A Study of Uphole to Determine the Shooting Medium for Seismic Reflection Survey at Himalayan Foot Hill Area

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Summary

Acquiring seismic reflection data in Himalayan Foot Hill is one of the challenging jobs for surface geophysicist due to its complex tectonic setting. Rough topographic condition with steep hill, thick thorny shrubs, pine trees and other logistic hindrances are the major disadvantage for better data qualities. The compactness and hardness of exposed rocks depend upon the type of the rocks formation. For these reasons, it is very difficult to choose a medium for blasting the energy source below the Low Velocity Layer (LVL). Frequent Uphole survey and experimentation for charge and depth are essential to find a shooting medium. Ghosting and interference effects are also prominent in this area.

Introduction

The high cliff, stiff hill and high angle thrusts, faults and folds mislead the acoustic wave to reach the sensors in surface after reflection from subsurface which causes poor seismic information to pin-point the hydrocarbon location. The important thinks is to control the acoustic wave and generate the energy source in a proper shooting medium. But choosing a shooting medium in highly undulatory, tectonically complex hilly terrain is very difficult because different rock formations of hardness and compactness are lying along the shooting profiles. Generally, the first energy arrival after an exploration under the ground is the result of a seismic wave traveling directly from the source to the sensors or it may be the energy that has refracted along a shallow layer boundary in the earth which may be a refraction arrival. The studies of first break energy on recorded seismic reflection data in this area indicate that direct wave arrives only in few nearby channels; maximum channels receive the first break signal from refracted wave.

Use of uphole survey to find a shooting medium

In Himalayan Foot Hill area, the weathering of surface rocks laying down as soft sediment overlaying the hard sedimentary rocks, is very thin and covered intermittently in small plain and valley area. Figure 1 shows the exposed tertiary sequence of North-Western Himalayan Foot Hill.

Usually, refraction surveys are used to determine the depth, dip and velocities of a Low Velocity Layer. However, area likes Himalayan Foot Hill, having complex LVL rock bodies of different thickness, the refraction method losses the accuracy of this thin layer's information. On the other hand, it will not be fruitful to conduct refraction survey in highly undulating hilly terrain for thin LVL. Because the common refracting medium in some place is must deeper as compare to LVL. So the common practice is to perform the uphole surveys to find the thickness of LVL within 30 to 40m depth it may encounters different layers of rock, like sand, silt and claystone from the formation of Siwalik, Dharamshala and Subathu/Bilaspur which are exposed in different part of this area. The compactness and hardness of these exposed rocks varies according to their age and exposed in surface. Due to this type of variation in the characteristic of rocks, it is very difficult to get a good shooting medium for proper acoustic energy distribution. For the same reason, the first break time of uphole survey also behaves erratic in nature. The timing will be more, when data are taken in lose shale or silt layer as compared to hard sandstone layer.

At the time of Himalayan orogenic formation the tremendous collision forces shattered the rock bodies into fracture, crack, joint etc, especially more within the fault and its nearby rocks. Neglecting this erratic behavior of the uphole timing for its different velocity of the near surface medium, we can generally divide the rocks into three layers within 35 to 40m depth. Including alluvium cover, the first layer thickness is maximum 5 m with velocity ranging from 360m/sec to 600 m/sec. The next layer below the surface layer is within the range of 20 m thickness and its velocity varies from 1000 m/sec to 2600 m/sec. The third layer, top of which we used to detonate the explosive is more hard compared to the above two layers, whose velocity ranges

