

HIDDEN LAYER PROBLEMS IN SEISMIC REFRACTION WORK

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ABSTRACT

In the first part, a scale-model experiment has been done to see what sort of characteristics the appearance of a thin high velocity screening layer provides.

Briefly the experiment showed:

- The apparent velocity is dependent on the thickness of the screening layer. The same happens with the attenuation coefficient of the refracted signal.
- The amplitude of the refraction signal coming from the layer after the "blind zone", decreases with the presence of the screening layer.
- The wavelength of the same as above refraction signal, increases with the thickness of the screening layer.

In the second part, the problem of the screening layer, is faced at some field refraction records taken at Pitch Hill, SE of Guildford, England.

Using an extension of the refraction theory for parallel layers and having the depth of the last refractor from some resistivity soundings, the thicknesses of the screening layer and the low velocity layer are found for a range of low velocities.

INTRODUCTION

Shallow thin high-velocity layers are the cause of many unwanted and confusing signals in the seismograms. They may also divert the greater part of the seismic energy, thus effectively masking deeper structures. In such cases, even using heavier charges, little reflection energy is received from deeper horizons.

Several authors have presented papers on the "blind zone" phenomenon (Berzon and Epitaneva, 1950; Rosenbaum, 1961; Levin and Ingram, 1962; Davydova, 1962; Whiteley and Greenhalgh, 1979). In this study, the screening characteristics of the high velocity layer over the low velocity layer are examined and a relative case history is studied.

MODEL STUDY

Model investigations on thin high-velocity layers have been directed towards:

1. Investigation of the physical phenomena connected with layer thickness variations, aiming at a better understanding of the elastic wave behaviour of the layer itself.
2. Importance of the problem with regard to seismic exploration. So the purpose is to investigate both the refractive and transmissive properties of thin high velocity layers.

The refraction event is a second-order amplitude phenomenon, so special precautions have to be taken to ensure that the amplitude of the refracted wave is as large as possible. Only in that way, can reasonably reliable quantitative conclusions on the amplitude data be drawn. The refracted wave amplitude levels are strongly dependent upon the actual velocity contrast between the media. A maximum amount of the elastic energy is available for propagation as a refracted wave, if the compressional velocity ratio (dV_p) is approximately 0.7. In this case the contrast $V_{\text{water}}/V_{\text{perspex}}$ is 0.5 and favours refraction of elastic energy, and the transmissive properties of the thin layer (perspex) is poor, making it rather effective screen.

I. The Model Setup

The whole model setup is shown in figure 1. As screening layer, thin plates of perspex are used and as "basement" a plate of aluminium. The surface and the low velocity layers are represented by the water.

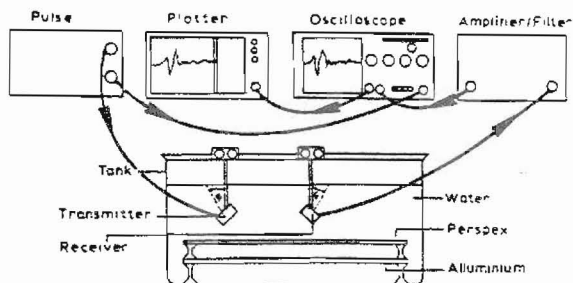


figure 1. The model setup

The P-wave velocities are:

$$V_{\text{water}} = 1476 \text{ m/sec}$$

$$V_{\text{aluminium}} = 5210 \text{ m/sec}$$

$$V_{\text{perspex}} = 2863 \text{ m/sec}$$

Having the model with the screening layer and using a range of angles of incidence, the final one which gives arrivals both from the perspex and the aluminium in the records is 30° . Evidence that the angle of incidence is a factor to see subscreening layers, is that for thickness of water, 8.5 cm, the angle must be 10° . So as a rule, the angle of incidence must be fairly small to see refractions from subscreening layers.

Changing the thickness of perspex (0.15 cm, 0.3 cm, 0.6 cm) or the thickness of water under the perspex (2.2 cm, 2.6 cm, 3.0 cm, 4.0 cm, 5.0 cm, 8.5 cm), records were taken with signals for various shot-detector distances.

II. Discussion on the Results from the Model

Considering the refraction from the perspex, the attenuation factor and the velocity as a function of the perspex thickness, are shown in figures 2 and 3 respectively.

