# Mohana Fawn Limestone gas play: a new discovery in Son Valley, Vindhyan Basin, India

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## Summary

The accelerated exploration activities within the Damoh-Jabera-Katni PEL block, Son Valley has led to establishing the Rohtas and Kaimur as gas plays within the Lower and Upper Vindhyan sediments respectively. Recently, an exploratory well (D), was targeted to explore the wedge out prospects within the Rohtas Limestone as well as the deeper Mohana Fawn Limestone. The conventional testing of an object in Mohana Fawn Limestone for the first time in this area led to the discovery of a new gas play. Integration of well and seismic data shows extension of the gas pool over a large area within the exploration acreage of Son Valley. The discovery has opened up new dimension in the exploratory successes in the Proterozoic Vindhyan Basin points towards the possibility of a separate Charkaria-Mohana Fawn Petroleum system in addition to the shallow Rohtas-Rohtas-Kaimur petroleum system in the area.

## Introduction

The Son Valley sector of Proterozoic Vindhyan Basin, in the central part of India, holds promise of emerging as a major hydrocarbon province in view of recent significant gas discovery within Meso Proterozoic Rohtas Formation (Lower Vindhyan) and Basal Kaimur clastic reservoirs (Upper Vindhyan) and very recently within Mohana Fawn carbonate reservoirs (Lower Vindhyan) in Nohta-Damoh-Jabera area. Presence of gas at different levels within the shallow carbonate and clastic reservoirs has been established after drilling a number of exploratory wells in recent times. Based on the analysis of geo-scientific data obtained from these wells and the resultant enrichment in understanding the hydrocarbon accumulation pattern, the shallower strati-structural plays within Rohtas, Mohana Fawn and Kaimur formations have emerged as the gas bearing targets in Son Valley, Vindhyan Basin. These are typical unconventional tight gas reservoirs having very low porosities, ultra low permabilities (mili-micro Darcy) and low reservoir pressure. Flow of gas from these reservoirs is primarily dependant on the presence of open /partially open fractures.

### Geological Setting

The Vindhyan Basin is genetically associated with two mega tectonic elements: Great Boundary Fault (GBF) to the northwest and Son-Narmada Lineament (SNL) to the south. The Bundelkhand Massif, located in the north-central part of the basin, divides it into two sectors: Chambal Valley to the west and Son Valley to the east *(Fig.1)*.

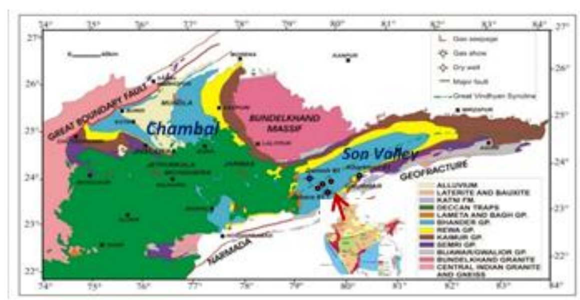


Fig 1. Geological map of Vindhyan Basin.

The basin fill in Son Valley constitutes a considerable thickness sedimentary succession, which is divisible into carbonate dominated Lower Vindhyan (Semri Group) and clastic dominated Upper Vindhyan (Kaimur, Rewa and Bhander Groups) sequences, separated by large hiatus (Table-1). The Vindhyan strata of Son Valley define a broad ENE–WSW trending regional syncline in the central part. The axis of the syncline is slightly curved (convex towards north) and plunges gently towards west. Detailed account of tectonic framework including the fault systems, paleo-structures, structural inversion and deformation history have been described by many workers from time to time (Jokhan Ram et al., 1996, Mahendra Pratap et al., 1999, Verma et al., 2002).

