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RESEARCH ARTICLE

Depositional Environment and Provenance of Tipam Sandstone Formation Exposed in Parts of Naga Schuppen Belt, Naga Hills, NE India

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Naga Hills, one of the seven sisters of NE India provides a unique opportunity to study Tertiary Geology. Three different morphotectonic belts of this geological terrain, i.e. Inner Fold Belt, Belt of Schuppen and the Naga Ophiolite Belts are home to the sediments of different times between Late Cretaceous to Recent. The focus of this study is situated in the Belt of Schuppen, the trust belt bounded by Naga thrust and Disang thrust. The age of the sediments of this belt is ranged from Oligocene to Recent. An economically important sedimentary unit the Tipam Group of rocks is well exposed in this belt. In this study, an approach has been made to understand the depositional environment and provenance characteristics of the Tipam Sandstone Formation of Tipam Group exposed in and around Kukidolong in Dimapur district. By the study of different facies parameters, the rocks of the study area have been divided into two lithofacies namely: Planar cross-bedded medium-grained sandstone (MSp) and Trough cross-bedded medium-grained sandstone facies (MSt). The facies characteristics and sedimentary structures observed in the area point towards a mid-channel- bar depositional system of a river as mighty as Brahmaputra. The heavy mineral assemblages found in this sandstone interpret a mixed provenance of igneous, metamorphic and sedimentary rocks .

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Introduction

Naga Hills, the northern extension of Indo–Myanmar Ranges occupies a significant part of the northeastern most of India. This NE-SW-oriented range is a museum of the Tertiary sediments as well as Mesozoic Naga Hills Ophiolites and Metasediments. Morphotectonically the range is divided into three morphotectonic belts namely, Belt of Schuppen, Inner Fold Belt and Ophiolite Belt.[1] The Belt of Schuppen is comprised of sediments ranging from Oligocene to Recent (Table 1), while the Inner Fold belt is the home of sediments ranging between the Late Cretaceous to Palaeocene ages.[2] One of the rock formations found in the Belt of Schuppen is the Tipam Sandstone Formation which belongs to the Neogene age. Besides its geological significance, the formation is important from an economic point of view as it reserves almost 90% of the total petroleum found in NE India. Lithologically the Tipam Sandstone Formation comprised of medium to coarse grained sandstone with high feldspar content. In this study, an approach has been made to understand the depositional environment and provenance characteristics of the rocks exposed in the Kukidolong area along the Dimapur–Kohima Road section (Fig. 1) .

Methodology

To understand the lithofacies Characteristics of the Tipam sandstones field studies have been

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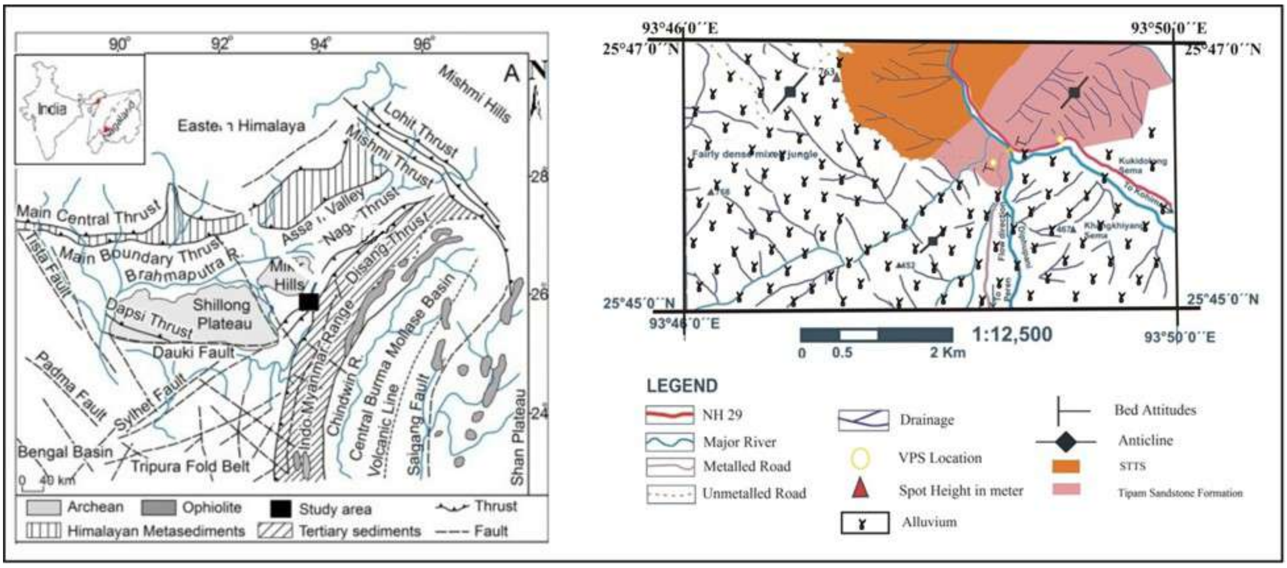