In figure 2, there is a general decrease of the attenuation factor going to larger thicknesses, but there is the anomaly to that decrease between 0.2 cm and 0.5 cm. The same behaviour of the curve has been found in model studies of Poley and Nootboom (1966).

In figure 3, there is a decrease of the apparent velocity for very small thicknesses. After a "large" thickness of the perspex, its apparent velocity becomes constant.

Let's consider now the refraction signal from the aluminium (under the low velocity layer, water) which is defined as the "deep refracted signal".

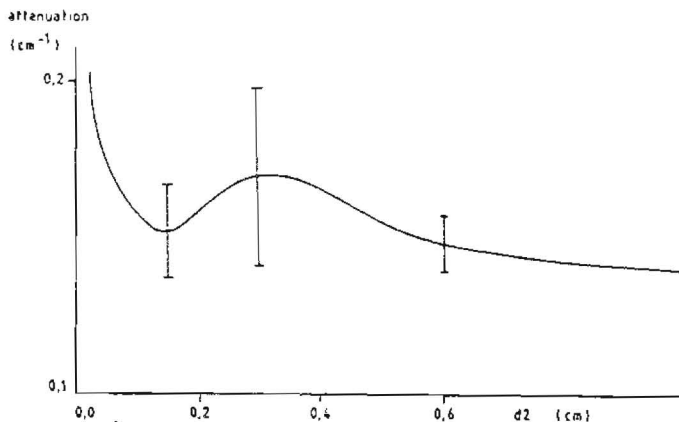


figure 2. The attenuation factor in respect with the perspex thickness (screening layer).

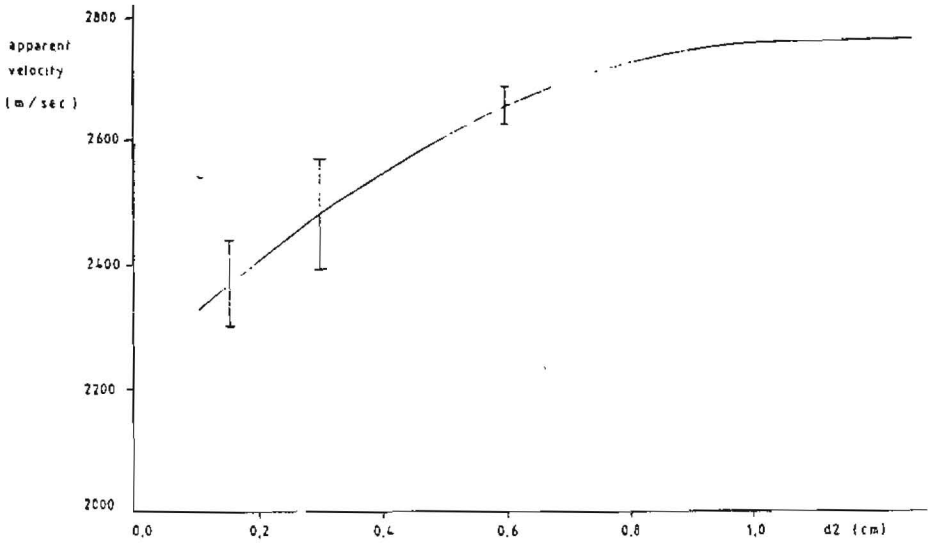


figure 3. The apparent velocity in respect with the perspex thickness (screening layer).

Let's consider now the deep refraction from the alluminium:
 1. For constant water thickness and varying perspex thickness:

In figure 4 the wavelength of the deep refracted signal is very small in the area of $d_2 = 0.15$ cm, then increases until d_2 becomes 0.35 cm and then remains steady. So the thicker perspex, the longer wavelength of the deep refracted signal.

