Successful model based exploration – A case study in Billakurru-Madupalli area, South East of Mandapeta field, KG-PG Basin

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Keywords

Billakurru area, Raghavapuram formation, envisaged geological model, slope fan channel complex

Summary

The study area comprising of Billakurru - Madupalli area and Vygreswaram-Mukkamala area is located south-east of Mandapeta field in East Godavari Sub-Basin of Krishna Godavari Basin (Fig-1). Established fields in the vicinity have many drilled wells which have tested and proved potential of Raghavapuram, Mandapeta and Gollapalli plays, represented mainly by structural prospects. Two wells drilled in Vygreswaram area (Wells-A & B) and one well in nearby Mukkamala area (Well-C) were considered as key wells for the G&G studies in study area. The three wells are gas producers within Raghavapuram formation. To identify any possible facies changes within Raghavapuram section of the three key wells, electrolog correlation was made and analyzed. Two packs within Raghavapuram sequence were identified. The estimated Sand-10 and Sand-20 from three wells belong to the packs identified.
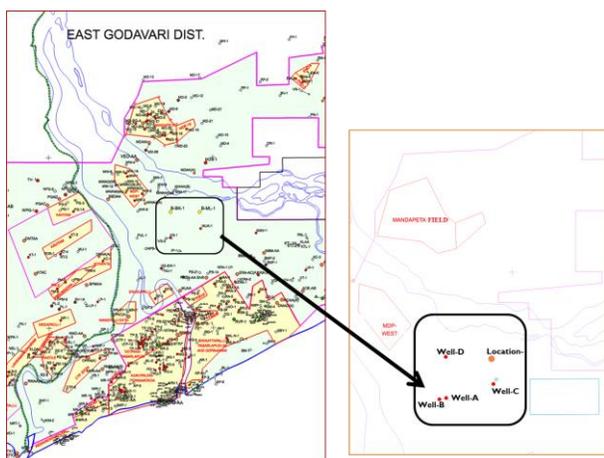

Figure 1: Location map of the study area with key wells.

In the study area, a broad slope fan complex, amalgamated with laterally accreting slope channel complexes having two fan lobes (Pack-1& Pack-2) were identified on the basis of the seismic geometry and mapped to the north of Vygreswaram-Mukkamala area. Collaborating and analyzing the 3D PSTM data of the study area, electro log data, regional seismic lines and seismogeological cross sections, a Geological model was envisaged and developed. Based on the envisaged model, the packs within Raghavapuram formation belong to slope-fan/channel deposits having sediment input from the north and northwest, deposited in the intra-slope sub-basins, which were formed as an axial low south of Poduru- Yanam High.

PSTM volume covering the area of study was scanned, to identify and correlate the two packs. As a result, correlation of top and base of identified packs was accomplished. Structure maps pertaining to top and base of packs and corresponding Isochronopach were also prepared. Analysis of all the outputs of the G&G studies revealed two depositional packs within Raghavapuram sequence, namely, an older fan lobe as captured by Pack-1 and a younger fan lobe represented by Pack-2. The Raghavapuram pay sand intervals of Wells-A, B & C forms part of the fan channel complex.

One exploratory Well-D was recently drilled at a favourable location to target Pack-1 defining the older fan lobe. On production testing, the well flowed commercial quantity of gas and condensate from Object-II within Raghavapuram sequence - proving the validity of envisaged geological model.

Introduction

Tectonic history: Krishna-Godavari Basin is a Continental passive margin Pericratonic basin, situated at east coast of India. Following the rifting along eastern continental margin of Indian Craton in early Mesozoic time, the Basin came into existence. It is bounded by Ongole Cross trend to the west and Pithapuram Cross trend towards east. The Krishna-Godavari Basin has a series of rift axis, parallel horsts and grabens, trending NE-SW. The five major

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onland tectonic elements are Krishna Graben, Bapatla Horst, West Godavari Sub-Basin, Tanuku Horst and East Godavari Sub-Basin. The West Godavari Sub-Basin is further subdivided into Gudivada and Bantumilli grabens by Kaza- Kaikalur High. The East Godavari Sub-Basin is sub divided into three tectono-stratigraphic limits, separated by Matsyapuri-Palakollu fault and Mori-Komarada fault systems.

