

Impact of an Earthquake on a Vertical Borehole

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Introduction :

For 35 years Gaz de France (GDF) has been using salt cavities and aquifer structures for the storage of natural gas. Whereas aquifer structures can hold huge quantities of gas but allow only small production rates, salt cavities contain much smaller amounts of gas but provides a much wider range of flow rates. This is why aquifer storages are used to cope with seasonal fluctuations in demand, while salt cavities are used for day-to-day adjustment to the demand. GDF currently uses 11 sites for underground storage (9 aquifer reservoirs, and 2 salt cavities).

A new set of salt cavities has been under development since 1990 near Manosque (Figure 1), in South-East France. This particular site is located in a seismic area and therefore raises new questions about safety with respect to seismic risks. The primary concern of GDF is the safety of the people on and around the site. The possible loss of the gas contained in the cavity would not be of major economic consequence as it would amount at worst to a comparatively small quantity.

A study has already been made (Geodynamique & Structures, external report, 1990) to determine the largest earthquakes that could be expected to occur near the storage site. Based mainly on the historical record, this study concluded that 2 major possibilities should be considered :

- An earthquake of magnitude $M_s \leq 5.5$ ($M_s = 6.0$ for safety) producing a local intensity of VIII and located under the site (based on earthquakes that occurred in 1509 and 1708 ; Lambert, 1988),

- An earthquake of magnitude $M_s = 6.2$ ($M_s = 6.7$ for safety), local intensity IX and located 20 km away from the site (based on a 1909 earthquake ; Levret et al., 1986, 1988).

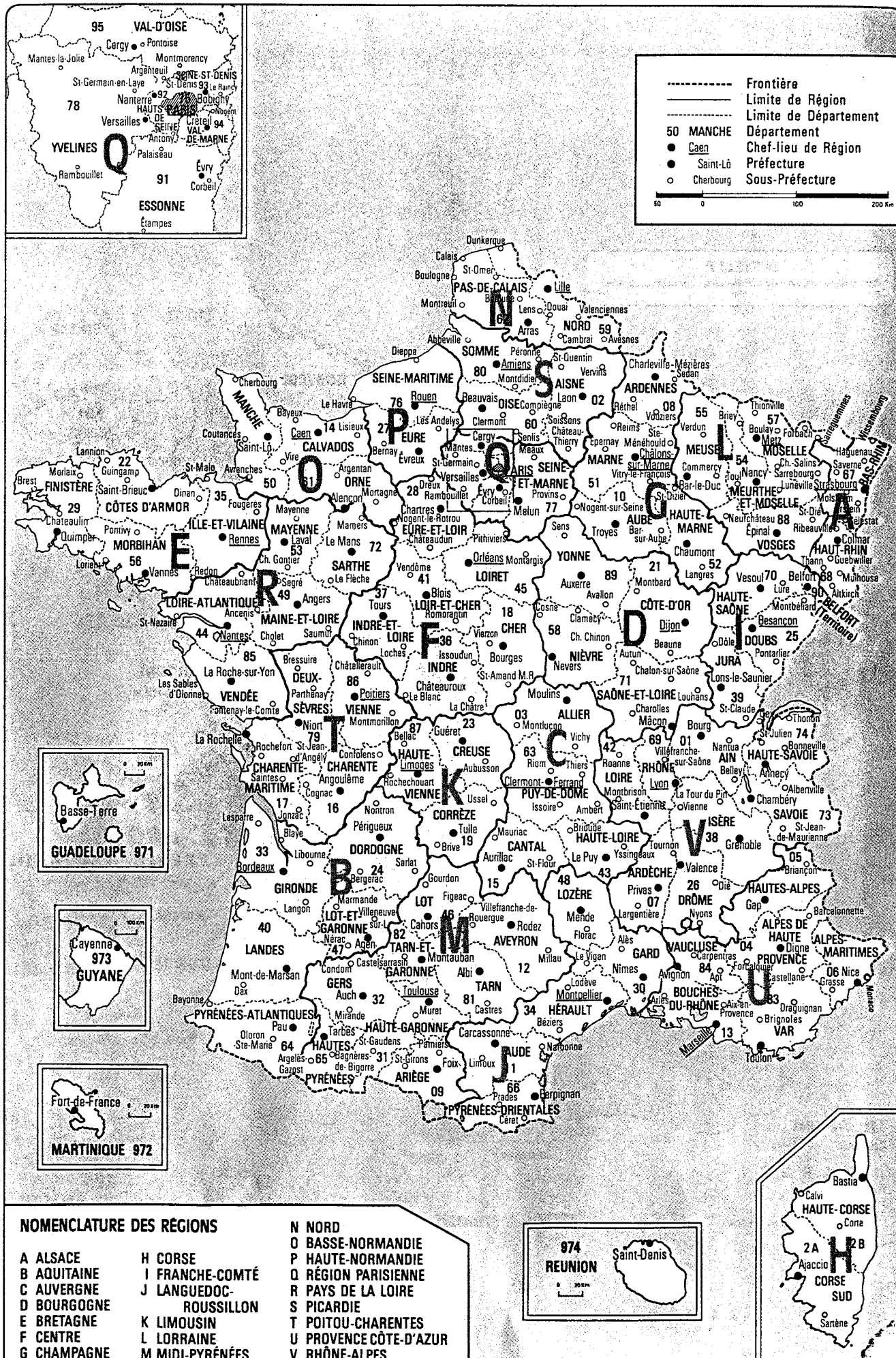
The purpose of this study is to evaluate the effect of each of these two earthquakes on the 1 km borehole linking the surface to the cavity. The surface effects are the subject of an internal study by GDF, and the stability of the cavity itself has also been checked (Geo. & Struc., external report, 1990). This evaluation is performed in three successive steps :

- Determine the structure of the site, the structure of the different layers, and extent, thickness, P and S velocities, and density of each layer. An assumption of 1-dimensional horizontally homogeneous structure is made.

- Given the above parameters, simulate the propagation of the waves through this layered medium from the hypocenter to the borehole and calculate the dynamic excitation in the vicinity of the borehole,

- Given the estimated seismic excitation, simulate the behavior of the casing, and of the cement that links between the casing and bedrock.

FRANCE ADMINISTRATIVE



I) site

1) Geography

The site is located near Manosque in southeast France, in the southern Alps, in the "Alpes de haute Provence" region (Figure1). The elevation is about 600 m above sea level. The Alps are one of the features resulting from the ongoing convergence of the African and the European tectonic plates along a north-south to northwest-southeast vector (Goguel et al., 1985). The collision of those continental plates induces stress into the different plates, therefore generating earthquakes on both sides of the Mediterranean sea.

2) Geology

A geologic study of the upper layers of the site has been made by Geostock, 1976. This is a description of the successive layers as result of this study (Table 1). Starting from bottom of the studied area, the geology is characterized by :

Sub-Salt Formation (thickness unknown ; depth > 1822 m)

Well layered, silty, black, brown or dark grey marl with some thin beds of white grained crystalline anhydrite, and some organic material.

Within these marls we can find

- sandstones with clay-limestone cement
- crypto to micro-crystalline dolomite
- green, brown-yellow, brown-red marl
- calcareous or magnesium clays. grey or beige.
- salt
 - Pink, beige, red, grey-white or transparent salt injected in joints and fractures
 - White or grey, well stratified with some black marl layers

This formation is regularly stratified, the layers are only slightly distorted, folded or faulted, and the boundary with the overlying salt formation is abrupt.

Salt Formation (thickness 942.5 m – depth 879.5–1822 m)

Except for the presence of some insoluble zones, the coarse-grained salt (NaCl) formation is homogeneous. Its most common color is light pink or brown-pink, but it can be transparent, white, grey, grey-beige, bright red to dark brown. Insolubles are of small size (millimeter to decimeter), constituting a breccia with a salt matrix. Insolubles are composed of differing types of anhydrite. Several massive banks of calcareous dolomite or anhydrite occur near the site, but none were intersected by drill hole EH26 (borehole of interest in this study).

Anhydrite Formation (thickness 404.5 m ; depth 465–879.5 m)

This formation shows substantial variation in thickness. The transition between the underlying salt formation and the anhydrite formation is abrupt. The transition to the overlying "lower marls" formation is gradational.

Lower Marls Formation (thickness 222.5 m ; depth 252.5–465 m)

From bottom to top :

- marl sequences

These sequences are distinguished by lithologic differences which appear in the gamma ray log (Appendix B).

This is a highly fractured area. Cores show a kind of tectonic breccia up to the red marls.

- red marls
- sandy limestone
- silty grey clay bed

Limestone with Traces of Bitumen Formation (thickness 75 m ; depth 177.5–252.5 m)

- marl bed
- limestone bed
- marl bed
- limestone bed

Upper Marl Formation (thickness 161.5 m ; depth 16.5–177.5 m)

Very similar to the lower marl formation. Nearly identical gamma ray log values.

- marl sequence
- red marl
- sandy lenses
- grey clay

Montfuron Limestone (thickness 16.5 m ; depth 0–16.5 m)

The small cubes of limestone that constitute this layer are characterized on the sonic log (Appendix B) by variable travel times. This has been interpreted as the result of tectonic relaxation (Geostock, 1976).

Stratigraphic age		Stratigraphic layers			Thickness	Depth	
Upper Oligocene	Aquitaniien	Limestone of Reillane				eroded	
		Marl of Viens				eroded	
Middle Oligocene	Upper Stampien	Limestone of Vacheres				eroded	
	Middle Stampien	Formation of Bois d'Asson Sandstone and marl				eroded	
	Lower Stampien	Limestone of Monfuron			16.5 m	0 to 16.5 m	
Lower Oligocene	Sannoisien	Formation of Passaire and of La Mort d'Imbert	Upper marls formation		19.5 m	16.5 to 36 m	
				Red marl of La Mort d'Imbert	46.5 m	36 to 82.5 m	
					95 m	82.5 to 177.5 m	
			Limestone with traces of bitumen formation			75 m	177.5 to 252.5 m
			Lower marls formation		30 m	252.5 to 282.5 m	
				Red marl	45 m	282.5 to 327.5 m	
					137.5 m	327.5 to 465 m	
			Anhydrite formation			414.5 m	465 to 879.5 m
			Salt formation			942.5 m	879.5 to 1822 m
			Black marls			?	1822 to ?

Table 1

Two geologic cross sections of the site can be seen on maps 1 and 2 (Appendix A). On map 1, we can see that the layers are rather flat and constant in thickness. They extend in both southwest and northeast directions. The topography is somewhat flat, with undulations not exceeding 200 m in amplitude. On map 2, the topography is still flat, but the shape of the layers clearly shows that the site is on the top of an eroded anticline. The northwest part of this anticline is normal faulted from top to bottom, with slip on the order of tens of meters. A summary of the age, thickness, type and depth of these layers is shown in Table 1.

3) Site

The site is located 2 km west-northwest of Manosque. There are 7 salt cavities, and 7 more to be mined. The study is conducted on cavity E.H. 26 (maps 1 and 2 of Appendix A). The following velocities, densities, and thicknesses are used to parameterize the region of this cavity.

4) Velocity and density

Velocity

P-wave velocity has been established from Schlumberger logs 1, 2 and 3 (Appendix B). For each layer this study uses the mean velocity, and assumes that the velocity is constant throughout the layer.

Log 1 (15m to 280 m)

Weathered surface (15–16.5 m)

No reliable reading can be made for the first layer because the signal is unstable.

Upper Marls (16.5–177.5 m)

Grey clay (16.5–36 m) The signal is too wide in range at the very beginning of the log to obtain a mean value between 16 and 28 m. Because this depth range has been geologically recognized as a single layer, the stable value of $75 \mu\text{s}/\text{ft} = 4.06 \text{ km/s}$ from 28 to 36 m is taken and applied to the entire layer.

Sandy lenses (36–82.5 m) Here again the signal has a wide range of values. But since the first 25 m and the last 15 m are in the same range, a value is taken from those extremes and decreased by 0.2 km/s to compensate for the lower velocity of the middle part. This layer appear to be a low velocity zone.

Red marl (82.5–113 m) and marl sequence (113–177.5 m) Mean values are easily determined.

Limestone with Traces of Bitumen (177.5–252.5 m)

The upper boundary of this formation is difficult to find on the logs (177.5m), but once this depth is known from the core sampling, the velocity is fairly well defined.

Lower Marls (252.5–465 m)

Silty grey clay bed (252.5–282.5 m) The velocity is close to the previous formation, but rather well defined.

Log 2 (280 to 1000 m)

Lower Marls (252.5–465 m)

Sandy limestone (282.5–327.5 m), red marls (327.5–415 m) and marl sequence (415–465 m) The signal is good. The layers appear homogeneous as their variation seems uniformly distributed. Mean velocities are easy to determine.

Anhydrite (465–879.5 m)

The response of the anhydrite material is very homogeneous as evidenced by only small oscillations around the mean velocity. However at 505, 550–560, 580–595, 750–760, and 795–800 m we can clearly see significant heterogeneities. These are expressions of the presence of lenses. Such lenses, probably consisting of embedded marls, are likely to be small as they do not appear at the same depths and with the same thicknesses in other nearby boreholes (Geostock, 1976). Therefore, they are ignored in the velocity model.

Salt (879.5–1000 m)

The salt layer appears essentially homogeneous below 900 m. The first few meters probably show some effects due to anhydrite.

Log 3 (1780 to 1894 m)

Salt (879.5–1000 m)

Bottom of the salt layer (1780–1822 m), still very homogeneous.

Sub-salt (>1822 m)

Beginning (1822–1894 m) of the subsalt formation (total thickness unknown). Although the mean velocity of the salt and the subsalt layers are close, they can be

easily distinguished from each other because of the very good stability of the velocity measurements within each layer.

Density

The density model was established using log 4 (Appendix B). This log is a composite one obtained by averaging over all of the density logs that have been made in the area of the storage site. The different formations are thus no longer simply identified by depth, as log 4 is not specific to the borehole of interest, but with the name, relative thickness and succession of layers. In the following paragraph, those formations will be referred to by their corresponding velocity log depth for easier understanding by the reader.

Montfuron Limestone (0–16.5 m)

At the top of the density log the surface density appears to be decreasing somewhat with depth. For simplicity, and because the velocity model in this layer is not well known, the density is assumed constant in this layer and equal to 2.30 g/cm^3 (log 4 of Appendix B).

Upper Marls (16.5–36 m ; 36–82.5 m ; 82.5–113 m ; 113–177.5 m)

The density log has rather wide ranges of values in those formations, but seems to be equally distributed on both sides of the mean.

Limestone with Traces of Bitumen (177.5–252.5 m), Lower Marls (252.5–465 m), Anhydrite (465–879.5 m) and Salt (879.5–1822 m)

The density log is probably disturbed by local lenses. Such lenses (which are probably small) are ignored and the mean of the base level is taken as the density value.

As the density log varies wildly in the transition zone (zone between the salt and the sub-salt formations that appears on several boreholes), but the velocity log (see above) is rather constant under the salt layer, it is assumed that there is no transition zone on the studied borehole and the value of the subsalt formation is allocated to the layer starting at 1822 m.

A summary of velocity and density models is shown in Table 2.

Description		Depth	Thickness	Density g/cm ³	P-wave velocity
Limestone of Monfuron		0 to 16.5 m	16.5 m	2.30	?
Marls		16.5 to 36 m	19.5 m	2.35	4.060 km/s
	Red marl	36 to 82.5 m	46.5 m	2.45	2770 km/s
		82.5 to 113 m	30.5 m	2.45	4.350 km/s
		113 to 177.5 m	64.5 m	2.45	3.590 km/s
Limestone with bitumen traces		177.5 to 252.5 m	75.0 m	2.55	3.810 km/s
Marls		252.5 to 282.5 m	30.0 m	2.50	3.300 km/s
	Red marl	282.5 to 327.5 m	45.0 m	2.45	3.050 km/s
		327.5 to 415 m	87.5 m	2.53	3.390 km/s
		415 to 465 m	50.0 m	2.53	3.810 km/s
Anhydrite formation		465 to 879.5 m	414.5 m	2.65	5.540 km/s
Salt formation		879.5 to 1822 m	942.5 m	2.15	4.690 km/s
Sub salt formation		1822 to 1894 m	72.0 m	2.60	4.510 km/s

Table 2

II) Superplane

1) Program description

Superplane is a program that calculates the response of a stack of layers to a P or S_V or $P+S_V$ plane wave incident from below with a given ray parameter and frequency content. All internal reflections and wavetype conversions are included and the free surface can be bounded by either air or fluid. The program is completely based on Kennett's (Kennett, 1983) generalized equations (Aki & Richards, 1980).

To summarize the modeling technique :

- ◆ horizontal layers
- ◆ uniform properties throughout each layer
- ◆ isotropic, homogeneous, elastic material in each layer
- ◆ each layer is characterized by its body wave velocity V_p , its shear wave velocity V_s , its attenuation coefficients Q_p and Q_s , its thickness, and its depth
- ◆ the excitation is for plane waves (the approach is therefore two dimensional as there is no lateral variation in the layers)
- ◆ the source wave is upcoming with a given ray parameter [$p = \sin(i_c)/V_p$ where i_c is the angle between the ray path and the vertical]
- ◆ the excitation is band limited
- ◆ the source spectrum is white and zero phase
- ◆ the calculation uses Kennett's (1983) technique
- ◆ the calculation is made over a specified frequency range and increment
- ◆ the calculation is performed over a specified depth range and increment
- ◆ the physics is linear therefore only the input frequency can appear in output for each calculation

Inputs

- ◆ V_p , V_s , Q_p , Q_s , thickness, depth, and density of each layer
- ◆ ray parameter
- ◆ minimum and maximum frequencies, and the frequency increment
- ◆ minimum and maximum depths at which to evaluate the seismic response and the depth increment
- ◆ type of input wave (P or S)

Outputs

- ◆ horizontal (U_x) and vertical (U_z) displacement calculated for each frequency and at each depth
- ◆ shear (T_{zx}) and normal (T_{zz}) stress calculated for each frequency and at each depth

Limitations

- ◆ no scattering
- ◆ no surface waves
- ◆ Q independent of frequency (no dispersion)
- ◆ no topographic effects
- ◆ constant amplitude of the source over all the considered frequencies
- ◆ not taking into account the magnitude of the earthquake $\rightarrow$ no absolute values in output
- ◆ linear

This program has been successfully tested (Shearer & Orcutt, 1987 ; Aster & Shearer, 1991). The numerous assumption made in this program and its limitations may seem to reduce substantially its applications. Nevertheless, it can simulate most of the principal behaviors such as free surface effect, impedance contrasts, resonances, and trapped waves (Shearer & Orcutt, 1987), and has been successfully used to fit the main features of real data rather well (Shearer & Orcutt, 1987 ; Aster & Shearer, 1991).

In the present study, the main concern is to estimate subsurface wave propagation. Thus, we are not too much concerned with surface waves. All estimates will be normalized by the surface excitation, where absolute values of displacement, velocities and acceleration have been estimated by Geodynamique & Structures (1990).

2) Parameters

Control parameters for the plane-wave simulations were assigned as follows (Table 3, 4 and 5, Figures 2 and 3) :

P-wave velocity thickness and density were estimated from the logs (see above) for all layers except the top 16.5 m. S-wave velocities were calculated from P-wave velocities by assuming a ratio of $\sqrt{3}$ for all layers except for the salt, where the S-wave velocity is known to be 2200 m/s. For the top 16.5 m, two different

models were used.

Depth	Thickness	Density g/cm ³	P-wave velocity	S-wave velocity
0 to 16.5 m	16.5 m	2.30	1.510 km/s	0.880 km/s
16.5 to 36 m	19.5 m	2.35	4.060 km/s	2.350 km/s
36 to 82.5 m	46.5 m	2.45	2770 km/s	1.600 km/s
82.5 to 113 m	30.5 m	2.45	4.350 km/s	2.510 km/s
113 to 177.5 m	64.5 m	2.45	3.590 km/s	2.070 km/s
177.5 to 252.5 m	75.0 m	2.55	3.810 km/s	2.200 km/s
252.5 to 282.5 m	30.0 m	2.50	3.300 km/s	1.900 km/s
282.5 to 327.5 m	45.0 m	2.45	3.050 km/s	1.760 km/s
327.5 to 415 m	87.5 m	2.53	3.390 km/s	1.960 km/s
415 to 465 m	50.0 m	2.53	3.810 km/s	2.200 km/s
465 to 879.5 m	414.5 m	2.65	5.540 km/s	3.200 km/s
879.5 to 1822 m	942.5 m	2.15	4.690 km/s	2.200 km/s
1822 to 1894 m	72.0 m	2.60	4.510 km/s	2.600 km/s

Table 3 : velocity model I

Depth	Thickness	Density g/cm ³	P-wave velocity	S-wave velocity
0 to 1.1 m	1.1 m	2.30	1.510 km/s	0.880 km/s
1.1 to 2.2 m	1.1 m	2.30	1.680 km/s	0.975 km/s
2.2 to 3.3 m	1.1 m	2.30	1.850 km/s	1.075 km/s
3.3 to 4.4 m	1.1 m	2.30	2.020 km/s	1.170 km/s
4.4 to 5.5 m	1.1 m	2.30	2.190 km/s	1.270 km/s
5.5 to 6.6 m	1.1 m	2.30	2.360 km/s	1.370 km/s
6.6 to 7.7 m	1.1 m	2.30	2.530 km/s	1.465 km/s
7.7 to 8.8 m	1.1 m	2.30	2.700 km/s	1.565 km/s
8.8 to 9.9 m	1.1 m	2.30	2.870 km/s	1.665 km/s
9.9 to 11.0 m	1.1 m	2.30	3.040 km/s	1.760 km/s
11.0 to 12.1 m	1.1 m	2.30	3.210 km/s	1.860 km/s
12.1 to 13.2 m	1.1 m	2.30	3.380 km/s	1.955 km/s
13.2 to 14.3 m	1.1 m	2.30	3.550 km/s	2.055 km/s
14.3 to 15.4 m	1.1 m	2.30	3.720 km/s	2.155 km/s
15.4 to 16.5 m	1.1 m	2.30	3.890 km/s	2.250 km/s
16.5 to 36 m	19.5 m	2.35	4.060 km/s	2.350 km/s
36 to 82.5 m	46.5 m	2.45	2770 km/s	1.600 km/s
82.5 to 113 m	30.5 m	2.45	4.350 km/s	2.510 km/s
113 to 177.5 m	64.5 m	2.45	3.590 km/s	2.070 km/s
177.5 to 252.5 m	75.0 m	2.55	3.810 km/s	2.200 km/s
252.5 to 282.5 m	30.0 m	2.50	3.300 km/s	1.900 km/s
282.5 to 327.5 m	45.0 m	2.45	3.050 km/s	1.760 km/s
327.5 to 415 m	87.5 m	2.53	3.390 km/s	1.960 km/s
415 to 465 m	50.0 m	2.53	3.810 km/s	2.200 km/s
465 to 879.5 m	414.5 m	2.65	5.540 km/s	3.200 km/s
879.5 to 1822 m	942.5 m	2.15	4.690 km/s	2.200 km/s
1822 to 1894 m	72.0 m	2.60	4.510 km/s	2.600 km/s

Table 4 : velocity model II

velocity-density model I with gradient

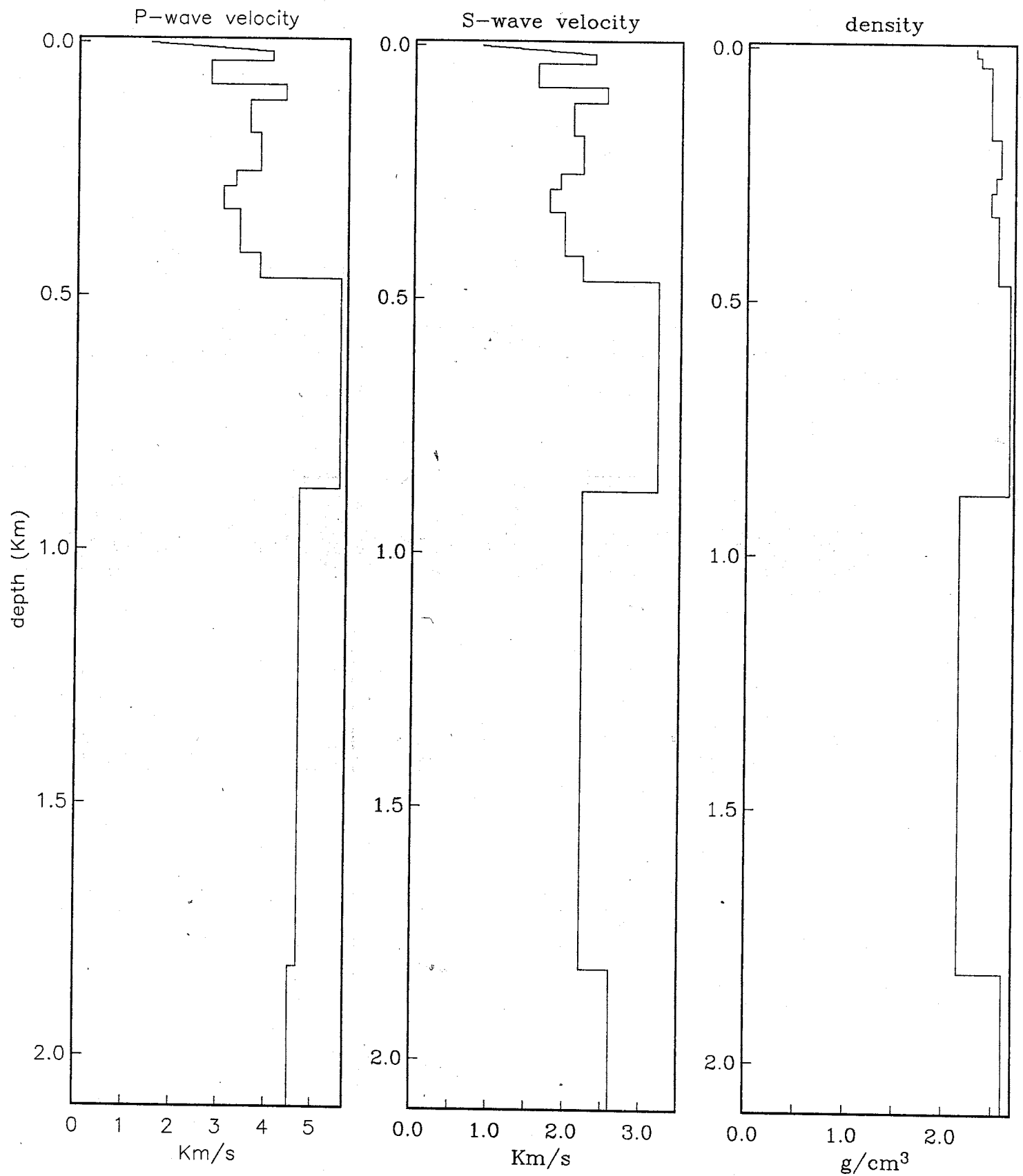


Figure 2

velocity-density model II with layer

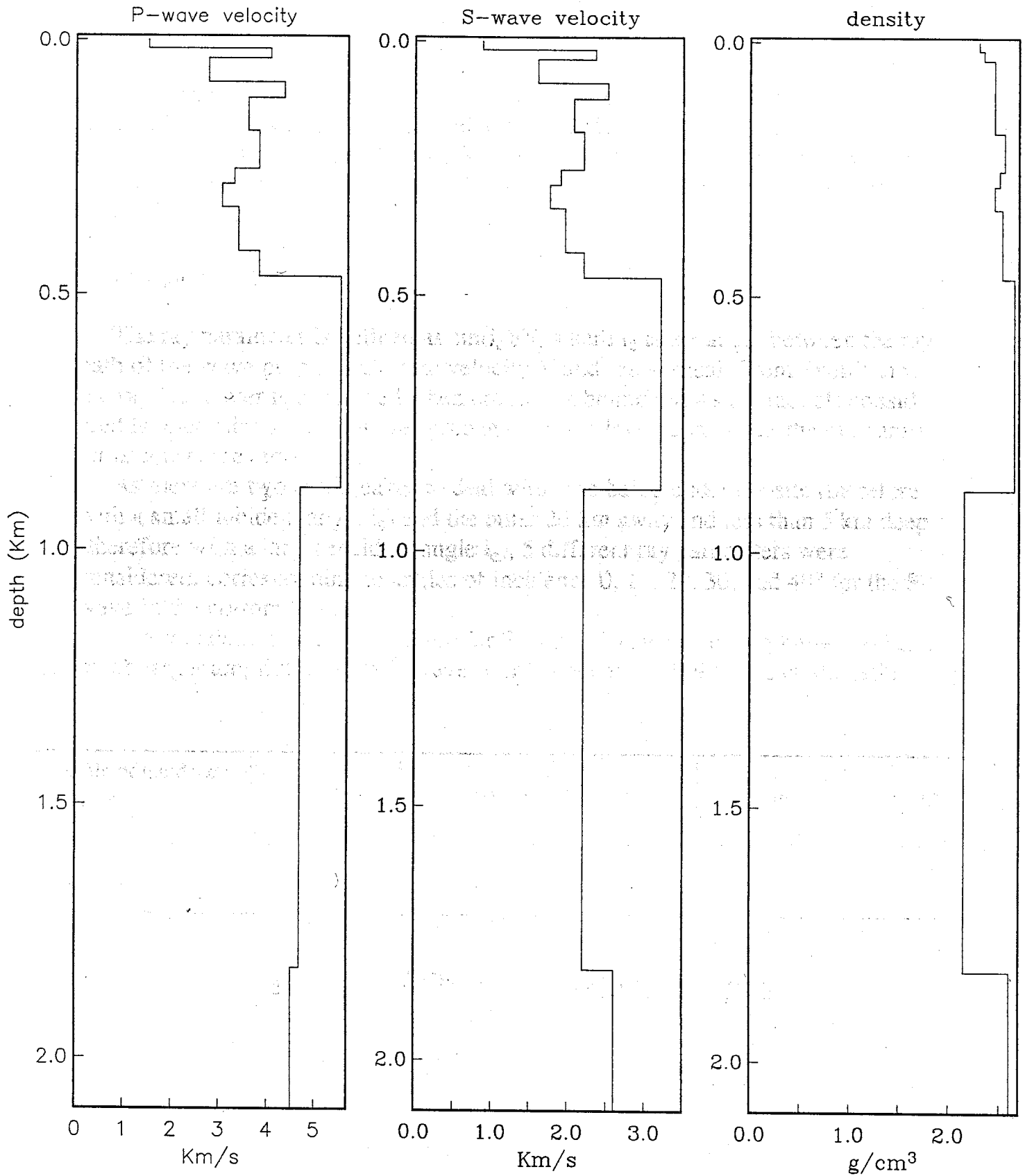


Figure 3

In the first model (velocity model I), a single near-surface layer of thickness 16.5 m was assumed. Its P-wave velocity is $V_p = 1510$ m/s (from Carmichael, 1989), its density of 2.30 g/cm^3 was estimated from the gamma ray-density log (Appendix B), and its S-wave velocity was calculated from V_p assuming a V_p/V_s ratio of $\sqrt{3}$.

In the second model (velocity model II), the top 16.5 m are represented by 11 layers of thickness 1.1 m with the velocity gradually increasing from 1.5 km/s in the top 1.1 m thick layer to 3.89 km/s in the bottom 1.1 m thick layer. The density is assumed constant and equal to 2.30 g/cm^3 throughout these 16.5 m. S-wave velocities are calculated as above.

Ray parameters

The ray parameter is defined as $\sin(i_c)/V$, where i_c is the angle between the ray path of the wave propagating with velocity V and the vertical. From Snell's law, the ray parameter is conserved when crossing a boundary. As the models considered here consist of plane waves propagating in a layered medium, the ray parameter is constant everywhere.

As there are two earthquakes to deal with, one being under the site (therefore with a small incident angle i_c) and the other 20 km away and less than 5 km deep (therefore with a larger incident angle i_c), 5 different ray parameters were considered, corresponding to angles of incidence 0, 10, 20, 30, and 40° for the S-wave in the bottom layer.

The calculations were conducted for S-waves because they are known to have much larger amplitudes than P-waves (Archuleta et al., 1992 ; Liu et al., 1992)

Angle of incidence of the S-wave at the bottom layer	0	10	20	30	40
Ray parameter	0.0000	0.0668	0.1315	0.1923	0.2472

Table 5 : ray parameters, angles

Depths

The 33 depths for which displacements were calculated are :

0, 8, 16, 17, 26, 35, 37, 60, 82, 83, 130, 177, 178, 215, 252, 253, 268, 282, 283, 305, 327, 328, 396, 464, 466, 673, 879, 880, 1090, 1300, 1400, 1600, and 1800 m.

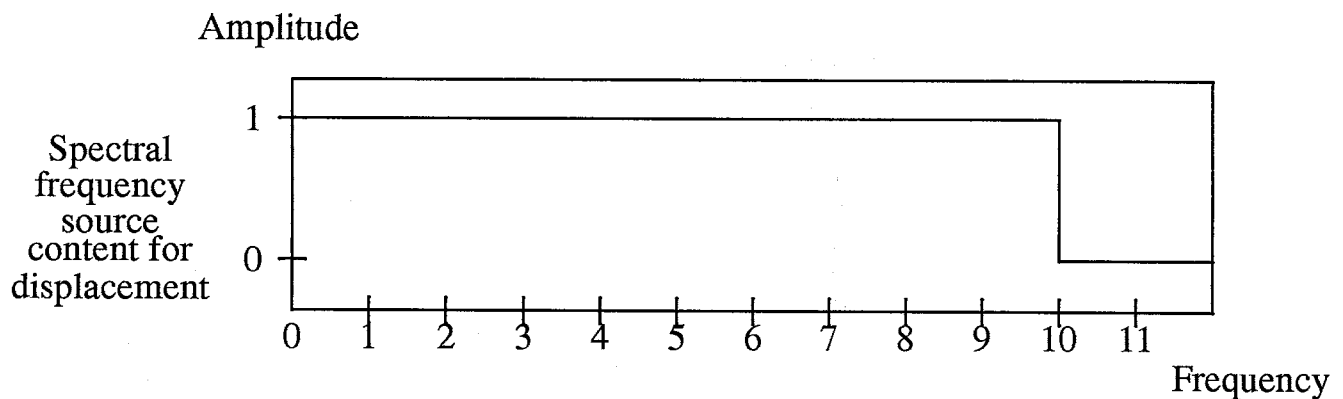
corresponding to the bottom depth, middle depth and top depth of each layer defined in velocity model I (Table 4 ; Figure 3).

Frequency range

In the literature, most authors agree that the spectral content of fault displacement can be reasonably well represented as constant up to a corner frequency f_c , after which the amplitude decreases rapidly. This corner frequency varies with the stress drop and magnitude (Aki & Richards, 1980) of the earthquake, but is generally less than 2 Hz for earthquakes above $M = 4.0$ (Combes et al., 1992 ; Mohammadioun, 1985 ; Aki and Richards, 1980 ; Mohraz, 1976). However, path and site effects can make the strong motion spectrum more broadband.

For earthquakes between $M = 2.8$ and 3.6, a recent study by Liu et al. (1992) in the Marina district of San Francisco shows a displacement spectral content of up to 10 Hz. Archuleta et al. (1992) and Mueller (1985) report a frequency content up to 15 Hz for the source for earthquakes of magnitude less than 5.

The frequency content of the source was taken to be white, zero phase, and band limited.



In this study, due to the linearity of the Superplane program, the choice of the

source frequency content is directly linked to the frequency response of the surface. The calculation is run with a frequency spacing of 0.01 Hz in both cases.

Attenuation factors Q_p , Q_s

As there were no data from the site on either Q_p or Q_s , it was decided to conduct this study for two extreme models. First, we assume typical near-surface values of $Q_s=Q_p=10$ (Aster & Shearer, 1991 ; Carmichael, 1989) for all layers, then we assume typical deeper values of $Q_s=Q_p=300$ (Shearer & Orcutt, 1987 ; Carmichael, 1989) (the smaller the Q value, the larger the attenuation).

3) Results

The results of calculations are shown in Appendix C, D, E, and F in different formats.

Appendix C shows displacement seismogram profiles. In each graph, the displacement (either U_x or U_z) is represented at different depths. The time axis has the same origin for all depths. Synthetic seismograms were calculated from the displacement output of Superplane by taking the inverse Fourier transform of the spectrum windowed by a cosine taper. Amplitudes are unnormalized, thus, only the relative shape of the seismograms is significant.

Appendix D shows the maximum displacement, velocity, and acceleration as a function of depth. Maximum values are calculated from the time series previously obtained (Appendix C) and normalized to 1 at the surface.

The maximum displacement in the time domain is the maximum value of the corresponding time series.

$$\text{Displ}_{\max}(d) = \frac{\max_n (|U_n(d)|)}{\max_n (|U_n(0)|)}$$

where $U_n(d)$ is the amplitude of the displacement at step time n , and depth d , and $U_n(0)$ is the displacement amplitude at the surface.

The maximum particle motion velocity is estimated as the maximum absolute difference between two consecutive values of the time series.

$$Vel_{\max}(d) = \frac{\frac{n}{\text{MAX}(|U_n(d) - U_{n-1}(d)|)}}{\frac{n}{\text{MAX}(|U_n(0) - U_{n-1}(0)|)}}$$

The maximum acceleration is evaluated as follows :

$$Acc_{\max}(d) = \frac{\frac{n}{\text{MAX}(|U_n(d) - 2 U_{n-1}(d) + U_{n-2}(d)|)}}{\frac{n}{\text{MAX}(|U_n(0) - 2 U_{n-1}(0) + U_{n-2}(0)|)}}$$

Appendix E gives the calculated maximum values.

Appendix F shows displacement spectral amplitudes for a white, zero phase source spectrum with a frequency content of 0 – 10 Hz.

Discussion

Seismogram profiles

The different effects of the two extreme Q models ($Q_s=Q_p=10$ and $Q_s=Q_p=300$) can be seen in Appendix C. As a example, we can compare the relative amplitude of a reflected wave to that of the incident wave at depth 1800 m on the first two seismogram profiles (vertical incidence). In the first one, the surface reflected wave has almost disappeared around 3.6 s, whereas in the second one the it can be recognized easily.

The different propagation velocities of P and S waves can also be seen in Appendix C. For example, for ($U_z, 20^\circ$, gradient, $Q=10$) we can see a large down-kick going from 2.05 s at 1800 m to about 2.7 s at the surface, and another down-kick starting at 1.95 s at 1800 m (just before the large one) and reaching the surface around 2.3 s. The low velocity down-kick (the large one) is an S-wave, while the other one is a P-wave. As the input wave is a pure S-wave, the upcoming P-wave is a S-to-P conversion at the lower salt layer boundary (depth 1822 m).

The free surface effect (the amplitude at the free surface is twice that at depths greater than about one wavelength ; Shearer and Orcutt, 1987) can clearly be seen

for Q values of 300, for example, in the profiles for (Ux, 0°, gradient, Q=300 or 10) (Appendix C).

Impedance contrast amplification also can be observed in Appendix C. It is particularly obvious on (Ux, 40°, gradient, Q=300) where an up-down-kick around 2.4–2.5 s doubles its amplitude in propagating from 465 m to 327 m.

The impedance effect arises from conservation of energy. Because the energy of a seismic wave is proportional to $\rho V A^2$ (where A is the wave amplitude, V is the velocity and ρ is the density ; Aki & Richards, 1980), it follows that when a wave is totally transmitted from one material to another, the amplitude of the wave will vary inversely with $(\rho V)^{1/2}$, and thus :

$$A_2 = A_1 \left[\frac{\rho_1 V_1}{\rho_2 V_2} \right]^{1/2} \quad (\text{Shearer \& Orcutt, 1987})$$

At a vertical incident angle (ray parameter $p=0$), the Uz seismogram profile is flat. This was expected because, with $p=0$, the P and S wave are uncoupled, and the input is a pure S-wave, no P-waves are generated.

Comparing layer and gradient model seismogram profiles for a given Q, it seems that there are very few significant differences, if any.

Frequency content (Appendix F)

The frequency content graphs shows a common general trend for all cases.

- At 1800 m the whole frequency spectrum from 0 to 10 Hz is represented in all simulations for both Q values and both velocity models.

- At the surface, the two velocity models still behave nearly identically, but the Q value has a major influence on the frequency content. All graphs at the surface show a decreased amplitude at high frequencies for the lower Q value.

The behavior at 1800 m is not surprising, as the incoming wave consists of just the source signal, disturbed slightly by the interface between the bottom layer and the salt layer. It thus shows a very similar frequency spectrum to the source excitation.

The higher the frequency, the more it is attenuated by low Q material. For higher Q, the general level of the signal at the surface is rather constant. This can be easily explained, as when Q is large, there is almost no attenuation, and the surface frequency spectrum essentially shows the amplifications from resonances occurring within the layers, the free surface effect, and the frequencies that do not reach the surface because they are preferentially reflected downward from boundaries layers.

The reason for calculating the response for frequencies up to 10 Hz was to identify any possible site resonances. For U_x , there is no noticeable resonance for incident angles of 0, 10, and 20°. For an incident angle of 30° there is a small resonance around 7 Hz and another one around 9.7 Hz. Looking at the corresponding seismograms (Appendix C ; U_x , 30°, gradient and layer, $Q=300$) we can identify the associated behavior. On the gradient seismogram the 9.7 Hz resonance is responsible for the small undulations seen on the surface seismogram. As it is not seen on the layer seismogram, it must be associated with the gradient layer itself. Conversely, the 7 Hz resonance can be seen on both seismograms around 415 m and is likely to be produced in this depth range.

For an incident angle of 40° we obtain 3 major peaks for frequencies 5, 8.5 and 9.5 Hz. The 9.5 Hz resonance can be seen on both seismograms (Appendix C ; U_x , 40°, gradient and layer, $Q=300$) in the acausal wiggles to the left of the direct arrival. The 5 Hz resonance is best seen on both seismograms following the direct arrival between depth 465 m and the surface (on the layer model it is hidden by a superimposed 8 Hz signal, which is generated by the surface layer, as it does not appear on the gradient seismogram).

U_z displays the same kind of behavior as U_x . Some small resonances can be observed between 5 Hz and 10 Hz, corresponding to multiple reflections occurring in the top 450 m and vanishing at greater depths.

Maximum displacements, velocities, accelerations relative to the surface (Appendix D)

These graphs also show some general trends. All maximum displacement, velocity, and acceleration graphs (except for the z component at vertical incidence) display the same general shape.

- For $Q_s=Q_p=300$, both layer and gradient velocity models show a constant relative maximum of approximately 0.5 from 1800 m up to about 400 m.

- For $Q_s=Q_p=10$ the relative maximum of both layer and gradient velocity models decreases between 1800 m and about 400 m. In general, the behavior of layer and gradient velocity models are very similar for a given Q .

- The relative maximum is always larger for the gradient velocity model than for the layer velocity model.

As shown above, there is no very large resonance (≈ 12 dB) even for a Q value as high as 300, and the small resonances which do occur are in the top 400 m. Therefore, for a high Q value a quasi-constant maximum level in displacement, velocity and acceleration up to the source corner frequency is expected. The behavior associated with low Q in the maximum graphs comes about as a result of the high

near-surface attenuation. It is not due to a signal increasing with depth, but is instead due to a loss in high frequency content when traveling through low Q, low velocity near surface material. In the field, layers below 400 m are very likely to have Q values significantly larger than 10. As a result, the real behavior is likely to more closely follow the high Q behavior under 400 m, and the low Q behavior in the top 10 to 400 m as shown by experiment (Aster & Shearer – part 2, 1991).

III) Simulation of the borehole behavior

The program that was used for this purpose is described in Yoon and McMechan (1992). This program was made to simulate sonic logs. Sonic logs use a signal that lasts a fraction of a second with frequencies on the order of 20 – 40 kHz (Serra, 1979). For the present study, frequencies are of the order of the unity. For the finite-difference algorithm to converge, it is necessary to have :

$$dt < \frac{dx}{V_{\max} * \sqrt{3}}$$

where dt is the step time, $V_{\max}$ is the maximum velocity and dx the size of a grid element. With $dx = 0.5$ cm, $V_{\max} = 5.5$ km/s the algorithm requires $dt < 5.25 \times 10^{-7}$ s. As the seismic excitation is several seconds long, this represents more than $1 \times 10^{+8}$ steps, or a time on the order of months to run a calculation on a Sun sparc 2 station. For these reasons, detailed simulation using this method will require additional study and access to supercomputer facilities.

Strain estimation

From the seismograms, we can estimate the strain near the borehole, assuming that the borehole does not affect wave propagation (this is true to the first order because the wave lengths of interest are much longer than the borehole diameter). The shear strain ϵ_{xz} is more likely to damage the borehole (Saito et al., 1983). This strain is defined as :

$$\epsilon_{xz} = \frac{\partial U_x}{\partial z}$$

which can be approximated by

$$\epsilon_{xz} \simeq \frac{U_x(z_1) - U_x(z_2)}{z_1 - z_2}$$

where $U_x(z_i)$ is the displacement in the x direction at depth z_i .

In order to obtain absolute values for ϵ_{xz} we must have absolute values for the displacement. To convert the relative values estimated from superplane to absolute values, we need to know only one absolute value, and use it to recalibrate the displacement. From Johnson (1978) and Mohraz (1976) the maximum horizontal displacement expected at the surface for the earthquakes we are dealing with is $U_{max} = 0.08$ m.

Appendix G shows the estimated strain ϵ_{xz} for the different velocity models, Q values and angles of incidence. Again, the behavior of the two velocity models is very similar. The maximum strain occurs in the top 100 m. This is probably due to the influence of the low velocity layer (36–82.5 m), and the surface layer. The maximum estimated strain is 1.5×10^{-3} .

The corresponding maximum shear stress is :

$$\tau = G\gamma = 9 \cdot 10^4 \cdot 1.5 \cdot 10^{-3} = 135 \text{ MPa} \quad (\text{Geo. \& Struc., 1990})$$

which is less than the elastic limit of steel (379 MPa ; Geo. & Struc., 1990).

V) Conclusions

The site structure for the upper 1890 m is well known for P-wave velocities, densities, and layer depths and thicknesses, with the exception of the surface layer. S-wave velocities are not well known except for the salt layer, and a ratio of $\sqrt{3}$ between the P and S velocities is used. As a result of simulations with Superplane, it seems that constraining velocity model for the top 16.5 m is not a major concern, as the results obtained using a gradient model and a single layer model are not significantly different. Nevertheless, the assumption of a surface velocity of 1510 m/sec could be easily checked in the field with a short-range refraction experiment..

For the models considered here, plane-wave simulations show that :

- for an S-wave source with a angle of incidence between 0 and 40°, no significant resonances are expected
- the maximum displacement, the maximum velocity, and the maximum acceleration at depths greater than 400 m are less than half of those at the surface
- the maximum displacement, the maximum velocity, and the maximum acceleration are smaller or at the most comparable to the surface in the top 400 m. The

amplification above 400 m was expected because of the lower velocities and the free surface effect.

This study has neglected the possibility of large surface waves and 3-dimensional effects due to the general anticlinal shape of the site that could result in topographic amplification (Bouchon, 1973). Both effects would increase the surface response and therefore reinforce the above conclusion regarding relative effects at depth.

The 3-D program written by Yoon and McMechan, 1992 that was considered for studying the behavior of an earthquake on the vertical borehole was not usable because of the disproportion between the diameter of the borehole and the wavelength of the excitation.

From the estimation of strain and stress on the borehole, the casing will remain within the elastic limit for the modeled earthquakes.

REFERENCES

- Aki, K. and P. G. Richards (1980). *Quantitative seismology Vol. 1 and 2*, W. H. Freeman, New York.
- Archuleta, R. J., S. H. Seale, P. V. Sangas, L. M. Baker and S. T. Swain (1992). Garney valley downhole array of accelerometers : Instrumentation and preliminary data analysis, *Bull. Seism. Soc. Am.* **82**, 1592–1621.
- Aster, R. C. and P. M. Shearer (1991). High-frequency borehole seismograms recorded in the San Jacinto fault zone, Southern California. Part 1. Polarizations, and Part 2. Attenuation and site effects, *Bull. Seism. Soc. Am.* **81**, 1057–1100.
- Bouchon, M. (1973). Effect of topography on surface motion, *Bull. Seism. Soc. Am.* **63**, 615–632.
- Carmichael, R. S. (1989). *Physical Properties of Rock and Minerals*, CRC Press, Boca Raton, Florida.
- Combes, P., J. Betbeder–Mativet and B. Mohammadioun (1992). Seisme de Spitak – L’événement sismique, rapport AFPS
- Geostock 1976, Synthèse géologique des travaux d’extension du site de stockage de Geosel–Manosque – campagne de forages Manosque II, report, Département Engineering Conception, Service Géologique.
- Geodynamique et Structure (1990), Site de stockage de Manosque, in Projet Geomethane – études Parasismiques, confidential report for Minister de l’Industrie.
- Goguel, J., J. Vogt and C. Weber (1985). La carte sismotectonique de la France, in *le génie parasismique*, V. Davidovici, Presses des Ponts et Chaussées, Paris.
- Johnson, J. A. and M. L. Traubenik (1978), Magnitude dependent near–source ground motion spectra, Earthquake Engineering and Soil Dynamics, Proc. of the ASCE Geotech. Engng. Dir., Specialty Conf., Pasadena.
- Joyner, W. B. and D. M. Boore (1981). Peak horizontal acceleration and velocity from strong–motion records including records from the 1979 Imperial Valley, California, earthquake, *Bull. Seism. Soc. Am.* **71**, 2011–2038.
- Kennett, B. L. K. (1983). *Seismic wave propagation in stratified media*, Cambridge University Press, Cambridge
- Lambert, J (1988). Revision de sismicité historique : les tremblements de terre de 1509 et 1708 dans la moyenne vallée de la Durance, BRGM, note technique SGN/CEG n° 15/88, Marseille.
- Levret A., C. Loup and X. Goula (1986), A new assessment of near field effects. Proceeding of the 8th European Conference on Earthquake Engineering (Lisbone, 7–12 Septembre 1986).

- Levret A., C. Loup and X. Goula (1986), Le seisme de Provence du 11 Juin 1909. Depouille-
ment du dossier inedit du commandant Spiess. Interpretation des observations macro-
scopiques. Rapport DAS n° 284.
- Levret A., C. Loup and X. Goula (1988), Le seisme de Provence du 11 Juin 1909. Observations
macrosismiques en zone proche. AFPS. Les mouvements sismiques pour l'ingenieur, 16
mars 1988.
- Liu, H., R. E. Warrick, R. E. Westerlund, E. D. Sembera and L. Wennerberg (1992). Observation
of local site effect at a downhole-and-surface station in the Marina district of San Fran-
cisco, *Bull. Seism. Soc. Am.* **82**, 1563-1591.
- Mohammadioun B. (1985). Calcul du mouvement du sol - Etat de l'art, in *le genie para-
sismique*, V. Davidovici, Presses des Ponts et Chaussees, Paris.
- Mohraz, B. (1976). A study of earthquake response spectra for different geological conditions,
Bull. Seism. Soc. Am. **66**, 915-935.
- Mueller, C. S. (1985). Source pulse enhancement by deconvolution of an empirical Green's func-
tion, *Geophysical Research Letters* **12**, 33-36.
- Rendon, H. F. and P. M. Davis (1992). Scattering of *SH* waves from a cylinder. Part I, *Bull.
Seism. Soc. Am.* **82**, 1475-1496.
- Saito, K., N. Nishio, and T. Katayama (1983). Earthquake behavior and safety of oil and gas
storage facilities, buried pipelines and equipment - Recommended practice for earth-
quake resistant design of medium and low pressure gas pipelines, 1983 International
Symposium on Lifeline Earthquake Engineering, Portland, Oregon.
- Savage, J. C. (1972) Corner frequency and fault dimensions. *J. Geophys. Res.* **77**, 149-172.
- Serra, O. (1979). *Diagraphies differees - Bases de l'interpretation*, Bull. Cent. Rech. Explor.-
Prod. Elf-Aquitaine, Pau.
- Shearer, P. M. and J. A. Orcutt (1987). Surface and near surface effect on seismic waves -
Theory and borehole seismometer results, *Bull. Seism. Soc. Am.* **77**, 1168-1196.
- Stevens, P. R. (1977). A review of the effects of earthquakes on underground mines, Rept. Dept.
of the Interior, Reston, Virginia.
- Yoon, K. H. and G. A. McMechan (1992). 3D finite difference modeling of elastic waves in
borehole environments. *Geophys.* **57**, 793-804.

