Key Fasit

BPG150

Midterm Test, 2013 October 17

Time allowed: 100 minutes

Tillatte hjelpemidler / Allowed auxiliary materials:
Approved calculator (no Internet), English-Norwegian dictionary

Write your answers in the test paper, following each question. It is okay if you need to use the back sides of some pages.

(But if you need more paper, just ask.)

Try to write your answers in English.
Det går også an med norsk.

This test will count for 50% of the semester component, i.e. 25% of the total course grade.

30% 1. Gardner and Wyllie equations

At the horizontal boundary between two sedimentary rock layers, relationships involving P-wave velocity (α), density (ρ) and porosity (ϕ) can be approximated using the so-called Gardner equation and the so-called Wyllie (or time-average) equation.

For a land-survey area in Kazakhstan, the upper layer is a shale with $\phi = 25\%$, composed of a clay-mineral matrix with $\rho = 2730$ kg/m^3 and α = 4280 m/s. The lower layer is a sandstone with $\phi = 22\%$, composed of a quartz-feldspar matrix with $\rho = 2600$ kg/m^3 and α = 5800 m/s. In both units, the saturant is brine (salt water) with $\rho = 1030$ kg/m^3 and α = 1510 m/s.

(a) Determine the bulk densities in each of these two layers, i.e. ρ_1.and ρ_2.

(b) Using an approximate relation, estimate the interval P-wave velocities of each layer, i.e. α_1.and α_2, and state which approximation you are using.

(c) Using a second approximation, estimate the interval P-wave velocities, α_1.and α_2, and state which approximation you are now using.

(d) Estimate the normal incidence P-wave reflection coefficient at the boundary using first one, then the other, pair of velocities.

① SH $\rho_m = 2730$ kg/m^3
$\phi = 25\%$ $\alpha_m = 4280$ m/s

$\rho_w = 1030$ kg/m^3
$\alpha_w = 1510$ m/s

② SS $\rho_m = 2600$ kg/m^3
$\phi = 22\%$ $\alpha_m = 5800$ m/s

(a) $\rho_1 = 0.25 \times 1030 + 0.75 \times 2730 = 2305$ kg/m^3
$\rho_2 = 0.22 \times 1030 + 0.78 \times 2600 = 2254.6$ —"— (or 2255)

(b) Using Gardner: $\rho = 310\,\alpha^{0.25}$

$\alpha_1 = \left(\frac{\rho_1}{310}\right)^4 = \left(\frac{2305}{310}\right)^4 = 3056.59$ or 3057 m/s

$\alpha_2 = \left(\frac{2254.6}{310}\right)^4 = 2797.89$ or 2798 m/s

(c) Using Wyllie: $\alpha = \left[\frac{1-\phi}{\alpha_m} + \frac{\phi}{\alpha_w}\right]^{-1}$

$\alpha_1 = \left[\frac{0.75}{4280} + \frac{0.25}{1510}\right]^{-1} = 2934.30$ m/s

$\alpha_2 = \left[\frac{0.78}{5800} + \frac{0.22}{1510}\right]^{-1} = 3569.16$ m/s

(d)

R at normal incidence:

$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1} \quad (V \equiv \alpha)$$

From Gardner:

$$R_G = \frac{2254.6 \times 2797.89 - 2305 \times 3056.59}{\text{''} \quad + \quad \text{''}}$$

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$$R_G = -0.05522$$

From Wyllie

$$R_W = \frac{2254.6 \times 3569.16 - 2305 \times 2934.3}{\text{''} \quad + \quad \text{''}}$$

