

# BPG150

Geofysiske metoder i petroleumsvirksomheten

Geophysical methods applied to petroleum

Avsluttende eksamen

Final Examination

24.11.2011

13.00 – 16.00

Hjelpemidler: kalkulator, ordbok

Supporting materials: calculator, dictionary

*Answer 4 whole questions out of 5.*

*Percentage weights are indicated.*

*Write as much as possible in these exam pages; back sides are okay too.*

*Write in either English or Norwegian.*

*Some formulae are listed at the end.*

Faglærer/Instructor: R.J. Brown

## 25% 1. Seismic

An explosive source is detonated at the surface of the Earth, with geophone receivers deployed also at the surface, in an area where there has been cyclic deposition of horizontal layers of carbonates and evaporites. This means that layers 1, 3 and 5 are limestone and have identical properties while layers 2, 4 and 6 are identical salt layers.

All the layers are 150 m thick. The limestones have  $V_p = 4500$  m/s and  $\rho = 2490$  kg/m<sup>3</sup>. The salt has  $V_p = 4500$  m/s and  $\rho = 2100$  kg/m<sup>3</sup>.

- 4% (a) Determine the vertical-incidence reflection coefficient,  $R_2$ , for a downward-travelling P-wave reflecting at the top of layer 2 (bottom of layer 1).
- 3% (b) Determine the corresponding reflection coefficient,  $R_3$ , at the top of layer 3.
- 4% (c) Determine the vertical-incidence transmission coefficient,  $T_2$ , for a P-wave travelling downward through the boundary from layer 1 to layer 2.
- 3% (d) Determine the vertical-incidence transmission coefficient,  $T_2'$ , for a P-wave travelling upward through the boundary from layer 2 to layer 1.
- 4% (e) Which of these two rocks obeys more closely the Gardner relationship between  $\rho$  and  $V_p$  – the limestone or the salt? Support your answer with some calculation.

- 7% (f) If we assume the limestone to be composed only of calcite ( $\rho = 2710 \text{ kg/m}^3$ ) and brine ( $\rho = 1030 \text{ kg/m}^3$ ), find the porosity,  $\phi$ , of that limestone. Give  $\phi$  to three figures.

25% 2. **Seismic, gravity, electrical**

- 3% (a) Consider again the same geology and same survey as in Question 1. For the reflection from the top of layer 4 (bottom of layer 3) find the zero-offset 2-way traveltime.

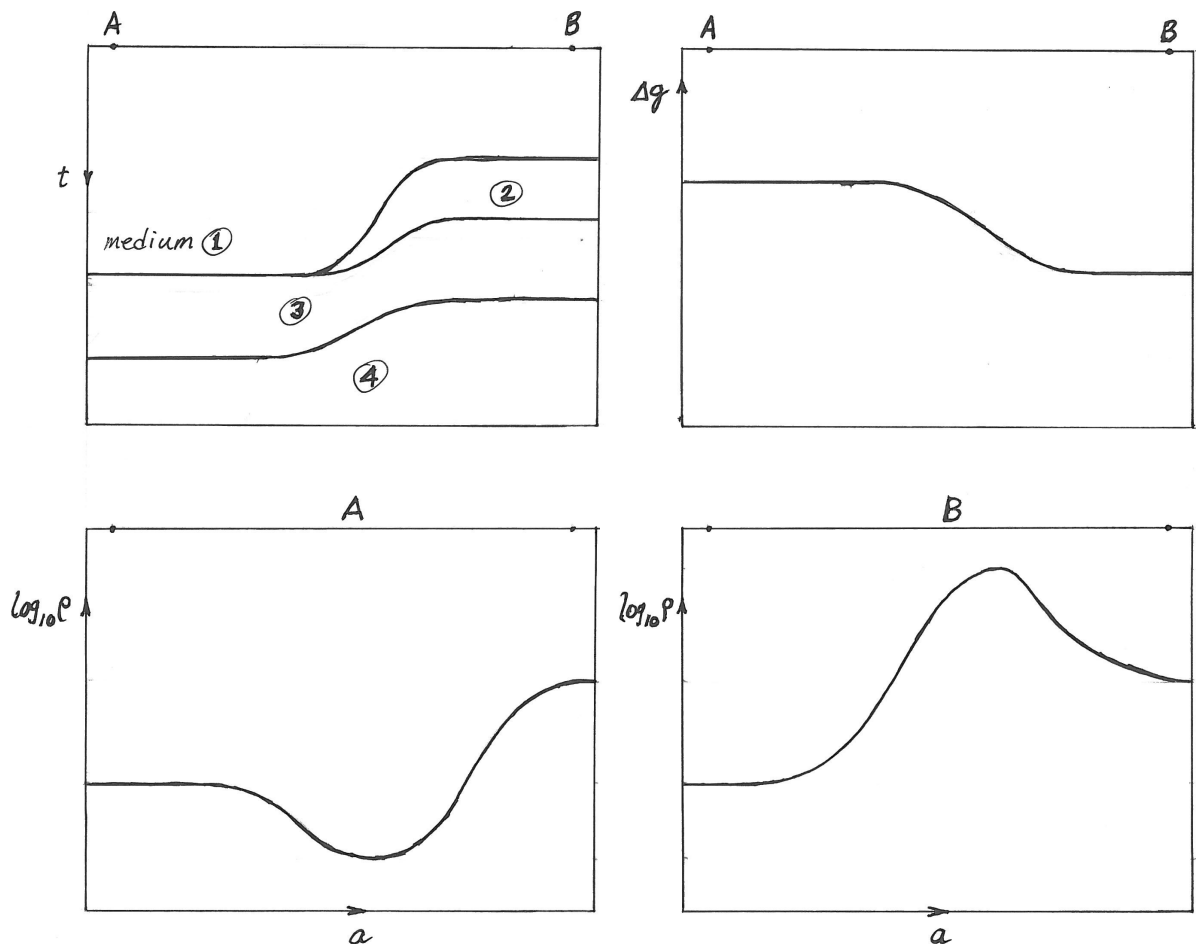
- 5% (b) For the same situation find the traveltime for the same reflection (from the top of layer 4) at an offset of 500 m. What is the normal moveout in this case?

