Structural Deformation of the Momeik Metamorphics, Northern Shan State: Criteria for Tectonics

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Abstract

The research area is situated within the north adjacent part of the Momeik Town. It is mainly composed of metamorphic (metapelite, metacarbonate and metaigneous) and associated igneous rocks. The present work deals to describe the petrographic criteria of structural deformation and to interpret the tectonic evolution of the study area. The investigations of numerous deformational criteria observed in various units of the study area point out that the research area might have been encountered four different styles of deformation during Tertiary period. These are (i) E-W compressional deformation (Eocene to Oligocene), (ii) NNW-SSE ductile-extensional deformation (Oligocene to Early Miocene), (iii) brittle-ductile deformation (Early to Middle Miocene), and (iv) brittle-extensional deformation (Middle Miocene). On the basis of the well-documented regional tectonic consideration combined with available field data and petrological interpretation, it might be concluded that the metamorphic rocks of the study area might have been exhumed by the extensional tectonics accompanied with E-W compressional deformation during Middle Miocene.

Keywords: petrographic criteria, deformation, tectonic evolution

Introduction

The study area, the north continuation of Mogok Metamorphic Belt, is situated within the northern adjacent part of the Momeik Town. The area is bounded by latitude 23°9' N to 23°19'N and longitude 96°32' to 96°43'E in one inch topographic maps of 93-A/11 and 93-A/12. It covers approximately about 285 square kilometer with 18 km in length and 16 kilometer in width of rugged and mountainous terrains (Fig.1-A).

The Mogok Metamorphic Belt containing the study area is mainly composed of metamorphic (metapelite, metacarbonate and metaigneous) and associated igneous rocks. The main objective of this work is to describe the petrographic criteria of structural deformation and to interpret the tectonic implication of the study area. To attain the petrographic criteria of structural deformation, more than twenty thin sections were cut from various representative rock samples.

Distribution of the Petrographic Units

The most abundant metamorphic rocks occupied in this area are metapelites (garnet-biotite gneiss, biotite gneiss, silliminite schist and biotite schist) which are well exposed at the southern and western parts of the study area. Metacarbonate units (forsterite-graphite marble, phlogopite marble, diopside marble, white marble and diopside calc-silicate rock) are found in the central and northeastern part of the area. Metaigneous rocks (Orthogneiss) are commonly observed along the Momeik fault zone in the southern part of the area, while the igneous units are found at central and northern parts. The geological map of the study area is as shown in Figure (1-B).

