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HEAVY MINERAL SUITE IN THE TURA SANDSTONE IN AND AROUND DOBAGIRI, EAST GARO HILLS, MEGHALAYA

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ABSTRACT

Heavy mineral analysis from the Tura sandstone of East Garo Hills District, Meghalaya was carried out for mineralogical studies. An attempt was made to determine the provenance, depositional environment and maturity of the sediments based on the study of the heavy minerals. The study reveals that the sediments were mature, waterlaid, and deposited in a water basin quickly after short transportation from the provenance of metamorphic and igneous rocks which are present in the Shillong Plateau, Meghalaya.

INTRODUCTION

The heavy mineral analysis is an important and useful tool as it bears character of the source rocks from which they are derived. Morton (1985) stated that the heavy mineral suites are not only controlled by provenance, but also affected by source area weathering processes of transportation, post-depositional alteration etc. Heavy minerals in clastic sediments have been used for deciphering the composition and tectonic history of provenance (Pettijhon *et al.*, 1973, Fuchtbauer, 1974). They are also useful in evaluating diagenetic history as well as the pre-depositional history (Lindholm, 1987).

The heavy mineral analyses were carried out from the Tura Sandstone for the following purposes: (1) to analyse the petrographic characters of various heavy mineral species, and (ii) to determine the provenance and maturity of the sandstones.

GEOLOGICAL SETTING

The Tertiary rocks are well developed in Meghalaya where they exhibit a more or less complete geological succession as shown in fig.-1. In Garo Hills, the sediments of Eocene age rest unconformably on the Precambrian Basement.

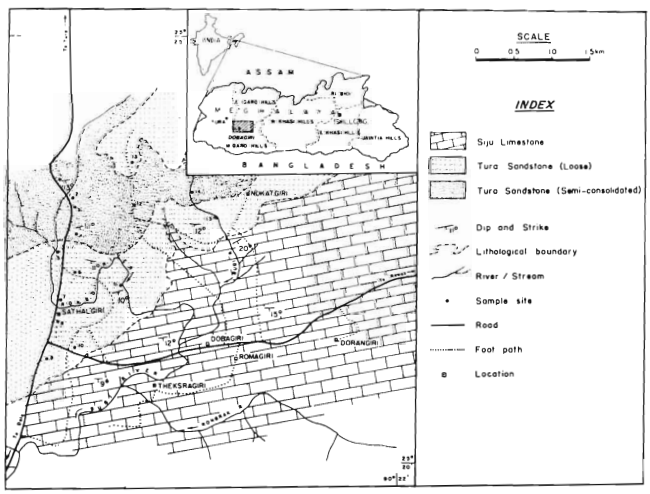

Fig.1. Geological map of the study area, Dobagiri, Meghalaya.

The stratigraphical succession (modified after G.S.I., 1989) of the area is given below.

Age	Group	Formation	Rock Types
Recent	Alluvium	—	Loose soil, clay, sand, pebbles and boulders
----------		Unconformity	----------
Eocene to Palaeocene	Jaintia	Siju Limestone	Thickly bedded fossiliferous limestone
		Tura Sandstone	Bedded and massive sandstones with clay and coal seams
----------		Unconformity	----------
		BASEMENT	

METHODOLOGY

There are various methods for the separation of heavy minerals. In the present study "funnel separation method" of Krumbein and Pettijhon (1938) was followed. For the purpose loose samples which were used for mechanical analysis were chosen by taking the separated grades from the sieves of 1Φ to 3Φ and mixed them thoroughly. The samples were then reduced to 10 gm from the 100 gm of sediments each by coning and quartering used for heavy mineral separation. The sediments of each sample were washed separately to remove clay-sized particles and then boiled with hydrochloric acid (1:1) for about 10 minute to remove iron coating and cementing materials. The samples were then washed again and dried in an electric oven and were thus made ready for heavy mineral separation. Separation of the heavies from the light minerals was done with the help of bromoform (Sp. Gravity 2.89).

PETROGRAPHIC DESCRIPTION OF HEAVY MINERALS

The heavy mineral suite of the sandstone formation consist of tourmaline, zircon, rutile, epidote, garnet,

hornblende, staurolite and opaque minerals. A brief account of the heavy minerals found in the Tura sediments is given below.

Zircon: Zircon occurs as prismatic, euhedral to subhedral grains with prominent crystal faces. Some grains are subrounded to rounded. The boundaries of the grains are characteristically dark. They show parallel extinction, pale higher order interference colour. The percentage of zircon varies from 0.92% to 10.40% of the total heavies (Table 1).

