Active Tectonics related to Stresses Transition of the Shan Scarp Shear Zone along the Western Shan-Thai Block, Myanmar

Sandy Chit Ko

Abstract

The study area is tectonically between Shan Thai Block in the east and Burma Plate in the west. Also lie the structural discontinuity between Shan Scarp Fault in the east and Sagaing Fault in the west. Its appear as NNW-SSE trending strike-slip shear zone, along which Mogok Metamorphic Rocks; Mesozoic granitoid rocks and Paleozoic to Mesozoic metasedimentary and sedimentary rocks of western Shan Plateau region. It's also may be Medial Suture Zone between Sibumasu and Burma Plate (Mitchell 2018). The prominent NNW-SSE trending structural features were cross cut by nearly NE-SW trending features and then these structures were cross cut by nearly NW-SE to NNW-SSE Brittle lateral faults. Ductile and Brittle structural fabrics are associated with the major features of the Mogok Metamorphic Belt, the Shan Scarp Shear zone and the Sagaing Fault. The fabric developments give information on the strain tensors transition of deeper ductile deformation to brittle deformation in shallow levels of the crust. Dacite are found at the base of Shan Scarp which can be revealed the dacitic rocks are key carriers for probing the tectonic evolution of convergent plate margins and are crucial rocks for better understanding continental crustal evolution (Boettcher 1973, Poli and Schimidt 2002, Shellnutt et al.,2014.) According to stress tensor analysis related to crustal evolution; the older prominent lineaments N-S to NNW-SSE trending give EW to ENW-WSW trending $\sigma 1$ horizontal $\sigma 2$ and vertical $\sigma 3$ which represented by crustal thickening (thrust belt). Crustal thickening lead increasing $\sigma 1$ stress component. The Shan Scarp area suffered a major change in tectonic regime during Miocene time. This transtensional regime would be characterized by NNW-SSE trending $\sigma 3$, orthogonal horizontal $\sigma 2$ and vertical $\sigma 1$. Continuous crustal block rotation due to northward migration of India Plate could be collapse of a thickened crust and decreasing $\sigma 1$ stress component to increase $\sigma 2$ stress component. Collapse of a pre-existing topography would also explain the exhumation of high grade metamorphic rocks along MMB (Bertrand et al. 2001). From Middle Miocene to present, the tranpressive stress regime generated lateral strike slip faults (where $\sigma 2$ stress show vertical) Shan Scarp Fault and Sagaing Fault. These tranpressional regime would be characterized by stress tensor of NW-SE trending $\sigma 3$, orthogonal horizontal $\sigma 1$ and vertical $\sigma 2$. This kinematic approach can be determined, earliest vertical $\sigma 3$ is changed to orthogonal horizontal position during transtension that would be collapse of high angle thrust belt. Then continuous tranpressional regime was evidenced by the stress regime transition of $\sigma 3$ unchanged while $\sigma 1$ and $\sigma 2$ component exchange orientation during crustal deformation of western Shan Plateau due to crustal block rotation and the northward migration of Burma Plate.

Key words : Shear zone, Continental Plate margin, Crustal evolution, Stress tensors, Northward migration

Introduction

The study area structurally lies between Sagaing Fault zone in the west and Shan Scarp Fault Zone in the east and also lie between Burma Plate and Shan-Thai Block (Sibumasu terrane). Regionally the study area covered between N 19 -20 and E96-97. As where the Sagaing Fault represented the eastern boundary of Burma Plate and the Shan Scarp Fault zone represented the western boundary of Shan Thai Block or Sibumasu (Figure.1). The fabric developments reveal the transition of deeper ductile stretching deformation to brittle deformation in the shallow level of the crust. From this microtectonic study indicate, the study area have suffered progressive deformation from lower crustal level to upper crustal

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level during uplifting of Shan Plateau. Along this traverse way is fault line across between Sagaing Fault and Shan Scarp Fault which is locally termed Tatkon Fault. Dextral shear sense evidences and some earthquake epicenters are found along these Tatkon cross fault lead to show active nature. The en-echalon folded nature are especially found in Shweminbon Formation under nearly E-W compressional field.