Appendix A

Content :

2 geologic maps

Appendix B

Content :

3 sonic logs
1 density log



Origine permanente des profondeurs	T.R.	Elev. : 35
Zéro log.	0	m. au-dessus origine permanente
Zéro Sondeur	0	m. au-dessus origine permanente
		T.R.
		Sol
		Elevation :

Plasma

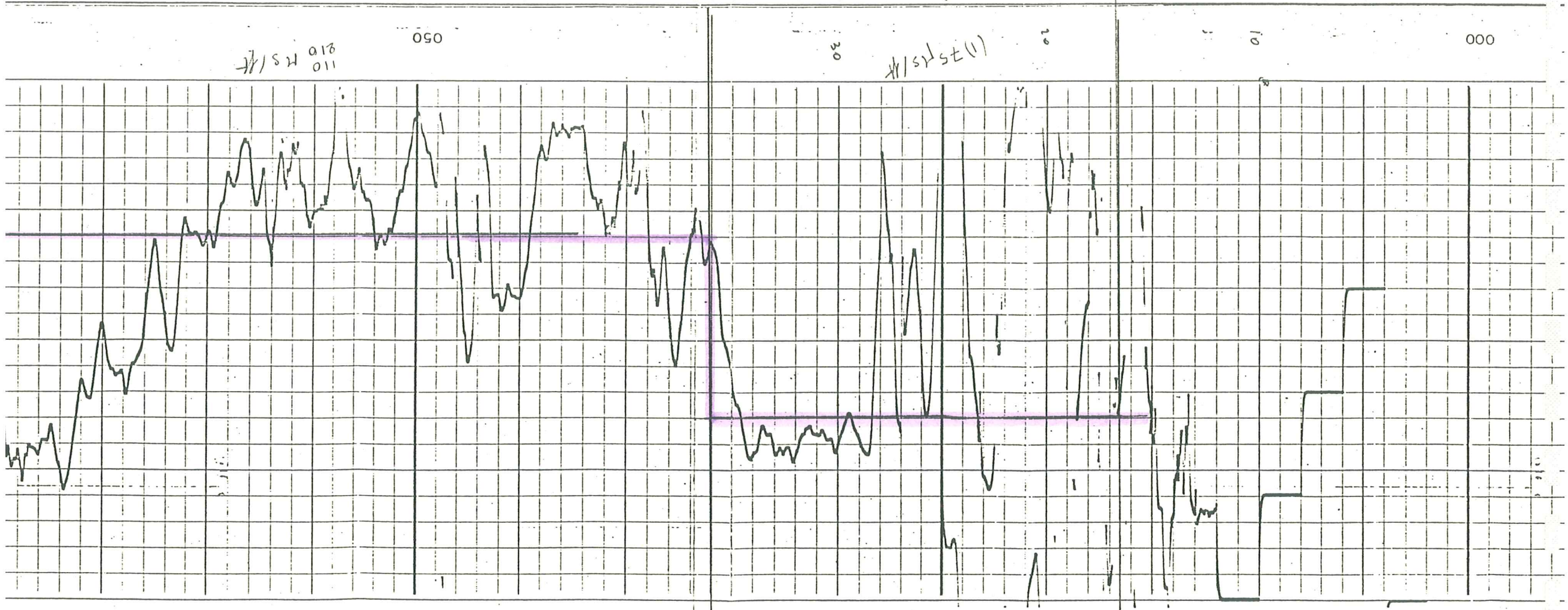
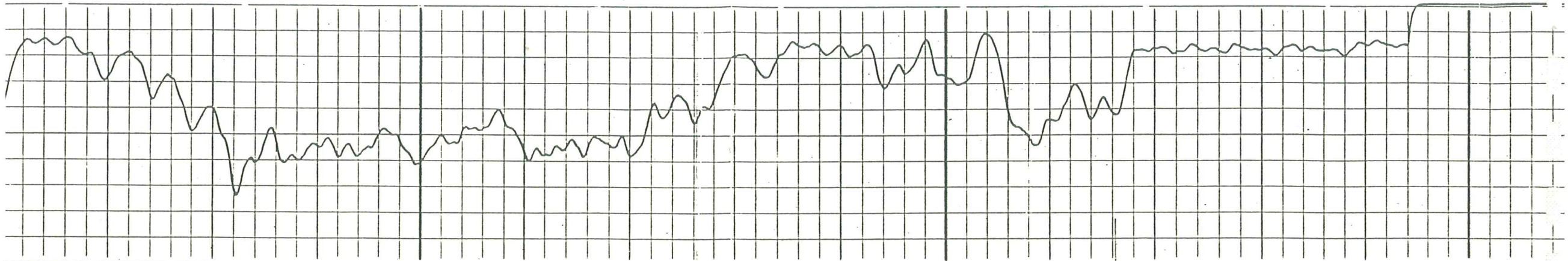
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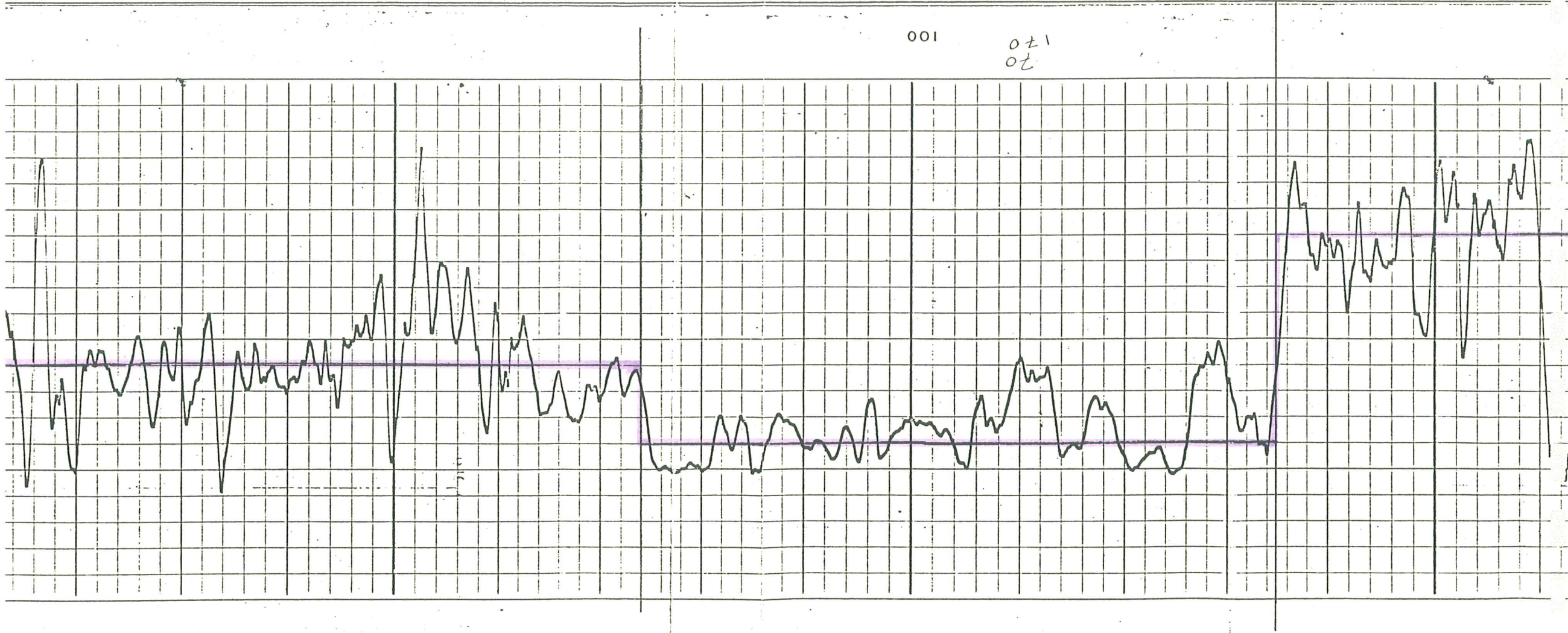
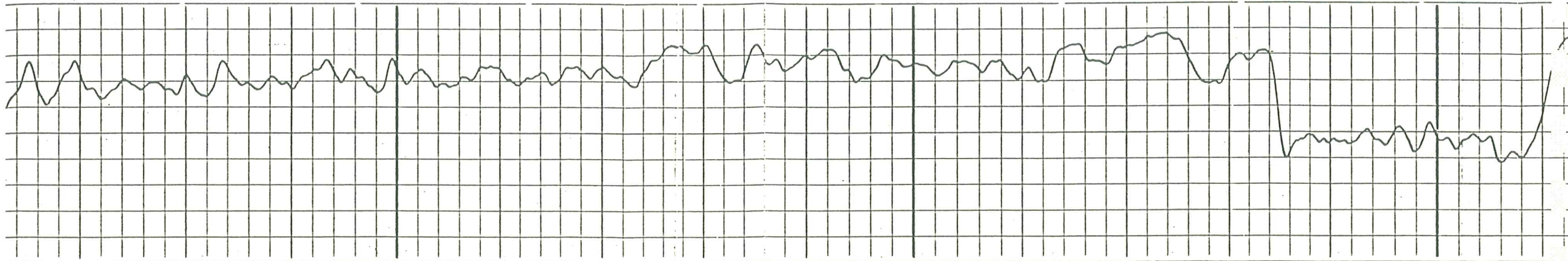
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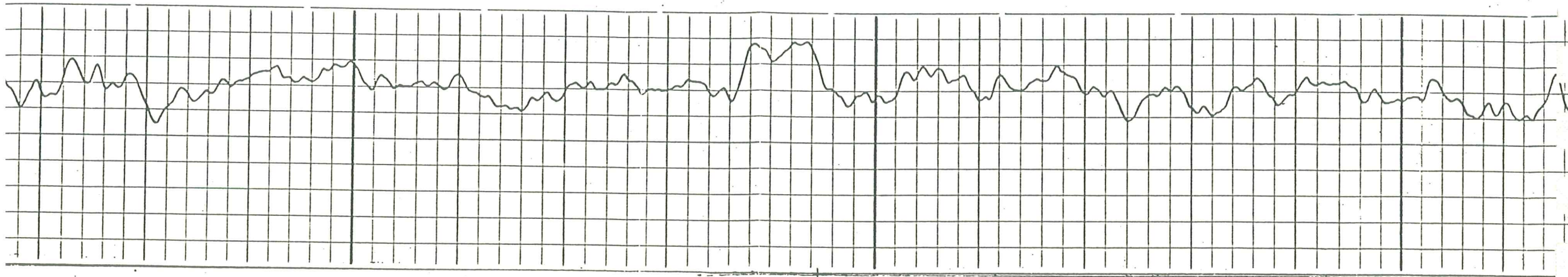
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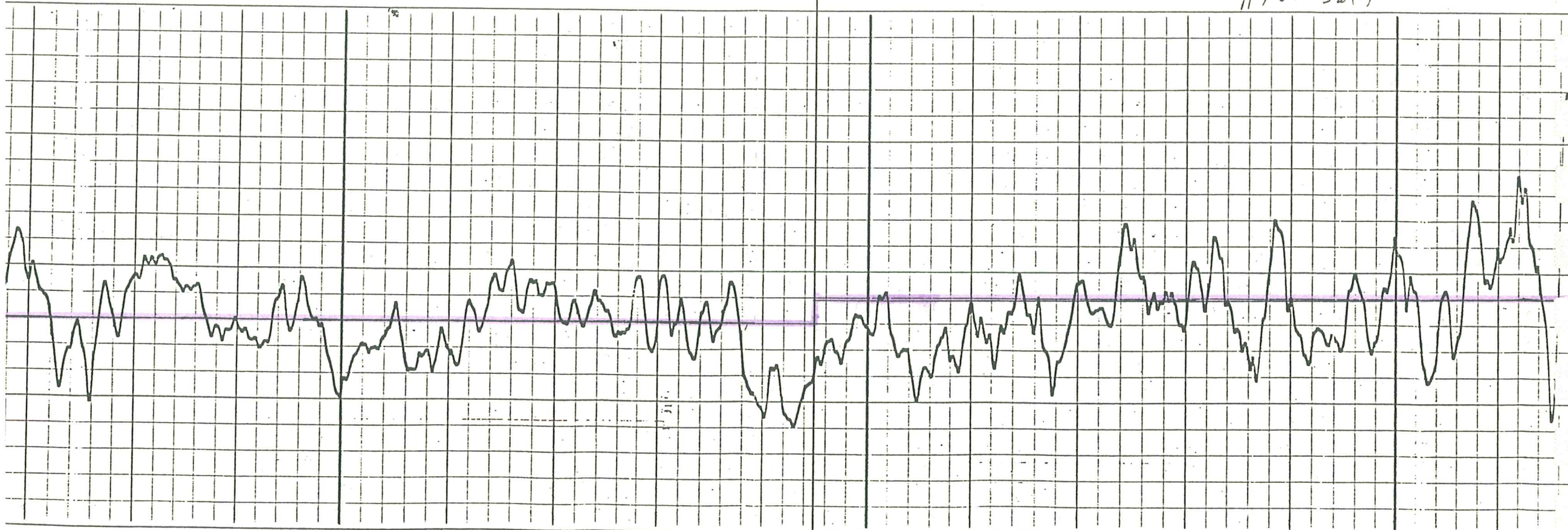


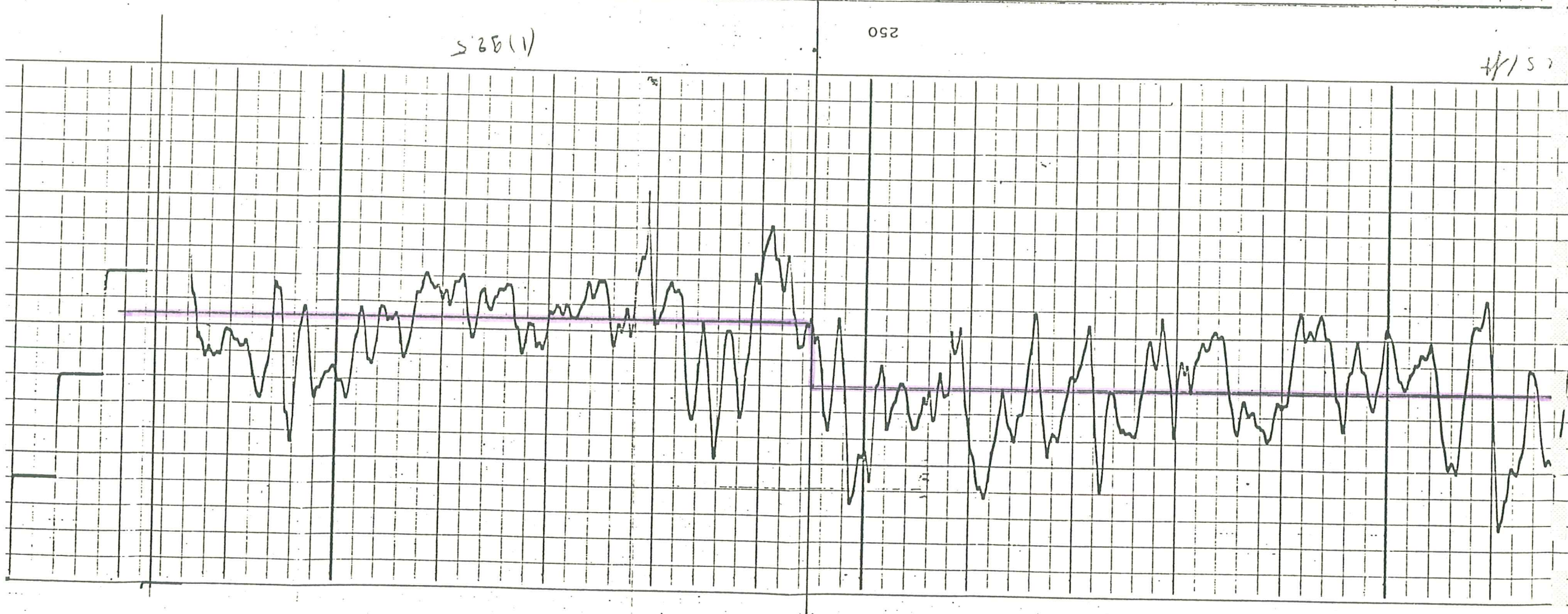
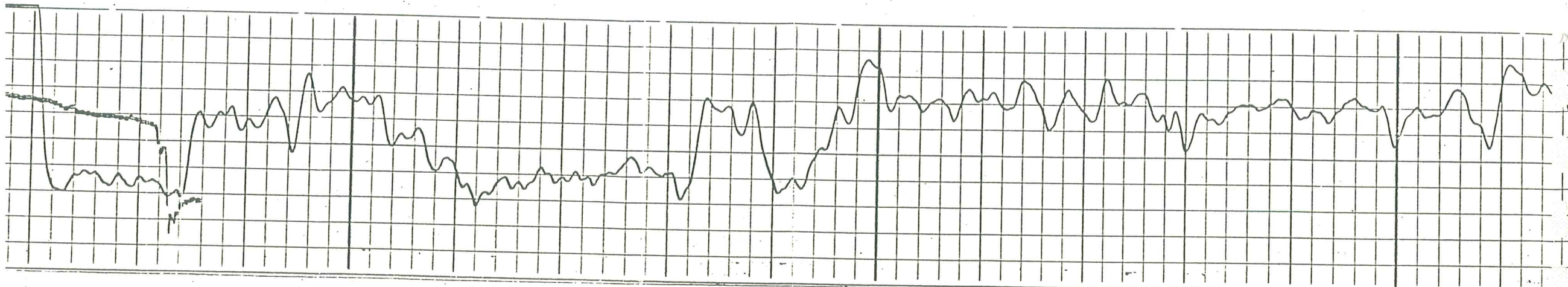
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Origine permanente des profondeurs	T.R.	Élev. :
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Zéro Sondeur	0	m. au-dessus origine permanente
Élev. : K.B.	SOL	T.R.

PL 118-103

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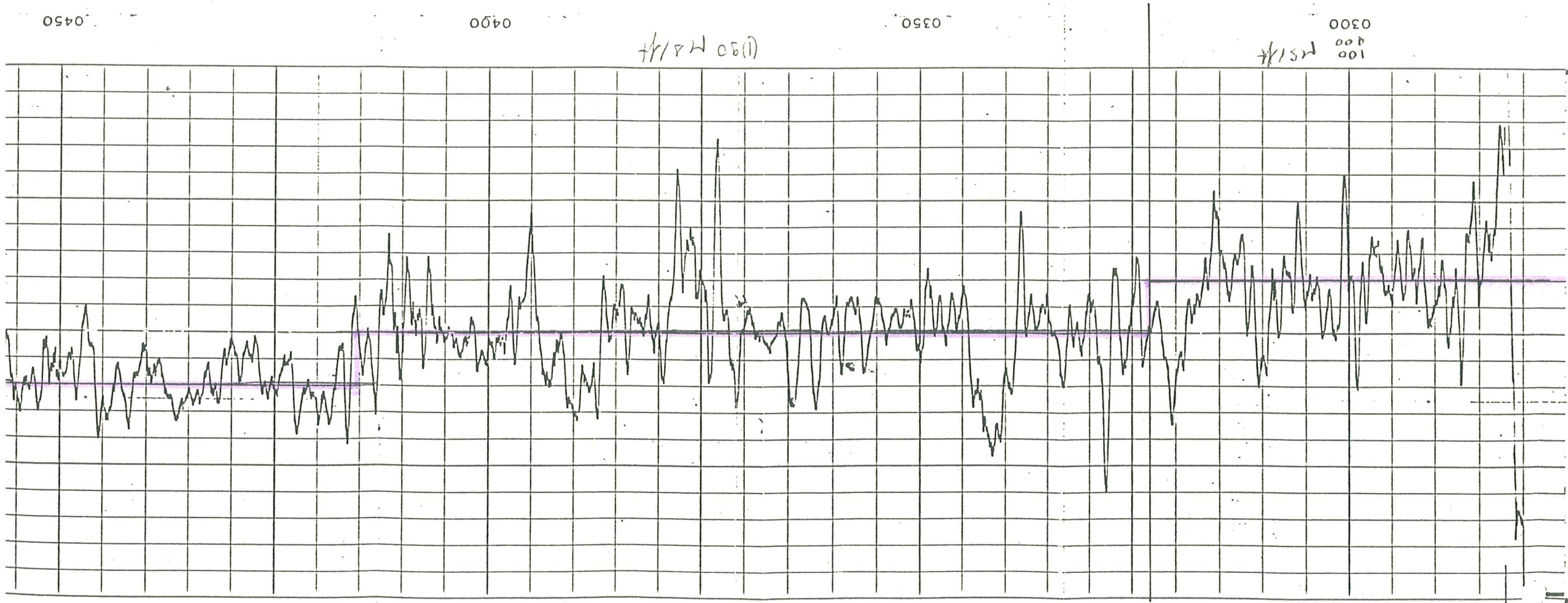
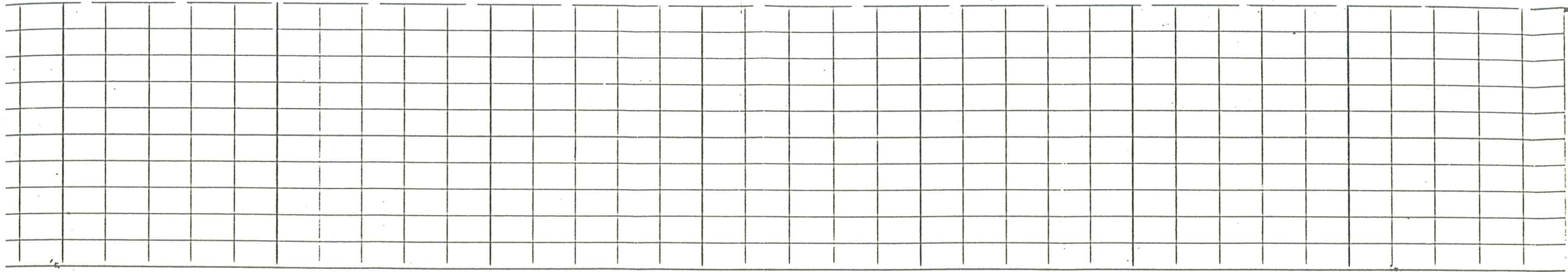
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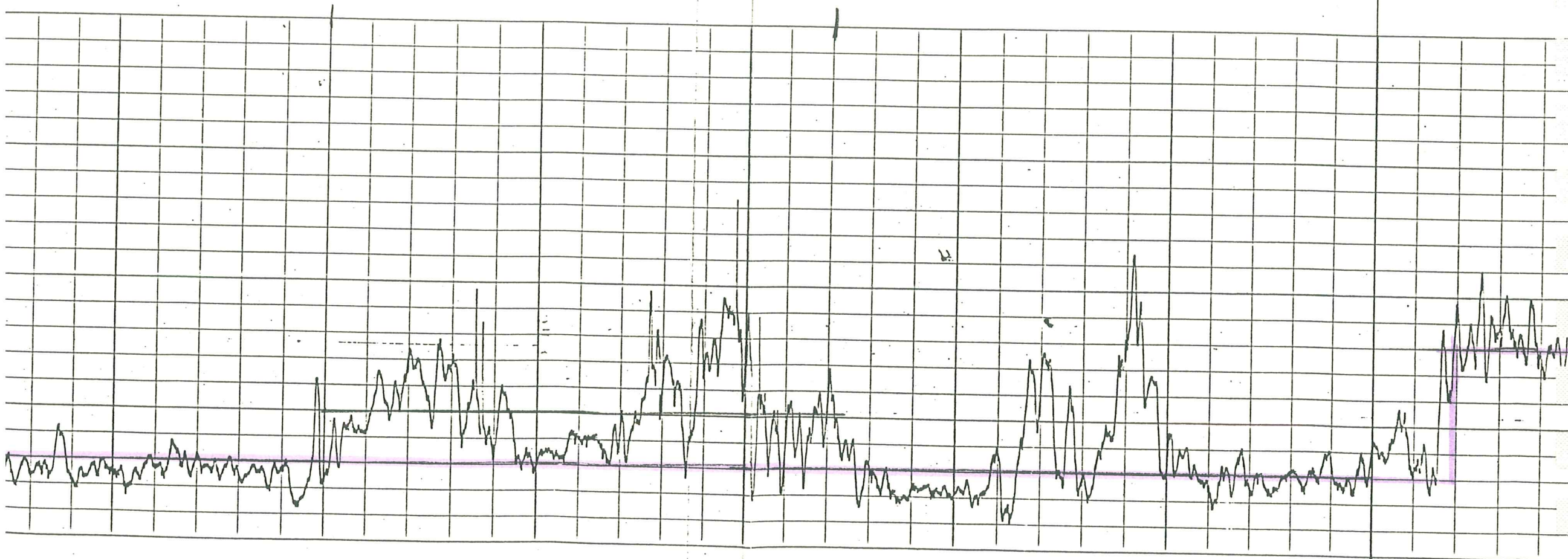
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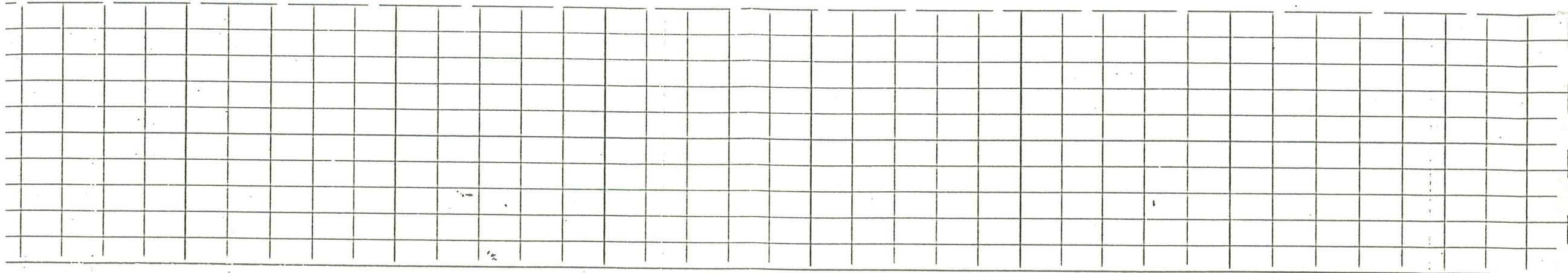


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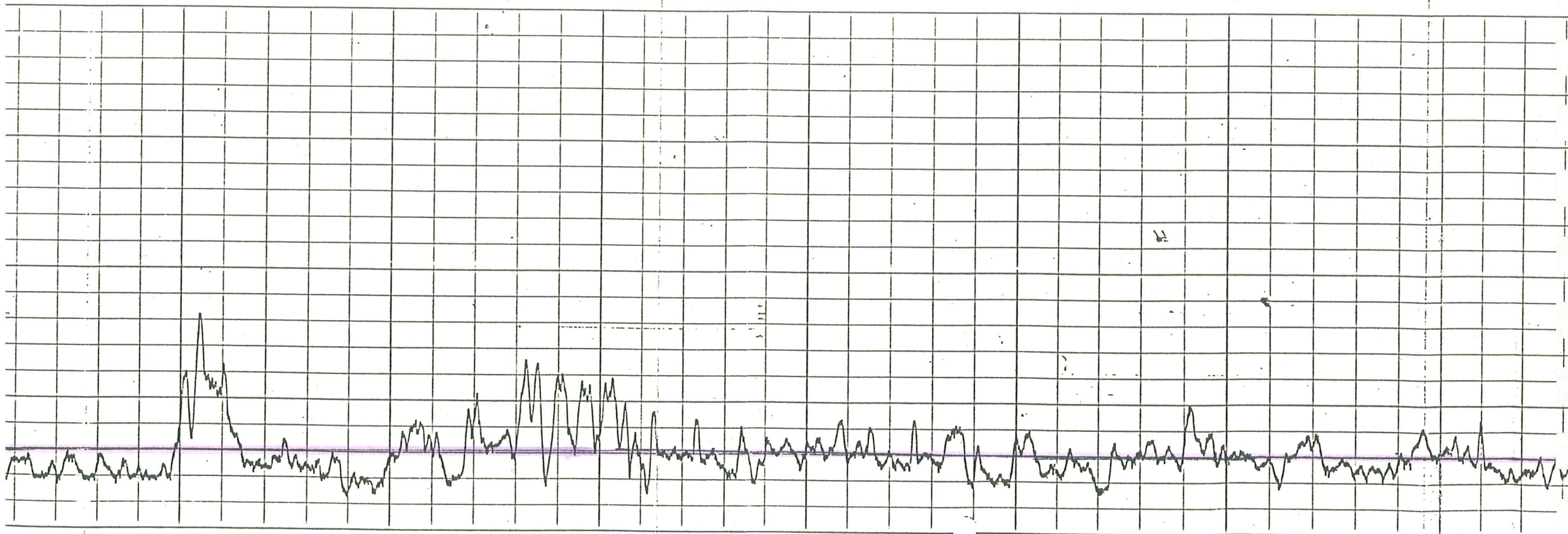


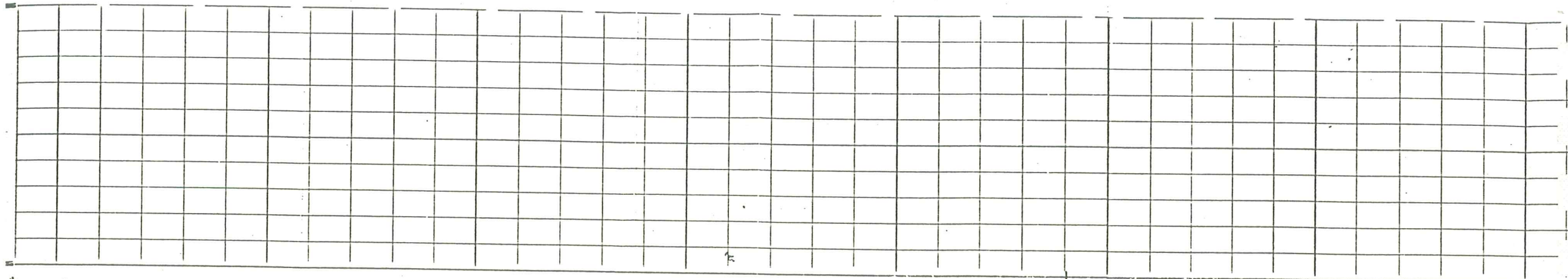
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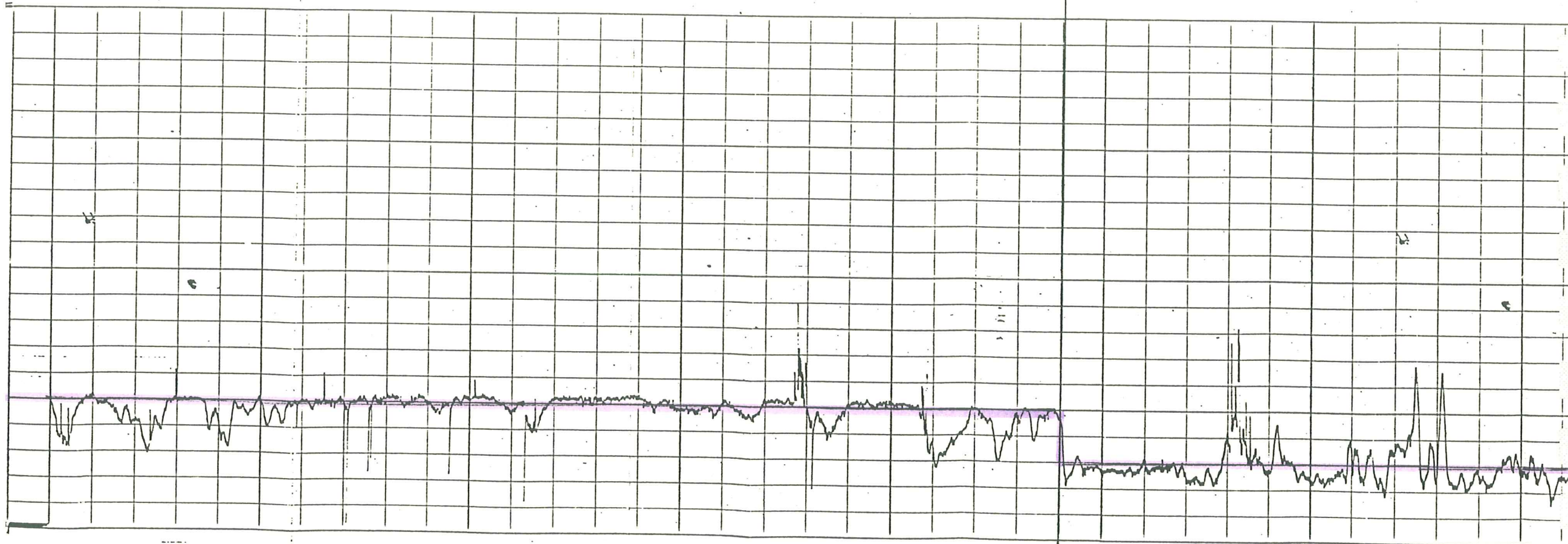


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DEPARTEMENT PROVENCE	
CHAMP MANOSQUE	
SONDAGE MAC EH 26	
COMPAGNIE GEOSOL	
Autres opérations:	
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Origine permanente des profondeurs	T.R.	Elev. :
Zero log	0	m. au-dessus origine permanente
Zero Sondeur	0	m. au-dessus origine permanente
T.R.		
SOL		
Elev. : K.B.		

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Profondeur Log.	1894.0		
Première lecture	1892.0		
Dernière lecture	1772.0		
Sabot Sondeur	932.14		
Sabot Log			
Diamètre trépan	12.14		
Boue : Nature	SALEE		
Densité Viscosité	1.39	42	
pH Eau libre	10.5	7	ml
Origine échant.	CIRCULATION		
Rm Temp. Mesure	0.074	18°C	
Rmf Temp. Mesure	0.043	18°C	
Rmctemp. Mesure	0.070	18°C	
Origine Rmf Rmc			
Rm à Temp. Fond	0.023	10°C	
Temp. après circ.			
Temp. Maximum	59°C		
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Observateur Cie	CARTE		

REMARQUES

Changements de Boue - Echantillons supplémentaires			
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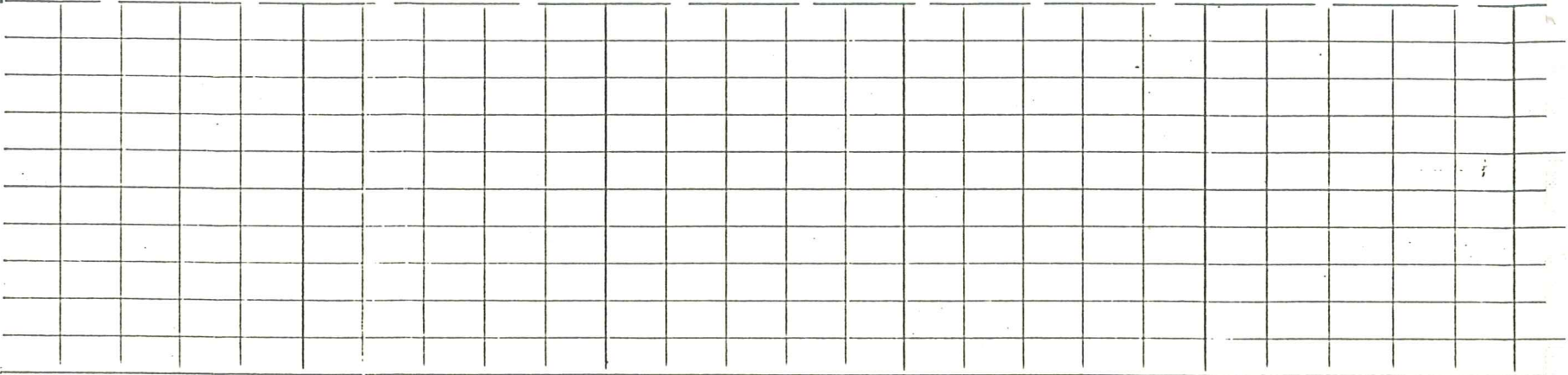
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Diamètre du trou en pouces

INTERVALLE DE TEMPS DE PARCOURS
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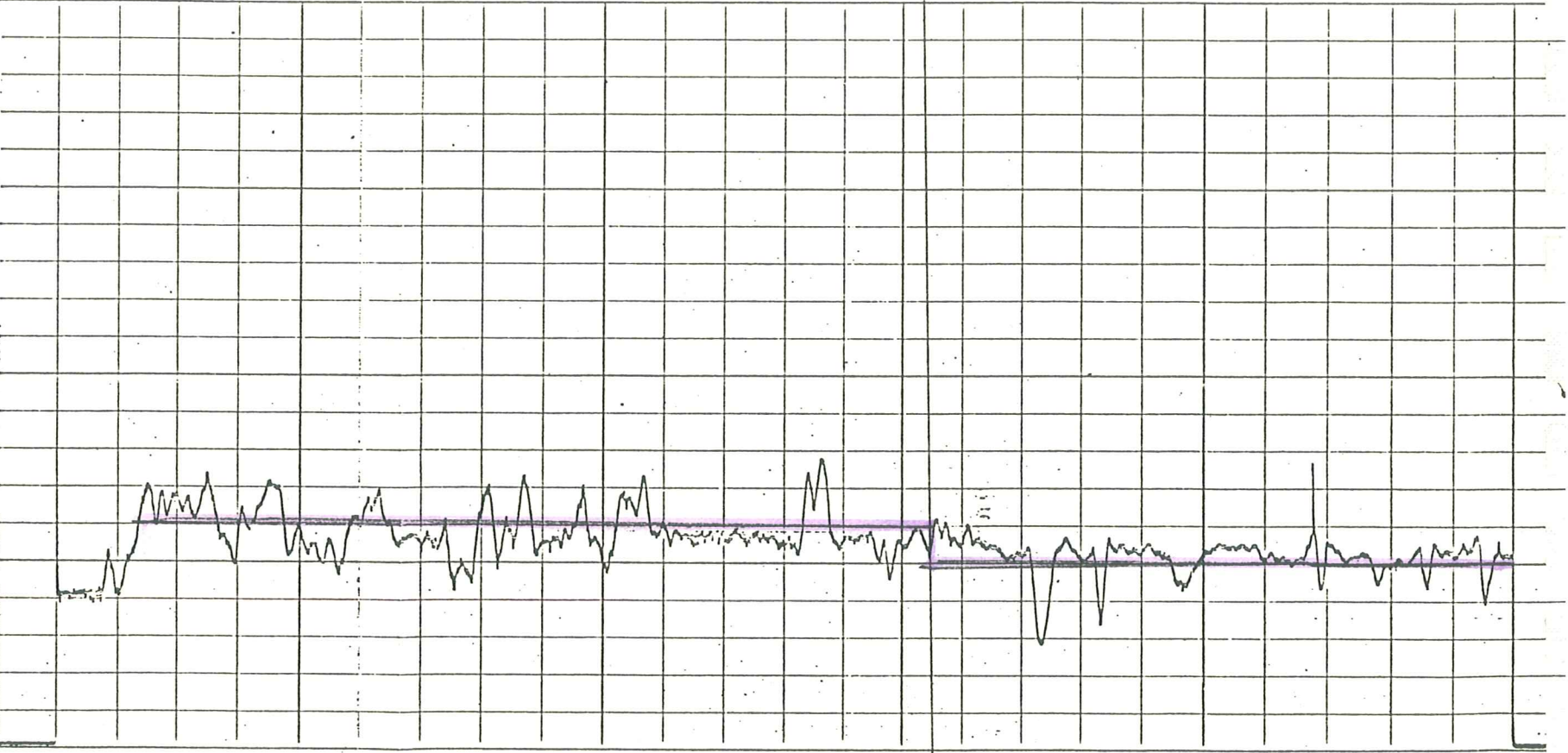
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Diamètre du trou en pouces

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POLARISATION SPONTANÉE
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Profondeurs

INTERVALLE DE TEMPS DE PARCOURS

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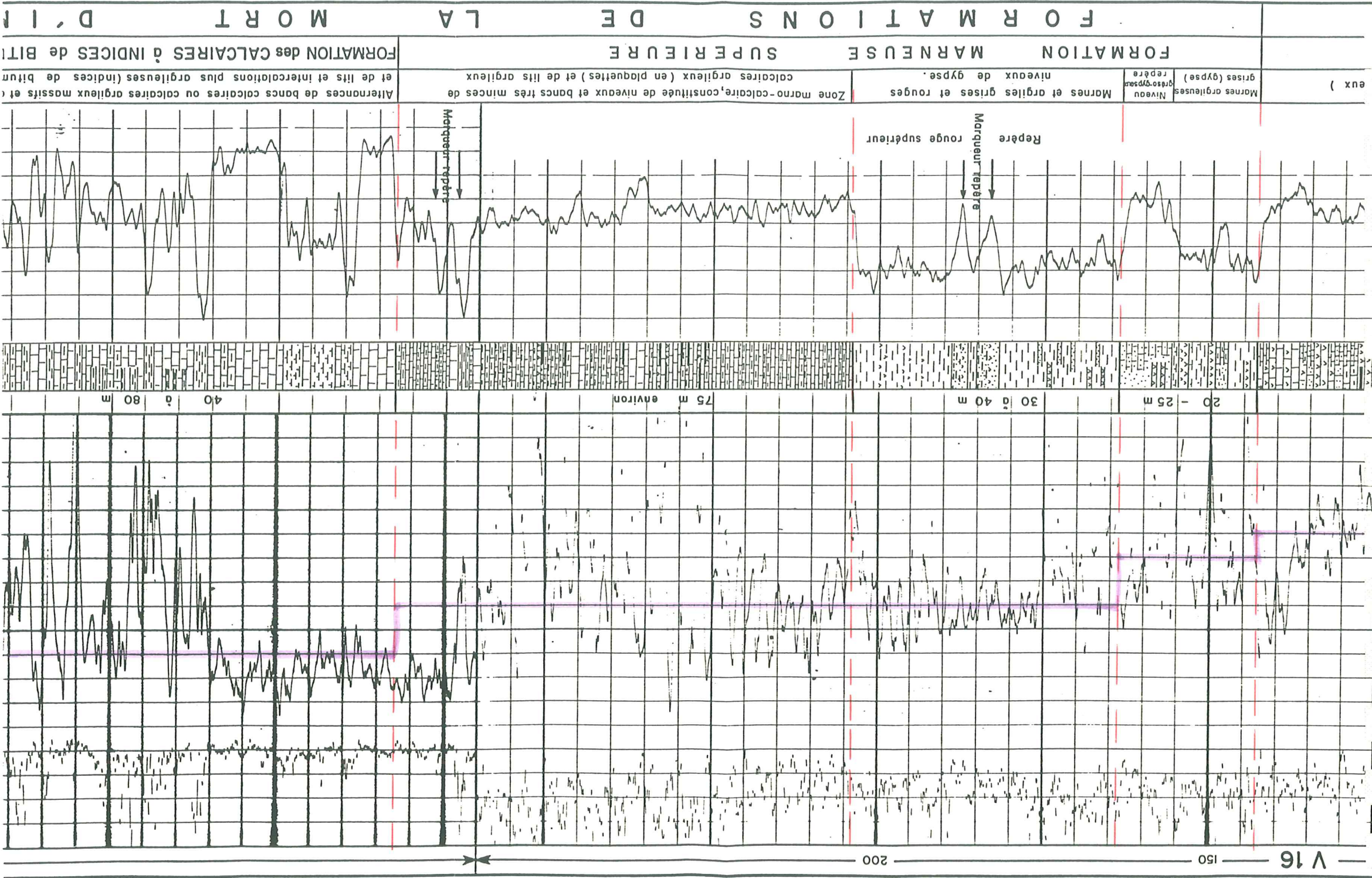
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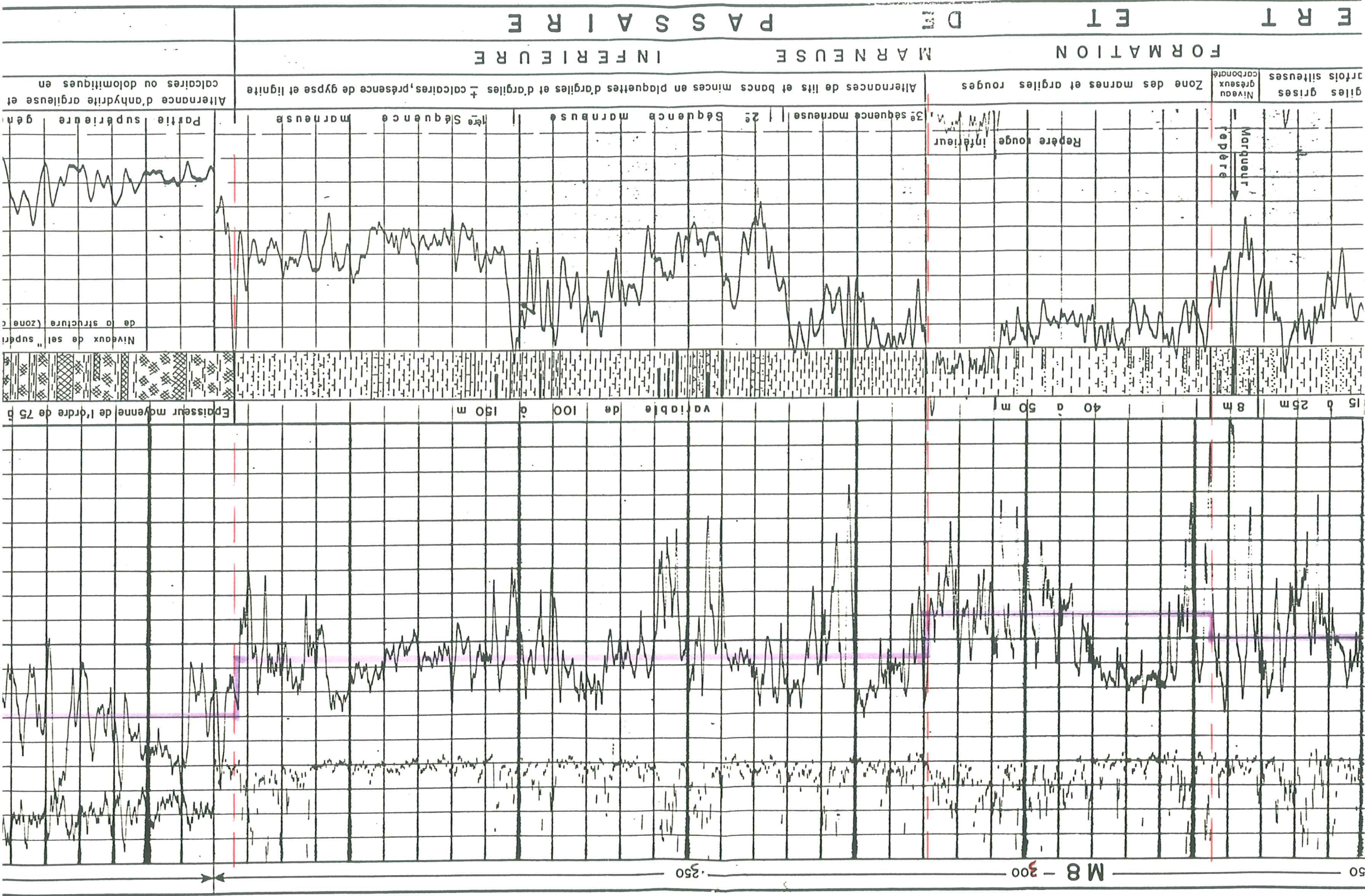
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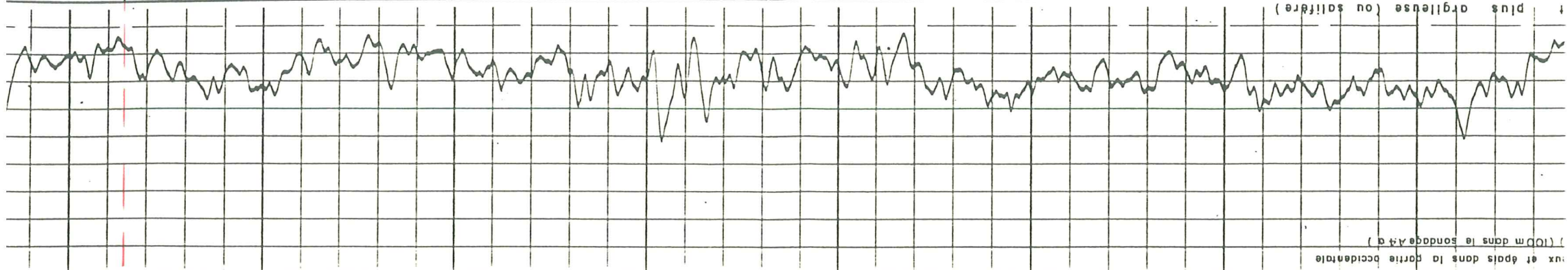
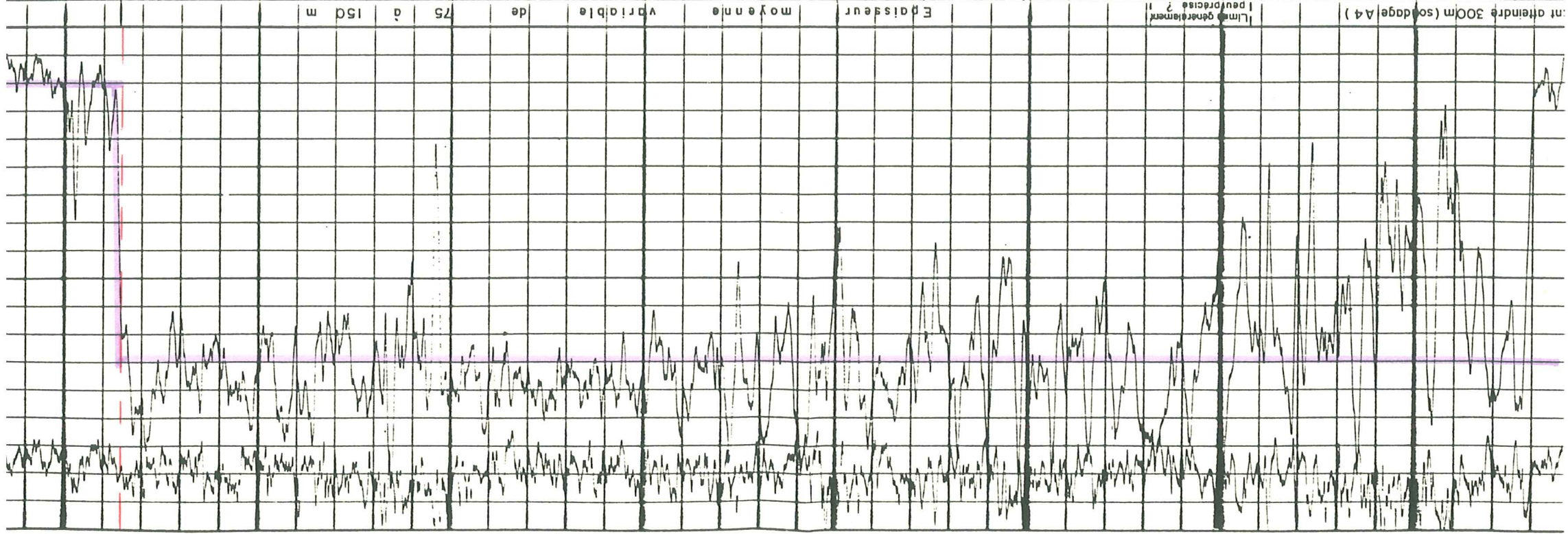
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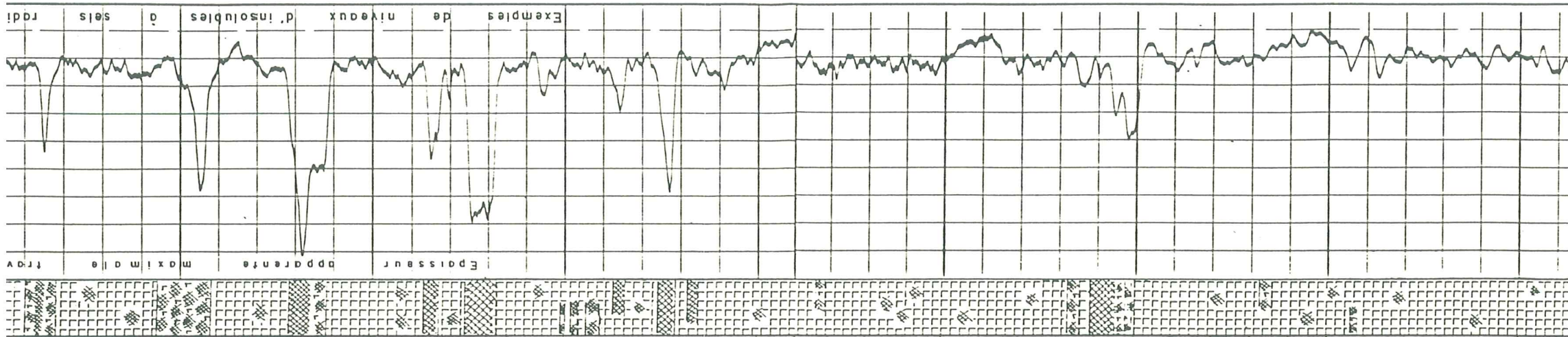
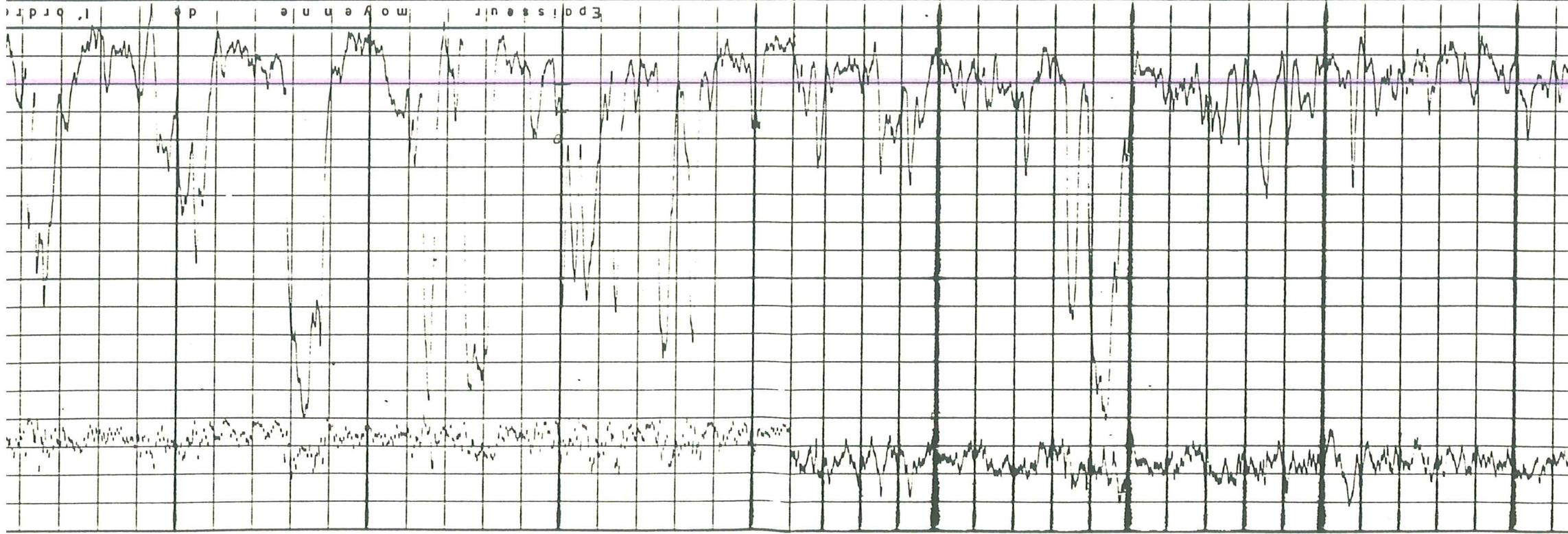
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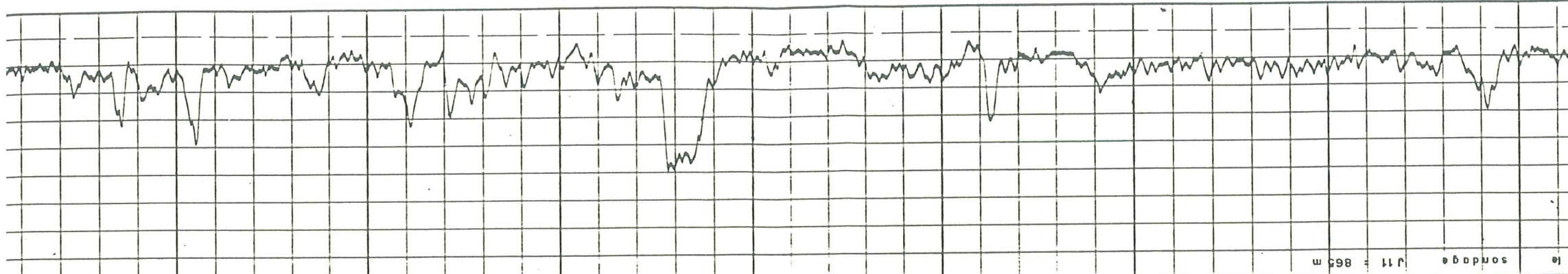
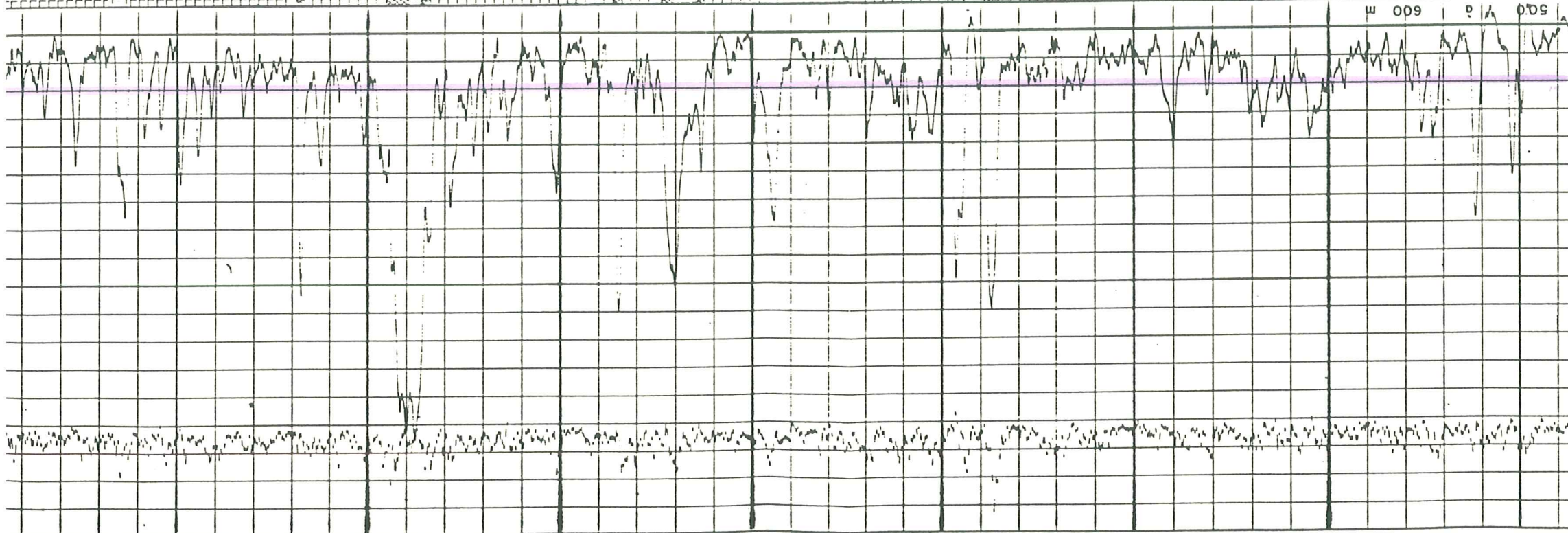


Exemples de niveaux d'insolubles à sels radi

jemme rose à rose - orangé, rarement blanc ou blanc - gris, renfermant de nombreuses inclusions millimétriques à décimétriques d'anhydrite cristalline, gris - clair, por

FORMATION SALIFERE

800 ————— H 13 ————— 850 ————— 900 ————— 950



orgileuses ; nombreux " bancs " métriques d'anhydrite " pseudo - bréchique " , généralement peu argileux (les " rognons " d'anhydrite massive claire sont fréquemment enrobés dans un

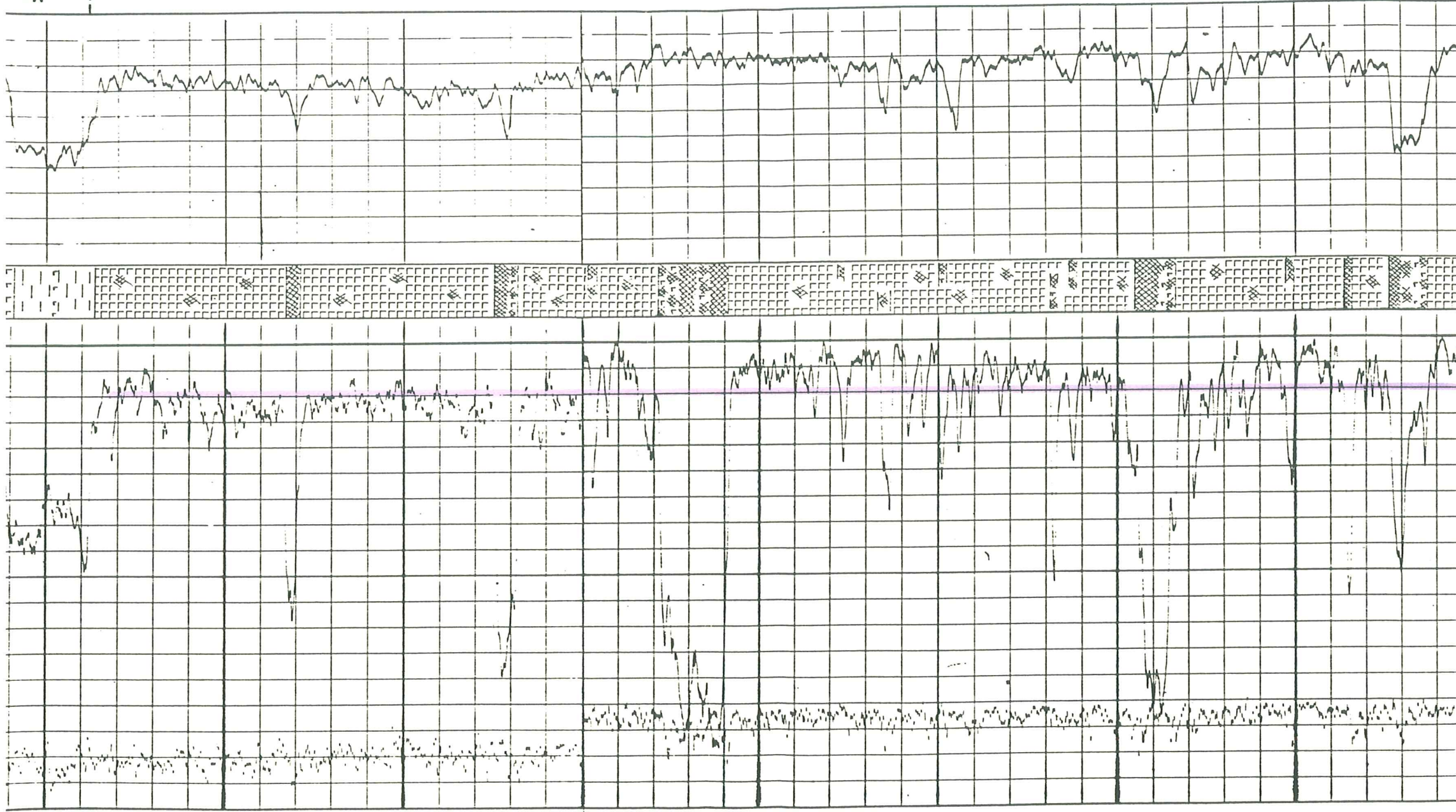
F O R M A T I O N

P 11

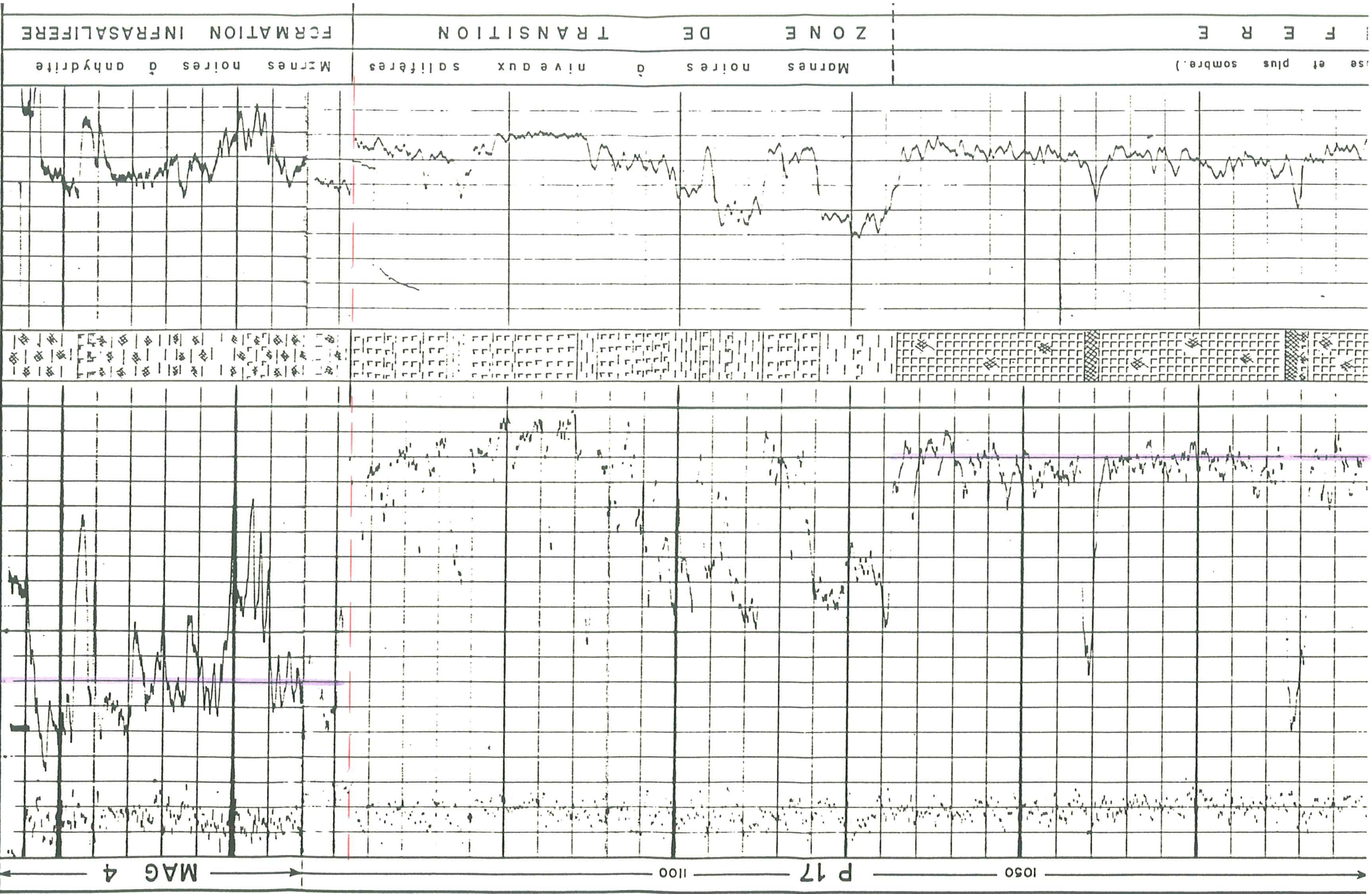
1050

950

900



Mari
argileux (les " rognons " d'anhydrite massive claire sont fréquemment enrobés dans une " gangue " plus argileuse et plus sombre.)
S. A L I F E R E
Z O N



