Heavy Mineral Analysis and Provenance Studies of Surma Sediments in and Around Nungba, Tamenlong District, Manipur, Northeast India

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Abstract: **-A thick sedimentary succession belonging to Surma Group (Miocene) is well exposed along the road section (NH-37) in and around Nungba, Tamenglong district, Western Manipur. The Surma sediments have been analyzed for their heavy mineral suite following heavy liquid separation technique. The research result reveals the dominance of transparent varieties over the opaques. The diagnostic non-opaque variety includes Zircon, Tourmaline, Rutile, Garnet, Phlogopite, Sphene, Scapolite, Humite, Glauconite, Glaucophane, Wollastonite, Sillimanite, Staurolite, Chlorite, Chloritoid, Chondrodite and Hedenbergite. The heavy minerals suite is characterised by the presence Euhedral, Anhedral as well as Rounded to Sub-rounded varieties indicating a mixed provenance for the Surma sedimentation. Among the opaque variety iron-oxide is most abundant. The value for ZTR Index has been calculated to be 40.4 indicating a mineralogically an overall submature for Surma sediments.**

Keywords: **Heavy minerals, Provenance, Surma Group, Tamenlong district, Manipur, Northeast India.**

I. INTRODUCTION

The understanding of sediment provenance is a key element in establishing the lithological variability, palaeoclimatic conditions, tectonic activities and exhumation history of the source terrain. Determination of sediment provenance is mostly done through heavy mineral studies as heavy mineral suits provide important information on the mineralogical composition of source areas (Morton,A.C. 1987). Nevertheless, heavy minerals have proved to be an effective tool in classifying the sedimentary sequences into different litho-stratigraphic units, especially when the rock column is.devoid of body fossils, as in the case of so called geosynclinal facies of Assam Tertiary(Evans, 1932), a part of which forms the present area of investigation occupying the hill tracts in and around Nungba, Tamenlong District, Manipur. The pioneering works of Mallet (1876), Oldham (1883), Evans (1932, 1964) and Mathur & Evans(1964) are the only basis for any type of geological studies in the region. No detail published works are available concerning the subject matter in the Manipur region, except for Soibam (1998), Kushwaha. et al., (2008) and Singh et al., (2010) who have provided some information on the structure and tectonics of the region besides trace fossils.In addition, Srivastava *et al.*, (1973), Nandy (1983), Sengupta(1990), Srivastava and Pandey (1973), Srivastava (2004) provided valuable information on the regional geological frameworks including lithostratigraphic and sediment logical aspects of the neighbouring areas.

II. GEOLOGY OF THE STUDY AREA

Among the Cenozoic orogenic belts of Indian sub-continent, Himalaya is the one where stratigraphic record of collision has been studied in some detail following plate tectonic paradigm, relatively few hard data on the subject have been reported from the Assam – Arakan Orogenic Belt (also known as IBR) a collision orogen that links E–W Himalaya to the N–S Andaman-Nicobar island arc. The northern part of the IBR that extends for about 200 km along the eastern margin of Northeast Indian craton is popularly known as Naga Hills in Nagaland and the Manipur.Hills in Manipur. The Naga - Manipur Hills sector of IBR has been divided into three morphotectonic units; namely from west to east (1) Belt of Schuppen, (2) Inner Fold Belt, and (3) the Ophiolite Belt (Mathur and Evans, 1964). Further, Manipur Hills has been locally divided into three broad physiographic divisions, i.e. Manipur Eastern Hills, Manipur Western Hill and Central Manipur Valley. The structural and tectonic pattern of Manipur Hills is transitional between the NE-SW trending pattern of Naga-Patkai Hills and N-S trend of Mizoram and Chin Hills (Soibam, 1998). The general structural and lithological trend of the rock formations of the state is NNE-SSW. It frequently varies between N-S and NE-SW although sometimes NNW-SSE trends are locally common(Brunnschweiler 1974). The study area constitutes a part of the inner fold belt of the Assam-Arakan basin located south of Kohima Synclinorium in and around Nungba, western Manipur. It comprises spectacularly developed rock sequences belonging to Barail (Oligocene) and Surma(Miocene) Groups. It is bounded between latitudes 24°45′- 63.24°50′ N and the longitudes 93°20′- 93° 30′ E of the topographic sheet Nos. 83H/5,83H/6 & 83H/9 and covers nearly 60sq km. The NH-37 passes through the middle of the study area connecting Silchar (Cachar district, Assam), the nearest railhead and airport, to the SW and Imphal, the capital town of Manipur, to the SE (Fig.1). A simplified lithostratigraphic succession of the study area is given in Table. 1.

