HYDROCARBON POTENTIAL OF THE DISANG GROUP OF ROCKS OF THE INNER PALEOGENE FOLD BELT OF ASSAM-ARAKAN BASIN EXPOSED ALONG THE DIMAPUR-SENAPATI ROAD SECTION OF NAGALAND AND MANIPUR, INDIA

ABSTRACT

Carbonaceous shales of the Upper Disang Formation of the Inner Paleogene Fold Belt of Assam-Arakan Basin, exposed along the Dimapur-Senapati road section of Nagaland and Manipur states of India have been studied for interpreting hydrocarbon potential. The Upper Disang Formation is mostly composed of alteration of shales, sandstones and siltstones. The shales are black coloured and splintery in nature. The shales and associated sandstones show sedimentary structures like bioturbation, cross bedding and ripple marks indicating shallow water origin. The shales contain appreciable amount of pyrites indicating marine influence in the depositional basin. The average TOC of the carbonaceous shale samples is 0.53% indicating poor generative potential. The poor generative potential of the formation is also supported by low S_1 (average 0.04mg/gTOC), S_2 (average 0.16mg/gTOC) and HI (average 36mg/gTOC). The organic matters are represented dominantly by Type IV kerogens (inertinite) with subordinate amount of Type III kerogens (vitrinite) as shown by both Rock Eval parameters and organic petrography. The dispersed organic matters (DOM) are identified as semifusinite and collotelinite under the microscope. The organic matters are interpreted to be inert/post mature kerogens from the maturity parameters like Rock Eval T_{max} (average 563°C), and mean vitrinite reflectance (average 2.0% in oil). The study indicates very poor hydrocarbon potential of the Upper Disang Formation of the Dimapur-Senapati road section.

Keywords: Upper Disang Formation, hydrocarbon potential, Rock Eval pyrolysis, organic petrography.

1. INTRODUCTION

The Disang Group of rocks (Lower Palaeogene) occupies a vast region in the Inner Paleogene Fold Belt of Assam-Arakan Basin in the states of Manipur, Nagaland, Assam and Arunachal Pradesh. It was first described from the Disang river section of Assam and Nagaland by Mallet (1876). The Disang Group of rocks are generally composed of dark grey and finely laminated shales with sandstone and siltstone intercalations. The lower part of the rock group, which is exposed in the vicinity of the Indo-Myanmar Ophiolite Belt is considered to be metamorphosed. The upper part, exposed in the central part of the basin is composed of unmetamorphosed sediments. Works on organic geochemistry and petrography of the Disang Group of rocks are very few. The Directorate of Hydrocarbon, Govt. of India, has mentioned about excellent source rock characteristics with TOC around 4% and 0.64 to 1.94%

vitrinite reflectance (www.dgh.gov.in, access on 04-03-2019). However, details about location of the study area is not mentioned in the document. Other notable publications on organic geochemistry and hydrocarbon potential of the Disang Group are those of Gogoi and Sarmah (2013) and Singh et al (2015). These papers examine hydrocarbon potential of the Disang shales, exposed in the Tirap District of Arunachal Pradesh and Manipur respectively. Both the papers highlight poor hydrocarbon potential of the Disang Group of rocks. However, the Disang Group is exposed in numerous geological sections in the states of Arunachal Pradesh, Assam, Nagaland and Manipur, which are still not studied for evaluation of hydrocarbon potential. The present paper studies organic geochemistry and petrography of the Disang shales exposed along the Dimapur-Senapati road section of Nagaland and Manipur (Fig. 1) for understanding hydrocarbon potential of this region.

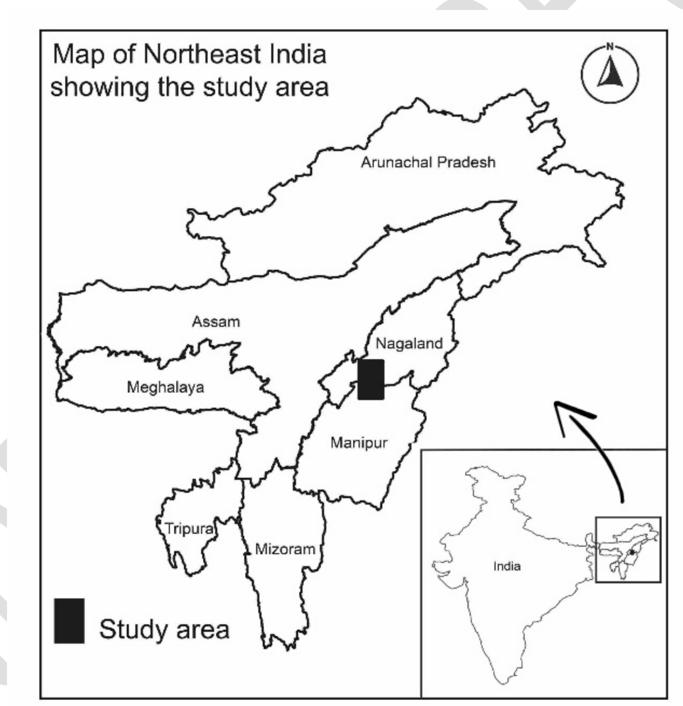

Fig. 1. Location map of the study area

2. GEOLOGY OF THE AREA

The Dimapur-Kohima-Senapati road section exposes rock formations of both the Schuppen Belt and Inner Paleogene Fold Belt of the Assam-Arakan Basin in a northwest-southeasterly trend. The Inner Paleogene Fold Belt exposes the uninterrupted sequence of the Disang and the Barail Groups along with the younger rock formations. However, the Disang Group is completely absent in the Schuppen Belt.

