



Problems and Challenges in Conducting Seismic Survey Operations in Logistically Difficult Hilly and Rugged Terrain of the Foothills of Uttaranchal – A Case Study

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Summary

Oil India Limited (OIL)'s exploration for hydrocarbons has moved today in to challenging and new frontier areas. The days of easy oil finds are behind us. Present day seismic surveys are being carried out in logistically difficult and hostile terrain conditions. OIL, recently, conducted seismic surveys (dynamite) in rugged terrain of the Himalayan foothills having dense forest cover in Kashipur PEL areas in the state of Uttaranchal. The environment is extremely challenging and logistically difficult, beside the surface logistics, it includes the difficult subsurface conditions as well. Past experience has shown for acquiring good quality seismic data that conventional shot-hole drilling techniques are no longer applicable in such complex areas which are underlain by boulder beds, loose gravels mixed with wet and loose sands, flowing water at shallow depths.

It is extremely important to monitor the "Quality" at the acquisition stage for obtaining meaningful data/information of the subsurface. For achieving good data quality, which is mainly dependent upon the optimum shot hole depth and shooting medium, proper advance planning for data acquisition in the forest infested areas in Uttaranchal foothills has played a pivotal role. Based on earlier experiences need was felt for deploying mechanized shot-hole drilling rigs having demonstrated proven capabilities for drilling in boulder bed areas in logistically difficult terrain.

The present paper discusses the case history of the acquisition of good quality seismic data by OIL in the logistically hostile, hilly and rugged terrain of Uttaranchal foothills deploying suitable state-of-the-art shot-hole drilling rigs (hydraulic and pneumatic) for achieving optimal shot-hole depth even in areas where the only approach is through steep climbing. These portable rigs, which are really miniature marvels has made shot hole drilling possible even in the toughest and steepest terrains, which otherwise would have been difficult even with heli-portable operations. During seismic survey operations various challenges have been faced in view of several factors like use of dynamite as energy source, reserve forest (ANR region), presence of wildlife, highly undulating terrain conditions etc. which called for practicing of stringent safety aspects and at the same time ensuring the quality of data acquired within the laid down time frame in the most cost-effective manner has also been dwelt upon.

Introduction

In the present scenario of hydrocarbon exploration, the major shift have taken place from big and easy structures to small and complex structures and traps like subtle pinch-out, from easy and smooth terrain to hilly and rugged terrain and from shallow water areas to deep water areas. 'Seismic exploration' is now rapidly approaching the situation where 'Difficult oil' from 'Complex environment' has to be explored and exploited.

The hydrocarbon exploration in the Himalayan foothills in particular and Ganga basin in general is yet to achieve commercial success, despite evidences confirming hydrocarbon generation in the basin. The geology of the Himalayas is highly complicated and is subjected to

intensive tectonic deformation with complicated structures and tectonics, which is still remain a mystery to be unearthed and is a future targets for hydrocarbon exploration.

Pursuant to OIL's strategy of systematic exploration in logistically difficult and frontier areas, OIL launched an aggressive 2D Seismic (Dynamite) survey by hiring the services of Seismic contractor in OIL's acreages in Ganga basin in the close proximity of Himalayan foothills.

For successful acquisition of seismic data, three important factors i.e. Quality of seismic data, optimum production and minimal cost while acquiring data are to be kept in mind. Production of the Seismic data and the cost depends on the effective utilization of manpower,

equipments, resources and cost-effective measures. 'Quality' depends on recording instruments, shot-hole drilling depths, ground equipments, use of good quality explosives, better understanding of surface and subsurface conditions, proper ground coupling of geophones and subsequent close monitoring, which is followed by corrective steps for the improvement of the seismic data to be acquired. It is well known fact that ensuring proper shot hole depth is the most fundamental and important requirement for acquiring good quality seismic data.

The present paper discusses the case history of the acquisition of good quality seismic data by OIL in the logistically hostile, hilly and rugged terrain of Uttranchal foothills deploying suitable state-of-the-art shot-hole drilling rigs (hydraulic and pneumatic) for achieving optimal shot-hole depth even in areas where the only approach is through steep climbing. During seismic survey operations various challenges have been faced in view of several factors like use of dynamite as energy source, reserve forest (ANR region), presence of wildlife, highly undulating terrain conditions etc. which called for practicing of stringent safety aspects and at the same time ensuring the quality of data acquired within the laid down time frame in the most cost-effective manner has also been dwelt upon.