Tourmaline: The tourmaline grains are elongated, prismatic, angular to subrounded. These are brown, dark grey, greenish brown to dark green in colour. The dominant varieties of tourmaline are dark brown coloured followed by dark grey grains. Green coloured variety of tourmaline constitutes a minor fraction (about 1%) of the total tourmaline present. All the grains are strongly pleochroic. "Hack saw" tourmalines are also observed. Total tourmaline percentage varies from 8.80% to 16.69% of the total heavies.

Rutile: The grains with peculiar blood red colour, pleochroic. The grain boundaries are dark. Grains are euhedral to oval-shaped. Percentage varies from 0.31% to 1.84% of the total heavies.

Epidote: Grains are mostly subangular, colourless to pale yellowish green with inclusions. It shows a brilliant to purplish and red interference colours and shining. The percentage range from 1.20% to 8.55%.

Garnet: Garnets occur as colourless to pale purple-coloured and subrounded to subangular in outline, high relief and isotropic, containing opaque inclusions. The percentage of garnet varies from 0.00% to 7.81% of total heavies.

Staurolite: Staurolites are light yellow to straw yellow in colour, mostly subangular and pleochroic from straw yellow to pale yellow. Staurolite percentage varies from 0.20% to 5.42% of the total heavies.

Hornblende: Hornblendes are subrounded to subangular, green to dark green, with prismatic cleavage, pleochroic and have characteristic blue interference colours with pink shades. Its percentage varies from 0.00% to 0.83% of the total heavies.

Opaque Minerals: Opaque minerals are subrounded to subhedral, and consist mainly of magnetite and haematite. Magnetite remains dark both under crossed nicols and polarised light. Haematite is dark under polarised light and deep brown under crossed nicols. These constitute the higher fraction of the heavy mineral suite having variations from 67.14% to 81.85%.

Table 1: Percentages of heavy minerals in Tura Sandstone, East Garo Hills, Meghalaya.

Sample	Tourmaline	Zircon	Rutile	Epidote	Staurolite	Hornblende	Garnet	Opaque Minerals
1.	10.70	4.60	1.84	8.06	2.08	0.46	—	72.25
3.	16.06	2.29	0.85	8.24	5.42	—	—	67.14
6.	16.69	1.62	1.01	7.08	3.01	—	—	70.58
7.	15.64	2.83	0.50	8.06	0.30	—	—	72.66
9.	12.97	0.92	0.77	6.18	2.34	—	—	76.81
10.	16.66	1.49	0.40	8.55	0.20	—	—	72.69
12.	8.80	10.40	0.60	1.20	2.60	0.40	—	76.00
13.	10.33	1.03	0.93	4.61	1.25	—	—	81.85
14.	14.74	2.51	1.26	7.78	1.68	—	—	72.03
15.	9.75	1.63	0.31	4.69	3.12	0.83	7.81	71.85
Average	13.23	2.89	0.85	6.45	2.20	0.17	0.78	73.39

STATISTICAL STUDY

The percentage of the various heavy minerals is shown in a histogram (fig. 2). Moreover, the length and

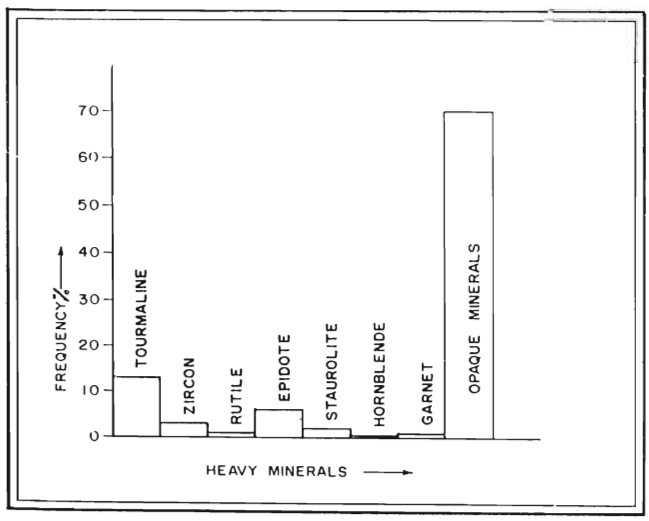

Fig.2. Histogram for frequency percentages of the heavy minerals.

breadth of tourmaline and zircon grains were measured separately (100 grains of each slide) and plotted on scatter diagrams as well as both the length and breadth ranges and elongation quotient are plotted against frequency percentages. Scatter diagrams are plotted according to Smithson (1939) (figs. 3 & 4; Tables from 2 to 7).

