Preamble

The rapid expansion of Geophysics during the past few decades has opened up a new era of state-of-the-art technology for hydrocarbon exploration and development. However, the story of oil exploration in India began in dense jungles and swamps in the extreme north-eastern corner of Assam in the early years of 19th Century. The petroleum industry in India which started off in 1890 with the discovery of Digboi oilfield in Upper Assam has during last five decades intensified its activities in various sedimentary basins in India Digboi where oil was discovered by the antecedent companies of Oil India Limited from the direct evidences of seepages and outcrops. This ushered the country in an era of petroleum, is perhaps the oldest producing field in the world today. The evidence of oil in foothill areas led to the speculation that oil might be also be present in the adjacent areas at much deeper levels. To study hydrocarbon occurrence in these deeper horizons, some new technique was felt necessary such as geophysical methods, which were deployed in those days to establish many medium to large size oil & gas fields.

The geophysicists in Upper Assam forged ahead from torsion balance surveys in 1925 to the area of gravity, magnetic and seismic surveys and efforts have been made to enhance the exploratory activities utilising these methods in order to establish hydrocarbon potential. With ever increasing demand of energy, the indigenous hydrocarbon production could hardly meet the nation self-sufficient due to continual growth in population. Government of India has taken many steps to accelerate the pace of exploration and production in the country. Geophysics has been playing an important role right from 1960s with the invention of digital equipment for data acquisition and computer for the processing. OIL has been adopting such geophysical technique from time to time.

Past (1925 TO 1976)

Oil industry was fortunate enough that such technique was available which was originally designed for studies in Geodesy as branch of mathematics dealing with figures and area of the earth. This technique was successfully adopted for geophysical surveys for oil in the Gulf Coast of USA in 1922. As sciences go, Geophysics is relatively young. It came into limelight only in 1924 with the discovery of number of oil bearing structure in the USA.

This technique was of EOTVOS torsion balance which was also used at Bordubi (Assam) in India during 1925, on the plains west of Digboi (Assam) by a Geophysical team from Eotvos Geophysical Institute, Budapest. But due to some interpretation problems, the idea of drilling was dropped even after discovery of Gravity high at Bordubi. It was during 1930s that much progress was made in the development of Geophysical methods of Exploration, for oil & gas. The torsion balance was unproved and ultimately replaced by the gravity meter while the development of seismic method established itself as an effective tool for subsurface mapping.

In 1937, an important forward step was taken which acted as a breakthrough in Geophysics. The Burmah Oil Company jointly with British Petroleum proposed to Govt. of India to carryout Geophysical survey of all the plains in India and the proposal was accepted.

During those days, rules governing the search for oil were framed under geological surveys and could not be found suitable for carrying out geophysical exploration. Therefore, a new form of grant was formulated known as a Geophysical License issued by Assam Government. The grant was for giving the exclusive rights to carryout geophysical surveys for a period of 5 years.

In accordance with the terms of the geophysical license, the Assam Oil Company began gravity and seismic survey of the alluvial area of Upper Assam. Although the gravity survey would not likely to give sufficiently precise evidence but resulted in defining the promising area in which seismic surveys would be taken up.

Seismic surveys were undertaken by Assam Oil Company Ltd in 1938 strongly suggested a “Seismic High” at Nahorkatiya (Assam) which was near to Bordubi high though but not coincident as discovered. The seismic high so discovered was concluded for drilling but the indications were that structure would probably be deeper than 3000 meters. Drilling technology had not been sufficiently advanced by that time for reaching such depths safely. It was only in May 1952 that drilling could be taken up on this structure and this resulted in the completion of Nahorkatiya-1 well as an oil producer. The popularity of Geophysics had begun particularly seismic surveys started gaining the momentum for oil & gas exploration.