The sedimentary sequence of the Disang Group exposed along the Dimapur-Senapati road section belong to its upper part (Upper Disang Formation). It is mostly composed of black coloured splintery shales, siltstones and silty sandstones. Ripple marks are very common sedimentary structure in the Disang rocks that indicates shallow water origin. The contact between shales with sandstones and siltstones is very sharp.

The boundary between the Disang and the overlying Barail Group is transitional and difficult to identify in the field. However, the first appearance of multistoried sandstones is considered as the base of the Barail Group (Kesari et al, 2011). The stratigraphy of the study area is shown in the Table 1. The geological map has been prepared (Fig. 2) with inputs from geological fieldworks carried out by the authors, satellite image/digital elevation model (DEM) analyses and online geological map of the Geological Survey of India available at http://bhukosh.gsi.gov.in.

Table 1: Generalized stratigraphic succession of the Inner Paleogene Fold Belt exposed along the Dimapur-Senapati road section (modified after Kesari et al., 2011 and Mathur and Evans, 1964).

Age	Rock Group	Formation
	Tipam Group	**Girujan Clay Formation:** Mottled clay, sandy shale, mottled coarse to gritty sandstones
		Tipam Sandstone Formation: Yellowish brown, massive, cross bedded ferruginous sandstones with subordinate shales and conglomerates.
~~unconformity~~~~~~~~~~~~~~~~~~~~~~~~		
Miocene	Surma Group	**Bokabil Formation:** Alternating sandstones and shales
		Bhuban Formation: Sandstones, siltstones, shales with pebble beds and conglomerates at the base
~~unconformity~~~~~~~~~~~~~~~~~~~~~~~~		
Oligocene	Barail Group	**Renji Formation:** Hard, ferruginous thickly bedded multistoried sandstones
		Jenam Formation: Alternating sandstone, siltstone and grey to dark grey shale with coal lenses

		Laisong Formation: Medium to fine grained, well bedded, hard, light grey sandstones alternating with shales and siltstones.
Paleocene to Eocene	Disang Group	**Upper Disang Formation:** Upper Grey, khaki grey, black splintery shales with silty interbands, lensoidal sandstones and rhythmites
Base not exposed		

