University of Stavanger

DATE: 25th of November 2020

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET-500 PVT of Reservoirs and Fluids

TIME: 4 hours

AID: All aids are permitted.

THE EXAM CONSISTS OF 2 PARTS ON 13 PAGES.

Part 1 is given equal weight as Part 2.

Part 1, (50*% of exam):*

PVT of Fluids (PVT analyses)

Representative hydrocarbon fluid samples are taken from a reservoir.
The following reservoir data are given:

Initial pressure:	P_i = 470 bar
Reservoir temperature:	T_{res} =90 °C
Bulk reservoir volume:	$V_{bulk} = 10^7 m^3$
Reservoir Porosity:	Ø = 0.20
Initial water saturation:	S_{wi} = 0.20

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 to the reservoir fluid in the laboratory.

b.

The molecule weight (M) 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. Use formula.
2. Derive a formula to calculate M_{C10+} for STO; $M_{C10+} = f((m\%)_i, (m\%)_{C10+}, M_i)$ where $i=C_1 - C_9$ for x_i and $i=C_1 - C_9$ for M_i. (m = mass)

The recombined reservoir fluid undergoes a constant mass expansion (CME) experiment and a Separator test in the laboratory. The results are reported in table 1 and table 2

Table 1 CME data at T_{res} :

Pressure Bar	Cell volumes cm^3	Rel Vol V/V_b
520	146.92	
470	147.82	
420	148.82	
370	149.94	
320	151.19	
P_b	V_b	
270	153.00	
220	163.56	
170	184.33	
120	232.88	
70	398.91	

Table 2 Separator test:

Pressure Bara	Temp, °C	GOR Sm^3/Sm^3	Gas Gravity Air =1	Oil Density g/cm^3	FVF* m^3/Sm^3
P_b	90.0			0.730	1.350
100.0	60.0	75.5	0.680	0.794	1.160
30.0	40.0	33.4	0.708	0.831	1.073
1.0	15.0	22.0	1.046	0.863	1.000

*FVF = formation volume factor

c.

1. Describe how a constant mass expansion (CME) experiment is performed.
2. Based on available data, find bubble point and cell volume at bubble point. Calculate V/V_b at all pressures.
3 Based on the given data, calculate $(GOR)_{tot}$

d.

Calculate:

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

e.

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

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

f.

Calculate:

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

g.

1. Calculate the oil density at bubble point, $(\rho_o)_b$, by using the added empirical correlations.
2. How does the result fit with the given experimental value?

h.

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

Important conversion factors, formula/correlations.

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/cm^3 = 62.43 lb/ft^3 = 350.54 lb/bbl

1 lb/ft^3 = 16.0185 kg/m^3

ρ_w = 0.999015 g/cm^3 (60 °F, 1 atm)

ρ_w = 0.9991 g/cm^3 (15 °C, 1 atm)

Specific density:

For liquids: Determined relative to water at sc.

For gases: Determined relative to air at sc.

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

$${}^oAPI = \frac{141.5}{\gamma_o} - 131.5$$

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

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

$$M_o = \frac{6084}{{}^oAPI - 5.9}$$

Volume:

1 bbl = 5.615 ft^3 = 0.15898 m^3

1 ft^3 = 0.0283 m^3

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 cm^3/g mole = 23.6447 m^3/kg mole (15 °C and 101.3250 kPa)

Air:

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

M_{air} = 28.96

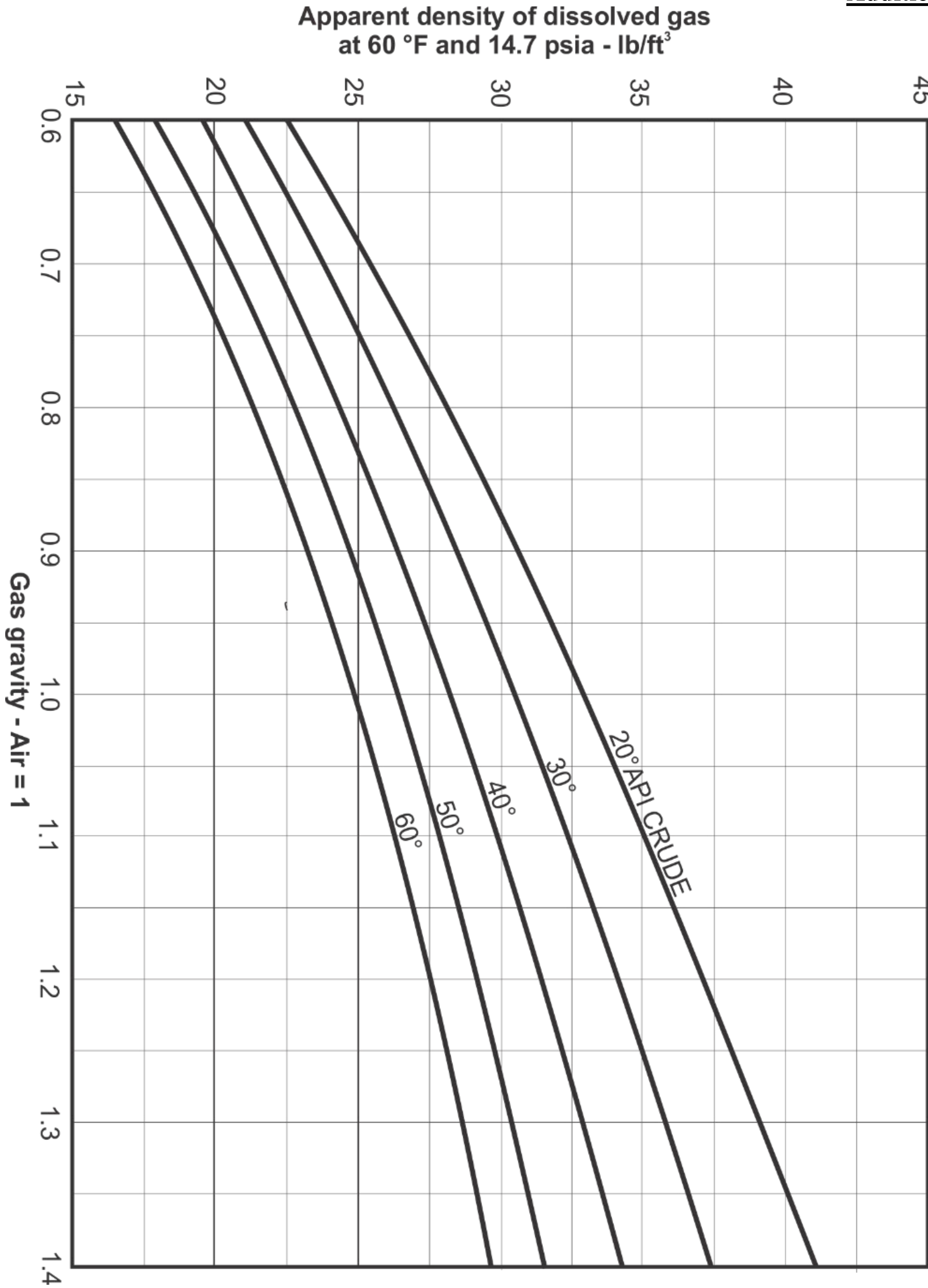
Gas constant:

R = 10.732 (psia, ft^3, °R, lb mole)