Immediately after discovery of NHK-1, gravity survey of the whole alluvial area using the unproved methods for aeromagnetic survey and seismic surveys in selected areas were carried out. The seismic surveys were carried by a British firm called SSL (Seismograph Services Ltd.) based on the results of which a number of structures were identified for drilling. During this period, a structure was delineated based on seismic surveys which relatively resulted in the discovery of Moran oilfield in October, 1956.
The period of hectic geophysical activity began in 1953 and continued since then to far-flung areas of Upper Assam up to 1957. There was no geophysical survey until 1963 but the time was utilised for considering the vast amount of information gathered and interpretation of data.

After incorporation of OIL INDIA LIMITED in 1959, the work of data compilation and interpretation was continued as stated and seismic data acquisition work was resumed in 1963 by hiring the services of SSL during 1963-64 and ONGC in 1964-65. That time the seismic data used to be recorded on analog magnetic tapes instead of on the paper records as done in the past. During these years, the surveys were also extended to the concessional areas falling in state of Arunachal Pradesh.

The introduction of the digital computer made a revolutionary impact in the geophysical industry. OIL had immediately adopted the technique of converting the data into the digital form which was earlier recorded in analog form. Since OIL did not have its own computer during those time, the digital seismic tape were then processed in the computer centers abroad and also in the ONGC Computer Center at Dehradun.

Seismic surveys were carried out every year from 1969 to 1974 by hiring seismic party from ONGC. The surveys were extended to most difficult area of our concessional areas falling in Jorajan (Assam) which had long been considered to be promising from geological point of view. Revolutionary advancement and changes in geophysical technology have significantly made an impact for recording of seismic data in digital format directly and processing thereof with the invention of digital computers. The remarkable changes in quality of data recorded and processed made the geoscientists feel more confident about the geological interpretation of seismic sections.

With the deployment of CDP (common Depth Point) technique in seismic surveys in the concessional areas of Assam held by OIL, a number of small & medium sized oil or gas fields such as Jaipur and Moran were discovered.

During 1972-74, OIL has also carried out detailed gravity-cum-magnetic survey in Manabhum area with the assistance of a Crew hired from ONGC. It was difficult to carryout seismic survey in these areas due to logistics problems, and Geophysicists had to get satisfied with whatever collection of data was possible on gravity and magnetic for obtaining some sub-surface information. The effectiveness of gravity and magnetic methods as reconnaissance tools could be increased by application of computers for generating computer programme for simulating the gravity and magnetic effects of subsurface, structures.

With the rapid development of digital electronics in computer industry, a number of digital seismic recorder started appearing in the international market, which could record seismic signals with greater accuracy, which was not possible with ordinary analog equipment.

Present (1977-2000)

During the late part of seventies, OIL drew up a plan to undertake in-house exploration activities in Assam & Arunachal Pradesh.

Geophysical Exploration in North-East

OIL did not hesitate to step into new digital revolution era and procured Digital Field System-V, popularly known as DFS-V and commissioned the same in February 1977 for deployment in the field for augmenting the exploration efforts of the Company.

To meet the growing demand for seismic data in order to generate drilling prospects, four digital seismic recording equipments were procured during the period 1984-1986 and an even number of additional seismic crews were raised.
Consequently, five seismic crews were in operation from 1987 onwards in various lease areas within Assam and Arunachal Pradesh. OIL has acquired about 37485 SLKM of 12/24/48 fold seismic data by deploying its in-house crews till year 1999-2000, which have yielded a large number of drillable prospects.

OIL has also commenced geophysical exploration in North Bank areas using in-house resources during middle eighties and acquired 2-D seismic data in Jonai area. Over a period of time, seismic data acquisition was accelerated across river Brahmaputra and OIL acquired additional PEL in Lakhimpur and its adjoining area and set up its project office at Guwahati. Based on data collected from ONGC and acquired in-house, OIL has so far drilled five wells in the North Bank of river Brahmaputra.

With the advancement of success in acquisition, processing techniques and interpretation thereof, using workstations a number of locations were released for drilling in those areas. Need was felt for deployment of 3D seismic data acquisition systems for these fields which were already developed based on the discovery using 2D seismic data. Accordingly, the First 3D seismic data acquisition System (SN-368) was deployed during the year 1993.