Figure 1. Location and geological map of the study area

Table 1. Tertiary succession of the outer and intermediate hills of Nagaland

Age	Group	Lithoformations	
		Outer and Intermediate Hills	
Recent - Pleistocene		Alluvium and high level terraces	
	Dihing	Boulder beds	
----Unconformity----			
Mio-Pliocene	Dupitila	Namsang Beds	
----Unconformity---			
Miocene	Tipam	Girujan Clay Tipam Sandstone	
	Surma	Upper Bhuban Lower Bhuban	
----Unconformity----			
Oligocene	Barail	Renji	Tikak Parbat
		Jenam	Baragolai
		Lai-song	Naogaon
Upper Creta-ceous - Eocene	Disang	Upper	
		Lower	
----Fault Thrust----			

carried out in terms of recording and measurements of vertical profile sections (VPS). Different lithofacies have been identified along suitable outcrops based on five parameters of facies, i.e. lithology, bed geometry, sedimentary structures, palaeocurrent direction and fossil content. Besides these, representative samples have been collected through the measured VPS for heavy minerals study to understand the provenance characteristics.

Results & Discussion

Lithofacies and Vertical profile section

Based on the different facies parameters following Mutti and Lucchi[3], Mial[4] and McCaffery & Kneller[5] the entire assemblage of Tipam Sandstone Formation of the study area has been studied through one vertical profile section and classified into two different lithofacies types namely Planar cross-bedded medium-grained sandstone facies (MSp) and Trough cross-bedded medium-grained sandstone facies (MSt). A brief description of the identified lithofacies is as follows:

Planar cross-bedded medium-grained sandstone facies (MSp)

These facies are characterized by buff to dirty white medium-grained fragile sandstone (Fig 2) and it makes the one-third thickness of the measured vertical profile section. The major sedimentary structures observed in this facies are channel lags and large-scale planar and trough cross-beddings imparting false bedded characteristics to the sandstone (Fig 3 a, b, e). The facies constitute nearly 33% of the total thickness measured. For descriptive dull

