ID:2010635

EXPLORATION IN KERALA-KONKAN BASIN, WESTERN OFFSHORE, INDIA- WHY & WHY NOT?

A.K.Mullick, R.R.Sundriyal,D.K.Jha & P.H.Mane

Western Offshore Basin, ONGC, Priyadarshini, EE Highway,Sion,Mumbai-400022, India

Presenting author, E-mail: ***mullick1@rediffmail.com***

Abstract

Kerala-Konkan basin, western offshore, India though located contiguous to the prolific producer Mumbai high in the immediate north is yet to find a place on the hydrocarbon map of India even after four decades of exploration. Present paper deals with critical analysis of the geoscientific data and suggests the strategy for further exploration in this basin.

The exploration results indicate that Tertiaries may be devoid of hydrocarbons in the basin. Recently drilled well, exclusively, for Mesozoics had to be terminated within the basalt as the anticipated Mesozoic sediments turned out to be basaltic section with 100m section of limestone development within. Whether it is time to wind up Tertiary exploration or to go for exploration of Mesozoics. The biggest challenge is whether the entire basin can be discarded with this limited drilling in an area of five lakh square km. or exploration should be continued. Presently, conceptualized modeling for basin evolution, application of advanced techniques of seismic API, G M modeling, velocity analysis, look-ahead VSP and data synthesis of drilled wells could not conclusively decipher the thickness of Deccan basalt and presence of sediments below basalt in the Kerala-Konkan basin. Therefore, it is suggested to establish the Mesozoic basin first, that too, by "Drill bit only. Due to huge financial exposure, National Oil Cos. with government support should find out 'what is there below basalts' and make efforts to put Kerala-Konkan basin on the hydrocarbon map of India.

Introduction

It is generally accepted that India was formed initially by progressive break-up of Gondwana super continent during 150-180 my ago during Middle to Upper Jurassic time. This resulted in the creation of west Gondwana (Africa) and east Gondwana (Madagascar, Seychelles, India, Antarctica and Australia) which itself started to break up about 120-130 my ago.This led to rifting of Western India from Madagascar about 90 my ago during Mid Cretaceous as evidenced by the known magnetic anomalies and the presence of a suite of basalts along the east coast of Madagascar. Magnetic anomaly data from the Mascarene Basin indicates that in the Campanian, India and Seychelles migrated north-eastwards from Malagasy. In the Late Cretaceous, the ridge axis between Madagascar and India jumped towards India in the nascent Indian Ocean separating the Seychelles platform from India. With the sharp increase in the spreading rate and rotation since Late Cretaceous, the Indian plate moved northeastwards and there was a soft collision with Tibet (Asia) in the Late Eocene and further collision at the end of Mid-Miocene, initiating the Ganges-Brahmaputra and Indus fan systems. The genesis of the basin is linked to the vent volcanism at the end of Cretaceous as the Indian plate over-rode the Reunion Hotspot leading to the outpouring of effusive rocks known as Deccan trap, one of the largest volcanic provinces of the world. This created the first structural differentiation and development of landforms. The emplacement of Deccan flood basalts between 62-67 Ma was concomitant to the rifting of Seychelles micro-continent and was followed by rapid sea floor spreading, creating present day Arabian sea.

The offshore Kerala-Konkan Basin is a part of a contiguous chain of elongate northwest-southeast trending basins in western offshore, limited between two basement arches, one Vengurla arch, to the north and other Trivandram arch to the south.The basin is typified by the presence of the basin-ridge configuration, comprising of the following six contiguous NW-SE trending tectonic elements from East to West **(Fig.1)** such as Shelfal Horst-Graben complex,Kori-Comorin depression,Kori-Comorin

ridge,Laccadive depression,Laccadive ridge and Arabian abyssal. The regional line WC2K2-09 shows the different tectonic elements **(Fig. 2).**The Laxmi and Laccadive ridges are believed to be continental remnants which rifted away from the western continental margin and were subsequently affected by volcanism, in the latter case by Reunion hotspot which forms part of the Chagos-Laccadive-Maldive hotspot trail (Naqvi, 2005).

