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# GEOCHEMICAL CHARACTERISTICS OF THE TIPAM SANDSTONE FORMATION EXPOSED ALONG TIPONG PANI RIVER SECTION, UPPER ASSAM, INDIA

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## ABSTRACT

A geochemical study was carried out on Tipam Sandstone Formation exposed along the Tipong Pani River section, which is 25km away from Margherita town of Tinsukia District, Assam. Major, trace and rare earth element composition of sandstones have been investigated to determine their provenance and tectonic setting. Geochemically, the Tipam sandstones are classified as wacke and litharenite with moderate $SiO_2$ content. The tectonic discrimination diagrams suggest an active continental margin setting for the Tipam sandstones. The $(La/Lu)_{cn}$ (~11.86), La/Sc (~3.6), Th/Sc (~1.50), La/Co (~1.40), Th/Co (~0.72) and Cr/Th (~15.13) ratios indicate derivation of the Tipam sandstones from felsic rock source. However, the high values of ferromagnesian trace elements such as Cr (~148.89ppm), Ni (~111.75ppm), Co (~18.52ppm) and V (~78.80ppm) may reflects some mafic/ultramafic input of ophiolitic derivation. Furthermore, ternary plot of La-Th-Sc, binary plots of Th/Sc-Zr/Sc and La/Sc-Th/Co also points towards felsic provenance of the Tipam sandstones.

**Key words**: Tipam Sandstone Formation, geochemistry, provenance, tectonic setting.

## INTRODUCTION

Sedimentary rocks are composed of detritus which acts as a principal source of information about the provenance history. The analysis of such clastic materials is considered as an invaluable tool to determine provenance, paleoweathering, paleoclimate, transportation, diagenesis and depositional settings (Bhatia and Crook, 1986; Armstrong-Altin et al., 2004). In geochemical studies, certain trace elements and REEs like La, Ce, Nd, Y, Th, Zr, Hf, Nb, Ti and Sc are very sensitive indicators of provenance and tectonic setting determination because of their relatively low mobility during sedimentary processes (Holland, 1978).

Tipam Sandstone Formations of Upper Assam shelf basin is medium grained sandstone characterized by 'salt & pepper' texture with bands of blue and bluish grey shale. Some impersistent and thin coal seams are found at the middle and lower part of the Tipam. It occurs in the subsurface of the Upper Assam plain and is well exposed in the type area of Tipam hills and different localities of Naga hills. They are overlain by undifferentiated grit beds of Surma Group and underlain by the Girujan Clay Formation.

The main purpose of this study is to evaluate the major, trace and rare earth element geochemistry of the Tipam sandstone Formation exposed along Tipong Pani River section near Margherita town of Tinsukia District in the Upper Assam in order to infer their provenance and tectonic setting.

## Geology and stratigraphy of the study area

Upper Assam basin is the northeastern most extension of the Assam-Arakan basin and is a NE-SW trending intermountain platform basin of Tertiary sedimentation bounded on the north by the Eastern Himalayas, on the east by the Mishmi massif, on the south by the Naga Patkai hills and on the west by the Mikir hills & Shillong Plateau. H. B. Medlicott (1865) and Mallet (1876) did the pioneering work in the field of geology of this region. Later on, Evans (1932, 1959) classified Tertiary sequence of Assam in detail which is still useful as basic classification.

The present study area is situated in Tinsukia district of Assam near Tipong colliery (Fig.1). It is situated in the Patkai hill ranges and exposed along the Tipong Pani river section. The Tipong Pani River section exposes most of the Paleogene and Neogene rock strata. Table-1 represents the generalized statigraphy of the Upper Assam shelf sediments after Handique et al. (1968).

## MATERIALS AND METHODS

For the present study, representative surface samples have been collected from the Tipam Sandstone Formation which is exposed along the Tipong Pani River section near Margherita. Ten sandstone samples were analyzed for major oxides and four sandstone samples were analyzed for trace and rare earth elements. Major oxides were determined by using Philips PW 1480 sequential X-ray fluorescence

