CHAPTER – VIII

SUMMARY AND CONCLUSION

The present study area covers the central part of the Tirap district of Arunachal Pradesh, India and it forms the northeastern extension of the Naga-Patkai Hills. The Paleogene and Neogene rocks are well exposed in this area. The present work is mainly confined to the Disang Group of rocks well exposed between Hukanjuri, Khonsa and Longding area of Tirap district. The Tertiary rock units are intensely folded and thrusted by several thrusts i.e. Disang Thrust, Margherita Thrust and Naga Thrust. The Disang Thrust separates Disang Group and Lower Barail Group of rocks from the imbricately thrusted and folded Barails and post-Barail rocks to the west of it. The present study is based on field investigation, sampling, petrography, geochemistry, clay mineralogy to decipher provenance and tectonic settings of the study area and to evaluate the source rock characteristics by studying disperse organic matters and Rock-Eval pyrolysis data of the Disang Group of rocks.

The Chapter–I and II include the background information of the area under study, previous geological work, objective of the present work and various methodologies used in the study. This shows present status of knowledge and information about the area and the need of further scientific investigation particularly to understand tectono-sedimentation history of the area which is still poorly understood.
The Chapter–III deals with the regional geological setting, the stratigraphic succession and the geological set up of the study area.

Chapter–IV deals with the clay mineralogy of the shale samples of Disang Group by using analytical techniques such as XRD, IR and DTA.

Chapter–V deals with the sedimentological studies, which involve extensive research on rock sequences which begins with lithofacies analysis, petrographical and mineralogical investigation and to study the tectono-provenance based on detrital modes.

Chapter–VI deals with the geochemistry of the sandstone and shale of the study area to understand source area lithology, tectonic settings, weathering intensity and palaeo-climatic imprints.

Chapter–VII incorporates all the findings and interpretation on source characteristics of the shale samples based on Rock-Eval pyrolysis and dispersed organic matter study.

Chapter–VIII incorporates the summary and conclusion which are made based on the interpretation of the data generated.

Reference cited pertaining to the Tirap district of Arunachal Pradesh including the present works is listed for the reader to extend his/her query beyond the stretch of the present area.
The present study is confined to the lithosequence of the Disang Group exposed between Hukanjuri-Khunsa-Longding area of Tirap district, Arunachal Pradesh. The conclusion drawn upon tectono-sedimentation history pertaining to Disang Group of Eocene age are broadly summarised below.

The main focus is around the unmetamorphosed lithounit of the upper part of the Disang Group, which occupy wide tract from Naga-Patkai Hill ranges to the border area of Indo-Myanmar. The structural disposition of the rock unit of Disang Group is very vital in the context of the evolution history of the basin within the framework of Indian Plate convergence with the Burmese Plate.

Divergent opinion exists among the geoscientist regarding the stratigraphic relationship, sedimentation history, provenance and configuration of depositional basin of the Disang Group of rocks occurring in the Naga-Patkai Hill ranges. It is not yet clear from the previous works how and where from the vast quantities of fine clastics with arenaceous sediments could have come into the Disang basin. It is therefore necessary to visualize some kind of separate source area of suitable composition that might have supplied the huge thickness of finer clastics during Disang time. Keeping in this problem in mind the present study has been taken up in an integrated manner to re-evaluate the existing concepts on the provenance, paleo-depositional setup, tectono-sedimentation history of Disang Group of rocks exposed in the area under study.

To achieve the objective of the present research work the following study have been made in an integrated manner to generate some significant information on
the Disang Group of rocks exposed in road, river and nala sections of Hukanjuri-Khonsa-Longding area of Tirap district, Arunachal Pradesh. The study comprises mainly four expects which include sedimentology, clay mineralogy, geochemistry and source rock analysis.

Study of clay mineralogy of the shale samples reveals the presence of different types of clay mineral species and their qualitative distribution in different sections of the study area. XRD data indicate the abundance of illite, kaolinite than chlorite and montmorillonite/mixed layer clay or hydro mica in the samples. Montmorillonite which is detected in the samples seems to be illite/smectite mix layer type as pure smectite peak 17 Å is not observed. Illite is favored by alkaline environment and presence of kaolinite indicates non acidic condition (Grim 1951). Chlorite remains unstable under a moderate chemical environment. Presence of kaolinite indicates strong leaching and removal of Ca, Mg, Na, K and Fe ions and addition of hydroxyl ion. The distribution of the clay mineral species in different parts of the study area indicates that kaolinite and illite content is comparatively more than the montmorillonite and chlorite. As a whole the distribution of clay in the samples shows that illite is proportionally more than the kaolinite and chlorite. This may suggest that clay minerals of shales of Disang Group might have undergone a mesogenetic stage of diagenesis during burial processes.

