



**2D High Resolution Seismic Survey for Coalbed Methane Exploration-A Case Study**

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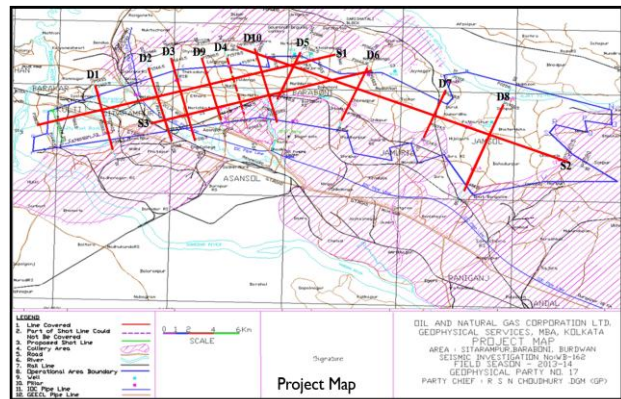
**Summary**

Over the years seismic survey is being carried out in Bengal Basin, but it was for the first time that the survey was done for Coal Bed Methane (CBM) exploration. CBM is a natural gas entrapped in the coal seams underground. Coalbed methane is distinct from typical sandstone or other conventional gas reservoir, as the methane is stored within the coal by adsorption. The methane is in a near-liquid state, lining the inside of pores within the coal (called the matrix). The open fractures in the coal (called the cleats) can also contain free gas or can be saturated with water. High rank coals at depths varying from 200m-1400m are generally considered as prospects for CBM exploration. So for the exploitation of CBM identification of the thickness, depth and continuity of coal seams is essential apart from the identification of fracture, faults etc. within the coal seams. The survey area lies in the CBM Block of North Raniganj, Sector-A in the Burdwan District of West Bengal. The coal fields of the survey area mainly have coals in Barakar and Raniganj formations. The area is also marked by various intrusive bodies such as dykes and sills etc. The High Resolution Seismic survey carried in the area comprised of 10 dip lines and 3 strike lines amounting to a total of 80 LKM.

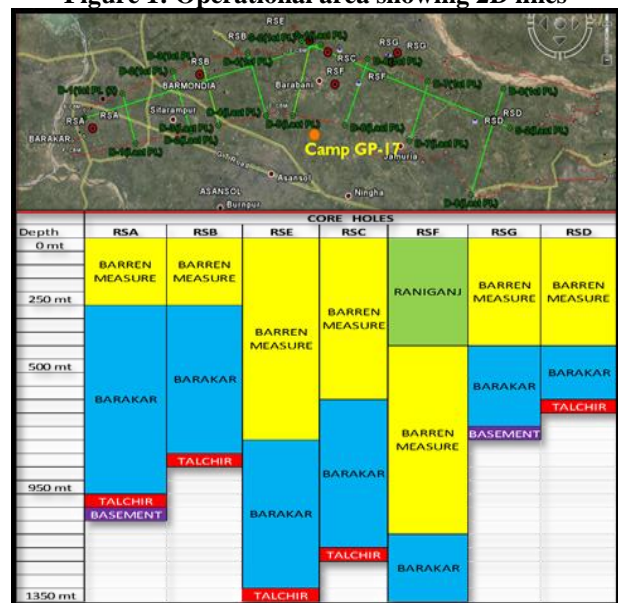
**Introduction**

For Coal Bed Methane (CBM) it is necessary to map the subsurface coal and to detect other spatial properties of the coal seam with a high degree of accuracy. Effective CBM exploration requires coal seams or zones of coal seams to be mapped in detail. The resolution required for coal seam mapping is in the order of a few meters, both vertically and laterally. Drilling can obtain detailed information at the well location about the coal seams but it is neither cost effective nor it can map lateral facies variations either within the coals or within the sediments that host the coals. Here the geophysical technology plays a vital role. This project of 2D High Resolution Seismic Survey (HRSS) was carried out in CBM Block of North Raniganj Sector-A with the objectives of mapping the areal extent of the coal seams in the subsurface and mapping of basement configuration as well as detecting presence of other geological bodies like the dykes or sills, which were present either as exposures or concealed in the subsurface. The imaging of these geological bodies is very much critical in developing Coal Bed Methane (CBM) as these intrusive bodies lead to the burning of the nearby coal and hence mapping them will help in estimating the correct

