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Lithofacies analysis of Surma-Tipam Transitional Sequences in parts of Naga Hills, Northeast India: A Case Study

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Abstract: *The study area south of Chumukedima in the Dimapur district of Nagaland provides unique opportunity to study the Surma – Tipam Transitional Sequences (STTS) hitherto undocumented in Naga Hills. Study of Vertical Profile Sections documents five distinct Lithofacies, namely Sand-Sale facies (SSH), Silty Shale facies (SLS), Sandstone facies (SST), Deformed Sand-Shale facies (DSS) and Hummocky Cross-stratified sandstone facies (HCS). Spectacularly preserved sedimentary structures include lunate ripples, ripple cross-laminae, parallel laminations, flaser and lenticular beddings, interfering ripples, trough cross beddings, herringbone cross-stratifications, hummocky cross-stratifications. An attempt has been made to develope facies scheme and interpret the depositional milieu for the development of STTS. The conceptual model depicts mudflat – mixedflat – sandflat environments in an intertidal – subtidal setting intermittently influenced by strom and fluvial processes.*

Keywords: *Lithofacies, depositional environment, sedimentary structures, Surma-Tipam TransitionalSequence.*

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I. Introduction

Naga Hills - the northern extension of Indo-Burmen ranges (IBR) links Himalayan orogen to the north and Andaman – Nikobar island to the south and thus occupies a significant position in understanding the geodynamic evolution of Northeast India – a part of the Assam-Arakan basin. The first stratigraphic classification of the Tertiary sedimentary sequence exposed in the region was provided by Mallet (1876). Subsequent pioneering works of Evans (1932, 1959) as well as Mathur and Evans (1964) provided detail stratigraphic classification of the Tertiary rocks of the region which was widely accepted (Table-1). Three distinct morpho-tectonic units from west to east, i.e. the Belt of Schuppen, the Inner Fold Belt, and the Ophiolite Belt, can be identified in the region, each being unique in lithologic packaging. The Belt of Schuppen comprising the present study area and bordering Assam plains to the west provides unique opportunity to study the Miocene Surma – Tipam transition along with older Barail group of rocks and the younger Dihing and Dupitila cover. The Surma - Tipam succession possesses a heterogeneous lithology made up of shale, silt and sandstone alternations containing flaser and lenticular beddings (typically resembling the lower division of Surma , i.e. Bhuban formation) interbedded with relatively medium to coarse micaceous and feldspathic sandstone showing channeled structure (typically resembling Tipam sandstone). Both of the lithologies i.e. those resembling Bhuban formation of Surma group and those resembling Tipam Sandstone formation repeat themselves in time for more than a kilometer. It is conspicuous to note that the above lithounits frequently display pinching trend. Unlike distinct order of superposition of Surma and Tipam lithostratigraphic divisions, the lithologies resembling Surma (Bhuban Formation) and those like Tipam within Surma -Tipam Transitional Sequences (STTS) repeat themselves in cyclic manner until true Tipam sandstone is reached. In the present investigation an attempt has been made to understand the depositional environment of STTS using lithofacies analysis.

