

Source Rock Analysis To Determine The Prospectivity Of The Permian Play In KG Basin

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Abstract:

Krishna Godavari Basin consists of a vast range of reservoirs ranging from Permian to Pliocene. Hydrocarbon exploration activities have been carried out all throughout the basin targeting different formations. Kommugudem formation in itself can be considered as a petroleum system having shale as source rock, channel sequences as reservoirs with stratigraphic entrapment. This article primarily discusses about the prospectivity of the Permian Kommugudem Formation and its geochemical properties and depositional setting. The Permian Kommugudem shale of Indian KG basin is characterized by rich clay content (>50%), very low permeability, fluvial to lacustrine depositional environment, is an effective source rock containing predominantly Type-III organic matter. Source rock studies including TOC, Vitrinite reflectance and Tmax have been carried out and represented in form of maps to highlight the areas suitable for Permian exploration.

Introduction:

The Krishna-Godavari Basin is located in the central part of the eastern passive continental margin of India. The structural grain of the basin is northeast-southwest. Exposures of Upper Cretaceous sedimentary rocks demarcate the Basin margin toward the northwest, where the northwest-southeast-trending Pranhita-Godavari Graben abuts the Basin. The Basin contains thick sequences of sediments with several cycles of deposition ranging in age from Late Carboniferous to Holocene. Magnetic and gravity data predicted the Basin architecture, which was subsequently confirmed by a multichannel seismic survey. The Basin is divided into Sub-Basins by fault-controlled ridges. Sediments accumulated in Sub-Basins is more than 5 km thick. Until the Jurassic period, sediments were deposited in the rift valley and in topographic lows. This sequence is completely overlain by a Lower Cretaceous, transgressive sedimentary wedge. Later, continued delta progradation characterized Basin sedimentation. With an areal extent of approximately 45,000 km², this proven petroliferous basin has potential reservoirs ranging in age from the Permian to the Pliocene. Good source rocks are known from sequences ranging in age from Permian-Carboniferous to early Miocene. Because the reservoir sand bodies have limited lateral variation, understanding the stratigraphy and depositional sub environments in different sequences is essential to decipher the favourable locales for reservoir sands. Tilted fault blocks, growth faults, and related rollover anticlines provide the structural traps.

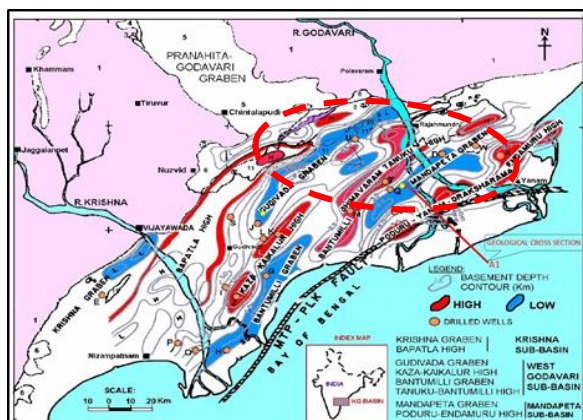


Figure-1: Basin Fill Map of Krishna Godavari Onland Basin. Area of Study demarcated in red. (Source: Status Report Of Shale Gas/ Oil Exploration Krishna-Godavari Basin-Phase I, COD-Shale Exploration, Vadodara, JUNE, 2017)

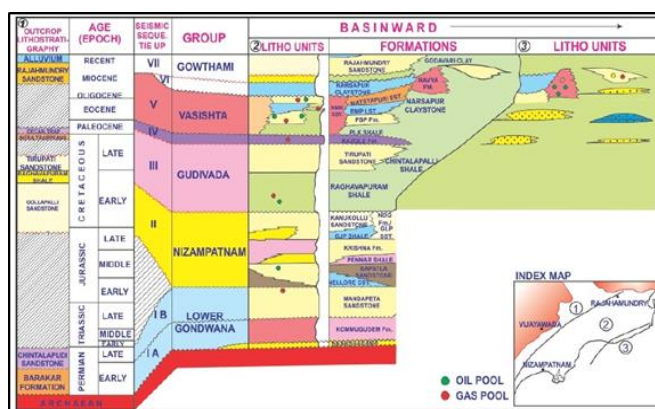


Figure-2: Stratigraphy of KG Basin (Source: ONGC Unpublished Report)