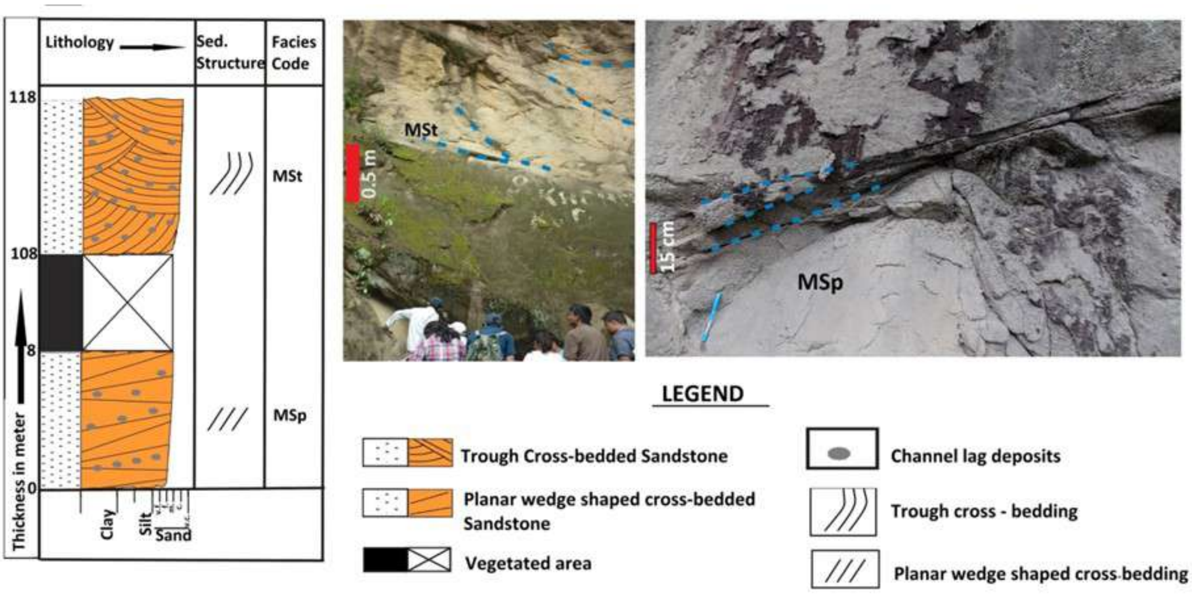

Figure 2. Vertical profile sections showing facies distribution and characteristics of Tipam Sandstone Formation of the study area

Figure 3. Planar wedge-shaped cross-bedding (a, b); large scale trough cross-bedding (c, d and red arrow marks in e) and lag deposits (blue arrow marks in e) observed in Tipam Sandstone Formation

purposes, this facies is named planar cross-bedded medium-grained sandstone facies.

Trough cross-bedded medium-grained sandstone facies (MSt)

The sandstone of this facies is characterized by a yellowish colour and it covers almost ten meters of the vertical profile section. The grains are coarser than that of MSp facies. The presence of large-scale trough cross-bedding (Fig 3 c, d) in high abundance is responsible for the frequent appearance of false beddings in these sandstones. It constitutes nearly 67% of the total thickness measured (Fig. 2). For descriptive purposes this facies may be referred to as cross-bedded medium-grained sandstone facies. The excessive development of large-scale cross-bedding (planar and trough types) in Tipam sandstone resulted in the false bedding characteristic of these massive sandstones. The huge accumulation of sand in a pattern of islands is a characteristic feature of a braided river system. These are known as Channel Islands, braid bars or channel bars which divide the channel or overhang the bottom.6 These are characterized by excessive development of large-scale planar and trough cross-beddings.

Complex interactions of sediment supply and water discharge are the main causes of braided patterns in rivers.[7] The development of different types of bars during low water discharge leads to splitting in the flow at several co-existing scales. In curved river channels, transverse bars are commonly developed and downstream they result in sand flats due to accretion.[8] Sand flats which are developed in mid-channel are called "mid-channel-bars" and those found in marginal positions are known as "side -bars".[7] Sediment accumulation on the sand flats of cross-channel bars are characterized by tabular sets of high angles cross-beddings.[8] Cross-bedding found in sand flats poses different scales, types and orientations from those of unimodal patterns generated by migration of dunes and linguiod bars (a variety of transverse bars) in the channel areas between sand flats. The shifting of channels and flats trough time results in complex finning upward cycles, the boundary between two cycles being very irregular with scour and fill structures.

A fining upward pattern of pebbly sediments overlain by sandy muddy horizons is the characteristic of braided river system deposits.[9] Ripple and mega-ripple beddings are characteristics of medium-grained sandstone units, whereas the finer ones present small ripple and partly climbing ripple laminations. Other sedimentary structures commonly found associated with the channel bar sediments are penecontemporaneous deformation structures.