Table 2: Length frequency percentage of tourmaline, Tura Sandstone.

Length (x 0.20mm)	Frequency percentage
0.6-0.8	4
0.8-1.0	5
1.0-1.2	13
1.2-1.4	23
1.4-1.6	17
1.6-1.8	20
1.8-2.0	8
2.0-2.2	4
2.2-2.4	2
2.4-2.6	1
2.6-2.8	1
2.8-3.0	0
3.0-3.2	0
3.2 and above	2

Table 3: Breadth frequency percentage of tourmaline, Tura Sandstone.

Breadth (x 0.20mm)	Frequency percentage
0.4-0.6	13
0.6-0.8	25
0.8-1.0	18
1.0-1.2	18
1.2-1.4	12
1.4-1.6	7
1.6-1.8	3
1.8-2.0	2
2.0-2.2	2

Table 4: Elongation quotient frequency percentage of tourmaline, Tura Sandstone.

Elongation Ratio	Frequency percentage
1.0-1.2	12
1.2-1.4	19
1.4-1.6	16
1.6-1.8	14
1.8-2.0	9
2.0-2.2	10
2.2-2.4	7
2.4-2.6	5
2.6-2.8	3
2.8-3.0	2
3.0-3.2	0
3.2-3.4	3

Table 5: Length frequency percentage of Zircon, Tura Sandstone.

Length (x 0.20mm)	Frequency Percentage
0.4-0.6	3
0.6-0.8	8
0.8-1.0	27
1.0-1.2	16
1.2-1.4	18
1.4-1.6	9
1.6-1.8	8
1.8-2.0	7
2.0-2.2	3
2.2 and above	1

Table 6: Breadth frequency percentage of zircon, Tura Sandstone.

Breadth(x 0.20mm)	Frequency Percentage
0.2-0.4	8
0.4-0.6	27
0.6-0.8	58
0.8-1.0	7

Table 7: Elongation quotient frequency percentage of zircon, Tura Sandstone.

Elongation Ratio	Frequency Percentage
1.0-1.2	8
1.2-1.4	14
1.4-1.6	5
1.6-1.8	11
1.8-2.0	4
2.0-2.2	9
2.2-2.4	14
2.4-2.6	12
2.6-2.8	4
2.8-3.0	3
3.0-3.2	6
3.2-3.4	4
3.4-3.6	0
3.6-3.8	1
3.8-4.0	5

The results obtained from the study of these diagrams give clues to the probable provenance and mode of deposition of the sediments. In the Smithson's diagram for Zircon (fig. 4d) the catenae makes a dome like shape getting a peak value between 1:5 and 1:2 lines and slightly incline towards 1:5 line, both 1:5 and 1:1 line act as its base. Moreover, the catenae along the 1:5 line extend more than along the 1:1 line. These features indicate that the sediments were subjected to less physical wear and tear and transportation. Smithson's diagram for tourmaline (fig. 3d), the catenae takes a dome shape towards the 1:2 line slightly inclining towards 1:1 line. The base of the catenae being almost equidistant from

