An analysis of Low Resistivity Low Contrast (LRLC) sand GS-11 in well A-7- A case study

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Keywords

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Summary

Gandhar is one of the major onland oil and gas fields in South Cambay basin, spreading over 800 sq. km. in the Jambusar-Broach block. The field is situated in the western flank of Broach depression between Dadhar river in the north and Narmada river in the south. The field which exhibits a significant geological complexity is producing significantly from multi layered sand bodies from GS-0 to GS-12. The present study analyses low resistivity pay of GS-11 sand unit in west of main Gandhar area where it is oil bearing.

In this study it was tried to analyze the log signatures of sand GS-11 in the block of well A-1 and correlate it with other geological data. So far, few exploratory and development wells viz A-1, A-4, A-5, A-6 and A-7 have been drilled in this block to explore and develop GS-11. Recently drilled exploratory well A-7 is an oil and gas producer from GS-11. This sand is of particular interest, as in the well A-7, OWC was inferred to be present below a calcareous streak. But a detailed look into the FMI log exhibits that the sand developed below the calcareous streak consists of scattered conductive minerals substantiated by SEM studies of SWCs, hence the low resistivity. Also SWCs within this interval exhibited GYF and cut indicating this sand to be hydrocarbon bearing. Moreover, from FMI log, it is evident that the feeding direction is NE-SW. A trend was sought to be established with wells drilled in the NE-E part of the area. A few correlation profiles have been defined to establish this trend. The findings of this study suggest that the sand GS-11 is a Low Resistivity Low Contrast (LRLC) hydrocarbon reservoir. The general trend of the pay sand GS-11 is from NE-SW with the quality and thickness of the sand getting better towards A-7.

Introduction

The location A-7 was released to ascertain the lower limit of A-1 oil pool in down-dip direction (Figure-1). The sand GS-11 in the down-dip well A-10 was proved as water bearing from petro-physical analysis. The location A-7 was envisaged to fall within a structural reversal between the wells A-11 in the north and A-12 in the south (Figure-2).

The well A-7 was drilled directionally down to 3030m (MD) and was terminated in Cambay Shale formation. The well has penetrated through 2030.40m in Post Dadhar Formation, 253.5m in Dadhar Formation, 602.4m in Ankleshwar Formation (78.5m in Telwa, 298.8m in Ardol, 15.7m in Kanwa, 210m in Hazad) and 11.5m in Cambay Shale Formation with respect to TVD. MDT pretests were carried out at 26 different depths. 5 nos. of MDT samples were collected from GS-12, GS-11 and GS-5C sands. MDT samples from GS-12 and GS-11 sand were found to be hydrocarbon bearing. Based on log correlation with nearby wells, the present well is structurally deeper at all formation tops as well as at the top of pay sands w.r.t to A-1 & A-6 and shallower w.r.t Gandhar-324. Top of GS-11 was encountered at 2705m (TVD-KB) at 677.8m horizontal drift.

