Myanmar Academy of Arts and Science

JOURNAL OF THE MYANMAR ACADEMY OF ARTS AND SCIENCE

Geology and Geography

Vol. XVI, No.5, October 2018

Myanmar Academy of Arts and Science

Journal of the Myanmar Academy of Arts and Science

Vol. XV, No.5

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

NATURE AND CHARACTERISTICS OF GOLD MINERALIZATION AT MODI TAUNG GOLD DEPOSIT, YAMETHIN TOWNSHIP, MANDALAY REGION*

Kyaw Linn Zaw[1], Ohn Thwin[2], Thet Paing Kyaw Win[3]

Abstract

The ModiTaung area is located 370 km to the north of Yangon. The segment of gold mineralization is of interest as it is the first reported gold deposits of slate-hosted mesothermal quartz-gold veins (orogenic gold deposit) in Myanmar. This slate belt consists of the argillaceous rocks namely Mergui Group (Late Palaeozoic age) and which is largely intruded by many plutons. The deposit is hosted within three major vein systems. They are made up of several veins which are spatially grouped into their respective systems. Vein textures are mostly of three types; book-and-ribbon texture, laminated to stylolitic texture and massive texture. Mineralized shear veins tend to follow three trends within brittle-ductile regimes and occur at the centre of the shear zone (C vein) or oblique to the shear zone boundary. Book and ribbon vein textures provide evidence that mineralization took place during D_2 within NNE trending shear zones.

Pyrite chemistry indicates two main episodes of gold mineralization: syngenetic gold precipitation in Py1 and an epigenetic gold mineralization in Py2 and Py3. Py1 is interpreted to be of syngenetic/diagenetic origin because of its higher Ag, Ni, V contents and the ratio Au/Ag is less than 1. Py2 and Py3 are of hydrothermal origin as they have low levels of Ni, V, and Ag with Co/Ni ratio and Au/Ag more than 1. Evidence of pulsed hydrothermal mineralizing fluids is also consistent with the presence of cobalt and nickel zoned micro-bands in the pyrite structure.gold in Py1 could have been remobilized by circulation of later magmatic and metamorphic fluids and concentrated elsewhere enhancing the gold content in later generations of pyrite (Py2 and Py3).

Keywords: *Mineralization, ModiTaung, Orogenic, pyrite chemistry, shear veins*

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Introduction

The ModiTaung area is located in central Myanmar, 150 km to the southeast from Mandalay and 370 km to the north from Yangon. The maximum elevation of the area is 1200m on the upland escarpment that divides the central plain and Paunglaung River valley. The area coverage of the area is the approximately 6105 acres (24.71 sq. km). Location map of approximate coverage of study area is shown in figure 1.

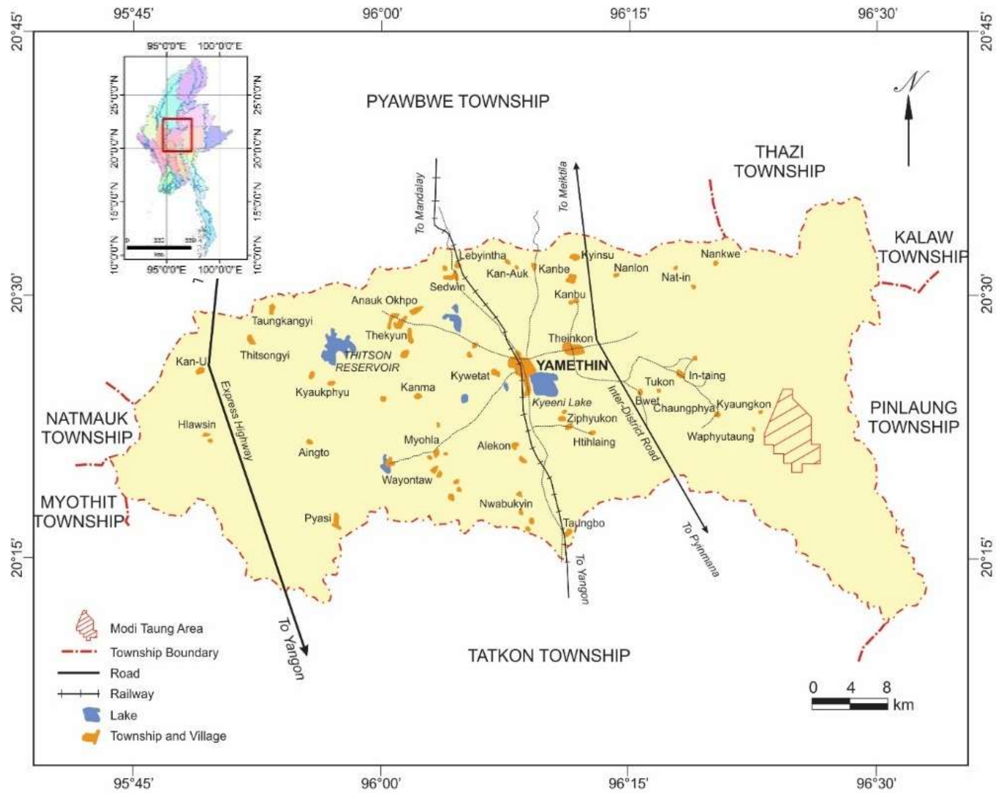


Figure 1. Location Map of the Study area

Deposit geology of the study area

The ModiTaung gold deposit is hosted in the sedimentary units of the Mergui Group, which itself is situated in the eastern extremity of the MMB. The Mergui Group is composed of two dominant sedimentary facies associations. A lower sequence is made up of massive to bedded shale, sandstone, rare limestone and channel fill pebbly wackes (Mitchell et al., 2004). The upper units of the Mergui Group include several polymict conglomerate units which occasionally host marine fossils (Mitchell et al., 2004). In ModiTaung area, there are two formations, Kogwe Mudstone and Poklokkale Pebbly Wackestone. The Kogwe Mudstone mainly consists of massive to laminated and locally calcareous mudstone and siltstone interbeddedquartzose sandstone which generally dips to northeast beneath Poklokkale Pebble Wacke. In the lower part, the Kogwe Mudstone includes channel-fill disorganized conglomerates with rafts of mudstones. It passes up transitionally into the Poklokkale Pebbly Wacke. This pebbly quartz wackes and pebbly mudstones or diamictites are interbedded with massive and laminated mudstones and siltstones, phyllite (Figure 2 A).The deposit geological map produced from field observations is shown in figure 2 B.

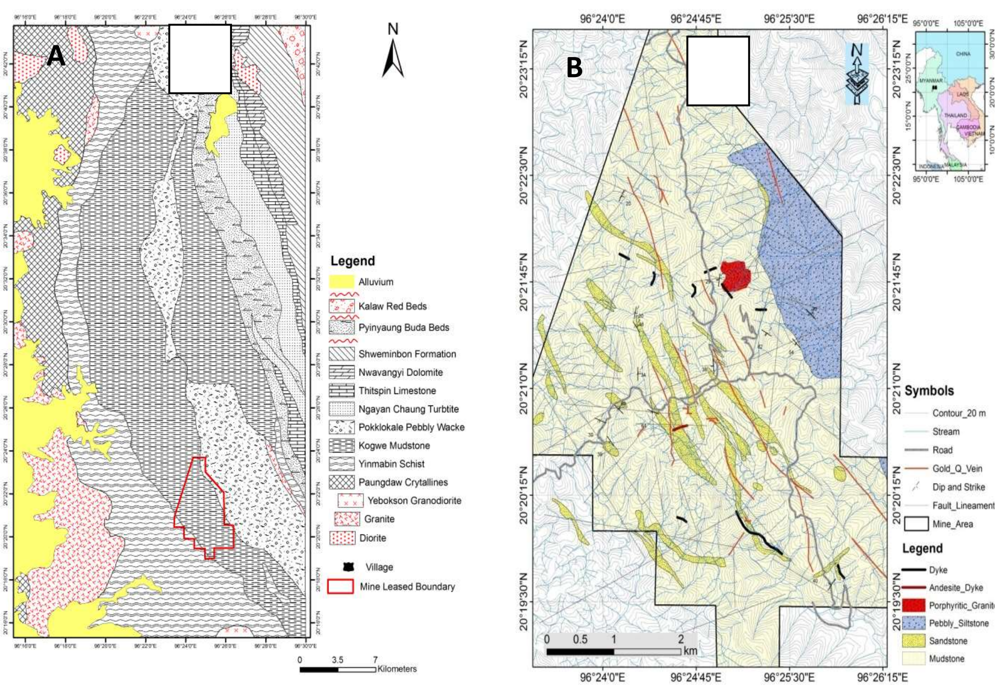


Figure 2.A. Geological Map around ModiTaung Area.
B. Deposit geological map of the Modi-Momi area.

Pebbly siltstone unit

The oldest stratigraphic unit exposed in the ModiTaung lease area is a pebbly siltstone which crops out in the eastern extremity of the lease area. The siltstone is characterized by occasional sub-centimetre scale lithic clasts which are supported by a weakly banded quartz dominated silty matrix (Figure 3). Clasts are polymict and range in shape from rounded to sub-angular. Some clasts display flattened edges; however, the term pebbly siltstone is preferred to tillite as no additional evidence of glacial input has been observed. No fossils were observed in the field, however Mitchell et al. (2004) noted the occurrence of Lower Permian fossils within the unit.

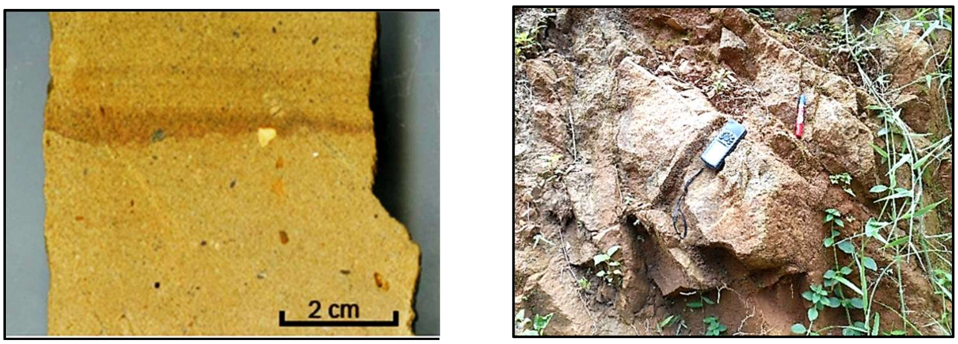


Figure 3.A. Pebbly siltstone exhibiting weak bedding textures and polymict lithic fragments. **B.** Outcrop of pebbly siltstone displaying load casts of sub-metre scale boulders.

Mudstone unit

Two mudstone units were observed in the ModiTaung lease area. The older unit is exposed in both the east and west of the study area where it conformably overlies the pebbly siltstone unit (Figure 4). This mudstone has an estimated thickness of ~ 40 m. The younger mudstone crops out throughout the central region of the lease area where it overlies a slate unit. This second mudstone is the youngest sedimentary unit exposed within the area. The thickness of this unit is unknown as it appears to have been thickened by east-west shortening of the strata. Pyrite is rarely observed and pyrite crystals never exceed 1 mm. In outcrops proximal to ore, the mudstone can be pervasively bleached and occasionally cut by carbonate veinlets; where present the veinlets broadly follow cleavage and cut bedding at a high angle.

Mudstone outcrops more distal to mineralization do not display these characteristics and are largely unaltered.

Figure 4:A. Outcrop nature of mudstone showing a tendency to break along bedding planes. **B.** Outcrop of mudstone near guest house

Sandstone unit

Sandstone is exposed in several regions in the ModiTaung lease area. However, regional folding has caused one unit to cropout in multiple locations and overrepresented the unit. Sandstone conformably overlies the older shale unit. The sandstone is weakly bedded to massive and is quartz dominated although rare magnetite is also present (Figure 5). The sandstone is medium-grained and highly silicified in all outcrops. This sandstone unit hosts gold mineralization in the Shwesin vein system and is overlain by slate which hosts gold mineralization in the Htongyi vein system.

Figure 5.A. Sandstone sample showing well sorted massive texture, S_2 can be seen (vertical) in this sample. **B.** Outcrop of highly silicified sandstone.

Slate unit

Slate crops out in two parallel narrow NNW trending bands, and these conformably overlie the sandstone unit previously mentioned and is in turn overlain by the younger mudstone unit. The slate is moderately foliated, generally cut by carbonate veinlets and displays a pervasively bleached texture (Figure 6).

Figure 6.A. Outcrop nature of Slate showing a pyrite bearing carbonate vein cutting a smaller quartz vein. **B.** Bleached texture and a series of veinlets.

Mineralized vein system in the study area

The ModiTaung gold deposit is hosted within three major vein systems. From east to west these are: Htongyi, Sakhangyi and Shwesin. Htongyi and Shwesin are made up of several veins which are spatially grouped into their respective system (Figure 7 A). The three vein systems generally strike NNE, however the veins converge in the north and south of the lease area and little is known about them outside this zone. Veins in the east of the lease area dip steeply to the west, while veins in the west dip steeply to the east. This observation suggests that the veins have the same origin and that a major fluid conduit existed in the middle of the lease area (Figure 7 B).

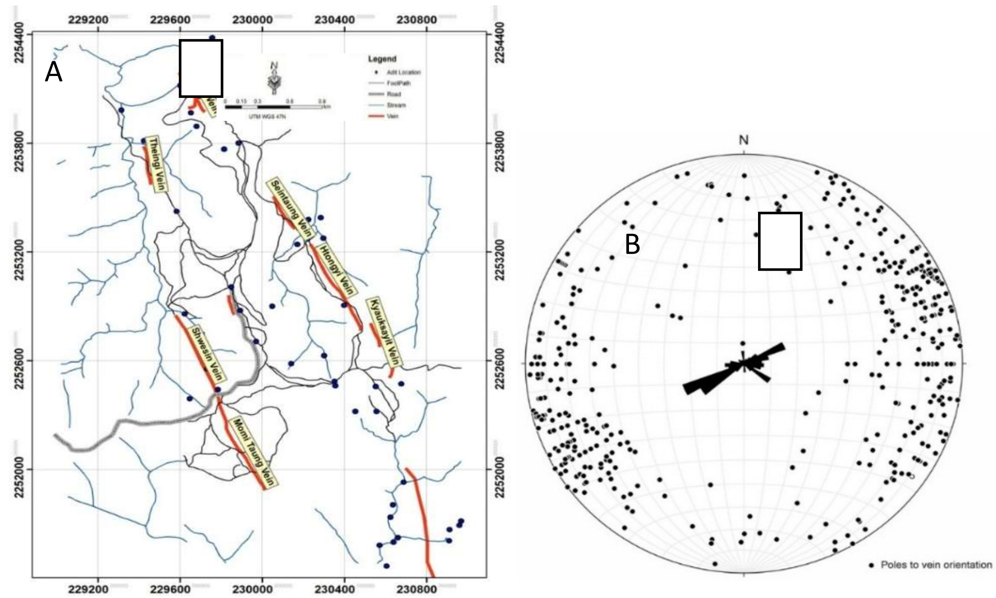


Figure 7.A. Location of three major veins system at ModiTaung area.**B.**Stereonet of poles to vein orientation demonstrating that the veins dominantly dip steeply to the northeast and southwest.

Channel sample across veins in adits assay up to 300 ppm Au; these high values tend to be in shallower obviously oxidized veins but value up to 100 ppm over 1 m occur beneath the oxidized zone. There is locally extreme variation in assays (3 to 300 ppm Au) across a single vein in channel samples less than a metre apart. Local veins segments with cm-scale parallel bands are containing coarse visible gold implying the existence of ore shoots, but the geometry of, or contours on, possible shoots are so far not known.

In the oxidize zone, which is up to 80 m thick, wall rock alteration is unimpressive, although mudstone slivers in book-and-ribbon textured veins are weakly or strongly altered to chlorite or chlorite and pyrite. Sandstones adjacent to veins are commonly silicified and sometimes bleached through supergene oxidation of pyrite and consequent kaolinization, with iron or manganese strains. Beneath the oxidized zone, phyllite within 5 to 10 m of veins shows abundant chlorite together with pyrite in fractures, and sandstones are grey-green, indicating chlorite or sericite and chlorite occurs as selvedges on quartz veins. It is uncertain whether the chlorite is similarly abundant further away from the veins.

The mineralization reaches a maximum elevation of 1326 m in the Sakhangyi vein system. The maximum depth explored thus far is 845 m in the Htongyi vein system. Vein width varies with elevation and ranges between centimetre and metre scale. The thickest veins tend to occur between ~ 1000m and 1200 m elevation and are part of the Htongyi vein system.

Nature of gold-bearing quartz veins

The book and ribbon, laminated, stylolaminated textures are typical of shear veins in mesothermal deposits (Figure 8). These textures are generally considered to result from repeated fracturing and quartz deposition during shear movement parallel or sub-parallel to the shear zone (Figure 9). If the country rock is mudstone, it is generally strongly foliated, chlorite altered, may contain pyrite and may be partly silicified. The quartz rich zone may be made up of an amalgamation of many quartz veins where the country rock slivers have variable separation widths or contain only very thin parallel slivers or exhibit stylolitic lines parallel to the vein boundary (Figure 10). The stylolitic laminations attest to high-pressure solution after vein formation.

The laminated veins are occasionally folded. Elsewhere the quartz is more massive with no or minor remnant country rock. The progression from a central zone of massive quartz to stylolaminated to an outer zone of book and ribbon structure is common and may result from progressive silicification during each quartz depositional event which gradually replaces the country rock. Pyrite patches varying from disseminated pyrite to almost 100% pyrite and pyrite-chlorite to chlorite foliated mudstone occur occasionally and are generally distributed along zones parallel to the laminations. The replacement of country rock fragments can often be defined by the clear quartz ghost-like patches containing alteration pyrite (Figure 11).

Figure 8.A. Book and ribbon texture in shear quartz vein. The dark patches are remnant mudstone of country rock. (Htongyi).**B.** Laminated quartz shear vein.

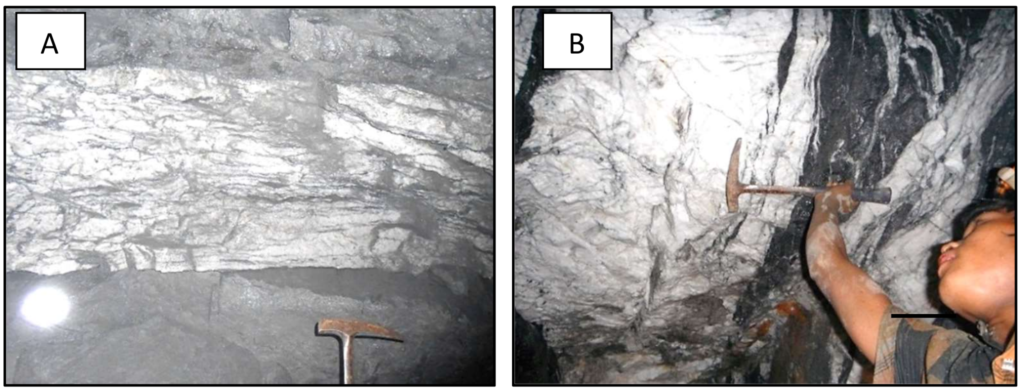


Figure 9.A. Stylolaminated quartz shear vein formed by high pressure and dissolution of country rock after vein formation. **B.** Massive quartz vein.

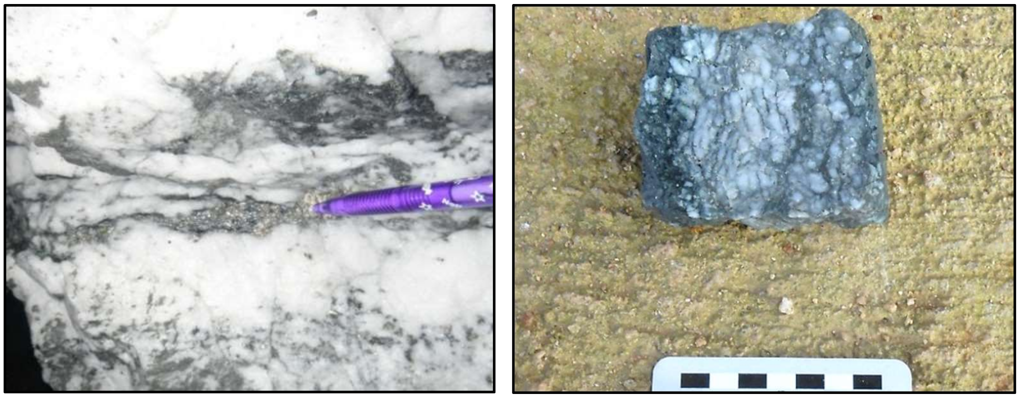


Figure 10. A. Book and ribbon structure. **B.** Laminated structure. **C.** Stylolaminated structure with pyrite patches. **D.** Brecciated structure.

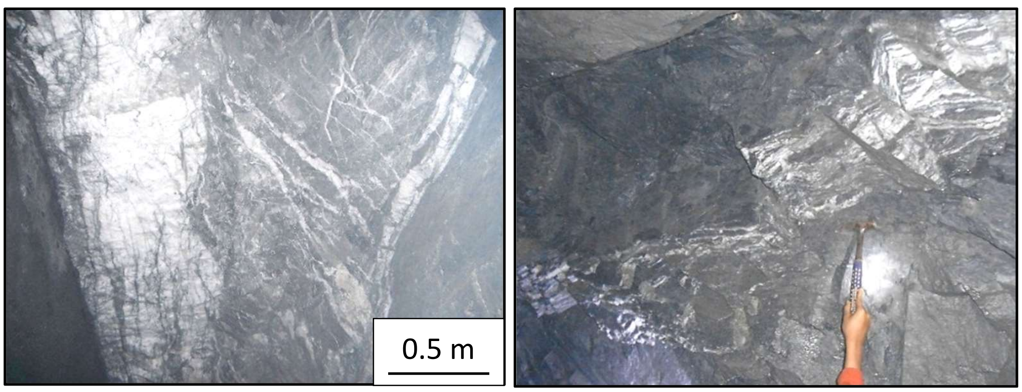


Figure 11.A. Complex shear vein with mudstone locally filling fractures in quartz. **B.** Ladder vein cross-cutting laminated quartz.

Slickensides commonly occur on discrete surfaces of individual quartz veins and adjacent country rock and are typically oblique with steep southerly plunge. Minor offset of shear veins and rock slivers along faults occur occasionally and the faults may offset the boundary shears or many appear to join them (Figure 11). The apparent joining of the two faults may be due to the late reactivation of the main boundary shear.

Shear veins tend to follow three trends within brittle-ductile regimes and occur at the centre of the shear zone (C vein) or oblique to the shear zone boundary (P and R veins in figure 12). The R (Reidel) is related to brittle fracture whilst the P (Pressure) vein is related to ductile fracture. All veins have the same sense of displacement as the main shear zone and may open at the same time such that related quartz vein deposition will show no crosscutting relationship. Overlapping of *en echelon* P oblique shear veins show the same sense of steeping (Figure 13). Right steeping indicates right lateral displacement and left steeping indicates left lateral displacement. In *en echelon* R shear veins the sense of overlapping will be opposite i.e. left steeping indicates right lateral movement. The three shear veins should theoretically trend within 30° of each other (i.e. 15° either side of the C vein). The various shear may open allowing for quartz deposition at different places and times. The compressional mineralization structure followed to the P shear direction (ENE-WSW) and vein trend tend to be (NNW-SSE) direction.

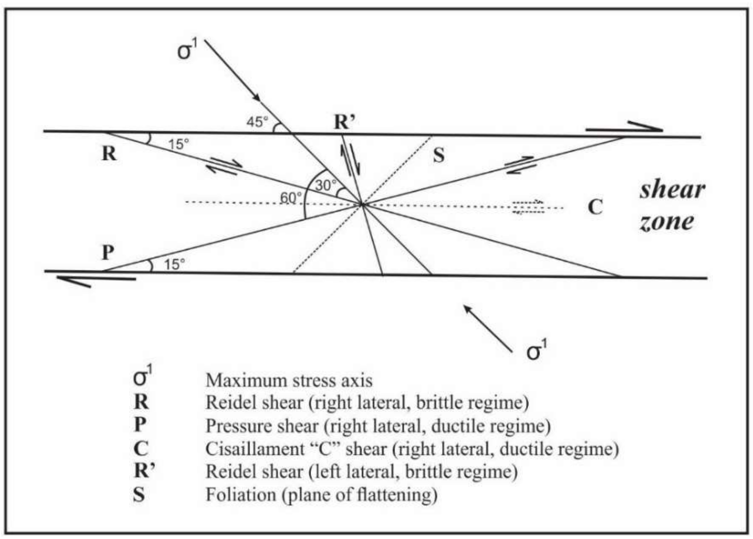


Figure 12. Theoretical geometry of shears within a right lateral, brittle-ductile, shear regime. A degree of extension may occur in all directions (Source, Worsley, 2001)

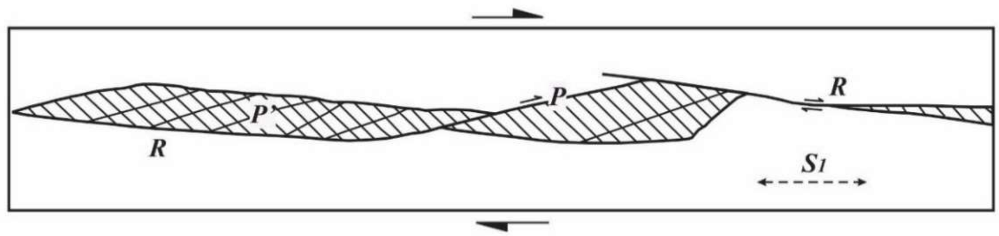
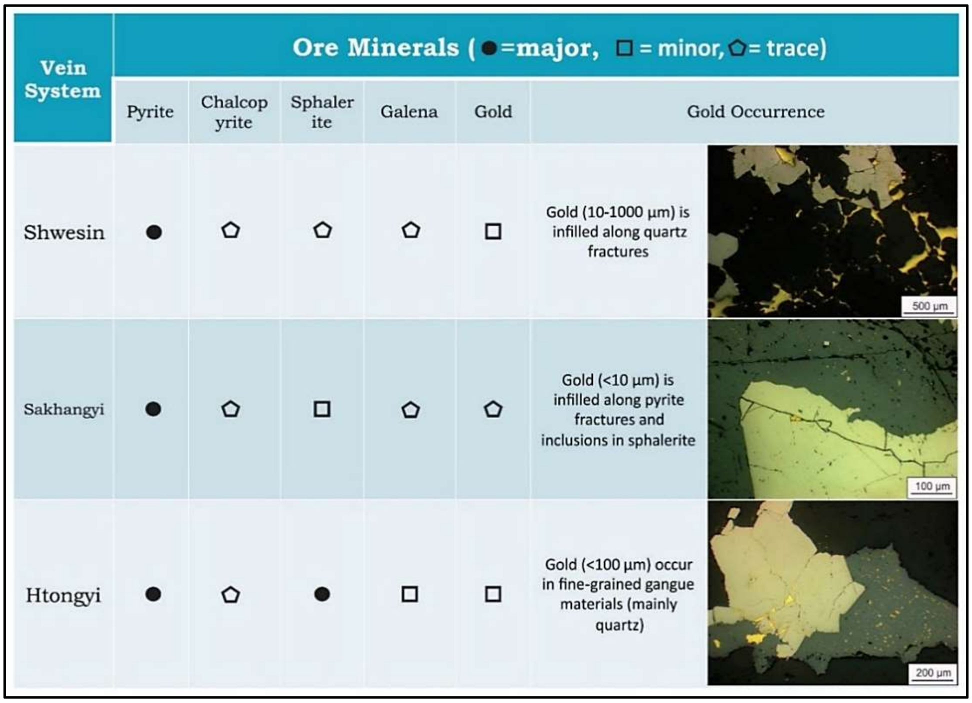


Figure 13. Tchalenko Shear box experiment. Diagram shows structures formed in clay in a direct shear test in shear box. P- pressure shear, R- Reidel shear, hatchings= particle orientation in zone of compression, white area= particle in initial fabric attitude (S1). (Source: Tchalenko, 1968)

Evidence for repeated ductile-brittle movement within the main shear zones includes local folding of laminations, foliated mudstone within fractures of the quartz veins, folded veins, possible ladder vein formation and multiple vein formation. If the main shear zone is developed within mudstone, there appears to be a tendency to develop more complex quartz vein arrays (possible jogs) whilst planar, simple quartz veins are developed in sandstone and at sandstone-mudstone boundaries.

Mineralization

Free visible gold can be observed in samples which exceed ~ 60 ppm Au. At lower grades microscopic gold occurs in fractures within pyrite and between the crystal boundaries of pyrite. Pyrite is the dominant sulphide mineral and shows at least three distinct forms. As yet it is unknown whether Au is preferentially associated with one particular pyrite generation. Galena was only observed in the Htongyi and Sakhangyi vein systems and shows a moderate correlation with high grade Au mineralization. No correlation between galena and Au was determined where Au grades are less than 100 ppm. Sphalerite and chalcopyrite are both rare in the ModiTaung gold deposit and dominantly occur within the Htongyi vein system. Sphalerite and chalcopyrite generally occur together. Both show multiple crystal textures which may indicate that they were emplaced via multiple mineralizing events (Figure 14). Quartz and calcite are the dominant gangue minerals, as would be expected in a vein type deposit. Carbonate accounts for less than 15 % of vein minerals which is consistent with the orogenic gold deposit model (Groves et al., 1998). Alteration minerals include graphite, sericite and chlorite. These form the dark bands in the book and ribbon zones of the Htongyi and Sakhangyi vein systems. The alteration minerals are likely to be the products of hydrothermal alteration of wall-rock lithics set in the veins during syn-shear veining.



Vein System	Ore Minerals (● =major, □ = minor, ⬠ = trace)					
	Pyrite	Chalcopyrite	Sphalerite	Galena	Gold	Gold Occurrence
Shwesin	●	⬠	⬠	⬠	□	Gold (10-1000 μm) is infilled along quartz fractures
Sakhangyi	●	⬠	□	⬠	⬠	Gold (<10 μm) is infilled along pyrite fractures and inclusions in sphalerite
Htongyi	●	⬠	●	□	□	Gold (<100 μm) occur in fine-grained gangue materials (mainly quartz)

Figure 14. The presence of sulphide minerals at representative vein systems.

Pyrite Chemistry

Pyrite samples analyzed from samples show similar textural and chemical aspects (Figure 15). Both these samples show an inner core pyrite Py1 with similar elevated levels of Sb, Bi, Cr, Ba, Mn, As and Au which are depleted in the outer euhedral pyrite Py2. The elevated As and Au in Py1 suggests that this pyrite is likely of diagenetic type from a depositional sedimentary source and that this Py1 has been remobilized by later metamorphic-magmatic fluids to form Py2 with lower concentrations of Py1 elements. The chemical signature of the inner pyrite core is closer in similarity to Py2. It is therefore suggested that this samples inner core is in fact a metamorphic type pyrite Py2. This pyrite has then been overgrown by hydrothermal pyrite associated with the quartz veining event and been enriched in Au and other elements such as Ni and As. Py3 has increased levels in all trace elements compared to the other pyrite types. The increased Au suggests that the pyrite has formed from an enriched hydrothermal source that formed after peak metamorphism. A summary of the pyrite samples analyzed and the pyrite types is supplied in Table 1.

Table1. Sumary comparison of sample numbers and their pyrite types with relavant element levels in ppm. Py1, Py2, and Py3.

Pyrite type	Au (ppm)	Ag (ppm)	As (ppm)	Ni (ppm)	V (ppm)
Py1	0.85	1.92	2681.80	306.45	4.98
Py2	0.77	0.77	1991.32	308.95	1.70
Py1	0.17	12.12	1103.59	145.47	-
Py2	0.052	3.33	760.91	156.09	-
Py2	0.041	0.44	51.82	15.50	2.62
Py3	0.33	0.81	1257.71	183.13	0.50

Study of the pyrite chemistry indicates two main episodes of Au mineralization: 1) syngenetic Au precipitation in Py1 and an epigenetic Au mineralization which also contributed to the formation of free gold in Py2 and Py3. Py1 is interpreted to be of syngenetic/diagenetic origin because of its higher Ag, Ni, V contents and the ratio Au/Ag is less than 1. Py2 and Py3 are of hydrothermal origin as they have low levels of Ni, V, and Ag with Co/Ni ratio and Au/Ag more than 1. Evidence of pulsed hydrothermal mineralizing fluids is also consistent with the presence of cobalt and nickel zoned micro-bands in the pyrite structure.

Au in Py1 could have been remobilized by circulation of later magmatic and metamorphic fluids and concentrated elsewhere enhancing the gold content in later generations of pyrite (Py2 and Py3). This interpretation is supported by the occurrence of pyritic slaty mudstone and the effect of low grade metamorphism with the capacity to mobilize sulphur and iron from early pyrite to form later hydrothermal pyrite (Large et al., 2007).

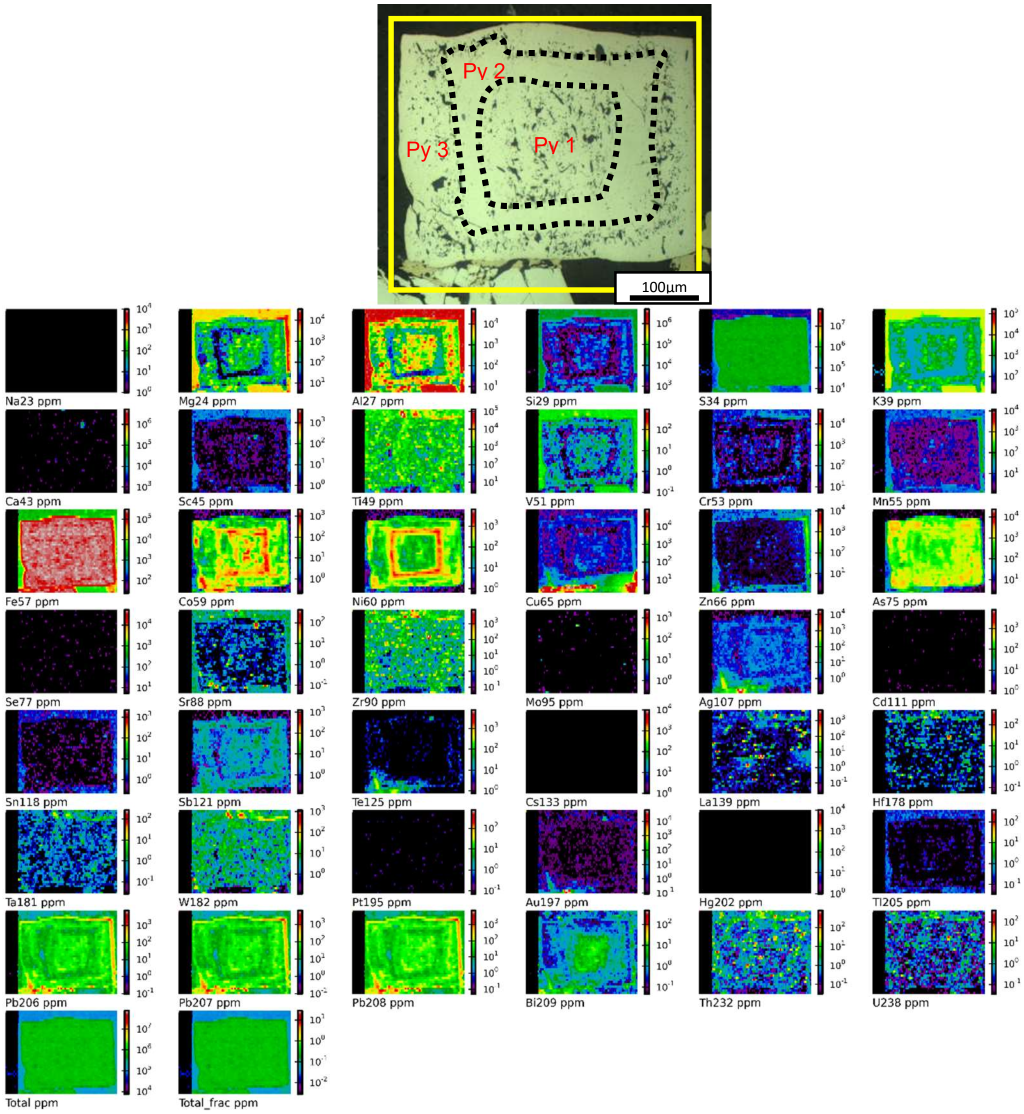


Figure 15.Pyrite map showing zoned pyrite euhedral grain comprising three pyrite generations. Pyrite 1 is enriched in V, Mg, Al, Bi, Sb, relative to pyrite 2 and 3. Gold inclusion is spotted from the rim of pyrite 3.

Conclusion and Discussion

The ModiTaung area is located in central Myanmar, 370 km to the north of Yangon, There are two formations, Kogwe Mudstone and Poklokkale Pebbly Wackestone.The sedimentary sequence has been intruded by at least three generations of igneous rocks.

The study area has been subjected to at least two deformation events as evidenced by S_1 and S_2 cleavages. S_1 is likely to represent the closure of the basin in which the sediments were deposited via east/west compression. The subduction related closure of the Paleotethys is likely to be the cause of D_1 as interpreted from S_1 cleavage. S_2 occurs almost at right angles to S_1 and suggests northeast/southwest compression. These two deformation events have led to the complex refolded fold geometry displayed in the host rocks of the area. Book and ribbon vein textures provide evidence that mineralization took place during D_2 within NNE trending shear zones and fault structures (Figure 16).

Pyrite is the dominant sulphide mineral and shows at least three distinct forms.Au is preferentially associated with one particular pyrite generation. Sphalerite and galena shows multiple crystal textures which may indicate that they were emplaced via multiple mineralizing events. The alteration minerals are likely to be the products of hydrothermal alteration of wall-rock lithics set in the veins during syn-shear veining.