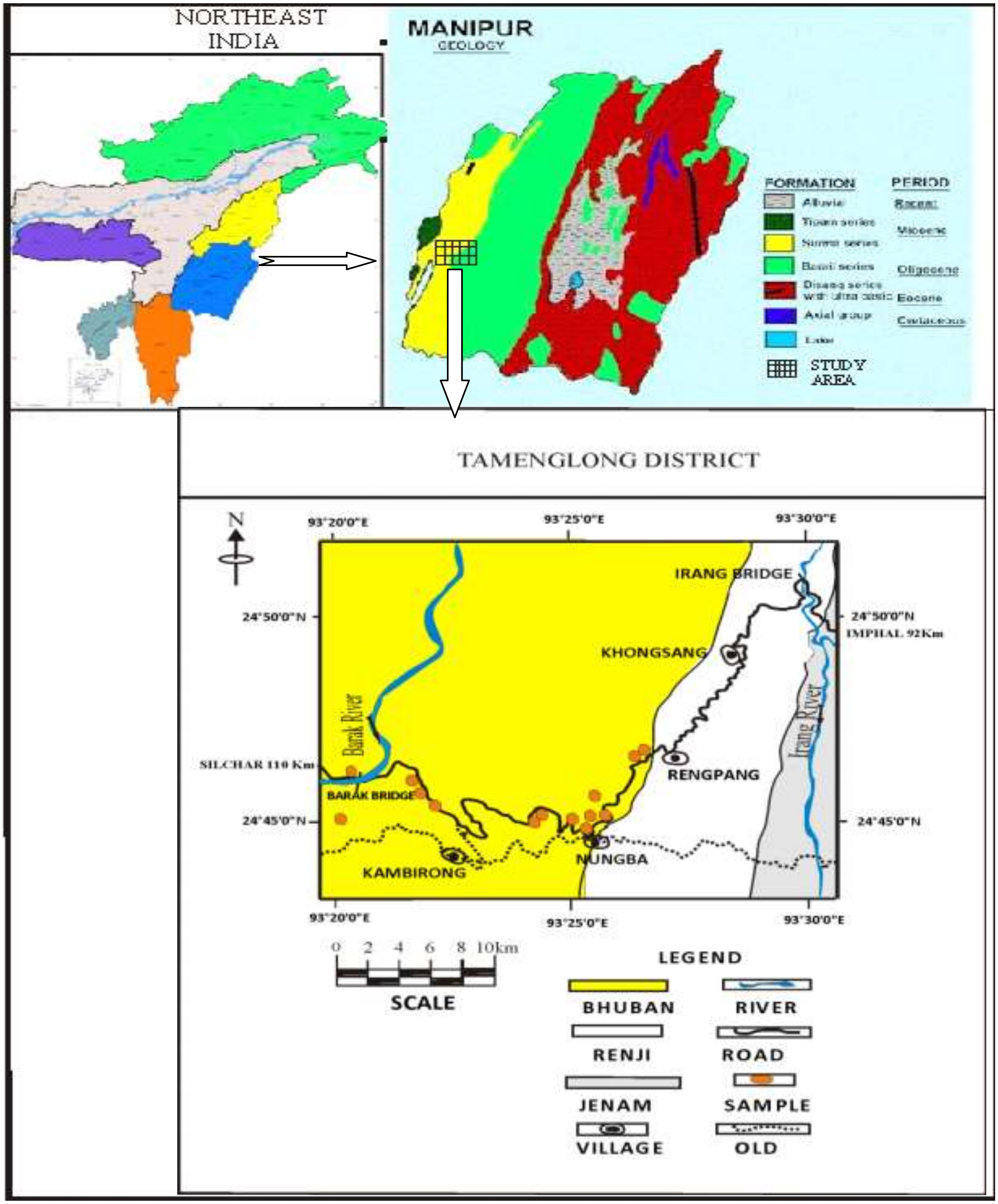


Figure.1. Location and geological map of the study area.

Table.1. A simplified lithostratigraphic succession of the study area (Modified afer Singh et al., 2010).

Group	Formation	Member	Lithology	Age
Tipam Gp.	Girujan Fm.	-	Molted clay, Sandy mottled clay and minor mottled sandstone	Miocene-Pliocene
	Tipam Fm.	-	False bedded medium to coarse-grained feldspathic ferruginous sandstone with occasional clayey layers	
Surma Gp.	BokaBil Fm.	-	Mainly argillaceous sediments with ferruginous sandstones, Siltstones, and shale.	Miocene
	Bhuban Fm.	Upper Bhuban	Medium bedded ferruginous sandstone and siltstone with minor sandy shale and occasional pebbly horizons	
		Middle Bhuban	Sandy shale, lenticular sandstone and occasional conglomeratic beds	
		Lower Bhuban	Light grey cross-bedded sandstone and lensoidal fossiliferous Khaki shale with conglomeratic horizon at the base and occasional intraformational clasts and coaly streaks	
Barail Gp.	Renji Fm.	-	Alternations of minor shale, Carbonaceous shale and ferruginous sandstones	Oligocene
	Jenam Fm.	-	Shale, sandy shale and carbonaceous shale.	
Base not exposed				

III. MATERIALS AND METHODS

Heavy minerals are high-density components of siliciclastic sediments. They comprise minerals that have specific gravities greater than the two main framework components of sands and sandstones, quartz (Sp. Gr. = 2.65) and feldspar(Sp. Gr. = 2.54 – 2.76). In practice, minerals with specific gravities greater than 2.8-2.9 are considered as heavy minerals, the limit of specific gravities being dependent on the density of the liquid used to separate them from the volumetrically more abundant light minerals. A total of 14 (forteen) fresh representative samples from Surma Group were analysed for the heavy minerals following the density separation method suggested by Folk (1980) and Middleton et al (2003). The following steps were employed:

1. Samples were cleaned, gently crushed and soaked with H_2O_2 for overnight and then boiled for about 5 minutes to complete disintegration and remove organic matter, if any.