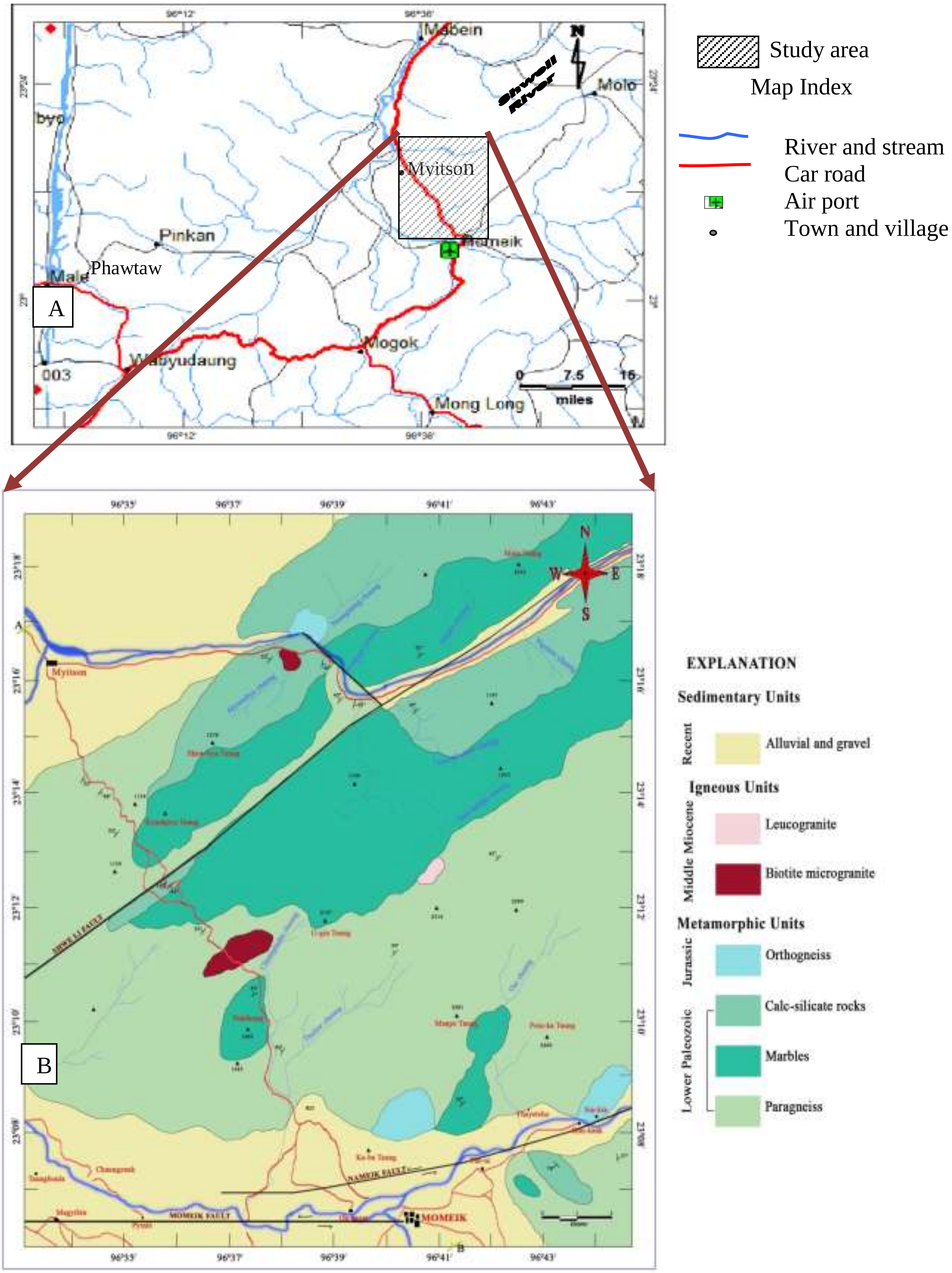

Figure (1-A&B) Location and geological maps of the Momeik-Myitson area

Petrographic Criteria for Structural Deformation

On the basis of field evidences and microscopic examination, four different types of structural deformation can be recognized in the Mommeik-Myitson area. These are (i) compressional deformation, (ii) ductile-extensional deformation, (iii) brittle-ductile deformation, and (iv) brittle - extensional deformation.

The structural features of compressional deformation are scarcely observed as dragfolding in calc-silicate rock which is intruded by leucogranite bodies at the downstream of Myintabye Chaung section (Fig.2). The axial plane of this dragfold runs nearly NE-SW and plunges to southwest. This minor structure also indicates that the major recumbent similar folding may exist regionally (Myint Lwin Thein et al., 1990).

Fig. (2) Dragfold found in calc-silicate rocks near the intrusion of leucogranitic bodies showing the field evidence of compressional deformation (Loc: N 23^{o} 16$^{'}$ 20$^{''}$ & E 96^{o} 38$^{'}$ 15$^{''}$).

The metapelites in the southern part of the study area are highly foliated and the foliation generally trends NW-SE with a low-angle dip (Fig.3-A). This foliation planes often bear NNW-SSE trending stretching lineations that indicate ductile, extensional deformation. Boudinage and pinch- and -swell structures are observed in biotite gneiss (Fig.3-B). They are developed in such a way that an originally continuous rigid band or layer existing between relatively plastic layers is stretched and become thinned where the rupture occurs. These structures are field evidences of ductile, extensional deformation.

