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Magnetostratigraphy of a Part of Middle Bhuban Sequence (Surma Group), Aizawl, Mizoram

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Abstract: A 560 m thick rock succession of Middle Bhuban Formation (Surma Group) exposed between Bawngkawn and Durtlang, Aizawl, Mizoram has been studied for its magnetostratigraphic attributes. A total of 7 normal and 7 reverse magneto-zones have been delineated in this section. The GPTS correlated ages of this section lie between ~21.77 Ma (at the base) to ~15.16 Ma (at the top) with a total duration of ~ 6.6 Ma. The GPTS event C6n occurring at the stratigraphic level between 146m to 266 m may be considered for basin wide correlation as it is the longest normal event that has been recorded with greater confidence *i. e.* better alpha- 95. The average sediment accumulation rate (SAR) estimated for this section is 8.48 cm/Ka. Overall the SAR is higher in the lower part of the section with a spike of 26.8 cm/Ka at <21 Ma. The decrease in SAR to 2.1 cm/Ka at around 18 Ma in the upper part of the section may be investigated for possible hiatus.

Keywords: Magnetostratigraphy, Sediment Accumulation Rate (SAR), Surma Group, Middle Bhuban Formation, Aizawl, Mizoram.

INTRODUCTION

The Assam-Arakan basin in the northeastern region of India (22º-28º N: 90º-96º E) is one of the largest sedimentary basins on land. This basin has nearly 13 km thick Mesozoic and Cenozoic sediments. The latter covers about 70% of the area of northeast. The basin occupies special significance in Indian Geology in terms of its tectonic evolution, and is well known for its oil and gas resources all over the world. A proper understanding of the evolution of this basin primarily requires the establishment of high-resolution stratigraphy and correlation of the exposed sequences within the basin. The sedimentary sequences of the basin are characterized by two distinct facies – the shelf and the basinal -, which are more conspicuous in the Palaeogene succession than in the Neogene one. The rocks of the shelf facies are exposed in the Garo Hills, Khasi-Jaintia Hills, parts of North Cachar and Mikir Hills and also in the subsurface below the alluvium of Upper Assam. The sedimentary rocks representing the basinal facies are developed in the Naga Hills, parts of North Cachar Hills, Manipur, Surma Valley of South Cachar, Tripura and Mizoram. Sufficient faunal control and distinctive rock types characterize the shelf deposits. These have yielded foraminifers and other microfossils that are excellent time indicators and are helpful in resolving stratigraphic problems. Hence, regional stratigraphy of shelf facies rocks has been fairly well established. Basinal sediments, on the other hand, lack reliable criteria of stratigraphic correlation, such as age-diagnostic fauna and marker horizons. Moreover, they show limited variety of rock types and widespread lateral litho-facies variations. Hence, the regional stratigraphy of these sediments is yet to be established (Ganguly, 1993).

Since magnetic stratigraphy is independent of such limitations, it may provide a robust tool for stratigraphic correlation. Moreover, magnetostratigraphy has been successfully used throughout the globe in varied depositional environments for stratigraphic correlation (Opdyke and Channel, 1996; Harsland et al. 1990). Magnetic polarity is independent of lithogenic constraints such as lateral lithofacies variations, permitting a good correlation amongst the Cenozoic successions of the Himalayan foreland belt. For over last two decades, magnetostratigraphy has been used to provide time constraints to the long continental sequences throughout the Himalayan foreland basin from Pakistan to India to Nepal (Tauxe and Opdyke, 1982; Raynold and Johnson, 1985; Appel et al. 1991; Tandon, 1991; Tandon et al. 1984; Johnson et al. 1985; Ranga Rao, 1993; Burbank et al. 1996; Brozovik and Burbank, 2000; Kotlia, et al. 2002; Sangode et al. 1996, 1999; Sangode and Kumar, 2003; Sangode and Bloemendal, 2004). This is more so for the sequences having high rate of sedimentation without major hiatuses as this allows the preservation of uninterrupted magneto-zone records. Hence, an attempt has been made to initiate magnetostratigraphic investigation in the Surma Basin of Northeastern region. A section along Bawngkawn – Durtlang road, north of Aizawl town, Mizoram (Fig.1) that exposes 560 m thick sequence of Middle Bhuban sediments (Bhuban Formation) of the Surma Group is selected for this purpose. This is the first attempt on the magnetostratigraphic aspects of the Neogene succession of the entire northeastern region.

