地震勘探原理 双语教学材料

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Seismic exploration Total Exercises

Question 1

(a) What is meant by AVO? Explain the physical basis of AVO and how AVO is used in hydrocarbon exploration.

(b) Explain what is meant by **deconvolution** in seismic data processing. Why is it needed and what does it do to seismic reflection data?

(c) Shear waves are increasingly used in seismic exploration.

Explain **two factors** that make the recording and analysis of S-waves more difficult that P-waves.

Describe **one example** where S-waves are more useful that P-waves in hydrocarbon exploration.

(d) Explain the origin of **statics** in seismic reflection exploration. Why are they a problem? Describe **two** ways in which they can be removed.

(e) What is the difference between **pre-stack** depth migration and **post-stack** depth migration? Include a diagram in your answer to explain the relevant steps in seismic data processing.

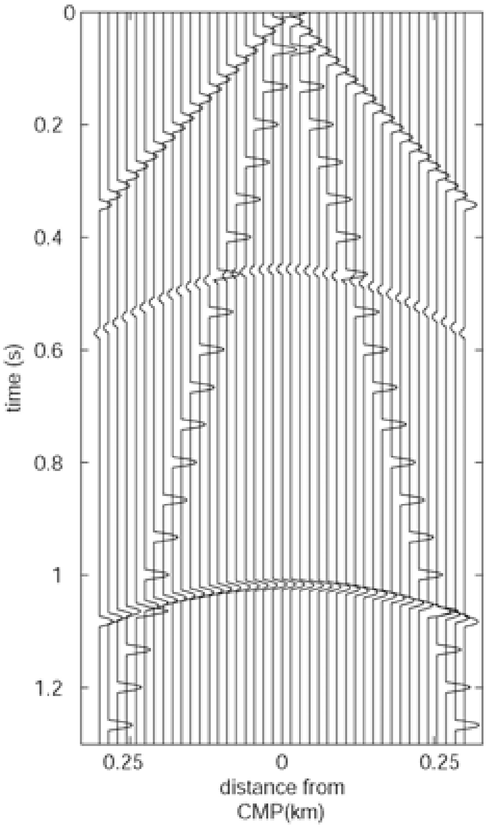
What **advantages** does post-stack depth migration have over pre-stack depth migration?

(f) The smallest vertical distance that can be resolved with seismic reflection is a quarter of a wavelength ($\lambda/4$). Explain this fact with the aid of a diagram.

Question 2

The figure below shows a **common mid-point gather** that was collected over a layered Earth. Selected travel times are listed in the table on the right.

x_{SR} is the distance between the shot and receiver.



x_{SR}(m)	ref1(ms)	ref2(ms)
0.000	457.143	1017.143
30.000	457.454	1017.307
60.000	458.406	1017.810
90.000	459.996	1018.651
120.000	462.220	1019.827
150.000	465.064	1021.342
180.000	468.516	1023.188
210.000	472.558	1025.366
240.000	477.198	1027.872
270.000	482.393	1030.706
300.000	488.130	1033.868
330.000	494.416	1037.358
360.000	501.187	1041.158
390.000	508.467	1045.263
420.000	516.198	1049.692
450.000	524.385	1054.424
480.000	532.983	1059.478
510.000	541.999	1064.806
540.000	551.381	1070.428
570.000	561.172	1076.370
600.000	571.280	1082.573

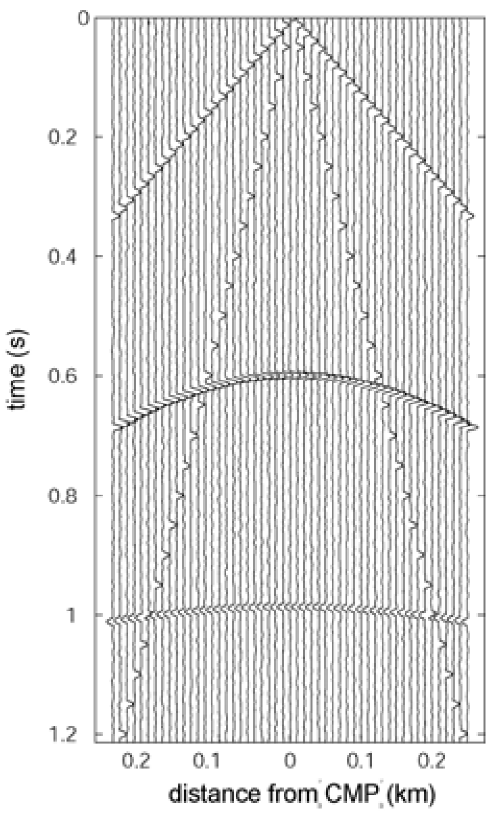
(a) **Qualitatively** describe the variation of velocity with depth.
(b) Compute the **velocity** (v_1) and **thickness** (z_1) of the upper layer
(c) Compute the **r.m.s. velocity** for the second reflection ($V_{rms,2}$)
(d) Compute the **velocity** (v_2) and **thickness** (z_2) of the second layer
(e) What is the **fold** of this CMP gather?
(f) Sketch the **multiple reflection** from the first interface on the CMP gather shown above. Indicate the **polarity** of the reflection.

