# Coal Characterization by Coal Bed Methane Drilling in Tatapani – Ramkola Coalfield, Surguja District, Chhattisgarh, India*

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## Abstract

In the ever-demanding energy scenario in India, CBM is considered to be an alternate and clean resource which may bridge up the demand supply gap to a large extent. Government of India therefore has been encouraging state as well as private companies for the exploitation of CBM. Tatapani-Ramkola is one such CBM block awarded by the government to the consortium of Dart Energy, GAIL, and Tata Power Company in the year 2006.

The exploration was carried out in the block by drilling 8 core wells (total drill 8212.50 m) of which four wells were cored to the depth below the target seams of the Barakar Formation while the other four wells could not penetrate through the entire Barakar strata because of depth and drilling constraints (Figure 1). The findings presented in this paper are based on the data obtained during the field operations and subsequent laboratory testing. This evaluation included coal bed gas content determination, coal bed gas resource estimation, as well as preliminary risk assessment of the key reservoir parameters such as permeability, gas saturation, and coal continuity that would lead to its production potential.

## Geological Set Up

Tatapani-Ramkola Coalfield represents an east-west trending synclinal sub-basin lying in the easternmost segment of South Rewa Gondwana Basin. The basin is enclosed on three sides by Proterozoic basement rocks, over which were deposited the Gondwana sediments represented by a variable thickness of different formations starting from Talchir, Barakar, Barren Measures, and Raniganj Formations exposed along the northern, eastern, and southern periphery of the basin. This coalfield has prominent boundary faults along its northern and southern periphery bringing Barakar, Barren Measures, Raniganj and even Panchet Formations in juxtaposition with the basement rocks, while in the southern margin, Talchir sediments rests unconformably on them (Figure 2).

The coal bearing lower Gondwana rocks occur as detached and fault bounded outcrops along the peripheral parts of the sub-basin while the rocks of upper Gondwana occupy the central and western part of the coalfield. There are breaks in the continuity of the coal bearing strata which may be attributed to either structural dislocation or overlapping of younger strata leading to the formation of a number coal-bearing area of limited extent (Das et al., 2001). The Tatapani-Ramkola is a composite basin comprising a northern strip of coal measures and associated Lower Gondwanas referred to as Tatapani Coalfield and a southern one called Ramkola Coalfield. The coal bed methane exploration in this virgin block primarily focuses on targeting the deep-seated seams lying below the thick pile of younger Gondwana sediments.

Tatapani-Ramkola Coalfield lying in the Surguja District, Chhattisgarh is an east-west trending synclinal sub-basin lying in the easternmost segment of ENE-WSW trending Son Valley master basin (Figure 3). The configuration has formed due to gradual change of strike from E-W in the northern part of the Tatapani Basin to N-S in the eastern end of Tatapani Field. Further southwest in Ramkola, the strike of the beds progressively swing from NE-SW to E-W in the western extremity of the coalfield. Structurally, the Tatapani-Ramkola Basin shows a broad synclinal structure with closure to the east. The syncline has E-W axial trend with younger Gondwana Formations exposed in the axial region (Ghosh et al., 1993). The Tatapani Coalfield defines the northern limb of the syncline whereas the Ramkola Coalfield forms its southern limb.

Morphotectonically, Tatapani-Ramkola Basin displays a half-graben configuration whose southern boundary is defined by en-echelon sets of border faults whereas the northern boundary has unconformable contact of the Gondwanas with the Pre-Cambrian basement.

## General Characteristics of Coal Seam

In the Tatapani-Ramkola Coalfield, Raniganj Formation and Barakar Formation are coal-bearing units. The Barakar Formation contains all the important coal seams and accounts for the entire coal resources of this coalfield. The Raniganj Formation contains inferior, thin coal seams of lensoid geometry and as such the coal seams are not of much economic importance (Raja Rao, 1983). Close examination of Barakar lithic-fill reveals that the basal 60–100 m of Barakar Formation is composed of coarse clastics and practically devoid of thick coal seams. The upper sequence, comprising very fine to coarse-grained sandstone with dark grey and carbonaceous shale, is relatively more argillaceous and contains all the important coal seams (Das et al., 2005).