STUDY AREA

Mizoram is the easternmost state of India. It covers an area of about 21,081 sq. km between latitudes 22°00' and 24°30'N and longitudes 92°15' and 93°25'E. The studied Bawngkawn-Durtlang section (Fig. 1) lies north of Aizawl along the NH 54 that connects Aizawl, the capital town of Mizoram with Silchar (Assam).

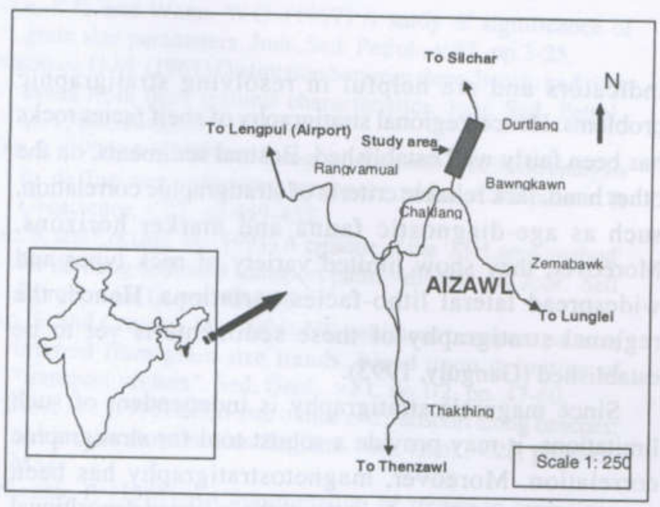

Fig.1. Location map of study area.

GEOLOGY OF THE STUDY AREA

Geologically, Mizoram is a part of the Neogene Surma Basin comprising a belt of elongated folds having sub-meridional trend and arcuate shape with westward convexity. The fold belt is elongated in the N-S direction almost parallel to the suture zone of the Arakan-Yoma subduction (Karunakaran, 1974; Ganguly, 1975, 1983; Nandi, 1982; Nandy et al. 1983).

The sedimentary succession of the Surma Group (Lower to Middle Miocene) is very well developed in the state. This group covers about 75% of the territory of the state. The stratigraphic succession of the state is given in Table 1. Surma Group has been divided into a lower Bhuban Subgroup and an upper Boka Bil Subgroup. Bhuban Subgroup is further divisible into Lower, Middle and Upper Bhuban Formations.

Proposed by Evans (1964), this classification of Surma Group is purely based on Sand-Shale ratio. However, Surma sequence shows widespread litho-facies variations, is traversed by numerous transverse faults, and lacks distinctive rock types (these being admixtures of sandstones and shales) and age-diagnostic fossils. Although, a large number of mega-biota, mainly bivalves, and a few foraminifers have been reported from the Surma Group of Mizoram (Jauhri et al. 2003; Mehrotra et al. 2001, 2003; Tiwari, 2001; Tiwari and Bannikov, 2001; Tiwari and Kachhara, 2001, 2003; Tiwari and Mehrotra, 2000, 2002; Tiwari et al. 1997, 1998), most of these are long-ranging and are not of much biostratigraphic significance. Hence, solely based on lithological consideration, it becomes difficult to identify isolated outcrops of different units and correlate them. Magnetostratigraphic inferences, coupled with litho- and biostratigraphic ones may play decisive role in solving these issues.

