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Evaluation of geochemical characteristics of shale of Disang Group in a part of Assam-Arakan basin in perspective of its hydrocarbon potential

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Abstract

The geochemical properties of shale were studied in the Assam-Arakan basin covering a portion of the Tirap district of Arunachal Pradesh. Here the dominant rock type is light to dark grey shale belonging to the Disang Group of Eocene age. The northeast-southwest trending shale of Disang Group exposed in Tisa river and Deomali-Longding road section showing distinct fissility parallel to the bedding plane. Grey to dark grey and fine-grained sandstone, which is either massive or thin bedded, occurs interbedded with shale. The Rock-Eval analysis of shale samples from the outcrops shows high Tmax values and lower TOC and S2 values. Thus, it transpires that source-rating of studied shale, is found to be poor and also its source proclivity is towards gas. Further, shale of Disang Group is found to contain over-matured organic matters, represented by Kerogen Type-III and Type-IV.

Key words: Disang Group; Rock-Eval; TOC; S2; Kerogen.

Introduction

The Disang sediments were deposited in deep marine environments close to an arc-trench system during the Eocene. Disang sediments of geosynclinals facies represents the lowermost section of the Tertiary sequence of Assam–Arakan Basin.[1] This paper presents findings of a study on shale of the Disang group in a part of the Assam-Arakan Basin, lying between latitudes 26°55' N and 27°10' N and longitudes 95° 20' E and 95°30' E. This part constitutes a portion of the Tirap District of Arunachal Pradesh (Fig. 1A). In the said region, two traverses were made along the (i) Tisa river and (ii) Deomali-Khonsa-Longding road (Fig. 1B). A thick sequence of shales, interbedded with thin fine to medium grain sandstone is found to be outcropped along these sections.

Rock-Eval pyrolysis and TOC determinations are the most widely used methods to characterize source rocks. Rock-Eval pyrolysis provides information on the quantity, type and

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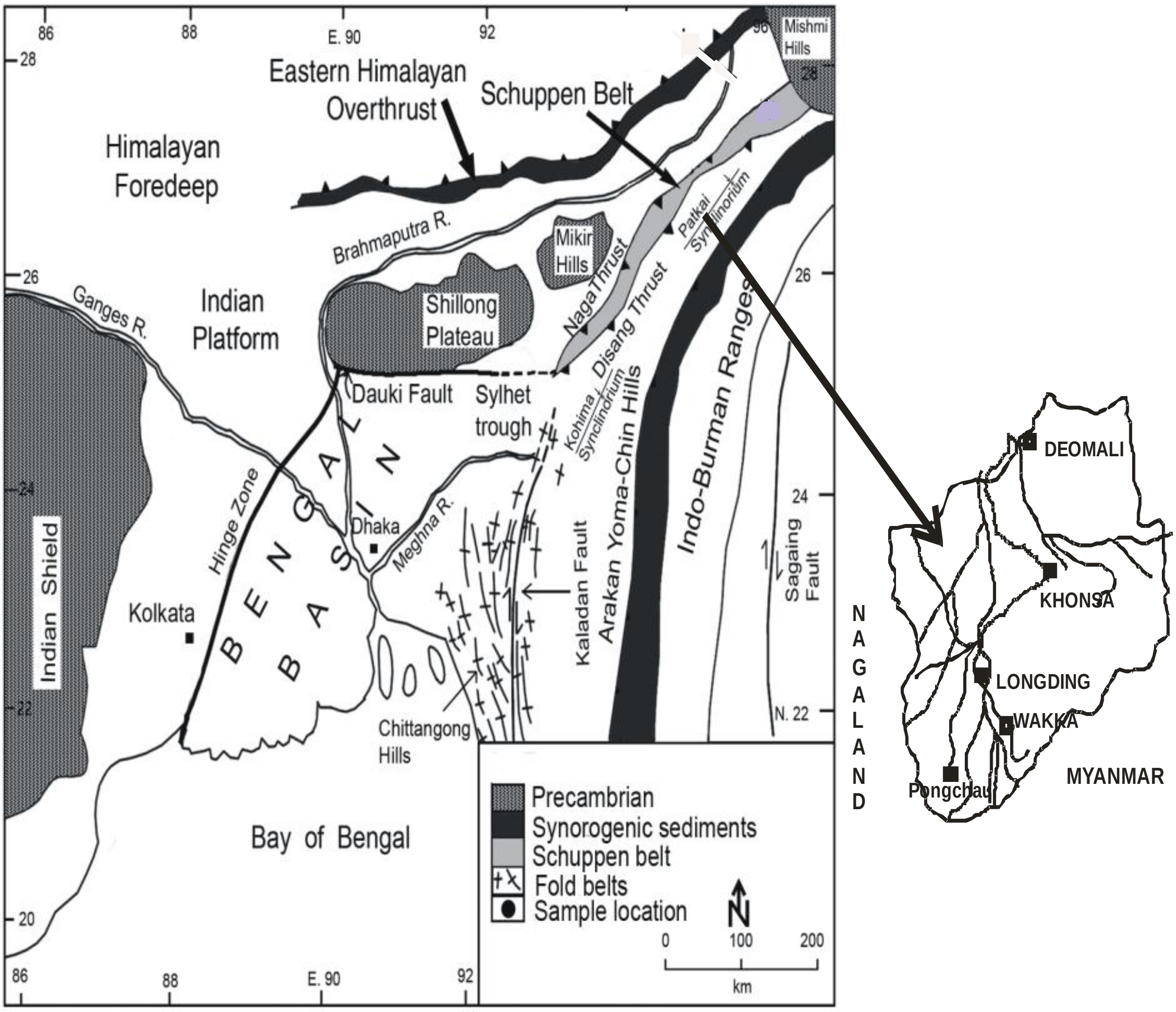