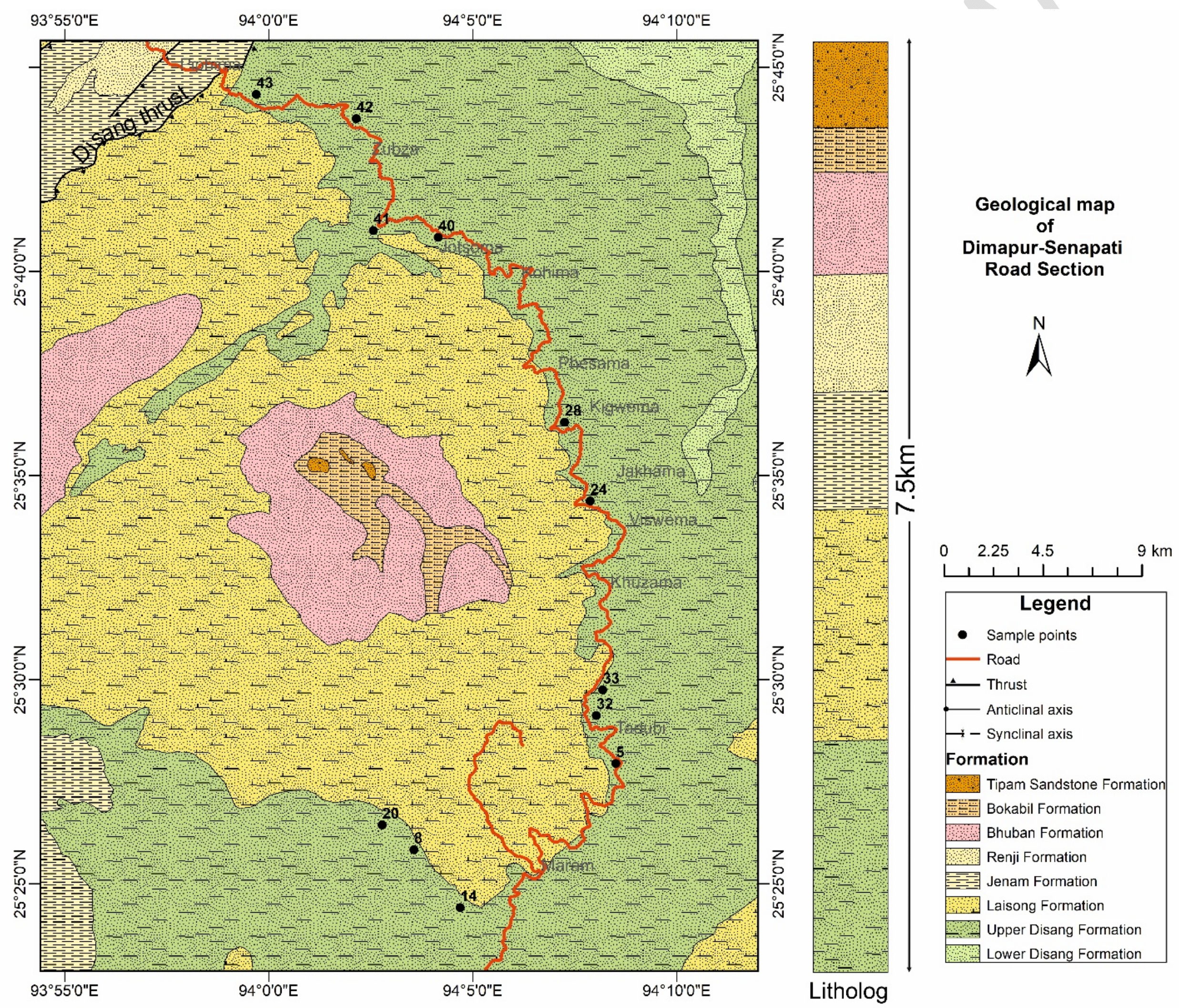

Fig. 2. Geological map of the study area

3. MATERIALS AND METHODS

Samples of carbonaceous shales of the Upper Disang Formation have been collected from Dimapur-Senapati road section for the present study. Samples are air dried and pulverized to 210-micron size for Rock Eval pyrolysis. Rock Eval pyrolysis is done using Rock Eval 6 (Make: Vinci Technologies, France) following procedures of Lafargue et al (2000). The Rock Eval 6 instrument is a completely automated device that employs programmed heating of two micro-ovens (pyrolysis and oxidation ovens) from 100° to 850°C. Pyrolysis at high temperature up to 850°C is necessary for complete thermal degradation of type III kerogens of terrestrial origin. A flame ionization detector (FID) measures the quantity of H/C gas during pyrolysis while an online infrared cell is employed to measure the quantity of CO and CO_2 generated during pyrolysis and subsequent oxidation. This technique uses temperature programmed heating of a small amount of rock (100 mg) in an inert atmosphere to determine the quantity of free hydrocarbons present in the sample (S_1 peak) and the amounts of hydrocarbons and compounds containing oxygen (CO_2) that are produced during the thermal cracking of kerogens present in the rock (S_2 and S_3 peaks respectively). Besides, the total organic carbon (TOC) content of the rock is also determined by oxidation in the second oven after pyrolysis. T_{max} is the temperature at which the maximum rate of hydrocarbon generation and represented by the top of the S_2 peak. The secondary parameters are Hydrogen Index ($HI=S_2x100/TOC$ mg/gTOC), Oxygen Index ($OI=S_3x100/TOC$ mg/gTOC), Production Index ($PI=S_1/(S_1+S_2)$ and Genetic Potential ($GP=S_1+S_2$). A separate set of samples are crushed into 1mm size for organic petrographical study and polished pellets are prepared. The organic petrographical study was done using a Leica DM3000 microscope fitted with both reflectance and fluorescence photometers. The ICCP (1994) schemes for classification of vitrinite (ICCP,1998), inertinite (ICCP, 2001) and liptinite (Pickel et al, 2017) have been followed in the present study.

4. RESULTS AND DISCUSSION

4.1 Richness of organic matters

The amount of organic matters in a sedimentary rock is the most important parameter for interpreting hydrocarbon source rock potential. The organic richness of sedimentary rocks can be evaluated by the TOC and the pyrolysis derived S_1 and S_2. The total organic carbon (TOC) of the Disang samples ranges from 0.29 to 1.10% with an average of 0.53%. The Rock Eval S_1 ranges from 0.01 to 0.09mg/gTOC (average 0.04 mg/gTOC) and S_2 from 0.05 to 0.44mg/gTOC (average 0.16mg/gTOC) (Table 2). These Rock Eval parameters reflect poor generative potential of the Disang shales of the study area (Peters, 1986). The same is also reflected by the TOC vs S_2 diagram (Fig. 3) made for the Disang samples. (Shalaby et al., 2013).

The hydrogen index (HI) of the samples ranges from 5 to 81mg/gTOC (average 36mg/gTOC) while the S_2/S_3 ratio ranges from 0.4 to 2 (average 1.0) (Table 2). These parameters indicate gas prone nature of the organic matters of the Upper Disang Formation (Peters, 1991).