LITHOSTRATIGRAPHY OF BAWNGKAWN-DURTLANG SECTION

Geologically, the Bawngkawn-Durtlang section belongs to the Middle Bhuban Formation of the Bhuban Subgroup, Surma Group (Lower Miocene - Middle Miocene age). This section exposes 560 m thick succession of Middle Bhuban Formation. Altogether, Nineteen beds have been delineated along this section (Fig. 2). The rock types exposed in the section are siltstone-shale alternation, sandstone-siltstone alternation, thinly laminated shale- sandstone alternation, sandstone-shale alternation, thickly bedded sandstone, silty sandstone, massive yellow and grey sandstone, sandstone with thin shaly intercalation, sandstone with thin shale partings and splintery shales. The sandstones are grey to brown and yellowish in colour, fine to medium grained, occasionally massive, compact, micaceous, relatively hard with cementing material of varying composition, viz. calcareous, siliceous and ferruginous. The shales are grey to brown in colour, micaceous, thinly laminated and occasionally clayey and splintery. The siltstones are also grey to brown in colour, fine to medium grained and micaceous. The trend of the beds here is NNW with dip up

Table 1. Stratigraphic succession in Mizoram (*after* Karunakaran, 1974; Ganju, 1975)

Age	Group	Subgroup	Formation	Generalized Lithology
Recent	Alluvium			Silt, clay and gravel
-Unconformity-				
Early Pliocene to Late Miocene	Tipam (+900 m)			Friable sandstone with occasional clay bands
-Conformable and transitional contact-				
Miocene to Upper Oligocene	SURMA (+5950 m)		Boka Bil (+950 m)	Shale, siltstone and sandstone
			-Conformable and transitional contact-	
		BHUBAN	Upper Bhuban (+1100 m)	Arenaceous predominating with sandstone, shale and siltstone.
			-Conformable and transitional contact-	
			Middle Bhuban (+3000 m)	Argillaceous predominating with shale, siltstone-shale alternations and sandstone
			-Conformable and transitional contact-	
			Lower Bhuban (+900 m)	Arenaceous predominating with sandstone and silty-shale
-Unconformity obliterated by faults-				
Oligocene	Barail (+3000 m)			Shale, siltstone and sandstone
-Lower contact not seen-				

to 22° due ENE. Several east-west trending shear zones that are 20 cm to 1.6 m wide traverse these beds. The top 2-6 cm of bed no. 10, i.e. massive brown sandstone, is fossiliferous and it yields fragmentary remains of pectinid bivalves. Bed no. 17 (sandstone with thin shale partings) at stratigraphic level 450 m is also fossiliferous and yields unidentifiable plant remains, probably leaves and seeds.

METHOD OF STUDY

Oriented block samples using standard palaeomagnetic methods (Collinson, 1983) were collected from 50 sites in the Bawngkawn-Durtlang section. Preference was given to obtain the palaeomagnetic samples from fine-grained sandstones and siltstones to avail stable results from the magnetic grain size in single domain range (0.03 to 0.08 microns). The samples were re-aligned to its field positions and drilled vertically to get 2.5 cm dia x 2.2 cm height cylindrical specimens. A total of 19 representative specimens from this section were finally selected for the rock magnetic studies to understand the magnetic mineralogy of the Middle Bhuban rocks. Isothermal Remanent Magnetization (IRM) and Anhysteretic Remanent Magnetization (ARM) experiments were performed using an Impulse Magnetizer and ARM attachment to alternating field demagnetizer. Magnetic susceptibility was measured in AGICO KLY-3S sensor and the frequency-dependence of magnetic susceptibility was measured using the dual frequency (0.47 kHz and 4.7 kHz) Bartington Instruments MS2B sensor. IRM's were imparted and measured at the following steps: 100, 300, 500, 800, 1000 mT forward and -20, -40, -50, -100, -300 mT backfield. Coercivity B_{0CR} of these samples exclusively vary in between 32 to 42 mT with rare values of 27 mT, indicating predominantly PSD-SD ferromagnetic mineralogy. The volume susceptibility of these samples varies from 11 to 32 x 10^{-11} m^3/kg.

Based upon the above rock magnetic information, further pilot demagnetization studies were conducted using thermal and alternating field demagnetization methods. Pilot demagnetization study was made in order to:

1) understand the remanent component assemblage,
2) study the changes in the vector direction during demagnetization, and
3) monitor the intensity decay and change in the initial magnetic susceptibilities for identification of Characteristic Remanent Magnetization (ChRM).