Figure 1A. Map showing the tectonic elements such as the eastern Himalayas and Indo-Burman Ranges. Samples were collected from the south eastern part of the Schuppen belt as shown in figure (after Hutchison, 1989).

thermal maturity of the associated organic matter as well as its hydrocarbon potential. Various recent reviews have been published on preservation of organic-rich source beds.[2-4] Details of the analytical methods have been reported by Espitalie *et al.*,[5] Tissot and Welte[6] and Peters.[7] Hydrogen index (HI) and Tmax are used to assess the oil and gas potential and maturity of source rock respectively. Measure of total organic carbon (TOC) is a non-specific method that only indicating the organic carbon compounds present in rock but unable to distinguish between various organic species. The higher enrichment of organic matter in sediments is one of the criteria for the identification of oil and gas source rocks. This paper is an approach towards finding total organic carbon and organic matter type present in shale of Disang group to assess the hydrocarbon potential. The area under study, is least studied. There is no published record found so far on Rock-Eval analysis of shale in the study area.

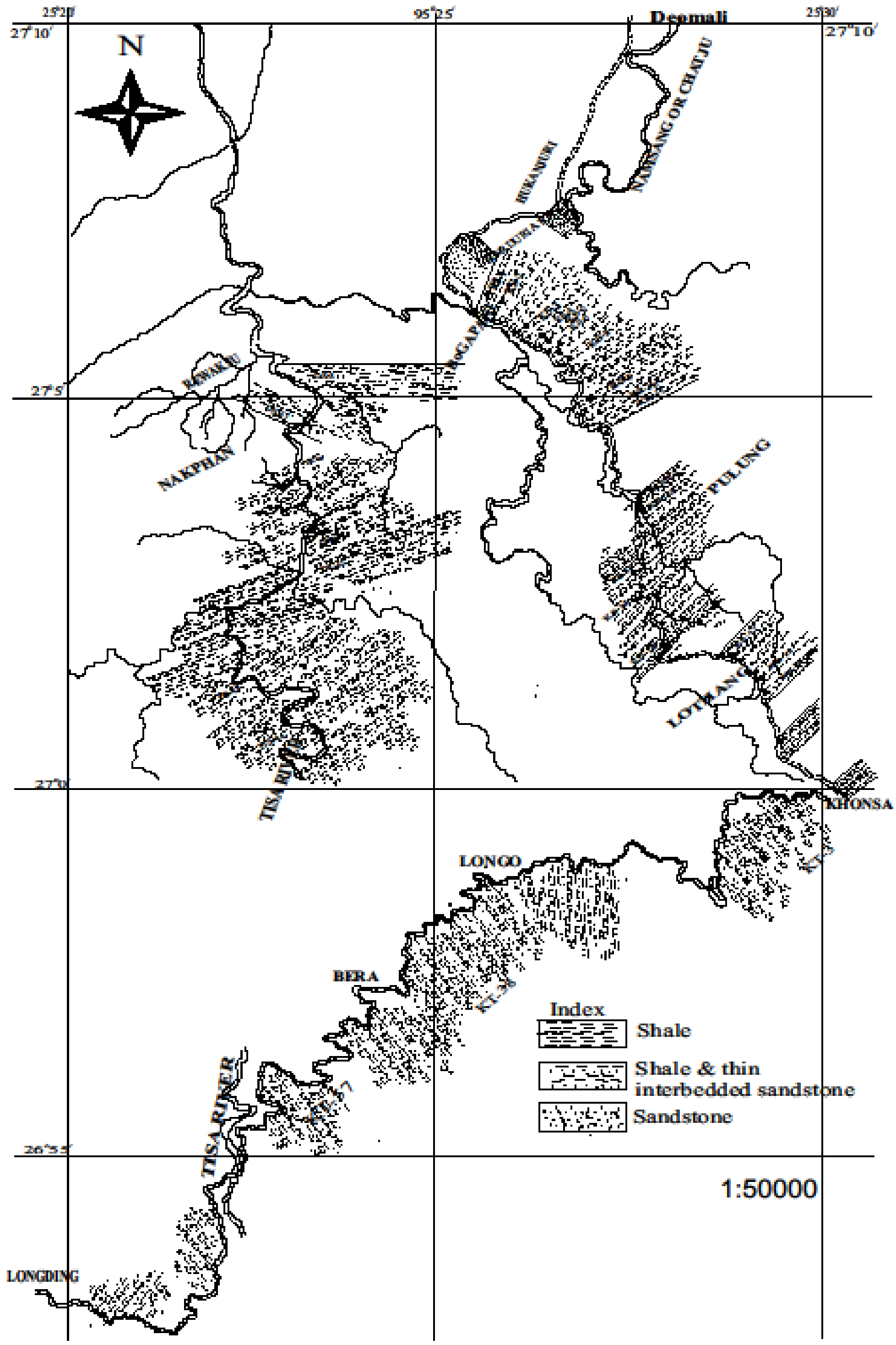

Figure1B. Location map showing Sampling position in Tissa river section and Deomali-Khonsa-Longding road section, Tirap District, Arunachal Pradesh.

Geological setup

The geology of Tirap district was first described by Mallet in his memoir on the coalfields of Naga Hills.[8] The general stratigraphic succession covering Tirap district of Arunachal Pradesh forward by Jhanwar *et al.*[9] is shown in Table 1. The Assam-Arakan basin occupies a vast tract of the Naga-Patkai hill ranges adjoin the Assam self basin of northeast India. In the Naga Patkai hill ranges the tertiary sediments are affected by numbers of major faults and thrust constitute the belt of schuppen. There is northeasterly plunging mega anticline called Nampong