BPG150

Geofysiske metoder i petroleumsvirksomheten

Geophysical methods applied to petroleum

Avsluttende eksamen

Final Examination

28.11.2013

09.00 – 12.00

Hjelpemidler: kalkulator, ordbok

Auxiliary materials: calculator, dictionary

Answer all 4 questions.

Percentage weights are indicated.

Write in either English or Norwegian.

Some formulae are listed at the end.

Faglærer/Instructor: Jim Brown

1. Marine seismic

Consider an east-west section from a marine seismic survey and a subsurface with four reflecting horizons. The uppermost 3 reflectors have horizontal boundaries, but the base of the fouth layer is dipping. The top layer is the sea, with a uniform depth of 535 m. The second layer (just below the seabed) is a mudstone; the third is a sandstone, and the fourth is a carbonate.

Sources and receivers are deployed very close to the sea surface (assume them to be at the sea surface). The observed zero-offset primary-reflection time for the seabed reflection is 0.718 s; for the second reflection it is 0.900 s and for the third reflection it is 1.113 s.

(a) What is the P-wave velocity of the seawater, α_1?

(b) Subsea refractions (through the mudstone) arriving at hydrophones at offsets of 1500 m and 2000 m have traveltimes of 0.924 s and 1.093 s respectively. Determine, α_2, the P-wave velocity of this shale.

(c) From velocity analysis, the stacking velocity for the base-of-carbonate reflection is found to be 2300 m/s. Estimate, α_3, the interval velocity of layer 3.

N.B: If you didn't find a value for α_2 in (b), assume any reasonable value just so you can continue.

(d) The fourth reflector horizon is dipping to the west (say, to the left). Draw a sketch of a common-shot gather, before NMO correction, for the 4 primary reflection arrivals *plus* the first-order water-column multiple (due to two bounces in the water column)?

(d) Estimate as best you can with this limited information the zero-offset reflection coefficient at the seabed.

(e) If you are told that the mudstone has a porosity of 20% and is saturated with the same seawater, determine the velocity of the mudstone rock matrix material.

2. Non-seismic

(a) Name six (6) important corrections that are commonly performed on gravity data and state very briefly the reason why each one is carried out.

(b) Where on the Earth is the normal value of g, gravitational acceleration, greatest?

State two (2) reasons why this is so.

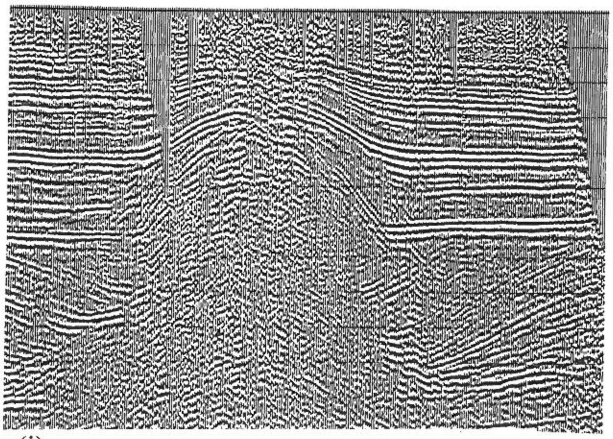
(c) Name two (2) important corrections that are commonly performed on magnetic data and state very briefly the reason why each one is carried out.

(d) Gravity surveys have on several occasions found positive anomalies that, when drilled, have resulted in discoveries of carbonate reefs. However, samples from many of these wells, and from nearby dry wells, have shown that the density of the reef was not greater than that of the adjacent shales, in fact often the reef had a slightly lower density. How might this rather common observation be reasonably explained?

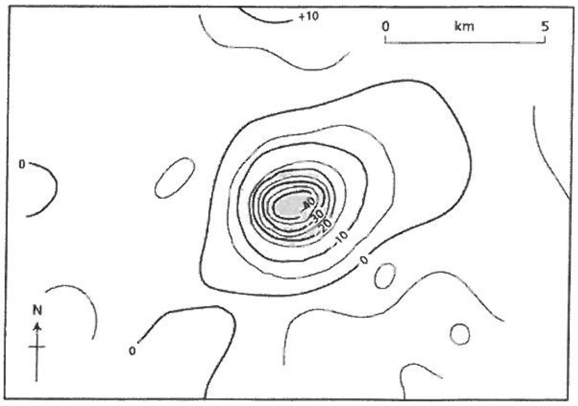
(e) A sedimentary section consists of four (4) layers of about equal thickness: (1) an uppermost layer of sandstone with high porosity saturated with a brine of high salinity; (2) a salt layer; (3) a layer of shale with low porosity saturated with a brine of low salinity; and (4) the deepest layer, a sandstone with low porosity saturated with oil. A resistivity survey is carried out over this section. Draw a rough sketch of the apparent resistivity versus array aperture (array spacing) that you would expect, assuming that the survey was extensive enough to show responses of all four layers.