Infra red spectra show the vibrational band in the range of 4000-200 cm\(^{-1}\) for the shale samples. Within the range two different strong broad bands occur in the region of 900-1200 cm\(^{-1}\) and 3200-3525 cm\(^{-1}\). The sharp doublet at or near 3590-3630
cm\(^{-1}\) and by a low intensity broad band in the region of 1575-1800 cm\(^{-1}\) shows the presence of kaolinite. The broad bands in the region of 900-1200 cm\(^{-1}\) and 3200-3525 cm\(^{-1}\) also indicate the presence of montmorillonite in the samples. The fairly broad and some time sharp band near 325-490 cm\(^{-1}\) indicate the presence of kaolinite, illite and montmorillonite (smectite) or fairly broad band in this region indicate the presence or clay mineral mixture. Illite and chlorite shows its existence by the occurrence of 750 cm\(^{-1}\) doublet and absorption band within 600-650 cm\(^{-1}\) in the IR spectra. Weak broad band in the in vicinity of 1440 cm\(^{-1}\) and 2800-2955 cm\(^{-1}\) is due to the presence of some impurities and KBr disc used as a “matrix” respectively.

The results of DTA curve of the clay mineral of Disang Shale indicate different characteristics of endothermic and exothermic peak positions in most of the thermograms. The endothermic peak near 80\(^{\circ}\)C represents the elimination of water and gases adsorbed on the powder surface, the exothermic transitions 300\(^{\circ}\) and 400 \(^{\circ}\)C with maximum peak between 350\(^{\circ}\)-360\(^{\circ}\)C may ascribed to the organic material associated with the samples. The prominent endothermic peak in the range of 500\(^{\circ}\)C to 580\(^{\circ}\)C with maximum peak near 570\(^{\circ}\)C is assigned to kaolinite; this peak is the result of decomposition of clay mineral and the elimination of water. Presence of chlorite is shown by the endothermic peak near 600\(^{\circ}\)C. DTA curves exhibit the development of endothermic peak between 500\(^{\circ}\)-580\(^{\circ}\)C and also show initiation of endothermic reaction started at or near 900\(^{\circ}\)C which favor the presence of illite,
though the exothermic peak above $900^\circ$C is missing. The occurrence of endothermic peak between $620^\circ$-$710^\circ$C indicates the presence of montmorillonite clay in the shale samples. The endothermic peak $800^\circ$-$900^\circ$C indicates the presence of carbonate in some studied shale samples. The absence of the endothermic peak in between $100^\circ$-$150^\circ$C shows the influence of organic matter present in the samples; due to which the peak in the region is missing in the DTA curve.

The results of XRD, IR and DTA reveal the presence of kaolinite, illite, chlorite and montmorillonite and some mix layer clay in the shale samples with the presence of carbonate in minor amounts. The Kaolinite, montmorillonite/smectite, illite, chlorite and micas may be present in the samples sedimentary rocks; also illite, chlorite and mica are common in low and medium grade metamorphic rocks (Boggs, 1992). Kaolinite is the product of chemical weathering of feldspar rich source area and illite is the predominant component of marine shales than non-marine shales (Keith and Degens, 1959). The Illite, chlorite and montmorillonite may be derived from the preexisting metamorphic and sedimentary rocks. Illite may also partly came from the digenetic alteration product of primary clays. Montmorillonite recorded in the samples possibly indicates the mafic volcanic source rocks and may form on diagenesis of illite. The presence of montmorillonite/ smectite in samples suggests temperate to subtropical climates, whereas illite/ hydro mica type indicating humid temperate climate, kaolinite indicate semi-arid to tropical climate (Einsele, 1992).
Chlorite in the samples may be coming from metamorphic source area and indicate a
cold or arid climatic condition.

For litho facies analysis field data collected from the outcrop section is
carefully organized and examined. The facies analysis reveals that the exposed
sections of the upper parts of Disang Group of the study area comprises of three to
four lithofacies association. These lithofacies association exhibit some meaningful
geological aspects of the lithounits.