Objective

The hydrocarbon exploration in the Himalayan foothills so far proved to be futile though oil and gas shows have been reported in many parts, but none of deep drilling well has encountered the much expected Eocene source rock i.e Subathu Formation. The objective of ongoing seismic survey in study areas is to delineate hydrocarbon prospect. Presence of apparent structural closures identified within tertiary and top part of Vindhya's has been observed in the available geological and geophysical data acquired through Vibroseis survey within the northern foothills belt. Also hydrocarbon shows has been observed in lower and middle Siwalik sands in OIL's only well drilled at Bilaspur (U.P). Seismic data interpretation suggests development of structural plays within Siwaliks/Tertiary in the areas lying in and close to the northern parts of the foothills of Kashipur PEL. However, owing to paucity of seismic data in the northern parts of the foothills belt, northward extension of the structure could not be confirmed so far. In order to confirm these structural closures OIL has planned seismic data acquisition in the Uttranchal foothills. Broadly the objective of acquiring better quality seismic data in the Uttranchal foothills belt is to locate the areas of good source

rock development and entrapment conditions for hydrocarbons.

Operational area & constraints

The area of survey (Figure-1) lies close to Himalayan foothills. Here the terrain is very tough and the topography is hostile. The entire area is prone to heavy rainfall and beset with a plethora of hindrances to seismic operation such as thick, tropical reserve forest cover, rivers, streams, nallahs, creeks etc. (Figure-2) and near surface boulder beds/hard rock formations and fairly steep rocky hills and valleys (Figure-3).

Main problem of the operation in such type of terrain is shot hole drilling. The presence of boulder beds



Fig. 1: Study area



Fig. 2: Topography of the study area



Fig. 3: Formation encountered in study area.

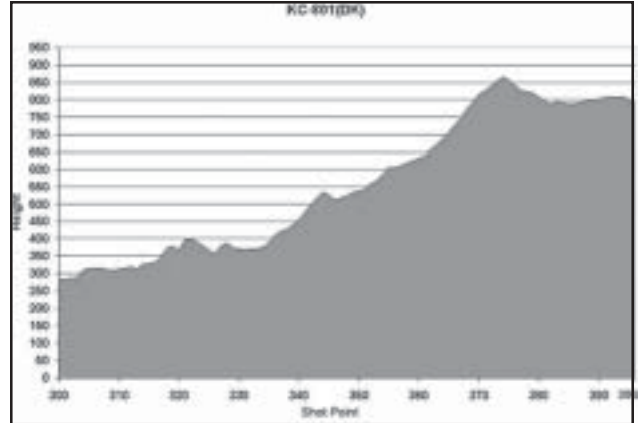


Fig. 4: Elevation differences along the seismic profile.

all along the foothills makes shot holes drilling very difficult. It has been observed that shot hole drilling in hard rock formation areas are relatively less difficult in comparison with the areas having boulder beds, loose gravels and wet and loose sands. Due to presence of the hillocks, surface undulations and thick forest cover, operational areas are connected by a very limited network of track and passage for movement. Moreover, the tracks and passages are very narrow with hairpin bends, cliffs and gorges. Trekking along seismic profiles for plantation of cables/geophones (also MRX boxes and batteries), movement of shot-hole drilling rigs along with accessories from shot point to shot point, checking of geophones /cables and trouble shooting etc., are extremely hazardous and time consuming. It can be visualize at places that the elevation differences are of the order of 600-800 meter within 200 meters (3-4 shot points) locations (Figures-4) and planned seismic profiles along with geological map of the study area is shown in figure 5.

Other operational constraints are including prior permission in the forest area. No-loss/felling of trees would be permitted whatever be the situation during operation and the areas under shawl plantation and ANR marked. Presence of wild animals, finding of suitable nearby campsite for accommodation of large number of crew members, parking of vehicles, suitable magazine sites for storage of explosives as per Explosive rules, nearby market, petrol pump, drinking water facilities etc. are also some of the problems particularly present in such hilly terrains.