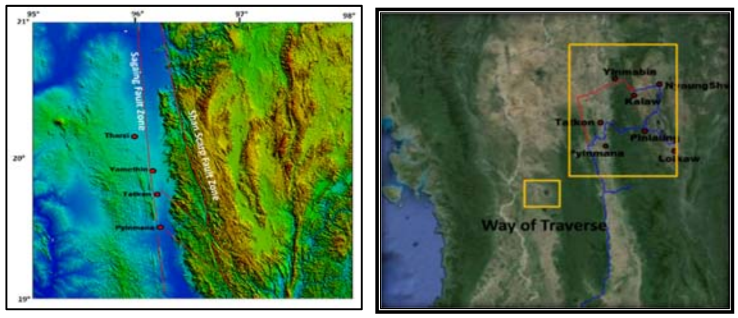


Figure (1). Satellite image; Regional structural feature and way of traverse of study area

Regional Tectonic Development in General

The continental SE Asia is a composite of the allochthonous terranes which originated from rifting of the margin of Gondwana and accreted to one another during the Paleozoic and Mesozoic (Metcalfe, 1988) (Figure.2). The Tibetan and Sibumasu blocks drifted northward during mid-late Permian initiating opening of the Neo-Tethys. The Sibumasu block (Shan-Thai block) was accreted to the Indochina block along the Nan-Uttaradit suture and to the Tibetan Changtang block to Eurasia along the Red river suture during the late Permian-mid Triassic (Cooper et al,1989;Acharyya,1998). The Indian and Australian continents separated during the Cretaceous leading to the opening up of the Jurassic Indian Ocean and closing of the Tethyan ocean. During late Jurassic after the Indosinian orogeny, the oblique subduction of Tethys was active along the western boundary of the Sunda Plate (or) Sibumasu block (Shan-Thai block). The activity was followed by the Cretaceous to Paleocene NE-SW directed collisions of Burma Plate and Shan-Thai block and then continuously by oceanic plate of the northeastern segment of India-Australia Plate collides with the western boundary of Burma Plate which is a sliver plate between India and Sunda Plate during Eocene to Recent. That regime so called India-Burma Plate –Shan Thai block collision. Most of the major tectonic features in Myanmar and surrounding are formed progressively since the beginning of the Cenozoic Era. Post-accretionary dispersion and crustal deformation have been recognizable throughout Myanmar such as Strike slip faults or Sagaing fault, Shan Scarp fault, Papun fault and Three Pagoda fault. (Hutchison, 1996; Morley, 2004; Soe Thura Tun, 2005)

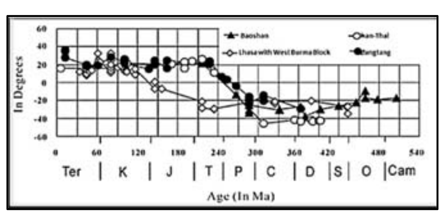


Figure (2). Curves for the evolution of paleolatitudes of the Qiangtang, Baoshan, Lhasa together with West Burma Block and Shan–Thai blocks. Ter, Tertiary; K, Cretaceous, J, Jurassic, T, Triassic, P, Permian, C, Carboniferous, D, Devonian, S, Silurian, O, Ordovician, Cam, Cambrian (Metcalfe, 1988, 1999: Li,et al 2004).

General Geology

The study area lies in the western part of Shan plateau region compries the granitoid rocks of W-Sn bearing Central Granitoid Belt of Myanmar and metamorphic rocks belong to Mogok Metamorphic Belt at the western part. Metasedimentary and sedimentary rocks of Mergui Group, Shweminbon Formation, Jurassic Loi-an Group and Kalaw Red Bed in the eastern part of the study area (Figure.3). The older graintiod plutons and metamorphic rocks of the study area posses NNW-SSE regional structural trend. Metasedimentary and sedimentary rocks of are roughly parallel to the general strike of regional structural trend which are exposed as rolling hill, highly folded with dense vegetation (Figure.4).

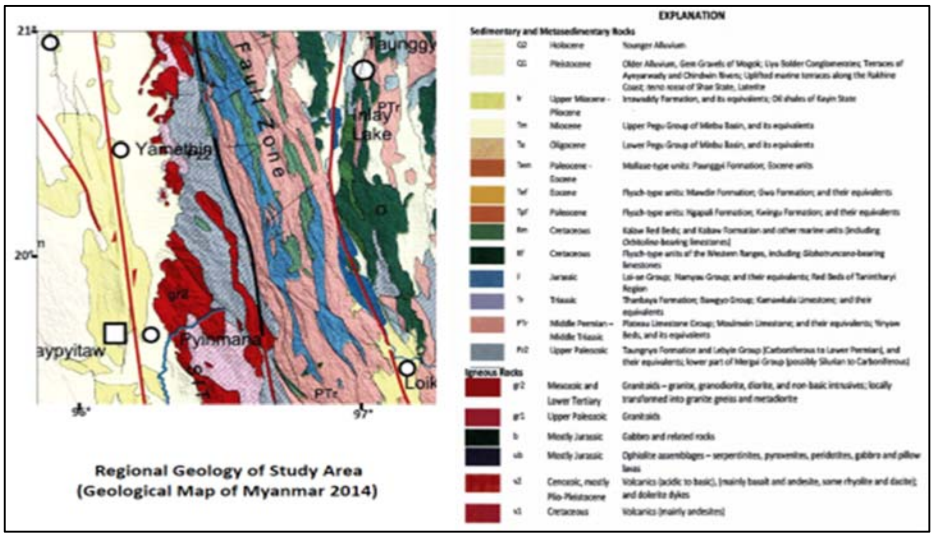


Figure (3). Regional Geology of Study Area [Geological Map of Myanmar (2014)].