The light to dark grey/black colour massive shale facies is regionally
extensive across the study area. This facies consists predominantly of massive
shales, which are light grey to dark grey in colour. A thin patch of silt/siltstones
within the shale bodies is also recorded in some places. The sand to shale ratio varies
between 1: 6 to 2:7

The light to dark grey thin laminated shale facies is common in the study
area. Shales are finely laminated and are severely jointed; these joints break the
shales into splintery blocks in the road section. Sand to shale ratio varies between 2:6
to 2.5:7.

The massive to thin bedded sandstone facies is recorded throughout the study
area with varying thickness. This facies is moderately sorted, very fine to medium
grained, structureless and massive appearance. Sand to shale ratio varies between 5:1
to 6:2.
The shale with interbedded sandstone/siltstone facies characterised by the massive to finely laminated shales having alternating thin bands of fine grained hard massive sandstone sandstones and finely laminated siltstone. The sand to shale ratio varies between 2:4 to 2.5:6.

The general concept about the shallowing of the basin with the increase in sand to shale ratio is not well defined in the study area. The lower section shows sand to shale ratio 1:3 to 1:6. The upper sections of the study area shows light to dark grey/black colour massive shale facies, light to dark grey thin laminated shale facies, Massive to thin bedded sandstone facies and shale with interbedded sandstone/siltstone facies with sand to shale ratio 1:4.3 to 1:5.4.

The predominance of fine argillaceous clastics with subordinate proportion of sandy unit in the Disang Group, the presence of various sedimentary features such as mesoscopic to small scale turbiditic graded sandstone, ball and pillow structure, flute marks suggest that the deposition of sediments took place by suspension, traction and saltation modes under low to high flow regime by low density turbidity current.

Petrographic study of the sandstone of the Disang Group shows that detrital modes of the sandstone comprised predominantly of nonundulatory monocrystalline quartz than the polycrystalline quartz, feldspar content in low plagioclase (varies between 0.75-1.75%) with lack of K-feldspar and considerable amount of sedimentary and metasedimentary lithic fragments with few volcanic rock fragments. Both detrital and diagenetic types of chert are observed, which are considered as sedimentary lithic. Radiolarian chert is also recorded in few samples.
The matrix content varies between 15.58-22.95% which make up the intergranular space of the framework grain of sandstone resulting in wacke texture. Muscovite is more dominant in proportion than biotite and shows kink bending microstructure due to compaction and deformation of the sediments. The relative percentages of quartz, feldspar and rock fragments are 83.81%, 1.68% and 14.51% respectively.

The sandstones are nomenclatured as sublithic arenites based on quartz (Q), feldspar (F) and rock fragments (L) (Folk, 1980) and the sandstones of Disang Group are lithic greywacke in nature owing to the matrix content greater than 15%.

The removal of labile component during transportation might have removed particularly volcano clastics which may have transformed to pseudomatrix during diagenesis. Diagenesis in sandstone is shown by the bending of the mica flakes, fracture of feldspar and rock fragments and flowage of unstable lithic grains, genesis of the clayey matrix, marginal corrosion of quartz grains by matrix and cement, and filling of fracture feldspar. The phyllomorphic stage of diagenesis with some small scale pressure solution feature is recognized. Point contact of quartz grain sand partial replacement of quartz by calcite cement also the result of diagenesis.

Result of heavy mineral analysis reveals that opaque minerals are the dominant in samples with concentration ranging between 42.50-59.09% followed by rutile (11.36-22.39%), tourmaline (7.79-16.42%), zircon (5.68-13.43%). Garnet (0-9.21%), epidote (0-7.89%), chlorite (0-5%), hornblende (0-4.5%) and hypersthene (0-2.74%). The ZTR value ranging between 69.44-97.22% (average 81.98%) for the
studied sandstone indicates that studied sandstones of Disang Group are mineralogically moderately mature.

The presence of mono crystalline quartz grin in samples indicates derivation from igneous rocks, whereas the dominance of non undulatory monocrystalline quartz with subordinate amount of polycrystalline quartz pointed towards the derivation of sediments from igneous as well as metamorphic source terrains. The plots of Diamond diagram following Basu et al. (1975) and Tortosa et al. (1991) indicate that the sediments of Disang were derived from middle to high grade metamorphic source rock. Q-F-R ternary plot of the detrital modes reveals that the sediments were derived from plutonic terrain (Basu et al., 1975) and the process of weathering and alteration have been taken place in humid climate (Suttner et al., 1981). Derivation of quartz grains from middle to upper grade metamorphic rocks.