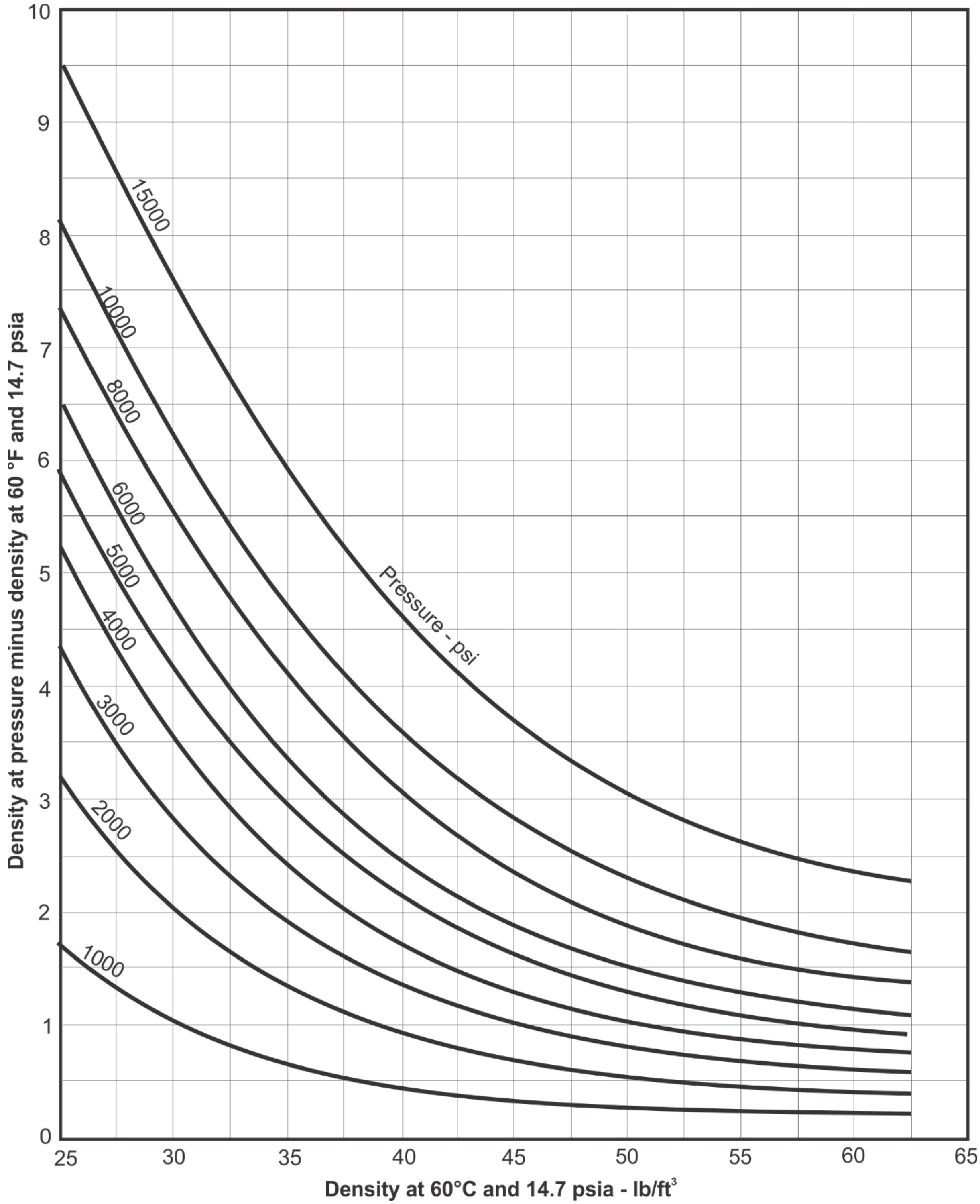
R = 0.082054 (atm, litre, °K, g mole)

R = 8.3145 (kPa, m^3, °K, kg mole)

Addition 2.