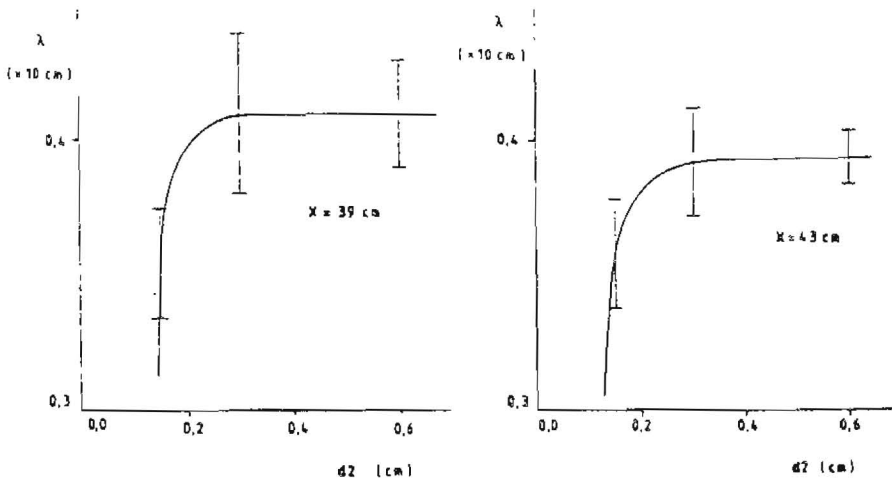


figure 4. The wavelength of the deep refracted signal in respect with the perspex thickness (screening layer) in two shot-detector distances ($x = 39$ cm, $x = 43$ cm).

In figure 5 the amplitude of the deep refracted signal decreases, and the decrease becomes more intense as the thickness of the screening layer increases.

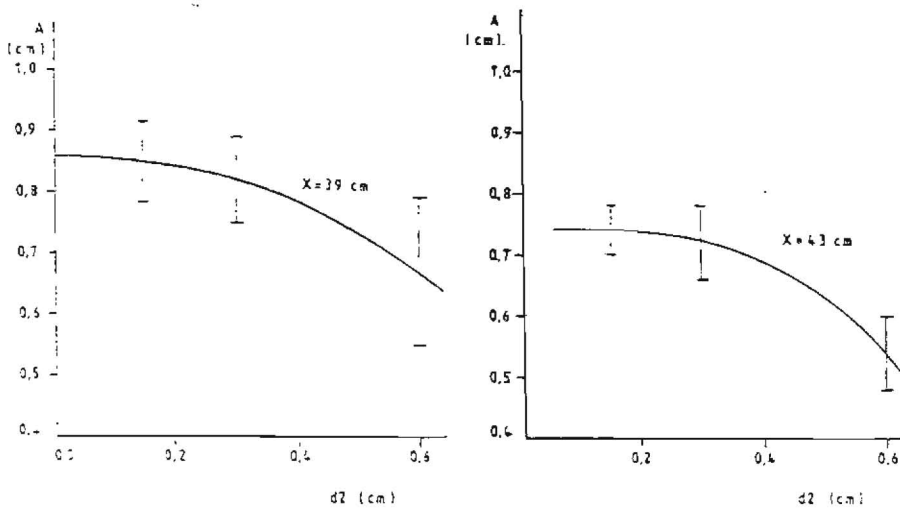


figure 5. The amplitude of the deep refracted signal in respect with the perspex thickness (screening layer) in two shot-detector distances ($x = 39$ cm, $x = 43$ cm).

2. For constant perspex thickness and varying water thickness (figure 6) the amplitude of the deep refracted signal decreases slightly until $d_3 = 3.0$ cm and then becomes approximately constant. The decrease lasts more and is more intense as the shot-detector horizontal distance increases.

Combining the results shown in figures 5 and 6 it can be concluded that the effect to the decrease of the amplitude is more due to the thickness of the screening layer than due to the thickness of the low velocity layer.

Finally in figure 7 a large decrease in the amplitude of the deep refracted signal at increasing perspex thickness when we consider the amplitude as a function of horizontal shot-detector distance for a series of perspex thicknesses.

All the above explain why the thin high velocity layer is called "Screening Layer".

ANALYTICAL FORMULATION FOR A MASKED LAYER UNDER A MULTILAYER OVERBURDEN

R.Schmoller (1982) gives a comprehensive way to face the L.V.L. problem.