General Stratigraphy: The generalized stratigraphy of Krishna-Godavari Basin is characterized by thick sedimentary sequences ranging in age from Late Permian to Pliocene. The oldest rocks encountered are Basement, mainly of Precambrian age. The Basement is successively overlain by Draksharama Argillite, a metamorphic basement derivative; Kommugudem Formation (Lower Gondwana) of Permo-Carboniferous age having alternate sand-shale-coal sequences; Mandapeta Formation (Upper Gondwana) of Late Permian age having dominantly tight sandstones with minor shales; Red Beds of Late Triassic to Early Jurassic age consisting of reddish brown ferruginous sandstones alternating with reddish brown Claystones; Gollapalli Formation of Upper Jurassic to Lower Cretaceous age having post Gondwana rift fill sediments of mainly massive sandstones. Raghavapuram formation is overlaid which provides source, reservoir and cap acting as a complete Petroleum system. The Raghavapuram shale sequence, overlying on early rift fill sequence, marks the marine transgression into major grabens of the Basin during Early Cretaceous period.

Established hydrocarbon plays: In terms of play perspective, Matsyapuri-Palakollu Fault system has differentiated the East Godavari Sub-Basin area into two sectors. The Cretaceous/Pre-Cretaceous Plays are well established to the north of this fault system, whereas, Tertiary Plays are established to the south of it. Mandapeta, Gollapalli, Raghavapuram and Tirupati Formations are the proven plays to the north of Matsyapuri-Palakollu fault system, whereas the Tertiary formation was the dominant play to the south of Matsyapuri-Palakollu fault system. However, after the encouraging leads within Gollapalli Formation and Raghavapuram Formation obtained in recent drilled wells, it is envisaged that the Gollapalli play and Raghavapuram play also extend further to south of this fault system into offshore shallow region.

Methodology

The lead for taking up integrated G&G studies within the study area was provided by three wells in Vygreswaram-Mukkamala area, which are gas producers, in commercial terms, from sands within Raghavapuram formation of Cretaceous age. Two drilled wells in Vygreswaram area were exploratory Well-A and development Well-B to exploit the gas from Sand-10 as estimated in Well-A. One exploratory Well-C was drilled in adjoining Mukkamala area. The primary focus was on evaluation of Cretaceous prospectivity in the study area, targeting mainly on Raghavapuram play, which has been proved in Wells-A, B & C, which are located towards south of study area.

In Well-A, Object-II within Raghavapuram formation was tested which flowed gas @ 2,21,867 m3/day with traces of condensate and little water with FTHP:5330 PSI and SCHP:5350 PSI. The Well-A was completed in Object-II.

Well-B was drilled to exploit the gas from estimated Sand-10 of Raghavapuram Formation from Well-A. Two new sands were identified within Raghavapuram Formation as Sand-A and Sand-B. Sand-A was tested in Object-IA and flowed feeble gas. Sand-B was tested in Object-IB and it flowed gas @36,720 m3/day, Q_C: Traces, Q_W: Traces with FTHP: 1107 PSI. Well-B was completed in Object-IB.

Well-C was drilled in Mukkamala area to explore sands within Raghavapuram Formation. Four objects within Raghavapuram formation were released for testing. Object-I flowed gas @24,582 m3/day, Q_C: Nil, Q_W: Nil with FTHP: 655 PSI. Object-IV flowed gas @43,080 m3/day, Q_O: 7.05 m3/day, Q_W: 2 m3/day with FTHP: 1340 PSI, CHP: 1500 PSI. The well was completed as Oil & Gas producer from Object-IV.

Integrated G&G studies - including analysis of electro logs; sedimentological, bio-stratigraphic & geochemical data and 3D PSTM volume - were carried out. It was observed that the estimated Sand-10 of Wells-A & B and Sand-20 of Well-C were within Raghavapuram formation as revealed in

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analysis of wireline log data. Electrolog correlation of the three wells was carried out to identify the facies changes within Raghavapuram formation (Fig-2).

During the G&G studies, a broad slope fan complex, amalgamated with laterally accreting slope channel complexes having two fan lobes (Pack-1& Pack-2) have been identified on the basis of the seismic geometry and mapped to the north of Vygreswaram area. Collaborating seismic data, electro log data, regional seismic line, seismogeological cross section (Fig-3), a Geological model was envisaged and developed. Based on the model, the packs within Raghavapuram formation belong to slope-fan/channel deposits having sediment input from the north and northwest, deposited in the intra-slope sub-basins, which were formed as an axial low south of Poduru- Yanam High (Fig-4). The fan lobe pinches out towards North and absent towards west in the study area as corroborated by log correlation also. These laterally accreting slope fan/channel complexes of Raghavapuram are highly prospective where thick reservoir facies with very good porosity and permeability are preserved.