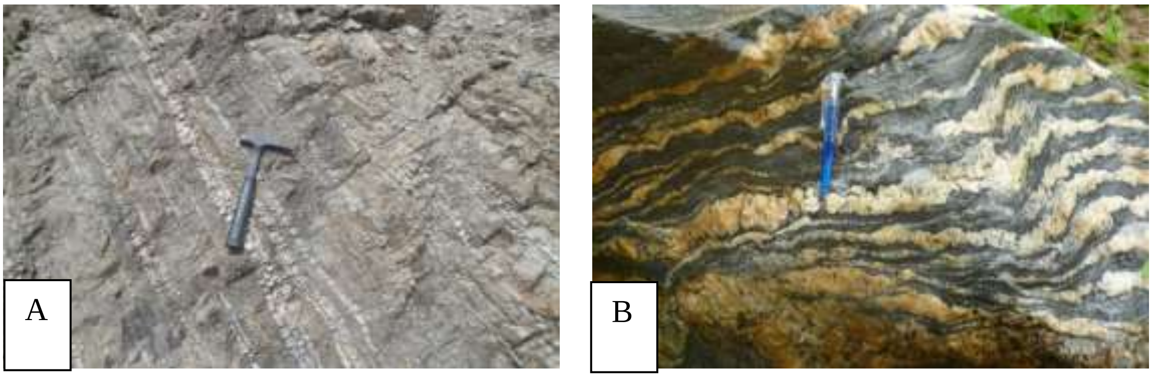

Fig. (3) Field evidences of ductile deformation in Momeik-Myitson area. (A) NW-SE trending foliation planes in biotite gneiss (Loc: N 23^{o} 08$^{'}$ 10$^{''}$& E 96^{o} 38$^{'}$ 30$^{''}$), and (B) Highly contorted and pinch-and-swell structure in biotite gneiss (Loc: N 23^{o} 08$^{'}$ 45$^{''}$ & E 96^{o} 43$^{'}$ 35$^{''}$).

Deformation twins with tapered termination in calcite grains are also observed in diopside calc-silicate rock (Fig.4-A). These facts indicate that these rocks have suffered from some degree of ductile deformation. Figure 4-B shows the nature of stretched garnet porphyroblast with stretching orientation 160^0 in garnet-biotite gneiss. Porphyroblasts are among the most useful tools for interpreting metamorphic deformational histories because they are mechanically more resistant to deformation, and can thus become porphyroblasts during later shearing (in Winter, 2010). So, stretched garnet is the microscopic evidence of ductile, extensional deformation.

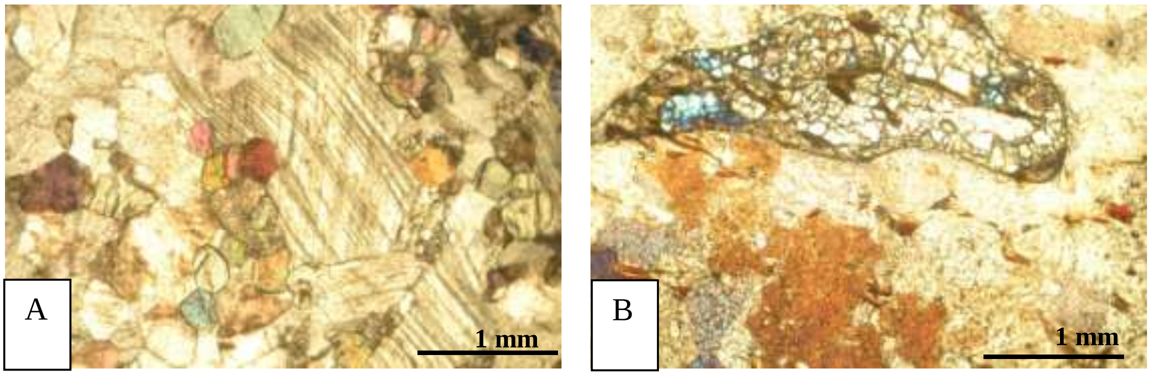

Fig. (4) Microscopic evidences of ductile deformation in Momeik-Myitson area. (A) Deformation twins with tapered termination of calcite grains in diopside calc-silicate rock; (B) Stretched nature of garnet porphyroblast in garnet-biotite gneiss

Characteristics of brittle-ductile deformation are observed in some paragneiss in which biotite-rich layers indicate ductile deformation, whereas more quartzo-feldsapathic layers are characterized by both ductile and brittle deformation (Fig.5-A and B).