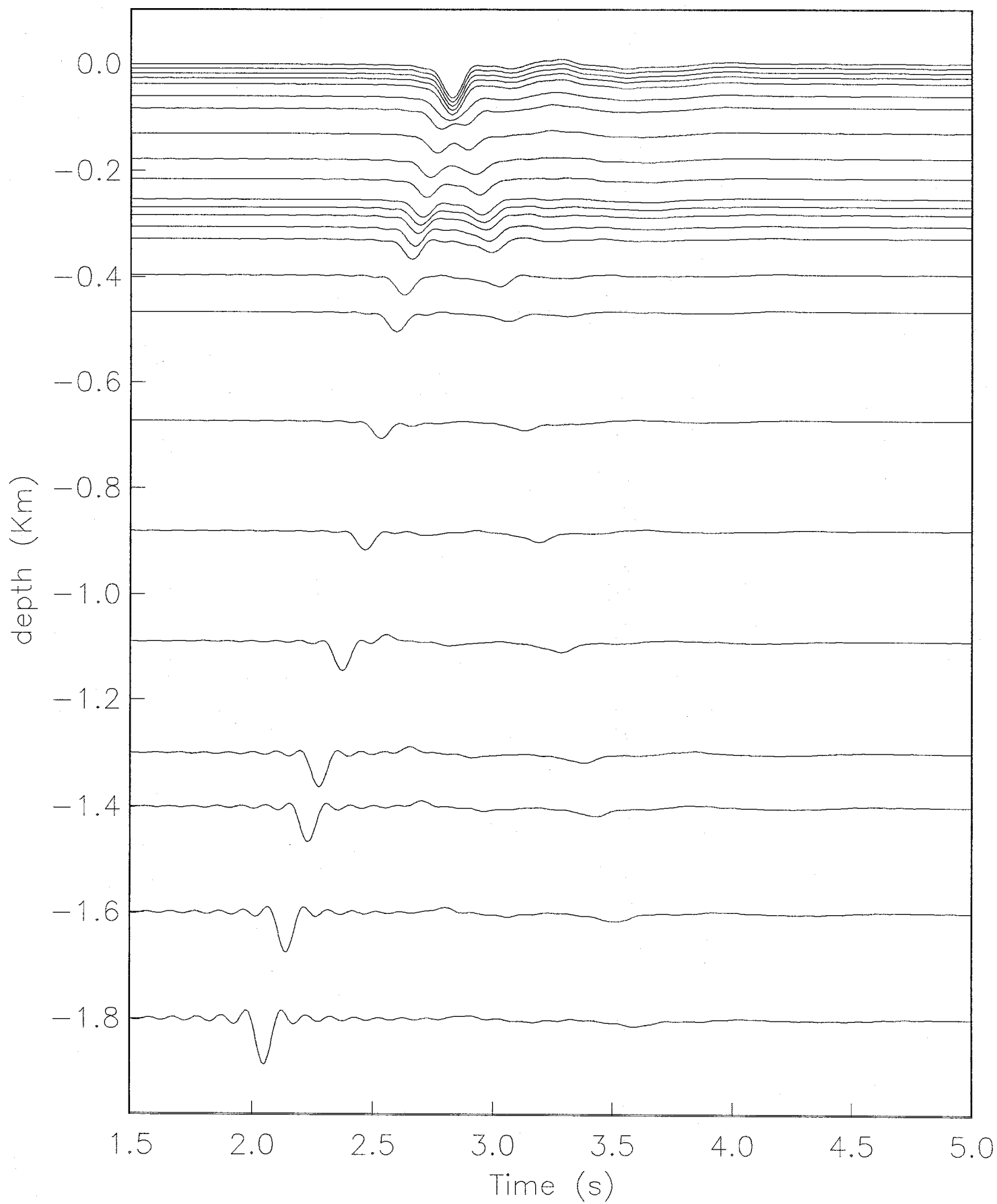
Appendix C

Content :