**Stratigraphic Nomenclature, Son Valley (ONGC) & H/C occurrence**

| AGE | GROUP | SUB GROUP | FORMATION |
|---|---|---|---|
| MESO TO NEO PROTEROZOIC | UPPER VIMDHYAN | BHANDER | MAIHAR SANDSTONE |
| | | | SIRBU SHALE |
| | | | NAGOD LIMESTONE |
| | | | GANURGARH SHALE |
| | | REWA | REWA SANDSTONE |
| | | | JHIRI SHALE |
| | | KAIMUR | KAIMUR SANDSTONE ★ |
| UNCONFORMITY | | | |
| PALEO PROTEROZOIC | LOWER VIMDHYAN | SEMRI | ROHTAS LIMESTONE ★ |
| | | | BASUHARI SHALE |
| | | ★ | MOHANA FAWN LIMESTONE |
| | | | CHARKARIA OLIVE SHALE ★ |
| | | | JARDEPAHAR PORCELLANITE ★ |
| | | | KAJRAHAT LIMESTONE |
| | | | ARANGI SHALE |
| | | | KARAUNDHI ARENITE |
| UNCONFORMITY | | | |
| EARLY PROTEROZOIC | BIJAWAR GROUP | | |
| ARCHEAN | BUNDELKHAND GNEISS | | |

Table 1. Stratigraphy of Son Valley

Son Narmada Lineament is a major crustal feature formed along the Archean structural trends and remained active throughout geologic history. It marks the tectonic sedimentation limit of Vindhyan Basin in south and south-east. The greater thickness of sediments in Son Valley area towards south implies an active southern margin along which relatively continuous subsidence was responsible for greater thickness of sediments. The northern and eastern margins of basin have gentle gradient. Intense structural deformation of the Lower Vindhyan Sequence in vicinity of SNL is evidenced by the presence of tight folds, normal and reverse faults, thrusted contacts and mylonitisation.

Initial tectonic evolution of Vindhyan Basin is controlled by basement related rift tectonics, which formed a number of horst and grabens along planes of weakness. Two main fault trends are evident, faults parallel to the SNL (E-W to ENE-WSW) as well as along NW-SE aligned oblique faults. The major half grabens are located along the down thrown side of these rift related faults. Some of these faults show syn-sedimentary vertical movements. In later phase of evolution, compressional reactivation of pre-existing extensional faults under the influence of wrench related strike–slip movement along the Son-Narmada Lineament (SNL) resulted in the formation of inversion structures like Damoh, Jabera and Kharkhari. Major oblique faults divide Son Valley into a number of tectonic blocks (Fig.2), notable among them are the Udaipur-Tendukhera block, Jabera-Damoh block and Satna-Rewa-Kaimur block (Mahendra Pratap et al., 1999). Among these blocks, the Jabera-Damoh block is tectonically the most disturbed.

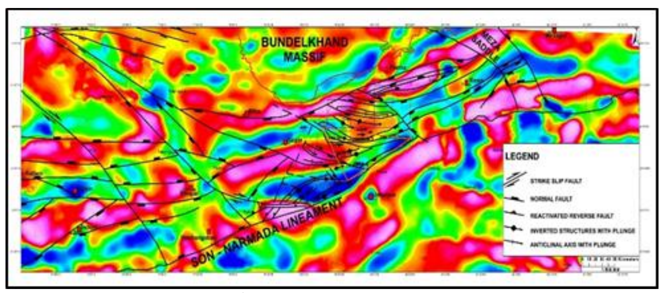


Fig 2.Tectonic map of Vindhyan Basin (Task Force Report Mahendra Pratap, 1999 etal) overlain on residual gravity map (KDMIPE report)

## G & G Evaluation

Well D, located on the southern flank of the Damoh High (Fig 3), was drilled to a depth of 1650m with an objective to explore the wedge out prospect of Rohtas Limestone. Based on the evaluation of geological and electrolog data, limestone reservoir within Mohana Fawn Limestone Formation appeared prospective from hydrocarbon point of view. The lithology is primarily limestone with thin beds of shale. Limestone is dirty white, greenish grey, hard and compact, massive, unfossiliferous and micritic in nature. Petrographic study of samples reveals presence of sparitised mudstone with silt size quartz grains as the dominant microfacies with tight nature of the mudstone with minor isolated micritic porosity.

