Noise Problem and Quality Seismic Data Acquisition in Himalayan Foot Hill Area.

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ABSTRACTS : Acquiring seismic data in tectonically complex area like rugged Himalayan Foot Hill terrain is one of the most challenging jobs for surface geophysicist. It is sometimes most difficult for surface geophysicists to obtain interpretable seismic data from geologically complex structure. Possible causes of poor quality seismic data may be attributable from severe static, ray path distortions due to complex subsurface structures or lack of energy penetration. The most inescapable handicaps of the seismic data acquisition are seismic noise. Often poor quality seismic data are associated with topographic highs formed by competent Cenozoic outcrops on the Himalayan Foot Hill. Due to severe topographic undulation, steep high, complex structures associated with thrust tectonics and extreme operational difficulty in acquiring seismic data, are the causes for poor data quality. Excessive amount of ground roll, with little apparent attenuation with time have been seen in this area. Near surface high angle thrust and subsurface thrust which have different thrust direction causes seismic energy to divert in different directions. Surface conditions also have a significant impact on the quality of data. Besides surface conditions environmental and demographic restrictions can have a significant impact on this field data quality. A proper earth model that can give us a realistic seismic picture of the target horizons are required to achieve a reliable acquisition parameter design and quality control.

Introduction:

In a geologically complex area of Himalayan Foot Hill, it is a challenging job for surface geophysicists to acquire the best quality seismic data. The poor quality seismic data may be due to severe static correction, ray path distortions in complex subsurface structures or lack of reflectivity contrast in different formation. One of the most severe problem in the seismic data acquisition is different types of noise accumulate with recorded data.

A common noise seen in the recorded data in this hilly area is ground roll or Rayleigh wave that travels along the surface, characterized by relatively low velocity, low frequency and high amplitude.

Constant effort had been adopted to obtain interpretable seismic data from this Himalayan Foot Hill area. Each and every points of quality control have been meticulously analyzed and monitored at the time of data acquisition. Regular checking of geophones, cables, instrument and ground electronics improve our data quality. On the surface of lose formation pits were made and Plaster of Paris were poured in it to make a hard layer for better coupling for geophones plantation.

Seismo-geological model was made and analysis for designing field parameters. The model shows that shadow zones for receivers, are one causes of poor data quality.

General Description:

Geophysical Parties of ONGC have been acquiring 50 and 60 fold seismic reflection data using 200 and 240 channels in various area of Himalayan Foot Hill of Himachal Pradesh. Fig: 1.

The topography of the area is highly rugged and undulatory in nature having elevation variations ranging approximately from 500 m. to 2000 m. above MSL. The entire area is covered by ridges, streams, crisscross ranges, deep valleys, pine forests, vegetation with thin population. The exposed rocks like Siwalik, Dharamshala, and Subathu formation are common in the operation area. The alluvium cover is only limited in small valley area.

Methodology:

To improve the quality of seismic data, it is extremely important to sharpen the survey parameter design process and meticulous monitoring of data. Using the state-of-the-art telemetry recording systems, like SN388, with on line quality monitoring capabilities, like trace attributes and analysis of shot records at the time of acquisition, can improve the data quality. Field processing unit for land crew is another addition to monitor the data quality. The methodology that have been constantly followed to monitor the data quality are as follows :

a) Instrument and field tests were taken before regular shots, to check the signal response and were modified as per manufacturer's specifications.
b) Signal responses were meticulously observed in instrument, as well as in recorded zoom plot. The bad responses were modified by checking the geophone responses and their plantation at the receiver point.
c) Geophones and cables were tested regularly as per the manufacturer's specification by the analyzer and tester respectively.
d) Tap tests were taken to check the general response of the geophone string.
e) Geophones were planted in pit, using a layer of Plaster of Paris, so that coupling with the ground would be proper and wind could not affect the signal.