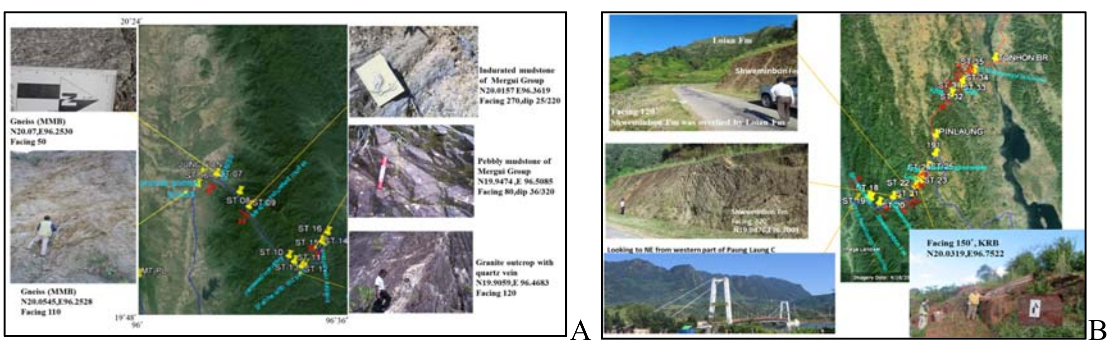


Figure (4) (A). Field observation of outcrop nature geology at the western part of Paung Laung (B). outcrop nature at the eastern part of Paung Laung Chaung.

Structural Feature Analysis

Fold and the Regional Structural Pattern

Field investigation along car road of Tatkon - Pin Laung and Yinmabin-Pyin Nyaung show that numerous small-scale folds, different styles, of folding and orientations of fold axes are observed in metasedimentary rocks of Mergui Group and especially in sedimentary rocks of Shweminbon Formation. The folded style of Shweminbon Formation at northern

(Yinmabin-Pyin Nyaung) and Southern (Tatkon-Pin Laung) area are similar (Figure.6) and fall under same compressional regime.

Average amount of eastern limb dipping are vary from 30° to 55° with the direction of mosty N to E and the western limb has direction ranging about 190° to 200° azimuth with gentle amount. Steroplot analysis indicates the fold axis is plunging towards NNW and SSE with small amount of plung angle not more than 15°. Mean orientation of fold axis and the regional structural trend is NNW-SSE in position (Figure.5).

Figure (5). Highly folded nature of Shweminbon Formation under E-W and ENE-WSW compressional stresses (19.976274N, 96.671722E).

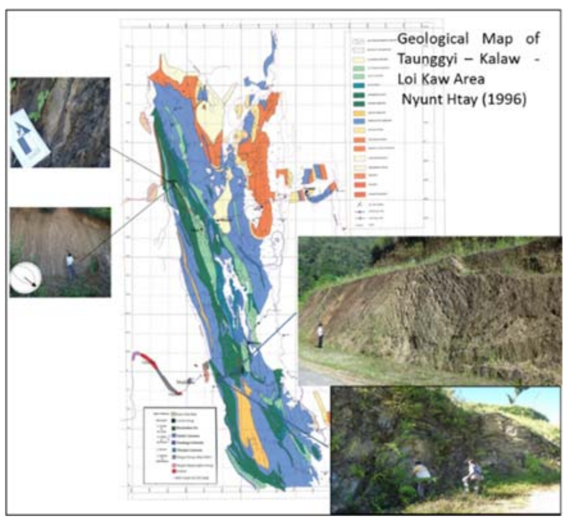


Figure (6) Comparism of similar folding nature of Shweminbon Formation under E-W or ENE-WSW compressional stresses along Pyinnyaung-Kalaw car road and Tatkon-Pinlaung car road.

Thrust Fault

According to the TM image interpretation and the combination of field investigation, the western Shan Plateau region is largely characterized by NNW-SSE to nearly N-S trending older thrust faults. Field measurement at the exposure; near Pyinnyaung Scarp at the western base of Shan Scarp where we get high angle dip and revere sense of shear under vertical (σ3) and also way point ST 07 near the base of Tatkon-Pinlaung car road shows the thrust plane inclined at about 25˚ and directed towards WNW (Figure (7)). On the basic of field measurement of the prominent slickenside on the thrust plane, stereoplot analysis show that maximum (σ1) position is about 20˚/78˚, the intermediate stress (σ2) is about 20˚/260˚, the minimum stress (σ3) is about 60˚/290˚. These stress regime indicate the σ1 and σ2 in orthogonal horizontal position and σ3 is vertical.