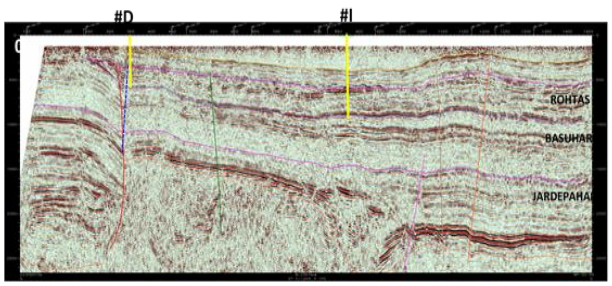


Fig 3. 2D Seismic section showing location of well D.

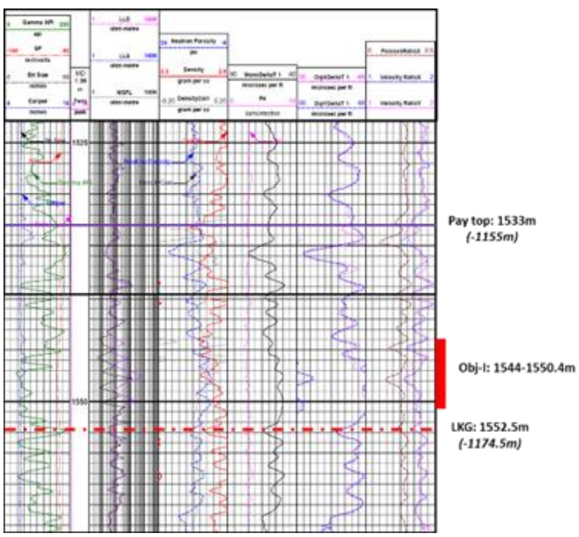


Fig4. Electro Log motifs against Object 1

On initial testing, the identified zone within Mohana Fawn Limestone flowed thermogenic gas @ 443 m3/d through 4mm bean. Bottom Hole Studies were carried out including build up study, which indicated sub-hydrostatic reservoir pressure (SBHP 29.7 Ksc and very low , FBHP 1.5 to 3 Ksc). The electrolog motif and processed log of the Mohana Fawn gas bearing zone are placed as Fig.4. The top of pay is at 1533m (1155m MSL) and the Lowest Known Gas (LKG) limit at the well is marked at a shale contact at the depth of 1552.5m (1174.5m MSL). Structure map on top of Mohana Fawn pay is placed as Fig.5. The net pay thickness is taken as 8m at the well, while a maximum pay thickness of 12m is expected at the structurally advantageous position.

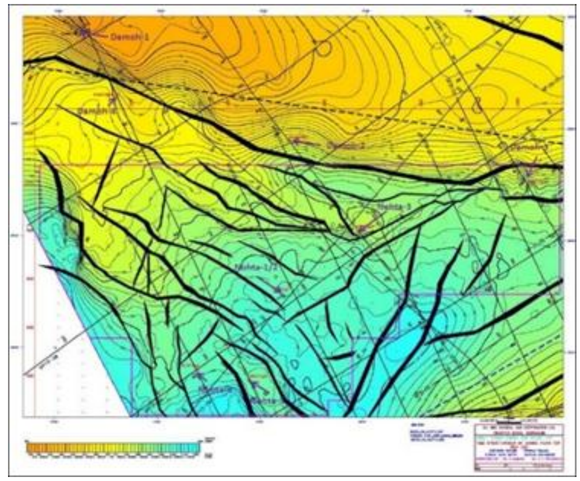

Fig. 5. Time structure map close to top of Mohana Fawn Limestone

In order to decipher the entrapment condition of this new gas pool, time structure map close to top of Mohana Fawn Limestone Formation was prepared which has brought out a fault bounded structural closure having an aerial extent of about 19 Sq.Km and the well D is located at the flank of the broad structure (Fig.6 ).