Tectonic Setting:

The major tectonic elements of K.G Basin have been deciphered on the basis of the regional composite Bouguer Anomaly map, Residual Gravity Anomaly map, Total Intensity Magnetic map etc. The Basin has undergone evolution from NW-SE trending failed rift system of initial Gondwana setting to NE-SW rifting during Late Jurassic – Early Cretaceous times indicating poly cyclic evolution history. The main Geo - tectonic elements in the basin constitute a series of NE-SW trending Horsts and Grabens. Major tectonic elements in the study area include Tanuku- Bantumilli Horst, Poduru Yanam high, Mandapeta Graben, Kavitam-Veeravasaram axial Low. Two major cross trends Chintalapalli cross trend and the Pithapuram cross trends define the Godavari Basin. The area encompasses two NE-SW trending Horsts – The Tanuku Horst to the North which takes a south-western swing and continues as Bantumilli horst and Poduru-Yanam High to the south which plunges in a south–westernly direction forming Kavitam Horst. The NE-SW trending axial low present in the area is bounded by Kavitam Horst to the South and Tanuku Horst to the North referred to as Kavitam low in the SW and Mandapeta low in the Mandapeta area (Figure-1).

Generalized Stratigraphy and Depositional Setting:

Krishna-Godavari Basin is orthogonally juxtaposed to NW-SE trending Pranhita-Godavari Graben. The present paper primarily deals with Pre-Cretaceous prospectivity, focusing mainly on Kommugudem Formation (Permian) with the area of study demarcated in red in Figure-1. The oldest rocks encountered are the Pre-Cambrian metamorphic rocks consisting of Gneiss and Quartzite. These are overlain by Argillite which are basement derivatives. The deposition of sediments in this part of Basin was initiated during Permian over Basement and was terminated with the breakup of the Indian land mass from Gondwanaland during Jurassic. The oldest sedimentary section, called Kommugudem Formation (Early Permian) rests on the crystalline basement. It is dominantly a coal shale sequence with subordinate sands deposited in a fluvio-lacustrine environment which marks the initiation of Gondwana sedimentation during Permian age (Figure-2 and 3).

Established Hydrocarbon Plays and New Envisaged Plays:

The Hydrocarbon prospectivity of the Basin has been well established. The Hydrocarbons have been encountered from almost all stratigraphic units from Basement to Pliocene. Sands within Kommugudem Formation are envisaged to be a new play as established within the south of Draksharama High and also Mandapeta Graben. Kommugudem play which is not yet vastly explored in the Basin is the future exploration target wherever suitable entrapment conditions are present.

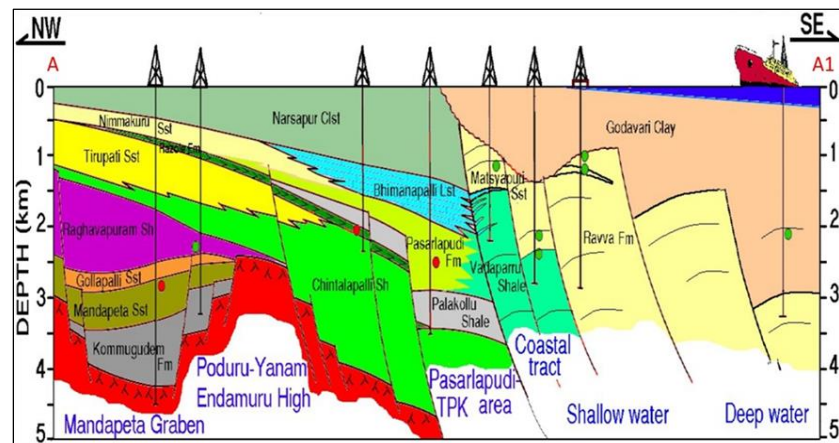


Figure-3: Schematic Geological Cross Line A-A1 (Figure-1)

Characteristics of Kommugudem Permian Shale:

The Permian Kommugudem Shale, is an effective source rock containing predominantly Type-III organic matter. The deposition of Kommugudem marks the initiation of Gondwana sedimentation during Permian. The cyclothemic sequences of coal, shale and sandstone have been deposited under fluvio-lacustrine environment. (Padhy et. al., 2013). The shale is characterized by dark grey to black hard compact, silty and occasionally carbonaceous nature. The sandstones in between are dirty white, feldspathic and medium to coarse grained which act as reservoir. The increase in accommodation space for sediment deposition

resulted in enhanced preservation of organic matter which turned out as good source rocks in coal-shale sequences.