After integration and calibration with well data, the seismic volume was scrutinized to deliberately look for and identify top and base of the two depositional packs. Accordingly, two horizons representing the top and base of two identified packs were correlated (Fig-5 and 6). Time structure maps of top and base of the depositional pack and Isochronopach map were prepared. The structure maps brought out the two depositional packs within Raghavapuram sequence, namely, an older fan lobe as captured by Pack-1 and a younger fan lobe represented by Pack-2. The two depositional packs mapped consisted Raghavapuram pay sands as observed in Vygreswaram-Mukkamala wells A, B & C. Thus, a broad laterally accreting slope fan channel complex, having two lobes within Raghavapuram formation, was mapped in the study area.

The geological model envisaged a slope fan channel complex system of thick and good quality reservoir facies, having sedimentary inputs from North in the area. Entrapment system was envisaged to be primarily strati- structural. Raghavapuram Formation
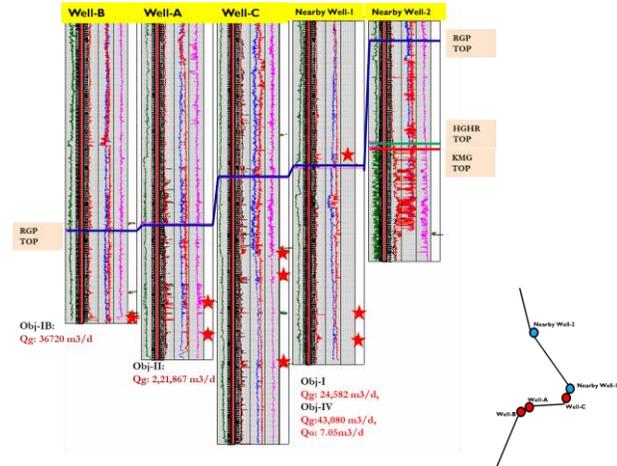

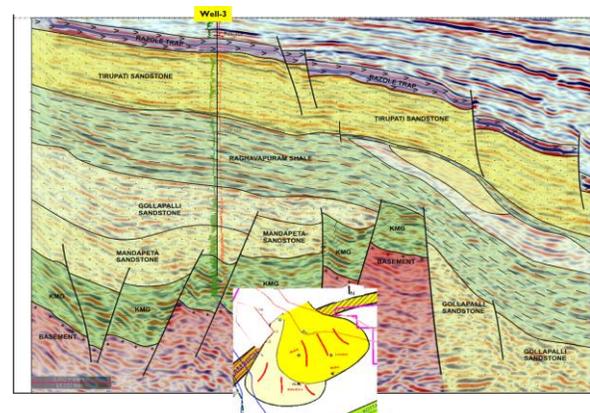*Figure 2: Electrolog correlation of three key wells with nearby wells.*

Figure 3: Seismogeological section (in dip direction) exhibiting the two depositional packs (older & younger) lying within Raghavapuram sequence.

is argillaceous in nature and alternations of sand and shale within Raghavapuram sequence would provide top and lateral seal. Sands embodied within Raghavapuram shale are ideally suited for hydrocarbon accumulation, having average porosity of about 12% and average permeability of about 1 to 100 mD.

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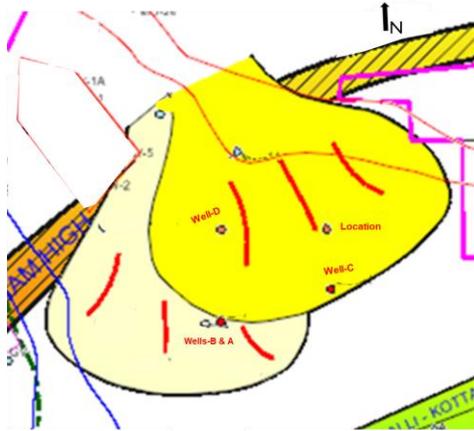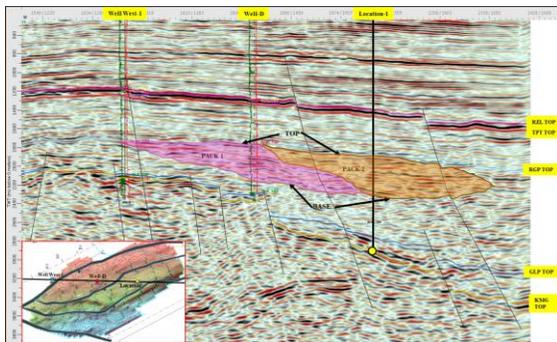

Figure 4: Geological model envisaged.