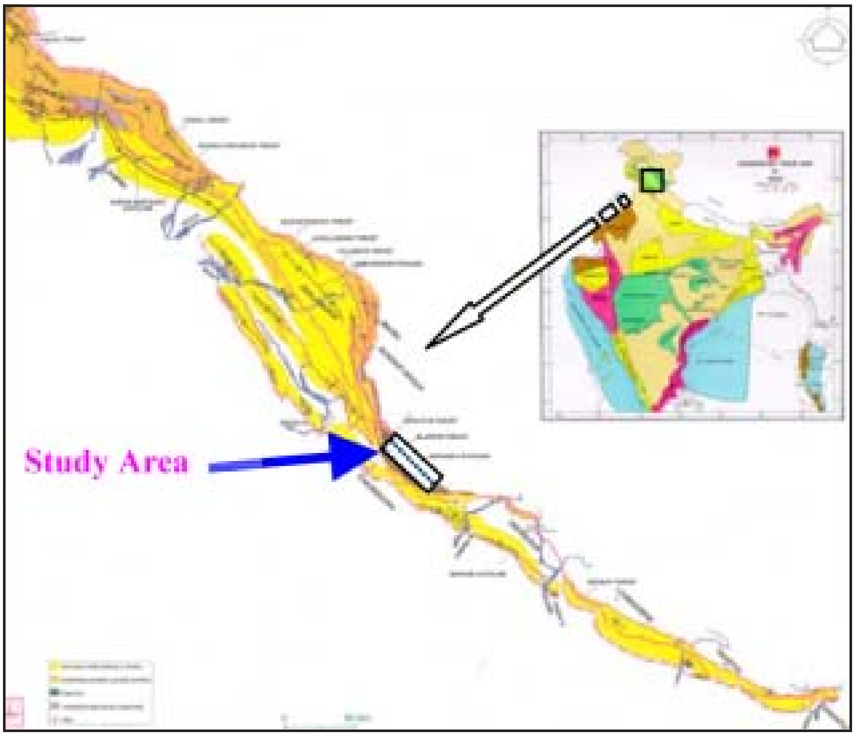

Fig: 1 Geological map of tertiary sequence of the North-Western Himalayan Foot Hill, showing the seismic acquisition area for this study.

from 2600 m/sec to 3000 m/sec. Fig: 2. Although the actual velocity of the same rock at the subsurface formation is much higher as compared to the exposed rock formation.

Difference Between Up Hole and Apparent Velocity

Up hole survey is used to measure the shooting medium and the velocity of LVL and below it. It is observed that the LVL layer's velocity calculated from up holes survey are much less than the apparent velocity measured from the first arrival waves of seismic field records. LVL velocity calculated from up hole survey is ranging from 360 m/sec to 2600 m/sec. The uphole experiments taken within 1.5 km range in different elevation level and rock formation, the velocity of LVL, do not excide 2600 m/sec. Although apparent velocity is slightly higher than the velocity measured from uphole. The apparent velocity of first break measured from recorded seismic data range form 2700 m/sec to 4400 m/sec which indicate that the first break arrivals of direct waves is limited to only a few near by channels, maximum channels receives refracted waves whose velocity is more than direct waves. Due to uneven LVL layer in undulating hilly terrain, the seismic energy generated below

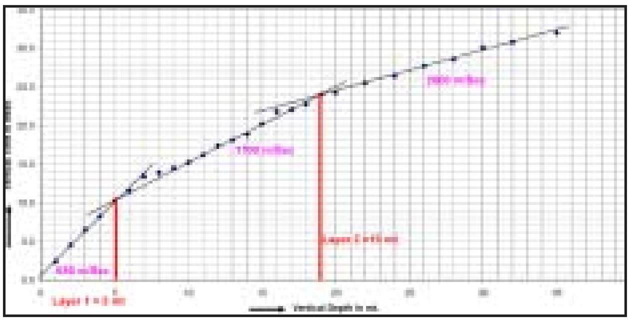

Fig: 2. A three layers uphole plot within the Himalayan Foot Hill Area, taken after slanting time correction

the LVL goes directly to the more high velocity layer and are transmitted between low velocity LVL and high velocity layer below it and is transmitted as refracted wave. This wave velocity is faster than the direct wave velocity. Fig. 3.

