JOURNAL INDIAN ASSOCIATION OF SEDIMENTOLOGISTS ISSN NO 2582 – 2020
Vol. 38, Issue 1, 2021, pp. 5-12
DOI: https://doi.org/10.51710/jias.v38i1.18

Tectonic Setting and Provenance of Eocene Sandstones of Disang Group, Tirap District, Arunachal Pradesh

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Abstract

The petrographic study of sandstone belonging to Disang Group of Eocene age shows that quartz and rock fragments are the main constituents among the framework grains. Feldspar percentage is low whereas plagioclase feldspar is dominant with the rare occurrence of K-feldspar. XRF-analysis reveals that SiO_2, AI_2O_3, Fe_2O_3, MnO, TiO_2, Na_2O, K_2O, CaO, MgO and P_2O_5 are the major and minor elements. SiO_2 constitutes the major proportion of the oxides in the sediments. The study reveals that the provenance of these sandstones is mainly the igneous and metamorphic rocks, and the tectonic setting was an active continental margin. The presence of higher content of chert and mafic rock fragments points towards the ophiolite zone as a provenance. Detritus were possibly derived from the uplifted fold thrust belt of the Myanmar's landmass with subordinate contribution from the Mishmi Hills region lying to the northeast of the study area.

Keywords: *Disang Group, plagioclase feldspar, ophiolite zone, geochemistry, provenance*

Introduction

Disang Group occupies a vast area in the Tissa and Tirap valleys. It is a thick sequence of splintery shales interbedded with sandstone and siltstone, extensively developed from the southern part to Nampong in the northeast. The present study area is confined to a part of the Tissa river section and Deomali-Khonsa road section bounded by latitude $27^{O}0^{/}$N-$27^{O}10^{/}$N and longitudes $95^{O}20^{/}$-$95^{O}30^{/}$ E (Fig.1A & Fig.1B). The Disang Group of rocks outcrop along the Khonsa-Longding and Wakka road sections of Tirap District, Arunachal Pradesh. They continue south westwards into Nagaland where they are subdivided into Lower Disang and Upper Disang formations (Sinha and Chatterjee, 1982). Apart from these, Disang Group

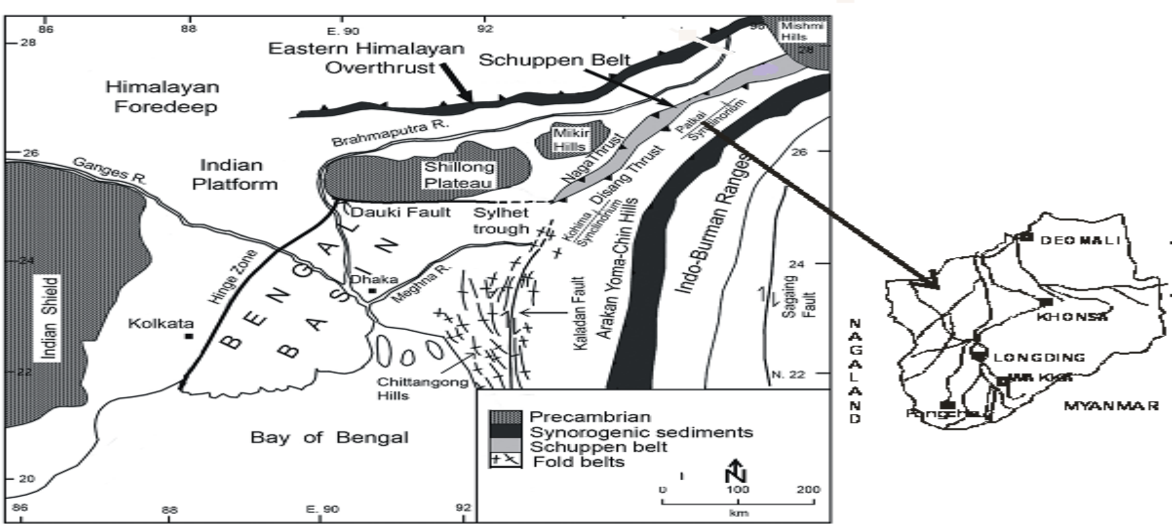

Fig.1A: Map showing the tectonic elements such as the eastern Himalaya and Indo-Burman Ranges. Samples were collected from the south eastern part of Schuppen. (after Hutchison, 1989).

