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

The 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 corroborated 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 inertodetrinite and vitrodetriniteunder the microscope. The organic matters are interpreted to be inert to post mature kerogens from the maturity parameters like Rock Eval Tmax (average 563°C), and mean vitrinite reflectance (average 2.0% in oil). The study indicates negative 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

Lower Paleogene Disang Group of rocks 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 in the Disang river section of Assam and Nagaland.The Disang Group of rocks are generally composed of dark grey and finely laminated shales with sandstone and siltstone alterations. The lower part of the rock group, which is exposed in the vicinity of the Indo-Myanmar Ophiolite Belt is considered to be metamorphosed, while the upper part, exposed along 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 that 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 in their respective study areas. However, the Disang Group of rocks is exposed in numerous geological sections 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 interpreting hydrocarbon potential of this region.

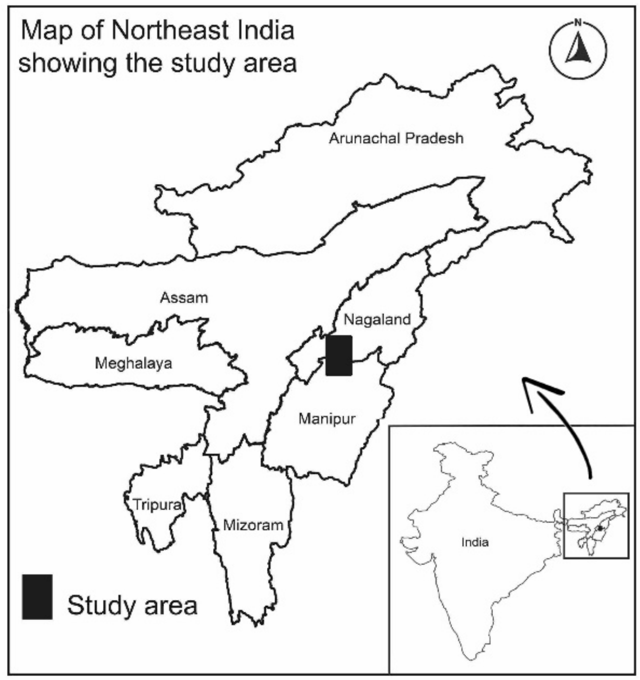

Fig. 1. Location map of the study area

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 Schuppen Belt exposes rock strata of the Barail, Surma and Tipam Groups, while the Disang and Barailand Surma Groups are exposed in the Inner Paleogene Fold Belt on the southeastern side of the Disang Thrust in the Kohima-Senapati region.

The upper part of the Disang Group (Upper Disang Formation) is exposed along the Dimapur-Senapati road section. It is mostly composed ofblack colouredsplintery shales, siltstones and silty sandstones. Cross-bedding and ripple marks within sandstones and bioturbations in the shales are occasionally seen, which indicate shallow water origin. The contact between shales with sandstones and siltstones is very sharp. The shales contain plants remains in places.

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 Disang Group of rocks forms a highly folded and thrusted monotonous pile of sedimentsexposingthe Barails at the synclinal cores along the road section. The stratigraphy of the road section is shown in the Table 1 and the geological map is shown in the Fig. 2.

