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RDG – A SUCCESS STORY OF TIGHT GAS DEVELOPMENT

Tight gas reservoirs are defined as low permeability reservoirs which require hydraulic fracturing and completions for economic production. Hydraulic fracturing is a technique in which frack fluid and proppant are injected into the formation at high pressures and rates to create high permeability flow channels from the reservoir into the well. It can be performed from either vertical or horizontal wellbore (see Figure 1).

In Barmer basin, Rajasthan, Cairn Oil & Gas, Vedanta Ltd. has producing tight gas field and multiple tight gas reservoir exploration prospects. Raag Deep Gas (RDG)field is the largest gas producing field in Barmer basin. Raageshwari Deep Gas is a low permeability gas condensate reservoir, with excellent gas quality of approximately 80% methane, low CO2 and no H2S. The gas has net calorific value of about 1070 BTU/SCF.

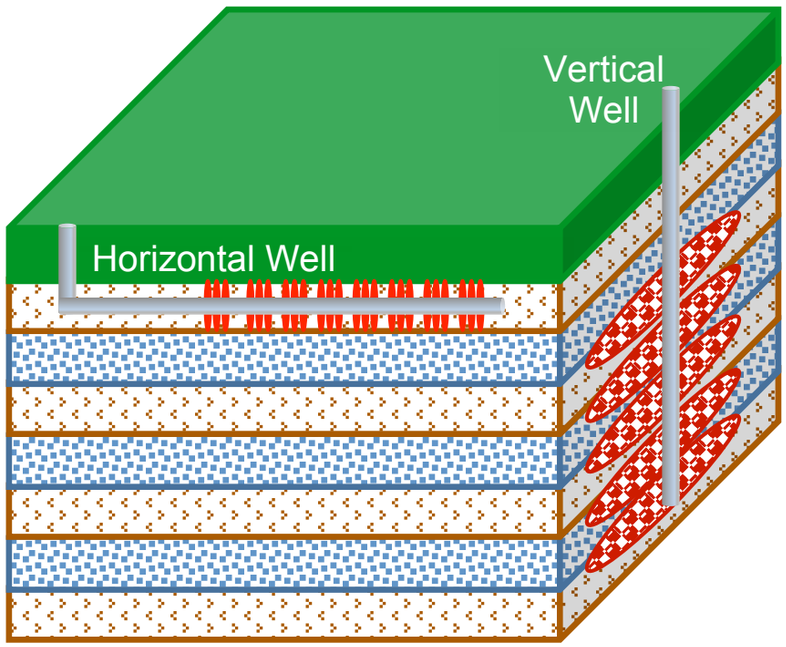

Figure 1: Vertical vs Horizontal Fracturing

The condensate gravity is ~ 560 API. Raageshwari Deep Gas field contains low permeability reservoirs consisting of sandstone (Fatehgarh) and volcanic (Basalt and Felsic) lithologies with permeabilities in the range of 0.01- 1md. Formation top of these reservoirs range from a depth of ~2700-3000m TVDSS with gross average reservoir thickness of entire column at ~750-800m.

A total of 105 wells have been drilled in RDG reservoir across four development phases. Next phase of development, i.e. drilling, frack and completion of 5 in-fill wells will commence from Marach 2025. Field is currently producing at the rate of ~105mmscfd. Raageshwari Gas Terminal (RGT) has an available processing capacity of ~250 mmscfd.

Considering the thickness of reservoir column, variable net to gross across each of the formation, high heterogeneity in terms of reservoir properties, near vertical / low inclination wells are drilled and multiple hydraulic fracturing stages are placed to connect the reservoir to achieve commercial production rates.

Typically 8 to 10 stages will be pumped in a given well. A stage is defined as a single pumping operation. In the case of RDG multiple hydraulic fractures are created in each stage by using limited entry. Limited entry uses engineered perforations to force fracturing fluid (water and proppant) into multiple zones during a single pumping operation. Thus with limited entry, as many as six fractures can be created simultaneously. The stages are separated using bridge plugs (Figure-2). So a typical sequence would be perforate the lower zone, frac the zone, set a plug, perforate the next higher zone .This sequence is known as plug and perf. The efficacy of the limited entry technique in RDG has been proved using post frac temperature surveys (to identify frac fluid injection points). And production logs to determine which perforation sets are producing. Figure 3 contains an example of the fracture simulation compared to the temperature survey (2nd track). Cooling (shift to the left) indicates where the fracturing fluid went and the fracture height. In order to maximize efficiency, Cairn introduced a strategy for rigging up to two or more wells at the same time. This minimizes down time and speeds up the entire completion process.

