

## Source rock characterization of Eocene shales from Giral lignite mine, Rajasthan, India

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Keywords: Basin modelling; Barmer basin; organic geochemistry

### 1. Abstract

A study was carried out using Rock-Eval 6 pyrolysis and kerogen kinetics (using OPTKIN software) to investigate various lithotypes from the Giral lignite mine in the Barmer basin. The objective was to determine the type of organic matter (OM), deposition environment, maturity and potential for hydrocarbon generation.

result, it is critical to conduct source rock characterisation in these places in order to better understand the quality of the organic matter (OM) and the environmental conditions that existed during the deposition of these rocks.

### 2. Introduction

The Rajasthan basin, located in northwest India, is a Category-1 sedimentary basin with a recent history of commercial hydrocarbon production (DGH, 2022; Kar et al., 2022; Fig. 1). The region is also marked by few lignite mines consisting of organic-rich shales, lignites, and shaly lignites (Kar et al., 2022). The lignitic coals can easily be fluidized due to their high volatile contents (Raju et al., 2013). As a

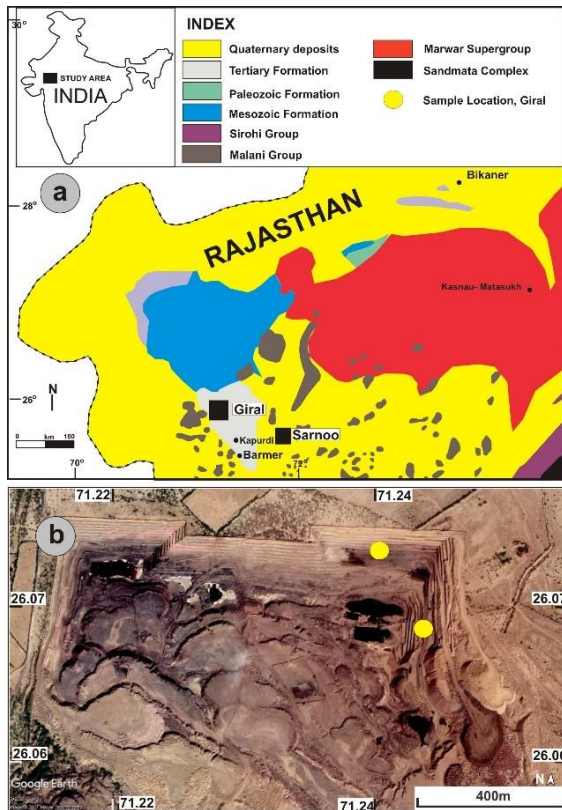


Fig. 1: a. Geological map of Barmer basin (after Roy and Jakhar, 2002). b. Yellow circles: sample locations from the Giral lignite mine. Reproduced from Fig. 1 of Kar et al (2022).

### 3. Materials and Methodology

Total 10 samples were collected from the Giral lignite mine, consisting of 3 lignites, 4 shaly lignites, and 3 shales. Shale-lignite alteration pattern exists in the mine (Figure 2). To determine the bulk organic geochemical parameters and kerogen degradation kinetics, the Rock-Eval pyrolysis facility equipped with the OPTKIN program (Version 3.0.3, 2014), was utilized. These analyses were conducted at the Rock-Eval facility at the CSIR-NGRI.

