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Seismic Data Acquisition In Complex Boulder Bed Area: A Case Study In Arunachal Pradesh, North East INDIA

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Summary

The area of operations is located in the eastern part of Assam-Arakan Basin close to the foothills of Himalayas in the Belt of Schuppen (Thrust Belt) to the South East facing the upper Assam foreland shelf. The area is filled of boulder bed, decidedly undulating topography, and complex and roofed by intense forest. Seismic data acquisition can provide a better reflection where there is sufficient shot hole depth and not having geologically so complex to get a fruitful reflected energy from the underground. However seismic data acquisition is a great challenging chore for the geoscientists, if the area is geologically complex and logistically difficult in natural world. Apart from this, if there is no energy penetration occurs to the subsurface, it is quite difficult to map the sub surface structure. The study area falls in the north eastern part of India, is one of the difficult and geologically complex areas, where seismic data acquisition is a great challenge task till this time. The energy penetration into the ground surface is very less due to not having sufficient shot hole depth. The area is full of boulders from the top of surface and it is not possible to make shot hole depth even a 3 m after struggling 8 to 10 hours. Due to unavailability of the desired suitable shot hole drilling rigs, in the earlier days, geo-scientists have to make a manual pits for blasting for carrying out 2D seismic data acquisition, where the quality of seismic data is not so encouraging. To map hydrocarbon prospects which are expected in both supra and sub-thrust structures at Girujam, Tipam and Barail levels in this area are situated as deep as 5500m. Thus, imaging both supra and sub-thrust structures in this area is a challenging task due to improper signal. In this paper, an attempt has been made a total overview of acquisition and shot hole drilling strategy and how drilling rigs are improved and could possible to make a drill hole upto a depth of 20 m has been discussed. The quality of seismic data is remarkably improved to map both supra and sub-thrust structures. A comparative study including signal quality and the stacked section prior to better shot hole depth has also been discussed and the results are tinted therefore.

Keywords: *Supra-Thrust, Sub-Thrust, Assam-Arakan, Boulder bed.*

Introduction

The area of operations and study is located in the eastern part of Assam-Arakan Basin close to the foothills of Himalayas in the Belt of Schuppen (Thrust Belt) to the South East facing the upper Assam foreland shelf. The area is logistically difficult and geologically complex with thrusts and fold structures. The aim of seismic data acquisition is to find out possible hydrocarbon prospects both in supra and sub-thrust structures in Girujam, Tipam & Barail formations and are likely to be as deep as 5500 meters. Thus, it was required to image both supra and sub-thrust structures. Basement in the area was expected to be between 5 and 8 kilometres. The surface is undulating with no. of streams passing through with near surface sand and boulders beds. Shot hole drilling is a problem for acquiring good quality seismic data. The shot hole drilling was a challenging task as the shot hole depth could not be achieved even upto 1m to 2 m. Later on after long experimentations with shot hole drilling methods & technology, KB-10/20 drilling rig was introduced in the area to drill 10m to 20m, first time in the north eastern part of India. The data quality improved remarkably, compared to the shot drilling using shallow depth. In this text the general overview of the area, the logistic, geology, drilling technology, experimental results, seismic acquisition/ processing parameter etc. are discussed. The study area and the location map have been shown in **Figure-1.**

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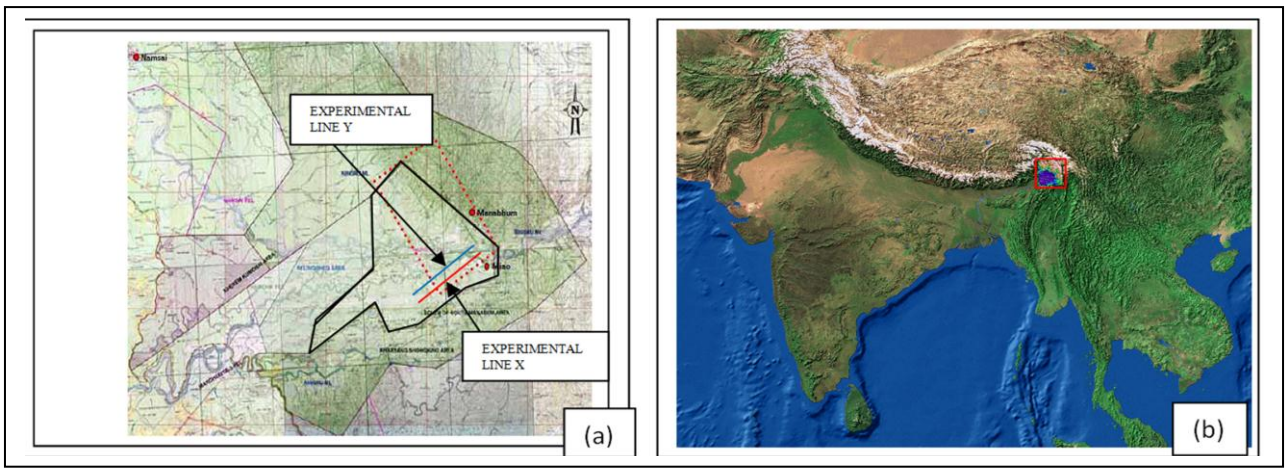