Assume that the density is the same in all layers.

Question 3

The figure below shows a **common mid-point gather** that was collected over a layered Earth. Selected travel times are listed in the table on the right.

Remember that when the shot is a $+x$, the geophone is at $-x$. Thus the offset is 2x



x(m)	ref1(ms)	ref2(ms)
100.000	614.699	990.808
80.000	609.463	989.326
60.000	605.353	988.161
40.000	602.394	987.336
20.000	600.606	986.836
0.000	600.000	986.667

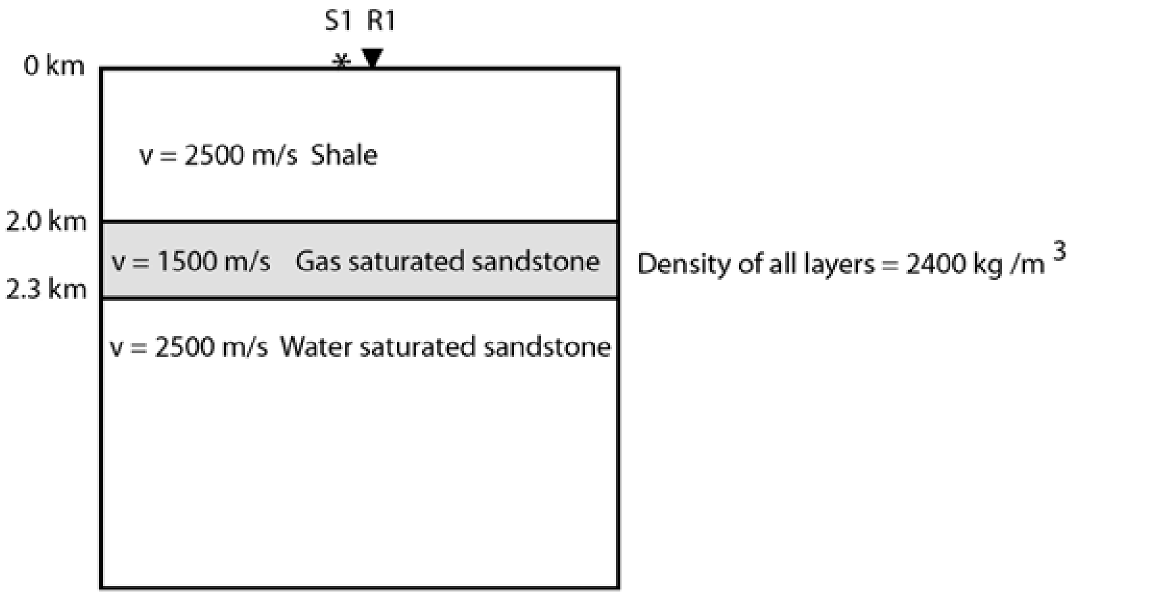
(g) On the figure, **label** each seismic signal that is observed.
(h) Compute the **velocity** (v_1) and **thickness** (z_1) of the upper layer
(i) Compute the **r.m.s. velocity** for the second reflection ($V_{rms,2}$)
(j) Compute the **velocity** (v_2) and **thickness** (z_2) of the second layer
(k) The reflection coefficient for the first reflection was measured at 0.33. Show that this is consistent with the values of v_1 and v_2
(l) The amplitude of the second reflection was –0.17. Compute the reflection coefficient at the second interface. Estimate v_3