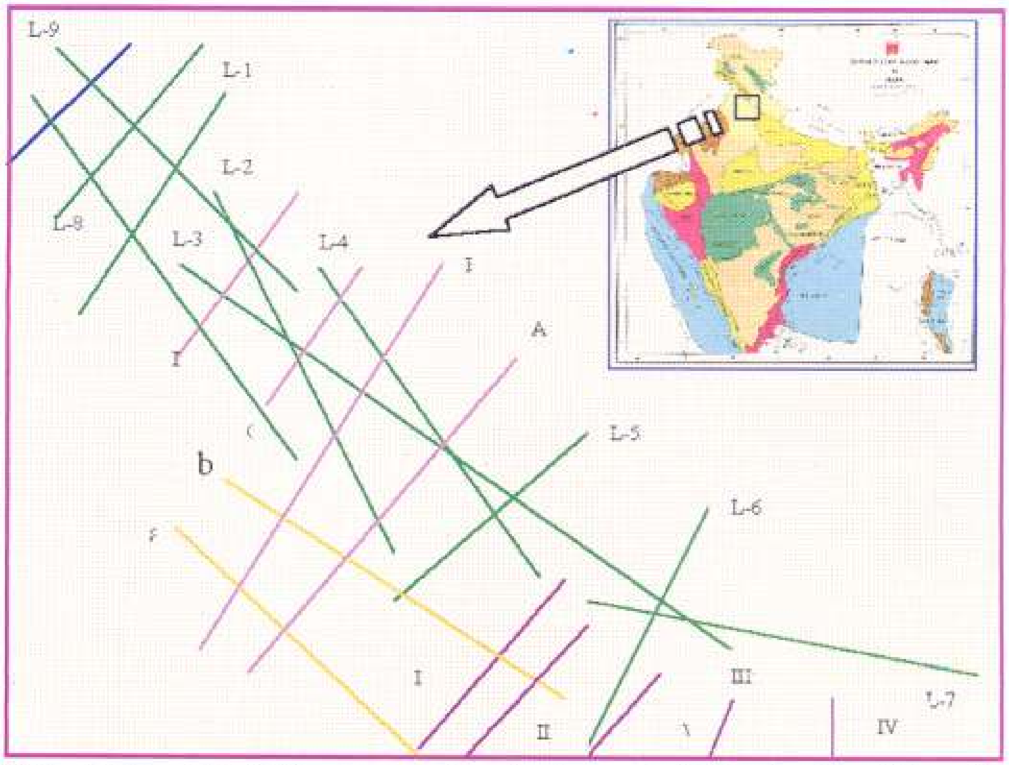


Fig: 1. Seismic profiles of different campaign (separate color) acquired in Himalayan Foot Hill area. The green lines are the data acquired in 2003-2004 campaign from where the following examples are taken, except Figure No. 2.

f) Ground electronics, cables and geophones were cleaned daily and dust caps were used to protect the connector pins and sockets.

g) In optimum shot holes depth, optimum charges were blasted with proper tamping of the holes.

Seismic Noise:

Sou1rce generated seismic noises like ground rolls, shallow refractions, multiples, guided waves etc. are coherent noise. Another omnipresent noise associated with an environment is called ambient noise. Sometimes the order of magnitude of these noises may be stronger than required seismic signals. Usually bigger charge is used to over come local ambient noise and deeper charge is used to suppress the source generated noise.

Incoherent noise or random noise is generally more difficult to cancel. This is usually associated with scattering from near-surface irregularities. This type of noise is particularly common in upper Siwalik exposed area where the shot point overlies or is close to gravel or boulders, all of which can cause scattering of waves. Sometimes the scattering occurs when stream banks and other topographic irregularities diffract energy from shot and return it to the recording line in the form of incoherent noise. Another cause of random noise may be persistence wind motion pássing through the pine forest. Many surface and near surface irregularities may cause the scattering which contributes to random noise. Fig: 2

Ground roll is one type of Rayleigh wave that arises because of the coupling of compressional wave (P) and the vertical component of shear waves (SV) that propagate along the free surface. These waves are prominent in this area because array could not be designed for receiver and shot hole due to highly undulatory nature of surface. In some places the hill slope is so steep that within 20 m group interval, the elevation difference is more than 20 m. In the recorded data, the ground roll, which dominates the required seismic signals, seen vertically up to 2.4 sec TWT and horizontally it affects maximum of 2.5 km distance from the shot point. It dominates the required seismic signals. Fig: 3.

