**Environment Friendly Seismic Surveys in Logistically Difficult Areas within Brahmaputra River-Bed – A Case Study**

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**Summary**
Recent hydrocarbon discoveries in Upper Assam have raised the hydrocarbon prospects of the Brahmaputra river-bed. However, difficult logistics and ecological fragility of the area makes conventional seismic surveys across the river-bed challenging. Oil India Limited deployed an in-house 2D seismic survey crew recently to undertake a seismic survey across parts of the river-bed. Using a mix of innovative survey design and operational methodology, the primary objectives of imaging the Upper Paleocene-Eocene sediments beneath the Brahmaputra river-bed was achieved.

**Introduction**
Upper Assam is one of the most prolific petroliferous basins of India. It is a Craton Margin Basin and can be subdivided into three parts: the Upper Assam Shelf, the Eastern Himalayas and the Naga Hills. The Upper Assam Shelf is constituted by a hidden basement ridge overlain by Upper Paleocene to Pliocene sediments; this is overthrusted to the northwest by the Eastern Himalayas and to the southeast by the Naga Hills. Course of river Brahmaputra, flowing east-west across Upper Assam, is considered the surface manifestation of the hidden basement ridge and divides the basin into two distinct units.

Oil India Limited (OIL) has been engaged in hydrocarbon exploration in Upper Assam for several decades now. Areas lying on the south of river Brahmaputra have been extensively covered by seismic surveys and numerous structural and stratigraphic plays have been established so far. On the other hand, seismic surveys have been undertaken in areas lying on the north of river Brahmaputra as well, and several identified structures have been probed through drilling. However, no commercially viable hydrocarbon reserves have been established in the area, though indications considered favourable for accumulation of hydrocarbons were encountered.

Several hydrocarbon bearing structures identified in areas lying on the south of river Brahmaputra has been found to extend deep into the riverbed. However, no commercial discovery of hydrocarbons made so far in areas lying on the north of river Brahmaputra. Therefore, seismic surveys across the Brahmaputra riverbed are key to further delineation of discovered hydrocarbon bearing structures on the southern bank on one hand, and illumination of structures beneath the riverbed and their role in Petroleum Geology of Upper Assam. The average width of the riverbed is about 18 to 20 Km. Primary targets for exploration in the riverbed are the Upper Paleocene-Eocene sediments that occur at depth range of 3500 to 4500m. The dip of the formation is generally gentle and is in the range of 5 to 7 degrees.

Notwithstanding its necessity, seismic surveys in a regular grid have not been attempted so far across the Brahmaputra riverbed due to difficult logistics. Rich flora & fauna and the ecological fragility of the area have added to the challenges. Therefore, it is recognized that any attempt to undertake seismic surveys across the riverbed has to be environment friendly. Given the constraints, an in-house crew was deployed to carry out seismic survey operation over parts of the riverbed. The area covered by the survey is shown in Figure-1. We present in this paper a case where the use of state-of-art technology acquisition technology and innovative data processing aided in overcoming the challenges and in realizing the broad objectives of the survey.

**Logistics & environmental challenges**

The Brahmaputra riverbed comprises of innumerable river islands, river channels and vast marshy land and remains submerged under water during major part of the year. Country or motorized boats are the only means of communication available to ferry men and material. The main streams of the river are quite wide at places (2-2.5
The riverbed is rich of flora & fauna and natural habitat of several rare species of fresh water dolphins and migratory birds. Marshes in the area are often used for fresh water fish cultivation and is a major source of employment and revenue. At several places, the marshes are home to migratory birds and have been have been declared as protected as Bird Sanctuaries.

Vegetation in the area is primarily restricted to elephant grass. Most of the area is covered with a thick column of sand and the ground water level in the area is shallow, leading to high aquifer pressure in the near surface.

The above constrained the seismic survey in terms of the following: -
a) Conventional energy source viz. dynamite or air-gun could not be fired in the vicinity of water bodies due to habitats of aquatic life.
b) It was not possible to lay and anchor hydrophones and OBC due to strong current and undulating river bottom.
c) Difficulties in shot hole drilling due to strong aquifer pressures in the near surface. Shallow holes would result in poor energy penetration into the subsurface.
d) Since the area is declared protected, noise pollution and strong shock waves in any form had to be avoided.
e) Safety of crew personnel is a major concern in river-bed survey. Crew members had to be suitably trained in order to mitigate the hazards in undertaking the survey.