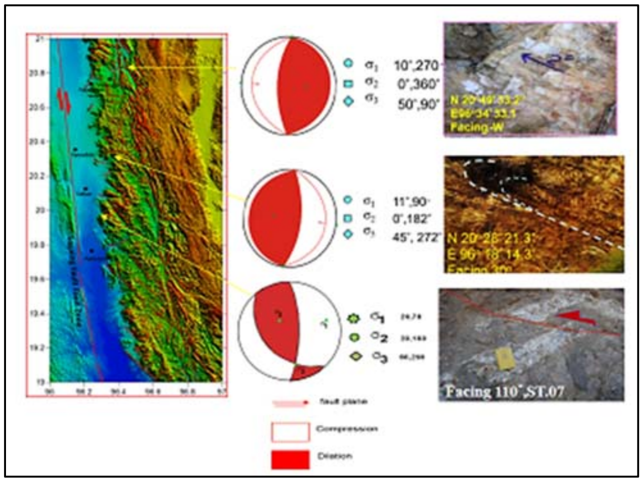


Figure (7). Reverse slip under compressional deformation along the western margin of Shan Scarp.

Another thrust evidence by stratigraphic nature in the eastern part of the research area is well recognized in the east of Paung Laung valley. As where, Shweminbon formation overthrust by the Loian Formation with SE dipping NW verging. Its looklikes horizontal bedded nature over the en-echalon folded nature of Shweminbon formation from the side view (figure 8,9).

Figure (8). Fold and thrust structural features formed during E-W compressional stress regime crustal thickening along Shan Scarp region. Curve arrow indicates the motion of hanging wall toward the front of the picture.

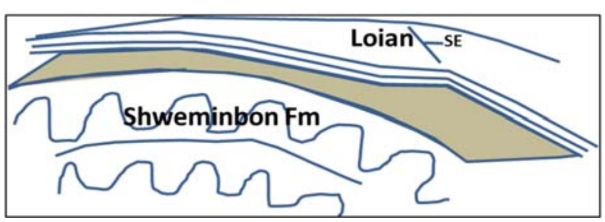


Figure (9). Idealized sketch shows SE dipping NE verging thrust nature of Loian Formation.

Strike Slip Faults

The N 50 W-N35W striking transpressional dextral faults form in Mogok Metamorphic Belt and metasedimentary rocks of Mergui Group at the western Shan Scarp region . The lineament of the fault are very clear and the mean stresses of that area show the maximum (σ1) position is about 20˚/285˚, the intermediate stress (σ2) is about 60˚/75˚, the minimum stress (σ3) is about 25˚/30˚ (Figure 10A). The field measurement of the fault plane and stereoplot analysis show that maximum (σ1) position is about 8˚/20˚, the intermediate stress (σ2) is about 70˚/270˚, the minimum stress (σ3) is about 20˚/110˚ . Another two sense of dextral shear form in metasedimentary rocks of Mergui group beside the Tatkon-Pin-Laung car road (figure 10B) show that the maximum (σ1) position is about 16˚/332˚, the intermediate stress (σ2) is about 60˚/246˚, the minimum stress (σ3) is about 24˚/75˚ at ST 09 and the maximum (σ1) position is about 30˚/308˚, the intermediate stress (σ2) is about 40˚/78˚, the minimum stress (σ3) is about 28˚/220˚.These stress regime indicate the σ1 and σ3 in orthogonal horizontal position and σ2 is vertical.

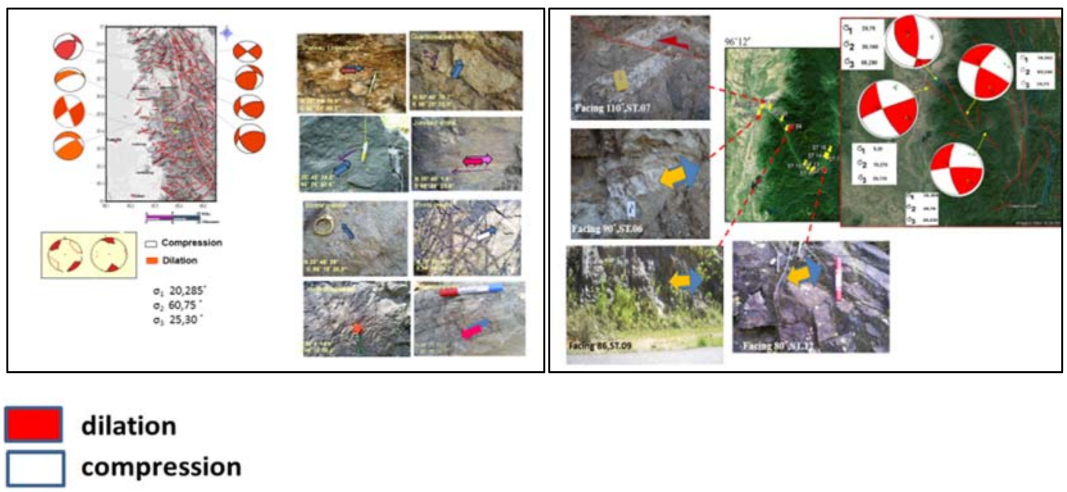
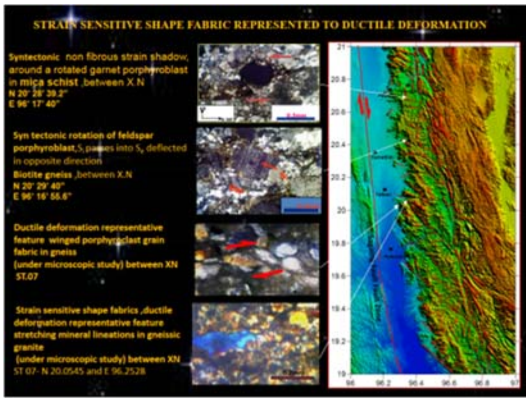