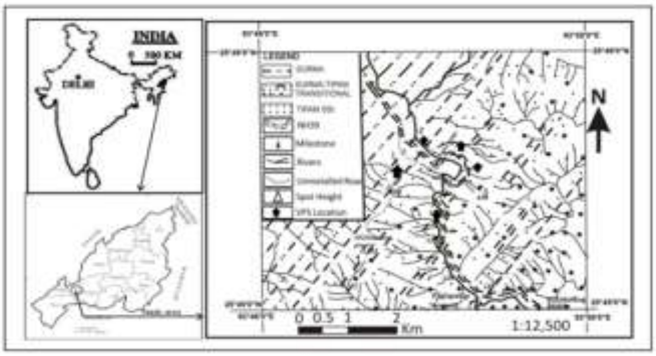
Age	Group	Litho-formations		
		Outer and Intermediate Hills		Eastern High Hills
Recent-Pleistocene		Alluvium and high level terraces		
	Dihing	Boulder beds		
------Unconformity------				
Mio-Pliocene	Dupi Tila	Namsang Beds		
------Unconformity------				
Miocene	Tipam	Girujan Clay Tipam Sandstone		
	Surma	Upper Bhuban Lower Bhuban		
------Unconformity------				
Oligocene	Barail	Renji	Tikak Parbat	Jopi / Phokphur Formation Tuffaceous shale, sandstone, greywacke, grit and conglomerate. Minor limestone and carbonaceous matter
		Jenam	Baragolai	
		Laisong	Naogaon	
Upper Cretaceous - Eocene	Disang	Upper		Shale / slate / phyllite with calcareous lenses in basal sections and invertibrate and plant fossils in upper sections with brine springs
		Lower		
------Base not seen------				

Table 1 : Tertiary succession of Naga Hills, NE Himalaya. (After Mathur and Evans, 1964)

II. Study Area

The area under study (Fig.1) falls between latitude 25^{0}45´N and 25^{0}50´N and longitude 93^{0}45´E and 93^{0}50´E of the toposheet no. 83G/13 of the Survey of India. It covers approximately 60 sq kms and includes areas lying near Chumukedima and Kukidalang villages of Dimapur district, Nagaland. The area can be approached from Dimapur, the nearest railhead and airport. The National Highway 39 passes through the middle of the study area that links Dimapur to the capital town Kohima. Chathe river, a tributary of Diphu Pani River drains across the area following NH39. The study area presents an immature topography where the altitude ranges between 205 meters and 430 meters above mean sea level. The general dip of the rocks ranges from 35° to 40° towards the SE direction.

Fig 1: location map of the study area



III. Methodology

The methodology involves measurements and description of vertical profile sections (VPS) at the suitable outcrop locations along road and river cuttings. A total of four vertical profile sections, i.e. two along the Chathe River (25^{0}47.880´N, 93^{0}47.915´E and 25^{0}47.140´N, 93^{0}48.558´E), one along the NH39 road section (25^{0}47.808´N, 93^{0}48.078´E) and one along the foot tract near the view point on the top of the Chumukedima Angami hill (25^{0}47.81´N, 93^{0}47.724´) were measured and recorded (Fig.1 & 2). The measured thickness of each VPS is more than 15 meters. All together five lithofacies were identified on the basis of five parameters, i.e. lithology, bed geometry, sedimentary structures, fossil contents and palaeocurrents. The different lithofacies identified are: Sand-Shale facies (SSH), Silty shale facies (SLS), Sandstone facies (SST), Deformed Sand-Shale facies (DSS) and Hummocky Cross-stratified facies (HCS).

Lithofacies description and interpretation

(1)Sand-Shale facies (SSH)

This lithofacies (Fig.3:b) is characterised by alternations of sand and mud units in which individual sand beds range between 2.5 to 3cms and shale beds vary between 2 to 2.5 cm., making up nearly 50-50 by volume. Wherever the shale beds overlie the sand beds, the contact between the two is always sharpe but the nature of the contact becomes erosional when sand units overlie the shale beds. The grain size of sandstone by and large is very fine to fine and shale becomes silty. The diagnostic sedimentary structures include flaser beddings, lenticular beddings (Fig.3e),wavy beddings besides ripple cross-laminations (Fig.3d), load structures (Fig.4a) and interference ripples (Fig.3:c). Preservation of ripple form laminations and translatent strata above parallel laminations (Fig.4:a) is characteristic to this facies. This facies is well developed in the northern part of the study area where it attains a total thickness of about 20 meters. Measured Palaeocurrent direction varies from 280^0N to 355^0N. A few burrow structures were also observed (Fig.4:c) in this facies.

