National Exams December 2014

98-Pet-B4, Petroleum Geology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK exam.
3. Candidates may use one of two calculators, the Casio or Sharp approved models.
4. FIVE (5) sections constitute a complete exam paper. Each section contains between 1 and 4 questions.
5. The first five sections as they appear in the answer book will be marked.
6. All sections are of equal value. All parts in a multipart question have equal weight.
7. Clarity and organization of your answers are important, clearly explain your logic.
8. Pay close attention to units, some questions involve oilfield units, and these should be answered in the field units. Questions that are set in other units should be answered in the corresponding units.
9. Useful formulas are provided at the end of questions.

Section 1 – Source Rock Geology and Characteristics (20 Marks)

Q1-1 (4 marks) Defend the statement: "hydrocarbons are generated from an inorganic source".

Q1-2 (4 marks) Defend the statement: "hydrocarbons are generated from an organic source".

Q1-3 (12 marks) Draw cross sections through four possible settings in which large amounts of organic matter can accumulate (the precursors to source rocks). For each setting explain why the environmental conditions promote the accumulation of organic matter.

Section 2 – Hydrocarbon Chemistry and Generation (20 Marks)

Q2-1 (8 marks) Provide the chemical formula and draw the structural formula for the following common hydrocarbon compounds:

a) Butane
b) Octane
c) Benzene
d) Cyclohexane

Q2-2 (8 marks) On the attached graph paper, produce a pressure versus depth plot. On the P-T plot, graphically illustrate where the oil and gas windows occur and the relative volume of each hydrocarbon that would be produced along the depth profile. Also, provide the typical temperature ranges for the oil and gas window. To properly complete the chart, assume that the average surface temperature is 0 °C and the geothermal gradient is 30 °C km^{-1}.

Q2-3 (4 marks) Define the following terms:

a) Total Organic Carbon
b) Bitumen
c) Type 1 Kerogen
d) Catagenesis

Section 3 – Migration (20 Marks)

Q3-1 (6 marks) Describe and illustrate three mechanisms that enable primary migration of hydrocarbons out of source rocks.

Q3-2 (4 marks) Calculate the maximum hydrocarbon column height that can be trapped in sandstone and below shale before the shale is breached. Assume that the rock is water wet. Equations are provided at the end of the exam booklet. Assumptions:

Pore throat diameter in sandstone: 30 μm
Pore throat diameter in shale: 5 μm
Interfacial tension: 20 dynes cm^{-1}

Hydrocarbon density: 800 kg m^{-3}
Freshwater density: 1000 kg m^{-3}

Q3-3 (10 marks) On the attached plan-view maps (**A** and **B**), use arrows to indicate the dominant migration pathways for hydrocarbons. Use 1, 2 and 3 to indicate your top three areas for exploration based on potential hydrocarbon charge.

Section 4 – Stratigraphic Traps (20 Marks)

Q4-1 (4 marks) Define the following:

a) Spill point
b) Evaporite
c) Diagenesis
d) Disconformity

Q4-2 (4 marks) Draw a cross section through a stratigraphic pinchout trap. Label the rock types of the reservoir and seal, and show where oil, water, and gas would be situated in the trap.

Q4-3 (12 marks) Describe and illustrate two examples of stratigraphic pinch out traps, two examples of unconformity bound traps, and two examples of diagenetic traps. On your diagrams, correctly label the likely rock types of the trap and seal, and indicate where hydrocarbons would accumulate.

Section 5 – Structural Traps (20 Marks)

Q5-1 (3 marks) List three major groups of structural traps.

Q5-2 (5 marks) Draw a cross section through a simple anticline trap. Assume that it is filled with oil, water and gas; indicate the relative positions of each fluid type and label all contacts, and rock types. Give the name of an oil field that is an anticline.

Q5-3 (8 marks) Draw a cross-section through a salt dome. Indicate at least 5 types of traps that can occur around salt domes. Don't forget a scale. Name an oil field or oil-producing region dominated by salt domes.

Q5-4 (4 marks) Draw a cross-section through an extensional basin. Label the footwall, hanging wall, and the position of potential reservoirs.

Section 6 – Geography of Petroleum Basins in Canada (20 Marks)

Q6-1 (10 marks) Draw a generalized NE-SW cross-section through the Western Canada Sedimentary Basin. Indicate the major rock types and the main play types that might be expected along the section. Include scales.