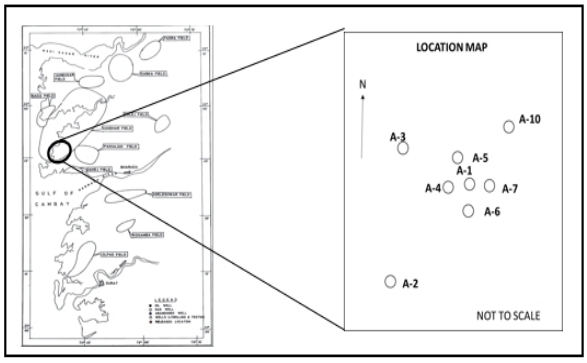

Figure – 1: Location map of study area

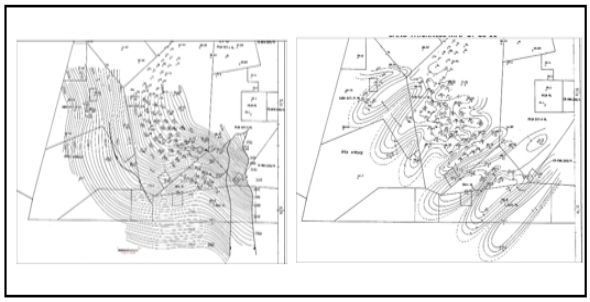

Figure – 2: Depth Map and sand thickness map of GS-11

From the G&G data generated from this well, sands GS-5C, GS-6B and GS-11 were observed to be well developed. On testing, GS-11 produced oil and gas on self with Qoil: 36.5 m3/day and Qgas: 8,986 m3/day via 6mm bean. No water cut is observed during initial testing.

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Hydrocarbon strike of commercial nature in this well has validated the concepts envisaged during identification of the prospect. But the extent of reservoir in down dip direction is yet to be demarcated.

Approach

So far, few exploratory and development wells viz A-1, A-4, A-5, A-6 and A-7 have been drilled in in the block to explore and develop GS-11 sand. Recently drilled exploratory well A-7 is oil and gas producer from GS-11. Log characteristics in this well and the nearby wells were studied carefully. A trend was sought to be established with wells drilled in the NE-E part of the area. A few correlation profiles have been defined and a relation was tried to be established with wells which are envisaged to be in the feeding direction of the GS-11 in the direction NE to SW.

A Brief History of GS-11 in A-1 Block

Based on well A-1, two wells viz. A-2 and A-3 were drilled in the up dip direction to explore GS-5C, GS-7 and GS-12 sands. The well A-2 drilled towards south-west of A-1 was found to be hydrocarbon bearing in GS-6B, while A-3 drilled towards north-west of A-1 was found to be water bearing. Log correlation of the wells A-3 , A-4 , A-1 and A-9 shows GS-11 to be shaled out towards A-4 although all other sands from GS-5C to GS-12 are well developed. Based on these data the effective sand thickness & relief map of GS-11 have been modified after drilling A-2, A-3 & A-4.

GS-11 in A-1 is the first hydrocarbon strike in the block of A-1. The in-place reserves were estimated to be 0.83MMt. To expedite the development and to monetize the field, four locations proposed in this area. All the four locations were released by the competent authority. One of the proposed wells A-4 was drilled towards west in PD/PDD category and was found to be devoid of GS-11 which forced to rethink and revise the existing model.

The block was re-calculated and the in-place reserves were re-estimated using the pressure and production data of A-1. The study was carried out at IRS, Ahmedabad using 'Material Balance' to estimate the reserves and finally the in-place reserves were revised to 0.748MMt which is 0.08MMt less than earlier estimation by REC. Since there is no much variance in in-place reserves, the area holding these reserves must also be nearly same. As the reserves towards south-west are negated after drilling A-4, it was opined that the possibility of the oil pool extension is towards down dip. Subsequently, A-6 was drilled as a development well towards south of A-1, and produced oil from GS-11. Encouraged by the success of A-6 and also the log data of A-1 is indicating a shale contact, an exploratory location was drilled in down dip direction to explore GS-11 as A-7.

Technical progress and observations

The log characteristics of well A-7 vis-à-vis the nearby wells were carefully studied. About 9m thick GS-11 (2820-2829m) is developed in this well.

- From the G&G data generated from this well, GS-5C, 6B and 11 sands were observed to be well developed. On testing, GS-11 (2820.5-2823m) produced Oil and Gas on self with Qoil: 36.5 m3/day and Qgas: 8,986 m3/day via 6mm bean. No water cut was observed during initial testing (Figure-3).