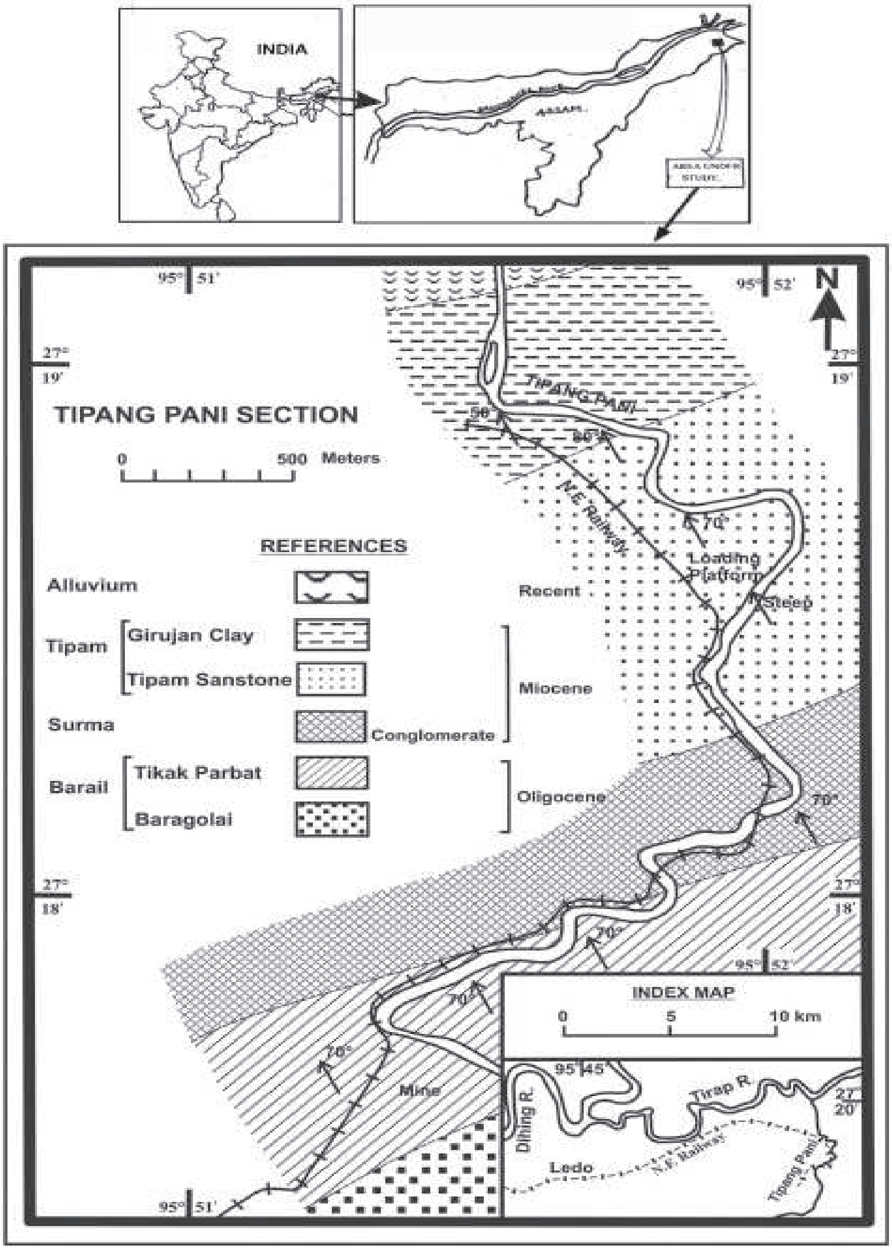

**Fig. 1.** Geological map of the Tipong Pani River section (modified after Das Gupta et al., 1964)

**Table 1:** Tertiary succession of Upper Assam shelf sediments, after Handique et al. (1989)

| **Epoch** | **Lithostratigraphic Groups** | **Units/ Formation** | **Thickness (m)** | **Major Lithological Types** |
|---|---|---|---|---|
| Recent<br>Pleistocene | Dihing | Alluvium[1]<br>Dhekiajuli[1] | 1300 – 2000 | Unconsolidated sands with clay and lignite sands |
| ……… | ……… | Unconformity | ……… | ……… |
| Pliocene | Dupitila | Namsang Beds | 0 – 1000 | Poorly consolidated sandstones with clay and lignite sands |
| ……… | ……… | Unconformity | ……… | ……… |
| | | Girujan clays<br>Tipam Sandstone | 100 – 2300 | Mottled clays with sandstone lenses |
| Miocene | Tipam | (Upper Middle)<br>(Lower not subdivided) | 300 – 500<br>100-200 | Essentially arenaceous sequence<br>Sand/Shale alterations sequence |
| | ? Surma[2] | | 100-200 | Arenaceous sequences<br>Sandstones with shale and grit beds |
| ……… | ……… | Unconformity | ……… | ……… |
| Oligocene | Barail | Not subdivided | 500 – 1200 | (Upper part: Mudstone/shale with sandstone bed and coal bands) (Argillaceous sequence)<br>(Lower Part: Sandstone with shale bands) (Arenaceous sequence) |
| Eocene[3] | Jaintia | Kopili Alterations | 280-500 | Splintery Shales with sandstone and fine grained sandstones with coal bands |
| | | Sylhet Limestone (Prang, Nurpuh, Lakadong) | 350 – 450<br>60 - 170 | Splintery shales with sandstone and limestone bands |
| | | Therria | | Sandstone, calcareous sandstone and limestone |
| ……… | ……… | Unconformity | ……… | ……… |
| | | Precambrian Granitic Basement | | |

Note: 1. It is difficult to distinguish these two rock units. From regional geological consideration, an unconformity could, however, be inferred between them.
2. Development of the Surma Group, which is extensive in the type area of Surma Valley in the Upper Assam shelf area. 3. Including Palaeocene rocks.

spectrometer at Sophisticated Analytical Instrument Facility (SAIF), Gauhati University, Assam. Quantitative analyses of trace and rare earth elements (REE) have been done by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at Indian Institute of Science (IISc.), Bangalore. For interpretation of trace elements we used Upper Continental Crust (UCC) normalization.

## RESULTS AND DISCUSSION

### Major elements

The major and minor oxide concentration of the studied sandstone samples in wt% is given in Table 2. Result shows that $SiO_2$ (68.67-72.22%; on average 70.24%) constitutes the major portion of the oxides followed by $Al_2O_3$ (11.25-12.66%; average 12.03%), CaO (3.68-4.90%; average 4.06%) and $Fe_2O_3$ (3.55-4.65%; average 4.02%).

**Table 2:** Major element concentrations in weight percent (wt. %) of Tipam sandstone Formation, Chemical index of alteration (CIA, Nesbitt and Young 1982) and $Fe_2O_3$ (T) represents total Fe expressed as $Fe_2O_3$.