The Disang shale samples contain very low genetic potential (GP) averaging at 0.2mg/gTOC (Table 2). According to Hunt (1996), the genetic potential <2mg/gTOC indicates poor generative potential. The plot of S_1+S_2 (GP) against TOC (Nady et al., 2015) also indicates poor hydrocarbon generative potential of the carbonaceous shales of Upper Disang Formation (Fig. 4).

Table 2: The results of Rock Eval pyrolysis of the samples of the Upper Disang Formation.

Sp No.	TOC (%)	S_1 (mg/g)	S_2 (mg/g)	S_3 (mg/g)	Tmax (°C)	S_2/S_3	HI (mg/g)	OI (mg/g)	GP (mg/g)	PI (mg/g)
5	1.07	0.05	0.05	0.13	607	0.4	5	12	0.1	0.49
8	0.49	0.06	0.18	0.1	582	1.8	37	20	0.24	0.26
14	1.10	0.03	0.18	0.19	601	0.9	16	17	0.21	0.15
20	0.43	0.04	0.16	0.15	606	1.1	37	35	0.2	0.19
24	0.29	0.01	0.11	0.14	515	0.8	38	48	0.12	0.09
28	0.31	0.01	0.08	0.15	576	0.5	26	48	0.09	0.13
32	0.37	0.09	0.18	0.09	549	2.0	49	24	0.27	0.33
33	0.40	0.08	0.17	0.13	561	1.3	42	32	0.25	0.31
40	0.45	0.01	0.06	0.12	601	0.5	13	27	0.07	0.12
41	0.59	0.01	0.07	0.19	599	0.4	12	32	0.08	0.11
42	0.31	0.04	0.25	0.24	477	1.0	81	77	0.29	0.13
43	0.56	0.07	0.44	0.29	477	1.5	79	52	0.51	0.14
Minimum	0.29	0.01	0.05	0.09	477	0.4	5	12	0.07	0.09
Maximum	1.10	0.09	0.44	0.29	607	2	81	77	0.51	0.49
Average	0.53	0.04	0.16	0.16	563	1.0	36	35	0.20	0.20

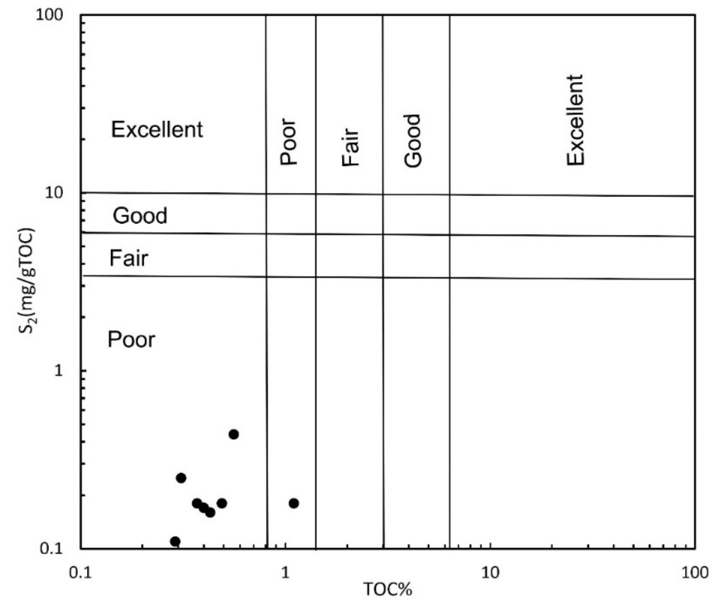

Fig. 3. Plot of S_2 against TOC indicating hydrocarbon generative potential

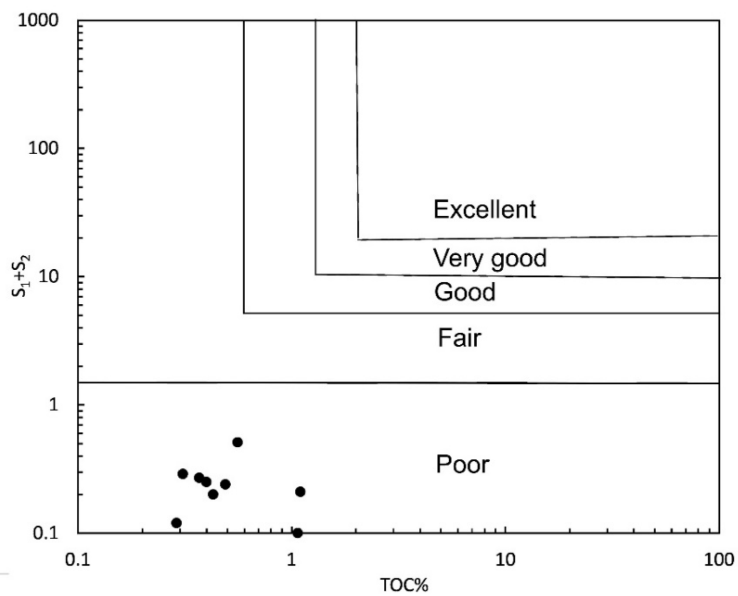

Fig. 4. Plot of S_1+S_2 against TOC indicating poor hydrocarbon generative potential

