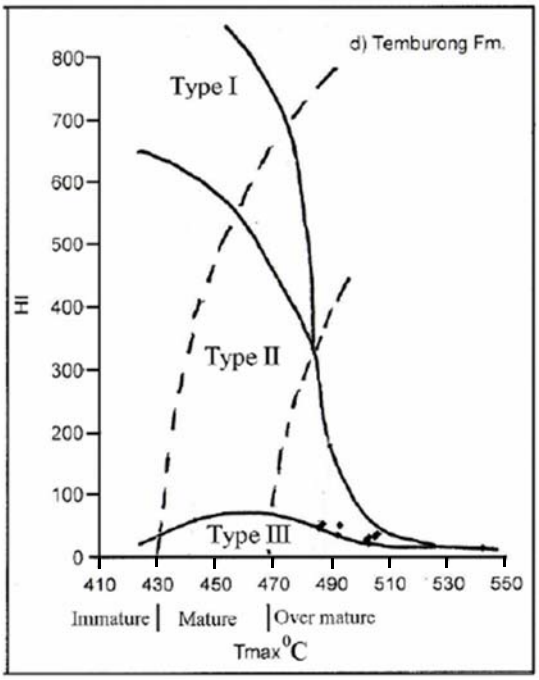

Figure 2. HI-Tmax cross plot diagram

7. Definition: What is secondary migration of hydrocarbon?

   List three major pathways for hydrocarbon migration.

Part II. Subsurface methods for reservoir characterization

Figure 3 shows the Upper Jurassic log curves of a well in the northern North Sea. The Sognefjord Formation is the main reservoir that comprises at least four sandstone layers. Complete tasks in Part II and Part III based on this figure.

8. Petrophysical methods

   (1) Based on given log curves, determine the depths of formation top and base. Hint: Count all sandstone layers into the Sognefjord Formation.

   What is your basis for defining the sandstone layers?

   What's the average transit time of the Sognefjord Formation ($\Delta t_{\log}$)?

   (2) The porosity of reservoir can be estimated from sonic logging as below:

$$\varphi_s = \frac{\Delta t_{log} - \Delta t_{Matrix}}{\Delta t_f - \Delta t_{Matrix}}$$

Calculate the sonic derived porosity (φ_s) for the Sognefjord Formation. Assume the interval transit time of the matrix is $54\ \mu s/ft$, the interval transit time of the pore fluid is $187\ \mu s/ft$.

(3) Assume all of the sandstone layers homogeneously consist of quartz grains and crude oil. Calculate the density of this kind of sandstone layers (ρ)? Assume the density of grain is $2.65\ g/cm^3$ and the density of fluid is $0.76\ g/cm^3$. Use the calculate estimated sonic derived porosity from Question 8.2.