2. Samples thus processed were then thoroughly washed with water and treated with N/10 HCl. After adding a pinch of $SnCl_2$, all the samples were boiled for 10-15 minutes so as to remove iron coatings, if any.

3. After cooling all the samples were thoroughly washed with water to remove the acid and then dried in the oven.

4. Nearly 2 to 2.5 gm of processed samples was poured in separating funnel containing bromoform and allowed to stand for about 10- 15 minutes so that heavy fraction of the sample could settle at the bottom of the separating funnel, i.e. just above the stopper.In order to release heavy minerals from the separating funnels the stopper was opened and closed intermittently for two to three times having a time interval of nearly 5 minutes in between. 5. Heavy minerals thus released were retained on a filter paper placed along with a funnel above the beaker which was lying just below the separating funnel to store the filtered bromoform for reuse.

6. Heavy minerals retained on filter papers were removed from the funnel, numbered and kept for drying overnight.

7. In order to prepare the grain mount, a pinch of heavy mineral residue was taken out of each dried filter paper with the help of non-sticking paper and then uniformly spread over the glass slide containing cooked Canada balsam.

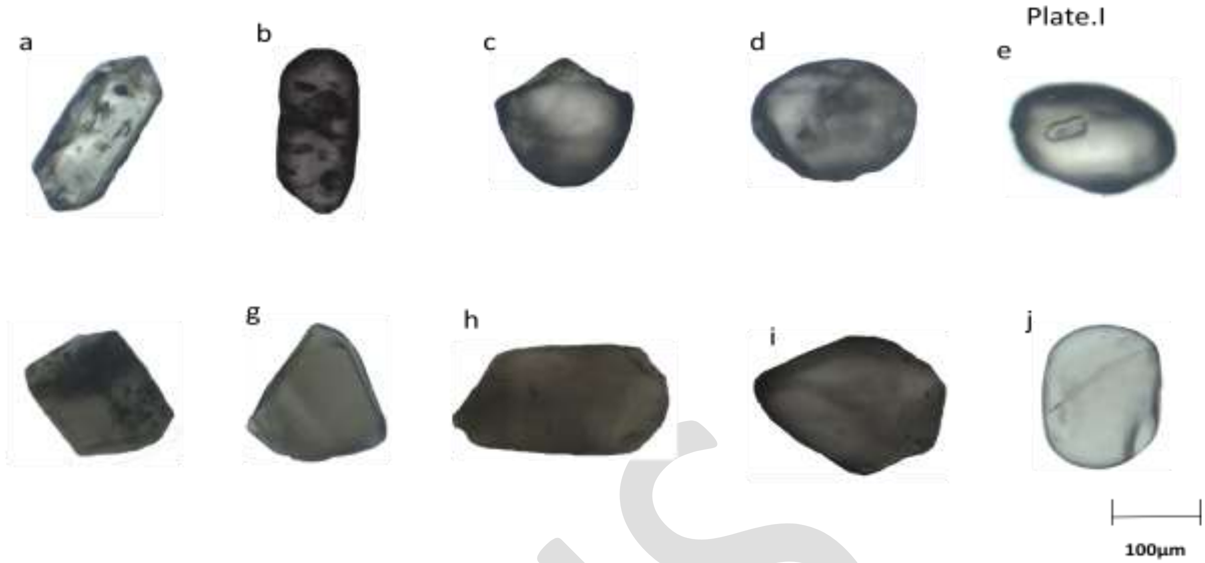
8. Glass cover slips were then placed above the grain area while gently heating the glass slide so as to remove the air bubble, if any, and allow the cover slip to set properly.

9. Grain mounts thus prepared were studied under the Leica Research Microscope at the Department of Earth Science, Assam 99.University, Silchar, Assam.