The velocity of ground roll varies with frequency, as a low speed surface layer overlies a much thicker material like Dharamshala formation, in which the speed of elastic wave is higher (more than 2500 m/sec). The properties of this surface layer govern the speed, since short waves do not penetrate the underlying material. Ground roll in which different wavelength travel with different speeds appears as a train of events in which successive cycles have increasing or decreasing periods. The ground roll frequencies of this area vary from 7.5 to 12.5 Hz and the velocity varies from 380 to 1280 m/sec.

The release of tamping materials after blast or the sound wave of blast causes low velocity air wave which we observed sometimes in the recorded data. To reduce the sound wave, the shot hole were filled with water in the lower

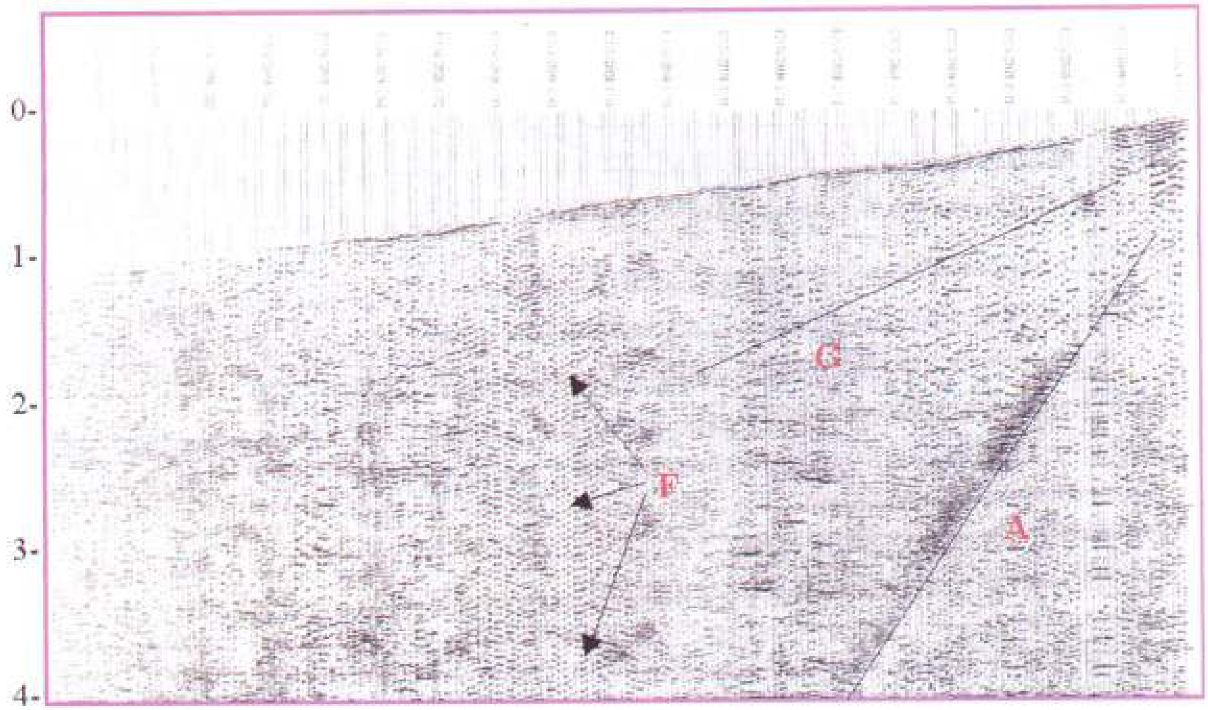
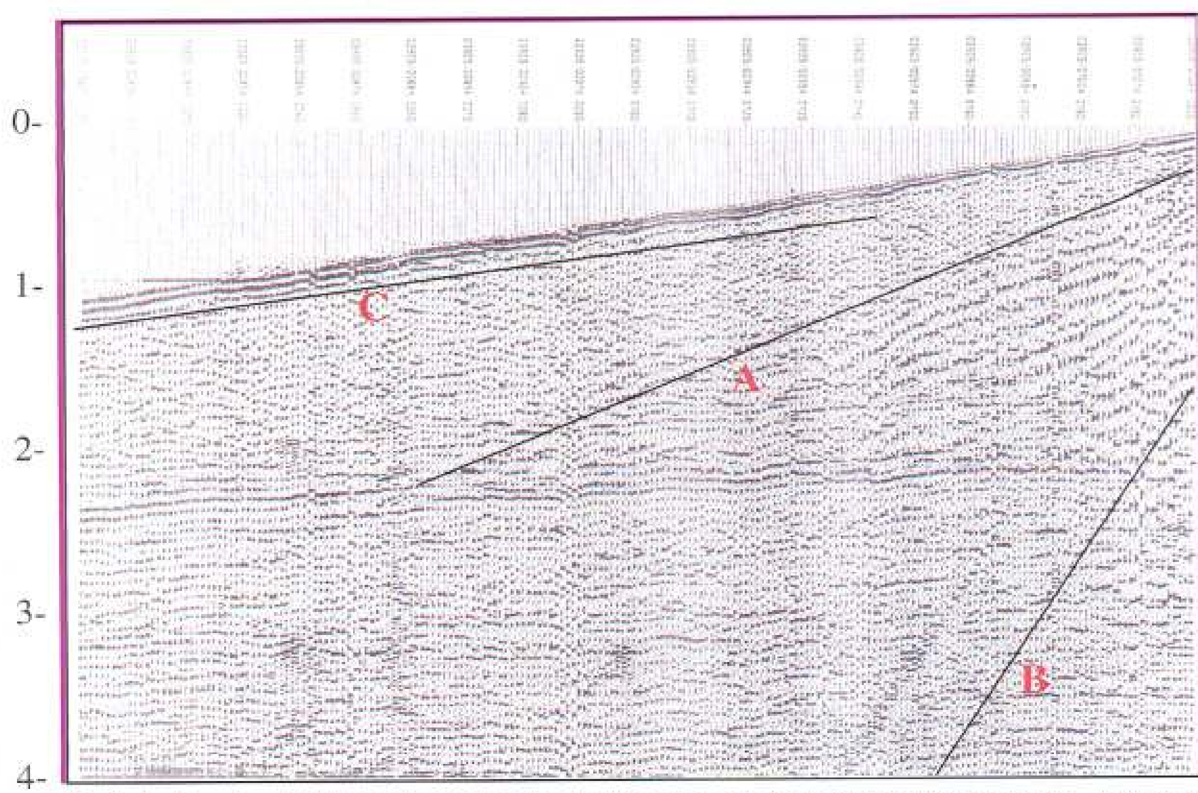