volume of the coal present in the area. Dykes have a direct effect on coal quality. The hot molten rock reduces the volatile content and cinders the coal seams. Thus, if dykes are properly modeled, these areas can be avoided while CBM exploration. By the modeling studies and data from 7 coreholes (Figure 2) drilled in the survey area it was found that coal seams varying from 1-12 m thickness were present in the area at a depth between 300 m to 1300 m. Hence to resolve these thin coal beds of shallow depths a 2D HRSS survey was carried out in the survey area. The Operational area with the 2D lines (Dip lines and strike lines) is shown in Figure1.



**Figure 1: Operational area showing 2D lines**



**Figure 2: Corehole correlation in the project area**

## Geology

The survey area comes under Raniganj Sub-Basin, which covers an area of 1550 sq.km, which is the easternmost member of the chain of Gondwana Basins. The basement of Raniganj sub-basin is represented by Archean metamorphic rocks. The basement rocks are unconformably overlain by **Talchir** Formation of Upper Carboniferous age. Talchir sediments are exposed along narrow irregular strip along the northern edge of the western half of the basin. Talchir Formation is conformably overlain by Barakar Formation, which is exposed as an irregular belt roughly parallel to the northern boundary of the coalfield. Eight regional coal seams have been identified within the Barakar Formation. The **Barren Measures** conformably overlies the Barakar Formation and is exposed as an irregular belt in the northern, north-eastern and western part. Raniganj Coalfield is the *Type Area* of **Raniganj** Formation, which conformably overlies the Barren Measures. **Panchet** Formation conformably overlying Raniganj formation is exposed in patches in the eastern, south-central and western part of the basin covering an area of 240 sq. km. The **Supra Panchet** strata unconformably caps the Panchet Formation at isolated outcrops in top of Panchet, Gaurandih and Biharinath hills, the three prominent topographic expressions in the coalfield.

Structurally, the basin shows a typical half graben configuration, elongated along a broad east-west trending and westerly plunging synform. The half-graben configuration is controlled by the prominent boundary fault to the south and haloclinal tilt of the basin floor towards it. Southern boundary fault dips steeply towards north with a throw of around 1000-1500m. Apart from the southern boundary fault (trending E-W to NW-SE), intra basinal faults also locally modifies the basin configuration, resulting in variation of bed dips. Intra-basinal normal faults trend NNW-SSE and WNWESE in the western part and ENE-WSW and WNW-ESE in the eastern part. Beds generally dip gently (around 10o), however, considerable steepening is observed near the boundary fault and adjacent to prominent intra-basinal faults. The most prominent intrusive in the Raniganj depression is the Salma Dyke which traverses across the coalfield from north to south dividing it into two halves.

## Objective of the Survey

The geological objectives of the survey are:

- To map Basement configuration
- To map vertical and lateral extension of coal seams
- To identify structural features (*presence of fault and its throw*)
- To identify Intrusive bodies

The Seismo-Geological objectives of the survey are:

1	Depth zone of interest	300 – 1300 m
2	Time zone of interest	200 – 1500 ms

## Field Procedure

Hydrocarbon targets are typically 1 - 5 km deep and so require lower frequency sources with a typical bandwidth of 8 - 60 Hz to generate a signal that can penetrate to such depths to provide a reflection. Hence conventional seismic surveys with greater shot interval and receiver interval as well as sampling interval of 2ms serve the purpose. Unlike conventional reservoirs, coal seams are the source, trap and reservoir for CBM. Very high frequencies and high bandwidth data is desirable for precise imaging of coal seams and the associated faults and fractures. Hence High Resolution Seismic Surveys are needed for CBM Exploration.

