Assessment of Basin Centered Gas Prospectivity in the Tankari Low, Cambay Basin, India

Ravi Misra*, S.K. Mahanta & R.P. Verma
**Office of Director (Exploration),ONGC; mishra_ravi@ongc.co.in*

Abstract

Basin Centered Gas Accumulations (BCGA) have emerged as significant component in the unconventional gas basket in USA and in many other countries. The success and rich experience with BCGA exploration & production in such countries has enthused other energy deficient countries to widen their portfolio of hydrocarbons and include the tight gas/ BCG/shale gas as focus area. The attraction with BCGA lies in its inherent closeness to conventional petroleum systems in terms of genesis and occurrence except that of reservoir characteristics. The principles & practices for the exploration for BCGA remain fundamentally similar except for the fact that the accumulation of BCGA is not controlled by structural / stratigraphic closures as in typical conventional plays but are of blanket in nature. This basic difference brings them into the fold of unconventional continuous type petroleum plays. The significant advantage with BCGA is that such plays are found in the deeper part of the basins which are under active production and where significant quantity of basin specific data is usually available except in some cases where seismic data quality vanishes due to deeper objectives. Technically, it may be treated as a step deeper in the basin where source facies attains thermal maturity dominantly in gas window & the reservoirs become tight (poor porosity & permeability) owing to diagenetic effects and compaction. Reservoirs in BCGA usually reach the irreducible water saturation limit and the most diagnostic feature include invariably abnormally pressured, low permeability tight reservoirs in association with reverse gas water contact.

Introduction

Cambay Basin, lies on the western onland margin of India and known as an oldest and most prolific oil & gas production. The basin is divided into four tectonic lows/depressions housing nearly 7km of thick disposition of sedimentary column. The basin has several pay zones ranging from Paleocene to Oligocene, but confined to basin margins leaving the central graben part deeper pays unexplored. The paper brings out the BCGA prospectivity assessment of one of the southernmost and deepest lows- the Tankari Low by adopting customized and synergistic studies. The study has brought out the BCG potential and identification of drillable prospects in the Tankari Low.

Study and Method

The sinusoidal basin disposition with low angle basin bounding listric faults array exhibits influence of oblique tensional/trans-tensional dynamics representing a typical half graben style of basin geometry (Fig. 1). The basin is subdivided into five major tectonic blocks based on basement faults as described from south to north-Narmada-Tapti block, Jambusar-Broach block, Mehsana-Ahmedabad block, Sanchor-patan block, Barmer -Sanchor block.

The rifting initiated at the end of the Cretaceous which was accompanied with eruption of massive flood basalt (Deccan Trap). The evolution of the basin has taken place in three different stages: Syn rift (Extensional, Paleocene- early Eocene), Post rift stage-I (Thermal subsidence, Middle Eocene- Early Miocene), and Post rift stage II (Structural inversion, Middle Miocene-Recent). It led to formation of various structural traps. The sediments have been deposited in the syn-rift and post-rift phases of basin development. About 8 to 11000m thick sediments have been deposited in syn-rift and post rift phases over the basement. Thick source sequence (Cambay Shale) has been deposited in the synrift phase. The overlying deltaic deposits in post rift phase constitute the multiple reservoir rocks. Intermittent transgressions provided cap rocks in addition to regionally deposited Tarapur shale/Telwa shale/ Kanwa shale.

The early phase of sedimentation represent trapwash /conglomerate and claystones of Olpad Formation which were deposited under continental environment as alluvial fan facies during Paleocene (Fig.3). This Formation unconfomably overlying the Deccan Trap is having gradational contact with the overlying and inter tonguing Older Cambay shale at some places. The Olpad Formation is unfossiliferous but based on its stratigraphic position vis-à-vis Cambay shale it is assigned an age from Paleocene to Lower Eocene. The origin of Olpad Formation can be attributed to weathering and leaching of pre-existing highs. The result of leaching could be in the form of 'wash and wacke' conglomerate and gritty sands accumulated on the crests and immediate slopes of the highs grading in to clay further downwards. The Olpad Formation is overlain by a thick sequence of dark & monotonous shale known as Cambay shale, which has conformable, gradational and inter tonguing contact with the underlying Olpad Formation (Fig. 3). The thick Cambay shales is separated by an unconformity, into two subunits named as OCS (Older Cambay Shale) and YCS (Younger Cambay Shale).