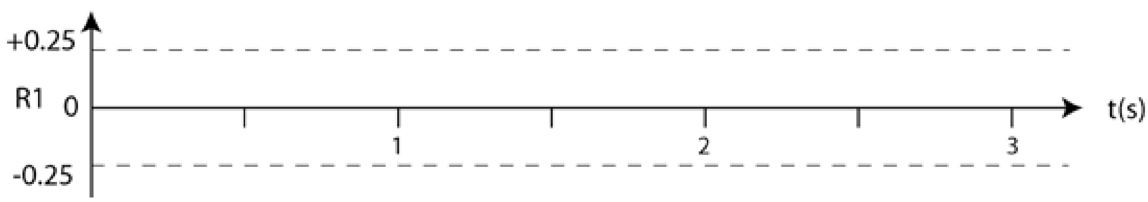
Assume that density is the same in all layers.

Question 4

A shot (S1) was fired at the surface at time $t=0$ and a seismic signal was generated with amplitude, A=1.

(a) Compute the **arrival time** and **amplitude** for the first **three reflections arrivals** to reach the geophone (R1)
(b) Sketch the seismic traces recorded at R1.
Show the amplitude and sign of each reflection
(c) The velocity of the gas is 300 m/s
The velocity of the sandstone matrix is 3000 m/s.
Calculate the porosity of the gas reservoir?

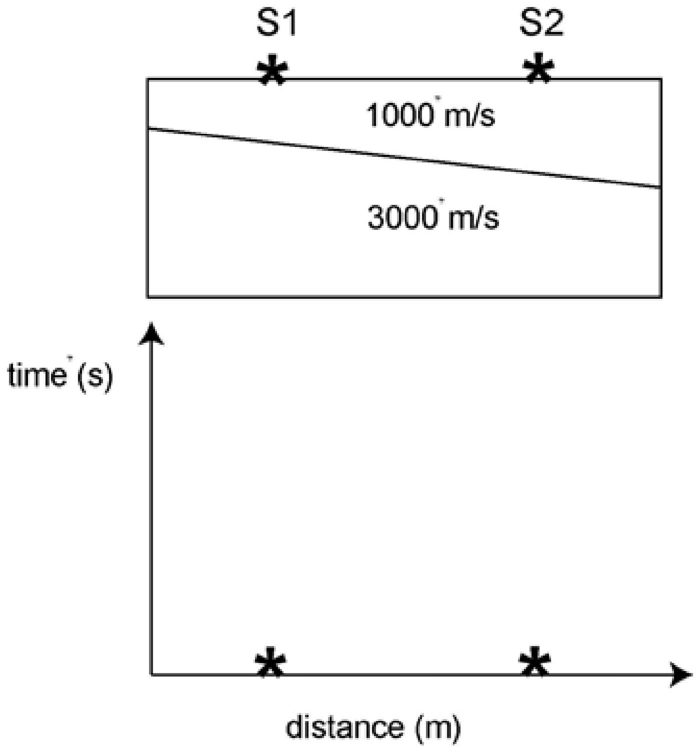




Question 5

The figure below shows the geometry of a seismic refraction survey.

Two shots were fired (S1-S2). Geophones extend from 'A' to 'B'.



(a) On the attached graph, draw the travel times that you would observe. Include both direct waves and refractions for the 2 shots

Indicate the **relative slope** of each curve where relevant.

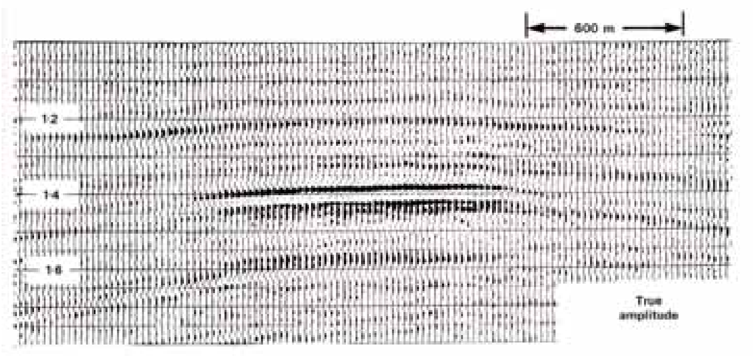
Also indicate **relative travel times** where necessary.

Also show the travel times for the **reflection** from the dipping layer

(b) Briefly explain **two** situations in which refraction exploration can fail to detect a subsurface layer.

Question 6

(g) The figure below shows a **seismic bright spot** due to a gas reservoir. Why does a concentration of gas produce a strong seismic reflection?