Interpretation

Presence of parallel laminations and ripple form laminations in association with translatent strata indicates fequent changes in the energy level of the basin. The load structures represent the unstable basinal condition. The cyclic pattern of the deposition promulgates the tidal domain. The flaser beddings, wavy beddings and lenticular beddings have been interpreted as common bedding types of mixed tidal flats (Reineck 1967). The origin of these structures is often related to the alteration of tidal currents and slack water (Reineck and Singh 1972). Interfering ripple systems produced by current and wave movement are common in intertidal zone (Sengupta 2007). Ripple cross-lamination, ripple form-lamination and translatent strata are results of relatively weak hydrodynamic conditions suitable for the development of a ripple surface and where a very large amount of sand or silt is available for deposition.

(2) Silty Shale facies (SLS)

A well developed section of this facies (Fig.3:a) is observed towards the northern part of the study area located in the Chathe river bed. The total measured thickness of this facies is about 5 meters. Lithologically it comprises alternating layers of very fine grained sandstone and silty shale beds. The thickness of individual sandstone beds ranges between 3 to 3.5 cm. whereas the same of the silty-shale is approximately 12 cm., comprising nearly 25:75 percent by volume. Not much variation is observed from SSH so for sedimentary structures are cioncerned. Besides flaser and lenicular beddings the other sedimentary structures in this facies include interference ripples, parallel laminations (Fig.4:b) and load structures (Fig.4:e).

Interpretation

The assamblege of sedimentary structures found in this facies indicates almost similar processes as interpreted for SSH facies except for a relatively lower energy condition as invecised from substancial fine grain sediments.

(3) Sandstone facies (SST)

This geometrically shoestring shaped sandstone facies (Fig.3:b) is more or less available throughout the study area as repeatitive units. The lithology of this facies includes medium to fine grained isolated sandstone bodies enclosed in very thin layers of shale. The thickness of the sandstone beds varies from 40 cm. to 115 cm.. Dominating sedimentary structures in this facies are herringbone cross-stratification (Fig.4:g, Fig.5:a), ripple cross-laminations, flaser beddings, lunate ripples (Fig.3:f), trough cross-beddings (Fig.4:d) and burrows. Palaeocurrent direction varies in between 280^0N and 330^0N.

Interpretation

The presence of herringbone cross-stratification in conjugation with mud drapping along the foresets and flaser bedding suggests a tidal depositional envirnment(Ali Adnan et. al. 2014). The presence of lunate ripple as well as trough cross-bedding has been interpreted as the product of upper-lower flow regime.

(4) Deformed Sand-Shale facies (DSS)

This unique facies (Fig.4:f) is well developed in the third lithosection located in the northernpart of the staudy area where it attains a total thickness of about 2 meters. Lithologically this facies is characterised by alternating beds of fine to medium grained soft sandstone and shale beds intricately moulded into convolute laminations (Fig.4:f).

Interpretation

Convolute lamination is interpreted as an indicator of basinal shaking or local liquefaction. (Ali Adnan et. al.,2014). The compitent and incopitent alternating bed sequnces and seismic shock is considered as the responsible mechanism for the formation of the convolute lamination.

(5) Hummocky cross-stratified sandstone facies (HCS)

This facies is well exposed in the top of Chumukedima Angami Hill that is lying in the northern part of the study area. It is overlying the Sand-Mud alternating facies. The total thickness of this facies is about 4 meters. The lithology is fine to very fine grained sandstone. The major sedimentary structures found in this facies is hummocky cross-stratificaton (Fig.5:b,c).