Plot of Q-F-L following Dickinson (1985) shows recycled orogen source and Qm-F-Lt diagram indicate towards the transitional recycled orogen suites. Sandstones of recycled orogen are characterized by abundance of quartz and sedimentary-metasedimentary lithic fragments. Source regions of recycled orogens are created by upfolding or upfaulting of sedimentary or metasedimentary terrains, and are deposited in the associated basin mainly result from the collision of continental blocks (Boggs, 1992) and are commonly feldspar poor. The Qp-Lv-Ls diagram of Dickinson and Suczek (1979) suggest collision orogen source and Lv-Ls-Lm plot of Dickinson and Suczek (1979) indicate that the sediments are derived from collision suture and fold thrust belt area. This Collision orogens are composed
of recycled sedimentary materials, intermediate quartz contents and contain an
abundance of sedimentary-metasedimentary rock fragments. Higher amount of chert
contents may be derived from melange terrains caught along the suture belts

Heavy mineral assemblages in the sandstone suggest acidic and basic
igneous, metamorphic source terrain as probable source, sedimentary recycling is
shown by the roundness of the gain. The presence of zircon, tourmaline and rutile
indicate an acid igneous of metamorphic rock as source. Epidote occurs in crystalline
limestone and schistose rocks of metamorphic origin. The presence of chlorite,
hornblende, epidote and garnets may have been derived from low to medium-grade
metamorphic terrain. The presence of hypersthenes indicates the possibility of the
source rock being basic igneous rocks.

Geochemical study of major oxide elements in the studied sandstone reveals
some significant interrelationships among the constituents. Harker diagram shows
positive and negative correlation of different oxide elements with SiO₂ which shows
significant ‘r’ values. The sandstone of Disang Group classified as subgreywacke or
low rank greywacke following the parameters as suggested by Blatt et al. (1972);
Pettijohn et al. (1972); Potter (1978) and Herron (1988). This wacke nature of
sandstone is also supported by the Log (Na₂O/K₂O) vs. Log (SiO₂/Al₂O₃) plot of
Crook (1974).

Bhatia (1983) defined four different tectonic setting such as oceanic island
core, continental island core, active continental margin and passive margin following
the parameters Fe₂O₃ + MgO, TiO₂, Al₂O₃/SiO₂, K₂O/Na₂O and Al₂O₃/(CaO +
Na$_2$O) and it has been observed that the plots are controlled by Fe$_2$O$_3$+MgO content, K$_2$O/Na$_2$O and Al$_2$O$_3$/SiO$_2$ ratio. In the Fe$_2$O$_3$+MgO vs. K$_2$O/Na$_2$O plot nearly 36% samples fall outside the predefined fields, whereas 6% samples suggest continental island arc, 40% suggest active continental and 12% indicate towards the passive margin tectonic set up. 6% sample fall in the common field of C (active continental margin) and D (passive margin). In Fe$_2$O$_3$+MgO vs. Al$_2$O$_3$/SiO$_2$ plot 12% samples suggest continental island arc field. TiO$_2$ vs. Fe$_2$O$_3$+MgO plot failed to give clear picture regarding tectonic setting. On the other hand in Fe$_2$O$_3$+MgO vs. Al$_2$O$_3$/(CaO+Na$_2$O) 26% samples suggest continental island arc, while 20% samples suggest oceanic island arc set up. Rest of the samples falls outside the predefined field as defined by Bhatia (1983). In K$_2$O/Na$_2$O vs. SiO$_2$ plot of Roser and Korsch (1986) 100% samples indicates towards the active continental margin tectonic set up, whereas SiO$_2$/Al$_2$O$_3$ vs. Log K$_2$O/Na$_2$O plot 26% samples indicates passive margin tectonic set up while 74% samples suggest active continental margin tectonic set up during deposition of Disang sediments. Present analysis shows that the K$_2$O/Na$_2$O ratio is varying between 0.53-1.39, where 60% samples having K$_2$O/Na$_2$O value less than 1, which indicates that sediments were derived from tectonically active region.