| Major oxides | TIP-1 | TIP-2 | TIP-3 | TIP-4 | TIP-5 | TIP-6 | TIP-7 | TIP-8 | TIP-9 | TIP-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 69.59 | 70.53 | 68.96 | 68.67 | 72.22 | 71.60 | 69.72 | 69.50 | 70.32 | 71.33 |
| $Al_2O_3$ | 12.00 | 12.00 | 11.85 | 12.50 | 12.56 | 11.25 | 12.08 | 11.87 | 12.66 | 11.57 |
| $Fe_2O_3$ (T) | 3.75 | 4.65 | 4.12 | 4.23 | 3.88 | 3.55 | 4.13 | 3.98 | 4.35 | 3.60 |
| MnO | 0.17 | 0.16 | 0.09 | 0.22 | 0.08 | 0.21 | 0.26 | 0.19 | 0.14 | 0.11 |
| MgO | 1.87 | 1.45 | 1.88 | 1.86 | 1.05 | 1.53 | 1.68 | 1.77 | 1.22 | 1.59 |
| CaO | 4.90 | 3.95 | 3.96 | 3.68 | 3.77 | 3.96 | 3.85 | 4.23 | 4.08 | 4.22 |
| $Na_2O$ | 3.25 | 3.55 | 3.54 | 3.87 | 3.39 | 3.56 | 3.17 | 3.23 | 3.33 | 3.44 |
| $K_2O$ | 1.78 | 2.12 | 1.89 | 2.08 | 2.52 | 2.64 | 2.41 | 2.15 | 2.51 | 2.50 |
| $TiO_2$ | 0.73 | 0.56 | 0.67 | 0.47 | 0.40 | 0.53 | 0.43 | 0.35 | 0.53 | 0.44 |
| $P_2O_5$ | 0.08 | 0.11 | 0.22 | 0.19 | 0.06 | 0.12 | 0.17 | 0.21 | 0.13 | 0.13 |
| Total | 98.12 | 99.08 | 97.18 | 97.77 | 99.93 | 98.95 | 97.90 | 97.48 | 99.27 | 98.93 |
| $Al_2O_3/SiO_2$ | 0.17 | 0.17 | 0.17 | 0.18 | 0.17 | 0.16 | 0.17 | 0.17 | 0.18 | 0.16 |
| $K_2O/Na_2O$ | 0.55 | 0.59 | 0.53 | 0.54 | 0.74 | 0.74 | 0.76 | 0.67 | 0.75 | 0.73 |
| $Na_2O/K_2O$ | 1.83 | 1.68 | 1.87 | 1.86 | 1.35 | 1.35 | 1.32 | 1.50 | 1.33 | 1.38 |
| $Al_2O_3/TiO_2$ | 16.44 | 21.43 | 17.69 | 26.59 | 31.4 | 21.23 | 28.09 | 33.91 | 23.89 | 26.29 |
| $Fe_2O_3$+MgO | 5.62 | 6.1 | 6 | 6.09 | 4.93 | 5.08 | 5.81 | 5.75 | 5.57 | 5.19 |

The $Na_2O$ and $K_2O$ contents range from 3.17-3.87% (average 3.43%) and 1.78-2.64% (average 2.26%) respectively. The MgO concentration ranges between 1.05 and 1.88%. MnO, $TiO_2$ and $P_2O_5$ contents are found in minor amounts and their concentrations range from 0.09-0.26%, 0.35-0.73% and 0.08-0.22% respectively.

Low values of $Al_2O_3/SiO_2$ ratio gives an indication of quartz enrichment in the sandstones. The higher value of $Na_2O/K_2O$ ratio than the $K_2O/Na_2O$ ratio indicates the dominance of plagioclase feldspar over the K-feldspar in the sandstones samples. The $K_2O/Al_2O_3$ ratio of sediments can be used as an indicator of source rock composition. Cox et al., (1995) suggested that the $K_2O/Al_2O_2$ ratios of clay minerals (0.0 to 0.3) and feldspar (0.3 to 0.9) are different. The $K_2O/Al_2O_2$ ratio of Tipam sandstones varies from 0.15 to 0.23 (avg. 0.19) which indicates the richness of clay minerals over K-bearing minerals such as K-feldspar and mica in the source rocks.

Using the diagram of Herron (1986) the Tipam sandstones are classified as wacke and litharenite (Fig. 2). On the bivariate plot of $Na_2O$ vs. $K_2O$ after Crook (1974), the sandstone data fall within the quartz intermediate field (Fig. 3).