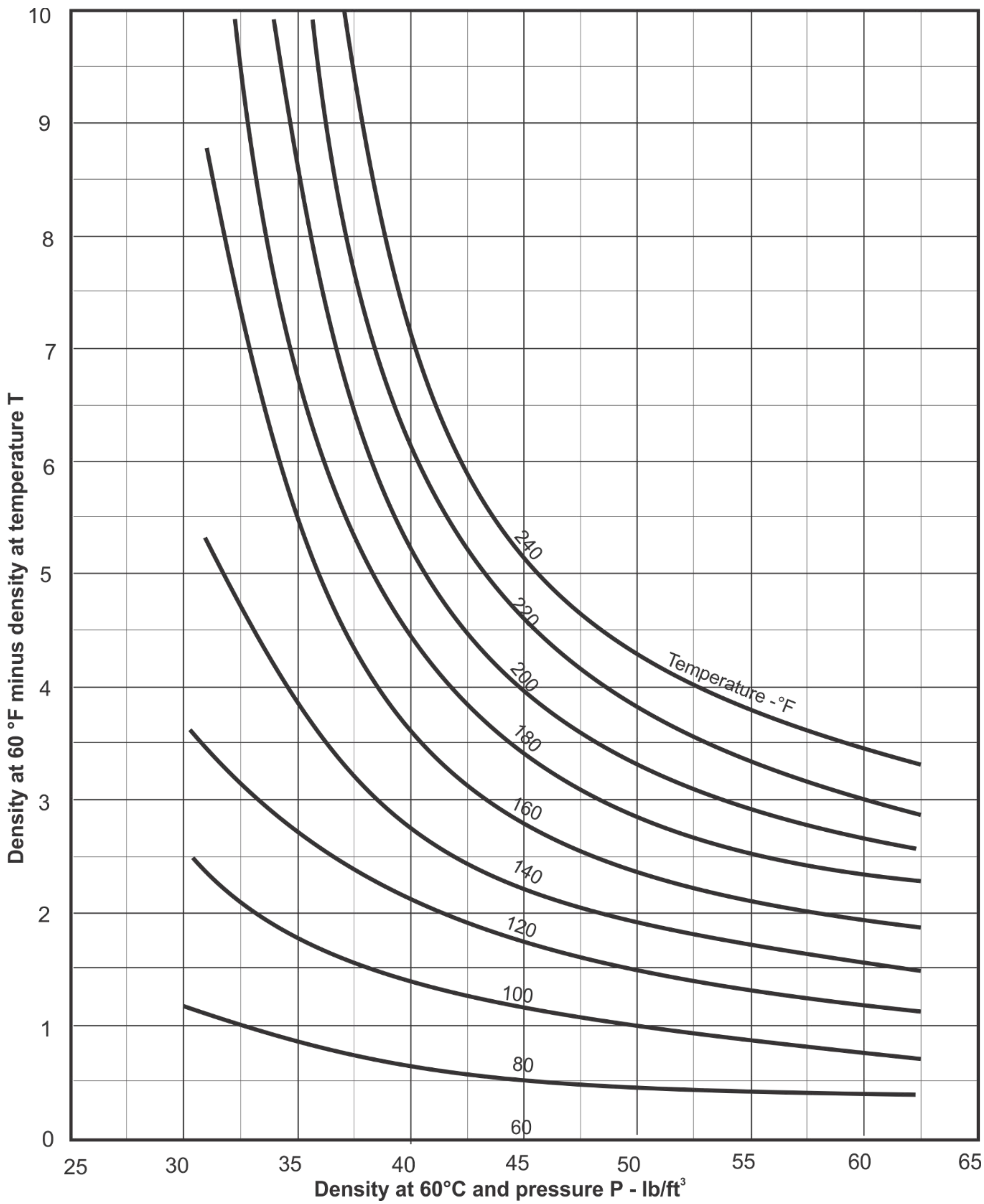

Apparent density of dissolved gas
at 60 °F and 14.7 psia - lb/ft³
15
20
25
30
35
40
45
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Gas gravity - Air = 1
20° API CRUDE
30°
40°
50°
60°

Addition 3.



Density at pressure minus density at 60 °F and 14.7 psia
Density at 60°C and 14.7 psia - lb/ft3
Pressure - psi
15000
10000
8000
6000
5000
4000
3000
2000
1000
0
1
2
3
4
5
6
7
8
9
10
25
30
35
40
45
50
55
60
65

Addition 4.

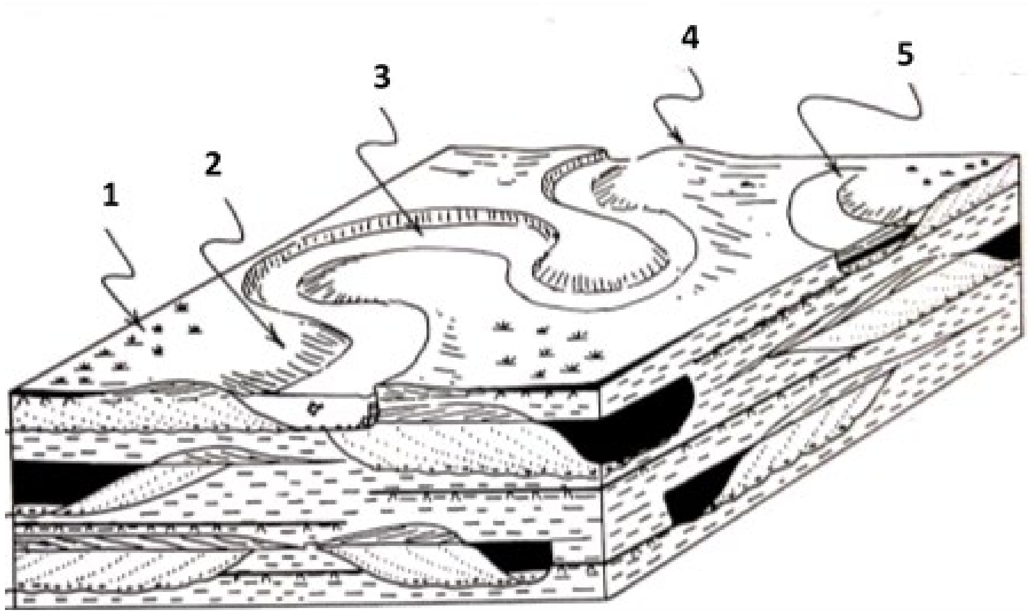


10
9
8
7
6
5
4
3
2
1
0
Density at 60 °F minus density at temperature T
240
220
200
180
160
140
120
100
80
60
Temperature - °F
25
30
35
40
45
50
55
60
65
Density at 60°C and pressure P - lb/ft³