4.2. Organic matter types

For precise identification of potential oil source beds determination of kerogen types is very essential (Demaison and Moore, 1980). The hydrogen index (HI) of the samples range from 5 to 81 with average of 36mg/gTOC (Table 2). HI values lower than 200mg/gTOC indicates presence of terrestrial organic matters (Hakimi and Abdullah, 2014). Low hydrogen index (HI) also indicates gas prone nature of the organic matters (Peters, 1986). The plot of HI against OI (Fig. 5), which is used as alternative of Van Krevelen diagram, indicates presence of Type III and IV kerogens in the carbonaceous shales of the Upper Disang Formation (Demaison et al., 1983). The plot of S_2 against TOC (Lengford and Blanc-Valleron, 1990) also indicates presence of Type III and IV kerogens in the samples (Fig. 6). Type IV kerogens usually have lesser than 50mg/gTOC of HI (Tissot and Welte, 1984).

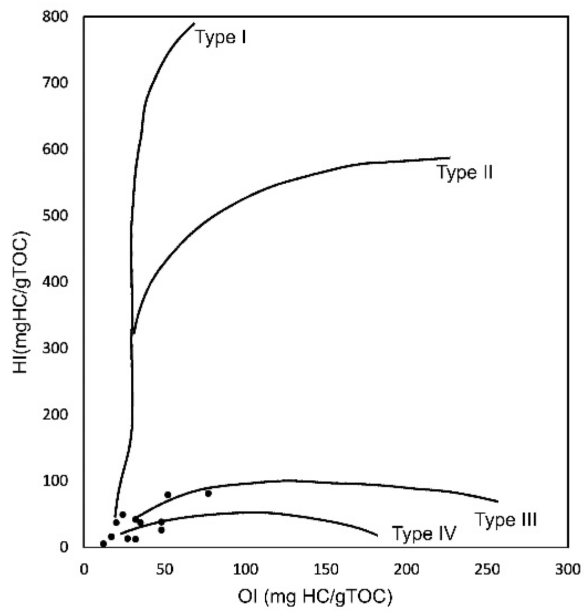

Fig.5. HI versus OI diagram showing organic matter types of the carbonaceous shales of Upper Disang Formation

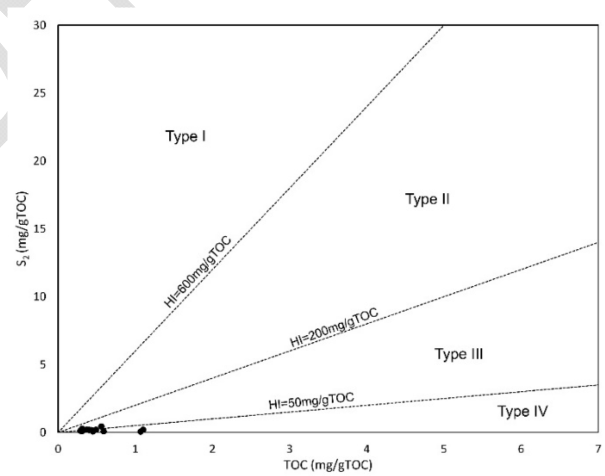

Fig.6. S_2 versus TOC diagram showing organic matter types in the carbonaceous shales of Upper Disang Formation

4.3 Thermal maturity

The thermal maturity of dispersed organic matter governs, in part, the character of the organic matter and, therefore, may influence interpretation of hydrocarbon generation (Hakimi and Abdullah, 2014). The thermal maturity of organic matters depends on burial depth of the sediment bed, geothermal gradient and age. The Rock Eval T_{max} is a direct measure of maturity of organic matters in the sediments. The Rock Eval T_{max} represents the temperature of maximum generation of hydrocarbon during the pyrolysis and is a good indicator of maturation for terrestrially derived organic matters (Tissot and Welte, 1984). The T_{max} of the samples range from 477 to 607°C (average 563°C) that indicates presence of over-mature organic matters in Upper Disang Formation (Fuan, 1991). The plot of T_{max} against production index (PI) of the samples (Fig. 7) indicates presence of inert carbon to post-mature organic matters in the samples (Atta-Peters and Garrey, 2014).