Use the data below to estimate the porosity of the gas reservoir

Reservoir (gas saturated sandstone)	v = 2200 m/s
Sandstone with no gas	v = 4200 m/s
Gas	v = 300 m/s

(h) Explain what is meant by **common mid-point profiling.**

Sketch the distribution of shot points and geophones for a **6-fold** CMP gather.

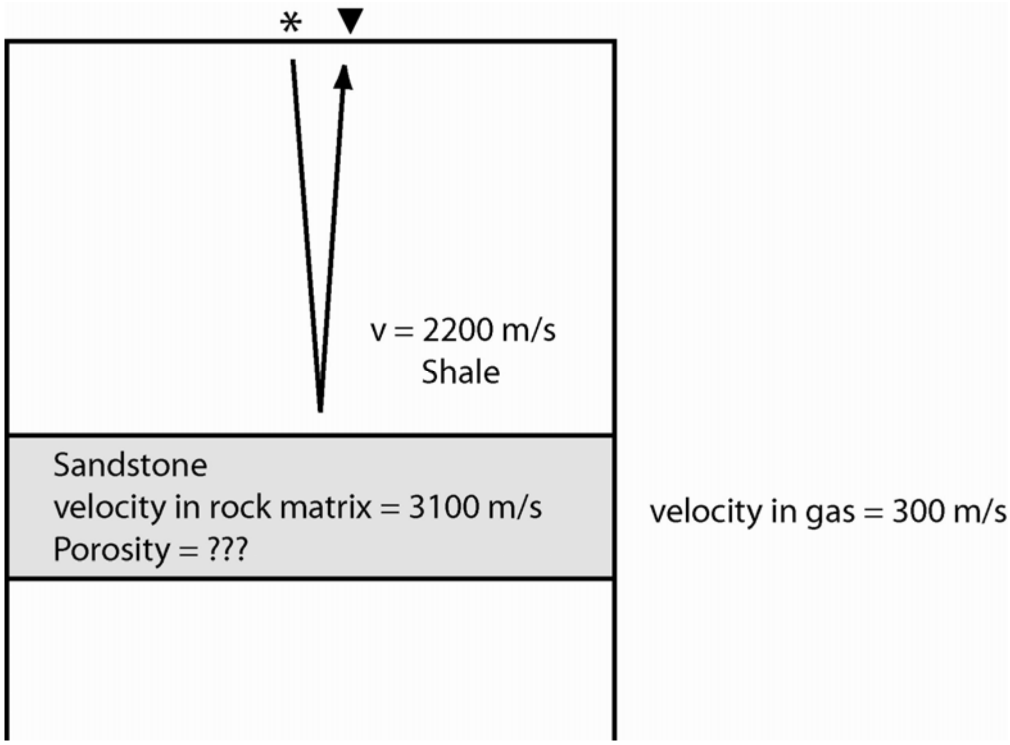
Describe **two advantages** of multichannel CMP profiling, compared to single channel profiling.

(i) The smallest vertical distance that can be resolved with seismic reflection is a quarter of a wavelength ($\lambda/4$). Explain this fact with the aid of a diagram.

Why does an increase in signal frequency not always improve data quality in a seismic survey?