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		

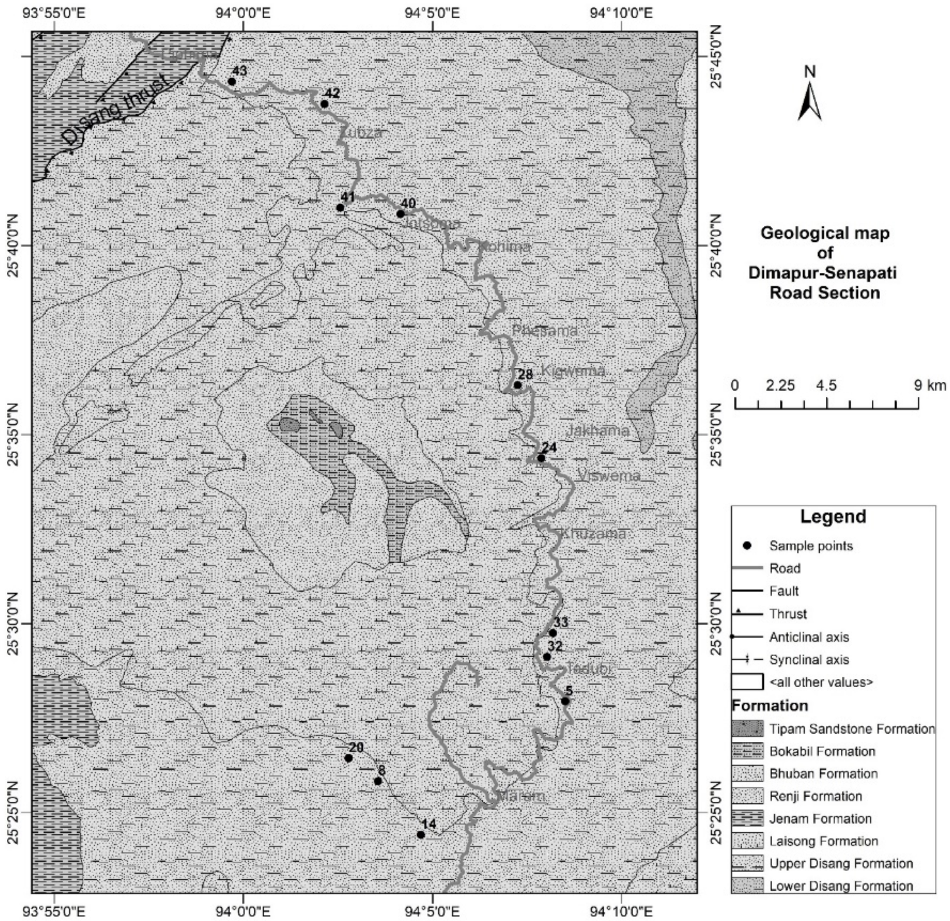

Fig. 2. Geological map of the study area

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 Espitalié (1976, 1986). The parameters determined in the pyrolysis experiment are TOC, S_1 (amount of free hydrocarbon on the samples), S_2 (hydrocarbon generated in pyrolytic degradation of the samples between 300 to 500°C), S_3 (amount of CO_2 evolved during the experiment that indicates amount of oxygen in organic matters) and T_{max} (temperature at which maximum release of hydrocarbon from decomposition takes place). 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 areprepared. The organic petrographical study was done using a Leica DM3000 microscope fitted with both reflectance and fluorescence photometers. The ICCP (1994) schemes forclassification ofvitrinite (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 matter in a sedimentary rock is the most important parameter in deciphering 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 S2/S3 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