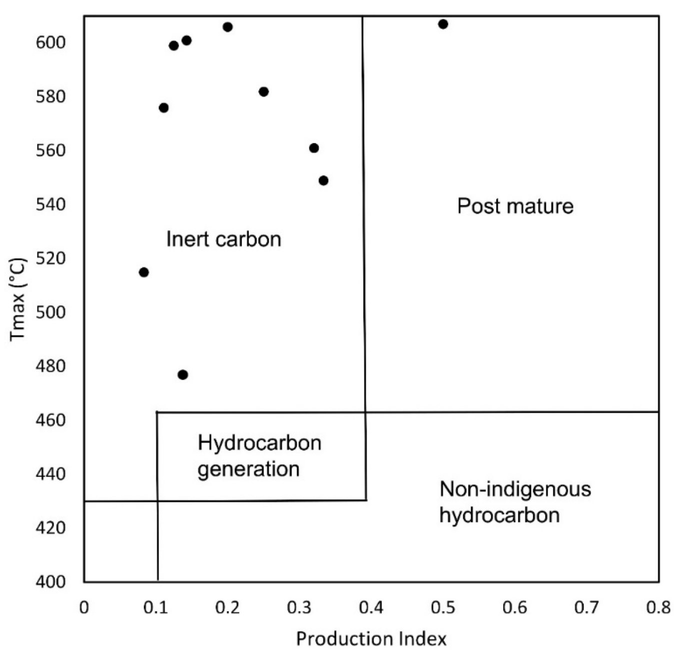

Fig.7. Plot of production index (PI) against Tmax indicating presence of inert carbon to post mature hydrocarbons in Upper Disang Formation

4.4 Organic petrography

The carbonaceous shale samples of Upper Disang Formation of the study area have been observed under microscope to characterize the dispersed organic matters (DOM). The results have been summarized in the Table 3. Only 7 samples out of 13 samples studied under the present study are found to contain dispersed organic matters that are visible under the microscope. The dispersed organic matters identified under microscope are dominantly composed of inertinite macerals (average 2.6% in volume percent of rock) with subordinate amounts of vitrinite (1.5% in volume percent of rock). Inertinite group of macerals ranges from 25 to 100% (average 59.0%) and vitrinite from 0.4 to 9.0% (average 3.5%) in volume percent of visible DOMs in the samples. Vitrinites are represented by collotelinite (Fig. 8). Collotelinites do not show any vegetal structures. They derived from woody tissues of stems, roots and leaves of herbaceous or arborescent plants. Primary structures in collotelinites disappear because of geochemical gelification (ICCP, 1994). Vitrinite macerals of the Disang shale samples are nonfluorescent. Vitrinite represents Type III kerogens. Inertinite macerals in the samples are identified as semifusinite (Fig. 9). Semifusinite shows higher reflectance than vitrinite and has partially visible cell structures. It is the most common type of dispersed organic matters in the Disang shale samples. Depending on chemical composition it belongs to both Type III and Type IV kerogens (ICCP, 2001). Liptinite macerals are completely absent in the samples.

From the maceral composition it is seen that the organic matters in the samples are dominantly represented by Type III and Type IV kerogens. Samples also contain appreciable amount of pyrites (average 2.5% in volume percent of rock) that indicates sea water influx into the depositional basin. The mean vitrinite reflectance (in oil) of the samples range from 1.0 to 2.9% with an average of 2.0% (Table 3). High vitrinite reflectance indicates that the organic matters in the samples are over-mature. The organic petrography of the samples indicates very poor hydrocarbon potential of the Upper Disang Formation.

Table 3. Maceral composition (in volume percent of rock) and vitrinite reflectance of the carbonaceous samples of Upper Disang Formation.

Sample No.	Maceral composition (in volume percent of rock)					Maceral composition (in volume percent of DOM)			Vitrinite reflectance (% in oil)		
	Vitrinite (%)	Liptinite (%)	Inertinite (%)	Silicate minerals (%)	Pyrite (%)	Vitrinite (%)	Liptinite (%)	Inertinite (%)	Min	Max	Mean
SP 5	0.0	0.0	9.0	84.3	4.9	9.0	0.0	100.0	2.1	4.3	2.7
SP-10	-	-	-	-	-	-	-	-	-	-	-
SP-11	0.3	0.0	0.1	99.6	0.0	0.4	0.0	25.0	1.1	2.1	1.7
SP 17	-	-	-	-	-	2.0	0.0	100.0	-	-	-
SP-19	0.0	0.0	2.0	97.8	0.2	2.3	0.0	26.1	2.4	3.4	2.9
SP-24	1.7	0.0	0.6	93.5	4.2	0.6	0.0	83.3	0.7	1.2	1.0
SP-28	0.1	0.0	0.5	98.2	1.2	-	-	-	1.3	2.4	2.0
SP 32	-	-	-	-	-	-	-	-	-	-	-
SP 33	-	-	-	-	-	-	-	-	-	-	-
SP 34	-	-	-	-	-	-	-	-	-	-	-
SP 36	-	-	-	-	-	-	-	-	-	-	-
SP-40	0.0	0.0	2.0	96.3	1.7	2.0	0.0	100.0	1.4	4.5	1.9
SP-41	5.6	0.0	0.0	88.0	6.4	5.6	0.0	0.0	1.6	2.3	2.0
Min	0.0	0.0	0.0	84.3	0.0	0.4	0.0	25.0	0.7	1.2	1.0
Max	5.6	0.0	9.0	99.6	6.4	9.0	0.0	100.0	2.4	4.5	2.9
Mean	1.5	0.0	2.6	93.5	2.8	2.7	0.00	72.4	1.5	2.9	2.0

