10th Biennial International Conference & Exposition

P 316

Exploring Possible Existence of Dense Ferruginous Sandstone Reservoir in Kalol Formation of Cambay Basin

*Katiyar Priyamvada *, Singh Manish Kumar **, Dave H. D***,*
*Nath Kameshwar *** & Sen S. K ****

Summary

It has been observed that a clean sand with typical fining-upward sand occurs within the Sertha Member of Kalol formation which, owing to its low gamma, low resistivity (~3 ohm-m) and high density (~2.5 to 2.6 gm/cc) prima facie appear non-reservoir and does not warrant any conventional testing for hydrocarbons. The abundant coal in Kalol formation indicates presence of reducing environment in ground water at the time of deposition and therefore precipitation of hydrous iron oxide cements in the channel bed on the depositing sand during lean season. It has been observed that well sorted clean porous sands are susceptible to cementation during the early diagenesis phase. It is important to understand whether this porosity occlusion has completely rendered the sand non-reservoir or it still contains sufficient porosity/hydrocarbons based on the calibration through core, high-resolution image well logs and pore fluids through lithology independent Magnetic Resonance log measurements. The economic driver behind the quest to characterize such dense sandstone reservoir is that the channel-levee-crevasse splay complex may represent large unexplored reservoir body within the prolific Kalol formation.

Keywords: *Sertha Member, FMI, CMR*

Introduction

Successful reservoir description requires detailed quantitative sedimentological and mineralogical data fully integrated with a petrophysical interpretation. Together, these data define the volume of hydrocarbons in a reservoir and describe the characteristic porosity, permeability and saturation of the reservoir. Additionally, the geological data should describe lateral and vertical variations of reservoir characteristics, and how those characteristics will effect hydrocarbon production. In recent years it has become even more necessary for specialists working in multidisciplinary groups to develop an increased understanding of the basis and further application of their colleagues' methods of analysis.

Dense sand occurring in kalol formation needs detailed investigation, as the conventional log analysis will interpret it as non-reservoir. The understanding of the depositional environment suggests that these dense sands may have reservoir potential depending upon the degree of hydrous iron oxide cementation. For detail investigation of these dense sandstone reservoirs high-

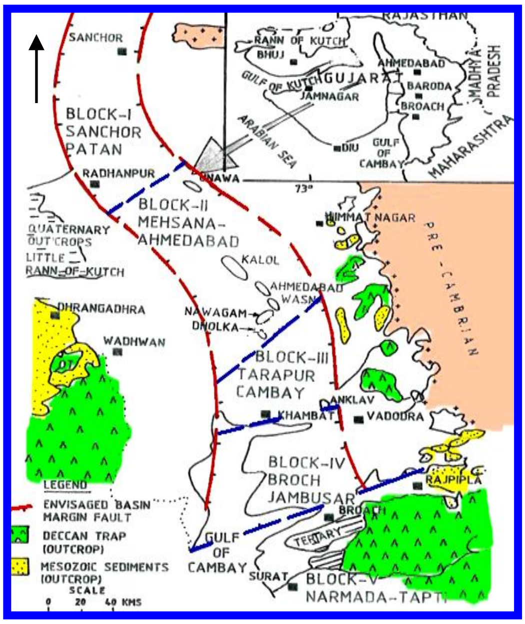

Fig. - 1: Location Map of Cambay Basin

ITM University, Raipur, **Schlumberger Information Solutions, Vadodara* ONGC, Vadodara*
** ITM University, Raipur (C.G.)*
E-mail: priyam.katiyar@gmail.com

resolution image logs, core and magnetic log measurements are required. In this study, we are proposing a workflow to better characterize such dense sandstone reservoirs.