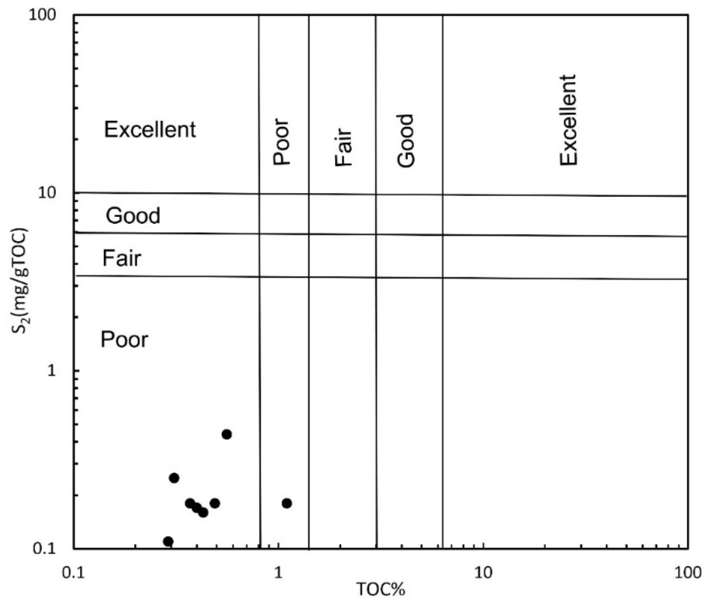

Fig. 3. Plot of S_2 against TOC indicating hydrocarbon generative potential

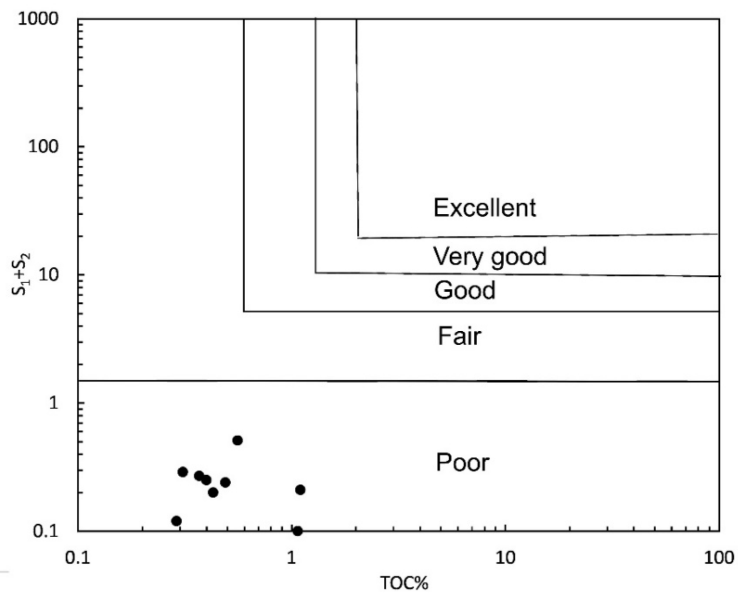

Fig. 4. Plot of S_1+S_2 against TOC indicating poor hydrocarbon generative potential

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).

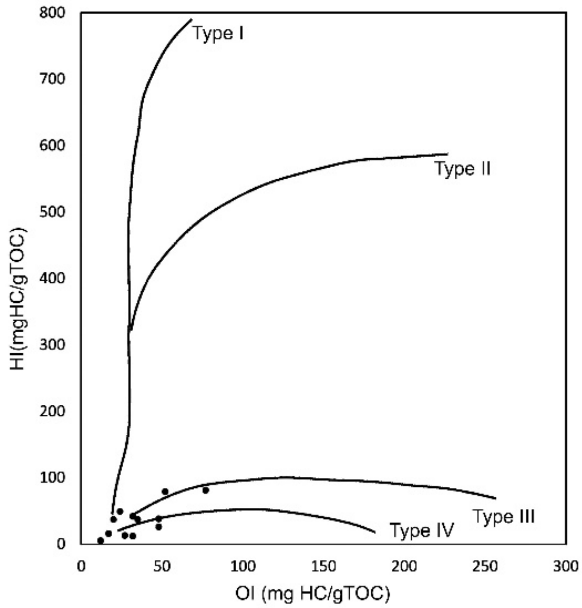

Fig.5. HI versus OI diagram showing organic matter types of the carbonaceous shales of Upper Disang Formation

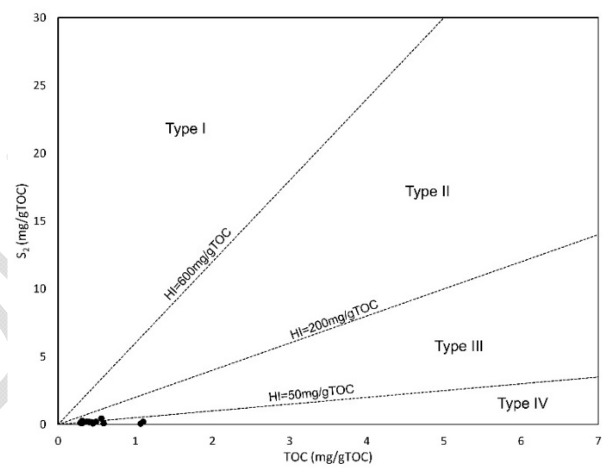

Fig.6. S_2 versus TOC diagram showing organic matter types in the carbonaceous shales of Upper Disang Formation

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 with average of 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).