40 seismogram profiles with frequency content 0 to 10 Hz

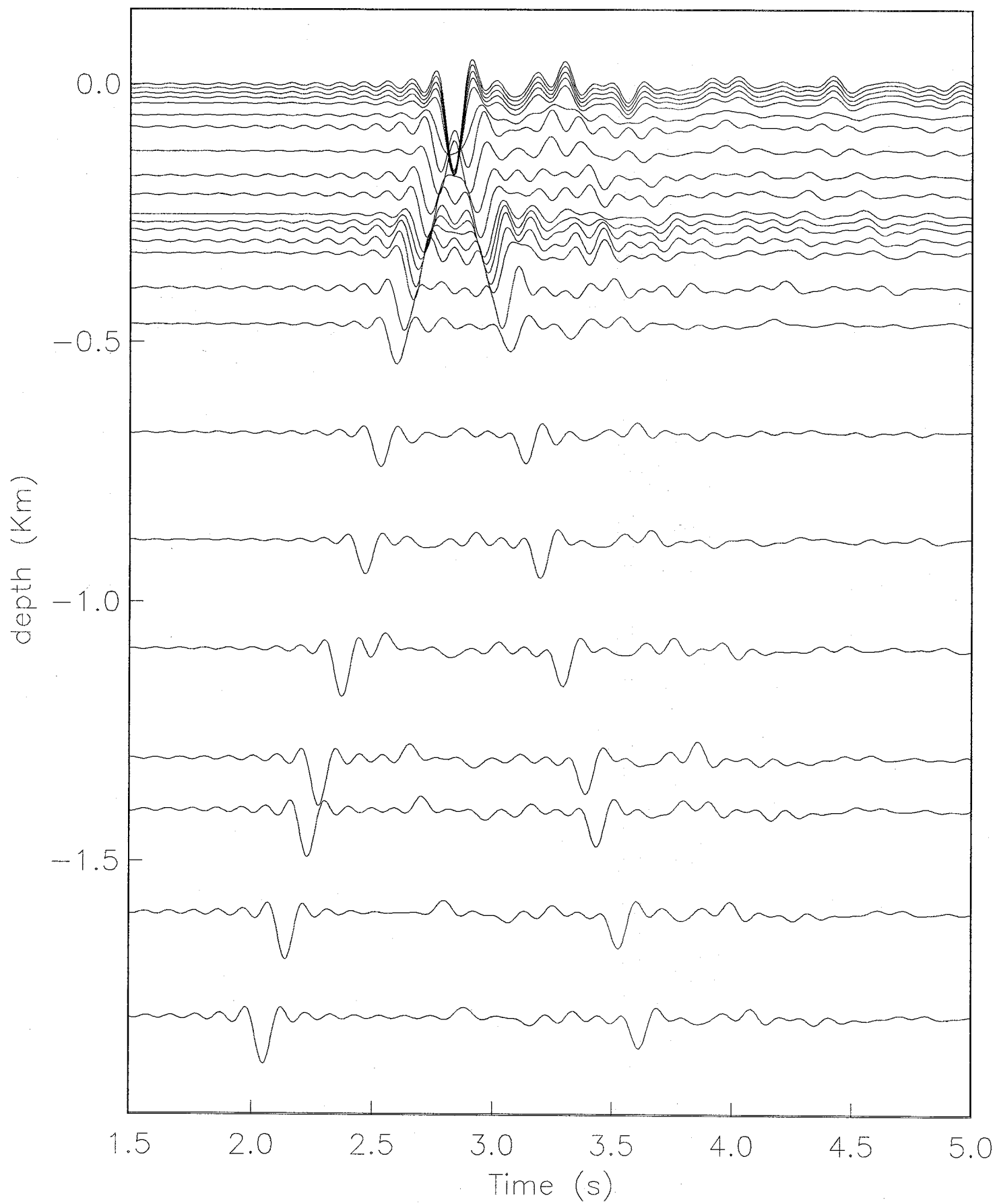
Ux

S waves | gradient | angle : 0 | QS=Qp=10



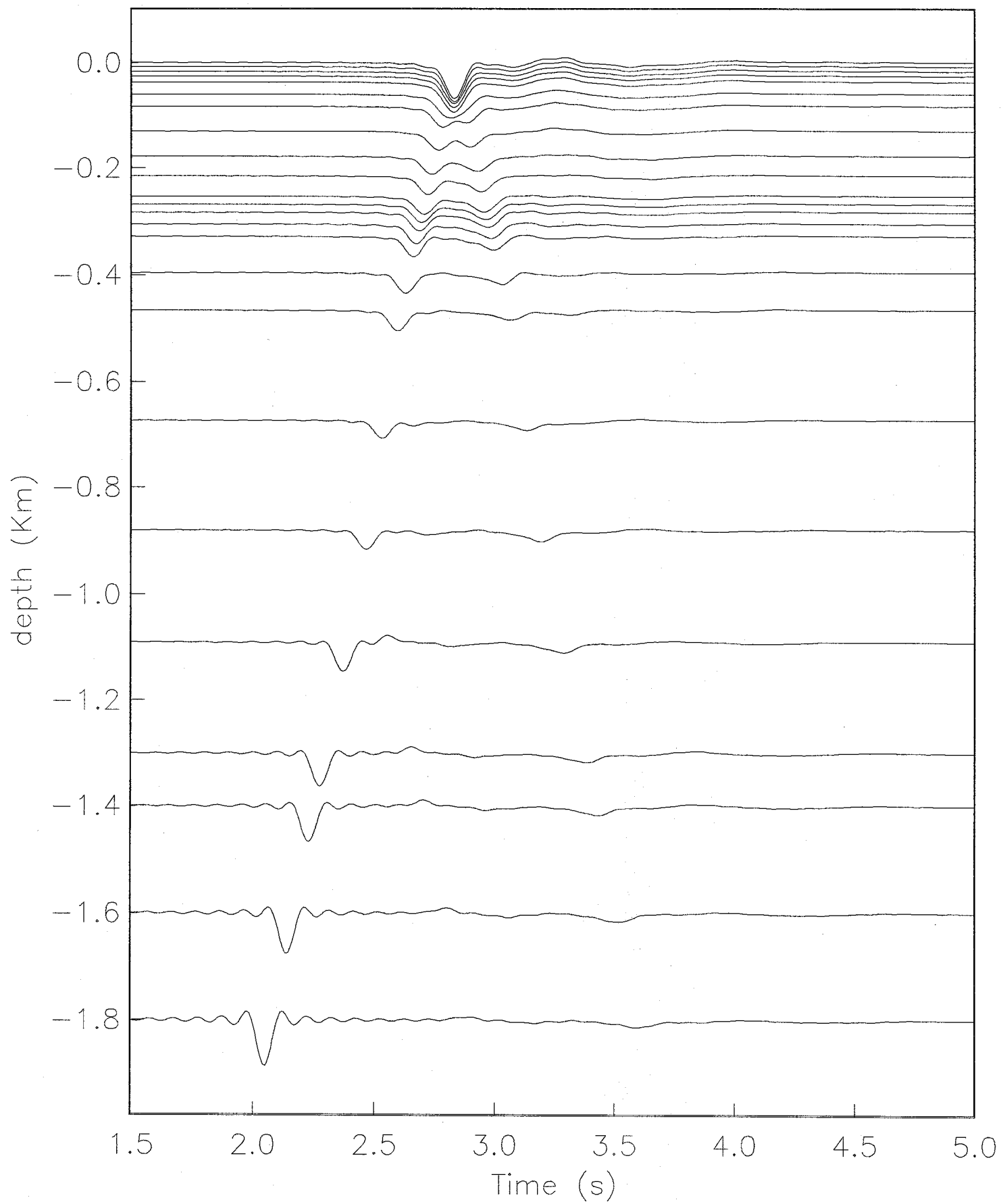
Ux

S waves | gradient | angle : 0 | QS=Qp=300



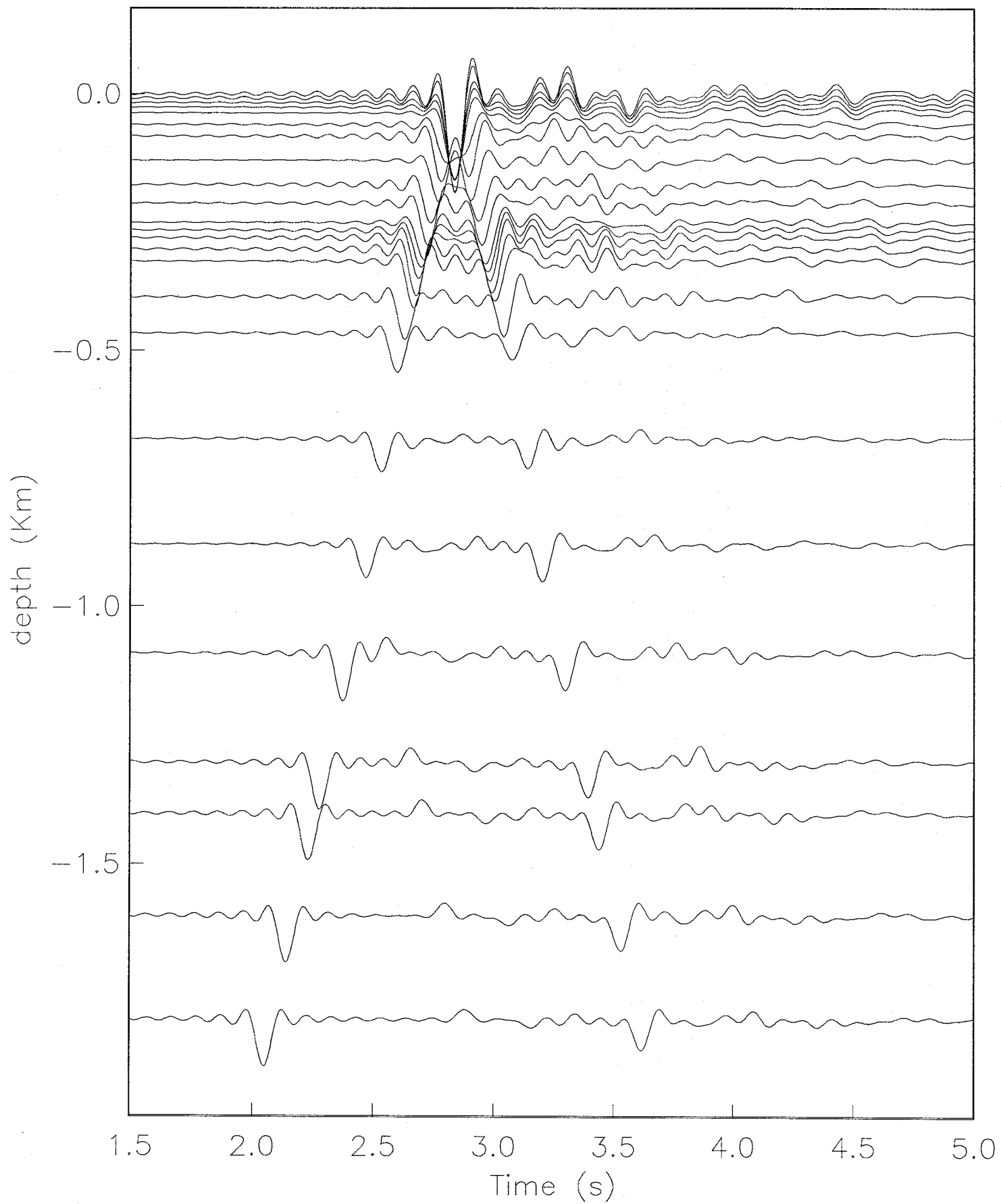
Ux

S waves | layer | angle : 0 | QS=Qp=10



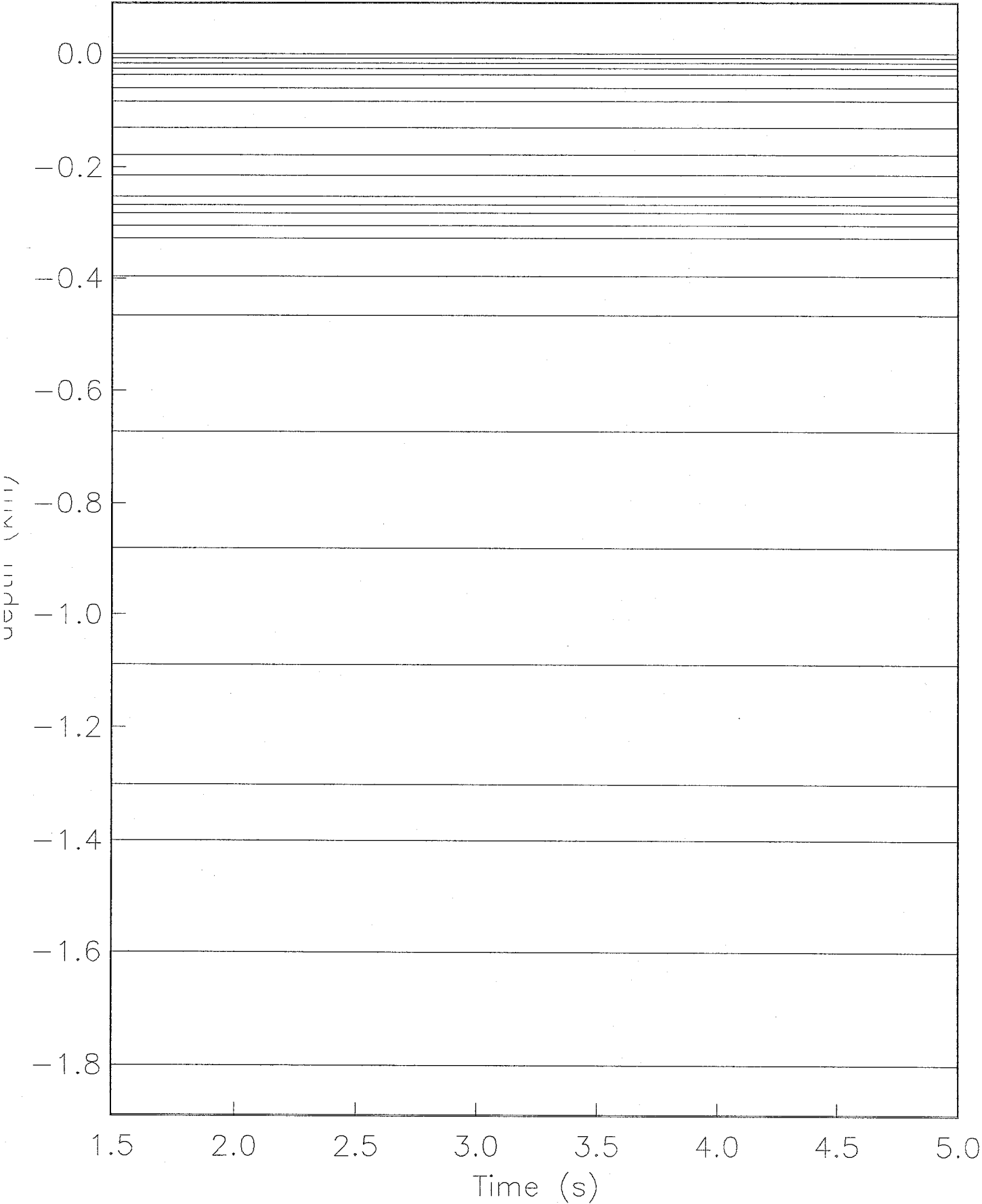
Ux

S waves | layer | angle : 0 | QS=Qp=300



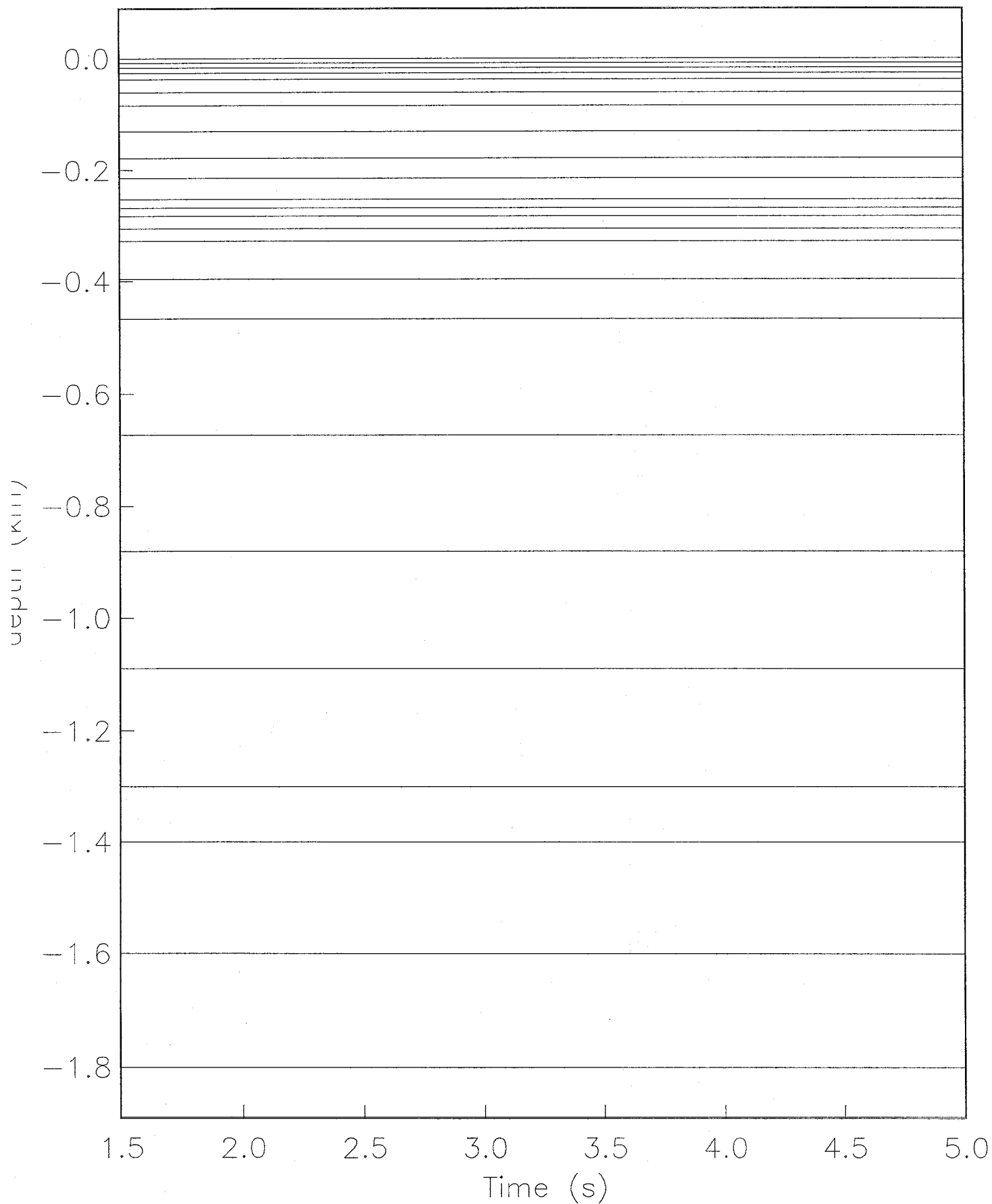
Uz

S waves | gradient | angle : 0 | Qs=Qp=10



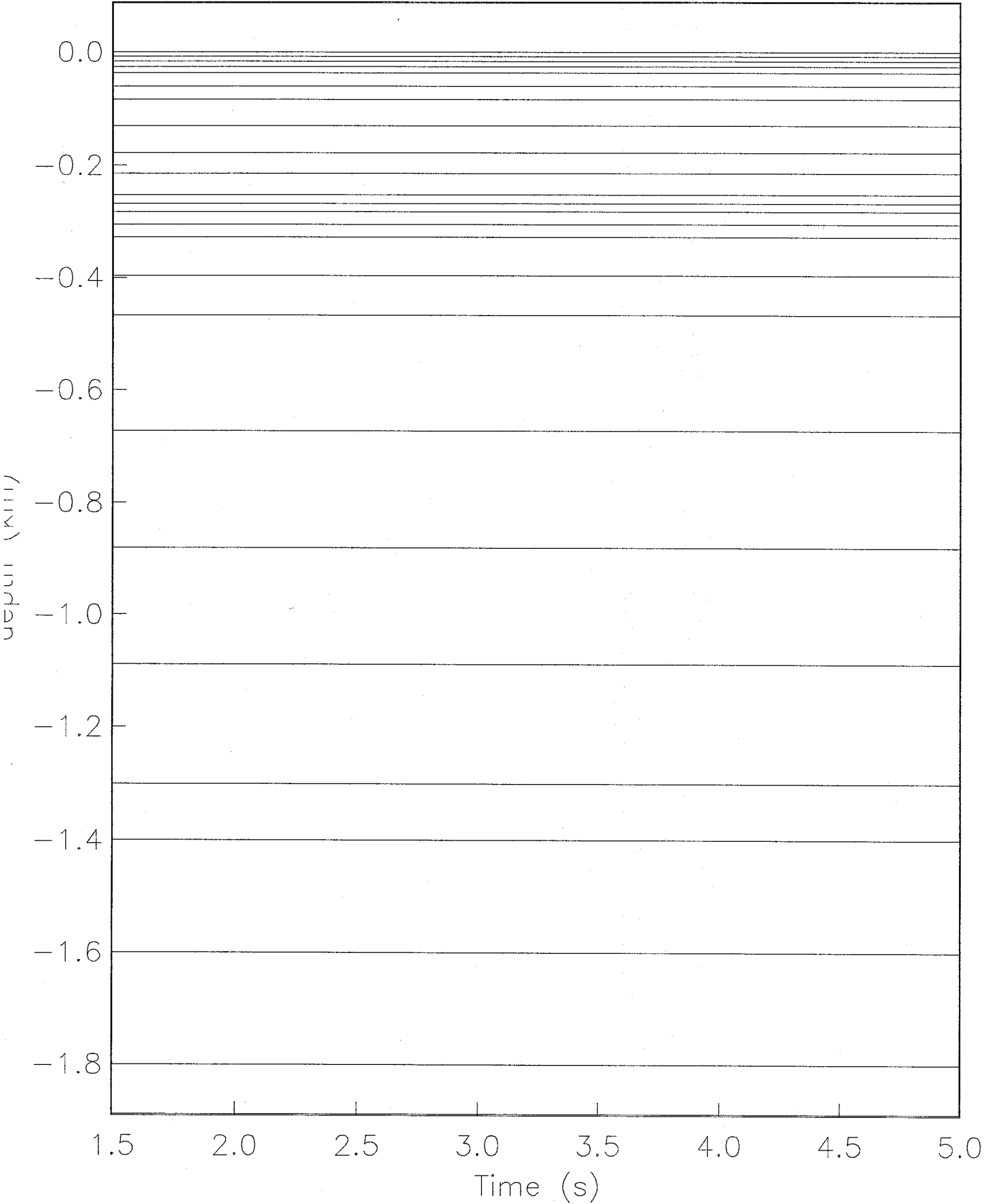
Uz

S waves | gradient | angle : 0 | Qs=Qp=300



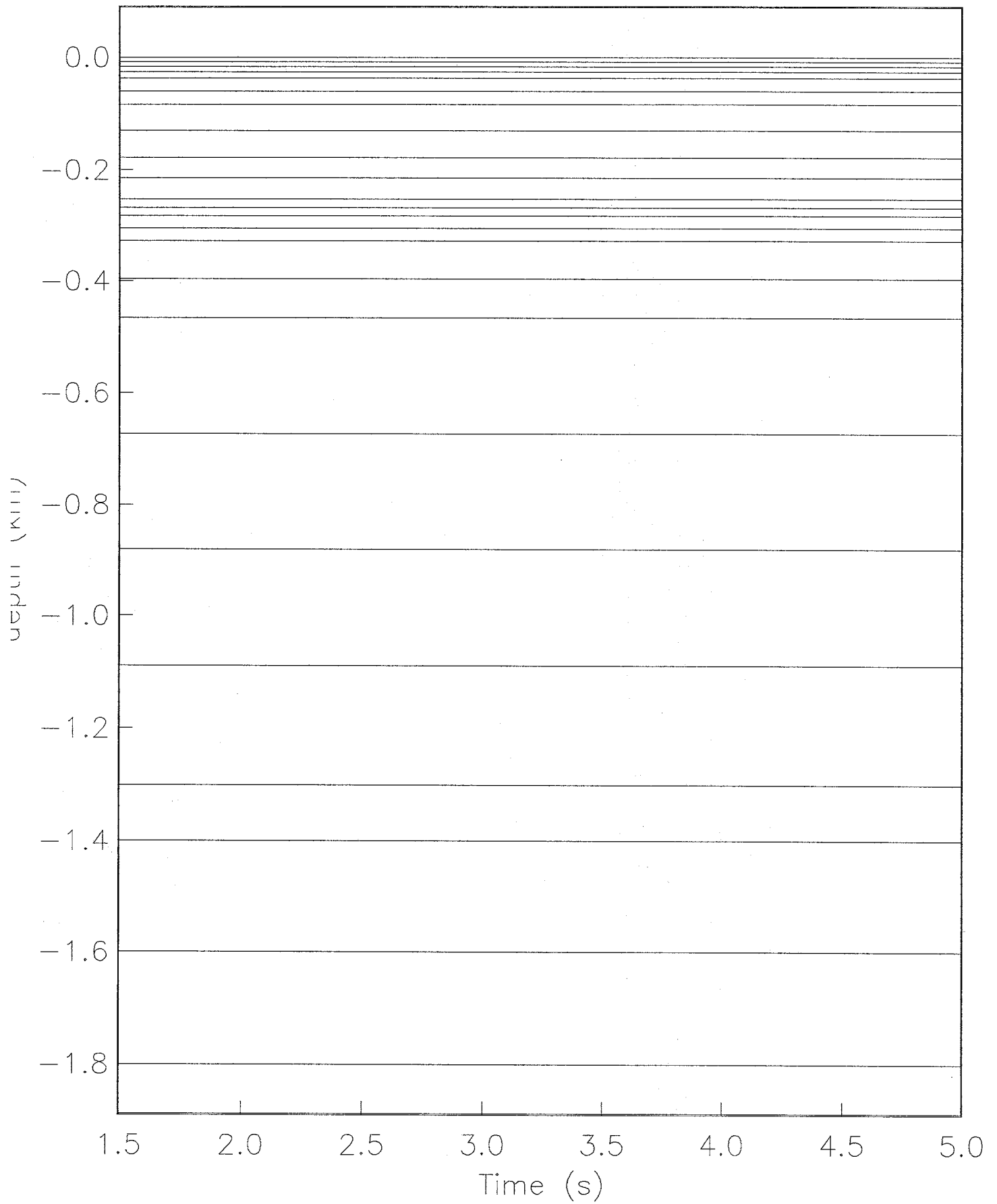
Uz

S waves | layer | angle : 0 | Qs=Qp=10



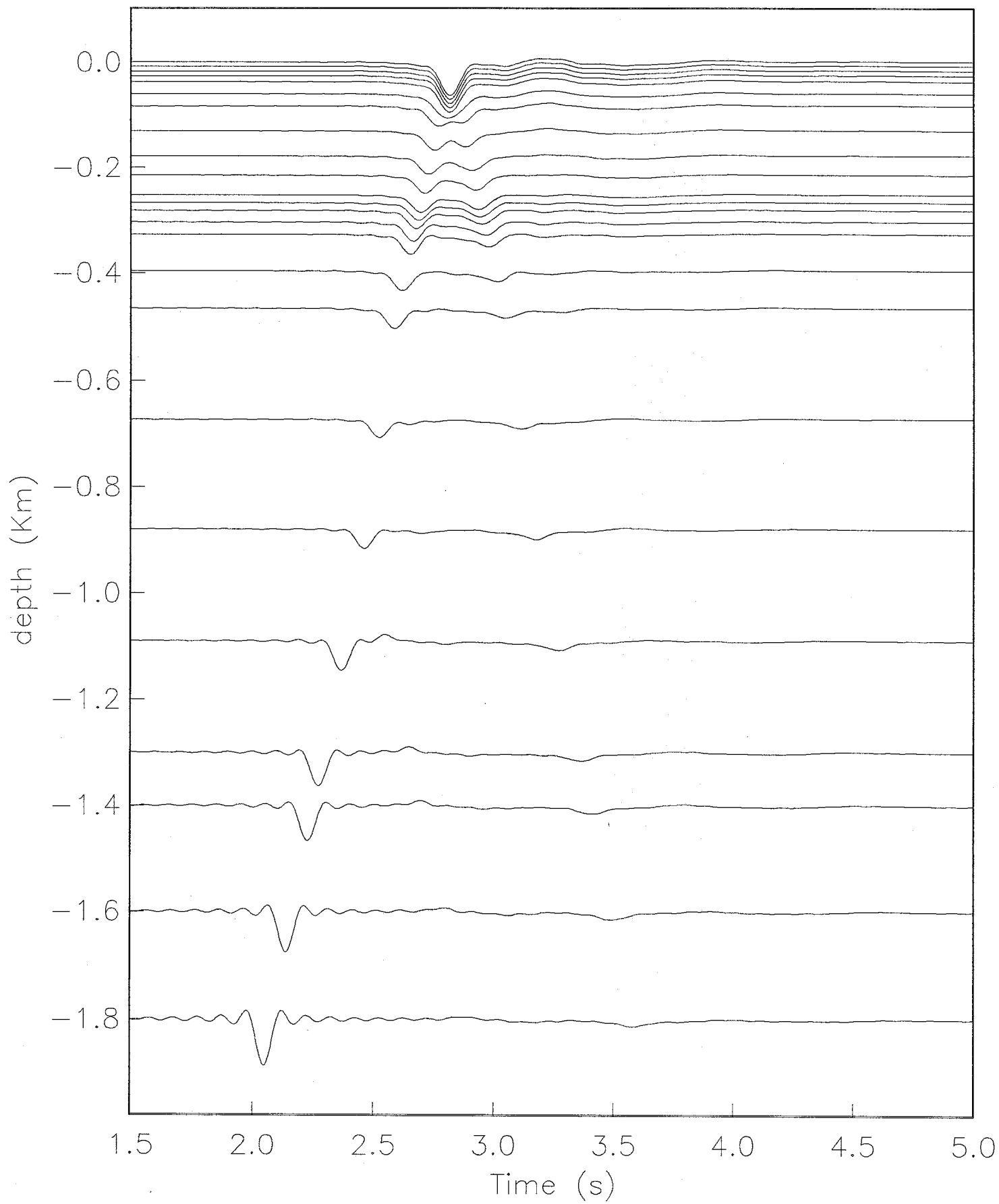
Uz

S waves | layer | angle : 0 | Qs=Qp=300



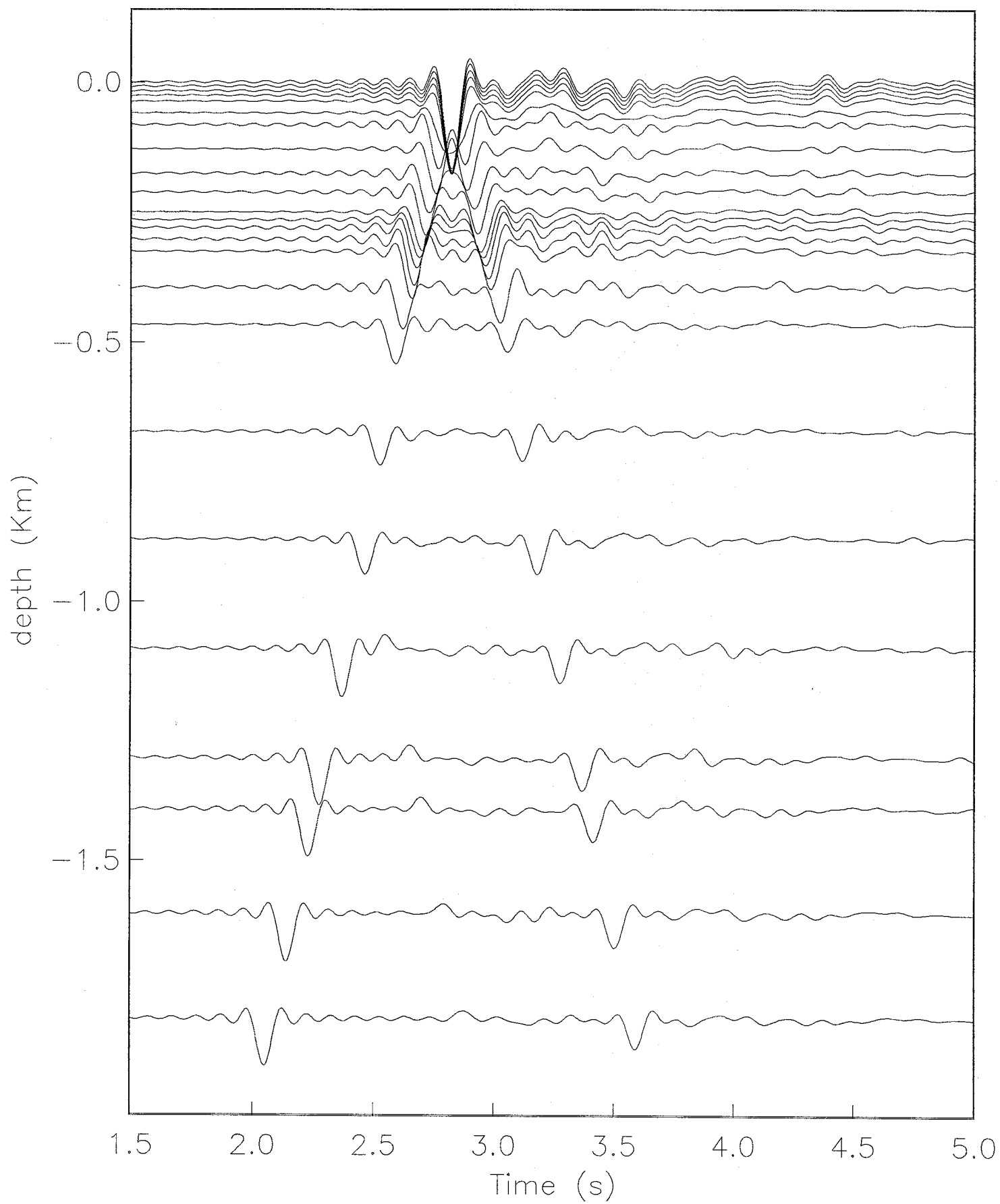
U_x

S waves | gradient | angle : 10 | QS=Qp=10



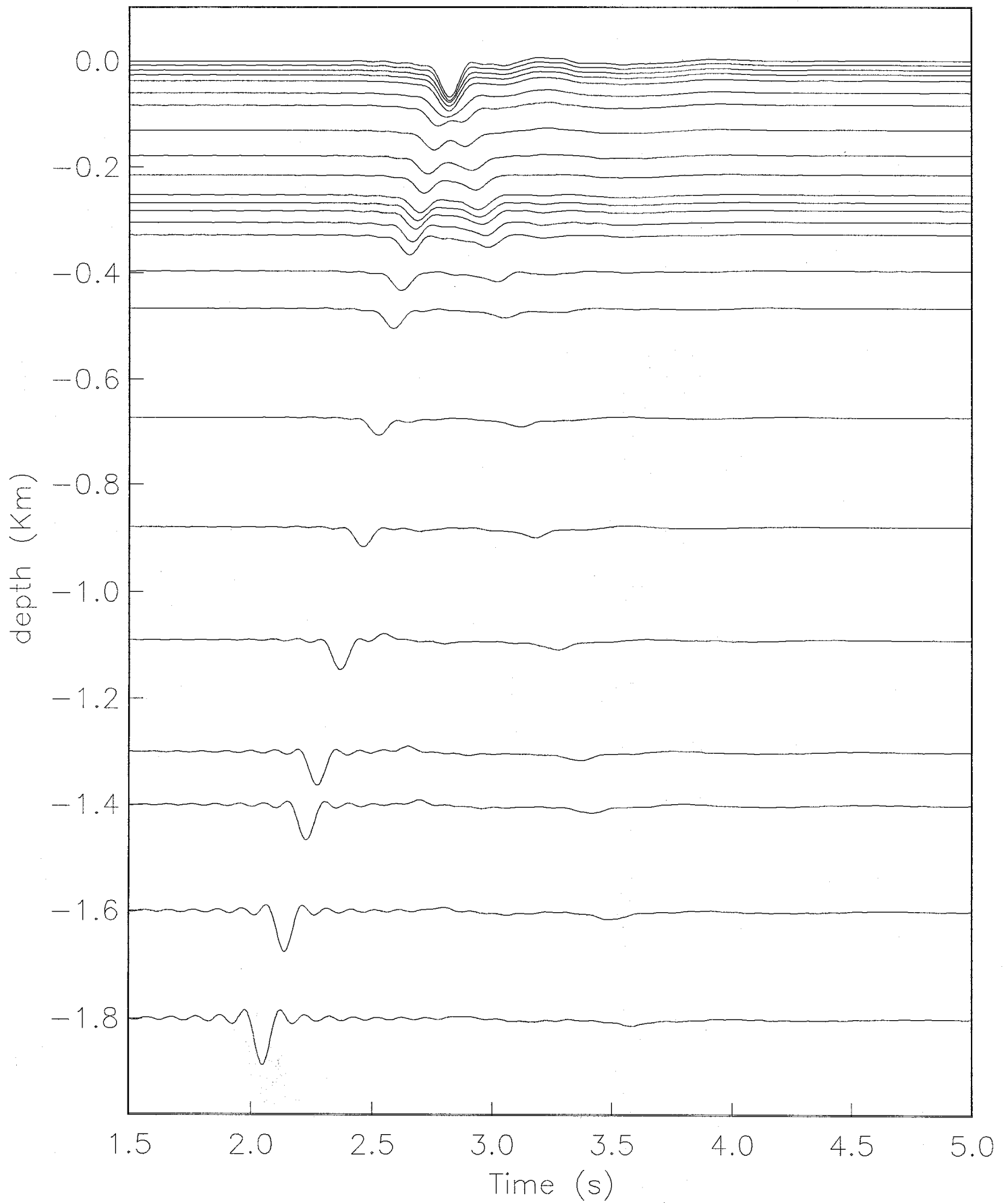
Ux

S waves | gradient | angle : 10 | QS=Qp=300



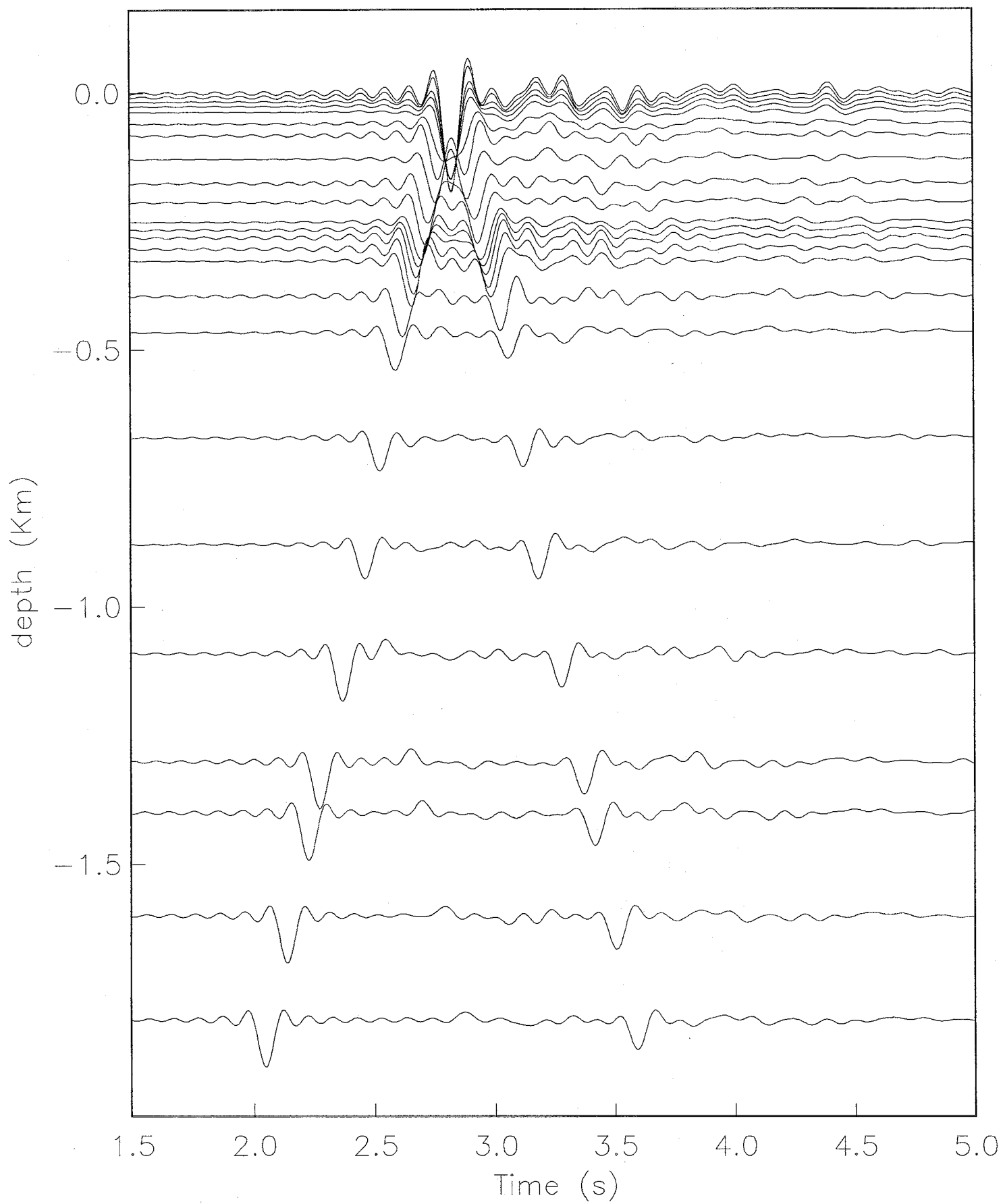
Ux

S waves | layer | angle : 10 | QS=Qp=10



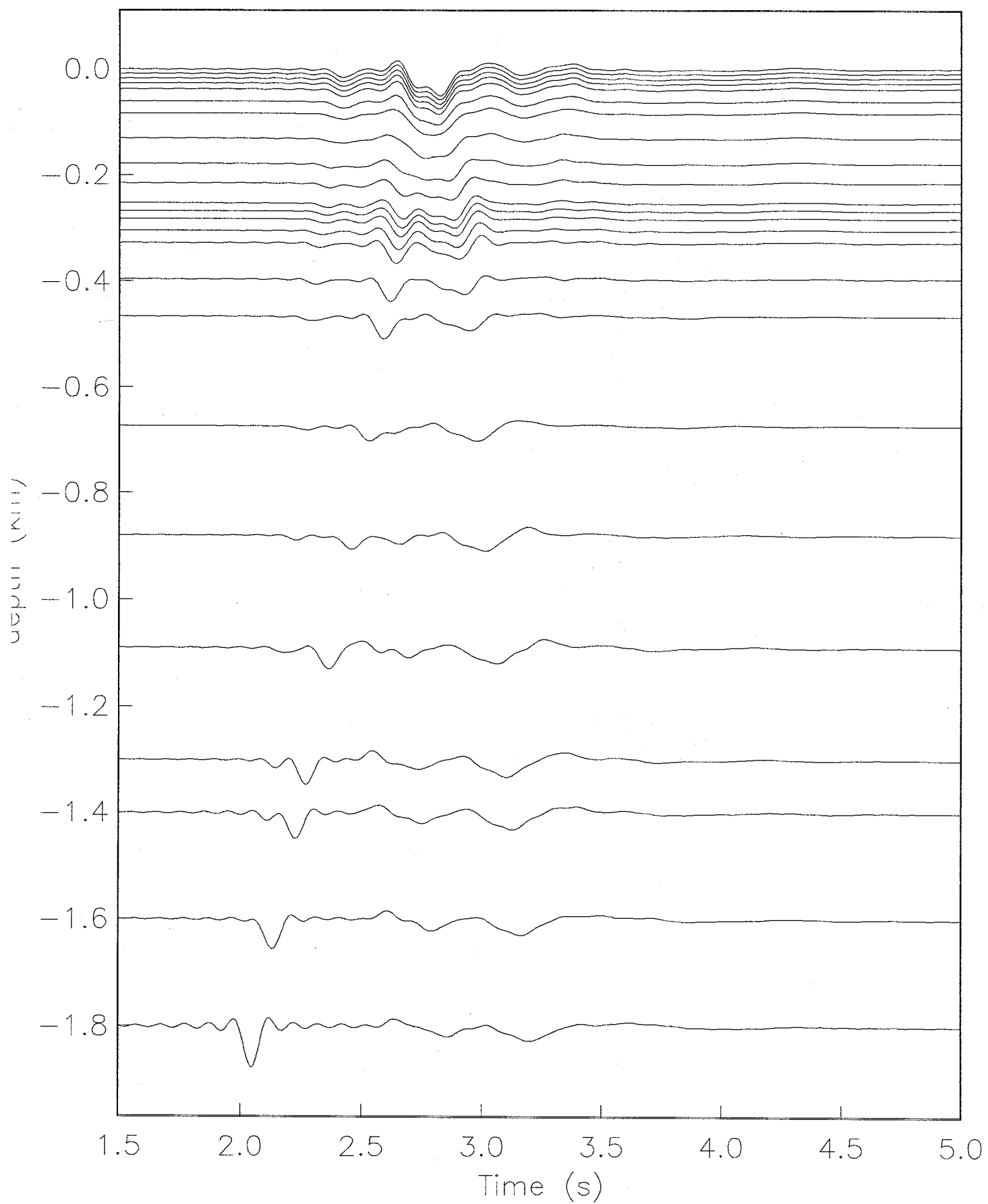
Ux

S waves | layer | angle : 10 | QS=Qp=300



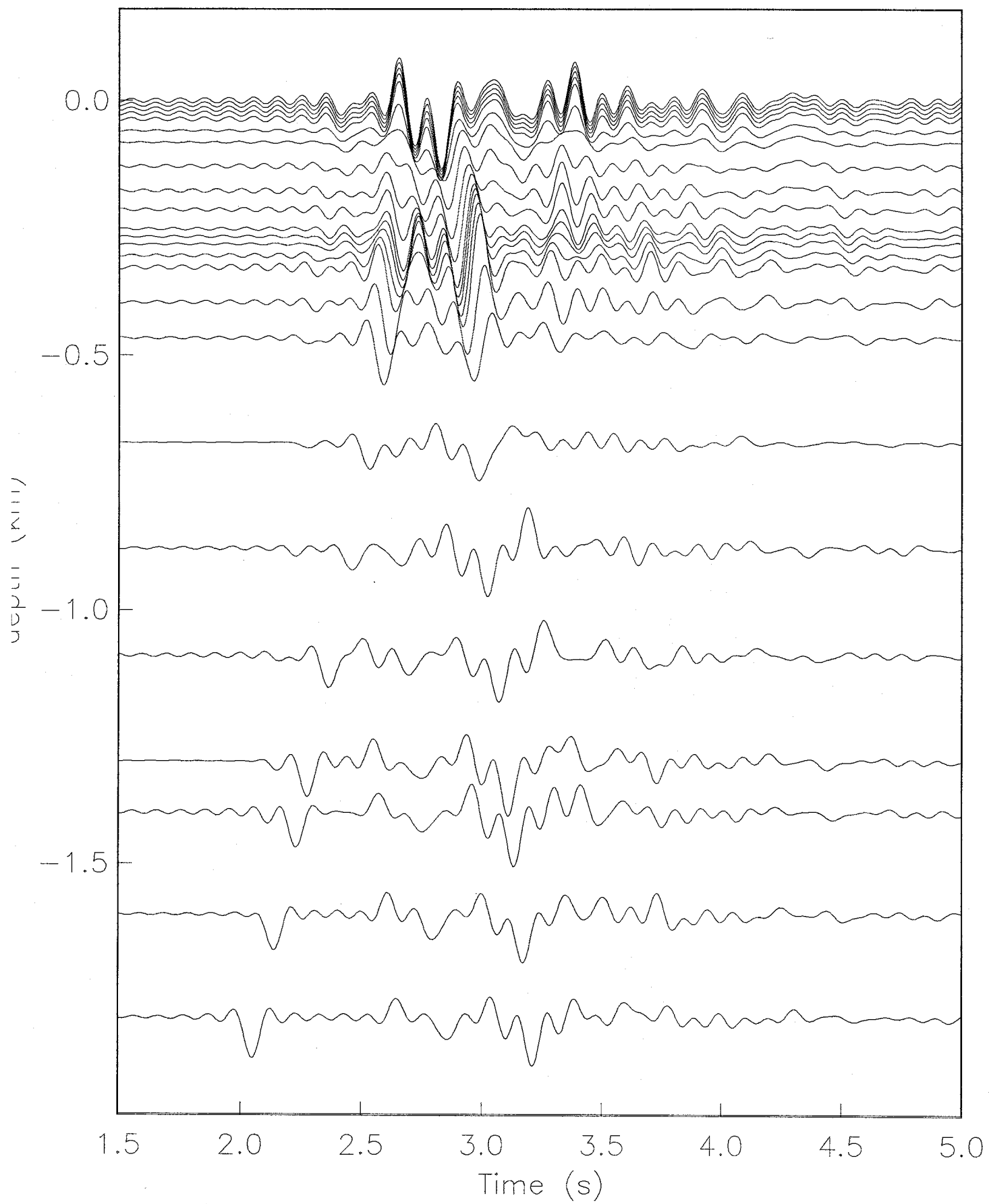
Uz

S waves | gradient | angle : 10 | Qs=Qp=10



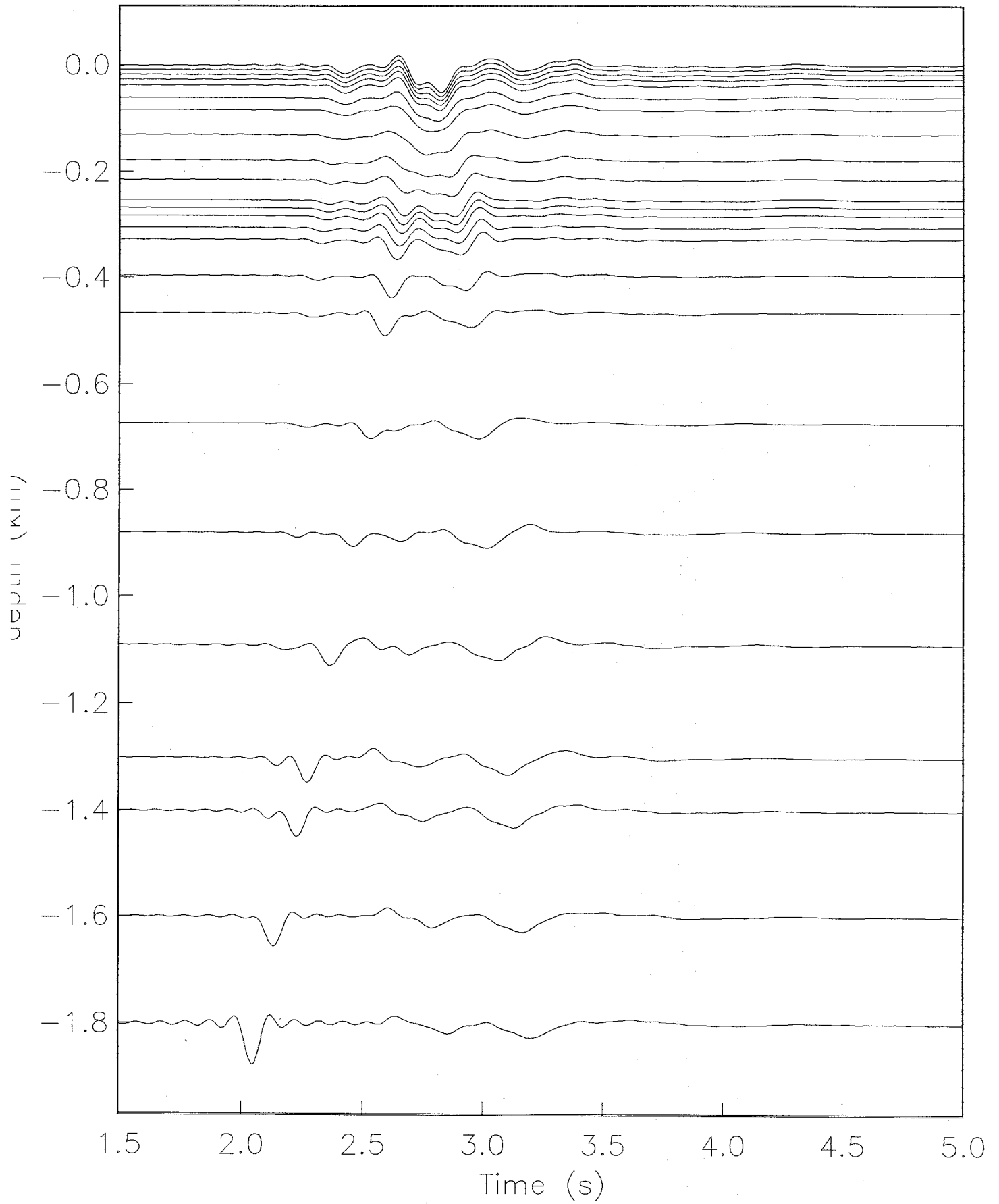
Uz

S waves | gradient | angle : 10 | Qs=Qp=300

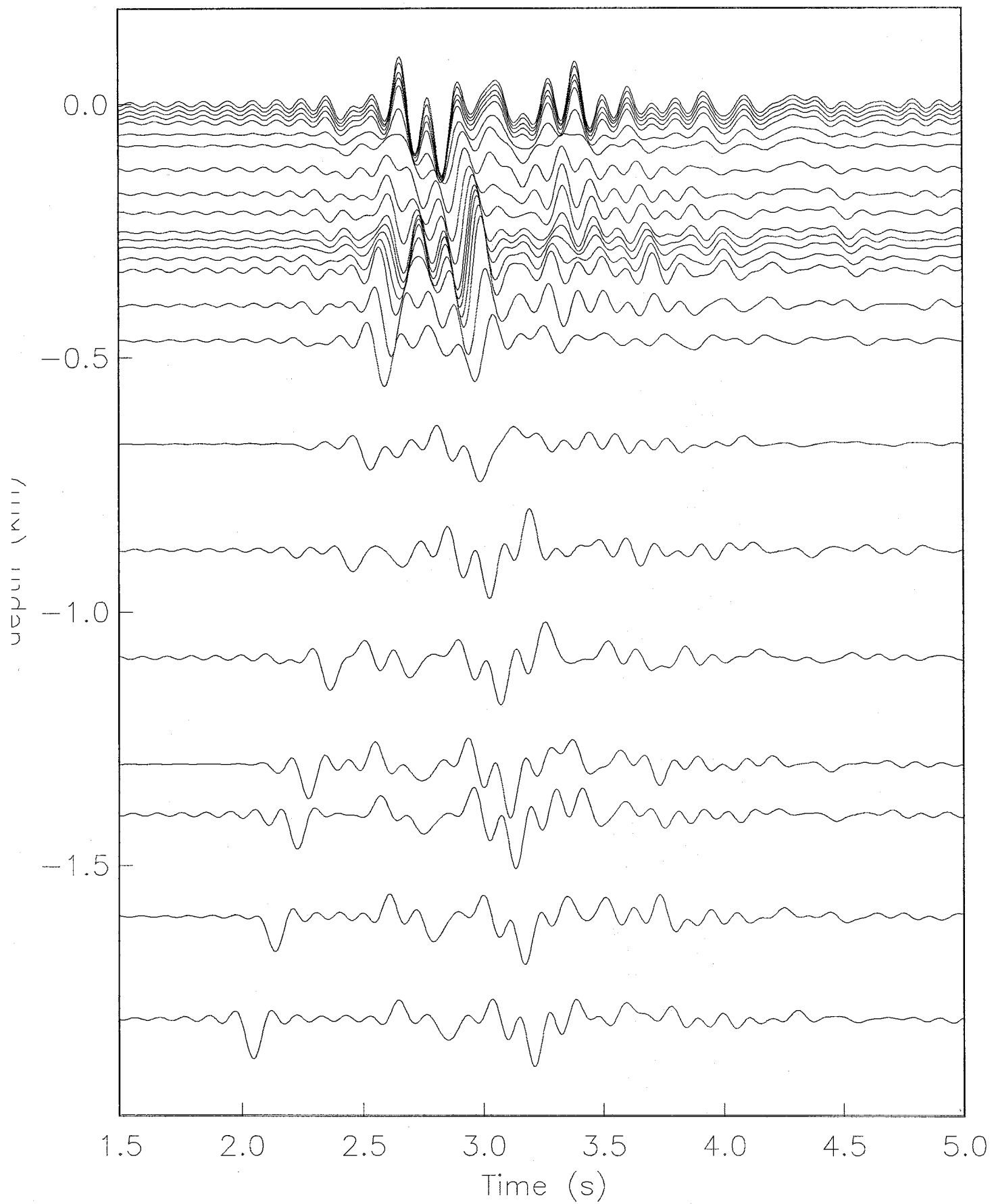


Uz

S waves | layer | angle : 10 | Qs=Qp=10

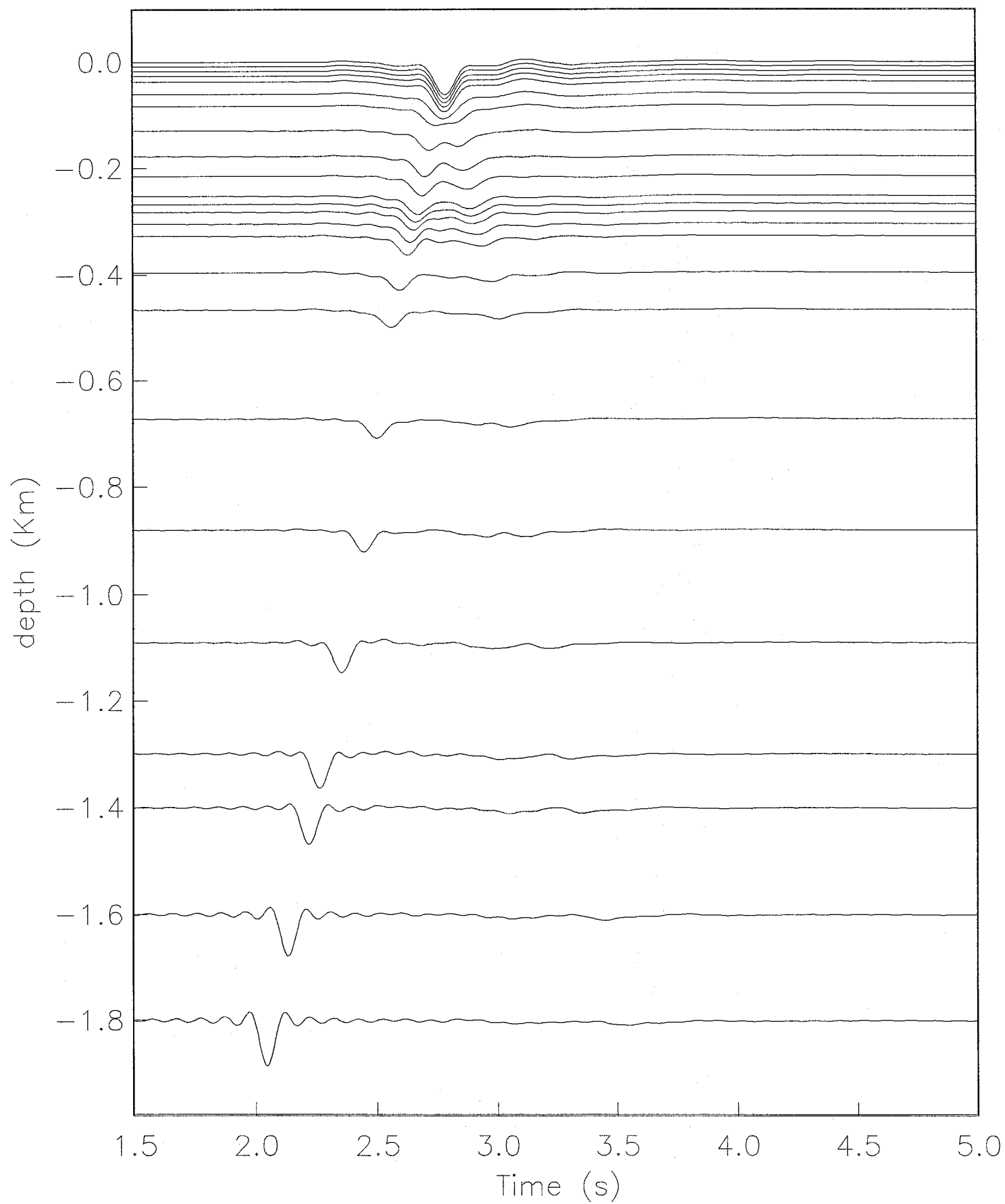


Uz
S waves | layer | angle : 10 | Qs=Qp=300



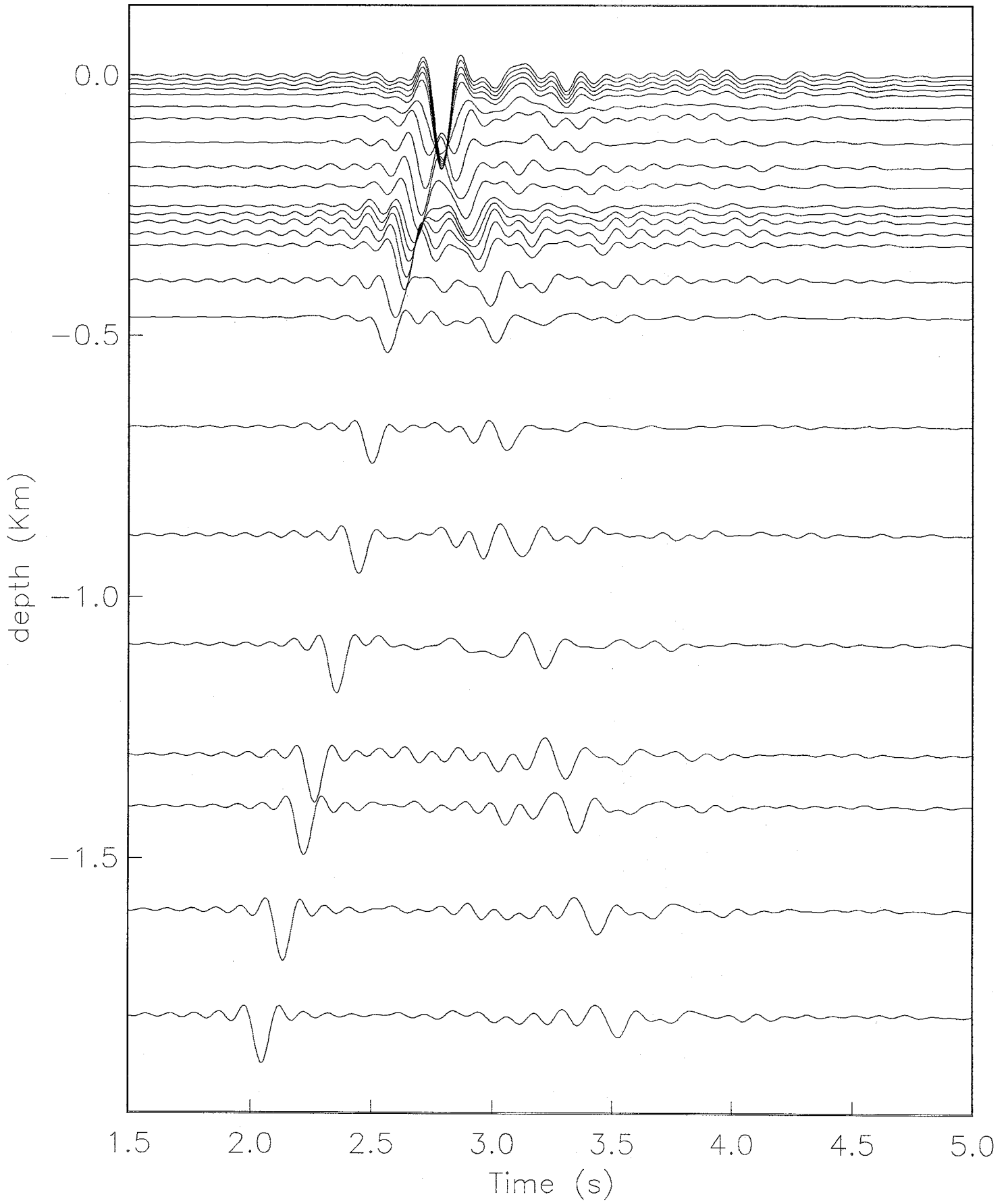
Ux

S waves | gradient | angle : 20 | QS=Qp=10



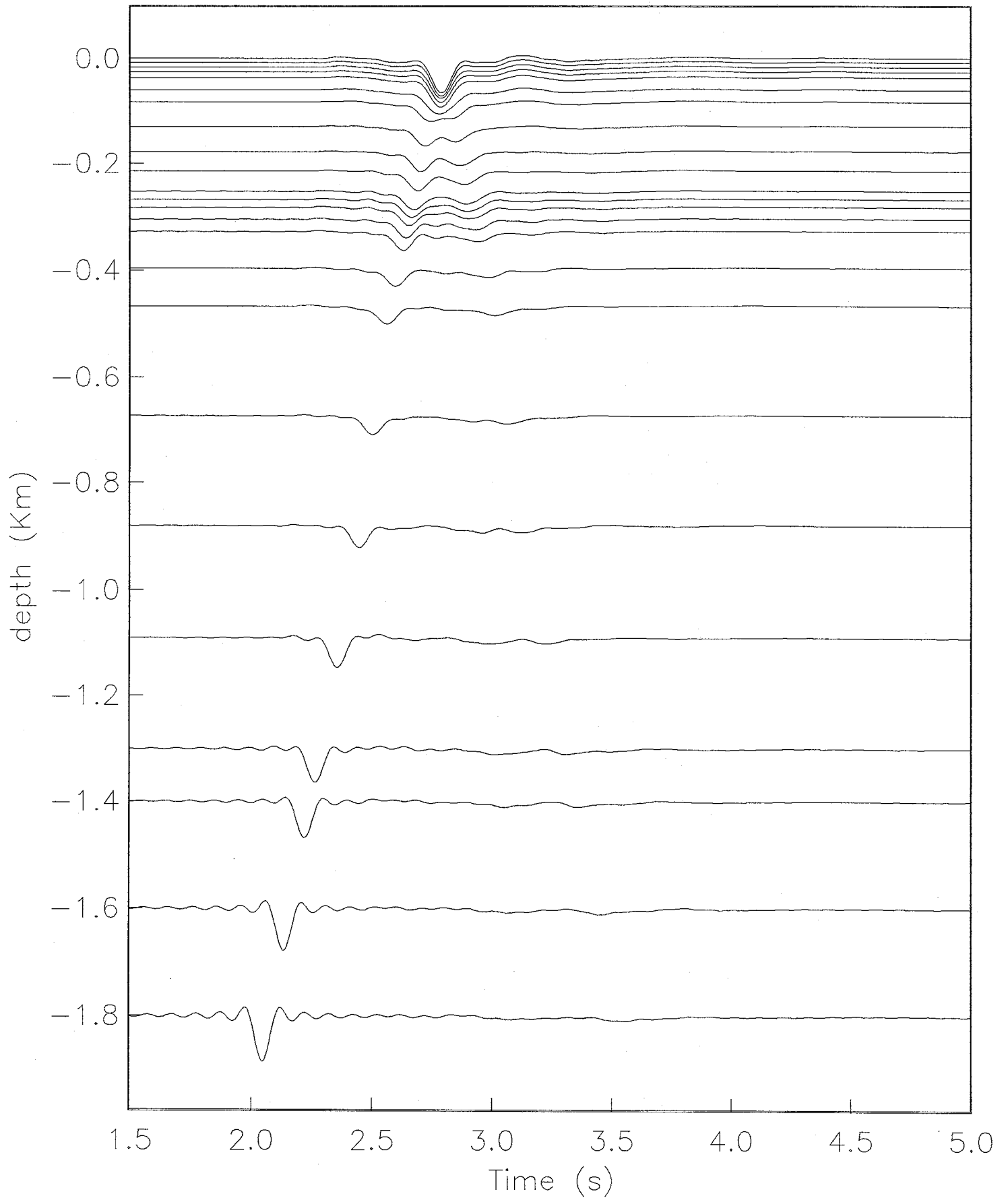
Ux

S waves | gradient | angle : 20 | QS=Qp=300



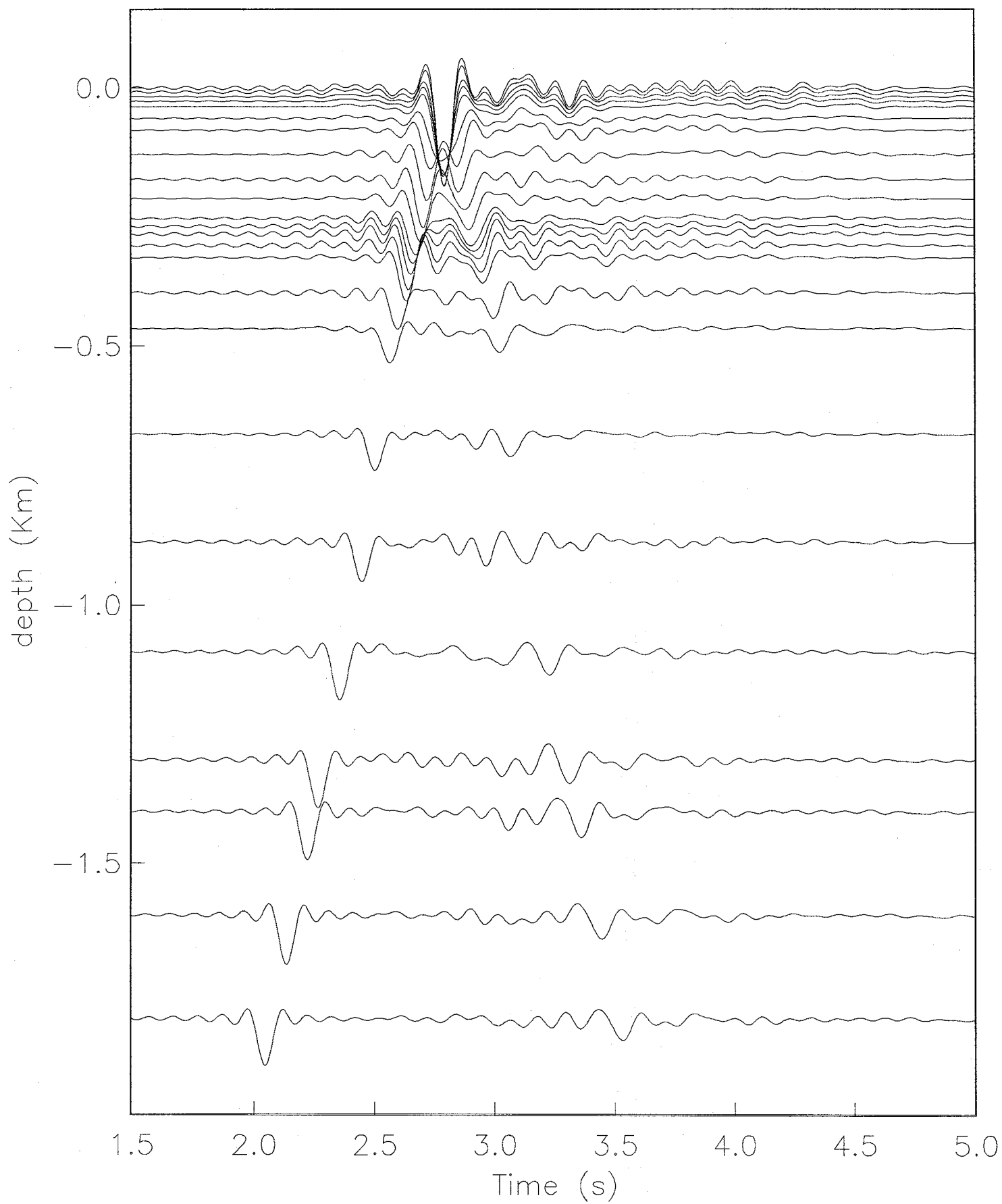
Ux

S waves | layer | angle : 20 | QS=Qp=10



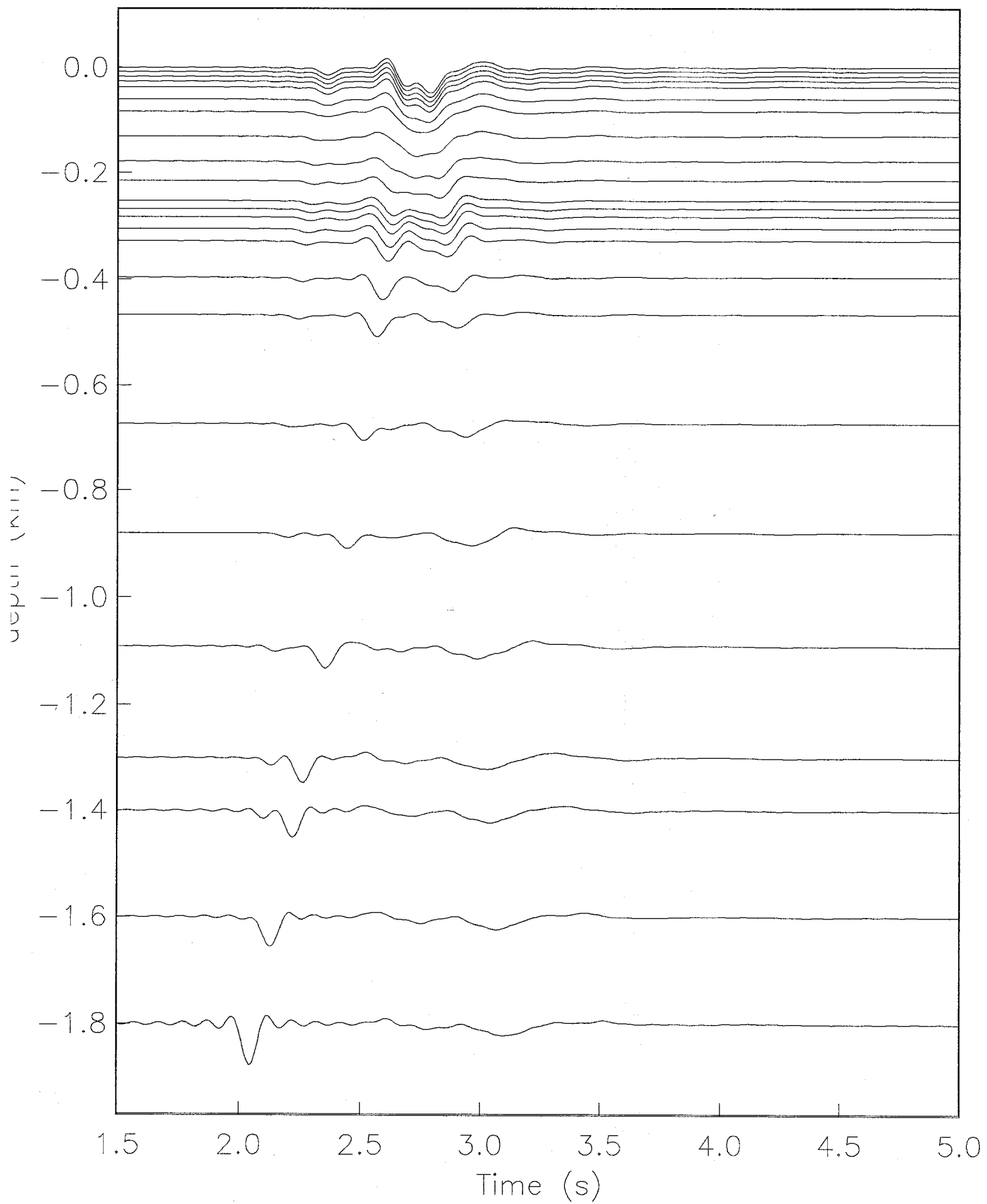
U_x

S waves | layer | angle : 20 | QS=Qp=300



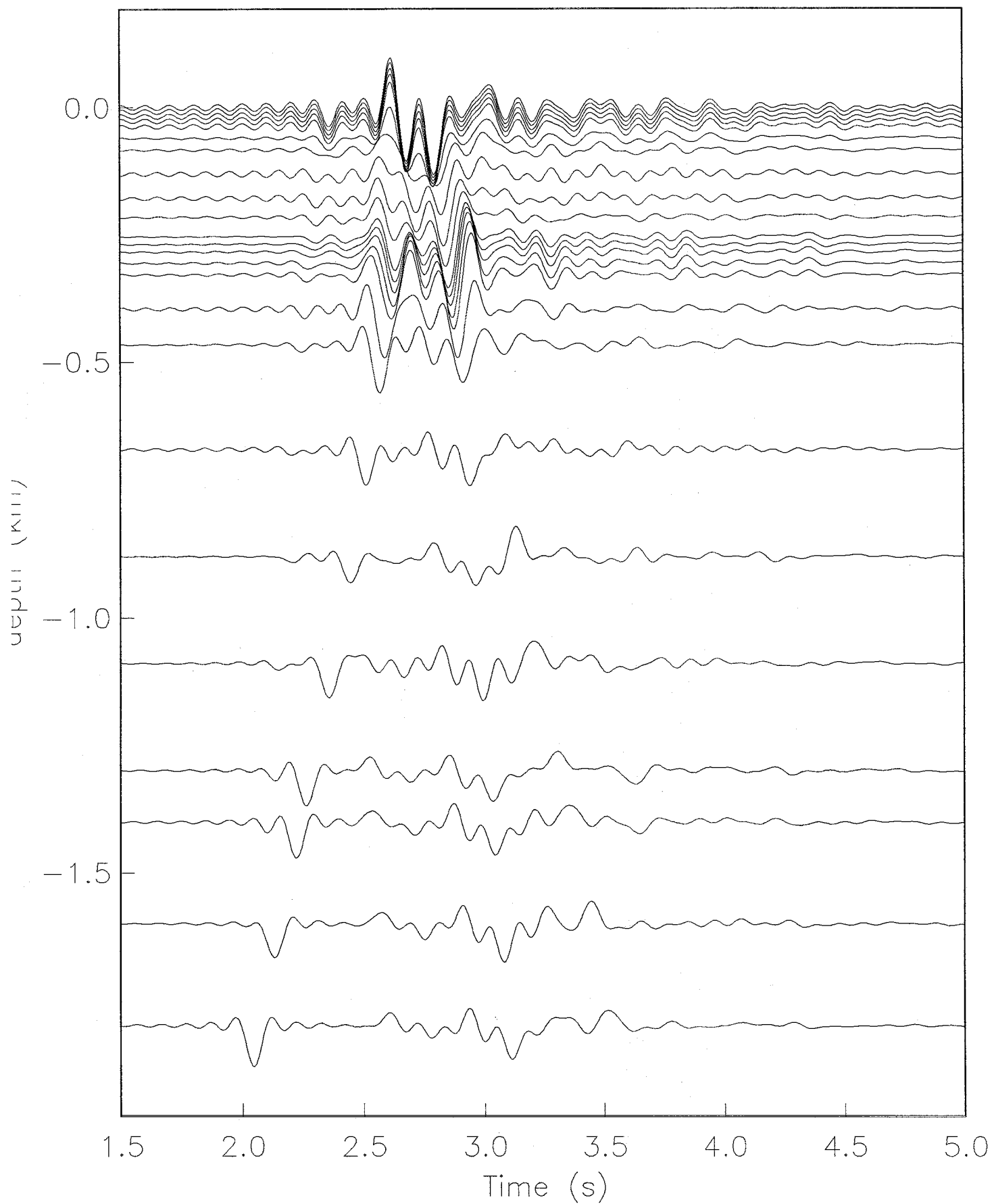
Uz

S waves | gradient | angle : 20 | Qs=Qp=10



