H16

OK

University of Stavanger

DATE: 21st of December, 2016

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET-500 PVT of Reservoirs and Fluids

TIME: 4 hours

AID: No printed or written means allowed. Definite basic calculator allowed.

THE EXAM CONSISTS OF 2 PARTS ON 8 PAGES AND 4 ADDITIVES.
Part 1 is given equal weight as Part 2.

REMARKS: All answers in English. Answers on carbon paper.

Part 1 Reservoir Geology (50% of exam)

Part 1a: 12 questions (25% Exam)

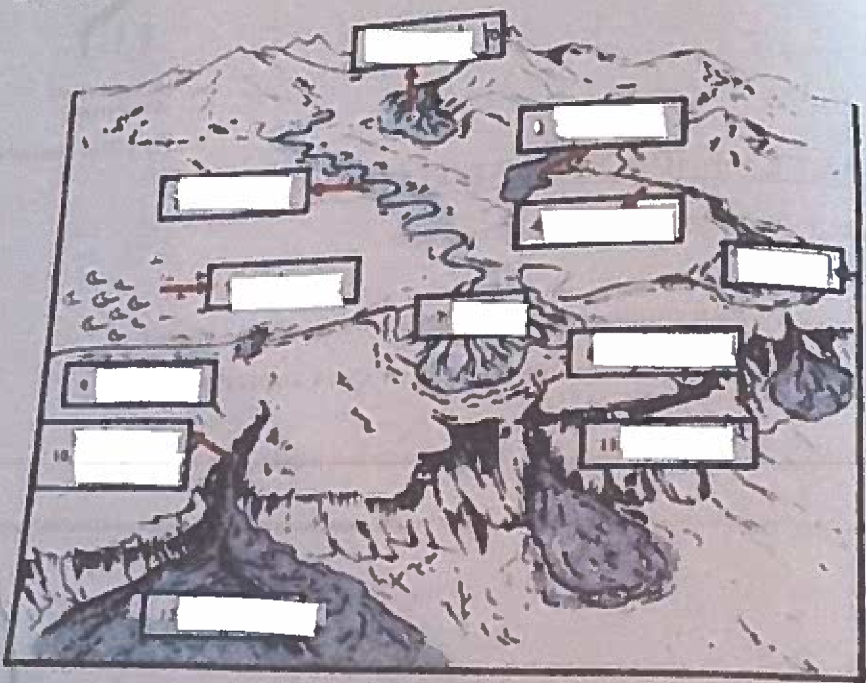
1. What are the main elements and processes of a Petroleum System, and how are they related to the main objectives of basin modelling.

2. According to Reading and Richards, submarine fans can be divided in 3 systems, what are they and describe them, and which is most likely to characterize North Sea Reservoirs > 80% Net-to-Gross sand? Finne

3. How do North Sea chalk reservoirs compare to more common limestone and dolomite carbonate reservoirs ?

4. What is a fault? What are the "hanging wall" and the "footwall"? What are the 3 main types of faults and illustrate how do the fault blocks move in each type?

5. Complete the following Depositional Environment diagram:



6. Briefly compare the following for Carbonate vs Sandstone reservoirs:

	Carbonate	Sandstone
Heterogeneity		
Amount of primary porosity in sediments		
Amount of dissolution porosity in sediments		
Permeability-Porosity-Depth Interrelation		
Influence of Diagenesis		
Percentage of Reservoirs in the world		
Percentage of HC reserves in the world		

7. Complete the distribution of global conventional Petroleum reserves:

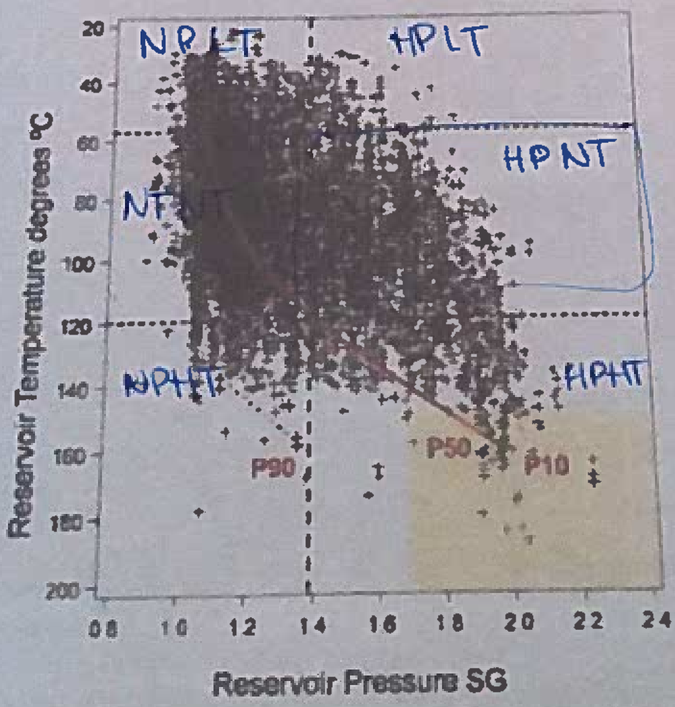
Reservoir Temperature	Oil Reserves (Including Gas Condensate)	Gas Reserves
< 60 °C Compaction Zone		
60 °C to 120°C Golden Zone		
>120°C Expulsion Zone		