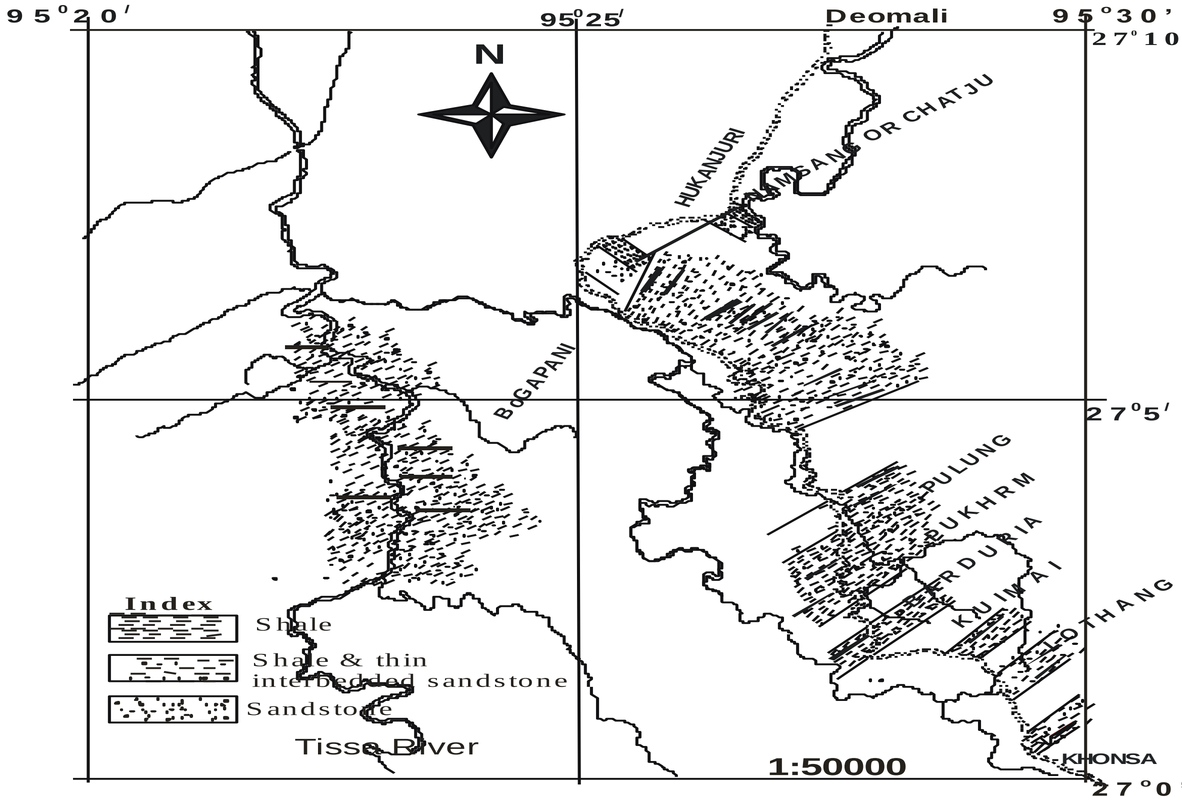

Fig.1B: Location map showing Sampling position in Tissa river section, Tirap District, Arunachal Pradesh

also occupies large areas in Changlang District of Arunachal Pradesh, Nagaland, Manipur states and in a small portion of the North Cachar Hills (Singh et al., 2008; Singh et al., 2017). The Disang Group of rocks exposed in the study area is represented by rhythmic alteration of shale, sandstone and siltstone. The sandstones are fine to medium grained and light grey in colour. The objective of the present study is to infer the provenance and tectonic setting of the sandstones based on petrography and major oxides study.

Geological setup

During the middle Eocene, collision of Indian plate with the Tibetan and central Burmese plates resulted in strong compressional forces from which the Assam-Arakan basin was formed. In this basin, the flysch type of sediments of Disang Group was deposited in a shallow but rapidly sinking basin during the Eocene period (Nandi, 2001). Kumar (2004) reported that the Disang sediments were deposited in deep marine environment close to an arc-trench system during the Eocene. The sub-flysch Barail sediments were accumulated in this basin under the coastal to fluvio-deltaic environmental set-up during Oligocene (Sinha and Chatterjee, 1982). During the Plio-Pleistocene periods due to continuing thrusting of the Asian and Burmese plates, compressional forces acted from two directions, one from the north and the other from the southeast. As a result of this southeast directional compressional force the development of the Naga-Schuppen belt took place. In the Naga Patkai hill ranges the Tertiary sediments were affected by number of major faults and thrusts which constitute the Schuppen belt. Southwest directional forces from the Mishmi Hills 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 NE-SW to assume NW-SE trend along with the Mishmi thrust. On the basis of structural elements the Naga-Patkai ranges are subdivided into two belts, viz., the Schuppen belt and the Kohima Patkai synclinorium (Mathur and Evans, 1964). The Disang thrust is the dividing line between these two structural belts, the area lying to its southeast forms Patkai Synclinorium, whereas 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 NW-SE trend. Of these folds, Patkai anticline exposes the Disang Group of rocks which occupy a large area of the Tirap and Tissa valleys.

Material and methods

Sandstone samples were collected from outcrops of the Tissa river section and Deomali-Khonsa road section. Major and minor geochemical elements were determined by using Philips PW 1480 sequential X-ray fluorescence spectrometer in Gauhati University, Assam. 1-2g of powdered samples (ASTM 250 mesh) were mixed with 0.5 g of grade E Merck boric acid (H_3BNO_3) and pressed in a steel mould under a pressure of 25 to 30 tons to make a pellet. A known sample of silicate rock was taken for reference. X40 software was used to calculate concentrations of oxides in weight percent. Thin-sections for the petrographic study were prepared in the Department of Dibrugarh University, Assam. Point counting of the sandstone thin sections was used for quantitative compositional analysis. The modal analysis was performed by counting more than 400 points per thin section, using the Gazzi–Dickinson point-counting method (Gazzi, 1966 in Dickinson, 1970). Crystals greater than 0.0625 mm within lithic fragments were counted as monocrystalline grains; this point counting method minimizes compositional dependence on grain size and, therefore, sandstones of different grain sizes can be compared (Ingersoll et al., 1984).