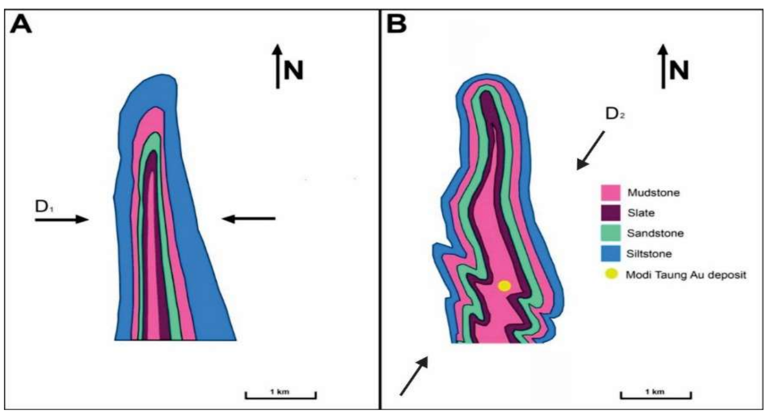


Figure 16.A. Inferred principal stress direction for the generation of S_1 cleavage. D_1 is shown as a major east-west compressional event resulting in north-south folds. **B**. Inferred principal stress direction for the generation of S_2 cleavage. D_2 is dominantly NNE-SSW compressional event resulting in a second generation of folds.

Acknowledgements

The authors wish to express their gratitude to DrTheingiKyaw, Professor and Head of Department of Geology, Hinthada University for her permission and valuable administrative support. We also wish to express our thank U SoeHtunShein (Chairman, National Prosperity Company), U TunAungSoe (Managing Director, and U ThihaZaw Lynn (Former Managing Director, NPGPG) for their invaluable help.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

A NEW OCCURRENCE OF THE MIDDLE DEVONIAN UNIT IN THE LASHIO AREA, NORTHERN SHAN STATE

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Abstract

A new occurrence of the Middle Devonian Unit equivalent to the Padaukpin Limestone in Wetwin-Padaukpin area is recognized for the first time in the lower part of the Maymyo Formation, Lashio area, northern Shan State. It exposed as isolated outcrops only at two localities in Lashio area. The unit mainly composed of from base to top; (1) medium- bedded, grey to dark grey calcitic limestone intercalated with thin-bedded, black shale with abundant recrystallized gastropods (Quarry near the Hseing Hkai car-road, N 22˚ 53´ 36´´ and E 97˚40´ 51´´); (2) medium-bedded, ligh grey to buff, argillceous limestone with buff to black shale and siltstone containing abundant crinoid stems, cystoid plates and brachiopods and (3) medium-bedded, light grey to grey, calcitic limestone and buff coloured argillaceous limestone interbedded with buff to black shale and siltstone comprising abundant tabulate and rugose corals (along the car-road from Lashio to Muse at mile post 5-6 furlong, N 22˚ 54´ 02´´ and E 97˚42´08´´). This unit is also the sandwiched unit in the Maymyo Formation and laterally passed into the dolomite or dolomitic limestone. The age of the unit exposed at the Lashio area is defined by the strong faunal evidences such as gastropods: *Muchisonia* sp., *Loxonema* sp. and *Euromphalus* sp. and important tabulate and rugose coral species: *Favositesgoldfusi*, *Alveolites* sp., *Coenites* sp., *Aulocystics* sp., *Stringophyllum* sp., *Grypophyllum* sp., *Temnophyllum* sp., *Acanthophyllum* sp., *Peripaedium* sp., *Cyathophyllum*sp. and abundant *Calceolasandalina*. *Calceolasandalina* which are known as a typical Middle Devonian (Eifelian) species in Myanmar, Europe, USSR, Asia and Australia. It is a more complete succession of the faunal assemblage with Middle Devonian age and slightly different in lithology and faunal content with the type section of the Padaukpin Limestone.

Keywords: Middle Devonian, Lashio area, tabulate and rugose corals

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Introduction

Location and size

The study area is situated in Lashio Township, Northern Shan State. It lies about 175 miles NE of Mandalay, about 46 miles NE of Hsipaw and about 54 miles SW of Mu-se. It is located between the North Latitude 22°52'-22°56' and East Longitude 97°38'– 97°48'. The study area is located at 2297 9/13UTM topographic map. It is about 5miles long north-south and about 11.18miles wide east-west covering approximately 55.35square miles. This area is readily accessible by automobile or train throughout the whole year. The location map of the study area is shown in Figure (1). This paper mainly deals with on the investigation of the lithostratigraphic unit of the Maymyo Formation in the study area.

Methods of study

The field investigation of the study area was carried out from October 2016 to March 2017.Several traverses across the regional structures were made. Routine geological observation, description and sampling were conducted along the traverse lines. The stratigraphic succession of different rock units was established and carefully studied with detailed laboratory investigations of representative samples and diagnostic fossils.

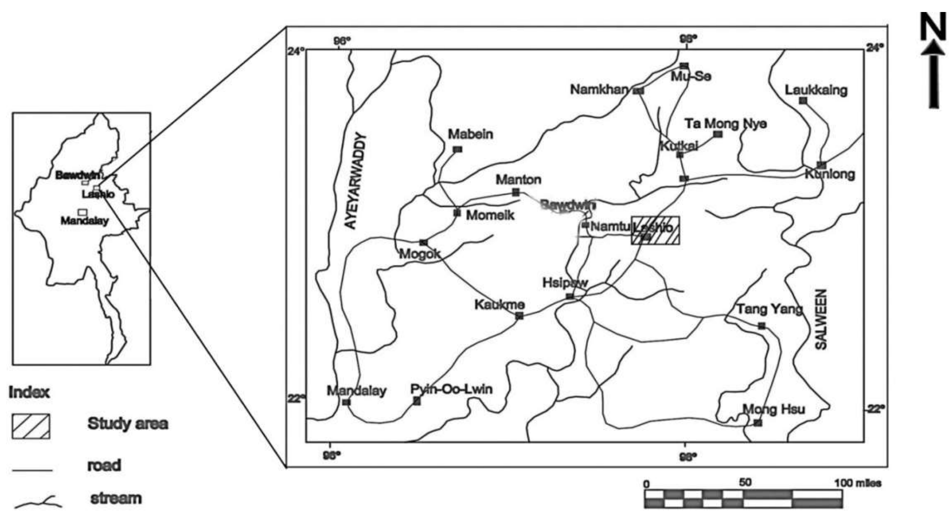

Figure 1. Location map of the study area.

Previous Work

The numerous work on the geology of the Shan State had been published by various authors. The geology of the Northern Shan State including the present area was described by La Touche (1913).Pascoe (1959), Brunnschweiler (1970), Amos (1975), Garson *et al* (1976) and Wolfart *et al* (1984). Tin Myo Myo Htwe, Hla Hla Htay and Nu Nu Yin (2003) investigated this area for their MSc dissertation. They gave accounts on the stratigraphy, geology and petrology of the Lashio-Panhone area, Northrn Shan State. Zaw Win (2010) described the stratigraphy and sedimentation of the Lashio and its environs, Lashio Township.

Results and Discussion

Stratigraphy

Stratigraphic Succession

The present area lies in the middle part of the Eastern Highland. It is constituted mainly of the Upper Paleozoic-Mesozoic units from Middle Devonian to Jurassic dolomitic limestone, dolomite, calcitic limestone, argillaceous limestone, siltstone, shale, sandstone and conglomerate. The lithostratigraphic units older than the Middle Devonian age are not exposed in this area. Geological map of the study area is shown in Figure 2.

The rocks of the present area can be differentiated into five lithostratigraphic units of formation rank on the basis of the lithology, stratigraphic position and faunal content. The stratigraphic succession in ascending order (from older to younger) is as follows;

Rock Units	Stratigraphic Sequence
5. Hsipaw Red Beds	Late Jurassic
4. Loi-an Group	Early – Middle Jurassic
3. Nwabangyi Dolomite Formation	Late Permian – Early Triassic
2. Plateau Limestone	Early – Middle Permian
1. Maymyo Formation	Middle Devonian

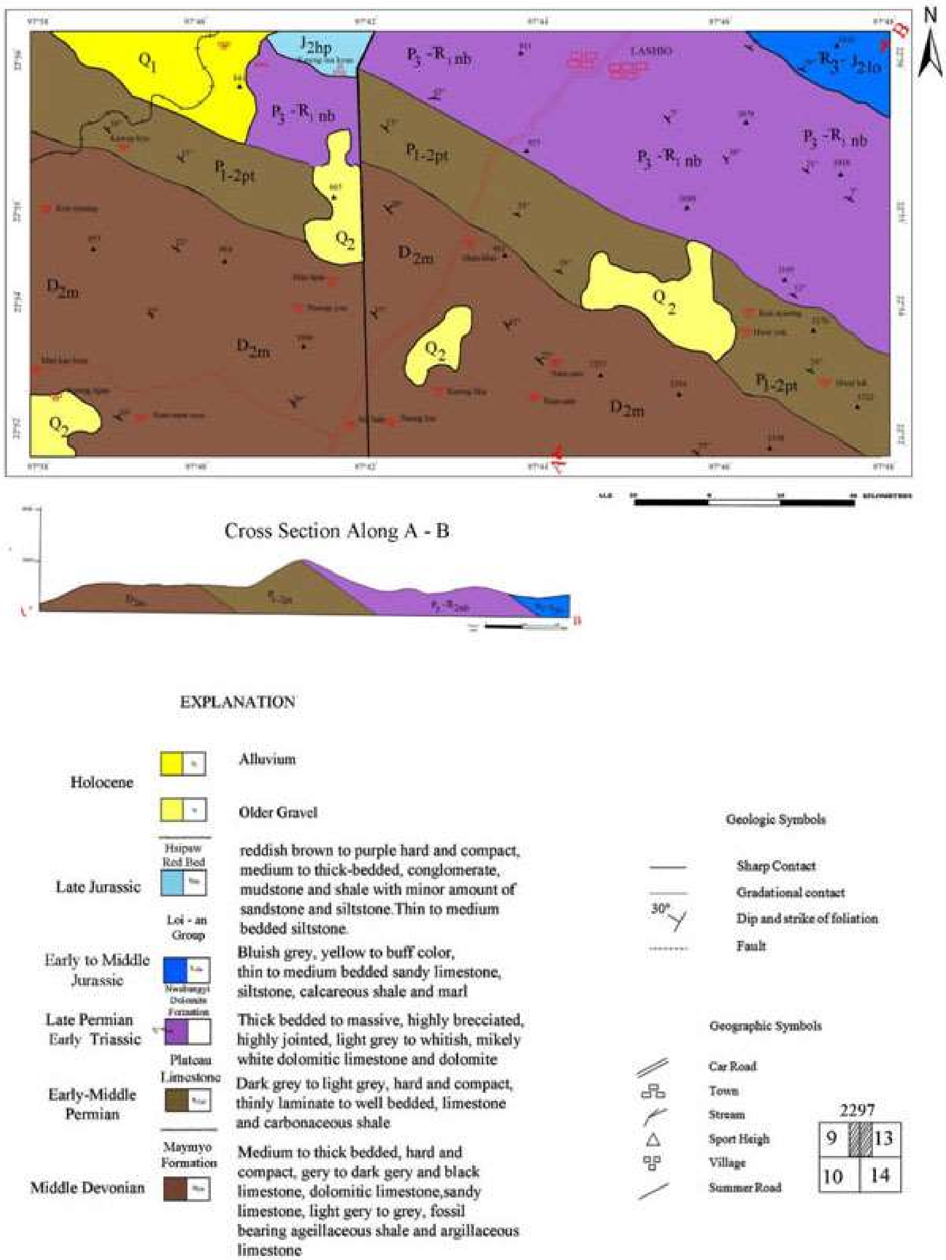

Figure 2. Geological map of the study area. (After Khin Nyein Chanthar et al, 2017)

The generalized composite stratigraphic column of the study area is shown in Table (1). The thickness of these beds varies from thin-bedded to massive. Permian to Jurassic units are successively overlain with gradational contact. There may be a major hiatus at the end of Middle Devonian with reference to the occurrence of carbonate breccias. This paper mainly deals with described on the stratigraphy of Middle Devonian unit.

Maymyo Formation

General Statement

The name “Plateau Limestone” was first given by La Touche (1913) for a unit of thick carbonate sequence which covers a large part of the Shan State. Brunnschweiler (1970) subdivided the Plateau Limestone into the Shan Dolomite of Devonian age and the Htoonbo Limestone of Carboniferous to Permian age. Amos (1975) proposed the Shan Dolomite group and can be subdivided into the Devonian Maymyo Dolomite Formation and the Permian-Triassic Nwabangyi Dolomite Formation. I.G.C.P (1980) gave the name “Maymyo Formation”.

Distribution

This Formation is mainly exposed in the south-eastern and south-western parts of the study area. Good exposures of this formation occur in the vicinity of Nam Khai and Me Han Villages. This unit also crops out along the Mandalay-Muse high way.

Lithology

The Maymyo Formation is mainly comprised thick-bedded to massive, white to light grey dolomite and dolomitic limestone. They are locally dolomitized and highly brecciated and well-jointed. The dolomitic limestones are mostly massive to rarely thick bedded (Figs. 3 - 5). At quarry near the HseingHkai car-road and the mile-post 5 and 6 furlongs along the Lashio-Muse car-road, fossiliferous units occurred in the Maymyo Fromation. Stained red by iron oxides along the joint planes can be seen in this Formation. These two units are sandwiched between the dolomitic limestones. This sandwiched nature is clearly seen at the mile-post 5 and 6 furlongs along the Lashio-Muse car-road. These two fossiliferous units are considered as the equivalent unit of the Padaukpin Limestone. They laterally passed into dolomite and dolomitic limestone. The composite stratigraphic measured section of the Maymyo Formation is shown in Fig.6.

Nature of Contact

The lower boundary of Maymyo Formation is not observed in this area. The Maymyo Formation is underlain unconformably by the Permian Plateau Limestone. This contact nature is clearly seem as carbonate breccias in (Fig.5). The upper contact is also a faulted contact with the Plateau Limestone due to Kyauk-taung longitudinal Fault.

Fauna, Age and Correlation

In the study area, abundant gastropods, crionoid stems and corals are observed in the Padaukpin Limestone of the Maymyo Formation. Except them, fossils are rare in this Formation due to the highly brecciation and intense dolomitization.

Figure 3. Thick-bedded to massive, white to light grey dolomite and dolomitic limestone of the Maymyo Formation. (N 22° 52' 56" and E 97° 41' 25")

Figure 4. Thick-bedded, grey to dark grey highly jointed dolomitic limestone of the MaymyoFormation (N 22° 53' 33" and E 97° 45' 28").

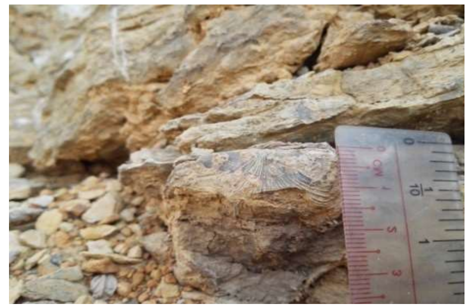

Figure 5. Unconformable evidence of carbonate brecciasbetween the dolomitic limestone of the Maymyo Formation and the Permian Plateau Limestone. (N 22° 52' 56" and E 97° 41' 25")

Figure 7. Medium to thick bedded, grey to dark grey, fossiliferousrecrystallized gastropods in limestone with silt patches of the Lower part of thePadaukpin Limestone near Lashio to HseingKhai car-road (N 22° 53' 36" and E 97° 40' 51")

Figure 8. Thin to medium-bedded, grey to dark grey, highly jointed limestone of the Lower part of the Padaukpin Limestone (N 22° 54' 04" and E 97° 42' 36")

Figure 10. Medium-bedded, buff to grey argillaceous limestone interbedded with shale containing abundant brachiopod fragments

Figure 11. Thin to medium bedded, buff to yellowish brown, highly jointed sandy limestone intercalated with black shale in the upper part of the Padaukpin Limestone (N 22° 54' 08" and E 97° 42' 06").

Figure 12. Medium-bedded, grey to buff, argillaceous limestone with abundant insitu tabulate corals of the upper part of the Padaukpin Limestone.

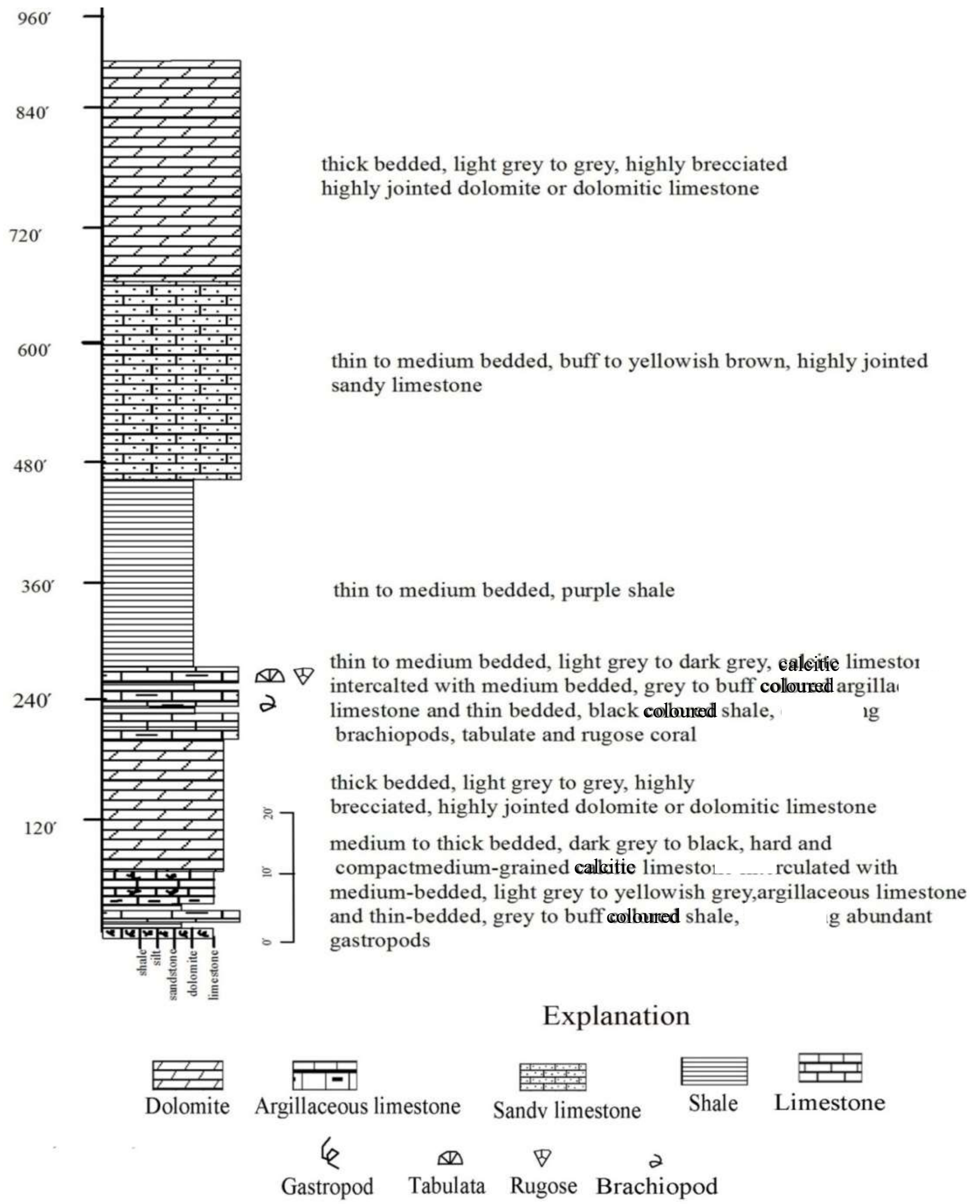

Figure 6. Composite Stratigraphic mesasured section of the Maymyo Formation (Along the Lashio-Muse Car-road; Base at N 22° 53' 36"-E 97° 40' 51" and top at N 22° 54' 20"-E 97° 42' 07").

On the basis of the stratigraphic position, the lithologic character and the sandwiched unit of the fossiliferous Padaukpin Limestone, the age of Maymyo Formation in this area is regardedas Middle Devonian (Eifelian).

Maymyo Formation can be correlated with the lower Plateau Limestone of La Touche (1913), Shan Dolomite of Brunnschweiler (1970), the Maymyo Dolomite Formation of Amos (1975), Maymyo Formation of I.G.C.P (1980), Maymyo Formation of Aye KoAung (2004), Maymyo Formation of KhaingKhaing San (2005).

Padaukpin Limestone

General Statement

The Padaukpin Limestone has previously been placed in the lower part of the Plateau Limestone (lower dolomitic part) of Devonian age (Reed, 1908&1929;La Touche,1913), the Shan Dolomite of Devonian age (Brunnschweiler,1970), and the lower division of the dolomitic part of the Plateau Limestone (Anderson *et al*., 1969) and the Maymyo Dolomite Formation (Amos, 1975). Aye Ko Aung (2001) proposed, on the faunal basis that the Wetwin Shale and the Padaukpin Limestone should be considered as the members the Maymyo Formation. The type section is located near Padaukpin village about 1.6km ESE of the Wetwin railway station on the Mandalay-Lashio track. Khaing Khaing San (2005) pointed out that Padaukpin Limestone and Wetwin Shale do not rank as Members. They are merely the fossiliferous sandwiched units of the Maymyo Formation which escaped the dolomitization process. This study also found that the Padaukpin Limestone as the sandwiched unit of the Maymyo Formation. Wetwin Shale is not exposed in this area.

Distribution

Padaukpin Limestone is mainly exposed in the south western part of the study area. Good exposures of Padaukpin Limestones occur at the mile post 5-6 furlong of the Mandalay-Muse high-way road and the quarry in the northern part of the Lashio to Hseing Khaicar road (N22º53'36" and E96º40'50").

Lithology

The Padaukpin Limestone consists of thin- to medium-bedded, grey to black calcareous limestone, argillaceous limestone and shale. In some places, where shale orargillceous materials are dominant, fossils fragments areabundantly occurred and easily extracted from this unit. Argillaceous limestone and shale usually associated with yellow, soft and loose claystone-mudstone. Brachiopods and corals are easily extracted from the soft, yellow, muddy horizon. The numerous fossils from Padaukpin Limestone include corals, brachiopods, gastropods, crinoids etc. The Padaukpin Limestone is limitedly exposed in this area and the occurrence of the Padaukpin Limestone is slightly different from the type section. The lower most part is medium. bedded, dark- grey to black, medium grained limestone intercalated with thin bedded, dark-grey to black shale containing abundant recrystallized gastropods 66feet in thickness (Figs. 7, 8&9). The middle part is medium to thick bedded, light grey to buff argillaceous limestone containing abundant crinoid stems and few small brachiopods (Figs. 10 & 13). The upper part is mainly composed of well-bedded, light grey to grey limestone and argillaceous limestone interbedded with thin-bedded, buff colored shale and claystone-mudstone containing abundant tabulate and rugosecorals. The lower part occurs as isolated outcrops, the middle and upper parts are continuously exposed alnong Lashio-Muse car-road and 80 feet in thickness (Figs.11, 12 & 13).

Fauna, Age and Correlation

The following important fossils are common in the Padaukpin Limestone. They arerecrystallized gastropods, brachiopods, crinoids, rugose and tabulate corals (Plates 1 & 2).

The fauna collected from the Padaukpin Limestone are;

Rugosa: *Calceola sandalina, Temnophyllum pyinoolwinensis*.,
Macgeea maniseptata, Cyathophyllum winwinkyiae,
Peripaedium minutum, Stringophyllum sp. A,B&C,
Enallophrentis sp., *Gurichiphyllum*sp.,
*Grypophyllum*sp., *Acanthophyllu* sp.

Tabulata: *Favosite goldfusi, Alveolites suborbicularis*,
Alveolites aff. *expatiate, Alveolites illusa*
Coenites escharoides, *Alocystis conigera*

Gastropoda: *Loxonema* sp.,*Euomphalus* sp., *Murchisonia* sp.

Brachiopoda: *Indospirifer* sp., *Mesodouvillina* sp., *Devonaria* sp.

Based on the previous work and the occurrence of above faunal assemblage the age of the Padaukpin Limestone in this area can properly be designated as Middle Devonian (Eifelian).

It can be correlated with the Padaukpin coral reef of La Touche (1913), Padaukpin Biostrome of Arderson (1969), Padaukpin Limestone Member of Aye Ko Aung (1995), Padaukpin Limestone of Khaing Khaing San (2005) and Pwepon Limestone of Khaing Khaing San (2005). The comaprison of the Middle Devonian unit in Padaukpin area and Lashio area is shown in Table (1).

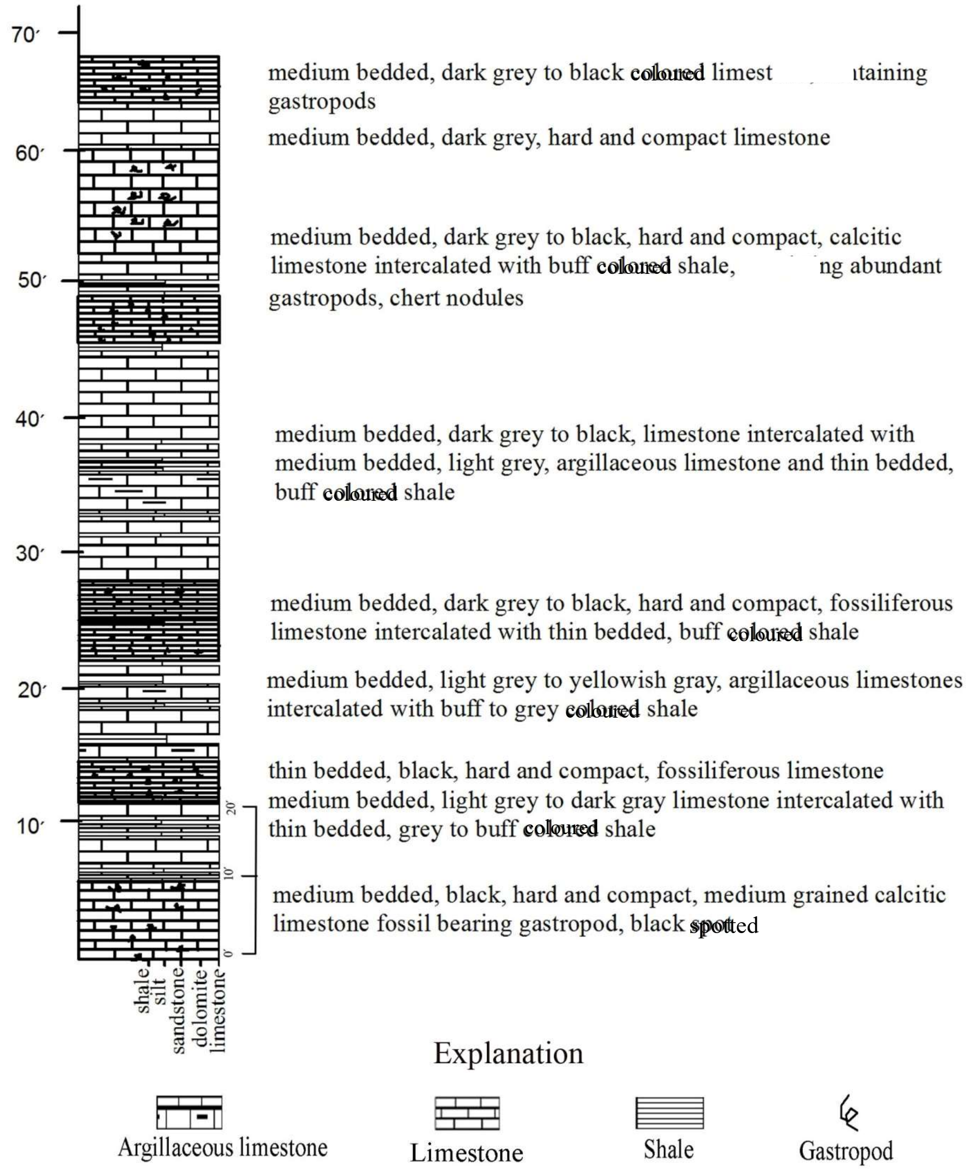

Figure 9: Stratigraphic mesasured section of the lower part of the Padaukpin Limestone (Quarry near the Hseing-Khai car-road; base at N 22° 53' 36"- E 97° 40' 51" and top at N 22° 53' 34"- E 97° 40' 48")

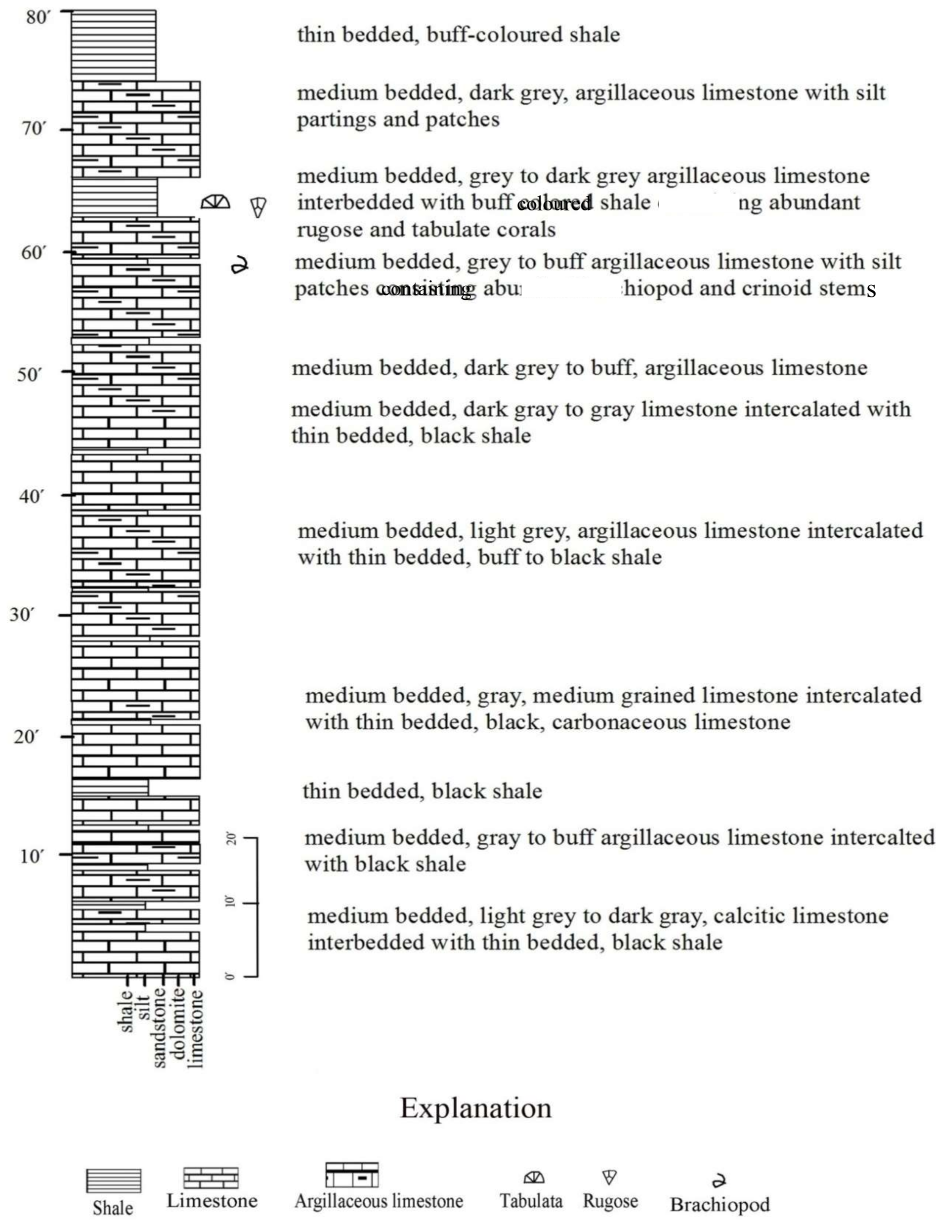

Figure 13. Stratigraphic mesasured section of the middle and upper parts of the Padaukpin Limestone (mile-post 5 to 6 furlong along the Lashio-Muse Car-road); Base at N 22° 54' 01" –E 97° 42' 08" and top at N 22° 54' 02"- E 97° 42' 07"

PLATE 1

Figures 1-7 are collected from the lower part and figures 8-11 are from the middle part of the Middle Devonian, Padaukpin Limestone, Maymyo Formation, Lashio, northern Shan State

Figures 1, 3. Recrystallized Murchisonia sp.,

Figure 2. Recrystallized *Euomphalus* sp.

Figure 4, 5. recrystallized Transverse and longitudinal section of the *Loxonema* sp.

Figures 6, 7. Highly recrystallized gastropod

Figure 8. Incomplete specimen of *Devonaria miuta,*

Figure 9. Incomplete specimen of *Mesodouvillina birmanica*

Figures 10, 11. Large crinoid stems

Figures 12, 13 are collected from the middle part and figures 14,15 are from the upper part of the Middle Devonian, Padaukpin Limestone, Maymyo Formation, Lashio, Northern Shan State

Figure 12. Unidentifiabe smaller brachiopod

Figure 13. Incomplete specimen of *Devonariamiuta*

Figure 14. Abundant tabulate corals in argillaceous limestone

Figure 15. *Stringophyllum* sp. in calcitic limestone with silt patches

PLATE 2

All specimens are collected from the upper part of the Middle Devonian, Padaukpin Limestone, Maymyo Formation, Lashio, northern Shan State

Figure 1. *Calceolasandalina,*	Figure 2. *Enallophrentis* sp.,
Figure 3. *Gurichiphyllum* sp.	Figure 4. *Acanthophyllum* sp.,
Figure 5. *Grypophyllum* sp.,	Figure 6. *Stringophyllum* sp.A
Figure 7. *Stringophyllum* sp.B,	Figure 8. *Stringophyllum* sp.C,
Figure 9. *Temnophyllum* sp.,	Figure10. *Macgeea* sp.,
Figure 11. *Cyathophyllum* sp.,	Figure 12. *Peripaedium* sp.
Figure 13. *Favositesgoldfusi,*	Figure14. *Alveolitessuborbicularis*
Figure 15. *Alveolites* aff. *Expatiate,*	Figure16. *Alveolitesillusa*
Figure 17. *Coeniteseschargides,*	Figure 18. *Aulocysticscornigera*

Table 1. Comaprison of the Middle Devonian unit in Padaukpin area and Lashio area.

Padaukpin Area	**Lashio Area**
Maymyo Formation	
➢ Less argillaceous	➢ More argillaceous with siltstone, shale &mudstone
➢ Occurrence of Wetwin Shale	➢ No occurrence of Wetwin Shale
➢ Less brecciation and friable	➢ More brecciation and friable
➢ Occurrence of relic fossils	➢ No occurrence of relic fossils
Padaukpin Limestone	
➢ Few occurrence of gastropods	➢ Abundant of recrystallized gastropods
➢ Abundant of brachiopods & bryozoans	➢ Few occurrence of brachiopods and bryozoans
➢ Abundant colonial rugose corals, i.e. *Phillipsastrea*, *Thamnophyllum*	➢ Few colonial rugose coral and absence of *Phillipsastrea*&*Thamophyllum*
➢ Less complete section	➢ Complete section and more abundant corals

Summary and Conclusion

The study area is situated in Lashio Township, Northern Shan State. The rocks of the present area can be differentiated into five lithologic units in asscending order: Hsipaw Red Bed (Late Jurassic), Loi-an Group (Late Triassic to Middle Jurasssic), Nwabangyi Dolomite Formation (Late Permian to Early Triassic) andMaymyo Formation.

This study is mainly deals with the Middle Devonian unit in Lashio area.It is mainly composed of thick-bedded to massive, white to light grey dolomite and dolomitic limestone. Fossiliferous Padaukpin Limestone is the sandwiched unit of the Maymyo Formation. Stratigraphy and paleontology of Middle Devonian unit in this area is slightly different from the type section of

Padaukpinarea. In this area, Maymyo Formation is more argillaceous with shale, siltstone and mudstone, more brecciated and friable with no occurrence of Wetwin Shale and relic fossils. The Padaukpin Limestone consists of medium- to thick-bedded, black to dark grey calcitic limestone containing abundant fossils of gastropods in the lower part at Hseing Hkaicar-road quarry. These gastropods are highly recrystallized and identified mainly by their shapes. The middle part of the Padaukpin Limestone consists of medium-bedded, dark-grey to buff limestone, argillaceous limestone, shale and siltstone with abundant crinoids and brachiopods. The upper part of the Padaukpin Limestone is composed of medium-bedded, grey to dark grey calcitic limestone interbedded with buff-coloured shale, siltstone and mudstone with abundant tabulateand rugose corals. The middle and upper part of the Padaukpin Limestone are clearly observed on the Lashio-Muse car road at 5 to 6 furlong mile post. Based on the fauna occurrence, the age of the Padaukpin Limestone can properly be designated as the Middle Devonian (Eifelian). The Maymyo Formation is also regarded as Middle Devonian (Eifelian) according to the fossiliferous Padaukpin Limestone. The comparison of the Middle Devonian unit in Padaukpin area and Lashio area is shown in Table (1).

Fossils dated Middle Devonian units are previously described as limitedly exposed unit in Myanmar such as Wetwin-Padaukpin and Pwepon. This area is the new occurrence of Middle Devonian unit which has been previously described as Triassic Nwabangyi Dolomite Formation in Northern Shan State as well as in Myanmar. It can be concluded that Middle Devonian unit is not limitedly exposed which are widely distributed unit in northern Shan State. So, it is necessary to reinvestigate the stratigraphy and paleontology of the Triassic Nwabangyi dolomite Formation in southern Shan State. Some may be the Middle Devonian units.

Acknowledgments

The authors would like to express their gratitude to Dr. Maung Maung Naing, Rector of Lashio University for his permission to do the present research. Unbounded thanks are due to Dr. Myint Thein, Rector (Retd.), University of Education, Mandalay and Dr. Ko Ko Gyi, Pro-Rector (Retd.), Pakokku University for their critical reading, constructive discussions, suggestions and comments.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

FLUVIAL – TIDAL TRANSITIONAL CHANGES OF SITTAUNG RIVER IN MYANMAR: EMPHASIS ON POINT-BAR GEOMORPHOLOGICAL CHARACTERS OF PAZUMYAUNG, MADAUK AND KYAIKTO AREAS

Thant Sin[1], Tun Naing Zaw[2]

Abstract

Three areas were selected and observed for this study which includes the Pazumyaung area, Madauk area and Kyaikto area along Sittaung River in Myanmar. Geomorphologic measurements, samples collection and outcrop measurements were carried out during dry season when water level was low and most of point bars were exposed. Geomorphological characters of Sittaung River were determined based on UTM maps, Google earth maps and Landsat images by using geospatial analysis, studying of scroll bar pattern and observing sinuosity and width of the river. The distinguishing of both surface sediment distribution and sedimentary structures of point bar were provided for the geomorphological characters. By the analytical data, the fluvial dominated zone is Pazumyaung area, tidal and fluvial transitional zone is Madauk area and tidal dominated zone is Kyaikto area. The water body changes and channel migration of Sittaung River are analyzed by using density slice on ENVI 4.7. South of Madauk area and Kyeikto area are highly environmentally changed areas where natural disasters such as river flooding and flooding related environmental problems in Sittaung River and its environs are likely to occur.