8. Which are the 4 main petroleum sedimentary basin types, which has the 75% of the world's conventional oil reserves, and give two reasons why?

~~Elluvial~~ continental, passiv margin, forland, techtonic Finne rift basin, tertiary deltas

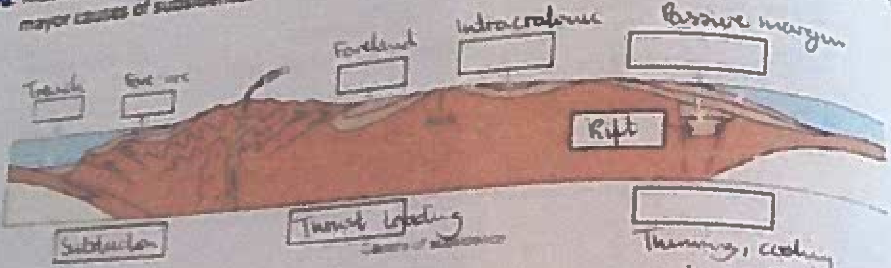
9. The precipitation rate of Quartz cementation in sandstone reservoirs is an exponential function of what subsurface parameter and linear function to what another parameter?

10. The figure below shows the relationship of pressure and temperature for Gulf of Mexico reservoirs. The pressure probabilities for P90, P50 and P10, as a function of temperature are shown as red lines. Divide the diagram into the following areas: NPNT, NPHT, NPLT, HPNT, HPLT, HPHT, where N= Normal, P= Pressure, T= Temperature, H= High, L= Low. Name 2 geological processes which may be responsible for the occurrence of HPHT, and what are the petroleum industries pressure and temperature boundaries for HPHT drilling?



Finne

N Make a sketch of the tectonic setting illustration below, and fill in the various basin types as well as major causes of subsidence.