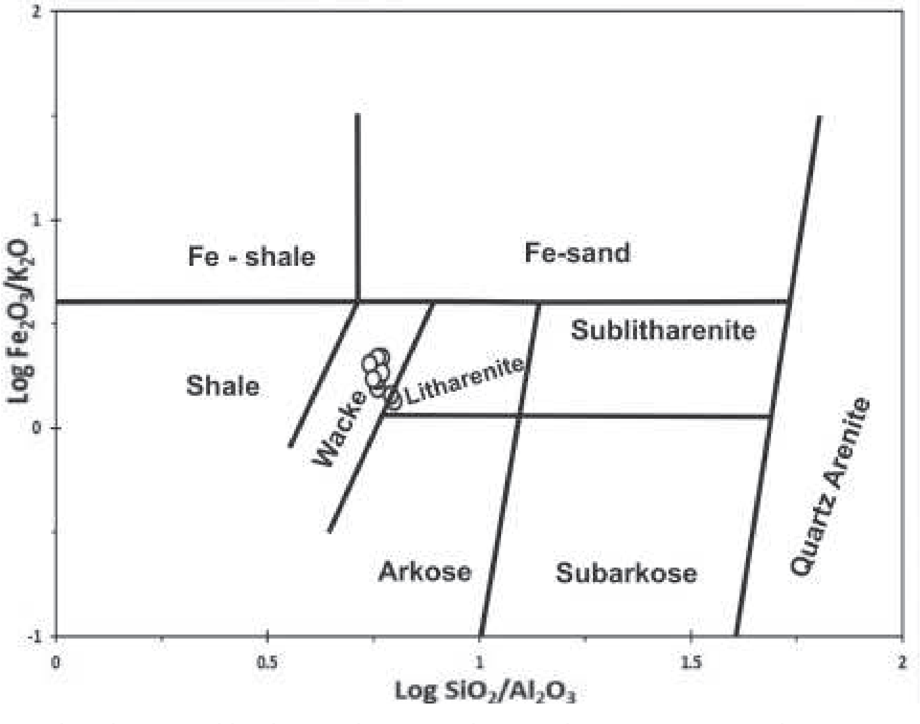

**Fig. 2.** Chemical classification of Tipam sandstones (after Herron, 1986).

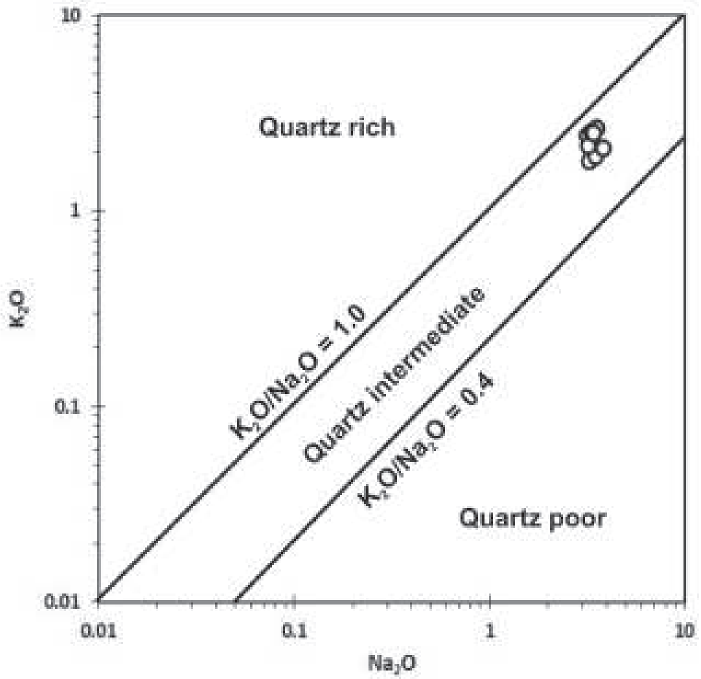

**Fig. 3.** Analysis of Tipam sandstones according to the richness of quartz content (after Crook, 1974).

## Trace and Rare earth elements (REE)

Trace and rare earth elements (REE) concentration of the sandstone samples are shown in Table 3. All the trace elements were normalized using upper continental crust (UCC) values of Taylor and McLennan, 1985 and are plotted in Fig.4.

The high values of ferromagnesian trace elements such as Cr (~148.89ppm), Ni (~111.75ppm), Co (~18.52ppm) and V (~78.80ppm) may suggest some mafic/ultramafic input of ophiolitic derivation. The samples TIP-3 & TIP-4 show very high values of Ba (3248ppm & 6742ppm respectively) and in all four sandstone samples values of Zr (avg. 33.79ppm) and Hf (avg. 0.76ppm) are somewhat depleted as compared to UCC. Ba enrichment in sedimentary rocks can be considered as an indicator of detrital flux (Nagarajan et al., 2007). The high content of Barium in Tipam sandstones indicates the presence of barite crystals of syn-sedimentary origin.

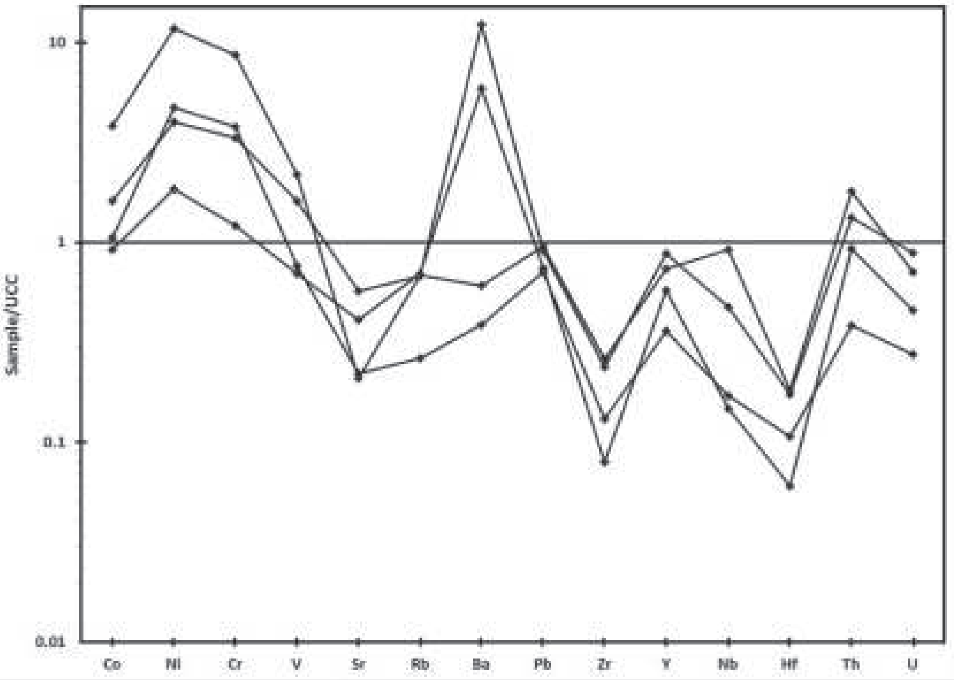

**Fig. 4.** Multi-element normalized diagram for the Tipam sandstones, normalized against upper continental crust (Taylor and McLennan, 1985).