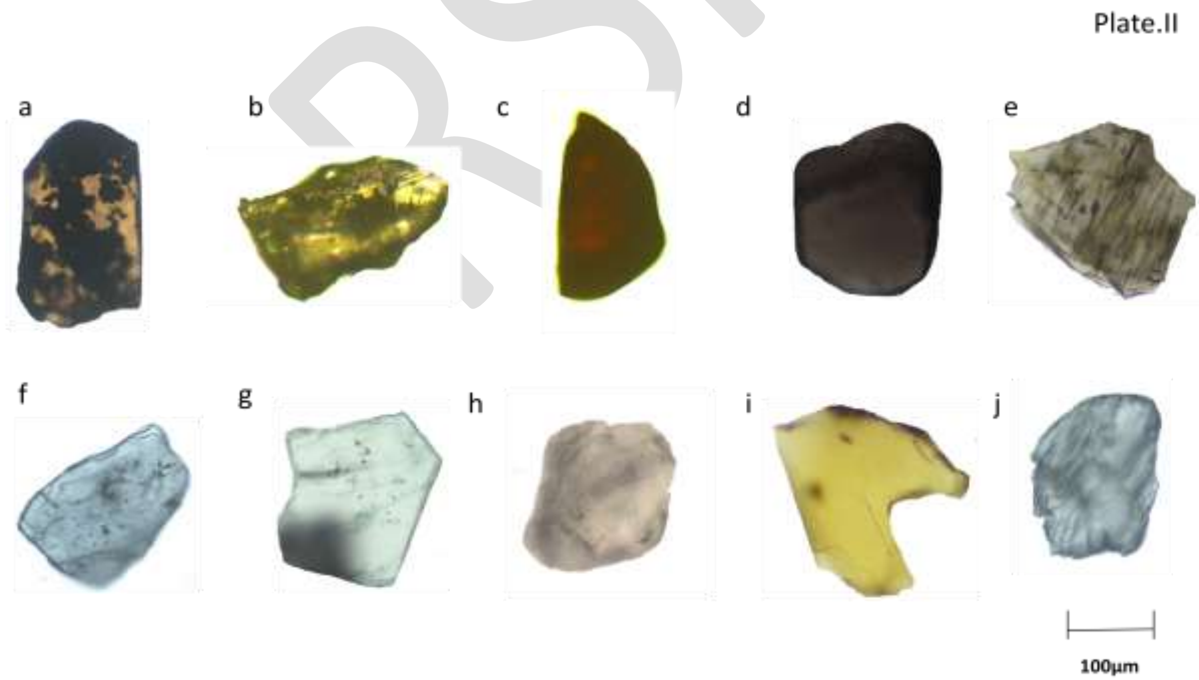
IV. RESULTS

The heavy mineral suite in the Surma sediments depicts a cosmopolitan nature. It comprises dominantly of non-opaque variety that includes Zircon, Tourmaline, Rutile, Staurolite, Garnet, Phologphite, Glauconite, Glaucophane, Chloritoid, Chlorite, Sphene, Wollastonite, Scapolite and Humite. A brief description of the heavy minerals is as follows:

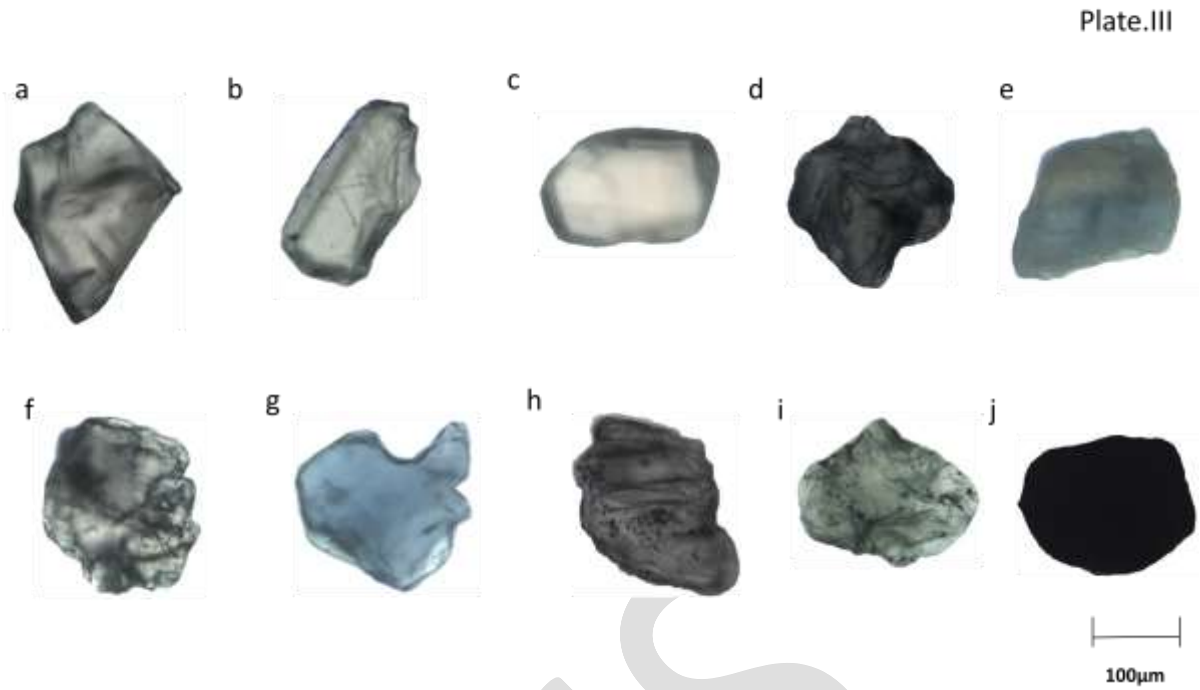
Heavy mineral species



Euhedral (a), sub-rounded to well rounded (c to e) grains of Zircon. Zircon (a and b) with and (c to e) without inclusions and with dark boundaries (a to e). Euhedral (f) , Sub-hedral (g to i) and rounded (j) varieties of Tourmaline.



Euhedral (a), orange and deep red (b to c) varieties of Rutile (a to c), Phlogopite(d), Sillimanite(e), Hedenbergite (f),Humite (g), Scapolite (h), Staurolite (i), Chlorite (j).



Euhedral (a), sub-hedral (b) and sub-rounded (c) varieties of Garnet , Glauconite (d) Glaucophane (e), Sphene(f), Wollastonite (g), Chloritoid (h), Chondrodite (i) Opaque minerals (j).