OIL has been in operation since and has acquired 1073.77 Sq.Km. of seismic data till year 1999-2000. The data has been successfully utilized for delineation of several structural and stratigraphic prospects. The data is also being routinely integrated with reservoir studies to understand and arrest the declining production trend of the aging fields from Assam.

Seismic data acquired during the seventies by hiring services and through deployment of in-house crew were initially processed using IBM computer at ONGC facility at Dehradun. To meet the growing data processing needs of the organization, development of infrastructure and commissioning of the state-of-art MEGASEIS processing system in 1980 at Duliajan. In-house processing on the system commenced from the same year and continued till 1990, when it was finally decommissioned, during which about 44587 SLKM of 2D seismic data was processed. The system catered for all seismic data processing requirement of OIL from its operational areas in Assam, Arunachal Pradesh, Mahanadi offshore & onshore, apart from seismic data from various spheres of ONGC. The system was also used extensively for reservoir simulation and modelling studies.

Between 1990 and 1992 OIL’S seismic data was processed by hiring services from M/s. Computech Limited at Calcutta. A total of about 3415 SLKM of 2D seismic data from Assam and Arunachal Pradesh was processed during the period.

Following the decommissioning of MEGASEIS processing system in 1990, CYBER 830 seismic data processing system was procured and installed at Duliajan in 1991. The system was equipped with the GEOMATIC software for data processing. Processing work commenced on the system from 1992. During the period from 1992-1996, about 30723 SLKM of 2D data from Assam, Arunachal Pradesh and Ganga Valley Project was processed on the system.

With the commencement of 3D seismic surveys in OIL’S operational areas in 1992-1993, the 3D data could not be taken up for in-house processing on CYBER 830 due to system limitations. Hence the data was taken up for processing by hiring the facilities of CGG-Pan India Ltd. at New Delhi. In-house 3D data processing capabilities necessitated upgradation of processing system capabilities. Consequently, the CYBER 830 system was replaced with the state-of-art ProMax 2D/3D processing system in the year 1996.

Introduction of Interactive Seismic Data Interpretation System during the eighties was a significant step towards reaping the benefit of integration of developments in Petroleum Geophysics & Information Technology in hydrocarbon exploration. During the later part of eighties,
OIL procured five interactive interpretation workstations for 2D and 3D seismic data interpretation during 1988-89 and installed them at Duliajan. The workstations were equipped with software for 2D and 3D seismic data interpretation, geoscientific data integration and imaging. With the induction of these workstations, OIL entered a new era in adoption of interpretation technology. All 2D & 3D seismic data interpretation work has been carried out since then on these workstations using in-house expertise. The workstations were in use till the beginning of 2000 when they were replaced with the state-of-art GeoFrame 3.7 Interpretation Workstations with Voxel Visualization technology for volume rendering.

OIL’S future thrust in the northeast for geophysical exploration will be on frontier areas. Areas identified for intensive exploration in the near future are logically difficult viz. thrust belt, areas covered with boulder beds & thick forests, and those lying under the Brahmaputra riverbed. Exploration in such areas calls for substantial capital investment and effective exploration strategy. Realizing the challenges posed by such initiatives, OIL recently carried out ground Gravity-Magnetic survey in about 4000 Sq.Km. of such area, which has yielded several leads for more detailed exploration in the form of seismic surveys.

Geophysical Exploration outside Assam and A.P.

The ultimate existence of an oil searching organization like OIL is dependent on the success of finding today, for the oil and gas requirement for tomorrow. OIL’S geophysical activities never slowed down and intact realising the importance of Geophysics for search of oil & gas, OIL has started taking concessional area outside Assam for extending its exploratory efforts outside Assam. And first such project was established at Bhubaneswar in State of Orissa.