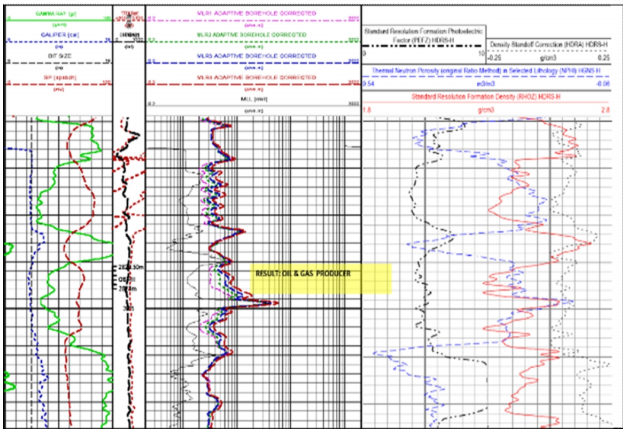


Figure –3: Log Motif of GS-11: 2820-2829m

- SWCs within the concerned interval exhibited GYF and cut indicating this sand to be oil bearing (Table-1).

Depth (m)	Length (cm)	Lithology	Description	HC Shows	Sand
2821.6	1.5	Sandstone	Colourless, milky white, dirty white, transparent to translucent, very fine to fine grained, occasionally medium grained, moderately sorted, sub angular to sub rounded, non-calcareous.	* Patchy GYF/ NC	GS-11
2823.4	2.5	Sandstone	Colourless, milky white, dirty white, transparent to translucent, very fine to fine grained, occasionally medium grained, moderately sorted, sub angular to sub rounded, non-calcareous.	Patchy GYF/ Faint cut	
2824.5	1	Sandstone	Colourless, milky white, dirty white, transparent to translucent, very fine to fine grained, occasionally medium grained, moderately sorted, sub angular to sub rounded, calcareous.	*Patchy GYF/ NC	
2827	2.5	Argillaceous Sandstone	Colourless, milky white, dirty white, transparent to translucent, very fine to fine grained, moderately sorted, sub angular to sub rounded, non-calcareous.	Patchy GYF/Faint Cut	

Table – 1: Side wall core lithological description report of the concerned interval

- The Sand GS-11 is a laminated reservoir with alternate layers of sand and shale.
- From SEM analysis of SWCs, sample analysis and other studies, presence of kaolinite is observed in the pore spaces and also the sand grains are coated with chlorite, may be due to bio-turbation (Figure-4).

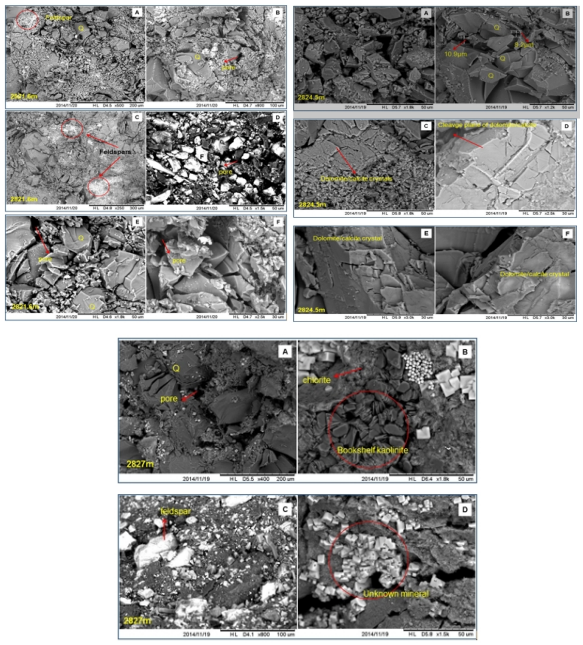
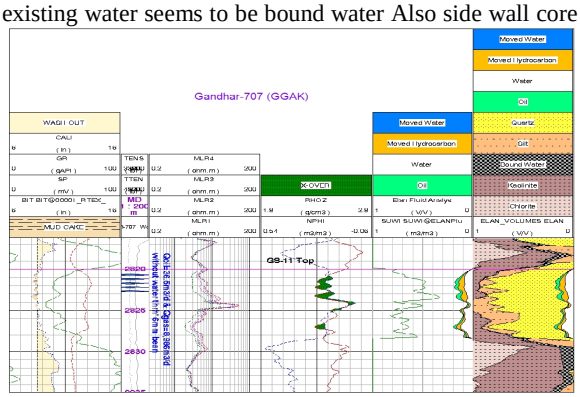