anticline in the western part of the Tirap District where Disang Group occupies a vast area at the core due to folding and faulting. During upper Eocene, ophiolites emplacement along the margin of the Indian plate is closely linked with the genetic history of the schuppen belt. During middle Eocene, collision of Indian plate with the Tibetan and central Burmese plates took place and as a result strong compressional forces were generated and Assam-Arakan Basin came into existence. In this basin, the flysch type of sediments of Disang Group was deposited in a shallow but rapidly sinking basin during Eocene period. The sub-flysch Barail sediments were accumulated in this basin under coastal to fluvio-deltaic basin set-up in Oligocene age.[10] In Plio-Pleistocene due to continuing thrust of the Asian and Burmese plates compressional force acted from two directions, one from north and the other from southeast. As a result of southeast directional compressional force the development of Naga Schuppen belt was taking place. Southwest directional forces also acted from the Mishimi Hills which resulted in the development of Mana Bhum Anticline and Roing Fault against which the block lying to the east was up-thrusted. These forces, possibly, also refolded the structure in the Naga Patkai ranges from northeast-southwest to assume northwest-southeast trend along with the Mishmi thrust. On the basis of structural elements the Naga-Patkai Ranges are subdivided in to two zone belts, viz., the Schuppen belt and the Kohima Patkai synnclinorium.[11] The Disang thrust is the dividing line between these two structural zone, the area lying to its southeast forms Patkai Synclinorium, here the rocks of the Disang, Barail Groups and post-Barail sediments have been folded into a number of north-easterly plunging folds which swerve to east-west and then to northwest northwest-southeast trend. Of these the folds, the Patkai anticline exposes the Disang Group of rocks which occupy large area of Tirap Valley.