The CBM exploration has established the developments of a total of twelve coal seams (I to XII in ascending order) were recorded in the Barakar Formation. Seam thickness ranges from 0.75 m to 11.67 m and were intersected between the depths of 564.50 m and 1061.15 m. Out of these, Seam III, IV, and V deserve special mention due to their thickness, regional persistency, and quality both in Tatapani and Ramkola areas The cumulative net coal content for the main regionally persistent seams III, IV, and V varies from 3.00 m to 10.20 m. Thicknesses of individual seams are almost uniform in nature and maintain uniform inter-seam partings over the area.

The Seam III is erratic in development but slightly of better quality. However, the combined Seam IV/V of the Sondiha area, (adjacent of CBM block) occurs as separate Seams IV and V in this area; of which the Seam IV is the thickest. Both Seam IV and V again are split into Top and Bottom sections. The top section - IV(T) maintains appreciable thickness (1.24 m to 7.12 m) while the bottom section - IV(B) maintains uniform thickness (2.48 m to 3.17 m). In the northern part of the area, the seam occurs as a composite seam with thickness of 2.64 m – 3.00 m (ATR – 3a and 4). Seam V shows same behavioral pattern as observed in case of the top section - V(T) as well as the bottom section - V(B) of Seam IV. The Seam VI overlies the Seam V with parting thickness ranging from 3.15 m to 6.40 m. The parting thickness is minimum (3.15 m) around ATR - 7 and shows general tendency of thickening (6.20 m) in the down dip direction. Seam VII, which succeeds Seam VI with intervening parting thickness of 5.10 m to 8.20 m and the thickness of the seam ranges from 1.00 m to 7.42 m (ATR – 3a) with three-split section. Seam IX attain maximum thickness of 11.67 m and occur as a single seam. (Figure 4).

The qualitative character of the coal seams of the Tatapani-Ramkola Coalfield has been assessed based on band-by-band analysis of the core hole cores obtained from explored block. In general, the coals are medium to high volatile, non-coking type with variable ash content. The coals have high carbon (78-81%) and calorific value (7200-7700 kcal/kg) and broadly correspond to high volatile bituminous "B/C" category.

General quality of the coal seam:

- Non-Coking
- High volatile
- Low to high moisture (generally medium to high moisture) – 1.5% - 6.8%
- Low to high ash (generally medium to high ash) - 9% - 39%

A total of seven samples from different core holes were petrographically analysed in the ACS Laboratories for studying the maceral contents and assessing the maturity of coal by measuring the maximum vitrinite reflectance ($R_O$ $M_{ax}$). The results are given in Table 1.

## Permeability of Coal

Permeability refers to the ability of the fluids to migrate through coal pore space and this is a crucial reservoir parameter affecting well deliverability. The fractures in coal serve as permeability avenues for Darcy flow of gas and water. The primary (or natural) permeability of coal is very low, typically ranging from 0.1 to 30 mD (Clarkson et al., 1997). Coal is a very weak (low modulus) material and cannot take much stress without fracturing, coal is almost always highly fractured and cleated. The resulting network of fractures commonly gives coal beds a high secondary permeability (despite coal's typically low primary permeability).

In the Tatapani–Ramkola CBM Block, in-situ cleat permeability of coal seams was determined using injection fall-off test (INFO) performed by the Mitchell Drilling International. The in-situ pressure data were then analyzed by the Geotecnic Reservoir Engineers and permeability values were determined. Most of the tests were successful and the final data seemed to be quite reliable. Apart from permeability, the data analysis of these tests gives an opportunity to determine reservoir pressure. Reservoir pressure can be taken directly from the pressure gauges before the injection started or inferred from the data analysis as extrapolated pressure.

The core hole wise details of INFO tests carried out in selected coal bearing zones to assess the permeability of the coal seams. Out of eight core holes INFO tests were done in seven zones of four wells. It could not be carried out in others either due to thin coal seams or very low gas content. The borehole wise details are given below in Table 2.

## Coal Bed Methane Prospects

It has been established that gas sorption by coal is closely related to its physical and chemical properties, which in turn are governed by coal type i.e. maceral composition and rank (Crosdale et al., 1998). Mineral mater and moisture content also influence desorption property of coals. Coal type may affect both adsorption capacity and desorption rate. Dominance of vitrinite (>60 %) results in high surface area in coals, and thereby increases methane adsorption capacity. Vitrinite-rich coals (bright coals) have greater methane adsorption capacity than inertinite-rich coals (dull coals) of equivalent rank. This is due to vitrinite predominantly possessing micro-pores compared to inertinite. In fact, inertinite macerals have the highest activation energy among coal macerals, and therefore have the lowest adsorving power (Misra et al., 1994).

