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Short communication

Significance of lithotypes for hydrocarbon generation and storage

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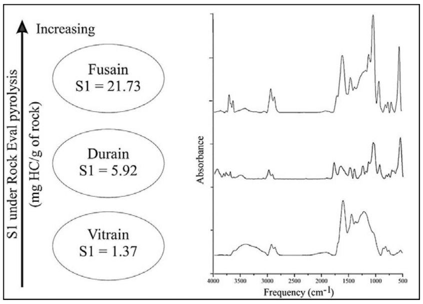
GRAPHICAL ABSTRACT



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ABSTRACT

This paper examines the hydrocarbon generation and storage potential of lithotypes, macerals, kerogen type relative to thermal maturity. To investigate authors had collected lithotype (vitrain, durain and fusain) samples from the high volatile sub-bituminous coal of Barjora area, SE of Raniganj coal basin, India. Relevant analyses viz. Rock Eval pyrolysis (REP), total organic carbon (TOC), micropetrography, vitrinite reflectance (Romv) and Fourier Transform Infrared Spectrometry (FTIR) were carried. The geochemical analysis indicates that the studied lithotypes have excellent potentiality of generating hydrocarbon in respect of TOC and S2 (under Rock-Eval pyrolysis) and it increases from vitrain to durain to fusain. Also, the free hydrocarbons which was recorded under S1 curve of Rock Eval pyrolysis, was observed to be highest within the fusain lithotype (21.73 mg HC/g rock). Further, the thermal maturity (Tmax: 418–423 °C) and mean vitrinite reflectance (Romv: 0.42–0.56%) indicate the samples are immature in nature. However, ↑Vt60 (vitrinite grains having a reflectance greater than 0.60%), indicates that thermogenic gas generation was occurring to some degree in almost all the samples. Moreover, comparison between geochemical and petrographical analysis it has been inferred that storing capability of hydrocarbons also increases from vitrain to durain to fusain. The higher capability of hydrocarbons within the fusain (in comparison to durain and vitrain) may be due to presence of large amount of fusinite and semifusinite macerals. The production index (PI) also shows similar trend with increasing S1 value. The FTIR study demonstrates that the fusain has higher intensity of aliphaticity than that of vitrain and durain. The higher intensity of aliphaticity in the fusain may be due to presence of considerable amount of bituminite and other liptinites within the cavities/cell lumens. All the observation suggests that fusain has the highest hydrocarbon generation and storage potentiality, whereas durain has less and vitrain has least generation potentiality in comparison to fusain.

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1. Introduction

Hydrocarbon generation potential of coals are dependent on the amount, type and maturity of the inherent organic matter present within them [1,2]. This organic matter within the coal changes from one lithotype to another with progressive changes of macerals composition [3–6]. Individual macerals and their associations in lithotypes may play different roles in generation and storage potentiality. Therefore, understanding the maceral compositions of lithotypes is important for gaining insights into their behavior during hydrocarbon generation and storage.

The classification of lithotypes are dominantly based on the bright versus dull bands depending upon color, texture and degree of gelification [7,8]. In the case of bituminous coals, lithotypes are classified into vitrain (bright coal), bright clarain (banded bright coal), clarain (banded coal), dull clarain (banded dull coal), durain (dull coal), and fusain (fibrous coal) [9,10]. The Diessel classification system uses a minimum lithotype thickness of 5 mm [10]; consequently, thinner bands become part of a thicker lithotype unit. Earlier workers have demonstrated that the macerals properties changes from vitrain to durain to fusain [5,11–13] as there is a progressive increase of inertinite and a decrease in vitrinite content. This variation in maceral composition also results in differing chemical properties of lithotypes. In the case of fusain intensity of aromaticity is higher than other lithotypes, whereas the chemistry of vitrain and durain can vary depending on the proportion of liptinite, vitrinite and inertinite macerals [14]. Generally, inertinite has more macropores and fewer micropores than vitrinite of the same rank [15–19]. Also, these pores and cleats in the lithotypes are the main storage sites and migration paths for hydrocarbons. Hence, coal lithotypes, their thickness, associated cleat and their extent plays a significant role in hydrocarbon generation and storage. Few studies have been done on pore characteristics, adsorption capacity of different lithotypes [14,20]. But little information is available about hydrocarbon generation and storage potential of lithotypes. The main objective of this study is to document the hydrocarbon generation and storage capability of various coal lithotypes samples from Barjora area, Raniganj basin, India. Here authors have investigated lithotype samples to depict their variation in maceral composition, functional group distribution, total organic carbon (TOC), kerogen type, Rock Eval pyrolysis characteristics and thermal maturity and compared with the lithotype samples of the Springfield, Danville and Hymera Coal Members from Illinois Basin, Indiana, USA.