Geology of the field

Cambay Basin is an aborted intra-cratonic N-S to NNW – SSE trending rift Graben situated between south east Saurashtra craton on the west, Aravali swell on the N-E and Deccan craton on the south east in the northwestern part of Indian peninsula in Gujarat State, lndia (Fig.-1). Tectonically, this basin is a marginal aulacogen type of rift basin (S.K.Biswas, 1998) bounded on its Eastern and Western margin by master faults trending parallel to sub-parallel to the basin margin (Fig-4). Based on the major basement faults, Mathur et al, 1968 has divided this Tertiary basin into five tectonic blocks from north to south namely I. Sanchor -Patan, II. Mehsana-Ahmedabad, III. Cambay-Tarapur, IV. Jambusar-Broach and V. Narmada – Tapti blocks (Fig-1). The NE-SW, ENE – WSW and NNW – SSE trending lineaments parallel to the regional Aravalli, Satpura and Dharwar trends respectively control the basin configuration. The basin configuration at the Deccan Trap level comprises 88 half grabens of which 26 have formed major depocentres in the early stages of basin evolution (Kundu et.al. 1996) (Fig.2).

Stratigraphy and Sedimentation

The sedimentation in the Cambay basin is primarily controlled by the Pre-rift, Syn-rift and Post – rift stages, which the basin witnessed together with the interplay of local – regional sediment dispersal patterns and drainage systems.

The basaltic floor viz., the Deccan Trap Formation of late Cretaceous- Lower Paleocene age forms the tectonic basement for the deposition of huge thickness of Tertiary – Quaternary sediments in the basin. Olpad Formation overlies the Deccan Trap Formation and has a gradational and inter tonguing relationship with the overlying Cambay shale formation. The Olpad facies is primarily controlled by the tectonic setup as well as by proximity to the paleosource or positive relief of Deccan Trap country. It is deposited in alluvial fans, alluvial fan deltas, over bank and lacustrine environments.

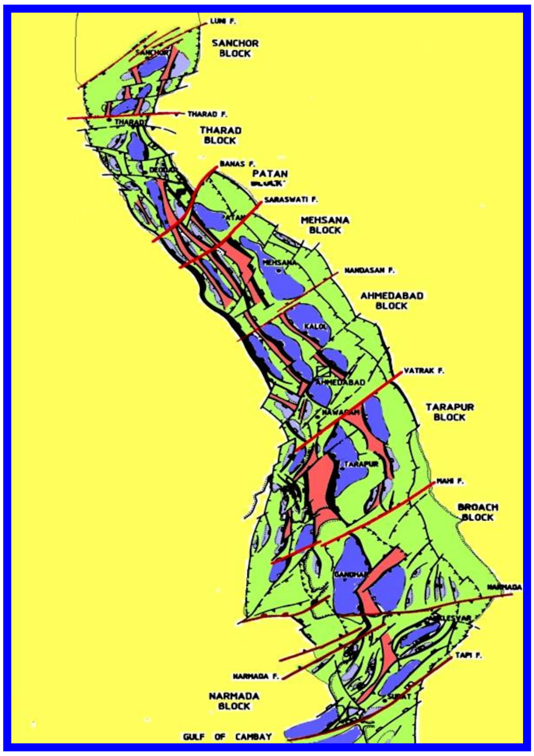

Fig.- 2: Tectonic map of Cambay Basin (after J.Kundu et.al, 1996)