Key words: Geomorphological characters, zone, Sittaung River

Introduction

The Sittaung river basin is located in central-south Myanmar and contains the Sittaung River. Twenty three major tributaries flow into the Sittaung River. The river is navigable for 40 km year-round and for 90 km during three rainy months. With distinct seasonality in river discharge and macrotidal range, the river has extensive fluvial-tidal transition zone from estuary to 150 km inland. This field study was conducted to understand the

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characteristics of point bar architecture of Sittaung River along fluvial-tidal transition zone.

Location of Study Area

The study area is located in the eastern part of Sagaing Fault. It lies between Latitude 17˚15′ N to 18˚ 00′ N and Longitudes 96˚ 45′ E to 97˚ 00′ E. The study area falls in the topographic maps of 1796 (13, 14, 15) respectively. The study area is situated in the Central lowlands of Myanmar drained by Sittaung River which forms main study for this research work. Three areas were selected and visited for this field study, which includes Pazumyaung area, Madduk area and Kyaikto area along the Sittaung River. (Figure.1)

Purposes of Study Area

The main purposes of this study are observation and determination for geomorphological characters, geomorphological zones and natural changes of Sittaung River in Myanmar by using the images geospatial analysis and geological data.

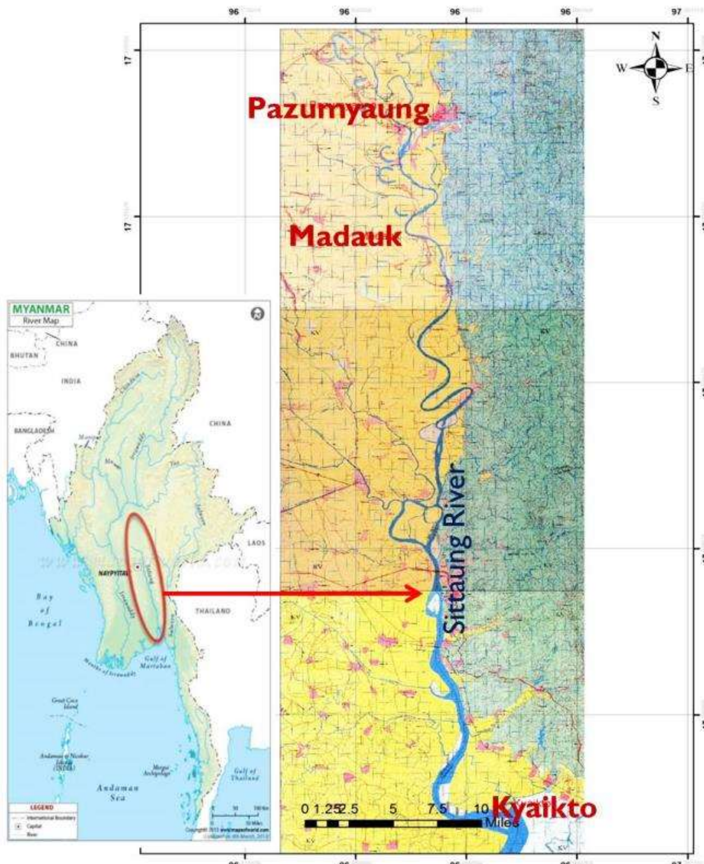

Figure 1. Location Map of Study Area

Previous work

In 2015, Field party of Geology Department, Dagon University and Seoul National University studied on the Geomorphological characteristics of channels in the fluvial-tidal transition zone of Sittaung River, Myanmar. In 2015, Max van Rest, Civil Engineering at Technical University of Delft studied on the Monitoring of the Sittaung River; including bathymetry and floodplains. In 2016, Takao Yamashita and Htay Aung, Graduate School for International Development and Cooperation, Hiroshima University investigated on the Projection and Historical Analysis of Hydrological Circulation in Sittaung River Basin, Myanmar.

Background Geology

Sittaung River drains the Central Basin and lowlands, lying between the Pegu Yoma and Shan Plateau with trend structurally parallel to Sagaing Fault. Sittaung River basin is overlain by the Pleistocene sediments such as soft sandstones, shale, clays and alluvial deposits. Sandstone is rather permeable where clay and silt show a lower value to the permeability of the soil. Pegu Yoma including the Pegu Group and Irrawaddy Formation are well-exposed to the west of Sittaung River. Shan Plateau including the Mogok Metamorphic Belt, Central Granitoid Belt, Taungnyo and Lebyin Formations and Plateau limestone and Loi-an Group are well-exposed to the east of Sittaung River. See Figure (2)

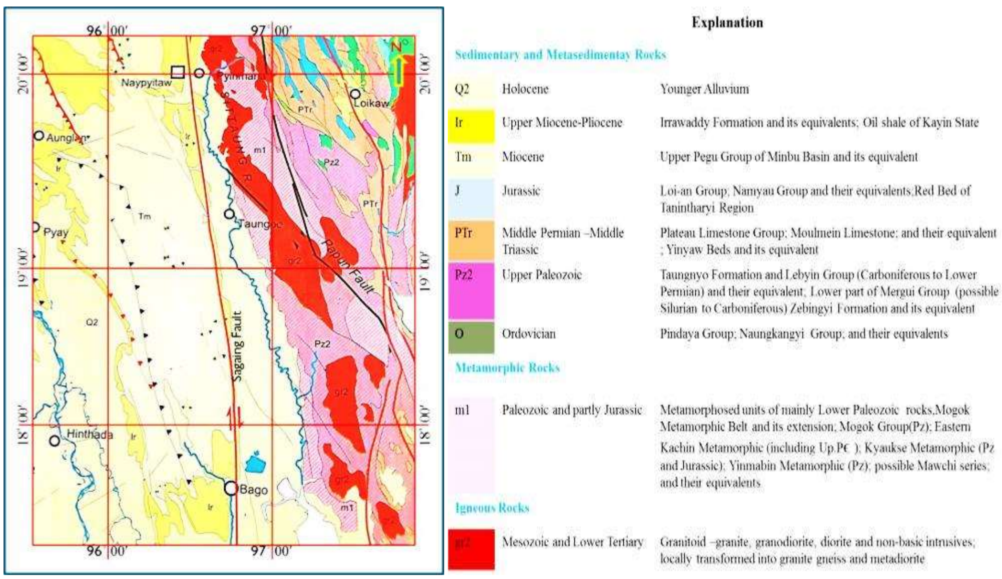

Figure 2. Regional Geological Map of Study Area (After MGS,2014)

Method of Study

Three areas were selected and visited for this field study, which included Pazumyaung area, Madduk area and Kyaikto area along the Sittaung River. At each station, we conducted geomorphologic measurements of point bars and dunes on the bars, can-coring of unconsolidated sediments, and outcrop measurements along the cutbanks. The study of project research is based on the UTM maps 2000 and the Landsat images 132_48N of 2000, 2005, 2010,2015. The Geospatial analysis software such as Global Mapper 15, ENVI 4.7, Arc Map 10.1, Microsoft Excel 2010 and SPSS are used for this project work.

The water body changes and coast line variation of Sittaung River were determined by the density Slice on ENVI 4.7. Choosing the Band 6 is suitable for Density Slice. The Slice range is 6 to 27 Red. The band combination of Band 685 and Band 654 (RGB) of Landsat image 2015(132_48N) displayed the morphological zonation of Sittaung River. The shape files of Sittaung River were successively analyzed on Arc Map 10.1 such as image digitizing and constructed the personal geodatabase that involved the Latitude and Longitude, sedimentary grain size and sedimentary structures. And the comparison of shape file of Sittaung River, Interpolation of sedimentary grain size distribution and Interpolated Line of morphological profiles of Sittaung River were conducted on Arc Map 10.1. The illustrated maps were created by using the layout view of Arc Map 10.1. Therefore, this project is the accomplishment of cartography, remote sensing interpretation, surveying, operational, statistical interpretation and analysis.

Results and Findings

Geomorphological Characters and Geomorphological Zones of Sittaung River

The Geomorphological Characters and Geomorphological Zones of the river were determined based on UTM maps, Google earth maps and Landsat images by using geospatial analysis, studying of sinuosity and width and scroll bar pattern of the river. The distinguishing of both surface sediment distribution and sedimentary structures of point bar were provided for the classification of geomorphological characters and zones.

Geospatial analysis

There are three morphological zones that can be classified by using the band combination of RGB, band 685 and band 654 on ENVI 4.7. The gradual change of one specific zone to another can be seen in the colour change along the river of the image. The Pazumyaung area is Zone 1, Madauk area is Zone 2 and Kyaikto area is Zone 3. See Figure (3.A)

Surface sediment distributionanalysis

The transported or deposited stream sediment is gradually decreased in grain size to the river mouth. There are three specific zones and areas which are fluvial dominated Pazumyaung area, zone1shows coarse sand, tidal and fluvial transitional Madauk area, zone 2 indicates medium sand and tidal dominated Kyaikto area, zone 3displaysvery fine sand and mud. See Figure (3.B)

Sedimentary Facies analysis

In the cores from Pazumyaung, tabular cross-bedded medium to coarse sands are dominant. The cross-beddings are unidirectional and have tangential contacts. Bioturbation is rare.These characters show fluvial dominated zone.

The cores from Madauk also show dominantly unidirectional, trough cross-bedded medium sands at lower part, and laminated muds at upper part.Laminated mudis slightly bioturbated and contains tidal laminations. These characters indicate tidal and fluvial transitional zone.

The cores from Kyaikto display inclined heterolithic stratification in which sands and muds are rhythmically laminated. Tidal cycles such as diurnal inequality and neap-spring tidal cycles are well preserved. These characters designate as tidal dominated zone. See Figure (3.C)

Sinuosity and width analysis

Sinuosity and width of Sittaung River were measured from satellite images. Based on the sinuosity and width, Sittaung River is morphologically divided into three zones.

The fluvial dominated zone (zone 1) is narrow with consistent width and intermediate sinuosity (<2). Tide-influenced and fluvial dominated zone (zone 2) shows downstream increase of width and greater sinuosity (>3). Tide dominated zone (zone 3) is wide with funnel-shaped width and low sinuosity (~ 1). The boundary between zone 2 and zone 3 is characterized by the greatest sinuosity. See Figure (4)

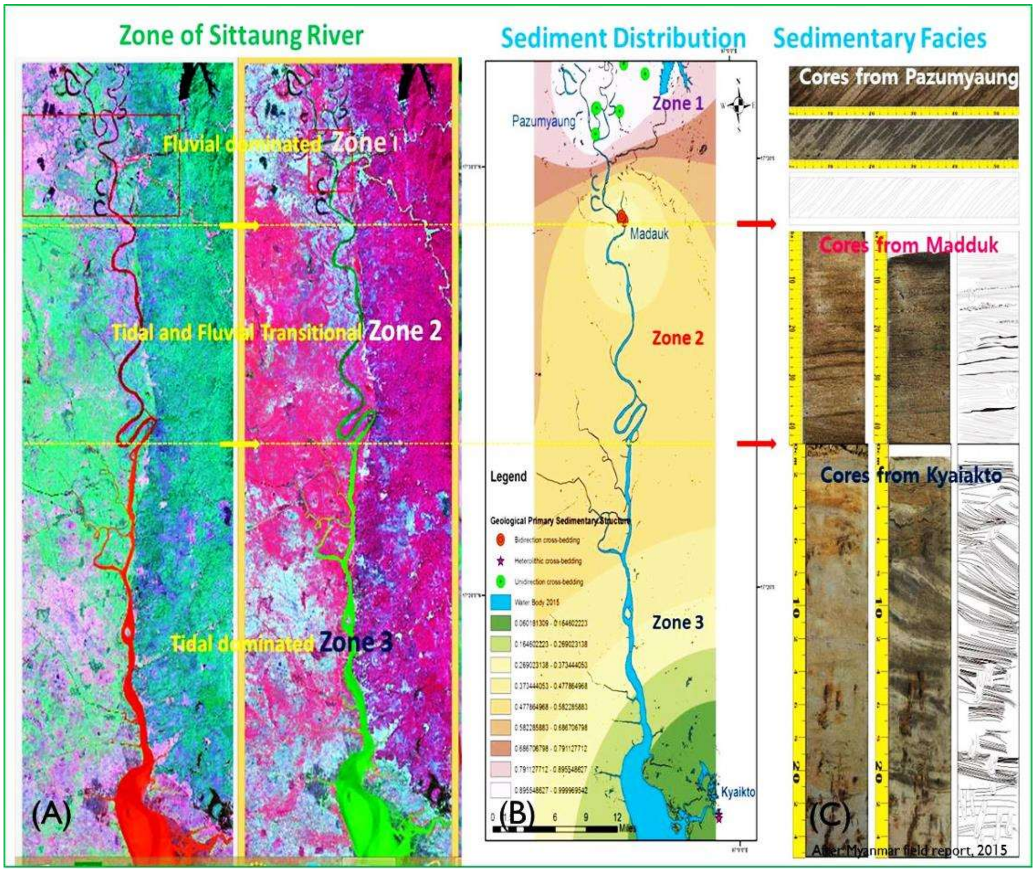

Figure 3. Three Zones of Sittaung River. **(A)**There are three morphological zones which are confirmed by Geospatial analysis of RS and Arc Map and geomorphological data in the field. In this case, the band combination of RGB, band 685 and band 654 of 132_48 N, 2015 Landsat image is suitable in River zones classification.**(B)** The interpolation of stream sediment distribution give the modified zone of sediment. **(C)** The primary sedimentary structures are cross-bedding that indicate the zone of river. The resulted three morphological zones are fluvial dominated Pazumyaung area, Zone 1, the tidal and fluvial transitional Madauk area, Zone 2 and the tidal dominated Kyaikto area, Zone 3, respectively.

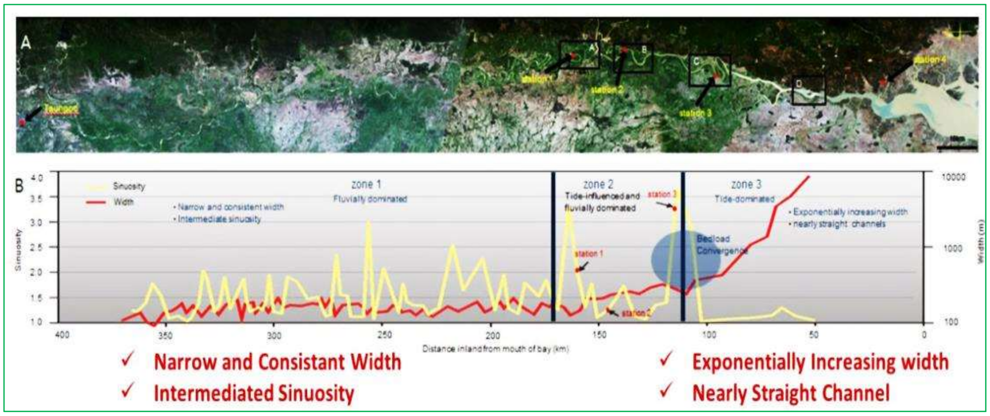

Figure 4. Sinuosity and Width of Sittaung River.

(A) Mosaics of satellite images showing Sittaung River in Myanmar with lengthy fluvial-tidal transition zone, approximately 150-180 km long from the mouth of estuarine embayment.

(B) Longitudinal distribution of channel sinuosity and width from the mouth of estuarine embayment to Taungoo. [After Myanmar Field Study Report (Feb. 6th to Feb. 12th, 2015)]

Scroll bar pattern analysis

Scroll bar patterns of the channels were analyzed by satellite and drone images. In Pazumyaung area which is fluvial dominated and characterized by large scroll bars, the channel moved mainly by expansion. Madauk area is located in tide influenced and fluvial dominated area. The scroll bars show extension and downstream translation patterns. Downstream Kyaikto is located in the tide dominated area, where scroll bars are not extensively developed. Scroll bars show downstream accretion. See Figure (5)

The scroll bar patterns are classified into three patterns. The first scroll bar pattern of Pazumyaung area shows the expansion of scroll bar migration which is named as fluvial dominated zone. The second scroll bar pattern of Madauk area displays the extension and translation of scroll bar migration which is regarded as the tidal and fluvial transitional zone. The third scroll bar pattern of Kyaikto area is not the extensive accretion of scroll bar migration which is known as tidal dominated zone respectively. See Figure (6)

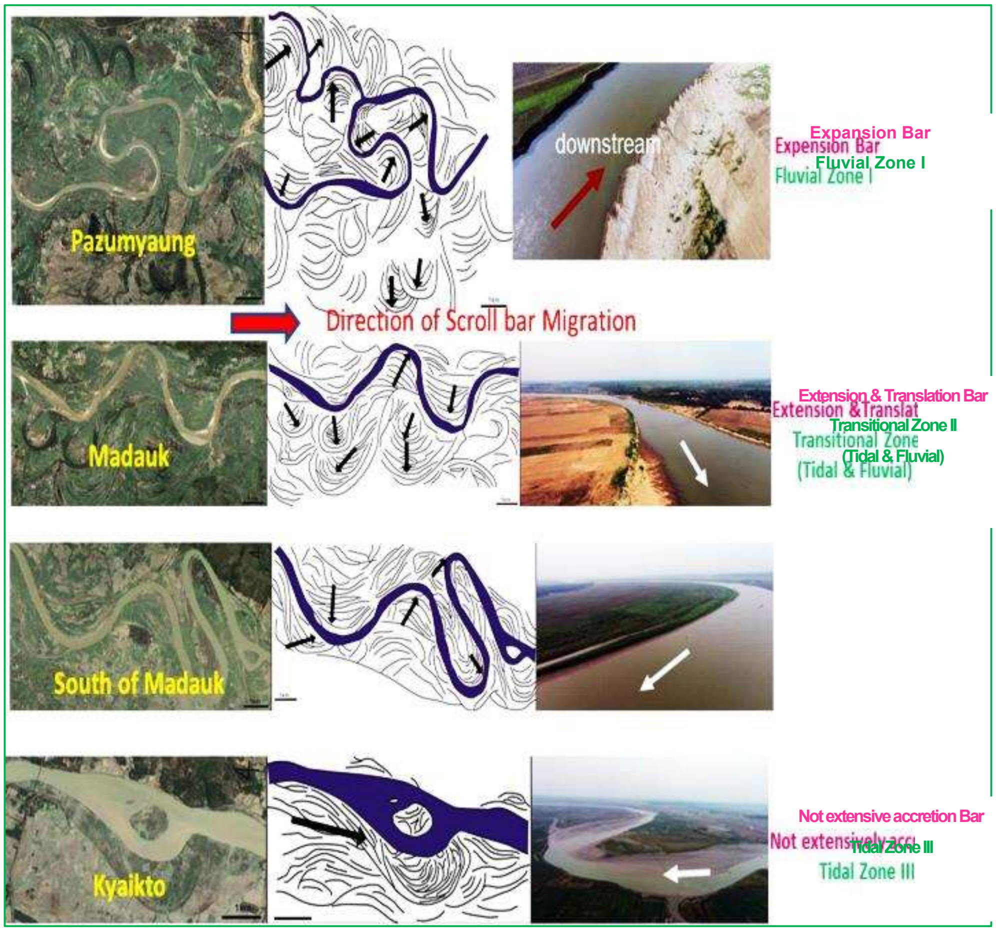

Figure 5. Scroll bar patterns of Sittaung River. [After Myanmar Field Study Report (Feb. 6th to Feb. 12th, 2015)]

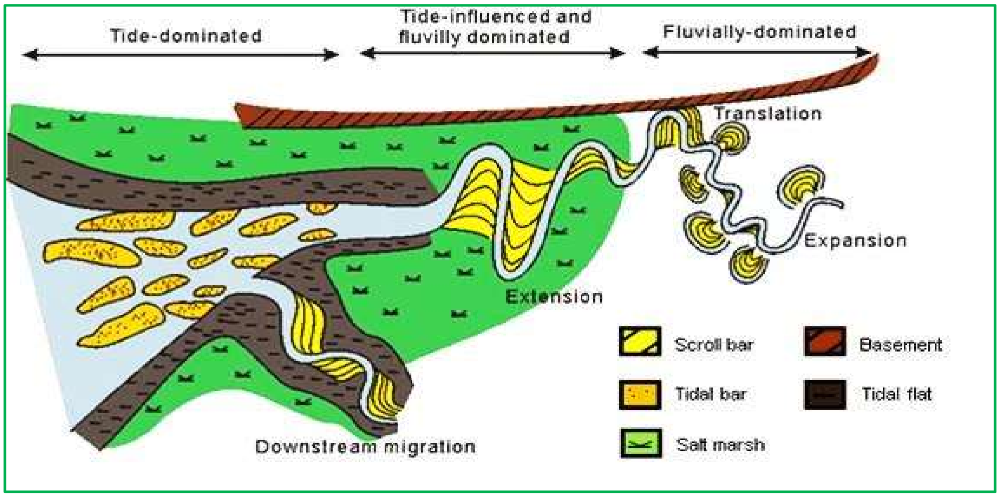

Figure 6. Schematic diagram showing major depositional components along the fluvial- tidal transition zone of Sittaung River.(Feb. 6^{th} to Feb. 12^{th}, 2015)

Natural Changes of Sittaung River

Geospatial Analysis

The main works of this project is based on the UTM maps and Landsat maps.The water body changes and coast line variation of Sittaung River are analyzed by using density slice on ENVI 4.7. Choosing the Band 6 is suitable for Density Slice. The Slice range is 6 to 27 Red. The Comparative studies of the Landsat image 132_48N, 2000, 2005, 2010, 2015 and UTM map 2000 give the water body area changes and variation of coast line of Sittaung River. The erosion and deposition sedimentary processes occurred more frequently in the three specified areas of Pazumyaung, Madauk and Kyaikto of Sittaung River which are designated as unstable coast line areas and flooding areas. See Figure (7).

The Natural Cross-Sectional Profiles of the river are determined based on the satellite image. The first profile line of Pazumyaung area displays the small width and depth of river and folded mountains with no tidal effect. The second profile of Madauk area shows the prominent width and depth of river and folded mountains which are tidal and fluvial transitional area. The third profile line of Kyaikto area shows the very large width and depth of river and large flat plain which is tidal dominated zone. All of these geomorphological profiles explain that the river is gradually getting wider and deeper towards the river mouth depending on the tidal effect. See Figure (8).The images analysis of water body indicates that the river is gradually getting deeper and wider from 2000 to 2015.The lower part of Sittaung Delta area, Kyaikto and Belin was constructed as a large delta by sediments from the upper and middle parts of the river. See Figure (9).

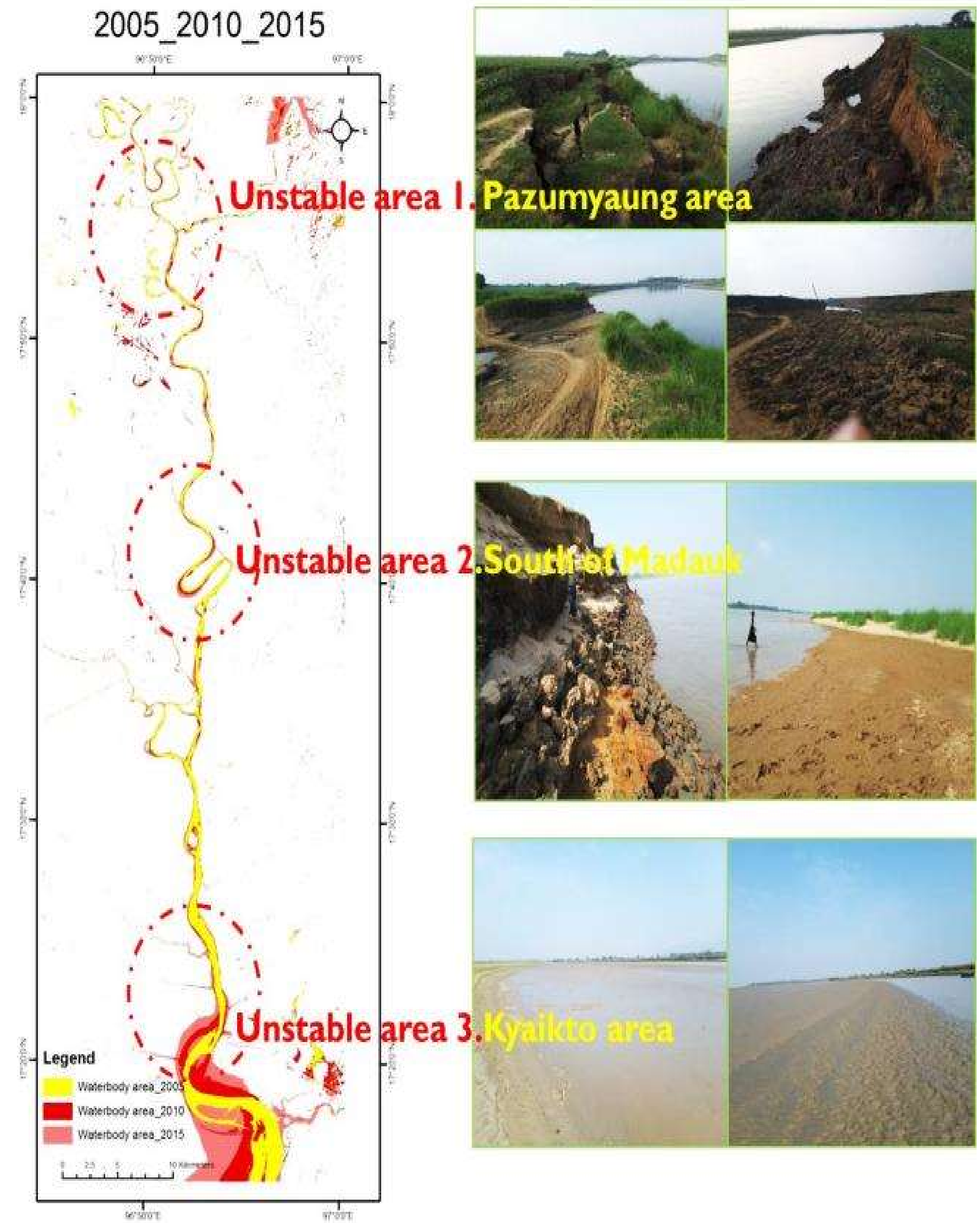

Figure 7. The Changes of Water Body area and Coast Line of Sittaung River in the Year of 2005 to 2015.

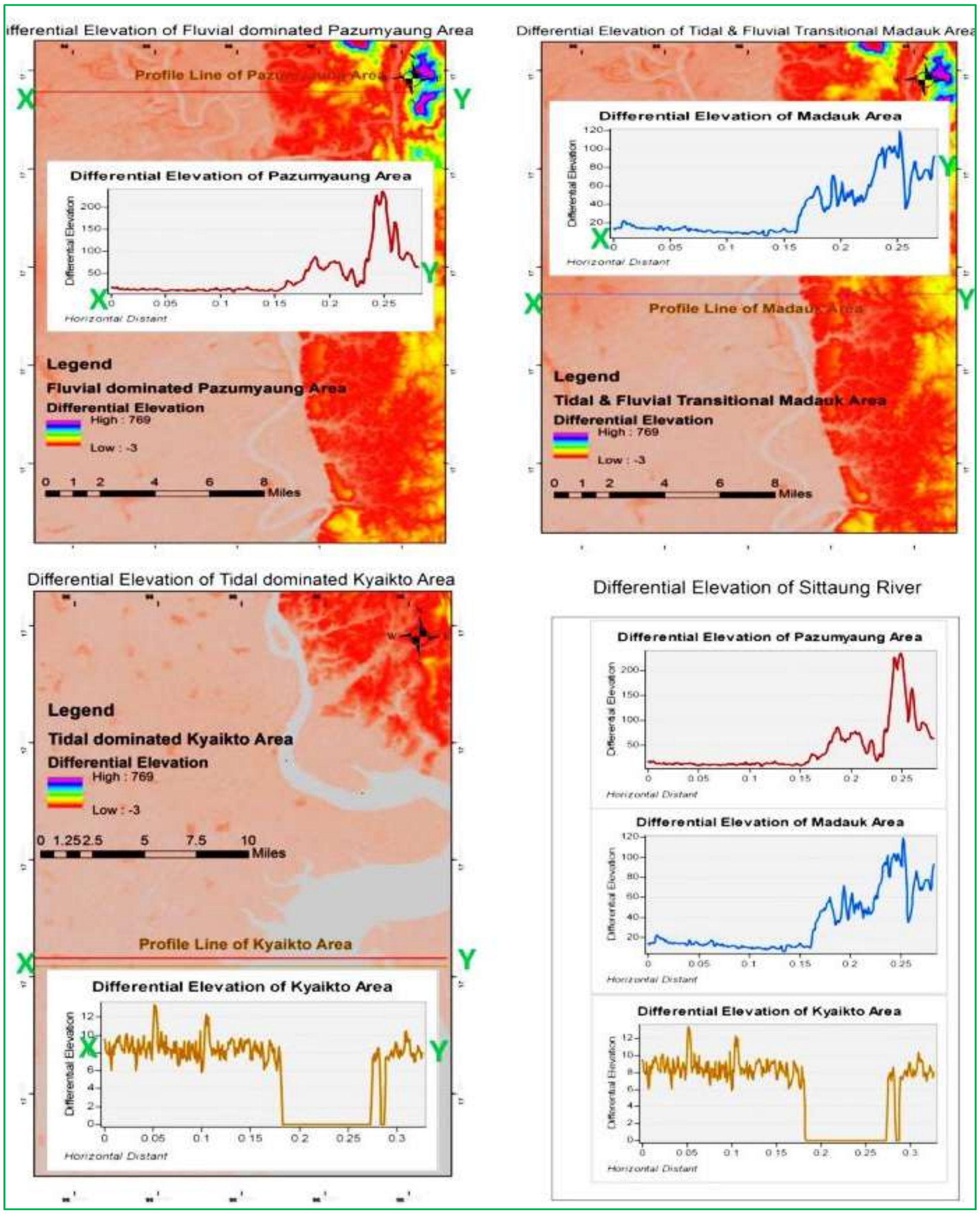

Figure 8. Differential Geomorphic Elevation of Sittaung River; width and depth of River is gradually increasing from fluvial dominated area to tidal dominated area.

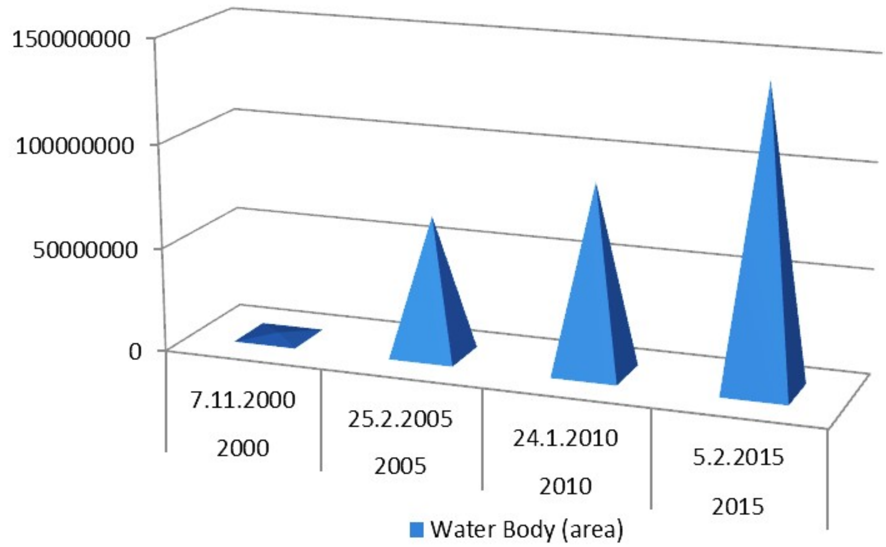

Figure 9. Histogram is showing the water body area of Sittaung River in the years of 2000 – 2005 – 2010 – 2015 by image interpretation. These water body changes indicate that the River is gradually getting deeper and wider from 2000 to 2015.

Summary and Conclusions

Geomorphological Characters and Zones of Sittaung River

The sedimentary facies (primary sedimentary structures), scroll bar patterns, sinuosity and width indicate the zones of Sittaung River as follows:

1. Pazumyaung area is fluvial dominated zone.
2. Madauk area is fluvial and tidal transitional zone.
3. Kyaikto area is tidal dominated zone.

Natural Changes of the Sittaung River

1. Waterbody of Sittaung River is regularly increasing from fluvial area to the delta area of Kyaikto.
2. The Surface Sediments are gradually decreasing in size from fluvial area to the delta area of Kyaikto.

3. The length and width of the river is progressively increasing from fluvial area to the delta area of Kyaikto.
4. South of Madauk area and Kyakto areaare highly environmentally changed areas where natural disasters such as river flooding and flooding related environmental problems in Sittaung River and its basin are likely.

Recommendation

From the environmental view, the best solution to minimize flood damage is floodplain regulation. In highly urban areas, however it will remain necessary to use physical barriers, reservoirs and channel works to protect existing development. Structural approaches of flood control include channelization, dams, retention ponds, reservoirs, levees, dikes and flood walls designed to keep out flood waters. Real-time monitoring of floods allow experts to forecast the arrival time and magnitude of the flood peak, and if necessary, issue early warnings. More public awareness programmes are needed to help people perceive the hazard of living in flood-prone area.

Acknowledgements

We would like to express special gratitude to Professor Dr Than Than Oo, Head of Geology Department, Dagon University for her kind permission for the preparation of the present research paper. We express our heartfelt thanks to Dr Kyi Kyi Maw, Professor of Geology Department of Dagon University for her encouragement throughout this work. We are indebted to Dr Khin Khin Htay, Associate Professor, Geography Department of Bago University for her close supervision and guidance throughout the research works. We would like to extend special thanks to Prof. Kyungsik Choi, School of Earth and Environmental Sciences, Seoul National University, Republic of Korea and his members for participation in the field work and sharing the experiences of field techniques and laboratory work. Our special thanks are due to Professor Daw Swe Swe Pwint, Head of English Department, Dagon University for reading the manuscript.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

THE EARLY PERMIAN BRACHIOPODA FROM ZWEKABIN RANGE, HPA-AN TOWNSHIP

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Abstract

This paper concerns with the Taungnyo Formation and the Moulmein Limestone from the Zwekabin Range with regard to their biostratigraphy and age according to the Early Permian Brachiopod fauna. Fourteen species belonging to thirteen genera are reported as collected from three localities of the Zwekabin Range. Two new species ? *Verneuilia* n.sp. and *Vediproductus* n.sp. are described. The most common species are *Spinomartinia prolifica*, *Retimarginifera alata, Retimarginifer* sp. and *Cancrinella* sp. together with *Productus* cf. *carbonaricus*de Koninck, *Kasetia kaseti* Waterhouse, *Phricodothyris* sp., *Chonetinella* sp., *Kutorginella* sp., *Neospirifer* sp., *Neochonetes* sp. and *Spiriferellina* sp. The three brachiopod biozones namely as *Arctitreta-Bandoproductus* Zone, *Spinomartinia prolifica* Zone and *Horridonia timanica* Zone which are regarded as Early Permian (Sakmarian to Kungurian) in age. The brachiopod fauna from the Taungnyo Formation and the Moulmein Limestone is considered to be equivalent of the early Permian brachiopod from the upper Kaeng Krachan Group and Rat Buri Limestone of Thailand.

Keywords : Early Permian, Brachiopods, Biozones, Zwekabin Range

Introduction

The Upper Paleozoic (Carboniferous-Permian) rock units in Hpa-an area, Kayin State can be subdivided into the Taungnyo Formation and the extensive Moulmein Limestone. The Moulmein Limestone consists predominantly of well-bedded, dark grey limestone and silicified argillaceous limestone. It is underlain by the clastic sediments of the Taungnyo Formation which is composed of gray and yellowish shale, mudstone, yellowish or buff-coloured, fine-grained sandstone and siltstone with interbeds of calcareous mudstone and marl. Bryozoans and mainly brachiopods were found in buff-coloured siltstone and calcareous mudstone of the Taungnyo Formation. Systematic field sample and data collections were made at three localities

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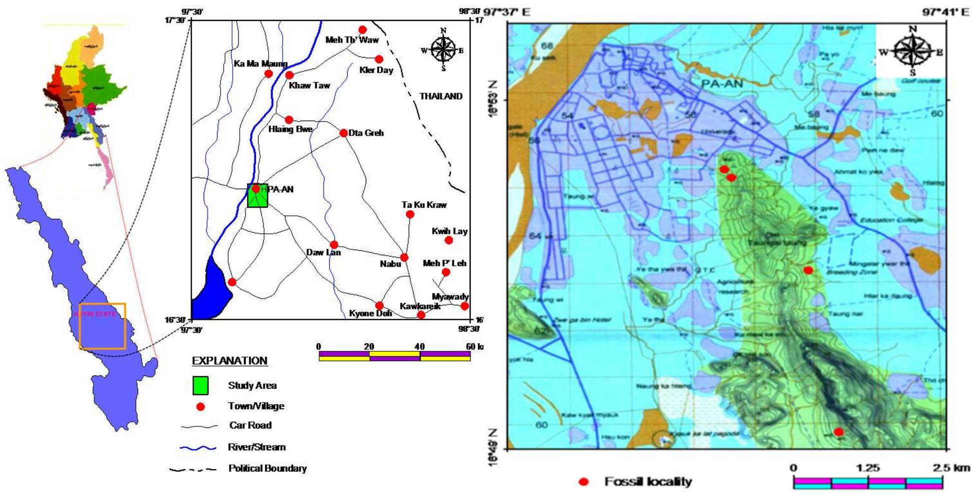
situated on the eastern foot hill (near Hla Ka Daung), northwestern part (Kya-in Taung) and western foothill of the Zwekabin Range. (Figure 1a,b)



(a) (b)

Figure 1(a.b) Location and Fossil Locality Maps of the Study Area

Previous Brachiopod Studies

Zaw Win and Kyaw Htin Khaing (2006) recorded five species of brachiopods from the upper part of the Taungnyo Group on the northwestern flank of the Zwekabin Range, Kayin State, including the following species:

1. *Spinomartina prolifica*
2. *Retimarginifera* sp.
3. *Phricodethyris* sp.
4. *Torinifer* sp.
5. *Chonetinella* sp.