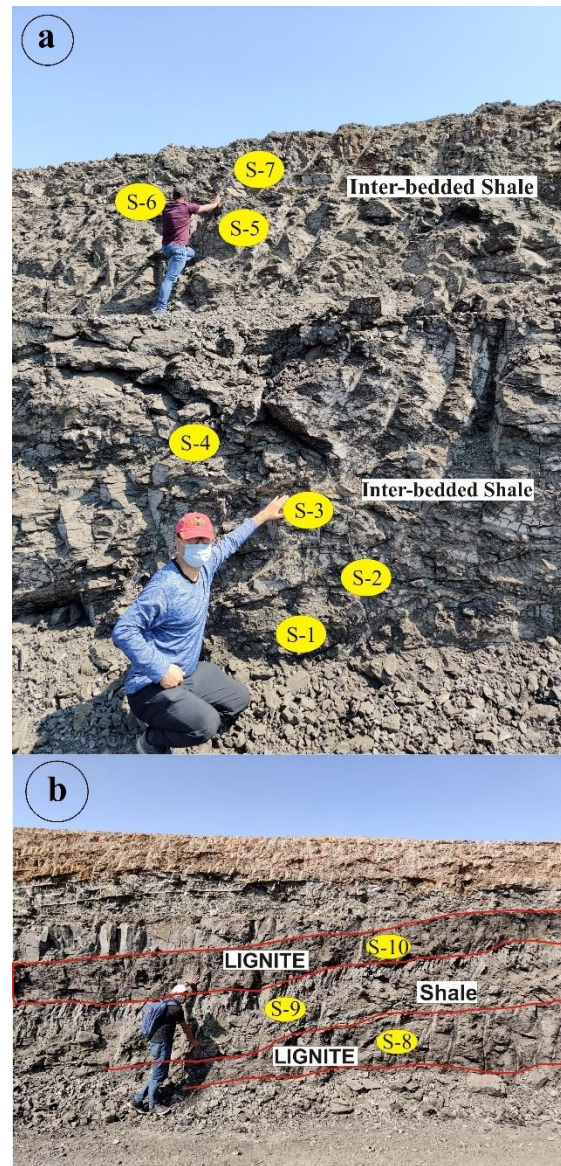


Fig. 2: a, b. Sample location, Giral lignite mine. Reproduced from figs. 2 & 3 of Kar et al. (2022).

### 4. Results & Discussions

#### 4a. Bulk organic geochemical parameters:

The total organic carbon (TOC) content of lignites is the highest (~ 30.76), followed by shaly lignites (~ 3.03) and shales (~ 1.05) (Table 1; Kar et al., 2022). The lignites also demonstrate the highest values for residual hydrocarbon (S1) and hydrocarbon generation potential (S2), followed by shaly lignites and shales. The examined samples exhibit a significantly higher S2 value than

S1, indicating favorable conditions for being a suitable source rock (Table 1) (Kar et al., 2022). The higher S2 values observed for lignites and shaly lignites suggest a substantial potential for hydrocarbon generation in these rocks. The lower OM content in shales is attributed to a higher rate of subsidence during peat formation, resulting in the dilution of OM with significant detrital material (Table 1) (Kar et al., 2022).

Despite the lignites and shaly lignites having a higher potential for hydrocarbon generation, they are thermally immature and have not reached their natural production state. This is determined by their Tmax value, which is < 435 °C for both lignites and shaly lignites, indicating an immature stage. In contrast, the shales have an average Tmax ~ 449 °C, indicating an early mature to oil window stage of maturity (Kar et al., 2022).

The hydrogen index (HI) versus Tmax plot indicates that lignites exhibit a dominant input of Type-III OM, while shaly lignites and shales display a Type-III to Type-IV input (Fig. 3). Furthermore, the plot clearly distinguishes an oil window maturity stage for shales, while lignites and shaly lignites are in an immature stage (Kar et al., 2022). In addition, the S2 (hydrocarbon generation potential) vs. TOC diagram highlights the excellent OM concentration and hydrocarbon potential of the Giral lignites. Similarly, shaly lignites demonstrate a very good to excellent OM concentration and a poor to good generation potential. However, the shale samples exhibit a fair to good OM concentration and a poor generation potential, mainly due to their lower organic content (Fig. 3) (Kar et al.,

2022).

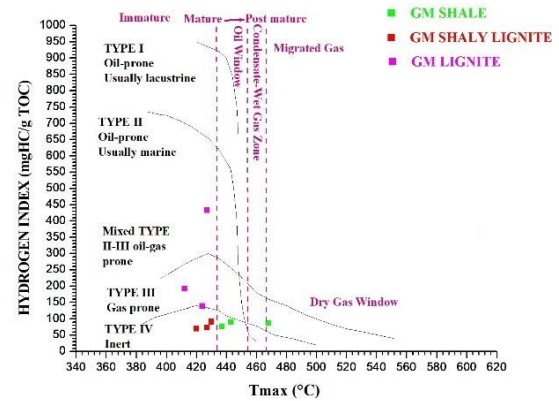


Fig. 3: Cross plot of hydrogen index (HI) vs. maximum temperature (Tmax). GM: Giral mine. Reproduced from fig. 7 of Kar et al (2022).