The facies are characterized by Trap wacke / Lithic wacke, Lithic sandstone / Lithic siltstone, trap wash and clay stone. The reservoirs are in general less porous and low permeable in nature. This formation has generated a substantial amount of hydrocarbons which are likely to be trapped in the Olpad section itself. The Synrift stage continued to Early Eocene times wherein, a thick sequence of Cambay shale was deposited. The section predominantly comprises black to dark gray shale with intervening sands / silts and is the main source of hydrocarbons generation in the Cambay basin. The Cambay shale formation is divided into two, the Older Cambay Shale (OCS) and the Younger Cambay Shale (YCS) formation. The OCS formation recorded the earliest marine sedimentation in the basin with episodes of deposition of coarser clastics. In the northern part of the basin the lower and upper tongue shaly units demarcate the three arenaceous members viz. Mandhali, Mehsana and Chhatral of YCS whereas it is relatively shaly in the southern part of the basin. The overlying Kalol formation of Middle Eocene age was marked by a synrift stage and was deposited in a negative and oscillatory rift fill stages. It is one of the major producers in the basin. The formation is mainly divided into two (the Sertha and Wavel members) by a short transgressive event marked by Kansari shale. The Kalol formation is characterized by intercalations of thin sandstone / siltstone, shale and coals. The two Para sequences viz., K-X and K-IX of Sertha member are separated by thin marine transgressive shale. The coarsening up is characterized by thin siltstones to fine grained sandstones, silty shale and end with coal deposition. In some of the areas an additional development of reservoir facies deposited above and below the coals are the main producers. The Sertha Member is characterized by stratistructural and stratigraphic plays whereas, the overlying Wavel member pays are dominantly structural plays. The overlying Tarapur shale and Dadhar formations were also deposited in a negative and oscillatory rift fill stage. The overlying Babaguru and Younger formations, the positive fills related to the interior sag phase of the basin were deposited in a post rift phase. The generalized stratigraphy of Cambay basin is diagrammatically represented in Fig.-3.

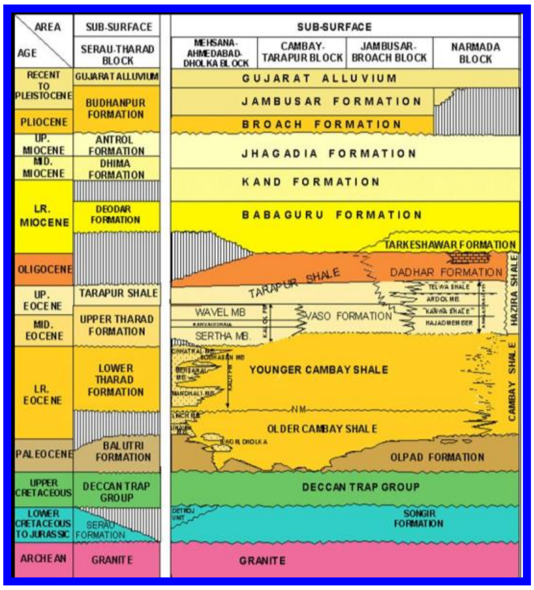

Fig.- 3: Generalized stratigraphy of Cambay Basin (after Mehrotra et al)

Need for the study

The incentive for characterizing probable dense sandstone Kalol reservoirs is that such zones are not amenable to quick look log interpretation due to envisaged heavy mineral assemblage, presence of early/late stage digenetic iron oxide cements which may render the interpretation of resistivity and density logs as equivocal leading to probable missed opportunities despite the clean nature of these channel sands (Fig. 4).

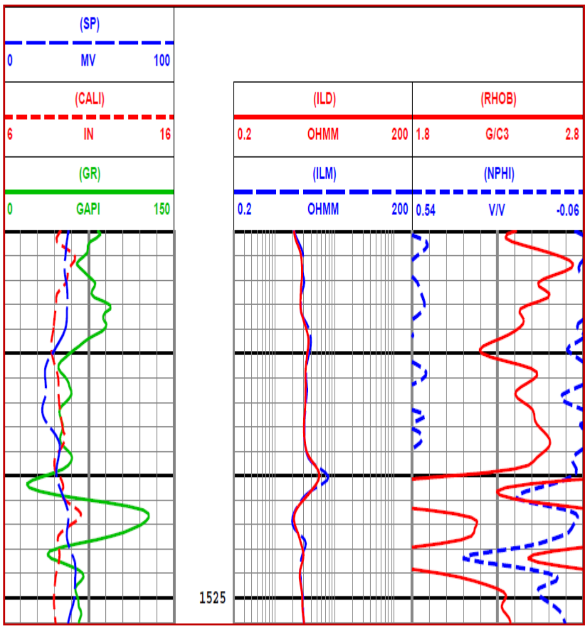

Fig.- 4: Log motif of Well A showing dense ferruginous sand

These sands may have reservoir potential, which may be missed in conventional log analysis. To better quantify the porosity of these sands detailed core study and modern high resolution image log analysis (FMI) is required. To investigate presence of fluids modern magnetic resonance logs are required.