The above mentioned fauna of the Taungnyo Group can be correlated with the *Spinomartina prolifica* fauna of the Early Permian Ko Yao Noi Formatiom of southern Thailand.

Stratigraphy of the Hpa-an Area, Kayin State

The stratigraphic classification of the Hpa-an Township (cited from Dr. Maung Thein, 2014)

Stratigraphic Units	Geological Age
Moulmein Limestone Group	Permian
Taungnyo Formation	Carboniferous-Early Permian

Taungnyo Formation

It is typically exposed along the Taungnyo Range south of Mawlamyine. The Carboniferous rocks of the Hpa-an District of the Kayin State are refered to Taungnyo Group by Brunnschweiler (1970) after Leicester (1930), gray and yellowish shale, mudstone, yellowish or buff-coloured, fine-grained sandstone and siltstone with interbeds of calcareous mudstone and marl. The calcareous sandstones at the top of the sequence contains gastropods, brachiopods (*Dictyoclostus, Mesolobus, Spirifer* spp.), bryozans, corals and ostracods and indicates Late Carboniferous age (Brunnschweiler, 1970).*Spinomartinia prolifica* assemblage occur in the siltstone and Taungnyo Group exposed along the northwestern flank of the Zwekabin Range. These fauna assemblage indicates that the Taungnyo Group is up to Early Permian (Late Sakmarian) (Zaw Win and Kyaw Htin Khine, 2006).In the present study, the brachiopod assemblage such as *Vediproductus* n.sp, *Productus* cf. *carbonaricus*de Koninck, *Cancrinella* sp., *Spinomartinia prolific* Waterhouse, *Kasetia kaseti* Waterhouse, *Retimarginifera alata* Waterhouse, *Phricodothyris* sp., *Torinifer* sp., *Retimarginifer* spp., *Chonetinella* sp., *Kutorginella* sp., ? *Verneuilia* n.sp., *Neospirifer* sp.and *Spiriferellina* sp. occurs in the northwestern part (Taungai Taung) and eastern foot hill (near Hlar Ka Daung) of the Zwekabin Range. The brachiopod assemblage bearing Taungnyo Formation can be correlated with Upper Kaeng Krachan Group in southern Thailand.

Moulmein Limestone

T.Oldham (1856) first gave the name to the limestone of Kayin State and Tanintharyi Region overlying the Mergui Group, forming isolated rock pillars. Brunnschweiller (1972) believed that the Moulmein Limestone overlies the Carboniferous Taungnyo Group. It is exposed as isolated rugged hills or ranges in the Hpa-an area. It is mainly composed of well-bedded dark grey limestone and silicified argillaceous limestone. Chert significantly common in the form of bands, layers, nodules and patches. *Neospirifer* sp. and *Spiriferellina* sp. occur in the northwestern part (Taungai Taung) of the Zwekabin Range. The Moulmein Limestone bearing a few brachiopods can also be correlated with the Ratburi Limestone of southern Thailand.

Biostratigraphy of the Zwekabin Brachiopod Fauna

Brachiopod bearing buff-coloured siltstone occurs in the upper part of the Taungnyo Formation which is well developed along the northwestern part (Taungai Taung) and eastern parts (near Hlar Ka Daung) of the Zwekabin Range. A few brachiopods occur in the cherty limestone of the Moulmein Limestone. The lithology of northwestern part of the Zwekabin Range exposure is generally made up of interbedded calcareous mudstone and siltstone. The beds dip at 20˚ to 25˚ to the west. Several fossiliferous horizons (H1-H5) were found in buff-coloured siltstone, calcareous mudstone and cherty limestone at the measured section (Figure 2). Brachiopods are rare and scattered in these calcareous beds. The measured section of the eastern part of the Zwekabin Range exposure is made up of laminated calcareous mudstone in the lower part. Above these calcareous mudstone horizons, a massive greenish to yellowish gray siltstone (H1-H3) yields an interval which is very rich in brachiopods (Figure 3). The exact geographic position of the fossil locality from UTM no. 1697- 09 at Grid no 566646, 677637.

The Zwekabin brachiopod fauna is comparable with three Early Permian brachiopod assemblage zones established by Shi et al. (1991) in the Sungai Itau Quarry in Malaysia and Waterhouse et al. (1981) in the Kao Noi and near Krabi in southern Thailand. The three brachiopod assemblage biozones of the Zwekabin Range are as follows:

3. *Horridonia timanica* Zone
2. *Spinomartinia prolifica* Zone
1. *Arctitreta-Bandoproductus* Zone

1. *Arctitreta-Bandoproductus* Zone : This zone which is best developed in the eastern parts (near Hlar Ka Daung) of the Zwekabin Range can be correlated with the *Arctitreta-Bandoproductus* Assemblage Zone in Sungai Itau Quarry in Malaysia. This zone includes *Torynifer* sp., *Kasetia kaseti* Waterhouse and *Phricodothyris* sp.

2. *Spinomartinia prolifica* Zone : The predominant brachiopod assemblage described in the present study is the *Spinomartinia prolifica* Assemblage Zone, occurring in the northwestern and eastern parts of the study area. This zone can be correlated with *Spinomartinia prolifica* Assemblage Zone in Krabi, southern Thailand and in Sungai Itau Quarry in Malaysia. It is characterized by the occurrence of the zonal species of *Spinomartinia prolifica* and also recognized by the common species of *Retimarginifera alata*, *Chonetinella* sp., *Kutorginella* sp., *Productus* cf. *carbonaricus*, *Vediproductus* n.sp.and ? *Verneuilina* n. sp.

3. *Horridonia timanica* Zone: The *Horridonia timanica* Zone is the uppermost zone, occurring in the northwestern part of the Zwekabin Range. It is characterized particularly by the abundance of *Cancrinella* sp., *Neospirifer* sp. and *Spiriferella* sp.

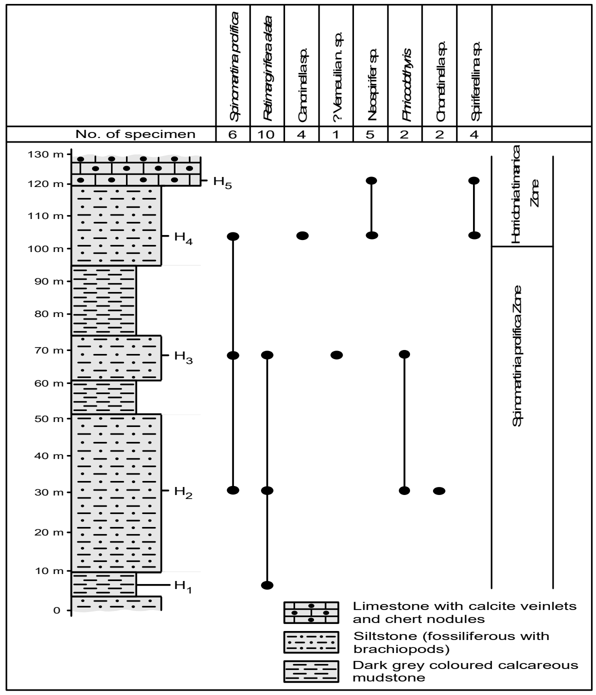


Figure 2. Columnar Section and stratigraphic range chart of the fauna of the upper part of the Taungnyo Formation and basal part of the Moulmein Limestone of the northwestern part (Taungai) of Zwekabin Range (Measured from 566646 to 568644)

The composition and age of the Zwekabin Brachiopod Fauna

Brachiopods are scattered throughout the upper part of the Taungnyo Formation, concentrated particularly in the buff-colored siltstone and other calcareous beds. The Zwekabin brachiopod fauna is generally made of those of thick shells and a few with spinose shells. Almost all brachiopods are preserved as complete external and internal moulds. The distribution of particular brachiopod species tends to be restricted within the fossiliferous intervals except for the dominant species of *Spinomartinia prolifica* Waterhouse and *Retimarginifera alata* Waterhouse which are more widely distributed.

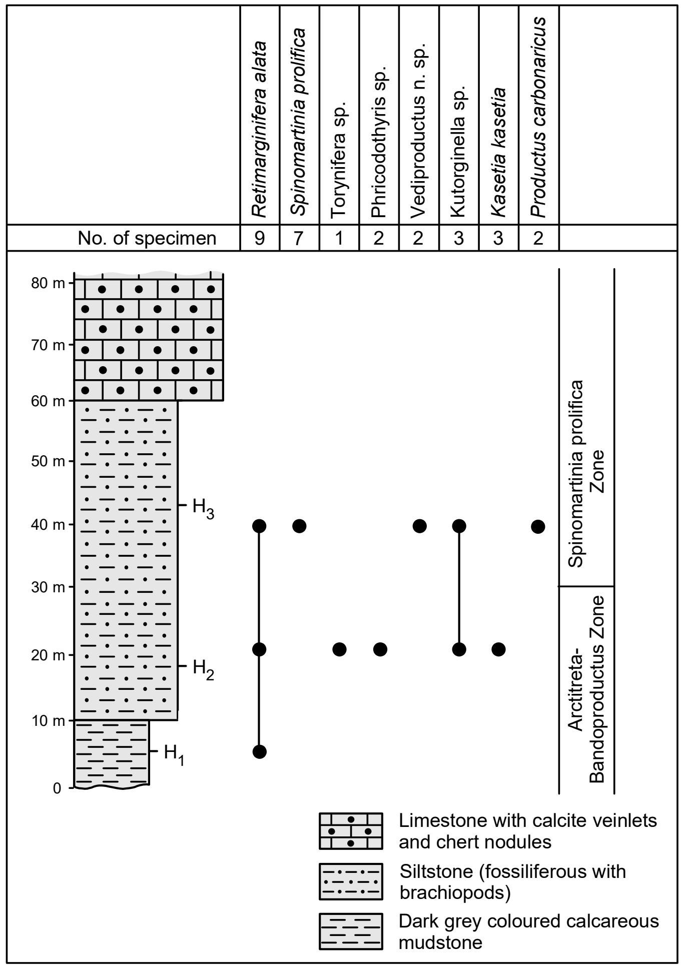


Figure 3. Columnar Section and stratigraphic range chart of the fauna of the upper part of the Taungnyo Formation and basal part of the Moulmein Limestone of the eastern foothill (near Hla ka Daung) of Zwekabin Range(Measured from 677637 to 676635)

Thirteen brachiopod genera were identified from the Zwekabin Range dominated by *Spinomartinia* and *Retimarginifera*. Among fourteen species identified are *Vediproductus* n.sp, *Productus* cf. *carbonaricus*de Koninck, *Cancrinella* sp., *Spinomartinia prolifica* Waterhouse, *Kastia kaseti* Waterhouse, *Retimarginifera alata* Waterhouse, *Phricodothyris* sp., *Torinifer* sp., *Retimarginifer* spp., *Chonetinella* sp., *Kutorginella* sp., ? *Verneuilia* n.sp., *Neospirifer* sp. *Spiriferellina* sp. These brachiopods are accompanied by some fenestellid bryozoa, corals, crinoids stems and echinoid plates.

The composition of the Zwekabin brachiopod fauna seem to be very close to that of the Ko Yao Noi and Krabi brachiopod fauna of southern Thailand described by Waterhouse (1981) and the fauna indicates a probable Sakmarian age. Shi and Archbold (1995) included the Kinta Valley fauna of Malaysia into the *Spinomartinia prolific* assemblage zone of Shan-Thai terrane or Sibumasu block. This assemblage has been established by Shi and Archbold for the Late Sakmarian fauna discovered by Waterhouse et al. (1981) from Ko Yoi and near Krabi in Southern Thailand and those of Kinta Valley.

The presence of *Phricodothyris* sp., *Torynifera* sp. and *Kasetia kasetia* Waterhouse in the Zwekabin fauna may represent earlier appearance of these species before the *Spinomartina prolific* assemblage zone can be assigned to the upper part of the *Arctitreta- Bandoproductus* zone of Early Sakmarian age. The closely associated fauna was also re-assigned to the same brachiopod zone, in the succeeding *Spinomartinia prolifica* assemblage zone of Late Sakmarian. The uppermost zone is the *Horridonia timanica* Assemblage zone characterized particularly by the abundance of including *Neospirifer* sp. and *Spirifella* sp which indicates Artinskian- Kungurian age. Thus, the age for these three Assemblage zones possibly ranges from Sakmarian to Kungurian age.

Summary and Conclusions

The Zwekabin brachiopod fauna consists of *Vediproductus* n.sp., *Productus* cf. *carbonaricus* de Koninck, *Cancrinella* sp., *Spinomartinia prolifica* Waterhouse, *Kasetia kaseti* Waterhouse, *Retimarginifera alata* Waterhouse, *Phricodothyris* sp., *Torinifer* sp., *Retimarginifer* sp., *Chonetinella* sp., *Kutorginella* sp., ? *Verneuilia* n.sp., *Neospirifer* sp. and *Spiriferellina* sp. Three Brachiopod Assemblage biozones namely as *Arctitreta-Bandoproductus* Zone, *Spinomartinia prolifica* Zone and *Horridonia timanica* Zone are recognized in the Zwekabin Range.

The *Spinomartinia prolifica* zone is closer in overall composition to fauna from the Moulmein Limestone. However, the Moulmein Limestone includes *Neospirifer* sp. and *Spiriferellina* sp. not so far found in the *Spinomartinia prolifica* Zone. The common fauna such as *Spinomartinia* and *Retimarginifera* has its characteristic species of Taungnyo Formation and these fauna indicates Late Sakmarian age.

The uppermost part of the Taungnyo Formation and the basal part of the Moulmein Limestone consist of Cancrinella, *Neospirifer*, *Spiriferellina* and fenestellid bryozoa which indicates a Early Permian (Kungurian) in age.

The age of the Taungnyo Formation could be provided by the correlation of the overlying Moulmein Limestone, from which brachiopod fauna has been described. The bases for the Moulmein Limestone may be Kungurian in age, and the uppermost portion of the Taungnyo Formation is up to Sakmarian to Kungurian.

Acknowledgements

We wish to express my sincere gratitude to Dr Mya Mya Aye, Rector of Hpa-an University and Dr Myat Thidar, Pro-Rector of the same University for their permission to do this research. We are also grateful to Dr Tun Tun Zaw (Lecturer, Department of Geology, Hpa-an University) for his suggestions and computing work throughout the course of the project.

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Plate (1) Brachiopods from the Taungnyo Formation, Eastern foot hill (near Hlar ka Daung) of the Zwekabin Range (A,B *Vediproductus* n.sp, dorsal and ventral external moulds, C *Productus* cf. *carbonaricus*de Koninck, ventral external valve, D,E *Spinomartinia prolifica* Waterhouse, ventral internal mould and dorsal external valve, F,G *Retimarginifera alata* Waterhouse, exterior ventral valves, H *Kutorginella* sp., dorsal external valve, I,J,K *Kasetia kaseti* Waterhouse, ventral internalvalves and ventral external mould, L, M *Phricodothyris* spp., ventral internal moulds

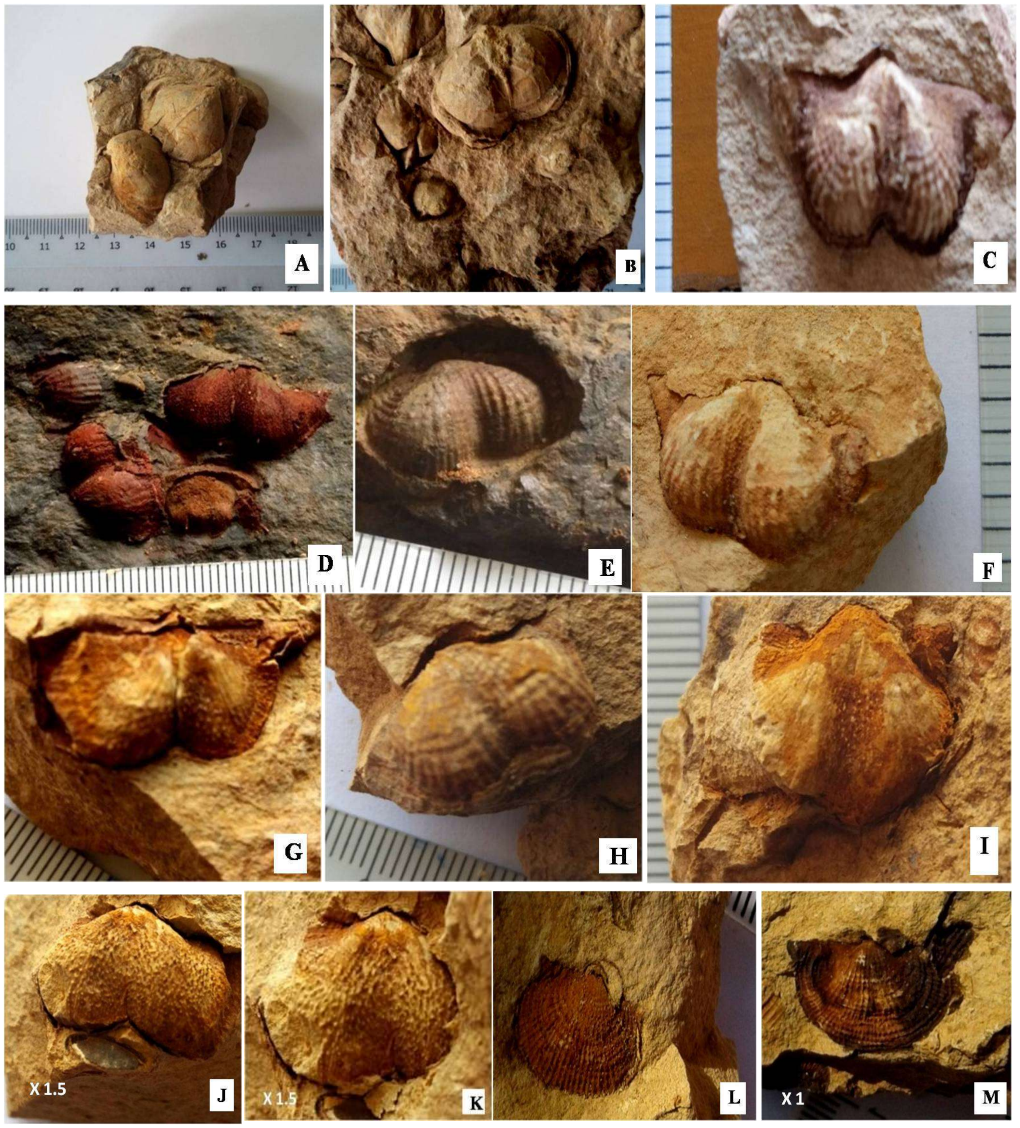

Plate (2) Brachiopods from the Taungnyo Formation, northwestern part (Kya-in Taung) of the Zwekabin Range (A,B *Spinomartinia prolifica* Waterhouse, ventral internal moulds, C-H *Retimarginifera alata* Waterhouse, exterior ventral valves, I-K *Retimarginifera* sp., L, M casts of exterior ventral valve and dorsal external valve)

Plate (3) Brachiopods from the Taungnyo Formation, northwestern part (Taungai Taung) of the Zwekabin Range A-D *Cancrinella* sp. ventral internal mould, dorsal external valve and dorsal internal moulds, E ? *Verneuilia* n.sp., ventral external mould, F, G, H *Neospirifer* sp., dorsal internal moulds and cast of dorsal interior, I *Spiriferellina* sp. ventral internal mould, J *Torinifer* sp. dorsal internal mould, K *Neospirifer* sp. dorsal internal mould L, M *Chonetinella* sp., dorsal external and internal moulds

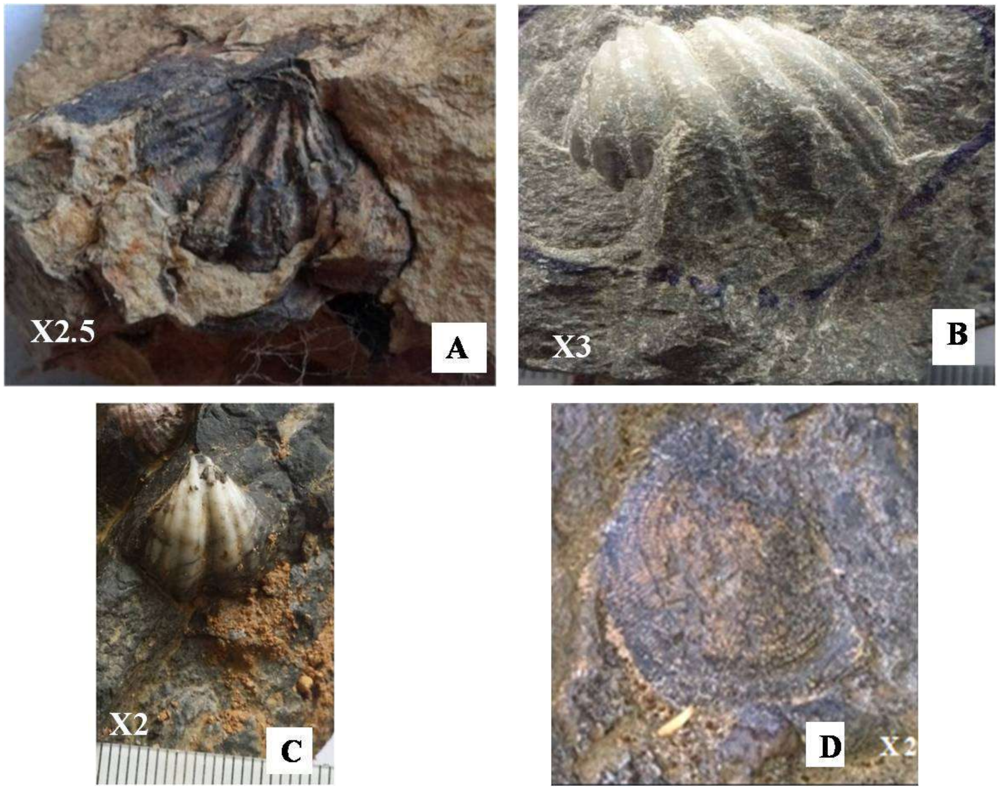

Plate (4) Brachiopods from the Moulmein Limestone, northwestern part (Kya-in Taung) of the Zwekabin Range A ? Neospirifer sp. ventral internal mould B,C *Spiriferellina* sp. dorsal external moulds and D, *Neochonetes* sp., dorsal external valve from western foothill of the Zwekabin Range

J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

GEOHAZARDS AND PRELIMINARY STUDIES ON ENVIRONMENTAL DEGRADATION IN BAGAN - NYAUNG OO AREA, MANDALAY REGION

Tun Naing Zaw[1] ,Swun Wunna Htet[2]& Min Thura Mon[3]

Abstract

Bagan-Nyaung Oo area is the most picturesqu earchitectural complex in Myanmar. Bagan–Nyaunng Oo area is situated between 94°45'00" E to 95°00' 00" E and 21°00' 00" to 21°15' 00" N. The research aims are to demonstrate the application of Remote Sensing (especially satellite image analysis) and to interpret the Engineering Geology approach to Environmental Geology and vice versa. The research area covers mostly the alluvial plain flanking the Ayeyarwady River and partly the debris and small fan materials derived from Tuywin Taung and Tantkyi Taung hills whichare exposed with rocks of Miocene to Oligocene. Bed rock in the area is mainly represented by rocks of Irrawaddy Formation (Late Miocene to Pliocene), Okhmintaung Formation (Upper Oligocene) and Padaung Formation and Shwezettaw Formation (Lower Oligocene). Mainly the alluvial soils of Quaternary-Recent are deposited on the plain and along the river banks by fluvial action.The areas susceptible to landslides, rock falls, mass movements, and debris flows hazards are demarcated in the Tuywin Taung and Tantkyi Taungthat have been encountered with a number of small tension cracks, active and old landslides. Side cutting in both sides of Ayeyarwady River banks is caused by river bank scouring and rain water resulting into steep slopes. In the rainy season, low lands adjacent to the Ayeyarwady River and the main streams in the area are affected by flood. Low to medium bearing capacity areas are concentrated in the areas where active alluvial fan and river bed deposits. Most of the plain area is covered by a firm soil with a stable bearing capacity and so appropriate for small to medium scale construction purposes. Several locations of construction materials quarry sites are seen in the study area. Improper quarrying of construction materials trigger the landslides and river bank scouring. Existing land use patterns in the study area are agricultural, sparse forest and scrub, settlements, industries, recreation centres infrastructures, small land fill and waste disposal sites. The root causes of river water pollution in Nyaung Oo area are direct connection of sewage drainage, sewage pipe line, haphazard disposal of industrial, hospital and hotels waste in open space and stream and improper dumping of solid wastes into the riverside area.

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Earthquakes on July 8th, 1975 and August 24th, 2016, severely damaged more than half of the important structures and irreparably destroyed many of them. Flood causes, destruction by earthquakes, landslides and erosion and LCLU (Land Cover/Land Use) evaluation are mentioned. The research would be a general help to planners and developers at local level particularly in hazard mitigation, environmental management and civil engineering developments within the research area.

Keywords –Environmental degradation, river bank scouring, bearing capacity, river water pollution, sewage, haphazard disposal, hazard mitigation

Introduction

Bagan-Nyaung Oo area, situated within the study are is the most picturesque architectural complex in Myanmar-Bagan, that reflects the day of the Buddhist religion, strengthening and aggrandizing the outlook of the whole of society. The World Heritage Site of Bagan is the Golden Land of wonders. Over 3,000 extant monuments are scattered across a vast arid plain that proclaims the piety and power of Myanmar's first empire. As a manifestation of a dynamic and original form of architecture, Bagan ranks among the other great Buddhist centres of South-East Asia, such as Angkorwat in Cambodia or Borobudur in Java, Indonesia.

Bagan is a global pilgrimage centre and contains ancient Buddhist shrines that have been restored and repaired to retain the original architecture. Earthquakes on July 8th, 1975 and 24th of August, 2016 severely damaged more than half of the significant structures and irreparably destroyed many of them. The study area is dominated by the ancient temples and pagodas. It also encompases both urban and rural environments.

Location

Bagan-Nyaung Oo area is situated between 94° 45' 00"E to 95° 00' 00"E and 21° 00' 00"N to 21° 15' 00"N. It is located on both sides of the Ayeyarwaddy River bank and approximately 145 km southwest of Mandalay and 187 km from Yangon. Bagan stands on the east bank of the Ayeyarwaddy, Figure (1).

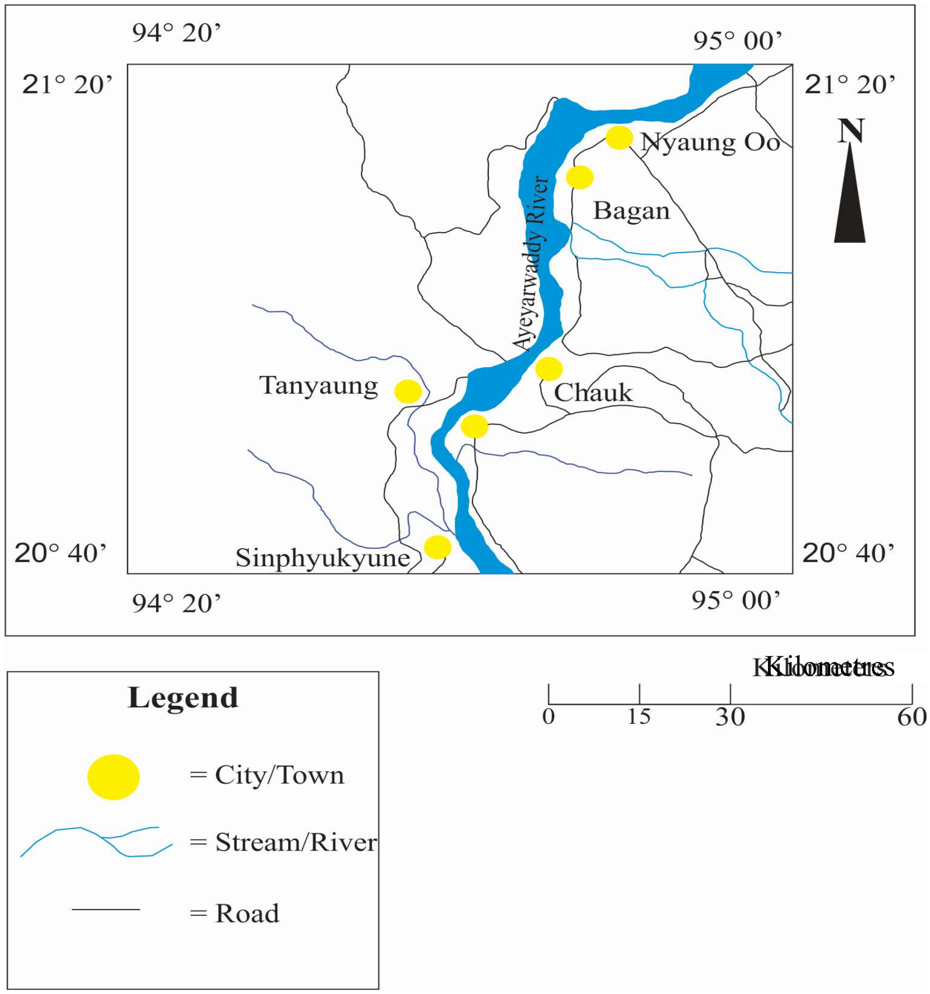


Figure 1. Location Map of the Research Area

Topography and Drainage

Generally, the study area is mainly within the low level plain flanking of the Ayeyarwaddy River. The elevation of the study area ranges from 5.2 m to 408m above mean sea level. Bagan-NyaungOo area lies on either side of Ayeyarwaddy River, as a vast plain on the eastern bank. There are hill ranges namely, TaywinTaung in the southeast and TantkyeeTaung in the west.

The drainage pattern in the study area is dominantly dendritic. Most of the drainage are very poorly but dense meaning the streams are all seasonal.

Ayeyarwaddy River tis the main perennial drainage channel of the studyarea fllowing in N-S direction. Its morphology is controlled by underlying structures and active tectonism.

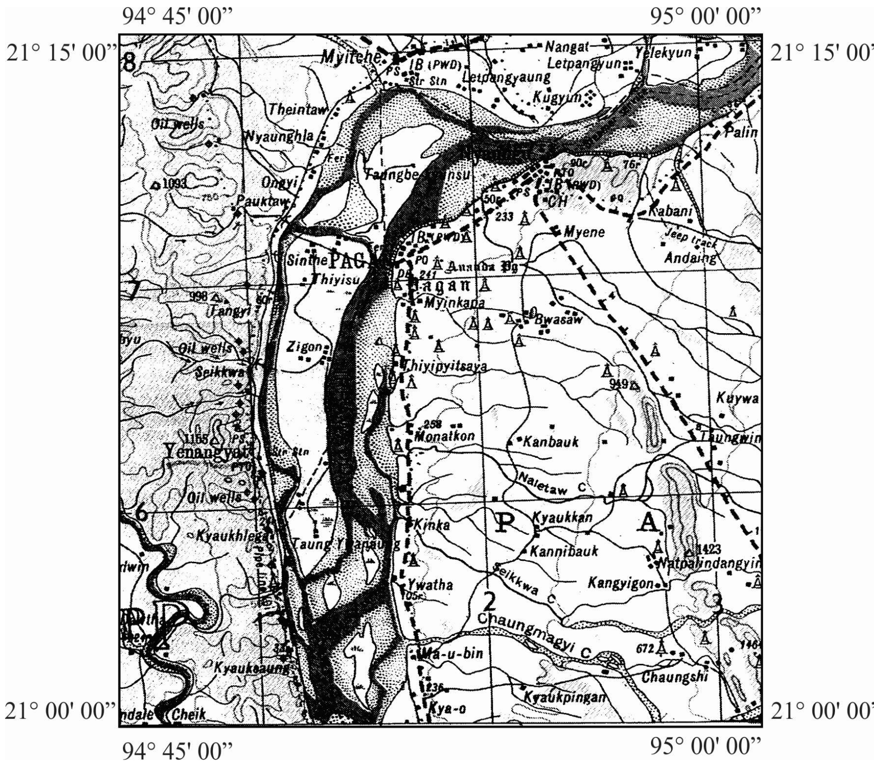


Figure 2. Topographic Map of the Research Area

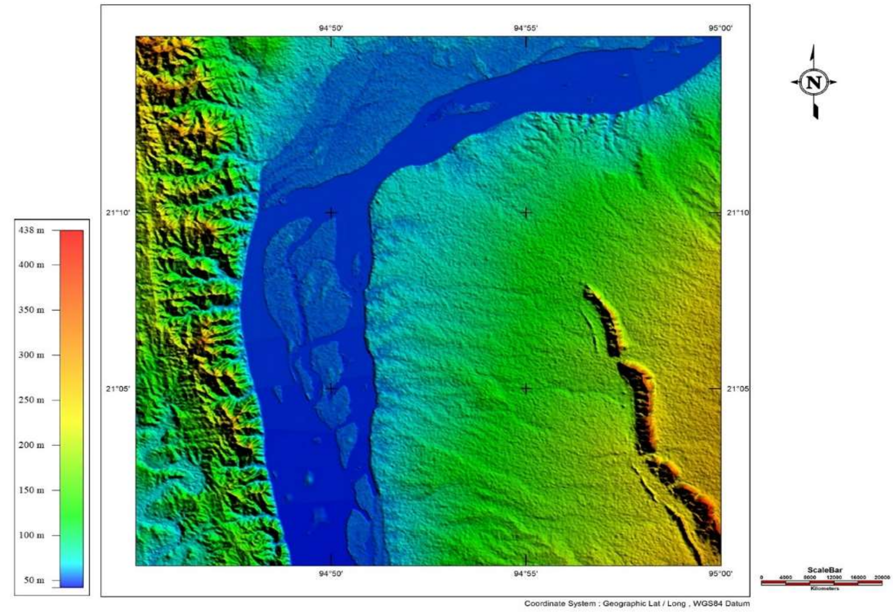


Figure 3. Physiographic Map of the Research Area

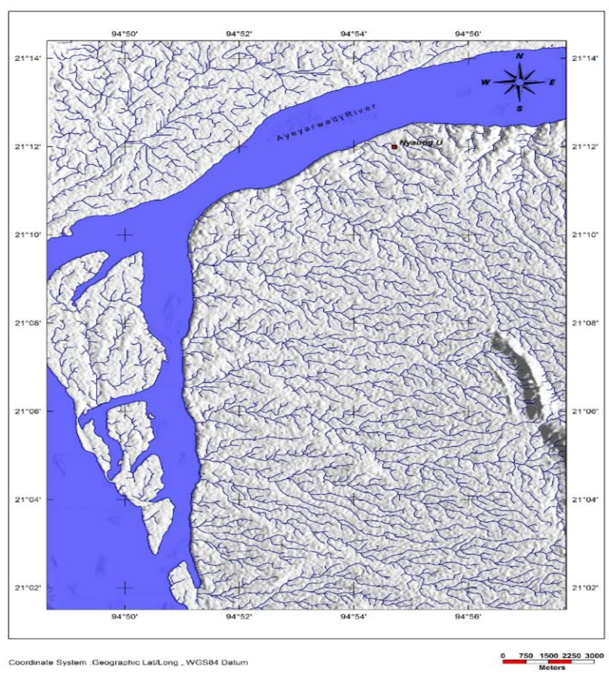


Figure 4. Drainage Map of the Research Area

Climate

The climate of the research area is tropical but the seasons can vary drastically. In summer (from March to May), the temperature rises to 43°C during the day and falls to 24°C in the night, with no rainfall. In the winter (from November to February), the temperature is about 30°C in the day and night temperature is about 30°C. Monsoon starts in June and ends in October. The rainy season lasts from May until October (see figure 5). Based on rain fall data, the highest peak of rainfall was recorded in 2000 during which high flooding along Ayeyarwaddy river occurraed, Figure 13a.

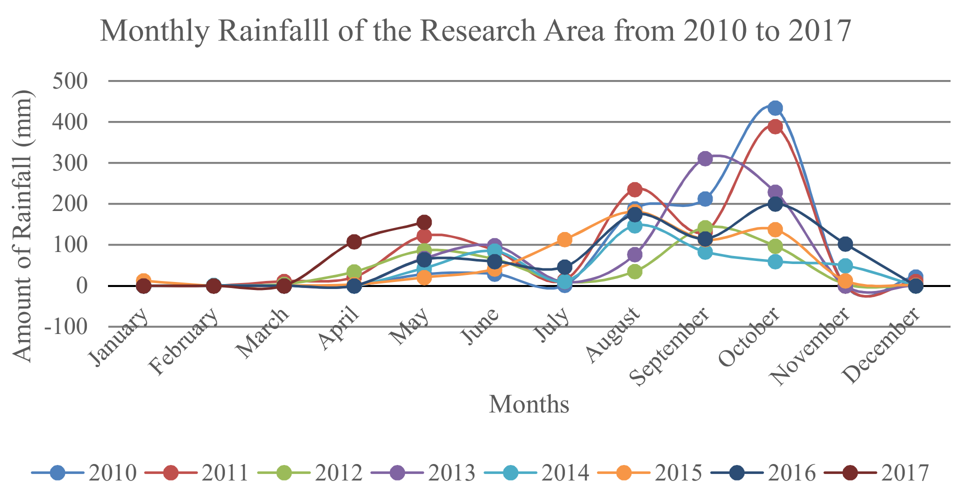


Figure 5. Monthly Rainfall of the Research Area from 2010 to 2017

Methods and Materials

The study aims at demonstrating the application of remotely sensed digital image processing and visual interpretation for engineering geology approach to environmental studies in a specific area. To carry out the ground survey for land interpretation it is necessary to check and link the information received from satellite images. The methodology of the study can be divided into interpretation of image, spatial analysis and field survey. Materials used in the study are maps, informations, software facilities and others.

(1) Satellite Images

The following satellite images were used:

Landsat 7,TM year of acquisition. (2010, 2015), path and row 133/045, 7 bands,

(2) Spatial Data

Topographic map, the scale of one-inch map sheet no. 84K/16 is used as the base map for geographic database of the research area. UTM (quarter-inch) and topographic map (quarter-inch) scale are used to identify the significant topographic features.

(3) Non-Spatial Data

Statistics data (monthly rainfall, monthly mean water level, and earthquake data from the Department of Meteorology and Hydrology (DMH).

(4) Softwares

Microsoft Excel 2013 for plotting the graph

Global Mapper 17

Geo Media Professional

CorelDRAW X8

ENVI 4.7.

Google Earth

(5) Technical Methods

Basically, technical methodology consists of three parts, the first one is visual analysis, the second is digital image analysis and the third is integration of field data and remote sensing analysis.