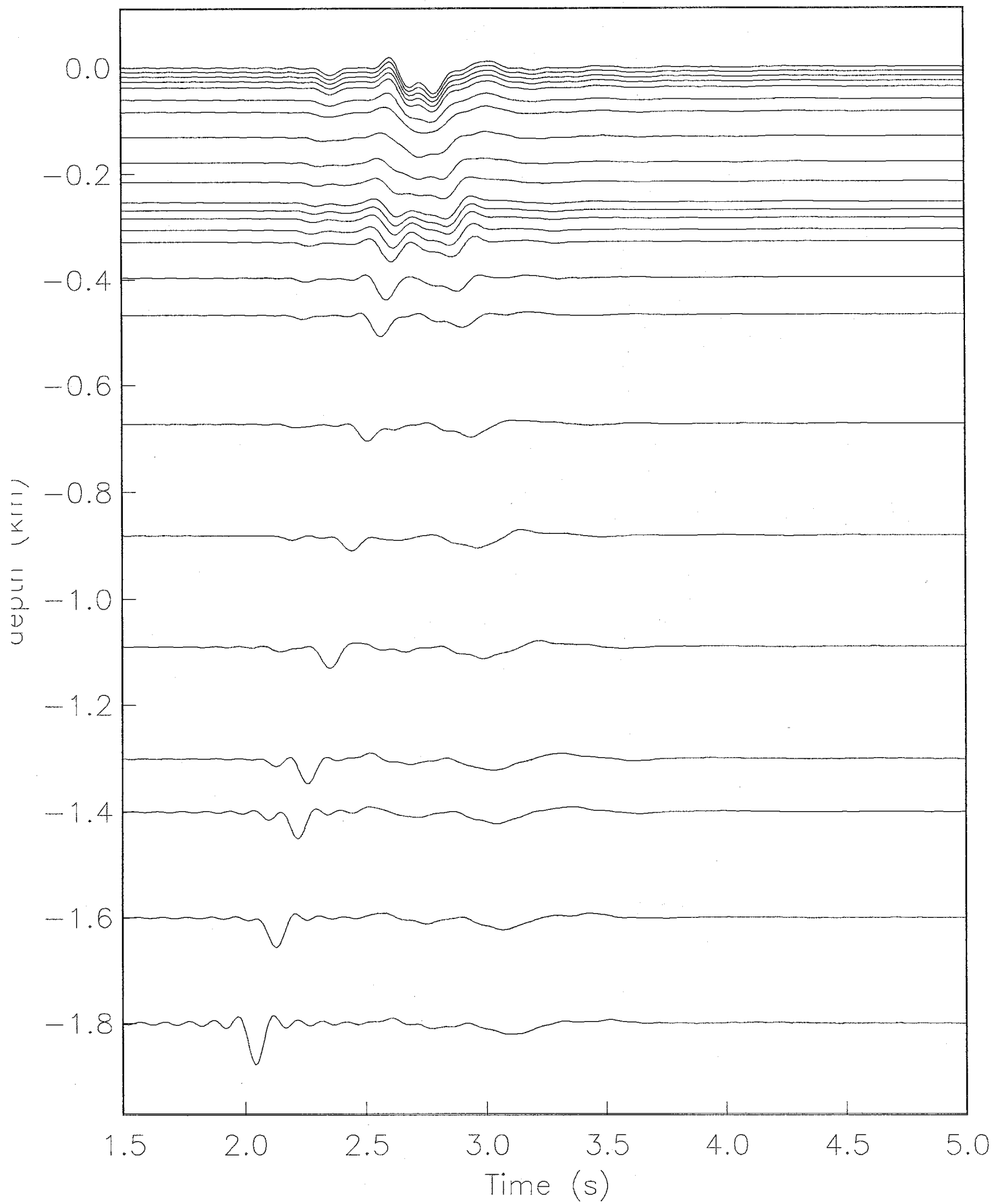
Uz

S waves | gradient | angle : 20 | Qs=Qp=300

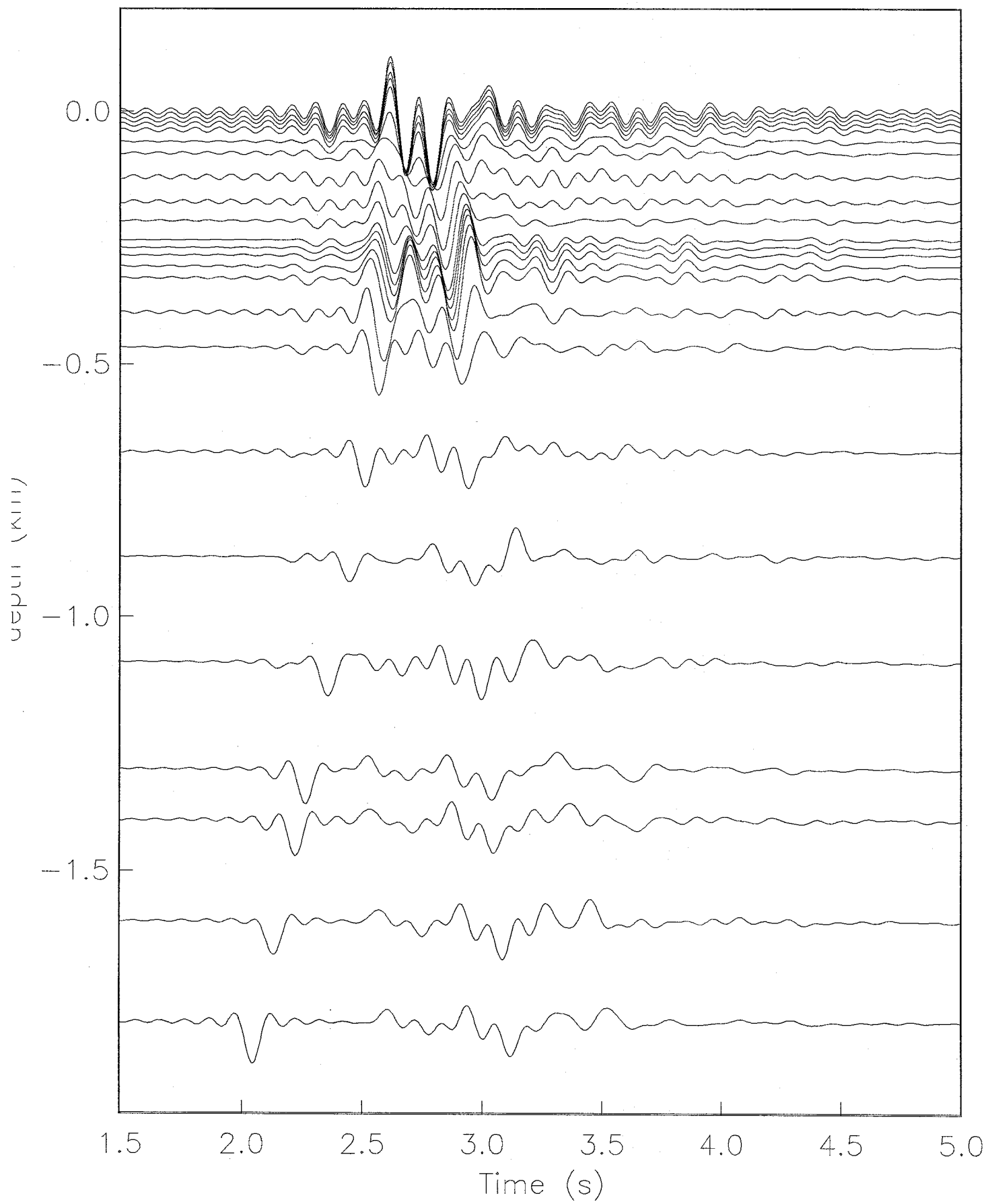


Uz

S waves | layer | angle : 20 | Qs=Qp=10

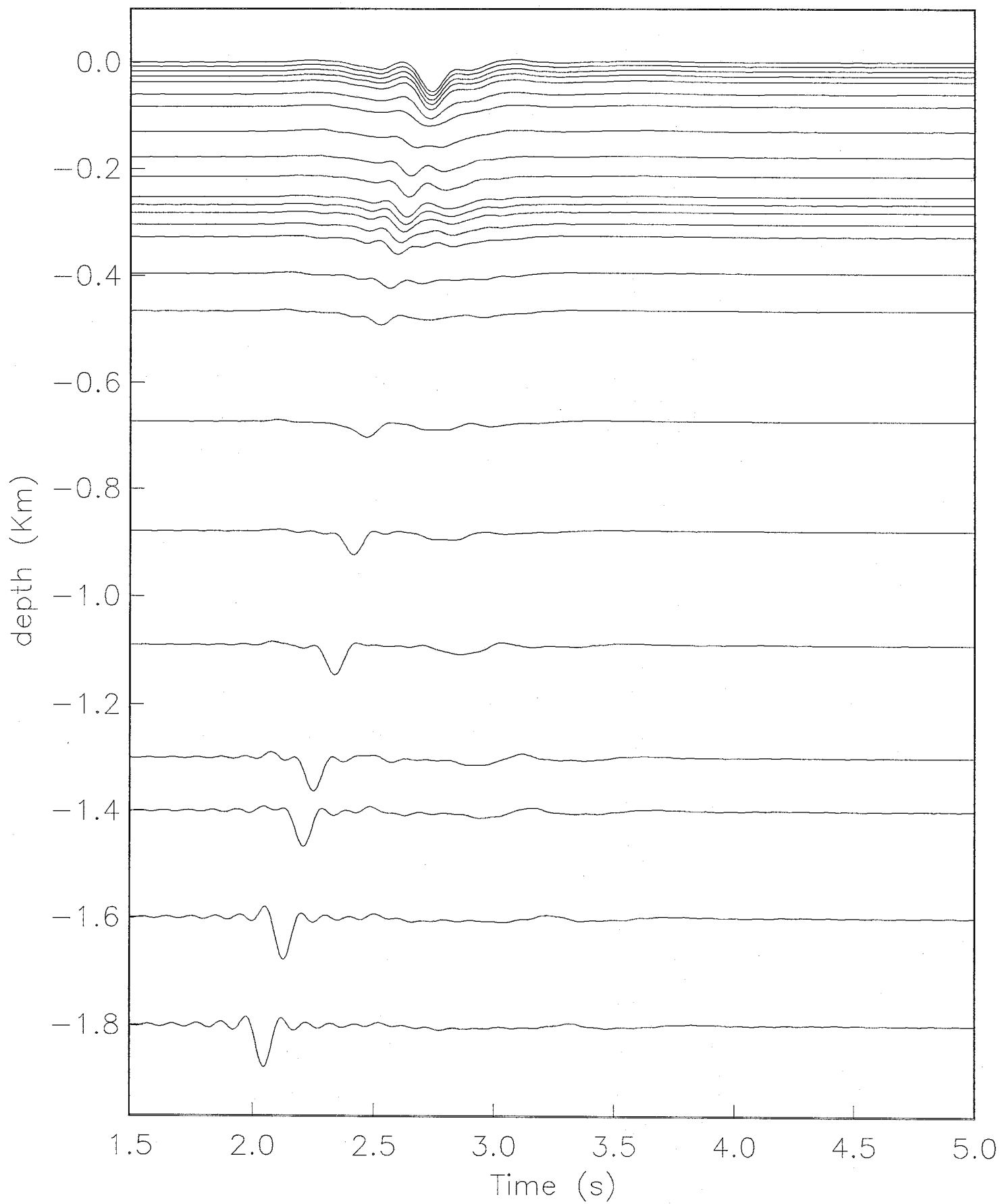


S waves | layer | U_z | angle : 20 | $Q_s=Q_p=300$



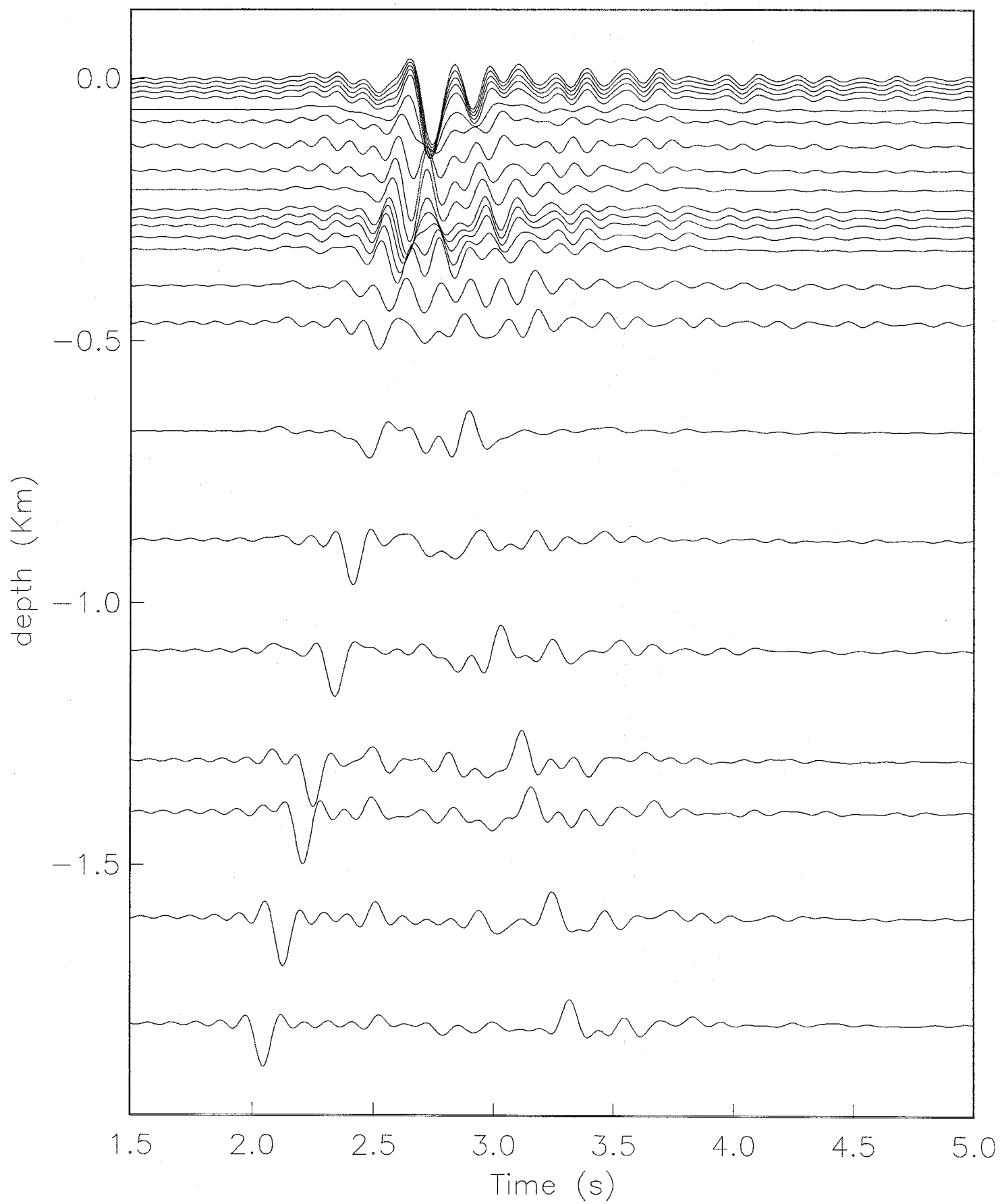
U_x

S waves | gradient | angle : 30 | QS=Qp=10



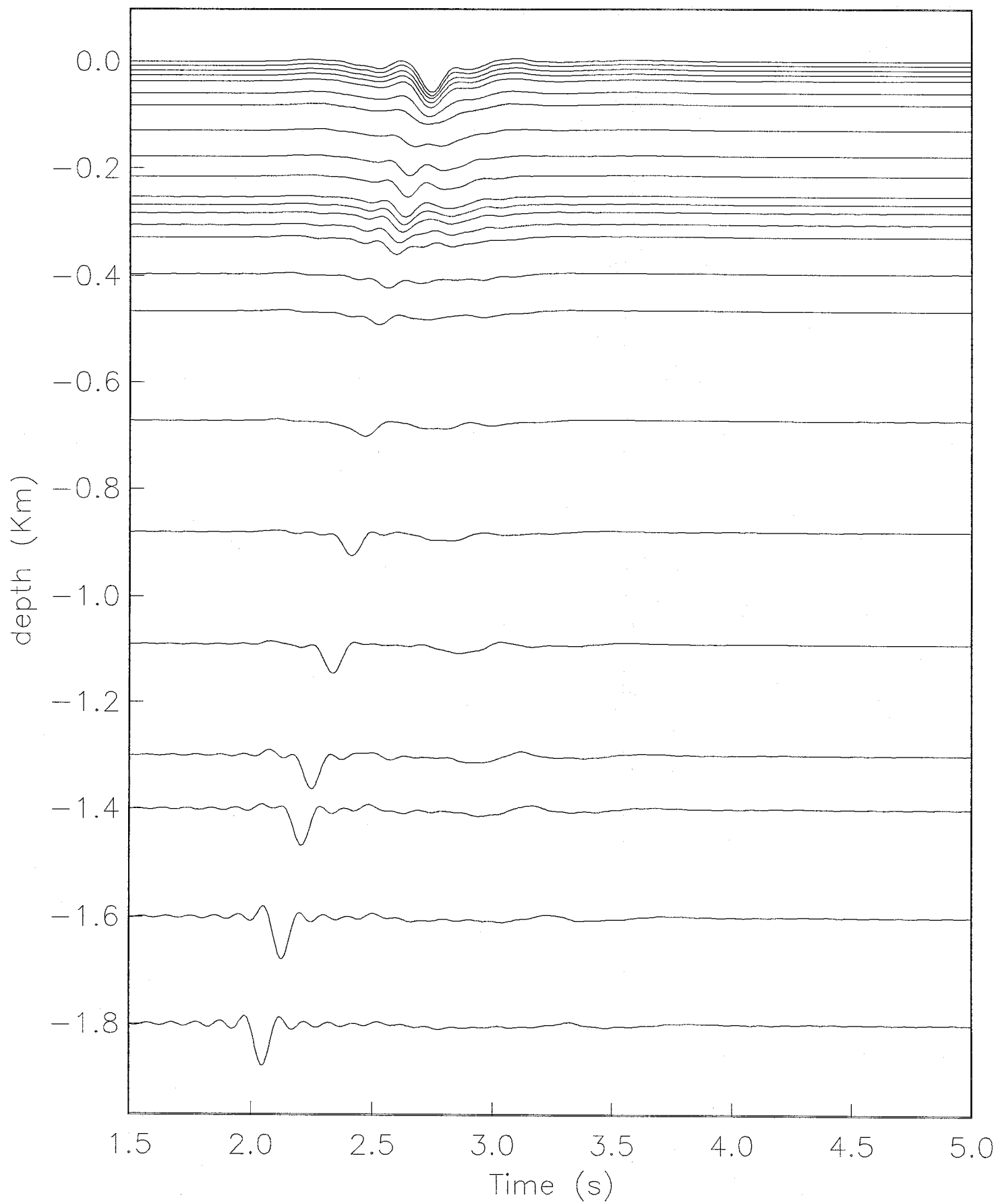
Ux

S waves | gradient | angle : 30 | QS=Qp=300



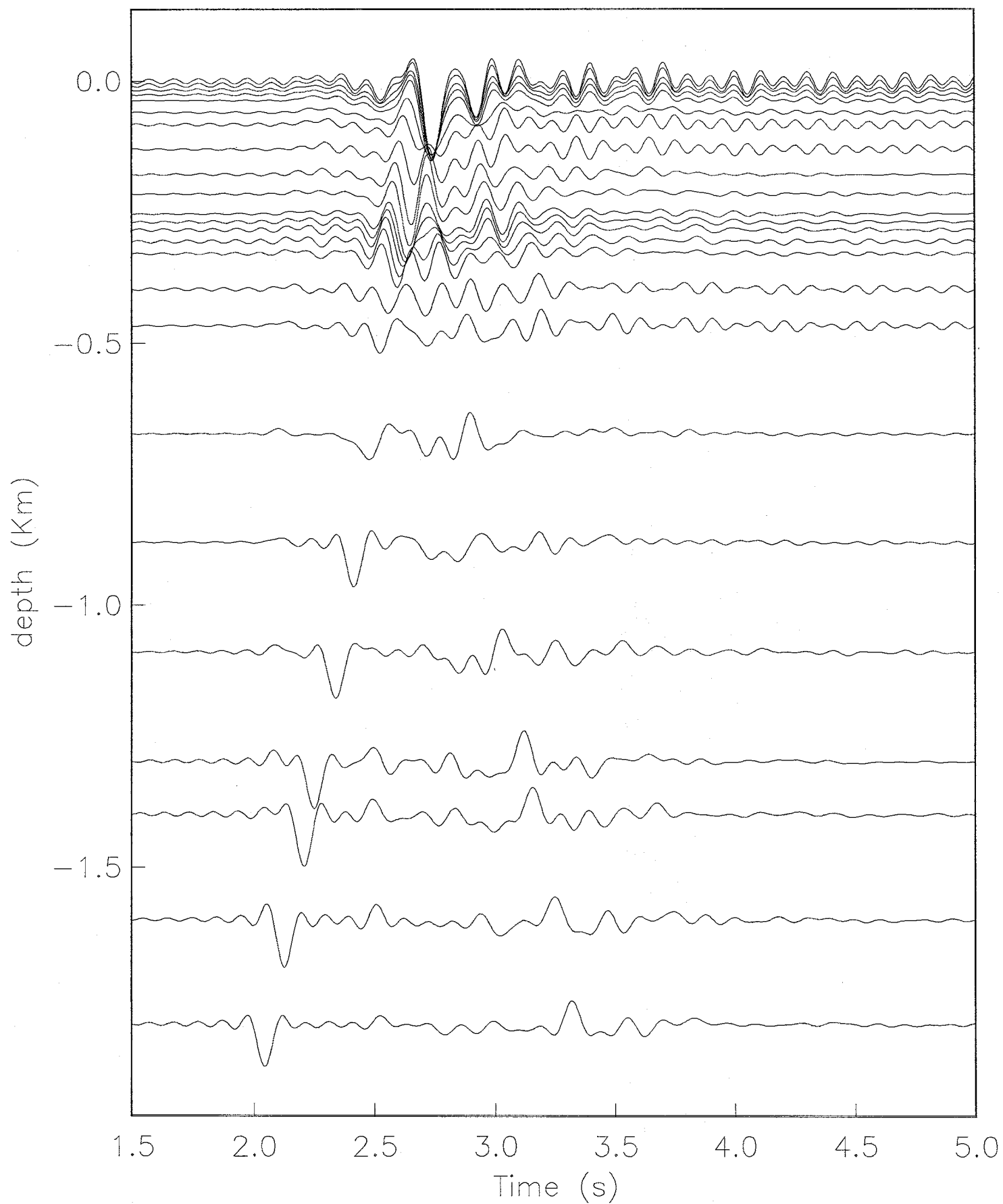
Ux

S waves | layer | angle : 30 | QS=Qp=10



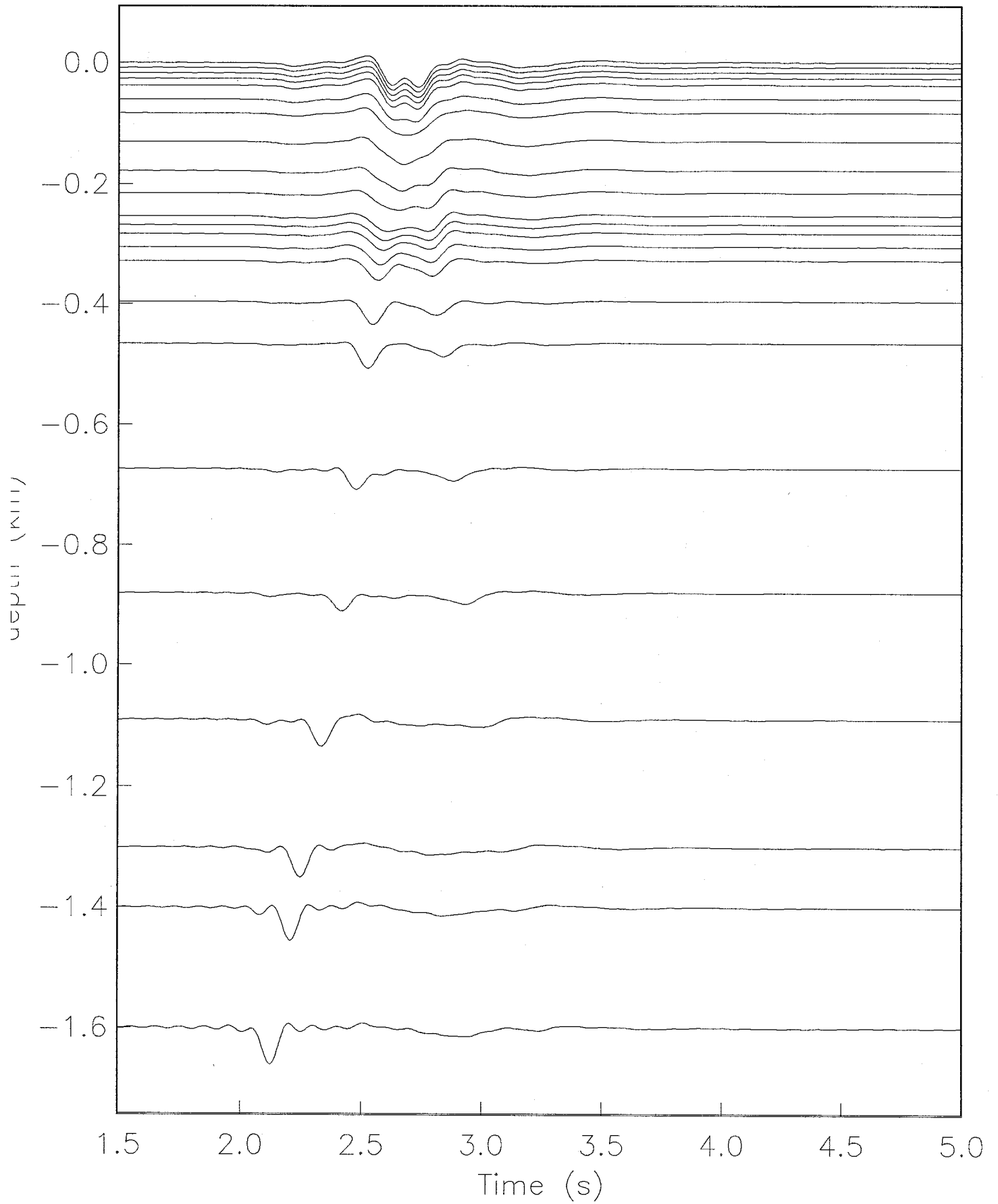
U_x

S waves | layer | angle : 30 | QS=Qp=300



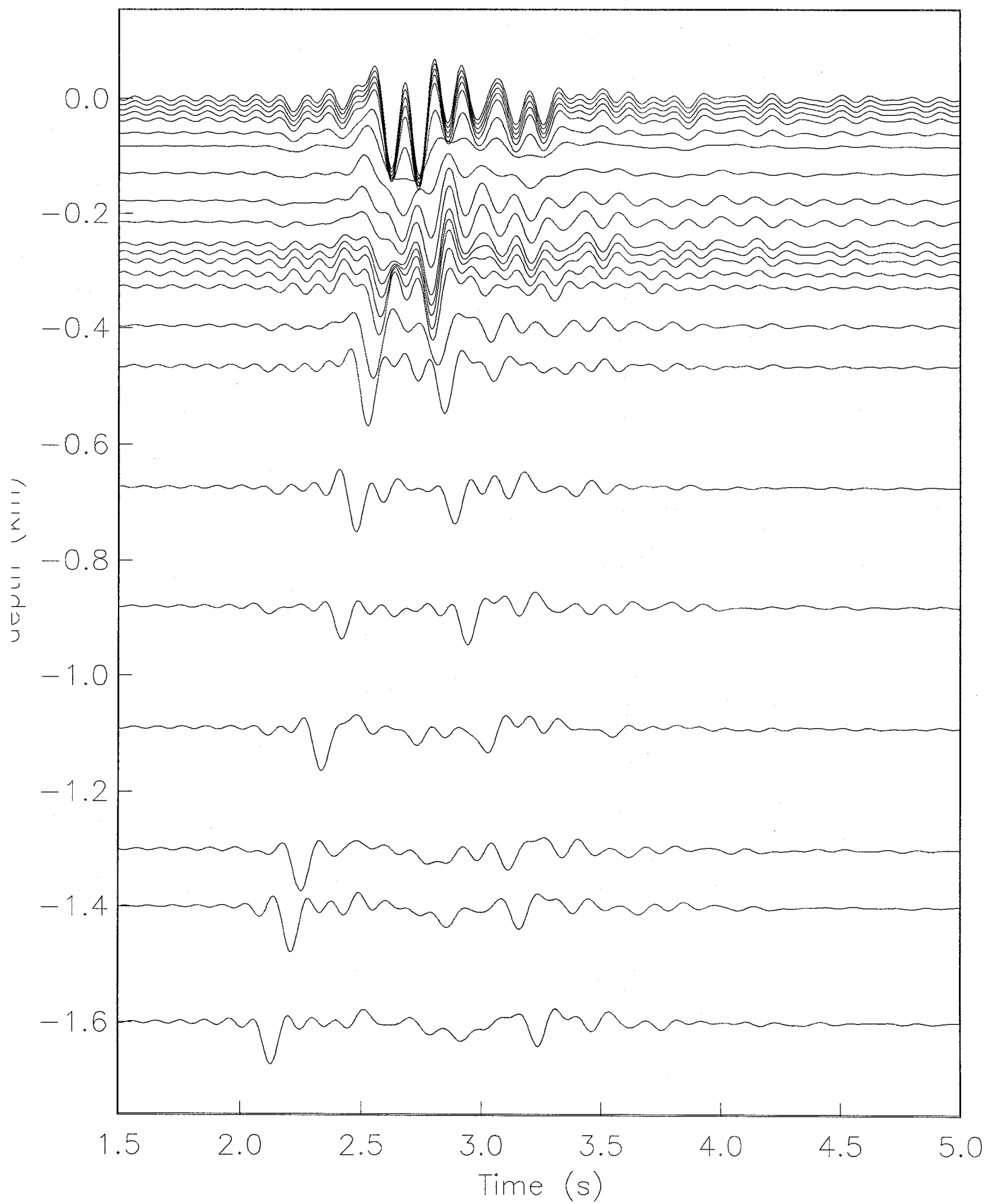
Uz

S waves | gradient | angle : 30 | Qs=Qp=10



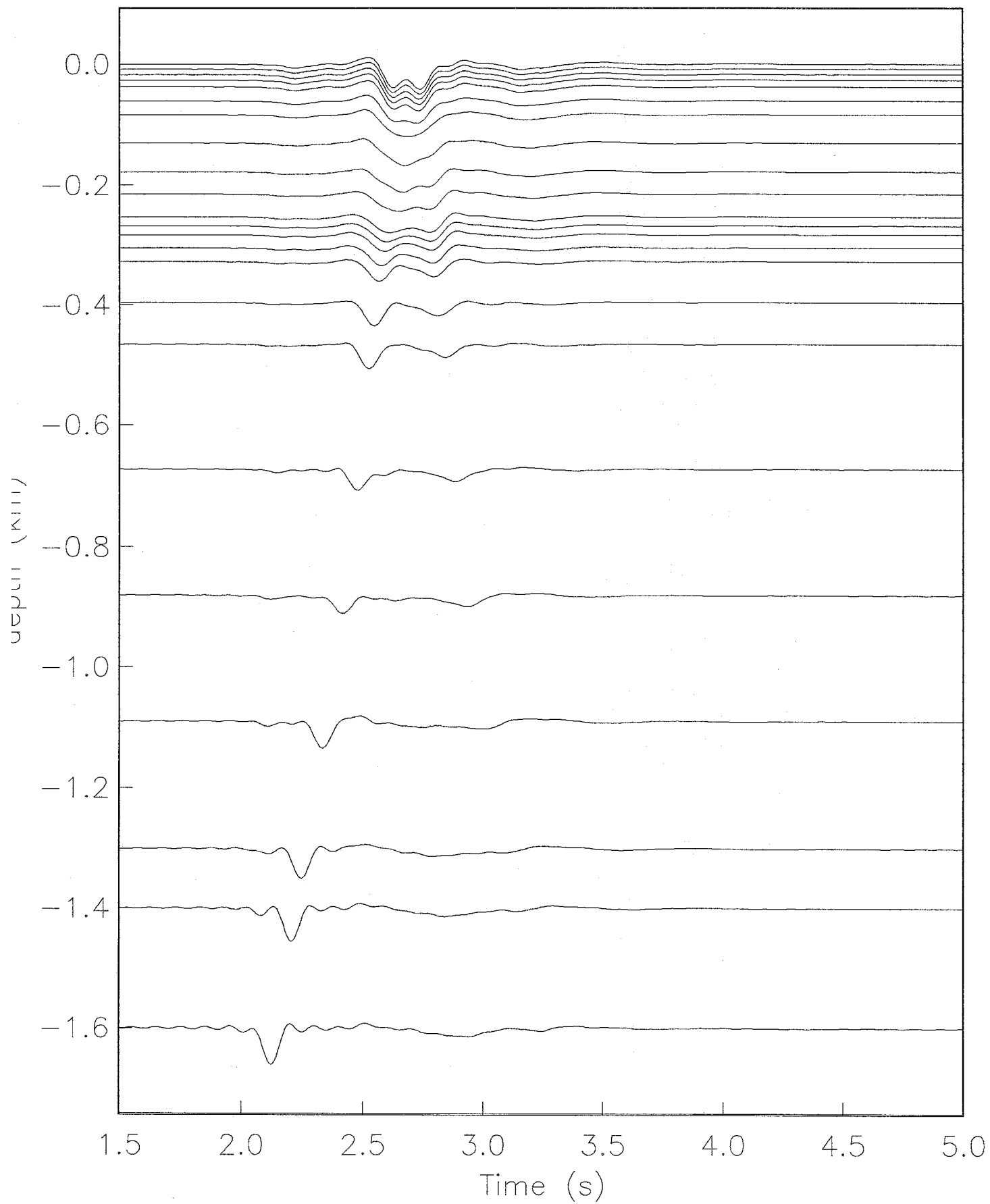
Uz

S waves | gradient | angle : 30 | Qs=Qp=300



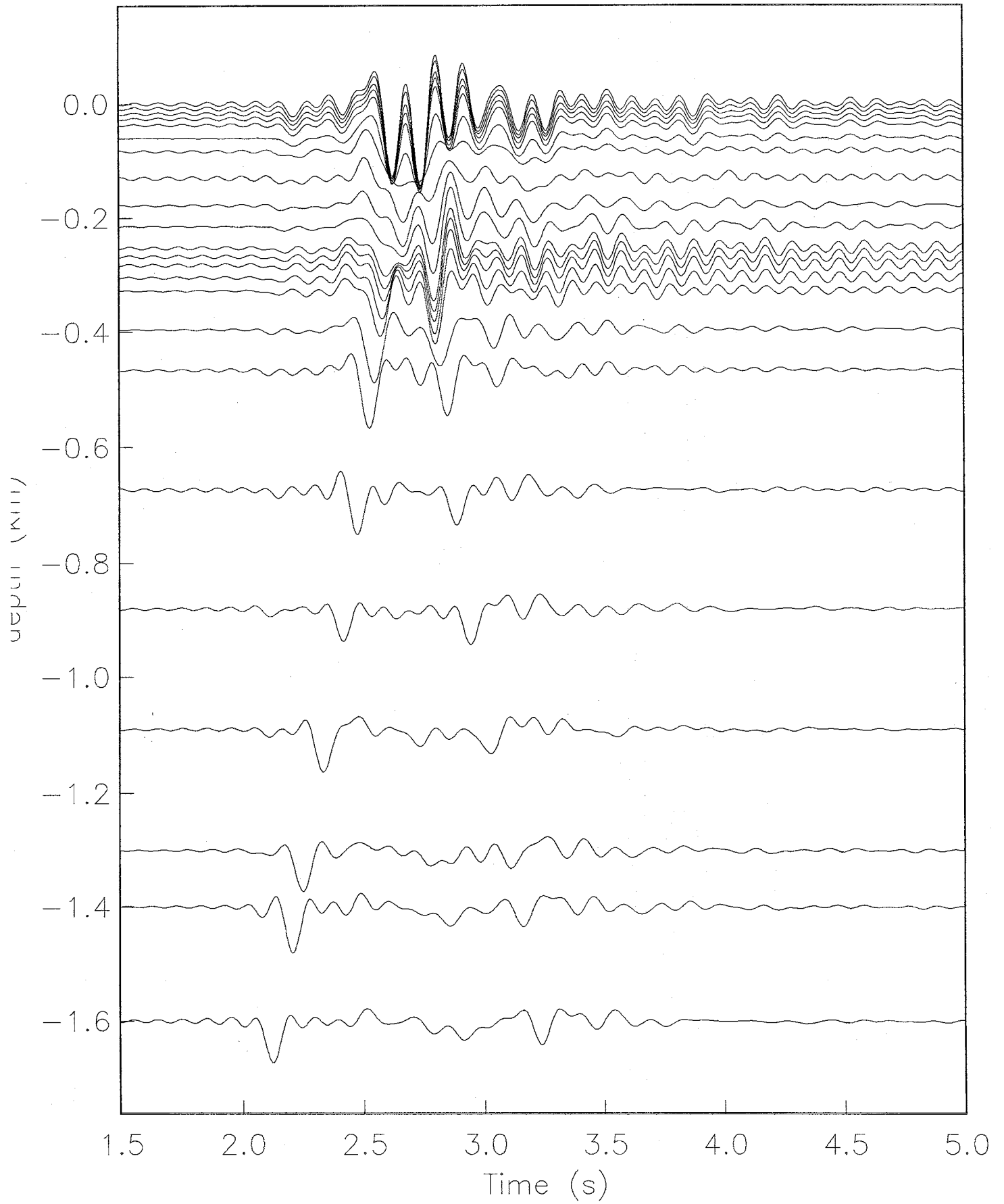
Uz

S waves | layer | angle : 30 | Qs=Qp=10



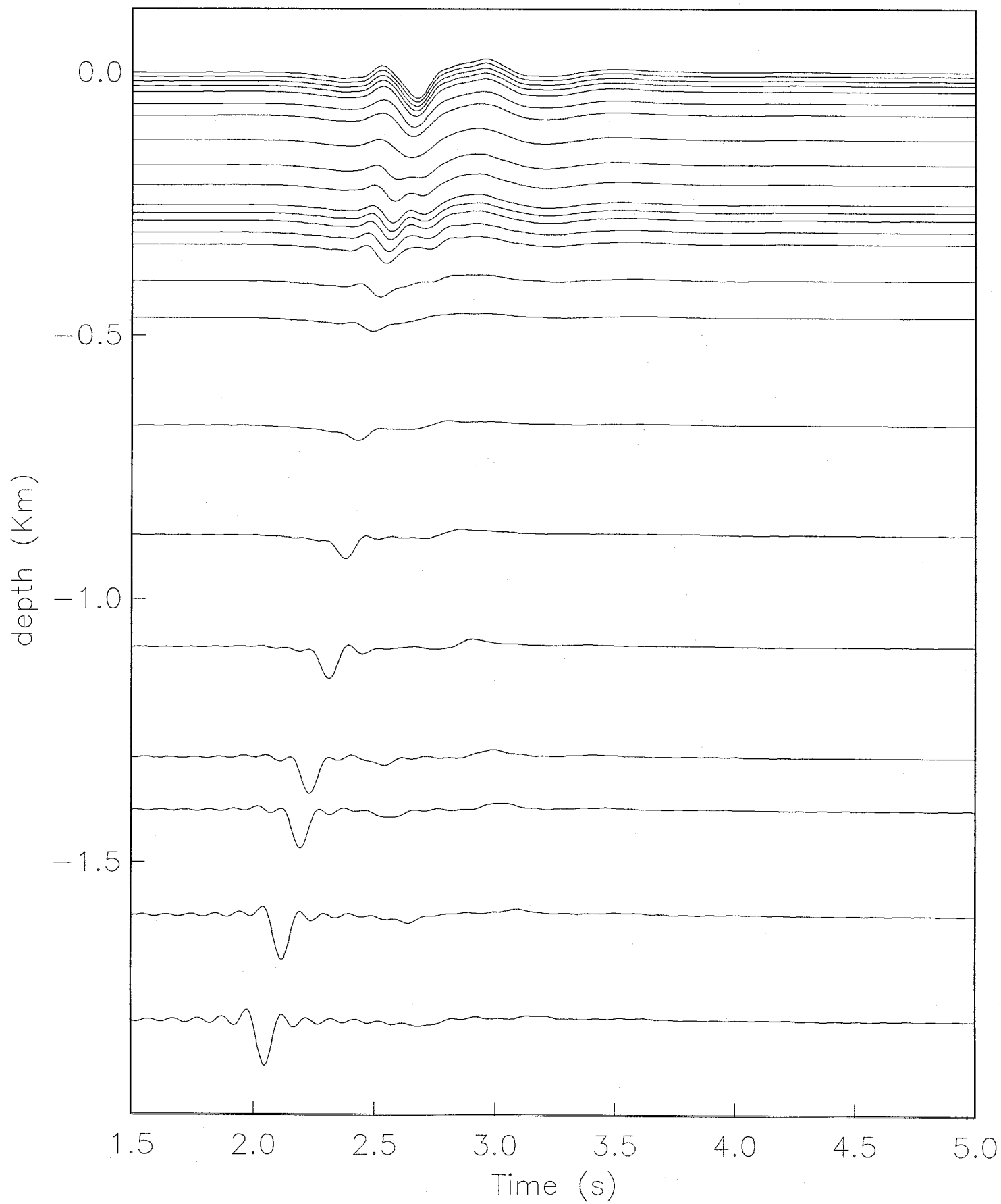
Uz

S waves | layer | angle : 30 | Qs=Qp=300

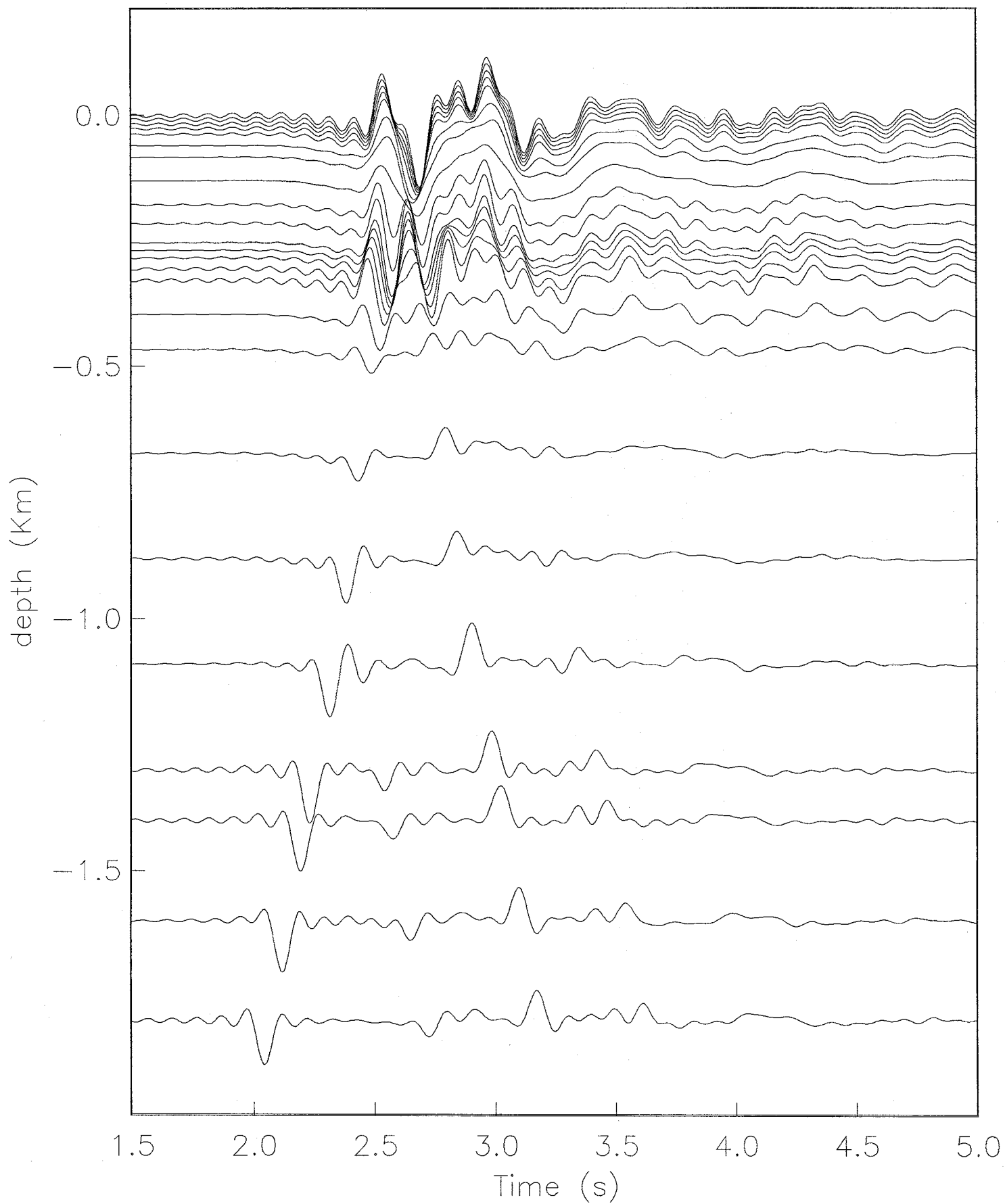


U_x

S waves | gradient | angle : 40 | QS=Qp=10

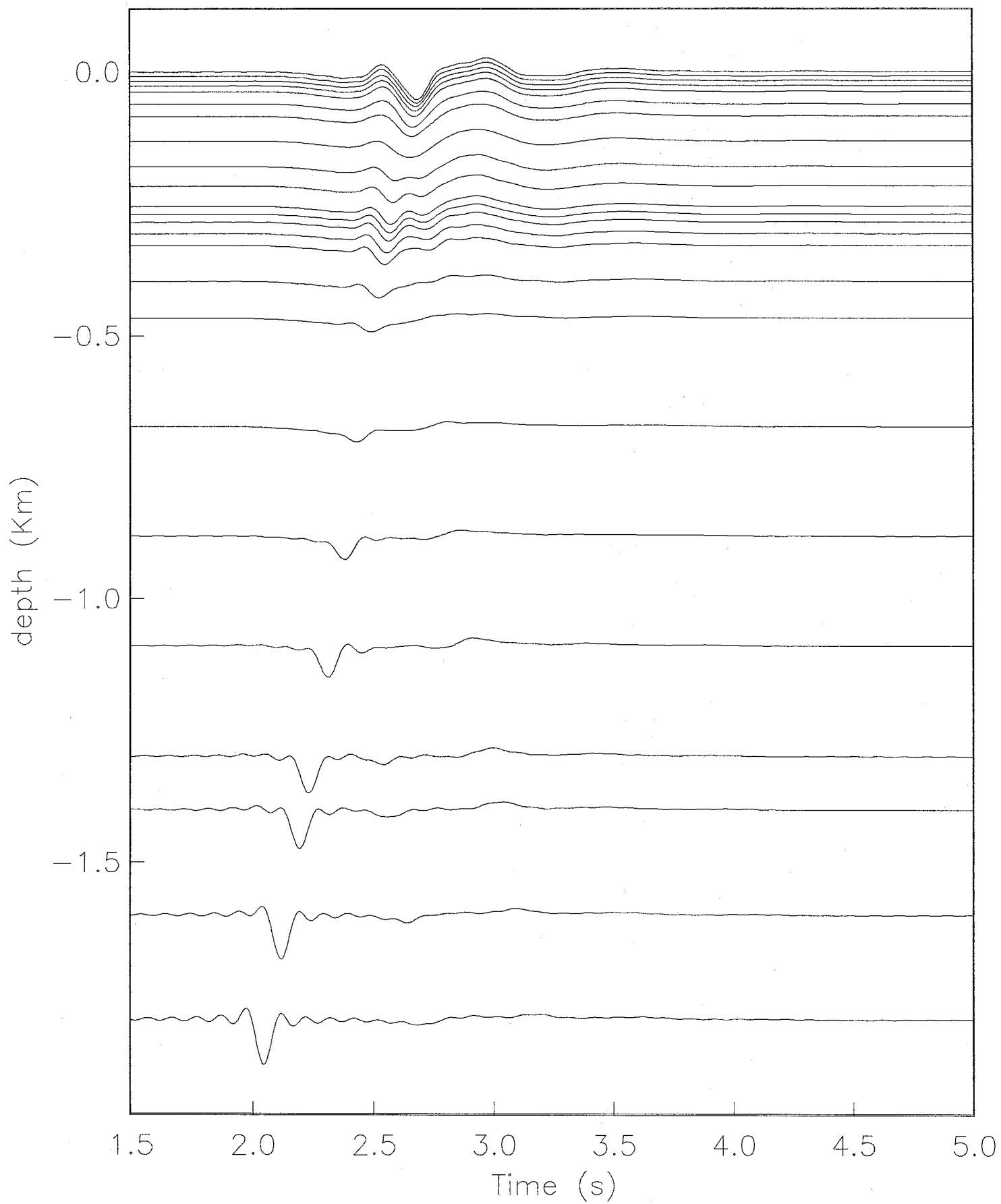


S waves | gradient U_x | angle : 40 | QS=Qp=300

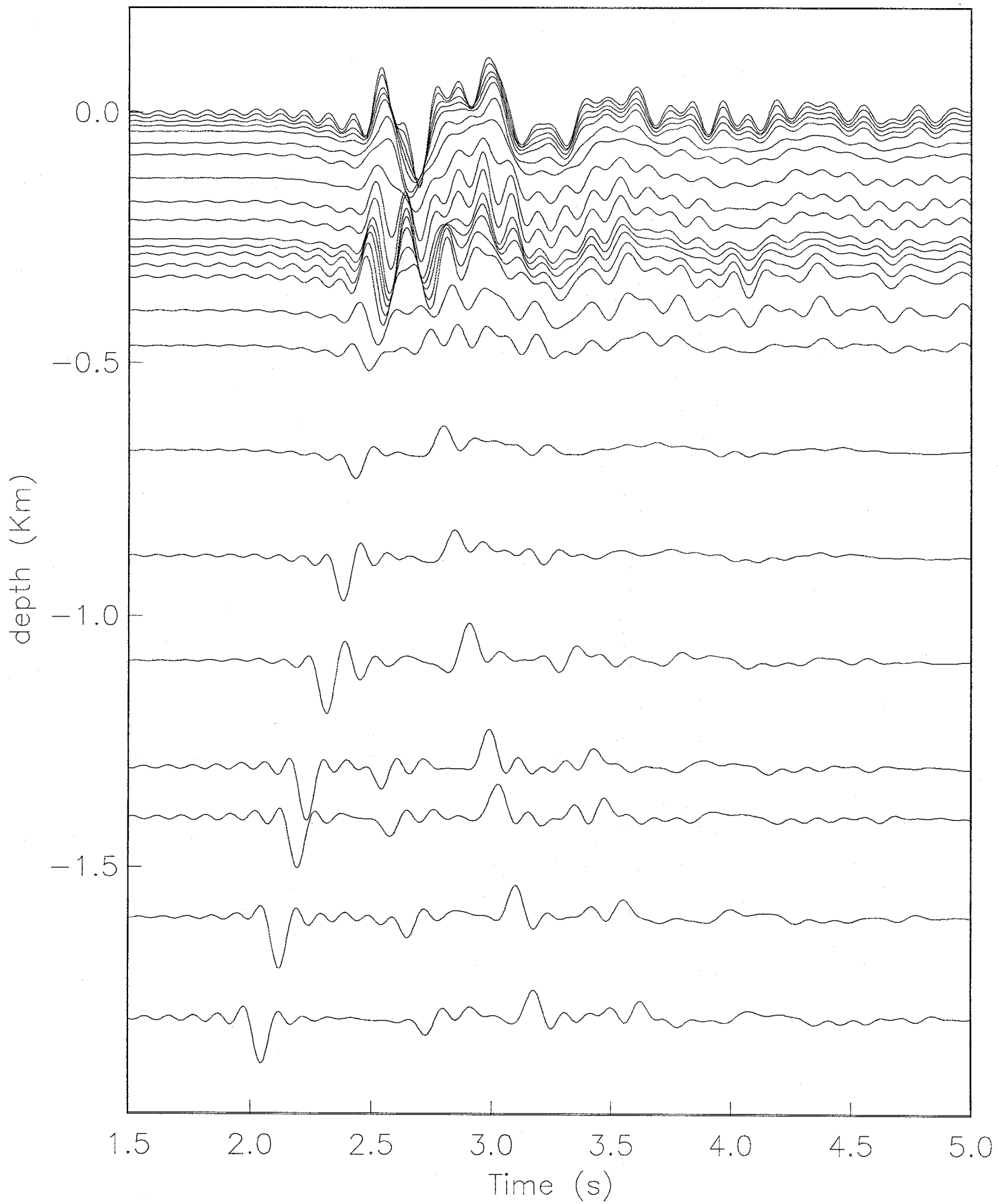


Ux

S waves | layer | angle : 40 | QS=Qp=10

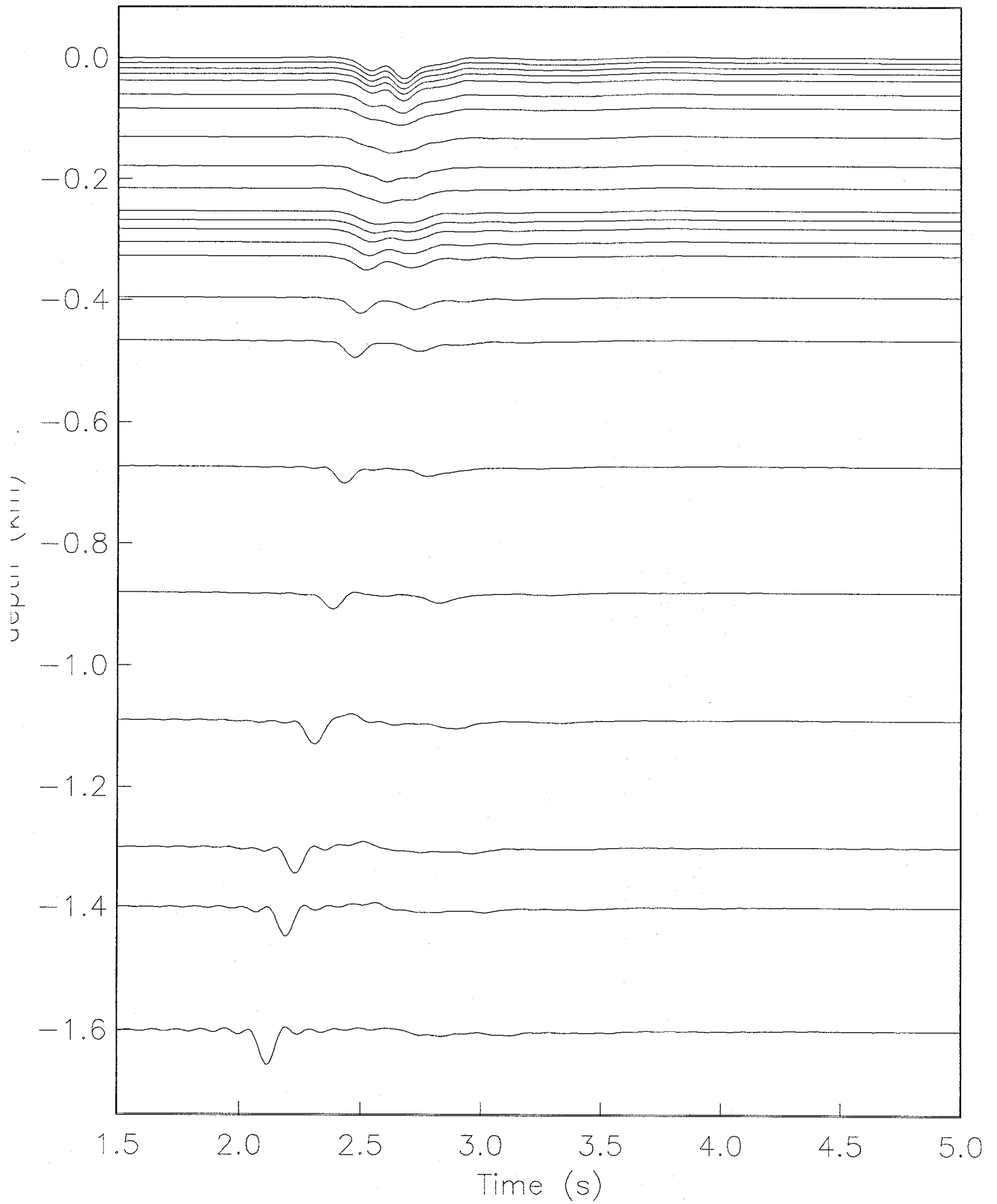


S waves | layer | U_x
angle : 40 | $Q_S=Q_P=300$



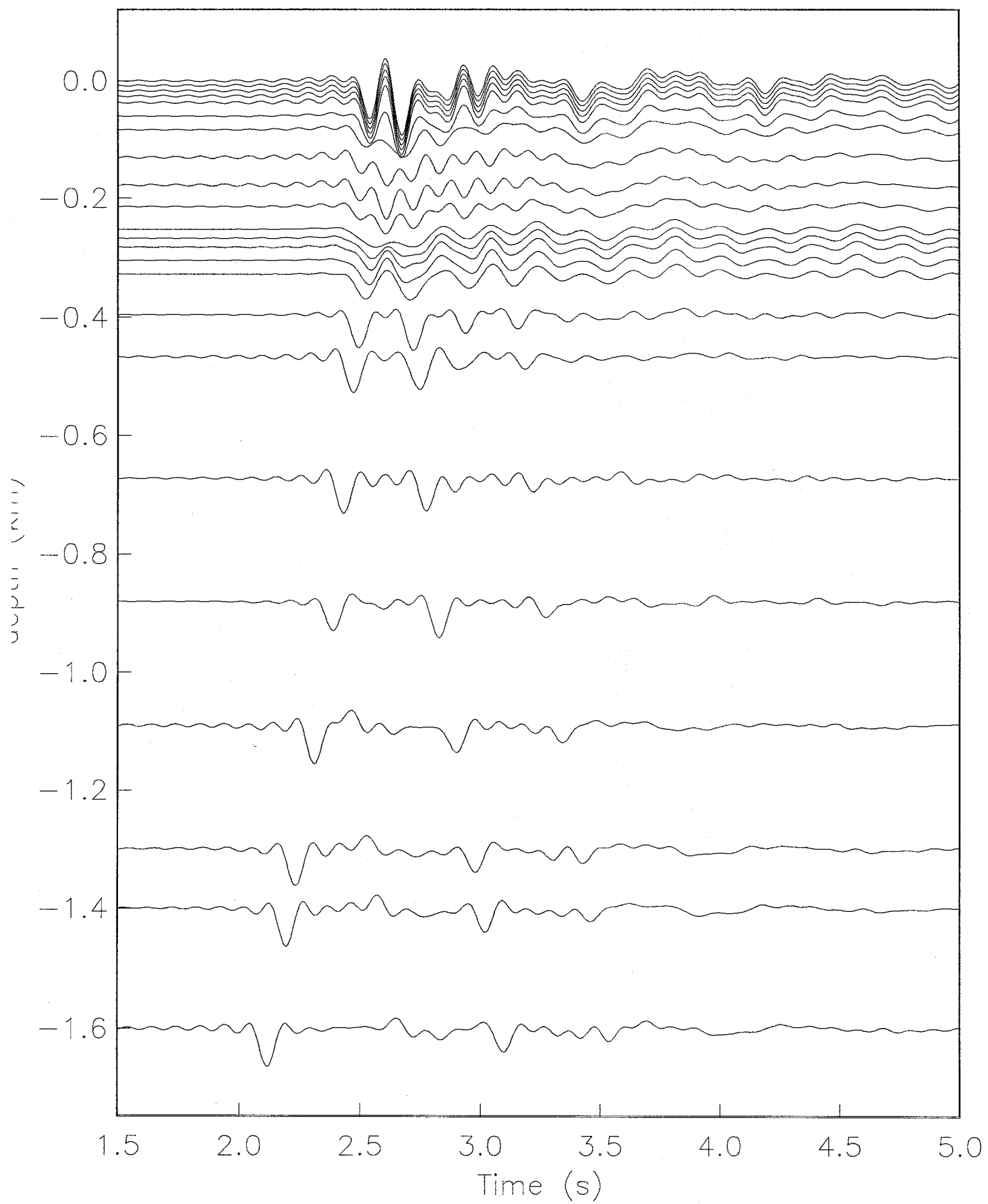
Uz

S waves | gradient | angle : 40 | $Q_s=Q_p=10$



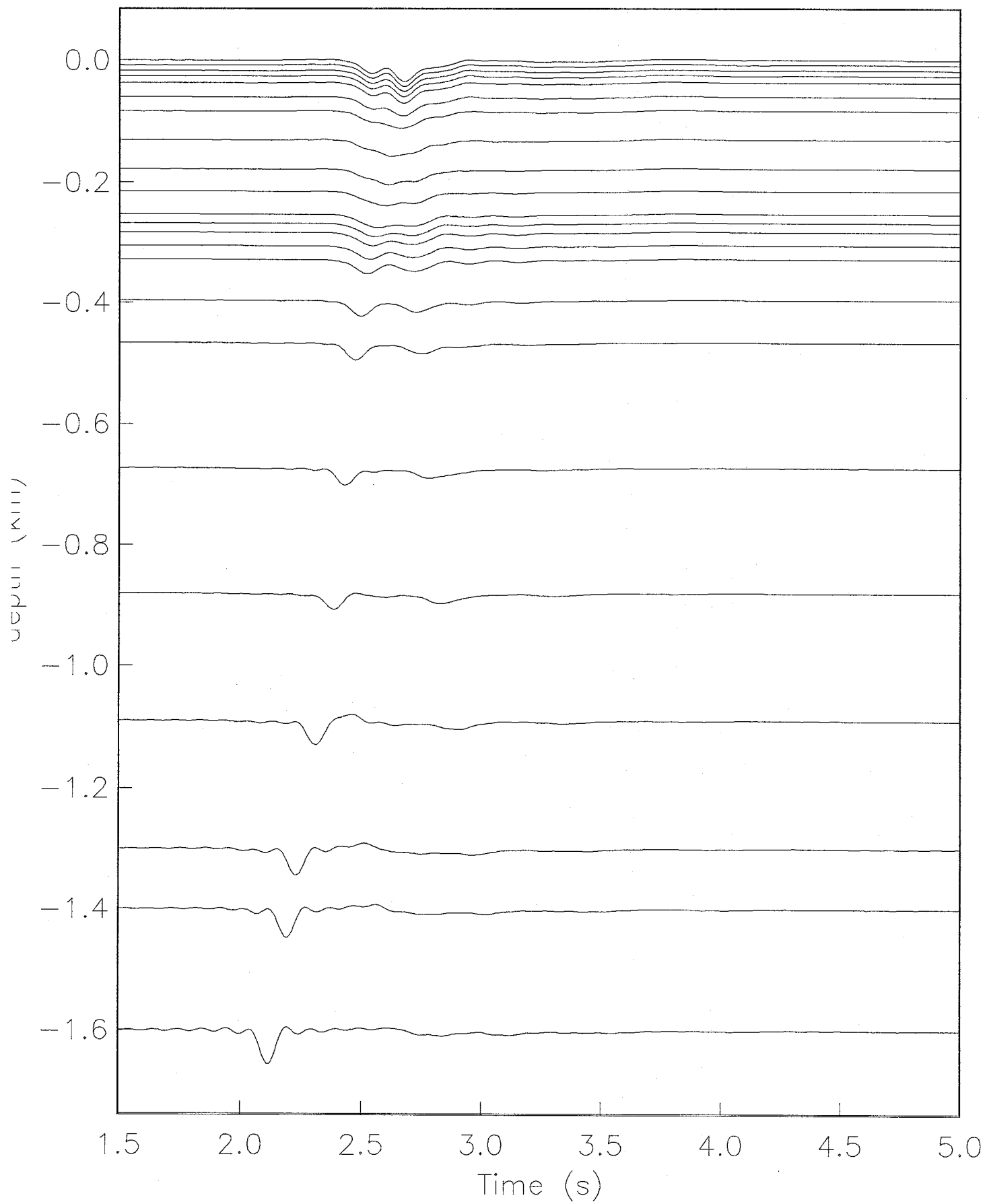
Uz

S waves | gradient | angle : 40 | $Q_s=Q_p=300$



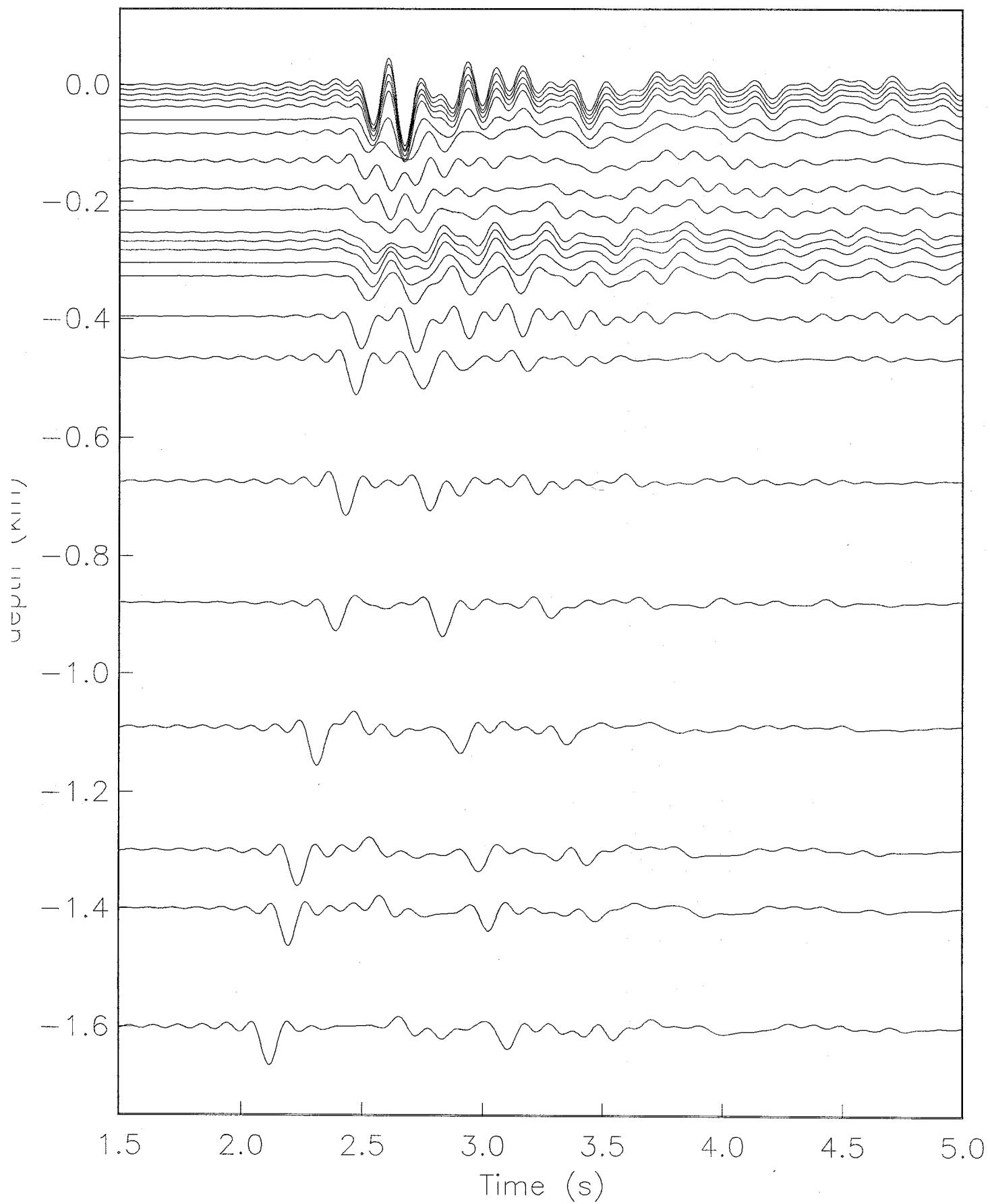
Uz

S waves | layer | angle : 40 | Qs=Qp=10



Uz

S waves | layer | angle : 40 | Qs=Qp=300



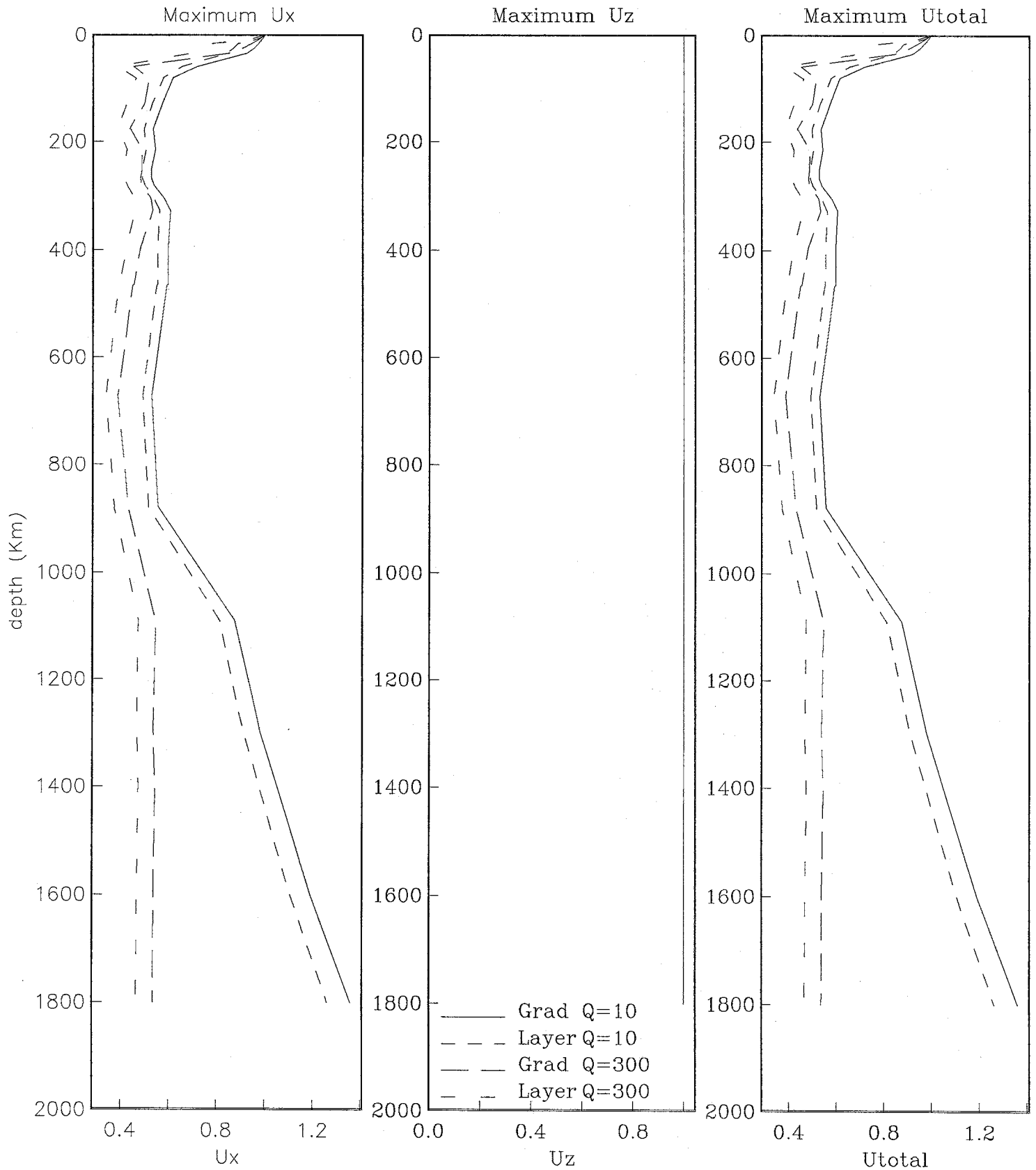
Appendix D

Content :

- 9 maximum displacement profiles for frequency content 0 to 10 Hz.
- 9 maximum velocity profiles for frequency content 0 to 10 Hz.
- 9 maximum acceleration profiles for frequency content 0 to 10 Hz.