A total of seven samples from different core holes in the block were spectrographically analysed in the ACS Laboratories for studying the maceral contents and assessing the maturity of coal by measuring the maximum vitrinite reflectance (Ro Max)which varies from 0.57 (south western part) to 0.94 (south central part). In view of maceral contents, vitrinite content (ranges from 29.9 to 67.4) is higher than that of liptinite and inertinite. Adsorption isotherm test was carried out for several coal samples. Adsorption isotherms were determined at the reservoir temperature, at pressure exceeding the reservoir pressure, and at equilibrium moisture conditions. Coal gas saturation was determined comparing the gas storage capacity of coal, as determined by isotherm, to the measured gas content. Altogether eleven samples were analysed for evaluation of adsorption properties and saturation values representing different depth zones and suggest that the seams are under-saturated to this extent and varies from 12.3% to 41%.

Due to lack of sufficient number of samples as well as an insufficient variation of sample bulk densities, a statistically valid correlation between gas content and bulk density of desorption samples could not be established. Also, there are no indications that sample gas content is a function of any other known variables. Therefore, the average total gas content on daf basis, was taken into consideration for determining the entire seam gas content, which was found to be not encouraging in respect of gas saturation. The rank and maturity of coal of Tatapani–Ramkola Coalfield is not suitably high for generation of thermogenic methane, rather lies dominantly at the threshold of its window of generation.

Using the CBM exploration data, gas in Place (GIP) for the entire block (458 km$^2$) was determined taking average gas content 0.79 m$^3$/t (raw), average net coal 15 m and average coal density 1.45cc/g. The GIP for the TR block has been estimated to be ~7.85 BCM (~277BCF). Only about a 40 km$^2$ area in the southwestern part have low to moderate gas saturation (20-40%). Slightly better gas content (as compare to rest of the area), gas saturation, coal thickness, and permeability in the southwest portion of the block warrants a separate GIP estimation. This area covering 40 km$^2$ with an average net coal of 25 m and average gas content of 1.05 m$^3$/ton (Raw) gives an estimated GIP of ~1.52 BCM (~53.7 BCF). This area constitutes only 8% of total CBM block but about 19% of total GIP (Block).

## Conclusions

The sedimentary history of Tatapani–Ramkola Basin, it has been established that interaction of at least three sets of fault control the sedimentation process. A wealth of sub-surface data have unequivocally established the role of syn-sedimentary faults in controlling the sedimentation as evidenced from abrupt thickening of inter-seam parting, splitting and attenuation of coal seams as well as deterioration of coal quality close to the fault in the downthrown side rather than upthrown side.

Petrographically, the coals are vitrinite rich (67% and 30%) in the upper seams while with more of inertinite (10% and 40%) in the lower coal seams. Unusual very high content of liptinite (6.5% to 16%) may indicate a mixed depositional environment.

Total gas content of each coal seam on dry ash free basis was estimated as a weighted average of total gas contents (daf) of total coal seam. The total gas content (daf) varies from 0.18 $m^3/t$ (North-Central part, depth of 832-834 m) to 2.69 $m^3/t$ (South–Central part, depth of 656.43-656.93 m) in the block area, which, in general, suggests better storage of CBM towards the south-central part of the coalfield.