Part 2, (50*% of exam):*

Reservoir Geology

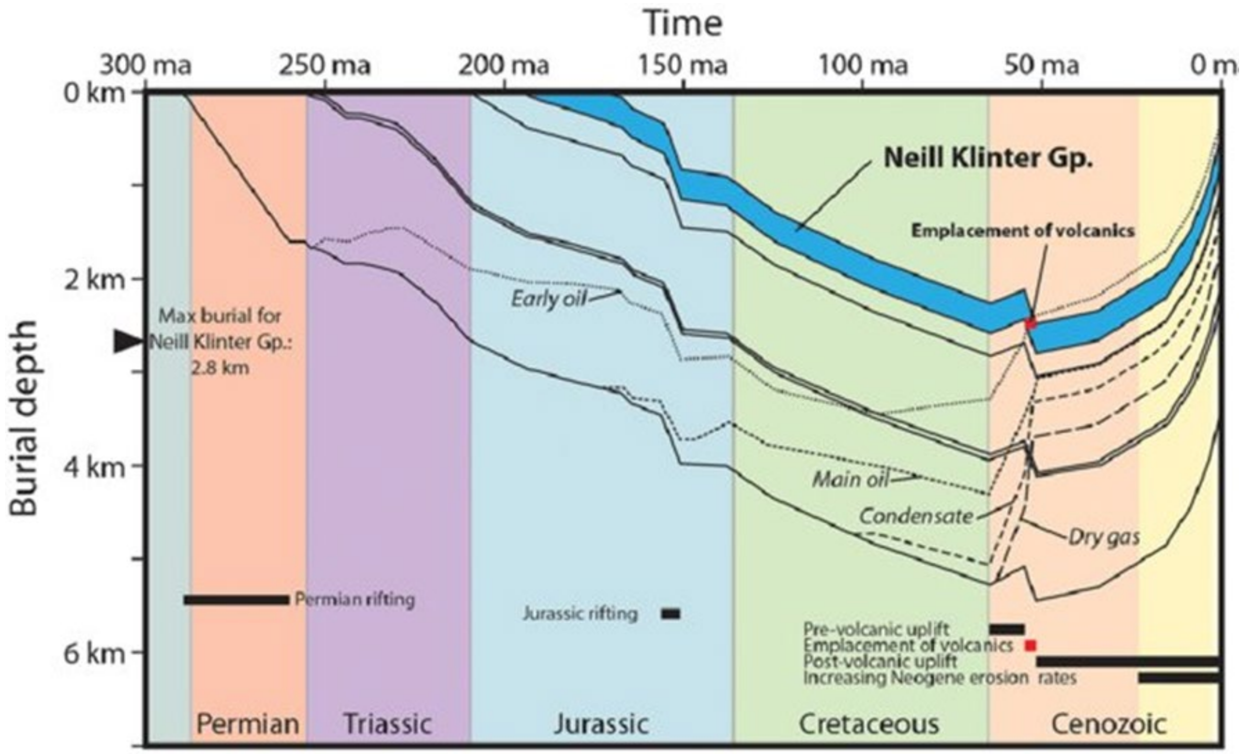
1. a) What kind of river is shown on the figure below?
   b) Give names to the numbered geometries (1-5) of the river system.
   c) Name three factors that control the shape and dimension of this type of river.
   d) Which part of the river system would make the best reservoir? Briefly explain why.



2. What delta-type is this, and what are the parallel lines along the coast?

3. In a warm, well-lit and shallow marine environment - where along a coastal profile would you expect to find (1) micrite and (2) sparitic rocks? How do these components form?