From the corewells drilled in the area and the modelling studies it has been found that the coal seam thickness varies from 1-12 m in the survey area. Accordingly a 2D high resolution seismic survey was planned in the area so as to map these coal seams and also to delineate the extent of the intrusive bodies such as sills, dykes etc. lying in the area. 10 Dip lines namely D1 to D10 and 3 Strike lines namely S1 to S3 were planned to cover a total of 80 LKM. The seismic survey was carried out using SVSM sensors with split spread geometry. The finalized field parameters based on the experimental surveys done are listed below.

Data Acquisition Parameters	
PARAMETERS	SURVEY GEOMETRY
Type of Spread Geometry	2D Split Spread
No of active receivers per line	600 (300+300)
Group Interval	5m
Shot Interval	10m
Fold	150
Spread Length/Max. Offset	2995.0m/1497.5m
Min offset	2.5m
Recording Instrument	I/O Scorpion IV (Digital)
Sampling Interval	1.0ms
Sensor	SVSM (3 component-MEMS)
Source	Explosive (Single Hole)
Charge Size	1 Kg
Record Length	6s
Record Format	I/O SEG Y

## Logistics and Difficulties

The survey area was a very logistically challenging area. It was an overlapping area with CIL, WBMDTC and JSWB Coal Blocks, Sitarampur and Kulti Coal Blocks of WBMDTC & JSWB were present in western part of area. The area was flanked by a lot of mining activities. Various Open Cast Mines & Active Mines as well as illegal mines were present in the area. IOCL & GEECL pipeline was passing through project area. Densely populated villages and towns e.g. Kulti and Niamatpur, Sitarampur, Nauni etc. were lying in the survey area boundary. Presence of stone crushers, railway tracks & busy roads (GT Road, NH 2), moving of heavy machineries in and around area also posed a great challenge in acquiring quality data. Also there were few approach roads to the seismic profiles which made the laying of seismic cables, positioning of recording instrument difficult. The logistics of the area is shown in Figure 3. There were frequent local agitations delaying the operation and leading to flip flop operations and revisiting single line.

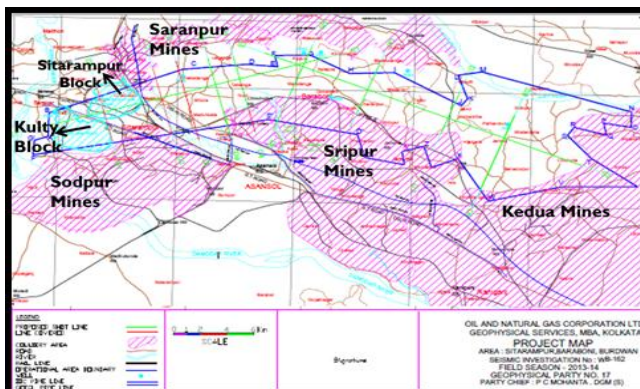


Figure 3: Logistic map of the survey area showing mine boundaries, IOCL pipeline etc.

## Special Efforts

Special efforts were made to acquire good quality data and overcome the logistic difficulties. Frequent meetings were done with the ECL, JSW etc and a mine boundary was prepared and overlaid on the survey area. Sometimes the flip flop operations were followed (Figure 4) leading to revisiting the same line to minimize the nonproduction days due to local agitation. Proper plantations and alignment of the receiver lines were ensured. The area was encompassed with several townships, opencast and underground coal mines and water-bodies. This accounted for certain skips, all these skips were monitored carefully and advance recovery planning was undertaken along with regular production to replenish the loss of fold.