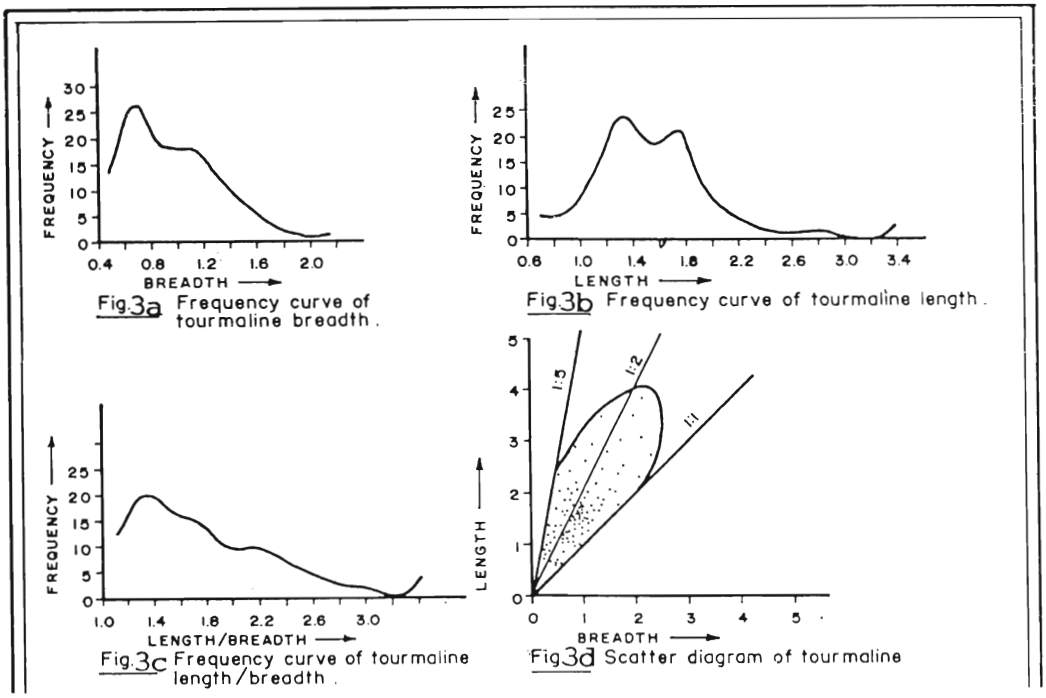

Fig. 3a. Frequency curve of tourmaline breadth. Fig. 3b: Frequency curve of tourmaline length. Fig. 3c: Frequency curve of tourmaline length/breadth. Fig. 3d: Scatter diagram of tourmaline.

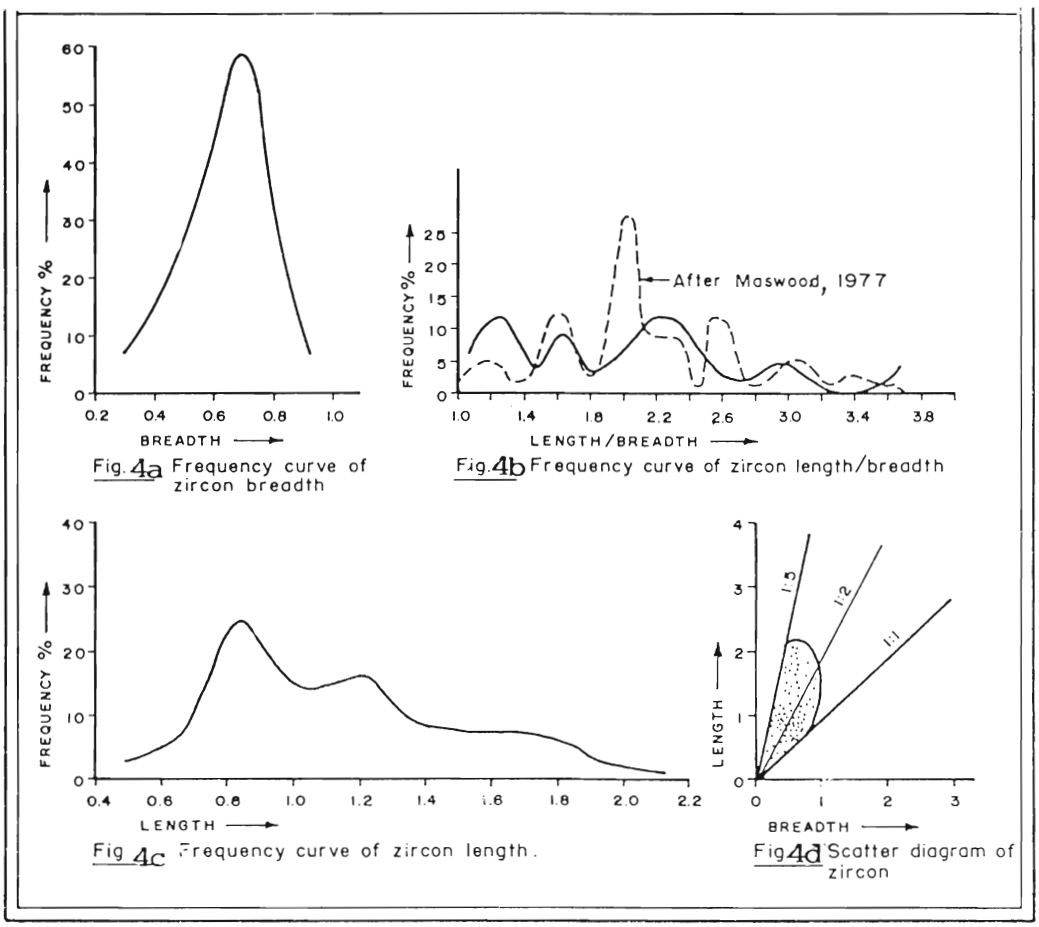

Fig. 4a. Frequency curve of zircon breadth. Fig. 4b: Frequency curve of zircon length/breadth. Fig. 4d: Scatter diagram of zircon. Fig. 4c: Frequency curve of zircon length.

the pole. These features indicate less physical wear and tear and short transportation. These studies indicate that the provenance is nearer to the site of deposition.