Figure-4: SEM images of side wall core

- FMI processed data shows the presence of conductive minerals (Figure-5).
- The above said observations may be the cause of low resistivity against GS-11.
- ELANPlus processed data has shown an estimated water saturation of 65-70% against the shaly sand interval (2826-2829m) below the calcareous streak which shows this sand to be interesting from hydrocarbon point of view substantiated by the SP log (Figure-6). If tested in all probability, this interval will produce clean oil as the existing water seems to be bound water Also side wall core



collected at 2827m was described as argillaceous sandstone exhibiting GYF/cut.

Figure–6: ElanPlus processed data

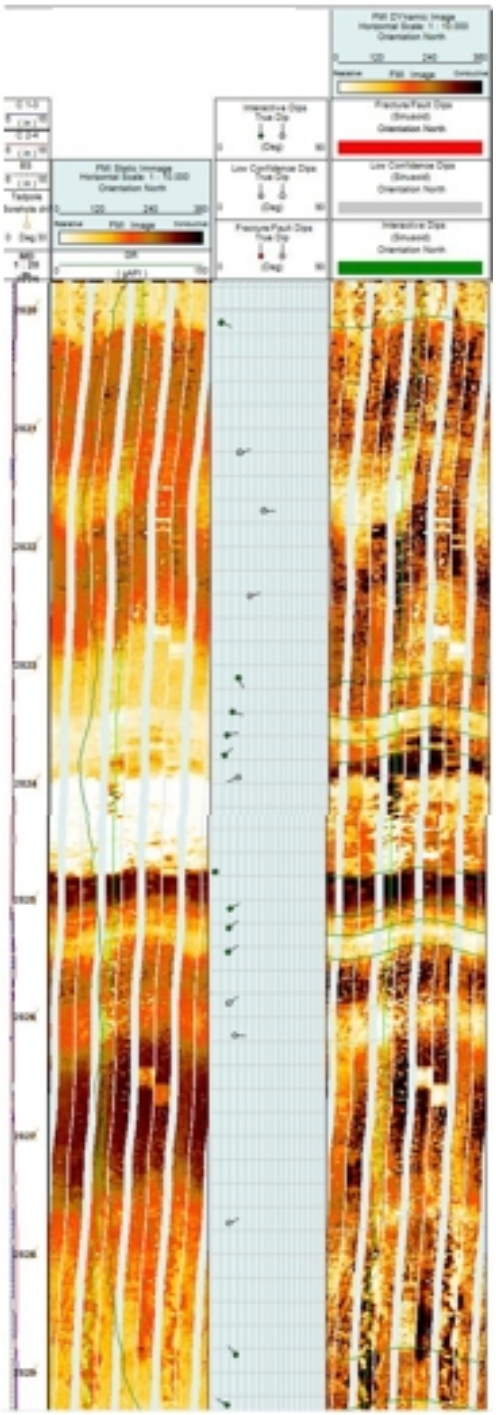
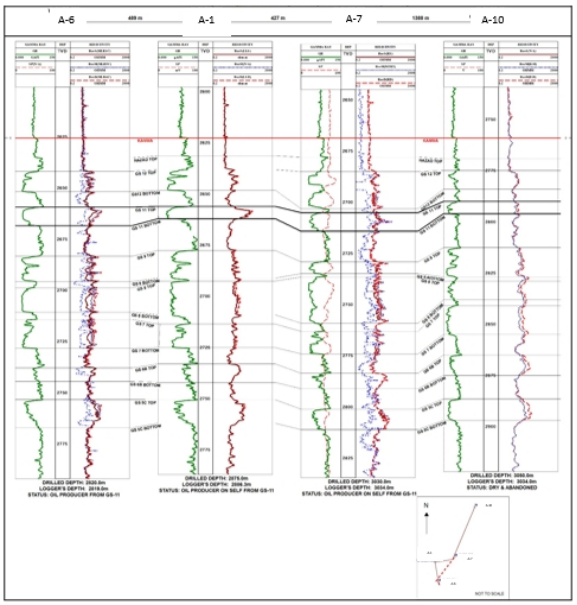