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$$R_W = 0.08666$$

$$\cancel{\frac{2000 \times 3500 - 2000 \times 3000}{+}} = \cancel{\frac{7000 - 6000}{12{,}300 \pm 2}} = \cancel{\frac{1000 \pm 2}{12{,}300 \pm 2}}$$

$$\cancel{\frac{\Delta R}{R} = 0.2\%}$$

$$\cancel{0.08666 \times 0.002}$$

$$\cancel{0.00017}$$

25% 2. Marine seismic

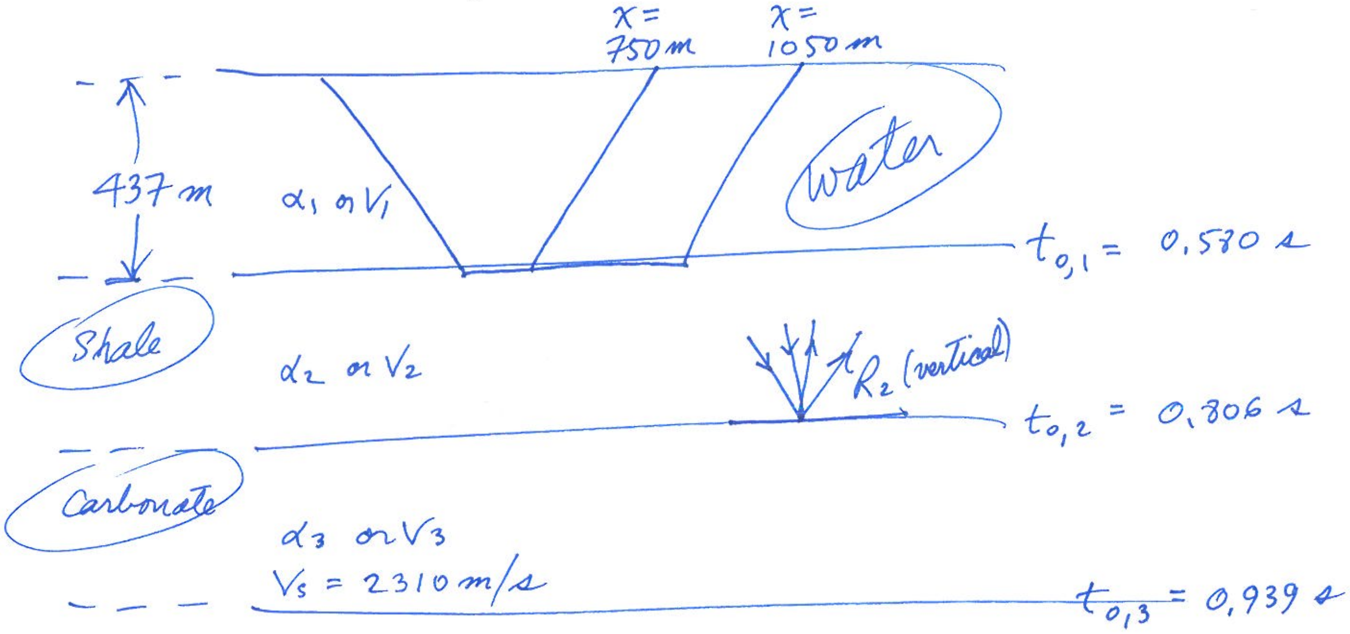
In a 2D marine seismic survey there are three layers to consider. The uppermost layer is the sea with a uniform depth of 437 m. Consider the two subsea layers to be shale (layer 2) and carbonate (layer 3). Sources and receivers are deployed very close to the sea surface (assume them to be at the surface). The observed zero-offset reflection arrival times are 0.580 s for the seafloor (or top-of-shale), 0.806 s for the base-of-shale (or top-of-carbonate) and 0.939 s for the base-of-carbonate.

(a) What is the P-wave velocity of the seawater, V_1?

(b) Subsea refractions (through the shale) arriving at hydrophones at offsets of 750 m and 1050 m have traveltimes of 0.764 s and 0.891 s respectively. Determine, V_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 2310 m/s. Estimate, V_3, the interval velocity of layer 3.
N.B: If you didn't find a value in (b) for V_2, use a rough estimate of 2500 m/s.

(d) Assuming the Gardner equation to be valid in layers 2 and 3, what is the zero-offset reflection coefficient at the top-of-carbonate (base-of-shale) interface?