Results and Discussion

Petrography: Petrographic study reveals that sandstones under study are fine to medium grained and are moderately sorted. Framework grains constitute quartz (monocrystalline quartz and polycrystalline quartz), plagioclase feldspar and rock fragments. Among the framework grains, quartz dominates over feldspar and rock fragments. Sedimentary/metasedimentary types are the main rock fragments, followed by metamorphic lithic fragments. Volcanic fragments were identified in two studied thin sections. The feldspar percentage is low with rare potash feldspar. The result of the modal analysis is shown in (Table 1).

Quartz - Quartz is the dominant detrital framework grain in sandstone samples (54.66-66.14%; average 60.21%). Quartz grains are fine to medium grained, angular to subangular and subrounded. Elongate quartz grains are rarely observed. Grain to grain contacts are mainly concavo-convex, long and point. Monocrystalline quartz (Qm) dominate over polycrystalline quartz (Qp). The non-undulatory type monocrystalline quartz (Qnu) is more dominant than the undulatory one (Qu).

Feldspar - Feldspar percentages vary between 0.75-1.90 %, (average 1.21%). Sandstones consist mainly of plagioclase feldspar and with the rare occurrence of K-feldspar. The grains are sub-angular and sub-rounded in habit and show clear distorted grain boundaries. Some plagioclase feldspars show bending of twin lamellae, which may be the result of the pressure effect.

Rock fragments - The percentage of rock fragments varies between 4.57-8.6 % (average 6.68 %, excluding chert). Rock fragments are mainly sedimentary (Lc) with a subordinate amount of metamorphic rock fragments. Sedimentary rock fragments are mainly chert, shale and siltstone. Metamorphic lithics (Lm) include mainly mica schist and few grains of quartz mica aggregate. Radiolarian chert is also observed in few studied samples.

Matrix - Matrix percentage is ranging from 15.58 to 22.95% (average 18.49%). Matrix occurs as crushed lithic grains, small mosaics of quartz grains, and phyllosilicates (particularly sericite, pseudomatrix) and as epimatrix.

Cement - Cement percentage varies from 6.39 – 9.86% (average 7.65 %). The quartz grains are indurated by mainly argillaceous/carbonaceous cement with a subordinate amount of ferruginous cement.

Mica - Muscovite is more abundant than biotite. Diagenetic mica is also observed within the argillaceous matrix as a layer or lenses with diffused boundaries.

Miscellaneous - Some grains of rutile and tourmaline are observed in the sandstones under the microscope and few reddish coloured altered grains occur in the sandstones which are rather difficult to identify.

Geochemistry: Results of Major and minor elements of sandstones is shown in Table 2. The results show that SiO_2 (64.03-67.89 wt. %) constitute the major portion of the oxides followed by Al_2O_3 (11.21-13.33 wt %) and Fe_2O_3 (6.09- 8.88wt %). The MgO content ranges from 1.32-2.12 wt % whereas, CaO concentrations vary from 0.11-5.08 wt %. The K_2O and Na_2O concentrations range from 1.23-3.48 wt % and 2.26-2.79 wt % respectively. MnO, TiO_2 and P_2O_5 contents are in minor amounts and their concentrations are 0.03-0.42 wt %, 1.08-1.43 wt % and 0.52-0.66 wt % respectively. The range of chemical variations depends on the absolute amount of quartz and the chemically unstable grains. A low concentration of plagioclase is corroborated in the petrographic observation and is supported by the small amount of CaO and Na_2O; however, K_2O may be derived from mica minerals. TiO_2 values suggest that samples contain opaque minerals. High Al_2O_3 is due to the presence of clays and subordinate micas and Fe_2O_3 may be derived from the cementing materials present in the samples at the grain boundaries.

Sandstone classification

The sandstones of the Disang Group are classified following Dott (1964) by their matrix content. Modal analysis reveals that the sandstones under study contains a high percentage of matrix (average 18.40%) for which they are classified as lithic-wacke as per Dott's classification (Fig.2) and is supported by the plot of Log $Na_2O/K2O_3$ vs Log SiO_2/Al_2O_3 (Fig.3; Pettijohn, 1975). According to Folk's (1974) classification, the modal data plot in the sublitharenite field (Fig.4) while noting that our modal analysis followed the Gazzi-Dikinson method.