Exploration History

The Kerala-Konkan Basin covers toatal area of 5,80,000 Sq.Kms. including deepwaters having 660 MMT of prognosticated hydrocarbon resources. The first seismic survey was carried out in 1964 and the 1st well was drilled by DSDP in the year 1973**.**But the first well, exclusively for hydrocarbon exploration K-1-1 was drilled in the year 1978 and total 18 numbers of wells **(Fig.3)** have been drilled in the basin till date with maximum drilled depth of 6207 mts and maximum water depth of 2135 mts.The drilling results have not yielded any hydrocarbon find. Out of these, 12 wells are drilled in the shelfal part in the shallow water set up and 6 wells in tilted fault blocks, independent closures and mostly,are targeted to Tertiary sequences.The drilling results indicated the presence of all petroleum system elements except the source-cum-generation potential.Even the sandstone of Kasargod Formation and Limestones of Karwar and Quilon Formations are proved to be excellent reservoirs as they produced good amount of water on testing. The deepest well KK4C-A-1 drilled in the deep water set up, tragetted the a Tertiary stratigraphic play, though resulted in a dry well , established the Early Eocene shelf, slope and depositional systems. A number of deepwater fan lobes **(Fig.4)** are identified and the largest fan was drilled, penetrating 3969 mts of Tertiary sediments.Here also,good reservoir and cap facies are found to be present.The absence of matured source facies resulted in a dry hole. Therefore, the hydrocarbon prospectivity of Tertiary sediments is perceived to be poor and the exploration of Mesozoic sediments below the Deccan Trap in the basin is in focus presently.

Advanced techniques of API were applied in the basin utilizing Sea Bottom Node (SBN) based Wide Angle Refraction cum Reflection Profiling (WARRP) seismic data and velocity modeling of the SBN data could not decipher the presence or absence of Mesozoics as there was no appreciable velocity reversal. **(Fig.5).** However, the well KKMZ-E-1 was drilled to a depth 4789mts (WD:1578mts), targetting to explore the half graben geometry within anticipated Mesozoics. After drilling 1194 mts of basalt, the well was terminated within Deccan basalt as the anticipated Mesozoics turned out to be layers of basalts**(Fig. 10).**The well had to be terminated within basalts on the basis of look ahead VSP which did not indicate any velocity reversal and the similarity of seismic signature further down.Ultimately, the well was declared dry and abandoned.

Technology Induction In Seismic Acquisition & processing

Seismic surve commenced in the basin in the year 1964. Till date around 1,70,000 LKM of 2D seismic, 11000 SKM of 3D seismic and 50,000 LKM of Gravity-Magnetic survey have been carried out. During the course of continued exploration, various advanced technology was inducted in seismic acquisition and processing.Prior to year 2002, K series, RE series, 88 SI series and KL series 2D seismic lines were acquired with record length of 7 seconds (max) with 2 km. offset.Then WC series with 8 second record length & 6 km.offset,GXT lines with 16 second record length & 10 km.offset, long offset data with 12 second record length & 12 km.offset were acquired.All available processing techniques in the industry , including Beam PSDM were utilized. Acquisition by Sea Bottom Node (SBN) based Wide Angle Refraction cum Reflection Profiling (WARRP) data, with15 second record length,12km offset,40-160 km.SBN offset, was also adopted in the basin with special processing techniques.Top of the trap is mappable in all the seismics and parallel seismic events below trap top looks like reflections of seidement layers, which are assumed to be Mesozoic sediments **(Fig.6)** These layers ultimately turned out to be basaltic layers on drilling.However, gradually sub- basalt imaging though improved considerably, failed to map the trap bottom in the basin. **(Fig.7).**