Direct arrivals or ground roll travel from the shot point horizontally and represent one way time rather than the two ways travel time associated with reflection events. The apparent velocity of first break of first few channels from the shot point are within the range of 2700 m/sec which must be the direct arrival. The direct wave with velocity

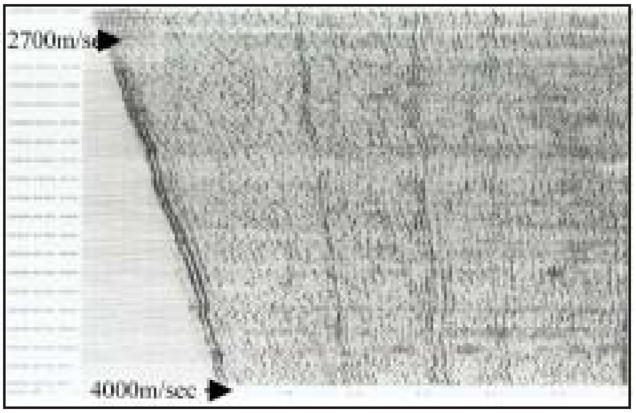

Fig: 3: A seismic record of Himalayan Foot Hill area and showing its apparent velocity in the near channels (2700m/sec) and far channels (4000m/sec)

2700m/sec arrives only few channels and ended above the undulating surface due to variation in profiles.

Causes of reverse polarity in uphole records

Ideally, for a good quality seismic data recording, the charge in holes should be placed beneath a thick LVL to minimize noise, and high frequency energy loss and to improve coupling of ghost reflections, which may be resulting from peg-leg reflections at the surface or within the weathering layer. Ghost notching can occur as a result of reflections from beneath the LVL and from the surface. Since ghost may occur at variable times because of topographical changes and variation in shot depth.

If a reflection coefficient is negative, the polarity of the reflected waves will be reversed from that of incident waves. When the wave passes from high velocity to low velocity medium and if refracted back to the higher velocity medium, the polarity of the wave will be reverse. In this foot hill area, reverse polarity signals can be observed in

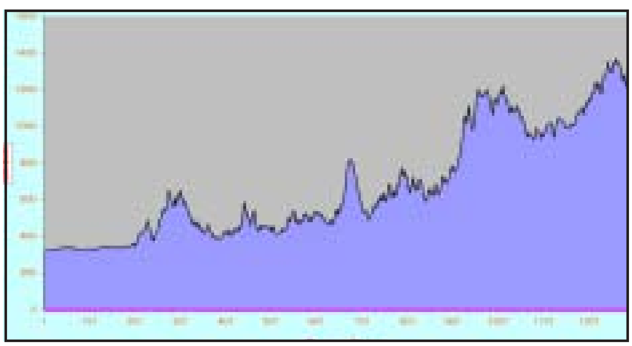

Fig: 4. Elevation of a seismic profile along which data have been acquired in Foot Hill area

the first break time of uphole records especially for receiver at an offset of 3m and 5m, from the depth of 1m and 2m. This type of reverse polarity can be explained as in the Figure 5A and 5B. The time variation in uphole data in deeper levels are also observed frequently. In Table 1, the 17m depth's time value is more than 18m, which may be due to peg-leg multiple or multiple.

Let the example of 5m offset as shown in Fig: 5A, if the shot is taken from E1, the travel time taken by the multiple reflection (Red arrows) within X layer will be more (12.8msec) as compared to the direct wave (Blue arrow) from the shot at E2 (11.7msec), Table1. The phenomena can be observed from the actual uphole data in Fig. 6a as compared to other records in Fig: 6b, c & d, because time value is more when signal come from 1m depth than from 3m, 5m and 7m depth. The reverse polarity can be observed in 1m uphole depth at 3m and above receivers offset.

It can also be explained as shown in Figure 5B, the wave energy, reaching the receivers at surface may be due to refraction through the interface of layers S and X. The direct signals from E1 to the receivers at 3m and 5m in surface will takes more time than the refracted signal between the

Table 1: An uphole data of 35 m depth in which geophone was placed at 5 m offset from the hole and slant distance and corrected times are calculated accordingly for uphole plot (Some values are omitted for space).