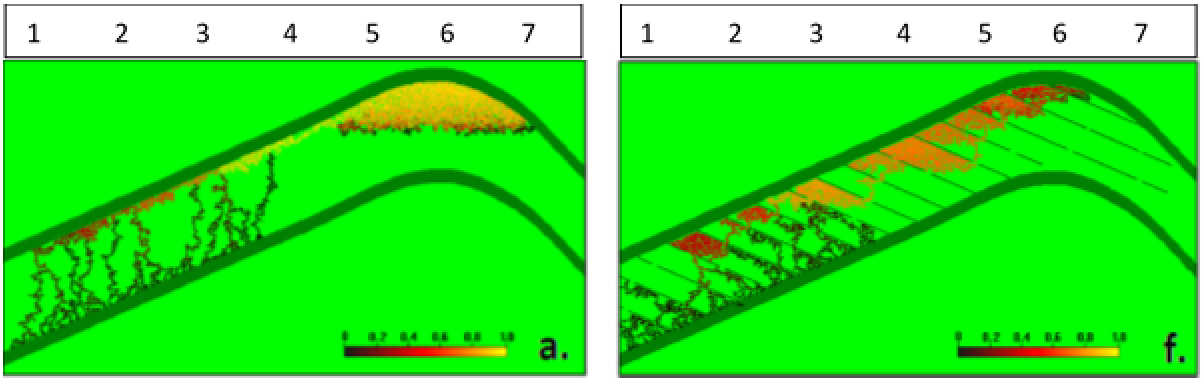
4. In the burial history diagram below:
a) What is a likely explanation for the steeply dipping curve at approx. 160 Ma in the burial history diagram below?
b) What effect can volcanic activity have had on the petroleum system in the burial history diagram?
c) What kind of process can cause the steep curve in the latest stage (ca 20-0 Ma) of the diagram?



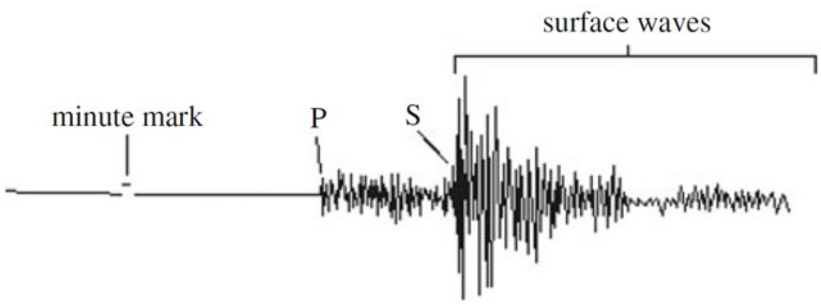
5. Give the name of a geological time period with widespread source-rock formation in the North Sea. Why and how did the material accumulate then?

6. In the figures below, the reservoir is the zone between the two thick dark green lines.
The yellow to red colour is petroleum. Reservoir a) is a homogenous sandstone, and reservoir f) is a heterogenous sandstone with thin interbedded layers of shale.
   a) Describe the possible production challenge in reservoir f).
   b) Based on the numbers above the two reservoirs – where would you place a production well in each reservoir, and why?

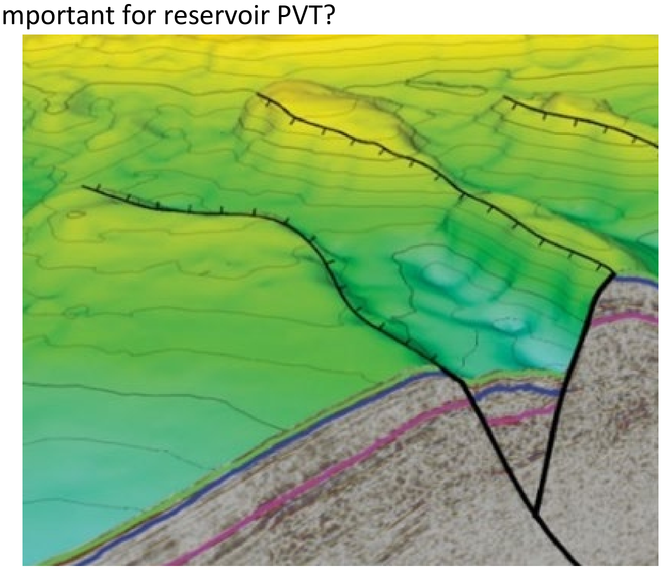
c) Suggest a method to improve the oil recovery in a) and / or f) (state for which reservoir the method is relevant) and explain why it should be relevant.