According to Bokman (1952) and Poldervaart (1955) the elongation quotient frequency curves are more useful in genetic studies than smithson's diagram. Hence, length, breadth and elongation quotient (length-breadth ratio) frequency curves of tourmaline and zircon have been studied. Breadth-frequency diagram of tourmaline (fig. 3a) shows that the maxima are few and broadly peaked. Length-frequency diagram (fig. 3b) of tourmaline shows few peaks with broad maxima. The elongation quotient-frequency diagram of tourmaline shows four peaks (fig. 3c). Breadth-frequency diagram of zircon (fig. 4a) shows single sharp peak. Elongation quotient-frequency diagram of zircon (fig. 4b) shows five broad peaks. The length-frequency diagram of zircon (fig. 4c) shows few peaks with broad maxima. The peakness of thess curves indicate mixing of sediments of two or more diverged source of the sediments. Elongation-frequency curve of zircon takes the shape of a similar curve (fig. 4b) as derived from pink granites occurring around Guwahati, Assam (Maswood, 1977).

Z.T.R. MATURITY INDEX

The mineralogical maturity of the heavy mineral assemblages of sediments is quantitatively defined by the Z.T.R. maturity index. The Z.T.R. index is the percentagve of the combined zircon, tourmaline and rutile grains among the transparent, non-micaceous and detrital heavy minerals (Hubert, 1962). The three minerals are the most resistant of all the minerals. So as the maturity of the sediments increase the less resistant, unstable minerals are dissolved down and the more resistant minerals thus increase their percentage. That is why the percentage of these resistant minerals may express the maturity of sediments.

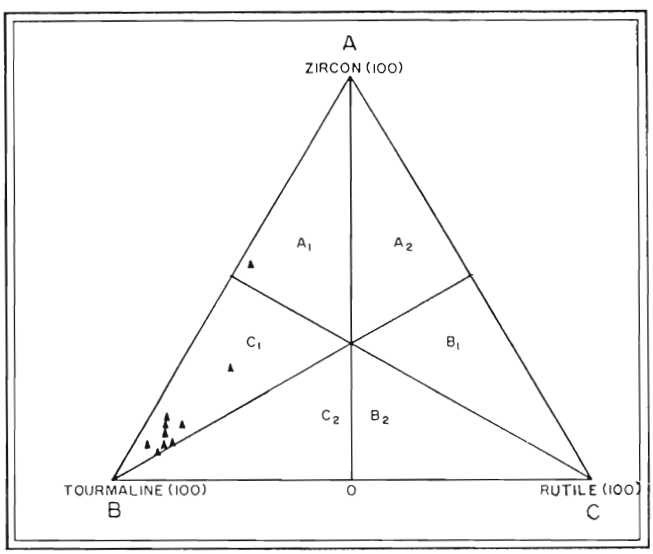

Fig.5. Z.T.R. triangular diagram.

In the calculation of Z.T.R. index the opaques and authogenic heavy minerals were omitted and the percentage of the heavy minerals were recalculated to 100% and the percentages of zircon, tourmaline and rutile were found out. The maturity index of the semples varies from 46.13 to 82.52 and average 66.96 (Table-8).

Table 8 : Percentages of Tourmaline, Rutile and Zircon, and Z.T.R. Index of Tura Sandstone.

Sample No.	Zircon	Tourmaline	Rutile	Z.T.R. Index
1	16.59	38.57	6.64	61.80
3	9.43	66.07	3.52	79.02
6	5.50	56.74	3.48	65.68
7	10.30	57.19	1.84	69.33
9	3.98	55.95	3.32	63.25
10	5.46	61.02	1.48	67.96
12	43.34	36.67	2.51	82.52
13	5.67	56.91	5.11	67.69
14	8.98	52.71	4.49	66.18
15	6.43	38.47	1.23	46.13
			Average	66.95

Z.T.R. TRIANGULAR DIAGRAM

The percentages of the three members of Z.T.R. index i.e. zircon (Z), tourmaline (T) and rutile (R) are taken for Z.T.R. Triangular Plot (modified after Hazarika, 1984). In the triangular plot the three apexes- A, B and C of the triangle represent 100% of zircon, rutile and tourmaline respectively. Bisectors of the three angles of the triangle causes the division of the triangle into six subtriangles. Each subtriangles are designated as A_1, A_2; B_1,B_2 and C_1, C_2 (fig. 5). In the tringular plot percentage of these three minerals varies as A_1 = Z>T>R, A_2 = Z>R>T, B_1 =R>Z>T, B_2 =R>T>Z, C_1 = T>Z>R, C_2 =T>R>Z.