- 6% (c) Draw a sketch of a sombrero-type gravity anomaly and briefly describe two geological scenarios in which profiles from a gravity survey could show sombrero-type anomalies.

11% (d) The following (very) rough sketches show results of :

- a reflection seismic survey along the profile **AB** (upper left);
- a Bouguer gravity survey along the same profile (upper right);
- a resistivity survey along a profile centred at **A** and at right angles to **AB** (lower left); and
- a resistivity survey along a profile centred at **B** and at right angles to **AB** (lower right).

In the seismic section, four units or media are numbered (1), (2), (3) and (4). In the resistivity surveys, the parameter  $a$  quantifies the electrode separation. A well at **A** tells us that (1), (3) and (4) are sedimentary rocks with brine-filled pore space. A recent well at **B** tells us that unit (3) is flat, i.e., its top and bottom surfaces have constant depths along the profile **AB**. From all this information, what would you conclude about medium (2) in terms of its physical properties ( $V_p$ , density, resistivity) and its lithology (i.e. rock type)? State how this conclusion is supported by (or is consistent with) all three types of geophysical data.

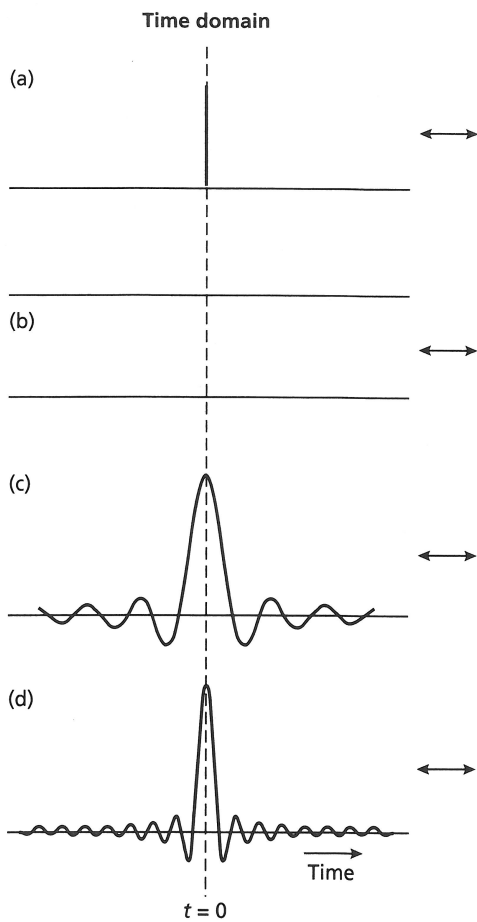




4% (c) In spite of our best efforts with the antialias filter, some noise at twice the limiting dominant frequency has leaked into our dataset, due to an instrumental flaw. At what frequency will this noise be aliased, given your choice of sampling frequency?

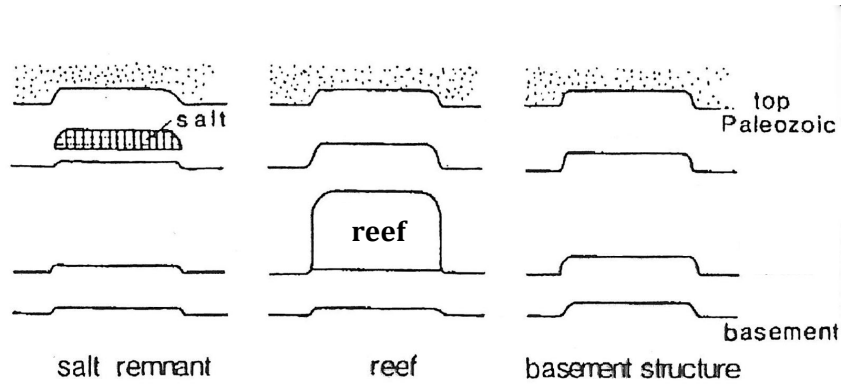
5% (d) If we wish to have a dynamic range of 90 dB, how many bits-per-word do we need?