Materials and Method

For Rock-Eval Approximately 100 mg of crushed rock was taken and placed into the Rock-Eval instrument. During the analysis, the sample was first heated to 300°C for three minutes in an inert atmosphere (helium). During this period the ‘free hydrocarbons’ were thermally desorbed from the sample. The abundance of free hydrocarbons was measured using a flame ionisation detector (FID) and recorded as the S1 peak in units of mg HC g rock^{-1}. The sample was then pyrolysed by increasing the temperature of the furnace from 300 to 550°C or 600°C at the rate of 25°Cmin^{-1}. The amount of hydrocarbons (pyrolysate) generated during this period was measured using a FID and reported as the S2 peak. The Tmax was measured in °C at which the maximum rate of pyrolysate generation occurs.

Result and Discussion

TOC % analyzed for study 47 representative samples from Deomali-Khonsa-Longding road section and a part of Tissa river section. The result of Rock-Eval data is given in Table 2**.** Results shows TOC value ranging between 0.17-1.26% for the samples collected from Tissa river section and 0.13-1.52% for the samples collected from road section. Nine Samples from river section symbolized as DS1, DS17, DS18, DS26, DS27, DS30, DS32, DS33 and DS44 and three samples from Khonsa-Longding road section

Table 1. Stratigraphic succession covering Tirap district, Arunachal Pradesh (after Jhanwar *et al.* 1999).

Group (Age)	Formation	Lithology
Recent	Alluvium	Loose sand, pebbles and boulders of sandstone and gneissic rocks, clay and silt
……………………………….unconformity……………………………………….		
Dihing Group (Plio-Pleistocene)	Dihing Formation (+3500 m)	Boulder of sandstone, gneisses, schist and basic rocks set in sandy and clay matrix ,Bluish grey, medium to coarse, gritty sandstone with sandy clay lenses
	Namsang Formation	Bluish to green, loose, unconsolidated sand beds with pebbles of quartzite and lignite fragments, carbonized and silicified wood
……………………………….unconformity……………………………………….		
Tipam group (Mio-Pliocene)	Girujan Formation (+ 1250 m)	Mottled, grey, bluish grey clays with greenish Sandstone beds and chert nodules
	Tipam Formation (+1500 m)	Bluish to green, medium to coarse, friable to well indurated sandstone intercalated with mottled clay, grit and conglomerate beds
Barail group (Oligocene)	Tikak parbat Formation (+1000 m)	white to grey , sandy clay- shale intercalated with brown, argillious sandstone and coal seams in the basal part
	Baragoloi Formation (+2000 m)	Grey to brownish red, thickly bedded, micaceous to argillaceous sandstone with pellets, Carbonaceous shale and coal stringers/lenses
	Naogaon Formation (+2250 m)	Grey hard flaggy thin bedded sandstone with intercalation of dark grey splintery shale and sandy shale
……………………………….unconformity……………………………………….		
Disang group (Eocene-Oligocene)	Disang Formation (+3500 m)	Dark grey to black splintery shale interbedded with fine to medium , gray, flaggy to massive sandstone and siltstone
……………………………….unconformity……………………………………….		
Metamorphic (Precambrian)		quartz-mica schist, quartzties, slate

Table 2. Result of Rock-Eval pyrolysis and TOC for the studied shale from Disang Group.