The lithofacies association, sedimentary structures and other features observed in the Tipam Sandstone Formation of the study area resemble channel bar and associated deposits of the present-day Brahmaputra River as described by Colemon[10]. The Salient features of the Tipam Sandstone Formation along with its two distinct lithofacies-MSp and MSt are outlined as below:

- Presence of large-scale planar wedge cross-bedding, concentration of pebble lags along channel floor and false bedded multi-storeyed sand accumulation in lithofacies MSp.
- Occurrence of large-scale trough cross-bedding and mud drapes in lithofacies MSt.
- A distinct fining upward sequence.
- Overall sheet-like geometry of the deposit.
- Massive nature in both facies.
- Moderately sorted nature of sediments with upward improvement.
- Highly fragile nature .

Provenance characteristics of Tipam Sandstone formation

The provenance characterization concerning Neogene Tipam sandstone sediments of the study area was accomplished following the heavy mineral analysis as given by Weltje & Eynalten[11]. The sandstones yield wide varieties of heavy minerals including significant species like garnet, staurolite, kyanite, sillimanite, sphene, epidote, hornblende, humite, clinohumite, chondrodite etc. besides ultra-stable zircon, tourmaline and rutile. The abundance of blood-red rutile is more remarkable than the other varieties of the group in this sandstone. Among tourmaline varieties dark green schorelite is common. The zircons are mostly euhedral and angular in shape. Zoisite and clinozoisites are two common varieties of the epidote family in Tipam sandstones. Most of the garnets pose high angularity in shape. Chondrodite is the common member of the humite group in this sandstone. The morphology of zircon grains is a key to understanding the genesis of the source rock. The first-generation euhedral zircon grains are abundant in the Tipam Sandstone Formation (Fig 4, plate I). These euhedral and angular zircon grains are indicative of igneous sources of the sandstone.[12] The presence of colourless zircon indicates the contribution from a metamorphic source, while zoned zircons are indicative of igneous sources.[13] The opaque and non-opaque inclusions in zircons indicate metamorphic and igneous sources whereas zircons without inclusion indicate derivation from pegmatitic sources. Pettijohn et al.[14] mentioned that the bipyramidal zircon grains are derived from alkaline rocks whereas prismatic zircons are indicative of granitic sources. The sedimentary source terrain is responsible for the derivation of rounded recycled zircon grains.

The presence of blood-red, elongated rutile (Fig 4, Plate I) is an indicator of sialic igneous sources.[15] The association of staurolite (Fig 4, Plate II) with ultra -stable zircon, tourmaline (Fig 4, Plate I) and rutile suggests either recycling of preexisting matured sediments or dissolution and elimination of less stable species during diagenesis.[16] The presence of euhedral to subhedral staurolite has been attributed to metamorphic source terrain.[17] Krynine[18] suggests that the pale yellow to brown prismatic varieties of tourmaline can be related to igneous parentage. Light greenish brown tourmaline is an indicator of