Interpretation

Hummocky cross-stratification or truncated wave-ripple laminae apparently is formed most commonly by redeposition below normal fair-weather wave base of fine sand delivered offshore by flooding rivers and scour of shoreface or shoals by large waves (Dott and Bourgeois,1982). Hummocky stratification is the most common storm deposits (Dott and Bourgeois, 1982). Harms et. al. (1975), attributes hummocky cross-stratification to oscillatory currents associated with storm waves.Though the lensoidal geometry of the sand body indicates a fluvial depositional process but the presence of the hummocky cross-stratification reflects a clear scenery of a tidal influence while the deposition of the facies. The uncommon presence of shallow water hummocky cross-stratification in the rock record is due to their low preservation potential owing to the reworking of these beds by physical and/or biological processes after storms (Duke,1987).

Table 2: Facies Scheme

Facies name	Facies code	Lithology	Sedimentary structures	Process Interpretation
Sand-Shale Facies	SSH	Fine grained sand and shale alternation	Flaser beddings, lenticular beddings, burrows ripple cross-laminations, ripple from-laminations, translatent strata	Tidal process (mixed flat)
Silty Shale facies	SLS	Silty shale and shaly sand	Load structure, ripple cross-lamination, flaser and lenticular beddings,	Tidal process (mud flat)
Sandstone facies	SST	Fine to medium grained sandstone and thin layers of shale	Burrows, trough cross-bedding, herringbone cross-stratification, flaser bedding	Fluviotidal process (Sand flat)
Deformed Sand-Shale Facies	DSS	Shale and fine grained sand	Flaser and lenticular beddings, convolute lamination	Synsedimentary deformational process
Hummocky cross-stratified sandstone facies	HCS	Fine grained sandstone	Hummocky cross-stratification	Innerself storm processes