Tankari Low is a part of one of the four major lows i.e. Broach-Jambusar, as defined above. It is an oval shaped deep

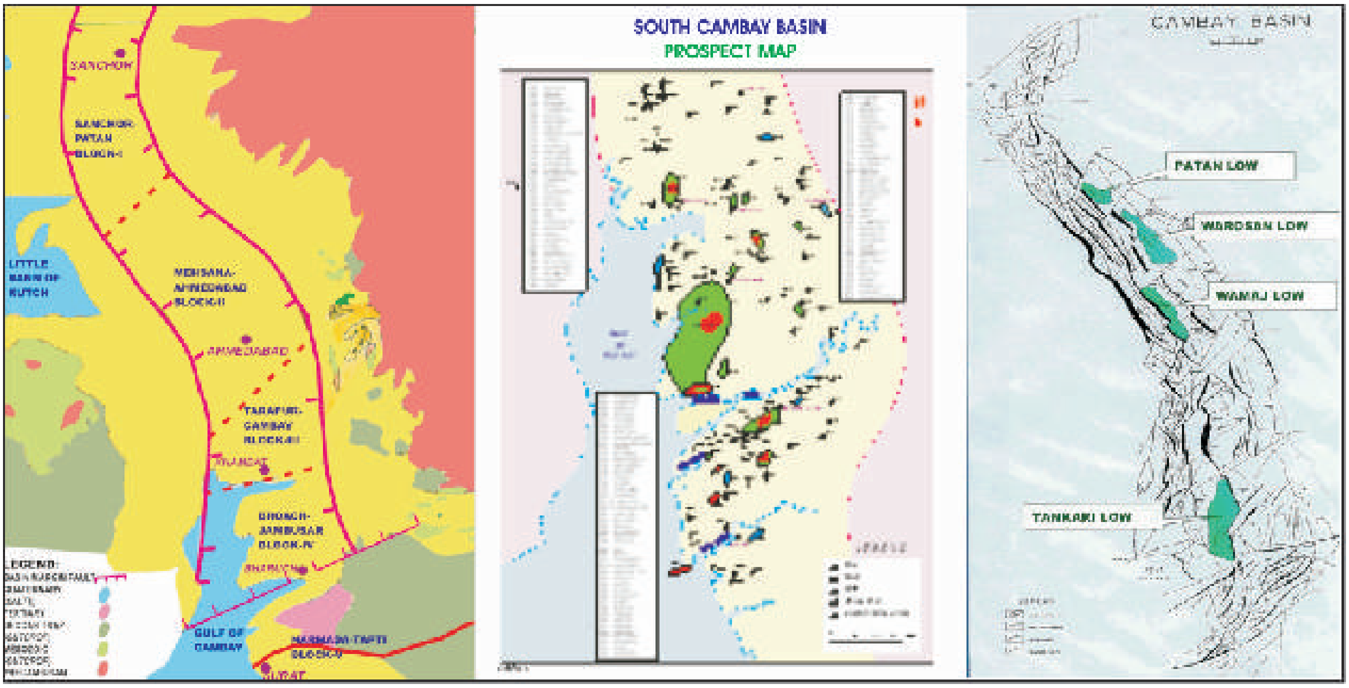

Fig. 1: The geologic & tectonic map, the prominent oilm& gas fields in Cambay basin and tectonic set up of cambay basin showing the disposition of Tankai low.

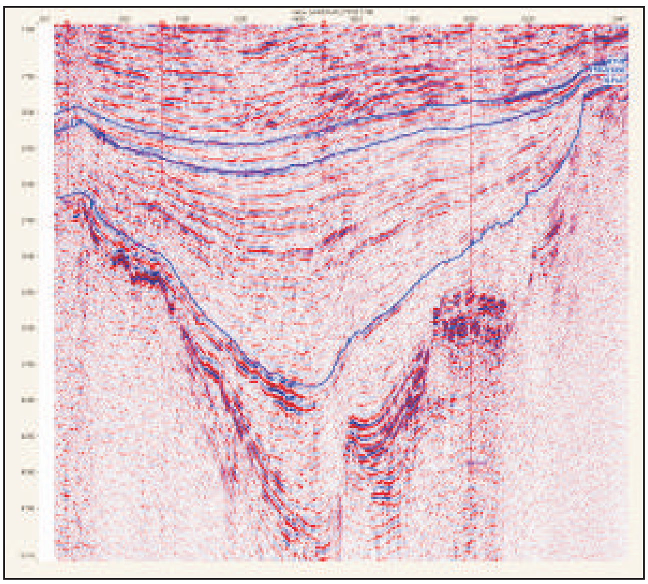

Fig. 2: A part seismic profile showing the Tankari Low

asymmetric low limited by basin margin en-echelon faults and Mahisagar & Narmada river fault systems. Broach depression had an intermediate position tectonically between Jambusar-Jantran depression and Narmada fault during paleogene sedimentation. In general Olpad Formation is characterized by three lithofacies; upper sandstone, Middle-Clay stones and the lower-trap wash facies. As the subsidence continued to be active, especially in the central part of the basin, the Olpad sediments attained a thick pile up to 3000m in the deeper part of Tankari depression (Fig. 4). thinner towards margins, still approximately, 1787m in Jambusar P-1 on the eastern margin. The Olpad Formation in

