Petroleum Geophysics in ONGC, India : A Memoir

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Petroleum Geophysics, a term, though not very commonly used, is an important pier in the foundation of Petroleum Industry. This branch of inexact science deals with application of modern concepts of rock physics and their pore fills leading to solutions of geologic problems related to finding and production of petroleum deposits.

Geophysical methods like Gravity, Magnetic, Electrical and Satellite imagery etc. are mostly used for reconnaissance purposes and though their contribution towards hydrocarbon exploration can not be undermined, it is the seismic technology, which has played the major role in exploration and exploitation of petroleum deposits. Seismic data acquisition, processing and interpretation have since evolved through tremendous innovations, keeping pace with increasing demands, for solutions to the geologic and engineering problems for economic development and production of hydrocarbons. We confine ourselves to the seismic interpretation and evaluation part here, in this memoir.

The narration is mostly from my memory and personal experience in ONGC (1959-96). ONGC being the oldest, largest and the premier E & P organization in the country, I believe, the chronicle also is a fair indicator of the history of Petroleum Geophysics in India during the period.

Petroleum Geophysics was born in 1957 in ONGC, when a number of gravity/magnetic and seismic parties were deployed as reconnaitary tools to gather data about different basins in India. The seismic techniques used during the late fifties and sixties were "Correlation point techniques" with analogues paper records of continuous profiling of single point, 100% data. Those were the days of mapping only the structural attitudes of prominent continuous reflectors without much idea about their lithology and depth of occurrence. There was more of computation than interpretation involved and it was common to come across "Seismic computation Offices" in big tents in field and in headquarters. The geophysicist doing the job was known as the "Seismic Computer".

The data, mostly of reconnaissance and regional nature, were mainly aimed at identifying the geological basins with their sedimentary fill and presence of large anticlinal structures. As a first step, the data provided valuable regional information, which were consequently used for assessing petroleum geologic parameters in the area for its hydrocarbon potential. However, notwithstanding the then prevailing seismic technology, a number of legible structures were drilled and met with early success in Gujarat and Assam.

In seventies, with introduction of the potent CDP techniques & computer processing facilities, the geophysicists, could not only map the structures in detail, but also predict depth of occurrence and lithology associated with the seismic reflectors from the analysis of NMO velocities. The first ever momentous application of such velocity analysis was on Bombay high. In 1971-72, interval velocity studies indicated presence of limestone reservoir in the structure. The geologists, however, were strongly in disagreement and in fact, suspected presence of any reservoir facies in Bombay High. However, the sheer giant size of the structure weighed for more in favor of drilling and the rest is annals today.

Subsequently, interval velocity analysis to predict lithology, especially in offshore data, (because of general good continuity and amplitude of reflectors), became a standard practice for assessment of reservoirs in a structure before recommendation for drilling. There were successes but some failures too. Velocity analysis results similar to that in Bombay High area lead to predict presence of carbonates in the M. Tapti & S. Tapti structures but the reservoirs turned out to be clastics. So much for the lack of understanding of regional geology.

In the meantime, oil production from the Bombay High had affected a tremendous spurt in exploration activities in ONGC. Seismic activities during 1975-80 were upped several notches to match vigorous drillings. Land seismic crews and computer processing capabilities were enhanced to a large extent and a departmental offshore seismic Vessel "ANWESHAK" was inducted in 1975. The exploration emphasis also shifted significantly to offshore basins and Anweshak acquired enormous amount of data both in east and west offshore basins. The interpreter was overloaded with data and worked hard to keep pace with increasing demands for mapping structural closures as prospective drilling locations. He was unable to monitor the drilling of prospects and the consequent results. He was always in a hurry; once mapping in an area was over, he was to rush to new areas where fresh data were pouring in, to map new prospects.

During this period due to accelerated exploratory inputs, a number of important discoveries were made both onland and offshore. Many large discovered fields in offshore were now awaiting delineation/development But dolefully, this was also the era of no (negative?) synergy between geophysicists and geologists. Cases of egoism versus arrogance persisted as could be seen in the case of Heera field.

The B-38 structure (later known as Heera) was mapped by the geophysicist at H3 and H4 seismic levels alongwith the customary H3-H4 time interval map-Seismically, the H3 horizon was seen to be terminating against the older

H4 horizon and the time interval map indicated absence of H3 formation on the crestal part of the structure. The first well drilled at the highest point, however, fortunately encountered a small thickness of H3 formation with oil. Cost intensive expendable wells were then drilled serially westwards to delineate the field, encountering progressively thicker oil columns till eventually testing water. The H3 and H4 horizons, were in fact, levels close to top and bottom of the reservoir and if the geophysicist had any inclination, he could have converted the time to depth and renamed the maps as top, bottom and gross reservoir thickness maps. These maps could then have been of immense help in providing vital clues to the geologists for planning the delineation and development wells more economically. Lack of entrepreneurship on the part of the maverick geophysicist failed to market his expertise and establish himself in the hub of the activities. The geologist, on his part, perhaps ignorant of the utility of a geophysicist, insolently proceeded to solve the problems single handedly with his intuition rather than with backing of any data.