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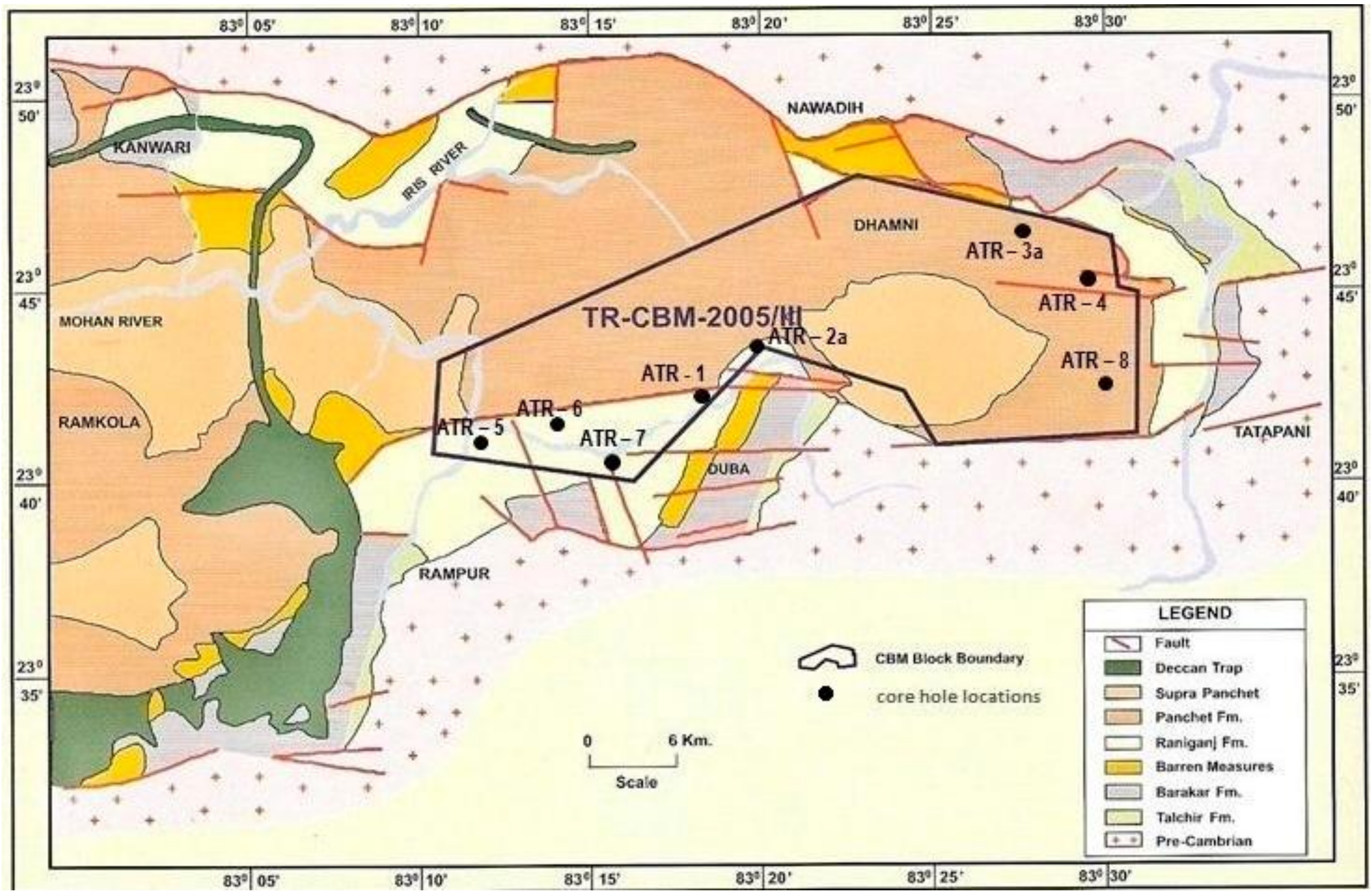


Figure 1. Geological Map with CBM Block Boundary of Drilling Location, Tatapani-Ramkola Coalfield.