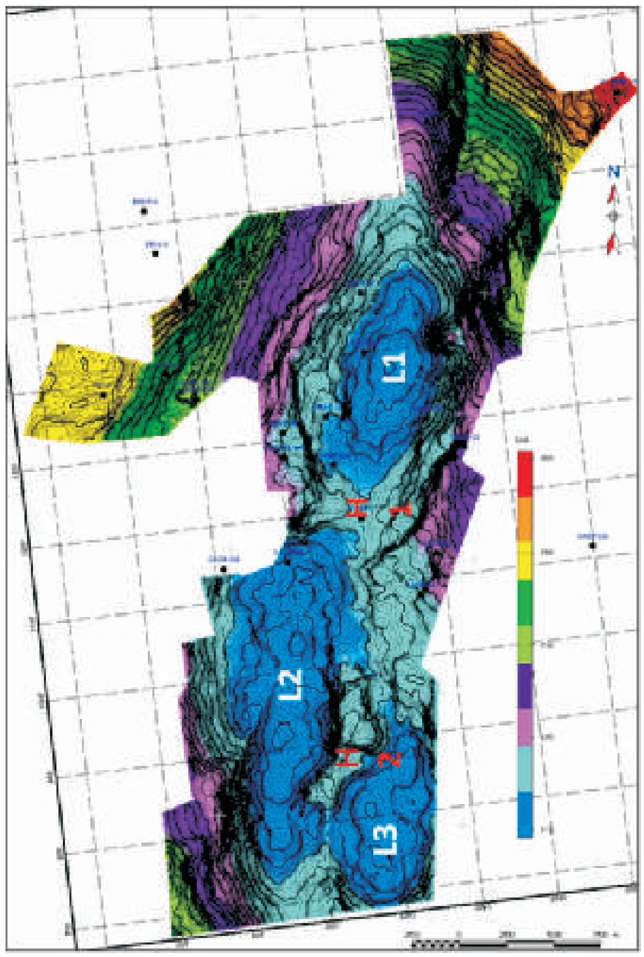

Fig. 3: Two way structure contour map showing the three sub lows mapped within Tankari Low

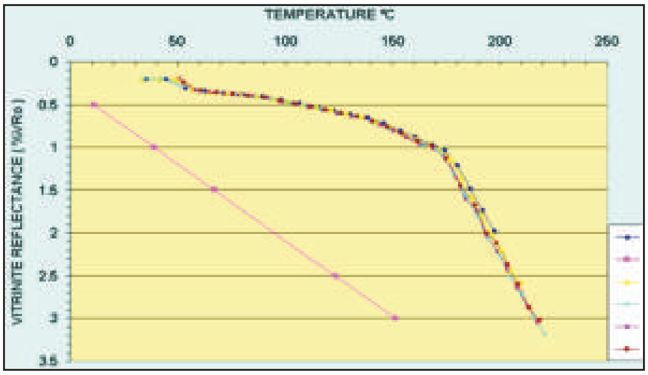

Fig. 4: Composite Pressure Domain analysis for wells

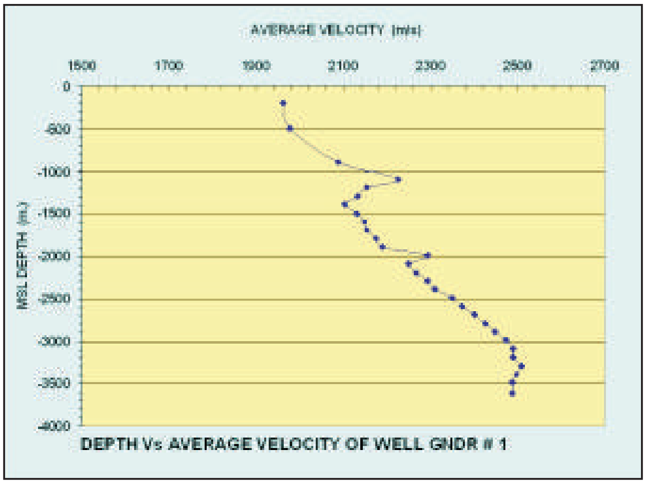

Fig. 5: The velocity inversion surface in a well indicating sharp break in trend

well J-P-1 consists of alternations of trap conglomerate (cobble-pebble sized)/ trapwacke (coarse to silt size grains) and variegated greenish to dark grey, even reddish brown and ash grey, hard to very hard compact and non calcareous greenish grey to dark grey trap wash embedded with in clay matrix.