Geochemistry of Permian Kommugudem Shale:

A detailed analysis of TOC logs along with other available information has resulted into detection of some interesting sections in Kommugudem Shale from perspective of hydrocarbon evaluation. Permian Shale is predominantly a Type III gas prone source facies. The average TOC of Kommugudem Shale ranges from 2% to 8% with maximum upto 12%. At places, anomalous TOC content is attributed to high carbonaceous/coaly nature of the shale. The Vitrinite reflectance values range from 0.8% to 1.5%. Thermal maturity in terms of Tmax for the source rock layers varies from 440-535°C. (Jha et. al., 2017 : Unpublished ONGC Report).

Methodology

The study includes data compilation of wells which were drilled down to Kommugudem Formation. Source rock data consisting of TOC, VRo and Tmax from multiple wells was analyzed. After analysis, final dataset has been created which were then plotted against the different wells in the KG Basin. The above parameters were studied and individual contour maps were prepared. Based on these maps interesting zones were identified for all of them. Further, a detailed study of all the source rock parameters was carried out along with seismic and well log data analysis and a promising area of interest has been identified (ref. Figure-5, 6 and 7).

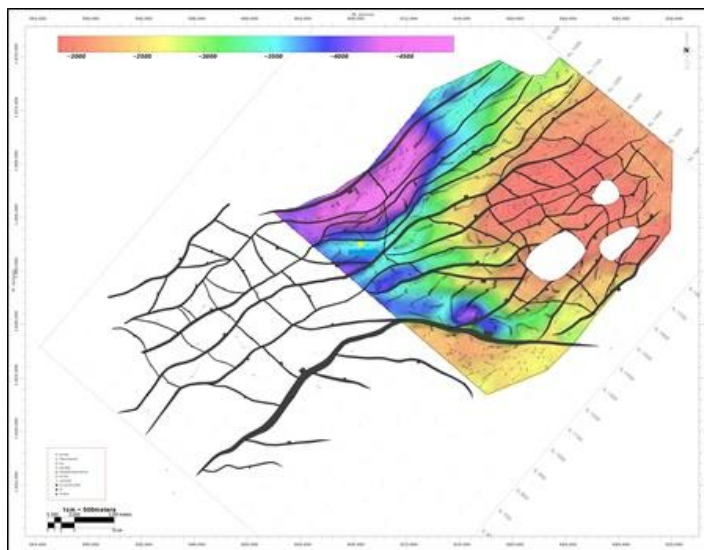


Figure-4: Structure Map at Kommugudem Top, Mandapeta-Endamurru Area (Source: GEOPIC, ONGC)

Analysis and Prospect Area

The important technical parameters for hydrocarbon evaluation are thickness and depth of the shale sequences, Total Organic Content (TOC %), Thermal Maturity (VRo), Tmax of the shale sequences and Log characteristic (Figure 11a and 11b).

Wells which have penetrated Kommugudem Formation of Permian age were considered for analysis and evaluation of the source rock parameters. The average thickness of Kommugudem shale deposited in the Basin is approximately 900-1000m with gradual thinning towards the Draksharama and Endamuru Highs towards the NE (Figure-4 and 8). The Permian Formation is characterized by relatively higher gamma and resistivity values of spiky nature when compared to the underlying and overlying Formations. The alternative high and low spiky values are due to the presence of carbonaceous shales and feldspathic sandstone (Figure-11). It is predominantly a Type III gas prone source facies.