Satellite Image Analysis

Satellite data of Landsat 7 Thematic Mapper TM were selected for the research. These data are recorded on seven bands with Landsat 7 satellite wherein the study area falls within path/row 133/045 with 30 metre ground resolution. Visual image interpretation and digital image processing were applied for classifying images in a base of land cover/landuse and to enhance image quality. In this research, ground control points were selected by following permanent features evenly distributed throughout the area and identified easily both in image and topographic maps. The Universal Transverse Mercator (UTM) projection method is employed in the research area. The scale of Topographic maps used this research area was quarter-inch.

Image enhancement and band combination in the manipulation of image density were carried out to see more easily certain features of the image. In this research, the false colour composite (R: G: B=4:5:3) was made for land use/land cover interpretation. TM images are analyzed to identify the major structural patterns and lithology and LCLU by using ENVI 4.7.

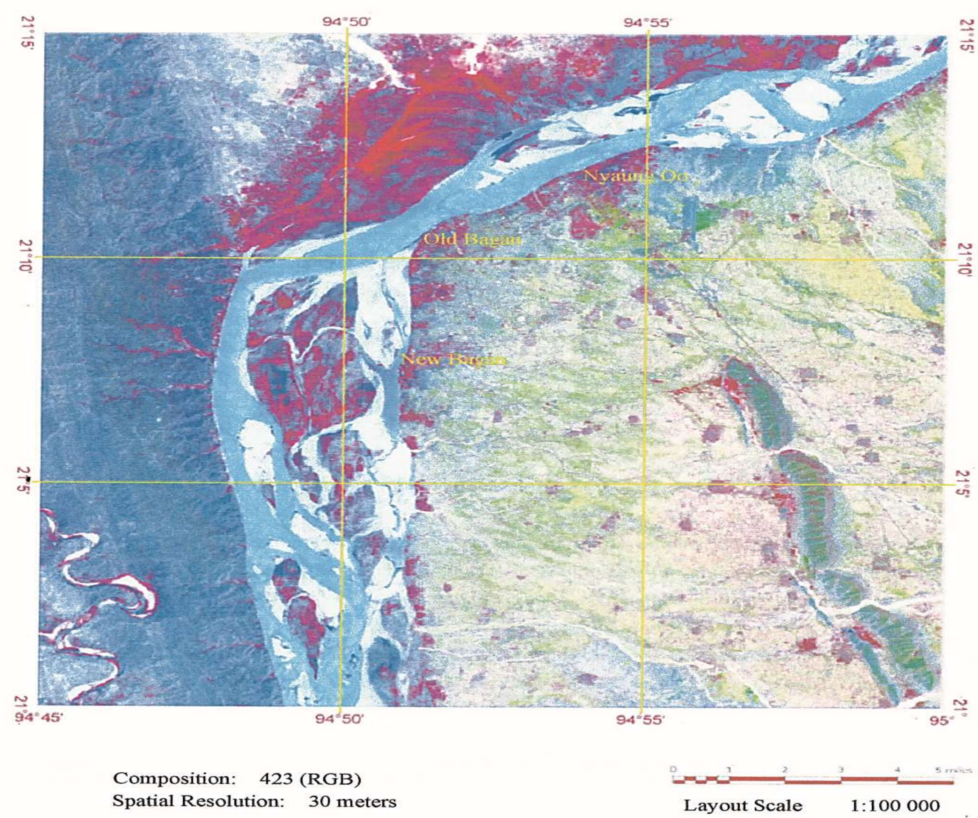


Figure 6. Satellite Image of the Research Area (Image Rectification)

Regional Geologic Setting of the Research Area

Coalesced Chindwin and Ayeyarwaddy Rivers formed elbeco occurs near Nyaung Oo and Bagan (the ninth century ancient city). High range Tuyin Taung (1423 ft) high gradually plunge to the northernmost tip as 948 ft. Tuyin Taung NE high is forming into broad high intrusive dome. The dome shapes are recognized as flower petal represented by 1000 ft contour interval. The height is compared to the west side of Tantkyi Taung, known as geologically as Yenangyat structure.

Recent alluvial is confined along the Ayeyarwaddy river banks. Topographic map all shows diverting straight ridges from the doming high towards the main Ayeyarwaddy cliff banks. Seasonal torrential rivers on Yenangyat fold (beside Myitche) and Sindewa, Pyaungpya (south of Myingyan) supply fertile soil distributing along the eastern Ayeyarwaddy river banks. This fertile soil strip fed and supported the cultural Bagan society beginning from the early 9th century.

A large syncline to the west of Yenangyat fold and the broad intrusion dome align towards Pliocene extinct Popa volcano in the south and Shinmataung to the north. Which particular rifting trend is responsible for the latest catastrophic earthquake still remains as the hot challenging riddle in the mind of every geologist.

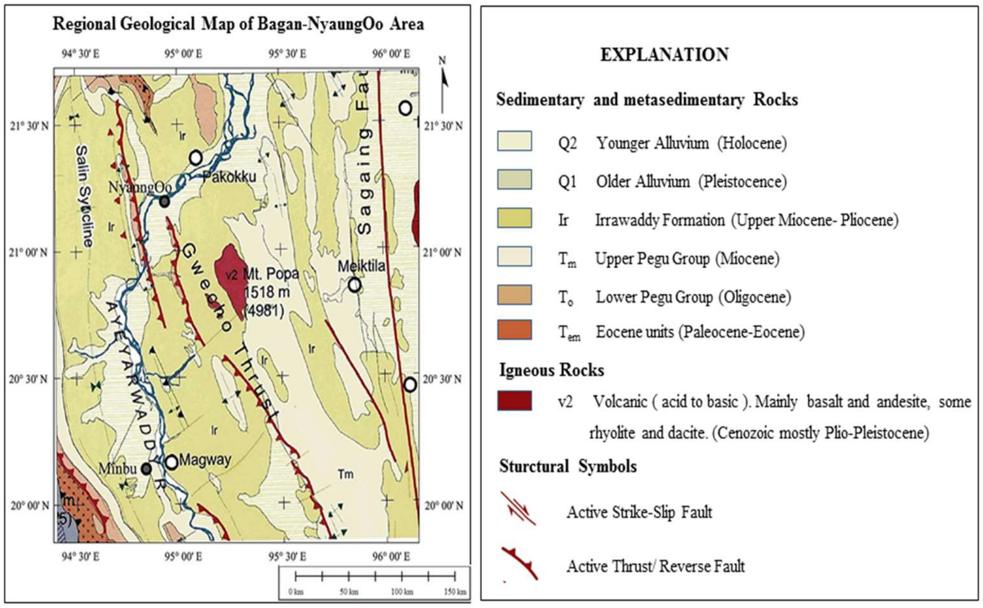


Figure 7. Regional Geological Map of the Research Area

The research area lies within the Central Myanmar Belt which is underlain by Eocene to Plio-Quaternary sediments and locally injected by Quaternary volcanoes (Pivnik et al., 1998). Central Myanmar Belt is structurally complex due to the multiple phases of deformation like folding, faulting oblique and dextral faulting and normal faulting (Pivnik, 1998). The regional structural trend of the research area ranges from NNW-SSE to NW-SE orientation. High relief of topography like Tantkgyi Taung, Tuyin Taung and thrust belt that represent the significant structural features of the research area.

Geology of the Research Area

The research area covers mostly alluvial plain, the debris and small fan materials derived from TuywinTaung and Tankyee Taung hills which are exposed with rocks of Miocene to Oligocene age.

In the research area, exposed rock units are Irrawaddy Formation (Late Miocene to Pliocene), Okhmintaung Formation (Late Oligocene), Padaung Formation and Shwezettaw Formation (Early Oligocene). The Shwezettaw

Formation is well-exposed along the Tuywin Taung Range. The Pyawbwe Formation well-exposed along the Tantkyi Taung Range.

The vast plain in the area consists of flood sediments derived by the Irrawaddy River. The alluvial soils (Quaternary-Recent) are deposited on the plain and along the Irrawaddy river bands. There are five types of soils classified as: (1) active alluvial fan, (2) river bed deposits, (3) gravel deposits, (4) colluvial soil and (5) residual soil.

Landslides and Erosion

Active and old landslides are marked in the research area along hill slopes of Tantkyi Taung and Tuywinn Taung Ranges. Small open cracks are denoted on the top parts of the landslides. In these ranges, slope angle of 40°-60° is unstable and can create further sliding in the rainy season. In addition to these, ranges with gully erosion and tension cracks are also recognized. Soil erosion and debris fall are also common on hill slopes of Tantkyi Taung and Tuywinn Taung Ranges because of soft sediments and fast weathering nature, deforestation as well as haphazard exploitation of construction materials. On the eastern flank of Tantkyi Taung Range, debris fall and soil erosion as well as landslides due to steep slopes are observed. High density of joints and differential erosion between soft mudstones and hard sandstones of Tantkyi Taung Ranges are developing to rock blocks which are liable to be detached creating landslide and debris fall hazards.

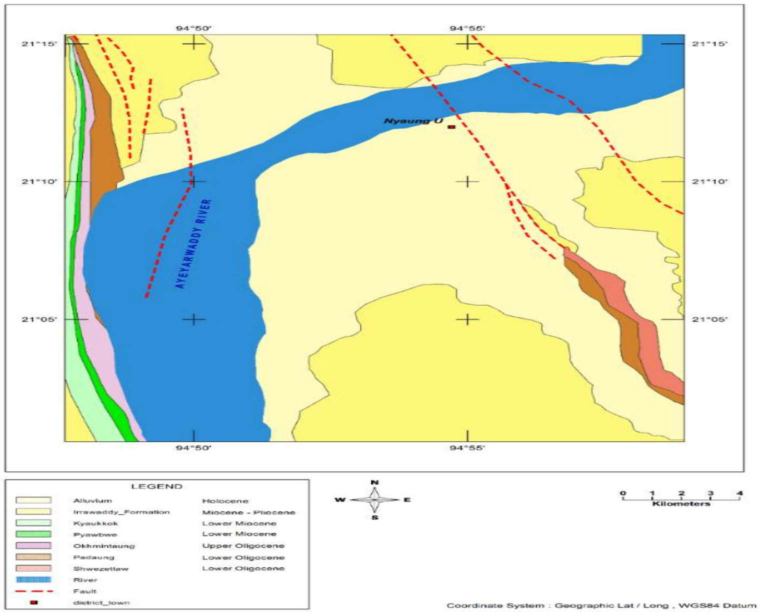


Figure 8. Geological Map of the Research Area (Tun Naing Zaw, Min Thura Mon, Swun Wunna Htet, 2017)

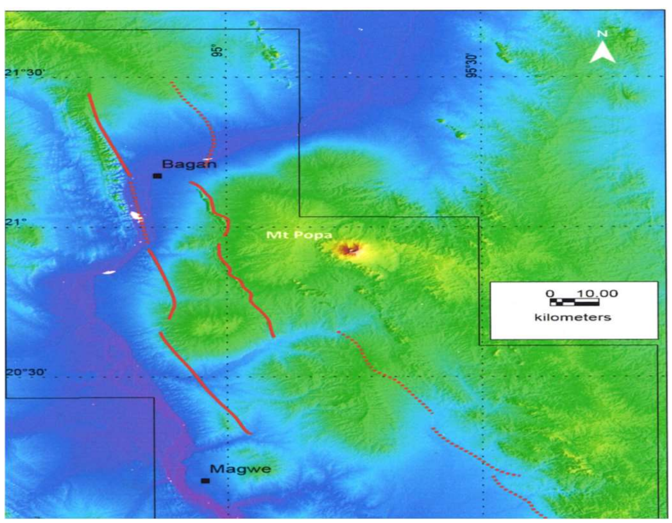


Figure 9. The Digital Elevation Model of the Bagan and Surrounding Areas showing the Surface Fault Trace of the Thrust Systems of the Research Area

Tantkyi Taung Thrust

It is clearly observed on the eastern limb of Tankgyi Taung anticline. Fault trend is running about 346° with steep slope and v-shaped gullies. Along the fault line, scarpsare characterized by erosional surface.Figure (9 and 10).

TuyinTaung Thrust

It is clearly observed in TuyinTaung near Bagan. Fault trend is running N330° and fault dips about 46° to the west. Figure (9 and11).

Left = Landslide (Facing-20°), Right = Old Landslide (Facing-80°)

Left = Cliff with debris at the bottom (Facing-70°),
Right = Old Landslide (Facing-50°),

Figure 10. Landslides in Tantkgyi Taung

Tuyin Taung (Facing=170°) (N 21 10’ 42.4”, E 94 52’ 31.6”)

Figure 11. Landslides in Tuyin Taung

Flood and Erosion

Both sides of Ayeyarwaddy River bank is eroded by both riverbank scouring and rain water resulting steep slopes. Slope failures causing landslides are common along the east bank of the river in the central portion of the research area. There is a number of river bank failures within 5 to 10 metres.

A buffer zone of 30m is desirable not to have any settlements and construction works to allow natural stabilization.

River bank cutting between Nyaung Oo and New Bagan is another threat to cutting failure that needs to be taken care of soil failure. Low land area gets flooded and covered with sediment deposited during the rainy season by flood.

Ayeyarwaddy River is generally bed load channel type. River flowing between the banks on the beds composed of sediments being transported by the river are sensitive to changes of sediments load, water discharge and variation of valley floor slope.

In the research area, west bank of Ayeyarwaddy River, three steps of river terraces are observed in Bagan-Nyaung Oo area (Chhibber, 1934) and alluvial terraces and colluvial deposits are widely distributed in the research area.

In the rainy season, lowlands adjacent to the river and the main streams in the area are likely to be affected by flood as they are prone to flood hazards. Hence, these areas are not suitable for human settlements but can be utilized for agriculture. A risk of flash flood can always be a threat in these areas in future in the rainy season .Figure (12 & 13).

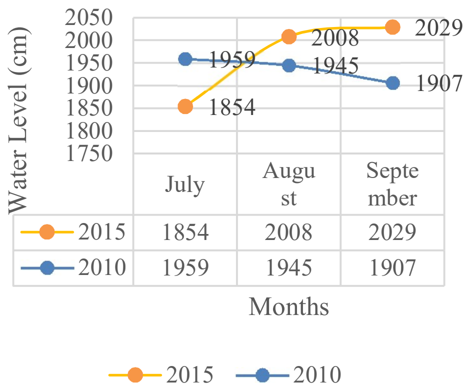


Figure 12. Monthly Mean Water Level of Research Area in 2010 and 2015

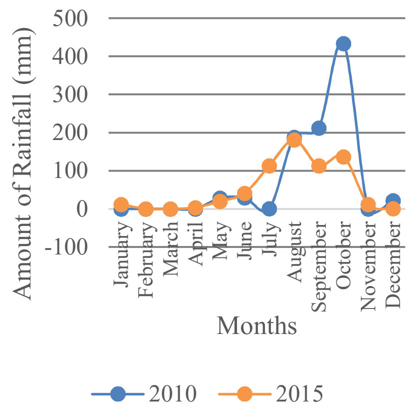


Figure 13. Monthly Rainfall of Research Area in 2010 and 2015

Location –N 21°09'33.6", E 94° 51' 34.5" Flooding in Mingaba village (25th August 2017)

Location: N 21°11’49.1’’, E 94°54’9.5’ Flooding in Streets in Nyaung-Oo Township (25th August 2017)

Location: N 21 11’13.4”, E 94 53’21.6” Flooding in Wetkyee Lake (25th August 2017)

Figure 14. (a, b, c & d) Flooding in Nyaung Oo Area

Figure 15. Increase in water level causes river flooding near the eastern bank of Ayeyarwaddy River (25th August 2017)

Figure 16. Flooding in Tantkyi village near the west bank of Ayeyarwaddy River (Location: N 21 9’11.2”, E 94 48’ 8.9”) (25th August 2017)

Figure 17. River flooding causes the villages in the central islands to evacuate the Theikkawa villagers to higher ground (25th August 2017)

According to the satellite image analysis, the rainfall in 2010 is significantly higher than that in 2015 (Figure 13) (2017 data not available during evaluation) resulting in the difference in volume of water body of Ayeyarwaddy River. In addition to the rainfall, the water level is higher 2015 than in 2010 due to the higher sedimentation of the river, thus sand bars and diluvium from river erosion and flood deposited. (Figure 18, a and b).

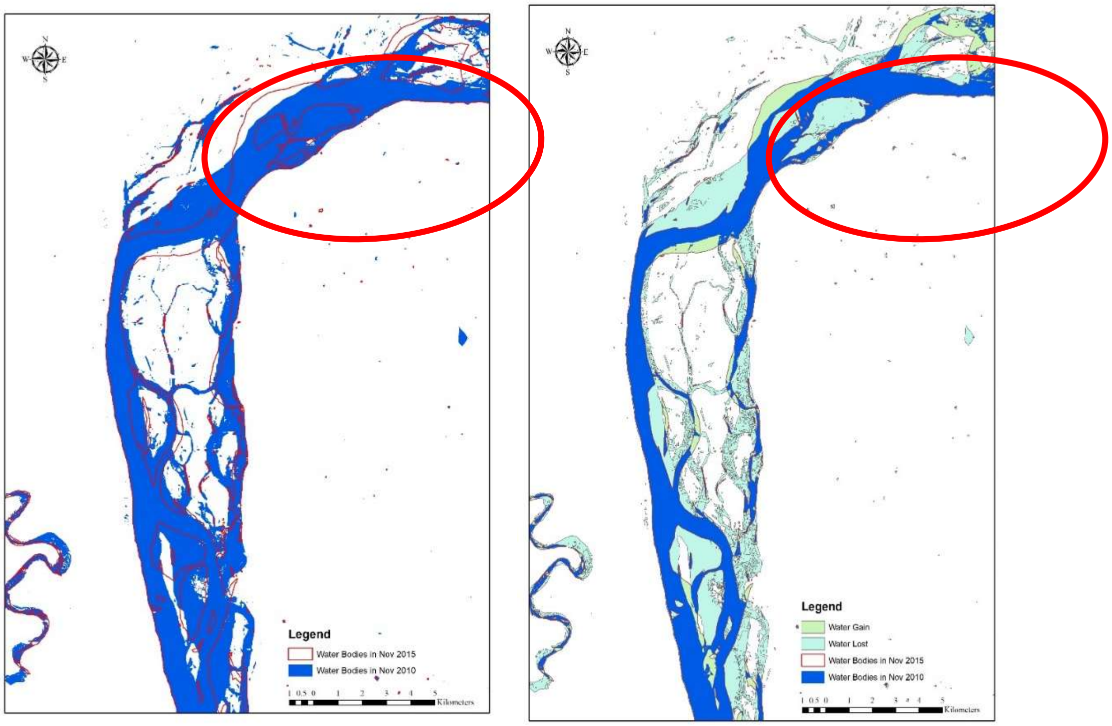
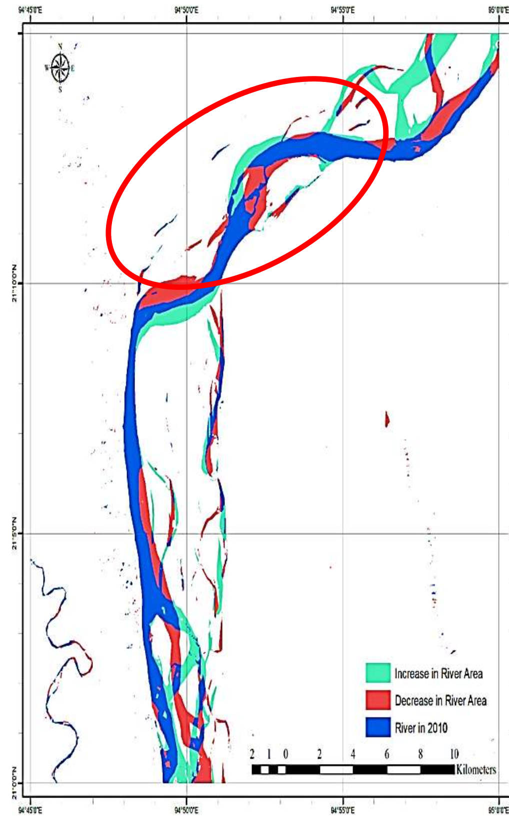


Figure 18. (a and b) Comparison of Water Bodies and Water Gain / Lost in 2010 and 2015 (Based on Satellite Images) as Shown with Red Circles

In 2010, the rate of western river bank erosion and deposition are obviously increased, therefore the west bank of Ayeyarwaddy River is more vulnerable to river bank erosion and flooding. See Figure (19, a and b). The same phenomenon happened in 2015. See Figure (20, a and b).



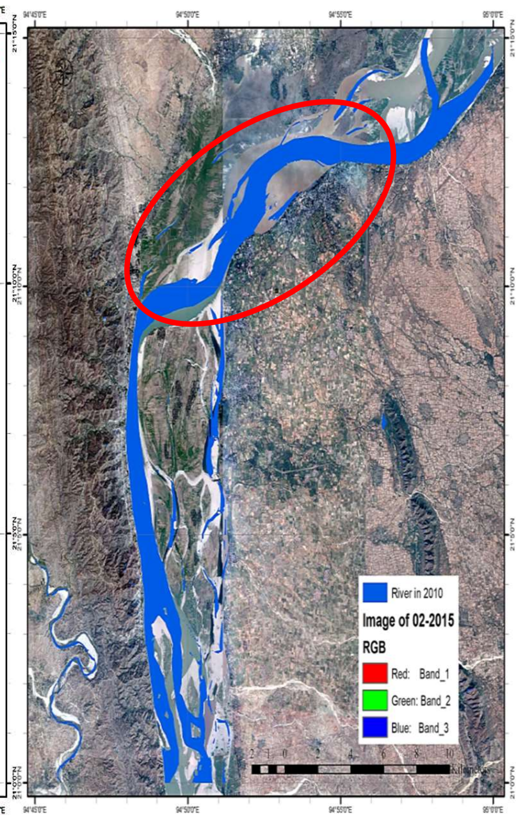


Figure 19. (a) **Figure 19. (b)**

Figure 19. (a and b) 2010 Ayeyarwaddy River Line with Increase and Decrease in Water Body

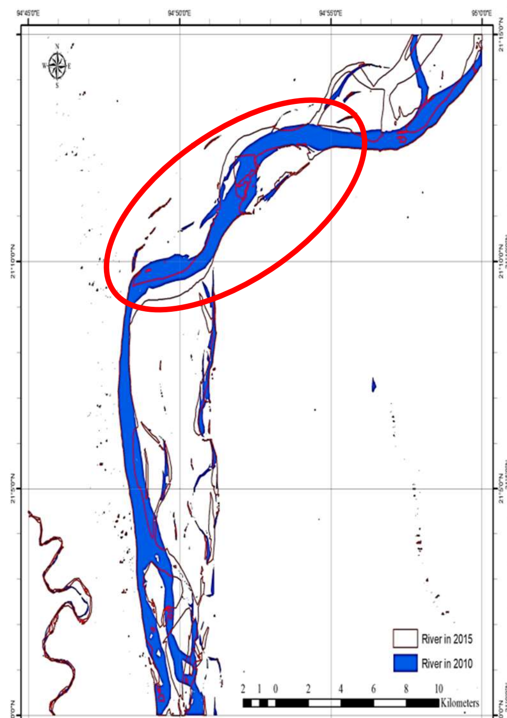


Figure (20, a)

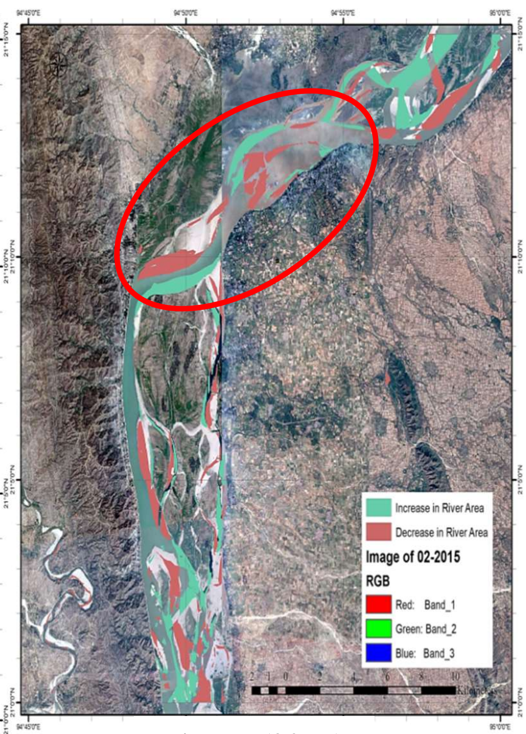


Figure (20, b)

Figure 20. (a and b) 2015 Ayeyarwaddy River Line with Increase and Decrease in Water Body

Sedimentation along Ayeyarwaddy River in March, 2017 as shown is Figure (21) implies that less volume of water body in the river at that time. This indicates that the intensity of flooding will increase during the rainy season.

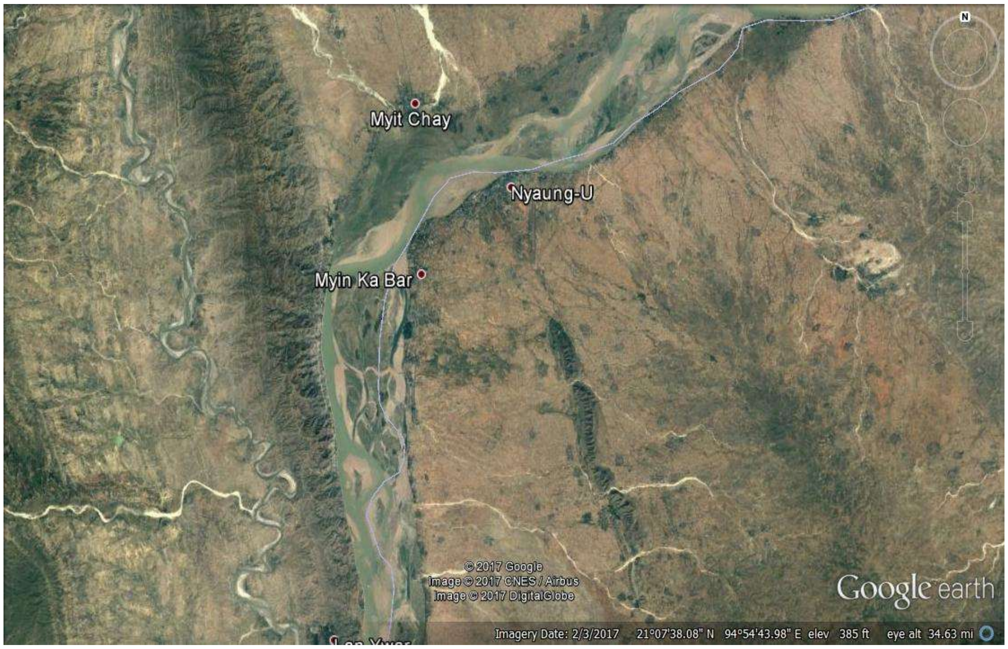


Figure 21. Recent Sedimentation along Ayeyarwaddy River Path Obtained from Google Earth (Imaged in 2nd March 2017)

Earthquakes

Earthquakes constitute a serious natural environmental hazard. There are many earthquakes every year in the research area, but most of these are relatively small events that do not release large amount of seismic energy. Historical accounts of two major earthquakes are shown in Table (1).

Table 1. List of the Earthquakes with Magnitude (>5) in Bagan-Nyaung Oo Area

No	Date	Epicentre		Richter Magnitude	Remarks
		Latitude	Longitude		
1	8th July, 1975	21.485°N	94.7°E	6.8	Many historical pagodas destoryed, 2 killed, 15 injured.
2	24th August, 2016	20.919°N	94.579°E	6.8	Damaged temples and pagodas= 397

The strongest intensity of 1975 earthquake was felt in Nyaung Oo, Pakoku, Yesagyo, Myaing, Chauk and Natmauk townships. Generally, intermediate depth earthquakes are likely in this region. The epicentre was located at the northern tip of TankyiTaung Thrust. Table (1). It is suggested that 1975 Bagan earthquake is related to the growth of Tankyi Taung Thrust at the west bank of Ayeyarwaddy River.

However, some researchers believed that the source of Bagan earthquake (1975) is Gwegyo thrust or Chauk-Yenangyat thrust which are located close to Bagan (most yulnerable area). According to focal mechanism of the earthquake (La Dein et, al., 1984), Bagan earthquake (1975) represents the subduction zone earthquake. Therefore, the possible source of Bagan earthquake (1975) is still controversial.

Bagan Earthquake, 1975

The distribution of microseismic intensities of 1975 Bagan Earthquake is shown in Table (2).

Table 2. Microseismic Intensity of the Bagan Earthquake (1975)

Town	Location		Intensity (MMI)	Destruction
	Latitude	Longitude		
Bagan (Ancient)	21.17°	94.86°	9	Destruction and collapse the upper part of Arnanda Pagoda and other ancient building and pagodas
Bagan (New)	21.13°	94.85°	9	Destruction of the old buildings and pagodas
Nyaung Oo	21.2°	94.92°	8	Large fracture at Shwe Sigon and Gu Pyauk Kyi Pagodas
Tantkyi Taung	21.16°	94.77°	8	Damage of Tankyi Taung Pagodas
Tuyin Taung	21.12°	94.94°	8	Destruction and large open fracture of Tuyin Taung pagoda

Table 3. 1975 Bagan Earthquake Damage Records (Shwe Gaing Tha, 1975 and Min Htwe Naung, 1978)

Locality/ city	Long	Lat	Damage description		MMI*
			Shwe Gaig Tha (1976)	Min Htwe Naung (1978)	
Myaing	94.854	21.61	15 pagodas collapsed to the bell. Duration 2 min		VIII
Bagan (Sandbars)	94.83	21.12	Liquefied.	Tsunami in the river. River flow towards upstream for a moment. Ground cracked about 200 yards. Sand shot up about 10 ft high	VIII
Nyaung-U	94.9	21.19	Pagodas and temples destroyed	2 people died. 15 Injured. Many Pagodas collapsed.	VIII
Yesagyo	95.24	21.63	57 Pagodas destroyed. Duration 2 min.		VII
Pakokku	95.08	21.33	80 buildings destroyed. Bridge cracked. People ran out of buildings. Couldn't stand on ground.		VII
Taungtha	95.445	21.28	Pagodas and temples destroyed		VI
Chauk	94.82	20.89	Parapet and stone wall along the river settled and destroyed. Some oil rigs toppled down.	1000 yard long stone wall fell into the river. One oil rig topple down into the river, 3 rigs tilted. One oil storage tank sunk into the ground.	VI
Kyaukpadaung (Indaw vil.)	95.12	20.84	Ground cracked about 2 miles.	One monument column toppled down.	VI
Natmauk	95.4	20.34	Railkway bridge settled 1ft and railway lines bent.		V
Minbu	94.87	20.16	One diapir sunk 2 ft and road uplifted 6 inches. Water pipe broken.		V
Phyu	96.43	18.48	4 min		IV
Latbadan	95.75	17.78	Local seich		IV
Thegon	95.41	18.65	30 second		III

Most of the earthquakes are shallow to moderate focus earthquakes with the moderate magnitude and the depth of hypocentre ranges from 10 km to 157 km under the earth's surface. Table (4).

Table 4. Instrumental Records of the Earthquakes (Moderate to Strong Earthquakes) in the Research Area (USGS, 1964 to 2013)

Date	Hypocentre		Richter Magnitude	Depth (km)
	Latitude (N)	Longitude (E)		
18/12/1972	21.23°	94.17°	5.3	72
8/7/1975	21.48°	94.70°	6.5	157
24/1/1982	21.45°	94.66°	5.4	113
27/7/1996	21.31°	94.8°	5.2	110
17/7/2005	21.02°	94.99°	5	120.3
3/3/2006	21.12°	94.47°	5.2	112.8

Bagan-Chauk Earthquake, 2016

The strongest intensity of 2016 Bagan earthquake was felt in Salin, Seikphyu and Chauk which are the most damaged towns and are situated near the intensity level 6. Seismic intensity 5.5 to 6 reached Pakokku, Nyaung Oo, Bagan, west of Kyaukpadaung and Yenanchaung. Due to its effect, many historical structures including monasteries, pagodas, stupas and temples were severely damaged or destroyed. Figure (14, 15, 16 and 17). Statistically, 270 Bagan monuments were destroyed and 3 people died. The buildings around Bagan other than the ancient monuments are also more or less damaged.

Figure (22, 23, 24, 25) The destruction of Ancient Bagan Temples and Pagodas Caused by (2016 Bagan Earthquake Source: Internet)

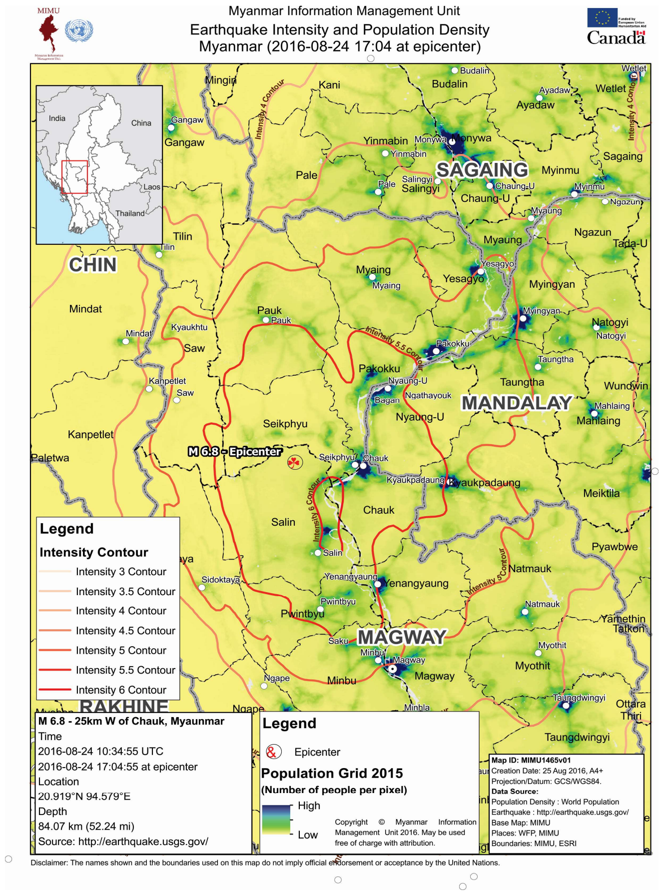


Figure 26. Earthquake Frequency and Population Density of the Research Area (Organized by Myanmar Information Management Unit, MIMU, European Union Humanitarian Aid, United Nations and Canada in 2016)

According to PGA and PGV data(USGS) from research area (Bagan, Nyaung Oo and surroundings), the instrumental intensity is VI to VII, so the area received strong to very strong quaking and potentially has light to moderate damage. Table (5).

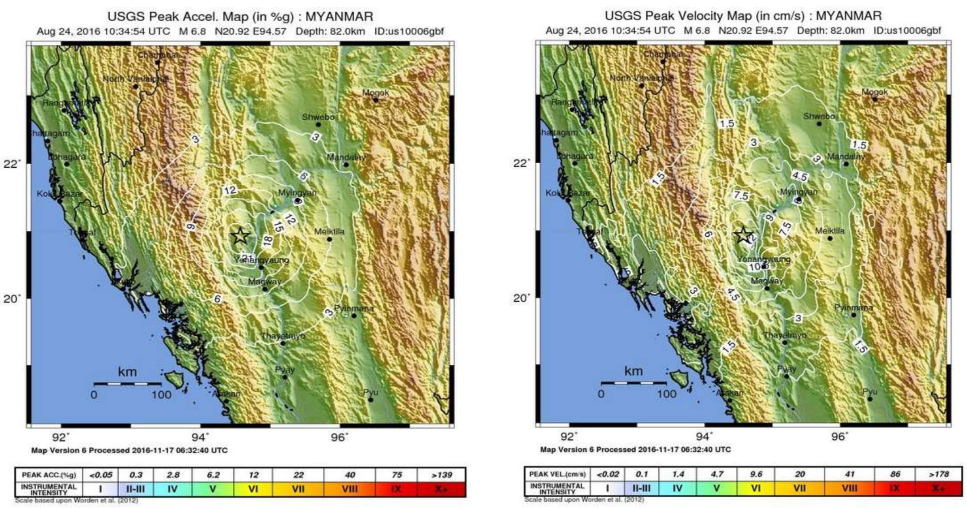


Figure (27, 28) USGS Peak Acceleration Map and Peak Velocity Map of the Bagan-Nyaung Oo Area

Table 5. SMI intensity scale (after Wald et al., 1999a)

Perceived Shaking	**Not-felt**	**Weak**	**Light**	**Moderate**	**Strong**	**Very Strong**	**Severe**	**Violent**	**Extreme**
Potential Damage	None	None	None	Very light	Light	Moderate	Moderate/ Heavy	Heavy	Very Heavy
PGA (%g)	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2	18-34	34-65	65-124	>124
PGV (cm/sec)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
Instrumental Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+

According to Department of Meteorology and Hydrology as shown in Table (6), the PGA value recorded the highest (0.12g Up and Down Shaking) from Nyaung-Oo station. Due to the intense up-and-down shaking, liquefaction and severe damage to the upper part of the ancient monuments happened.

Table 6. 2016 Chauk Earthquake PGA Data from DMH

Recorded Stations	PGA (g)		
	NS	EW	UD
Nyaung Oo	0.08	0.09	**0.12**

Possible earthquake source of 2016 Bagan earthquake is subduction-related but is still controversial because of its various hypocentre depth information (82 km measured by USGS while others got 84.1 km), mechanism is composite (generic) with a magnitude of 6.8 on Richter Scale at which its epicentre was 16 miles west of Chauk.

(http://earthquake.usgs.gov/earthquakes/eventpage/us10006gbf#shakemap).

Land Use

In the research area, existing land use patterns are agricultural land, sparse forests and scrub, settlements, industrial, recreation centres, infrastructures and small land fill/ waste disposal sites.

(1) Engineering Approach to Land Use for Construction

The research area has heterogeneous soil distribution character with different engineering properties. Low to medium-bearing capacity (1.8 to 4TS F) areas are concentrated in the area where active alluvial fan and river bed deposits have high permeability and loose density. Most of plain area is covered by a firm soil with a stable bearing capacity and so appropriate for small to medium scale construction purposes.