The recalculated percentages of zircon, tourmaline and rutile (Table-9) were plotted on the triangular diagram (fig. 5). The plotting of these percentages give the clue to the maturity as well as the nature of the source rocks. In the present study, the samples fall in the subtriangle C_1 mainly indicating high percentage of tourmaline, exception being with one of the samples which falls in the subtriangle A_1 indicating higher percentage of zircon than the other two. The C_1 field indicates moderate maturity as well as dominating metamorphic provenance of the sediments.

Table 9: Percentages of Zircon, Tourmaline and Rutile for Z.T.R. Triangular Plot.

Sample No.	Zircon	Tourmaline	Rutile
1	26.84	62.41	10.74
3	11.93	83.61	4.45
6	8.37	86.39	5.24
7	14.94	82.49	2.65
9	6.29	88.46	5.25
10	8.03	89.79	2.18
12	52.52	44.44	3.04
13	8.38	84.07	7.55
14	13.57	79.65	6.78
15	13.94	83.39	2.67

DISCUSSION AND INTERPRETATION

The heavy mineral assemblage comprising garnet, epidote, staurolite is suggestive of a metamorphic provenance (Choudhari and Gill, 1981). Blatt *et al.* (1972) suggested a metamorphic source for brown and pale-brown varieties of tourmaline. Epidote and tourmaline may also suggest the derivation from low and medium-grade metamorphic rocks (Heinrich, 1956). Epidote may also be derived from acid igneous rocks. The angular garnet grains indicate their derivation from crystalline rocks. A provenance of metamorphosed argillaceous sediments is suggested by the presence of rutile (Morton, 1985). Presence of hornblende indicates that the sediments were partly derived from basic igneous rocks. Tourmaline occurs as large prismatic grains with dark brown to dark grey colour and angular grains with green colour indicates that the sediments were derived from granitic and pegmatitic rocks (Krynine, 1946). Opaque minerals are mainly derived from igneous rocks though few may be authogenic. Zircon is the most important common heavy mineral of the sediments and it has been regarded as one of the most important provenance indicators. Zircon usually derived from acid igneous rocks shows several broad peaks in its length breadth ratio frequency curve (Maswood, 1977). Moreover, zircon is regarded as one of the most stable minerals hardly affected by weathering (Pettijhon, 1957). The euhedral form of zircon present in the sediments suggest that the sediments were partly derived from acid igneous rocks (Poldervaart, 1955). Staurolite indicates both metamorphic and igneous derivation. Concertinas ("Hacksawed" staurolites) are the evidence of post-depositional intrastratal solution effect on the sediments. The green tourmaline indicates pegmatitic origin. Zircon and rutile may have been derived from sialic igneous and crystalline metamorphic rocks (Friedman and Johnson, 1982). Rutile may be partly derived from schists (Force, 1980). Considering the above, the sandstones may be interpreted as of dual origin from metamorphic and igneous rock provenance.

According to Raju (1967), "the incoming of each diagnostic mineral species in the sediments may be the result of a corresponding disturbance in the source area which in some cases at least seem to be on a major scale". The variation in frequency of various heavy minerals may partly be due to effect of intrastratal solutions as suggested by Pettijhon (1984) and Gazzi (1965), and partly due to the difference in grain-size as well as the specific gravity of the detritus. Higher percentage of the opaques which are mainly composed of iron oxides may be derived from gneisses and granites. These oxides may also be formed from the mafic minerals in an oxidizing environment. The Smithson's diagrams of zircon and tourmaline indicate less wear and tear and short transportation of the sediments. The Z.T.R. maturity index, the Z.T.R. triangular plot all indicate that the sediments were mineralogically matured.

CONCLUSION

From the above study, it is apparent that bulk of the heavies have been derived from a mixed assemblage of Precambrian igneous and low to high-grade metamorphic rocks present in the Shillong Plateau. It is also inferred that these sediments were mineralogically matured, waterlaid and deposited in a shallow basin quickly after short transportation.

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