Provenance and Tectonic settings

Point counting parameters defined by Dickinson (1985*)*, Ingersol and Suczek (1979) and Dorsey (1988) were considered. The main assumption behind sandstone provenance studies is that different tectonic settings contain characteristic rock types which, when eroded, produce sandstones with specific compositional ranges (Dickinson, 1985*)*. Quartz is the dominant minerals in the present case, where non-undulatory is dominant over undulatory types. Undulatory extinction characterizes quartz derived from metamorphic source rocks; non-undulatory extinction indicates volcanic rocks or grains recycled from older sandstone (Basu, 1985). Polycrystalline grains composed of five or more crystals with straight to slightly curved inter-crystal

Table 1: Results of modal analysis of sandstone of Disang Group, Tirap District

Sample	Qm		Qp		F	Mica	chert	Rock fragments (L=Ls+Lv+Lm)	Matrix	Cement
	Undulatory (Qu)	Non undulatory (Qnu)	2 to 3	>3						
DS-1	6.27	30.47	8.42	9.50	1.08	1.79	5.38	8.60	18.64	9.86
DS-10	7.15	34.98	5.72	14.94	1.75	0.79	3.18	6.04	15.58	9.86
DS-16	5.95	32.92	7.71	9.11	0.88	1.40	6.13	8.06	19.61	8.23
DS-20	8.11	34.32	6.55	13.26	1.09	1.72	3.74	7.96	16.38	6.86
DS-29	7.54	35.79	5.61	12.98	1.40	1.23	4.56	5.79	17.37	7.72
KS-1	6.16	32.65	6.16	11.75	0.93	2.24	3.17	5.78	22.95	8.21
KS-5	8.25	32.99	5.77	11.75	1.44	1.03	3.92	7.63	20.82	6.39
KS-9	7.16	33.99	6.62	12.70	1.25	1.43	3.76	6.98	18.60	7.51
KS-17	7.96	31.65	7.59	13.38	1.63	1.81	3.07	7.41	17.36	8.14
KS-20	9.45	34.93	6.75	14.39	0.75	2.25	2.10	7.20	15.59	6.60
KS-29	7.74	33.23	6.37	15.33	0.91	1.37	3.34	5.31	18.66	7.74
KTL-1	9.50	28.50	6.04	12.44	1.90	1.04	4.32	7.77	21.59	6.91
KTL-5	7.02	30.53	6.67	14.21	0.88	1.75	3.16	8.25	18.95	8.60
KTL-12	8.03	33.86	8.03	16.22	1.26	0.94	2.99	4.57	15.59	8.50
KTL-16	9.55	31.77	6.77	13.89	1.56	1.39	3.99	6.25	17.36	7.47
KTL-25	6.15	30.92	7.54	16.77	0.92	1.23	5.85	6.31	17.85	6.46
KTL-38	7.55	31.56	7.03	14.75	1.54	0.86	4.12	4.97	20.93	6.69
KTL-41	6.17	31.49	7.63	16.40	0.81	1.79	2.92	6.82	19.32	6.66
KTL-54	7.11	31.58	7.97	17.21	1.14	1.42	2.99	5.26	18.21	7.11

Table 2: Major oxides (%) composition of studied sandstone of Disang Group

Sample no	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI
DS-1	65.34	11.45	6.48	0.22	1.67	4.74	2.68	3.48	1.39	0.57	2.21
DS-3	67.89	11.59	6.15	0.16	1.72	5.08	2.61	2.7	1.41	0.52	2.11
DS-10	66.26	12.34	8.88	0.22	1.32	0.11	2.65	2.48	1.2	0.54	4.21
DS-16	64.47	12.1	6.73	0.12	1.81	2.05	2.33	3.15	1.08	0.57	5.62
DS-20	65.64	11.78	6.58	0.22	1.67	1.74	2.34	2.48	1.32	0.61	6.22
DS-29	65.15	11.55	7.15	0.16	1.47	2.18	2.26	3.14	1.43	0.54	5.5
DS-43	66.46	13.33	6.85	0.03	1.31	0.21	2.42	2.48	1.26	0.66	4.81
KS-1	64.03	12.15	7.21	0.21	2.12	2.3	2.34	1.23	1.23	0.64	6.71
KS-5	65.47	11.99	8.43	0.33	1.34	1.25	2.53	1.64	1.35	0.57	5.96
KS-9	64.22	12.12	8.29	0.42	1.61	1.09	2.79	2.12	1.24	0.58	5.87
KS-13	65.23	12.34	7.68	0.32	1.42	0.11	2.45	2.34	1.26	0.59	7.31
KS-20	65.47	11.21	6.09	0.12	1.92	2.21	2.57	2.15	1.17	0.59	6.69

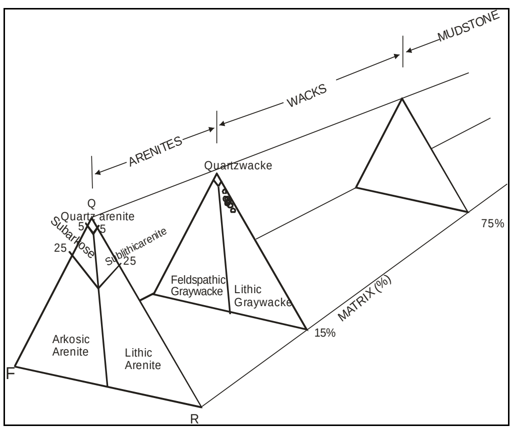

Fig. 2: Sandstone classification of Disang Group (Dott, 1964)