(a) $\alpha_1 = \dfrac{2 \times 437}{0.580} = 1506.90$ or 1507 m/s

(b) $\alpha_2 = \dfrac{1050-750}{0.891-0.764} = \dfrac{300}{0.127} = 2362.20$ m/s

(c) Let $V_s \approx V_{RMS}$

$$V_{RMS,3}^2 = \frac{\alpha_1^2 \tau_1 + \alpha_2^2 \tau_2 + \alpha_3^2 \tau_3}{(\tau_1+\tau_2+\tau_3)} \cdot \frac{2}{2} \Rightarrow$$

$$V_{RMS,3}^2 \cdot t_3 = V_{RMS,2}^2 \cdot t_2 + \alpha_3^2 (t_3 - t_2)$$

OR directly $\alpha_3^2 = \dfrac{V_{RMS,3}^2\, t_3 - V_{RMS,2}^2\, t_2}{t_3 - t_2}$

$$\alpha_3^2 = \frac{2310^2 \times 0.939 - (1506.9^2 \times 0.58 + 2362.2^2 \times 0.226)}{0.133}$$

$\alpha_3 = 4276.61$ m/s or 4276 m/s

[OR $\alpha_3 = 4141.36$ m/s with $\alpha_2 = 2500$ m/s]

(d) Normal inc. refl. coeff: R_2

$$R_2 = \frac{\rho_3 \alpha_3 - \rho_2 \alpha_2}{\rho_3 \alpha_3 + \rho_2 \alpha_2}$$

If Gardner valid then $\rho = 310\,\alpha^{1/4}$

and $\rho\alpha = 310\,\alpha^{5/4}$

$$\text{So } R_2 = \frac{\cancel{310}(\alpha_3^{5/4} - \alpha_2^{5/4})}{\cancel{310}(\alpha_3^{5/4} + \alpha_2^{5/4})}$$

$$R_2 = \frac{4276.61^{5/4} - 2362.20^{5/4}}{4276.61^{5/4} - 2362.20^{5/4}}$$

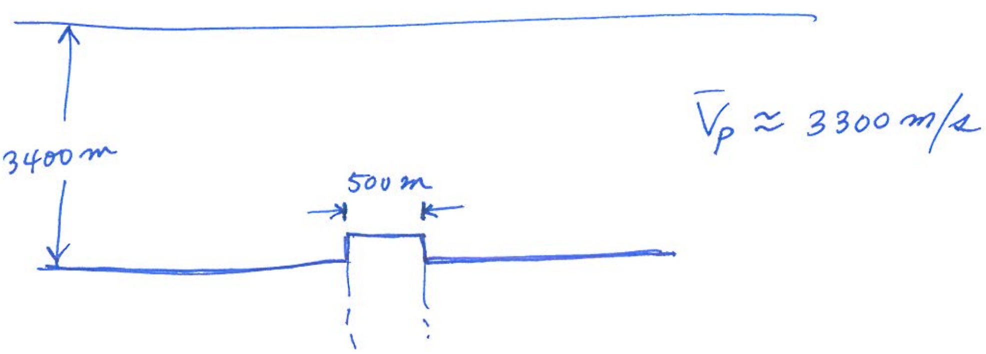
$R_2 = 0.3548$ or 0.355

20% **3. Resolution**

(a) In a particular survey area, there has been vertical faulting of the Cambrian basement (with large fault throws) at an approximate depth of 3400 m. Average P-wave velocity in the section from the surface down to this formation is ~3300 m/s. We would like to be able to resolve fault blocks on a 2D seismic section with widths as small as 500 m. What frequencies would be needed to accomplish this horizontal resolution?

(b) Does horizontal resolution depend on any other survey parameters? If so, give details.

(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 4750 m/s, and that the dominant frequency of reflections from these depths is about 45 Hz, what fault-throw magnitudes should we be able to resolve?