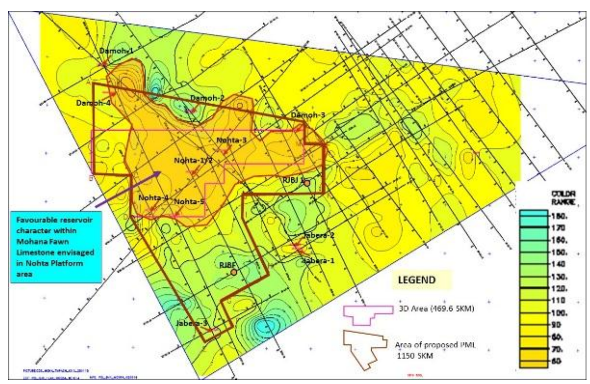


Fig. 6 Time thickness map of Mohana Fawn Limestone showing the area of Mohana Fawn prospectivity.

The gas shows within Mohana Fawn Limestone was also observed in well E during drilling at a depth of

2473m (Total gas: 12.4%, C1:7.41%, C2: 1.17%, C3: 0.2%). Electrolog correlation of the adjoining wells penetrating Mohana Fawn Limestone indicates presence of gas pool in well E as well and points towards the likely extension of this new play over a large area.

Geochemical analysis of the gas samples of Mohana Fawn Limestone reservoir was carried out by KDMIPE. The molecular and carbon isotopic composition of the gases indicate thermogenic origin (C1 81%). However, based on carbon isotopic values, the Mohana Fawn gas appears to be different from the Rohtas and Kaimur gases (Fig 7). The Mohana Fawn gas exhibit a lighter methane carbon isotopic values and have a normal carbon isotopic trend in the hydrocarbon components ($\delta 13C1 < \delta 13C2 < \delta 13C3$). The Rohtas and Kaimur gases, on the other hand, show a distinct isotopic reversal, i.e $\delta 13C2$ and $\delta 13C3$ are isotopically lighter than $\delta 13C1$.

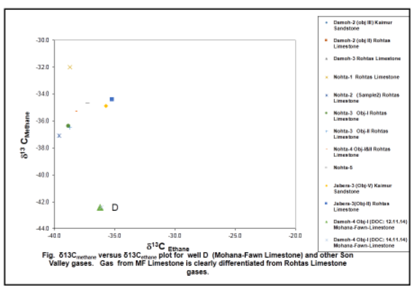


Fig. 7. Carbon isotopic ratio plots showing the character of gas in Mohana Fawn Limestone (source: KDMIPE Reports)

The different chemical and isotopic composition of the gas as compared to the Rohtas and Basal Kaimur gas, points towards a different source for the Mohana Fawn gas. The organic rich shale within Charkaria Formation have exhibited good source potential in wells K and E (TOC: 0.42-1.84%) and might have acted as source for the Mohana Fawn gas accumulation in the present well. Thus, in addition to the already established Rohtas-Rohtas-Kaimur petroleum system, the possibility of a separate Charkaria-Mohana Fawn petroleum system exists in this part of Son Valley.

### Reservoir Character

The reservoir encountered within Mohana Fawn Limestone in well D have moderate to good petrophysical character. Although the zone does not show fracture development in XRMI log, the matrix porosity seems be good. In addition, reservoirs within Rohtas and Kaimur Sandstone were also encountered with poor distribution of fractures. In fact, the distribution of fractures are poor in this well compared to the other wells drilled so far in Damoh and Nohta areas.