**Table 3:** Trace and Rare earth element concentrations in ppm for Tipam sandstone Formation.

| Trace Elements and REE | TIP-1 | TIP-2 | TIP-3 | TIP-4 |
|---|---|---|---|---|
| V | 131.4 | 45.77 | 41.71 | 96.33 |
| Cr | 304.3 | 132.4 | 42.44 | 116.4 |
| Co | 38.17 | 10.59 | 9.215 | 16.09 |
| Ni | 235.4 | 94.41 | 37.06 | 80.14 |
| Cu | 56 | 19.34 | 10.3 | 26.23 |
| Zn | 107.3 | 26.65 | 23.46 | 52.59 |

(Cont...)

| | | | | |
|---|---|---|---|---|
| Ga | 20.51 | 7.739 | 9.187 | 16.65 |
| Rb | 77.08 | 29.49 | 78.36 | 76.16 |
| Sr | 73.37 | 77.77 | 143.1 | 199.2 |
| Y | 16.22 | 7.912 | 12.61 | 19.28 |
| Zr | 49.8 | 25.01 | 15.18 | 45.18 |
| Nb | 23.01 | 4.273 | 3.693 | 11.84 |
| Sc | 14.81 | 2.147 | 5.902 | 13.11 |
| Ba | 335.6 | 212.4 | 3248 | 6742 |
| Hf | 1.057 | 0.623 | 0.351 | 1.01 |
| Ta | 1.519 | 0.302 | 0.325 | 0.911 |
| Pb | 19.05 | 14.28 | 14.91 | 18.29 |
| Th | 19.32 | 4.1 | 9.908 | 14.23 |
| U | 1.997 | 0.77 | 1.284 | 2.473 |
| La | 41.39 | 10.54 | 16.12 | 28.87 |
| Ce | 90.99 | 22.97 | 32.65 | 61.39 |
| Pr | 9.948 | 2.661 | 3.628 | 6.699 |
| Nd | 38.3 | 10.69 | 13.91 | 25.98 |
| Sm | 8.794 | 2.806 | 3.485 | 6.435 |
| Eu | 2.448 | 1.049 | 2.644 | 5.063 |
| Gd | 7.037 | 2.452 | 3.092 | 5.34 |
| Tb | 0.867 | 0.348 | 0.421 | 0.728 |
| Dy | 3.86 | 1.727 | 2.24 | 3.687 |
| Ho | 0.746 | 0.342 | 0.45 | 0.809 |
| Er | 2.003 | 0.928 | 1.42 | 2.301 |
| Tm | 0.265 | 0.125 | 0.191 | 0.321 |
| Yb | 1.926 | 0.903 | 1.496 | 2.44 |

(Cont...)

| | | | | |
|---|---|---|---|---|
| Lu | 0.234 | 0.116 | 0.178 | 0.293 |
| ?REE | 208.81 | 57.66 | 81.93 | 150.36 |
| Cr/Ni | 1.29 | 1.40 | 1.15 | 1.45 |
| V/Cr | 0.43 | 0.35 | 0.98 | 0.83 |
| Ni/Co | 6.17 | 8.92 | 4.02 | 4.98 |
| Th/U | 9.68 | 5.33 | 7.72 | 5.75 |
| Rb/Sr | 1.05 | 0.38 | 0.55 | 0.38 |
| La/Sc | 2.80 | 4.91 | 2.73 | 2.20 |
| Th/Sc | 1.30 | 1.91 | 1.68 | 1.09 |
| La/Co | 1.08 | 0.99 | 1.75 | 1.79 |
| Th/Co | 0.51 | 0.39 | 1.08 | 0.88 |
| Cr/Th | 15.75 | 32.29 | 4.28 | 8.18 |
| $(La/Lu)_{cn}$ | 18.37 | 9.42 | 9.41 | 10.23 |

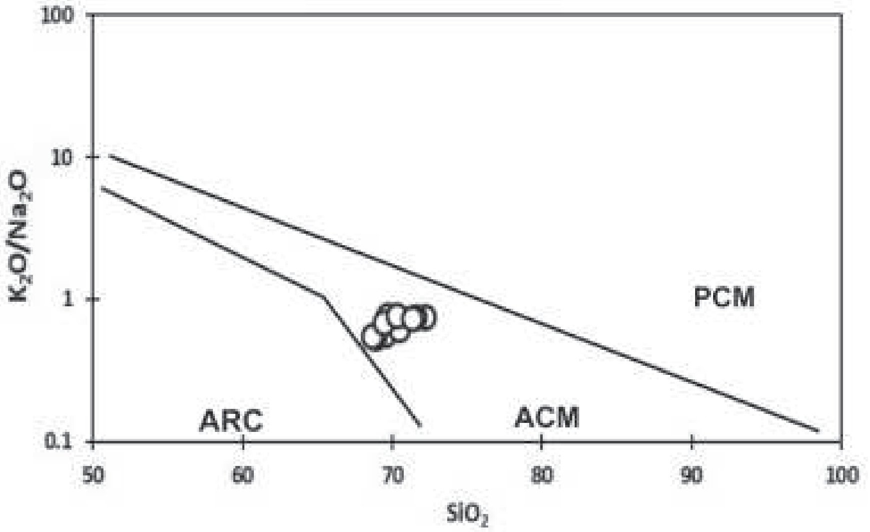

**Fig. 5.** Tectonic discrimination diagram for Tipam sandstones. Boundaries are after Roser and Korsch, 1986. PCM= passive continental margin, ACM= active continental margin, ARC= oceanic island arc margin.

## Provenance and Tectonic setting

Tectonic setting discrimination diagram on the basis of major element data were proposed by Bhatia (1983) and Roser & Korsch (1986). According to Roser and Korsch (1986) $SiO_2$ content and $K_2O/Na_2O$ ratio increases from volcanic arc to active continental margin to passive margin settings. In the diagram shown in Fig. 5, all of the Tipam sandstone samples fall in the field of active continental margin. Bhatia (1983) used different combination of major oxides for discrimination of tectonic settings of sedimentary rocks. The different fields of discrimination diagram includes A = Oceanic island arc margin; B = Continental island arc; C = Active continental margin; D = Passive margin. Most of the Tipam sandstone samples fall in the continental island arc and active continental margin fields of the $TiO_2$ versus $Fe_2O_3$ + MgO plot (Fig. 6A). All the samples also fall in the active continental margin field of the $Al_2O_3/SiO_2$ versus $Fe_2O_3$ + MgO diagram (Fig. 6B).