(a) We want to find f_c at which $w_F = 500$ m

$w_F = \sqrt{2\lambda z}$ i.e. $500\text{ m} = \sqrt{2 \times 3400 \times \lambda}$

$\bar{\lambda} = \frac{\bar{V}_p}{f_c} = \frac{3300}{f_c}$, ~~so~~...

$500^2 = 6800 \times \frac{3300}{f_c} \Rightarrow f_c = \frac{68 \times 33}{5^2} = 89.76$ or 90 Hz

We'd need $f \gtrsim 90$ Hz -2 for this

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(b) Depends also on spacing of receivers. A general rule is to ~~use~~ have at least 4 receivers (groups) per Fresnel zone width.

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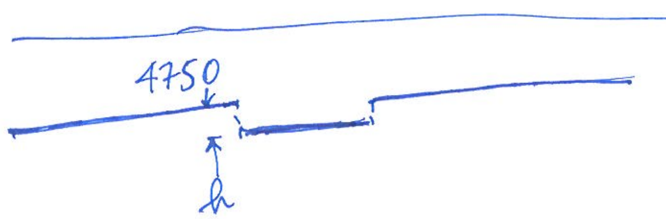
(c)



$f \approx 45$ Hz

$h = \frac{\lambda}{4}$ ✓ $\lambda = \frac{V}{f}$ ✓

$h = \frac{V}{4f}$ ✓ $= \frac{4750}{180}$ ✓ $= 26.39$ m ✓

$h \approx 25$ m ✓

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25% 4. Geophysical concepts and data processing

(a) Each of the following two cases shows some geophysical scenario or image. In the first case (Fig. 4-1) there are two panels showing similar aspects of the same scenario; in the second case (Fig. 4-2), just one panel. State or explain briefly what each case (or figure) represents, i.e., describe what's going on here in each of these scenarios or images.

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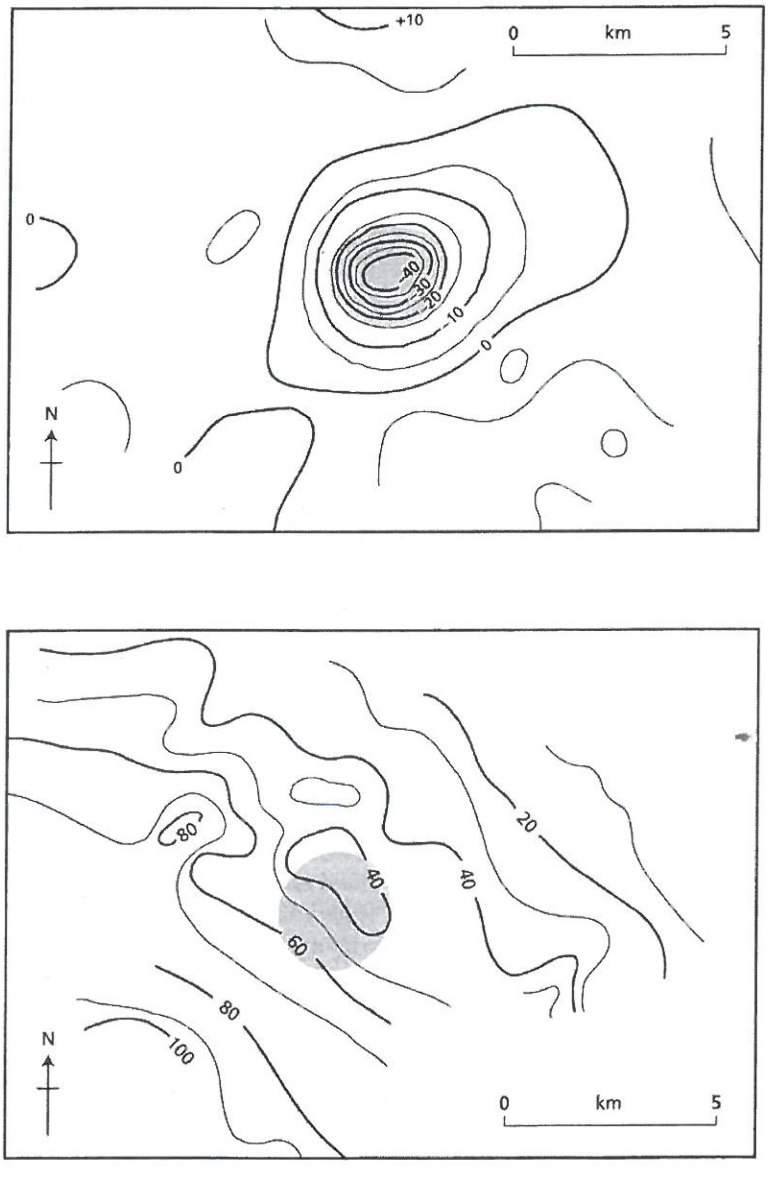