Suggested Workflow for Reservoir Characterization:

Operational Observations:

1. During the drilling of the well precaution needs to be exercised regarding using optimal mud weight and to minimize the formation exposure to the drilling fluid to ensure minimal fluid invasion.
2. Well-site geologist needs to take care of even feeble hydrocarbon shows. Drill stem tests are needed to be carried out carefully.

Core Study

1. It would be important to take conventional core for elaborate laboratory studies for presence of

hydrocarbons, depositional environment and bulk and heavy minerals assemblage (Zircon, tourmaline, rutile and magnetite etc.). These heavy minerals may be prime cause for high density of sandstone. Prominences of these minerals suggest good reservoir quality.

2. Forward modeling of density from laboratory determined bulk and cementing mineral composition/percentage and heavy mineral assemblage for unraveling the presence of porosity. Even 10%- 20% of the heavy iron oxide cements can affect the density to the extent that it starts appearing non reservoir. Moreover, the simultaneous suppression of resistivity creates problem in identifying such sand as an object for conventional testing.
3. Petrographic and Cathodoluminescence studies for understanding the sand maturity, mineralogy and nature and episodes of cementation and effects of late stage diagenesis.

Petrophysical Data

1. Core studies on physical samples need to be supplemented by high resolution Formation Micro-Scanner (FMS) or Formation Micro-Imager (FMI) well log measurements to understand the quantity and geometry of the occurrence of early stage or late stage conductive authigenic cements. Visualizing sedimentary features lets us define important reservoir geometries and petrophysical reservoir parameters. Borehole imaging is the preferred approach for determining net pay in the laminated sediments of fluvial and turbidite depositional environments and for stochastically modeling the sand-shale distribution
2. Combinable Magnetic Resonance (CMR) log to be recorded for pore fluid characterization. The high-resolution CMR-Plus combinable magnetic resonance tool with high-logging-speed capability enhances the precision of nuclear magnetic resonance (NMR) logging. CMR determines reservoir's permeability, water cut, and hydrocarbon pore volume are obtained at logging speeds 3 to 5 times faster than those of conventional NMR tools.
3. Elemental Capture Spectroscopy sonde (ECS) to determine relative elemental yields by measuring the gamma rays produced when neutrons bombard the formation and lose energy as they are scattered, primarily by hydrogen. The primary formation elements measured by the ECS sonde in open and cased holes are the most commonly occurring elements: silicon, iron, calcium, sulfur, titanium, gadolinium, chlorine, barium, and hydrogen

Way Forward

Once this kind of dense reservoir is characterized comprehensively in the test case, optimization of log-suite can be done for similar sands encountered in other wells and conventional testing can be decided on the basis of the experience gained.

References

Hurst and J. S. Archer, Sandstone reservoir description: An overview of the role of geology and mineralogy, Department of Reservoir Evaluation, Statoil, Forus, Posboks 300, N-4001 Stavanger, Norway, and ERC Energy Resource Consultants Ltd., 15 Welbeck Street, London W1M 7PF

Ahmed A. Abdul Ghani, Dense Rock Bodies in Lower Cretaceous of East Abu Dhabi (United Arab Emirates), #90105 (2010), AAPG GEO 2010, Middle East Geoscience Conference & Exhibition

Salman Bloch, Robert H. Lander, and Linda Bonnell, Anomalously high porosity and permeability in deeply buried sandstone reservoirs: Origin and predictability