Figure – 5: FMI log of Object-III: 2820.5-2823m

• Correlation of wells A-7 and A-6 (400m west of A-7) suggests that the sand lobes of GS-11 are different as can be inferred from resistivity patterns (Figure-7a).



Figure–7(a): Stratigraphic log correlation with nearby wells

• The stratigraphic correlation of A-7 with distantly located (5.2 Km East) located well A-8 shows GS-11 to be better developed towards A-7 also the permeability of the sand is better in A-7 than A-8 as interpreted from log data (Figure-7b).

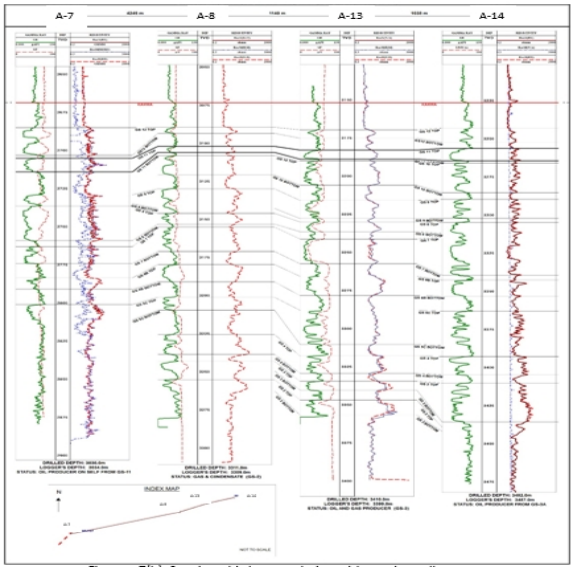


Figure7(b): Stratigraphic correlation with nearby wells

• FMI log also indicates that the paleo-current direction is from North-East to South-West. It is also corroborated from correlations with A-8.

It is known that the principal causes of Low resistivity-low contrast (LRLC) reservoirs are:

1) Laminated sequences of sand and shale,
2) Dispersed clay,
3) Clay coating,
4) Presence of conductive minerals like pyrite, siderite, illmenite etc.
5) Small grain size,
6) Presence of high amount of clay bound and capillary bound water.

And the major depositional systems containing LRLC reservoirs are:

1) Channel fills,
2) Delta front deposits,
3) Turbidites and
4) Deep water fans including levee-channel complexes.

In the past, these intervals were often overlooked, considering them to be wet or tight. These LRLC intervals which contain significant reserves, can be recognized today through proper identification and evaluation techniques using advanced logging techniques and samples/cores.

Conclusions and Recommendations

From the studies carried out, it is envisaged that the pay sand GS-11 is a Low resistivity-low contrast (LRLC) pay sand. The decrease in resistivity below the calcareous streak in GS-11 of A-7 may not be interpreted as water bearing. The general trend of the pay sand GS-11 is from NE-SW with the quality and thickness of the sand getting better towards A-7, which may increase the chances of encountering the sand in West/West-Southwest of well A-7 – well A-6 alignment or may help in delineating the pay sand boundary. The sand GS-11 is not developed further SW in A-2. But in the down-dip direction i.e. towards NE of A-7 is a promising direction. A few step out wells may be planned towards east and south-eastern direction of A-7 in down dip direction for delineation of the pool. 3D-3C seismic data acquisition is already planned in the area for better understanding of reservoir / entrapment mechanism and sand dispersal pattern.

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