In graphite marble, graphite flakes are characterized by shape-fabric orientation that indicates the ductile deformation in first phase, while dolomite crystals show brittle fragmentation that indicates brittle deformation in second phase (Fig.6-A). In phlogopite marble, cleavages of calcite crystals show slightly curved nature of ductile deformation in the first phase, while subhedral forsterite grains exhibit highly cleavable nature of brittle deformation in the second phase (Fig.6-B). These structures are the criteria for two-phase style of brittle-ductile deformation.

Fig. (5) Field evidences showing two-phase style of brittle-ductile deformation in Momeik-Myitson area. (A) Biotite rich layer showing first phase and quartzofeldspathic layer indicating second phase in biotite gneiss (Loc: N 23° 13' 20'' & E 96° 35' 50''), (B) Biotite rich layer showing first phase and quartzofeldspathic layer indicating second phase in garnet-biotite gneiss(Loc: N 23° 16' 15'' & E 96° 37' 51'').

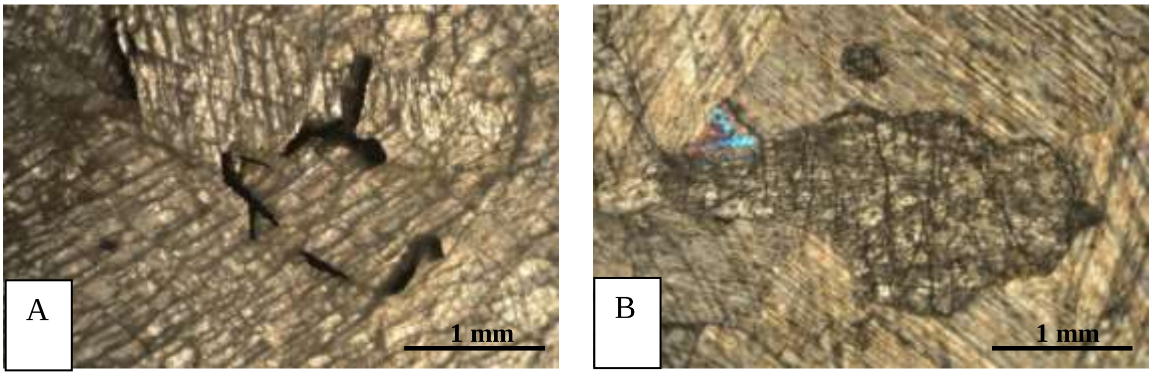

Fig. (6) Microscopic evidences of brittle-ductile deformation in Momeik-Myitson area. (A) Shape-fabric orientation of graphite flakes in first phase and fragmentation of dolomite crystals in second phase. Graphite marble,XN (B) Curved twin planes of calcite grain in first phase and highly cleavable nature of forsterite grain in second phase. Phlogopite marble,XN.