Understanding Basalts In The Basin

Since Mesozoic sediments lie below the thick pile of Deccan basalt**,**understanding the spatial and temporal distribution of the Deccan traps is the key for the Mesozoic exploration.There are three distinct volcanic episodes in the Kerala-Konkan basin. These are: Early Late cretaceous continental

flood Basalt (85Ma), Deccan trap continental flood basalts (66-65Ma) and Laccadive ridge-reunion Ocean Island Basalts (62-58Ma).The lithostratigraphy of the basin is comprised of two different events of sedimentation, before and after the Deccan basalt eruption. This Deccan basalt is enormously thick and it forms the technical/acoustic basement for the overlying Tertiary sediments. The thickness and number of flows and its geographic variation are the important attributes for selection of areas and even for deciding the parameters for seismic data acquisition, and subsequent processing. The number of flows is directly proportional to the number of energy loss points/depths due to velocity variation. Even the entire GME cycle of the Petroleum system, more particularly, exploring the Mesozoic Petroleum system has got bearing on the distribution, depth, thickness, time (age), frequency and geo-chemistry of the trap/basalt flow. Imaging the Mesozoic sediments below the basalts by seismic surveys has always been difficult due to its horizontal and vertical anisotropy layering causing extensive seismic noises. Also penetrating the mesozoics by planned drilling also becomes costly due to the huge thickness, its uncertainty and unpredictable trend of occurrence over the area. Ultimately, for the Mesozoic exploration, the Deccan trap thickness has to be penetrated by the acoustic energy during acquisition and also by the cost intensive basalt-drilling. Therefore, mapping the trap thickness and number of flows is important.Even the high rate of basal heat flow during rifting and volcanic eruptions may affect the processes of hydrocarbon generation(Shah, 2010)

It is known that The Deccan Traps are one of the largest continental flood basalt provinces in the world, occupying about 500,000 SKM in peninsular India. The duration of activity was ranging from 0.5 my (Hofmann et al 2000) to 8-9my (Sheth et al 2001), with its peak at 65Ma (K/T boundary).The severity of the flow can be imagined from the fact that maximum stratigraphic thickness of the trap is reported as 3000m and as many as 29 flows are reported from 500m thick basaltic sequence in the on-land part of western India (GSI 2000). Similar variation in thickness and age over varied geographic location is also exhibited in the offshore part of the basin. Out of 18 wells drilled in the entire basin, basalts were encountered in 13 wells, with the unpredictable thickness ranging from 22m+ to 1316 m+. The remaining 5 wells were terminated before reaching the trap floor. The geological age of the flows in the various wells varies from 102Ma to 54 Ma.

Mesozoic Sediments in the Basin

Out of the 18 wells drilled in the basin, two wells (K-1-1 and CH-1-1) have proved the presence of Mesozoic (Late Cretaceous) sediments in the basin **(Fig.8).** The sedimentological and biostratigraphic data from this sequence has indicated dominantly marine sediments in CH-1-1, whereas, a non-marine sequence of dominantly sandstones with minor claystones is observed in the well K-1-1.The oldest sediments penetrated in the area have been dated to be of Late Cretaceous age (Maestrictian-Santonian (Ali, 1988, and Mittal, 1988) and assigned it as Cochin Formation in CH-1-1 well. The well bottomed in sub-aqueously extruded trachytes of pre-Santonian age that are probably equivalent to flood basalts present on the west coast of Madagascar dated at 90 Ma. The Cochin formation at CH-1-1 was deposited in an open marine upper bathyal to deep inner neritic environment, and consists of calcareous sandstone units separated by thick calcareous claystones and silty calcareous claystones. A total of over 1,000 meters of Late Cretaceous sediments were drilled in CH-1-1. Unfossiliferous gritty sands and gravels drilled in well K-1-1 between 1,177 m and 1,747 meters are interpreted to be of Late Cretaceous in age, representing a coastal plain setting landward of the marine facies penetrated by CH-1-1 and were deposited in a continental (fluvial?) environment (Zutshi et al. 2000)