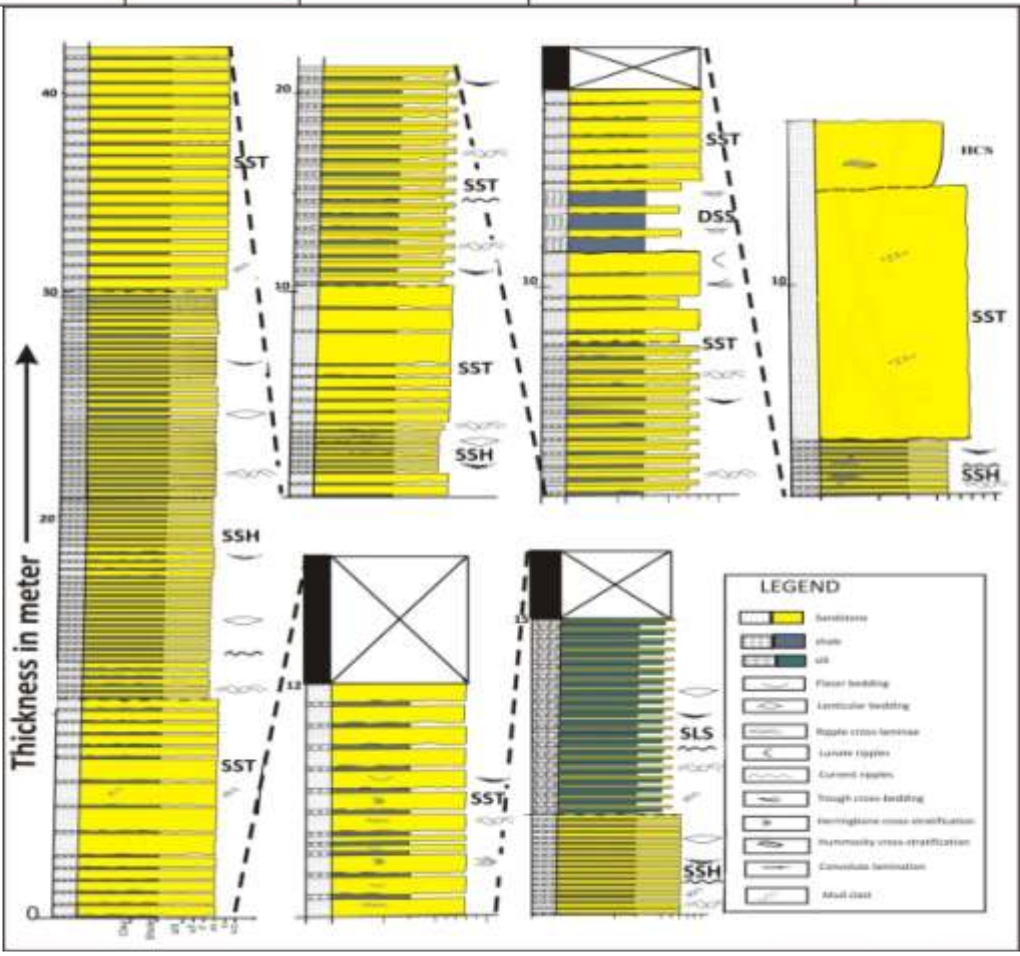


Fig.2 : Vertical profile sections showing STTS

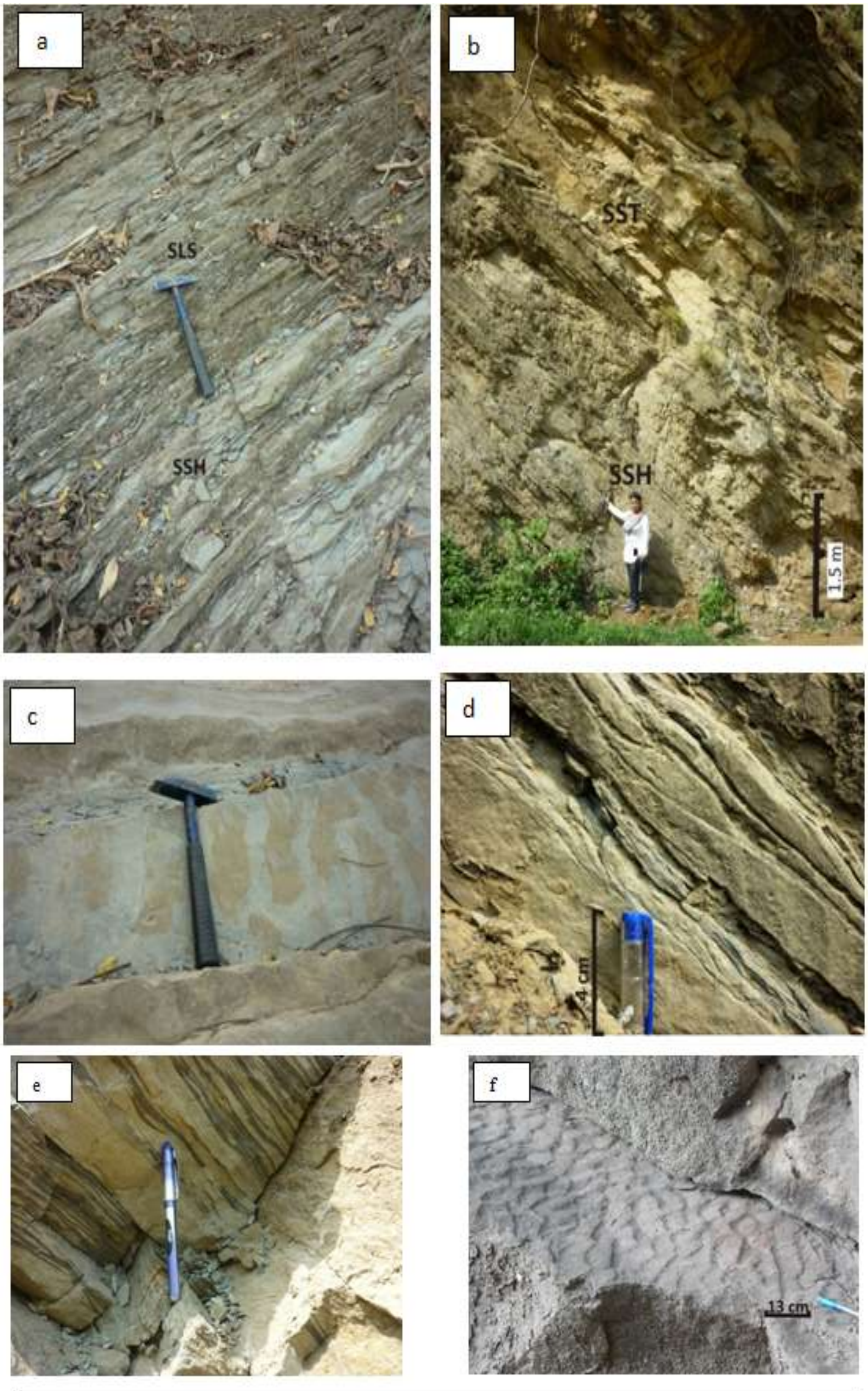


Fig.3: (a) Photograph of Silty shale facies exposed in the river bed; (b) Photograph of Sand-shale facies exposed in Patkai; (c) Interfering ripples exposed in the Chathe river bed at patkai ; (d) Ripple cross-lamination observed in the Shaly sandstone facies ; (e) flaser and lenticular beddings; (f) lunate ripples