Shales with high gamma, high resistivity, high TOC content (>2-3 wt %), high maturation value (Vro >1.0) and thermal maturity in terms of Tmax > 465°C have been considered ideal for Permian shale gas exploration (Padhy et. al., 2013). The TOC (Figure-5) value of the wells in the study area range from 0.89-13.1% with some anomalous high values due to presence of carbonaceous shale. Thermal maturity in terms of vitrinite reflectance VRo (Figure-6) ranges from 0.55-1.42% and Tmax (Figure-7) varies from 434-530°C. Based on the analysis of the source rock data considering the above parameters, new prospective area for exploration has been identified in the tectonic low of the northern flank side of Draksharama-Podur-Yanam High. The area falls in the eastern and north eastern part of the KG Basin containing the Mandapeta,

Mandapeta West, Endamuru and Ramachandrapuram fields which has been earmarked as area of interest in Figure-5, 6, 7 with the structural highs depicted in red and lows in blue color.

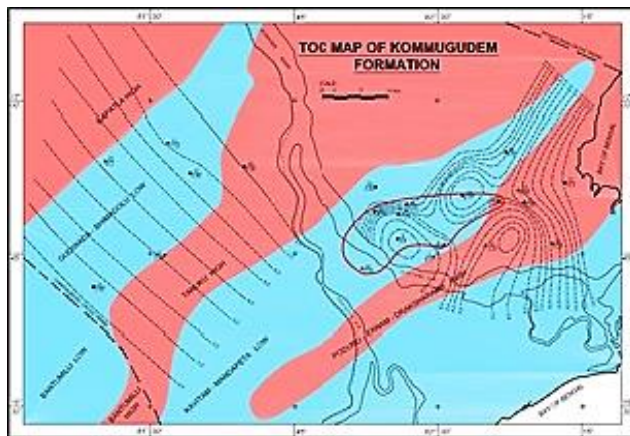


Figure-5: TOC map of Kommugudem Formation with Area of Interest encircled (Highs depicted by red and lows depicted by blue)

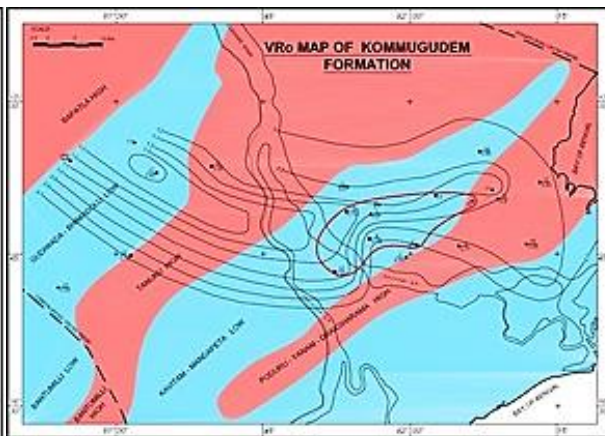


Figure-6: VRo map of Kommugudem Formation with Area of Interest encircled (Highs depicted by red and lows depicted by blue)

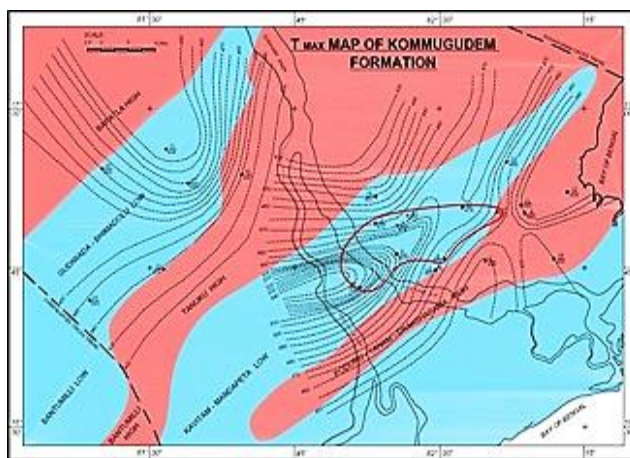


Figure-7: Tmax map of Kommugudem Formation with Area of Interest encircled (Highs depicted by red and lows depicted by blue)