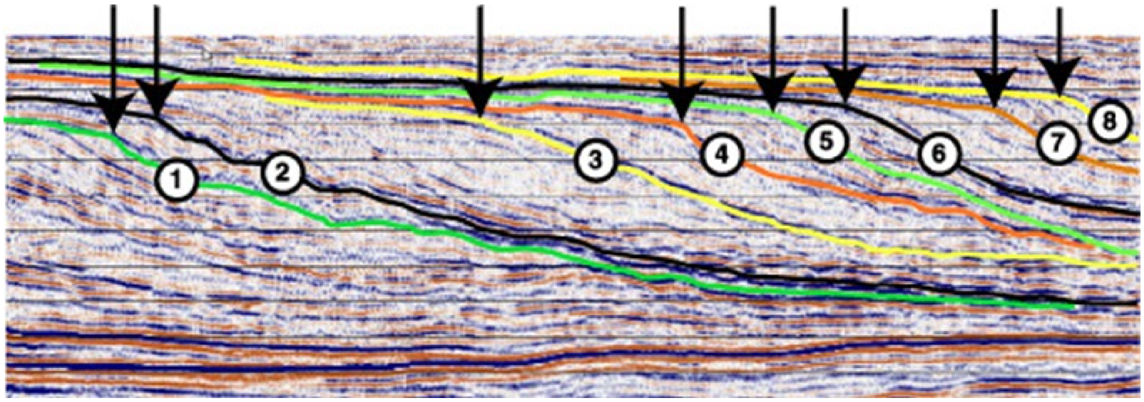
7. A seismogram (figure below) is a record written by a seismograph in response to ground motions produced by earthquakes.
a) As an earthquake hit, the P-waves and S-waves will not arrive to the recorder at the same time. Why not?
b) Briefly explain why some seismograms only have P-waves recorded after an earthquake.



8. a) What kind of faults can you see in the seismic section below? Name the tectonic setting this is likely to be part of.
b) How can faults be important for reservoir PVT?



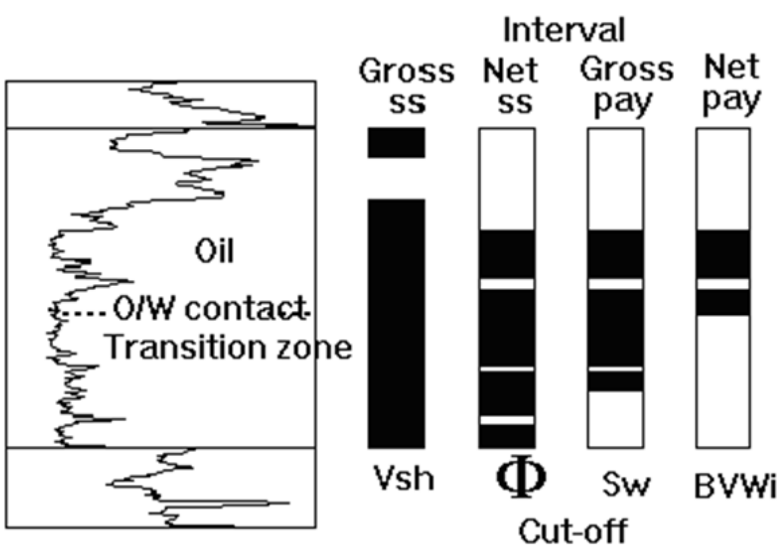
9. Seismic sequence analysis
   a) What is the geological explanation for the clinoforms in the seismic section below? Where in the section (left/right) is the coast (proximal) and where is the basin (distal)? The arrows mark the change in slope for each coloured seismic line.
   b) Is this sedimentary system prograding, aggrading or retrograding?



10. Assume that you are investigating a potential reservoir sandstone that shows signs of these diagenetic processes:
    mechanical compaction,
    quartz cementation,
    dissolution of feldspar, and
    pore-filling illite cementation.

    How will each of these processes influence the reservoir quality (porosity and permeability)?

11. What is the definition of Net Pay? Based on the figure below, briefly describe each step (cut-off) you need to take to get from gross sandstone (ss) to net pay, based on the gamma-ray log and the four steps below.