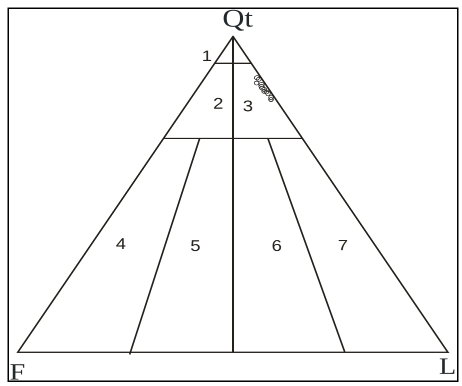

Fig.4: Triangular diagram shows minerlaogical classification of the studied sandstone of Disang Group (Folk, 1974). Where, Q: Total quartz; F: Feldspar; L: rock fragments 1. Quartz arenite; 2. Subarkose; 3. Sublitharenite; 4. Arkose; 5. Lithic arkose; 6. Feldspathic litharenite; 7. Litharenite

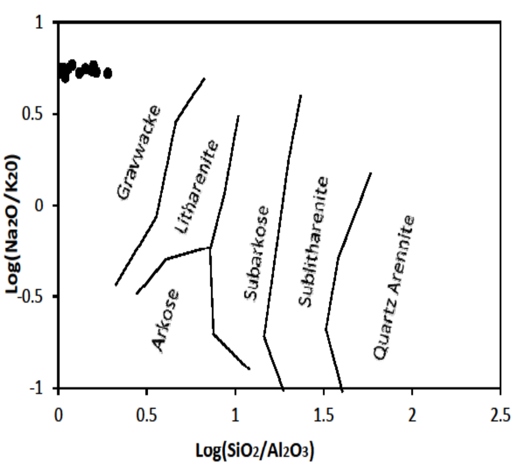

Fig.3: Chemical composition of sandstones plotted on Pettijohn scheme (after Pettijohn, 1975)

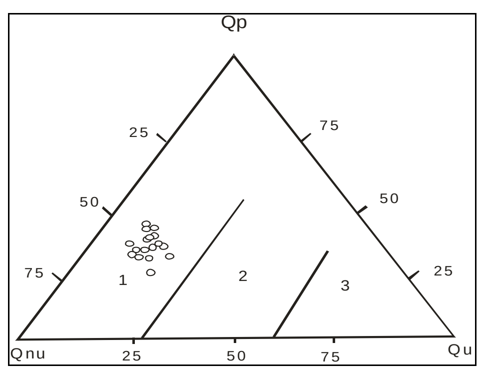

Fig.5: Ternary plot of detrital quartz types of the Disang Sandstone (after Basu et al., 1975). Open circles represent the studied samples; Qp = Quartz polycrystalline; Qnu = Quartz non-undulatory (monocrystalline); Qu=Quartz undulatory (monocrystalline).

boundaries have also been observed which suggests an origin from plutonic igneous rocks (Folk, 1974; Blatt et al., 1980). Plagioclase feldspar is of volcanic or hypabyssal origin (Pittman, 1963). The present investigation shows that the sandstones are abundant in quartz and, sedimentary and metasedimentary lithic fragment. This type of mixed character of lithic fragments is generally found in recycled orogenic sources. Source regions of recycled orogens are created by upfolding or upfaulting of sedimentary or metasedimentary terrains which mainly result from the collision of continental blocks (Boggs, 1992). Metamorphic rock fragments are present in all the studied thin sections suggesting contribution from metamorphic provenance as well.

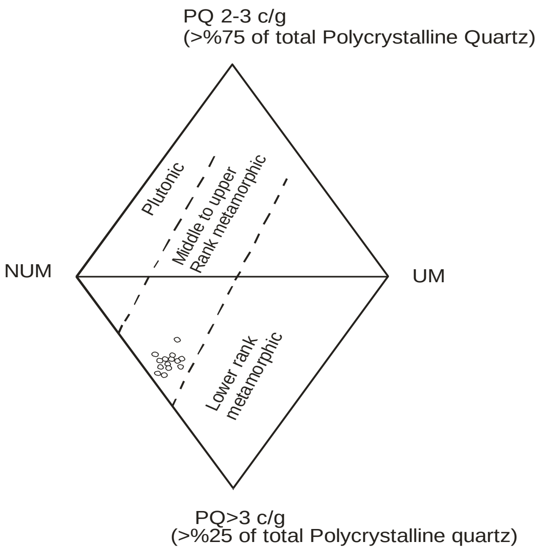

Fig. 6: Diamond diagram used to discriminate sands sourced by different types of crystalline rocks, on the basis of the extinction pattern and polycrystallinity of quartz grains of sandstone of Disang Group (after Basu et al., 1975)