Fig: 2. A shot gather of 200 channels, recorded in the Upper Siwalik rock formation of Himalayan Foot Hill, using 7.5 kg charge at a depth of 16 m, showing with gain applied. There is no prominent reflector except ground rolls (G), high amplitude air wave (A) and 50 Hz mono-frequency signal (F). It is full of random noise and weak first breaks seen in the far channels as the energy could not reach the far channels.



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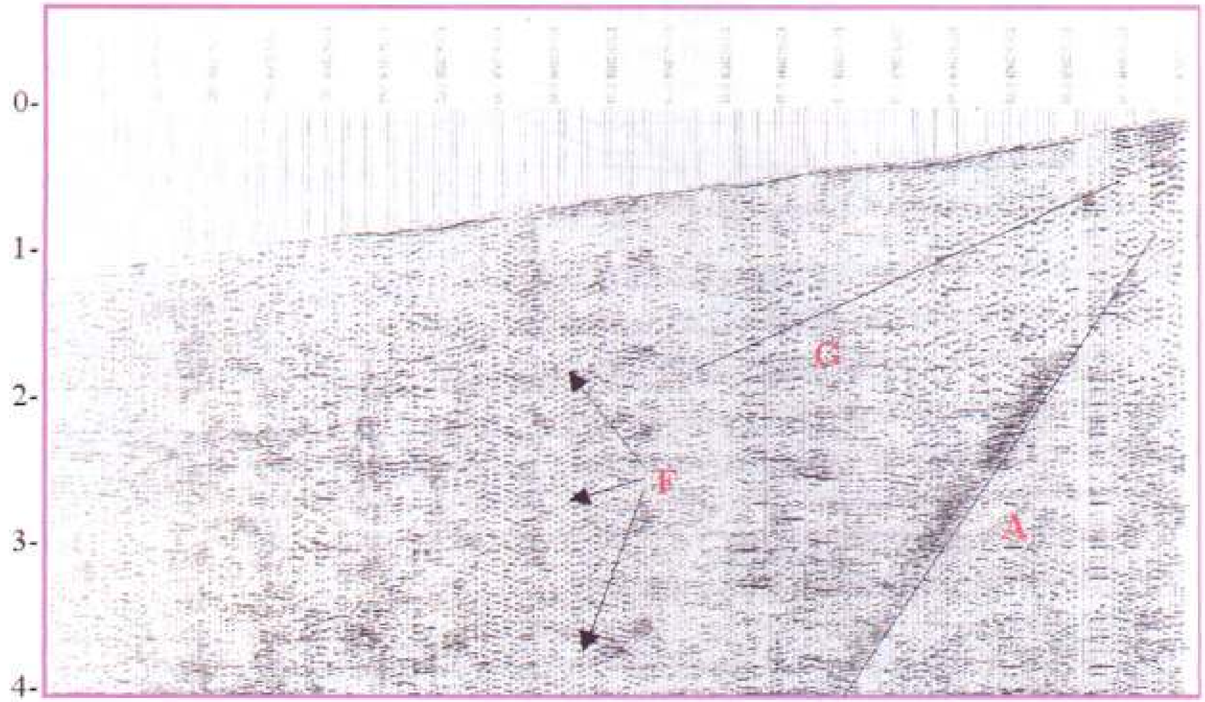

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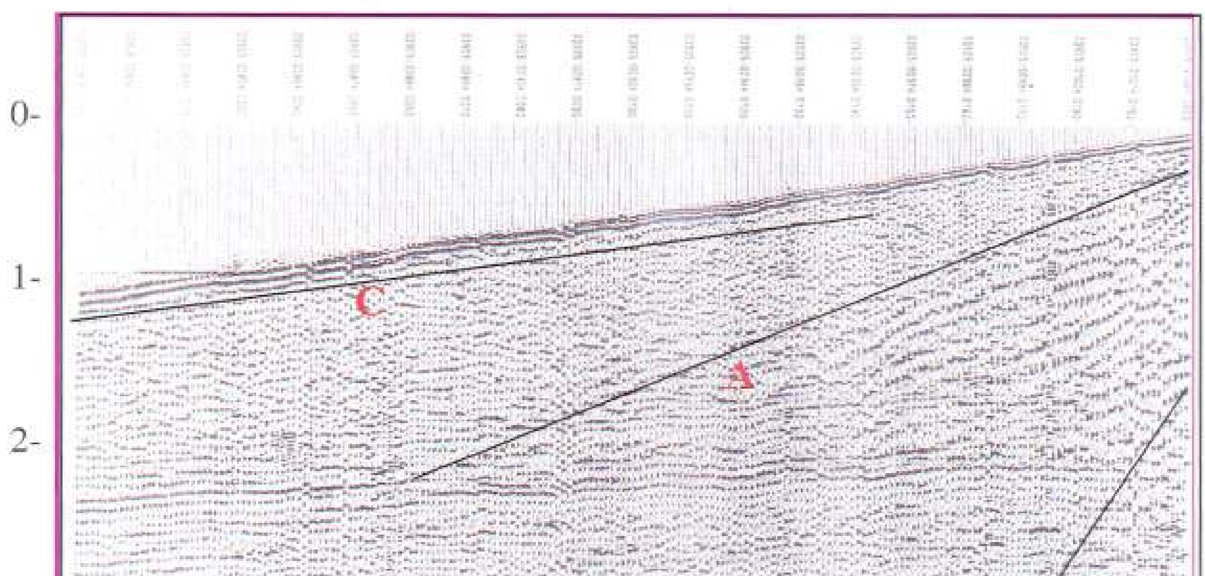

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portion and then fill it up with soil to compact the hole so that tamping materials do not come out after the blast.