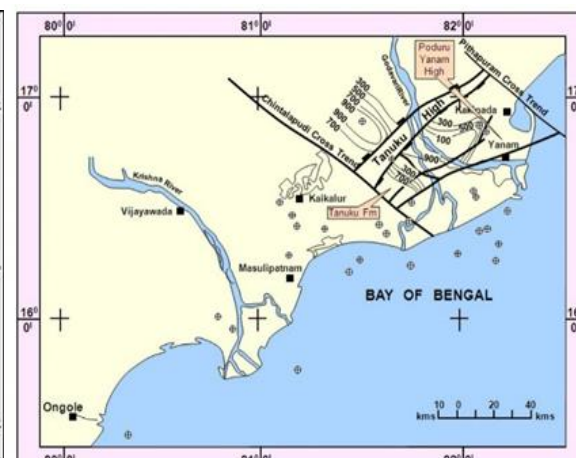


Figure-8: Isopach map of Kommugudem Formation (Source: Status Report Of Shale Gas/ Oil Exploration Krishna-Godavari Basin-Phase I, COD-Shale Exploration, Vadodara, JUNE, 2017)

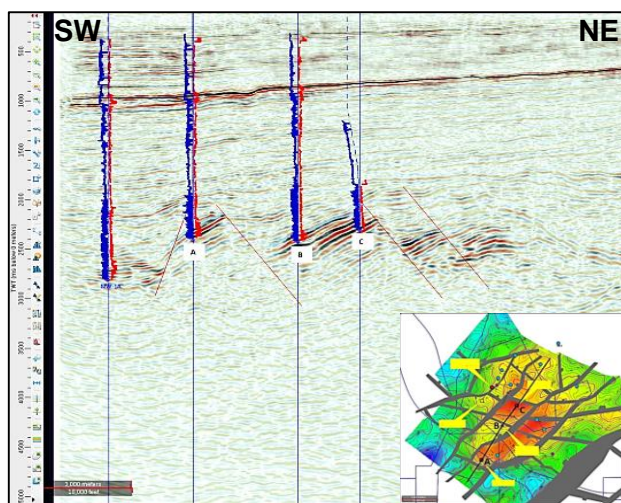


Figure-9: Seismic section Along Strike direction of Basin in Area of Interest

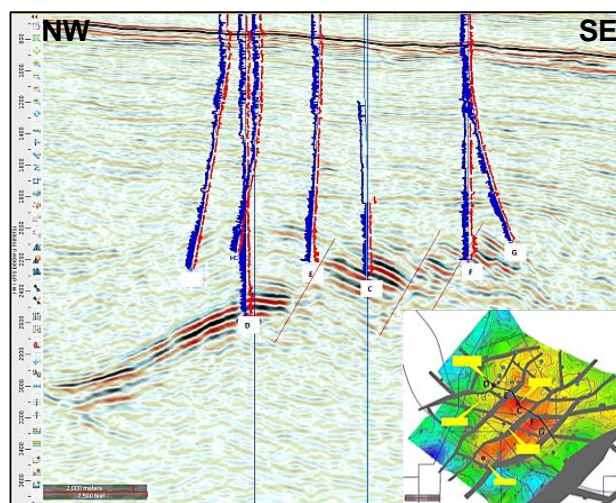


Figure-10: Seismic section Along Dip direction of Basin in Area of Interest

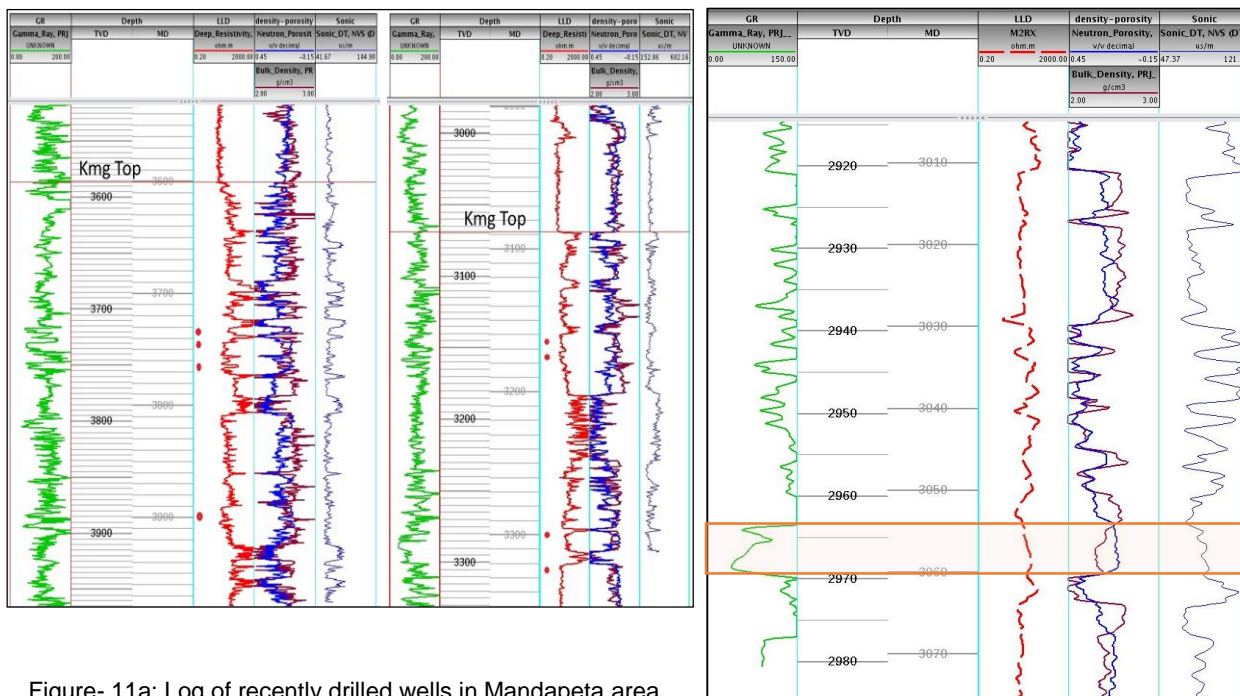


Figure- 11a: Log of recently drilled wells in Mandapeta area showing alternative high and low gamma (spiky nature), high resistivity in Kommugudem Formation.

Figure- 11b: Log motif highlighted flowed commercial quantity of gas in Kommugudem Formation in a well falling in the Area of Interest.

Source rocks of the identified area has average TOC values ranging from 0.89-13.1%, Tmax is greater than 465°C with VRo ranging from 0.9-1.13% which makes them the areas of interest for further exploration of Permian Formation in KG Basin.

Wells drilled down to Kommugudem Formation have been considered and analyzed and based on identification and demarcation of the promising area of interest, additional seismic studies have also been carried out. Two seismic sections along the strike (Figure-9) and dip (Figure-10) of the Basin have been shown. These include the recent wells which have been tested in Kommugudem Formation and encouraging results are observed. The earlier wells had not targeted Kommugudem Formation at deeper levels. Well A has flowed around 7,000m³/d gas, Well B gave gas indication, Well E has flowed around 10,000 m³/d gas and Well C has flowed gas in commercial quantity of the order of 60,000m³/d. The