The Mohana Fawn Formation, consisting of limestone-shale alternations with intercalated siltstone and minor amount of sandstone, is inferred to be deposited in a broad carbonate tidal flat environment. This is clearly brought out by the Time Thickness map (Fig 6) which shows a more or less uniform thickness distribution over the area with localised lows near Damoh and West of Jabera (120-170 ms TWT thickness). Between the Damoh and Jabera lows, a broad platformal set up was prevalent over the Nohta area extending up to well D (70 -90 ms TWT thickness) which is similar to the depositional set up of the overlying Rohtas Limestone and points towards the presence of favourable reservoir character within Mohana Fawn Limestone in this area.

### Prospectivity Analysis

Analysis of electrolog and seismic data of the drilled wells reveal that equivalent of gas pool penetrated in well D is present over a large area of the block. In well E, gas shows were observed during drilling within Mohana Fawn Limestone at 2473m. The Mohana Fawn gas zone in well D manifest as moderate to high amplitude and low to moderate frequency seismic event (Fig.8). Similar seismic response is also seen within Mohana Fawn Limestone in well E (corresponding to the zone of gas indication during drilling). However, the zone could not be tested due to limitations in casing design. Equivalent of Mohana Fawn gas pool in wells G and I exhibit encouraging seismic response (Fig.9) similar to the gas well D. Since the objective of these wells was to probe the hydrocarbon potential of Rohtas Limestone only, these wells did not penetrate the Mohana Fawn

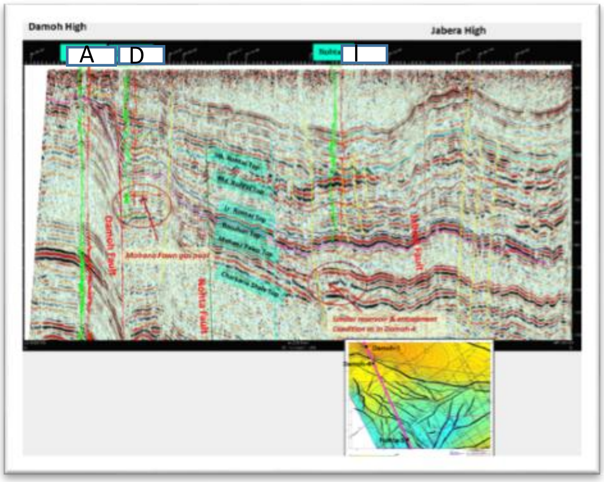


Fig.8. 2D Seismic line showing position of wells A, D and I.

Limestone section.

**Prospective areas for Mohana Fawn gas play**

In order to decipher the likely extent of this new gas pool, seismic inversion analysis along the 2D line passing through well D was carried by calibrating with the logs of well D (Fig.10). The analysis reveals the presence of a low impedance layer corresponding to the Mohana Fawn gas bearing zone encountered in well D within an overall high impedance interval. The impedance section also suggests a better and thicker reservoir development towards SE of well D.

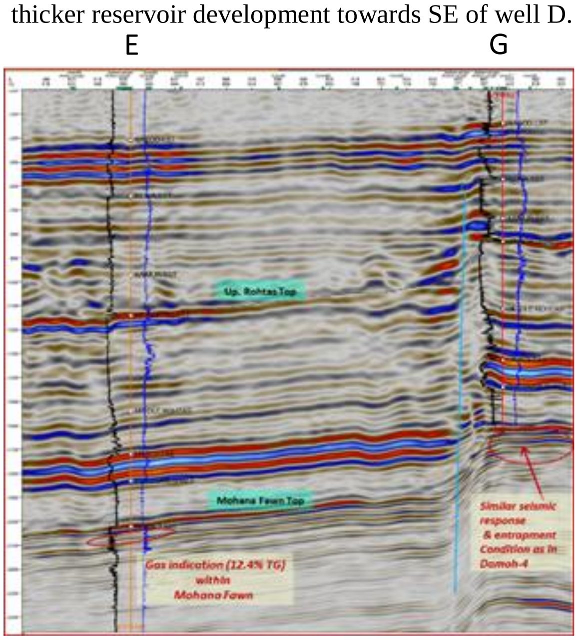


Fig.9.Arbitrarary depth section (3D) showing zone with gas indication in well E (not tested) and G (MF Limestone not drilled).