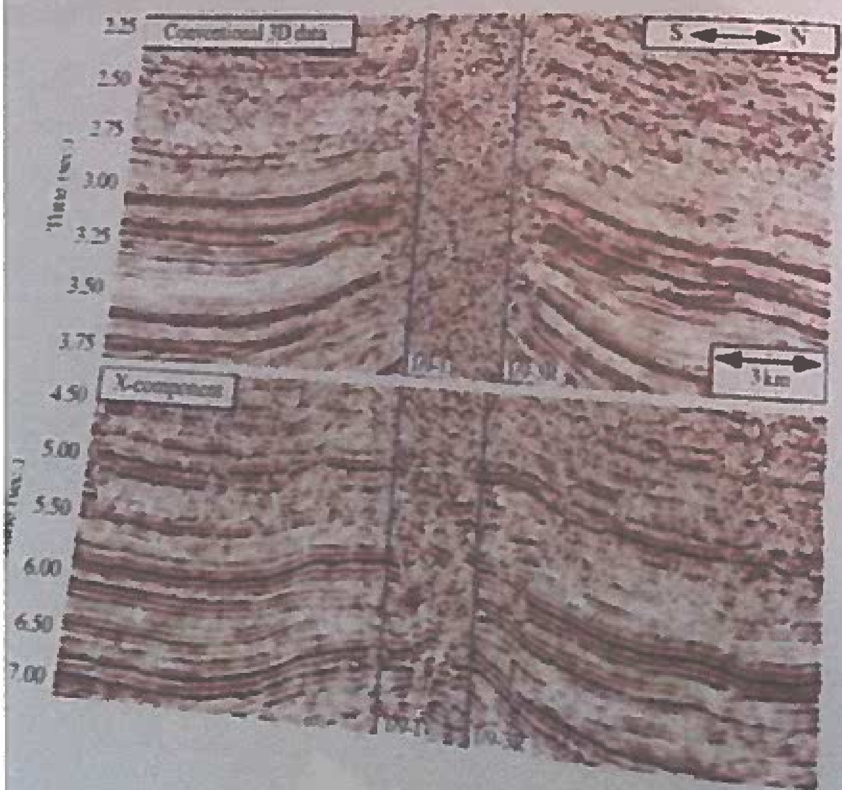
12. GEOPHYSICS/SEISMIC INTERPRETATION RESERVOIRS & FLUIDS

a) The figure below shows two seismic datasets acquired at approximately the same location, i.e., for the same part of the subsurface. Describe as fully as you can these two sections and the several differences between them. Your answer should include, but not be limited to:

i. The details of what kind of dataset each one is (including what is meant by the annotations on the figures);

ii. What the zone in the middle (demarcated by the vertical blue lines) represents, and why it looks better on one section than on the other;

iii. An explanation of the time-scale values on the left.



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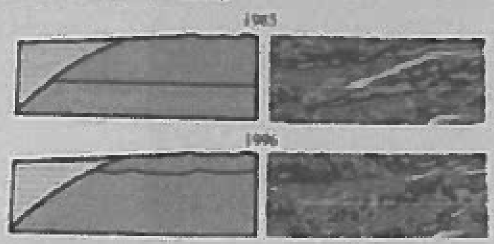
b) In a similar ... reservoir ...

Part 1b (25

You have ... prospect...

b) In a similar way, give your own account of what the figure below shows after 11 years of reservoir production history.



Part 1b (25% of exam):

You have been tasked to estimate the volumes of oil/gas of 3 Norwegian Continental Shelf (NCS) prospects in term of:

a) In-place resources of oil/gas in cubic meters at reservoir conditions.
b) Recoverable reserves of oil/gas inn cubic meter (and barrels for oil) at surface conditions.

You must consider both the oil case and gas case, even though oil/gas may be the most likely outcome. Your employer is mostly interested in high value oil reserves, and also expects your recommendation of which prospect to prioritize for drilling.
Your subsurface team has provided you with the following information:

Prospect	Water Depth	Dimensions	Depth Crest	Depth Spill Point
1	370	8 x 15 km	1100	1200
2	900	20 x 40 km	2700	3000
3	360	12 x 20 km	4600	5400

Prospect	Reservoir T °C	Gross Thickness	Geol. Age	Depositional Environment
1	45	85 m	Triassic	Deltaic (tidal)
2	96	300 m	Paleocene	Deep Marine
3	170	350 m	Jurassic	Shallow Marine

Additional information:
Prospect 1 has a very weak flat seismic feature near the spill point.
Prospect 2 has a strong flat seismic feature near the mapped spill.

Tasks:

- ✓ State the reservoir analogue.
- ✓ Do the calculation clearly.
- ✓ Identify the reservoir target(s) that are within the Golden Zone.
- ✓ State your further plan for the drilling, prioritization, identify possible production/reservoir/fluid related challenges and drilling risks.

Part 2, PVT of Fluids 8 Questions (50% *of exam*):

Representative hydrocarbon fluid samples are taken from a reservoir.

Based on the measured compositional data of the reservoir fluid, a constant mass expansion (CME) and a separator test can be modelled. See Table 1 and Table 2, respectively.

Table 1 CME data at T_{res} :

Pressure Bar	Rel Vol V/V_s	Compressibility 1/Bar	Y-factor
500	0.9634	1.134 E-04	
450	0.9693	1.240 E-04	
400	0.9759	1.364 E-04	
350	0.9832	1.510 E-04	
300	0.9914	1.686 E-04	
253.3	1.0000	1.884 E-04	
250	1.0033		4.02
200	1.0725		3.68
150	1.2087		3.30
100	1.5271		2.91
50	2.6158		2.54

Table 2 Separator test:

Pressure Bara	Temp, °C	GOR Sm^3/Sm^3	Gravity Air =1	Oil Density g/cm^3	FVF* m^3/Sm^3
253.3	80.0			0.732	1.340
100.0	60.0	73.7	0.682	0.796	1.155
30.0	40.0	31.1	0.710	0.834	1.070
1.0	15.0	21.3	1.048	0.865	1.000

*FVF = formation volume factor

The following reservoir data are given:

- Initial pressure: P_i = 450 bar
- Reservoir temperature: T_{res} =80 °C
- Bulk reservoir volume: $V_{bulk} = 10^8 m^3$
- Reservoir Porosity: Ø = 0.25
- Initial water saturation: S_{wi} = 0.2.

a.
The reservoir fluid was sampled at a test separator.