Figure (10). Outcrop scale shear sense indicator under transpressional deformation(A)Yinmabin- Tatkon area (B) Tatkon – Pinlaung Area

Microtectonic Analysis

In general, deformation in such high-strain zones usually contains a rotation component, reflecting lateral displacement of wall rock of segments with respect to each other; this type of high strain zone is known as a shear zone. Shear zones can be subdivided into brittle zones, brittle-ductile zones and ductile zones (Sibson, 1977). Deformation along the shear zones result in the formation of fabrics defined by the petrofabrics study in which were characteristic fabrics and mineral assemblages that reflect P-T conditions, flow type and movement sense in shear-zones. The microscopic fabrics studied along the shear zones in the western margin of Shan block region under petrographic microscope, numerous oriented samples were collected during the field periods. All observations are for sections parallel to the stretching lineation (extension lineation of rocks) and normal to the foliation. Microtectonic analysis along the fault provide strong evidence for dextral strike slip motion and changing crustal level between the Sagaing Fault and the Shan Scarp.The petrofabrics development and associated shear zones were shown in Figure(12). These fabrics, mainly observed in the study area are strain- sensitive shape fabrics, and strain-insensitive shape fabrics.



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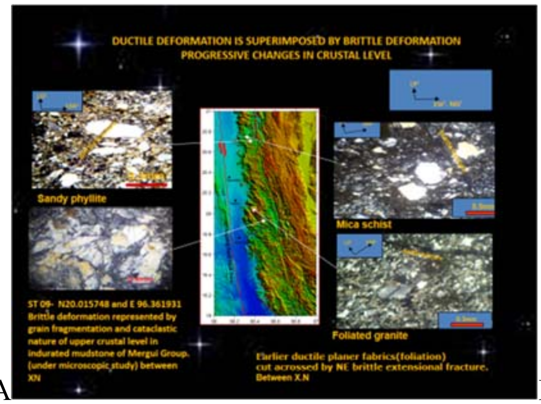

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Figure (11). Some Deformation fabrics along the western margin of Shan-Thai Block (A) Strain sensitive shape fabric of ductile deformation, (B) Brittle deformation represented grain fragmentation fabrics.

Ductile deformation represented fabrics ; Stretching mineral lineations

One of the ductile deformation represented strain sensitive shape fabrics, stretching mineral lineations is a recognizable linear component in rocks and are defined by an alignment of elongated quartz and feldspar crystals, long tails of feldspar porphyroclasts, ribbon like porphyroclasts and streaks of smeared-out minerals. These linear structure are well developed in banded gneiss and foliated granite of Mogok Metamorphic Belt at the western base of Shan Scarp Region.

Winged porphyroclasts fabrics

In ductile shear zones contain rigid grains within a strongly deformed, fine granined matrix. Porphyroclasts are commonly flanked by tapering aggregates which form a structural unit with the porphyroclast have the same mineral composition as the porphyroclast are known as a mantled porophyroclast.The rim of the porphyclast then recrystallises to a core-and –mantle structure (Box; White 1976). The fine grained soft mantle can be deformed into wing (or) tails that extend on both sides of the porphyroclast parallel to the shape fabric (Passchier and Simpson 1986). In simple shrar, a boundary can be defined between the far field displacement paths and the elliptical paths, known as a separatrix (Passchier et al 1993). In simple shear flow can have 'eye-shape' or a 'bow-tie shape' in a section normal to the rotation axis of porphyroclast. The σ type winged porphyroclast fabrics indicates that the rocks has undergone simple shear, ductile extensional deformation (Figure .11A)

Brittle –Ductile deformation represented Antithetic offset grain fabrics

Brittle ductile deformation represented strain insensitive shape fabrics are single grain of rigid porphyroclast may be transected by sets of micro-shear zones or faults,which cause relative displacement of the fragments can be antithetic or synthetic and depends not only on the bulk shear sense but also on the initial orientation of the microfaults which may be partly controlled by crystallographic directions in the porphyroclast. These fabrics can be used as shear sense indicator. The antithetic offset grain fabric in biotite gneiss represented by feldspar porphyroclast showing grain scale fault with the opposite sense of shear.