Figure-1. The study area (a) and the location map (b)

General Geology

The study area is located in the eastern part of Assam-Arakan Basin close to the foothills of Himalayas in the Belt of Schuppen (Thrust Belt) to the South East facing the upper Assam foreland shelf. The area is bounded by Noa Dihing River in the North, South Manabum in the South East, Kharasang oil field in the South West and Schuppen Belt in the South. A little part the area falls towards North of Noa Dihing River. The main source rock identified in the known oil and fields of Upper Assam Basin is the coal of Barail formation. The surface geology are in order alluvium, Dhekiajuli, Namsang, Girujan, Tipam, Barail and prospects are expected in both supra and sub-thrust structures at Girujam, Tipam and Barail levels. Hydrocarbon structures are likely to be deep seated

Figure 2 : The area of study shows boulder bed and hilly terrain area

Figure 3. A line supervisor is passing along the seismic line (a) and the drilling rigs inside the forest with drilling crews (b).

complex with thrusted and folded structures covering completely boulder bed. Basement in this area is expected to be at a depth range of 5-8 kms. The main hydrocarbon associated with thrusts as deep as 5500m.Thus, it is required to image both supra and sub-thrust structures in this area. The surface topography is filled with boulder bed which is shown in **Figure-2.**

Logistics and Topography

The area is completely covered by boulders, highly undulating topography, complex and roofed by dense forest. Ideally due to boulder bed, shot hole drilling is quite difficult and even if drilling of 3 m takes whole day. OIL introduced latest drilling rigs and started upto 20 m of shot hole depth in this area and the data quality and S/N ratio has remarkably improved. In this paper, an attempt has been made, how shot hole drilling was overcome which resulted in acquiring high quality seismic data for delineation of both supra and sub-thrust hydrocarbon prospects at Girujan, Tipam and Barail level. The block is covered with thick tropical forests, shallow river channels / river sands, rocky / hilly terrain with steep slopes & cliffs and some flat terrain. The areas surrounded by forests host and variety of vegetation with thick undergrowth. Parts of these forest-covered areas are unapproachable by motorable roads throughout the year. Proposed seismic lines may traverse through these thick forests, marshy lands, uneven/rugged topography, frequent water logged and surface/near surface fully boulder covered areas. Surface elevations in the areas of operation are in the range of **100-500**mts. The **Figure 3** shows the elevation and logistic for traverse shooting along the seismic lines.

Experimental Survey

The 2D acquisition was taken up using split spread geometry with 240 receiver stations and 4 trace (channel) gap/offset either side of the shot point. Each receiver group consisted of 12 geophones, planted inline at 3 meter intervals centered at the receiver flag. Production seismic data (7 second record length) was recorded at 2 millisecond sample rate, 12dB fixed gain with a linear phase high cut filter of 0.8 Nyquist (200 Hz). The charge size for shot points varied from 1 to 3 kilograms and also Up-hole times were also recorded. Noise from various sources was noted on the single fold shot records, typically from river flows, human activities, engines, power-lines, farm machinery and ground roll. The coherent noise was effectively removed using conventional noise suppression algorithms. The in-field processed sections contain continuous reflections up to 6 - 6.5 seconds. Experimental work was performed on few shot points in a line to determine the optimum production shot hole depth.

Shot hole depths ranged from 4 to 12 meters with specified charge sizes. When the experimental test dataset was analyzed for the different shot hole depths, it was noted that signal levels increased with depth. When comparing the field records at 5-6 meters and 10-12 meters there was a

remarkable difference in the relative signal levels. However, the decision was made to continue drilling wells up 20 m with single hole pattern with a charge size of 2.5 kilograms. In case when drilling of single holes of 20 m depth is difficult, then it was decided to drill pattern holes consisting of 2 x 10m shot holes. **Figure 4** shows the experimental survey and shot pattern test configuration. Three types of sources with 2.5 Kgs, 3.0 Kgs and 5.0 Kgs with single shot hole patterns are tested. **Figure 5** shows the receiver array diagram with receiver interval. The receivers are kept bunch wherever the elevation variation is more than 3 m else receivers are kept with 3 m interval with maximum 33 m interval of from first receiver to 12 the number of receiver.