interval tested in Well C has been marked in Figure-11b. Although many wells drilled in this area have not been tested in or drilled down to Kommugudem but the recent successes open up new sands and demand further probing into the Permian Kommugudem Formation. Thus, based on the commercial success of the recent well with encouraging results in other wells along with detailed study of seismic data shall result in development of further prospects in this area.

Conclusion:

- The Kommugudem formation is fluvial to lacustrine in nature consisting of channel and bar filled sequences which act as stratigraphic traps and also fault closure has proclivity to entrap hydrocarbon.
- A detailed analysis of available information has resulted into detection of some interesting areas in Kommugudem Shale from perspective of Permian hydrocarbon exploration.
- The TOC values are in the range of 0.89-13.1% with some anomalous high values due to presence of carbonaceous shale with thermal maturity in terms of Tmax varying from 434°C to 530°C and the vitrinite reflectance VRo ranging from 0.55 to 1.42%.



- These characteristics of the Permian Kommugudem encourage more exploration activities in the sands accompanied with the shale present in the formation for both conventional and unconventional plays.
- Recent wells tested within Kommugudem Formation in Mandapeta area have yielded good amount of gas.
- Prospective areas for exploration of Permian shale are in the tectonic low of the northern flank side of Draksharama-Podur-Yanam High which lies in the eastern and north eastern part of the Krishna Godavari Basin containing Mandapeta, Mandapeta West and Ramachandrapuram fields.

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