Discussions & Conclusions:

Drilling through 3969 mts of Tertiary sediments in the deepest well KK4C-A1 in the best possible basin depocentre, did not indicate the presence of hydrocarbon in spite of finding good reservoir and cap facies.The absence of matured source facies resulted in a dry hole. Exploration results till date have indicated poor prospectivity of Tertiary petroleum system. Mesozoic Petroleum System largely remains in speculative realm because only two wells have indicated the presence of Mesozoic sediments without any hydrocarbon show.Deciphering the presence of Mesozoic sediments is not possible even after the application of all possible seismic acquision & processing technology.Velocity and GM modeling could not indicate the presence of sediments below the Deccan Basalt.

In any sedimentary basin, permanently calling off exploration is a very crucial decision for explorationists and similar situation prevails in Kerala-Konkan basin at present.Nearly 2500 crores of rupees have already been spent in course of the continued exploration in the basin.Moreover, drilling only 18 wells in an area of 5,80,000 Sq.Kms. is not adequate to decide the complete calling off

exploration.The geoscientific data gathered so far do indicate that Tertiary sediments are barren of hydrocarbons in the basin.The absence of hydrocarbons in Tertiary can be attributed to poor quality and quantitry of source rocks The PETROMOD study indicated that the entire Tertiary section comes in immature regime**(Fig.9).** Therefore, exploration can be paused for Tertiary sediments for the time being.

As far as hydrocarbon potential of Mesozoics is concerned it is early to draw a conclusion, since the presence of Mesozoic sediments have not yet been proved conclusively.Moreover, it imay be presumed that absence of HC shows in the Tertiary section may indicate absence of hydrocarbon generation even in Mesozoics.At many places, faults extend from below traps cutting through the entire Tertiary sediments and there is no hydrocarbon show within Tertiary sediments during drilling.Secondly, while drilling through Deccan traps in all these 13 wells, no hydrocarbon shows in the form total gas count or increase in background gas count were obsereved. It is worthwhile to mention here that there was gas shows in the Deccan trap section during drilling in case of Kutch Offshore wells, in which hydrocarbon was discovered in Mesozoics.

However, it is not prudent to discontinue exploration for Mesozoics, since most of the drilled wells have not completely penetrated the entire basalt thickness to reach the Mesozoic sediments.There is no conclusive evidence about the absence of Mesozoic sediments or Mesozoic basin below Deccan basalt. But, there is evidence of presence of Mesozoic basin since two wells penetrated Mesozoics which should be chased further.It is improbable to believe that Mesozoic sediments are only present around the well bore area.Globally, 54% of oil and 44% of gas reserves are being produced from Mesozoics and in India too,Mesozoics are hydrocarbon producers in various onland and offshore basins.The recent hydrocarbon discovery in Mesozoics in Kutch offshore basin should be an encouraging factor for continuing exploration in Kerala-Konkan basin. M/s MGS acquired 800LKM of Sea Bed Node (SBN) based Wide Angle Refraction cum Reflection Profiling seismic data (WARRP).The interpretation alongwith velocity and GM modelling suggested the probable presence of older stratigraphic succession of Jurassic-Cretaceous sequence, hitherto not explored in the basin. Maturity modeling in 1D PETROMOD, at various points has been carried out. Source rocks, if present in Mesozoics indicate that the sediments are matured enough to generate and expel the gaseous hydrocarbon with oil window from 78 to 65 ma and gas window from 65-32 ma. The Transformation Ratio reached critical moment (50%) at 42 ma**(Fig.9).** The extension of Mesozoic basin can only be proved by drilling couple of wells through Deccan basalt around the area where Mesozoic sediments are encountered.All possible techniques ofseismic API, GM modeling etc have conclusively failed to map the Deccan Trap bottom and presence of sediments below Deccan trap.Therefore, there is no option left, the only way is to prove the presence and extent of Mesozoic basin by “Drill Bit Only”.