Shot Hole Drilling

The seismic data acquisition started since 2008 in the area, however, due to shot hole drilling problems, the progress of data acquisition was very low. Russian UKB 12/25 rigs were imported specifically for drilling in the elevated parts of the study area and mounted on caterpillar tracks which provided the capability of climbing elevations up to a 45 degree gradient. Unfortunately these rigs did not achieve the desired depths in the local lithology due to heavy boulder beds. The surface and near surface is fully covered/ filled with course and medium size boulders. **Figure 6** shows that how the boulders are exposed from the top of the surface to a depth of few meters as by naked eye visualization.

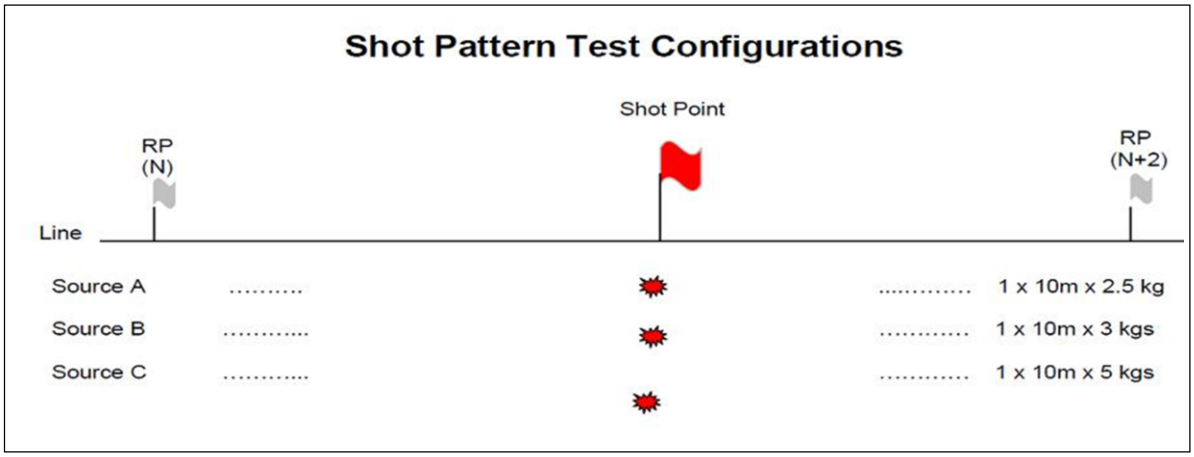

Figure 4. Experimental survey and shot pattern test configuration

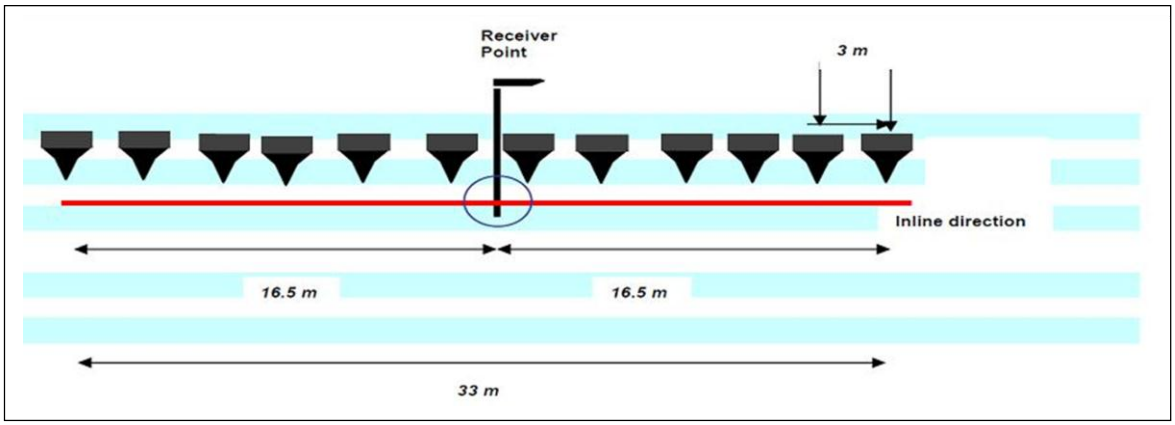

Figure 5. The receiver interval along the shooting direction.