The partial thermal demagnetization was carried out in four batches of 10 specimens each at the temperature intervals of 100, 200, 300, 400, 450, 500, 550, 575, 600, 650, 675 and 700°C with NRM measurement and magnetic

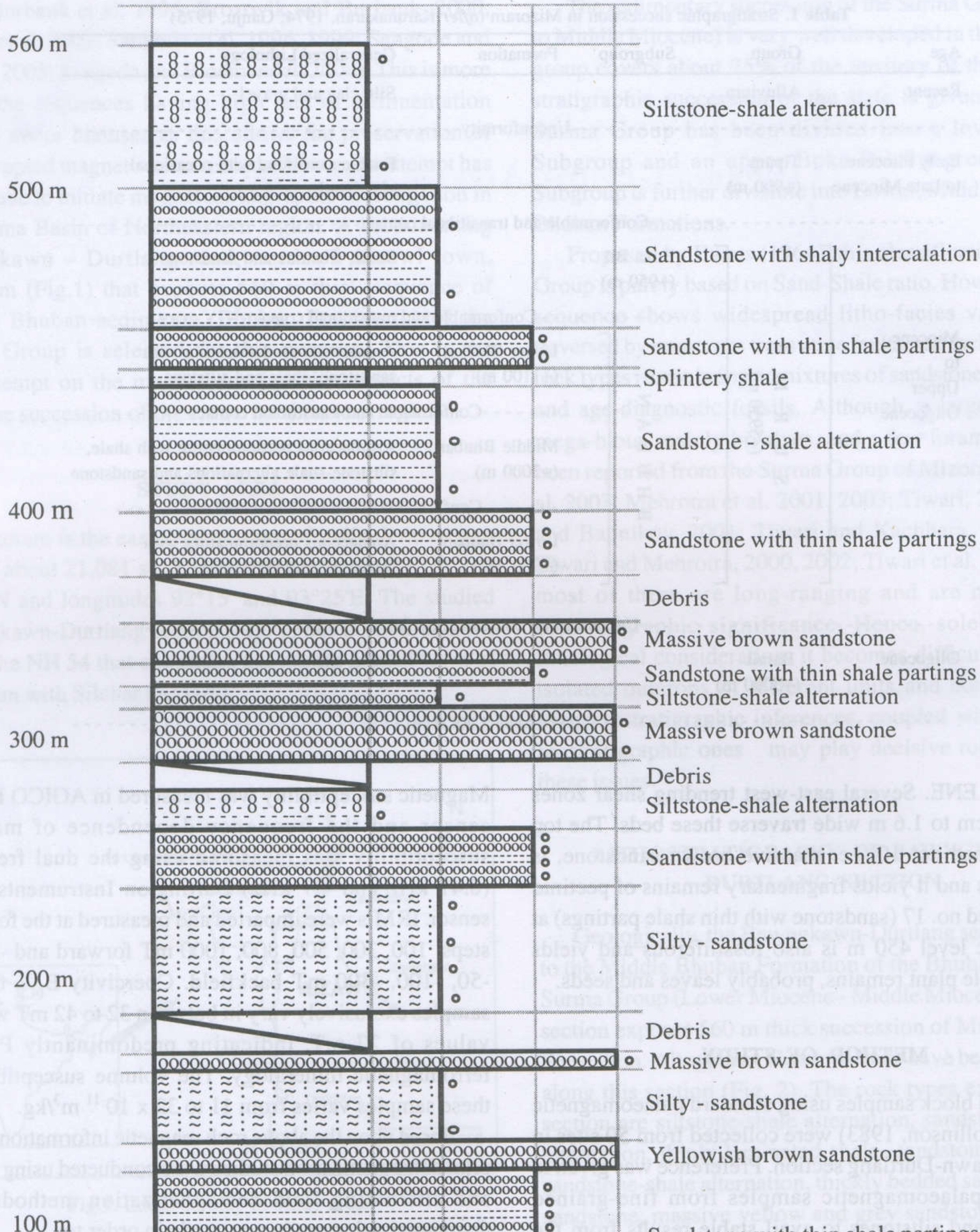

Fig.2. Litholog of Middle Bhuban exposed along Bawngkawn-Durtlang section. O=sample positions in ascending order beginning from the bottom of the section.

susceptibility monitoring at each step. Progressive thermal demagnetization was carried out using Magnon International TD-800 thermal demagnetizer and Schonstedt Digital Spinner Magnetometer (DSM-2). After demagnetizing at any particular temperature the samples were cooled to room temperature in the near zero magnetic field (~5 nT) of the demagnetizer and were immediately analyzed in the DSM-2 to find out the D, I and intensity of the NRMs.