From the comparison of discrimination diagram adopted form the Bhatia (1983) and Roser and Korsch (1986) it has been observed that there exists an active continental margin tectonic set up at the time of deposition of Disang sediments.
The discrimination function plot of F2 vs. F1 of Roser and Korsch (1988), suggest sediments were mainly derived from mafic igneous province with subordinate contribution from intermediate igneous region. The plot of TiO$_2$ vs. Al$_2$O$_3$ following Amajor (1987) shows that sediments of Disang Group were derived from granitic to mixed granitic basaltic or intermediate sources rocks. The Log K$_2$O/Na$_2$O vs. Fe$_2$O$_3$+MgO plot of Roser and Korsch (1988) most of the samples clustered in the field of recycling orogenic source which is demarcated by a line joining andesite, dacite, rhyolite and granite.

Geochemical study of shale samples involves determination of major oxide elements and trace and REE. Some trace and REE helps to infer the provenance more accurately than major oxides elements due to their low mobility. Harker diagram shows the relationship of oxide elements with SiO$_2$ which shows the genetic relationship among the oxide elements. The average chemical composition of shale of Disang Group is compared with PAAS to show the composition variation.

Bhatia (1983) discrimination plot for tectonic settings indicate towards the oceanic island arc settings during the deposition of shale sediments. The 80% samples fall in the oceanic island arc field in Fe$_2$O$_3$+MgO vs. TiO$_2$ plot and nearly 45% in Fe$_2$O$_3$+MgO vs. Al$_2$O$_3$/SiO$_2$. In Fe$_2$O$_3$+MgO vs. K$_2$O/Na$_2$O and Fe$_2$O$_3$+MgO vs. Al$_2$O$_3$/CaO+Na$_2$O plots all the samples fall outside the predefined field. In K$_2$O/Na$_2$O vs. SiO$_2$ and SiO$_2$/Al$_2$O$_3$ vs. Log K$_2$O/Na$_2$O plots of Roser and Korsch (1986), 75% and 90% samples respectively suggest active continental margin tectonic setup, while 18% samples indicate towards the oceanic island arc and 7%
passive margin tectonic set up in K₂O/Na₂O vs. SiO₂ plot and 6% samples suggest evolved arc setting and 4% passive margin tectonic set up in SiO₂/Al₂O₃ vs. Log K₂O/Na₂O plot.

Comparison of Bhatia (1983) and Roser and Korsch (1986) discrimination diagram shows two main tectonic settings i.e. oceanic island arc and active continental margin set up exists at the time of deposition of Disang sediments.

The Al₂O₃/TiO₂ ratio varies between 9.55-54.90 (average 21.54), which suggest intermediate to felsic granitoid rocks as source rocks. The TiO₂ vs. Al₂O₃ plot of Amajor (1987) shows that these sediments were derived from granitic to mixed granitic basaltic rocks sources. Plot of discrimination function F1 against F2 shows major contribution from mafic igneous province with minor contribution from intermediate igneous province (after Roser and Korsch, 1988). The mafic source is also supported by the less abundance of Ba/Sc (10.11-24.21 ppm, average 14.34 ppm) and Ba/Co (8.29-19.56 ppm, average 12.51 ppm) ratios than PASS (Ba/Sc=40.62 and Ba/Co=28.26) samples. The comparison of the average value of the ratio of La/Sc (0.79), Th/Sc (0.79), Th/Co (0.67), Th/Cr (0.07) and Cr/Th (16.43) of shale samples with felsic and basic rocks as well as to Upper Continental Crust (UCC) and PAAS values indicate felsic source rock. The higher content of Cr (average 213.38 ppm) over PASS value (Cr>110) and Ni (average 108.63 ppm) and the positive correlation of Cr with Ni (r = 0.374) may be related to mafic source rock. The Cr/Ni (average 2.02) ratio varies from 1.41 to 4.8 (average 2.02) indicate mixed provenance of felsic and mafic rocks while average value is close to PAAS
(Cr/Ni =2) indicate towards felsic rock as source. High Cr/Zr (average 1.09) than PASS (0.5238) indicates towards mafic source, whereas Y/Ni vs. Cr/V and K2O vs. Rb scatter plot indicate towards intermediate source. Slightly LREE enriched and flat HREE pattern with negative Eu anomaly with higher LREE/HREE ratio (10.85) and high ratio of (LaN/YbN = 14.25-21.63) suggest derivation of sediments from felsic source, also the average value of (Gd/Yb)N (2.73) for the present study is close to average value of Granitoids (2.30).