Q6-2 (10 marks) On the attached map of Canada, indicate as many basins and arches as you are aware of. Marks are given for the correct placement of lines for arches and specific basin names.

Useful Equations:

$$P_d = \frac{2\gamma \cos\theta}{R}$$

Where:

P_d = Pressure of diplacement (dynes cm^{-2})
γ = interfacial tension (dynes cm^{-1})
θ = wettability angle (expressed as the contact angle between rock and hydrocarbon)
R = radius of the largest connected pore throats (cm)

$$z = \frac{4\gamma}{D} \cdot \frac{1}{(\rho_w - \rho_{HC})g}$$

Where:

z = height of HC column needed to breakthrough a pore throat
D = diameter of largest connected pore throat (effective pores)
ρ_w = density of water
ρ_{HC} = density of hydrocarbon
g = gravity

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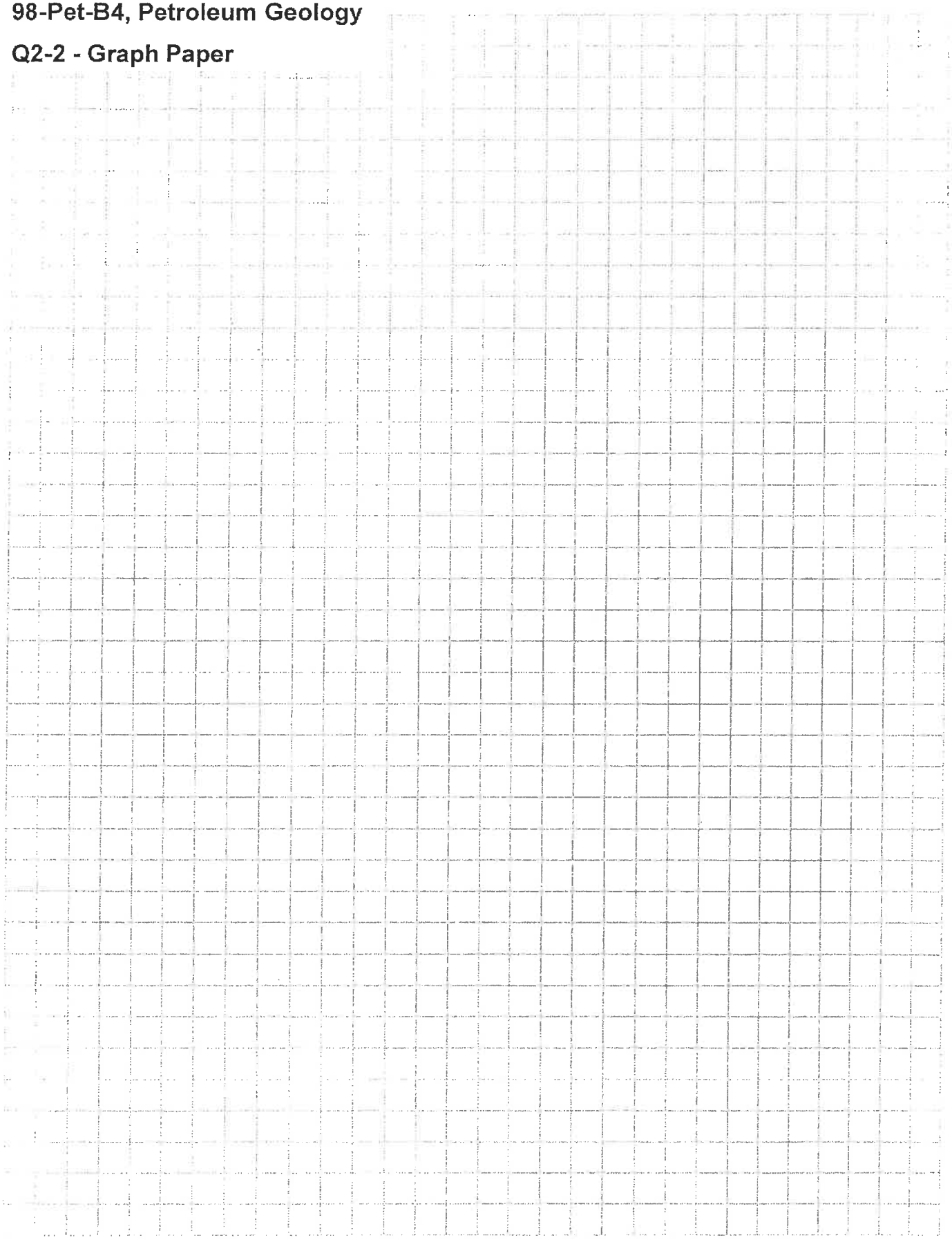
Q2-2 - Graph Paper