Similarly alternating field demagnetization studies were carried out at the steps of 10, 20, 30, 40, 50, 60, 70 and 100 mT. Results of the partial thermal and alternating field demagnetizations are plotted as the Vector End Point diagrams (VEP)/Zijderveld diagrams. The VEP plot displays both the direction and the intensity of the NRM. The trajectory of the magnetic vector in the VEP reflects the changes in Declination (D), Inclination (I) and intensity during demagnetization with removal of successive harder components. All the VEPs are displayed on two orthogonal planes i.e. solid circles on to the horizontal plane and the open circles on to the vertical plane.

RESULTS AND DISCUSSION

Magnetic Polarity Reconstruction

The site mean direction (after bedding/tilt correction), resultant vector (R), precision parameter (k), angular dispersion (s), confidence limit (α-95) for each bed was calculated using derivatives given in Butler (1992, 1993 and 1998). Finally, the VGP latitude of each horizon is plotted against the measured litho-column to reconstruct the local magnetic reversal pattern (see Fig. 3). The positive and negative values of the VGP latitude indicate respective normal and reverse polarity of the geomagnetic field. These magnetic reversals are correlated with Geomagnetic Polarity Time Scale (GPTS) of Cande and Kent (1995) based upon iterative matching of the local polarity pattern with the GPTS. A total of 7 normal and 7 reverse magneto-zones are obtained for the Bawngkawn – Durtlang section (see Fig. 3.3). These match fairly well with the corresponding magneto-zones available on GPTS. Thus, the GPTS correlated ages of this section falls between ~21.77 Ma (at the base) to ~15.16 Ma (at the top). It estimates a total 6.6 Ma duration for the accumulation of 560 m thick sedimentary pile in this section. After the final correlation the seven normal polarity events are given in Table 2.

It is evident from the above that the longest normal event recorded with greater confidence (better alpha-95) prominently occurring as C6n at stratigraphic level between 146 m to 266 m may be considered for basin wide correlation. The low densities of the sampling sites, larger alpha- 95 and intermediate VGPs necessitates further detailed sampling from 466 m onwards in the section.

Table 2. Normal polarity events

Sl. No.	GPTS Events	Duration (Ma)	Stratigraphic level (m)
1	Top of C6AAn	21.768	4
2	C6An.2n	21.320 – 20.996	14 to 45
3	C6An. In	20.725 – 20.518	93.5 to 112
4	C6n	20.131 – 19.048	146 to 266
5	C5En	18.781 – 18.281	289 to 306
6	C5Dn	17.615 – 17.277	320 to 340
7	C5Cn	16.726 – 16.014	377 to 466

The zero stratigraphic level of this section corresponds with the base of foraminiferal zone N 5 and 560 m level with that of the top of N 8. On comparison with the Nanno zones, the zero level of the studied section starts with the lower part of NN 2 and the top of the section with the top of NN 5 (see Fig. 3). Thus the studied section may be assigned to Early Miocene - lower part of Middle Miocene.

Sediment Accumulation Rates (SAR)

Sediments accumulation rates in cm/Ka have been estimated from the duration of the events (fourteen in number- seven normal and seven reverse) obtained from the GPTS and the sediments accumulated during the corresponding events obtained from the MPTS of the Bawngkawn – Durtlang section. These data are plotted to obtain SAR curve (see Fig. 4). The average sediment accumulation rate for this section is 8.48 cm/Ka. An account of the variation in the rate of sedimentation are given in Table 3. Overall, the SAR is higher in the

Table 3. Estimate of sedimentation rate using magnetostratigraphic ages from the Bawngkawn-Durtlang section