The sediments of Disang Group might have undergone sediment recycling prior to the deposition. In Th/Sc vs. Zr/Sc plot samples follow the zircon addition trend and thus indicating sediment recycling The Th/U (2.6 to13.16, average of 9.72) and Zr/Sc ratio (7.85-11.53, average 11.35) ratios and Th/U vs. Th plot also indicate that the sediment of Disang Group passes through recycling.

The sediments of Disang Group were deposited in marine environment which is shown by the plot of K2O/Al2O3 and MgO/Al2O3 (Roaldest, 1978). While the bivariant plot of SiO2 vs. Al2O3+K2O+Na2O proposed by Suttner and Dutta (1986) indicates that the semi-arid climatic conditions prevailed at the time of deposition. The low U/Th ratio (0.08 to 0.13) and V/Cr (0.06-1.07) ratios indicate that shales sediments were deposited in an oxic environment. Whereas Ni/Co (2.57-7.67) ratio indicates towards the anoxic to oxygenated condition. The Ni/Co ratio below 5 indicates oxic environments, whereas ratios above 5 suggest suboxic and anoxic environments (Jones and Manning, 1994). The CIA (51.23-72.99) and CIW (60.11-83.52) favor moderate weathering in the source areas whereas the CIA (65.3-92.08)
and CIW (81.03-94.17) of shale samples indicate the presence of clay and intense chemical weathering in the source area. The considerable weathering and alteration is also shown by triangular plot of $\text{Al}_2\text{O}_3-(\text{CaO+Na}_2\text{O})-\text{K}_2\text{O}$. The higher Rb/ Sr ratio than average Upper Continental Crust (0.32), the average Post-Archean Australian Shale (0.80) indicates significant weathering in the source area. The plot of $\text{SiO}_2$ vs. $\text{Al}_2\text{O}_3+\text{K}_2\text{O}+\text{Na}_2\text{O}$ shows semi arid climatic condition (Suttner and Dutta, 1986), while the ternary plot Q-F-RF shows humid climatic condition (Suttner et al., 1981). Presence of P-feldspar in the samples suggests rapid deposition in humid climatic condition.

Organic matters recorded in shale samples are classified black debris/charcoal, structured terrestrial (wood/cuticle), biodegraded organic matter, spores/pollen, amorphous organic matter, fungal remains and structured marine (phytoplankton) following Masron and Pocock (1981) classification scheme. Apart from these two fungal spores *Frasnacritetur* sp. and *Alternaria* sp. are identified in the shale samples.

The average concentration of organic matters in shale samples of Disang Group (Humic and Sapropelic) are compared with the organic matter measured in a well of Bangal basin and found near shore shallow marine depositional environment for the shale samples. In the Tyson, (1995) ternaries plot of Phytoclasts-AOM-Palynomorphs majority of the samples fall within the marginal dysoxic-anoxic basin with two samples indicate highly proximal shelf or basin and one samples pointed towards the hetrolithic oxic shelf (proximal shelf). Abundant of black debris (54.05-
92%) in samples indicates aerobic source area. The presence of structured terrestrial with high percentages of opaque black debris/charcoal indicates low sedimentation rate and oxidation of organic particles or terrestrial sources. The presence of yellowish to grey colour amorphous organic matter in shale samples indicates reducing conditions and increase water column resulting in dysoxic or anoxic bottom conditions. The presence of Frasnacritetritus Sp. and Alternaria sp. indicates tropical to subtropical, warm-humid climate at the time of deposition.

To evaluate the oil potential of shale of Disang Group different perimeters such as TOC, Tmax, HI and PI are used in different plots to find out the type of organic matter, their itch to produce hydrocarbon and potential. The organic matter in shale samples are of Type-III and Type-IV kerogen as indicated by HI vs. Tmax and TOC vs. S2 plots and are prone to produce gas rather than oil. The presence of Type-IV Kerogen in shale samples is supported by the presence of higher percentages of black debris. Low S2 (0-0.23 mg/g rock) values in shale samples indicate that these samples can produce only gas. The Tmax values for the shale sample collected from road and shale section ranging between 354°-587°C and 419°-567°C respectively. The samples DS-16 and KT-44 considered as immature as Tmax value 416°C and 354°C respectively which indicate their potentiality towards oil generation, but low S1(0-0.11 mg/g) and S2 (0-0.23 mg/g rock) concentration do not support to generate oil from them. The other samples contain over mature organic matter in them as shown by the Tmax value (more than 465°C). The PI
values for the shale samples ranging between 0-0.66 pointed towards mature to over mature organic matter. The plot of Production Index (PI) vs. Tmax shows that the most of the samples fall in the over mature field with one sample in dry gas field, one sample in wet gas field and three samples from river section fall in the oil window field. Plot of (S1+S2) vs. TOC shows that the hydrocarbon generation potential of shale samples is poor in the study area.