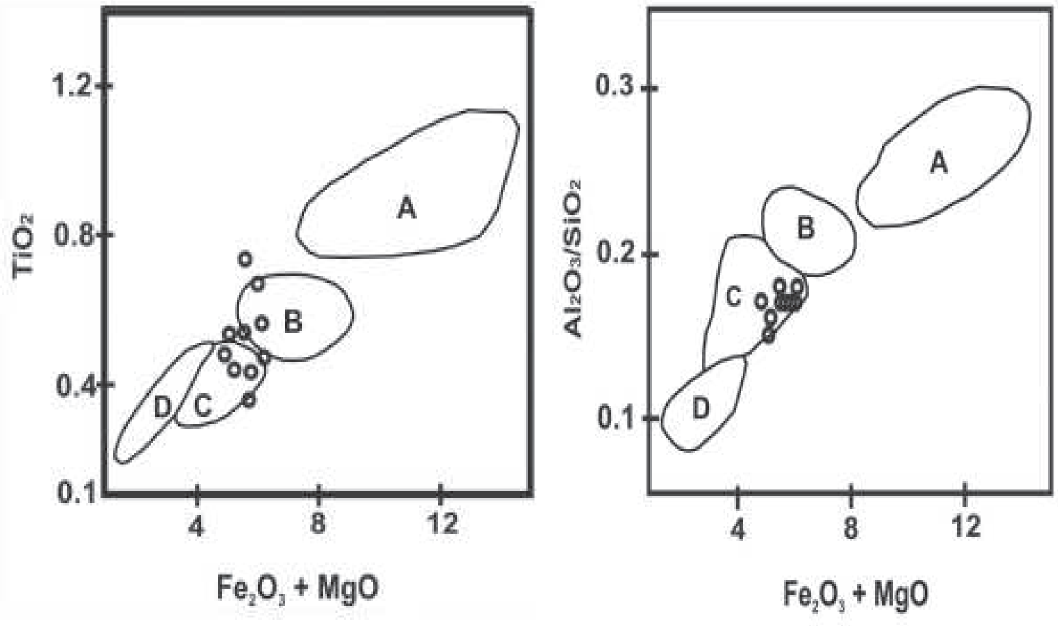

**Fig. 6.** Tectonic discrimination diagrams for Tipam sandstones (after Bhatia, 1983). (A)

Provenance analysis based on major oxides was done by different authors. Hayashi et al. (1997) suggested $Al_2O_3/TiO_2$ ratio increases from 3 to 8 for mafic igneous rocks, from 8 to 21 for intermediate rocks and from 21 to 70 for felsic igneous rocks. The value of $Al_2O_3/TiO_2$ ratio of the Tipam sandstone samples ranges from 16.44 to 33.91 (average 24.7) suggests that intermediate to felsic granitoid rocks must be the probable source rocks for them. The bivariate plot of $TiO_2$ versus $Al_2O_3$ is used to distinguish between granitic and basaltic source rocks (Amajor, 1987). In Fig. 7, the $TiO_2$ versus $Al_2O_3$ plot of Tipam sandstones indicates provenance of material from granitic source region. Roser and Korsch (1988) utilized discrimination function based on variables like $Al_2O_3$, $TiO_2$, $Fe_2O_3$ (T), MgO, CaO, $Na_2O$ and $K_2O$ contents to decipher the provenance of sediments. In discrimination diagram (Fig. 8), the Tipam sandstones fall within felsic igneous field and two samples fall within recycled mature polycyclic quartzose provenance field.

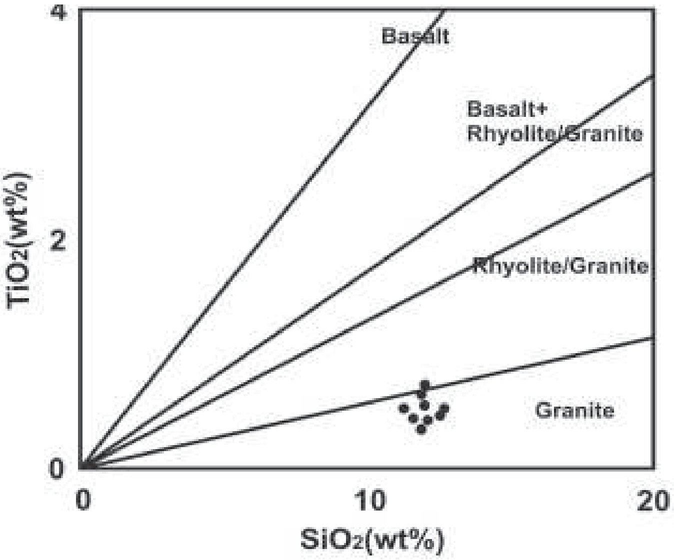

**Fig. 7.** $TiO_2/Al_2O_3$ binary plot (after Ekosse 2001)

Some authors suggested that provenance analysis based on certain trace elements and REE are most suitable because of their low mobility during transportation, diagenesis and their low residence time in sea water (e.g. Bhatia, 1983; Taylor and McLennan, 1985; Bhatia and Crook, 1986), whereas major elements are highly mobile during weathering and alteration. Trace elements like Zr, Nb, Hf, Y, Th and U (high-field-strength elements or HFSE) are found to be enriched in felsic rather than mafic sources because of their immobile nature (Feng and Kerrich, 1990). The studied sandstone samples show higher content of Nb, Y, U, Th, U with high å REE which probably reflects a felsic source with high concentration of these elements.