3. Integrated geophysics

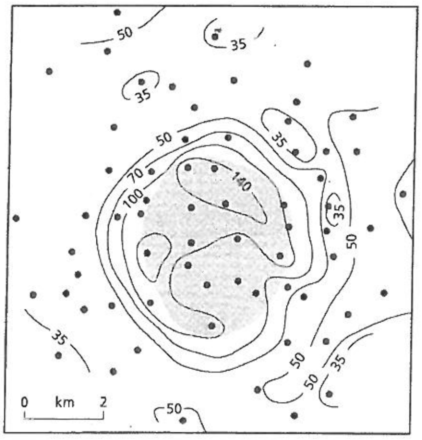
The following figures from Keary et al. (2002) show 5 different types of geophysical survey used to explore for the same objective.



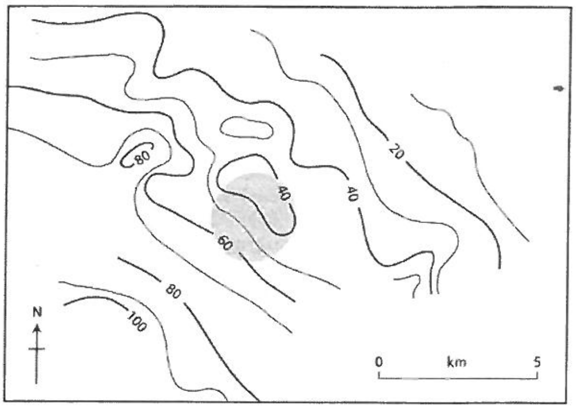
(i)



(ii)



(iii)

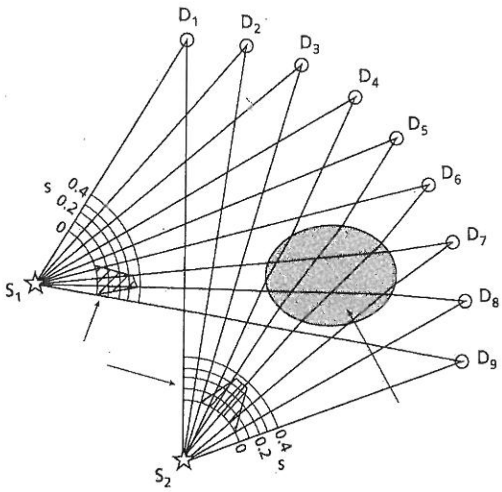


(iv)

(a) What is the common objective of these surveys?

(b) For plots (i) to (v), state what kind of survey is involved, and what parameter has been recorded and plotted in each case. For (iii) it may not be 100% clear what parameter is plotted, but suggest one realistic possibility.

(c) For each of the 3 contoured plots, (ii), (iii) and (iv), construct a N-S profile (i.e. from north to south).



(v)

(d) In a different basin, where salt-dissolution remnants are known to occur, you are asked by your exploration manager to assume the following model: a salt layer, and layers above and below, were originally deposited flat, with horizontal boundaries; then most of the salt layer was dissolved away by formation waters, leaving a single disk-like remnant Roughly circular in plan view. Based on this assumption, sketch the following five N-S sections or profiles. [In the case of (v) it is still N-S, though this now has a slightly different meaning.]

(i) a reasonable geologic section, showing about 2 or 3 layers above and below the salt.

(ii) a reasonable N-S reflection-seismic section recorded over the same salt remnant. Again, show about 2 or 3 horizons above and below the salt.

(iii) a reasonable N-S profile from a gravity survey

(iv) a reasonable N-S profile from a magnetic survey

(v) a reasonable resistivity profile, with N-S electrode separation.