The mineral matrix present in the shale samples can influence the pyrolysis behavior of organic matter and their presence in sample causes reduction in S1, S2 peak and increase in Tmax values which mislead in correct identification of correct organic matter. Low organic matter concentration in samples shows poor TOC. Excessive presence of siderite as mineral matrix causes carbonate decomposition before 390°C therefore poor organic matter type and wrong source proclivity would be inferred. Therefore detail study of organic matter is necessary along with Rock-Eval analysis to evaluate to oil shale property.

**Conclusions:**

From the above findings of the following inferences have been drawn:

- The distribution of the clay mineral species in different sections of the Disang Succession indicates that kaolinite and illite content is comparatively more than the montmorillonite and chlorite.

- The lithofacies analysis reveals that the lithosequence of Disang Group of the study area comprises of three to four lithofacies association i.e. light to dark
grey/black colour massive shale, light to dark grey thin laminated shale facies, massive to thin bedded sandstone facies and shale with interbedded sandstone/siltstone facies and represents distal to mid fan turbidite sequence of channel facies, levee and mud rich facies.

- The sandstones are nomenclatured as sublithic arenites to lithic greywacke. The low content of feldspar, abundance of sedimentary to metasedimentary lithics and pseudomatrix, presence of volcanic rock fragments and radiolarian chert grains suggest that the detritus were possibly derived from subduction complexes in recycled orogenic set up.

- Heavy mineral assemblages of stable and unstable variety of heavy mineral suggest acidic and basic igneous, and metamorphic source terrain as probable source. Mineralogically the sandstone of the Disang Group are moderately mature, as indicated by ZTR index.

- The geochemical composition of sandstone and shale samples indicate some consistency in major oxides, trace elements and REE distribution. Average major elemental composition of Disang sediments is constant with the average composition of Post-Archean Australian Shale (Taylor and McLennan, 1985). There is a similarity in major oxide concentration of sandstone and shale of Disang Group in respect of SiO₂, Al₂O₃ and Fe₂O₃. From chemical point of view sandstones are classified as are sub-greywacke or low rank greywacke. The shale area enriched with Sc, Cr, Ni, V, Zn, Nb,
Pb and Rb/Sr and depleted in Ba and Co in comparison to Post-Archean Australian shale (PAAS). The ratio of trace elements in shale indicate felsic and basic source rock derived from upper continental crust. The Cr/Zr value is higher than the PASS indicating derivation of sediments from mafic source. The binary plots of major oxides and the distribution diagram of tectonic setting of both sandstone and shale suggest mainly two tectonic setup active continental margin and oceanic island arc. It also suggests that the sediments of Disang Group deposited in marine environment under oxic to anoxic conditions. The shales exhibit slight LREE enriched and relatively flat HREE pattern with low negative Eu anomaly in REE plots. These plots indicate the derivation of the shale from felsic source rock. Higher values of CIA and CIW shows significant weathering at the source area when climatic condition was humid.

- In the regional context of the evaluation of the Indo-Myanmar mobile belt the findings of the present study support the conclusion that the Disang sediments were deposited in shallow marine basin in collision suture zone related to active continental margin-oceanic island arc setting. Having identified the provenance as mix rocks of recycled orogen with detritus were possibly derived from the uplifted fold thrust belt of Burmese (Myanmar) landmass comprising of igneous and metamorphic basement complex with older sedimentary sequences and some contributions of detritus from Mishmi Hills region lying to the NE part of the study area cannot be ruled out. Finally
a postulated paleotectonic and depositional set up of the Disang basin has been put forwarded to portray the subduction-collision features associated with the basin formation.

- The types and distribution of dispersed organic matters in Disang shales indicate a near shore shallow marine basin set up with dysoxic-anoxic conditions and the presence of Frasnacritetrs Sp. and Alternaria sp. suggest tropical to subtropical, warm-humid climatic condition during Disang sedimentation.

- The Rock-Eval data suggest that the Disang shale contains Type-III and Type-IV organic matter which are prone to produce gas rather than oil.