Events	Duration (Ma)	Thickness (m)	Rate (cm/ka)
C6Aan	0.091	4	4.4
C6Aan-C6An.2n	0.448	10	2.23
C6An.2n	0.324	31	9.6
C6An.2n-C6An.1n	0.181	48.5	26.8
C6An.1n	0.207	18.5	8.94
C6An.1n-C6n	0.387	34	8.8
C6n	1.083	120	11.08
C6n-C5En	0.267	23	8.6
C5En	0.5	17	3.4
C5En-C5Dn	0.666	14	2.1
C5Dn	0.338	20	5.91
C5Dn-C5Cn	0.551	37	6.71
C5Cn	0.712	89	12.5
C5Cn-C5Bn.2n	0.859	94	11

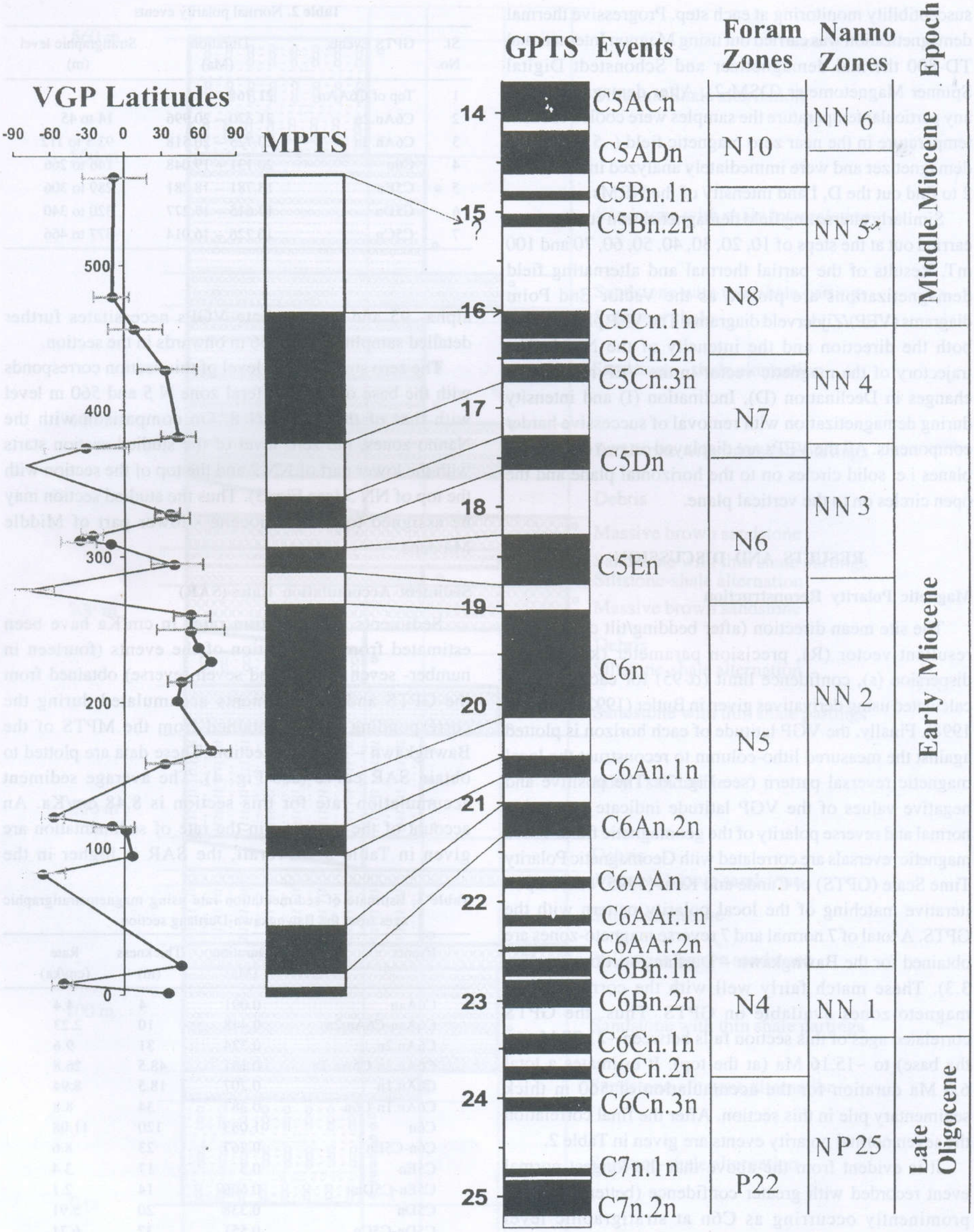

Fig.3. VGP latitudes and magnetic polarity correlation to GPTS (Cande and Kent, 1995), Foram and Nanno zones for the Bawngkawn-Durtlang section (Aizawl).

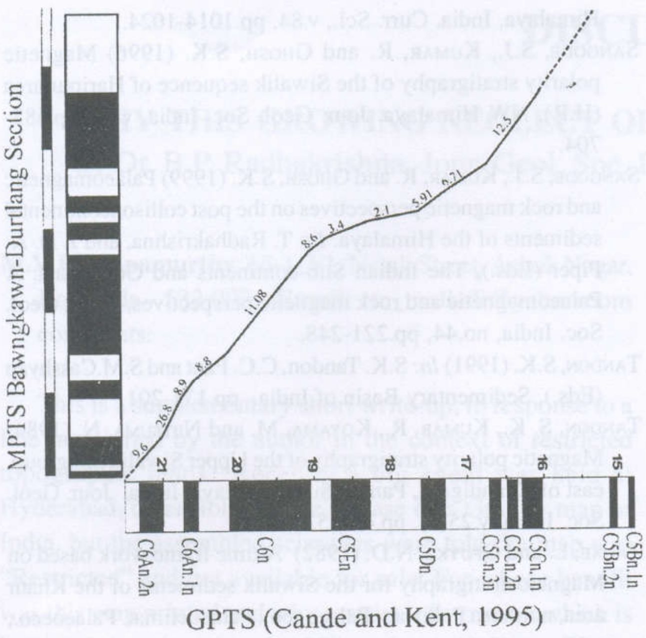

Fig.4. Estimated rate of sedimentation in the Bawngkawn-Durtlang section (Middle Bhuban, Surma Group), Aizawl, Mizoram. Number shown on the curve are rate in cm/ka.

lower part of the section with a spike of 26.8 cm/Ka at <21 Ma. There is a drop in SAR (2.1 cm/Ka) around 18 Ma that gradually reaches to 12.5 cm/Ka at around 17 Ma. This drop in SAR to 2.1 cm/Ka at 18 Ma needs to be investigated for possible hiatus. Since there is no control of reversal after 16 Ma the preceding rate has been extrapolated to the top of the section (at 560 m) to get an approximate age of > 15.16 Ma.

CONCLUSIONS