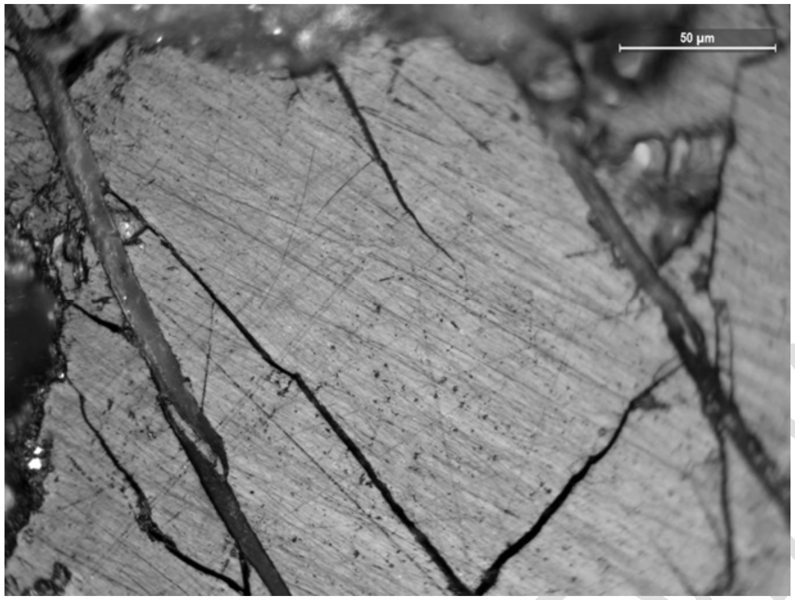

Fig. 8. Collotelinites as dispersed organic matter in carbonaceous shale samples of Upper Disang Formation

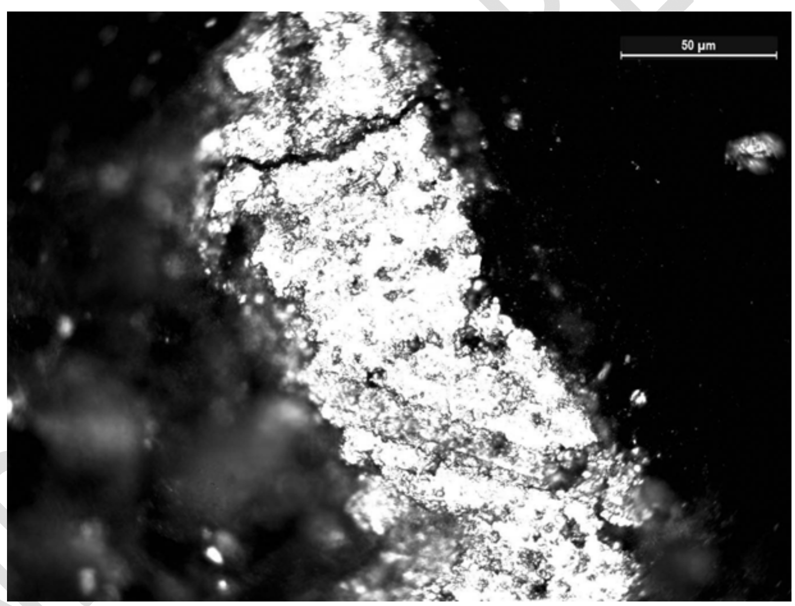

Fig. 9. Semifusinite as dispersed organic matters in the carbonaceous shales of Upper Disang Formation

5. CONCLUSION

i. The following interpretation are drawn from the study:

ii. Presence of ripple marks in the rocks of Upper Disang Formation indicates shallow depositional environment. Appreciable amount of pyrites in the carbonaceous shale samples points to incursion of sea water into the depositional basin.

iii. The shales of Upper Disang Formation contain very low amount of organic matters to be good petroleum source rocks. The average TOC content of the studied samples is only 0.53%. Other Rock Eval parameters like S_1, S_2, hydrogen index (HI) and genetic potential (GP) also point to poor generative potential and gas prone nature of the organic matters.

iv. The organic matters in the Upper Disang Formation of the study area is dominantly represented by Type IV kerogens with subordinate amount of Type III kerogens as shown by the parameters of Rock Eval pyrolysis. The average hydrogen index (HI) of the samples is 36mg/gTOC that indicates presence of terrestrial organic matters. This is also supported by organic petrographical analysis of the dispersed organic matters (DOM) of the samples. Visible dispersed organic matters (DOM) in the samples are identified as inertinite (average 2.6%) and vitrinite (1.5%) in volume percent of the rock.