In the western part, the well Nada-1 encountered 265m thick Olpad Formation where few zones in the top part have low water saturation & indicated fluorescence with positive cut and gas show while drilling. The Olpad section comprises of sediments of shale siltstone and dirty immature sands with minor claystone associated with trap fragments and trap derivatives, with the active subsidence in the western part, Cambay Shale and Olpad sequences are the effective source rocks for oil & gas accumulations in Cambay Basin. Banerjee et al, (2000) have assessed source potential of rocks in these areas in detail and concluded that these lows have potential to generate gas for BCGS (Pahari, 2007).

Assessment of BCG potential

The Tankari Low, Cambay basin has been evaluated in a synergistic manner incorporating geological, geochemical, petrophysical and geophysical analysis. Some special BCG attributes were also worked out like velocity analysis, pressure domain analysis and seismic attributes analysis to zero in for possible sweet spot identification and proposing drillable locations and testing BCG concept. For BCG evaluation geologic, geochemical, petrophysical, seismic, and overpressure analysis have been carried out.

Geochemical analysis

In Tankari Low, Olpad Formation has attained a wide range of thermal maturity between vitrinite reflectance values of 0.8 and 2.8%, 1.1 and 3.6% 1.2 and 2.0 % in wells G-20, G-36, and Nada-1 locations respectively (Pahari,2007) (Fig. 5). Maturity modeling in the Tankari low reveals that the onset of oil window maturity (0.6% Vro) varies from 2400m to 2950m depth and wet gas and condensate window maturity (1.3% Vro) ranges from 4200m to 5350m depth. Dry gas window maturity (2.0% Vro) is in the depth range of >5000m.

In well Nada-1, the maturity (Vro) of Olpad Formation in general lies above 1.2%. At the depth of 4075m the Vro reaches the value of 2.0% indicating that the lower section is over-matured (Niranjan & Shukla, 1996) well within the gas zone suitable (GOR) BCG system. The section is organically rich though out and S2 values are in general above 1.0 mg HC/g rock in depth interval 3425-4065m. In Jambusar P-1core total organic content in the core samples is in the range of 0.12-4.0% and S2 values are in 0-2.47mg HC/g rock range. Due to deep burial of Olpad Formation, it has high values of Vro (1.18-3.57%, it is capable of generating only gas. The gas window in the well Nada-1 appears at 3200m and in Gandhar -36 it appears at 3800m.

Seismic characterization

The evidences of inversion structures, reverse faults as well as normal faults are recorded in several instances. The area surrounding the inversion structures are cut by numerous faults hence are likely to increase the system permeability and may serve as sweet spots. To detect and delineate areas of enhanced deliverability and storage (i.e., porosity and permeability) or 'sweet spots' below the pressure boundary 3D mega merged, reprocessed PSTM seismic data was analyzed and interpreted. Horizons corresponding to the top of Y-marker and near top of Olpad based on well data and seismic signature mapped (Fig. 6).

A composite and integrated interpretation was attempted incorporating various parameters overlain on each other, clearly brings out the gaseous zone (below Vro 1.0), supported by TOC>2.0, and gas cut mud, as encountered in the drilled wells. The reflector corresponding to trap top which is the technical basement for the low is observed in the northwest part of the area around wells Devla-2 and Barkhodra-1, drilled in the flanks, however, in the deeper parts of the low the reflector is not observed due to noise as well as its deeper depth (Fig. 2). Owing to these reasons it could not be mapped and a regionally present reflector near