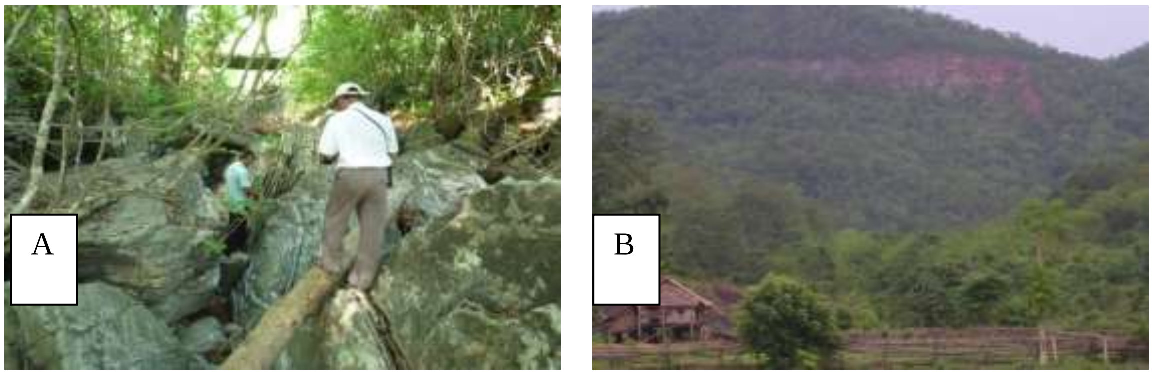

Fig. (7) Field evidences of brittle extensional deformation in Momeik-Myitson area; (A) Steeply inclined planes of banded calc-silicate rocks along the normal fault (Loc: N 23^{o} $12^{'}$ $10^{''}$ & E 96^{o} $36^{'}$ $55^{''}$); (B) Scarp face about half mile SE of Thayetcho village (Loc: N 23^{o} $12^{'}$ $10^{''}$ & E 96^{o} $36^{'}$ $55^{''}$).

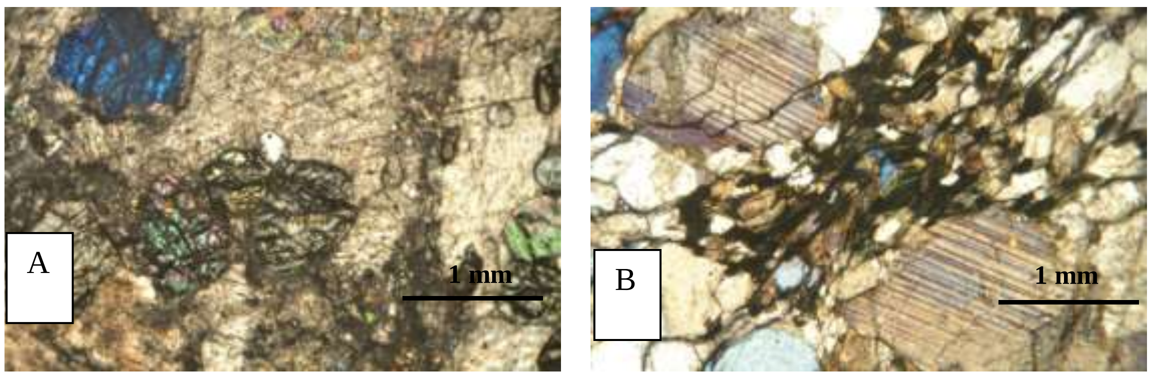

Fig. (8) Microscopic evidences of brittle-extensional deformation in Momeik-Myitson area.(A) Well-defined, cleavable nature of diopside grains in diopside marble, XN.(B) Highly fractured, xenoblastic grain of plagioclase crystal that cuts across along the foliation plane with sense of motion either NNW or SSE in biotite gneiss,XN.

Steeply inclined planes observed in banded calc-silicate rocks along the Shweli fault plane (Fig.7-A) correspond to the brittle extensional deformation and sinistral fault scarp observed where observed where garnet biotite gneiss exposed along the Mommeik fault plane (Fig.7-B).

For microscopic evidences, Figure 8-A shows well-defined, cleavable nature of diopside grains in diopside marble, and sometimes in basal section in which these two cleavage sets intersect one another at nearly right angles. Figure 8-B shows highly fractured, xenoblastic grain of plagioclase crystal that cuts across along the foliation plane with sense of motion either NNW or SSE in biotite gneiss. The above-mentioned criteria point out that these rocks have suffered by brittle, extensional deformation.