Gravel deposit in Nyaung-Oo area, being derived from landslide-induced active alluvial fans and river bed deposits by erosional forces, is locally developed on the both banks of the rivers and streams. It consists of sub-angular to pebbly and gravelly rounded quartzite, gneiss and phyllite with fine sand, silt and clay matrix. **Colluvial soil** occurred at the base of slopes and consists of clay, silt and sand with angular gravel to cobble size fragments of shale, phyllite and quartzite/ meta-sandstone). These colluvial deposits are derived from old landslides.

In Bagan area, **residual soil** is developed in place on flat to gentle hill slopes. It mainly consists of clay, silt, and gravel size rock fragments. Mostly, the residual soil in New Bagan is derived from Irrawaddy Formation. Four boreholes data measured by JICA Project and Ministry of Construction are used in engineering analysis for calculation of bearing capacities of each boreholes and test pits. Figure (29, 30, 31).

We would like to conclude that the bearing capacity of gravel bed in Nyaung-Oo is sufficient for shallow foundation, however, without the compaction of gravel soil under the footing of the specific foundation, It is likely that the differential settlement will occur causing the foundation unstable due to the poorly sorted gravels.

For Bagan area, since the residual soil comes from Irrawaddy Formation which has a bearing capacity of 2.9 – 4 TSF at the depth of 2m according to geotechnical analysis, shallow foundation with square footing for two to three-storey houses and hotels are suitable for construction. In spite of the availability, the Ministry of Construction stipulates only to build structures of 30ft high with two levels.

Depth	Bearing Capacity
2.1 Ft	1.7 TSf
3.2 Ft	2.5 TSf
4.3 Ft	2.3 TSf
5.3 Ft	2.4 TSf
6.5 Ft	2.7 TSf
7.5 Ft	2.8 TSf
8.6 Ft	2.9 TSf

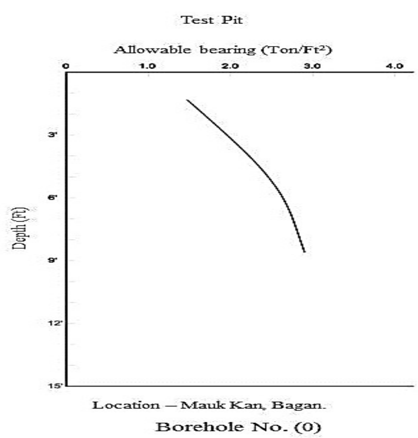


Figure 29. Test Pit Result of Borehole No.(0), Mauk Kan, Bagan

Depth	Bearing Capacity
2.1 Ft	2.9 TSf
3.2 Ft	3.3 TSf
4.3 Ft	3.7 TSf
5.4 Ft	3.8 TSf
6.5 Ft	4 TSf

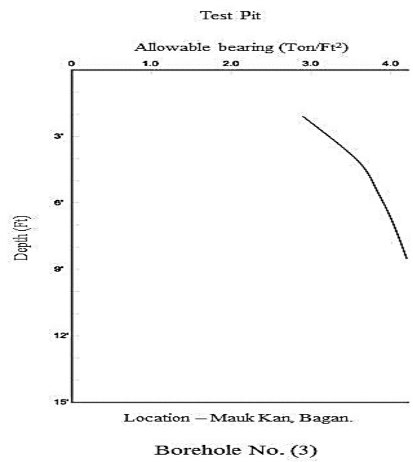


Figure 30. Test Pit Result of Borehole No.(3), MaukKan, Bagan

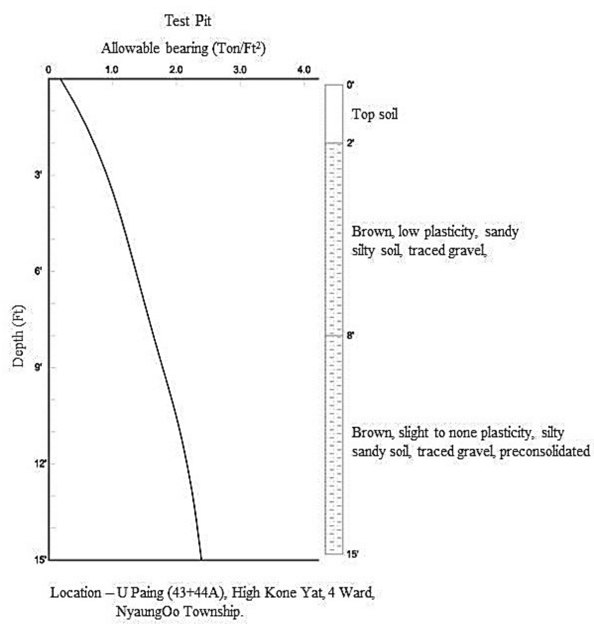


Figure 31. Test Pit Result of Nyaung-Oo Township

(2) Agricultural and Scrub Lands

Most of the flat, lowlands in the plain along the river bank and hill sides are covered by sparse forests and scrubs. Open forests, swamp forest, orchard, palm trees, scrub, bush and grass are categorized in the research area. Low angle sloping lands (hill sides) are good for dry cultivation (maize, millet, wheat and cereals).

(3) Urban Settlement and Industrial Areas

Urban settlements include existing area, planned area, proposed area, and expanded area. Proper drainage system in Nyaung Oo and Bagan is adequate now. Crucial area of man-made pollution is located in the east of NyaungOo. On the banks of the Ayeyarwaddy River, squatters' settlements are creating.

Figure (32, 33) (Left)Urban Settlement and Agricultural and Scrub Land (Right)

(4) Recreation Centres and Open Spaces

Lawkananda reserve forest near New Bagan is the only existing public and natural park in the area. The research area has religious and cultural values where most of pagodas are located form north to south. Bagan golf field and Recreation Park are located west of NyaungOo beside of the main highway road.

(5) Landfill and Waste Disposal Sites

NyaungOo municipality lacks sanitary landfill site to manage safe disposal of its solid wastes produced from the urban settlement and industries. It is temporarily dumping its daily wastes on the river bank.

(6) Cultural Heritage Site

Bagan, being regarded as the Golden Land of Wonders, is a tourist attraction filled with cultural monuments and the ancient Bagan's amusing architectures of First Myanmar Empire. The present government is now trying their best to make Bagan to be one of the World's Heritage Sites approved by UNESCO. In our field trip, we observed some places of Bagan's monuments suffering from environmental degradation. Thus, here we will mention some facts to remedy the deteoration based on our field data.

Bagan has over 3,000 ancient monuments scatterred across the vast arid plain. They can be categorized into four types: (1) temple, (2) stupa, (3) monastery and (4) unexcavated mounds. Figure (32) Most of the monuments in Bagan were destroyed by the earthquakes in the past. Table (2) and (3). The repaired parts and upper parts of the monuments (square tower, spire) after 1975 earthquakes were collapsed Figure (33). Vegetation and microorganisms encroaching on the monuments are damaging them. Figure (34). Further studies related with cultural heritage sites and maintenance of monuments are essential for Bagan.

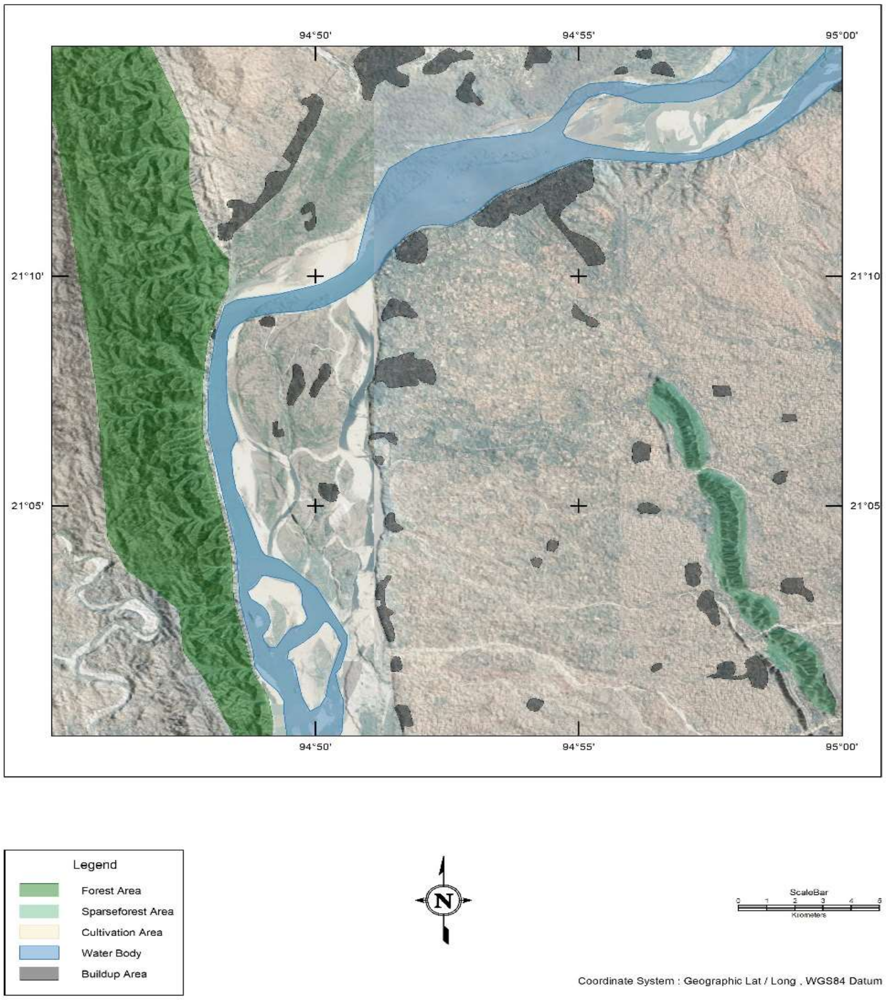
Temple

Monastery

Figure (32) Various Types of Monuments

Figure (33) Damages in Repaired Parts and Upper Part of Monuments

Figure (34) Damages Due to Vegetation and Microorganism



Figure(35) Land Use Map of the Research Area

Summary and Conclusions

(1) The study area is situated between E 94° 45’ and E 95°, N21° and 21° 15’. It is located on NyaungOo area, Mandalay Region.

(2) The study showed that remote sensing techniques are useful tools for assessing and analyzing the geological purposes.

(3) TM images are analyzed to identify the major structural patterns and lithology and LULC.

(4) Bagan stands on the east bank of the Ayeyarwaddy River.
(5) Bagan, an old capital of Myanmar, is famous global pilgrimage centre and contains ancient Buddhist shrines.
(6) An earthquake on July 8, 1975, severely damaged more than half of the significant structures are irreparably destroyed many of them.
(7) Statistically, 270 Bagan monuments were destroyed and 3 people were dead. The buildings around Bagan other than the ancient monuments are more or less damaged by 2016 Bagan Earthquake
(8) Shake-Map can be used to observe damage patterns and can also be generated for different anticipated scenarios to aid emergency planning and hazard mitigation.
(9) Old and new landslides are found on the flanks of Tantkyi Taung and Tuywin Taung.
(10) Floods are the most common and the most destructive geologic hazards. We need to control flooding by non-structural approach through sound flood plain management and engineering efforts such as artificial levees, flood-control dam and channelization.
(11) Essential protection of western Ayeyarwaddy River bank, Nyaung-Oo and Bagan banks are required to reduce erosion.
(12) Squatters' settlements on the banks of the Ayeyarwaddy River are creating an alarming threat of encroachment of the river bank and flood plain. It is advised that settlements in these areas must be prohibited.
(13) Sanitary condition of solid waste disposal sites are essential in Bagan-Nyaung Oo area.
(14) Learnt from the 2016 Bagan-Chauk earthquake destroying 270 monuments, we need to particularly establish earthquake awareness by the public, accelerated research on earthquake and earthquake engineering and new technology and methods of repairing the monuments without disfiguring ancient architecture and cultural treasures.
(15) Effects of disasters will be different, past and present, depending on the density of population and highrise structures. Thus we suggest that more preparedness for mitigation of natural hazards is necessary at all times.

Acknowledgements

The authors are deeply grateful to Professor and Head, Dr. Day Wa Aung, Department of Geology, University of Yangon, for allowing us to do this research.

Heartfelt thanks are extended to Professor Dr. U Thein (Retired Rector), for his suggestion and advice given to us during the preparation and compilation of our research.

We would like to express our sincere thanks to U Win Maw, Retired Chief Executive Officer, MOGE, for his encouraged discussions, suggestions and permission.

Our special thanks go to Dr. Ohn Thwin, Retired Professor, Department of Geology, University of Yangon for his participation of field trip and his helpful comments and advice.

With our deepest gratitude, we acknowledge U Than Htay, Deputy Director General (Retd.), DGSE, Ministry of Mines, for his kindness to immensely improve not only English but also the geologic sense of this paper.

We acknowledge JICA Projects in Nyaung-Oo Area and Administration Department with gratitude for their vital technical data support.

We also thanks the Department of Meteorology and Hydrology for their relevant data and information.

Finally, the authors would like to deeply thank U Than Htut Khine, (1984Geology),Deputy Director, Directorate of Hotels and Tourism (Bagan Branch), for his generous hospitability and informations concerning land use/ land cover.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

Petrography and Lithofacies Analysis of Shwezetaw Formation, Northern Part of Letpanto Area, Pauk Township, Magway Region, Myanmar

Phone Pyae Nyunt[1] and Day Wa Aung[2]

Abstract

The present study area occupies a small portion of the Minbu basin. The study area is mainly underlain by mollassic clastic sedimentary rocks of Pegu Group in Tertiary Age. The stratigraphic units, namely, the Shawezetaw Formation (Early Oligocene), the Padaung Formation (Middle Oligocene) and the Kyaukkok Formation (Middle Miocene) are exposed in the study area. The Shwezetaw Formation consists of fine to medium grained, grey to yellowish brown coloureds and stone, which are Lithic Arkose and Feldspathic Litharenite in composition. The diagenesis of the study area can be categorized into two main stages such as early diagenesis and late diagenesis. Packing of the sandstone is largely dependent on the grain size, shape and sorting. The Shwezetaw Formation has four lithofacies representing two lithofacies association. They are delta plain facies association and delta front facies association. The Shwezetaw Formation was deposited in deltaic depositional environment during a regressive phase of sea level.

Introduction

The study area is located in the northern part of the Pauk Township, Pakokku District, Magway Region. It lies between the latitude 21° 41' N and 21° 45' N and longitude 94° 30' E and 94° 35'. Location of the study area, shown in (Fig. 1).

The geology of the study area had been carried out by many geologists but the main aims of the present paper are to study the sandstone petrography of rock units with emphasis on diagenesis, and the pore space nature, and to carry out sedimentary facies analysis.

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2. Dr, Professor and Head of the Department of Geology, University of Yangon

Regional Geology and Stratigraphy

The study area is located in the Salin Basin (Minbu). Salin Basin is situated in the northern part of the Central Myanmar Basin. On the west flank of the basin, the Western Outcrops are separated by the Kabaw Fault complex from the Triassic and younger rocks of the Indo – Burman Ranges (Pivnik*et al*, 1998). The long and continuous syncline occupying the entire western part of the Salin Basin also known as the Salin Synclinorium. The study area is located in the northern part of Salin basin. Most of the Oligocene - Miocene rocks mainly constituting of clastic rocks of Central Cenozoic Belt (Central Basin of Than Nyunt and Chit Saing, 1978) are very limited in distribution and are found mostly in Minbu infrabasin. The general regional geology map of the study area is shown in Fig. 2.

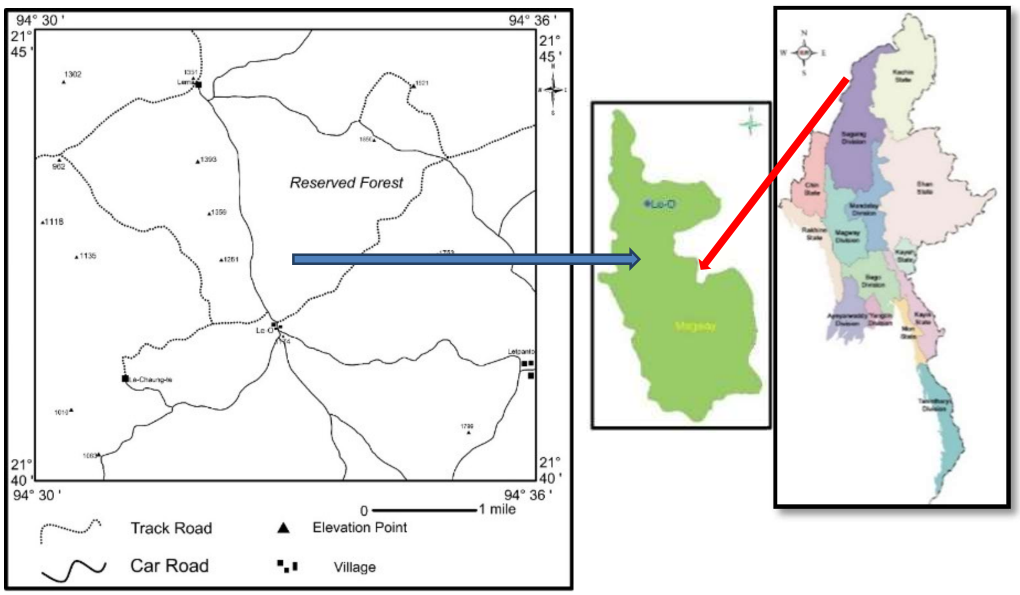
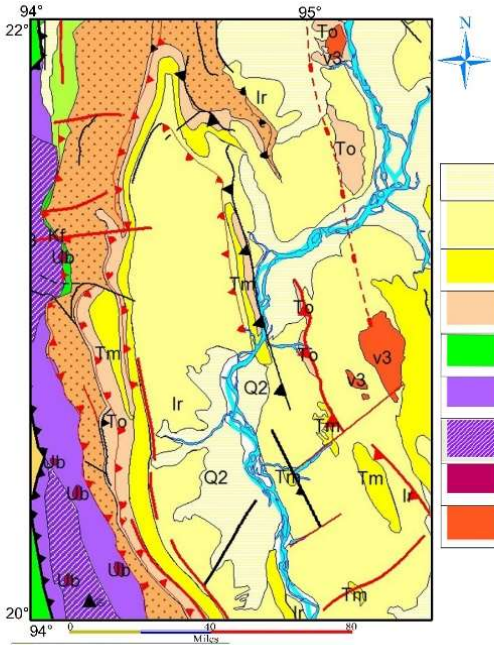


Figure 1. Location of the study area



EXPLANATION

Q2	Holocene	Younger Alluvium
Tmp	Upper Miocene - Pliocene	Irrawaddy Formation; Oil Shales of Karen State, and its equivalents
Tm	Miocene	Mollase-type (marine and non-marine) units; Upper Pegu Group of Minbu Basin
To	Oligocene	Mollase-type (marine and non-marine) units; Lower Pegu Group of Minbu Basin
Kf	Cretaceous	Marine units of the Western Ranges, including *Globotruncana*-bearing limestones
Tr	Triassic	Thanbaya Formation, Bawgyo Group, Kamawkala Limestone and their equivalents
m3	Mesozoic, mostly Triassic	Metamorphics of Western Ranges and Jade Mines area, including Kanpetlet Schists
ub	Mostly Jurassic	Ophiolite Assemblages – serpentinites, pyroxenites, peridotites, gabbro nd pillow lava
v3	Cenozoic, mostly Plio-Pleistocene	Volcanics (acidic to basic), (mainly basalt and andesite, some rhyolite and dacite); and dolerite dykes

Figure 2. The general regional geology map of the study area (Myanmar Geosciences Society; Revised Version, 2011)

The study area is mainly composed of mollassic clastic sedimentary rocks of Pegu Group in Tertiary age. The stratigraphic succession of the study area is shown in Table. 1. The geological map of the study area can be seen in Fig. 3.

Shwezetaw sandstones are yellowish brown, grey brown, fine to medium grained and thick bedded to massive. This Formation is mainly consists of sandstone and interbedded with minor amounts of sandy shale, silty shale and clay, also intercalated with clay partings, coal stringers and micaceous sandstone, (Fig. 4). This Formation also consists of abundant silicifiedfossil wood. In the study area, the stratigraphic thickness of the Shwezetaw Formation is 2540 feet.

The Padaung Formation is mainly consist of clay, light grey coloured and fairly soft, clay and shale interbedded with dark grey to yellowish brown coloured sandstone, thin to medium bedded and fine to medium grained. Sedimentary structure of flaser and lenticular beddings are shown in (Fig. 5).

Table 1. The stratigraphic succession of the study area.

Stratigraphic Succession	Lithologic Subunit	Lithologic Description	Geologic Age	Thickness Feet
Irrawaddy Formation	Sandstone	Unconsolidated sandstones interbedded with gritty beds	Late Miocene to Pliocene	2230
	Unconformity			
Kyaukkok Formation	Sandstone	Thin to thick bedded, light grey to yellowish grey sandstone	Middle Miocene	1750
	Unconformity			
Padaung Formation	Clay	Dark green to dark bluish grey colour, fine to medium grained, thin to medium bedded, locally massive	Middle Oligocene	1190.8
Shwezetaw Formation	Sandstone	Yellowish brown to yellowish grey loose sandstone, medium to thick-bedded	Early Oligocene	2540
	Unconformity			
Yaw Formation	Sandstone	Shales interbedded with siltstone beds	Late Eocene	2850

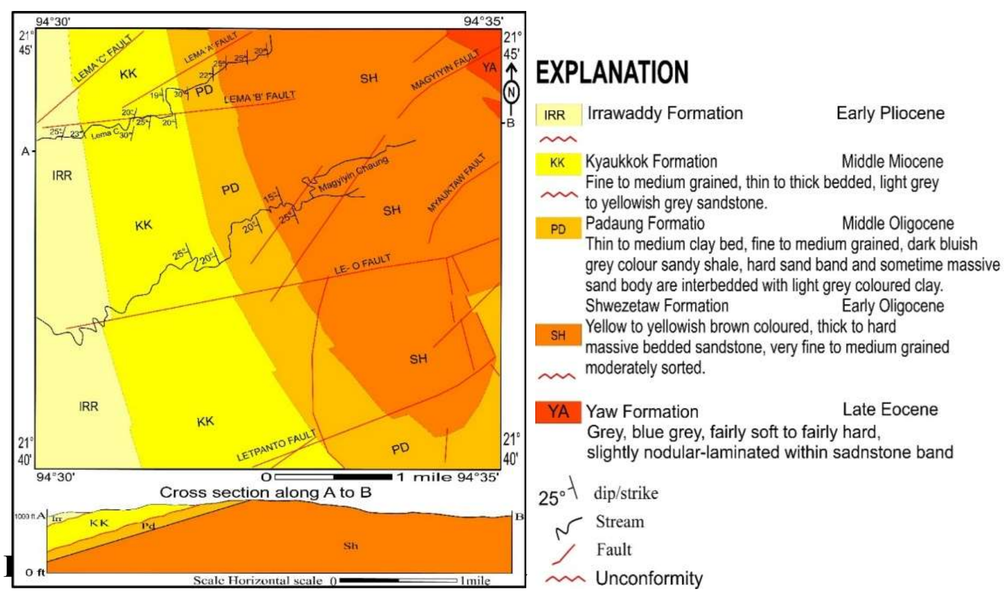


Figure 3: Geology map of the study area (MOGE, 1988)

Figure 4. Small coal seams intercalated with sandstone of Shwezetaw Formation (GPS N21°43'32" E 94°32'45.2", Photo Facing 155°)

Figure. 5 Flaser interbedded with dark grey coloured sandstone of Padaung Formation (GPS N21°42'.35" E 94°31' 48.6", Photo Facing 255°)

The Kyaukkok Formation consists of massive to thick bedded, yellowish grey to greenish grey, fine to medium grained sandstones and are interbedded with bluish grey shale which are soft laminated and carbonaceous and fine alternations of sandstones and clays, (Fig. 6). The Kyaukkok Formation overlies unconformably the Padaung Formation.

Figure 6. Bluish grey shales are interbedded with thick bedded yellowish grey coloured sandstoneof Kyaukkok Formation (GPS N21°44‘00.5" E 94°31"18.2", Photo Facing 185°)

Methods of Study

In the field, tape and compass traverse method was applied for geological mapping and section measurement. Thin sections were systematically studied under the polarizing microscope. To learn the content of the framework grain and cement, point counting by using mechanical stage was also carried out for modal analysis. From point counting, the various detrital grain were recorded. Based on point counted data and microscopic study, classification of rock type, pore space analysis, packing and diagenesis can be interpreted.

Petrography of Shwezetaw Sandstones

The sandstones of Shwezetaw Formation are fine-to medium grained, grey to yellowish brown coloured and mainly composed of detrital fragments such as quartz, feldspar, mica, rock fragments and minor accessories such as chert, schist, serpentine, authigenic clay mineral and volcanic fragment. Detrital quartz constitutes 26% to 33% of the total detrital fractions. In quartz population, 87% to 100% is monocrystalline quartz and 0% to 13% is polycrystalline quartz. Feldspar constitutes 27% to 36% of the total detrital fractions. Detrital feldspars are orthoclase, plagioclase and microcline. Orthoclase feldspar constitutes 94% to 96% and plagioclase feldspar comprise 6% to 4% of the total feldspar fragments. Mica constitutes 3% to 6% of the total detrital fractions. Biotite mica is more abundant than muscovite. Rock fragments consists of 17% to 21% of the total detrital fractions. The iron-oxide cement constitutes 0.7% to 5.2% of the total rock volume. Calcite cement contains 17% to 20% of the total rock volume. The sandstone of Shwezetaw Formation can be named as Lithic Arkose and Feldspathic Litharenite,(Fig. 7).

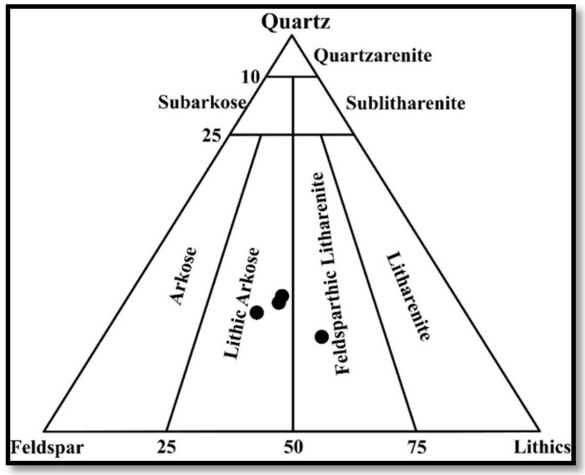


Figure 7. Triangular diagram of Folk's (1974), Shwezetaw sandstone showing of Shwezetaw sandstone

Sandstone Diagenesis

Effects of Compaction

Compaction involves dewatering and a closer packing of grains (Tucker, 1991). The petrographic features such as the packing readjustments of the framework grains, ductile deformation, grains bending, fracturing and pressure solution are observed in the sandstones of the study area due to the effects of compaction, (Fig. 8). Quartz overgrowth, bending and splitting of mica flakes, breaking down of shell fragments developed by the initial compaction are the early diagenetic features (Tucker, 1991).

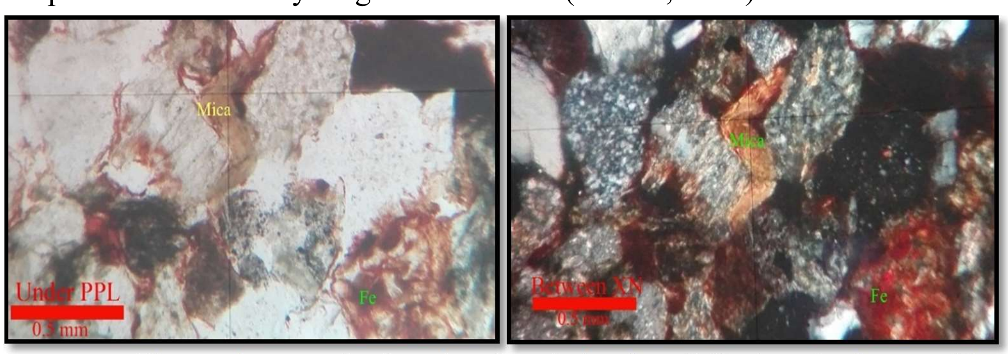


Figure 8. Photomicrograph showing bended mica (Mica),early iron oxide cementation (arrow) and iron oxide replacement by feldspar (Fe) of sandstone in Shwezetaw Formation

Quartz Overgrowth

Some syntaxial overgrowth were recognized around monocrystalline quartz grain, (Fig. 9). The three most probable sources of silica that form these quartz overgrowths are pressure solutions, the transformation of smectite to illite in the adjacent interbedded shale units (Boles and Franks, 1979) and the solubility of silica with increasing pH, so silica cements occur where acid fluids have moved through the pore.

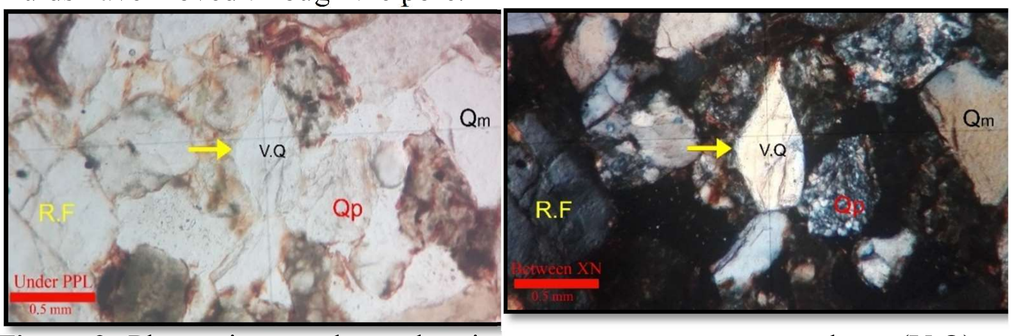


Figure 9. Photomicrograph showing quartz overgrowth (V.Q), polycrystalline quartz (Q_p) monocrystalline quartz (Q_m) and rock fragment (R.F) of sandstone in Shwezetaw Formation

Early Iron-oxide Cementation

The iron oxide cement plays a minor role in the cementing material of Shwezetaw sandstone. The iron oxide occurs in cement as well as coating on detrital grains. Some iron oxide inclusions observed in the calcite cement, this means that the iron cementation took place in an earlier stage. This cement is found as filling of interstitial pores and minor amount is present as coating on detrital grains. Moreover, some bioclasts and volcanic rock fragment are also coated with iron-oxide, (Fig. 8).

Clay Coating (Chlorite rims)

Diagenetic chlorite are observed as rims around the detrital grains in the Shwezetaw sandstone, (Fig. 10). The chlorite rims and pore infillings appear to form by direct precipitation and only where chlorite occasionally replaced lithic and feldspar grains and there are evidence of pre-existing minerals being altered to form clay (Imam and Shaw, 1985).

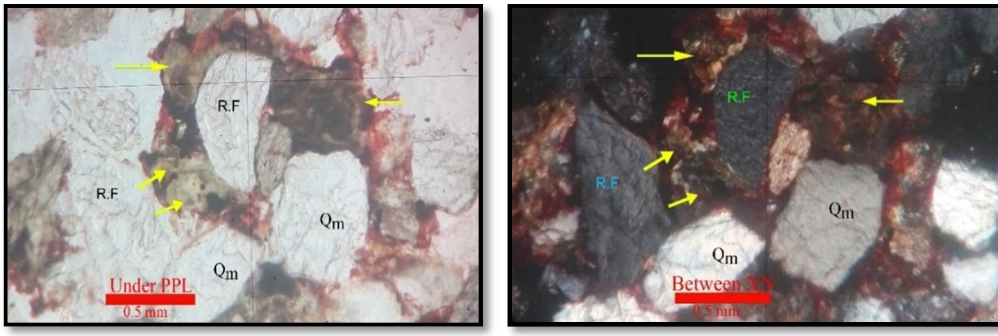


Figure 10. Photomicrograph showing chlorite rims around the detrital grains (arrow) of sandstone in Shwezetaw Formation

Pore Lining Clay

Pore linings are formed by clay coating deposited on surfaces of framework grains, except at points of grain to grain contact, (Fig. 11). The individual clay particles or aggregates commonly exhibit a preferred orientation normally or parallel to the detrital grain surface. Pore linings grow outward from the grain surfaces and may merge with the linings on adjacent grains. Pore lining clays may be developed during subsequent cementation by such materials as quartz and feldspar overgrowths (Wilson and Pittman, 1977).

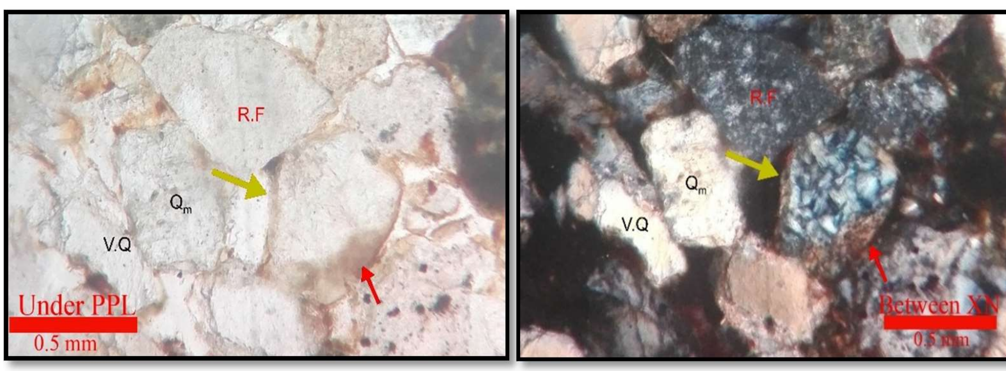


Figure 11. Photomicrograph pore lining clay (arrow), volcanic quartz (V.Q), monocrystalline quartz (Q_m) of sandstone in Shwezetaw Formation

Late Hematite Cementation and Pigmentation

The hematite typically occurs as a very thin coating around grains, but it also stains red infiltrated or authigenic clay minerals and authigenic quartz and feldspar. These features of the hematite, together with the absence of hematite coating at grain contacts indicate as late hematite cementation (Tucker, 1991), (Fig. 12).

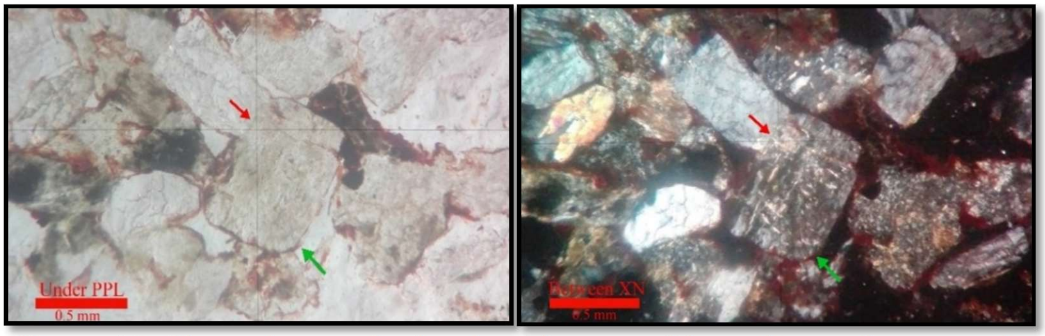


Figure 12. Photomicrograph showing absence of hematite coating at grain contacts(red arrow) and late hematite coating is on detrital grains boundary (green arrow) of sandstone in Shwezetaw Formation

Carbonate Cementation

The source of the calcium carbonate may be the pore water itself, but in marine sandstone, much is probably derived from dissolution of carbonate skeleton grains (Tucker, 1991). As a result of calcite precipitation there is commonly a displacement of grains so that they appear to float in the sediment, (Fig. 13).

Dissolution of Grains

Secondary porosity can be formed by the pressure dissolution of detrital grains and authigenic minerals. Siebert *et al.,(1984)*proposed that the clay and organic matter in shales produce the necessary water, acid and complexing agents for the dissolution of framework grains, resulting in the creation of secondary porosity. Pressure induced dissolution, due to compaction, has resulted in some suturing between quartz grains, (Fig. 13).

Replacement

Calcite commonly partially replaced and corrosion of grain can be observed in the sandstones, (Fig. 13). The detrital framework grain appears to float in iron, calcite cement and there is also evidence of corrosion by the cementing fluid along the outer margins of the grains (Imam and Shaw, 1985).

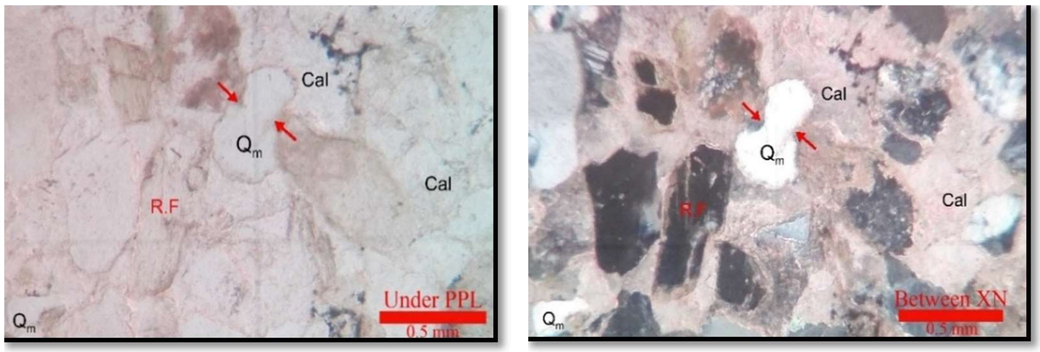


Figure 13. Photomicrograph showing calcite cement (Cal) corroded by monocrystalline framework grain dissolution has been quartz (Q_m) of sandstone in Shwezetaw Formation

Paragenetic Diagenesis

Diagenetic paragenesis of the Shwezetaw sandstones is shown in Table. 2. The following paragenetic sequence outlines the diagenetic events that modified the sandstone framework and pore space.

Table 2. Paragenetic sequence of postdepositional changes in Shwezetaw sandstones.