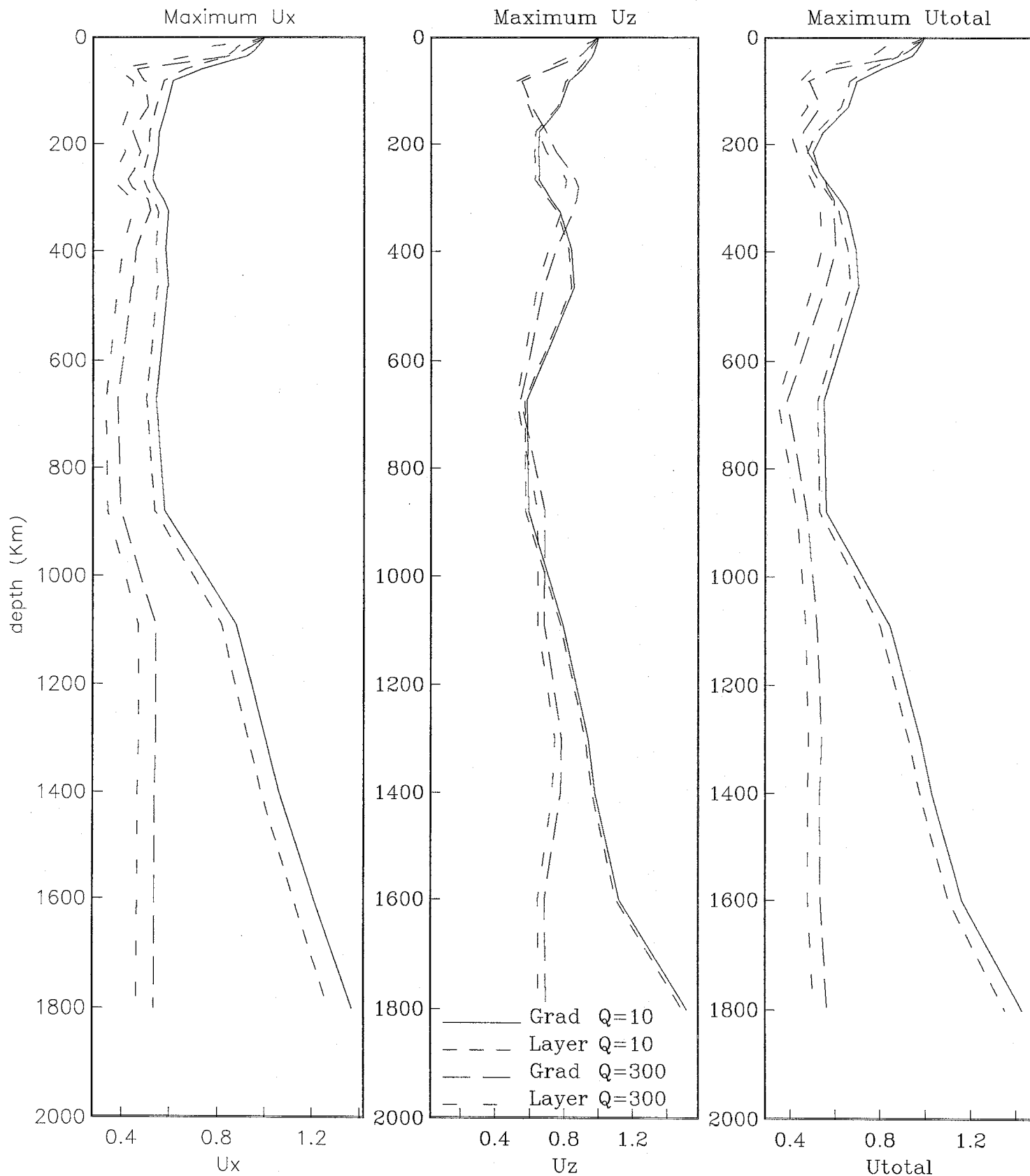
Maximum Displacement

incident angle : 0



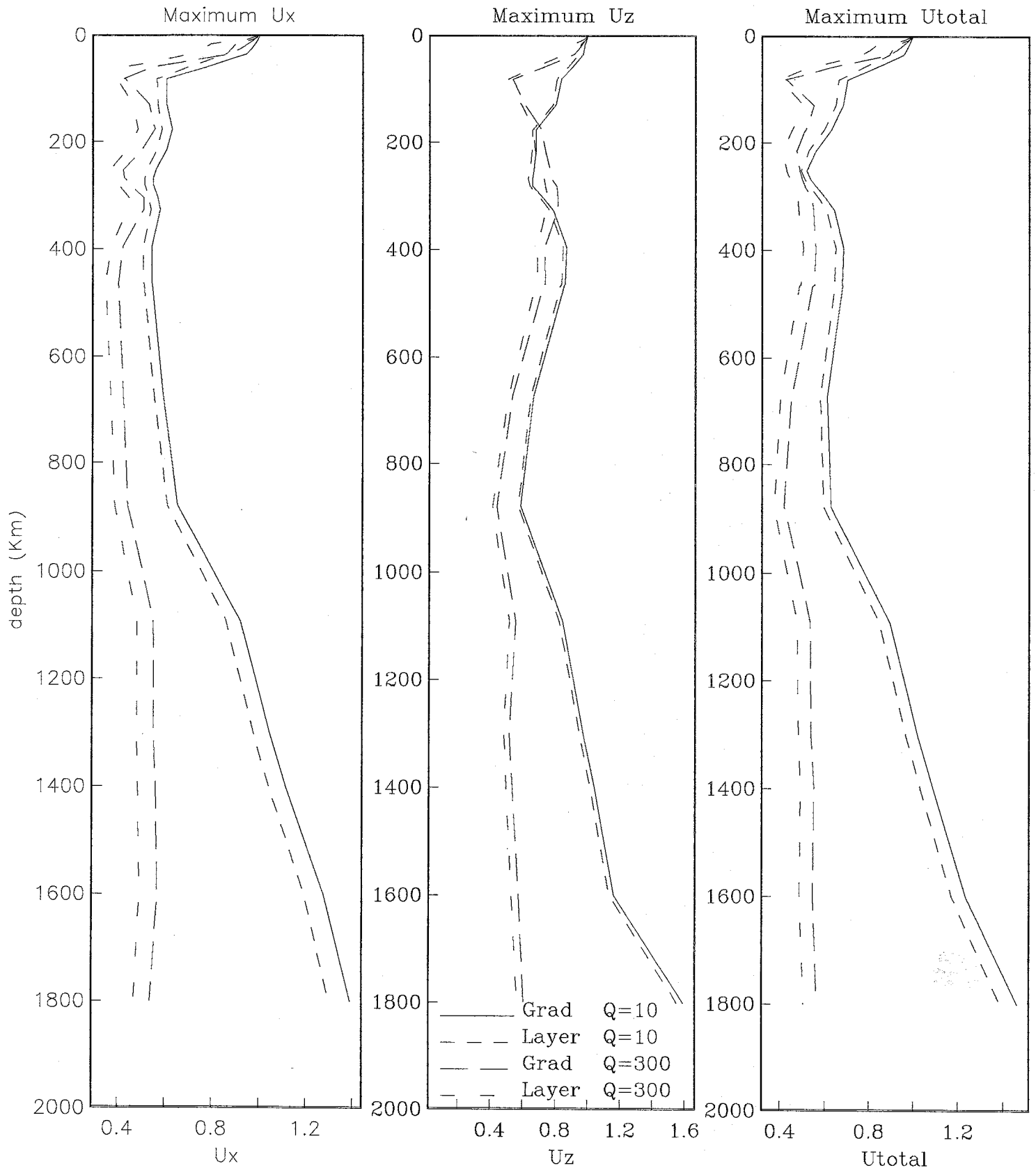
Maximum Displacement

incident angle : 10

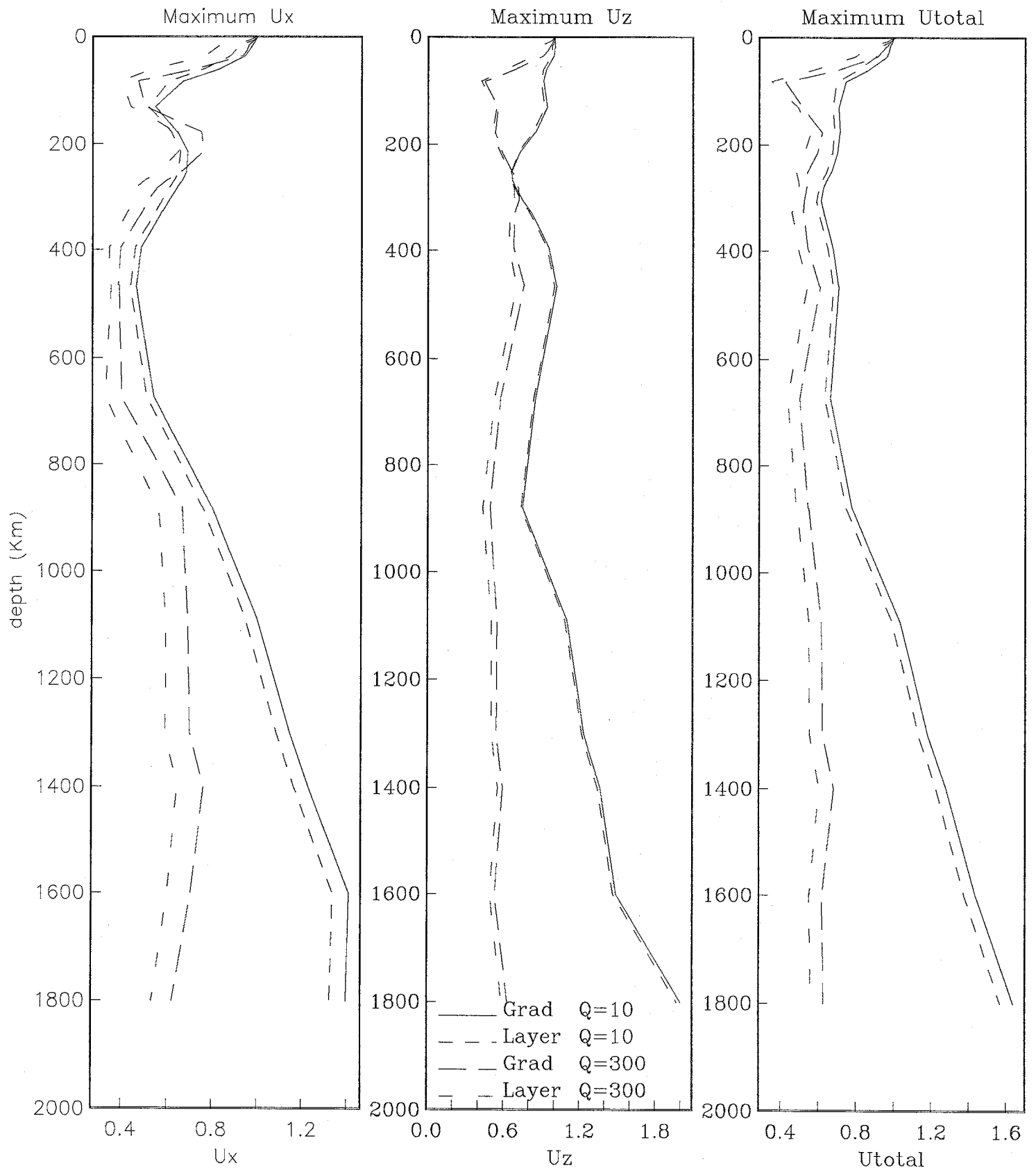


Maximum Displacement

incident angle : 20

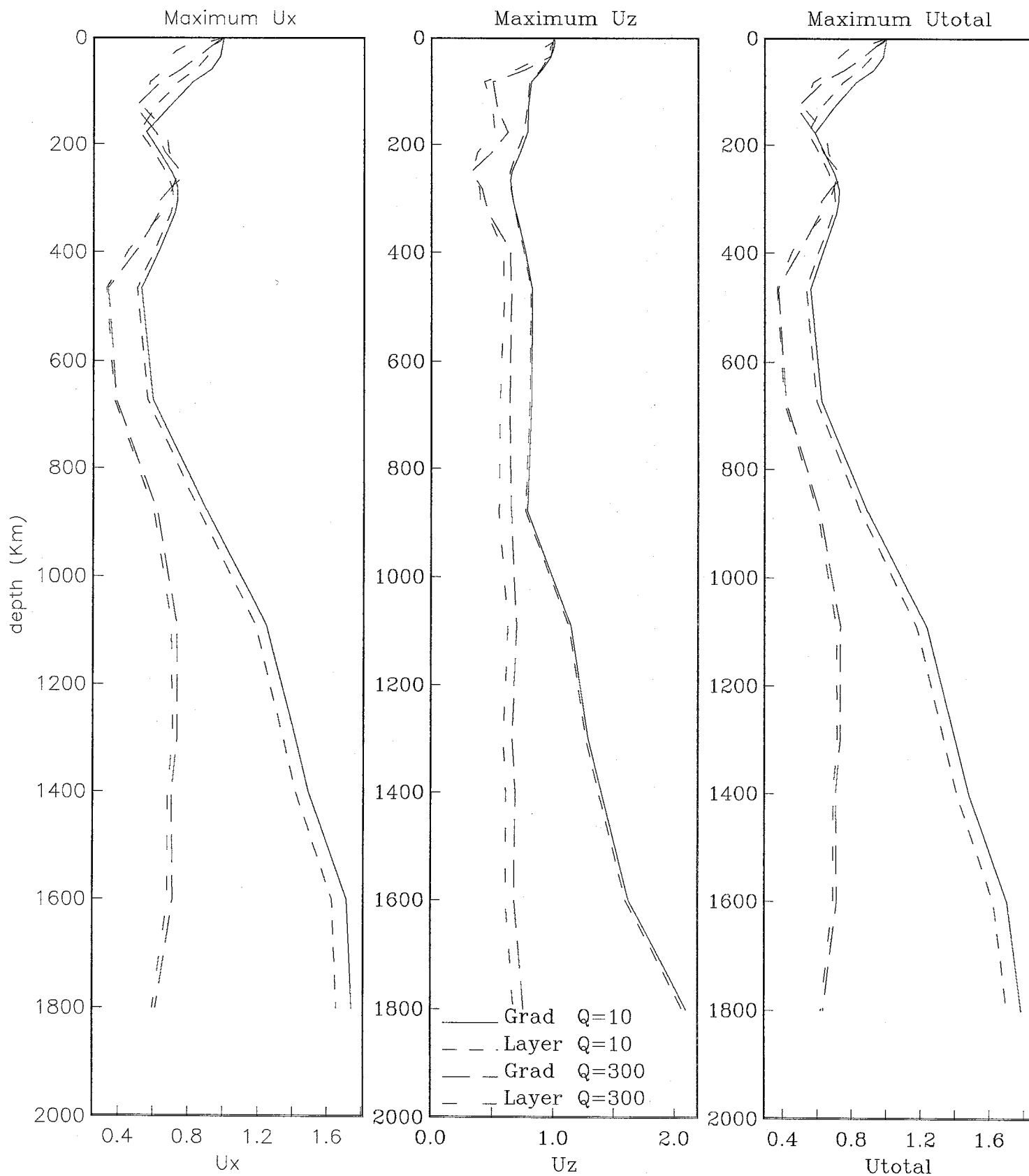


Maximum Displacement incident angle : 30

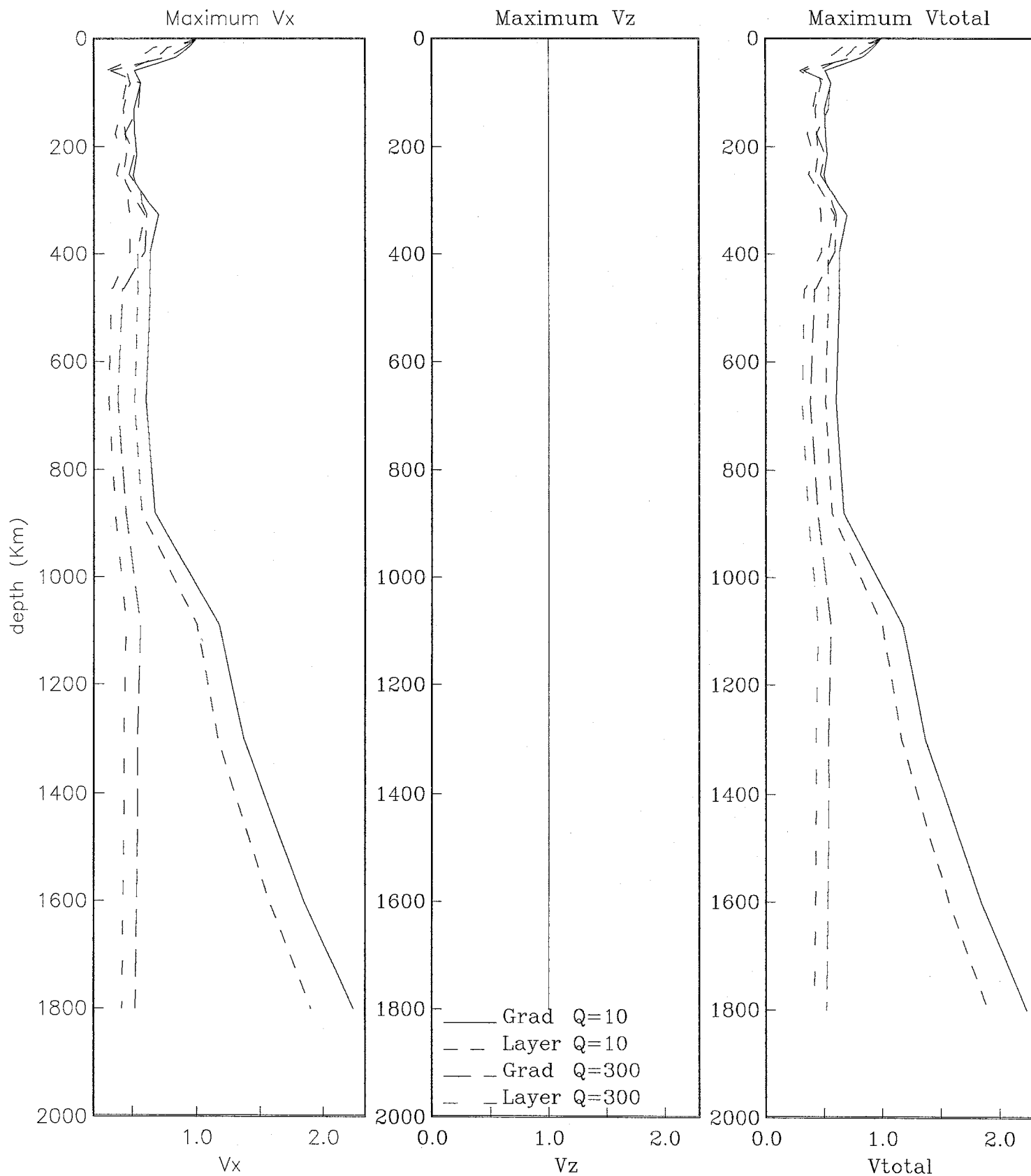


Maximum Displacement

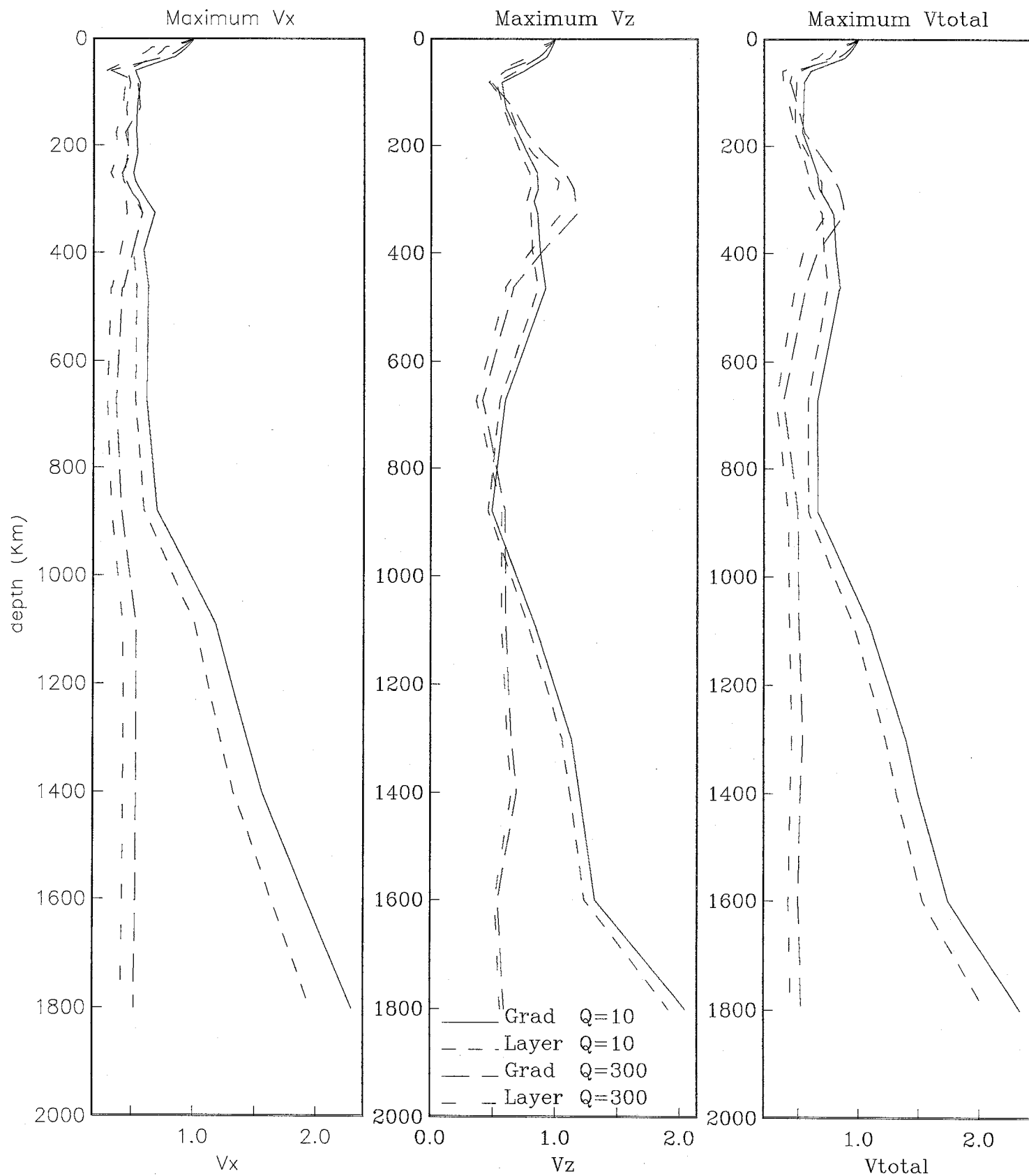
incident angle : 40



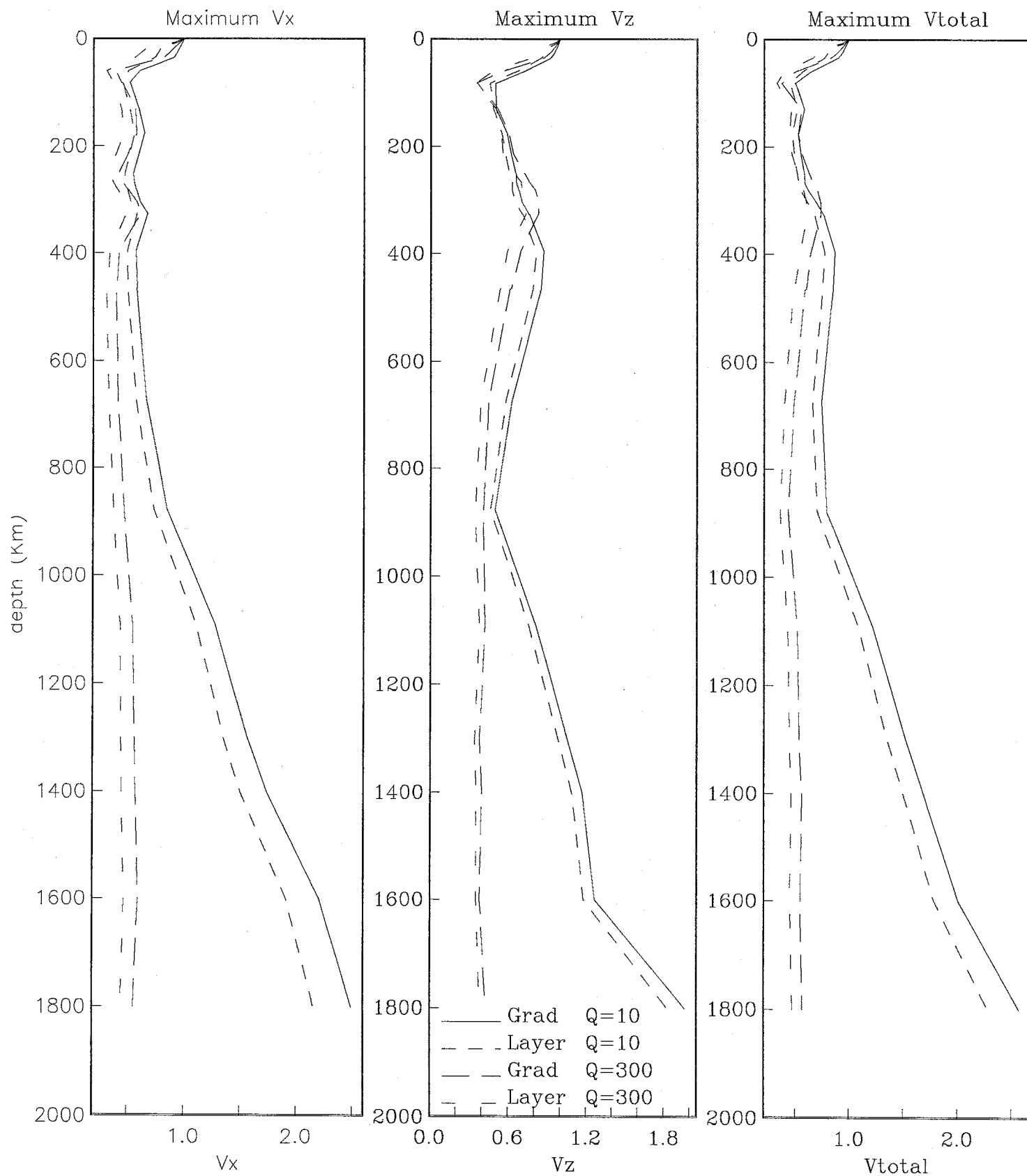
Maximum velocity incident angle : 0



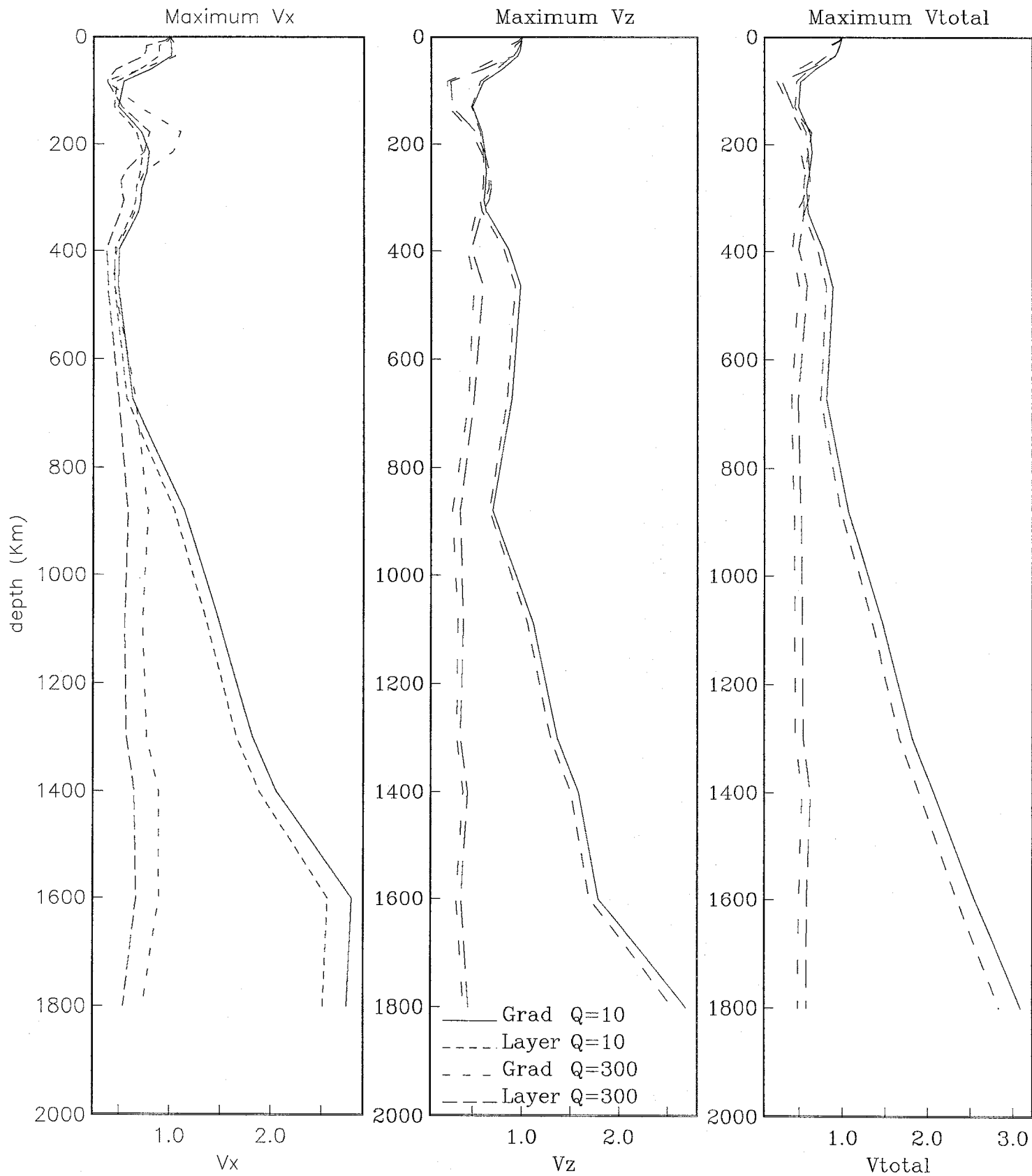
Maximum velocity incident angle : 10



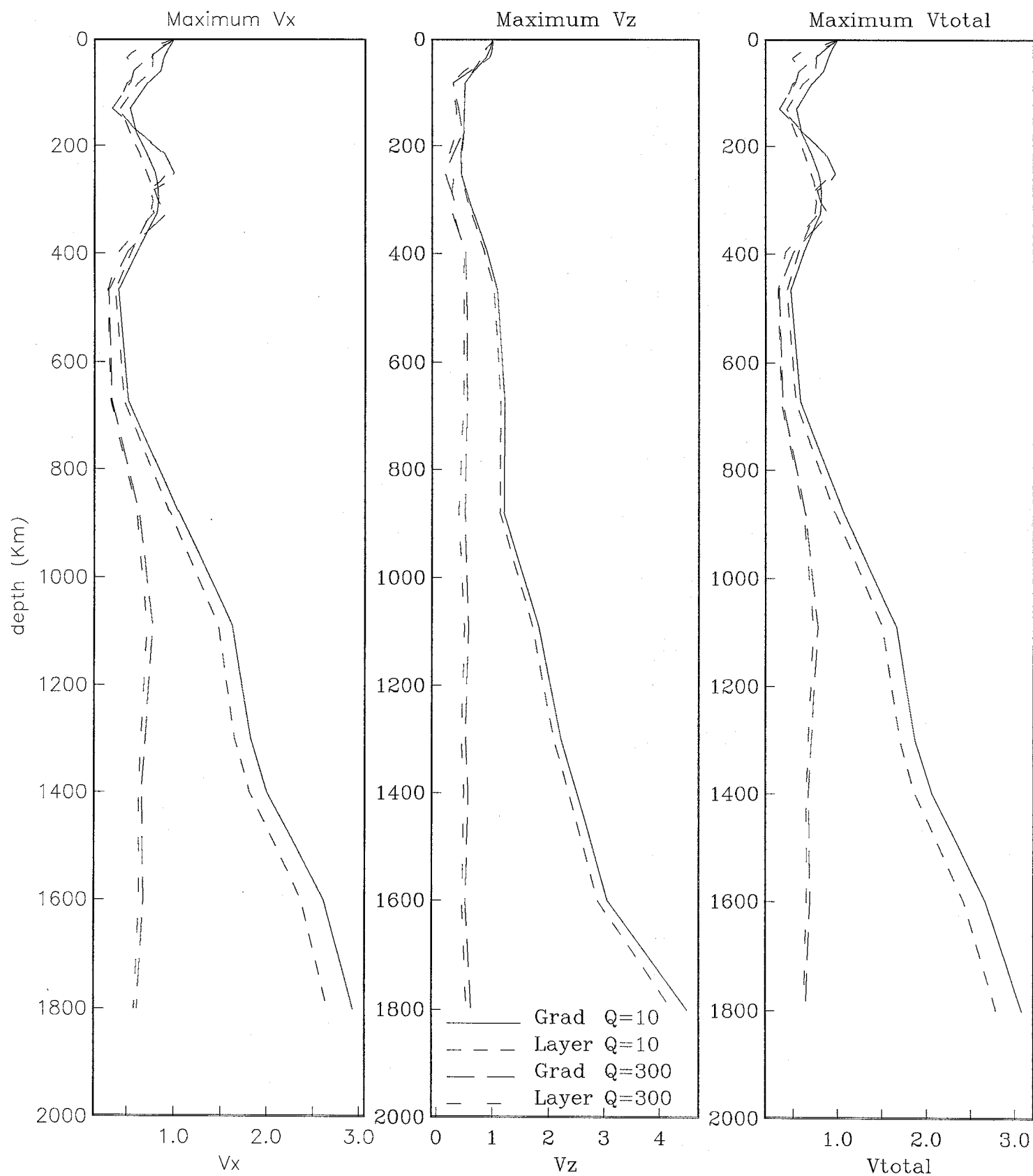
Maximum velocity incident angle : 20



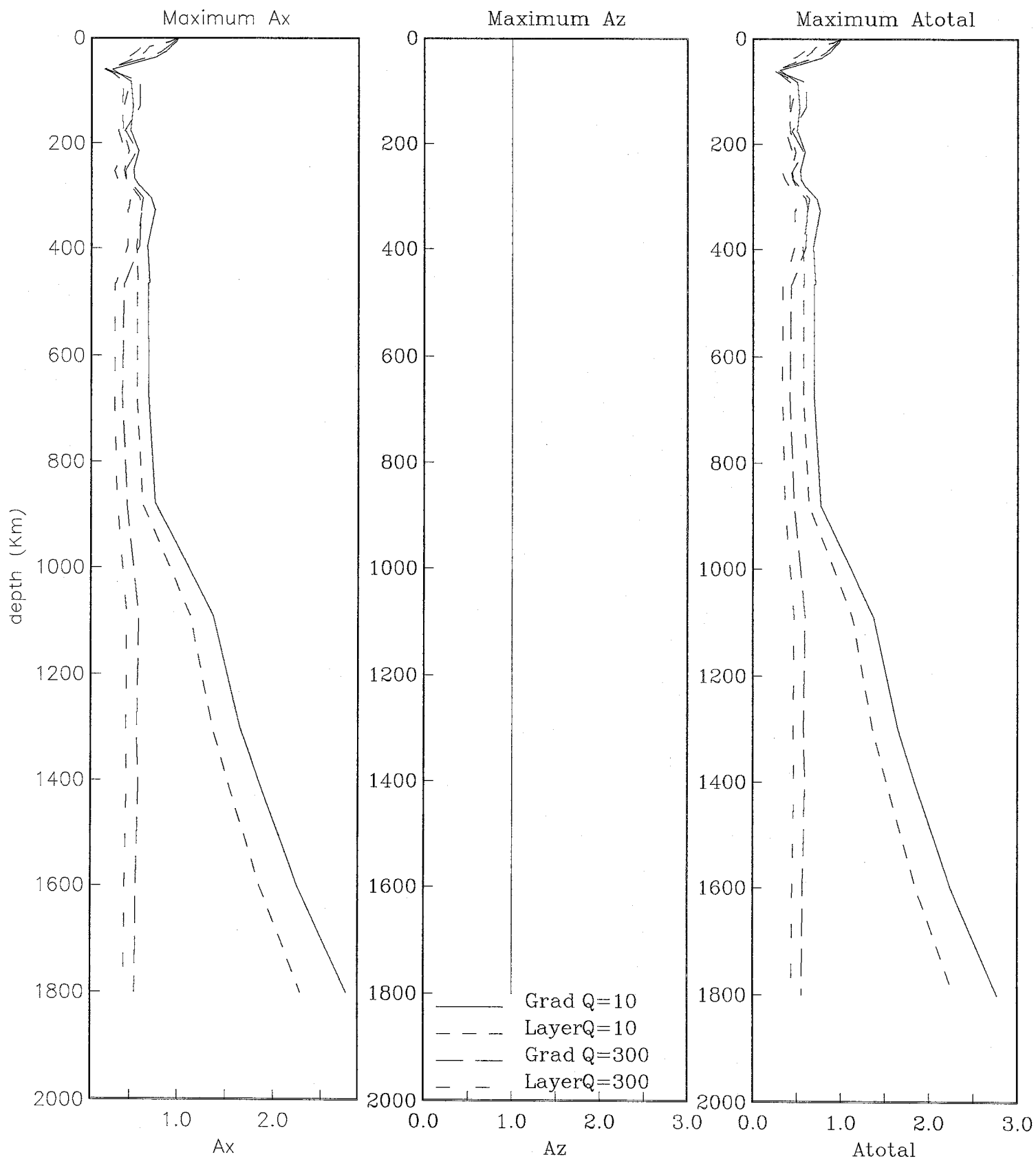
Maximum velocity incident angle : 30



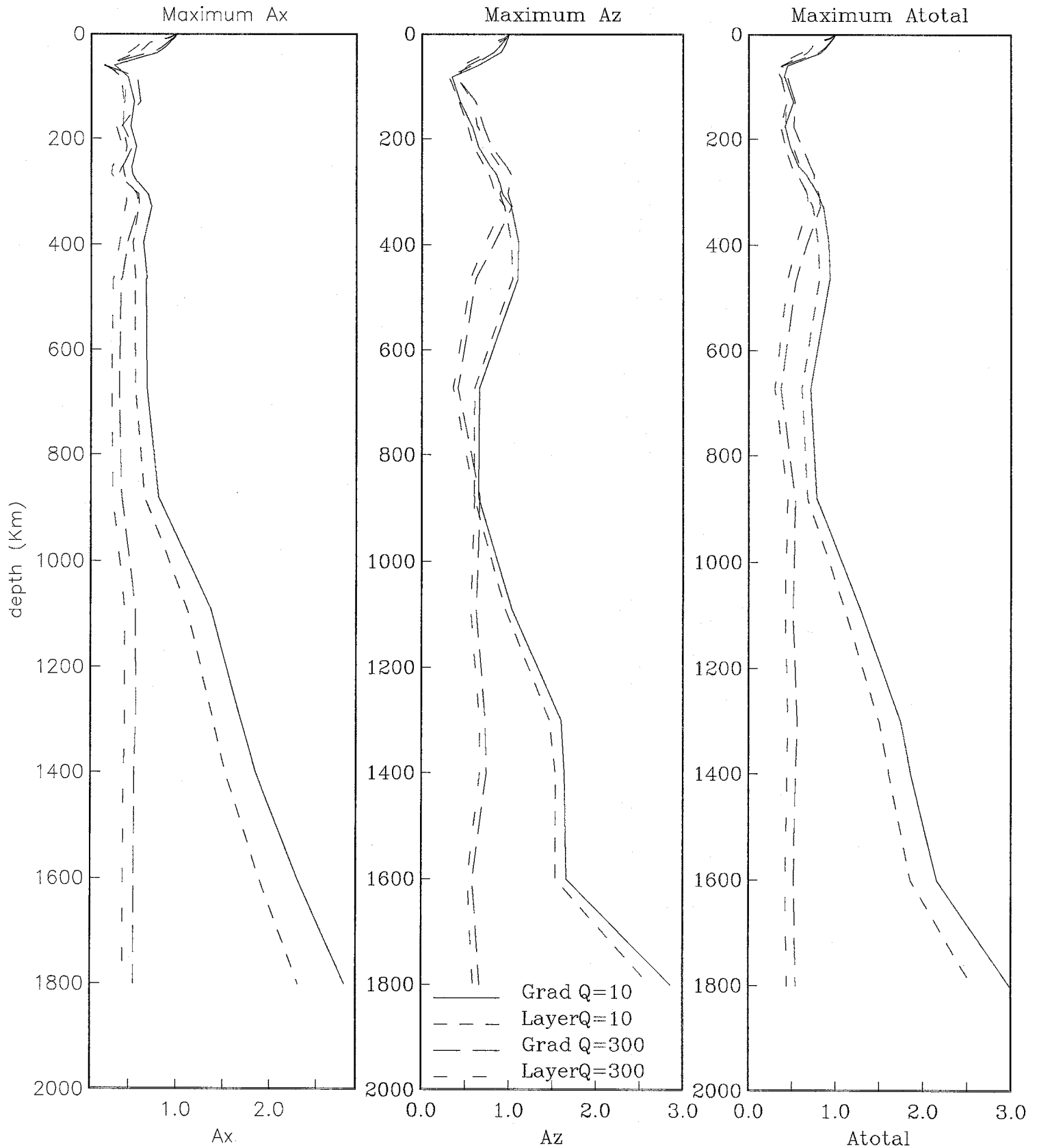
Maximum velocity incident angle : 40



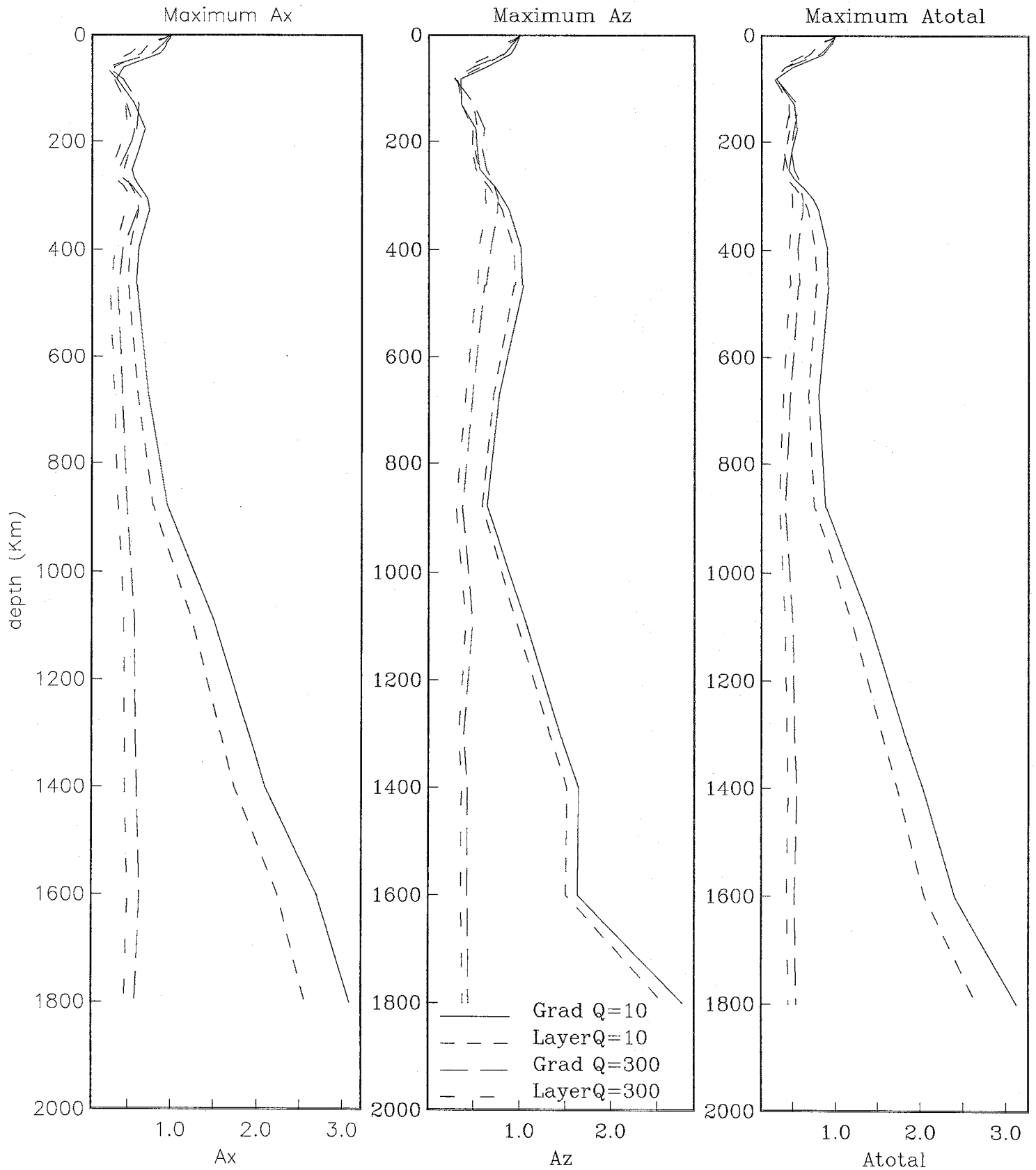
Maximum acceleration incident angle : 0



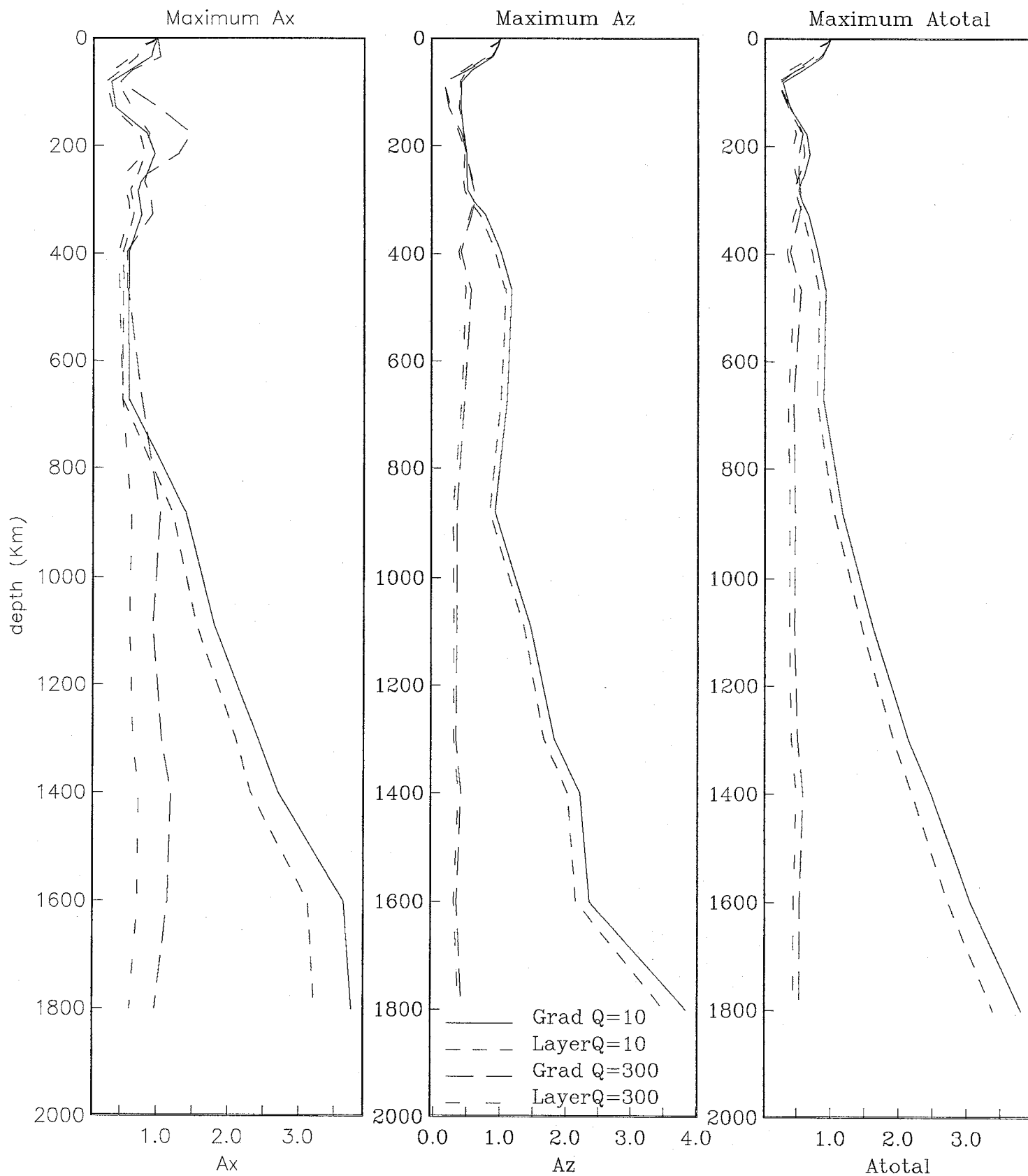
Maximum acceleration incident angle : 10



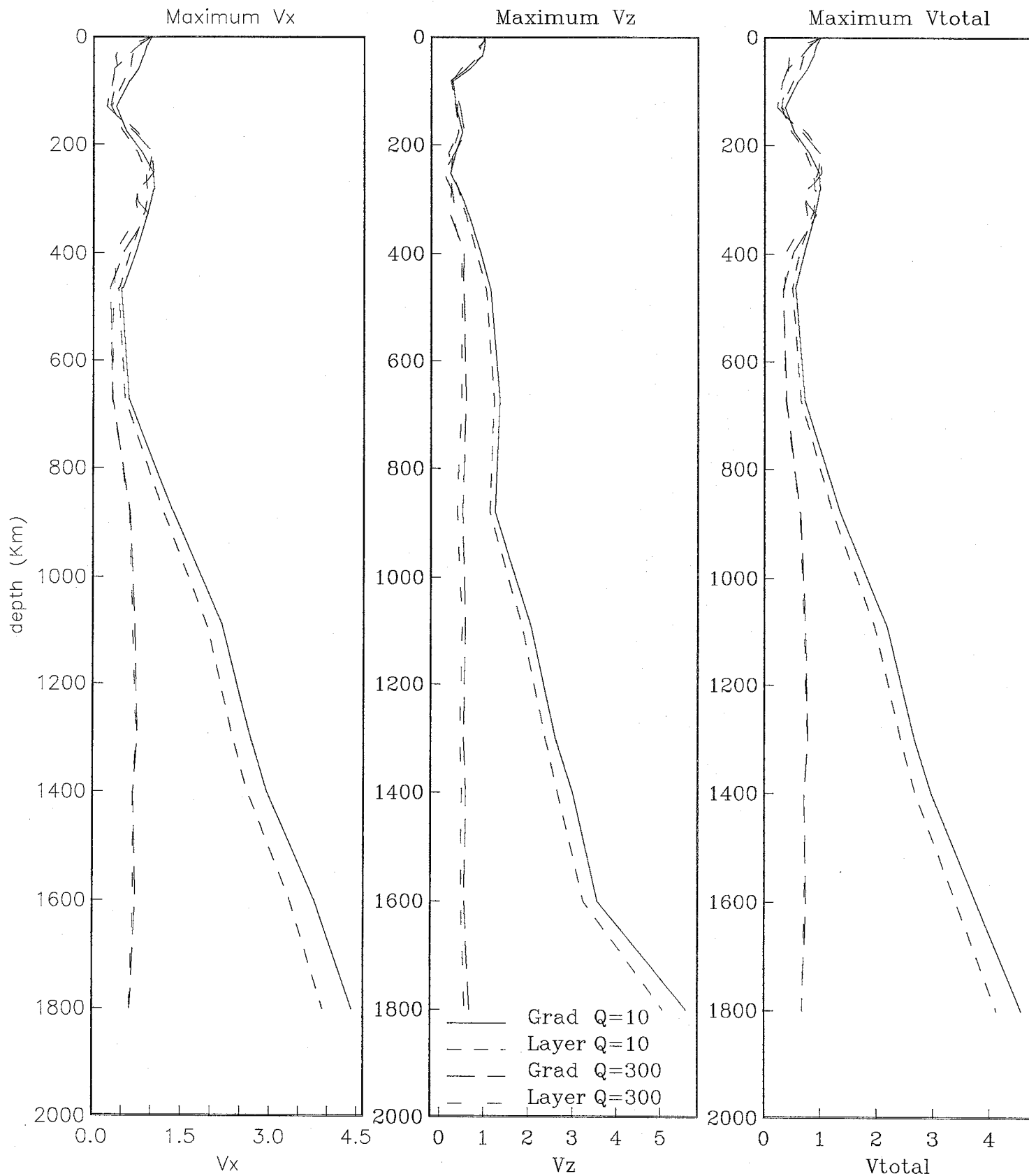
Maximum acceleration incident angle : 20



Maximum acceleration
incident angle : 30



Maximum acceleration incident angle : 40



Appendix E

Content :

20 tables containing maximum displacements, velocities, accelerations for angles of incidence 0, 10, 20, 30, and 40, depths 0, 8, 16, 17, 26, 35, 37, 60, 82, 83, 130, 177, 178, 215, 252, 253, 268, 282, 283, 305, 327, 328, 296, 464, 466, 673, 879, 880, 1090, 1300 and 1600 m, gradient and homogeneous top 16.5 m of ground, Q values 10 and 300, for a frequency content 0 to 10 Hz.

Incident angle : 0

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
0	10	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	10	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	10	G	0.9886	1.0000	0.9886	0.9732	1.0000	0.9732	0.9787	1.0000	0.9787
	10	L	0.9729	1.0000	0.9729	0.9462	1.0000	0.9462	0.9211	1.0000	0.9211
	300	G	0.9763	1.0000	0.9763	0.9630	1.0000	0.9630	0.9557	1.0000	0.9557
	300	L	0.9472	1.0000	0.9472	0.9191	1.0000	0.9191	0.9094	1.0000	0.9094
16	10	G	0.9727	1.0000	0.9727	0.9395	1.0000	0.9395	0.9255	1.0000	0.9255
	10	L	0.8963	1.0000	0.8963	0.7932	1.0000	0.7932	0.7281	1.0000	0.7281
	300	G	0.9457	1.0000	0.9457	0.9137	1.0000	0.9137	0.8994	1.0000	0.8994
	300	L	0.7983	1.0000	0.7983	0.6906	1.0000	0.6906	0.6582	1.0000	0.6582
17	10	G	0.9708	1.0000	0.9708	0.9323	1.0000	0.9323	0.9255	1.0000	0.9255
	10	L	0.8863	1.0000	0.8863	0.7738	1.0000	0.7738	0.7018	1.0000	0.7018
	300	G	0.9414	1.0000	0.9414	0.9075	1.0000	0.9075	0.8913	1.0000	0.8913
	300	L	0.7796	1.0000	0.7796	0.6624	1.0000	0.6624	0.6264	1.0000	0.6264
26	10	G	0.9511	1.0000	0.9511	0.8927	1.0000	0.8927	0.8723	1.0000	0.8723
	10	L	0.8669	1.0000	0.8669	0.7356	1.0000	0.7356	0.6579	1.0000	0.6579
	300	G	0.9032	1.0000	0.9032	0.8467	1.0000	0.8467	0.8270	1.0000	0.8270
	300	L	0.7428	1.0000	0.7428	0.6120	1.0000	0.6120	0.5644	1.0000	0.5644
35	10	G	0.9239	1.0000	0.9239	0.8390	1.0000	0.8390	0.7872	1.0000	0.7872
	10	L	0.8410	1.0000	0.8410	0.6859	1.0000	0.6859	0.5965	1.0000	0.5965
	300	G	0.8503	1.0000	0.8503	0.7639	1.0000	0.7639	0.7324	1.0000	0.7324
	300	L	0.6954	1.0000	0.6954	0.5488	1.0000	0.5488	0.4897	1.0000	0.4897
37	10	G	0.9124	1.0000	0.9124	0.8162	1.0000	0.8162	0.7766	1.0000	0.7766
	10	L	0.8304	1.0000	0.8304	0.6651	1.0000	0.6651	0.5877	1.0000	0.5877
	300	G	0.8279	1.0000	0.8279	0.7286	1.0000	0.7286	0.6922	1.0000	0.6922
	300	L	0.6759	1.0000	0.6759	0.5228	1.0000	0.5228	0.4610	1.0000	0.4610
60	10	G	0.7195	1.0000	0.7195	0.5158	1.0000	0.5158	0.3085	1.0000	0.3085
	10	L	0.6555	1.0000	0.6555	0.4528	1.0000	0.4528	0.2605	1.0000	0.2605
	300	G	0.4533	1.0000	0.4533	0.3286	1.0000	0.3286	0.2437	1.0000	0.2437
	300	L	0.3871	1.0000	0.3871	0.2973	1.0000	0.2973	0.2300	1.0000	0.2300

Incident angle : 0

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
82	10	G	0.6150	1.0000	0.6150	0.5615	1.0000	0.5615	0.4936	1.0000	0.4936
	10	L	0.5763	1.0000	0.5763	0.4801	1.0000	0.4801	0.4158	1.0000	0.4158
	300	G	0.5133	1.0000	0.5133	0.5535	1.0000	0.5535	0.5855	1.0000	0.5855
	300	L	0.4593	1.0000	0.4593	0.4461	1.0000	0.4461	0.4833	1.0000	0.4833
83	10	G	0.6150	1.0000	0.6150	0.5651	1.0000	0.5651	0.5053	1.0000	0.5053
	10	L	0.5761	1.0000	0.5761	0.4814	1.0000	0.4814	0.4237	1.0000	0.4237
	300	G	0.5176	1.0000	0.5176	0.5594	1.0000	0.5594	0.6016	1.0000	0.6016
	300	L	0.4624	1.0000	0.4624	0.4515	1.0000	0.4515	0.4913	1.0000	0.4913
130	10	G	0.5732	1.0000	0.5732	0.5102	1.0000	0.5102	0.5266	1.0000	0.5266
	10	L	0.5312	1.0000	0.5312	0.4266	1.0000	0.4266	0.4167	1.0000	0.4167
	300	G	0.5001	1.0000	0.5001	0.5449	1.0000	0.5449	0.6058	1.0000	0.6058
	300	L	0.4239	1.0000	0.4239	0.4098	1.0000	0.4098	0.4337	1.0000	0.4337
177	10	G	0.5352	1.0000	0.5352	0.5154	1.0000	0.5154	0.4989	1.0000	0.4989
	10	L	0.4978	1.0000	0.4978	0.4433	1.0000	0.4433	0.4211	1.0000	0.4211
	300	G	0.4356	1.0000	0.4356	0.4372	1.0000	0.4372	0.4406	1.0000	0.4406
	300	L	0.3867	1.0000	0.3867	0.3611	1.0000	0.3611	0.3720	1.0000	0.3720
178	10	G	0.5347	1.0000	0.5347	0.5174	1.0000	0.5174	0.5064	1.0000	0.5064
	10	L	0.4974	1.0000	0.4974	0.4450	1.0000	0.4450	0.4263	1.0000	0.4263
	300	G	0.4396	1.0000	0.4396	0.4442	1.0000	0.4442	0.4507	1.0000	0.4507
	300	L	0.3900	1.0000	0.3900	0.3643	1.0000	0.3643	0.3768	1.0000	0.3768
215	10	G	0.5438	1.0000	0.5438	0.5330	1.0000	0.5330	0.5883	1.0000	0.5883
	10	L	0.5050	1.0000	0.5050	0.4518	1.0000	0.4518	0.4860	1.0000	0.4860
	300	G	0.4894	1.0000	0.4894	0.5124	1.0000	0.5124	0.5734	1.0000	0.5734
	300	L	0.4241	1.0000	0.4241	0.4154	1.0000	0.4154	0.4436	1.0000	0.4436
252	10	G	0.5282	1.0000	0.5282	0.5062	1.0000	0.5062	0.5362	1.0000	0.5362
	10	L	0.4893	1.0000	0.4893	0.4293	1.0000	0.4293	0.4368	1.0000	0.4368
	300	G	0.4877	1.0000	0.4877	0.4731	1.0000	0.4731	0.4487	1.0000	0.4487
	300	L	0.4158	1.0000	0.4158	0.3719	1.0000	0.3719	0.3370	1.0000	0.3370
253	10	G	0.5286	1.0000	0.5286	0.5054	1.0000	0.5054	0.5372	1.0000	0.5372
	10	L	0.4897	1.0000	0.4897	0.4293	1.0000	0.4293	0.4377	1.0000	0.4377
	300	G	0.4874	1.0000	0.4874	0.4747	1.0000	0.4747	0.4487	1.0000	0.4487
	300	L	0.4146	1.0000	0.4146	0.3762	1.0000	0.3762	0.3339	1.0000	0.3339

Incident angle : 0

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
268	10	G	0.5283	1.0000	0.5283	0.5226	1.0000	0.5226	0.5415	1.0000	0.5415
	10	L	0.4906	1.0000	0.4906	0.4470	1.0000	0.4470	0.4491	1.0000	0.4491
	300	G	0.4831	1.0000	0.4831	0.5219	1.0000	0.5219	0.4567	1.0000	0.4567
	300	L	0.4152	1.0000	0.4152	0.4170	1.0000	0.4170	0.3609	1.0000	0.3609
282	10	G	0.5390	1.0000	0.5390	0.5603	1.0000	0.5603	0.5936	1.0000	0.5936
	10	L	0.5013	1.0000	0.5013	0.4797	1.0000	0.4797	0.4947	1.0000	0.4947
	300	G	0.4872	1.0000	0.4872	0.5605	1.0000	0.5605	0.5231	1.0000	0.5231
	300	L	0.4266	1.0000	0.4266	0.4646	1.0000	0.4646	0.4149	1.0000	0.4149
283	10	G	0.5417	1.0000	0.5417	0.5643	1.0000	0.5643	0.6032	1.0000	0.6032
	10	L	0.5038	1.0000	0.5038	0.4831	1.0000	0.4831	0.5018	1.0000	0.5018
	300	G	0.4896	1.0000	0.4896	0.5646	1.0000	0.5646	0.5312	1.0000	0.5312
	300	L	0.4274	1.0000	0.4274	0.4665	1.0000	0.4665	0.4181	1.0000	0.4181
305	10	G	0.5796	1.0000	0.5796	0.6264	1.0000	0.6264	0.7213	1.0000	0.7213
	10	L	0.5385	1.0000	0.5385	0.5363	1.0000	0.5363	0.5974	1.0000	0.5974
	300	G	0.5255	1.0000	0.5255	0.5728	1.0000	0.5728	0.6378	1.0000	0.6378
	300	L	0.4572	1.0000	0.4572	0.4658	1.0000	0.4658	0.5024	1.0000	0.5024
327	10	G	0.6047	1.0000	0.6047	0.6972	1.0000	0.6972	0.7585	1.0000	0.7585
	10	L	0.5607	1.0000	0.5607	0.5925	1.0000	0.5925	0.6228	1.0000	0.6228
	300	G	0.5336	1.0000	0.5336	0.6096	1.0000	0.6096	0.6177	1.0000	0.6177
	300	L	0.4590	1.0000	0.4590	0.4794	1.0000	0.4794	0.4817	1.0000	0.4817
328	10	G	0.6055	1.0000	0.6055	0.7008	1.0000	0.7008	0.7606	1.0000	0.7606
	10	L	0.5614	1.0000	0.5614	0.5952	1.0000	0.5952	0.6237	1.0000	0.6237
	300	G	0.5338	1.0000	0.5338	0.6086	1.0000	0.6086	0.6157	1.0000	0.6157
	300	L	0.4593	1.0000	0.4593	0.4783	1.0000	0.4783	0.4738	1.0000	0.4738
396	10	G	0.5970	1.0000	0.5970	0.6348	1.0000	0.6348	0.6830	1.0000	0.6830
	10	L	0.5547	1.0000	0.5547	0.5397	1.0000	0.5397	0.5658	1.0000	0.5658
	300	G	0.4822	1.0000	0.4822	0.5967	1.0000	0.5967	0.5976	1.0000	0.5976
	300	L	0.4220	1.0000	0.4220	0.4809	1.0000	0.4809	0.4738	1.0000	0.4738
464	10	G	0.5964	1.0000	0.5964	0.6324	1.0000	0.6324	0.7064	1.0000	0.7064
	10	L	0.5533	1.0000	0.5533	0.5387	1.0000	0.5387	0.5807	1.0000	0.5807
	300	G	0.4549	1.0000	0.4549	0.4347	1.0000	0.4347	0.4447	1.0000	0.4447
	300	L	0.3948	1.0000	0.3948	0.3427	1.0000	0.3427	0.3498	1.0000	0.3498

Incident angle : 0

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
464	10	G	0.5964	1.0000	0.5964	0.6324	1.0000	0.6324	0.7064	1.0000	0.7064
	10	L	0.5533	1.0000	0.5533	0.5387	1.0000	0.5387	0.5807	1.0000	0.5807
	300	G	0.4549	1.0000	0.4549	0.4347	1.0000	0.4347	0.4447	1.0000	0.4447
	300	L	0.3948	1.0000	0.3948	0.3427	1.0000	0.3427	0.3498	1.0000	0.3498
466	10	G	0.5922	1.0000	0.5922	0.6368	1.0000	0.6368	0.6926	1.0000	0.6926
	10	L	0.5497	1.0000	0.5497	0.5421	1.0000	0.5421	0.5728	1.0000	0.5728
	300	G	0.4490	1.0000	0.4490	0.4198	1.0000	0.4198	0.4346	1.0000	0.4346
	300	L	0.3898	1.0000	0.3898	0.3317	1.0000	0.3317	0.3386	1.0000	0.3386
673	10	G	0.5301	1.0000	0.5301	0.6043	1.0000	0.6043	0.6947	1.0000	0.6947
	10	L	0.4923	1.0000	0.4923	0.5145	1.0000	0.5145	0.5746	1.0000	0.5746
	300	G	0.3873	1.0000	0.3873	0.3834	1.0000	0.3834	0.4185	1.0000	0.4185
	300	L	0.3380	1.0000	0.3380	0.3119	1.0000	0.3119	0.3355	1.0000	0.3355
879	10	G	0.5567	1.0000	0.5567	0.6704	1.0000	0.6704	0.7670	1.0000	0.7670
	10	L	0.5167	1.0000	0.5167	0.5707	1.0000	0.5707	0.6333	1.0000	0.6333
	300	G	0.4308	1.0000	0.4308	0.4471	1.0000	0.4471	0.4688	1.0000	0.4688
	300	L	0.3732	1.0000	0.3732	0.3640	1.0000	0.3640	0.3641	1.0000	0.3641
880	10	G	0.5576	1.0000	0.5576	0.6708	1.0000	0.6708	0.7702	1.0000	0.7702
	10	L	0.5174	1.0000	0.5174	0.5700	1.0000	0.5700	0.6342	1.0000	0.6342
	300	G	0.4310	1.0000	0.4310	0.4472	1.0000	0.4472	0.4668	1.0000	0.4668
	300	L	0.3730	1.0000	0.3730	0.3630	1.0000	0.3630	0.3657	1.0000	0.3657
1090	10	G	0.8756	1.0000	0.8756	1.1750	1.0000	1.1750	1.3723	1.0000	1.3723
	10	L	0.8127	1.0000	0.8127	1.0000	1.0000	1.0000	1.1316	1.0000	1.1316
	300	G	0.5465	1.0000	0.5465	0.5616	1.0000	0.5616	0.5936	1.0000	0.5936
	300	L	0.4748	1.0000	0.4748	0.4493	1.0000	0.4493	0.4674	1.0000	0.4674
1300	10	G	0.9816	1.0000	0.9816	1.3696	1.0000	1.3696	1.6489	1.0000	1.6489
	10	L	0.9111	1.0000	0.9111	1.1652	1.0000	1.1652	1.3596	1.0000	1.3596
	300	G	0.5377	1.0000	0.5377	0.5400	1.0000	0.5400	0.5755	1.0000	0.5755
	300	L	0.4682	1.0000	0.4682	0.4322	1.0000	0.4322	0.4579	1.0000	0.4579
1400	10	G	1.0520	1.0000	1.0520	1.5270	1.0000	1.5270	1.8404	1.0000	1.8404
	10	L	0.9764	1.0000	0.9764	1.2995	1.0000	1.2995	1.5175	1.0000	1.5175
	300	G	0.5448	1.0000	0.5448	0.5415	1.0000	0.5415	0.5875	1.0000	0.5875
	300	L	0.4744	1.0000	0.4744	0.4323	1.0000	0.4323	0.4658	1.0000	0.4658
1600	10	G	1.1916	1.0000	1.1916	1.8426	1.0000	1.8426	2.2447	1.0000	2.2447
	10	L	1.1060	1.0000	1.1060	1.5676	1.0000	1.5676	1.8509	1.0000	1.8509
	300	G	0.5384	1.0000	0.5384	0.5327	1.0000	0.5327	0.5654	1.0000	0.5654
	300	L	0.4688	1.0000	0.4688	0.4259	1.0000	0.4259	0.4467	1.0000	0.4467

Incident angle : 10

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
0	10	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	10	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	10	G	0.9885	0.9944	0.9908	0.9774	0.9871	0.9817	0.9785	0.9849	0.9810
	10	L	0.9733	0.9913	0.9798	0.9440	0.9746	0.9559	0.9292	0.9710	0.9464
	300	G	0.9775	0.9778	0.9823	0.9641	0.9757	0.9724	0.9608	0.9655	0.9688
	300	L	0.9475	0.9676	0.9590	0.9195	0.9588	0.9375	0.9092	0.9490	0.9272
16	10	G	0.9732	0.9871	0.9786	0.9437	0.9717	0.9580	0.9247	0.9648	0.9361
	10	L	0.8975	0.9668	0.9230	0.7879	0.9085	0.8395	0.7345	0.8852	0.7836
	300	G	0.9477	0.9535	0.9590	0.9169	0.9470	0.9370	0.9059	0.9270	0.9271
	300	L	0.7977	0.8982	0.8407	0.6926	0.8544	0.7618	0.6585	0.8324	0.7391
17	10	G	0.9713	0.9863	0.9771	0.9412	0.9696	0.9560	0.9247	0.9610	0.9361
	10	L	0.8880	0.9636	0.9159	0.7690	0.8999	0.8248	0.7168	0.8770	0.7674
	300	G	0.9437	0.9500	0.9557	0.9108	0.9429	0.9322	0.9000	0.9229	0.9218
	300	L	0.7789	0.8892	0.8259	0.6641	0.8410	0.7402	0.6277	0.8179	0.7151
26	10	G	0.9521	0.9775	0.9620	0.8968	0.9509	0.9251	0.8710	0.9358	0.8915
	10	L	0.8684	0.9557	0.9008	0.7315	0.8824	0.7950	0.6637	0.8515	0.7233
	300	G	0.9067	0.9221	0.9267	0.8530	0.9085	0.8890	0.8353	0.8783	0.8741
	300	L	0.7430	0.8650	0.7980	0.6107	0.8102	0.7008	0.5692	0.7796	0.6678
35	10	G	0.9259	0.9662	0.9417	0.8413	0.9263	0.8854	0.7957	0.9019	0.8282
	10	L	0.8429	0.9455	0.8812	0.6839	0.8595	0.7579	0.6018	0.8202	0.6741
	300	G	0.8558	0.8913	0.8867	0.7743	0.8654	0.8302	0.7471	0.8256	0.8059
	300	L	0.6964	0.8365	0.7610	0.5427	0.7712	0.6506	0.4954	0.7341	0.6083
37	10	G	0.9151	0.9622	0.9335	0.8175	0.9164	0.8682	0.7849	0.8868	0.8160
	10	L	0.8322	0.9415	0.8731	0.6640	0.8502	0.7429	0.5752	0.8063	0.6575
	300	G	0.8340	0.8821	0.8696	0.7402	0.8486	0.8049	0.7078	0.8073	0.7768
	300	L	0.6771	0.8262	0.7457	0.5142	0.7558	0.6299	0.4662	0.7177	0.5860
60	10	G	0.7292	0.9042	0.8013	0.5253	0.7500	0.6009	0.3333	0.6440	0.4437
	10	L	0.6615	0.8806	0.7478	0.4582	0.6921	0.5109	0.2566	0.5766	0.3718
	300	G	0.4647	0.7151	0.5835	0.3248	0.5942	0.4525	0.2289	0.5233	0.3856
	300	L	0.3822	0.6685	0.4943	0.2902	0.5408	0.3654	0.2257	0.4554	0.3076

Incident angle : 10

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
82	10	G	0.6123	0.8301	0.6993	0.5631	0.5736	0.5400	0.4753	0.3488	0.4022
	10	L	0.5739	0.8111	0.6669	0.4830	0.5294	0.4790	0.4035	0.3034	0.3607
	300	G	0.4931	0.5573	0.4822	0.5400	0.4887	0.4234	0.5647	0.3876	0.4308
	300	L	0.4443	0.5248	0.4454	0.4381	0.4623	0.3695	0.4554	0.3863	0.3631
83	10	G	0.6122	0.8269	0.6989	0.5672	0.5678	0.5432	0.4860	0.3379	0.4141
	10	L	0.5737	0.8095	0.6669	0.4855	0.5236	0.4816	0.4133	0.3055	0.3723
	300	G	0.4995	0.5552	0.4892	0.5469	0.4902	0.4320	0.5824	0.3945	0.4460
	300	L	0.4472	0.5220	0.4510	0.4421	0.4688	0.3746	0.4615	0.3916	0.3723
130	10	G	0.5864	0.7716	0.6616	0.5409	0.6011	0.5383	0.5538	0.4327	0.5125
	10	L	0.5429	0.7631	0.6297	0.4540	0.5799	0.4701	0.4398	0.4165	0.4362
	300	G	0.5092	0.6121	0.5360	0.5657	0.6602	0.4956	0.6180	0.6146	0.5324
	300	L	0.4326	0.5943	0.4778	0.4193	0.6318	0.4254	0.4477	0.5792	0.4260
177	10	G	0.5548	0.6562	0.5507	0.5351	0.6955	0.5291	0.5129	0.5698	0.4120
	10	L	0.5155	0.6351	0.5201	0.4599	0.6521	0.4683	0.4274	0.5197	0.3624
	300	G	0.4453	0.6944	0.4587	0.4431	0.7690	0.5493	0.4157	0.7039	0.5180
	300	L	0.3920	0.6484	0.4019	0.3666	0.7029	0.4760	0.3492	0.6302	0.4212
178	10	G	0.5543	0.6555	0.5474	0.5376	0.6980	0.5312	0.5129	0.5723	0.4175
	10	L	0.5151	0.6351	0.5169	0.4620	0.6537	0.4699	0.4301	0.5209	0.3685
	300	G	0.4453	0.6959	0.4582	0.4453	0.7725	0.5536	0.4275	0.7018	0.5180
	300	L	0.3924	0.6484	0.4010	0.3679	0.7035	0.4786	0.3569	0.6357	0.4261
215	10	G	0.5496	0.6506	0.5030	0.5450	0.7741	0.5967	0.5731	0.6415	0.4806
	10	L	0.5103	0.6287	0.4775	0.4624	0.7212	0.5267	0.4726	0.5847	0.4195
	300	G	0.4777	0.7516	0.4801	0.4811	0.9035	0.6713	0.5353	0.7972	0.6137
	300	L	0.4135	0.6959	0.4281	0.3841	0.8167	0.5701	0.4185	0.7413	0.5129
252	10	G	0.5313	0.6544	0.5293	0.5113	0.8502	0.6527	0.5301	0.7799	0.5744
	10	L	0.4921	0.6314	0.5030	0.4344	0.7908	0.5734	0.4292	0.7146	0.4925
	300	G	0.4482	0.8392	0.5357	0.4219	1.0754	0.7813	0.4275	0.9635	0.7080
	300	L	0.3727	0.7768	0.4773	0.3248	0.9643	0.6514	0.3185	0.8852	0.5932
253	10	G	0.5298	0.6548	0.5314	0.5117	0.8519	0.6543	0.5258	0.7836	0.5813
	10	L	0.4907	0.6315	0.5049	0.4347	0.7912	0.5740	0.4283	0.7158	0.4965
	300	G	0.4458	0.8404	0.5364	0.4161	1.0784	0.7840	0.4216	0.9696	0.7127
	300	L	0.3721	0.7807	0.4793	0.3249	0.9708	0.6518	0.3138	0.8889	0.5957

Incident angle : 10

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
268	10	G	0.5288	0.6543	0.5552	0.5261	0.8540	0.6605	0.5355	0.8528	0.6609
	10	L	0.4905	0.6306	0.5264	0.4508	0.7972	0.5737	0.4416	0.7668	0.5651
	300	G	0.4247	0.8659	0.5562	0.4262	1.1165	0.8017	0.3843	1.0203	0.7532
	300	L	0.3625	0.8128	0.4952	0.3529	1.0247	0.6868	0.3062	0.8962	0.6009
282	10	G	0.5400	0.6791	0.5817	0.5582	0.8584	0.6711	0.5817	0.8855	0.7142
	10	L	0.5020	0.6634	0.5513	0.4788	0.7966	0.5863	0.4823	0.7970	0.6076
	300	G	0.4422	0.8821	0.5656	0.4682	1.1471	0.8359	0.4510	0.9980	0.7529
	300	L	0.3885	0.8061	0.5107	0.3962	1.0149	0.6880	0.3692	0.9035	0.6268
283	10	G	0.5402	0.6812	0.5832	0.5627	0.8582	0.6746	0.5871	0.8881	0.7211
	10	L	0.5023	0.6655	0.5527	0.4827	0.7950	0.5893	0.4885	0.7993	0.6125
	300	G	0.4434	0.8813	0.5676	0.4694	1.1464	0.8362	0.4627	0.9980	0.7600
	300	L	0.3897	0.8036	0.5107	0.3995	1.0106	0.6857	0.3769	0.9053	0.6278
305	10	G	0.5722	0.7236	0.6224	0.6219	0.8251	0.7313	0.7000	0.9220	0.7963
	10	L	0.5317	0.7081	0.5890	0.5296	0.7666	0.6412	0.5796	0.8422	0.6802
	300	G	0.5078	0.8706	0.5974	0.5534	1.1593	0.8646	0.5980	0.9838	0.8103
	300	L	0.4408	0.7952	0.5374	0.4491	1.0235	0.7101	0.4708	0.8944	0.6731
327	10	G	0.5932	0.7719	0.6544	0.6848	0.8527	0.7846	0.7323	1.0113	0.8506
	10	L	0.5499	0.7583	0.6194	0.5842	0.8009	0.6909	0.5991	0.9420	0.7345
	300	G	0.5194	0.8516	0.5961	0.5823	1.1737	0.8786	0.6039	1.0243	0.8219
	300	L	0.4472	0.7824	0.5364	0.4554	1.0464	0.7261	0.4631	0.9381	0.6805
328	10	G	0.5943	0.7746	0.6547	0.6839	0.8540	0.7875	0.7366	1.0176	0.8571
	10	L	0.5509	0.7609	0.6198	0.5831	0.8020	0.6936	0.6027	0.9455	0.7389
	300	G	0.5168	0.8522	0.5964	0.5831	1.1758	0.8797	0.5961	1.0304	0.8235
	300	L	0.4447	0.7813	0.5351	0.4550	1.0452	0.7245	0.4554	0.9417	0.6822
396	10	G	0.5815	0.8422	0.6939	0.5964	0.8752	0.8083	0.6495	1.1057	0.9210
	10	L	0.5405	0.8269	0.6581	0.5093	0.8137	0.7085	0.5389	1.0209	0.7955
	300	G	0.4600	0.7542	0.6038	0.5084	0.8996	0.6559	0.4804	0.8357	0.6727
	300	L	0.4025	0.7104	0.5426	0.4065	0.8016	0.5356	0.3908	0.7177	0.5502
464	10	G	0.5923	0.8567	0.7062	0.6354	0.9197	0.8427	0.6903	1.0943	0.9337
	10	L	0.5496	0.8419	0.6697	0.5397	0.8607	0.7416	0.5664	1.0325	0.8149
	300	G	0.4451	0.6802	0.5595	0.4287	0.6566	0.5515	0.4216	0.6126	0.5487
	300	L	0.3842	0.6420	0.5009	0.3344	0.5964	0.4646	0.3277	0.5519	0.4468

Incident angle : 10

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
464	10	G	0.5923	0.8567	0.7062	0.6354	0.9197	0.8427	0.6903	1.0943	0.9337
	10	L	0.5496	0.8419	0.6697	0.5397	0.8607	0.7416	0.5664	1.0325	0.8149
	300	G	0.4451	0.6802	0.5595	0.4287	0.6566	0.5515	0.4216	0.6126	0.5487
	300	L	0.3842	0.6420	0.5009	0.3344	0.5964	0.4646	0.3277	0.5519	0.4468
466	10	G	0.5897	0.8575	0.7053	0.6330	0.9176	0.8370	0.6806	1.0943	0.9291
	10	L	0.5472	0.8427	0.6688	0.5373	0.8587	0.7367	0.5584	1.0325	0.8110
	300	G	0.4406	0.6811	0.5577	0.4168	0.6625	0.5538	0.4098	0.6126	0.5436
	300	L	0.3807	0.6431	0.4996	0.3253	0.6029	0.4676	0.3200	0.5537	0.4444
673	10	G	0.5416	0.5833	0.5518	0.6223	0.5965	0.6551	0.6892	0.6566	0.7139
	10	L	0.5028	0.5715	0.5228	0.5303	0.5554	0.5761	0.5681	0.6021	0.6137
	300	G	0.3821	0.5472	0.3863	0.3700	0.4130	0.3734	0.3902	0.4101	0.3699
	300	L	0.3327	0.5223	0.3442	0.2958	0.3604	0.3121	0.3092	0.3546	0.2986
879	10	G	0.5781	0.5931	0.5610	0.7061	0.4917	0.6597	0.8065	0.6491	0.7861
	10	L	0.5366	0.5759	0.5316	0.6010	0.4591	0.5795	0.6637	0.5963	0.6759
	300	G	0.3949	0.6873	0.4731	0.4138	0.5957	0.4931	0.4176	0.6633	0.5346
	300	L	0.3399	0.6451	0.4297	0.3329	0.5679	0.4133	0.3215	0.5993	0.4460
880	10	G	0.5784	0.5926	0.5612	0.7053	0.4908	0.6588	0.8065	0.6478	0.7857
	10	L	0.5369	0.5753	0.5318	0.6006	0.4587	0.5791	0.6637	0.5963	0.6759
	300	G	0.3954	0.6867	0.4747	0.4141	0.5972	0.4929	0.4196	0.6633	0.5386
	300	L	0.3395	0.6459	0.4304	0.3320	0.5676	0.4149	0.3231	0.6029	0.4484
1090	10	G	0.8799	0.7928	0.8449	1.1850	0.8365	1.0908	1.3656	1.0340	1.2919
	10	L	0.8168	0.7789	0.8011	1.0095	0.7818	0.9589	1.1150	0.9571	1.1133
	300	G	0.5417	0.6846	0.5207	0.5372	0.6021	0.5013	0.5706	0.6227	0.5108
	300	L	0.4708	0.6484	0.4688	0.4276	0.5694	0.4233	0.4538	0.5592	0.4182
1300	10	G	1.0026	0.9412	0.9793	1.4328	1.1326	1.3958	1.6882	1.5975	1.7438
	10	L	0.9306	0.9233	0.9280	1.2202	1.0560	1.2265	1.3894	1.4617	1.4964
	300	G	0.5429	0.7865	0.5412	0.5386	0.6497	0.5329	0.5745	0.7282	0.5578
	300	L	0.4712	0.7461	0.4832	0.4295	0.6163	0.4451	0.4538	0.6612	0.4513
1400	10	G	1.0600	0.9791	1.0295	1.5594	1.1984	1.4979	1.8495	1.6352	1.8618
	10	L	0.9840	0.9621	0.9762	1.3280	1.1197	1.3165	1.5221	1.5313	1.6116
	300	G	0.5372	0.7797	0.5318	0.5363	0.6912	0.5121	0.5569	0.7404	0.5413
	300	L	0.4667	0.7305	0.4780	0.4282	0.6494	0.4319	0.4415	0.6648	0.4417
1600	10	G	1.2069	1.1216	1.1626	1.9166	1.3244	1.7450	2.2903	1.6604	2.1549
	10	L	1.1203	1.1012	1.1021	1.6321	1.2363	1.5335	1.8850	1.5313	1.8549
	300	G	0.5374	0.6864	0.5349	0.5322	0.5396	0.4966	0.5529	0.5781	0.5169
	300	L	0.4654	0.6493	0.4780	0.4228	0.5158	0.4160	0.4354	0.5228	0.4188