Tectonic Interpretation

Based on the well-documented regional tectonic consideration combined with available field data and petrofabric interpretation, a simplied tectonic evolution of the study area can be highlighted as follow.

Protolith of metasedimentary rocks were probably formed under shelf conditions in the Pro-Shan region of Sibumasu terrane that located in a greater Indian-Australian Gondwana margin during the Early Paleozoic. Deposition continued, and separation of a continental strip including Sibumasu terrane initiated at the end of the Sakmarian stage of the Early Permian. These terranes drifted northwards to collide with Cathaysialand. Collision of Sibumasu terrane with Cathaysialand closed the Paleo-Tethys in the Permian-Triassic. Welding of Sibumasu and Cathaysialand continued and completed to form mainland Southeast Asia in Late Triassic-Jurassic times. From Middle Jurassic-Early Cretaceous interval, the Indian oceanic plate moved northeastward and subducted under southwestern margin of Southeast Asia. This phase of subduction is accommodated by the emplacement of granitic plutons now exposed along the western margin of the Shan-Tanintharyi Massif and in the Central Myanmar basin. During this phase, preexisting rock assemblages have suffered different deformational styles in accordance with their temporal and spatial distribution.

During the Late Cretaceous-Eocene interval, India Plate moved northwards and collide with Eurasia plate. This tectonic regime caused crustal thickening and thrusting upon collision zone. As a result, E-W compressional deformation, magmatism and prograde regional metamorphism occurred along the Shan scarp region. At the time between Oligocene and Middle Miocene, collision of India continent with Eurasia plate resulted the change in the direction of movement and brought about the clockwise rotational movement of SE Asia peninsula. This tectonic regime caused ductile deformation upon the protolith mixture along the western margin of Shan plateau. At Middle Miocene, progressive northward motion of East Himalaya Syntaxis favoured formation of a series of detachments along the western margin of Shan Plateau. These tectonic processes resulted a transcurrent shear zone which tended to exhume the metamorphic rocks of the study area (i.e, Mogok Metamorphic Belt) accompanied with brittle-ductile deformation from middle and lower crust level. Due to crustal relaxation at that time, the intrusion of Kabaing granite may have taken place. Brittle extensional deformation such as faulting and fracturing (i.e, Shweli fault) occurred and truncated the older structures at upper crustal level of the study area during Late Miocene. Pre-existing normal faults were reactivated into sinistral strike-slip fault (i.e, Momeik fault) and later, Sagaing fault (Late Miocene – Recent) initiated with right lateral motion.

Therefore, it might be concluded that the metamorphic rocks of the study area might have been exhumed by the extensional tectonics accompanied with E-W compressional deformation during Middle Miocene.