Zircon: Zircons are represented by prismatic, elongated, oval, rounded to sub rounded grains with or without inclusions Plate.I (a to e). Colourless variety dominate over the pinkish to yellowish brown variety. Zircon is the most common heavy minerals present in almost all the samples analyzed. Most of the zircon grains are colorless or slightly greyish in color under plane polarized light. High refractive index, parallel extinction, absence of cleavage, high order interference color and zoning are some of the prominent optical properties observed under the microscope. It occurs as prismatic euhedral Plate.I(a) as well as sub-angular to sub-rounded Plate.I (c to e) grains.

Tourmaline: Tourmaline grains show an intense pleochroism from pale green to dark green and pale brown to brownish color. Moderately higher relief, parallel extinction and high order birefringence are some of the common features. It exhibits a variety of color ranging from pale green, greenish yellow to pale brown. It is also one of the most abundant grains found in almost all the samples. Prismatic euhedral Plate.I(f) and sub-rounded Plate.I(h to j) grains are common.

Rutile: Rutile is characterized by blood red and pale to dark brownish yellow colors with high relief, faint pleochrosim and lack of cleavage. The polymorph Anatase possesses typical yellowish to orange color with prominent growth bandings that appears as step like under the microscope. Both euhedral Plate.II (a) as well as sub-hedral Plate.II (b and c) varieties are present.

Garnet: Garnets are easily identifiable because of their high relief and isotropic nature. These occur as colourless to pink euhedral, rounded to subrounded or irregular grains with uneven / conchoidal fractures Plate.III (a to c).

Phlogopite: Phlogopite shows pale brown to colourless nature in plane polarized light with slight pleochroism and a slight inclined extinction Plate.II (d).

Hedenbergite: Hedenbergite appear as pale green with non non-pleochroic or weak pleochroic. It exhibits 2 sets of perfect cleavage and display inclined extinction Plate.II(f).

Chlorite: Chlorites exhibit various shades of green color and first order to second order interference colours. Pleochroism is not always visible and extinction almost parallel to cleavage traces or to fibers Plate.II(j).

Sillimanite: The alumino-silicates are represented by sillimanite. It occur as long, slender, elongated, prismatic or irregular shaped grains. These show distinct cleavage, parallel extinction, second and third orders interference colours with shades of yellow, green and pink Plate.II(e)..

Staurolite: Staurolite, a significant metamorphic mineral, makes its presence felt in the Surma sediments. It exhibits yellowish to brawnish color with strong trichroism from light yellow-pale yellow to golden yellow. It has moderately high relief with straight extinction and relatively low birefringence Plate.II (i).

Kyanite: Kyanite occurs as colourless, moderately rounded elliptical grains. Step like variations in the interference colours and inclined extinction are diagnostic.

Glauconite: Glauconite is dark green in color and almost translucent with parallel extinction, and moderate to strong birefringence Plate.III (d) .

Glaucophane: Glaucophane displays vivid shades of blue color with gentle inclined extinction and moderate to high birefringence Plate.III (e).

Sphene: Sphene exhibits colorless or light brown color with weak pleochroism. It has high dispersion and nearly fourth order interference color with symmetrical extinctionPlate.III (f).

Chloritoid: It exhibits variety of colours from green to greenish, grey to colourless. Chloritoid grains are identified by its moderate birefringence colours, parallel extinction with biaxial(+) orientation Plate.III(h).

Wollastonite: Wollastonite displays colorless to bluish shades with moderately high relief. It exhibits 2 sets of perfect and one set of imperfect cleavage with lower birefringence and parallel extinction Plate.III(g).

Scapolite: Scapolite exhibits colorless with non-pleochroic. It has low relief and parallel extinction Plate.II(h).

Humite group: Humite and clino-humite appear as colorless to pale brown colour, humite display parallel extinction whereas clino-humite being incline. Weak pleochroism with low refractive index Plate.II(g).

Chondrodite: Chondrodite occurs as lumps of anhedral tabular to sub-rounded grains. It displays shades of brown,reddish brown, pale green and brownish yellow with low pleochroism and inclined extinction Plate. III(i).

Opaque minerals: The only opaque minerals that can be identified in the present study is magnetite.It does not transmit light Plate.III(j).

The percentages of the heavy minerals present in the studied Surma Sediments have been presented in Table 2 and 3 and shown graphically in Fig.2,3 and 4.

Table.2. Heavy minerals percentage of the study area.

Sr. no	.Sample no.	Zircon%	Tourmaline%	Rutile%	Garnet%	Sphene%	Phlogopite%	Glauconite%	Glaucophane%	Staurolite%
1	**RS2**	24	9	4	54	2	6	0	0	0
2	**RS3**	23	23	0	31	0	0	8	0	0
3	**RS4**	18	36	0	9	0	9	9	0	0
4	**RS5**	9	24	0	30	0	3	0	0	0
5	**RS6**	15	24	3	46	0	9	0	0	0
6	**RS23**	39	16	3	6	0	6	3	3	3
7	**RS26**	5	5	0	0	0	0	0	0	0
8	**RS31**	22	3	11	3	5	8	0	0	0
9	**RS33**	5	7	7	55	5	1	0	1	1
10	**RS34**	6	13	7	41	1	4	0	0	1
11	**RS35**	22	11	22	0	0	0	0	0	0
12	**RS38**	29	7	12	23	5	4	0	2	0
13	**RS42**	16	15	6	53	0	4	0	0	0
14	**RS51**	46	11	14	0	8	8	0	0	0

Table.3. Heavy minerals percentage of the study area.