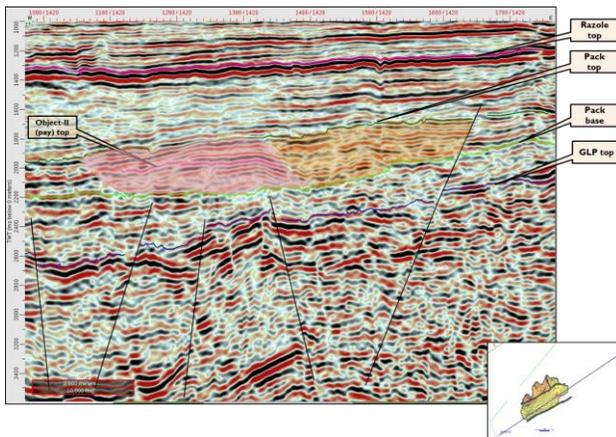*Figure 5: Arbitrary line showing two Packs 1 & 2 with top & base horizons.*

Figure 6: Crossline (W-E) showing pack with top & base horizons.

Carbonaceous shales within Raghavapuram sequence are main source rocks, especially High Gamma High Resistivity (HGHR) unit of Lower Raghavapuram have a good potential to generate hydrocarbons.

Validation of model and drilling results

Taking cognizance of the merits of the model envisaged, structure maps prepared and the lead obtained from three gas wells, an exploratory location was released at a favourable locale within Pack-1, representing older fan lobe. The released exploratory Well-D was recently drilled with T.D of 2900m targeting Pack-1. The well was further deepened to 3150m to explore the hydrocarbon potential of Synrift play. Gas shows were observed within Gollapalli formation during drilling. On evaluation of log data, the Well-D indicated hydrocarbon bearing zones within Raghavapuram sequence as envisaged in the geological model. Four objects were identified for initial production testing in Well-D, of which Object-I was in Gollapalli formation and remaining three objects were in Raghavapuram formation.

On production testing, Object-I – representing a fault closure at Gollapalli top level - produced gas @ 47,193 m³/day at FTHP: 1220 PSI, SCHP: 1400 PSI. Object-II within Raghavapuram sequence produced gas @ 1,17,504 m³/day, Q_C: 30.14 m3/day at FTHP: 3150 PSI, SCHP: 3400 PSI.
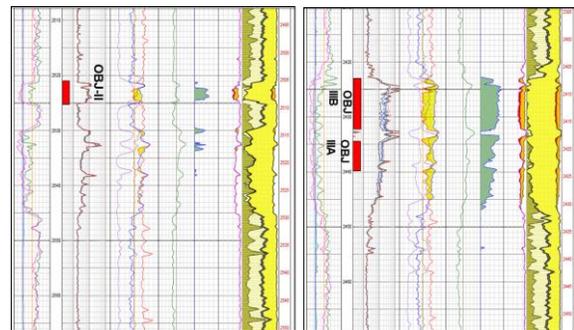

Figure 7: Log motif of tested Object-II and untested Object-III within Raghavapuram in Well-D.

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Log motif of tested Object-II and the untested Object-III of Well-D is given in (Fig.7). G&G studies suggest that the depositional pack within Raghavapuram formation of Well-D is older. The Well-D was completed in Object-II as Gas producer. Reasonable quantity of reserves was accreted w.r.to Well-D. As a part of the plan to go for early monetization of hydrocarbon bearing wells, the exploratory Well-D was put on production and the gas output is being marketed to a nearby industrial consumer, bringing in considerable revenue. The drilling success of Well-D of slope fan channel complex in Raghavapuram formation has proved the Geological Model - based on which, the well was drilled mainly as a stratigraphic prospect. Another exploratory Location-1, has already been released to test Pack-2, representing the younger fan lobe - which will further reinforce the strength and extent of the envisaged geological model.

Conclusion

The study area, covering Billakurru and Madupalli areas, has successfully been explored by testing of the Geological Model which was envisaged through integrated G&G studies. So far, potential of Raghavapuram play has been established and proved in many drilled wells in East Godavari Sub-Basin areas, based mostly on structural prospects. However, a pioneering effort was expended to envision and test a geological model, in the area of study, which was founded on integrated G&G studies - bringing out two stratigraphic prospects. The gas Well-D has been earning revenue through marketing of produced gas. The early monetization of the exploratory Well-D will lead to more such integrated G&G studies, visualizing and conceptualizing appropriate geological model for testing of potential plays in prospective areas of the Basin.

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