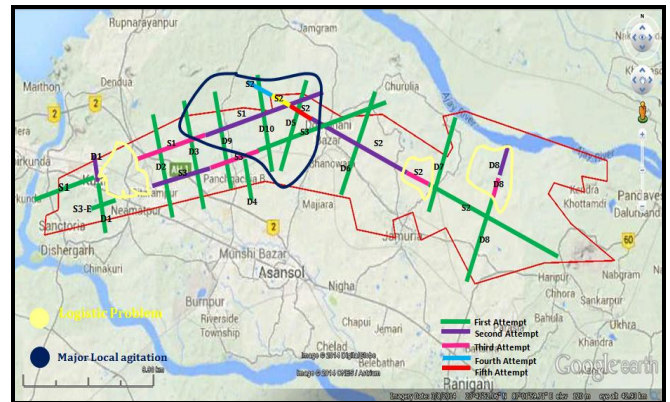


Figure 4: Flip flop operations in the project area due to logistic difficulties

## Data processing

The CBM data was processed at RCC Kolkata. Regular 2D processing steps were followed. Manual editing of data was done to remove high frequency noises due to stone crushers, mining activities, moving vehicles etc. The PSTM stack sections along line D-6 and S-2 is shown in Figures 5 and 6 respectively.

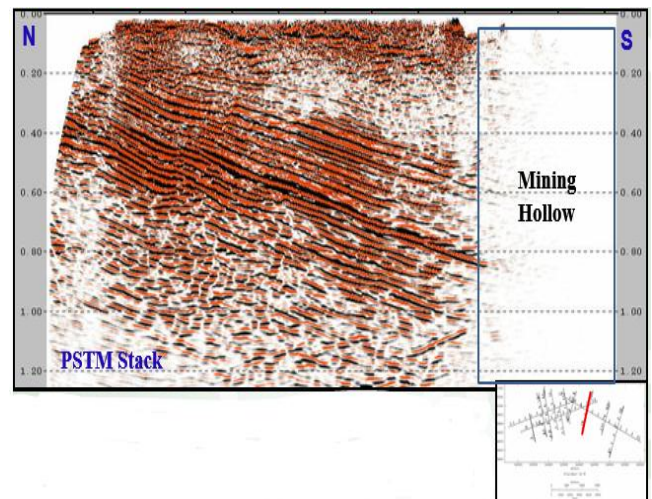


Figure 5: PSTM Stack along Line D-6

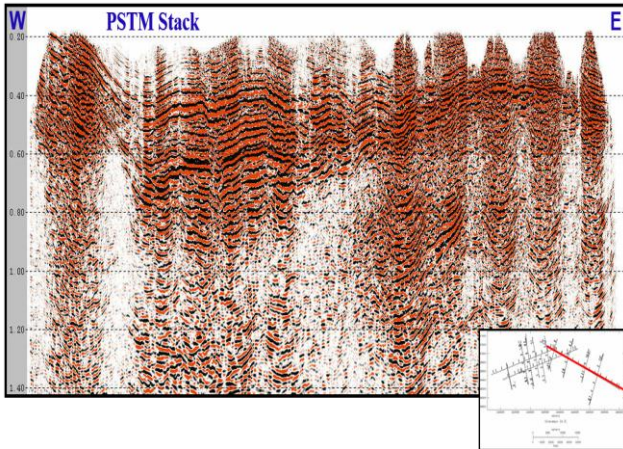


Figure 6: PSTM Stack along Line S-2

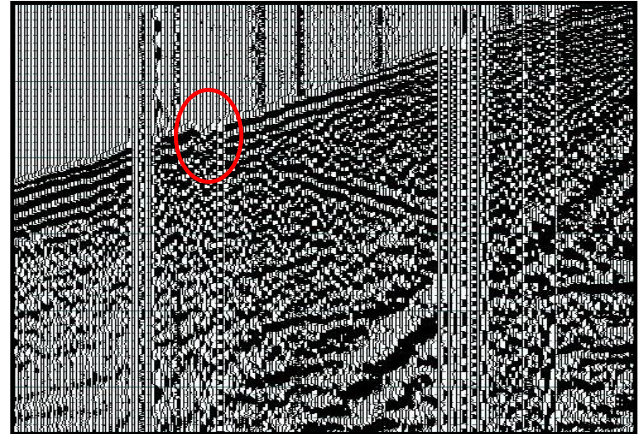


Figure 8: Anomalous first arrivals on the probable top of the dyke

## Results and Discussion

1. The party has been able to identify Dyke from raw shot gathers which was one of its primary objectives. The first arrival shows an anomalous trend on the raw shot gather which can be the probable top of dyke Figure 8. The prominent reflected arrival present in the gather due to the presence of dykes is shown in Figure 7 which complies with the NORSAR simulated section indicating the presence of dyke shown in the Figures 9 & 10. Weak or no reflections were observed on the side not facing the source point due to the presence of dyke.