Sr. no.	Sample no.	Sillimanite%	Scapolite%	Humite%	Chloritoid%	Chlorite%	Chondrodite%	Kyanite%	Hedenbergite%	Wollastonite%	Opague %	ZTR %
1	**RS2**	0	0	0	0	0	0	0	0	2	0	37
2	**RS3**	0	0	0	0	8	0	0	0	8	0	46
3	**RS4**	0	0	0	0	0	9	0	0	0	0	54
4	**RS5**	0	6	9	0	0	15	3	0	0	0	33
5	**RS6**	0	3	0	3	0	0	0	0	0	0	42
6	**RS23**	0	16	6	0	0	0	0	0	0	0	58
7	**RS26**	0	75	10	0	0	5	0	0	0	0	10
8	**RS31**	0	5	0	0	0	3	0	0	0	38	36
9	**RS33**	0	4	3	1	0	5	1	0	0	9	19
10	**RS34**	0.5	7	7	0	0	12	0	0	0	1	26
11	**RS35**	0	22	0	0	0	11	0	11	0	0	56
12	**RS38**	0	4	2	1	0	4	0	1	0	9	51
13	**RS42**	0	2	1	0	0	2	0	0	0	2	27
14	**RS51**	0	2	0	2	0	4	0	0	4	0	71

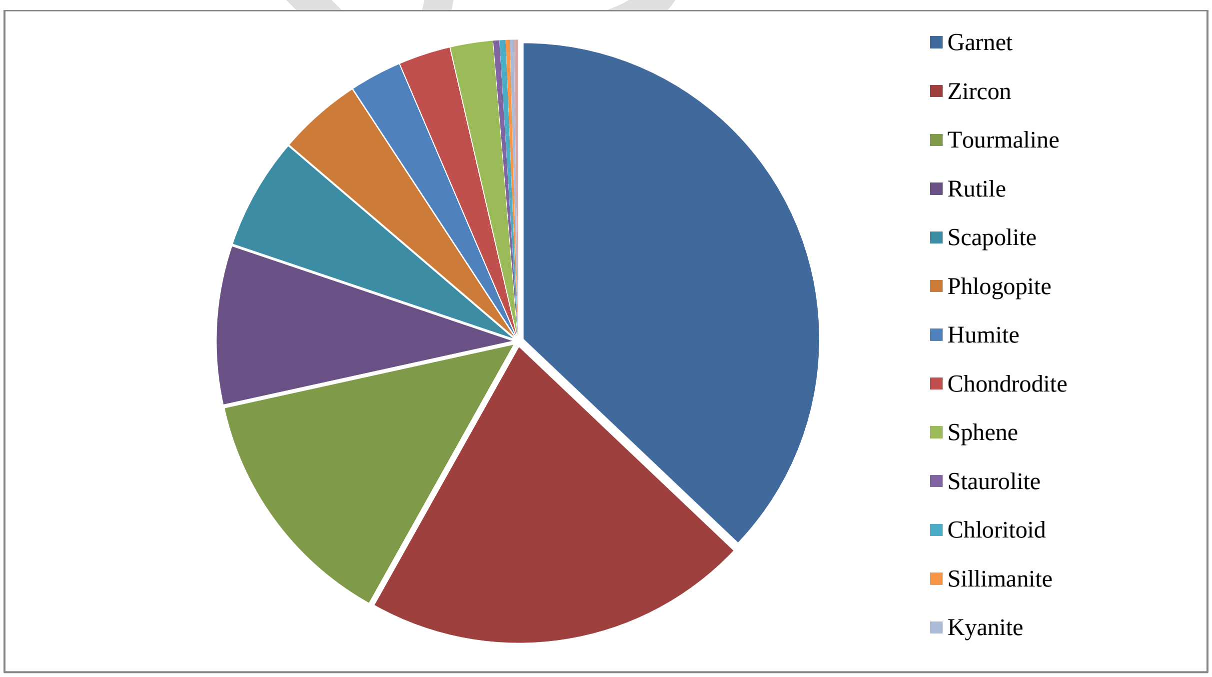


Figure.2. Distribution of various Non-opaque heavy minerals in the Miocene sediments of the study area.