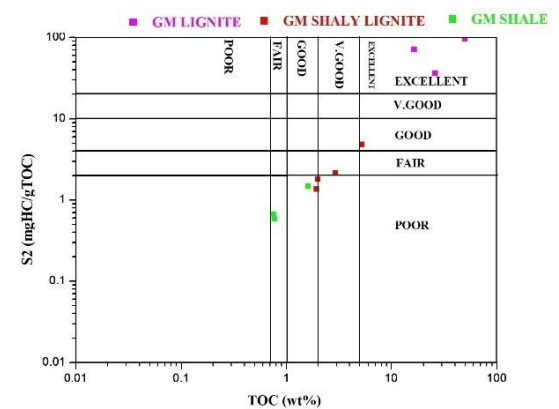


Fig. 4: Cross plot of S2 vs TOC. GM: Giral mine. Reproduced from fig. 8 of Kar et al, 2022

#### 4b. Kerogen kinetics

Kerogen degrades and is transformed into oil and gas. Primary cracking refers to the transformation of oil from complex kerogen, which includes several parallel reactions. Secondary cracking refers to the conversion of oil to gas through simple reactions (Espitalie et al., 1987). These reactions follow the first-order kinetics rule, and the rate constant follows the Arrhenius equation (Pitt, 1961; Tissot and Espitalie, 1975). Hence the kinematic method can be used to determine the heterogeneity of OM along with their

hydrocarbon generation rate and kerogen transformation ratio (Kar et al., 2022).

The distribution of activation energy solely depends on the different bond types present in the sample. Broader activation energy is marked by complex heterogeneous OM, whereas narrow activation energy is marked by simple homogeneous OM (Espitalie et al., 1987; Kar et al., 2022). Giral samples have a wider range of activation energy distribution, ranging from 52 to 84 kcal mol<sup>-1</sup> with a peak of 62-64 kcal mol<sup>-1</sup>. This reflects a diverse OM input to the region (Type-III kerogen) (Fig. 5).

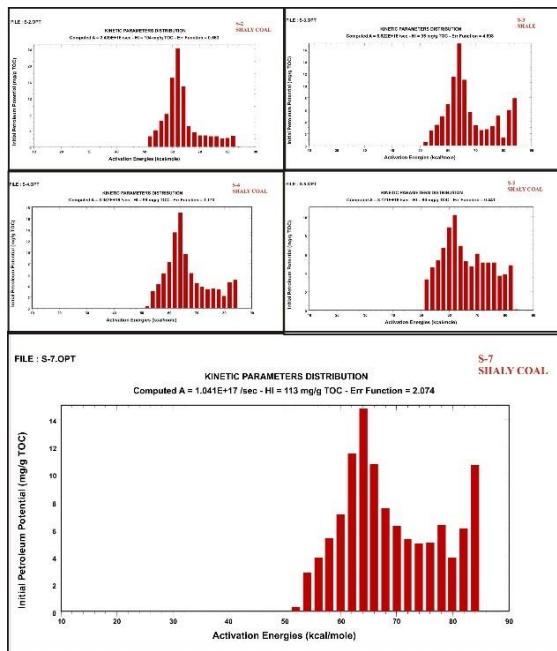


Fig. 5: Distribution of activation energy. Reproduced from fig. 12 of Kar et al, 2022

Hydrocarbon generation rate (HGR) can be used to classify the type of OM intake. In the HGR curves, a tight temperature range indicates homogenous samples, whereas a wider temperature range indicates heterogeneous OM input (Espitalie et al., 1987; Kar et al., 2022). Giral samples with a broader HGR range (360-540 °C) suggests a heterogeneous (Type-III) OM input (Fig. 6). But the relatively earlier transformation of these samples represents

a suitable OM for kerogen transformation (Kar et al., 2022).

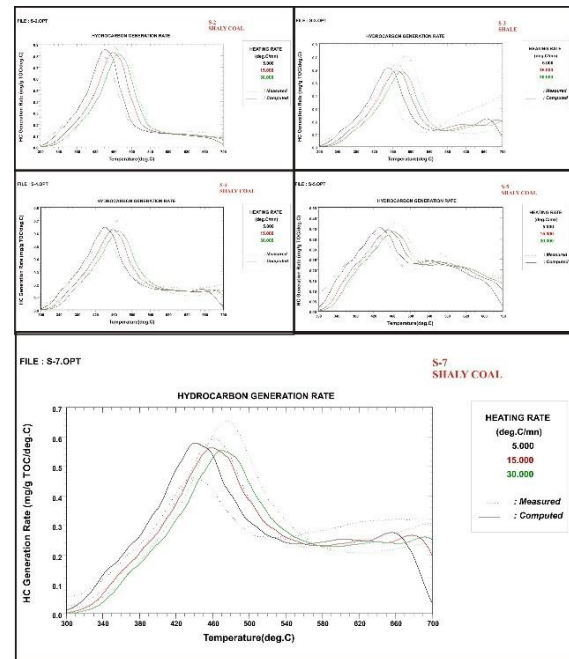


Fig. 6: Hydrocarbon generation rate. Reproduced from fig. 13 of Kar et al, 2022

The kerogen transformation ratio (KTR) is used to classify the kerogen type and its potential for transformation. The presence of a homogeneous Type-I kerogen indicates a fast spike in KTR with a sharp slope, but for heterogeneous Type-III and II kerogens, the transition is gradual and the slope is gentle (Tissot and Espitalie, 1975; Mani et al., 2015; Kar et al., 2022). Giral samples transformation shows a relatively gentle slope demarcating heterogeneous Type-III kerogen, but the relatively earlier transformation makes then suitable for the artificial conversion into different hydrocarbon products (Kar et al., 2022; Fig. 7).