The occurrence of mafic rock fragments and high chert content suggests their derivation from the ophiolite zone. A plot of Qp-Qnu-Qu (Fig.5; Basu et al., 1975), suggests that quartz grains of the studied sandstones are of plutonic origin whereas, the diamond plot shows that the sediments were derived from medium to high rank metamorphic source (Fig.6; Basu et al., 1975). In the Qt-F-L plot (L: Lv + Ls + Lm, Fig.7; Dickinson et al., 1983) samples are falling in the recycled orogen field whereas the Qm-F-Lt plot (Lt: L+ Qp, Fig.8; Dickinson and Suczek, 1979) shows that samples are dominantly from transitional recycled orogen; three samples fall in the recycled orogen field. A plot of Log K_2O/Na_2O versus Fe_2O_3+MgO also supports the recycled orogen source for the studied sandstone (Fig. 9). The discriminant functions of Roser and Korsch (1988) were used to discriminate between the four sedimentary provenance fields. In Fig. 10 (Roser and Korsch, 1988) majority of samples fall in the mafic igneous province field whereas four samples fall in the intermediate igneous field and one sample falls in the quartzose sedimentary province field. The discriminant diagram after Roser and Korsch (1988) shows that the sandstones are scattered in the P1 (mafic igneous provenance) and P4 (quartzose sedimentary provenance) field supports the interpretation that sandstones were derived from Quartzose sedimentary provenance and mafic igneous provenance (Fig. 11). Plot adopted from Amajor (1987) indicates towards the basaltic sources (Fig. 12). A plot of Qp-Lv-Ls suggests that the sandstones were derived from collision suture and fold thrust belts (Fig. 13). Active margin (fore arc, continental arc, back arc, strike slip) sediments are characterized by a mixture of arc derived material and old upper crustal sources, whereas passive margin sediments are generally dominated by old upper crustal sources (McLennan et al., 1990). K_2O/N_2O and SiO_2 are increasing from oceanic island arc to active continental margin to passive continental margin.

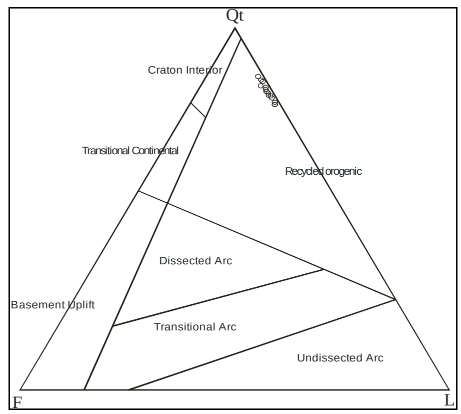

Fig.7: QtFL plot showing composition of studied sandstones of Disang Group. Provenance fields are from Dickinson (1985).

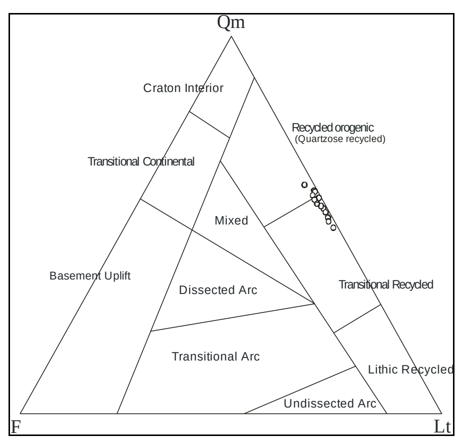

Fig.8: QmFLt plot for sandstones of Disang Group (Dickinson, 1985). Where Lt= Ls+Lv+Lm+ Qp+ Chert

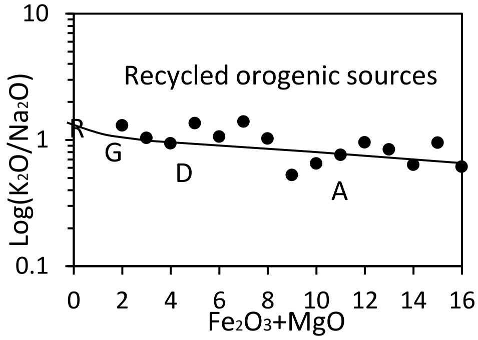

Fig. 9: Plot of K_2O/Na_2O versus Fe_2O_3+MgO. A, D, R and G Mean andesite, dacite, rhyolite and granite, respectively from developed for the Southern Welsh Basin, Edge (PM) of Continents. The Solid Line Connecting A, D, R and G is the Average Basalt. Samples above the line represent the Recycled Orogenic Sources (Roser and Korsch, 1988)

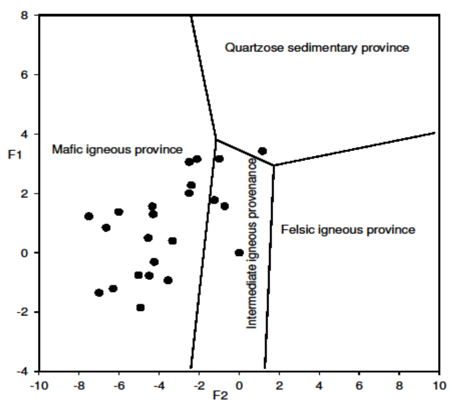

Fig. 10: Discrimination diagram for sedimentary provenance (Roser and Korsch, 1988), F1 and F2 are the Discriminating function.