Brittle deformation represented grains fragmentation

Brittle deformation operates in the shallow part of the earth's crust generally within the 5-10 km level of the earth surface, where the deformation mechanism is mainly driven by the brittle mechanism, to form the fracturing and faulting of rocks. In the western part of Shan Block region, metamorphic rocks, metasedimentary rocks and their associated intrusive igneous rocks commonly display characters of ductile deformation, brittle-ductile deformation and then later, these structures are significantly superimposed by the brittle extensional deformation (Figure.11B).

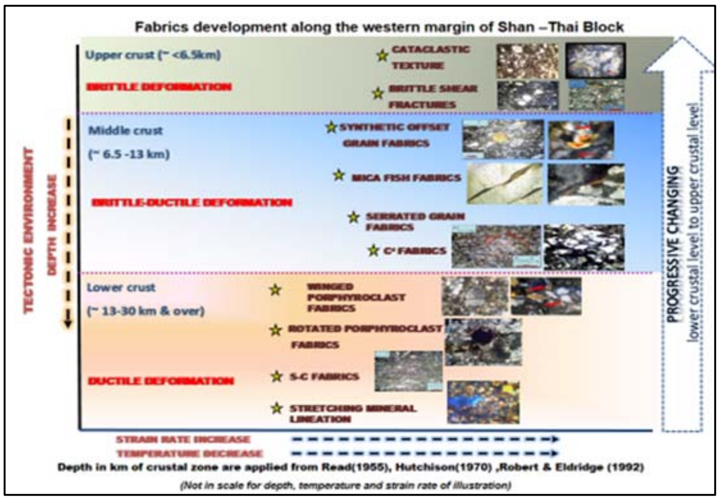


Figure (12). Fabric developments indicate the deformation changing from lower crustal level to upper crustal level.

Structural Feature and Stresses Orientation Changing of Shan Scarp Region

This research area is a structural discontinuity between Shan Plateau (orShan-Thai terrane)in the east and Sagaing Fault in the west. It appears as NNW-SSE trending strike-slip shear zone and Mogok Metamorphic Rocks; Mesozoic granitoid rocks and Paleozoic to Mesozoic metasedimentary and sedimentary rocks of western Shan Plateau region are well exposed.

In conjunction with regional tectonic data the results of the present study are as follows:I-type granitic rocks intruded locally probably during as early as Jurassic related to E-dipping subduction beneath the Shan Thai Block.Regional tin-bearing granitoids are of calc-alkaline, paraluminous, collision-related S-type granitoid batholiths. They were probably emplaced during Late Cretaceous-Eocene E-W -compressional deformation or collision period.

Prior to magmatic activities, regional metamorphism underwent gradually uplifting the crustal level, thus leading to various tectonic regimes.Post-kinematic younger granitoids of late Eocene-Miocene age may be related to crustal thinning extensional deformation as suggested by their trend across the older regional and stratigraphic trends.

The prominent NNW-SSE trending structural features were cross cut by nearly NE-SW trending features and then these structures were intersected by nearly NW-SE to NNW-SSE Brittle lateral faults. Ductile and Brittle structural fabrics are associated with the major features of the Mogok Metamorphic Belt, the Shan Scarp Shear zone and the Sagaing Fault. The fabric developments reveal the information on the strain tensors transition of deeper ductile stretching deformation to brittle deformation in shallow levels of the crust.