Figure 4-1

Both show expressions of salt (dome) – above the gravity effect; below magnetic.

Above: { – low ρ
i.e negative Δρ

~~(low mag. susc.)~~
small and negative magnetic susceptibility } :Below

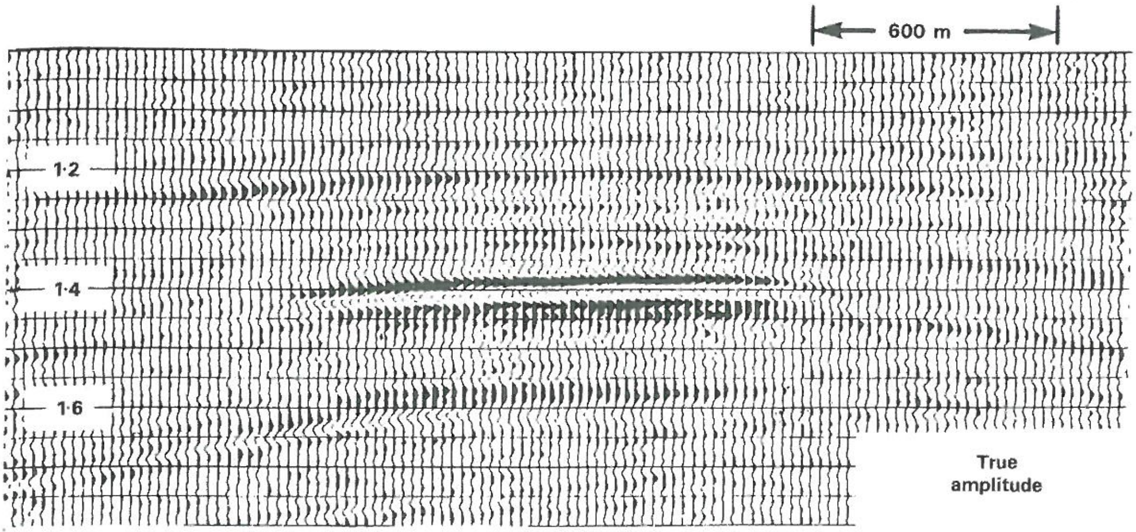

Figure 4-2

At ~ 1.4 s, a high-ampl. refl'n in middle of fig., lower to both sides. This high-amp ⇒ "bright spot" indicative of change from sides, from brine (sides) to hydrocarbon (esp. gas) in pores below the reflecting horizon.

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(b) Each of the following figures (4-3 and 4-4) shows two seismic sections from the same location. The difference between (a) and (b) in both cases is that some data-processing step has been applied to (a) in order to get (b).

(i) Briefly describe the main visual difference(s) between the two figures in each example.

(ii) On the basis of this visual difference, make an intelligent guess as to what additional process has been applied.