Bay Exploration Project (Mahanadi onshore / offshore), Bhubaneswar

OIL has diversified its activities outside NE and a project was established as Bay Exploration Project at Bhubaneswar (Orissa) during the year 1977-78. For the first time, during 1978, OIL had carried out Aeromagnetic surveys through NGRI and seismic offshore surveys by Delta Exploration Inc. of USA in Mahanadi offshore areas. A total of 3178 line kms in offshore, 3800 line kms onshore alongwith 1575 line kms. Of DSS (Deep Seismic) and 7269 line kms of seismic in (North East Coast) NEC area was carried out. On the basis of these surveys, locations have been released for offshore drilling in Mahanadi basin and so far drilled 15 nos. of Exploratory wells out of which 7 offshore, 4 onshore and 4 on NE Coast. But no commercial hydrocarbon could see established, however, indications of hydrocarbons were obtained in few wells. Drilling operations have been suspended in 1988. Main part of area has been offered under NELP for carrying out further exploration.

Rajasthan Project, Jodhpur

Exploration for Hydrocarbons in Rajasthan was initiated by ONGC and later joined by OIL INDIA LIMITED for carrying extensive geophysical work in the Jaisalmer & Bikaner-Nagaur Basin when PEL over an area of 28600 sq. kms was granted in 1983. OIL started its exploration activities in 1984 and carried out vibroseismic surveys by hiring the services of Geophysical Company M/s Compagnie Generale De Geophysique (CGG), France. The seismic data acquired was processed at Computer Centre at Jodhpur, which was installed by CGG. A total of 11920 line kms of 2D and 300 sq.kms of 3D Seismic Survey was carried out.

Thus, OIL’S geophysical activities were not only confined to Northeast OIL INDIA LIMITED has expanded its geophysical base from eastern part to western part of the country. Based on the results of geophysical surveys, OIL has proposed and drilled many locations in these basin. The discovery of gas has been commercialised. OIL has been supplying natural gas to Rajasthan State Electricity Board (RSEB) for generating electricity.

OIL has also discovered heavy oil of 19.5° API based on the seismic surveys so far carried out by OIL. The efforts are on to bring this heavy oil to the surface by deploying the suitable techniques. So far, a cumulative of 46 wells have been drilled by OIL based on geophysical surveys.

Saurashtra Exploration Project, Rajkot

Geophysical exploration in Saurashtra offshore initiated during late eighties with the grant of 26000 sq.kms. areas in offshore. The Saurashtra Exploration Project (SEP) was established in 1989 at Rajkot (Gujarat) and the seismic survey in offshore areas commenced subsequently. A total of 8730 line kms alongwith Gravity Magnetic Survey was carried out by M/s Western Geophysical (WGC). Based on the results of the seismic data interpretation, three wells were drilled in the area without any commercial success.

Ganga Valley Project

OIL has diversified its activities for exploration in the areas of Ganga Basin after obtaining the PEL for 13000 sq.kms area known as Kashipur PEL area. The seismic data acquisition commenced in December 1990 by hiring the seismic contractor M/s Alpha Geo (India) Ltd. So far, a total of about 5000 LKM of seismic data have been recorded. The data have been processed in OIL INDIA LIMTTED’s own Computer Centre at Duliajan (Assam) and carried out the detailed geological interpretation.

A High Resolution Aeromagnetic Survey and low altitude 34221 LKM (HRAS) survey was carried out by hiring the services of AMSE wing of GSI, Bangalore. The results
of the same were also integrated with the studies of seismic survey along with the Remote Sensing and Geomicrobiological/Geochemical studies.

After combining all the geophysical investigations and geological studies, a exploratory drilling location was released for drilling near Kashipur area of Ganga Basin. The well was drilled down to 4816-m.

The seismic surveys in the Ganga Basin by OIL are still in progress in order to identify the future drillable prospects in the area.

Future of Geophysics

Petroleum Geophysics is a mature discipline now and finds its application in every state of oil field life cycle. There will be no slowing down of OIL’S geophysical activities both in data acquisition and data processing. Future of Geophysics lies in the frontier and logistically difficult areas to unfold such areas for future prospects for oil and gas exploration and exploitation.