**Acquisition methodology**

In order to overcome the challenges highlighted above, the following methodology was adopted during acquisition:

a) **Recording system & ground electronics:** Considering the logistics of the area it was felt that the conventional line telemetry system with microwave links would be unsuitable. Instead, the state-of-art radiotelemetry data acquisition system was deployed for the operation wherein Station Units (SU) are not required to be connected physically with the Central Control Unit (CCU). The SUs are connected with the CCU placed in a remote location through radio link.

b) **Operational plan:** Taking into account the operational ease, without compromising the broad objectives of the survey, it was decided to implement an ‘end-on’ shooting spread. Since the area comprised of numerous river islands separated by river channels, it was decided to shoot individual lines in small parts and then put together so that the movement of ground electronics at any point of time could be minimized. A number of fly camps set up at various points along the profile served as the hub for operations.

c) **Safety considerations:** Narrow river channels flowing with rapid current could be negotiated only by deploying small boats in order to ferry men and materials. This made the working conditions hazardous. Crew members were sensitized about the hazards in undertaking the survey and imparted necessary training on survival techniques. The working hours were also limited so that operations did not stretch beyond sunset under any circumstances.

d) **Shot hole drilling:** The shot holes drilled in the area were prone to collapse due to shallow groundwater level in the area. Further, the thick column of sand lead to poor coupling and low penetration of energy into the subsurface. The possibility of increasing the charge size and casing the shot holes were explored, but were discarded for the fear of disturbing the natural habitat of rare species in the area in the form of sound waves and strong ground rolls. Instead, the shot holes were drilled using bentonite and loaded with the optimal charge size immediately on completion.

e) **Compensating low fold and missing offsets:** In order to ensure environment friendly operations, it was decided not to use any type of energy source i.e. dynamite / air-gun in river channels and marshy areas. Further, it was not possible to lay out hydrophones or
OBC in the major channels due to strong current and uneven river bottom. The impact of these skipped shots and receivers on fold and offset distribution in each CMP was simulated. It was observed that skipping of shots and receivers in such large numbers would lead to poor imaging of target horizons beneath the riverbed (Vermeer, 1990). The possibility of compensating for the skipped shots and receivers was explored by simulating compensatory shots recording a reversed ‘end-on’ spread, having unique shot-receiver combination, without duplication of the fold. It was observed that in most of the CMPs, the low fold and missing offsets could be recovered. Across the wider river channels, shallower offsets below 1500m were missing for several CMPs. Since the target horizons for the survey were the Eocene sands at 3500 to 4500m depth, it was still considered adequate for imaging the zone of interest. It was decided the impact of missing shallow offsets during velocity analysis would be negotiated during the processing effort. A comparison between the fold and offset distribution before and after compensation is shown in Figures 2a & 2b.

f) Deployment of Marsh Geophone: In order to minimize the number of skipped receivers, efforts were made to deploy marsh geophones wherever possible viz. in standstill water bodies, abandoned river channels and swamps, except under situations where the conditions did not permit deployment at all. Innovative buoys in the form of wooden planks, rubber floaters and small country boats were used to keep the SUs afloat.

g) Survey Technology: There are no permanent topographic features and benchmarks available in the river-bed, which could help in surveying the reference points. Every crossing between the seismic lines were surveyed using latest Differential Global Positioning System (DGPS) to serve as control / reference point. Electronic Total Stations were used to stake out shot and receiver points with high accuracy.

Data processing

a) Statics Computation: Due to difficult logistics in the area, Up-Hole / LVL surveys could not be carried out in a regular grid intervals. Therefore, refraction static was computed from the first break.

b) Velocity modeling: In spite of best efforts to compensate for the low fold and missing offsets across the wider channels, several CMP were deficient in offsets below 1500m. It was feared that in absence of shallow and intermediate offsets for CMPs lying beneath the river channels, the velocity estimation using conventional techniques might not be reliable. To overcome this problem, the missing velocities were interpolated from adjacent CMPs where entire velocity profiles were available. In order to account for lateral velocity variations, a correlation between the structural trend and velocity profile in the area was established. It was observed that the lateral velocity variation more or less follows the structural trend.

Results

Despite the severe constraints in undertaking a conventional seismic survey in the Brahmaputra river-bed, innovative acquisition and processing techniques helped in realizing the broad objectives of imaging under the river-bed. Processed data from the area illuminated the horizons belonging to Upper Paleocene-Eocene, which are the exploration targets in the area. A composite seismic section A-B-C (Refer Figure-1) is shown in Figure-3. As is clearly evident, the section shows good resolution of the reflectors and perfect tie between intersecting lines at the crossing points.

Conclusions

This paper demonstrates how application of innovative techniques in undertaking 2D seismic surveys in a logistically difficult, hazardous and environmentally protected river-bed area with rich biodiversity.

Despite severe constraints in during acquisition that could have potentially marred the basic objective of the survey, through deployment of suitable equipment and a mix of innovative survey design and operational methodology, the primary objective of imaging under the Brahmaputra river-bed could be achieved. This data will be invaluable in furthering out understanding of the Petroleum Geology of Upper Assam, and evaluating hydrocarbon prospects in areas north of river Brahmaputra.

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Reference