1. Describe how representative hydrocarbon fluid samples are taken from a reservoir using a separator test. Make also a sketch of the system.
2. Describe how the fluid samples from the separator test are recombined in the laboratory to the reservoir fluid.

b.
The molecule weight of Stock Tank Oil (STO) are needed for mathematical recombination.

1. M_{STO} is determined experimentally in the laboratory. Describe shortly the principles of the analysis and formula.
2. Derive a formula to calculate M_{C10+} for STO; $M_{C10+} = f((w\%)_i, (wt\%)_{C10+}, M_i)$ where $i = C_1 - C_9$ for x_i and $i = C_1 - C_9$ for M_i.

$\Delta T = $ MSTO/ MSTO/m_b/1000

c.

1. What is the bubble pressure, P_b, at T_{res}? How could we verify that the value of P_b is determined correctly?
2. Based on the given data, calculate $(GOR)_{tot}$

$Y = \frac{P_b - P}{P(V/V_b - 1)}$

GOR TOT =

d.
Calculate:

1. Initial oil formation factor, $(B_o)_i$
2. Initial oil in place, IOIP, in Sm^3, and Initial gas in place, IGIP, in Sm^3.

$B_{oi} = B_{ob} \cdot \frac{V}{V_b}$

IOIP = HCPV / BoL

IGIP = IOIP · GOR TOT

e.
Suppose that the HCPV is constant during pressure depletion. Calculate the recovery from P_i to P_b:

1. STO in Sm^3, and
2. Gas in Sm^3.

VSTO = HCPV / BoL − HCPV / Bog

Vg = VSTO · GOR TOT

f.
Calculate:

1. Average specific density of produced gas.
2. Average molecule weight of produced gas

$(\gamma_g)_{av} = \frac{93,7 \cdot 0,682 + 36,1 \cdot 0,710 + 21,3 \cdot 0,48}{GOR_{TOT}}$

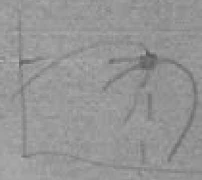
$(M_g)_{av} = M_{air} \cdot (\gamma_g)_{av}$

g.
Calculate $(\rho_o)_b$ by using the added empirical correlations, and the given values in the separator test.

2: $(\rho_g)_{ad}$ =

3: correction

h.
Sketch both hydrocarbon phase envelopes that develops in the first stage separator at equilibrium in the same PT diagram. Put in important values and numbers on the axes, and give a description of the total system.



Addition 1.

Important formula/correlations in PVT-Analysis.

Temperature:

°K = 273.15 + °C
°F = 1.8 x °C + 32
°R = °F + 459.69

Pressure:

1atm = 1013.250 mBar = 1.013250 bar = 101.3250 kPa = 0.1013250 MPa = 14.69595 psia
psia = 14.69595 + psig
1 atm = 760.002 mmHg at 0 °C

Density:

1 g/cm³ = 62.43 lb/ft³ = 350.54 lb/bbl
1 lb/ft³ = 16.0185 kg/m³
ρ_w = 0.999015 g/cm³ (60 °F, 1 atm)
ρ_w = 0.9991 g/cm³ (15 °C, 1 atm)

Specific density:

For liquids: Determined relative to water at sc.
For gases: Determined relative to air at sc.

$$\gamma_o = \frac{\rho_o}{\rho_w} = \frac{141.5}{131.5 + {}^{\circ}API}$$

$$^{\circ}API = \frac{141.5}{\gamma_o} - 131.5$$

Cragoe's formula (empirical formula giving molecular weight of hydrocarbons):

$$M_o = \frac{6084}{^{\circ}API - 5.9}$$

$$\gamma_g = \frac{M_g}{M_{air}} = \frac{M_g}{28.96}$$

Volume:

1 bbl = 5.615 ft³ = 0.15898 m³
1 ft³ = 0.0283 m³
1 US Gallon = 3.785 litre
1 Imp. Gallon = 4.546 litre
Molar volume of gas at standard conditions:
V_m = 379.51 SCF/lb mole (60 °F and 14.69595 psia)
V_m = 23644.7 cm³/g mole = 23.6447 m³/kg mole (15 °C and 101.3250 kPa)