F1=(56.50TiO_2-10.879Fe_2O_3+30.875MgO-5.404Na_2O +11.112K_2O)/Al_2O_3-3.89

F2=(30.638TiO_2-12.541Fe_2O_3+7.32MgO+12.031Na_2O +35.402K_2O)/ Al_2O_3-6.382

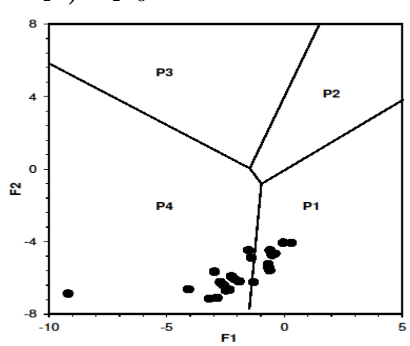

Fig. 11: Discrimination function diagram for the provenance signature of the sandstone using major elements (after Roser and Korsch, 1988)

DF1=(-1.773TiO_2+0.607Al_2O_3+0.760Fe_2O_3-1.5MgO+ 0.616 CaO +0.509Na_2O-1.224K_2O-9.190)

DF2=(-0.445TiO_2+0.070Al_2O_3+0.250Fe_2O_3-1.142MgO +0.438CaO+1.475Na_2O-1.426K_2O-6.861)

P-1: Mafic igneous provenance, P-2: Intermediate igneous provenance, P-3: Felsic igneous provenance, P-4: Quartzose sedimentary provenance

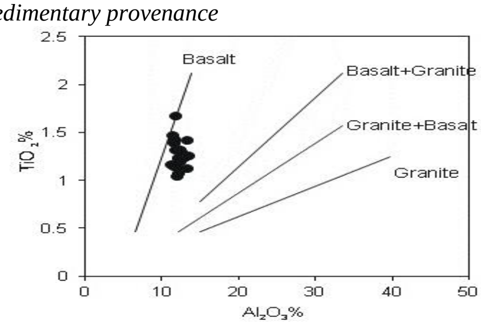

Fig.12: TiO_2 vs. Al_2O_3 binary plot (Amajor, 1987)

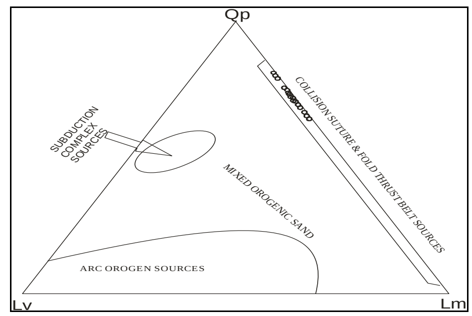

Fig.13: QpLvLs plots for framework modes of the studied sandstones showing different provenance fields after Dickinson and Suczek (1979)

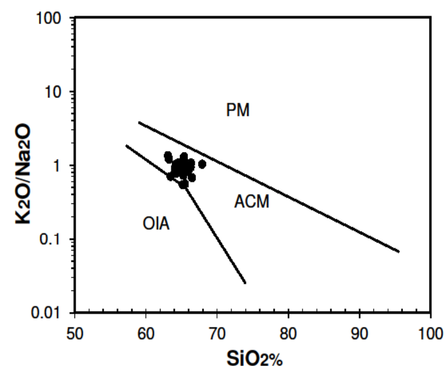

Fig. 14: K_2O/Na_2O Vs SiO_2 tectonic discrimination plot for the analyzed sandstone samples (after Roser and Korsch, 1986) OAI = Oceanic island arc; ACM=Active continental margin; PM=Passive margin

The ratio of K_2O/Na_2O Vs SiO_2 (Fig. 14) is used to discriminate the tectonic setting (Roser and Korsch, 1986). It is found that in K_2O/Na_2O Vs SiO_2 all the samples plot in the active continental margin field.

Conclusions

The results of this investigation show that sandstone of Disang Group under study can be classified as lithic wacke based on matrix content and mineralogically they are classified as sublithic arenites. Based on the integrated petrographical, major and minor elemental studies it can be concluded that these sediments were mainly derived from igneous and metamorphic sources in an active continental margin tectonic setup. The low content of feldspar, abundance of sedimentary and metasedimentary lithics and pseudomatrix, presence of volcanic rock fragments and radiolarian chert grains suggest that the detritus were possibly derived from subduction complexes in a recycled orogens. Detritus were possibly derived from the uplifted fold thrust belt of Myanmar's landmass comprising of igneous and metamorphic basement complex with older sedimentary sequences with minor contributions of detritus from Mishmi Hills region lying to the NE of the study area.

Acknowledgement

The authors are grateful to the authorities, to the laboratory attendant of the Department of Applied Geology; Dibrugarh University for assisting in laboratory work. Anonymous reviewers are thanked for constructive suggestion for improvement of the MS

References

Amajor, L. C. (1987). Major and trace elements geochemistry of albino and Touronian shale from the Southern Benue trough, Nigeria. *Journal of African Earth Science,* 6, 633-641.

Basu, A., Young, S.W., Suttner, L.J., James, W.C. and Mach, G.H. (1975). Reevaluation of the use of undulatory extinction and polycrystallinity in detrital quartz for provenance interpretation. *Journal of Sedimentary Petrology,* 45, 873-882.