Assuming that in a section of $n+1$ layers the n th layer is masked and using the intercept times $t_{0,2}$, $t_{0,3}$, e.t.c. and the velocities V_1 , V_2, \dots, V_{n-1} , V_{n+1} from the T-X plots,

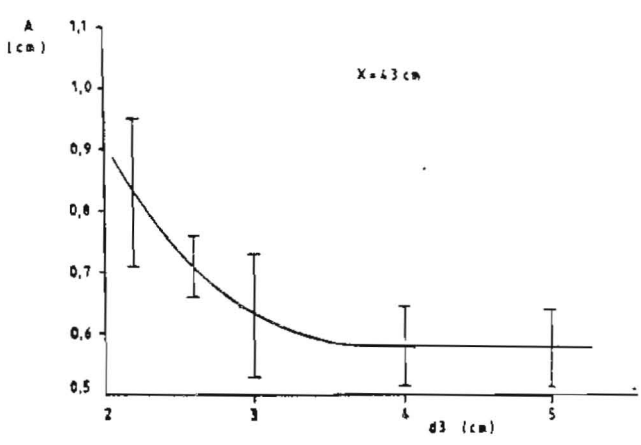
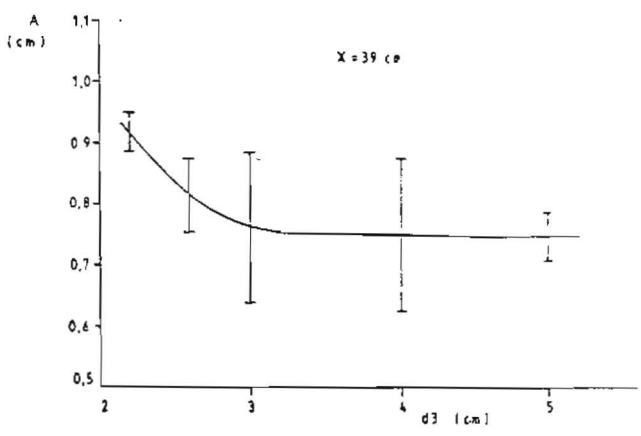
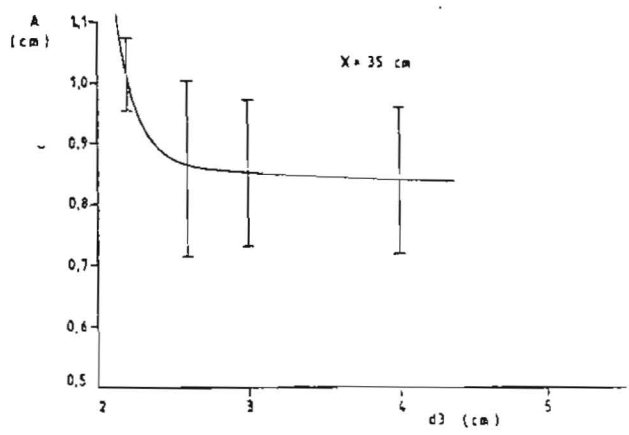


figure 6. The amplitude of the deep refracted signal in respect with the water thickness (L.V.L.) in three shot-detector distances ($x = 35$ cm, $x = 39$ cm, $x = 43$ cm)

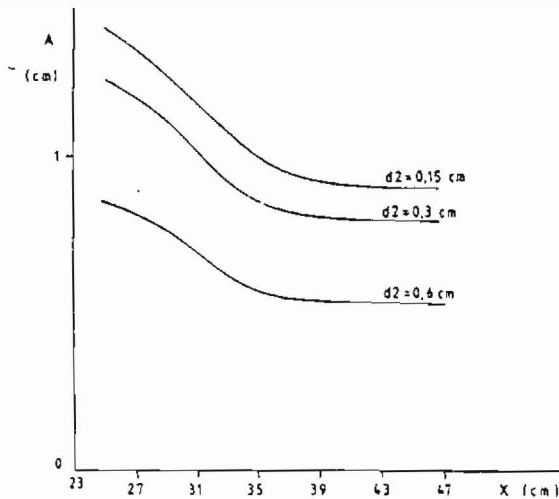


Figure 7. The amplitude of the deep refracted signal in respect with the horizontal shot-detector distance in three perspex thicknesses ($d_2 = 0.15$ cm, $d_2 = 0.3$ cm, $d_2 = 0.6$ cm).

one can use the following relation and find the thicknesses of $n-2$ layers.