Shot hole drilling

The present challenging environment for seismic survey in logistically difficult boulder beds/hard rock areas require not only untiring efforts, hard work, innovative ideas, but also need to shaping and tuning the human-ware to meet the challenges but latest available and affordable *state-of-*

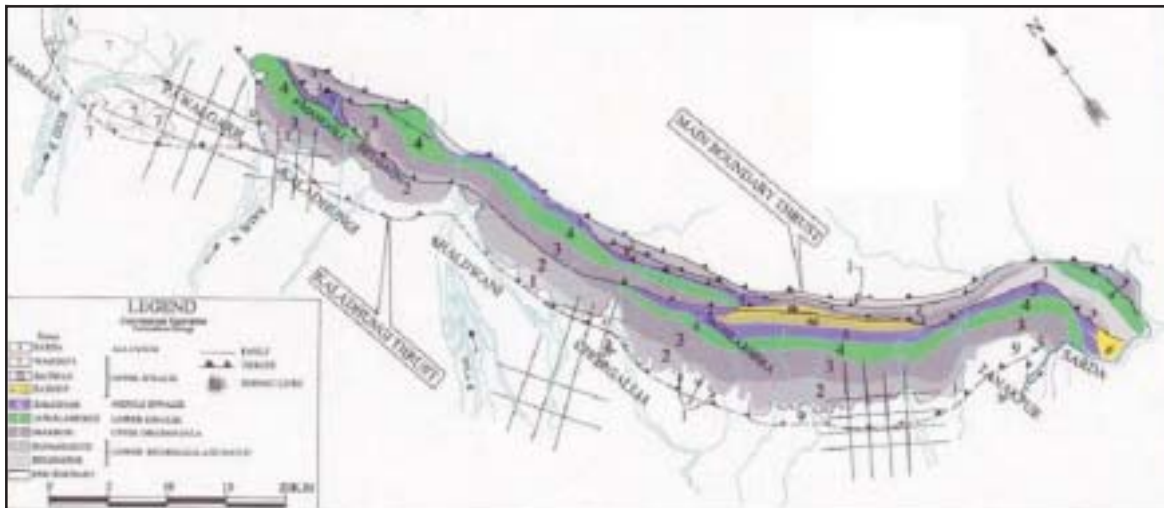


Fig 5: Geological Map of the study area with planned seismic lines..

the-art with technology for shot hole drilling. Considering this aspect of shot hole drilling, seismic contractor was advised to arrange different types of portable mechanized shot hole drilling rigs suitable for drilling in the above mentioned areas. So the four types of latest generation shot hole drilling rigs have been deployed. Three types of portable rigs are imported one while one type of portable rig is indigenous. Out of these four (4) types mechanized shot hole drilling rigs deployed in the area, the imported A & B type shot hole rigs are found most suitable to the study area. Prior to deployment of these latest generation portable shot hole drilling rigs, the earlier efforts of the national oil companies towards this mission was not be successful. Even OIL has also tried to drill shot hole in the same area earlier but could not go beyond 5 m in depth.

The type A rigs (Figure-6a) are man portable, extremely lightweight mechanical rigs. The rotary movement is through a 5.5 H.P. engine. The pull up and pull down is manual. The uniqueness of the A type rig is that the basic rig can be carried by 1-2 people. This feature of the type-A rig makes it possible to drill even at locations where access is only climbing. The some specification of type A rigs are given below:

Specification of type-A rig

Configuration	Man portable drill machine
Weight	35 Kilograms
Power	5.5 H.P Engine
Depth	Rated to 20 meters
Capability	For water flush drilling For air flush and down hole drilling
Top Drive	140 ft-lbs of torque



(a) (b)
Fig 6: A & B type shot hole drilling rig.

The B type rigs (Figure-6b) are powerful man portable hydraulic rigs. The rigs can be broken down in to 5-6 modules each weighing around 40-50 kg for easy transportation from shot point to shot point. The entire rig can be broken down in to separate modules for transportation within 15-20 minutes. The module can be reassembled at the drilling point in almost the same time. These powerful imported type-B rigs are suitable for both DTH (down hole hammer) drilling using air as well as rotary mud drilling. Specification of Type-B Rig:

Configuration :	0.97 Meter wide track unit (Dimension 0.97 m x 1.32 m x 2.92m)
Weight	300 Kgs
Power	25 HP Engine
Depth	Rated to 35-50 meters depending on the formation
Capability	For water flush or wet anger drilling For air flush and down hole hammer drilling
Top Drive	1000 ft-lbs of torque
Pull Up	2360 kg Capacity
Rotary Speed	Variable up to 160 rpm
Hydraulics	Single hydraulic pump, Top drive and down pull Motors, all controls at drillers station.
Diameter	For holes up to 99mm.