A common type of coherent noise seen in this area comes from low frequency wave trapped near the surface, called surface wave or guided wave. It is seen parallel to the first break (below 1 to 4 msec. TWT from first break). The guided wave generated due to strong velocity contrast between week weathered layer and strong formation like Dharamshala where refracted energy propagates in the form of a head wave. It is not seen near the shot point, as the ground roll dominates the guided wave.

The electrical 50 Hz signal pick up from the transmission line is common in this area. This mono-frequency wave is not always exactly 50 Hz because it does not go out after applying 50 Hz filter. This high frequency noise severely affects the recorded data in rainy days as leakage occurs from the over flowing electrical lines.

Requirement for good Seismic Signal:

To get the valid information of subsurface, we need high Signal to Noise ratio (S/N) of seismic signal which means that the seismic trace has high amplitudes at times that correspond to reflection and little or no amplitude at other times. During acquisition, it has been tried to achieve high S/N by maximizing signal with a seismic source of sufficient power detonated in optimum depth. The surface layer is covered with alluvial and exposed hard rocks of different formation, so optimization experiment on charge and depth has been carried out at an interval of 1 to 2 km for regular shot. Here the energy source, 7.5 kg explosive is sufficient for good record, but the shot hole depth varies from 12 m. to 19 m. Beyond 7.5 kg charge sizes, it creates more ground roll. On the other hand, smaller charge sizes may have higher frequency content, but less energy going into the ground and energy does not reach the far channel of spread.

The frequency content of a signal from an impulsive source is not subject to control. In case of dynamite; it is influenced by the material and its moisture content in which the explosion occurs by the charge size, the shot hole depth, and other factors. The explosive used here is Calvex (TM) of class II which has good performance as an impulsive source.

The CDP interval of 10 m in this area is sufficient to avoid spatial aliasing of the signal, attenuate noise and obtain signals that can benefit in subsequent processing.

One characteristic of a good seismic signal is high resolution or resolution power – the ability to distinguish the top and bottom of the reflectors and quantify the strength of the reflection. This is achieved by recording a high band-width or wide range of frequencies. The greater the band-width, the greater is the resolving power of the seismic wave. The recorded data reveal that the average range of maximum band width is 8 Hz to 65 Hz.