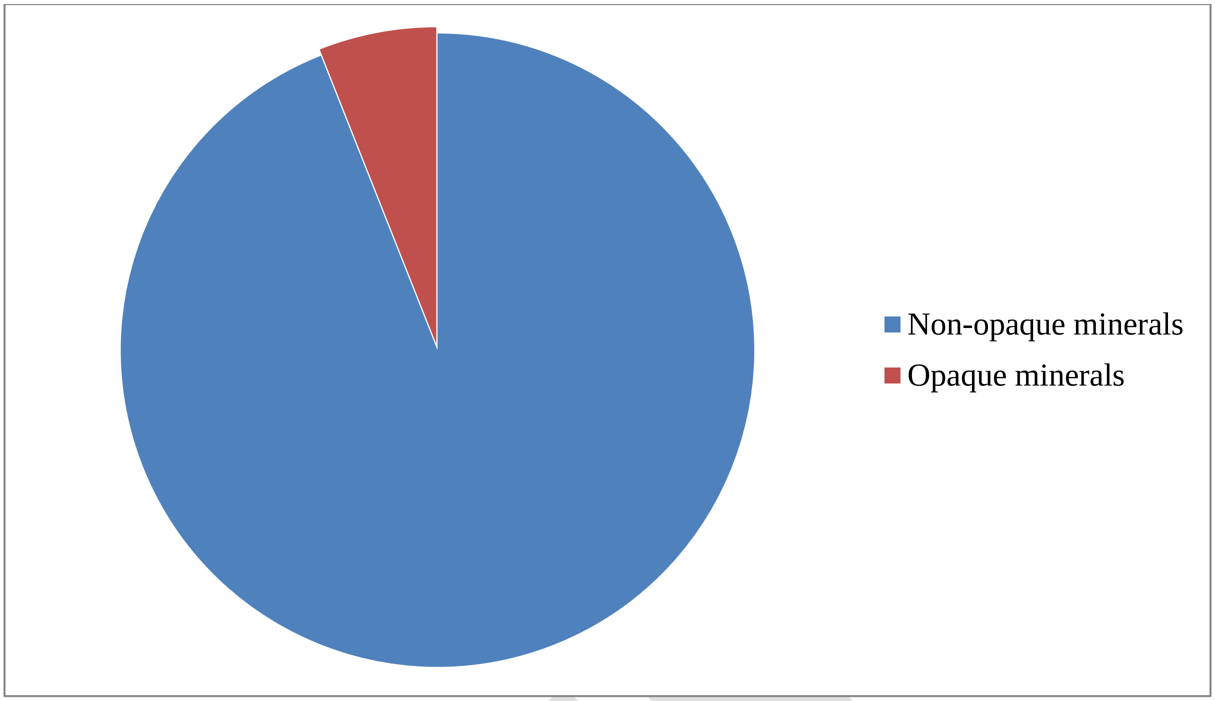


Figure.3. Pie diagram showing the percentage of Opaque and Non-opaque minerals of the studied Surma rocks.

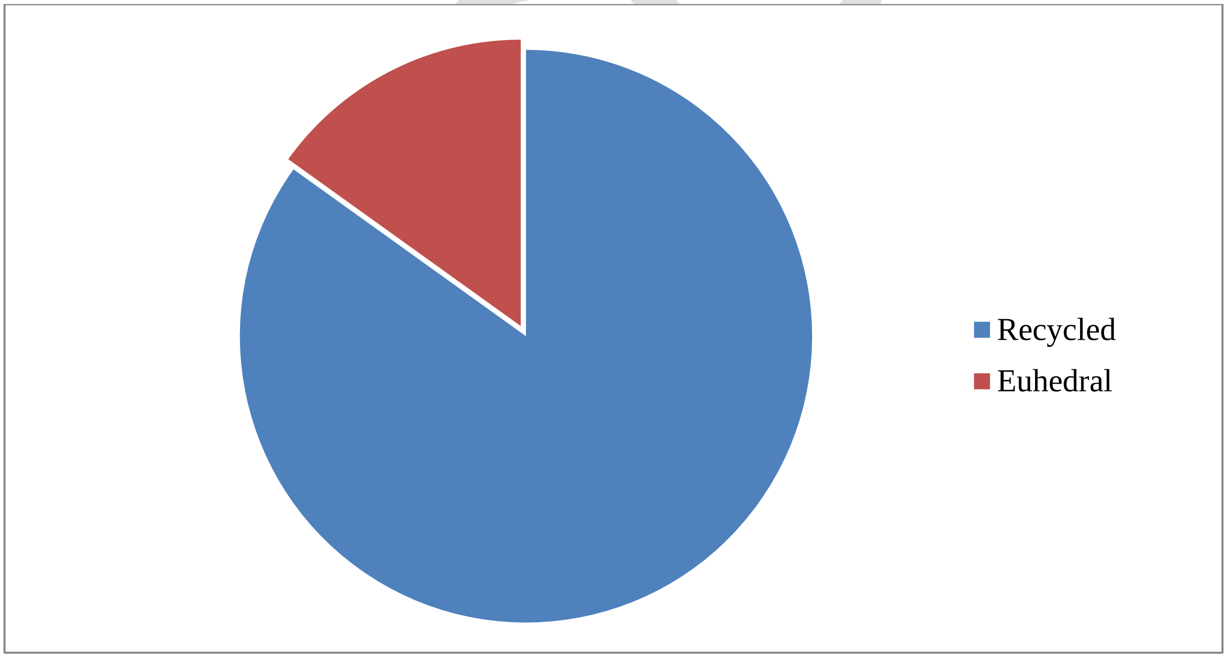


Figure.4. Distribution based on the shape of the Non-opaque heavy minerals in the Miocene sediments of the study area

IV. ZTR INDEX

The ZTR maturity index can be calculated by using the formula:

$$\text{ZTR maturity index} = \frac{(\text{Zircon} + \text{Tourmaline} + \text{Rutile}) \times 100}{\Sigma \text{ non-opaque minerals}}$$

The mineralogical "maturity" of heavy mineral assemblages is quantitatively defined by zircon-tourmaline-rutile (ZTR, Hubert, J.F. 1962) index. The ZTR index is the percentage of the combined zircon, tourmaline, and rutile grains among the transparent, nonmicaceous,detrital heavy minerals. Because of their high mechanical and chemical stability, zircon, tourmaline, and rutile are concentrated with quartz plus chert and metaquartzite rock fragments as sandstones become progressively more quartzose. As the ZTR index increases, concentration of the varieties of zircon, tourmaline, and rutile occurs, together with a decrease in the number of species of transparent heavy minerals. The ZTR index in respect of Surma sediments has been found to be 40.40% suggesting miner logically an overall sub mature nature.