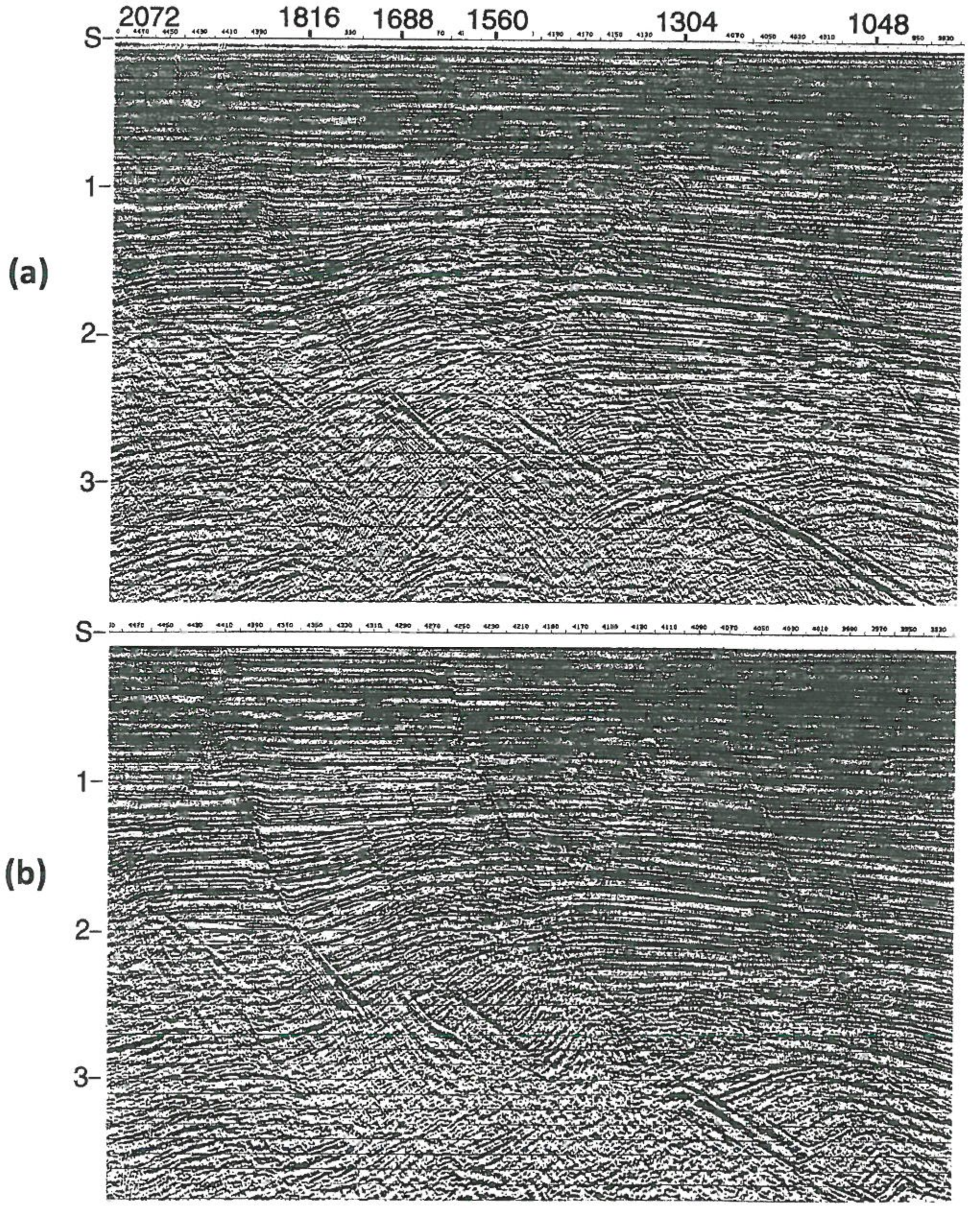

Figure 4-3

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In (a) diffractions and intersecting events
In (b) clearer dipping events and prob. faults