$$H_k = \left(\frac{t_{0,k+1}}{2} - \sum_{l=1}^{k-1} \frac{H_l \cos F_{l,k+1}}{V_l} \right) \frac{V_k}{\cos F_{k,k+1}} \quad (1)$$

where $\sin F_{l,k+1} = \frac{V_l}{V_{k+1}}$ for $k = 1, 2, 3, \dots, n-2$

In the case of the absence of the n th layer ($H_{n,\min} = 0$), the thickness $H_{n-1,\max}$ can be found using the relation (1). If the layer above the n th is absent ($H_{n-1,\min} = 0$), the thickness $H_{n,\max}$ is given by the following relation.

$$H_{n,\max} = H_{n-1,\max} \sqrt{\frac{(V_{n+1}/V_{n-1})^2 - 1}{(V_{n+1}/V_n)^2 - 1}} \quad (2)$$

The general case of a masked layer, without restriction to the blind zone solution, can be formulated as follows:

$$Z_t = H_{n-1, \max} = H_n \left(1 - \sqrt{\frac{(V_{n+1} / V_n)^2 - 1}{(V_{n+1} / V_{n-1})^2 - 1}} \right) \quad (3)$$

where $V_n < V_{n-1} < V_{n+1}$ and $Z_t = H_{n-1} + H_n$

A FIELD EXAMPLE OF A SCREENING LAYER

I. The Case

The characteristics, a relatively shallow (thin) high velocity layer provides, have been found in the refraction records taken in the area of Pitch Hill, in Surrey, for Conoco Oil Company (figure 8).

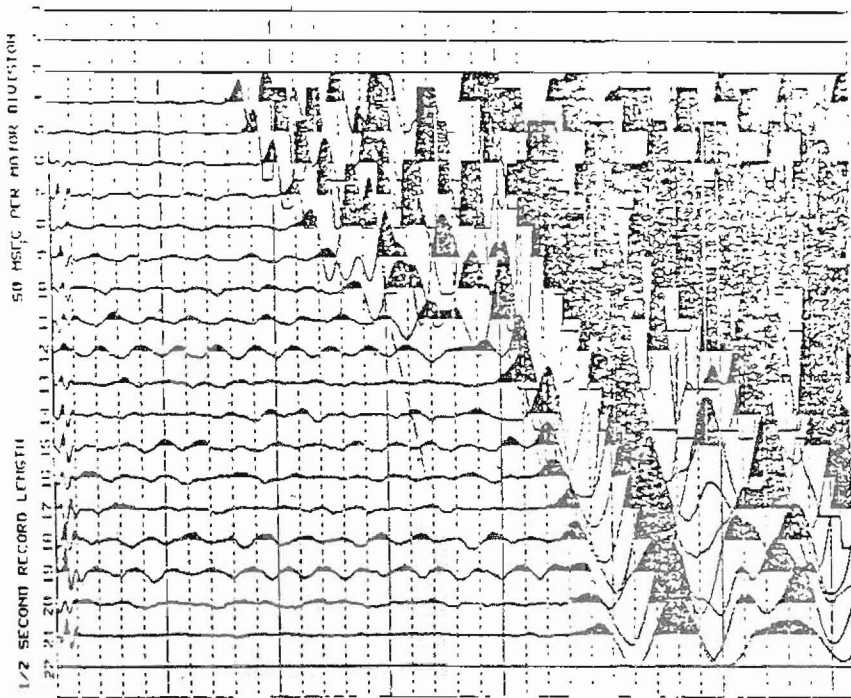


figure 8. A refraction record taken in the area of Pitch Hill, in Surrey for Conoco Oil Company. The case of the screening layer presence.

II. Geology of the Area of Pitch Hill

The major area is called Leith Hill District and includes four hills. Among them is Pitch Hill (Coneyhurst Hill) (figure 11).-

The geological formations met at this area are:

1. Weald Clay
2. Lower Greensand.

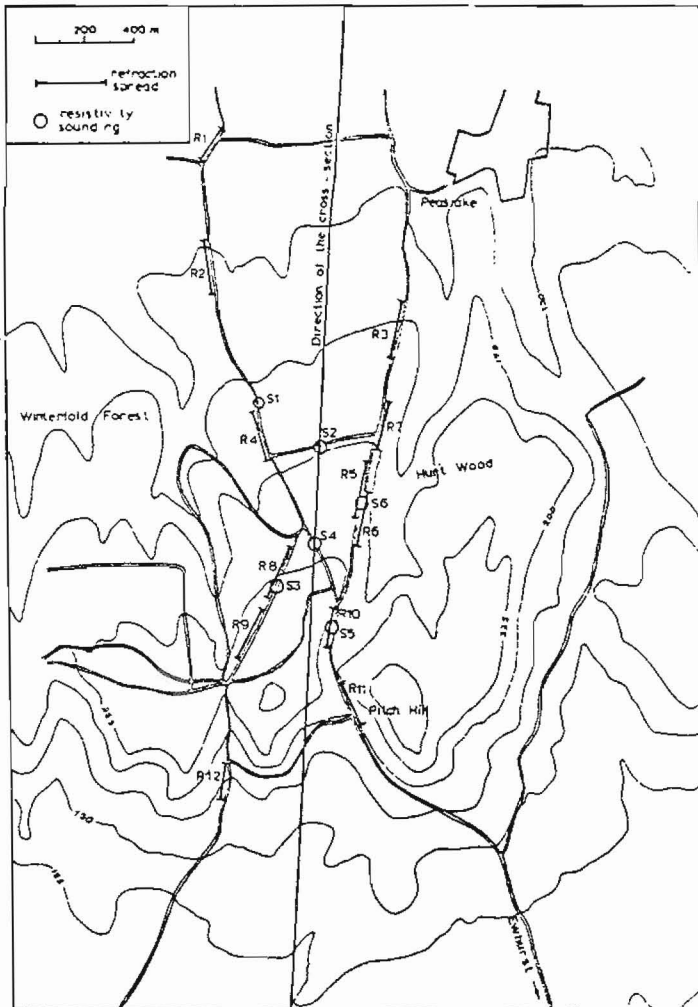


figure 9. Map of the area of Pitch Hill, Surrey.

There are two major divisions of the Greensand escarpment.

a. The Hythe Division.

It is essentially sand and greenish grey sandstone with interspersed lenticular beds of chert. The chert occupy the topmost part of the hill and being resistant to erosion have protected the underlying sands and clay which without this would have been easily denuded. Some samples taken from the field gave in the laboratory P-wave velocities shown in the Table 1.

b. The Atherfield Clay

TABLE 1

	Dry Sandstone	Saturated Sandstone	Chert
V	1959.0	2459.0	2988.0
m/sec	1792.0	2515.0	
	979.0	2153.0	

III. The Refraction Data

The position of 10 refraction spreads is shown on the map of the area (figure 9).

The seismic source is a land-airgun. The recording instrument is a 24-channel Nimbus. The geophone array is linear with a 10 m spacing.

The appearance of the screening layer (chert) is evident on the seismograms (figure 8). Picking the first breaks from the seismograms, the velocities and the intercept times of the refraction lines can be found from the T-X plot.

In order to find the depth of the water-table, 5 resistivity soundings have been done with the Schlumberger configuration (figure 9).

IV. The Interpretation

The sequence of the layers encountered here is: Soil, Weathered Greensand, Chert, Dry Greensand, Wet Greensand (Saturated Sandstone). The third layer is the screening one and the fourth is the masked one.

Using the velocities and the intercept times, H_1 , V_1 , H_2 , V_2 , V_3 , $H_{3,max}$, V_5 can be found with the relation (1).

Having the depth of the water table (D_w), Z_t is given as follows:

$$Z_t = D_w - H_1 - H_2 \quad (4)$$

Then using the relations (2), (3) and (4), $H_{4,max}$, H_4 (thickness of the L.V.L.) and H_3 (thickness of the screening layer) can be found for a range of low velocities.

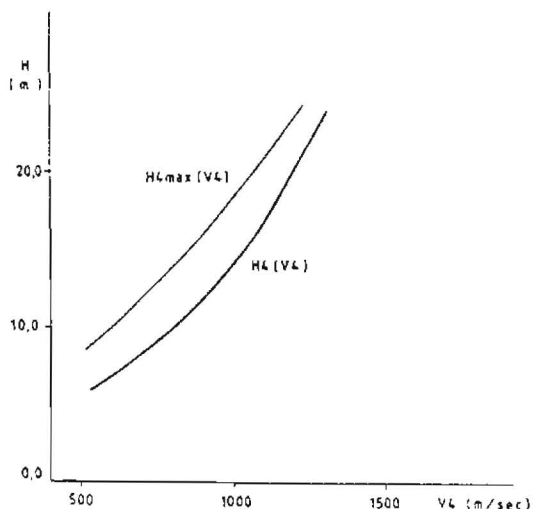


Figure 10. The maximum thickness and the thickness of the low velocity layer (L.V.L.) in respect with the corresponding velocity

In figure 10 $H_{4,max}$ and H_4 are plotted against low velocity. The value of low velocity chosen for this case is 1100 m/sec and that because of the laboratory measurements in the samples. Generally, the right low velocity value, chosen by the curve $H_n(V_n)$, is that where the "knee" of the curve appears.