No.	Paragenesis Sequence
1	Compaction
2	Quartz overgrowth
3	Early iron-oxide cementation
4	Clay coating (chlorite rims)
5	Pore lining clay
6	Carbonate Cementation
7	Dissolutionof Grains
8	Replacement
9	Late Hematite cementation and pigmentation

Grains Packing Analysis of the Shwezetaw Sandstone

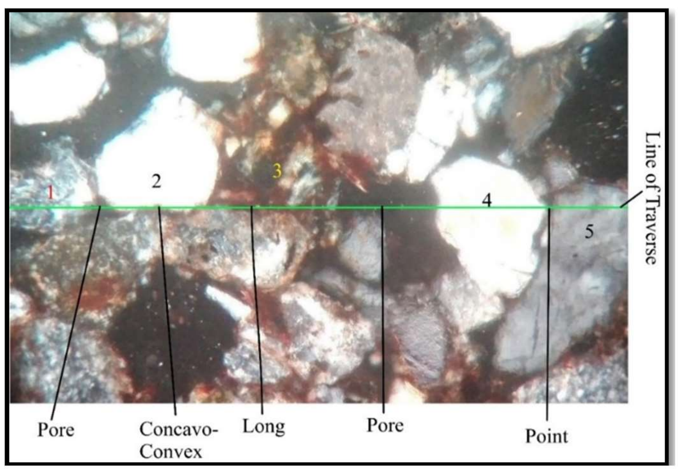
The packing of sediment grains is an important consideration since it affects porosity and permeability. Packing is largely dependent on the grain size, shape and sorting. The type of contact between grains is studied in thin section. In the ideal case of packed spheres, the only observed contacts between grains would be tangential ones. But in the case of nonspherical grains or where compaction has taken place, three other types of contacts can be observed (Taylor, 1950). The four possible types of contacts are (a) point, (b) long, (c) concavo-convex and (d) suture contact that appears as a straight line in the plane of section.

Kahn (1956) devised packing proximity measures for use in thin section studies. The packing proximity is the ratio of the number of grain to grain contacts (encountered in a traverse across the thin section) to the total number of contacts of all kinds encountered in the same traverse, (Fig. 14).If the grains have only small areas of contact with each other, most of the contacts observed in a thin section will be contacts between a grain and matrix or cement; so the packing proximity will be small. In a rock in which there has been compaction without the introduction of much cement, most of the grain contacts observed will be grain to grain contacts and packing proximity will be large. Grains packing analysis of the Shwezetaw sandstone is shown Table. 3 and in Fig. 15.

For Examples-

Packing proximity = 60%

Pore space proximity = 40%



$$\text{Packing Proximity} = \frac{\text{Total number of contacts encountered } 3 \times 100}{\text{Total number of grains encountered } 5}$$

Figure 14: Grain contact types contact types and packing proximity (J. S. Kahn, 1956)

Table 3. Relationship between grain to grain contacts, total grain number, pore space number and porosity

Sample No.	Point contact	Suture contact	Long contact	Concavo-concave contact	Pore space	Total grains number	Total grain contacts	Packing proximity (%)	Pore space proximity (%)
1	31	5	81	20	65	207	137	66%	34%
2	33	3	141	23	72	278	205	73%	27%
3	33	10	163	15	38	271	221	81%	19%
4	46	-	266	9	54	370	320	84%	16%
5	22	1	310	3	42	363	336	92%	8%

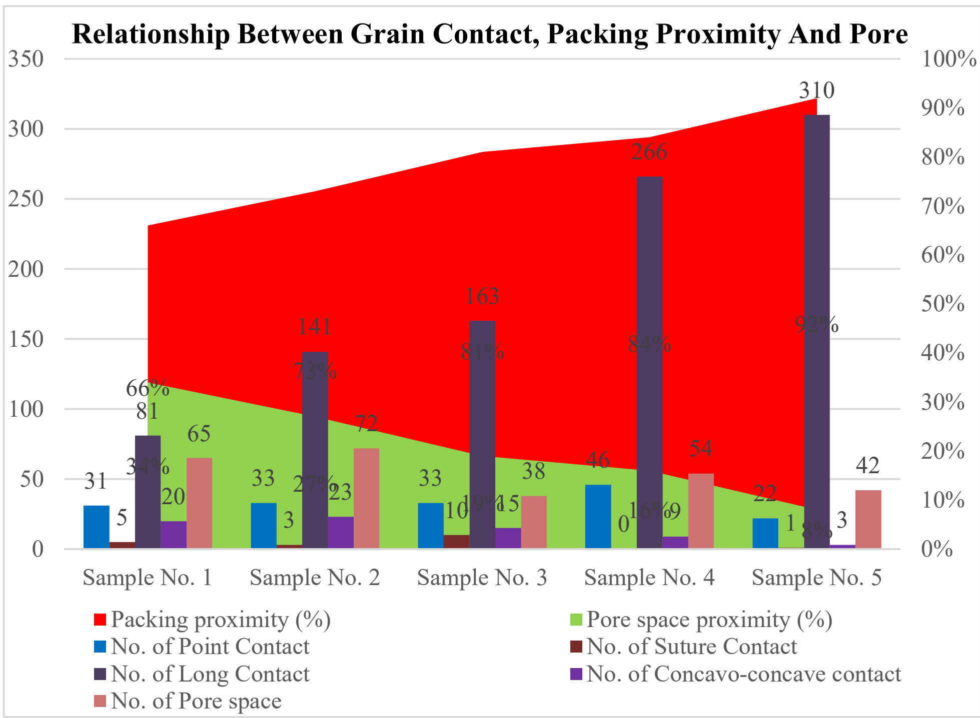


Figure 15. Relationship between grain contact, packing proximity and pore space proximity

Shwezetaw sandstones exposed in the study area are found to be a mixture of medium and fine detrital grain. Most distributary channel sandstones consist of medium detrital grain size but some constitute fine detrital grain. Inter granular pore filling is more or less found in medium grain sandstones and between the detrital grains are filled with fine detrital grains, (Fig. 16). The effect of inter pore filling clay in sandstone, the reservoir has a decrease in the porosity but does not affect the permeability (Wilson and Pittman, 1977). Sandstones that have many fine detrital grains can be found in crevasse splay environment. In the many fine- grained sandstone, pore space diameter is small. Compared with distributary channel, crevasse splay environment has more clay matrix. The decreased porosity and permeability of fine detrital grained sandstones is well marked.

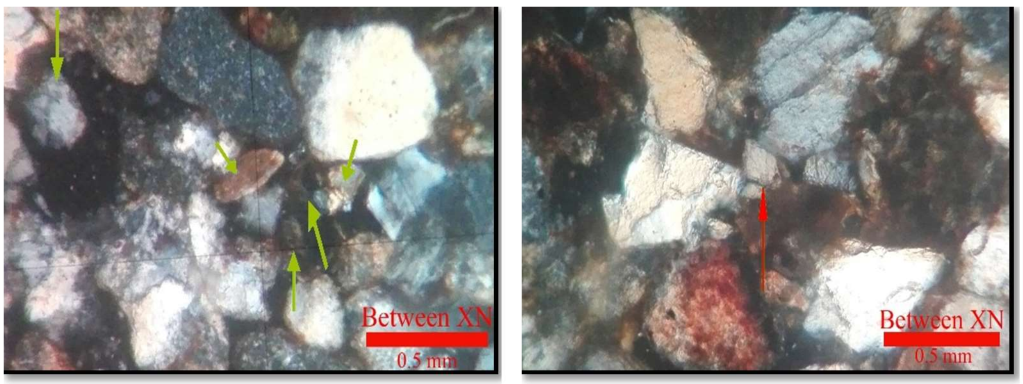


Figure16. Photomicrograph showing the detrital grains being filled with fine detrital grains (arrow) of sandstone in Shwezetaw formation

Iron oxide cements can be found not only on the boundary of detrital grains but they also fill pore space and fracture grains, and these effects decrease both porosity and permeability.

Another important case is grain contact. Sandstones which consist of many long contact, suture contact and concavo-convex contact can generate the decreased permeability and porosity. The reason of many long contact is having the same grain size, grain shape and grain orientation. Suture and concavo-convex contact can be caused by the effect of compaction. If there are many point contact, there will be many blank pore spaces and will increase chance of permeability and porosity, (Fig. 17). Replacement, pore filling and pore lining can be found in authigenic clay. Replacement and pore filling can decrease porosity and pore lining can decrease permeability. Other important controls in porosity and permeability are sorting, packing and textural maturity.

Figure 17. Photomicrograph shows point contacts, porosity and permeability nature (arrow) of sandstone in Shwezetaw formation

Lithofacies Analysis

Thick Bedded to Massive Cross Bedded Sandstone Facies

This facies is mainly consisted of thick bedded to massive, buff coloured, fine to medium grained unidirectional cross bedding sandstones. The thickness of sand beds varies from 90 centimetres to massive,(Fig. 18). The bed base type of this facies is erosional. Thin shale lamination and small gravel size mud pebbles are present in some sand beds, (Fig. 19). Sometimes, shale layers are ranged from 10 centimetres to 50 centimetres thick intercalated with sand beds are also noted. This facies is well observed in the Lema– Chaung section. Facies log is shown in Table. 4.

The sandstone with cross bedding of fine- to medium-grained and medium size cross bedding indicates the depositional areas decrease in velocity. The cross bedded sandstone on erosional base points out that the deposition is a channel where erosive base occurs. The unidirectional paleocurrent indicates that the depositional process was influence by rivers. Beds and cross laminae usually are separated by thin mud drapes and clay or shale lineation is a major feature of distributary channel (Allen, 1989).

Therefore, the depositional environment should be assigned as distributary channel in delta plain environment.

Figure 18. Thick bedded to massive, unidirectional cross bedding of Shwezetaw Formation (GPS N21°44'33.5" E 94°32' 17.9", Photo Facing 270°)

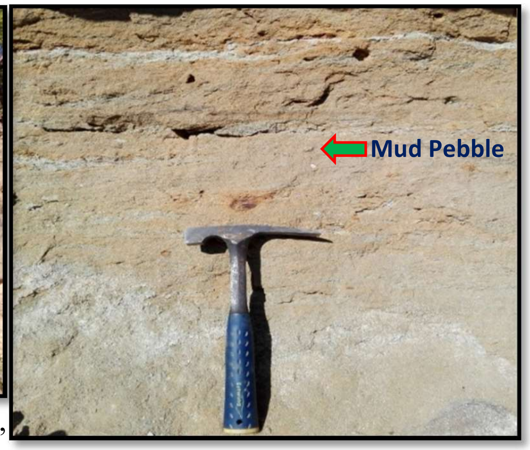


Figure 19. Thin shale lamination and small gravel size mud pebbles are present in sand beds of Shwezetaw Formation (GPS N21°44'33.5" E 94°32'17.9", Photo Facing 270°)

Medium to Thick Bedded Very Low Angle Cross Bedded Sandstone Facies

This facies is mainly consisted of medium grain, medium to thick bedded, light yellow to light grey coloured sandstone. The thickness of sand beds varies from 30 centimetres to 120 centimetres. Shale layers rarely intercalated with sand beds and shale layers are ranging from 10 centimetres to 90 centimetres, (Fig. 20). The bed base type of this facies is erosional type. The main primary sedimentary structure is very low angle unidirectional cross bedding, (Fig. 21). These cross beddings are 20 centimeter in height and 90 centimeter in length. Cross bedding angles are ranging from 10° to 15°. This facies is well exposed at the Lema-Chaung section. Facies log is shown in Table. 5.

Very low angle cross bedding and fine to medium grains indicate the high velocity depositional environment. The intercalated shale shows that deposition in quiet relatively deep water from out of suspension (Selley, 1984). The unidirectional low angle cross bedding represents the channel characteristic features by the fluvial influence (Galloway, 1975). The sandstone with low angle cross bedding on erosional base points out the deposition is a channel where erosive base occurs. Therefore, the depositional environment should be distributary channel in delta plain environment.

Figure 20. Shale layers are intercalated with medium to thick bedded, very low angle,crossbedded sandstone of Shwezetaw Formation (GPS N21°44'30.8"E 94°32' 14.8", Photo Facing 230°)

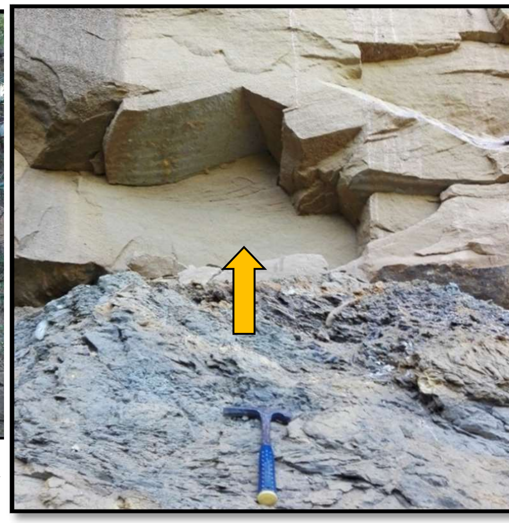


Figure 21. Very low angle cross bedding (arrow)of Shwezetaw Formation (GPS N21°44'30.8" E 94°32'14.8", Photo Facing 230°)

Sand – Mud Interlayer Facies

This facies is mainly composed of light grey coloured, thick bedded sandstones interlayered with mud. Generally 30 centimetres to 60 centimetres thick sand layers are interlayered with 15 centimetres to 30 centimetres thick mud layer,(Fig. 22). The thickening upward character is shown in sand layers. The sand – shale ratio is generally 2:1. The thickness of this facies is from 60 centimetres to 120 centimetres. The bed base type of this facies is wavy to transitional type. This facies generally underlying is thick bedded to massive cross bedded sandstone facies and overlying is medium- to thick cross-bedded sandstone facies. This facies is poorly exposed at the Lema-Chaung section. Facies log is shown in Table. 6.

Figure 22. Thin to medium bedded sand – interlayer of Shwezetaw Formation(GPS N21°44'23.9" E 94°32'02.3", Photo Facing 145°)

The sand – mud interlayer beddings are mostly related to slack water and the tidal current periods (Reineck and Singh, 1980). This facies is formed by under the condition of current or wave action deposition and alternating. Moreover, this facies is vertically associated with medium to thick cross bedded facies. Therefore, this sand – mud interlayer facies was deposited under low energy condition and depositional environment may be distributary mouth bar area.

Medium to Thick Cross Bedded Sandstone Facies

This facies is mainly composed of fine to medium grain, medium to thick bedded, light grey to grey colouredcross bedded sandstone(Fig. 23).The thickness of sand beds is from 30 centimetres to 190 centimetres with thickening upward nature(Fig. 24). The bed base type of this facies is erosional type. The size of the cross bed sets is approximately 20 centimetres high and 60 centimetres in length and approximately inclined to 30°. The shale layers are interbedded with sand beds. This facies is vertically associated with thick bedded to massive cross bedded sandstone facies. This facies is well exposed at the Lema – Chaung section. Facies log is shown in Table. 4.

This facies is the result of deposition from migrating small waves. This lithofacies sequence of cross bedded sandstone indicate that sediments were deposited in the unidirectional current of the distributary channel. The erosional bed denotes the base of the channel and the cross bedded sandstones are due to the deposition of sand and the water velocity decreased towards upper horizon. Therefore, this facies can be interpreted as distributary channel in a lower delta plain.

Figure 23. Cross bedding and small mud ripples are found in sand bed of Shwezetaw Formation (GPSN21°44'22.1" E 94°31'56.0", Photo Facing 195°)

Figure 24. Medium to thick cross bedded sandstone of Shwezetaw Formation (GPS N21°44'22.1" E 94°31'56.0", Photo Facing 195°)

Facies Association

Thick-bedded to massive cross bedded sandstone facies, medium to thick bedded very low angle cross bedded sandstone facies, and medium to thick cross bedded sandstone facies of the Shwezetaw Formation can be grouped into a delta plain area which represents an area where these sediments were deposited. The delta plain facies association mainly consists of distributaries channel sands and delta plain mud. The sedimentary structure of large to medium scale cross – bedded sandstone with unidirectional cross bedding shows that the deposition took place in a channel of upper delta plain. The deposition of cross bedded sandstone with mud clasts is the typical delta plain deposits. In delta front facies association, sand – mud interlayer facies of the Shwezetaw Formation can be grouped to point out an area of deposition, namely delta front environment.

Table 4. Thick bedded to massive cross bedded sandstone facies and medium to thick cross-bedded sandstone facies log

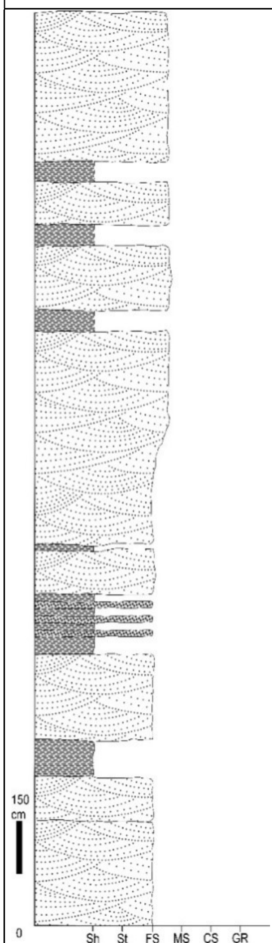
Facies Log	Description	Sedimentary Structure	Depositional Environment
	**Medium to Thick Cross Bedded Sandstone Facies** The thickness of sand beds various from 30 centimetres to 190 centimetres. The natural of beds are medium to thickening upward sequence. The shale layers are interbedded with sand beds. The bed base type is erosional type.	Cross bedding and locally sand layers show small mud ripples	Distributary channel in a delta plain
	Thick Bedded To Massive Cross Bedded Sandstone Facies The bed base type of this facies is erosional type.Thick bedded to massive, buff colour, fine- to medium-grained sandstones. Thin shale laminations and small gravel size mud pebbles are present in some sand beds.Shale layers are intercalated with sand beds.	Primary sedimentary structure is unidirectional cross bedding.	Distributary channel in delta plain

Table 5. Medium to thick bedded very low angle cross bedded sandstone facies log

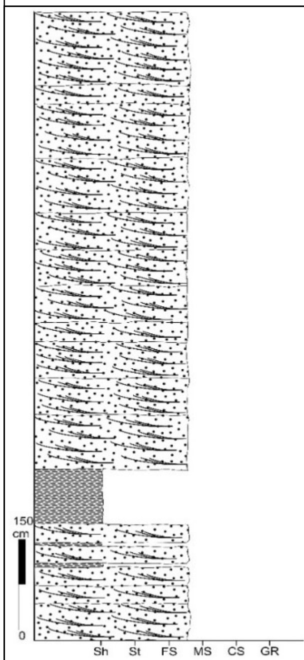
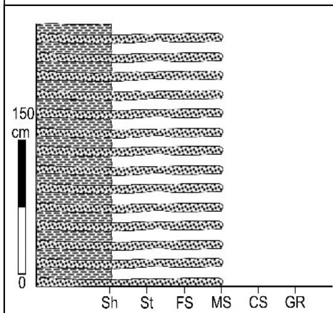
Facies Log	Description	Sedimentary Structure	Depositional Environment
	Fine- to medium-grained, medium- to thick-bedded, light yellow to light grey coloured sandstone. Shale layers rarely intercalated with sand beds are range from 10 centimetres to 90 centimetres. These low angle cross bedding angles range from 10° to 15°. The bed base type of this facies is erosional type.	Main primary sedimentary structure is very low angle cross bedding.	Distributary channel in delta plain

Table 6. Sand mud interlayer facies log

Facies Log	Description	Sedimentary Structure	Depositional Environment
	Light grey coloured, thick-bedded sandstones are interlayered with mud. The thickening upward character is shown in sand layers. The sand – shale ratio is generally 2:1. The bed base type of this facies is wavy to transitional type.	Thin to medium-bedded sand – interlayer.	Distributary mouth bar in delta front.

Sedimentation History of Shwezetaw Formation

From the facies analysis, the depositional history of the Shwezetaw Formation can be interpreted. A fluctuation of sea level took place within the Oligocene time and the gradual shallowing of sea during the early Oligocene led to the deposition of sandy strata of the Shwezetaw Formation in the marginal marine to deltaic environment with sandstones interbedded with minor clay and shale. The deltaic deposits of the Shwezetaw Formation were deposited on the prodelta to shelf mud of the Yaw Formation. This means that the Shwezetaw Formation was deposited in a regressive phase, (Fig. 25). The deltaic deposition protruded into the open sea by its fluvial dominated natures. The sand body of distributaries channel, distributaries mouth bar and delta front sand bar deposited in that available depositional area. This sand body was overlain by thick bluish grey shale pointing out that the depositional area was transgressed again.

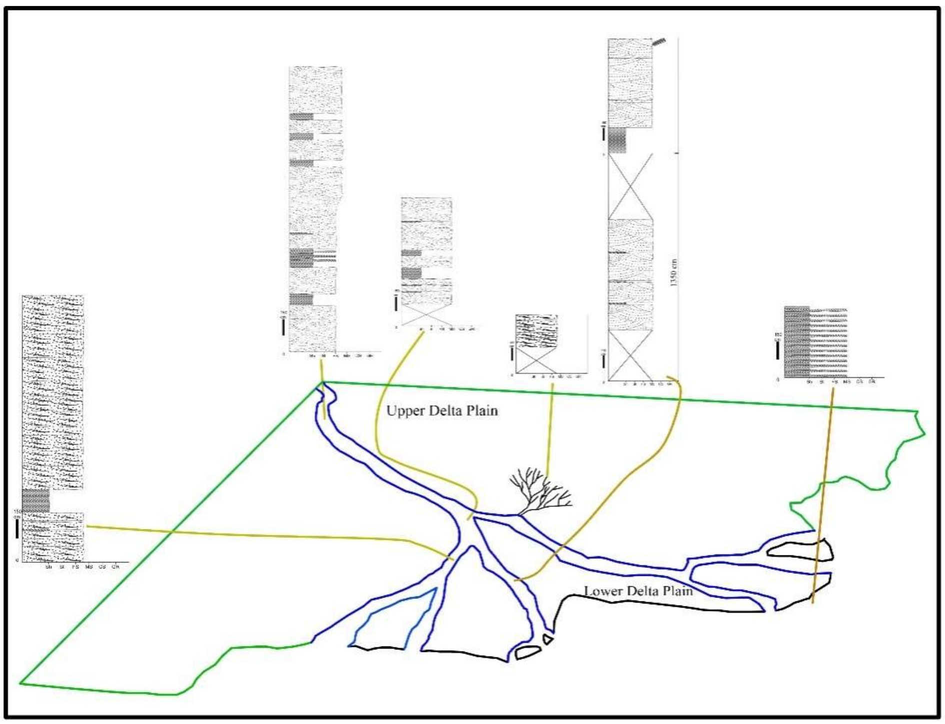


Figure 25. Potential paleo-environment depends on lithofacies of Shwezetaw Formation

Conclusions

Shwezetaw sandstones are fine- to medium-grained mainly made up of detrital grained chemical cement, lithic arkose and feldspathic litharenite in composition. The diagenetic features such as compaction, quartz overgrowth, early iron-oxide cementation, clay coating (chlorite rim), pore lining clay, carbonate cementation, dissolution, replacement and late hematite cementation (pigmentation) are found in Shwezetaw sandstone. By the packing analysis, if there are many point contacts, there will be many blank pore spaces and will increase chance of permeability and porosity. If sandstones have absence or less amount of point contact and has more amount of other three types of grain contact or has one of three other types of grain contacts as dominant type, it is not good for quality of reservoir.Due to the study on the petrography compared with packing analysis, the Shwezetaw sandstone are deposited in the distributary channel have medium detrital grain size but some constitute fine detrital grain and diminished due to clay content. Inter pore filling is more or less found in medium grain sandstones. The effect of inter pore filling in sandstone, the reservoir has a decreased in the porosity but does not effect on permeability. Iron oxide cements can be found not only on the boundary of detrital grains but they also fill pore space and fracture grains, and this effects decrease both porosity and permeability. By the facies study, the sedimentary facies such as thick bedded to massive cross bedded sandstone facies, medium to thick bedded very low angle cross bedded sandstone facies, sand-mud interlayer facies and medium to thick cross bedded sandstone facies encountered in Shwezetaw Formation which represent the fluvial dominated delta environment.

Acknowledgements

The authors wish to express their thanks to the Myanmar Academy of Art and Science Association for accepting the paper. They also gratefully acknowledge U Win Paing family Le – O village and the villagers for their helps during the field trip.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

GRANULITE AND ITS *P-T* CONDITION OF THE MOUNT LOI-SAU AND ITS ENVIRONS, MOGOK TOWNSHIP, MANDALAY REGION AND MOMEIK TOWNSHIP, SHAN STATE (NORTH)

Wai Yan Lai Aung*

Abstract

A new unit composed of felsic and mafic granulitic rocks are exposed in the study area. Granulite (Latin granulum, "a little grain") is a name first introduced by petrographers. Such a rock is characterized by a mineral assemblage that was developed under high-grade metamorphic conditions. Granulites were observed around Mogok and Momeik area. The writer will try to draw some comparisons between felsic and mafic granulite of the study area with reference to the theoretical definitions by some authors and websites.

The study area is situated in the remote area between Mogok Township, Mandalay Region and Momeik Township, Shan State (North), on either side of Mogok-Momeik motor road. The study area, which is a segment of the Mogok Metamorphic Belt, is mainly composed of metamorphic rocks and granitic and syenitic intrusions. Taking the metamorphic rock units of the study area into consideration, granulite rock is fairly exposed and it is associated with both sillimanite-garnet-biotite gneiss and interbedded with marble and calc-silicate rocks. Granulite unit is intruded by syenitic and granitic rock. Granulite can be subdivided into two distinct units based on pyroxene percentage (< and > 30%); felsic granulite (<30%) (sapphirine-hypersthene-garnet-biotite granulite) and mafic granulite (>30%) (pyroxene granulite), respectively.

Petrochemically, sillimanite-garnet-biotite gneisses in the study area have reached granulite facies (730-810 ºC & 6.5-9.3 kbar), characterized by the mineral assemblages and petrochemical results from EPMA and XRF. The *P-T* condition of granulite rocks in the study area should probably be the same as and/ or greater than the *P-T* condition of the high-grade gneiss of the study area, according to the mineral assemblages: orthopyroxene + alkali feldspar + biotite + chlorite + plagioclase +garnet + quartz + rutile + sillimanite + sapphirine + opaque + hercynite + sillimanite + sericite + zircon + ilmenite of felsic granulite and mineral assemblages clinopyroxene + biotite + plagioclase (andesine) + alkali feldspar + quartz + perthite + orthopyroxene + sphene + opaque + chalcedony + antigorite of mafic granulite.

Key words: *felsic granulite, mafic granulite, sillimanite-garnet-biotite gneiss, EPMA, hercynite, sapphirine..*

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Introduction

The topic will deal with a new unit composed of felsic and mafic granulitic rock in the study area. Granulite (Latin granulum, "*a little grain*") is a name first introduced by petrographers. Such a rock is characterized by a mineral assemblage that was developed under high-grade metamorphic conditions. Granulite was first described in Bohemian Massif. As things stand, granulite rock was found around Mogok and Momeik area. The author drew some comparisons between felsic and mafic granulite of the study area with reference to the theoretical definitions by Weiss (1803), Michel Lévy (1874), Moorhouse (1959), Cogné (1961), Mehnert (1972), Winkler and Sen (1973), Alex Streckeisen (1975) and (*www.alexstrekeisen.it*), and some other authors and websites.

Location of the study area

The study area is situated in the remote area between Mogok Township, Mandalay Region and Momeik Township, Shan State (North), and located at about north of Mogok and south of Momeik, near the Mogok-Momeik highway. It lies between Latitudes 22° 56' 30" N - 23° 01' 00" N and Longitudes 96° 34' 30" E - 96° 41' 30" E. The study area is accessible by car from Mandalay, a city in Central Myanmar, which can be reached by air, rail, and road from Yangon, but the accessibility to the study area is limited due to some minor of insurgency. The location map is shown in (Fig. 1).

Practical naming of granulite in the study area

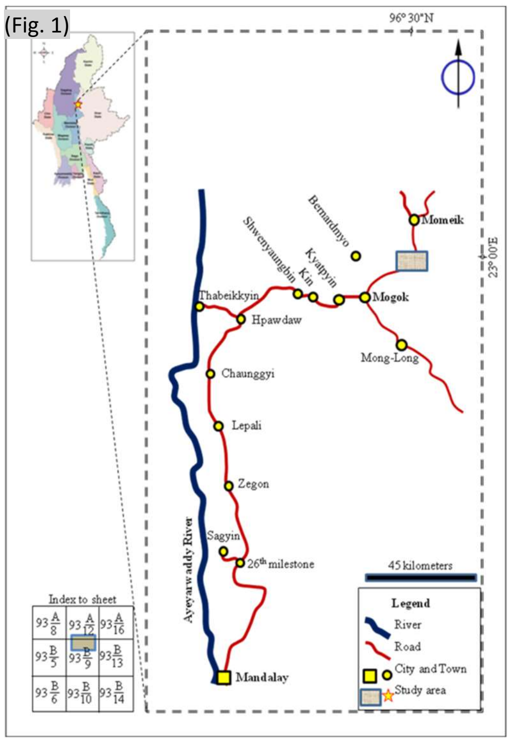
Granulite can be subdivided into two distinct units based on pyroxene percentage (< and > 30%); felsic granulite (<30%) (sapphirine-hypersthene-garnet-biotite granulite) and mafic granulite (>30%) (pyroxene granulite), respectively.

Mineral assemblages of granulite rocks in the study area are as follows:

Felsic granulite = orthopyroxene + alkali feldspar + biotite + plagioclase + chlorite + garnet + quartz + rutile + sapphirine + ilmenite + hercynite + sillimanite + zircon.

Mafic granulite = clinopyroxene + biotite + plagioclase + alkali feldspar + quartz + perthite + orthopyroxene + ilmenite + sphene + chalcedony + antigorite.

Mineral percentages of felsic and mafic granulites are shown in bar graphs (Fig. 2).



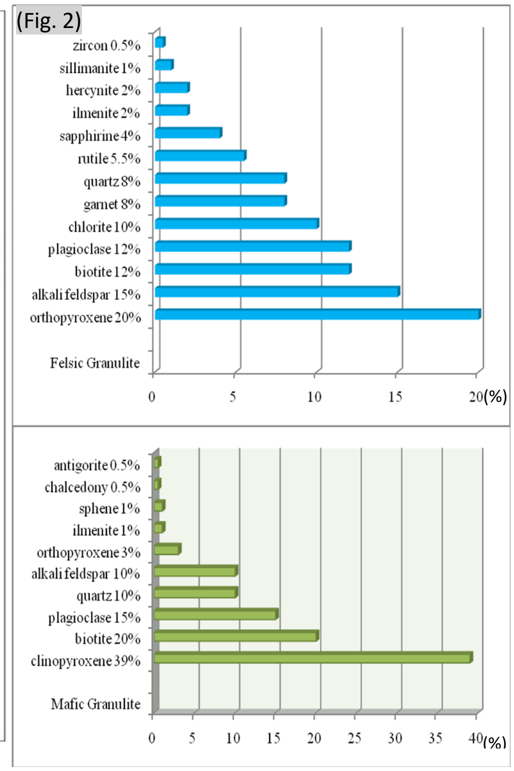


Figure1. Location map of the study area.

Figure 2. Mineral percentages bar graph of felsic granulite (sample no. 8B) and mafic granulite (sample no. 44) of the study area.

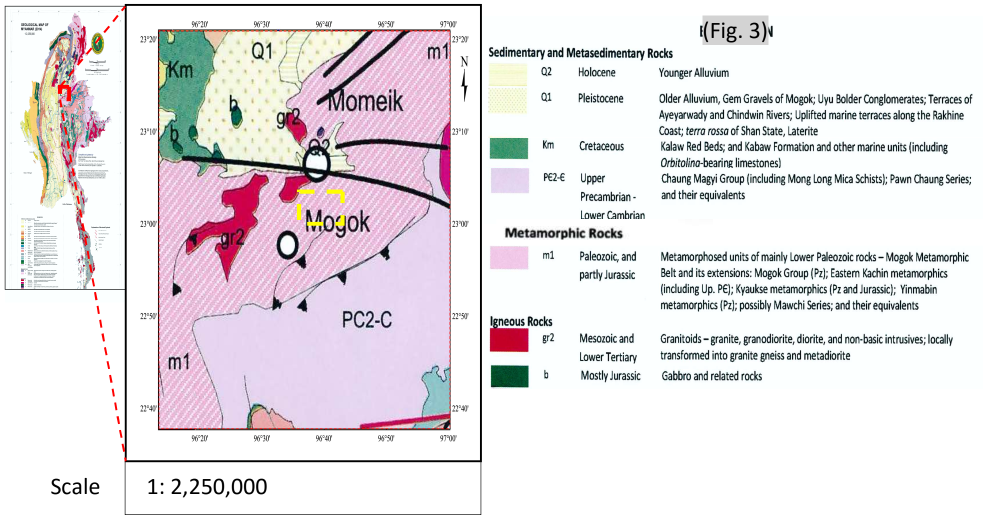


Figure 3. Regional geological map of the study area and its environs (After Geological Map of Myanmar Geosciences Society, 2014).

Geologic Setting

The study area, Mount Loi-Sau is situated in the northern part of Mogok Metamorphic Belt (MMB) of Searle & Ba Than Haq (1964). It is relatively narrow, elongated, sigmoidal belt which is generally oriented north-south, adjacent to the N-S trending Sagaing Fault in the west and Shan Scrap Fault in the east (Bertrand, 1999). The geology of Mogok area is very complex, and characterized by steeply dipping, deformed, medium to high grade metamorphic rocks consisting mainly of mica schist, marbles, calc-silicate rocks, gneisses and quartzites, which are often intruded by many granitic and syenitic intrusive rocks. Regional geological map of the study are is shown in (Fig. 3) (Myanmar Geosciences Soceity, 2014).

Rocks in the investigated area are categorized into medium- to- high-grade metamorphic rock units (Late Oligocene) and younger igneous intrusions (Early Cretaceous to Middle Miocene). The metamorphic rocks covered about 90% of the whole area which is principally underlain by sillimanite-garnet-biotite±ilmenite gneiss, garnet-biotite gneiss, spinel-diopside-forsterite-phlogopite marble, white marble and calc-silicate rocks.

Moreover, two types of granulite, namely felsic and mafic granulites are also recently contributed from the study area (Wai Yan Lai Aung, 2016) (Fig. 4).

General geology of granulite in the study area

Taking the metamorphic rock units of the study area into consideration, granulite rock is only fairly exposed and it is associated with sillimanite-garnet-biotite gneiss. This unit is intruded by syenitic and granitic rock, which can be subdivided into felsic granulite (sapphirine-hypersthene-garnet-biotite granulite) and mafic granulite (pyroxene granulite).

Felsic granulite is discovered at the base of Mount Loi-Sau (Loc: Lat : 22º 58' 49.4" N, Lon : 96º 37' 52.2" E) and associated with sillimanite-garnet-biotite gneiss. They comprise garnetiferous rock with a strongly gneissose texture. They show NE-SW trend and west dipping at 48º (Fig. 5, A).

On the other hand, good exposure of mafic granulite is found beside Mogok-Momeik motorway that is intruded by syenitic rock which is partially foliated (Loc: Lat : 22º 58' 33.6" N, Lon : 96º 34' 17.0" E, Fig. 5, B). Mafic granulites are of massive and banded type. It is very similar to calc-silicate rock in appearance but mafic granulites are mainly composed of pyroxene, feldspar, quartz and biotite minerals. It can be called ~~as~~ pyroxene granulite. This granulite shows NNE-SSW trend and west dipping at 85º. At this outcrop, the enclaves of pyroxene granulite can be seen clearly in syenitic rock.

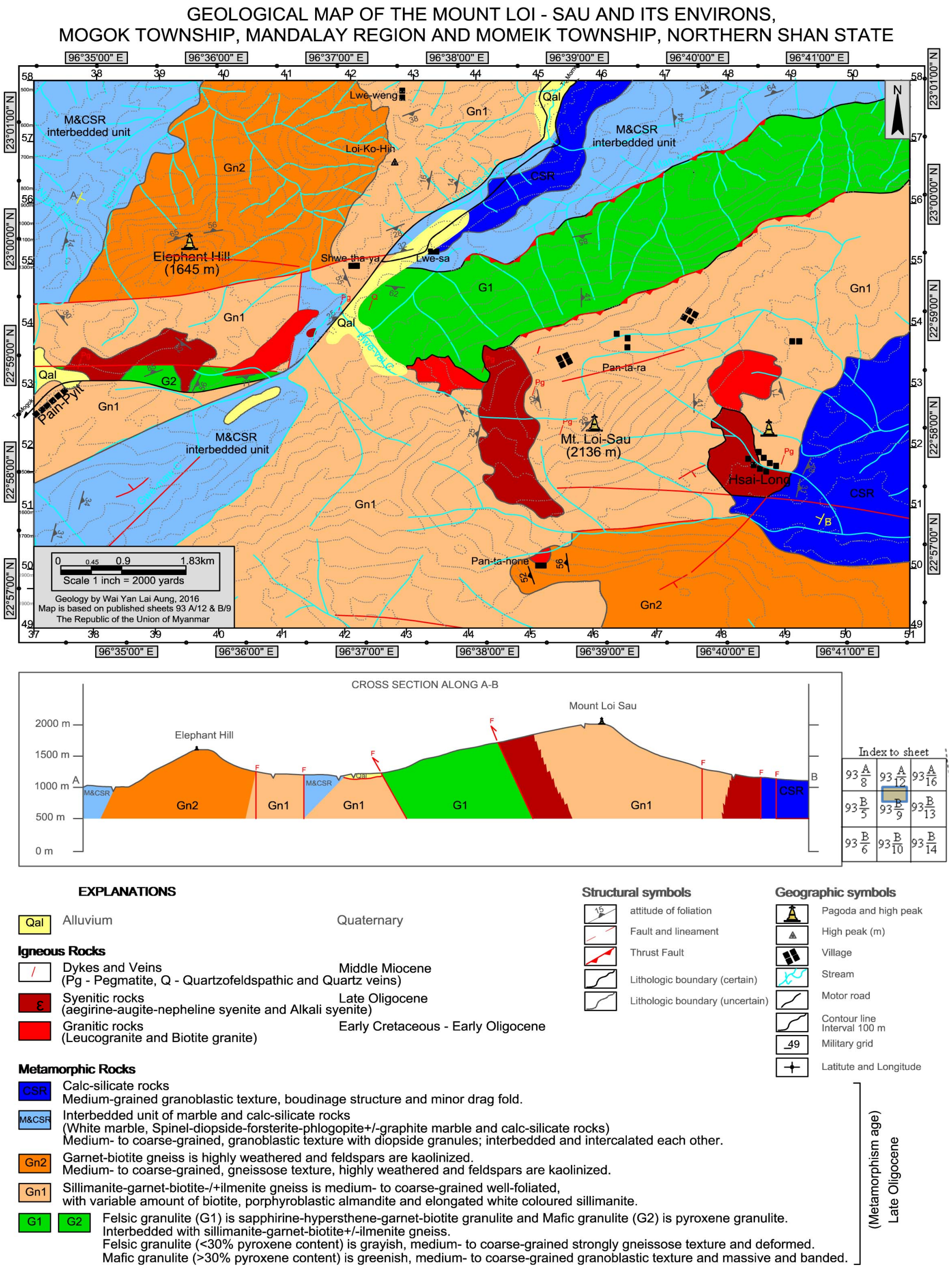


Figure 4. Geological map of the study area.