Globally, recommended mode of development of a tight gas reservoir is to reduce the well spacing for most optimal sweep / drainage of reservoir. However, number of wells that can be drilled are driven primarily by commercials and revenue generated. In a tight gas reservoir field that has reached its optimal well capacity, it is recommended to lower

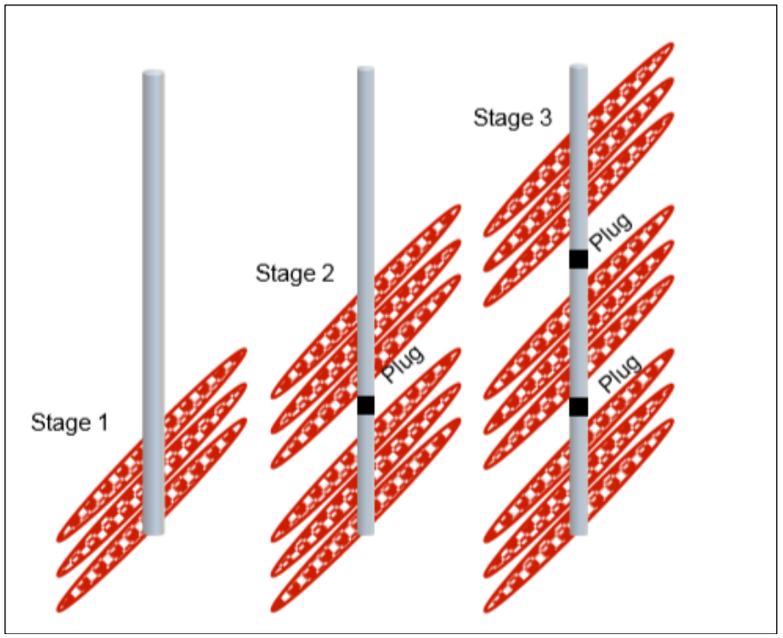

Figure 2:Raageshwari Deep Gas – Structral Map & Type Log

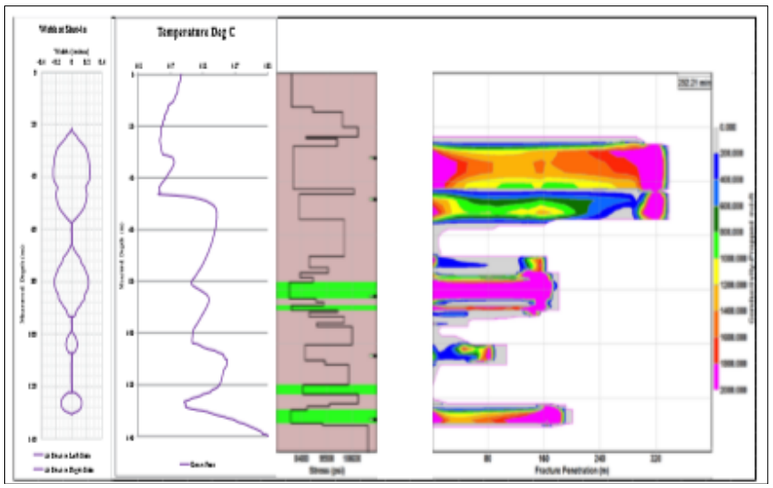

Figure 3: Raageshwari Deep Gas Production History

the surface pressures to further improve the field recover / EUR. Modelling work suggests significant gain in terms of field estimated ultimate recovery by lowering the terminal inlet pressures. This would be considered as a next significant phase of field development to enhance the field recoveries. Reduction of plant inlet pressures by installing compressors at inlet is currently under design phase. On completion, the plant inlet pressure is expected to drop from 12.5 barg to ~5 barg, leading to incremental drawdown on wells and hence adding to reserves base.

There is a plan to carry out re-processing of the Orthorhombic 3D Wide Azimuth seismic data acquired in 2014, to further delineate positioning of boundary faults in RDG area. This may potentially open up additional area for development. Additionally, potential to drill horizontal wells to sweep the relatively undrained zones has also been investigated. However, considering the reservoir complexities and heterogeneities, appropriate technologies and approach are still under advisement.

EXPLORE INDIA WITH CAIRN

Cairn Oil & Gas, part of Vedanta Limited, is India's largest private oil and gas exploration and production company, contributing about a quarter of India's domestic production. With a world-class resource base, Cairn has an interest in 62 blocks in India spread over 60,000 square kilometres with gross 2P (Gross Proved Plus Probable Reserves) and 2C (Gross Contingent Reserves) of 1.4 bn boe.

Cairn has producing assets across Rajasthan, Andhra Pradesh, Gujarat, and Assam, and has spearheaded several technological innovations with high-reward prospects, over the last 30 years of its operations. The company has a vision to contribute 50% of domestic production, executing one of the largest exploration projects in India across its diversified portfolio comprising conventional and unconventional projects such as Tight Oil & Gas, Deep & Shallow Water, ASP and CBM, reinstating the faith in the country's hydrocarbon potential.

Cairn is committed to achieving Net Zero by 2030 by prioritising environmental resilience and is driving transformative social impact at scale. It has become the first Indian company to sign the United Nations Environment Programme's methane reporting and reduction initiative – OGMP 2.0.

30 YEARS OF ENERGISING INDIA

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