Since the area had rocky formations, it has been decided to go in with the DTH drilling using hammer with button bit and compressor (rotary mud drilling using an insert bit proved ineffective during field trials as the pebbles, loose gravels are encountered). Imported hammers and button bits have been used based on formation encountered. The loose gravels, loose pebbles with sand formations caused the dispersion of compressed air through the formation, instead of flushing the cuttings up the hole. This problem has been solved by usage of drilling foam/soap water and chemicals during the drilling.

The drilling of shot holes is carried out with the help of air compressors, which have been connected to drill machines through imported hose pipes. The compressors are placed at one suitable point to drill 15 to 20 holes. Sometimes compressors placed around 1.5 to 2.0 KM away from shot point to be drilled.

Field experimentation

Onsite experiments were carried out to see the capabilities of these portable mechanized shot hole drilling



rigs to drill in boulder beds, loose gravels, hard rocks even in the steep terrain. Some experiments are also carried out to optimize charge size, charge depth and to study the noise characteristics for designing of receiver pattern in the study area.

Data acquisition parameter

Wire line telemetry recording (I/O System Two) has been used for carrying out 2-D Seismic data acquisition. The field experimentation suggests some parameters in respect to acquisition and instrumentation as given below:

Acquisition parameters

Charge size	: 5 Kgs
Charge depth	: 15mts (sticky clay medium)
Receiver array	: 24 elements, Linear
Geophone spacing	: 2 mts
Base spacing	: 50 mts

Charge depth is kept as a dynamic parameter along the line, which is decided by the advance Up-hole surveys at an interval of 1 km along the line. Daily monitoring of the shooting medium in the study area was done. Uphold studies have been carried out for near surface lithology and velocity modeling.

Instruments parameters

Instrument	: I/O System Two
Format	: SEG-D (6250 BPI)
Sampling interval	: 2 ms
Record length	: 6 sec.

The key issue- seismic data quality

During the seismic data acquisition, the infield data quality assessment is the prime concern of field geophysicist. Critical study of the behaviour of the seismic response, topographic variation, near surface geology and noise behaviour from previous investigation in such type of area are carried out as a part of data acquisition and also following quality control measure were regularly done in the field:

- Monitor the shot hole depth in proper shooting medium regularly in hilly and difficult terrain and also taking corrective and effective measures whenever they are necessary for handling the shot hole depth. Mud was tempted after loading the charge for obtaining better source of seismic wave.

- Daily visual quality control check of raw shot records. Seismogram are critically examined to identify noisy/spikes channel/shots, misfire, reverse and cross-feed traces.
- Study of Q.C Stack: to identify regular noises, if generated from rig, compressors, dense plantation of trees (unpredicted air currents to shake/deviate the sensors planted near roots of trees) etc.

Discussions and conclusion

The subsurface condition in major part of the study area is made up of boulders, pebbles, loose gravel and wet and loose sand. This makes drilling very difficult, as the holes drilled tends to collapse due to the presence of the loose gravels and wet & loose sands. It has also been observed in some patches that there is a cavity creation subsurface i.e the bore diameter on the top is normal while at the bottom it ends up very high. In dense forest covered areas in the drilled shot holes, many a times explosive charges can not be loaded due to dangling criss cross roots of big trees in the drilled holes. It is observed that although the hole measuring rods can be easily lowered to the drilled depth in full length, the explosives cylinder cannot be lowered due to obstruction of the dangled roots in the shot holes.

In some areas, the flowing water at very shallow depths is encountered made the shot hole drilling literally difficult. Some of the areas have the presence of steep hills where the placement of the rig itself becomes difficult; the subsurface terrain changes are dramatic even within the same line although visibly the top surface conditions are same and similar. Such is the complexity of the area that two adjacent drilled shot holes are found different with each other.