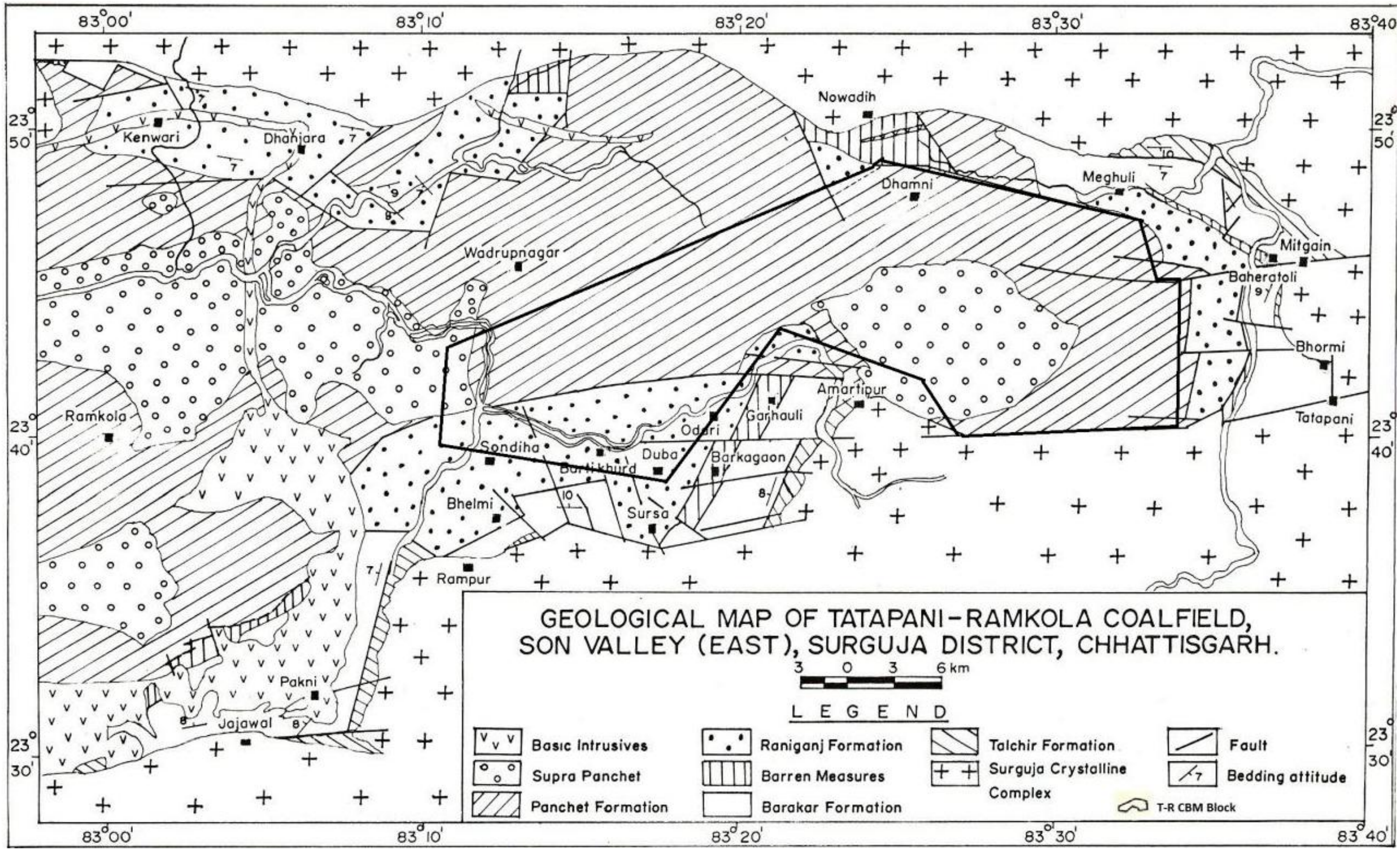


Figure 2. Geological Map of Tatapani-Ramkola Coalfield, Son Valley (East), Surguja District, Chhattisgarh.