Incident angle : 20

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
0	10	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	10	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	10	G	0.9915	0.9934	0.9906	0.9815	0.9882	0.9819	0.9879	0.9856	0.9734
	10	L	0.9755	0.9895	0.9806	0.9486	0.9756	0.9610	0.9200	0.9712	0.9418
	300	G	0.9791	0.9860	0.9817	0.9637	0.9800	0.9703	0.9602	0.9690	0.9681
	300	L	0.9510	0.9770	0.9603	0.9207	0.9636	0.9369	0.9130	0.9512	0.9342
16	10	G	0.9797	0.9851	0.9817	0.9613	0.9728	0.9590	0.9398	0.9675	0.9543
	10	L	0.9070	0.9612	0.9271	0.8095	0.9070	0.8431	0.7500	0.8858	0.7958
	300	G	0.9523	0.9684	0.9585	0.9180	0.9545	0.9334	0.9119	0.9307	0.9280
	300	L	0.8110	0.9106	0.8475	0.7059	0.8599	0.7692	0.6732	0.8252	0.7563
17	10	G	0.9784	0.9834	0.9805	0.9577	0.9706	0.9562	0.9518	0.9651	0.9414
	10	L	0.8984	0.9572	0.9202	0.7955	0.8982	0.8304	0.7400	0.8747	0.7795
	300	G	0.9487	0.9659	0.9554	0.9126	0.9507	0.9285	0.9057	0.9234	0.9240
	300	L	0.7935	0.9018	0.8333	0.6793	0.8463	0.7484	0.6437	0.8110	0.7339
26	10	G	0.9640	0.9776	0.9704	0.9374	0.9510	0.9311	0.9157	0.9374	0.8957
	10	L	0.8807	0.9491	0.9062	0.7694	0.8796	0.8037	0.7000	0.8503	0.7513
	300	G	0.9167	0.9441	0.9273	0.8709	0.9180	0.8854	0.8470	0.8850	0.8748
	300	L	0.7602	0.8831	0.8057	0.6274	0.8159	0.7089	0.5878	0.7717	0.6928
35	10	G	0.9443	0.9710	0.9558	0.9077	0.9247	0.8946	0.8675	0.9049	0.8562
	10	L	0.8611	0.9434	0.8920	0.7421	0.8543	0.7687	0.6500	0.8182	0.6958
	300	G	0.8767	0.9158	0.8902	0.8231	0.8745	0.8298	0.7820	0.8358	0.8146
	300	L	0.7186	0.8573	0.7703	0.5752	0.7754	0.6595	0.5205	0.7228	0.6365
37	10	G	0.9358	0.9677	0.9493	0.8924	0.9137	0.8765	0.8434	0.8905	0.8365
	10	L	0.8525	0.9402	0.8855	0.7300	0.8440	0.7555	0.6300	0.8049	0.6848
	300	G	0.8599	0.9048	0.8750	0.8002	0.8570	0.8082	0.7526	0.8193	0.7903
	300	L	0.7016	0.8468	0.7560	0.5579	0.7590	0.6402	0.4959	0.7024	0.6160
60	10	G	0.7746	0.9022	0.8270	0.6137	0.7273	0.6456	0.4458	0.6354	0.4862
	10	L	0.7013	0.8739	0.7687	0.5111	0.6677	0.5659	0.3400	0.5698	0.4037
	300	G	0.5492	0.7221	0.6156	0.3946	0.5633	0.5009	0.2631	0.4872	0.4003
	300	L	0.4300	0.6661	0.5188	0.3150	0.4842	0.4050	0.2308	0.4000	0.3350

Incident angle : 20

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
82	10	G	0.6083	0.8333	0.7042	0.5209	0.5110	0.4988	0.3627	0.3610	0.2953
	10	L	0.5660	0.8084	0.6646	0.4593	0.4646	0.4514	0.3250	0.3226	0.2745
	300	G	0.4245	0.5397	0.4248	0.4444	0.3559	0.3732	0.4235	0.2889	0.2954
	300	L	0.3865	0.5092	0.3984	0.3725	0.3517	0.3269	0.3629	0.2906	0.2717
83	10	G	0.6047	0.8325	0.7020	0.5241	0.5024	0.5046	0.3699	0.3526	0.3027
	10	L	0.5642	0.8072	0.6626	0.4620	0.4576	0.4566	0.3330	0.3204	0.2830
	300	G	0.4308	0.5348	0.4314	0.4543	0.3602	0.3802	0.4361	0.2932	0.3050
	300	L	0.3915	0.5087	0.4041	0.3757	0.3551	0.3320	0.3711	0.2978	0.2797
130	10	G	0.6052	0.8006	0.6828	0.6006	0.5039	0.5836	0.5747	0.3610	0.5106
	10	L	0.5682	0.7836	0.6503	0.5208	0.4842	0.5182	0.4800	0.3659	0.4488
	300	G	0.5324	0.6096	0.5515	0.5734	0.5193	0.5542	0.6226	0.4982	0.5487
	300	L	0.4616	0.5872	0.5022	0.4450	0.5033	0.4630	0.4680	0.4945	0.4675
177	10	G	0.6279	0.6786	0.6278	0.6529	0.5890	0.5277	0.6964	0.5174	0.5408
	10	L	0.5859	0.6582	0.5948	0.5645	0.5492	0.4697	0.5740	0.4823	0.4557
	300	G	0.5557	0.7124	0.5125	0.5814	0.6037	0.5268	0.5975	0.6150	0.5075
	300	L	0.4840	0.6630	0.4538	0.4677	0.5463	0.4466	0.4795	0.5339	0.4142
178	10	G	0.6280	0.6790	0.6254	0.6515	0.5894	0.5251	0.6964	0.5162	0.5401
	10	L	0.5860	0.6564	0.5925	0.5633	0.5502	0.4703	0.5740	0.4823	0.4551
	300	G	0.5555	0.7133	0.5088	0.5822	0.6050	0.5279	0.5975	0.6113	0.5026
	300	L	0.4838	0.6624	0.4503	0.4681	0.5456	0.4465	0.4762	0.5354	0.4148
215	10	G	0.6056	0.6789	0.5581	0.6029	0.6215	0.5520	0.6253	0.5331	0.4849
	10	L	0.5643	0.6551	0.5275	0.5208	0.5761	0.4901	0.5150	0.4812	0.4122
	300	G	0.5008	0.7352	0.4735	0.5052	0.6359	0.5621	0.4948	0.5894	0.4736
	300	L	0.4350	0.6735	0.4130	0.3977	0.5584	0.4671	0.3892	0.5024	0.3875
252	10	G	0.5612	0.6653	0.5185	0.5543	0.6560	0.5827	0.5446	0.5596	0.4492
	10	L	0.5231	0.6393	0.4925	0.4799	0.6093	0.5179	0.4500	0.5166	0.3791
	300	G	0.4226	0.7656	0.4868	0.4216	0.7224	0.6345	0.3878	0.6332	0.5084
	300	L	0.3643	0.6984	0.4287	0.3340	0.6465	0.5270	0.2956	0.5591	0.4295
253	10	G	0.5605	0.6643	0.5192	0.5520	0.6572	0.5838	0.5422	0.5656	0.4498
	10	L	0.5225	0.6389	0.4931	0.4780	0.6090	0.5176	0.4510	0.5222	0.3792
	300	G	0.4214	0.7668	0.4871	0.4219	0.7255	0.6374	0.3857	0.6332	0.5077
	300	L	0.3635	0.6982	0.4301	0.3345	0.6509	0.5307	0.2939	0.5622	0.4320

Incident angle : 20

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
268	10	G	0.5495	0.6568	0.5348	0.5601	0.6603	0.5880	0.5651	0.6378	0.5019
	10	L	0.5128	0.6289	0.5081	0.4854	0.6261	0.5306	0.4710	0.5854	0.4261
	300	G	0.4240	0.7732	0.4974	0.4552	0.7613	0.6650	0.4340	0.6953	0.5575
	300	L	0.3706	0.7265	0.4440	0.3702	0.6949	0.5673	0.3481	0.5858	0.4509
282	10	G	0.5493	0.6561	0.5602	0.5795	0.6768	0.6219	0.6205	0.7148	0.5915
	10	L	0.5129	0.6391	0.5314	0.5021	0.6290	0.5500	0.5180	0.6475	0.5012
	300	G	0.4534	0.8042	0.5105	0.5029	0.8042	0.7044	0.5367	0.7190	0.5768
	300	L	0.3999	0.7356	0.4463	0.4093	0.7045	0.5757	0.4368	0.6189	0.4776
283	10	G	0.5505	0.6589	0.5625	0.5817	0.6771	0.6252	0.6265	0.7196	0.6020
	10	L	0.5141	0.6417	0.5336	0.5037	0.6286	0.5528	0.5240	0.6552	0.5082
	300	G	0.4563	0.8057	0.5110	0.5091	0.8061	0.7063	0.5409	0.7208	0.5783
	300	L	0.4026	0.7350	0.4457	0.4140	0.7040	0.5754	0.4433	0.6236	0.4812
305	10	G	0.5677	0.7252	0.6073	0.6123	0.7018	0.6973	0.7253	0.8087	0.7276
	10	L	0.5300	0.7045	0.5748	0.5294	0.6498	0.6158	0.6020	0.7339	0.6143
	300	G	0.5083	0.8130	0.5431	0.5850	0.8300	0.7339	0.6583	0.7609	0.6094
	300	L	0.4451	0.7506	0.4783	0.4784	0.7341	0.6049	0.5222	0.6252	0.4874
327	10	G	0.5773	0.7823	0.6437	0.6763	0.7547	0.7618	0.7494	0.8845	0.7953
	10	L	0.5387	0.7605	0.6086	0.5851	0.7027	0.6758	0.6210	0.8071	0.6713
	300	G	0.5093	0.8133	0.5477	0.6194	0.8278	0.7368	0.6122	0.7555	0.6076
	300	L	0.4394	0.7376	0.4815	0.4901	0.7301	0.6074	0.4696	0.6362	0.4895
328	10	G	0.5772	0.7852	0.6449	0.6785	0.7598	0.7653	0.7494	0.8869	0.7961
	10	L	0.5386	0.7633	0.6098	0.5871	0.7078	0.6785	0.6200	0.8093	0.6736
	300	G	0.5085	0.8118	0.5486	0.6169	0.8258	0.7351	0.6101	0.7555	0.6077
	300	L	0.4386	0.7382	0.4822	0.4875	0.7306	0.6075	0.4663	0.6331	0.4871
396	10	G	0.5428	0.8673	0.6851	0.5777	0.8703	0.8669	0.6229	1.0072	0.8949
	10	L	0.5062	0.8464	0.6494	0.4994	0.8132	0.7719	0.5170	0.9313	0.7574
	300	G	0.4183	0.7309	0.5579	0.4274	0.6927	0.6441	0.4382	0.6843	0.5497
	300	L	0.3679	0.6871	0.5030	0.3453	0.5890	0.5433	0.3498	0.5512	0.4520
464	10	G	0.5440	0.8582	0.6790	0.5880	0.8496	0.8499	0.5952	1.0265	0.9033
	10	L	0.5087	0.8359	0.6434	0.5099	0.7884	0.7542	0.4980	0.9501	0.7740
	300	G	0.4002	0.7349	0.5537	0.4076	0.6238	0.6026	0.3941	0.6314	0.5752
	300	L	0.3453	0.6837	0.4918	0.3172	0.5491	0.4950	0.2989	0.5402	0.4697

Incident angle : 20

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
464	10	G	0.5440	0.8582	0.6790	0.5880	0.8496	0.8499	0.5952	1.0265	0.9033
	10	L	0.5087	0.8359	0.6434	0.5099	0.7884	0.7542	0.4980	0.9501	0.7740
	300	G	0.4002	0.7349	0.5537	0.4076	0.6238	0.6026	0.3941	0.6314	0.5752
	300	L	0.3453	0.6837	0.4918	0.3172	0.5491	0.4950	0.2989	0.5402	0.4697
466	10	G	0.5462	0.8524	0.6805	0.5835	0.8496	0.8502	0.6036	1.0361	0.9129
	10	L	0.5107	0.8302	0.6446	0.5060	0.7884	0.7543	0.5030	0.9368	0.7679
	300	G	0.4000	0.7248	0.5456	0.4015	0.6102	0.5890	0.3795	0.6131	0.5575
	300	L	0.3469	0.6738	0.4845	0.3127	0.5370	0.4841	0.2890	0.5228	0.4546
673	10	G	0.5919	0.6643	0.6113	0.6700	0.6262	0.7433	0.7386	0.7750	0.7990
	10	L	0.5529	0.6473	0.5793	0.5801	0.5809	0.6596	0.6140	0.7118	0.6786
	300	G	0.4214	0.5333	0.4513	0.4186	0.4489	0.4903	0.4319	0.4836	0.4654
	300	L	0.3674	0.5095	0.4015	0.3346	0.3874	0.4008	0.3415	0.4094	0.3819
879	10	G	0.6529	0.5859	0.6281	0.8487	0.4988	0.7911	0.9590	0.6414	0.8779
	10	L	0.6100	0.5710	0.5953	0.7343	0.4635	0.7026	0.7950	0.5898	0.7470
	300	G	0.4411	0.4400	0.4184	0.4738	0.4081	0.4348	0.4864	0.3777	0.4052
	300	L	0.3859	0.4119	0.3744	0.3793	0.3468	0.3608	0.3842	0.3055	0.3330
880	10	G	0.6537	0.5871	0.6297	0.8523	0.5004	0.7942	0.9639	0.6462	0.8830
	10	L	0.6106	0.5721	0.5969	0.7370	0.4646	0.7049	0.8010	0.5931	0.7522
	300	G	0.4428	0.4396	0.4198	0.4736	0.4085	0.4340	0.4885	0.3759	0.4064
	300	L	0.3865	0.4122	0.3742	0.3784	0.3473	0.3597	0.3892	0.3071	0.3380
1090	10	G	0.9201	0.8458	0.8933	1.2783	0.8139	1.2215	1.5060	1.0614	1.4019
	10	L	0.8592	0.8238	0.8465	1.1067	0.7570	1.0852	1.2500	0.9612	1.1879
	300	G	0.5519	0.5564	0.5350	0.5526	0.4222	0.5207	0.5765	0.4891	0.4959
	300	L	0.4809	0.5166	0.4760	0.4394	0.3783	0.4308	0.4532	0.4126	0.4047
1300	10	G	1.0433	0.9751	1.0188	1.5642	1.0553	1.5244	1.9036	1.4440	1.8182
	10	L	0.9743	0.9507	0.9658	1.3537	0.9827	1.3549	1.5800	1.3304	1.5493
	300	G	0.5536	0.5166	0.5396	0.5680	0.3818	0.5360	0.5891	0.3923	0.5169
	300	L	0.4811	0.4837	0.4820	0.4473	0.3435	0.4495	0.4598	0.3417	0.4285
1400	10	G	1.1134	1.0448	1.0888	1.7357	1.1721	1.6891	2.0964	1.6486	2.0294
	10	L	1.0398	1.0186	1.0321	1.5014	1.0910	1.5010	1.7400	1.5188	1.7293
	300	G	0.5625	0.5354	0.5522	0.5776	0.3977	0.5618	0.6017	0.4288	0.5419
	300	L	0.4863	0.4987	0.4907	0.4527	0.3559	0.4645	0.4631	0.3669	0.4425
1600	10	G	1.2765	1.1633	1.2357	2.2049	1.2712	2.0087	2.6988	1.6366	2.4014
	10	L	1.1922	1.1342	1.1714	1.9073	1.1825	1.7872	2.2400	1.5078	2.0463
	300	G	0.5697	0.5740	0.5462	0.6005	0.3831	0.5491	0.6373	0.4343	0.5154
	300	L	0.4936	0.5299	0.4859	0.4747	0.3556	0.4531	0.4943	0.3622	0.4230

Incident angle : 30

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
0	10	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	10	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	10	G	0.9891	1.0010	0.9912	1.0038	0.9954	0.9865	0.9839	0.9826	0.9824
	10	L	0.9794	0.9980	0.9836	0.9835	0.9854	0.9708	0.9444	0.9725	0.9654
	300	G	0.9819	0.9866	0.9843	1.0226	0.9909	0.9861	1.0078	0.9803	0.9786
	300	L	0.9590	0.9729	0.9657	0.9495	0.9645	0.9548	0.9229	0.9577	0.9489
16	10	G	0.9768	1.0000	0.9813	1.0087	0.9872	0.9684	0.9516	0.9588	0.9543
	10	L	0.9236	0.9785	0.9372	0.8998	0.9318	0.8692	0.7917	0.8699	0.8358
	300	G	0.9606	0.9681	0.9645	1.0377	0.9753	0.9712	1.0235	0.9508	0.9482
	300	L	0.8434	0.8949	0.8685	0.7823	0.8647	0.8359	0.7214	0.8438	0.8103
17	10	G	0.9753	1.0000	0.9808	1.0093	0.9861	0.9660	0.9516	0.9540	0.9511
	10	L	0.9160	0.9763	0.9310	0.8913	0.9250	0.8585	0.7778	0.8584	0.8201
	300	G	0.9578	0.9654	0.9616	1.0398	0.9726	0.9687	1.0196	0.9459	0.9429
	300	L	0.8287	0.8846	0.8560	0.7658	0.8519	0.8207	0.6940	0.8263	0.7917
26	10	G	0.9608	0.9970	0.9737	1.0136	0.9743	0.9446	0.9355	0.9208	0.9111
	10	L	0.9002	0.9745	0.9179	0.8928	0.9119	0.8358	0.7500	0.8251	0.7854
	300	G	0.9499	0.9406	0.9374	1.0512	0.9494	0.9469	1.0314	0.9066	0.9041
	300	L	0.8000	0.8628	0.8307	0.7609	0.8258	0.7888	0.6791	0.7927	0.7553
35	10	G	0.9448	0.9910	0.9635	1.0082	0.9543	0.9153	0.9194	0.8764	0.8789
	10	L	0.8816	0.9692	0.9061	0.8873	0.8924	0.8073	0.7222	0.7832	0.7433
	300	G	0.9346	0.9068	0.9131	1.0502	0.9119	0.9122	1.0392	0.8557	0.8539
	300	L	0.7686	0.8329	0.7989	0.7433	0.7900	0.7490	0.6517	0.7474	0.7077
37	10	G	0.9390	0.9876	0.9586	1.0022	0.9450	0.9034	0.9032	0.8590	0.8637
	10	L	0.8747	0.9659	0.9014	0.8813	0.8832	0.7961	0.7083	0.7659	0.7283
	300	G	0.9262	0.8934	0.9035	1.0449	0.8957	0.8962	1.0353	0.8344	0.8328
	300	L	0.7580	0.8207	0.7863	0.7307	0.7752	0.7334	0.6343	0.7314	0.6910
60	10	G	0.8308	0.9301	0.8638	0.8129	0.7915	0.6826	0.6290	0.5689	0.5900
	10	L	0.7598	0.9068	0.8075	0.7087	0.7386	0.6068	0.5000	0.4971	0.4753
	300	G	0.7243	0.6835	0.7033	0.7236	0.5964	0.5963	0.6549	0.4967	0.4981
	300	L	0.5407	0.6132	0.5755	0.4634	0.5238	0.4775	0.3948	0.4368	0.3869

Incident angle : 30

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
82	10	G	0.6756	0.9065	0.7466	0.5483	0.6107	0.5167	0.3677	0.4041	0.3086
	10	L	0.6124	0.8884	0.6984	0.4773	0.5764	0.4688	0.2972	0.3858	0.2707
	300	G	0.4775	0.4518	0.4337	0.3693	0.2741	0.3005	0.4882	0.1459	0.2168
	300	L	0.3968	0.4195	0.3479	0.3739	0.2385	0.2346	0.4353	0.1639	0.2239
83	10	G	0.6686	0.9081	0.7428	0.5374	0.6030	0.5100	0.3645	0.4057	0.3018
	10	L	0.6059	0.8909	0.6950	0.4693	0.5721	0.4652	0.2931	0.3858	0.2707
	300	G	0.4737	0.4449	0.4226	0.3784	0.2672	0.2976	0.5063	0.1467	0.2186
	300	L	0.3968	0.4214	0.3541	0.3743	0.2316	0.2365	0.4430	0.1549	0.2276
130	10	G	0.5446	0.9371	0.7064	0.4861	0.4874	0.4895	0.4210	0.3978	0.4047
	10	L	0.5146	0.9180	0.6756	0.4454	0.4815	0.4467	0.3806	0.3728	0.3776
	300	G	0.4997	0.5521	0.5140	0.6921	0.2834	0.4202	1.0157	0.2151	0.4188
	300	L	0.4394	0.5401	0.4897	0.5221	0.2473	0.3808	0.6493	0.2380	0.3832
177	10	G	0.6407	0.8451	0.7122	0.7130	0.5850	0.6159	0.8564	0.4422	0.6430
	10	L	0.6135	0.8252	0.6838	0.6633	0.5701	0.5701	0.7542	0.4379	0.5822
	300	G	0.7469	0.5306	0.6180	1.0992	0.5245	0.6370	1.4667	0.4115	0.5892
	300	L	0.6311	0.5047	0.5569	0.7949	0.4664	0.5317	0.8905	0.3693	0.4909
178	10	G	0.6434	0.8412	0.7116	0.7169	0.5860	0.6176	0.8645	0.4453	0.6483
	10	L	0.6160	0.8220	0.6832	0.6668	0.5721	0.5717	0.7597	0.4422	0.5856
	300	G	0.7503	0.5276	0.6177	1.1020	0.5287	0.6389	1.4706	0.4148	0.5902
	300	L	0.6343	0.5011	0.5561	0.7971	0.4713	0.5327	0.8955	0.3737	0.4900
215	10	G	0.6890	0.7203	0.6983	0.7949	0.6168	0.6448	0.9645	0.4849	0.6890
	10	L	0.6556	0.7082	0.6718	0.7297	0.5998	0.5952	0.8292	0.4552	0.6137
	300	G	0.7559	0.5832	0.5920	1.0279	0.6134	0.5989	1.2980	0.4787	0.5338
	300	L	0.6463	0.5692	0.5223	0.7433	0.5809	0.5084	0.8184	0.4715	0.4189
252	10	G	0.6813	0.6538	0.6653	0.7730	0.6297	0.6139	0.8661	0.4881	0.6123
	10	L	0.6453	0.6533	0.6400	0.7062	0.6008	0.5652	0.7361	0.4399	0.5408
	300	G	0.6627	0.6590	0.5387	0.7494	0.6594	0.6115	0.8745	0.5410	0.5291
	300	L	0.5646	0.6325	0.4797	0.5523	0.6444	0.5630	0.5572	0.5504	0.4848
253	10	G	0.6810	0.6539	0.6640	0.7709	0.6297	0.6115	0.8645	0.4897	0.6108
	10	L	0.6447	0.6533	0.6386	0.7042	0.6013	0.5629	0.7333	0.4413	0.5383
	300	G	0.6568	0.6611	0.5386	0.7486	0.6605	0.6124	0.8588	0.5410	0.5281
	300	L	0.5593	0.6342	0.4798	0.5510	0.6459	0.5642	0.5498	0.5518	0.4863

Incident angle : 30

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
268	10	G	0.6661	0.6639	0.6405	0.7463	0.6251	0.5960	0.7774	0.4913	0.5524
	10	L	0.6302	0.6597	0.6164	0.6858	0.6022	0.5518	0.6639	0.4393	0.4928
	300	G	0.5986	0.6886	0.5374	0.7083	0.6737	0.6204	0.8275	0.5705	0.5386
	300	L	0.5021	0.6558	0.4896	0.5134	0.6579	0.5732	0.5080	0.5796	0.5109
282	10	G	0.6430	0.6878	0.6225	0.7223	0.6225	0.5846	0.7403	0.4976	0.5272
	10	L	0.6087	0.6788	0.5990	0.6658	0.5964	0.5433	0.6333	0.4538	0.4789
	300	G	0.5557	0.7086	0.5347	0.7158	0.6796	0.6217	0.8655	0.5918	0.5483
	300	L	0.4617	0.6738	0.4944	0.5180	0.6574	0.5711	0.5510	0.5956	0.5241
283	10	G	0.6414	0.6896	0.6220	0.7196	0.6220	0.5853	0.7323	0.4976	0.5305
	10	L	0.6072	0.6805	0.5985	0.6648	0.5959	0.5438	0.6292	0.4552	0.4802
	300	G	0.5523	0.7098	0.5342	0.7136	0.6796	0.6213	0.8694	0.5934	0.5494
	300	L	0.4585	0.6749	0.4945	0.5164	0.6571	0.5707	0.5550	0.5971	0.5252
305	10	G	0.6075	0.7405	0.6125	0.7141	0.6076	0.5880	0.7581	0.6038	0.5801
	10	L	0.5758	0.7279	0.5878	0.6584	0.5648	0.5431	0.6611	0.5332	0.5222
	300	G	0.5147	0.7163	0.5217	0.7080	0.6584	0.6003	0.9176	0.6049	0.5624
	300	L	0.4428	0.6785	0.4846	0.5376	0.6144	0.5345	0.6045	0.5912	0.5152
327	10	G	0.5778	0.8067	0.6248	0.6858	0.6297	0.5991	0.7855	0.7559	0.6675
	10	L	0.5467	0.7933	0.5968	0.6264	0.5871	0.5454	0.6764	0.6777	0.5858
	300	G	0.4912	0.6820	0.5167	0.6542	0.5913	0.5486	0.9341	0.5623	0.5389
	300	L	0.4269	0.6461	0.4550	0.5089	0.5330	0.4628	0.6169	0.5358	0.4624
328	10	G	0.5755	0.8094	0.6259	0.6852	0.6369	0.6005	0.7871	0.7639	0.6699
	10	L	0.5445	0.7961	0.5978	0.6259	0.5949	0.5466	0.6764	0.6835	0.5894
	300	G	0.4909	0.6790	0.5182	0.6475	0.5868	0.5452	0.9361	0.5590	0.5355
	300	L	0.4261	0.6436	0.4560	0.5030	0.5281	0.4585	0.6144	0.5328	0.4598
396	10	G	0.4860	0.9517	0.6761	0.4932	0.8562	0.7724	0.6129	1.0000	0.8080
	10	L	0.4585	0.9378	0.6477	0.4544	0.8121	0.7094	0.5306	0.9162	0.7250
	300	G	0.3942	0.6736	0.5414	0.4683	0.4813	0.4880	0.5851	0.3951	0.4032
	300	L	0.3412	0.6325	0.4889	0.3712	0.4390	0.4175	0.4614	0.3664	0.3564
464	10	G	0.4647	1.0109	0.7044	0.4845	0.9784	0.8807	0.6129	1.1601	0.9204
	10	L	0.4397	0.9941	0.6744	0.4489	0.9241	0.8055	0.5319	1.0607	0.8223
	300	G	0.3820	0.7575	0.6026	0.4338	0.5990	0.5897	0.5843	0.5459	0.5518
	300	L	0.3468	0.6962	0.5403	0.3871	0.5090	0.4923	0.4808	0.4745	0.4624

Incident angle : 30

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
464	10	G	0.4647	1.0109	0.7044	0.4845	0.9784	0.8807	0.6129	1.1601	0.9204
	10	L	0.4397	0.9941	0.6744	0.4489	0.9241	0.8055	0.5319	1.0607	0.8223
	300	G	0.3820	0.7575	0.6026	0.4338	0.5990	0.5897	0.5843	0.5459	0.5518
	300	L	0.3468	0.6962	0.5403	0.3871	0.5090	0.4923	0.4808	0.4745	0.4624
466	10	G	0.4626	1.0149	0.7067	0.4845	0.9795	0.8838	0.6048	1.1696	0.9320
	10	L	0.4378	0.9980	0.6759	0.4484	0.9255	0.8085	0.5292	1.0838	0.8412
	300	G	0.3870	0.7534	0.6070	0.4490	0.5938	0.5851	0.6000	0.5541	0.5612
	300	L	0.3500	0.6918	0.5375	0.3806	0.5047	0.4879	0.4692	0.4701	0.4630
673	10	G	0.5375	0.8484	0.6611	0.6285	0.8942	0.8128	0.6097	1.1030	0.8975
	10	L	0.5080	0.8340	0.6320	0.5726	0.8476	0.7452	0.5222	1.0072	0.7991
	300	G	0.3977	0.5724	0.4969	0.6597	0.5079	0.4842	0.7922	0.4557	0.4576
	300	L	0.3253	0.5268	0.4339	0.4940	0.4526	0.4070	0.5246	0.4146	0.3736
879	10	G	0.7938	0.7459	0.7765	1.1364	0.6980	1.0655	1.3871	0.9192	1.1726
	10	L	0.7522	0.7341	0.7437	1.0394	0.6636	0.9787	1.2083	0.8381	1.0413
	300	G	0.6611	0.4903	0.5426	0.7809	0.3664	0.5132	1.0353	0.3459	0.4791
	300	L	0.5580	0.4336	0.4806	0.5812	0.2890	0.4347	0.6418	0.2832	0.3984
880	10	G	0.7974	0.7458	0.7799	1.1413	0.6995	1.0694	1.4032	0.9176	1.1729
	10	L	0.7557	0.7341	0.7470	1.0439	0.6646	0.9821	1.2222	0.8382	1.0525
	300	G	0.6655	0.4900	0.5463	0.7880	0.3659	0.5182	1.0471	0.3475	0.4854
	300	L	0.5617	0.4330	0.4840	0.5863	0.2882	0.4389	0.6493	0.2847	0.4013
1090	10	G	1.0000	1.0964	1.0321	1.4905	1.1166	1.4793	1.8064	1.4580	1.6250
	10	L	0.9477	1.0802	0.9890	1.3636	1.0589	1.3581	1.5556	1.3584	1.4600
	300	G	0.6909	0.5464	0.6144	0.7325	0.3979	0.5315	0.9490	0.3459	0.4699
	300	L	0.5941	0.5017	0.5481	0.5529	0.3425	0.4462	0.6244	0.2978	0.3948
1300	10	G	1.1445	1.2356	1.1800	1.8151	1.3647	1.8207	2.4193	1.8225	2.1418
	10	L	1.0853	1.2162	1.1307	1.6594	1.2936	1.6704	2.1111	1.6618	1.9233
	300	G	0.7006	0.5411	0.6222	0.7730	0.3705	0.5401	1.0667	0.3311	0.5124
	300	L	0.5934	0.5025	0.5516	0.5695	0.3341	0.4533	0.6716	0.2964	0.4253
1400	10	G	1.2280	1.3638	1.2801	2.0529	1.5819	2.0718	2.7097	2.2187	2.4781
	10	L	1.1638	1.3425	1.2262	1.8768	1.4995	1.9006	2.3194	2.0231	2.1989
	300	G	0.7628	0.5936	0.6795	0.8905	0.4427	0.6245	1.2000	0.4098	0.5977
	300	L	0.6452	0.5529	0.6026	0.6485	0.3964	0.5256	0.7512	0.3693	0.4960
1600	10	G	1.4103	1.4881	1.4359	2.8009	1.7874	2.5558	3.6290	2.3613	3.0580
	10	L	1.3365	1.4648	1.3754	2.5606	1.6943	2.3448	3.1250	2.1532	2.7230
	300	G	0.7053	0.5291	0.6188	0.8950	0.3757	0.5817	1.1529	0.3410	0.5438
	300	L	0.6016	0.4903	0.5505	0.6676	0.3268	0.4907	0.7363	0.3007	0.4540

Incident angle : 40

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
0	10	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	10	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	300	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	10	G	0.9967	0.9943	0.9969	0.9728	0.9826	0.9735	0.9661	1.0026	0.9682
	10	L	0.9806	0.9939	0.9819	0.9488	0.9745	0.9504	0.9098	0.9907	0.9133
	300	G	0.9674	1.0035	0.9699	0.9377	1.0019	0.9407	0.8987	1.0061	0.9013
	300	L	0.9283	0.9934	0.9325	0.8839	0.9823	0.8867	0.8386	0.9896	0.8445
16	10	G	0.9918	0.9899	0.9922	0.9438	0.9593	0.9450	0.9237	0.9948	0.9280
	10	L	0.9295	0.9757	0.9339	0.8279	0.8962	0.8328	0.7519	0.9182	0.7802
	300	G	0.9328	1.0009	0.9377	0.8714	0.9941	0.8776	0.7951	1.0012	0.8188
	300	L	0.7914	0.9381	0.8028	0.6568	0.8916	0.6658	0.5418	0.8982	0.5765
17	10	G	0.9914	0.9895	0.9918	0.9407	0.9564	0.9420	0.9153	0.9974	0.9199
	10	L	0.9229	0.9731	0.9277	0.8116	0.8852	0.8170	0.7444	0.9065	0.7726
	300	G	0.9282	1.0004	0.9334	0.8628	0.9927	0.8694	0.7811	1.0000	0.8087
	300	L	0.7741	0.9304	0.7909	0.6284	0.8789	0.6384	0.5068	0.8825	0.5438
26	10	G	0.9874	0.9841	0.9876	0.9117	0.9235	0.9158	0.8898	0.9767	0.9020
	10	L	0.9144	0.9692	0.9201	0.7791	0.8543	0.7856	0.6992	0.8925	0.7290
	300	G	0.8941	0.9918	0.9011	0.7985	0.9744	0.8080	0.6834	0.9832	0.7344
	300	L	0.7260	0.9195	0.7599	0.5495	0.8540	0.5598	0.4131	0.8642	0.4889
35	10	G	0.9821	0.9756	0.9819	0.8885	0.8790	0.8955	0.8729	0.9483	0.8838
	10	L	0.9074	0.9619	0.9131	0.7630	0.8133	0.7543	0.6692	0.8645	0.7046
	300	G	0.8594	0.9736	0.8675	0.7332	0.9398	0.7453	0.6065	0.9475	0.6608
	300	L	0.6937	0.8983	0.7283	0.4934	0.8144	0.4877	0.3849	0.8277	0.4609
37	10	G	0.9792	0.9720	0.9790	0.8834	0.8625	0.8901	0.8559	0.9354	0.8672
	10	L	0.9043	0.9585	0.9100	0.7686	0.7960	0.7586	0.6617	0.8528	0.6964
	300	G	0.8488	0.9636	0.8620	0.7141	0.9231	0.7267	0.5832	0.9292	0.6387
	300	L	0.6840	0.8882	0.7231	0.4971	0.7971	0.4914	0.3804	0.8146	0.4534
60	10	G	0.9303	0.9042	0.9268	0.8518	0.6544	0.8390	0.7797	0.6641	0.7681
	10	L	0.8428	0.8905	0.8465	0.7630	0.6403	0.7528	0.6316	0.5794	0.6363
	300	G	0.7561	0.7679	0.7562	0.5664	0.5929	0.5547	0.3667	0.5888	0.4166
	300	L	0.6627	0.6878	0.6752	0.6068	0.4836	0.6035	0.4199	0.4700	0.4308

Incident angle : 40

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
82	10	G	0.8308	0.8175	0.8298	0.7270	0.5082	0.7159	0.6356	0.2997	0.6115
	10	L	0.7479	0.8037	0.7537	0.6242	0.4954	0.6176	0.5263	0.2430	0.5164
	300	G	0.6459	0.5115	0.6345	0.5328	0.2899	0.5213	0.3423	0.2558	0.3376
	300	L	0.5842	0.4383	0.5813	0.5047	0.2736	0.5024	0.3928	0.2705	0.3931
83	10	G	0.8254	0.8141	0.8247	0.7201	0.5073	0.7092	0.6271	0.2817	0.6031
	10	L	0.7428	0.8003	0.7489	0.6142	0.4945	0.6078	0.5263	0.2430	0.5161
	300	G	0.6399	0.5024	0.6282	0.5261	0.2893	0.5148	0.3353	0.2624	0.3304
	300	L	0.5789	0.4286	0.5757	0.4948	0.2762	0.4924	0.3860	0.2779	0.3861
130	10	G	0.6892	0.7891	0.6957	0.5306	0.4908	0.5313	0.3965	0.3566	0.3782
	10	L	0.6073	0.7799	0.6214	0.4202	0.4827	0.4243	0.3114	0.3505	0.3059
	300	G	0.4941	0.5344	0.4802	0.3347	0.3863	0.3395	0.2305	0.4452	0.2294
	300	L	0.5336	0.4925	0.5155	0.3776	0.3467	0.3733	0.3025	0.3814	0.3127
177	10	G	0.5567	0.7848	0.5855	0.5942	0.4773	0.5898	0.5716	0.4935	0.5460
	10	L	0.5186	0.7584	0.5432	0.5256	0.4763	0.5209	0.5113	0.4089	0.4995
	300	G	0.6088	0.6232	0.5834	0.6326	0.4558	0.6171	0.6915	0.5491	0.6813
	300	L	0.6701	0.5133	0.6481	0.6282	0.3334	0.6213	0.7483	0.3838	0.7483
178	10	G	0.5575	0.7834	0.5860	0.5996	0.4753	0.5950	0.5769	0.4910	0.5510
	10	L	0.5213	0.7567	0.5451	0.5300	0.4754	0.5252	0.5263	0.4065	0.5141
	300	G	0.6112	0.6215	0.5857	0.6425	0.4530	0.6268	0.7055	0.5491	0.6951
	300	L	0.6717	0.5106	0.6496	0.6363	0.3304	0.6293	0.7619	0.3786	0.7618
215	10	G	0.6317	0.7251	0.6401	0.7098	0.4269	0.7015	0.8390	0.3488	0.8050
	10	L	0.6011	0.6909	0.6090	0.6298	0.4444	0.6223	0.7594	0.2757	0.7413
	300	G	0.6621	0.4894	0.6360	0.8904	0.2862	0.8687	1.0081	0.3234	0.9932
	300	L	0.6863	0.3720	0.6646	0.8710	0.2241	0.8610	1.0090	0.1992	1.0087
252	10	G	0.6990	0.6545	0.6947	0.7946	0.4308	0.7825	1.0254	0.2351	0.9804
	10	L	0.6665	0.6404	0.6639	0.7060	0.4390	0.6963	0.9098	0.2453	0.8871
	300	G	0.7533	0.3182	0.7267	0.9961	0.1435	0.9720	1.0314	0.0894	1.0156
	300	L	0.7301	0.3339	0.7124	0.9190	0.2812	0.9086	0.9526	0.2426	0.9529
253	10	G	0.7011	0.6532	0.6964	0.7951	0.4337	0.7829	1.0254	0.2377	0.9805
	10	L	0.6685	0.6406	0.6655	0.7063	0.4399	0.6965	0.9023	0.2523	0.8797
	300	G	0.7540	0.3207	0.7274	0.9946	0.1468	0.9705	1.0233	0.0903	1.0076
	300	L	0.7307	0.3332	0.7130	0.9162	0.2827	0.9058	0.9503	0.2452	0.9507

Incident angle : 40

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
268	10	G	0.7231	0.6441	0.7139	0.8143	0.4734	0.8028	1.0339	0.3204	0.9881
	10	L	0.6886	0.6412	0.6817	0.7393	0.4563	0.7302	0.9098	0.3294	0.8891
	300	G	0.7450	0.3677	0.7187	0.9297	0.1974	0.9074	0.9208	0.1678	0.9072
	300	L	0.7236	0.3664	0.7064	0.8504	0.2881	0.8413	0.8668	0.2624	0.8680
282	10	G	0.7341	0.6487	0.7238	0.8241	0.5150	0.8112	1.0424	0.4134	0.9981
	10	L	0.7045	0.6469	0.6967	0.7535	0.4918	0.7429	0.9248	0.4019	0.9039
	300	G	0.6986	0.4068	0.6771	0.7999	0.2437	0.7808	0.7567	0.2550	0.7459
	300	L	0.7066	0.3880	0.6929	0.7509	0.2764	0.7454	0.7754	0.2534	0.7804
283	10	G	0.7353	0.6498	0.7247	0.8254	0.5179	0.8123	1.0339	0.4160	0.9899
	10	L	0.7060	0.6481	0.6979	0.7530	0.4954	0.7423	0.9398	0.4089	0.9183
	300	G	0.6968	0.4100	0.6754	0.7861	0.2503	0.7673	0.7404	0.2617	0.7315
	300	L	0.7058	0.3888	0.6921	0.7515	0.2746	0.7459	0.7698	0.2558	0.7748
305	10	G	0.7349	0.6663	0.7242	0.8274	0.5837	0.8150	0.9831	0.5349	0.9447
	10	L	0.7115	0.6629	0.7030	0.7691	0.5528	0.7585	0.9173	0.4907	0.8991
	300	G	0.6378	0.4361	0.6220	0.8299	0.3142	0.8109	0.7590	0.3049	0.7473
	300	L	0.6769	0.3934	0.6656	0.7555	0.2655	0.7494	0.7291	0.2407	0.7341
327	10	G	0.7235	0.6880	0.7106	0.8123	0.6573	0.8010	0.9322	0.6305	0.8997
	10	L	0.7002	0.6827	0.6907	0.7495	0.6230	0.7401	0.8797	0.5631	0.8649
	300	G	0.6311	0.4582	0.6155	0.9118	0.2849	0.8919	0.9348	0.2279	0.9205
	300	L	0.6525	0.4456	0.6412	0.7788	0.2986	0.7704	0.7675	0.2611	0.7675
328	10	G	0.7210	0.6893	0.7104	0.8100	0.6621	0.7985	0.9322	0.6357	0.8995
	10	L	0.6983	0.6841	0.6902	0.7458	0.6257	0.7363	0.8647	0.5724	0.8502
	300	G	0.6311	0.4634	0.6153	0.9108	0.2825	0.8911	0.9383	0.2285	0.9240
	300	L	0.6518	0.4507	0.6403	0.7769	0.3049	0.7685	0.7630	0.2676	0.7630
396	10	G	0.6346	0.7619	0.6349	0.6094	0.8955	0.6168	0.7373	0.9070	0.7156
	10	L	0.6065	0.7518	0.6089	0.5484	0.8434	0.5553	0.6391	0.8131	0.6326
	300	G	0.5060	0.6423	0.4970	0.5073	0.5100	0.4988	0.5332	0.5339	0.5275
	300	L	0.4569	0.5830	0.4546	0.4117	0.4877	0.4104	0.3905	0.4830	0.3923
464	10	G	0.5355	0.8204	0.5624	0.4135	1.0726	0.4707	0.5170	1.1292	0.5600
	10	L	0.5105	0.8099	0.5377	0.3763	1.0173	0.4287	0.4511	1.0280	0.5069
	300	G	0.3432	0.6483	0.3740	0.3076	0.5208	0.3371	0.2980	0.5278	0.3448
	300	L	0.3338	0.5926	0.3673	0.2967	0.4761	0.3246	0.3657	0.4883	0.3698

Incident angle : 40

Depth	Qs= Qp	1st Layer	maximum displacement			maximum velocity			maximum acceleration		
			Ux	Uz	Ut	Vx	Vz	Vt	Ax	Az	At
464	10	G	0.5355	0.8204	0.5624	0.4135	1.0726	0.4707	0.5170	1.1292	0.5600
	10	L	0.5105	0.8099	0.5377	0.3763	1.0173	0.4287	0.4511	1.0280	0.5069
	300	G	0.3432	0.6483	0.3740	0.3076	0.5208	0.3371	0.2980	0.5278	0.3448
	300	L	0.3338	0.5926	0.3673	0.2967	0.4761	0.3246	0.3657	0.4883	0.3698
466	10	G	0.5302	0.8238	0.5582	0.4029	1.0755	0.4645	0.4831	1.1395	0.5647
	10	L	0.5058	0.8134	0.5337	0.3656	1.0200	0.4228	0.4361	1.0397	0.5112
	300	G	0.3364	0.6527	0.3729	0.2965	0.5293	0.3358	0.2969	0.5369	0.3414
	300	L	0.3270	0.5969	0.3656	0.2844	0.4829	0.3215	0.3488	0.4935	0.3539
673	10	G	0.5962	0.8188	0.6245	0.5108	1.2159	0.5771	0.6186	1.3540	0.7263
	10	L	0.5678	0.8048	0.5961	0.4649	1.1430	0.5243	0.5489	1.2220	0.6565
	300	G	0.3867	0.6384	0.4185	0.3317	0.5429	0.3779	0.3399	0.5857	0.4005
	300	L	0.3744	0.5609	0.4076	0.3203	0.4782	0.3608	0.3296	0.4830	0.3900
879	10	G	0.9021	0.7840	0.8906	1.0401	1.2052	1.0631	1.3559	1.2507	1.3511
	10	L	0.8575	0.7702	0.8490	0.9419	1.1311	0.9637	1.1955	1.1285	1.2148
	300	G	0.6185	0.6518	0.6120	0.6251	0.5031	0.6279	0.6333	0.5156	0.6408
	300	L	0.5993	0.5528	0.5985	0.5992	0.3954	0.6073	0.6242	0.3916	0.6396
880	10	G	0.9058	0.7852	0.8941	1.0503	1.2014	1.0733	1.3644	1.2558	1.3593
	10	L	0.8610	0.7714	0.8523	0.9535	1.1275	0.9751	1.2030	1.1332	1.2222
	300	G	0.6219	0.6522	0.6153	0.6304	0.5047	0.6330	0.6426	0.5156	0.6500
	300	L	0.6024	0.5528	0.6015	0.6044	0.3953	0.6125	0.6287	0.3916	0.6438
1090	10	G	1.2471	1.1444	1.2372	1.6256	1.8170	1.6620	2.1949	2.0517	2.1895
	10	L	1.1836	1.1263	1.1779	1.4698	1.7104	1.5050	1.9323	1.8551	1.9663
	300	G	0.7361	0.6960	0.7354	0.7729	0.5660	0.7754	0.7253	0.5796	0.7410
	300	L	0.7040	0.6259	0.7117	0.7125	0.4951	0.7261	0.6840	0.5065	0.7168
1300	10	G	1.4156	1.2884	1.4032	1.8207	2.2178	1.8694	2.6695	2.6098	2.6736
	10	L	1.3439	1.2687	1.3365	1.6512	2.0865	1.6973	2.3759	2.3832	2.4274
	300	G	0.7375	0.6622	0.7337	0.6970	0.5182	0.7044	0.7660	0.5369	0.7807
	300	L	0.7123	0.5899	0.7160	0.6520	0.4449	0.6681	0.7506	0.4569	0.7758
1400	10	G	1.4906	1.3961	1.4816	2.0005	2.5053	2.0586	2.9576	2.9974	2.9725
	10	L	1.4152	1.3737	1.4110	1.8116	2.3570	1.8667	2.6241	2.6636	2.6839
	300	G	0.7057	0.6860	0.7068	0.6558	0.5626	0.6681	0.6938	0.5918	0.7184
	300	L	0.6844	0.6085	0.6919	0.6246	0.4846	0.6433	0.6862	0.4935	0.7183
1600	10	G	1.7141	1.6210	1.7030	2.6143	3.0561	2.6652	3.7712	3.5659	3.7657
	10	L	1.6274	1.5963	1.6221	2.3674	2.8743	2.4169	3.3459	3.2477	3.4080
	300	G	0.7139	0.6786	0.7131	0.6774	0.5156	0.6876	0.7311	0.5522	0.7472
	300	L	0.6843	0.6097	0.6914	0.6294	0.4547	0.6484	0.6975	0.4830	0.7259

Appendix F

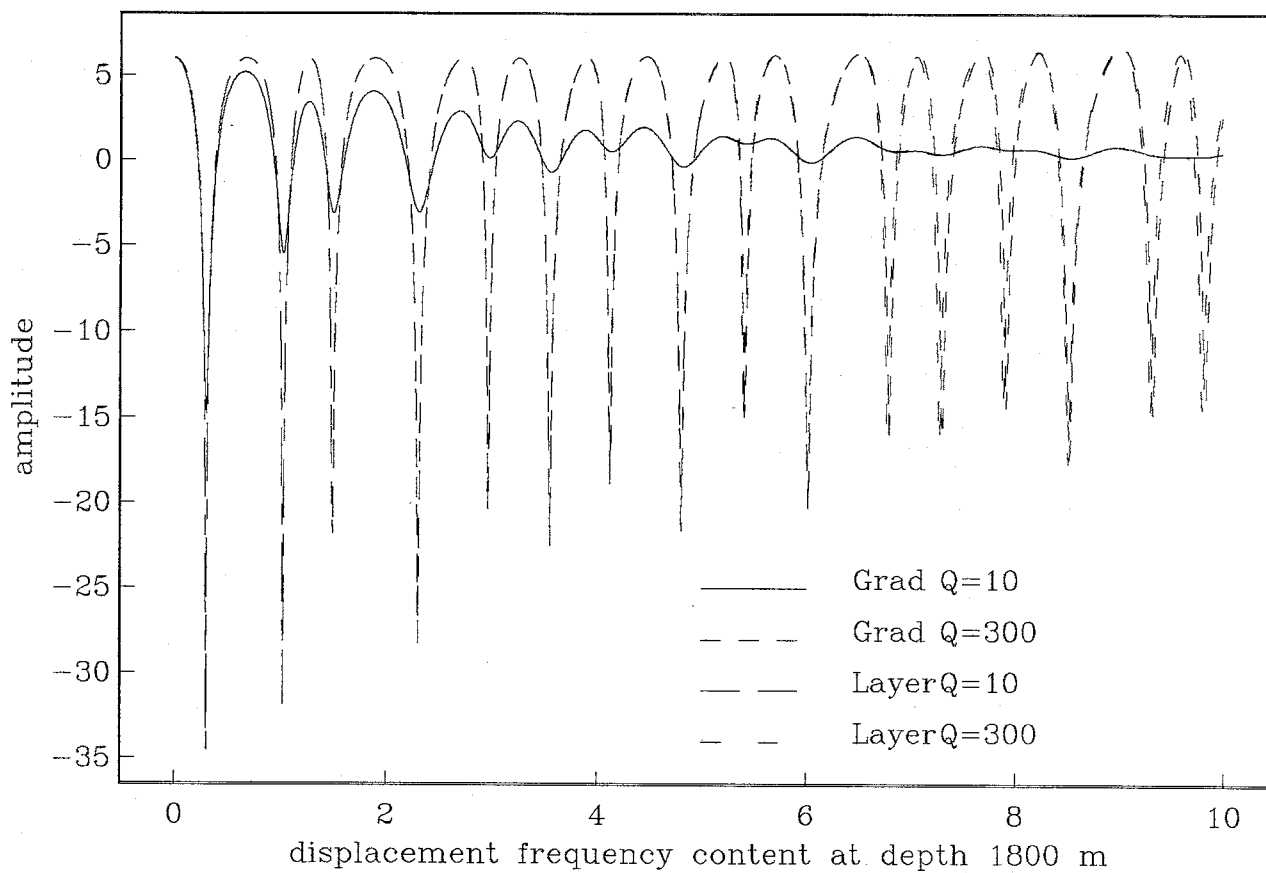
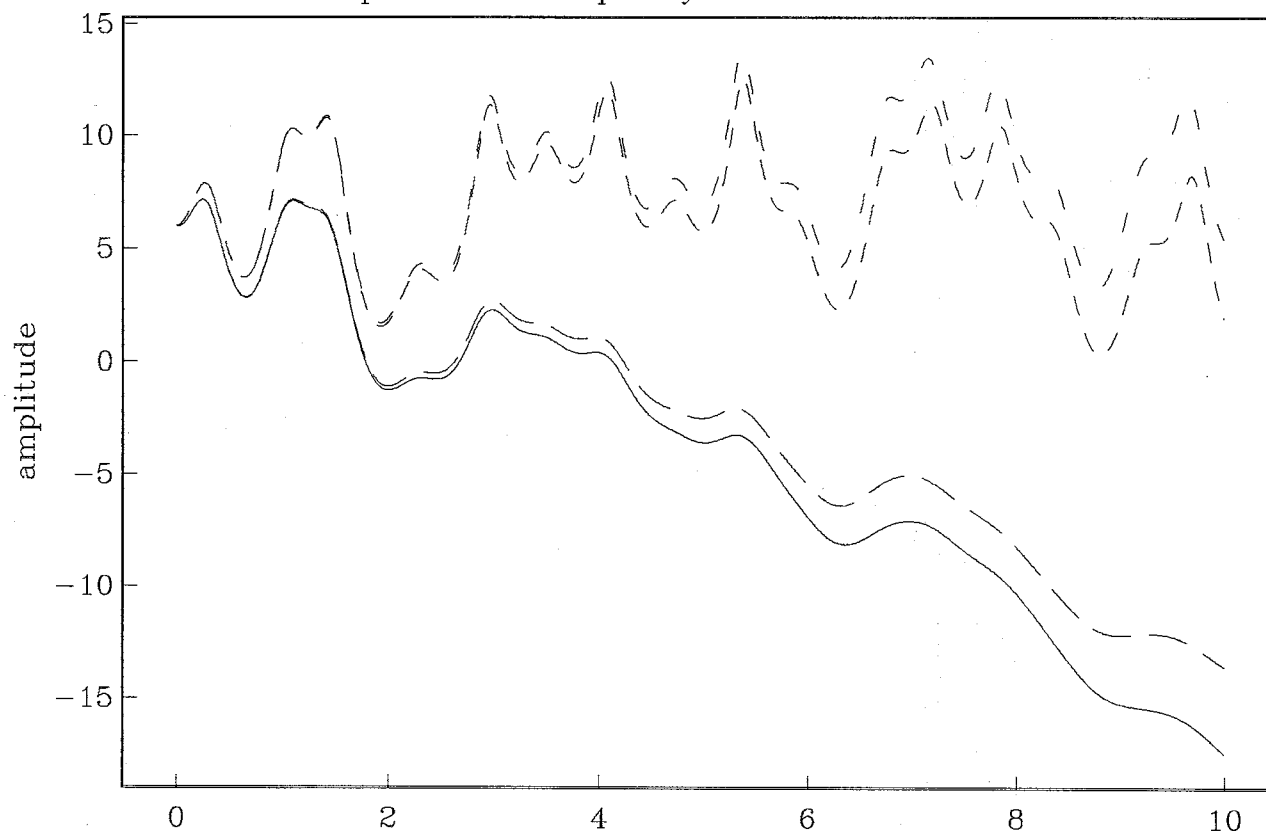
Content :

10 spectral amplitude graphs for displacement.