Further German KB-10/13 rig and CompAir compressor units achieve the desired target depth when drilling through boulder type weathering layers. However problems were encountered when pulling out of the hole i.e. extracting the drill stem which causes excessive time. After extensive research and development (R&D) to provide a viable solution using specific tools to achieve optimal performance when drilling 10-20 m in boulder type lithology. A new integrated technology using KB-10 / KB-13 rigs introduced for shot hole drilling rigs in the proposed area with simultaneous use of casing pipe. **Figure 7** shows the KB-10 drilling rig and the compressor (compare C-60).

Figure. 6. The hand dug holes show that the boulders are extended from the surface to the deeper part

Figure 7 : KB-10 drilling rigs and the compressor (compare C-60)

All shot holes were cased to their respective target depth with plastic (PVC) casing which was capped for loading and shooting at a later date. A CompAir C-60 compressor towed by a dedicated 4x 4 vehicle or tractor units was utilized for DTH. Dynamite was used as the energy source, 2.5 kilogram charge in single hole shooting and 0.5 kilogram in pattern holes. Prior to the start of daily production instrument tests were performed and analyzed for both the active and look ahead channels. The test sequences included Instrument Noise, Distortion, Crosstalk, Instrument Gain, Phase, Common Mode Rejection Ratio (CMRR), Geophone Tilt, Field Noise, Internal Pulse and Geophone Tap. Each string of geophones was tested using the SMT-200 geophone tester.

Seismic Data Acquisition

A high quality state-of-art 24 bit telemetry system along with latest compatible accessories like cables, geophones, suitable energy sources (Dynamite and detonators) has been introduced for seismic data acquisition in the area. Mechanized shot hole drilling rigs has been used in the area having surface / near surface pebbles/small boulders for drilling shot holes upto a depth of 20 m. As the area is logistically difficult and geologically complex with imbricate thrusts, modelling exercises and laboratory simulations with the best geometry has been carried out for data acquisition. Pre-seismic survey modelling on the basis of available information/ data, in and around the area, was necessary for the most scientific spread generation/ parameter selection for acquiring good quality seismic data in this highly complicated thrusted and folded area.

Seismic Data Processing

Seismic recording taken up at 1 m shot hole depth on experimental line X (refer **Figure 1 (a)**).The amplitude & frequency spectrum of the recorded data shown in **Figure 8(a)** and Stacked section in **Figure 8(b).** Seismic data acquisition carried out on another Experimental line Y (shown in **Figure 1 (a)**) with shot hole depth around 10m. The acquired data amplitude & frequency spectrum are shown in **Figure 9(a)** and Stacked section in **Figure 9(b).** The data acquired with 10 m shot hole depth shows far better S/N ratio and mapable horizons which is evident from **Figure 9 (a) and (b).** that the single fold data recorded is completely filled with noisy traces with shot hole for 1 m only. The energy penetration is less and the amplitude spectrum also shows maximum noisy. However, in **Figure 9 (a and b),** the single fold trace records shows a better quality of records with broad amplitude spectrum. In both the cases, the stacked section using shot hole depth of 10 m shows more and meaningful results to map the sub surface with desired structures.

Seismic Data Interpretation

Few old seismic lines were also processed with newly acquired seismic data in the area. An integrated approach has been adopted for interpretation incorporating all geological, geochemical and well data in around the area. A no. of prospects and leads are identified and prioritized in the study area for exploratory drilling.

