PREFACE

It so happened one day, by coincidence, that I met my old college friends inside the campus of Manipur University, Canchipur. I visited the campus for a private matter while the other friends had a common purpose. They came to submit their names for a Refresher Course. I felt a little awkward for being uninformative about the course. But I have had many excuses since I was working at a private college which was located in a remote area of the state. Somehow, they were positive with me sympathetically, and they could manage everything for my admission to that Refresher Course. During that time, I had been deviated a little away from my field of study, being compelled to teach mathematics as a major subject at the higher secondary level. Somehow rather, I had to manage to attend the said course as I diverted from my tight schedule in that private college. Unbelievably, that very particular Refresher Course really refreshed my geological mind and it was a turning point for me to be back into the limelight of my research work. According to the announcement, it was compulsory for all the participants to present a seminar paper during that course. Randomly, I picked up a topic on - The Evolution of the Imphal valley. First hand information and materials relating to the topic were collected from a project report entitled - Imphal Valley- A Transtensional Basin” submitted by Prof. Soibam Ibotombi, Department of Earth Sciences, Manipur University. In that short discourse, hundreds of questions haunted my mind for which I was not ready to get the immediate answers. And the dream of a research work along the Indo-Myanmar Ranges (IMR) was being realized. But it was still a dream remained unfulfilled for more than one year and so after the Refresher Course. At last, with full determination, I approached Prof. Soibam Ibotombi, the supervisor of this thesis, to undergo my research work leading to the doctoral thesis. Two options were placed before me for my field of studies. Immediately, I chose the present
topic *Crustal shortening across the Indo-Myanmar Ranges of Northeast India and Its Tectonic Implications*, without any hesitation.

Interestingly, Indo-Myanmar Ranges is a real paradise least exposed, virgin land and less known. Its naturally well arranged parallel ranges, sparkling streamlets flowing through gorges and valleys, evergreen virgin forest on lofty heights, typical flora and fauna, dispersed villages of the tribes and beauties of the spring seasons, but all these are in the midst of ethnic conflicts, communal clashes, bandhs and blockades, general strikes, and insurgency. By the rich cultural heritage which is associated with the people, and the land of this very region, it is justified that a civilization prevails in this region philosophically; culture is the product of the civilization. But in the purview of modern civilization, it seems to remain still, the existence of a paradise kept untouched by the modern hands. With all these in my mind, I was curious that if we could share our love, care and understanding with the folks about their lives, the lands, and nature’s enchanting beauty not only for the geological knowledge but also for the experience we had during this work were worth mentioning. It was my pleasure to opt this challenge.

The first hurdle of the venture started with the collection of toposheets. States like Nagaland, Manipur and Mizoram are international Border States to Myanmar where insurgency is prone. Due to heavy security reasons, toposheets covering these border line areas were upheld. Somehow, a few low resolution sheets and some discontinuous segments were able to be acquired. Later, it was easier to get DEM satellite imageries from ESRI websites and used it with Google Earth Images.

Topography of the IMR is very rough. Ridges are flanked by steep hillsides, deep valleys and gorges. Being tectonically controlled, the major streams followed thrust zones, fault planes and
sometimes cut deep gorges along synclinal troughs. Neo-tectonic activities are still continuing and landslide is very common in all the hill roadways. Most of the inter village roads are under construction during the period of fieldwork. Transportation was always a big problem for any fieldwork programme. Sometimes, the team traversed more than twenty kilometers of hilly foot-track to reach the determined field spot, climbing up and down more than one thousand meters elevations. Especially Ophiolites are exposed well on hilltops of high elevations. Kamjong, Makuching, Gamnom, Sanshak, Siroih, Phungrei, and Poi are some of the ophiolite exposure site in Manipur Hills segment. Even though the lateral extent is less than a hundred kilometers, due to lack of road connectivity, one fieldwork season cannot cover a desirable area at a time.

IMR is in the monsoon region of India. Rainy season of six months is exposed to pre-monsoon and monsoon rains, from March-April to August-September. It is not a good time for any fieldwork in all the three states. Vegetation cover is so thick at this time hiding any exposure and the scene will persist for next few months, till December. December to January is too cold for higher altitude locations making inconveniences in transport, accommodation and working. The month of February is the only suitable time for fruitful fieldwork in this terrain. However, fieldworks were conducted at any time if the situation was viable.