The final cross-section is shown in figure 12.

ACKNOWLEDGMENTS

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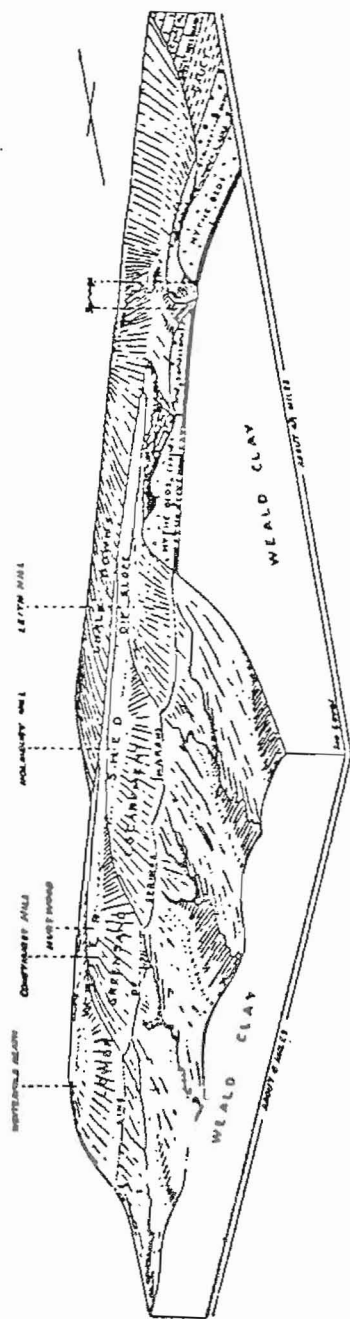


Figure 11. Block-diagram to show the relationship of scenery to geology in the Leith Hill District of Surrey.

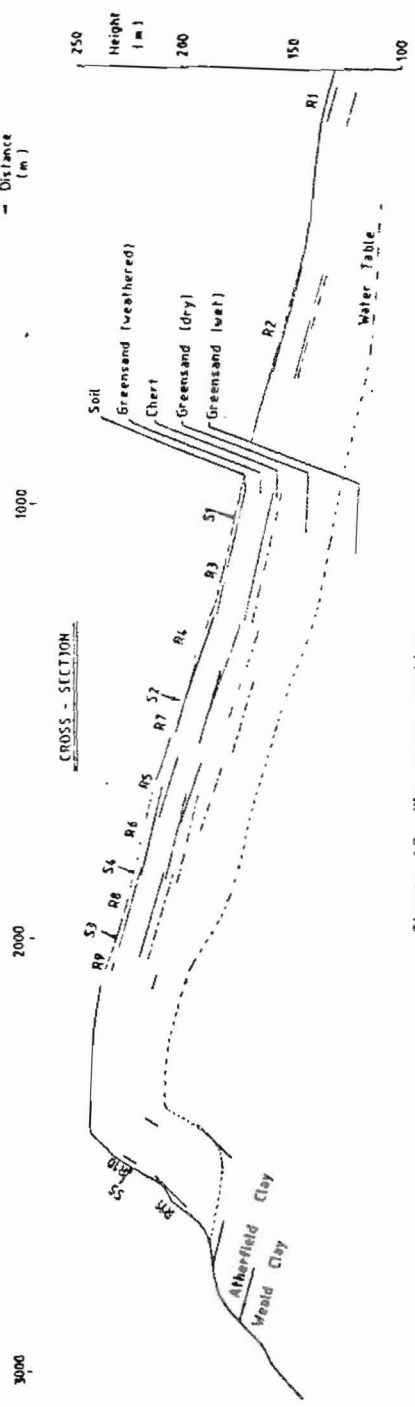


Figure 12. The cross-section.

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