Taking clue from the 2D impedance study, model based Post stack inversion of the adjacent Nohta 3D volume was also carried out to identify prospective areas for exploring Mohana Fawn gas play within the 3D area. Additionally, amplitude (RMS & AAA), instantaneous frequency and sweetness maps corresponding to the gas bearing window within Mohana Fawn Limestone were also generated and analysed within the 3D area. Since the flow of gas from the unconventional tight gas reservoirs is dependant on both matrix and fracture porosities, the fracture trends derived from 3D ant track attribute were also evaluated along with other seismic attributes for delineating the fracture corridors favourable for gas accumulation. The map (Fig. 11) has brought out a number of favorable clusters for chasing the Mohana Fawn gas lead over a large area of the Block to the south of Damoh High.

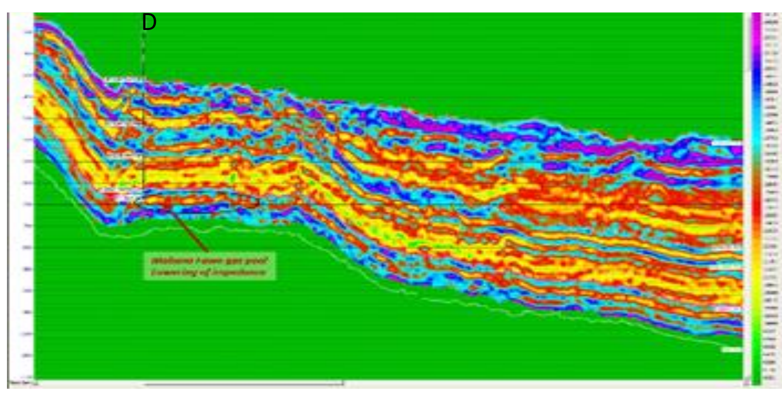


Fig.10 Impedance section along a 2D seismic line showing low impedance against gas bearing MF Limestone in well D

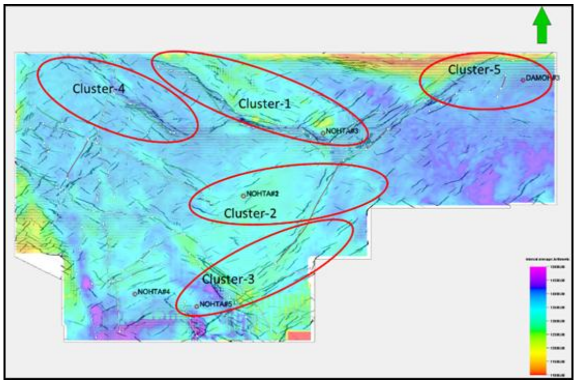


Fig. 11. Impedance map a window 20-60 m below the top of Mohana Fawn Limestone corresponding to gas bearing zone superimposed on the ant track derived fracture trend showing the prospective clusters

### Conclusions

A new gas discovery from Lower Vindhyan Mohana Fawn Limestone is established which is thermogenic and composed predominantly of methane (81%). The carbon isotopic values of methane are lighter as compared to Rohtas & Kaimur gases, which points towards the possibility of a separate Charkaria-Mohana Fawn Petroleum system in addition to the shallow Rohtas-Rohtas-Kaimur petroleum system in the area. The organic rich shales within Charkaria Formation might have acted as source while the overlying Basuhari Shale has acted as an effective seal. This new gas play along with the already established shallower Rohtas and Kaimur gas plays enhanced the prospectivity of the Son Valley sector of Vindhyan basin for exploitation as well as opening up large area for future exploration.

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