In the studied samples Cr (~148.89 ppm), Ni (~111.75 ppm), Co (~18.52 ppm) and V (~78.80 ppm) are enriched with respect to the average composition of the Upper Continental Crust (UCC). This enrichment may suggest some mafic/ultramafic input from the source region. Garver et al. (1996) mentioned that the high values of Cr (>150 ppm) and Ni (>100 ppm) with a ratio of Cr/Ni between 1.3-1.5 are indicative of presence of ultramafic rocks in the source. The studied Tipam sandstones have high concentration of Cr, Ni and a Cr/Ni ratio of 1.3 which implies that the existence of some mafic/ultramafic input of ophiolitic derivation from the source region cannot be ruled out completely.

Rare earth elements, Th and Sc are more abundant in felsic rocks and their weathering products than in mafic igneous source rocks, whereas Co, Sc and Cr are more common in mafic rocks and their weathering products than in felsic rocks (Cullers et al., 1979; Bhatia and Crook, 1986; Wronkiewiez and Condie 1987; Cox et

**Table 4:** Range of elemental ratios of Tipam sandstone Formation in this study compared to elemental ratios in sediments derived from felsic rocks, mafic rocks and in the Upper Continental Crust

| Elemental ratio | Tipam sandstones | Ranges in sediments from felsic sources$^1$ | Ranges in sediments from mafic sources$^1$ | Upper Continental Crust$^2$ |
|---|---|---|---|---|
| Eu/Eu* | 0.95-2.64 | 0.40-0.94 | 0.71-0.95 | 0.63 |
| $(La/Lu)_{cn}$ | 9.41-18.37 | 3.00-27.0 | 1.10-7.00 | 9.73 |
| La/Sc | 2.20-4.91 | 2.50-16.3 | 0.43-0.86 | 2.21 |
| Th/Sc | 1.09-1.91 | 0.84-20.5 | 0.05-0.22 | 0.79 |
| La/Co | 0.99-1.79 | 1.80-13.8 | 0.14-0.38 | 1.76 |
| Th/Co | 0.39-1.08 | 0.04-3.25 | 0.04-1.40 | 0.63 |
| Cr/Th | 4.28-32.29 | 4.00-15.0 | 25-500 | 7.76 |

[1] Cullers et al. (1988); Cullers (1994, 2000); Cullers and Podkovyrov (2000).

[2] McLennan (2001); Taylor and McLennan (1985).

al., 1995). The ratios such as Eu/Eu*, (La/Lu)$_{cn}$, La/Sc, Th/Sc, La/Co, Th/Co and Cr/Th are used by different authors to discriminate between mafic and felsic source of sedimentary rocks (e.g. Cullers et al., 1988; Cullers, 1994, 2000; Cullers and Podkovyrov, 2000). In the present study (La/Lu)$_{cn}$, La/Sc, Th/Sc, La/Co, Th/Co and Cr/Th values of Tipam sandstones are more similar to values for sediments derived from felsic source rocks than to those for mafic source rocks (Table 4), suggesting derivation from felsic source rock.

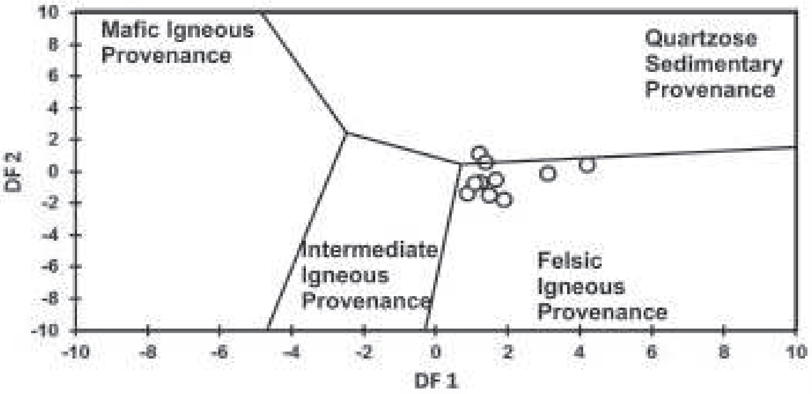

**Fig. 8.** Discrimination diagram for sedimentary provenance (after Roser and Korsch, 1988).

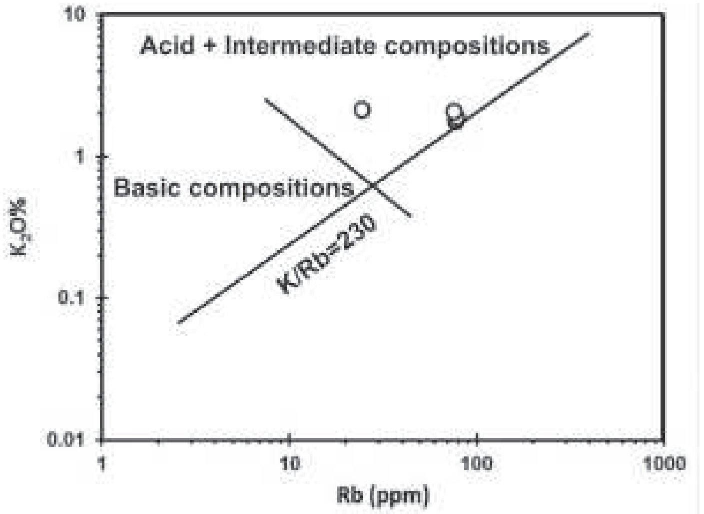

**Fig. 9.** Distribution of K and Rb in Tipam sandstones relative to a K/Rb ratio of 230 (= main trend of Shaw, 1968).

Felsic provenance of the Tipam Sandstone Formation is also supported by binary plot of $K_2O$ vs. Rb (ppm) (Fig. 9) in which samples fall within acid and intermediate composition (Shaw, 1968). In Fig. 10, the Th/Co vs. La/Sc plot after Cullers (2000) also reflects the felsic provenance. The ternary diagram of La-Th-Sc (Fig. 11) can be used to infer the provenance characteristics of sedimentary rocks. The average composition of granite, andesite and basalt (Condie, 1993) and UCC