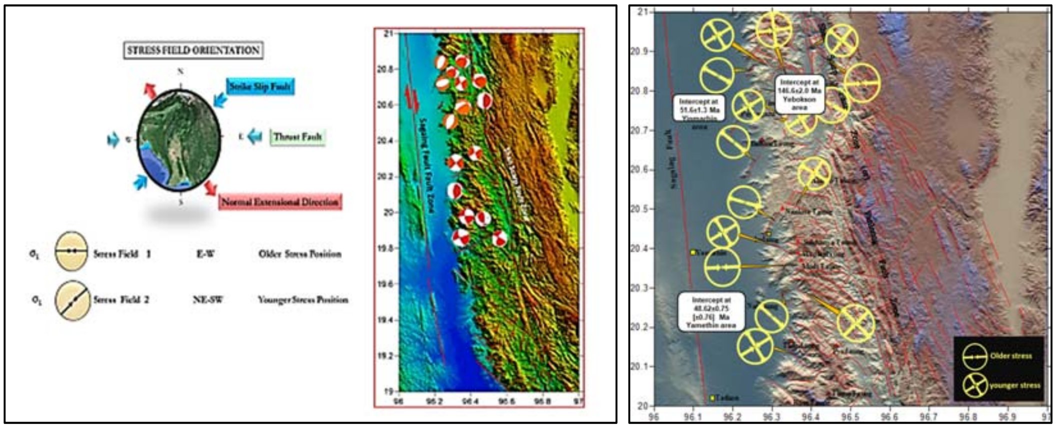
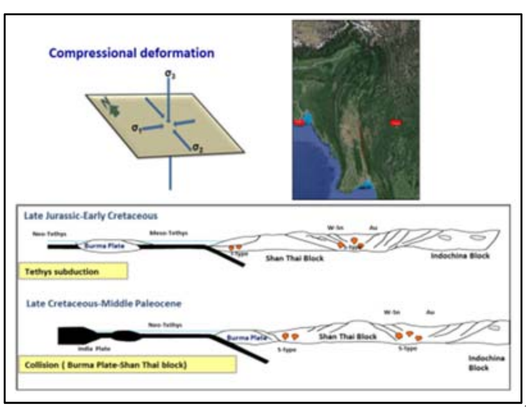


Figure (13). Stress Field distribution along the western margin of Shan- Thai Block.

According to stress tensor analysis (Figure.13), the older prominent lineaments N-S to NNW-SSE trending give EW to ENE-WSW trending $\sigma_1$horizontal $\sigma_2$and vertical $\sigma_3$which are represented by crustal thickening (thrust belt)(Figure.14A). This crustal thickening lead to increasing $\sigma_1$stress component .The Shan Scarp area suffered a major change in tectonic regime during Miocene . This transtensional regime would be characterized by NNW-SSE trending σ_3, orthogonal horizontal σ_2 and vertical σ_1 (Figure.14B).Continuous crustal block rotation due to northward migration of India Plate could be collapse of a thickened crust and decreasing $\sigma_1$stress component to increase σ_2 stress component (Figure.14C). Collapse of a pre-existing topography would also explain the exhumation of high grade metamorphic rocks along MMB(Bertrand et al. 2001). From Middle Miocene to present , the tranpressive stress regime generated lateral strike slip faults (where σ_2 stress show vertical)which activated as the Shan Scarp [1], the Sagaing Fault [2] and other lateral strike slip faults(Figure.14D). These tranpressional regime would be characterized by stress tensor of NW-SE trending σ_3,orthogonal horizontal σ_1 and vertical σ_2.



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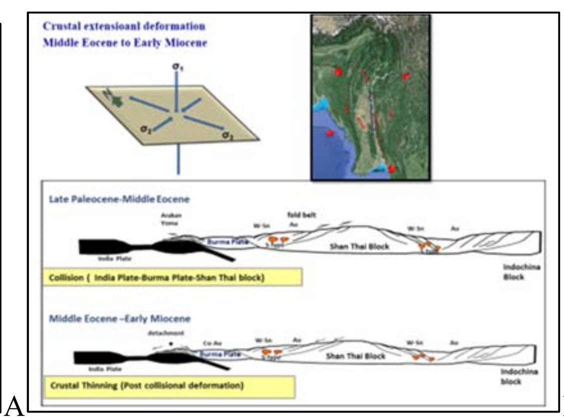

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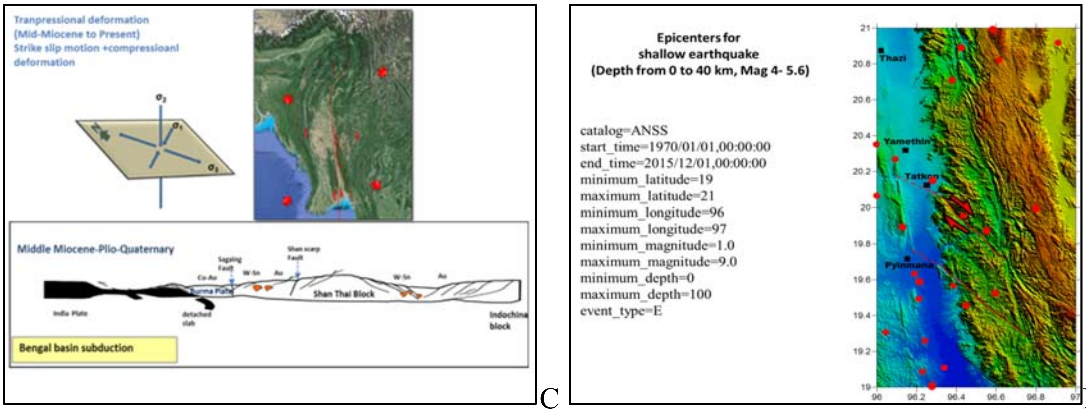

C D

Figure (14). Stresses orientation changing (A) ENE-WSW trending $\boldsymbol{\sigma_1}$,horizontal $\boldsymbol{\sigma_2}$and vertical $\boldsymbol{\sigma_3}$; (B) NNW-SSE trending $\boldsymbol{\sigma_3}$, orthogonal horizontal $\boldsymbol{\sigma_2}$ and vertical $\boldsymbol{\sigma_1}$;(C) NW-SE trending $\boldsymbol{\sigma_3}$,orthogonal horizontal $\boldsymbol{\sigma_1}$ and vertical $\boldsymbol{\sigma_2}$ and (D) Active nature of Shan Scarp Shear Zone.