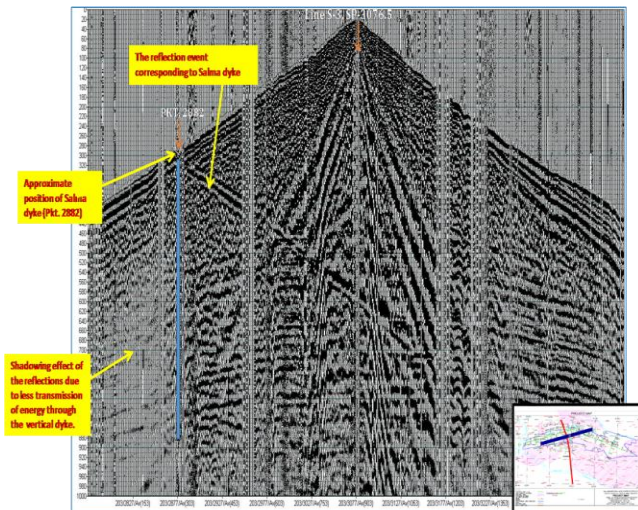


Figure 7: Raw gather showing the reflection pattern in presence of Dyke

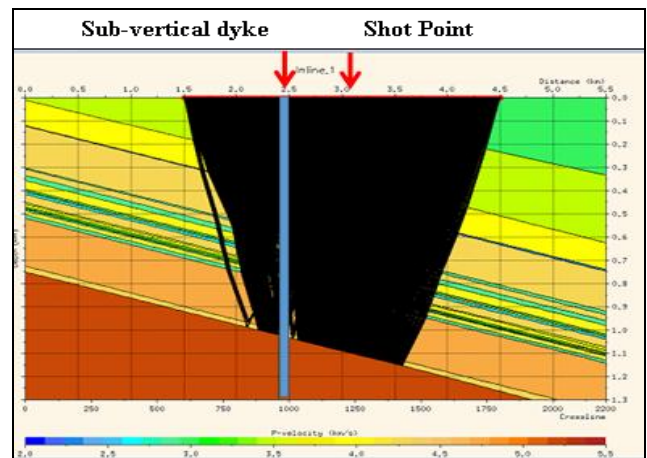


Figure 9: 2D Ray trace modeling on NORSAR for Dyke

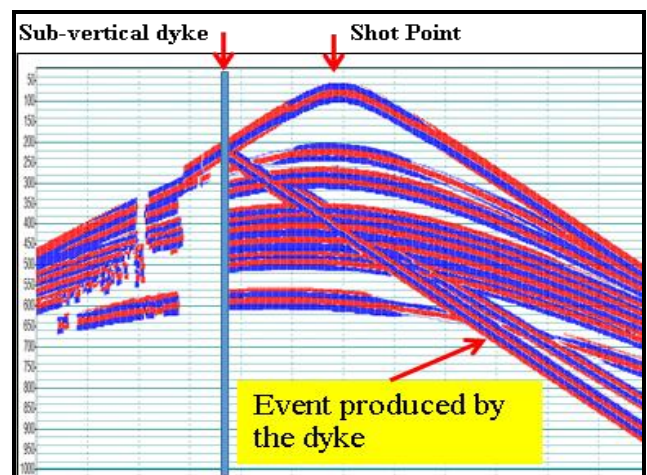
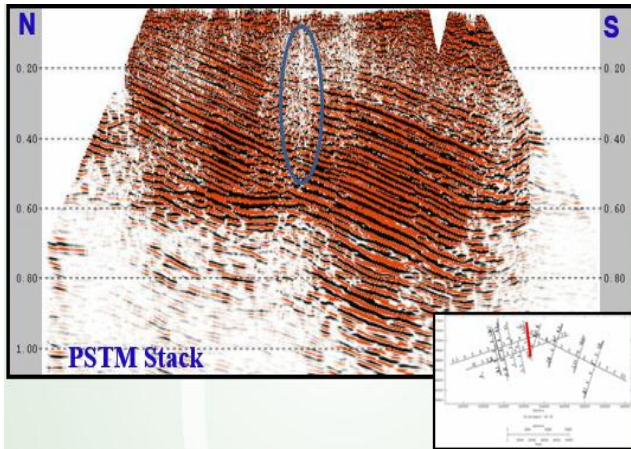