Because of perceived poor prospectivity of the basin, the euphoria of private players to continue exploration in the basin, have vanished. In the NELP era, no private player is expected to sink money for drilling the thick pile of basalts in the offshore to explore the speculative Mesozoic petroleum system below basalts. The onus lies with the National Oil Companies to find out the thickness of basalt and ‘what is there below basalts’ and to put the Kerala-Konkan basin on the hydrocarbon map of India, like the prolific producer Mumbai high in the immediate north and Kutch offshore to the further north.

Also GOI should play crucial role in the form of offering incentives and financial assistance for drilling R&D wells designed to penetrate the entire basalt thickness, before permanently abandoning the basin. Alternatively, a consortium of different private players and govt. companies should be formed to take up the challenge of discovering the Mesozoic basin in this part of western offshore, India.

Acknowledgement:

The authors are grateful to Shri A. K. Dwivedy,ED-Basin Manager for his encouragement to publish the paper. Views expressed in the paper are that of authors and not of the organisation they represent.

References

1. Glyn Roberts et.al.(2008):Observation on the petroleum potential of deep offshore west coast India from newly reprocessed 2D seismic data. First break volume 26, September 2008
2. Hetu C Seth, 2006, Plume related regional pre-volcanic uplift in the Deccan Traps: absence of evidence, evidence of absence, www.mantlePlumes.org
3. B.Samant and D.M.Mohabey, 2009, Palynoflora from Deccan volcano-sedimentary sequence (cretaceous-Palaeogene transition) of central India: implication for spatio-temporal correlation,J.Biosci.34(5), November 2009,811-823.
4. S.V.Rao et.al. Sedimentary Processes and structural framework of Konkan basin-western offshore, India. Proc.Vol.National seminar, Four decades of marine Geosciences in India- A retrospect, GSI, Mangalore
5. J.Shah et.al. 2009, Hydrocarbon in sub basalt sediments-Basin Modelling of Kerala-Konkan Basin,offshore West India, 71st EAGE Conference & Exhibition- amsterdam, 8-11 June 2009.
6. R.Fainstein & D.Joshi, 2010, Sub-basalt Strata Geophysical Imaging,72nd EAGE Conference & Exhibition incorporating SPE EUROPEC 2010, Bacelona, Spain, 14-17 June 2010.
7. Unpublished Reports, ONGC

Figures:

Fig.1 Tectonic Framework

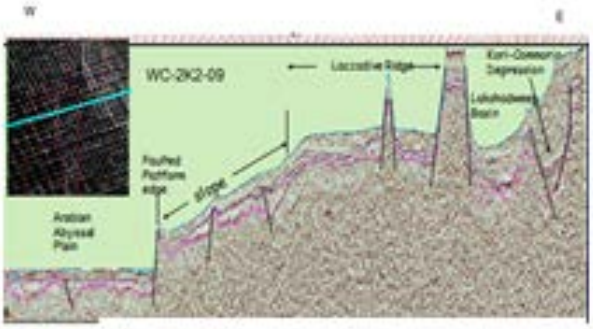


Fig.2 Tectonic Elements along WC-2K2-09

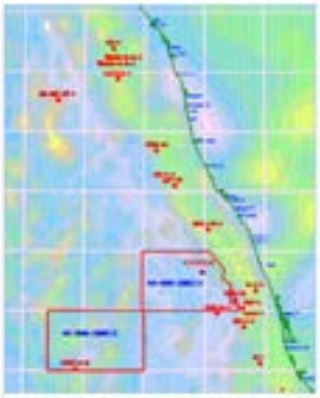


Fig.3: Drilled wells in the Basin

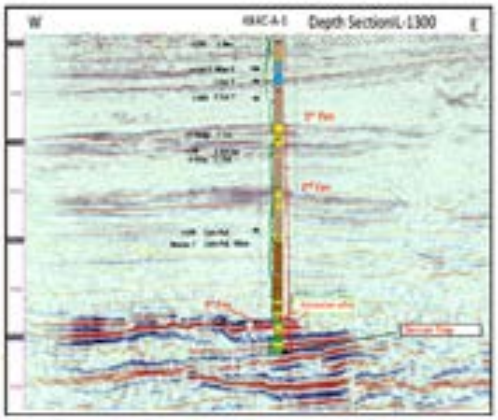


Fig.4: Fan Lobes drilled, terminated in Deccan Basalt KK4C-A-1

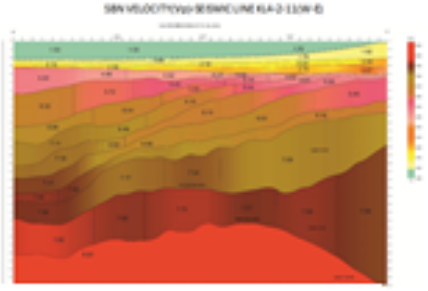


Fig.5: Velocity Modelling of SBN data

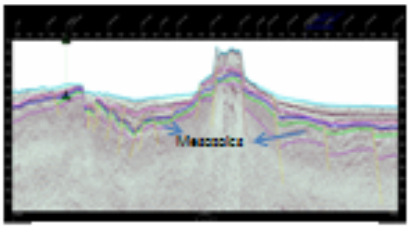


Fig.6: Envisaged Mesozoics

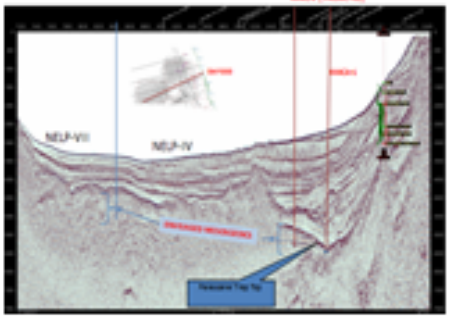


Fig.7: Envisaged Mesozoic sequences turned out as Basalts on drilling

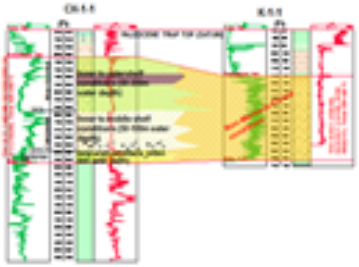


Fig.8: Late Cretaceous in drilled wells

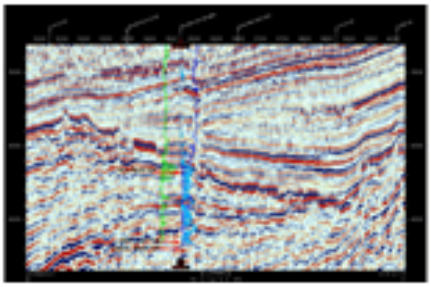
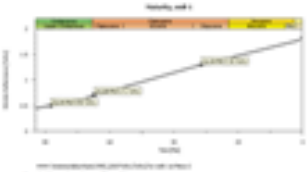
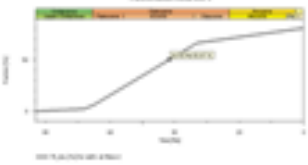


Fig.10: 2D line (PSTM)Showing drilled depth in KKMZ-E-A



A: Vitrinite Reflectance



B: Transformation Ratio

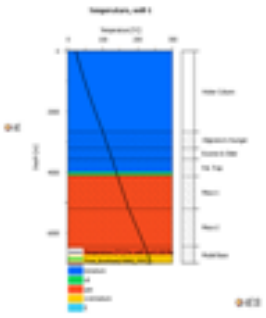


Fig.9: 1D PETROMOD indicates Immature Tertiary & generation potential of Mesozoics