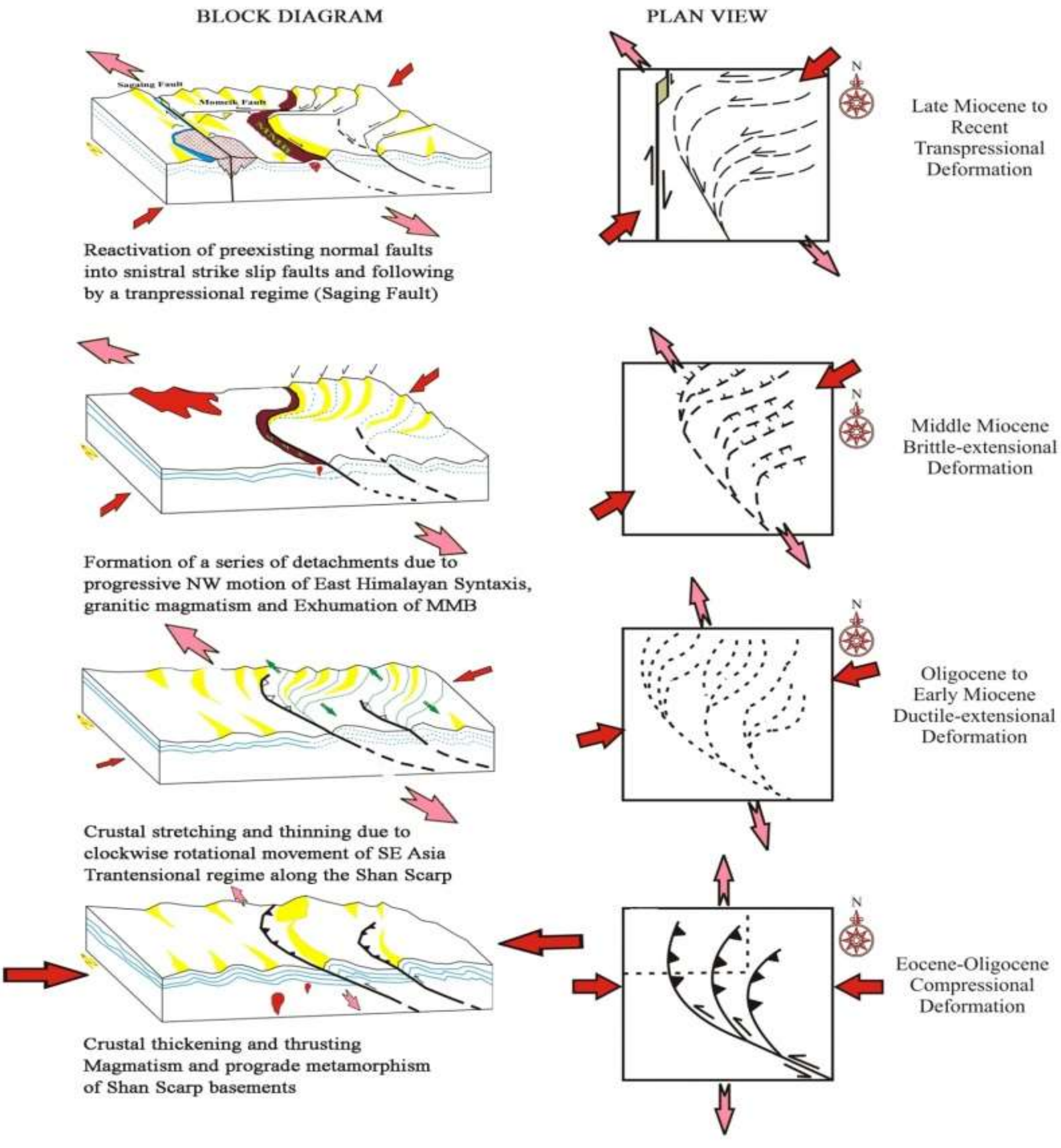

Fig. (9) Tertiary uplifting and exhumation of the study area. Dotted rectangle indicates approximate area of the block diagram. (modified after Win Naing,2008)

Conclusion

The research area was dominated by metamorphic (metapelite, metacarbonate and metaigneous) and associated igneous rocks. The tertiary deformation pattern of the study area can be recognized in four different stages from the petrographic observations. Tectonic constraints which influenced the rocks of the study area are interpreted based on the chronological data and information from the works of GIAC Project (1999), Bertrand and Rangin (2003), Win Naing (2008) and present observation. The investigation of the deformational criteria might be revealed that the metamorphic rocks of the study area might have been exhumed by the extensional tectonics accompanied with E-W compressional deformation during Middle Miocene.

Acknowledgements

I wish to express to Professor U Hla Moe, Head of Geology Department in Yadanabon University for his kind permission to carry out this work and his constructive comment and suggestions. I also would like to express my sincere thanks to the Department of Geology, Monywa University and Myanmar Environment Institute (MEI) for giving a chance to take part in “The First Myanmar National Conference on Earth Science”. My gratitude goes to Prof. and Head, Dr Zaw Myint Ni and Prof. Dr Myo Thant, Department of Geology, Monywa University who courage me and suggests me in this writing. Finally, I thank my fellow colleagues from the Department of Geology, Yadanabon University for the stimulating discussions.

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