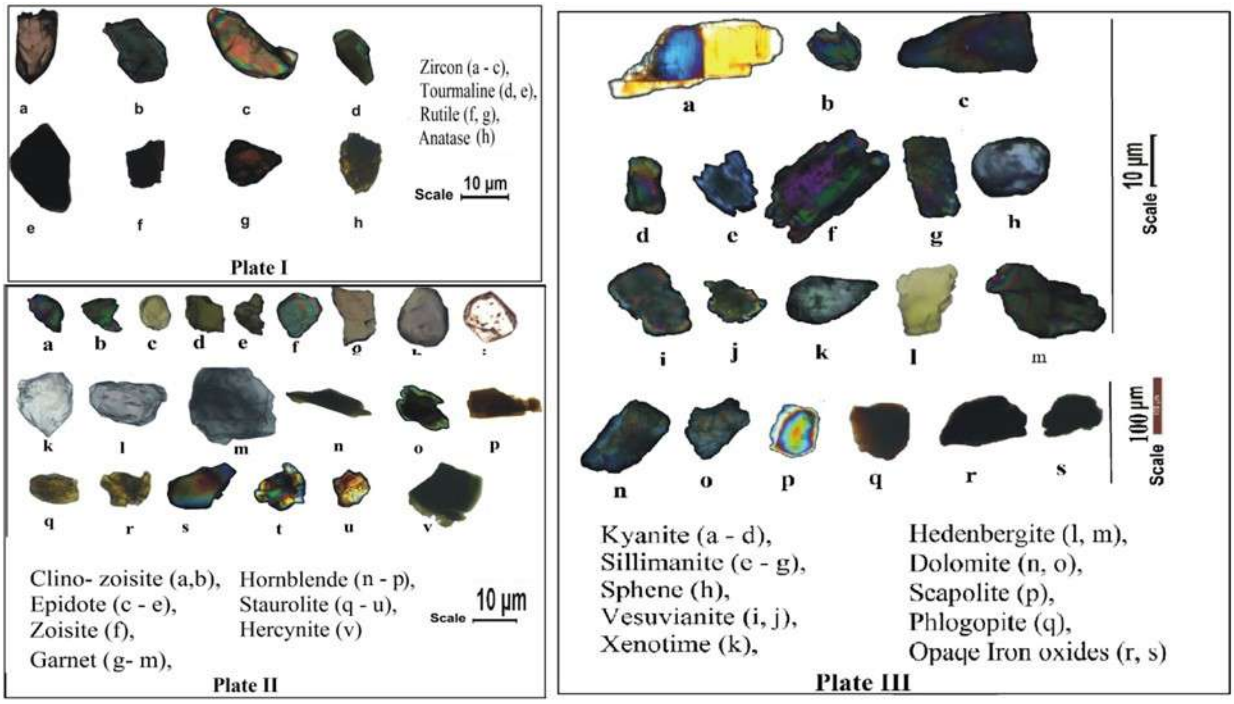

Figure 4. Showing heavy minerals observed in the Tipam Sandstone Formation of the study area in three different photo plates in different scales.

granite pegmatitic source.[19] The occurrence of pale brown and brown varieties of tourmaline has been attributed to the metamorphic source.[20] The presence of chloritoid and epidote (Fig 4, Plate II) suggests a contribution from metamorphic provenance.[21-24] The association of epidote-chloritoid- staurolite- hornblende (Fig 4, Plate II) can be related to metamorphic provenance.[16] Association of kyanite, sillimanite, hedenbergite, schorlite, anatase and garnet represents a metamorphic source terrain.

Based on occurrences of heavy minerals in the Neogene Tipam Sandstone Formation, the following five assemblages can be identified along with their source rock characteristics:

i) Humite- clinohumite- chondrodite-phlogopite- scapolite- wollastonite- sphene - tourmaline- hercynite- vesuvianite-epidote- brookite- iron oxide, which characterizes a contact dolomitic marble and scarn source rock.
ii) Zircon- tourmaline (schorlite)- sphene-hornblende- hedenbergite is an indicative of granite and granitoid source.
iii) Tourmaline (schorlite)- kyanite- sillimanite-staurolite- hornblende- hedenbergite-rutile- anatase- garnet signifies a regionally metamorphosed source terrain.
iv) Tourmaline (schorlite and dravite) - garnet-xenotime indicates pegmatitic source.
v) Rounded reworked grains of zircon-tourmaline-rutile-dolomite etc. indicate a sedimentary source terrain.

Conclusion

The Tipam sandstones of the study area have been divided into two lithofacies, namely planar bedding medium-grained sandstone facies (MSp) and trough cross-bedded medium-grained sandstone facies (MSt). The rocks of both facies are fragile and massive in nature. Large-scale planar wedge-shaped cross-bedding, channel lag deposits and mud drapes are characteristics of the MSp facies, while large-scale trough cross-bedding and mud drapes are characteristics of MSt facies. The facies association as well as the sedimentary structures observed in Tipam sandstones can be attributed to mid-channel-bar deposits of braided river systems. The huge thickness and massive nature of these mid-channel-bar deposits indicate either a palaeo-Brahmaputra River system or a river system as mighty as Brahmaputra.

The heavy mineral assemblage of the Tipam Sandstone Formation shows a cosmopolitan nature. Besides ultra-stable zircon, tourmaline and rutile it contains many other significant species such as epidote, hornblende, garnet, humite, staurolite, kyanite, sillimanite, sphene etc.. The heavy mineral assemblage of Tipam sandstones interprets a mixed contribution from igneous, metamorphic and sedimentary sources.

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