A total of 7 normal and 7 reverse magneto-zones are delineated within 560 m thick Middle Bhuban succession exposed along Bawngkawn – Durtlang section, Aizawl, Mizoram. These match fairly well with the corresponding magneto-zones available on GPTS. The GPTS correlated ages of the Bawngkawn - Durtlang section falls between ~21.77 Ma (at the base) to ~15.16 Ma (at the top). A total of 6.6 Ma duration has been estimated for the accumulation of 560 m thick sedimentary pile in this section. The longest normal event recorded with greater confidence (better alpha- 95) prominently occurring as C6n may be considered for basin wide correlation.

The average sediment accumulation rate for this section is 8.48 cm/Ka. Overall, the SAR is higher in the lower part of the section with a spike of 26.8 cm/Ka at <21 Ma. There is a drop in SAR (2.1 cm/Ka) around 18 Ma that gradually reaches to 12.5 cm/Ka at around 17 Ma. This drop in SAR needs to be investigated for possible hiatus. The deposits of the Middle Bhuban marine sequence show sedimentation rate between ~ 2.1 – ~ 26.8 cm/Ka) without major hiatuses. This might have permitted the preservation of uninterrupted magneto-zone records. Therefore magnetic polarity stratigraphy of Cenozoic succession of northeastern region may form a robust tool for its correlation.

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