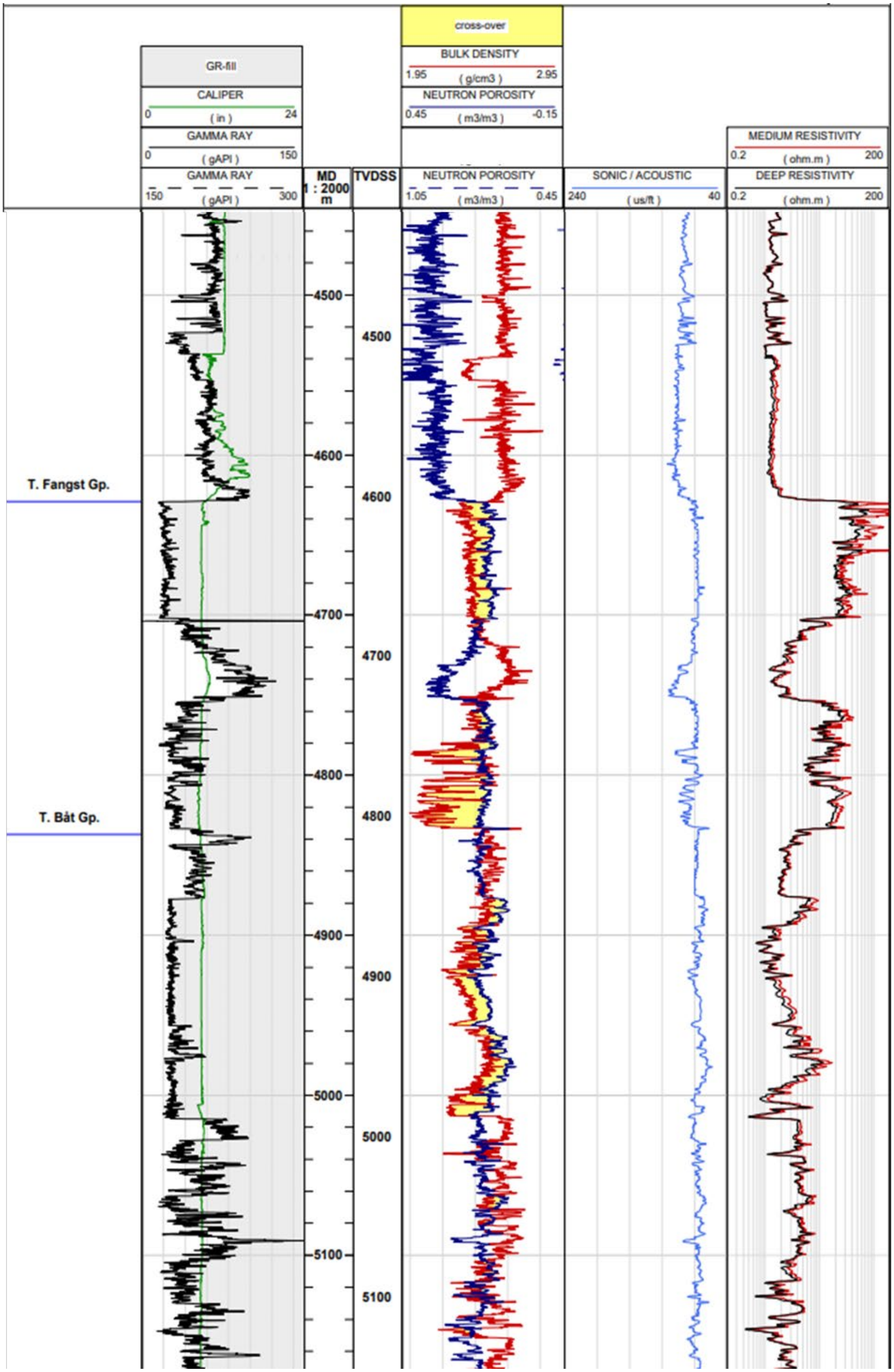
12. Define each of the elements of the HCPV-formula and briefly explain how to find all the information needed to calculate the HCPV.

$$(HCPV) = GRV \times N/G \times \varphi \times S_{hc}$$

13. The exploration well below is from a field with a water depth of 370 m, where gas is produced from a sandstone reservoir.
Based on the well-logs:
    a) At which depth will you expect to find the GWC. Briefly explain why.
    b) Calculate the porosity of the gas -filled Upper T. Fangst Group, based on the density log.

- Density Logs
    - $\phi_{den} = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$
        - ρ_f: *fluid density*

	ρ matrix (gr/cm^3)
Sandstone	2.648
Limestone	2.710
Shale	2.565
Gas	0.256
Oil	0.871


cross-over
GR-fill
CALIPER
0 (in) 24
GAMMA RAY
0 (gAPI) 150
GAMMA RAY
150 (gAPI) 300
MD 1 : 2000 m
TVDSS
BULK DENSITY
1.95 (g/cm3) 2.95
NEUTRON POROSITY
0.45 (m3/m3) -0.15
NEUTRON POROSITY
1.05 (m3/m3) 0.45
SONIC / ACOUSTIC
240 (us/ft) 40
MEDIUM RESISTIVITY
0.2 (ohm.m) 200
DEEP RESISTIVITY
0.2 (ohm.m) 200
T. Fangst Gp.
T. Båt Gp.
4500
4600
4700
4800
4900
5000
5100