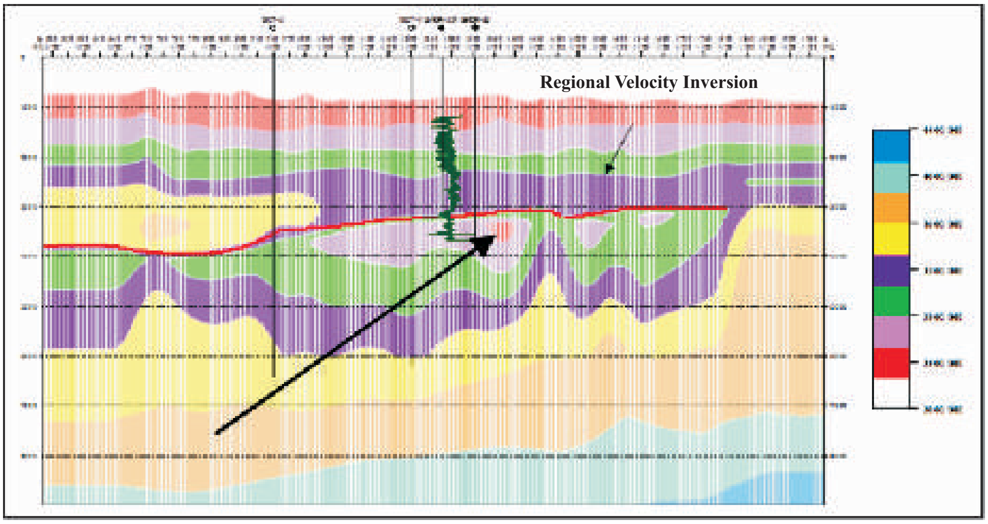

Fig. 6: Regional over pressure domain mapped by velocity inversion and fall in velocity function indicating possible BCG zone.

the Olpad top was mapped as shown in fig. 3. The time thickness map indicates that the paleo-low axis trending NNE-SSW, as observed in map corresponding to near Olpad top remained depocenters for Cambay shales also.

Special Attributes Applications

The Cross plots between temperature and Vro was plotted for the wells Gandhar-1, Gandhar-22, Gandhar-36 and Nada-1. The correlation fit line falls in all the cases above the median standard line, indicating the systems to be of overpressure nature below approx. 3000m depth (Fig. 4). The velocity function analysis was carried out for Gandhar well no's 1, 9, 15, 22 and 36 all of which indicate a sharp to moderate decline and break in trend line of normally increasing velocity. The trend line shift is clearly indicative of fall in velocity because of gaseous anomaly zone(Fig. 5). The observation is also corroborated by the low frequency reflectors in this area.

Conclusions

A comprehensive analysis and integration of all the factors governing Basin centered gas accumulation has been carried out and based on which prospectivity has been evaluated. The area represents a high pressure locale with discrete fall in velocity function indicating gas window. Based on which an area lying between Gandhar-1, Gandhar-22, Gandhar-36 & Nada -1 covering an extent of around 200sq km appears prospective and two drillable prospects were mapped for testing the concept in the two lows mapped (Fig.3) and potential BCGA in the basin for the first time.

References

Bandyopadhyay, K.K. (1994) Well Completion Report of well Tankari-1. Unpublished ONGC report.

Banerjee A, Pahari, S; and Jha Mamta (2000) Geochemical Data Handbook, KDMIPE, ONGC Unpublihed report.

Basin - Centered Gas Systems of the US, Project DE-AT26-98FT40031, (2000).

Bharsakale et al; (2004) Integrated study of deeper prospects in Broach (Tankari low) block. KDMIPE unpub report.

Kundu. J., Kar, S., Prakash A. and Prasad B., (1996) Basement configuration and distribution of depocenters of Cambay basin. Unpublished report, KDMIPE, ONGC.

Law Ben E., (2002) Basin-centered gas systems, AAPG Bulletin Vol.86,no.11 pp1891-1919.

Mayor S., et al Identification of preferred reservoir development in Olpad Fm. for the exploration of deeper prospects, Broach Block, Cambay Basin.

Niranjan, Neelam and Shukla, R.K. (1996) Evaluation of source rock potential of Olpad formation in Broach-Jambusar block. Unpublished ONGC report.

Pahari, S. (2007) Thermal Maturity / hydrocarbon generation modeling in Tankari Low and Wamaj Low of Cambay Basin to assess the potential for Basin Cenetred Gas Accumulation. Unpub report, KDMIPE, ONGC.

Raju, D.S.A.N. (1988) Well Completion Report of well Jambusar-P-1. Unpublished ONGC report.

Ray G.K. et al;(2001) Quantitative genetic modeling of Cambay basin. KDMIPE unpublished report.

Singh H. et al. (2004) Thermal maturation studies in basinal depocenters of Ahmedabad and Broach blocks of Cambay basin.

Thomas N.J., Gideon, ND, Ramakrishna, M.J, Banerjee A, Samanta, U, Juyal, B.M, Singh Geeta, (1999) Unconventional Deep Gas Resources in Indian Basins: A Task Force report. KDMIPE, ONGC Dehradun.

Verma, R.P., Bharsakale, A., Saha, P.K (2007). Assessment of different basins of India and identification of favorable depocenters for Basin Centered Gas exploration. Unpublished ONGC report.