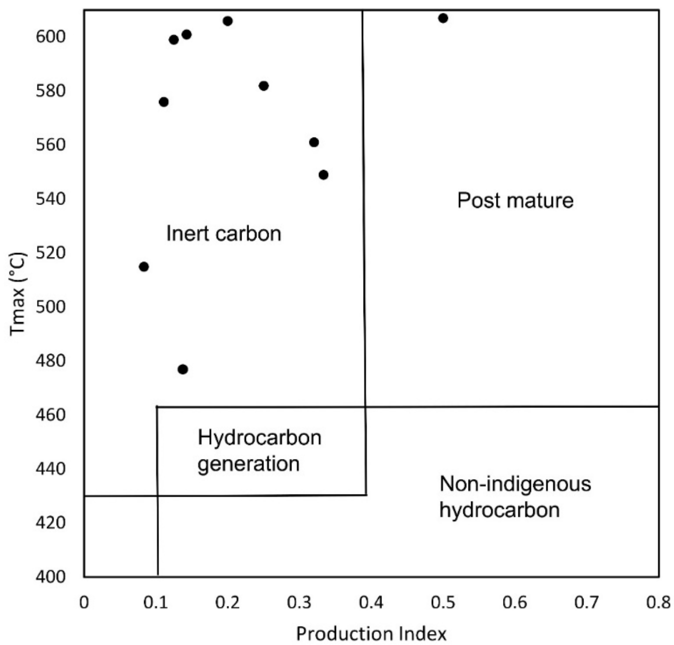

Fig.7. Plot of production index (PI) against Tmax indicating presence of inert carbon to post mature hydrocarbons in Upper Disang Formation

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 assemifusinite (Fig. 9). Semifusinites show higher reflectance than vitrinites and have partially visible cell structures. It is the most common dispersed organic matters in the Disang shale samples. Depending on chemical composition it belongs to both Type III and Type IV kerogens (ICCP, 2001). The samples do not contain any liptinite macerals.

From the maceral composition it is seen that the organic matters in the samples are dominantly represented by Type III and Type IV kerogens. The 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 negative 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 coal)					Vitrinite reflectance (% in oil)		
	Vitrinite (%)	Liptinite (%)	Inertinite (%)	Silicate minerals (%)	Pyrite (%)	Min	Max	Mean
SP 5	0.0	0.0	9.0	84.3	4.9	2.1	4.3	2.7
SP-10	-	-	-	-	-	-	-	-
SP-11	0.3	0.0	0.1	99.6	0.0	1.1	2.1	1.7
SP 17	-	-	-	-	-	-	-	-
SP-19	0.0	0.0	2.0	97.8	0.2	2.4	3.4	2.9
SP-24	1.7	0.0	0.6	93.5	4.2	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	1.4	4.5	1.9
SP-41	5.6	0.0	0.0	88.0	6.4	1.6	2.3	2.0
Min	0.0	0.0	0.0	84.3	0.0	0.7	1.2	1.0
Max	5.6	0.0	9.0	99.6	6.4	2.4	4.5	2.9
Mean	1.5	0.0	2.6	93.5	2.8	1.5	2.9	2.0

Table 4. Maceral composition of the samples (in volume percent of total DOM) of the Upper Disang Formation

Sample No.	Vitrinite	Liptinite	Inertinite

	(%)	(%)	(%)
SP 5	9.0	0.0	100.0
SP-11	0.4	0.0	25.0
SP 17	2.0	0.0	100.0
SP-19	2.3	0.0	26.1
SP-24	0.6	0.0	83.3
SP-40	2.0	0.0	100.0
SP-41	5.6	0.0	0.0