Vertical Depth	Up hole Time	Slant Distance	Vertical Time after slantDistance correction
1	**12.8**	5.1	2.5
2	**11.7**	5.4	4.3
3	**11.5**	5.8	5.9
4	**11**	6.4	6.9
6	**11**	7.8	8.5
8	**11.8**	9.4	10.0
10	**11.5**	11.2	10.3
12	**12.8**	13.0	11.8
14	**13.5**	14.9	12.7
16	**14.8**	16.8	14.1
17	**16.0**	17.7	15.3
18	**15.2**	18.7	14.6
20	**16.5**	20.6	16.0
22	**17**	22.6	16.6
24	**18**	24.5	17.6
26	**18.2**	26.5	17.9
28	**19**	28.4	18.7
30	**19.6**	30.4	19.3
35	**21**	35.4	20.8

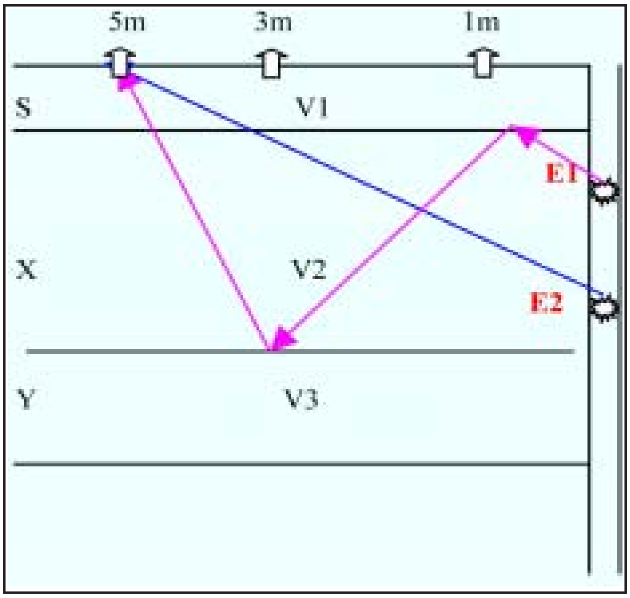

Fig. 5A

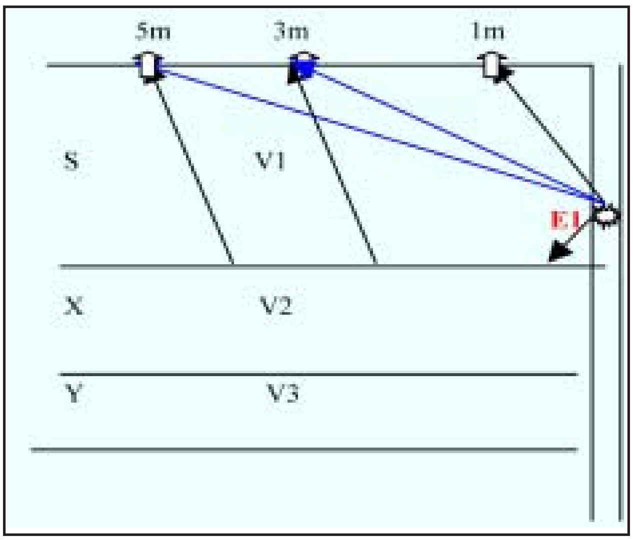

Fig. 5B

Fig.5: Diagram A & B showing generation of multiples or ghost in uphole survey which reverse the polarity of first break as shown in Fig: 6. Here velocity is V1<V2<V3.

interface S and X, as given in fig: 6 a & b and Table1**.** This is because the refracted waves pass some distance through high velocity medium where direct wave travel through Low Velocity medium. This type of time variation and reverse polarity observed in uphole survey in this foot hill area.

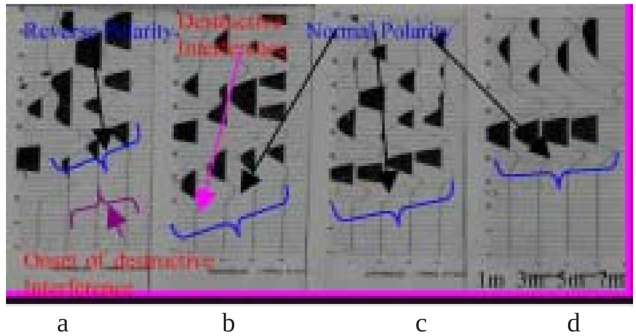

Fig. 6: Uphole record of (a) 1m, (b) 3m, (c) 5m and (d) 7 m depth. Note the reverse polarity in first break time in (a).