The eighties, indeed, saw the veritable growth of Petroleum Geophysics in ONGC. Wide scale application of "Seismic Stratigraphy", an innovative powerful technique to understand evolution and evaluation of geological basins, lead to identifying potential prospects for drilling. Tremendous improvements in data acquisition and processing together with powerful interpretive tools like VSP, seismic attributes analysis and inversions (seislog) became very beneficial to the industry The geophysicist could now look beyond obvious structural closures to map subtle stratigraphic traps and reservoir geometry. Dependable depth maps could be prepared to predict reservoir depths, one of the most important parameters, in deciding locations for drilling of delineation / development wells.

In 1982, a small group of geophysicists was asked to work for the first time in the Development Geology group (Bombay Offshore) to help solve the geologic problems associated with field development and production. The group had an excellent synergy with the geologists and soon desired results followed. The existing data were reinterpreted; fresh time maps after seismic calibration with well data were made and converted to depth to provide structural configuration and geometry of reservoirs. This facilitated to a great extent in better estimate of inplace hydrocarbon reserves and also in deciding

suitable appraisal / development well locations. The synergists approach had its first important bearing on Bombay High field. In 1984, a number of flank water injection wells were planned to be drilled on the western side of the Bombay High field. Re - mapping of reservoir top, however, indicated that the depths were likely to be shallower than earlier mapped and consequently would have considerable oil in this part of the field. A few wells drilled later on confirmed the seismic predictions and this resulted in significant upward estimate of in place reserves and in suitable modification of the injection wells locations.

The late eighties, however, became the watershed in the field of petroleum geophysics with the induction of 3D seismic technology. Extensive 3D seismic surveys were carried out both onland and offshore. A 3D seismic survey vessel "SAGAR SANDHANI" was acquired by ONGC. With improved data resolution in both spatial and temporal domain, advanced processing software and powerful interactive interpretation workstations, data evaluation became sophisticated to take up the new challenges of reservoir mapping. The velocity computation for depth conversion, in general, became more reliable from 3D data, though in some cases the intricate problem remained under solved as in the case of Ravva field. The velocity field was extrapolated to the flank area from a number of wells unfortunately located in a line along the crestal part of the structure to prepare a depth map. Later on, an appraisal well drilled down flank encountered the reservoir top at a shallower depth proving the seismic prediction fallacious. Incidentally, it also encountered free water deeper than hitherto accepted OWC and the reserves and field worth jumped up considerably overnight !

Preparation of accurate depth maps has been always a difficult job and continuous to be the "Achilles' Heel" for the geophysicist despite large improvements in data quality and analysis. The enormity of extrapolation of a velocity field over the entire prospect, away from a handful of known velocity points, is well known to all practicing geophysicists. The geologists and the reservoir engineers, however, desired (rightly so) and expect an accuracy of at least ± 10m in depth prediction, which is difficult if not impossible, specially at greater depths.

The nineties, indeed saw the maturing of petroleum geophysics and geophysicists. The geophysicist had realised his role and responsibilities in exploration and exploitation of hydrocarbons alongside the geologist and the engineers. He had started involving himself in the petroleum geologic problems and had begun to understand the nuances of expressions like structural and stratigraphic straps, multiple and thin reservoirs, fluid contacts, porosities and saturations, pressure communications, aquifers and drive mechanisms etc. "Reservoir Seismic" came to focus as the most effective tool for the geoscientists. The geophysicist realised the need to move back and forth with existing seismic data and redo the maps, when and where necessary, with new information picked from well data and production behaviors. In some cases, where the existing data was considered not amendable to solve a specific geologic problem, a 3D or 4D data acquisition was recommended to the management. Interdisciplinary synergy between the geophysicist and geologist by this time well established was extended to include reservoir engineers. The petroleum geophysicist was forced to expand his knowledge domain to fundamentals of other disciplines for effective communication and interaction. It was also clearly

established by this time that the involvement of the geophysicist did not necessarily end with the drilling of the discovery well but continued through the process of development and production of a field and in some cases till depletion.

Epilogue

Sometime in 1992, a small group of dedicated geophysicists in GEOPIC, Dehradun spawned on the bright idea of forming an association of Petroleum Geophysicists. From that nucleus, grew the present SPG to its full glory today. The society has been an excellent platform for the Petroleum Geophysicists, of India and the world to launch programmes for training, to arrange expositions of state of art new techniques and technologies and most importantly, to provide continuing education to the non-technical managers who take crucial fiscal decisions in the Petroleum Industry. The geophysicist in the coming millennium is thus geared to have greater business and management responsibilities in vital financial decisions. He has to be more imaginative, combative and competitive and most importantly cost effective to uphold himself in the intricate industry of the future.