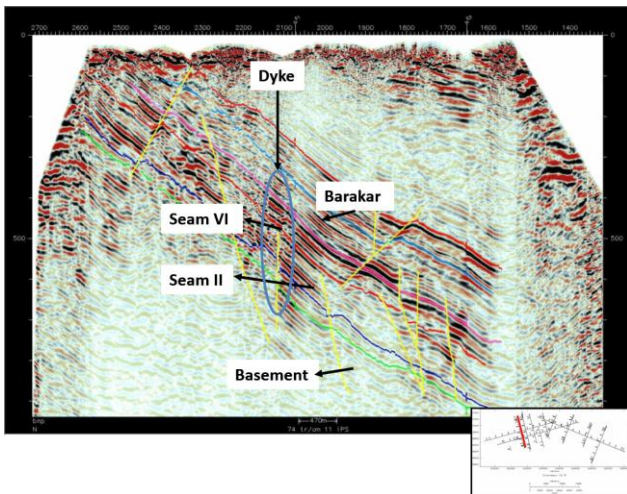
Figure 10: 2D Ray trace modeling on NORSAR with output shot gather

2. The presence of Dyke was confirmed on the processed sections also. Figure 11 shows the PSTM stack section along line D-10 where a no-reflection zone marks the presence of dyke.



**Figure 11: PSTM Section depicting Dyke Position in Line D-10**

3. Figure 12 shows the final interpreted section along Dip Line D-2. Two prominent coal seams and a dyke have been interpreted along the line. The reflectors are broken, sub parallel, discontinuous and patchy in nature.

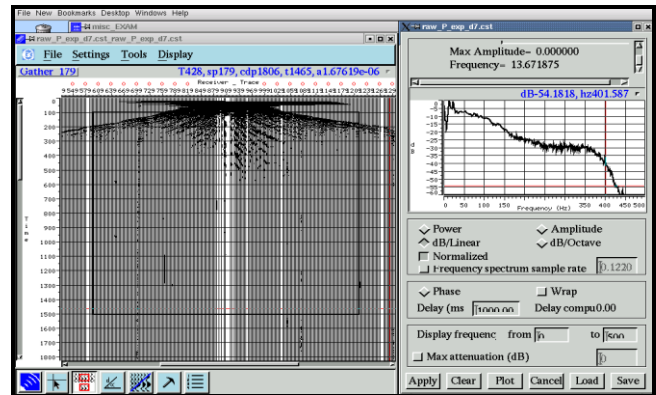


**Figure 12: Interpreted Seismic section along Dip line D-2 showing signature of dykes**

## Conclusions

High frequency seismic data acquired in this project helped in mapping of various coal seams present in the area which would not have been possible through a conventional

seismic survey. Moreover, it also helped in mapping of various intrusive bodies especially the Salma Dyke.



**Figure 13: Amplitude spectrum of a raw shot gather**

Stratigraphies of coal seams influence a seismic dataset. For a single seam environment, depth of coal seam will only marginally alter the seismic response with deeper reflection events suffering only a minor reduction in high frequency energy compared to shallow reflection events. However in multi-seam environment it is very difficult to extract a clean high resolution image of coal seams at depth. Seismic energy suffers a transmission loss as it passes through multiple coal seams in a geological sequence. Also in the present survey area there were several open cast and underground mines as well as illegal mines. The voids created in the subsurface by these mining activities resulted in severe transmission loss of the seismic signal. Thus seismic reflection events for deeper seams in multi-seam environment can be affected by poor signal to noise ratio. This can lead to seams being poorly imaged.

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