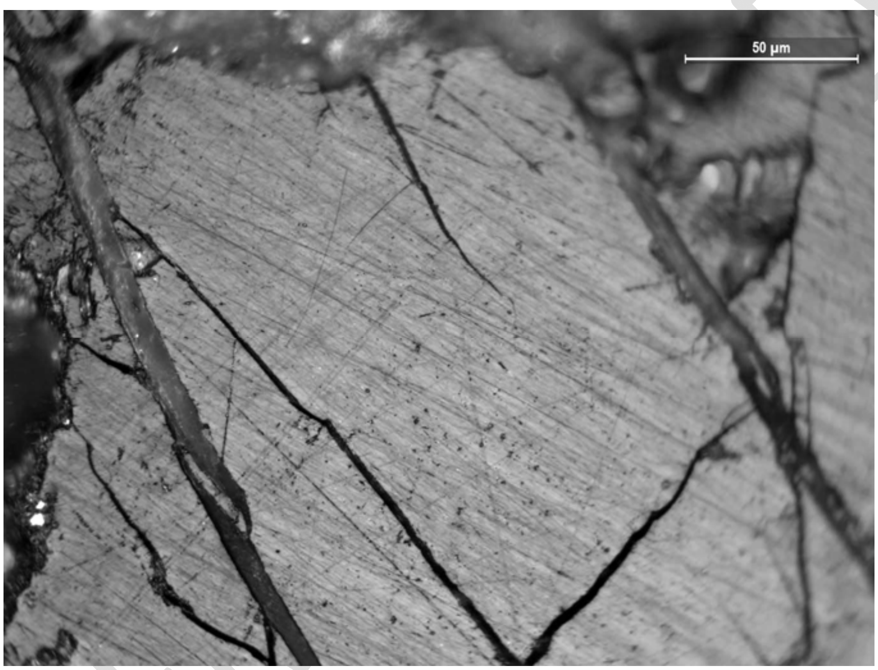

Fig. 8. Collotelinites as dispersed organic matter in carbonaceous shale samples of Upper Disang Formation

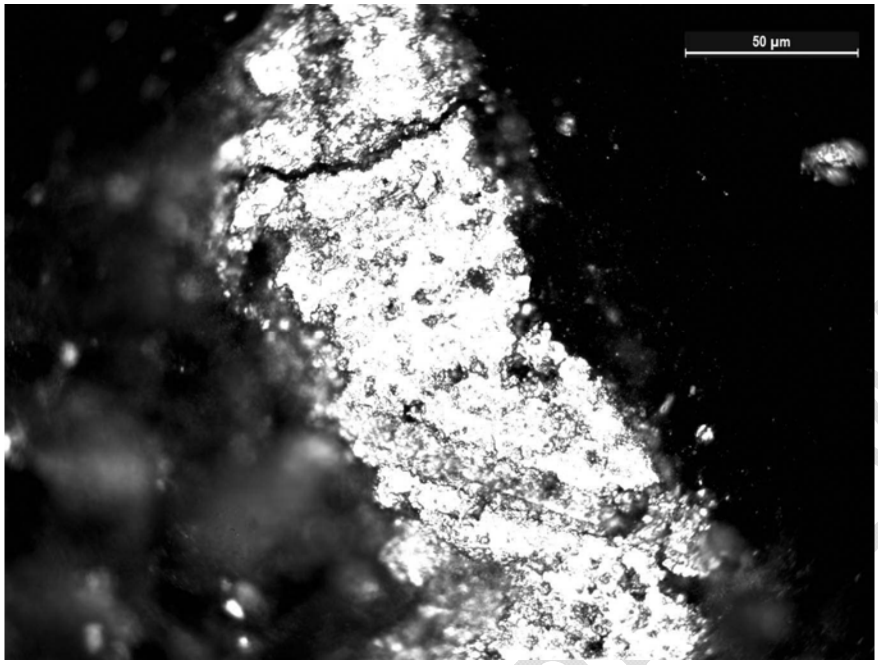

Fig. 9. Semifusinite as dispersed organic matters in the carbonaceous shales of Upper Disang Formation

5. CONCLUSION

The organic geochemical and petrographical analyses of the carbonaceous shales of Upper Disang Formation, exposed along the Dimapur-Senapati road section of Nagaland and Manipur, India shows that:

1. Presence of sedimentary structures like ripple marks, current bedding and bioturbation 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.
2. 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.
3. 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 which indicates presence of terrestrial organic matter. 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.
4. Organic petrographical 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. All 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). The results of organic petrographical modal analysis indicates presence of both Type III and Type IV kerogens in Disang shales.

5. 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 that the organic matters of the Upper Disang Formation are over mature.
6. In general, the present study showsvery poor hydrocarbon generation potential of the Upper Disang Formation characterized by presence of poor quality and over mature organic matters in very insignificant quantity.

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