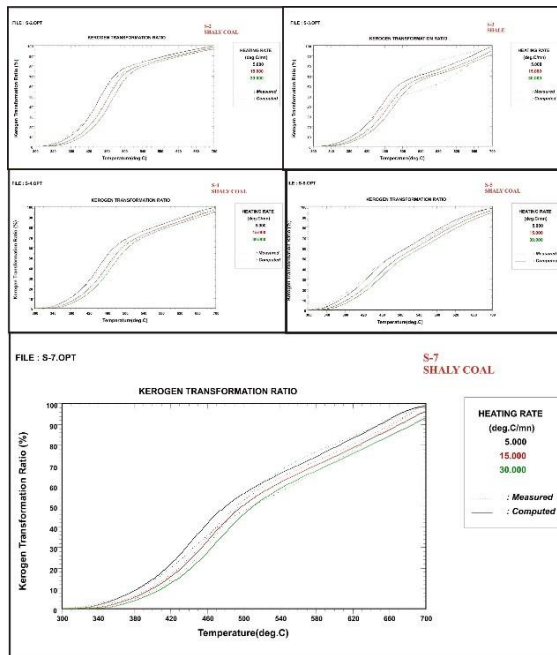


Fig. 7: Kerogen transformation ratio. Reproduced from fig. 14 of Kar et al, 2022

## 5. Conclusions

A dominant terrestrial Type-III heterogeneous kerogen input to the location. Giral lignites and shaly lignites are rich in OM, whereas the shales are with lean OM concentration. Both lignites and shaly lignites possess a very good hydrocarbon generation potential. Despite their promising potential, the examined samples are not yet mature enough to naturally reach the stage of hydrocarbon generation. However, the kerogen kinetics study suggests that these rocks can transform faster. This indicates that these rocks are suitable for artificial processes to convert them into various hydrocarbon products. Kar et al. (2022) presented this work in detail.

**Acknowledgments:** Funded by a seed project received from the Centre of Excellence in Oil, Gas and Energy, IIT Bombay (grant number RD/0120-PSUCE19-001) awarded to Soumyajit Mukherjee.

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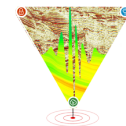
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**Table 1.** Rock-Eval data for shales, shaly lignites and lignites from the Giral mine, Barmer Basin (reproduced from Kar et al., 2022).

Sam ple	Lithology	Qty	TOC (%)	Tmax (in °C)	S1 (mg HC g <sup>-1</sup> rock)	S2 (mg HC g <sup>-1</sup> rock)	S3 (mg HC g <sup>-1</sup> rock)	S2/S3 (no unit)	HI (mg HC g <sup>-1</sup> TOC)	OI (mg HC g <sup>-1</sup> TOC)	PI (No unit)
S-1	Lignites (GM)	10.39	49.83	412	3.05	95.91	23.99	3.99	192	48	0.03
S-2	Shaly Lignites (GM)	60.49	5.24	430	0.18	4.84	4.11	1.17	92	78	0.04
S-3	Shale (GM)	60.46	1.62	443	0.09	1.48	7.91	0.18	91	488	0.06
S-4	Shaly Lignites (GM)	60.46	2.93	427	0.15	2.14	3.4	0.62	73	116	0.07
S-5	Shaly Lignites (GM)	60.96	1.94	420	0.22	1.36	1.05	1.29	70	54	0.14
S-6	Shale (GM)	60.33	0.76	468	0.14	0.66	3.29	0.20	87	433	0.18
S-7	Shaly Lignites (GM)	60.39	2	430	0.13	1.8	3.1	0.58	90	155	0.07
S-8	Lignites (GM)	11.29	26.06	424	1.07	36.21	14.93	2.42	139	57	0.03
S-9	Shale (GM)	60.32	0.77	437	0.12	0.59	7.02	0.08	77	912	0.17
S-10	Lignites (GM)	60.8	16.39	427	1.72	70.92	5.21	13.61	433	32	0.02