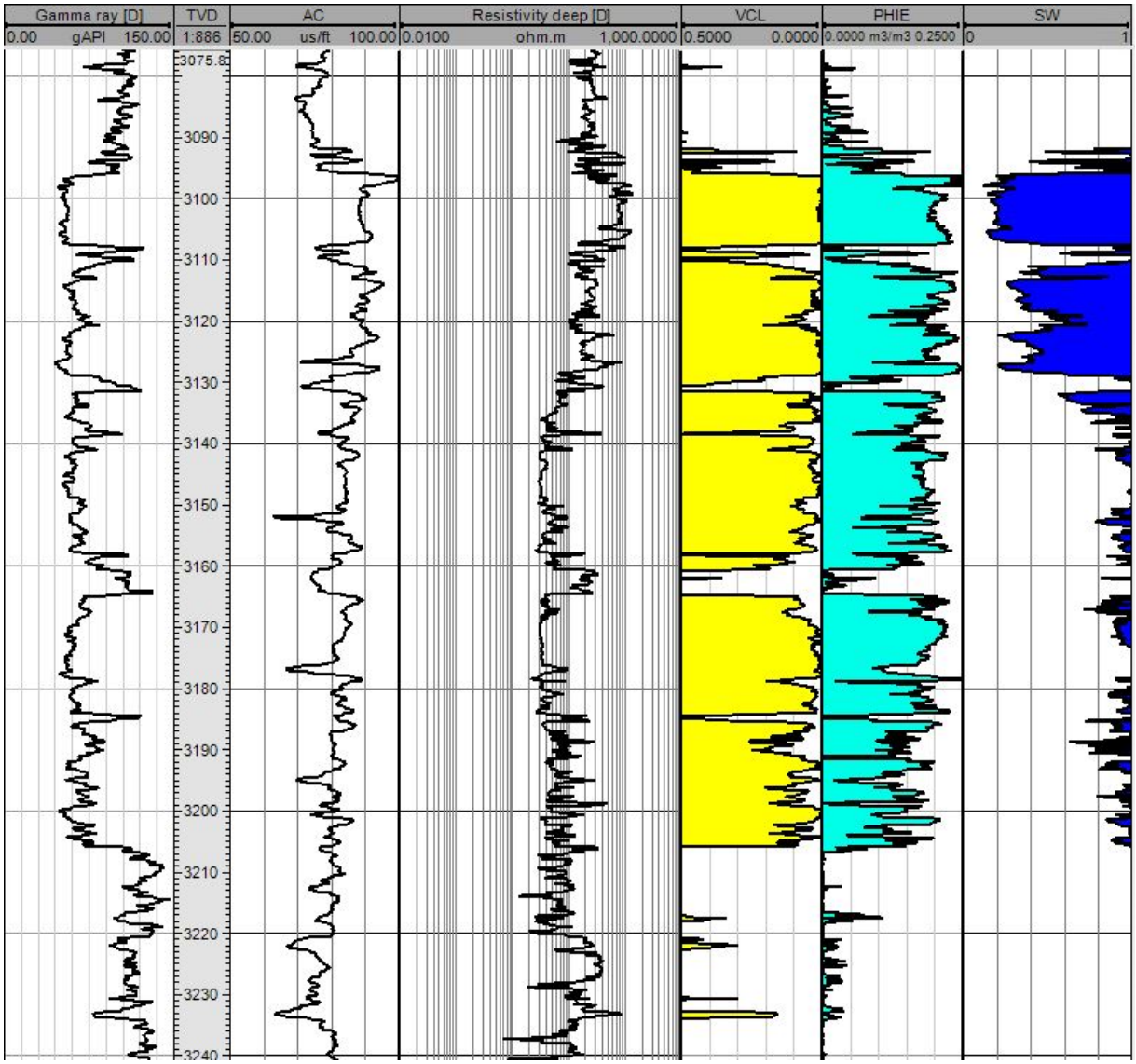

Figure 3. Composite logs of well 35/11-13, northern North Sea. TVD = Total vertical depth; AC = Acoustic; VCL = Clay volume; PHIE = Effective porosity; Sw = Water saturation.

9. Geophysical approach

   (1) Acoustic impedance is the product of velocity (v) and density (ρ). Reflection coefficient (R) simplifies the difference in acoustic impedance between stratigraphic layers divided by their sum.

   Calculate the reflection coefficient (R) at the top of the sandstone formation.

   Hint: Use the calculated density of sandstone reservoir (ρ) from Question 8.3. Assume the density and velocity of rock above the Sognefjord Formation is 1.85 g/cm^3 and 3420 m/s, respectively. The velocity of the Sognefjord Formation is 5500 m/s.

   (2) Vertical resolution of seismic data represents the distance between two interfaces as separate reflectors. In general, layers can be discerned/distinguished when their thickness is more than 1/4 to the dominant wavelength. Based on your sandstone layered determined in Question 8.1, calculate the minimum frequency requirement that allows all these layers to be discerned.

   Hint: Focus on the thinnest sandstone layer in the Sognefjord Formation.

10. Using all well logs in Figure 3 and given cut-offs, calculate the thickness of gross sandstone, net sandstone, gross pay, and net pay. Calculate the net-to-gross ratio (N/G) of the pay zone that contains hydrocarbon.

    Cut-offs:

    Clay content $V_{sh} = 10\%$

    Porosity $\varphi = 10\%$

    Water saturation $S_w = 80\%$

    Bulk volume water $BVW = 25\%$

Part III. Volumetric calculation

BONUS QUESTION (correct answer will credit an incorrect answer in 1-10)

Gross rock volume (GRV) is the volume of rock between the top and base of reservoir that contains hydrocarbon. It can be calculated with area (A) multiplied by gross pay thickness (h). Using a simplified cylinder model, calculate the gross rock volume (GRV), net rock volume

(NRV), net pore volume (NPV), hydrocarbon pore volume ($HCPV$), and hydrocarbon initial in place ($HCIIP$) of sandstone reservoir.

Hints: (1) Assume area $(A)\ is\ 420\ km^2$; (2) For the net pay thickness (h) and net-to-gross ratio (NGR), you should use your own calculation in Question 10; (3) You may use the sonic derived porosity from Question 8.2; (4)You need to find out average hydrocarbon saturation from well log; and (5) Assume the oil formation volume factor (FVF) is 1.25.