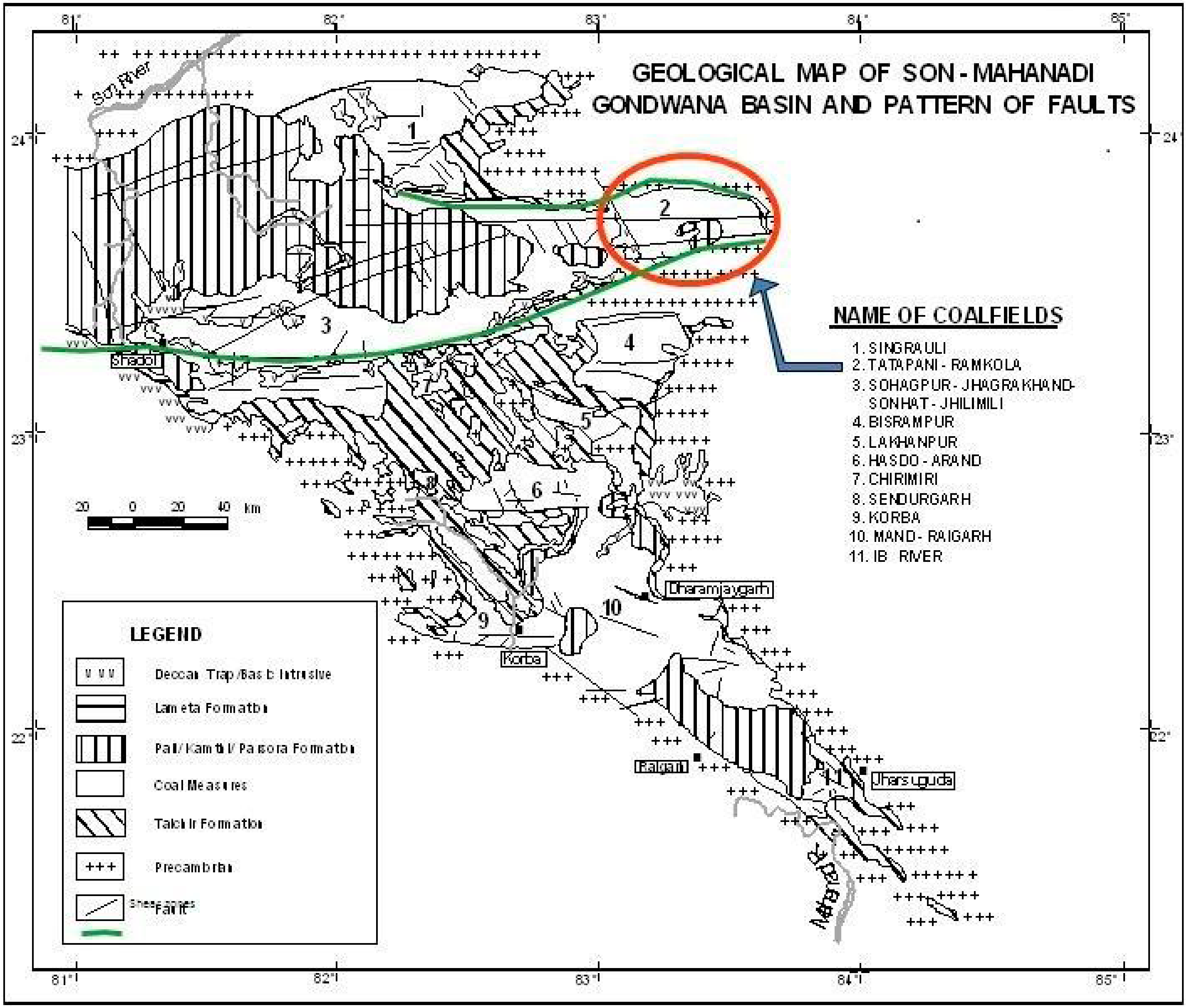


Figure 3. Geological Map of Son-Mahanadi Gondwana Basin and Pattern of Faults.