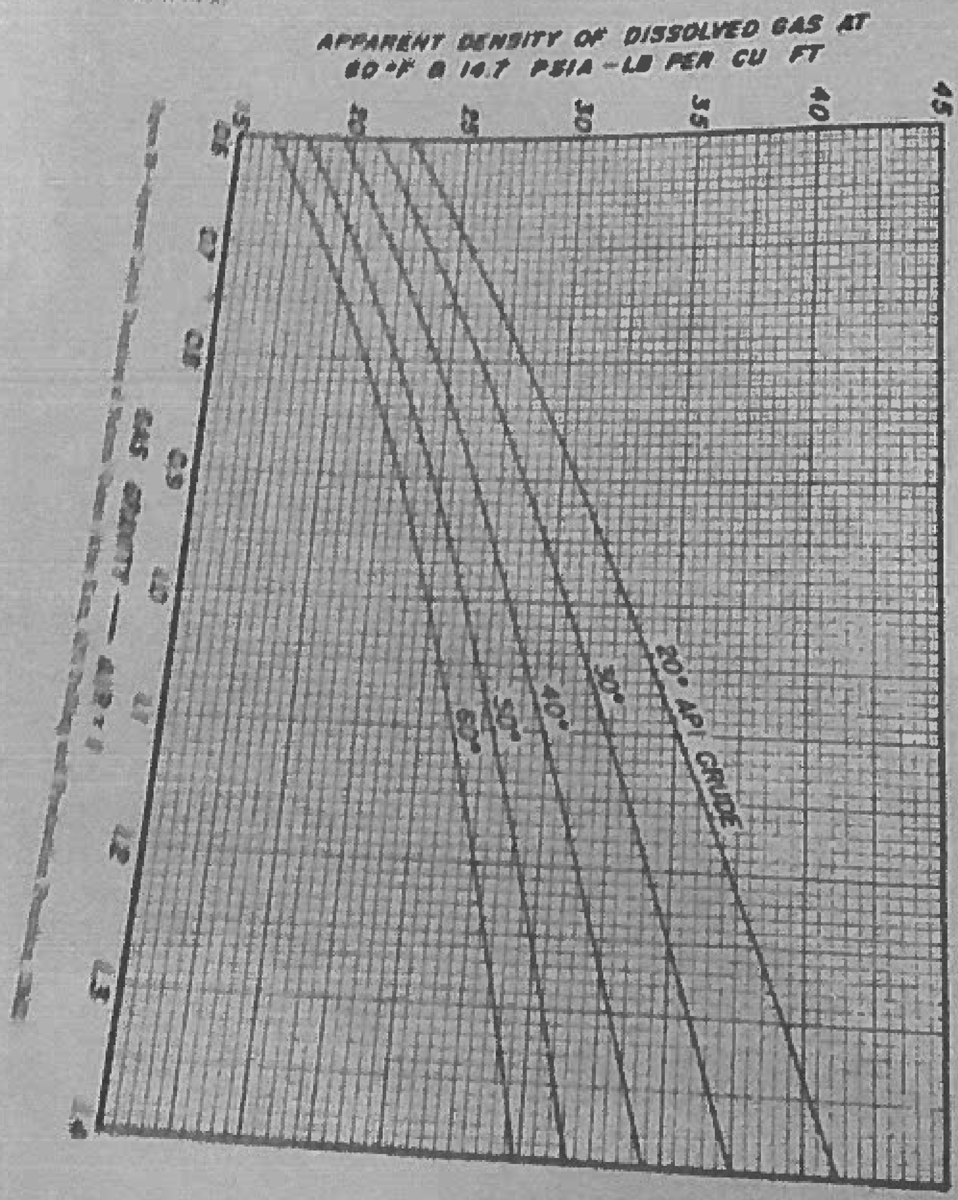
Air:

Z_{air} = 0.9959 (60 °F, 14.69595 psia)
M_{air} = 28.96

Gas constant:

R = 10.732 (psia, ft³, °R, lb mole)
R = 0.082054 (atm, litre, °K, g mole)
R = 8.3145 (kPa, m³, °K, kg mole)

Addition 3



APPARENT DENSITY OF DISSOLVED GAS AT 60 °F & 14.7 PSIA – LB PER CU FT
20
25
30
35
40
45
20° API CRUDE
30°
40°
50°
60°