2. Materials and methods

2.1. Collection of samples

Raniganj basin is the largest coal basin in India which contains sub-bituminous to bituminous rank coal, in which the lithotypes are well developed and distinct. To fulfill objectives authors collected seven coal block samples (CG 1551, CG 1552, CG 1553, CG 1554, CG 1555, CG 1556 and CG 1557), belonging to the Raniganj Formation of upper Permian age, from the Barjora area, South Eastern part of Raniganj basin, in West Bengal province of India. Different parameters such as texture, lustre and the proportion of bright versus dull bands [21] are used to differentiate among the lithotypes using minimum 5 mm thickness following [10]. Three different lithotypes (vitrain, fusain and durain) are chosen and collected from the respective coal block. Vitrain and durain lithotypes are separated from coal sample CG 1552 and fusain is separated both from sample CG 1552 and CG 1557. However, the fusain band thickness is < 5 mm, but to study its characteristics authors have considered as a separate lithotype. To obtain sufficient amount for fusain, authors have combined multiple layers of fusain band.

2.2. Rock Eval pyrolysis and TOC analyses

The Rock Eval 6 was used for carrying out pyrolysis and TOC analyses at CSIR-National Geophysical Research Institute, Hyderabad, India. Out of the seven coal samples, four samples (CG 1551, CG 1552, CG 1555 and CG 1557) and three different lithotypes (vitrain: CG 2028, fusain: CG 2029 and durain: CG 2030) were selected for the analyses. The samples were crushed and screened through British Standard Specification 72 mesh size (−212 μm size). The sieved samples were well homogenized before carrying out the analyses. Parameters such as TOC content and S1, S2, S3 pyrolysis yields and the temperature of maximum S2 pyrolysis yield (T_{max}) were measured, while hydrogen (HI), oxygen (OI) and production (PI), bitumen (BI) indices were calculated and interpretative guidelines had been discussed by several workers [22–25]. Moreover, the estimate vitrinite reflectance (EVRo) has been calculated from the obtained T_{max} values of Rock Eval pyrolysis [26]:

$$\%\,\mathrm{EVRo} = 0.0180 \times T_{max} - 7.16 \tag{1}$$

The calculated EVRo was then compared to the measured mean vitrinite reflectance in oil (Romv) to evaluate the stages of maturity as indicated by the two maturity parameters.

2.3. Micropetrographic analysis

Micropetrographic analysis of the samples was carried out under reflected light using a 'LEICA DM2700 P' microscope with an oil immersion lens and attached fluorescence facility following the standard procedures [27–29] at Coal Geology and Organic Petrology Laboratory, Department of Applied Geology, Indian Institute of Technology (Indian School of Mines), Dhanbad, India. The pellets (polished section having

Table 1
Results of Rock Eval pyrolysis and TOC content of studied samples.

Sample no.	S1	S2	S3	T_{max}	TOC	TOC_o	HI_{PD}	HI_o	GP	BI	OI	PI	*f*	A factor	C factor
CG 1551	2.51	156.41	1.73	423	60.82	58.60	257	127.91	158.92	4.13	2.84	0.02	−1.29	0.457	0.097
CG 1552	0.66	99.48	7.17	420	55.76	55.00	175	134.36	100.14	1.18	12.86	0.01	−0.38	0.445	0.145
CG 1555	5.28	138.17	2.09	422	56.35	54.07	245	129.63	143.45	9.37	3.71	0.04	−1.14	0.465	0.142
CG 1557	9.60	74.34	2.65	418	48.52	47.86	153	135.30	83.94	19.79	5.46	0.11	−0.17	0.432	0.151
CG 2028	1.37	112.00	3.70	423	69.99	69.67	160	128.78	113.37	1.96	5.29	0.01	−0.28	0.651	0.484
CG 2029	21.73	109.35	2.30	421	59.24	56.77	185	74.10	131.08	36.68	3.88	0.17	−1.87	0.647	0.477
CG 2030	5.92	121.64	2.26	423	50.97	48.49	239	124.34	127.56	11.61	4.43	0.05	−1.17	0.525	0.461

Explanations: S1 = free hydrocarbon present in the rock (mg HC/g of rock); S2 = remaining generation potential (mg HC/g rock); S3 = oxidizable carbon (mg CO_2/g rock); T_{max} = temperature at which maximum amount of S2 pyrolyzate (°C); TOC = total organic carbon (wt%); TOC_o: original TOC content of the studied samples; HI_{PD} = present day hydrogen index, [(S2/TOC) × 100 mg HC/g TOC]; HI_o: original hydrogen index of the studied samples; GP = genetic potential (S1 + S2); BI (bitumen index) = S1 × 100/TOC; OI = oxygen index [(S3 × 100)/TOC (mg CO_2/TOC)]; PI = production index; *f* = fraction of conversion that the kerogen has undergone; A factor = (2860 + 2930 cm^{-1})/(2860 + 2930 + 1630 cm^{-1}) under FTIR; C factor = (1705 cm^{-1})/(1705 + 1630 cm^{-1}) under FTIR. Note: CG 2028: vitrain separated from CG 1552; CG 2029: fusain separated from both CG 1552 and CG 1557 and after that there were mixed; CG 2030: durain separated from CG 1552 manually from coal samples.