4. Seismic processing and resolution

(a) In Figures 1 to , describe the essential differences between the 2 parts, (a) and (b), and then make an intelligent guess as to what processing step was applied to (a) to get (b).

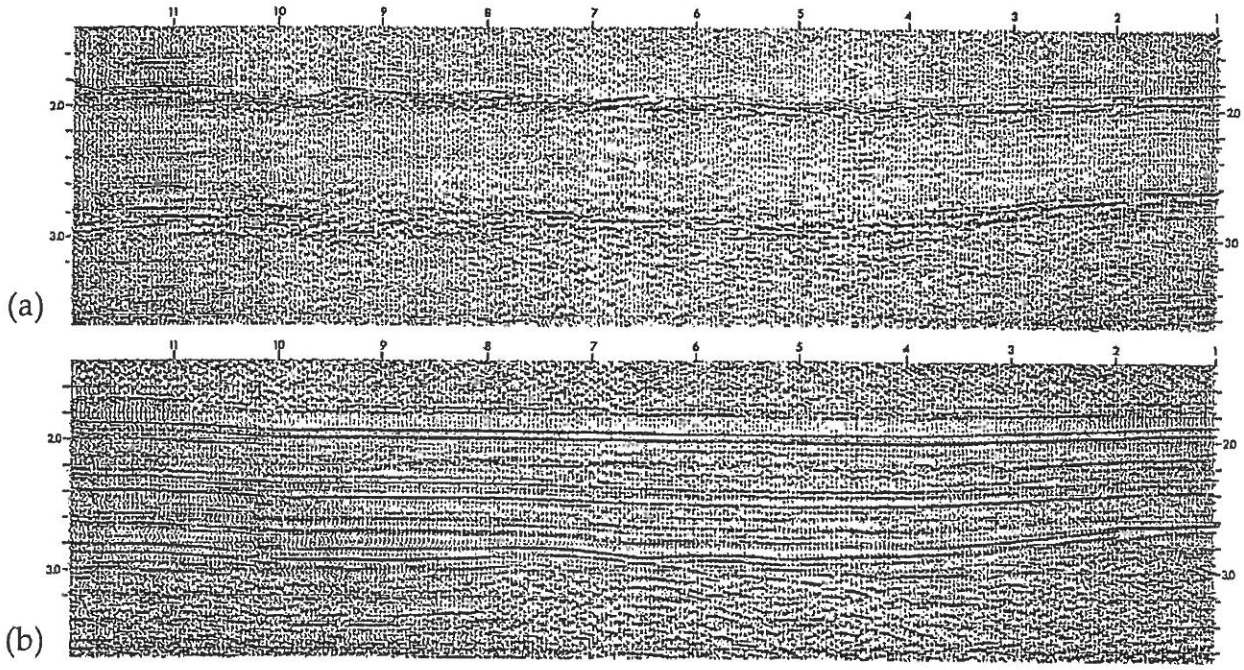
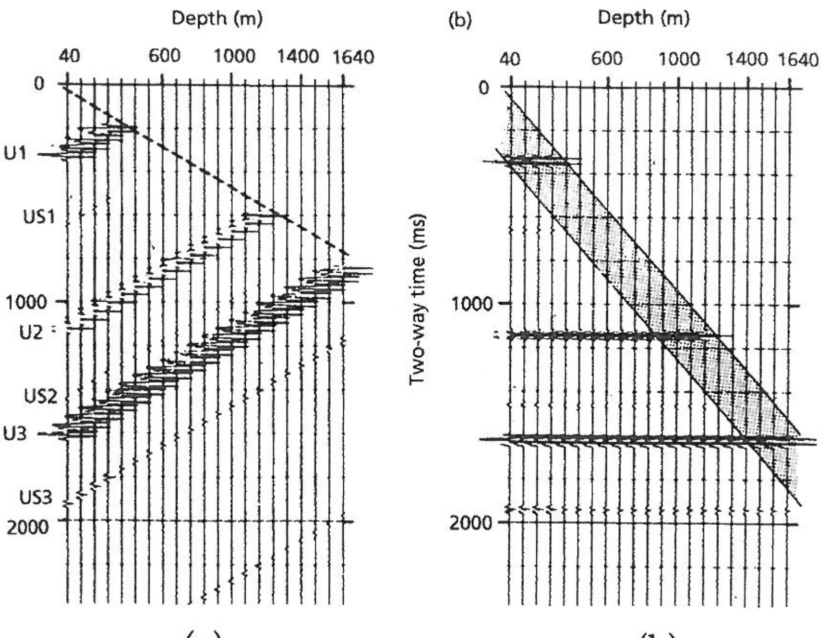