Achieving good shot hole depth as well as good quality seismic data in hilly and hostile terrain under extremely testing and challenging situations where the only approach is through narrow forest passage and steep climbing is not only a realization for the first time in the Himalayan foothills but it has also become a trend setter for future venture in such type of areas.

Besides shot hole depth and ground survey accuracy, the actual seismic data is going to Common Depth Point (CDP) stacking has been carefully planned and modeled otherwise the main casualty in such area are the near offset traces, it could be other offset traces also. Lack

of near offset traces in the depth point gather for stacking may cause inaccuracy in the positioning stacked data temporarily and also leading to considerable frequency content variation. These pitfalls have been taken care meticulously.

The stacked sections (Figures-8) and the representative field monitor record throw light on quality of data obtained from a toughest and steepest terrain shot point as some of the deeper events can be seen even in the monitor record (Figure-9) from the study area. For QC/QA purpose lines at field are being processed even up to DMO /Migration stage.

The availability of processing technology (Promax System - in the field) for on line monitoring of seismic data has boosted the confidence of the crew to take appropriate

steps in monitoring and improving the data quality with cost effective manner in such difficult areas.

At places due to loose gravel/boulder and shallow water tables shot hole tends to collapse too often. As this latest generation portable rigs are capable of providing simultaneously suitable casings of drilled shot hole. These are a viable option in boulder beds area and may be effectively deployed in our study area. Any compromise at the 'Shot hole depth' stage directly affects the quality of data acquired, which can not be recouped by any processing technique at a later stage. Deployment of suitable *state-of-the-art* portable mechanized rigs has been the key to success for obtaining the high quality data.

Initially the level of productivity of seismic data has been found very low (in the order of 3-4 shots per day) for various reasons like lack of understanding the real challenge of surface and subsurface image pattern in this geologically complex regime, Lack of trained expertise on latest generation shot hole drilling rigs. However, quickly after visionary approach of senior management, innovative idea, team-spirit, training and understanding of surface and subsurface conditions etc made remarkable improvement not only in the quality of seismic data but also on the level of productivity as it has gone up to the order of average 37-40 shots per day. OIL has been carrying out its operation in a planned manner by drilling shot holes in advance and leaving cable/geophones and portable shot hole drilling rigs and accessories in the field itself after day's work with proper security. Thus, the seismic investigation was a great success.

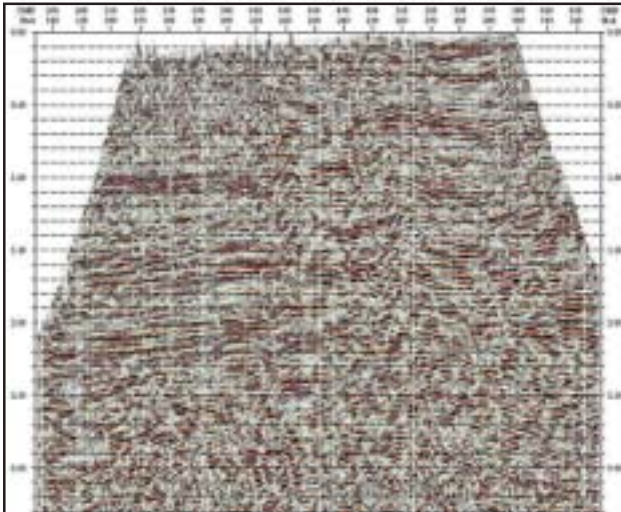


Fig 8: Representative seismic section

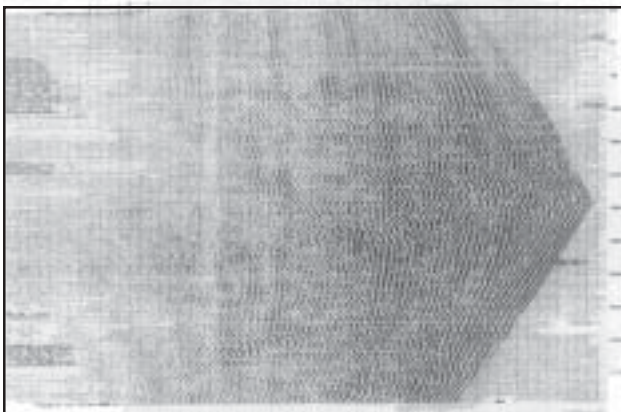


Fig 9: Monitor record

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