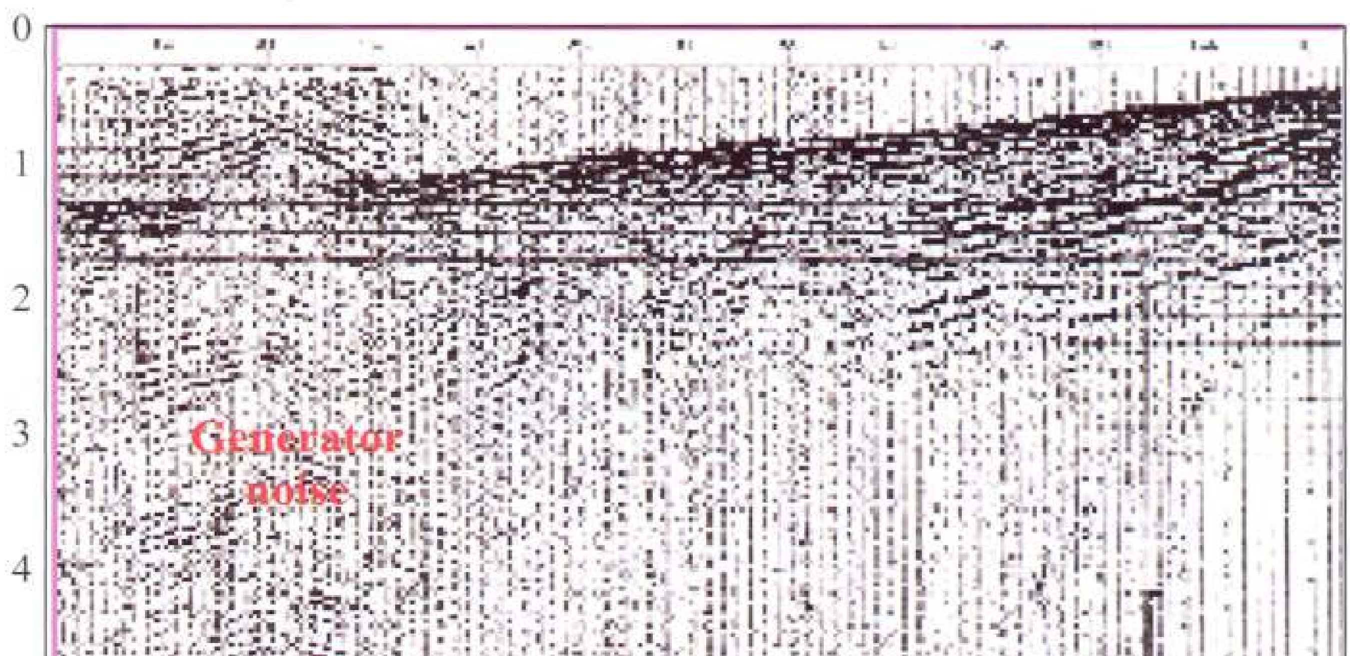

Fig: 4. The characteristic feature of generator noise from a recording truck a few meters from the line spread, no gain applied here. Sometimes it is unavoidable due to lack of instrument position in hilly terrain.

Another requirement for good seismic data is adequate subsurface coverage. Considering the migration aperture and Fresnel zone, the spread length has been kept a little greater than the depth of the reflection being imaged for full fold coverage of subsurface. In this area, maximum of lowest target depth we have to image is less than 4 km. So the spread length was always kept more than 4 km.

Model Studies:

Subsurface modeling is a valuable tool to analyze the effect of different survey parameters like group interval, shot interval, spread length, shooting configuration and direction. Ray trace modeling plays a critical role in understanding imaging issues in structurally complicated area. The aim of the model is to predict the target illumination and relate this to the image the target structures after seismic processing. A uniform fold or illumination is usually the ideal result and deviation (e.g. shadow zones and variation) indicate regions where imaging problem or acquisition related amplitude variations might be expected. Using different survey parameter, synthetic stack sections can be prepared by generating synthetic seismic trace on the model. Now by analyzing these stack section we can conclude which survey parameters should be used for better subsurface imaging.

From the ray trace diagram we can see the shadow zone for the receivers which may cause poor data quality. The spread configuration and the acquisition parameters obtained by the modeling studies are confirmed or refined after the field experimental work. Fig: 5,

How noises were optimized:

The upper Siwalik formation is mainly composed of gravels and boulders. Its thickness varies from place to place. So if source and receiver are placed in this formation, maximum of the seismic energy will be lost within this rock formation. It neither transmits nor receives the energy. To avoid this problem, we increased the shot hole depth upto 25 mts. so that the charge reaches the middle Siwalik formation.

Pits of 75x35 cm. and 30 cm deep were made, in which Plaster of Paris was poured to make a layer of 5 cm thick. The geophones were planted in these pits for proper coupling with the ground. If the surface is exposed hard rock, we made geophone's nail size holes in the rock by drilling machine and planted the geophones in the holes. For better coupling of the geophones, Plaster of Paris was poured in the holes.

A large portion of the operation area is full of pine trees and constant wind passing through it, creates noise in the receivers. To avoid this type of noise the geophones were planted sufficient distance away from the trees. Though the population in the foot hill area is thin, the demographic noise is not unavoidable. It can be controlled by good relation