Migration

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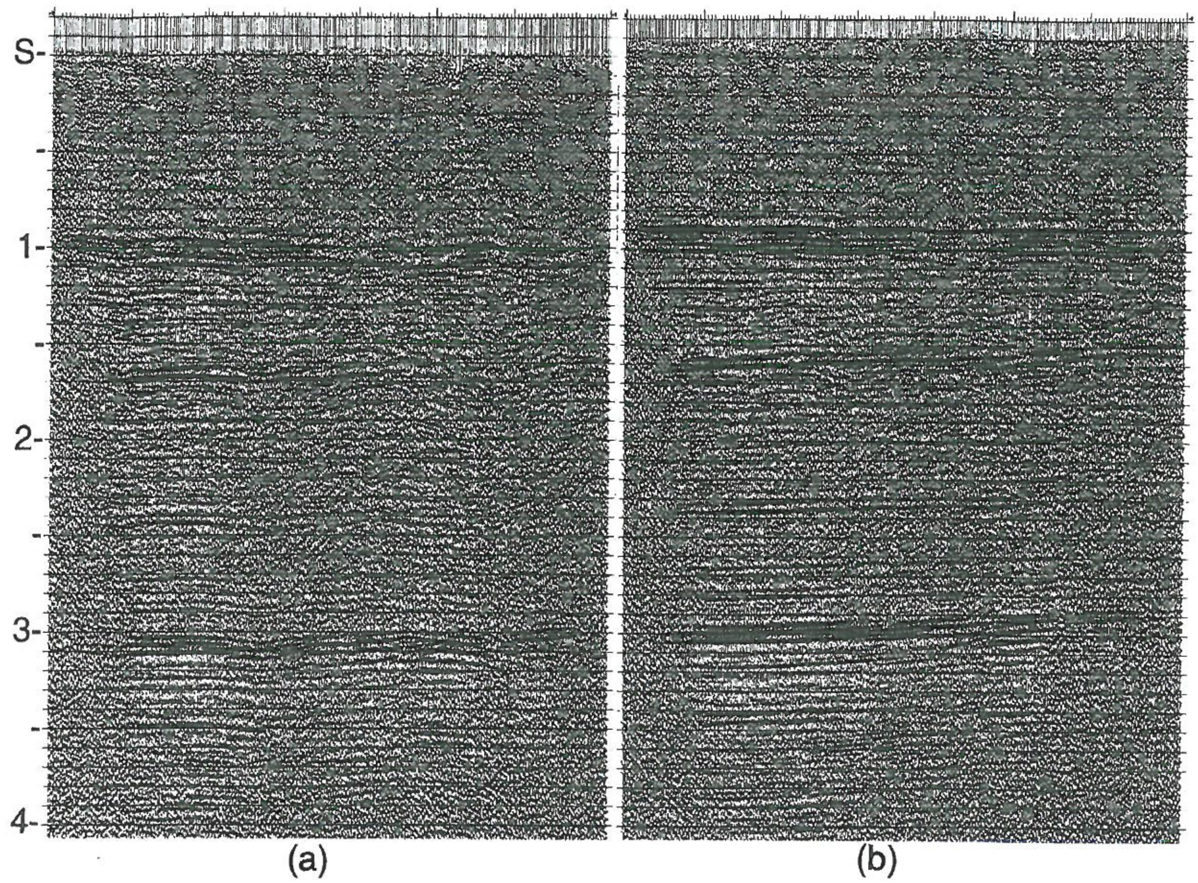

Figure 4-4

(a) Delays that are ~ consistent vertically in section.

(b) Delays on events levelled out and stacking clearly of better aligned waveforms.

Statics

Some geophysical formulae:

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

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

$$V = \lambda f$$

$$V_\mathrm{a} = \frac{V}{\sin i}$$

$$\frac{1}{V} = \frac{\phi}{V_\mathrm{f}} + \frac{1-\phi}{V_\mathrm{m}}$$

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

$$\alpha \equiv V_\mathrm{P} = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}$$

$$\beta \equiv V_\mathrm{S} = \sqrt{\frac{\mu}{\rho}}$$

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

$$R_{12} = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1}$$

$$w_F = \sqrt{2\lambda z}$$

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

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

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

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