Conclusions

The study area lie between Sagaing Fault zone and Shan Scarp Fault Zone.and also lie between Burma Plate and Sibumasu or Shan –Thai Block. The juxtaposition of Mogok Metamorphic Belt (MMB)-Tin bearing central granitoid belt-Metasedimentary rocks of Mergui Group or Slate belt and sedimentary rocks of Cambro-Cretaceous Limestone Plateau sequence of Shan-Thai Block (Chhibber 1934;Mitchell at al 2002) show nearly N-S linear array.

Strike slip related faults on the satellite images are discrete, with sharp, straight, slightly wavy and branching patterns.Under the early compressional field generated regionally fold and thrust belts in the area. Identified the Mogok Metamorphic rocks, Slate Belt and Plateau limestones as NNW-SSE trending lithology belt which divided by NNW-SSE trending thrusts. These thrust may have a early Cretaceous history(Mitchell et al.2002). Shan Scarp Fault zone which clearly divided from metasedimentary rocks of Mergui Group and Sedimentary units of Shan Plateau region (or Shan- Thai or Sibumasu terrane).Its propably be the suture of west Burma Plate and western margin of Shan-Thai (Sibumasu terrane).Crustal thickening and heating from the Burma Block –Shan Thai collision of continental crust associate with I type granites on a subduction margin .The combined effects were sufficient to generate S-type granites. That crustal thickening change to tranpression or extensional stresses led to later metamorphic core complex. (Morley 2004). The Shan Scarp may probably be the western boundary of Sibumasu (or) as well as the suture zone between Burma Plate and Sibumasu.

The active nature of Shan Scarp Fault was changed to inactive or stable position after cooling stage of forceful injection of granitoid intrusion and exhumation of MMB.The northward migration of Burma Plate due to Sagaing Fault dextral motion which may lead to some active nature on cross faults between Shan Scarp Fault zone and Sagaing Fault zone.

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References

Berley, M.E.,Pickard, A.L., and Khin Zaw(2003) Jurassic to Miocene magmatism and metamorphic belt and the India-Eurasia collision in Myanmar.J. Tectonics.Vol 22,pp4-12.

Bertrand, G., and Rangin,C., Tin Aung Han, Myint Thein, Ohn Myint, Win Maw and San Lwin (1999) Cenozoic Metamorphism along the Shan Scarp(Myanmar): evidences for the ductile shear along the Sagaing Fault or the northward migration of the Eastern Himalayan Syntaxis. pp 915-918.

Li, P.W., et al.(2004) Paleomagnetic analysis of eastern Tibet: implication for the collisional and amalgamation history of the Three Rivers region, SW China. Journal of Asian Earth Sciences 24 (2004),pp 291-310.

Metcalfe,I.,(1998) Paleozoic and Mesozoic geological evolution of the SE Asian region multidisciplinary constraints and implications for biogeography.In: Hall,R., Blundell,D.(Eds), Biogeography and Geological Evolution of SE Asia. Backhuy, Publishers, Amsterdam, The Netherlands,pp.25-41.

Mitchell, A.H.G (2006) Rock relationships in the Mogok metamorphic belt, Tatkon to Mandalay, Central Myanmar. J.Asian Earth Sciences, 20p.

Mitchell, A.H.G (2015) The Medial Myanar suture zone and the western Myanmar Mogok foreland. J.Myanmar Geosciences Society,vol.6no.1,73-88, January 2015

Morley,C.K.(2004) Nested strike-slip duplexs and other evidence for late Cretaceous Paleogene transpressional tectonics before and during India-Eurasia Collision, in Thailand,Myanmar and Malaysia. J. Geol.Soc.London. Vol 161,No.5,pp 799-812.

Passchier, C.W & Trouw, R.A.J (1996) Microtectonics. Springer-Verlag, Berlin,289p.

Win Naing (2006) Cenozoic deformation patterns in the South Western Shan Plateau with special emphasis on the Ductile shearing along the Papun fault zone. Ph.D Thesis, University of Yangon.245p.

Sandy Chit Ko (2010) Structural study of the area along the accreted belt of the western margin of Shan-Thai Block. Ph.D Thesis, University of Yangon.190p.