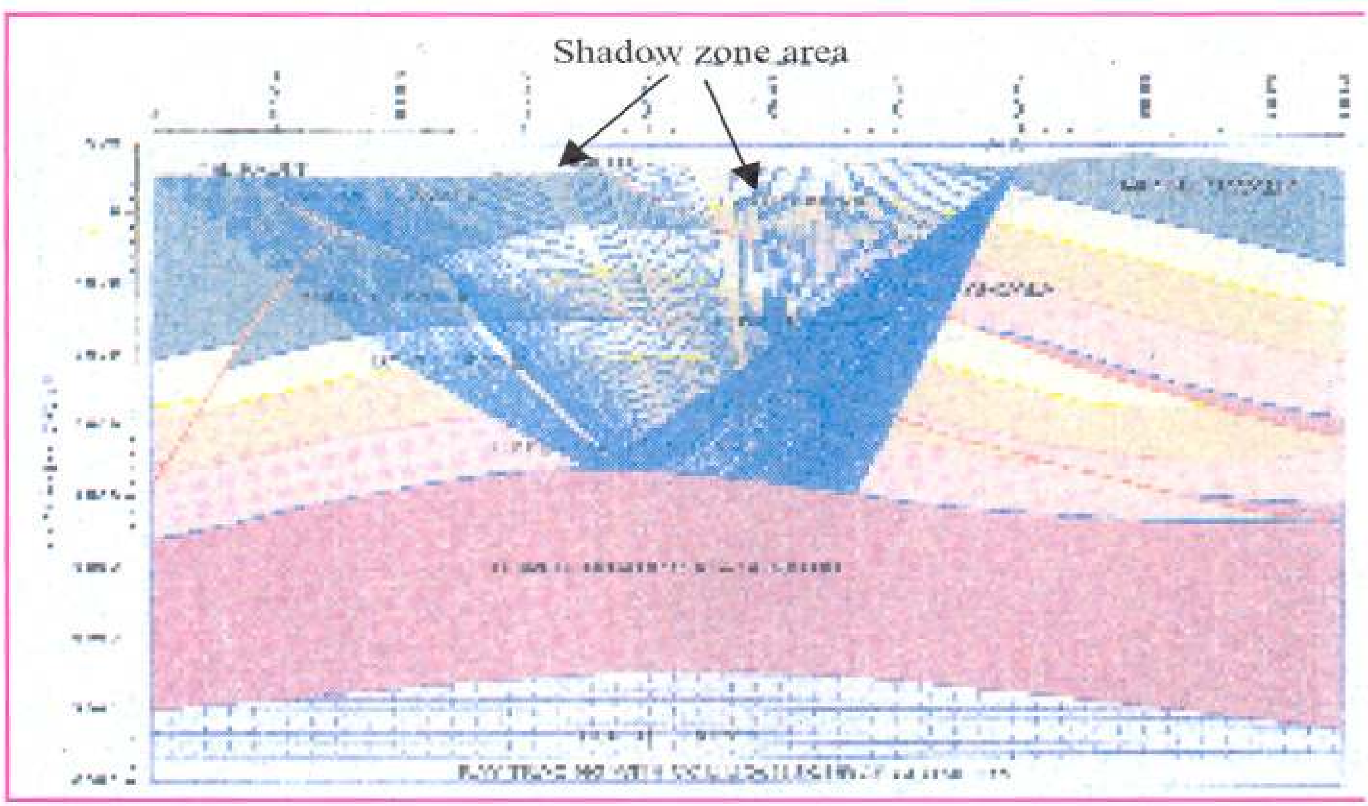

Fig: 5. A seismo-geological model showing the rays of a shot for End-On shooting configuration. Here the Group Interval is 50 m and no. of channels are 200. The shadow zones are visible here.

with the local people. The net work of electric and telephone lines passing over the profiles are the major causes of leakage of 50 Hz noise. To avoid this noise, we have to keep the geophones and the cables in dry condition with proper insulation.

The energy penetration to the subsurface is very poor if shot was taken in the steep side of the hill as the maximum energy has been lost by the side wall of the hill. So to compensate the seismic energy we increased the shot hole depth upto 20 mts.

In this highly undulating area, array design for shot hole and receiver can not be carried out to suppress the ground roll. But in few places, shot holes of equal depth in perpendicular direction were used to reduce the ground roll.

These efforts improved our seismic data tremendously as compared to the earlier data.

Result:

A number of deeper reflectors are present in the record having good signal to noise ratio. But the reflectors are not continuous due to highly undulatory surface. The reflectors, seen here are (R1, R2, R3, R4 and R5) almost straight in nature. The reflector (R3) is more prominent may be due to limestone. Fig: 6.

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