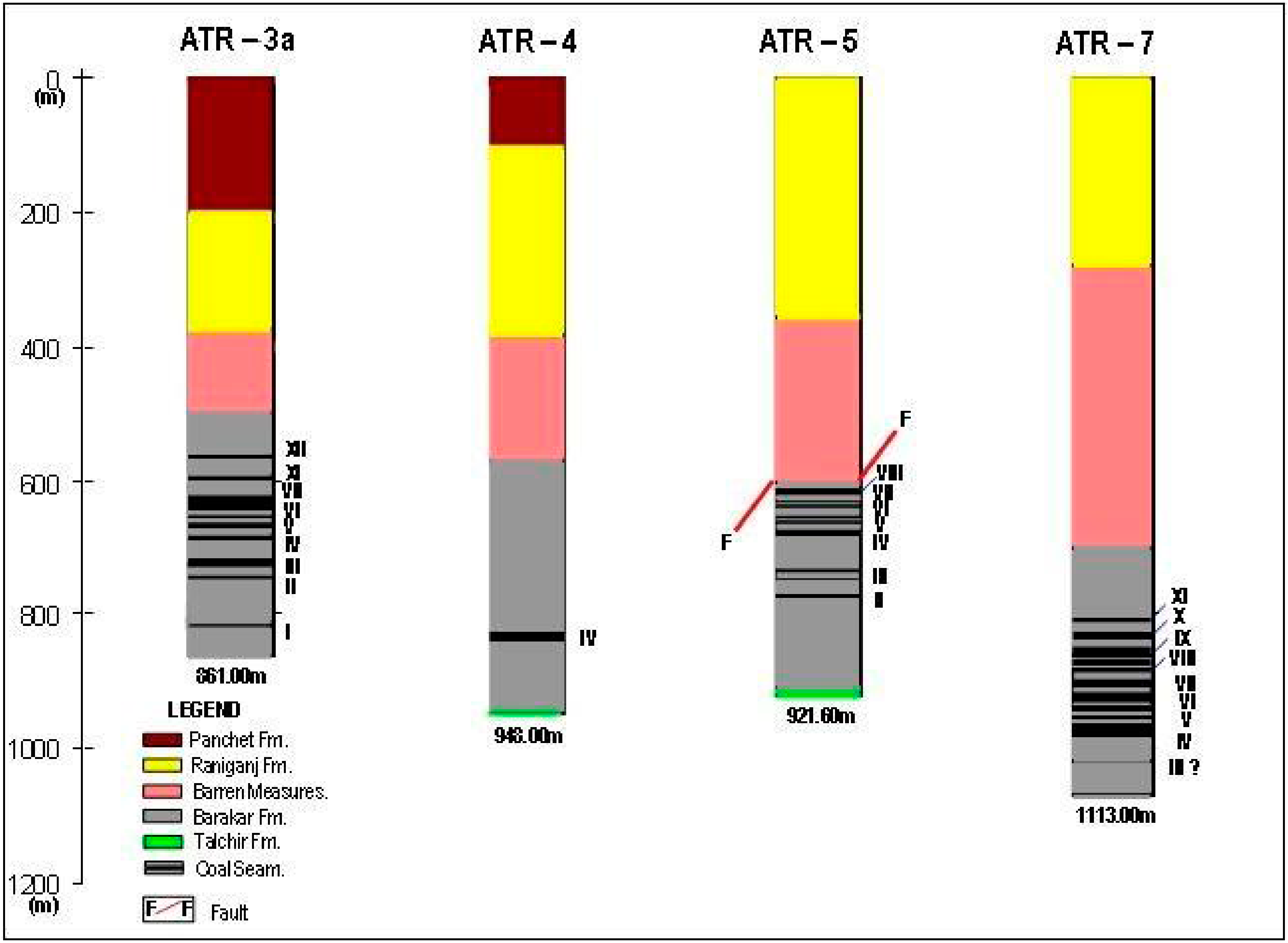


Figure 4. Coal Seams Intersected in Coreholes Drilled in Tatapani-Ramkola CBM Block, Surguja, Chhattisgarh.

| Core hole ID | Sample No | Depth (m) | $VR_O$ % Max . | Maceral Analysis as Analysed (%) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Vitrinite | Liptrinite | Inertinite | Minerales |
| ATR - 1 | 1 | 891.15 | 0.66 | 67.4 | 6.5 | 9.6 | 16.5 |
| ATR – 2a | 6 | 1081.4 | 0.94 | 55.2 | 14.5 | 20.1 | 10.2 |
| ATR – 3a | 3 | 565.73 | 0.67 | 35.7 | 10.7 | 19.4 | 34.2 |
| ATR – 5 | 1 | 627.2 | 0.57 | 36.6 | 16 | 36.5 | 10.9 |
| ATR – 5 | 9 | 772.2 | 0.58 | 29.9 | 7 | 59.9 | 3.3 |
| ATR – 7 | 23 | 1015.88 | 0.90 | 44.5 | 10.5 | 40 | 5 |
| ATR - 8 | 3 | 1002.1 | 0.72 | 58.8 | 8.1 | 9.6 | 23.5 |

Table 1. Vitrinite Reflectance and Maceral Data of Coal Samples from T- R CBM Block.

| Core Hole No | Brief Description | Resulted value |
|---|---|---|
| **ATR-3a** | Due to the very low gas contents one INFO test was done in the hole from 564-570m. | 1.2mD |
| **ATR-4** | As only one seam was recorded a permeability intersected in this well at 830.5 - 835m. | 0.1mD |
| **ATR-5** | Two INFO tests were conducted at 670-678m and 735-743m | 18.49mD and 1.43mD |
| **ATR-7** | Three INFO tests were completed in ATR-7. The intervals were from 936-949m, 966-976m and 1003-1010m. | 1.7mD, 11.5mD and 14mD |

Table 2. In-situ Permeability of Coal Seams Determined Using Injection Fall-off Test of CBM Block.