V. DISCUSSIONS

The Surma sediments of the study area possess a diversified group of heavy minerals(Plate.I to III). Such diversifications have been attributed to contributions and mixing of different types of grains from different source rocks as well as supply of same kinds of grains from different rocks (Pettijohn et.al, 1987). The initial sediment. source characteristics are further modified especially when dispersal pathways are complex and involve recycling of previously deposited sediments (Weltje and Eynatten, 2004). The complexity of these interdependent modifications, including post-depositional diagenetic changes, imposes certain limits on the capability of oneself to infer characteristics of source area from the properties of their products (Siever, 1988). Among the common heavy minerals found in the sediments of the study area, four distinct suites could be identified, namely (1) Chondrodite – Phlogopite – Scapolite – Wollastonite – Sphene –Hedenbergite- Iron oxide, characterizing a contact dolomitic marble and skarn source rock, (2) Zircon– Tourmaline (Schorlite) — Rutile(Anatase) – Garnet (inclusion free), indicative of granitic and mafic igneous rocks, (3) Staurolite –Sillimanite-Kyanite-Fluorite-Chlorite – Glaucophane – Garnet (with inclusion) – Mica,signifying a regionally metamorphosed source terrain, and (4) Recycled grains of Zircon- Tourmaline - Rutile – Glauconite - Garnet etc. pointing towards a sedimentary source terrain. Based on the above observation it may be concluded that the Surma sediments received their detritus from a mixed source terrain comprising igneous, metamorphic and sedimentary rocks. Further, the absence of hacksaw terminations in the heavy minerals point towards a low grade diagenetic environment.

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REFERENCES

[1]. Brunnschweiler, R.O (1974) . Indo -burman ranges. Geol Soc Lond Spl Pub 4, 279–299.
[2]. Evans, P (1932) . Tertiary Succession in Assam. Trans. Min. Geol. Inst. India, v.27.
[3]. Evans, P (1986) . Tertiary succession in Assam. Trans. Min. Geol. Inst. India, 37, 155-188.
[4]. Evans, P (1964). The tectonic framework of Assam. Jour. Geol. Soc. India Vol.5, 80-96.
[5]. Eynatten, H (2004). Statistical modelling of compositional trends in sediments. Sedimentary Geology 171, 79-89.
[6]. Folk, R.L (1980) . Petrology of Sedimentary Rocks. Hamphill's, Austin, Texas, pp. 182.
[7]. Hubert, J.F (1962) . A zircon-tourmaline-rutile maturity index and independence of composition of heavy mineral assemblages with gross composition and texture of sandstone. Journal of Sedimentary Petrology, v. 32, 440-450.
[8]. Chandra M, Kundal P & Kushwaha R.A.S (2010). Ichnology of Bhuban and Boka Bil Formations,Oligocene-Miocene Deposits of Manipur Western Hill,Northeast India.GSI.Vol.76, 573-586.
[9]. Mathur, L.P. and Evans, P (1964). Oil in India Proc. 2nd International Geol.Congress, New Delhi, India,pp. 1-85.
[10]. Middleton et al. (2003). Encyclopedia of Sediments and Sedimentary rocks. Springer, pp. 821.
[11]. Morton, A.C (1987) . Stability of detrital heavy minerals in Tertiary sandstone from North sea basin. Clay Minerals, v.19, 287-308.
[12]. Nandy, D.R (1983) . The Eastern Himalaya and the Indo-Burman Orogen in relation to the India plate movement. Geol. Surv. Ind. Misc. Pub. No 41(3). 153-159.
[13]. Oldham, R. D (1883) . Report on the Geology of Manipur State and Naga Hills. Men. Geol Survey of India. Vol. XIX part IV.
[14]. Pettijohn F. J, Potter P. E & Siever R (1987). Sand And Sandstones, second version. Springer-Verlag, New York, pp. 553.
[15]. Kushwaha R. A. S. & Chandra M (2008). Ichnofossils from the Eocene – Oligocene Deposits between Bijang and Tupul, Manipur, India, Jour. Indian Association of Sedimentologists, Vol. 27, No.1. 35-44.
[16]. Sengupta S, Ray K.K, Acharyya S.K & De- smith, J.B (1990) . Nature of Ophiolite occurrence along the eastern margin of Indian plate and their tectonic significance. Geology, Vol. 18, 439-442.
[17]. Siever R (1988) . Sand Scientific American Library, New York, pp 237.
[18]. Soibam I (1998). On the geology of Manipur. In: Proceedings of 9th Manipur science congress, Imphal, pp 12–19
[19]. Weltje G.J (2004) . A quantitative approach to capturing the compositional variability of modern sands. Sedimentary Geology 171, 59-77