Destructive Interference

The frequency spectrum may be increase with depth but can be distorted by the surface ghost. Ideally, the charge should be placed beneath the weathering or LVL layers to improve signal-to-noise ratio and less surface noise. If the ghost arrival time corresponds with a true reflection, there may be destructive interference between these waves. The reverse polarity and increase in first break time value in less source depth in uphole data can also be explained as mentioned below. In the Fig: 7, red line represents a direct down going wave and the black line represents the wave reflected from the surface.

The complex near surface and complex underground structure of Himalayan Foot Hill causes various interference waves which make low S/N ratio. The interference waves may come from any direction to the

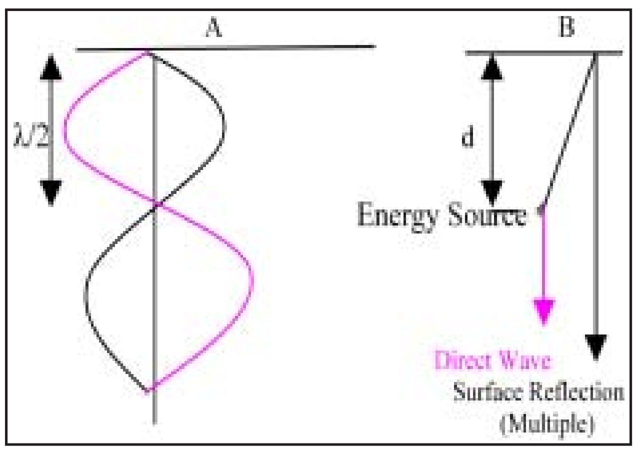

Fig. 7: Diagram of destructive interference. In diagram A shows two signal destructed with each other and in B shows the same phenomena for 180° phase shift to produce a destructive interference.

receiver line. The studies of uphole indicate the existence of interference effect.

If two waves propagation have the same wavelength, the destructive interference occurs when they arrive exactly 180° out of phase. Because the reflection coefficient is negative for the multiples waves, the down going reflected wave experiences a 180° phase shift relative to the direct wave. We can take the same example of Fig: 6a, where there are no signals at earlier first break time due to destructive interference which are shifted with reverse polarity in all offset signals except in 1m offset. Onset of destructive interference can be observed in first break time in 1m receiver offset for 3m uphole depth due to less than 180° phase difference which causes a small kink in the signal.

As we know that less charge can produce high frequency. The frequency calculated from the uphole survey are more than 180 Hz, in which we used to blast only 4 to 6 nos. of detonators as compared to 10 to 12.5 Kg charge in normal production. In normal data recording, the frequency ranges from 5 to 45 Hz.

Conclusion

In the complex geological setting of Himalayan Foot Hill, the interference waves coming from different direction to survey line which causes low S/N ratio. Dip angle stratum divert the acoustic wave and ultimately reduce the foldage. So 100 foldge had been adopted to have a sufficient number of fold. To acquire good data, it does not only depend upon the shooting medium but also depend upon the condition of receivers, source and system perturbations. Uphole study is one way to understanding the complicated structure of limited portion.

Seismic noises can be reduced by keeping the energy source in proper depth using optimum charges. But it also depends upon good coupling of geophones, the perturbations occurred in geophone’s parameters, like sensitivity, natural frequency, distortion, tolerances and tilting. Controlling the profile at the time of shooting for local noise can reduce the unwanted noises.

In constant velocity LVL, the explosive depth of energy source may be adjusted to reduce the ghosts problem. However, in undulating area the LVL velocity varies along the line, so changing the source depth will not solve the problem of ghosts in all places. But short distance uphole study can reduce these problems.

The variation of Uphole times in different levels and the reverse polarity indicate that ghost is prominent in this area, which may produce complicated seismic signals to process the data.

Acknowledgment

The author is thankful to Sh. H. Das, Deputy General Manager (GP)-Head Geophysical Services, Frontier Basins, ONGC, Dehradun and Y. P. Avasthi, Deputy General Manager (GP), Frontier Basins, ONGC, Dehradun for their assistance and support to publish this paper. The author also thankful to G. Singh, S.G (S), Party Chief, GP-82, FB for sparing my time to write this paper.

Views expressed in this paper are that of the author(s) only and may not necessarily be to ONGC.

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