Figure 1



(a) (b)

Figure 2

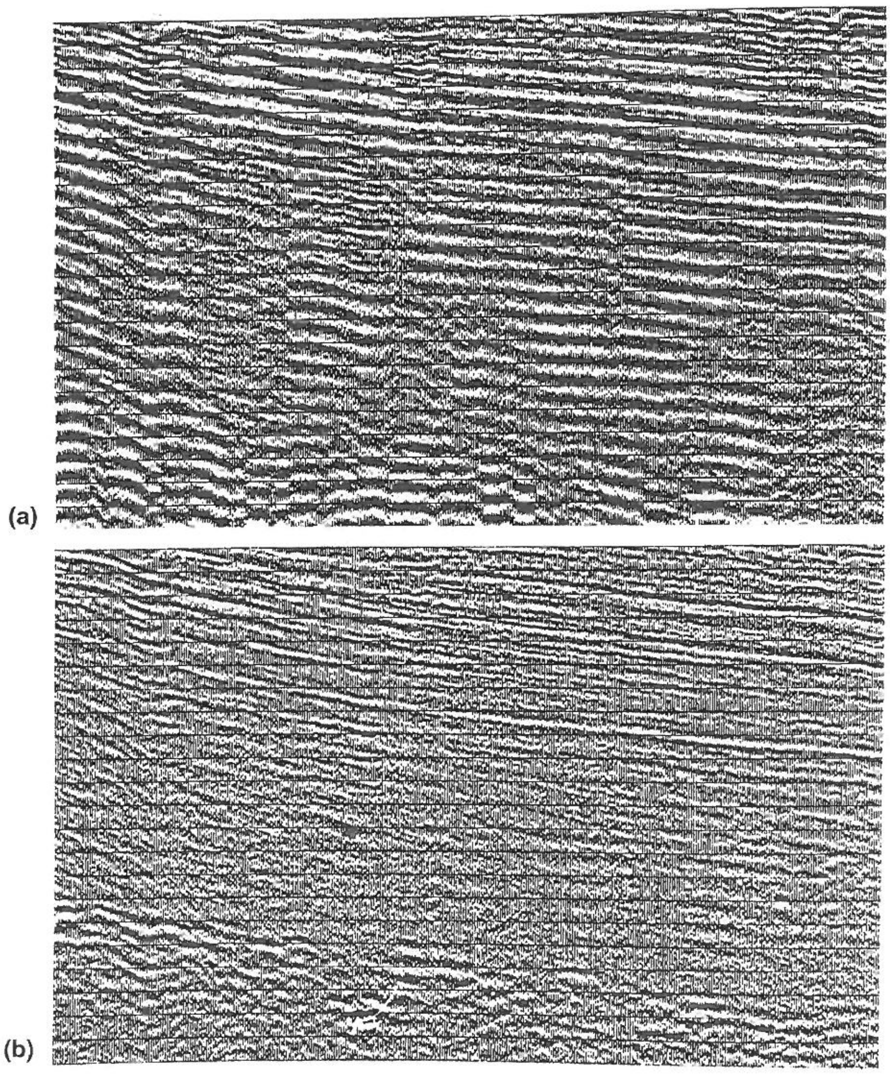


Figure 3

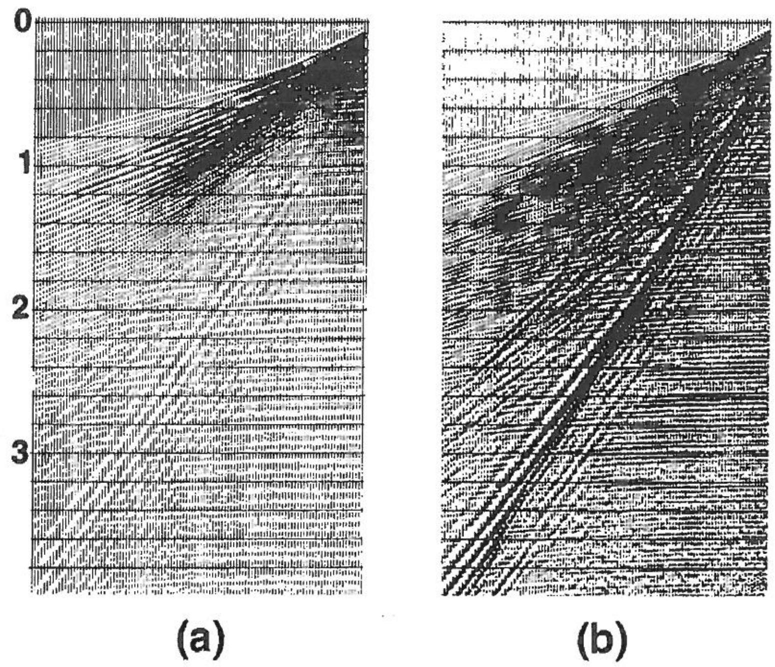


Figure 4

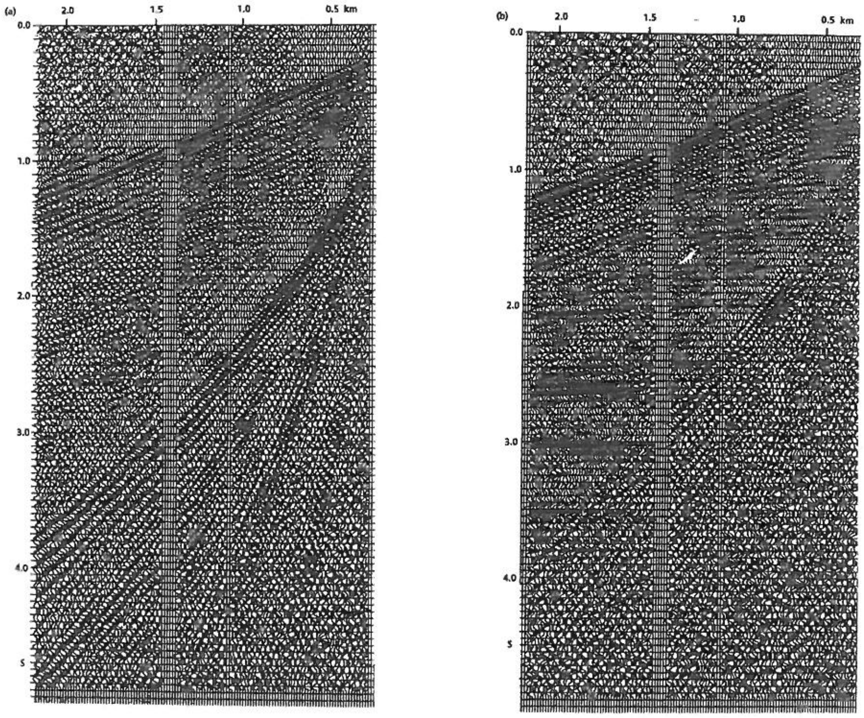


Figure 5

(b) In a particular survey area, there has been vertical faulting of the Cambrian basement (with large fault throws) at an approximate depth of 2000 m. Average P-wave velocity in the section from the surface down to this formation is ~2500 m/s. We would like to be able to resolve fault blocks on a 2D seismic section with widths as small as 300 m. What frequencies would be needed to accomplish this?

(c) In a neighbouring survey area, there are similar faults but with quite small vertical throws. Here we would like to locate these faults by resolving these rather small throws. Assuming that carbonates lie immediately over the basement with velocities of about 4250 m/s, and that the dominant frequency of reflections from these depths is about 30 Hz, what magnitudes (i.e. what sizes) of fault-throw could we probably resolve?

Some geophysical formulae:

$$F = \frac{G m_1 m_2}{r^2}$$

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

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

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

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

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

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

$$V = \lambda f$$

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

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

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

$$V_{RMS,n} = \left[\sum_{i=1}^{n} \alpha_i^2 \tau_i \Big/ \sum_{i=1}^{n} \tau_i\right]^{\frac{1}{2}}$$

$$\alpha_n = \left[\frac{V_{RMS,n}^2 t_n - V_{RMS,n-1}^2 t_{n-1}}{t_n - t_{n-1}}\right]^{\frac{1}{2}}$$

$$t_n = 2(\tau_1 + \tau_2 + \ldots + \tau_n)$$

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

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