Sl no	Sample ID	Oil S1 (mg/g rock)	S2 (mg/g rock)	Tmax (0C)	TOC (%)	HI (mg/g TOC)	PI (S1/S1+S2)
1	DS1	0.07	0.23	499	0.5	46	0.23
2	DS2	0.11	0.17	499	0.38	44	0.39
3	DS3	0.02	0.06	510	0.22	27	0.25
4	DS7	0.1	0.2	500	0.49	40	0.33
5	DS8	0.02	0.04	447	0.17	23	0.33
6	DS11	0.03	0.1	567	0.27	37	0.23
7	DS13	0.04	0.02	437	0.21	9	0.66
8	DS16	0	0.01	419	0.27	3	0
9	DS17	0.03	0.23	559	0.5	46	0.12
10	DS18	0	0.03	532	0.54	55	0
11	DS19	0	0.01	448	0.28	3	0
12	DS20	0.02	0.13	533	0.47	28	0.13
13	DS26	0	0.06	558	0.59	10	0
14	DS27	0	0.02	502	0.52	3	0
15	DS30	0	0.29	538	1.26	23	0
16	DS32	0	0.08	525	0.5	16	0
17	DS33	0	0.1	529	0.52	19	0
18	DS34	0	0.02	463	0.29	6	0
19	DS35	0	0.02	448	0.33	6	0
20	DS36	0	0.13	505	.	*	0
21	DS39	0	0.09	514	0.35	25	0
22	DS40	0	0.02	441	0.34	5	0
23	DS44	0	0.11	530	0.54	20	0
24	KS1	0	0	***	0.21	0	-
25	KS2	0	0.04	544	0.3	10	-
26	KS5	0	0.01	482	0.37	2	-
27	KS7	0	0	***	0.22	0	-
28	KS10	0	0	***	0.24	0	-
29	KS11	0	0	***	0.23	0	-
30	KS12	0	0	***	0.13	0	-
31	KS13	0.02	0.07	491	0.46	15	1.07
33	KS17	0	0	***	0.2	0	-
34	KS18	0	0	***	0.13	0	-
35	KS19	0	0	***	0.15	0	-
36	KT4	0	0.03	584	1.12	0	-
37	KT5	0	0.04	587	1.52	0	-
38	KT17	0	0.02	471	0.38	0	-

39	KT22	0	0.02		0.65	0	-
40	KT30	0	0.01		0.19	0	-
41	KT44	0	0	354	0.14	7	-
42	KT54	0	0	475	0.29	3	-
43	KT55	0	0	532	0.3	20	-
44	KT62	0	0.02	532	0.28	7	-
45	KT63	0	0.11	498	0.4	27	-
46	TL1	0	0		0.44	0	-
47	TL10	0	0		0.21	0	-

symbolized as KT4, KT5 and KT22 having TOC % above the threshold 0.5 % (0.5-1.52%).Those samples having less than 0.5% TOC content is considered as poor source rating and those fall in between the 0.5-1% their source rating is considering as fair such as DS1, DS17, DS18, DS26, DS27, DS32, DS33, DS44 and KT22. Three samples (DS30, KT4 and KT5) having more than 1% TOC content and are considered as good source potential of hydrocarbon (Table 2). The Cross plot of TOC Vs S2 (Fig. 3) [12] has been used in the present study to interpret the Rock-Eval data; it shows that the samples are fall within the type-III field and this type of organic matter generally gas prone. Where S2 peak is a measure of pyrolyzable organic matter and is a better indicator of hydrocarbon potential of rock. Tmax is the temperature at which the S2 (mg/g rock) peak reaches its maximum amount of hydrocarbon generation during Rock-Eval pyrolysis.[13-14] According to Peters[4], Tmax depend on the type of organic matter from which they are derived, he also suggested that PI values less than about 0.08 and Tmax <430°C, indicate immature organic matter, whereas Tmax > 470°C points to the wet gas zone. Tmax is a good maturity indicator between 420 and 460^0C in type-II kerogen and between 400 and 600°C in terrestrially derived Type-III Kerogen.[14] The Tmax value increases with increasing maturation of organic matter. The low Tmax value indicates that the organic matter has not generated a substantial amount of hydrocarbon. The Tmax values ranging between 354-587°C and 419-567°C for the shale samples collected from road section and river section respectively (Table 2). Few samples such as DS8, DS13, DS34, DS35 and DS40 from river section showing Tmax value in between 435 -465°C and these can be considered as mature. Sample coded as DS16 having Tmax value 416°C falls in the range of 430-435°C and can be considered as immature, rest studied shale overcome the value 465°C. These samples contain over mature organic matter. KT44 samples from road section falls in the immature stage with Tmax value 354°C and rest of the samples fall in over mature stage. Jones and Dumaison[15] recognized four kerogen type and their productivity based on different range of HI and OI. HI (2-55 mg/g TOC) values in the studied shale samples shows that samples are of Type-III and Type-IV kerogen and indicate their productivity towards gas. Espitalie *et al.*[17] and Delvaux *et al.*[18] used HI Vs Tmax (Fig. 4A & B) cross plot to infer the organic matter type. Considering both the plots it has been observed that organic matter present in the rocks are type-III and therefore the shale samples under study are having probability of gas rather than oil. The PI values 0.12-1.07 for the studied shale samples pointed towards mature to over mature organic matter content. The plot of Production index (PI) Vs Tmax (Fig. 5)[18] is used to assess thermal maturity of the sample under study conversely in the study area. The overall maturity trend in the study area shows that most of the studied samples are over mature and they can produce only dry gas where as one samples showing his productivity towards wet gas and three other samples from river section