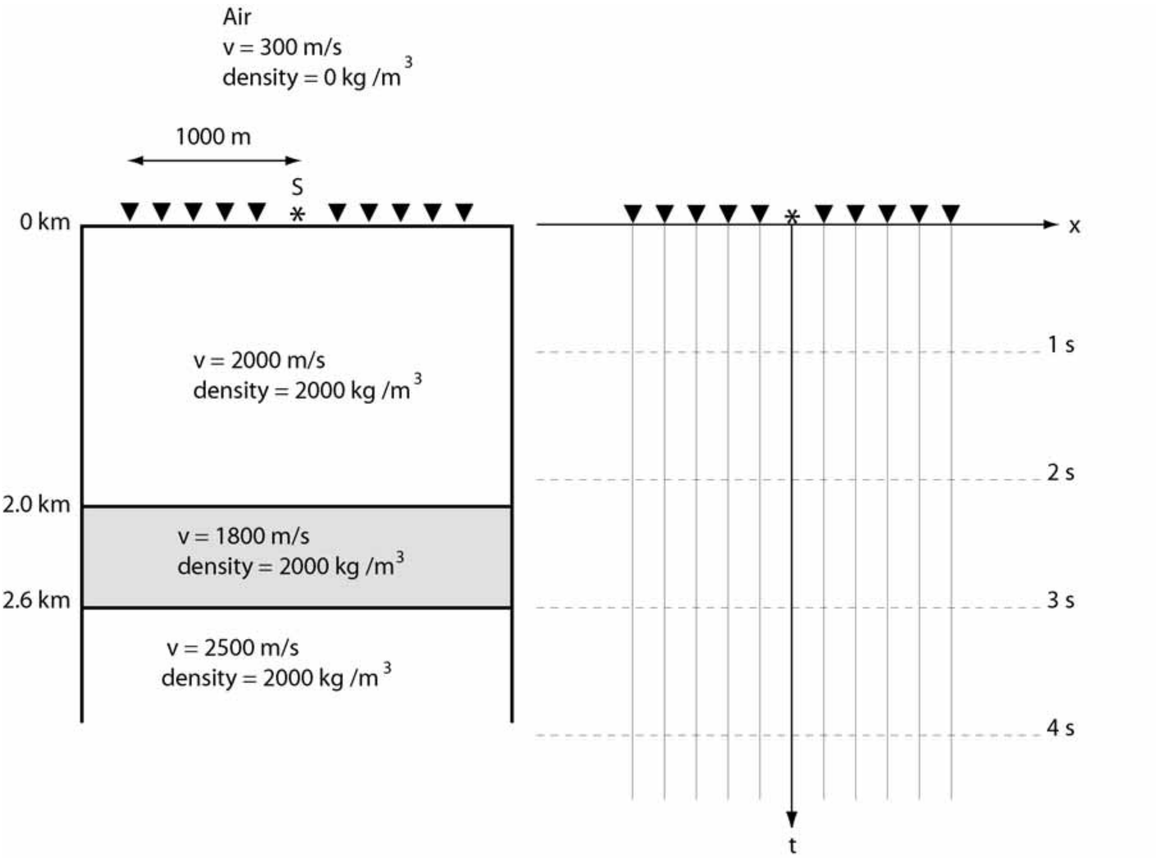
Question 7

A seismic reflection from the top of a gas reservoir is being studied.
The P-wave velocities are shown in the figure below.
The density is the same in all layers.
Noise in the seismic data means that the smallest reflection coefficient that can be measured is 0.01
All pore space is filled with gas



The geophysicist claims that the presence of gas can be detected when the porosity is 5%   Is this true?   **(8 points)**

Question 8



The structure above is investigated with a shot gather that used 10 geophones.

On the figure above, draw the seismic traces that will be recorded.

Be quantitative where possible.

Include:

- the direct wave (exact travel times)
- first reflection (zero-offset travel time, amplitude, exact NMO)
- second reflection (zero-offset travel time, amplitude, qualitative NMO)
- third reflection (zero-offset travel time, amplitude, qualitative NMO)

Formulae that may be useful

v = velocity
x = source-receiver offset

t = travel time
ρ = density

$v = \frac{distance}{time}$

For a porous rock, the velocity (v) is given by the time average equation:

$$\frac{1}{v} = \frac{\Phi}{v_f} + \frac{(1-\Phi)}{v_m}$$ where Φ = porosity, v_f = velocity in fluid; v_m = velocity in rock matrix

Seismic impedance , $Z = \rho v$

Seismic wave travelling from layer 1 to layer 2, at normal incidence

Amplitude reflection coefficient, $R = \frac{Z_2 - Z_1}{Z_2 + Z_1}$

Amplitude transmission coefficient, $T = \frac{2Z_1}{Z_2 + Z_1}$

Normal move out (NMO) = $\Delta t = t - t_0 = \frac{x^2}{2t_0 v^2}$

t_0 = travel time at normal incidence
x = distance from shot to receiver

Dix equation $$v_n = \left[\frac{V_{rms,n}^2 t_n - V_{rms,n-1}^2 t_{n-1}}{t_n - t_{n-1}}\right]^{\frac{1}{2}}$$

where v_n = interval velocity of n^{th} layer
and $V_{rms,n}$ = r.m.s velocity of n^{th} reflector
t_n = normal incidence travel time for n^{th} reflector

Normal moveout (NMO) = $\Delta t = t - t_0 = \frac{x^2}{2v^2}$

t_0 = travel time at normal incidence