v. Organic petrographic analysis shows dominance of inertinites (average 59%) over vitrinites (average 3.5%) in the dispersed organic matters (DOM) of the Disang shales. The vitrinite macerals are represented by collotelinite, while the inertinite macerals by semifusinite. These macerals are product of terrestrial plants. Vitrinites macerals belong to Type III kerogen, while the semifusinites belong to both Type III and Type IV kerogens, depending upon its reactivity (ICCP, 2001).

vi. The average Rock Eval T_{max} of the samples is 563°C which indicates presence of inert to post mature organic matters that fall in the dry gas window of petroleum generation. The mean vitrinite reflectance (average 2.0%) of the samples also confirms it.

vii. In general, the present study shows very poor hydrocarbon generation potential of the Upper Disang Formation characterized by presence of very low amount of inferior quality and over-mature organic matters.

REFERENCES

Atta-Peters, D, and Garrey, P. Source rock evaluation and hydrocarbon potential in the Tano basin, South Western Ghana, West Africa. International Journal of Oil, Gas and Coal Engineering. 2014. 2(5): 66-77.

Available: http://dghindia.gov.in /assets/downloads/56cc43934337fAssam-Arakan_Basin.pdf

Demaison, GJ, Hoick, AJJ, Jones, RW, Moore, GT. Predictive source bed stratigraphy; a guide to regional petroleum occurrence. In: Proceedings of the 11th World Petroleum Congress, London. 1983; 2:17–29.

Directorate General of Hydrocarbon. Assam Arakan Basin. Accessed on 04-03-2019.

Fuan, F. Geochemical characteristics of Type IV kerogen from Lower Paleozoic source rocks in Lower Yangtze area. Journal of Southeast Asian Earth Sciences. 1991; 5(1-4): 39-42.

Gogoi, BK and Sarmah, R. Geochemical Characteristics of Shale of Disang Group, Tirap District, Arunachal Pradesh. International Journal of Scientific & Technology Research. 1991; 2(11): 186-192.

Hakimi, HH and Abdullah, WH. Source rock characteristics and hydrocarbon generation modelling of Upper Cretaceous Mukalla Formation in the Jiza-Qamar Basin, Eastern Yemen. Marine and Petroleum Geology. 2014; 51: 100-114.

Hunt, JM. Petroleum Geochemistry and Geology, second ed., W.H. Freeman and Company. 1996.

ICCP. The new inertinite classification (1994), Fuel. 1996; 80: 459-471.

ICCP. The new vitrinite classification (1994). Fuel. 1998; 77(5): 349-358.

Kesari, GK, Das Gupta, G and Prakash, HSM. Geology and mineral resources of Manipur, Mizoram, Nagaland and Tripura. GSI Miscellaneous Publication no. 30, Part IV. 2011; 1(2): 96.

Lafargue, E, Espitalié J, Marquis, F and Pillot, D. Rock Eval 6 application in hydrocarbon exploration, production and soil contamination studies. In Revenue de I'nstitut Français du Petrolé. 2000; 53(4): 421-437.

Langford, FF and Blanc-Valleron, MM. Interpreting Rock-Eval pyrolysis data using graphs of pyrolizable hydrocarbons vs. total organic carbon. AAPG Bulletin. 1990; 74: 799-804.

Mallet, FR. On coalfields of Naga Hills bordering the Lakhimpur and Sibsagar Districts, Assam. Mem. Geological Survey of India. 1876; 12(2).

Nady, MMEl, Ramadan, FS, Hammad, MM and Lofty, NM. Evaluation of organic matters, hydrocarbon potential and thermal maturity of source rocks based on geochemical and statistical methods: Case study of source rocks in Ras Gharib oilfield, central Gulf of Suez, Egypt. Egyptian Journal of Petroleum. 2015; 24: 203-211.

Peters, KE. Guidelines for evaluating petroleum source rock using programmed pyrolysis. AAPG Bulletin. 1986; 70(3): 318-329.

Pickel, W, Kus, J, Flores, D, Kalaitzidis, S, Christanis, K, Cardott, BJ, Misz-Kennanf, M, Rodrigues, S, Hentschel, A, Hamor-Vidoh, M, Crosdale, P, Wagner, N and ICCP. The new liptinite classification- ICCP system 1994. International Journal of Coal Geology. 2017; 169: 40-61.

Shalaby, M & Hakimi, M and Abdullah, W. Modeling of gas generation from the Alam El-Bueib Formation in the Shoushan Basin, northern western Desert of Egypt. International Journal of Earth Sciences. 2013; 102: 319-332.

Sing, YR, Singh, BP and Jianguo, L. Hydrocarbon Potential of the Paleogene Disang Group, Manipur Region, India-A Palynological Approach. in Mukherjee, S, editor. Petroleum Geosciences: Indian Contexts, Springer. 2013; 191-204.

Tissot, BP and Welte, DH. Petroleum Formation and Occurrence. 2nd Ed. Berlin: Springer-Verlag; 1984.