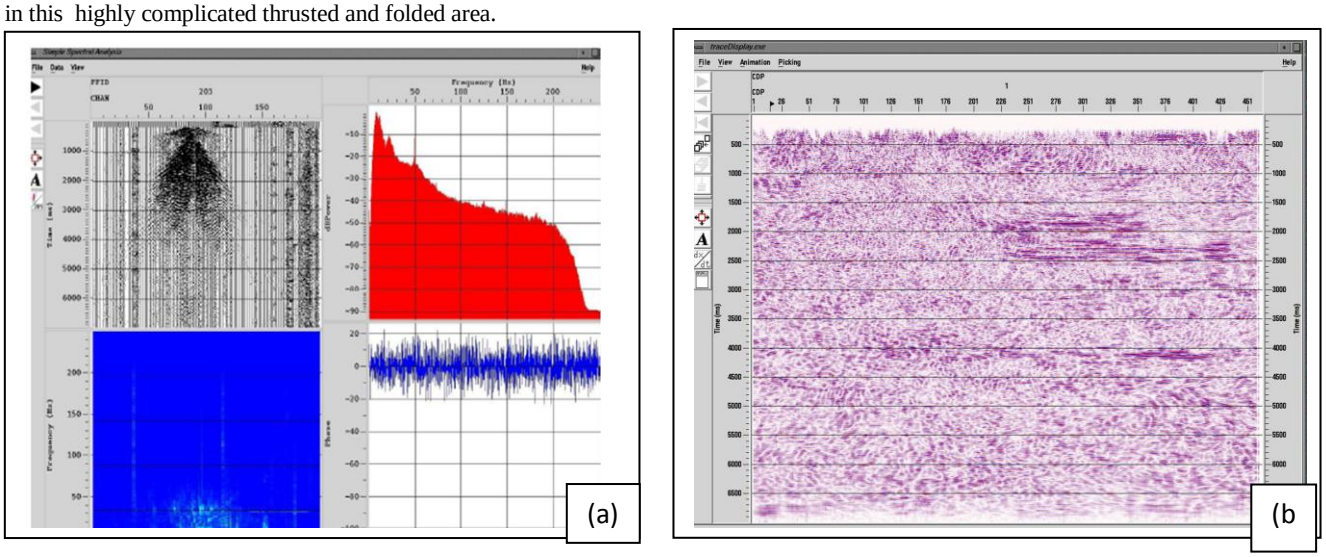

Figure 8. A seismic record taken at 1 m shot hole depth shows poor energy reflection and its amplitude and frequency spectrum (a) and the Stacked section (b)

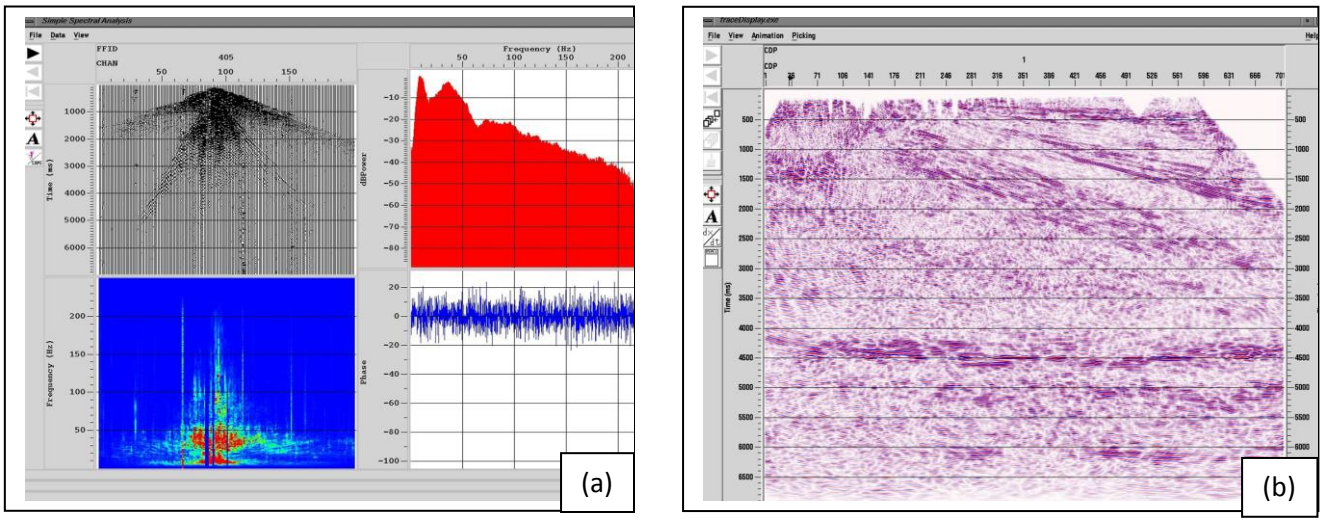

Figure 9. A seismic record taken at 10 m shot hole depth shows better quality of records and its amplitude and frequency spectrum (a) and the stacked section (b)

Conclusion

The area of operations situated in Assam-Arakan Basin close to the foothills of Himalayas in the Belt of Schuppen (Thrust Belt) to the South East facing the upper Assam foreland shelf. The area having undulating topography, complex and covered by intense forest. Seismic data has given reasonably better subsurface image where shot hole depths are deeper causing energy penetration and good refletions. However seismic data acquisition is a great challenge for the geoscientists, if the area is geologically complex and logistically difficult. The energy penetration into the ground becomes very limited due less shot hole depths causing poor subsurface imaging. KB-10/13 drilling rigs are introduced and drilled shot holes successfully from 10 m to 20 m. The data quality has been remarkably improved. The results from the comparative study are analysed and highlighted in the text.

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