Basu, A. (1985). Reading provenance from detrital quartz, G.G.ZUFFA (Ed.) *Provenance of Arenites*, 231-247.

Blatt, H., Middleton, G. and Murray, R. (1980). Origin of Sedimentary rocks, 2nd Ed. Prentice-Hall, New Jersey, 782.

Boggs, S. (1992). Sedimentary Petrology. Blackwell scientific Publications.

Dickinson, W. R. (1970). Interpreting detrital modes of greywacke and arkose. *Journal of Sedimentary Petrology,* 40, 695-707.

Dickinson, W. R. (1985). Interpreting provenance relations from detrital modes of sandstones. In: Zuffa, G. (Ed.), Provenance of Arenites. Reidel, Dordrecht, 333–361.

Dickinson, W. R. and Suczek, C. A. (1979). Plate tectonic and sandstone composition. Bulletin of *American Association of Petroleum Geology,* 63, 2164–2172.

Dickinson, W. R., Beard, L. S., Brakenridge, G. R., Erjavec, J. L., Ferguson, R. C., Inman, K. F., Knepp, R. A., Lindberg, F. A. and Ryberg, P. T. (1983). Provenance of North American Phanerozoic sandstone in relation to tectonic setting. *Geological Society of American Bulletin,* 94, 222–235.

Dorsey, R. J. (1988). Provenance evolution and unroofing history of a modern arc continent collision: Evidence from petrography of Plio-Pleistocene sandstones, eastern Taiwan. *Journal of Sedimentary Petrology,* 58, 208-218.

Dott, R. H. Jr. (1964). Wacke, greywacke and matrix – what approach to immature sandstone classification?. *Journal of Sedimentary Petrology,* 34, 625-632.

Folk, R. L. (1974). Petrology of Sedimentary Rocks: Austin, TX, Hemphill Press, second edition, 182.

Gazzi, P. (1966). Le arenarie del flysch sopracretaceo dell'Appennino modenese; correlazioni con il flysch di Monghidoro. *Mineralogicae Petrografica Acts*, 12, 69-97.

Hutchison, C. S. (1989). Geological Evolution of South East Asia. Oxford University Press, New York.

Ingersoll, R. V. and Suczek, C. A. (1979). Petrography and provenance of Neogene sand from Nicobar and Bengal fans. DSDP sites 211 and 218. *Journal of Sedimentary Petrology,* 49, 1217-1228.

Ingersoll, R. V., Bullard, T. F., Ford, R. L., Grimm, J. P., Pickle, J. D. and Sares, S. W. (1984). The effect of grain size on detrital modes: a test of the Gazzi-Dickinson point-counting method. *Journal of Sedimentary Petrology,* 46, 620–632.

Kumar, P. (2004). Provenance history of the Cenozoic sediments near Digboi-Margherita area, eastern syntaxis of the Himalayas, Assam, northeast India. Unpublished M.Sc. thesis. Auburn University, Auburn, 131.

Mathur, L. P. and Evans. P. (1964). Oil in India, International geological Congress Twenty- Second Session, India, 7-52.

McLennan, S. M., Taylor, S. R., McCulloch, M. T. and Maynard, J. B. (1990). Geochemical and Nd-Sr isotopic composition of deep-sea turbidities: Crustal evolution and plate tectonic associations. *Geochimica Cosmochimica Acta,* 54, 2015-2050.

Nandi, D. R. (2001). Geodynamics of Northeastern India and its adjoining rejoin. *Abstract Publication Kolkata,* 39-49.

Pettijohn, F. J. (1975). Sedimentary rocks, 3rd Ed.: New York, Harper & Row, 628.

Pittman, E. D. (1963). Use of zoned plagioclase as an indicator of provenance. In: Sand and Sandstone (cd. by Pettijohn, Potter and Siever, 1987). *Journal of Sedimentary Petrology*, 33, 380-386.

Roser, B. P. and Korsch, R. J. (1986). Determination of tectonic setting of sandstone-mudstone suites using SiO_2 content and K_2O/Na_2O ration. *Journal of Geology,* 94, 635-650.

Roser, B. P. and Korsch, R. J. (1988). Provenance signatures of sandstone-mudstone suits determined using discriminant function analysis of major element data. *Chemical Geology,* 79, 119.

Singh, Ch. G. and Kushwaha, R. A. S. (2008). Petrographic analysis of Tertiary Sediments between Imphal and Moreh, Manipur. *Journal of the Indian Association of Sedimentologists,* 27, 23-34.

Singh, Y. R., Singh, B.P. and Ranjeeta Devi, S. (2017). Source Rock Characterization, Diagenesis and Depositional Environment of the Upper Disang Formation from Gelmoul Area of Manipur, NE India. *Journal of the Indian Association of Sedimentologists,* 34, 1-7.

Sinha, N. K. and Chatterjee, B. P. (1982). Notes on the Disang Group in parts of Nagaland and its Fossil fauna. *Records of the Geological Survey of India,* 112 (4), 50-52.

(Received: 27 April 2018; Revised version Accepted: 31 May 2021)