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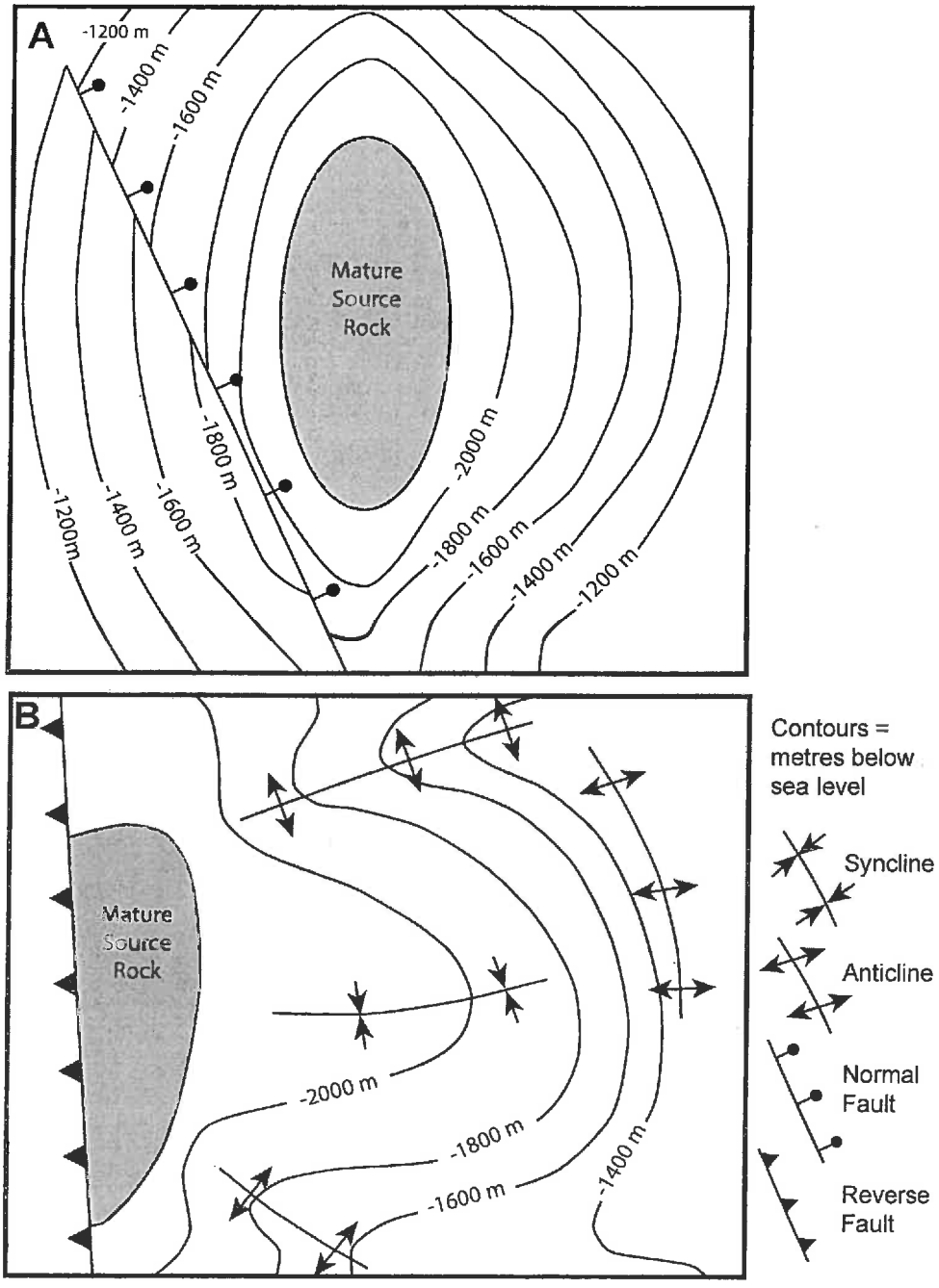
Q3-3 - Plan View Maps



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Q6-2 - Sedimentary Basins in Canada