Not only that, with the advancement in geophysical technology, the areas already covered with seismic and other geophysical methods such as gravity & magnetic, there is a need to deploy new geophysical tools. There are areas in USA, which have been seismically covered more than twenty times. Virtually every coverage, often with new tods and techniques, brought out a new truth and the repetition of the surveys in many cases led to the identification of new traps.

OIL’S major production today is from the Eocene reservoirs. Future activities, therefore, will also focus on the exploration of these Eocene sands. These reservoirs are thin, subtle and deeper than the productive Barail sands of the Oligocene age. These deep and subtle sand bodies will also demand a radically different approach to exploration. Further, as the shallower Eocene prospects reach a mature state in their life cycle, the focus of exploration within the Eocene will progressively shift towards deeper horizons. OIL intends to leverage its 3D seismic capabilities to discover and develop these subtle reservoirs. In future, OIL has a plan to cover all prospective areas in South bank by high quality 3D seismic survey.

Globally, Petroleum Geophysics is being extensively used in exploration as well as for optimal well placement during the development stage. It provides significant input for reservoir delineation, characterization and modelling. It is often used for online well path monitoring and also to obtain information ahead of the bit during drilling operations. This helps in successful drilling of wells through overpressure zones. 4D seismic surveys are being routinely used for reservoir monitoring and implementation of EOR schemes, apart from guiding in-fill drilling programmes. The dimensional aspect to Petroleum Geophysics has been added by acquisition of Multi-component surveys. Such surveys are yielding meaningful information viz. lithology discrimination, fluid mapping, flow monitoring, mapping of fractures, direction of anisotropy, direction of maximum stress, etc. OIL intends to leverage such technologies to the fullest in order to derive incremental improvement in it’s success rate in finding new hydrocarbon reserves, optimizing production from discovered fields and revitalizing the aging fields to step up production from them.

Conclusion

Petroleum Geophysics in OIL has played a vital role in identifying the drillable prospects not only in the areas of Northeast but also in western part of the country including Mahanadi onshore/offshore areas for exploration.

A total of about 11000 sq.km. of area has been covered by Aeromagnetic surveys in Assam & Arunachal Pradesh and 13,000 sq.km. in western U.P. In total, a total of 56% areas of Assam & Arunachal Pradesh have been covered by seismic alone and 44% of the area is yet to be covered out of the total PEL area held by OIL. About, 96000 SLKM

Dynamite blasting during Seismic Survey in Ganga Valley.
of 2D Seismic Data & 1100 sq.km. of 3D Seismic Data have been processed/reprocessed in-house till date.

Petroleum Geophysics has so far played leading role in the course of exploration history of OIL. OIL’s very high success ratio is the standing ovation to the successful application of Petroleum geophysics in exploration. The introduction of latest geophysical technology at right time has helped OIL in carrying out exploration on most cost-effective manner. It may be noted that the cost of production of hydrocarbon by OIL is lowest in the country.

The exploration works carried out in future are being challenging. The areas to be explored within Assam are logistically difficult and geologically complex. The reservoir sands are expected to be thin and deeper. The areas outside of Assam, though are promising, but will require extensive exploration work to establish the leads and prospects. In such areas the success ratio is bound to be lower than the maintained earlier.

Also, there are unconventional areas such as reservoir delineation, characterization, production monitoring, drilling where petroleum geophysics has found major role worldwide towards cost effective way of exploration. In fact. Petroleum geophysics is being used throughout oil-field life cycle from discovery to divestment to optimize the life cycle of a field and recovery. Application of Petroleum geophysics in these areas will increase many folds in future at OIL.

Petroleum geophysics is developing in rapid pace to deal all type of challenges imposed by logistics and geology. The key to the success and survival in the present challenging environment face by OIL will be undoubtedly the application and induction suitable geophysical technology.

**Acknowledgement**

Geophysical investigations got better, thanks to a group of engineers and geophysicists who develop the world’s most advanced acquisition, processing and interpretation systems. Timely deployment of such geophysical tools in OIL has played a significant role in hydrocarbon exploration.

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