(The amplitudes are in dB)

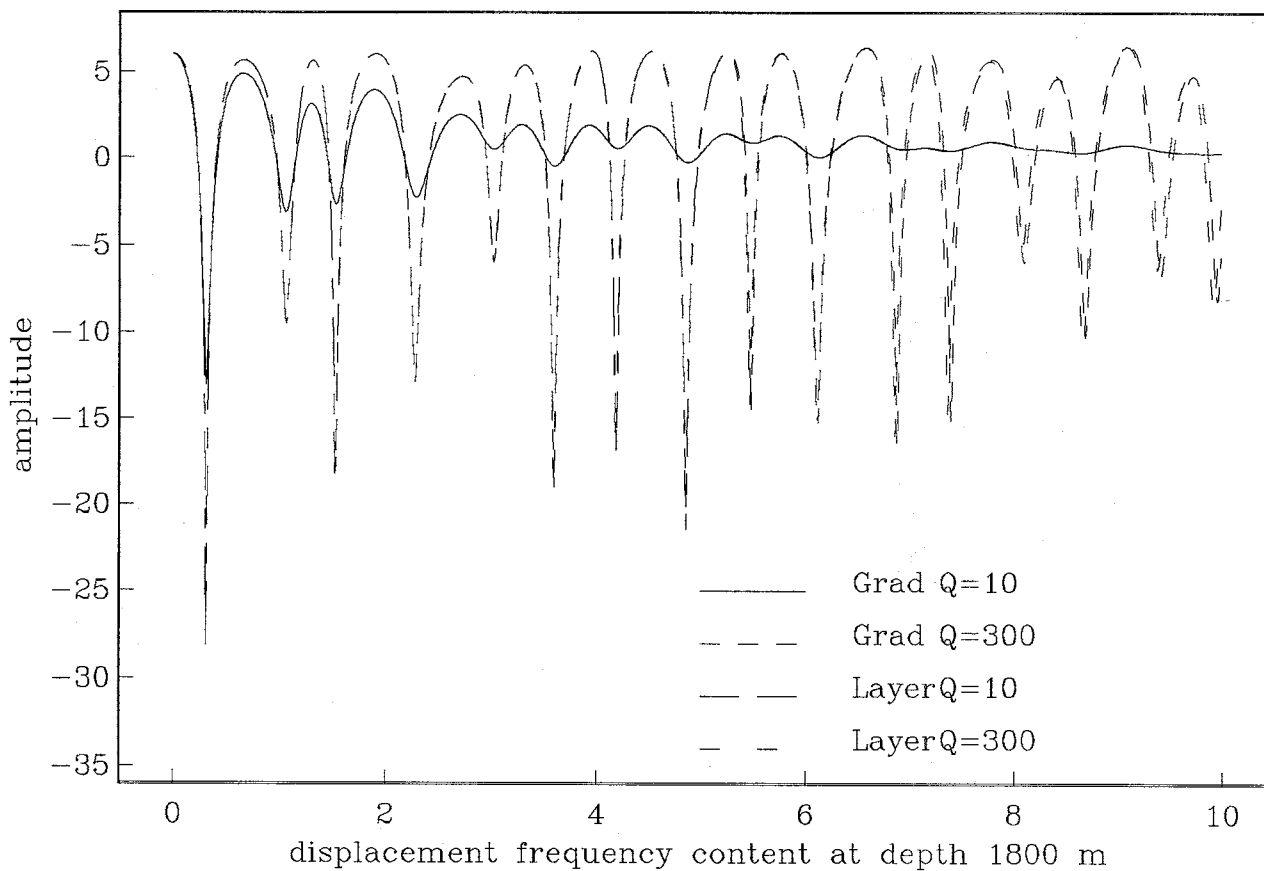
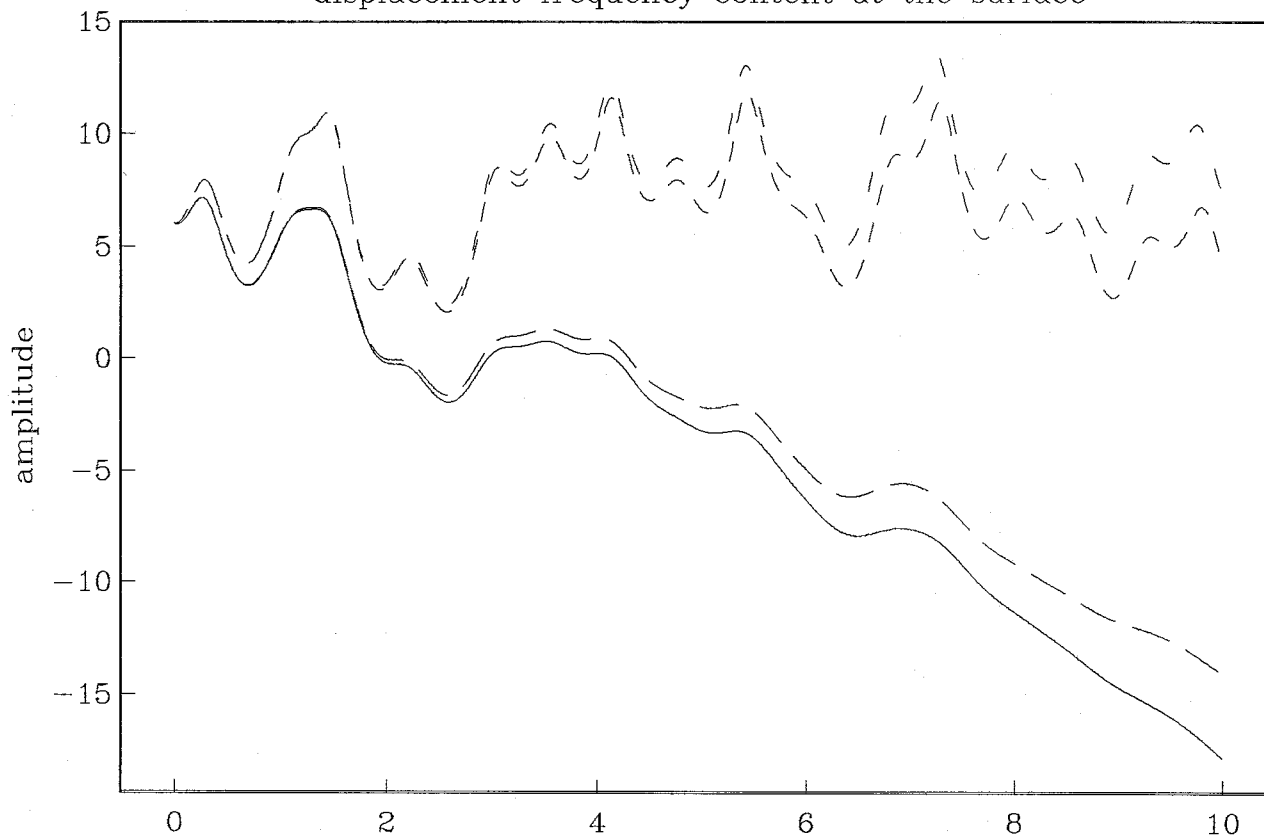
Ux | Incident angle : 0

displacement frequency content at the surface



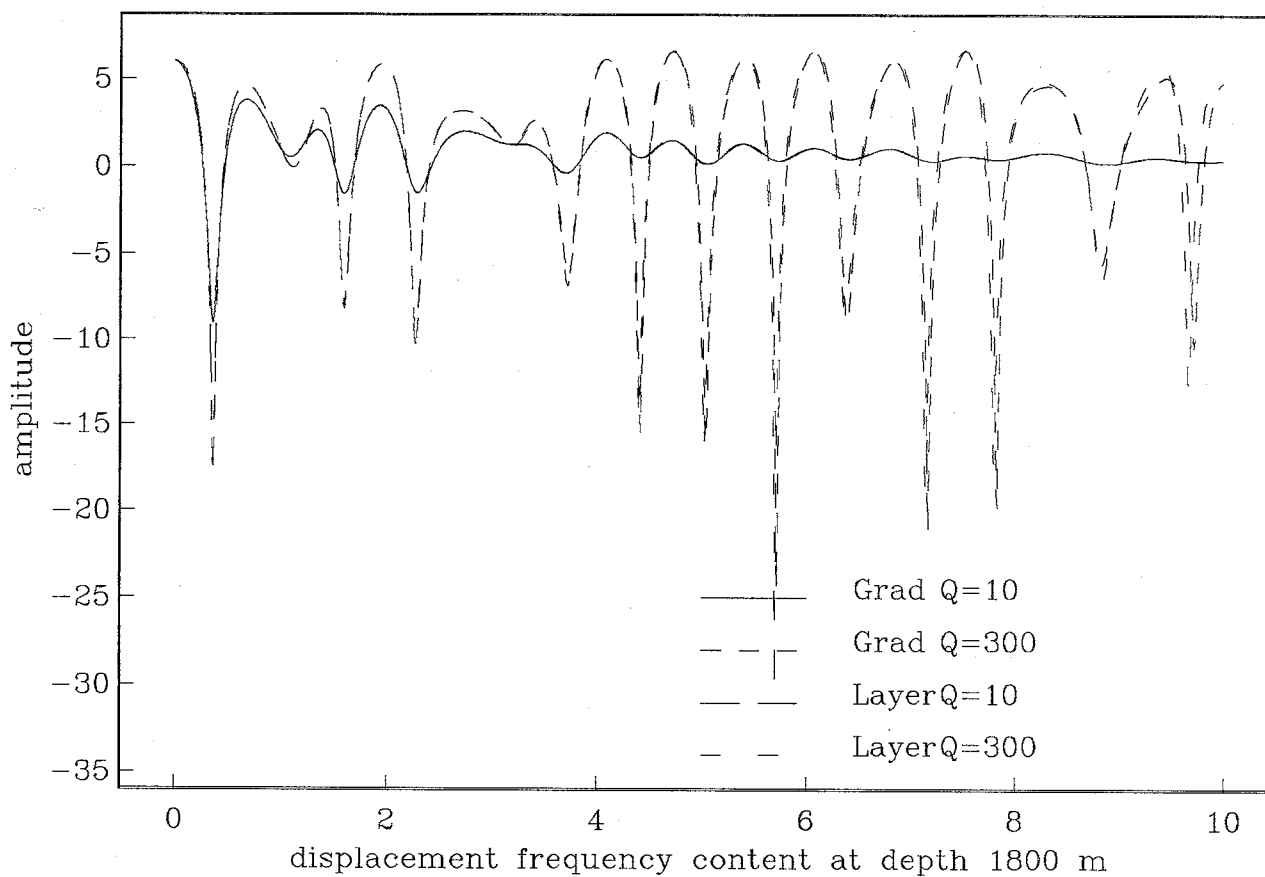
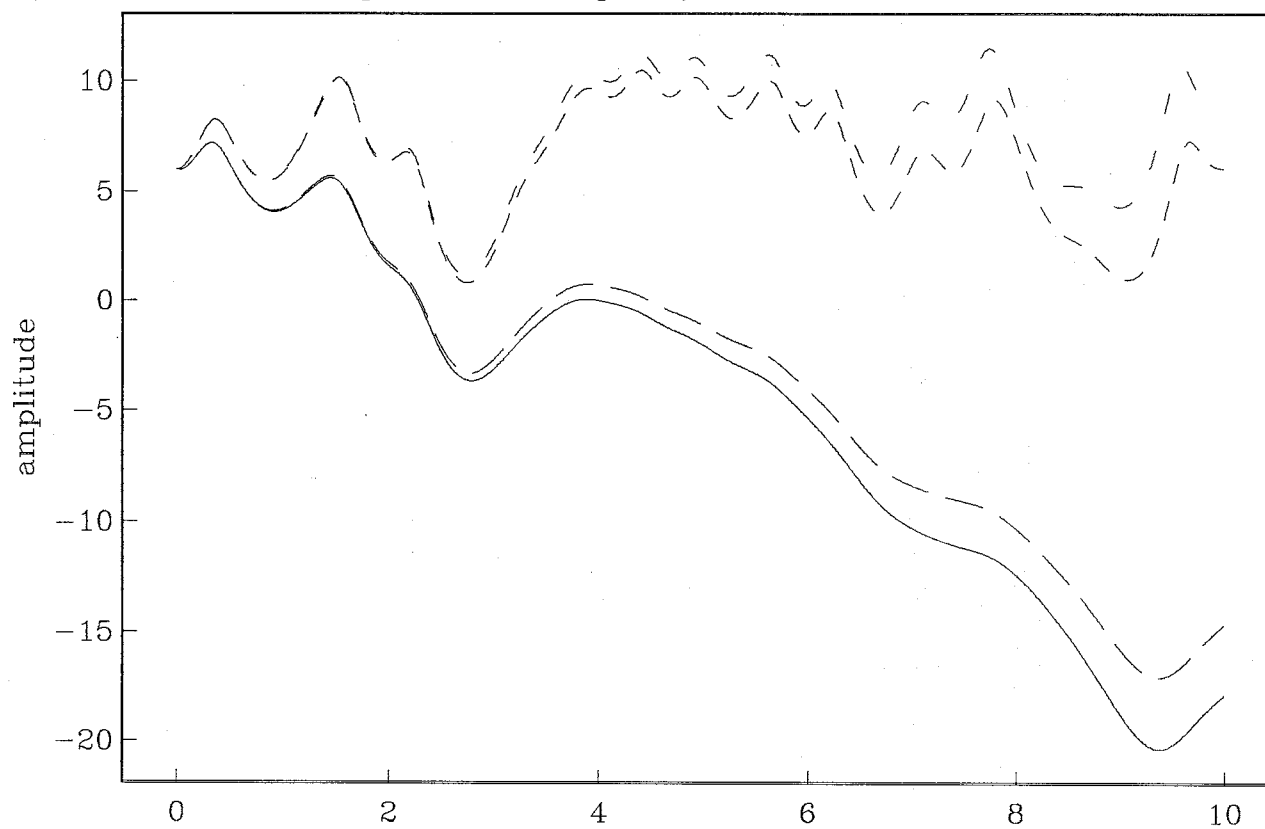
Ux | Incident angle : 10

displacement frequency content at the surface



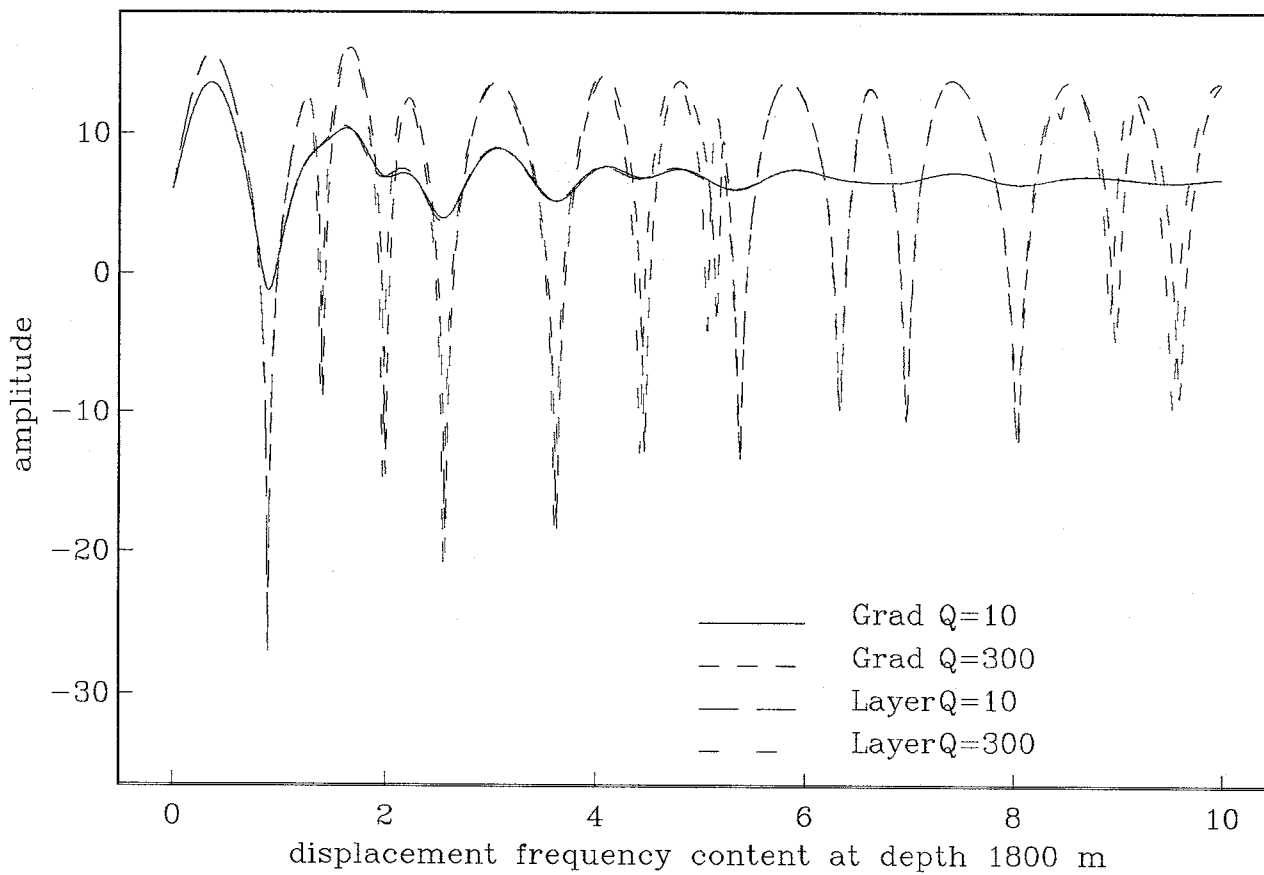
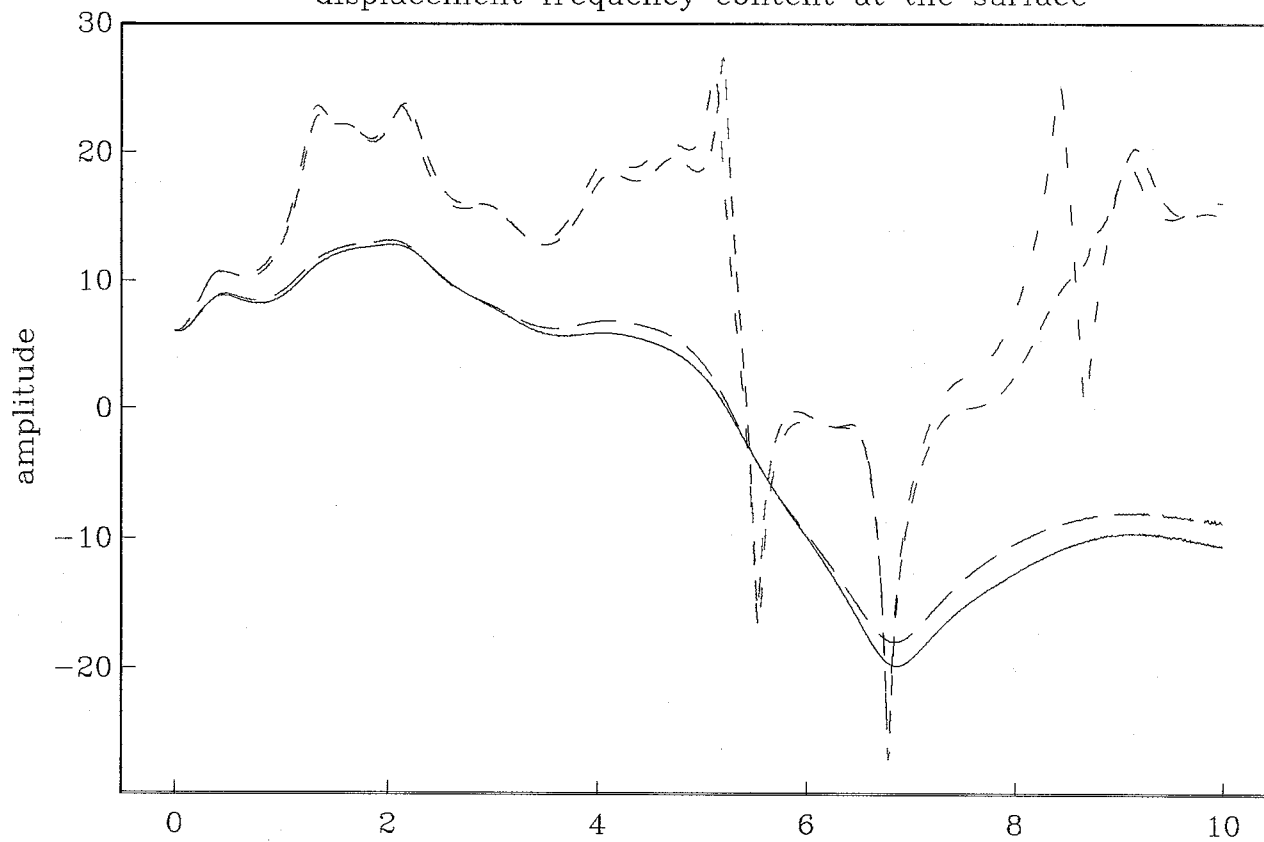
Ux | Incident angle : 20

displacement frequency content at the surface



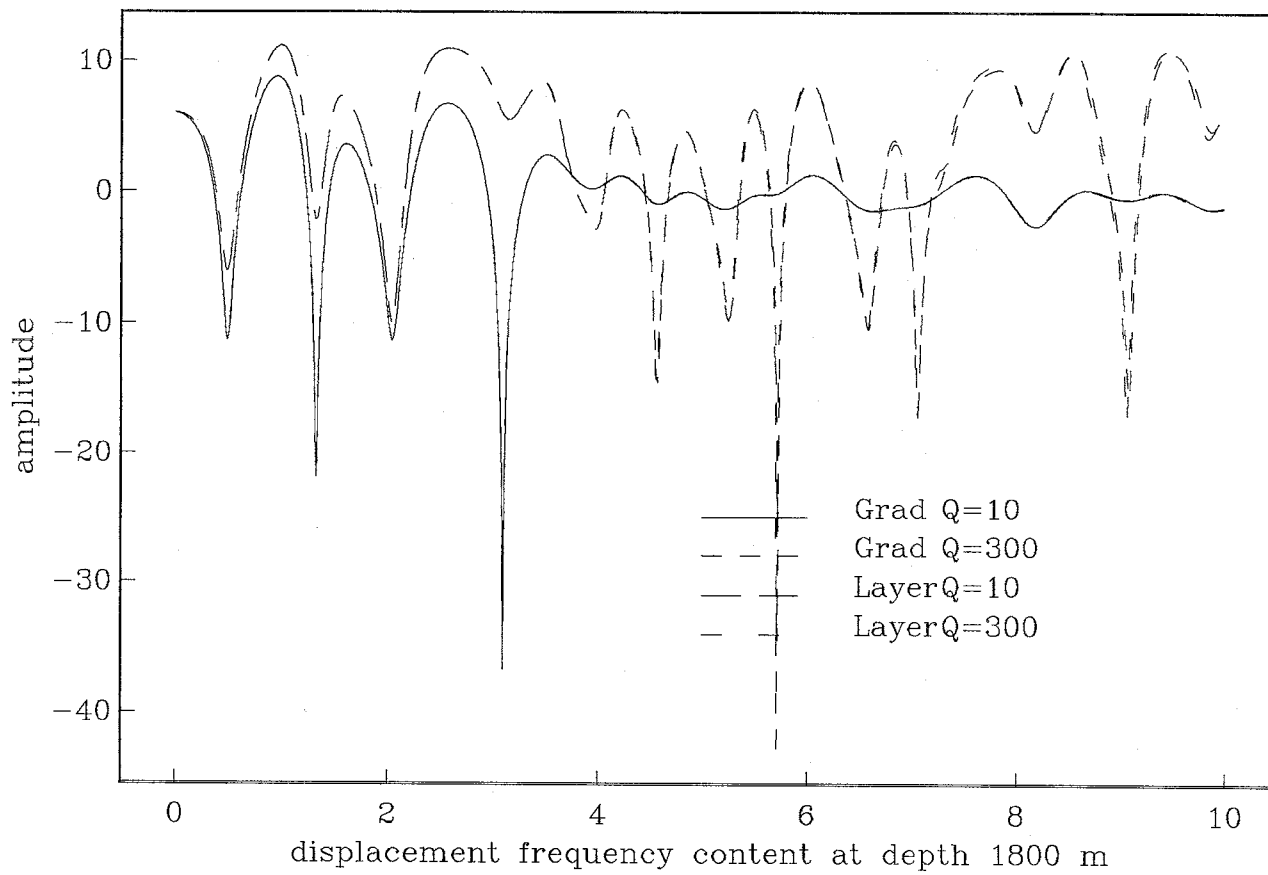
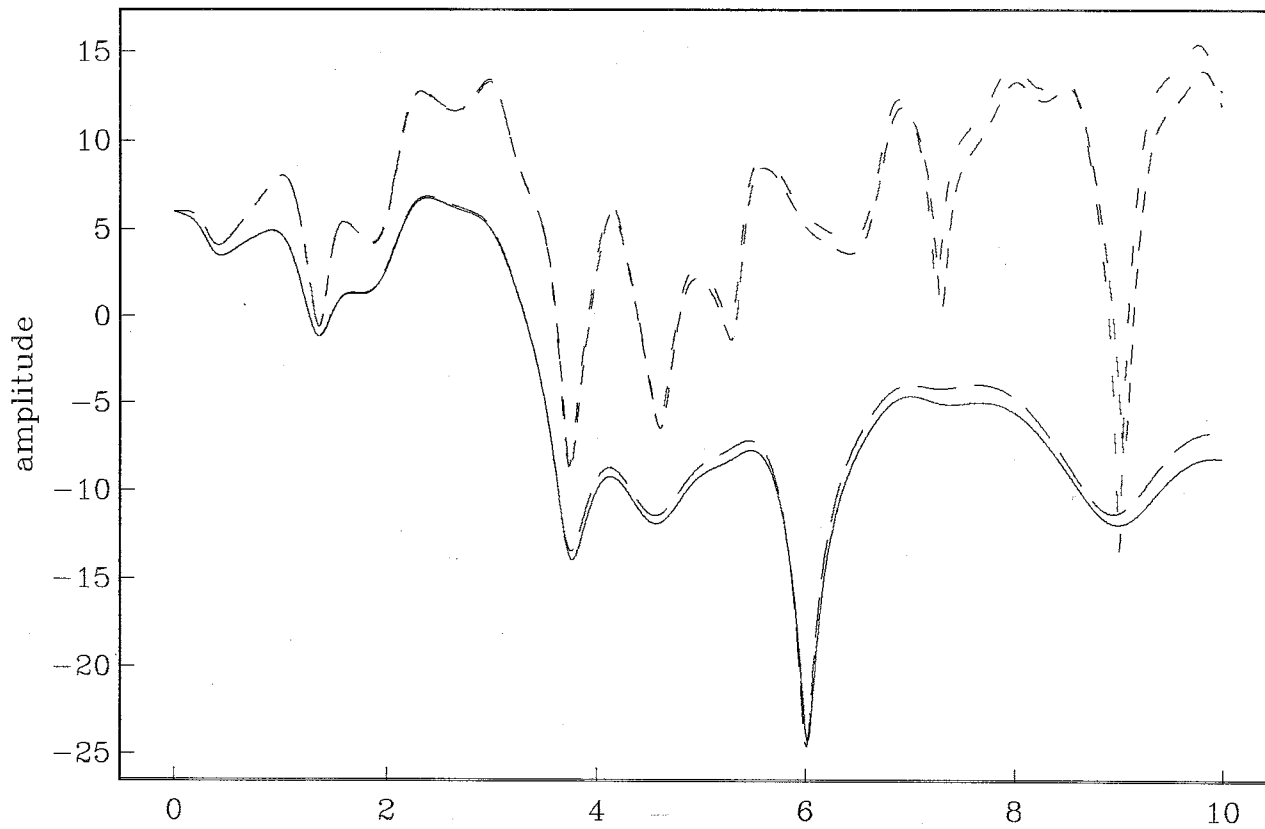
Ux | Incident angle : 40

displacement frequency content at the surface



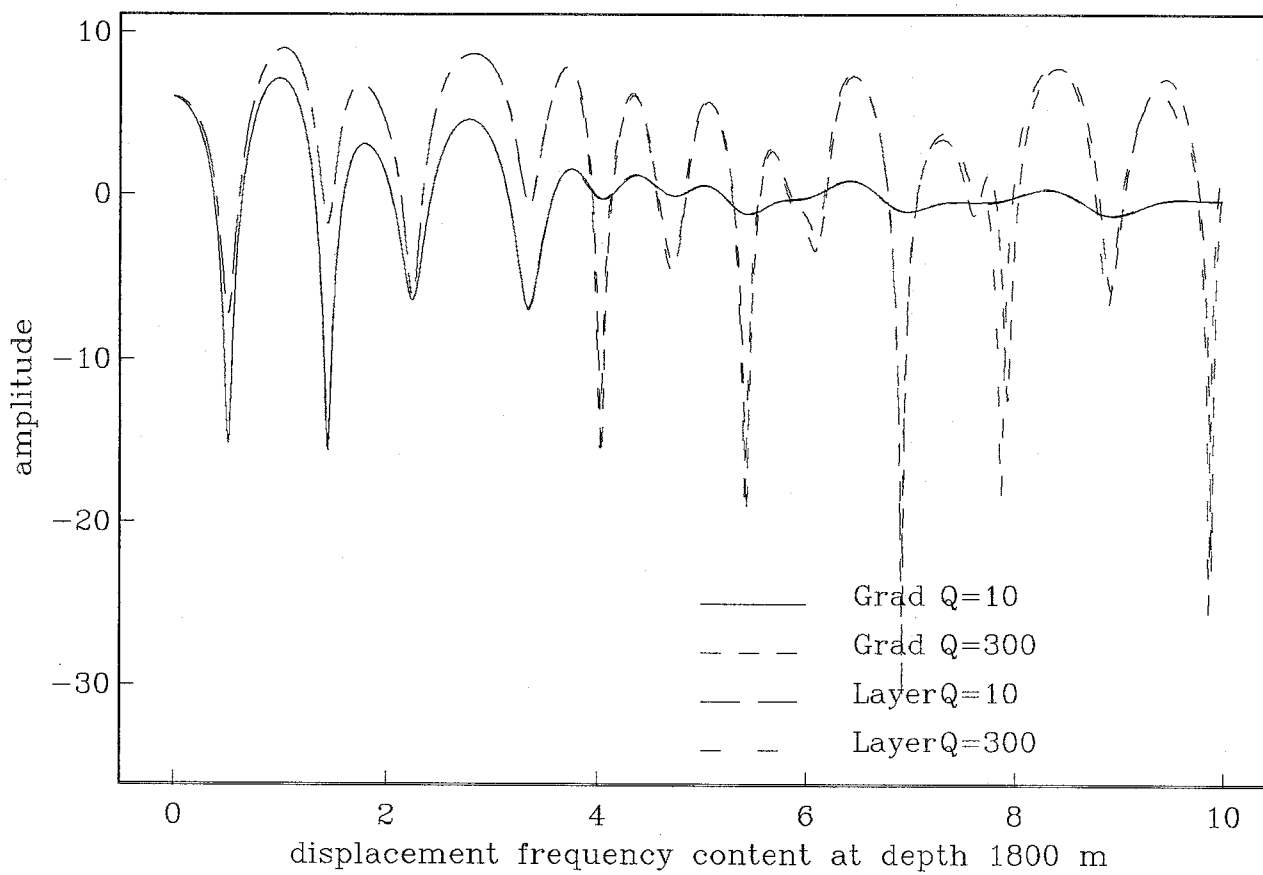
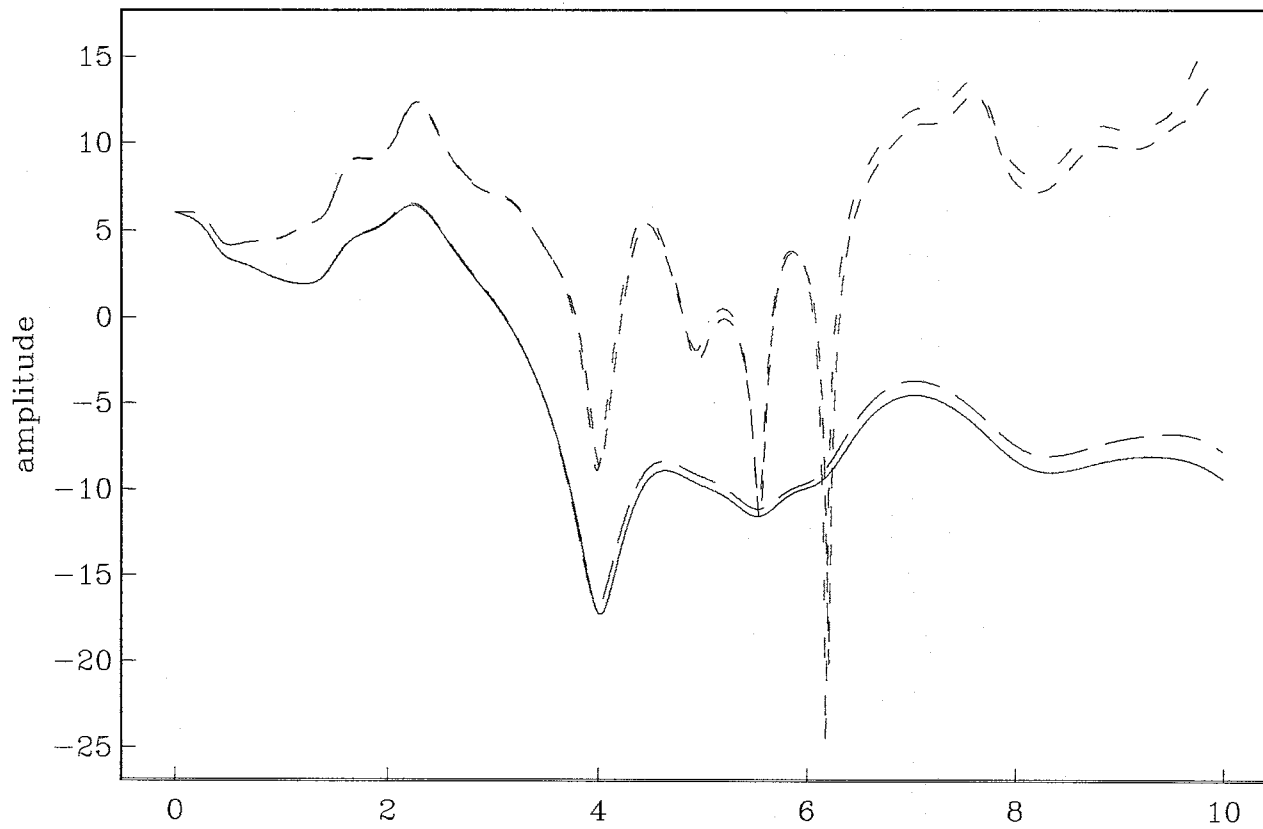
Uz | Incident angle : 10

displacement frequency content at the surface



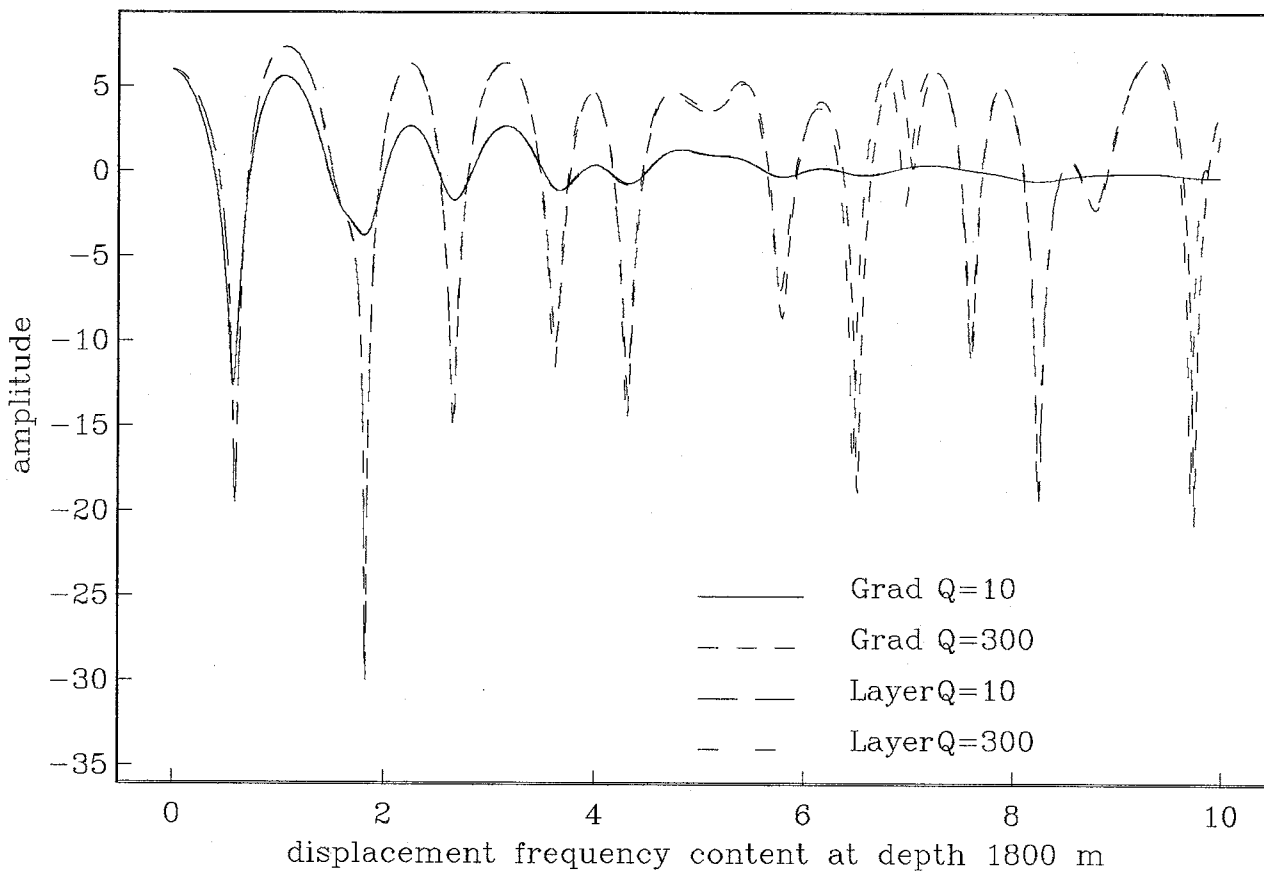
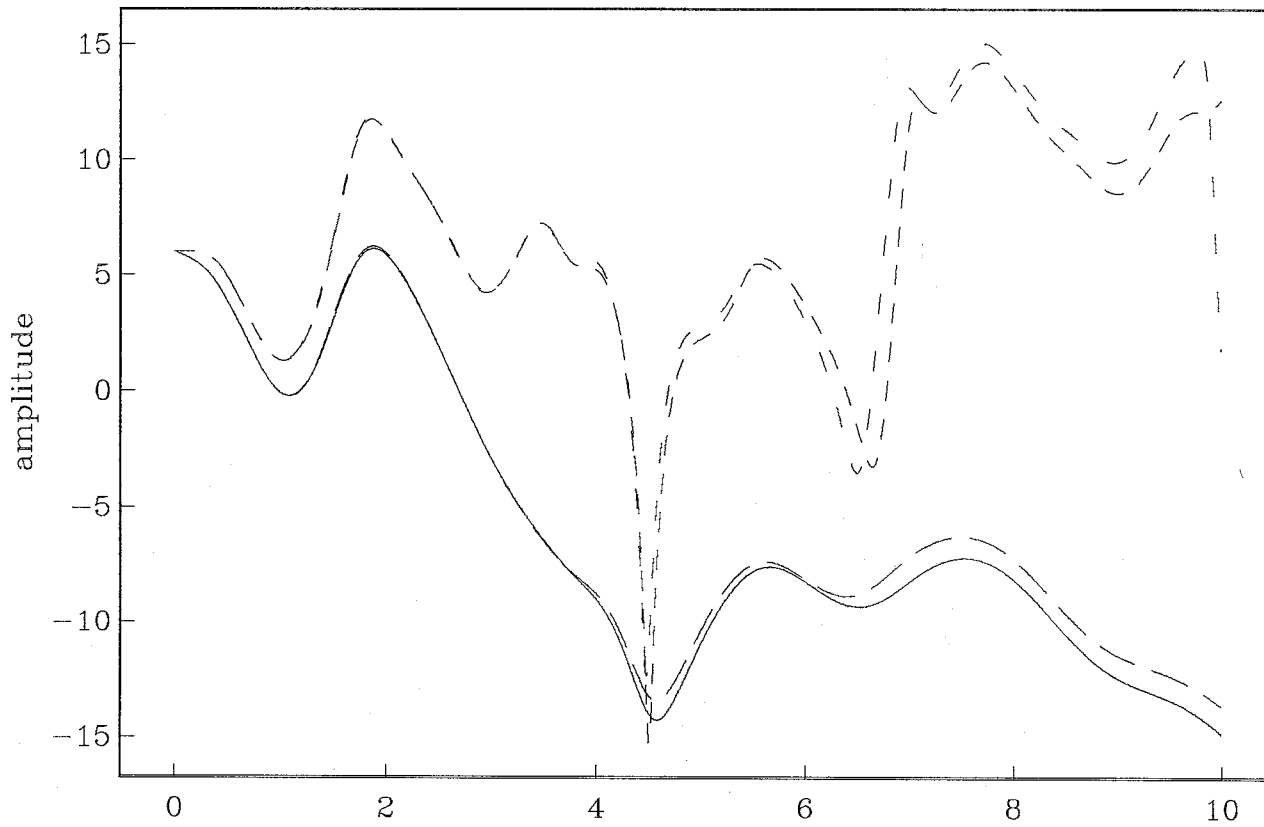
Uz | Incident angle : 20

displacement frequency content at the surface



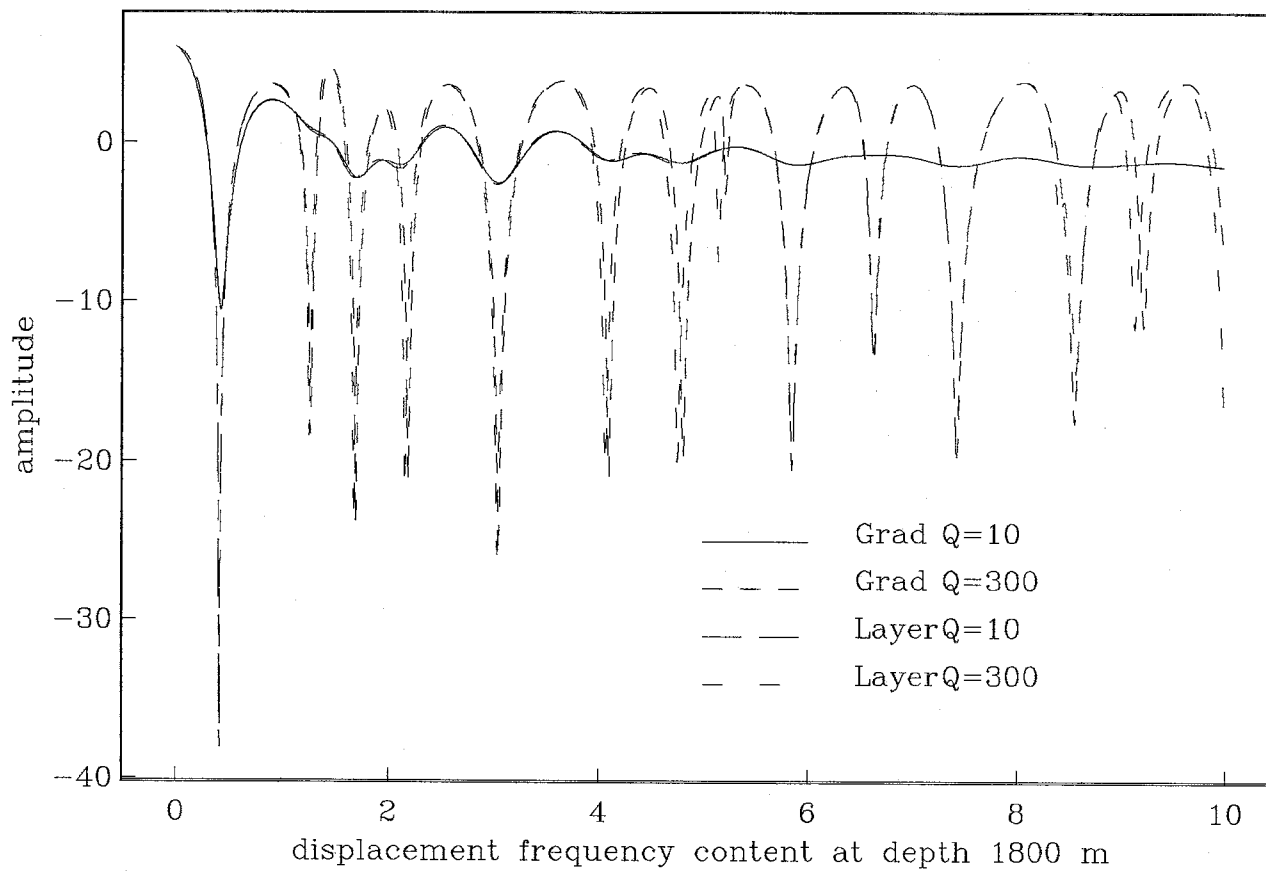
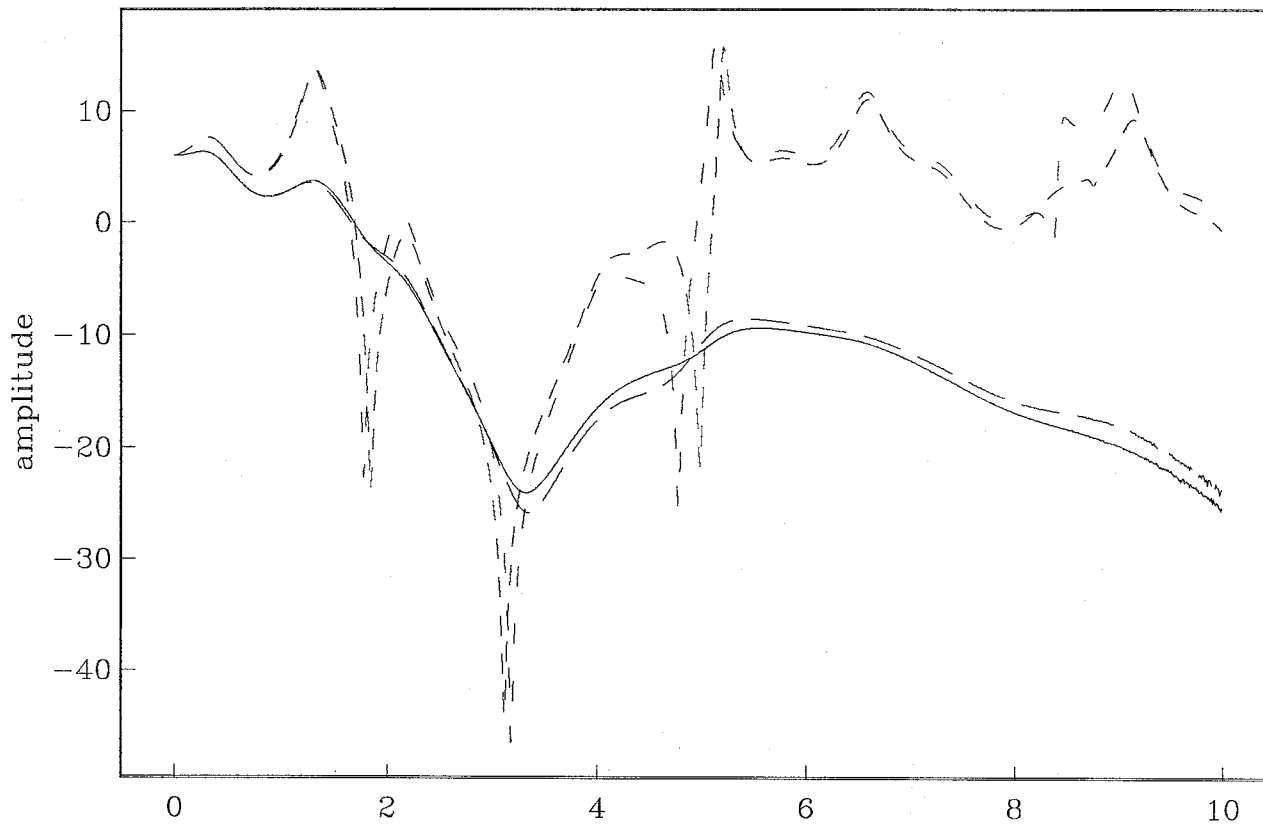
Uz | Incident angle : 30

displacement frequency content at the surface



Uz | Incident angle : 40

displacement frequency content at the surface

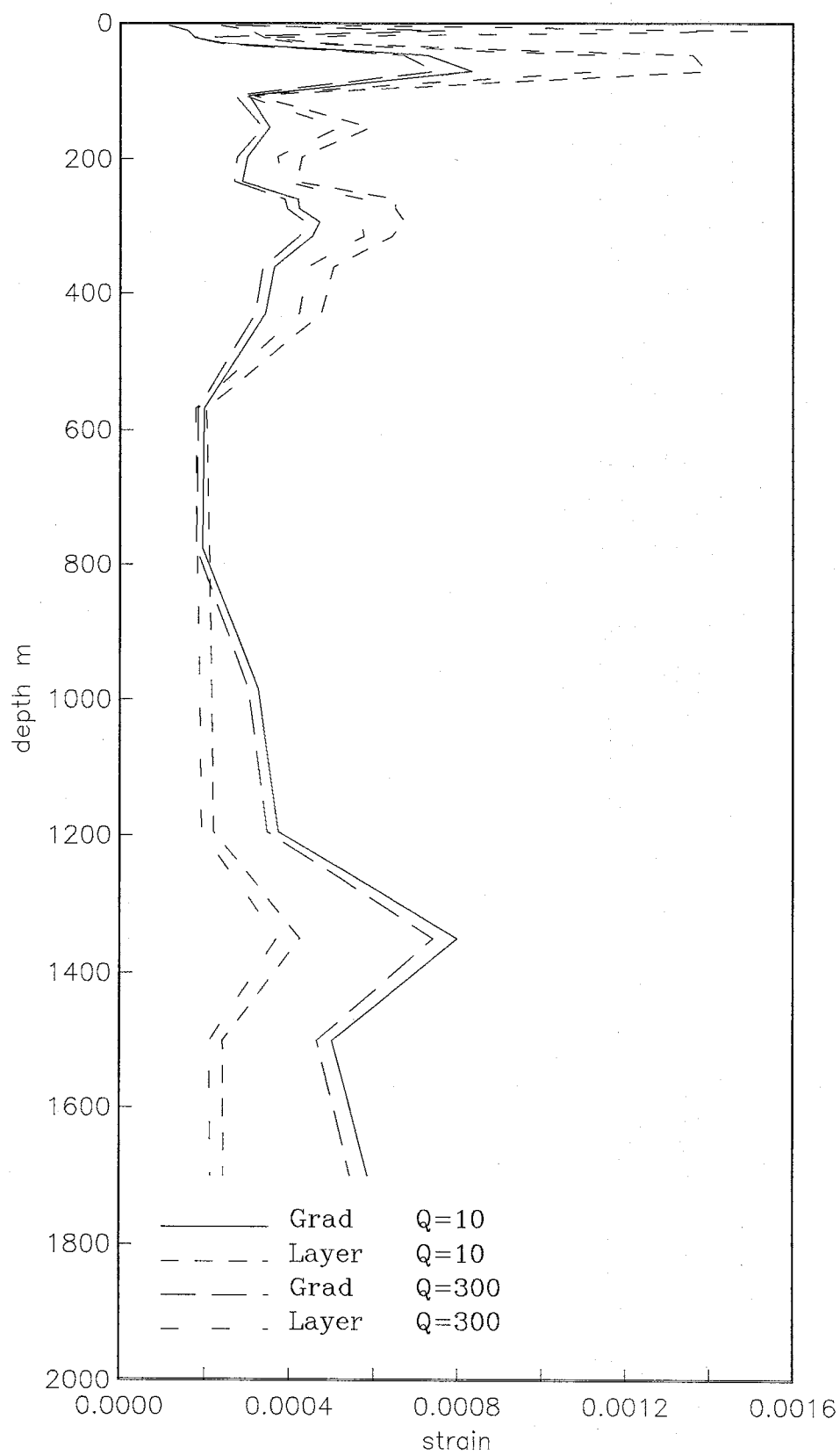


Appendix G

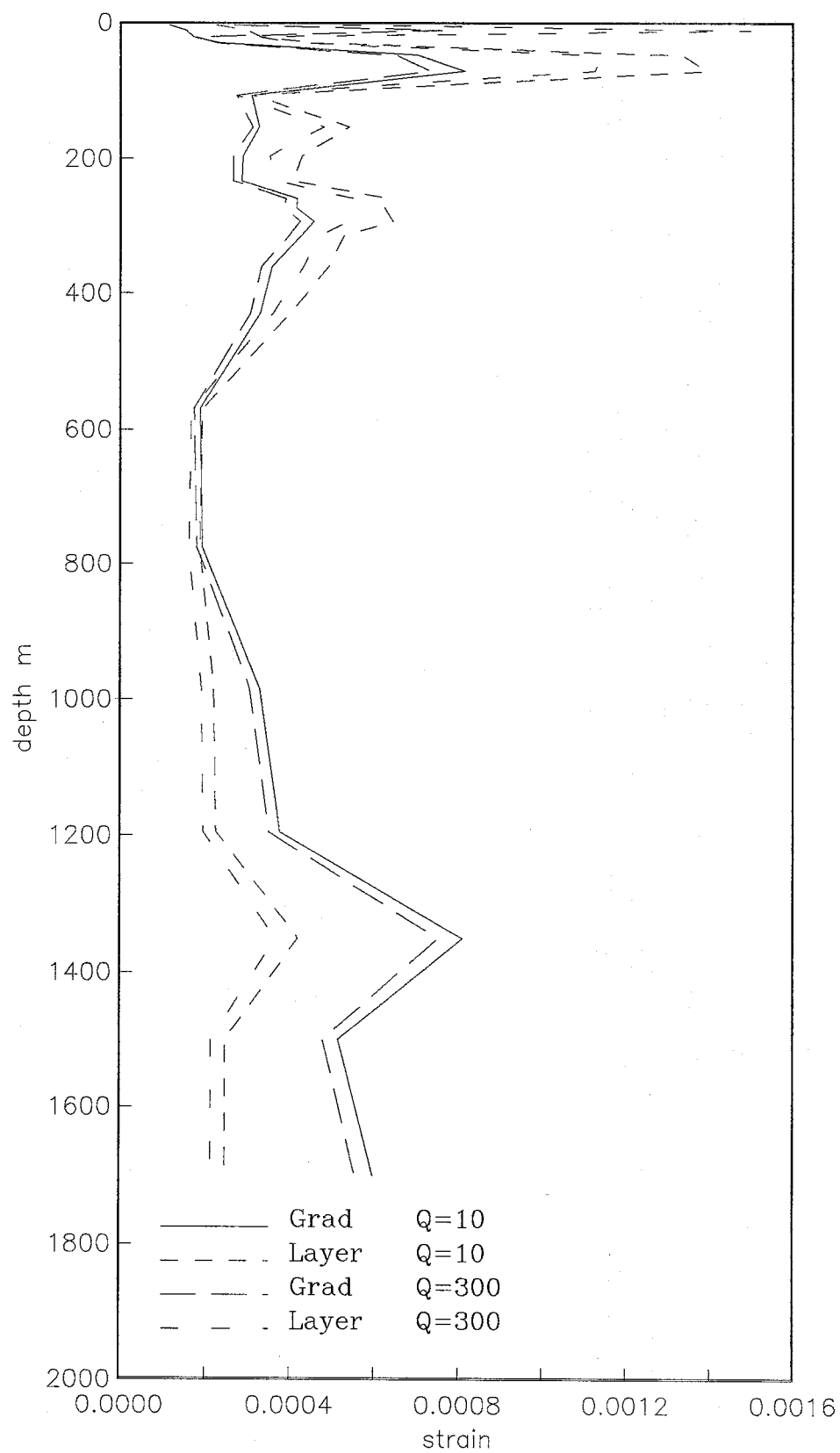
Content :

5 maximum strain profiles with frequency content 0 to 10 Hz

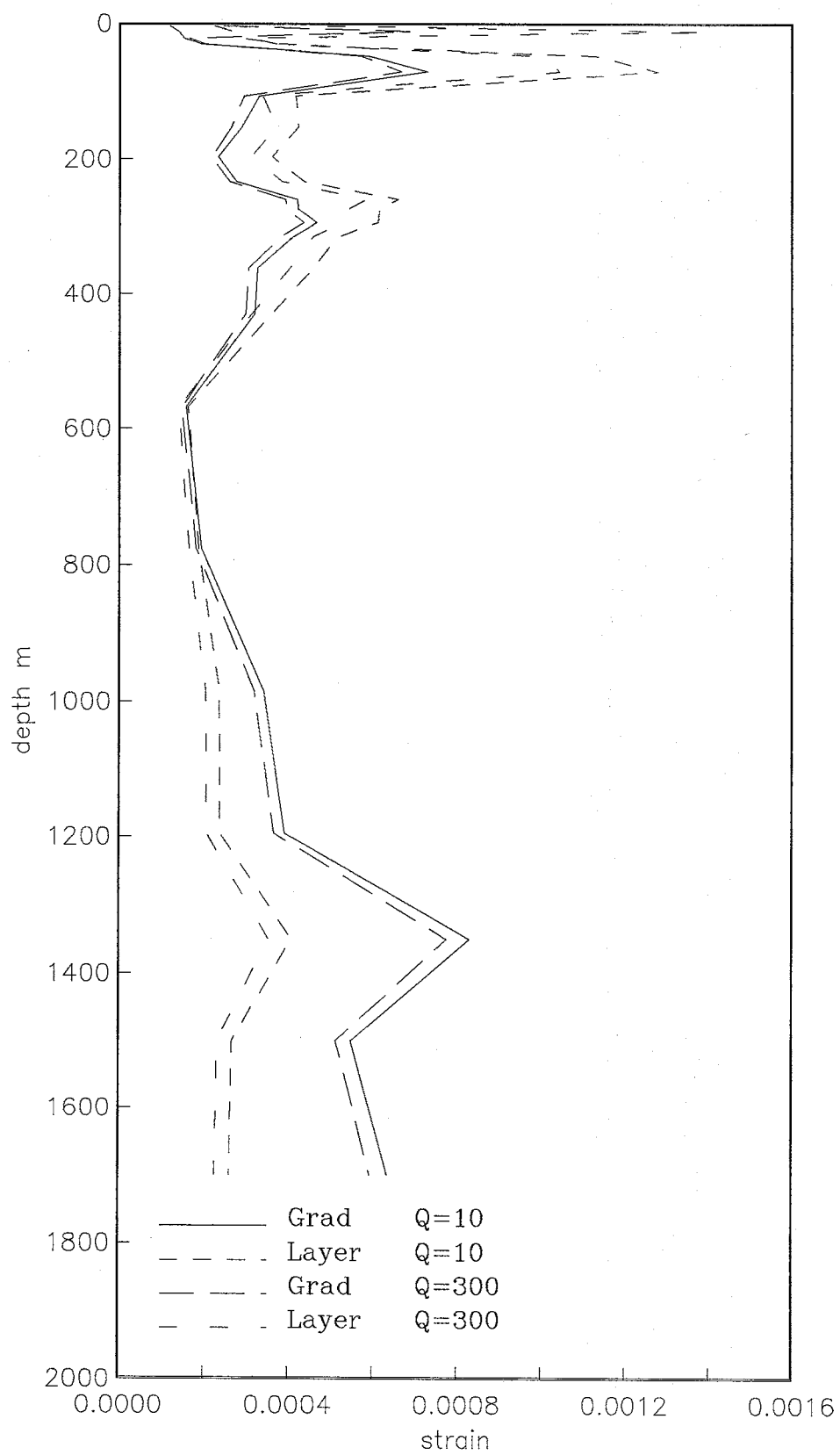
Maximum strain
incident angle : 0



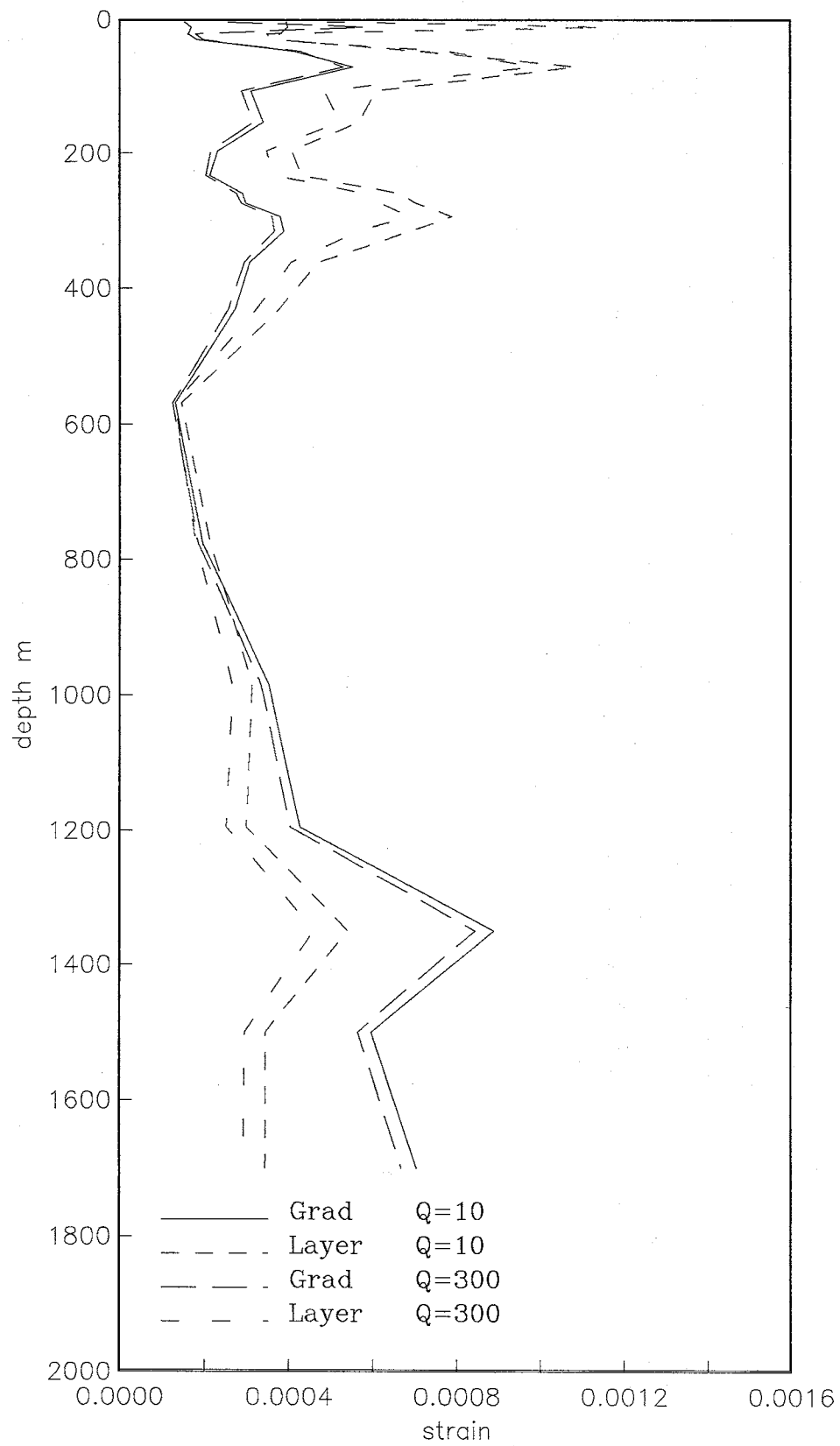
Maximum strain
incident angle : 10



Maximum strain
incident angle : 20



Maximum strain
incident angle : 30



Maximum strain
incident angle : 40