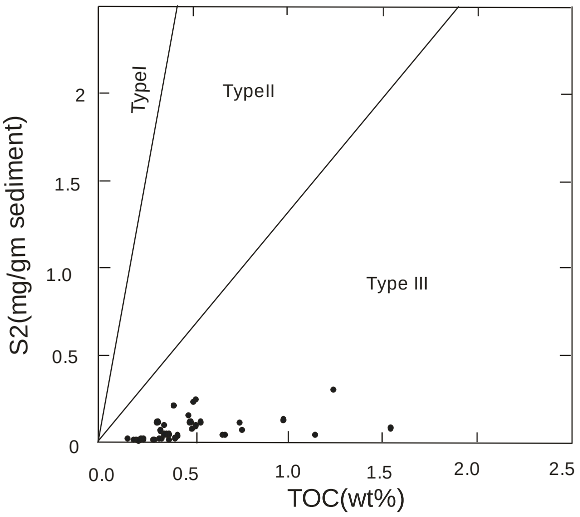

Figure 3. S2 Vs Total organic carbon (TOC) For Type-i,ii,iii, Kerogen. Fields are taken from Lengford and Blanc-Valleron (1990).

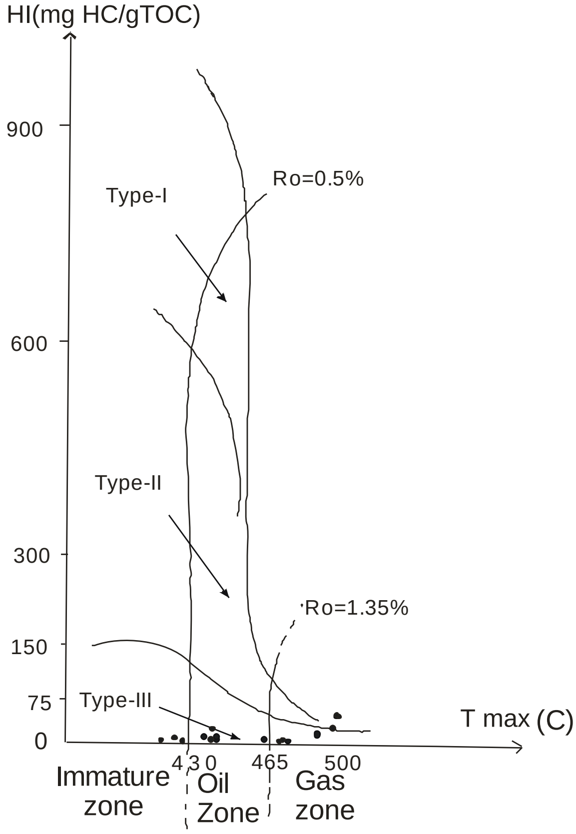

Figure 4A. Estimation of organic matter type and degree of maturation for shale of Disang Group