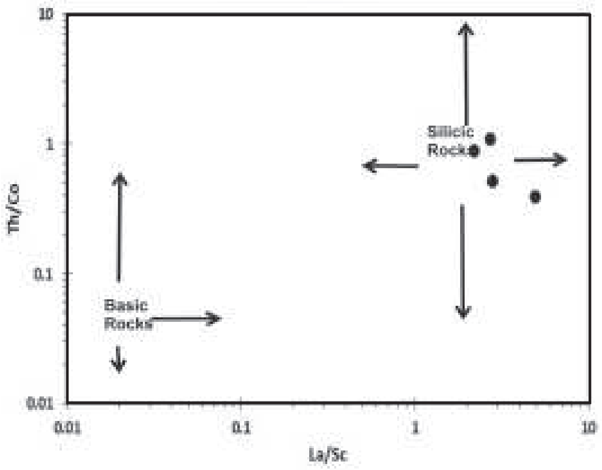

**Fig. 10.** Th/Co versus La/Sc diagram for Tipam sandstones (after Cullers, 2002).

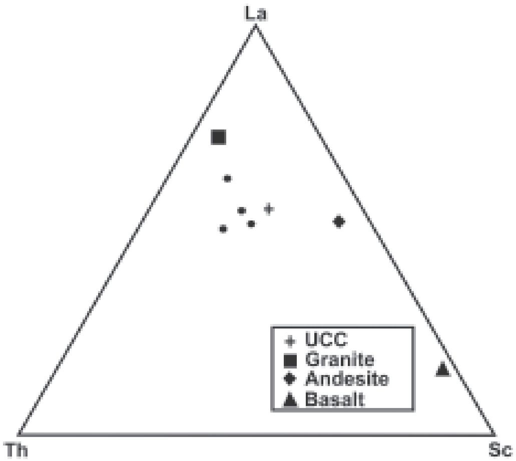

**Fig. 11.** La-Sc-Th ternary diagram for the Tipam sandstones. Values of UCC after Taylor and McLennan (1985); Granite, Andesite and Basalt are after Condie (1993).

are used in this diagram for comparison. In this diagram, the samples of Tipam sandstones plot nearer to UCC and granite composition, which suggest that these sandstones were derived probably from felsic source rocks.

The Th/Sc vs. Zr/Sc plot is used to determine the provenance, sorting and recycling of sedimentary rocks (McLennan et al., 1993). Zr/Sc ratios would increase by an addition of zircon mineral during sorting and/or recycling processes (McLennan et al., 1993). In the Th/Sc versus Zr/Sc plot trend 1 reveals the direct contribution from primary source rocks and trend 2 shows the influence of sedimentary processes. In this diagram (Fig. 12), the studied sandstones are clustered around average granodiorite and granitic composition confirming their direct derivation from igneous rocks.

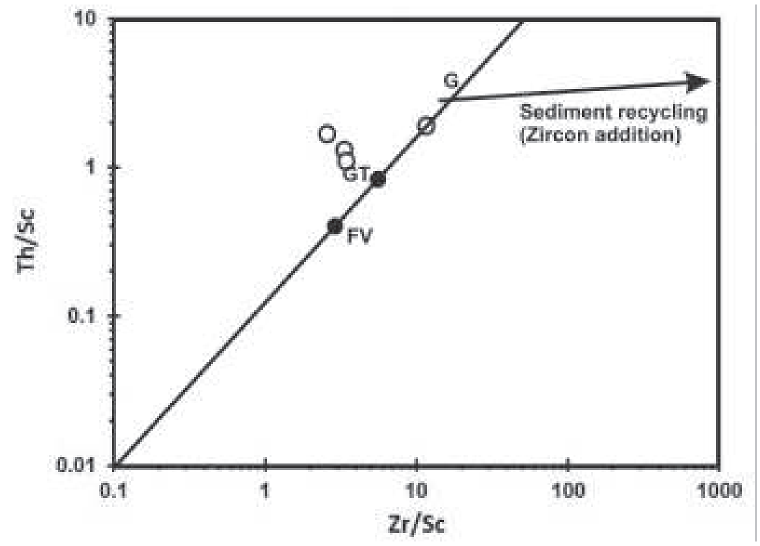

**Fig. 12.** Th/Sc-Zr/Sc diagram (McLennan et at., 1993) shows that the Tipam sandstones are cluster around average granodiorite and granite. Values of G: granite, B: basalt, GT: granodiorite and FV: felsic volcanic are after Condie (1993).

## CONCLUSIONS

Based on major element geochemistry, the Tipam sandstones are classified as wacke and litharenite with moderate SiO$_2$ contents. Tectonic discrimination diagrams suggest an active continental margin setting for these sandstones.

$(La/Lu)_{cn}$, La/Sc, Th/Sc, La/Co, Th/Co, Cr/Th ratios indicate the derivation of these sandstones from felsic source rocks. The high values of ferromagnesian trace elements like Cr, Ni, Co, V and Cr/Ni ratio (average 1.32) may reflect some mafic/ultramafic input of ophiolitic derivation. K/Rb ratio, La-Th-Sc diagram, Th/Sc versus Zr/Sc and La/Sc versus Th/Co binary plots also points towards felsic provenance of the Tipam sandstones.

Integrating the geochemical characteristics which preserve the signatures of source rock composition, it can be concluded that the Tipam Sandstone Formation is wacke and litharenite in character and it was deposited in an active continental margin and the sediments were derived from mixed sources of mostly felsic rock along with some mafic/ultramafic input of ophiolitic derivation.

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