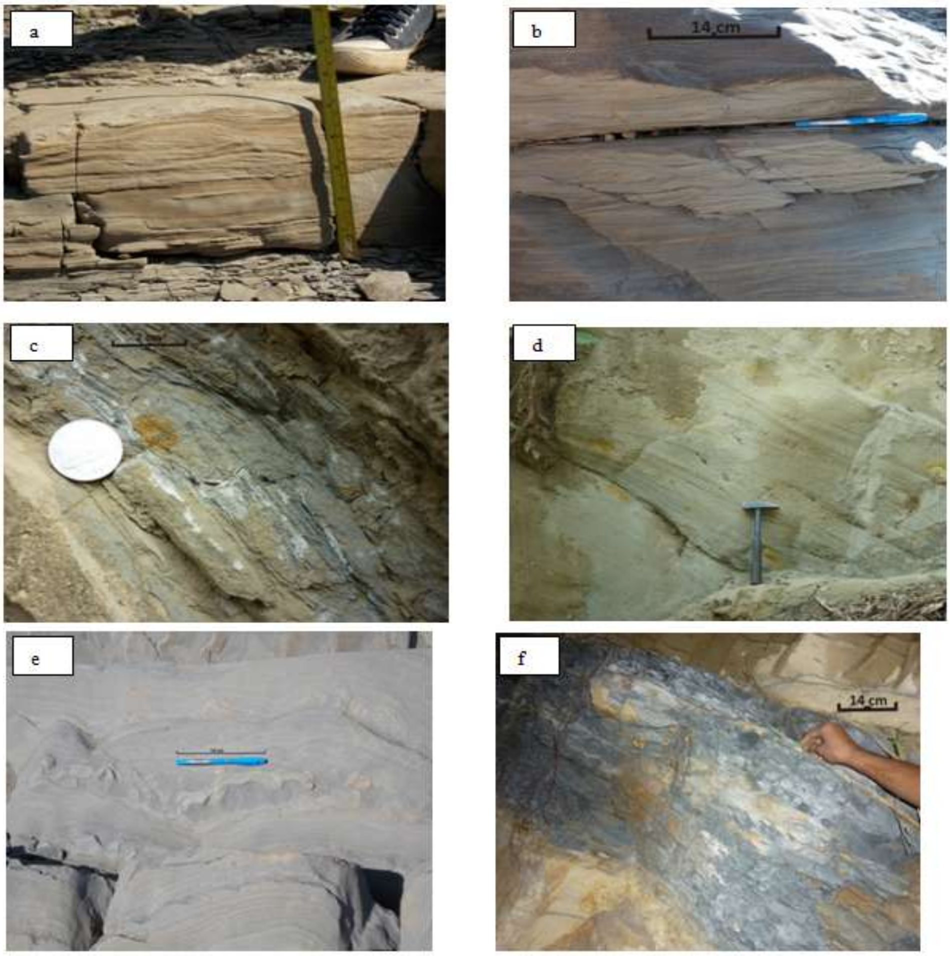


Fig.4: (a) translatent strata and ripple cross-lamination; (b) parallel laminations and ripple cross-laminations ; (c) burrows; (d) trough cross-bedding (e) convolute lamination ; (f) load structures ; (g) herringbone cross-stratification;

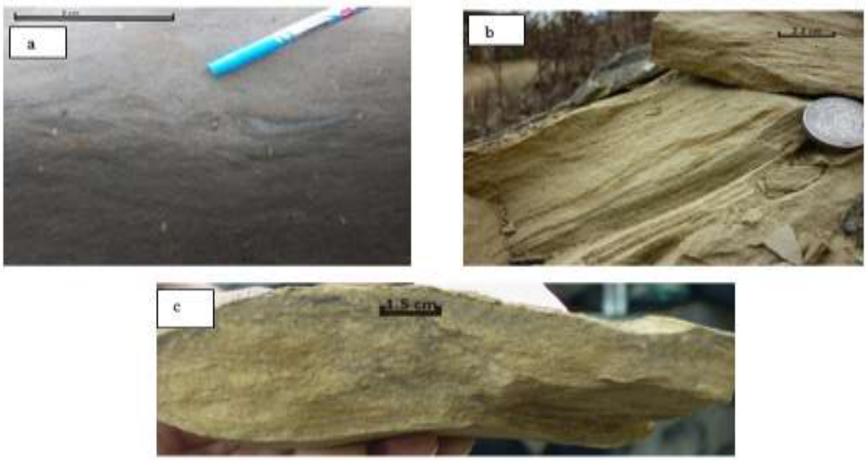
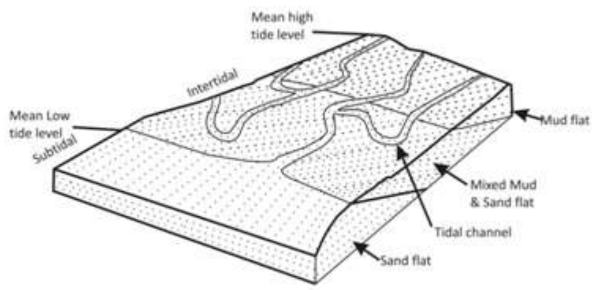


Fig.5: (a) Herringbone cross-stratification ; (b) Hummocky cross-stratification ; (c) Hummocky cross-stratification

IV. Conclusion

Study of STTS involving lithofacies analysis broadly indicates an interaction of tidal and fluvial regimes through time. Presence of flaser and lenticular beddings in Silty shale (SLS) and Sand-Shale (SSH) lithofacies point towards mixed flat of intertidal zone (Reineck, 1967). Preservation of climbing ripple in association with horizontal lamination, translatent strata and ripple form-laminations indicates surplus supply of sand in a fluctuating energy condition. Presence of lunate ripple, large scale trough cross-bedding and hummocky cross-stratification together with thick channeled sandstones belonging to SST lithofacies further indicates a sand flat environment. Further, sedimentary structures like convolute lamination and load structures are significant indicators of prevailing basinal instability during the deposition. In addition, presence of hummocky cross-stratification depicts storm event during the development of STTS, the depositional milieu being mudflat – mixedflat – sandflat in an intertidal – subtidal setting intermittently influenced by fluvial processes. A conceptual model for the deposition of STTS is shown in Fig. 5.

Fig. 5: Schematic depositional model for the Surma-Tipam Transitional Sequence in Chumukedima area showing domains of sedimentation in mixed flat and sand flat in itertidal zone



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