6% (e) The following figure shows four wavelets or functions in the time domain. For each one, sketch a reasonable amplitude spectrum, i.e. in the frequency domain.



#### 25% 4. Gravity, magnetics, seismic

- 9% (a) Parallel updoming structures like those shown below are observed on a seismic section in a frontier area where there is not a lot of geological information, but where there is magnetic and gravity coverage. Explain briefly how we could combine the magnetic and gravity information to help decide among the three geological possibilities shown.



- 6% (b) Explain briefly for each of these three cases, shown on the previous page, why the updoming form often repeats itself in a nearly parallel way on seismic reflectors above or below the expression of the primary structure (the salt remnant, the reef, the basement high) associated with the updoming.

4% (c) List 4 types of data correction that are usually applied in gravity data reduction.

3% (d) List 3 other data corrections that are not so commonly applied in gravity data reduction.

1% (e) State 1 type of data correction that usually is applied in magnetic data reduction.

2% (f) State 2 other magnetic data corrections that are not so commonly applied in data reduction.

## 25% 5. Gravity, magnetics

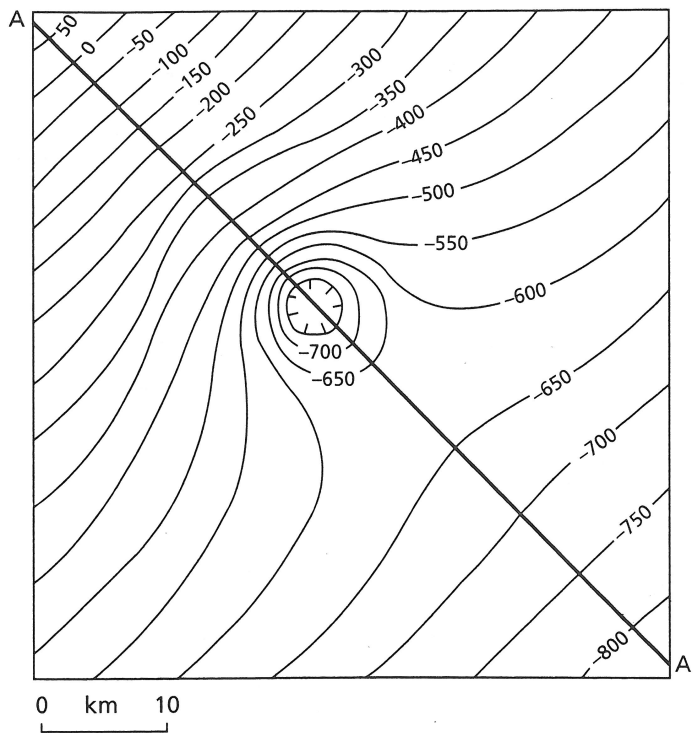
6% (a) The expression for  $\Delta g$  for an infinite horizontal cylinder, or line of mass, is:

$$\Delta g = \frac{2G\mu z}{r^2}$$

where  $\mu$  is mass per unit length. Derive the relationship connecting anomaly width and depth of body for this case. Don't just write the relationship down – derive it. And make sure that you define or explain the meaning of each symbol in your relationship.

7% (b) The following figure shows a contour map from a gravity survey. Draw three sketches:  
 (i) showing the profile AA',  
 (ii) showing a reasonable map of the regional field, and  
 (iii) showing a reasonable map of the residual field.





- 6% (c) Give a reasonable example of a geological feature – in terms of lithology and approximate shape – that could cause the anomaly in the middle of this survey area.

3% (d) Where on the Earth could we observe a magnetic inclination of  $\pm 90^\circ$ ? Be specific.

3% (e) Where inside or outside the Earth does the geomagnetic field originate? Be specific.

### Some geophysical formulae:

$$F = \frac{Gm_1m_2}{r^2}$$

$$\rho = 310V_p^{0.25}$$

$$t^2 = t_0^2 + \frac{x^2}{V^2}$$

$$t \approx t_0 + \frac{x^2}{2V^2t_0}$$

$$V_p = \left[ \frac{K + \frac{4}{3}\mu}{\rho} \right]^{1/2}$$

$$V_s = \left[ \frac{\mu}{\rho} \right]^{1/2}$$

$$\frac{1}{V} \approx \frac{\phi}{V_f} + \frac{1-\phi}{V_m}$$

$$V_{\text{rms}, n} = \left[ \frac{\sum_{i=1}^n V_i^2 t_i}{\sum_{i=1}^n t_i} \right]^{1/2}$$

$$V_a = \frac{V}{\sin i}$$

$$V = \lambda f$$

$$DR = 20 \log_{10} \left[ \frac{A_{\text{max}}}{A_{\text{min}}} \right]$$

$$R_2 = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1}$$

$$w_F = (2\lambda z)^{1/2}$$

$$\text{fold} = \frac{N}{2n}$$