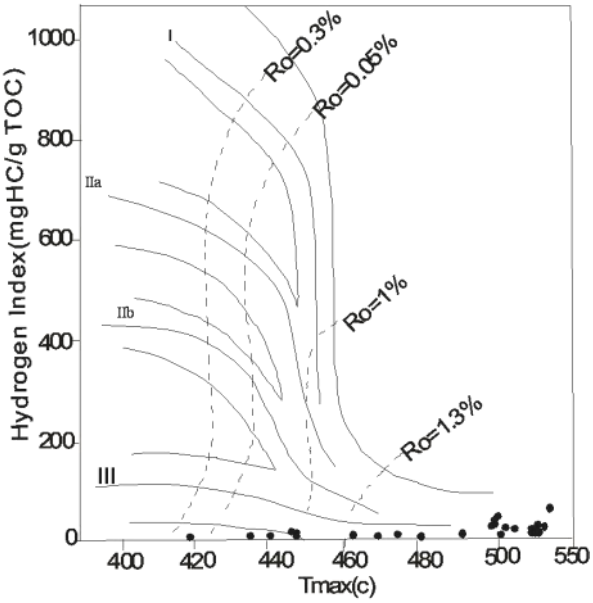

Figure 4B. Hydrocarbon Index (HI) Vs T-max diagram for shale of Disang Group under study (Field After Devaux *et al.,* 1990).

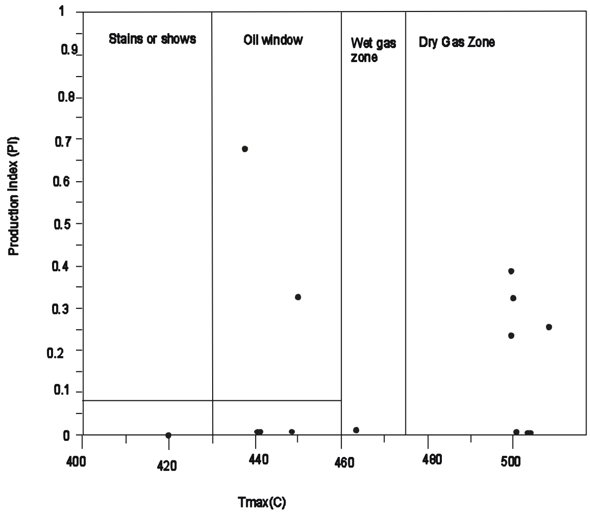

Figure 5. Maturation potential of the studied shale of Disang Group based on Rock-Eval pyrolysis data Tmax and PI (after Ghori and Haines, 2007).

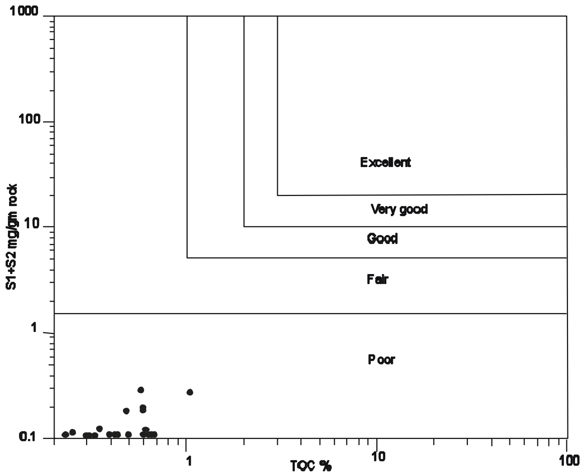

Figure 6. Petroleum-generating potential of shale of Disang Group (after Ghori and Haines, 2007).

are in the oil window stage. (S1+S2) Vs TOC (Fig. 6)[18] is used to define the generation potential of the studied rock units and the result shows that hydrocarbon generation potential of the shale samples under study is poor. Here S1 represents the fraction of original kerogen in the source rock that has been converted to hydrocarbons.

Conclusions

S_2 values of shale samples are found to be low. Also their overall TOC value is low. As such they indicate poor oil source-rock potential.

From Tmax values, it is found that organic matters present in the shale samples are over matured and they represent Type-III and Type-IV kerogen. PI value suggest mature to over mature organic matter.

The S_2 values obtained are, in general, very low indicating poor hydrocarbon potential. This observation is also supported by HI values.

Consideration of HI values along with Tmax values shows that shale of Disang Group contains organic matter of the Kerogen Type-III and Type-IV and majority of the samples fall in the gas zone.

Taking into consideration the high maturation of the organic matter along with their high Tmax values, low TOC and low S2 values, also considering the different plots adopted; it can be inferred that the oil source-rock potential of shale of Disang Group in the study areas is very poor. However, Plots of PI Vs Tmax pointed towards dry gas proclivity of studied shale.

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