The regions under the IMR states are inhabited by tribal communities except the Imphal valley of Manipur and Dimapur area of Nagaland. Trespass and working in these tribal areas sometimes necessitate the local custom and traditions to be followed. Dictates from unwanted elements are also a matter of insecurity. Common law is of little significance and local adjustment is (necessity of the hour) very much required for any type of approach. Generally, headmen or chiefs of the villages are well informed in advance, sought their
credence, before we approached for the fieldwork. Being an insurgency prone area, the armed forces personals had never been given up their suspicious look towards, even if they understood the purpose of the work. Once in an attempt to reach a far corner of Manipur state nearby Chin Hills, the team was stuck up in a series of armed forces security camps, and at last left us at our own risk in a straight, abandoned in precaution of suspected mines. Part of the track was blocked by piled up rock debris and unable to pass through. Trying to find an alternative route, two days were wasted unnecessarily to communicate responsible persons but in vain. At that time all the alternative routes passed through some camp areas, controlled by insurgent groups.

Collecting samples for paleomagnetic studies had some discrepancies. Generally core samples are drilled in situ from the rock exposures by marking the orientation of the core with respect to north direction. For many reasons, our terrain is not convenient for carrying the drilling machines and accessories into the field site. So block samples were collected with proper orientation and core samples were extracted by drilling in laboratory. Block samples were also to be taken not less than the dimension of 8x6x4 cubic inches, while a core sample has a maximum length of 4 inches with 1 inch cylindrical diameter. Specimens were prepared and only the magnetic susceptibility could be measured in the University Laboratory. For the first time in the Universities of Northeast India, facilities for paleomagnetic studies which was provided by the Department of Science and Technology, Government of India, was installed at Mizoram University, Aizawl. But handling of the instruments was being authorized to the Department of Geology, Mizoram University only. We were to wait their nod for a reasonable long time to measure the required magnetic properties. We had to wait their positive indications for a reasonable long time to measure the required magnetic properties. At last the measurement of the samples was done
analytical part of the work was also a big challenge with regard to the software tools and equipments. As far as possible, manual practice and simple mathematical applications were used for the analysis. However, it had to be made adaptable to the fast growing advancement in the electronic world. Soft-wares were too expensive and it was beyond the affordable limit of the scope of the work. A version of Arcgis together with ASTER GDEM imageries was available for some time free on line. Such imageries were very useful in the present work for extracting section profiles and filled up the gaps in the areas of missing toposheets. Charts, diagrams and figures were drawn by using Microsoft Office tools only, especially, Excel and Words (2007 version). A copy of Paleomagnetic Analysis Program, (version 4.3) software was delivered to me from IIGM Allahabad which had been used for all the paleomagnetic data generations. Applications of stereo-net plot were used with GEORIENT software for the evaluation of the data analysis results.

Compilation part of the work was again the most provoking task. We could not underrate the concern of personal problems, social events and environmental conditions which imposed time and again a digression in the mental framework. It is not a simple matter to make up an effort overcoming such mental disturbances. Ineluctable family occasions, and unavoidable social circumstances had disrupted the progress of the work many a times.

The first chapter is a general introduction of the thesis with highlights on the conceptual background of plate tectonics, Tethys Sea, Ophiolite Belt of the IMR, general accounts of the IMR states of India along with objectives and methodology of the present work and field techniques employed. The second chapter dealt with the general
geological and tectonic setting of the region with review of the related works. Chapter 3 presents the calculation of shortening along different profile sections, minor structures and inferred folds to evaluate the tectonic shortening in this region. Chapter 4 made an attempt to calculate the pole of rotation related to the shortening and comparison with various pole of rotation derived by other sources. Chapter 5 put up a preliminary idea of using paleomagnetic traces in the ophiolite rocks in the Ophiolite Belt of the IMR to decipher the pre-subduction stage of the tectonic setting of the region. Chapter 6 dealt with probable setting of the basin evolution during the IMR Orogeny. Chapter 7 is presented as general discussion with concluding remark of the thesis.

The overall work of the thesis is mainly confined to the quantitative measure of various crustal components, application of simple trigonometric and geometric formulae and calculations, to describe complicated rotation movements of the crustal blocks. An evolutionary model of the Indo-Myanmar ranges is presented based on the preliminary results, in consistent with the information derived from review of the previous works and related publications. Study area covers a regional scale framework and it requires further investigations. The present work is intended to pave a way for detailed research of the IMR. More accurate and credible data source may improve and affirm the thesis with required modifications.

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