Figure 5.A Felsic granulite (Loc : Lat : 22º 58' 49.4" N, Lon : 96º 37' 52.2" E) (Looking 60º).

Figure 5.B Mafic granulite (Loc : Lat : 22º 58' 33.6" N, Lon : 96º 34' 17.0" E) (Looking 10º)

Confusions Between Felsic and Mafic Granulite in the Study Area

Felsic granulite (sapphirine-hypersthene-garnet-biotite granulite)

Megascopically, felsic granulite is medium- to coarse-grained with a strongly gneissose texture and well-jointed as it is always the case in nature. In hand specimen, quartz, feldspar, biotite, garnet, pyroxene are easily identifiable with the naked eye. In hand specimen, mostly pyroxene, quartz, feldspar and biotite show separate bands as mineralogical banding. Fresh surface of felsic granulite is whitish grey and weathered surface is reddish grey. Garnet is 0.4 cm to 1 cm in diameter while feldspars are sometimes up to 1 cm (Fig. 6, A).

Mafic granulite (pyroxene granulite)

Megascopically, pyroxene granulite is medium- to coarse-grained, of banded and massive type in nature. Most biotites are weathered and segregated as separated layers with the pyroxene + quartz + feldspar assemblages. Its fresh surface is greenish and weathered surface is dark green. Pyroxene is up to 1 cm in diameter (Fig. 6, B).

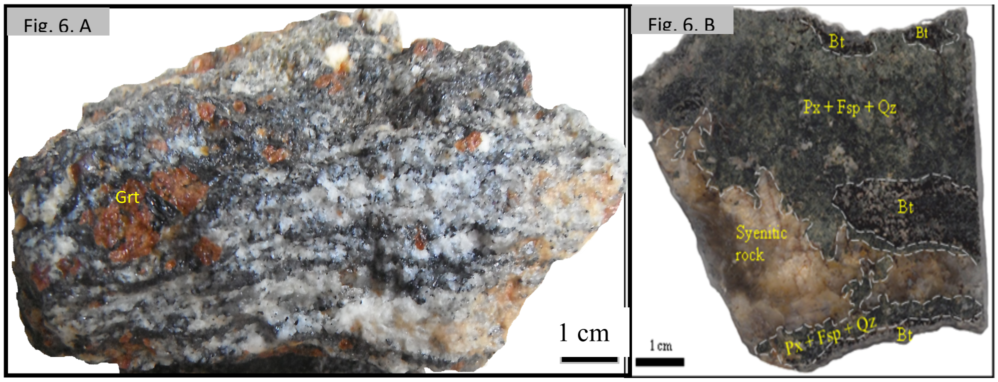


Figure 6. A Macroscopic view of felsic granulite
(Loc : Lat : 22º 58' 49.4" N, Lon : 96º 37' 52.2" E) (sample no. 8B).
Figure 6. B Macroscopic views of mafic granulite rocks' polished surfaces
(Loc : Lat : 22º 58' 33.6" N, Lon : 96º 34' 17.0" E) (sample no. 44)

Felsic granulite (<30% pyroxene content) is strongly deformed, grayish and can be confused with gneiss unit.	Mafic granulite (>30% pyroxene content) is massive and banded, greenish and can be confused with calc-silicate rocks.

Microscopic Description and Interpretation of Granulite

Felsic granulite (sapphirine-hypersthene-garnet-biotite granulite)

Microscopically, it is medium- to coarse-grained with a strongly foliated gneissose texture. It is mainly composed of orthopyroxene, plagioclase, alkali feldspar, garnet, biotite, chlorite, and quartz. Rutile, sapphirine, hercynite, sillimanite, sericite, ilmenite and zircon are accessory minerals (Fig. 7, A). Hypersthenes occur as pale red subhedral crystals and show greenish to pale reddish paleochroic colour under PPL, showing high relief, parallel extinction and first order pale red interference colour between crossed nicols. Hypersthene is associated with biotite, and sometimes with garnet, sapphirine and hercynite. Most plagioclases are cracked. They are found as anhedral to subhedral grains, surrounded by rim myrmekite and albite to andesine in range. Saussuritization is also common along the twin plane. K-feldspars are coarse-grained and in anhedral to subhedral forms. They are more or less kaolinized. Myrmekitic inclusion is present in perthitic orthoclase. Quartz is medium- to coarse-grained in groundmass and naturally shaped into a ribbon-like structure and also present in garnet as inclusion. Biotite crystals are strongly pleochroic varying from light yellow to reddish brown. Some orthopyroxene and biotite crystals indicate preferential orientations by the position of some prismatic crystals. Most biotites are altered to chlorite and associated with rutiles. Rutiles in felsic granulite occur as small acicular black crystals. They are always associated with biotite and chlorite, and also found as inclusion in biotite and chlorite. Anhedral garnets are found with quartz and biotite inclusions and chloritization occurs along garnet cracks. Subhedral to rounded garnet without inclusion may probably be magmatic garnet within the granitic melt formed due to the dehydration melting of biotite according to the reaction: Biotite + Sillimanite + Plagioclase + Quartz = Garnet + K-feldspar + Melt. Hercynites, iron alumina spinels, are found as equant grains. They show high relief, olive green under plane polarized light and isotropic between cross nicol. Sapphirines occur as disseminated grains or aggregates and body colour is bluish green and it gives weak pleochroism. In the study area, they are associated with pyroxene, spinel, garnet and quartz. This may be formed where rims of idiomorphic sapphirine have developed over spinel. The presence of spinel relics in sapphirine are shown in symplectic intergrowths of the two minerals (Fig. 7, B). Its development can be explained by the simple reaction: Spinel+Silica = Sapphirine (Deer, Howie & Zussman, 1992). Sillimanite is present in perthitic orthoclase and found as medium-grained slender prismatic crystals. Reaction rim around sillimanite shows a corona-like texture in felsic granulite rock (Fig. 7, C). Ilmenites occur in elongated forms. They are present in chlorite as foliated opaque minerals. Zircons are also enclosed in orthopyroxene mineral as inclusions.

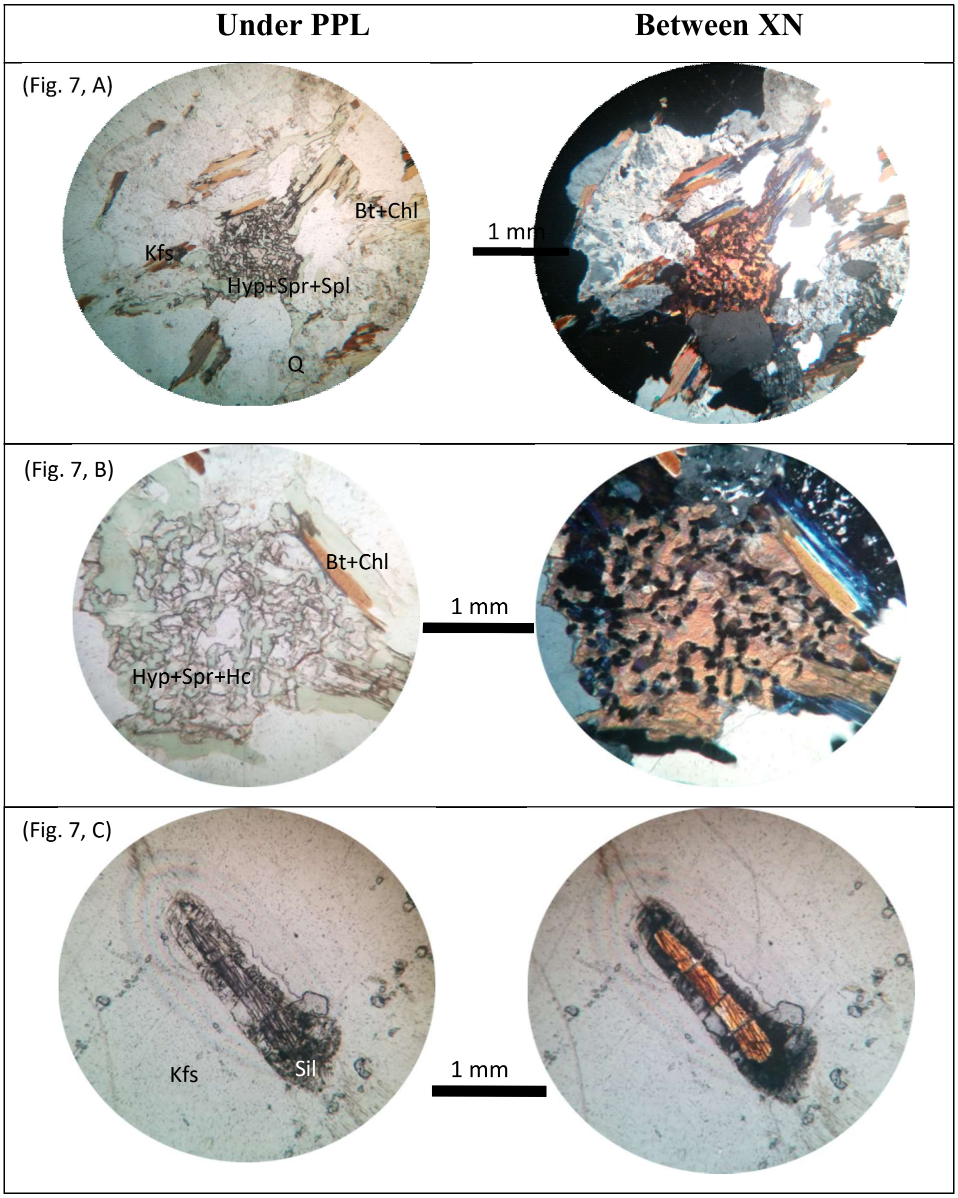


Figure 7.A Mineral assemblages of hypersthene, spinel, sapphirine (spr), biotite, orthoclase and quartz in felsic granulite.

Figure 7. B Symplectic intergrowth of sapphirine developed over spinel in felsic granulite.

Figure 7.C Reaction rim or corona-like texture around sillimanite in felsic granulite.

Mafic granulite (pyroxene granulite)

Microscopically, it is medium- to coarse-grained and shows a granular and polygonal texture (Fig. 8, A). It is mainly composed of pyroxene, plagioclase and biotite while the minor components are alkali feldspar and quartz. Orthopyroxene, sphene, chalcedonic silica, antigorite and ilmenite are accessory minerals. Clinopyroxene (diopside) are noted for their second order bright interference colours and oblique extinction (38^{o} - 42^{o}). Plagioclases are marked by polysynthetic twins. With Michel Levy's method applied, they show calcic plagioclase (andesine and above). Along the fracture or cracks of plagioclase, alterations are dominant and they may be relatively related to the calcium. Untwined feldspars are sodic and potassic feldspars. Alterations and rim myrmekitic texture occur along the boundary of the feldspars. Biotite occurs as tabular grains and shows strong pleochroism varying from light yellow to reddish brown with accumulated group. It is altered to chlorite. Many quartz grains are enclosed in porphyroblasts of plagioclase with poikiloblastic nature. Quartz can also be seen as an initial stage of exsolution texture. Some of the microscopic sequential alterations indicate the process of metasomatism. Later phases of silicification, filled up with chalcedonic silica (cryptocrystalline silica) into vesicles and then followed by saussuritization within intergranular grains. They are sequential processes. However, there is still a question about the origin of biotite between vesicles that are original grains. There are still some evidence~~s~~ of metasomatism process. Former pyroxene are completely recrystallized and replaced by hydrated minerals as antigorite (serpentine). Orthopyroxene is also replaced by alkali feldspar that is surrounded by clinopyroxene and sphene (Fig. 8, B). Rotated orthopyroxene porphyroblasts (helicitic or snowball texture) can be seen (Fig. 8, C). Foliation planes serve as layers of quartz in this orthopyroxene porphyroblast. It is noteworthy that the quartz layers in the orthopyroxene crystal are curved, indicating that the orthopyroxene grows during the rotation process. The relatively straight layers in the core of the orthopyroxene crystal, however, indicate that most of the rotation occurred during the growth of the outer part of the crystal. Some minerals also show replacement structure that is replaced by quartz in clinopyroxene minerals. Minerals of mafic granulite have fractures and alterations along cracks. The fact that this deformation is caused by dynamic metamorphism should be taken into consideration.

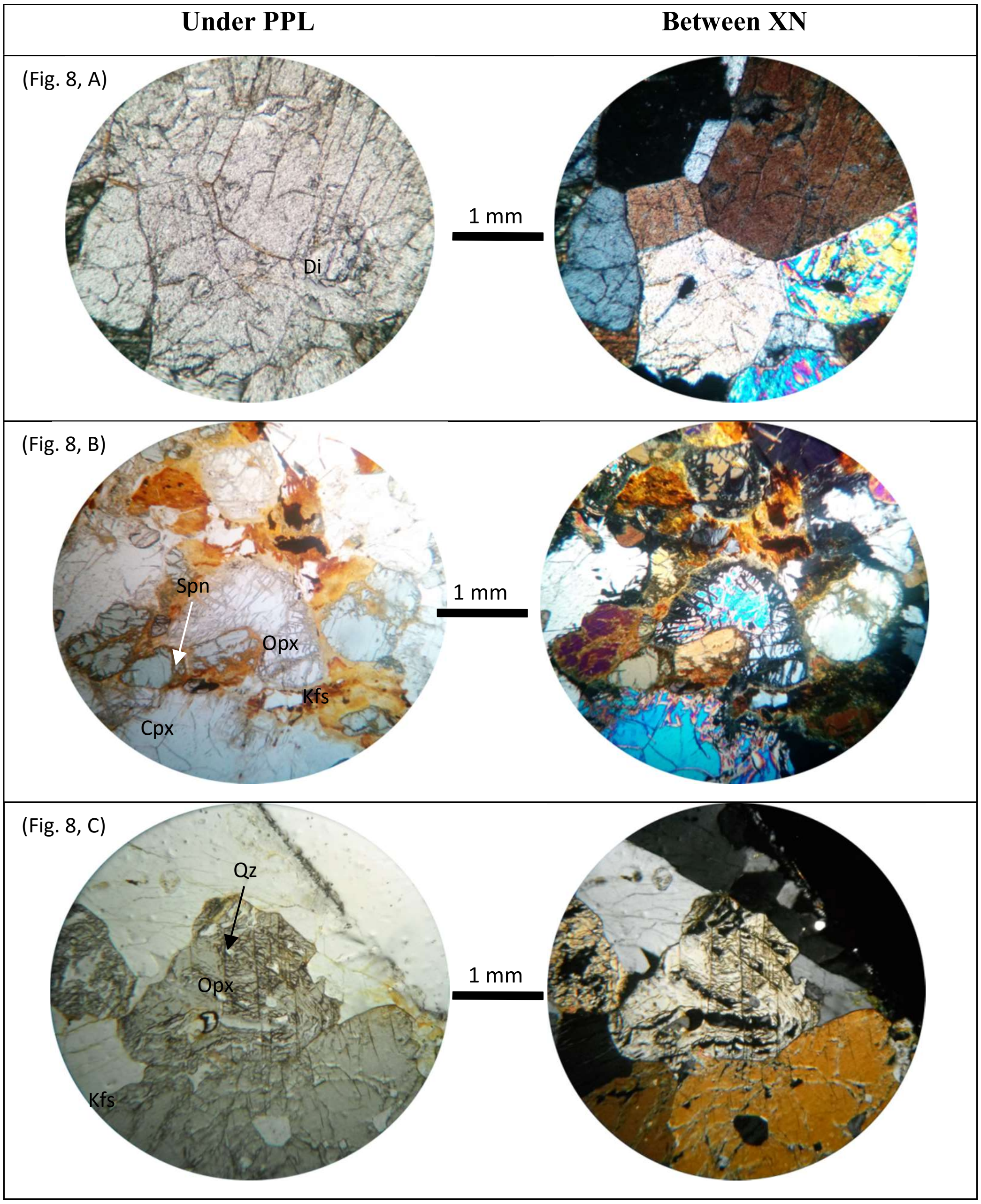


Figure 8. A Polygonal texture with pyroxene crystals in mafic granulite.

Figure 8. B Replacement of alkali feldspar in orthopyroxene in mafic granulite.

Figure 8. C Quartz inclusion in orthopyroxene (Opx) in mafic granulite.

Metamorphic Facies and Grade

Granulite is the type rock of the granulite facies although not all rocks in the granulite facies will be granulites. Only metamorphic rocks with mineral assemblages diagnostic of that facies, of the regional hypersthene zone, should be called "Granulites" (Winkler, 1979). Representative facies diagrams of the study area are presented based on mineral assemblages of petrographic studies by AKF Diagram (Fig. 9).

Significant phenomena of cordierite and/ or garnet in granulite facies

The study area may probably be the upper part of the granulite facies by the presence of almandine and lack of cordierite.

In the presence of quartz and sillimanite, the association and coexistence of almandine-rich garnet and cordierite is a significant phenomenon (Hensen & Green, 1971; Currie, 1971). The pair cordierite + almandine are restricted to a specific *P-T* range in high-grade metamorphism and the regional hypersthenes zone (granulite facies), verified in (Fig. 10, A & B).

(Fig. 10, A) show that *P-T* diagram of coexisting Crd + Alm + Sil + Qz for various FeO/(MgO+FeO) ratios of the bulk composition. If the ratio is increased then the stability field of garnet is reduced and that of cordierite extends towards higher pressure.

(Fig. 10, B) show that *P-X* diagram, reproduced at 700ºC, of coexisting cordierite and garnet, in the presence of ilmenite and quartz. Below the lower curve only cordierite is stable, above the upper curve only garnet is stable. In between the two curves cordierite and garnet coexist, together with sillimanite and quartz. The tie lines join compositions of coexisting cordierite and garnet at different pressures and constant temperature.

Pressure divisions for the granulite facies can be based on the presence of cordierite or almandine, although the absolute conditions affecting the appearance of these minerals include temperature. Cordierite indicates relatively low pressures, cordierite with almandine indicates intermediate pressures, and almandine without cordierite indicates high pressures. The reaction: Fe-Mg cordierite = Fe-Mg almandine+sillimanite+quartz+H_2O (Hyndman, 1985).

Cordierite could appear at 800 to 850ºC and at pressures no higher than about 4 kb. In the presence of almandine, pressure for Mg-cordierite is at 800ºC to would be greater than 7.5 kb. Partial melting of assemblages containing cordierite+ garnet + K-feldspar + sillimanite + biotite + plagioclase + quartz should occur near 700ºC (Holdaway & Lee, 1977). In the formation of the granulite facies, *P-T* estimates range from 700 to 980ºC at about 4 to 10 kb for cordierite-bearing areas and from 700 to 1050ºC at about 8 to 14 kb for cordierite-free areas.

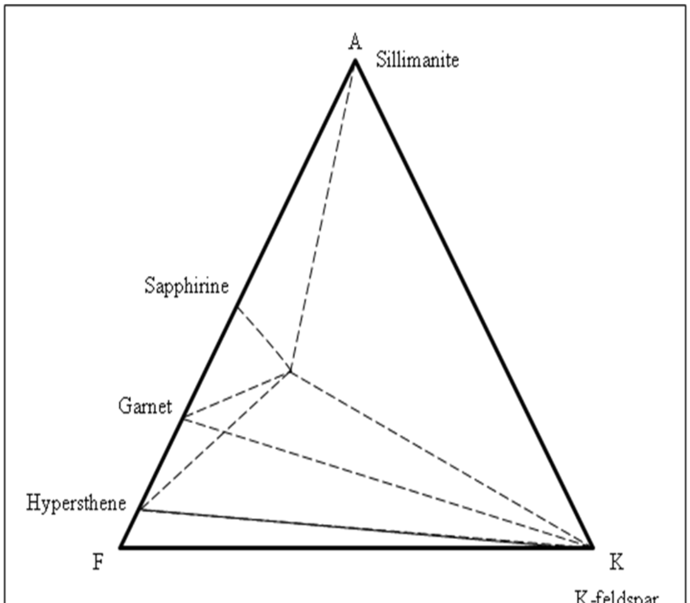


Fig. 9

Figure. 4.15 Representative facies diagram of granulite recognized in the Mount Loi-Sau and its environs, AKF diagram of granulite facies (After Hyndman, 1985).

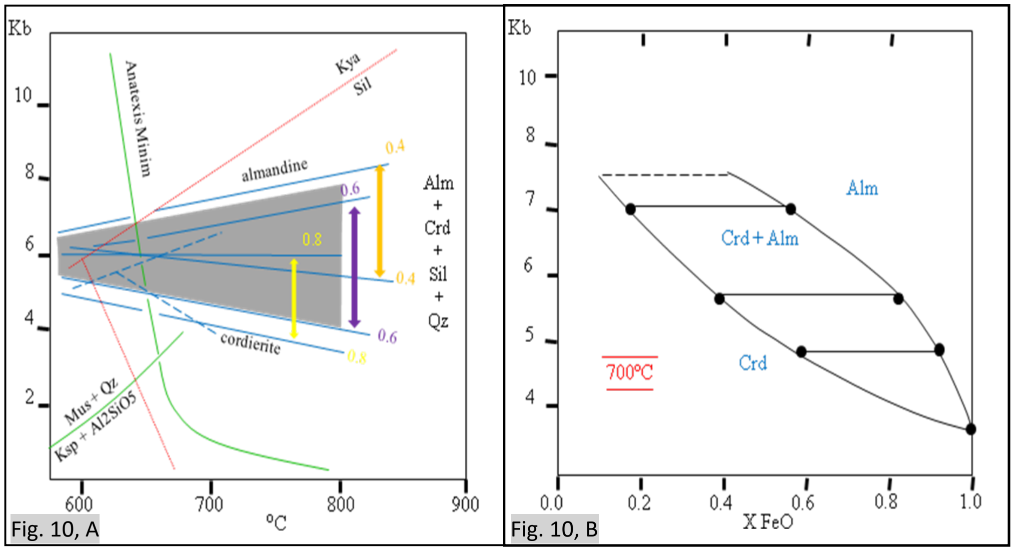


Figure. 4.16 (A) *P-T* diagram of coexisting Crd + Alm + Sil + Qz for various FeO/(MgO+FeO) ratios of the bulk composition. If the ratio is increased then the stability field of garnet is reduced and that of cordierite extends towards higher pressure. (Hensen & Green, 1971).

(B) *P-X* diagram of coexisting cordierite and garnet (in the presence of ilmanite and quartz) at 700ºC (Currie, 1971).

Significant phenomena of hypersthene in granulite facies

Hypersthene is the most diagnostic mineral in high-grade regional metamorphic rocks, granulites. In the regional hypersthene zone, hypersthene may also form in pelitic and semipelitic rocks due to the partial decomposition of biotite according to the reaction:

Biotite + Quartz = Hyperthene + Almandine + K feldspar (Winkler, 1979). Orthopyroxene takes place at about 700ºC to 900 ºC (Winkler, 1979). The assemblage hypersthene + sillimanite + quartz is the high pressure and stabilized at about 10 kb (Newton, 1972).

Significant phenomena of sapphirine in granulite facies

The formation of sapphirine is confined largely to high-grade metamorphic terrains belonging to the granulite facies. The presence of spinel relics in sapphirine is shown in symplectic intergrowths of the two minerals (Fig. 7, B), records changing conditions of temperature and pressure. In some occurrences the rims of idiomorphic sapphirine have developed over spinel. Its development can be explained by the simple reaction:

$$2MgAl_2O_4 \quad + \quad SiO_2 \quad \rightarrow \quad Mg_2Al_2(Al_2Si)O_{10}$$

$$\text{Spinel} \quad + \quad \text{Silica} \quad \rightarrow \quad \text{Sapphirine}$$

(Deer, Howie & Zussman, 1992). Sapphirine is formed at very high temperature zone and the stability field of sapphirine is at 600°-1500° C & at least 7 kbar (Seifert, 1974).

The assemblage sapphirine + quartz found in some high pressure granulite terrains indicates that water pressure was very much lower than total pressure. The association of sapphirine + quartz indicates pressures greater than about 8 kb. It is the same significance to the paragenesis hypersthene + sillimanite + quartz (Newton, 1972).

Possible physicochemical conditions of metamorphism

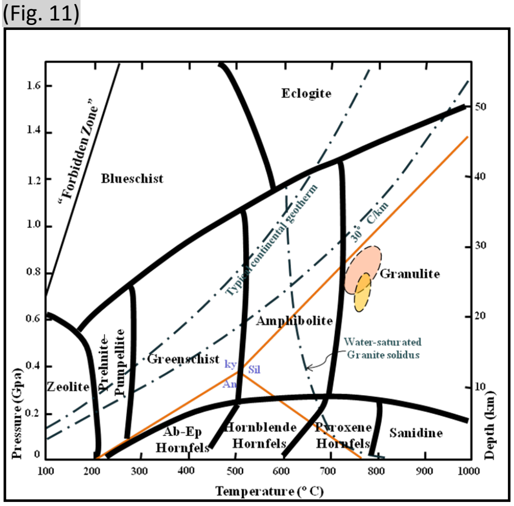
The rare paragenesis is found in the study area; hypersthene + sillimanite + quartz and sapphirine + quartz and it is the rare occurrence of paragenesis (Hensen & Green, 1973). These assemblages are related by the reaction and indicate at high temperatures (and high pressures):

Hypersthene + Sillimanite → Sapphirine + quartz

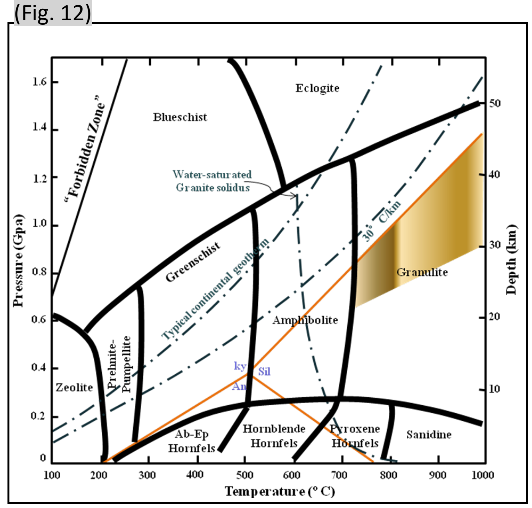
Petrochemically, sillimanite-garnet-biotite gneisses in the study area have reached granulite facies (730-810 ºC & 6.5-9.3 kbar), characterized by the mineral assemblages and petrochemical results from EPMA and XRF (Wai Yan Lai Aung, 2016) (Fig. 11). The *P-T* condition of granulite rocks in the study area should probably be the same as and/ or greater than the *P-T* condition of the high-grade gneiss of the study area, according to the mineral assemblages orthopyroxene + alkali feldspar + biotite + chlorite + plagioclase +garnet + quartz + rutile + sillimanite + sapphirine + opaque + hercynite + sillimanite + sericite + zircon + ilmenite of felsic granulite and mineral assemblages clinopyroxene + biotite + plagioclase (andesine) + alkali feldspar + quartz + perthite + orthopyroxene + sphene + opaque + chalcedony + antigorite of mafic granulite.

A possible physicochemical condition of metamorphism is shown in (Fig. 12), (after Winter, 2013). *P-T* condition of the granulitic rocks of the study area estimated in golden gradient.

(Fig. 11)



(Fig. 12)



	Sample 1A	At 6.5 to 9.3 kb, between 740 and 810ºC.
	Sample 1B	At 6.2 to 8 kb, Between 750 and 790ºC.

Figure 11. Temperature-Pressure diagram showing the stability field of sillimanite-garnet- biotite gneiss (sample 1A & 1B) from the study area (Wai Yan Lai Aung, 2016), estimated in coloured circles with the aid of electron microprobe analysis (EMPA).

Figure 12. Temperature-Pressure diagram showing the stability field of granulitic rock of the study area (After Winter, 2013), estimated in golden gradient with the aid of mineral assemblages and creative thinking.

Acknowledgements

This is a part of PhD Dissertation of the author and laboratory analyses of this study were financially supported by the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland and University of Yangon (UY). The author wishes to acknowledge gratefully Prof. Dr Day Wa Aung, Head of the Department of Geology, University of Yangon, for his kind permission to undertake this research, providing valuable advice and encouragement. I am deeply grateful to Prof. Dr Christoph A. Heinrich, Prof. Dr Lucie Tajčmanová, Department of Earth Sciences, Institute of Geochemistry and Petrology, ETH Zurich, Prof. Hla Kyi, Part-time Professor, Applied Geology Department, Prof. Thein Win, Pro-Rector (Retd.), West Yangon University are also acknowledged for their practical guidance and for this keen interest taken in the preparation of this research. The author is also much indebted to Dr Thet Tin Nyunt, Professor, University of Yangon and Dr Htay Win, Professor (Retd.), East Yangon University for their taking great pains to finish some vital part of this research. The author's heartfelt thanks are extended to some important persons who proposed the interesting remote area, and who accompany and follow the author to the insurgent area, only half expecting the area to be secure within the author's field trips; U Aung Kyaw Htoon, Part-time Lecturer, Dagon University, U Tin Tun, Former Associate Professor, University of Yangon, Dr Thet Tin Nyunt, Dr Kyaw Khaing Win, Mg Lwin Moe Aung and Mg Han. The author thanks to the personal concerned of local authorities and people from the study area for their kindness, hospitality, security and care during the author's stay.

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PETROGRAPHIC DESCRIPTION OF IGNEOUS ROCKS OF THE ASIN AREA, YE TOWNSHIP, MON STATE

Aye Nyein Thu[1], Su Su Hlaing[2], Myat Thuzar Soe[3]

Abstract

The research area is situated 9.6 km to the Southwest of Ye. The structural trend of research area is generally N-S to NNW-SSE. It is mainly composed of igneous rocks such as diorite, porphyritic biotite granite, biotite granite, biotitemicrogranite, microdiorite dyke and pegmatite dykes. Hypidiomorphic granular texture is found in all units of the research area. In granitic rocks, quartz, orthoclase, biotite and plagioclase are major constituents. Zircon, sphene, apatite and opaque are minor constituents. Feldspar occurs as phenocrysts. Biotite was altered to chlorite along the cleavage planes and some are bent due to deformationin porphyritic biotite granite. Hornblende is the chief mafic mineral in diorite. In microdiorite dyke, biotite is main mafic mineral and altered to chlorite. In IUGS classification, biotite granite and porphyritic biotite granite fall in syeno granite and diorite falls in quartz monzodiorite fields. Igneous rocks can be used as construction and road materials and decorative stones.

Key word: Porphyritic biotite granite, biotite granite, diorite, biotitemicrogranite, microdiorite dyke.

Introduction

The research area is Asin Area in Ye Township. It lies between Longitude 97° 43' 40" E to 97° 48" 15" E and Lattitude15° 11' 45" N to 15° 15' 00" N in one inch topographic map No. 95E/11 and 95E/12. The area coverage is about 40.32 Km^2. The location map of the research area is shown in Figure (1).

Regional Geologic Setting

The granitic body of the research area is trending nearly N-S. Igneous rocks in study area presents in Tenasserim granitoids of the Sino-Burman Ranges, Bender (1983). It also liesin the Central Granitoid Belt. The granitoid rocks in the Central Granitoid Belt were possibly emplaced during continent-arc collision at the early stage of westward migrating, east-dipping subduction

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zone during the Late Mesozoic and Early Eocene (KhinZaw, 1990).Three Pagoda Fault lies in the northeasternpart of the research area. It is a major sinistral shear zone and composed of high-grade metamorphic rocks, (Morley 2002). The study area is underlain by Paleozoic metasedimentary rocks of Mergui Group and Mesozoic to Tertiary igneous intrusions, Figure (2).

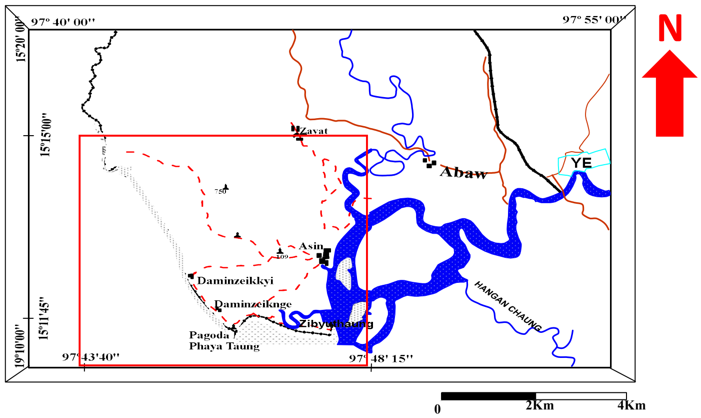


Figure 1. Location map of the research area

Geology of Research Area

The geological map of the research area is shown in Figure (3). The research area is mainly composed of igneous rocks. Biotite granites are the most abundant rock type of the research area. It is well exposed at the rock mine and central part of the study area, Figure (4-a). Porphyritic biotite granite is second widely exposed rock type. It occurs in the central part of the researcharea, Figure (4-b). Biotitemicrogranite is common at the Myintmotaung and Phalaingtaung, Figure (4-d). Diorite is exposed near Chaungwa, Figure (4-e). Microdiorite is exposed as dyke intruding the porphyritic biotite granite. It can be seen at Kyanbid Monastery, Figure (4-f). Quartz veins are common in all rock units of the research area. Especially, it can be found at Phayar Taung, Figure (4-c).Biotite Microgranite is intruding porphyritic biotite granite at the Phayartaung. It indicates that the porphyritic biotite granite is older than biotitemicrogranite, Figure (5-a). Biotite granite is intruding into porphyritic biotite granite located 15° 11' 52.6" N and 97° 46' 04.1" E. It again indicates that the biotite granite is younger than the porphyritic biotite granite, Figure(5-b).Porphyritic biotite granite intruded by microdiorite dyke at Kyainbid Monestry. It indicates that the microdiorite dyke formed later than porphyritic biotite granite, Figure (5-c). Porphyritic biotite granite intruded into diorite and shows that diorite is older than porphyritic biotite granite. Quartz veins cut all the igneous rocks. These dykes and veins can be considered to have occurred in the last phase of the igneous activity, Figure (5-d).

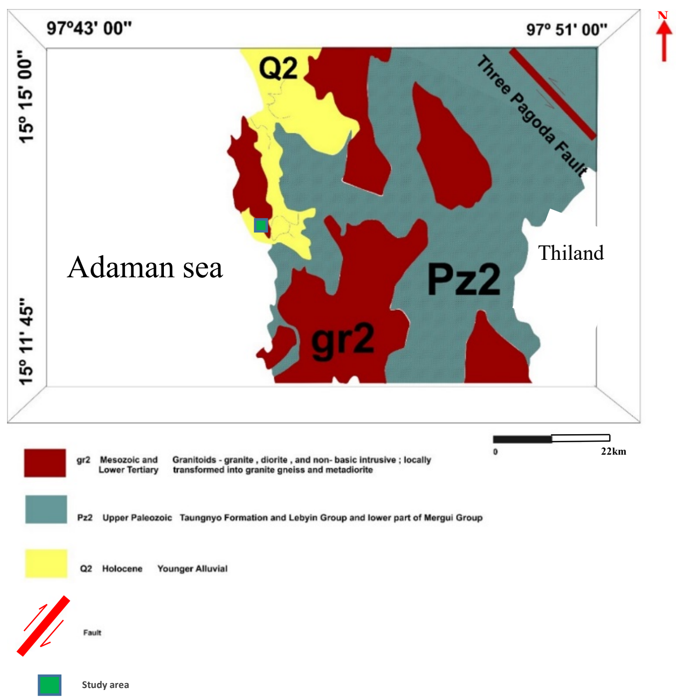


Figure 2. Regional geological setting of the research area and its environs.(Myanmar Geoscience Society, 2014(1:2000000)

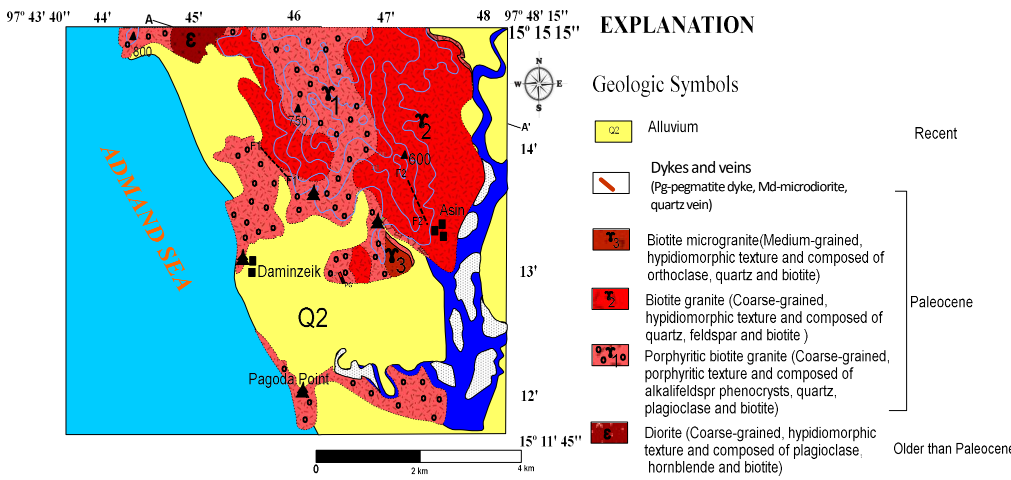


Figure 3. Geological map ofAsin Area, Ye Township (After Aye Nyein Thu, 2017).

Rock Sequence of the research area

Rock Type	**Possible Age (After PhyoThinzarTun, 2016)**
Alluvium	Quaternary
Dyke and Vein	
Quartz Vein and Pegmatite dyke	
Microdiorite Dyke	
Igneous Rocks	
Biotitemicrogranite	Paleocene
Biotite Granite	
Porphyritic Biotite Granite	
Diorite	Older than Paleocene

Figure (4-a) Segregation of mafic minerals in biotite granite at rock quarry, (Looking -165°).

Figure (4-b) Outcrop nature of porphyritic biotite granite at Phayartaung, (Looking-60°).

Figure (4-c) Quartz vein in porphyritic biotite granite at Phayartaung (Looking 140°).

Figure (4-d) Rectangular joint on biotitemicrogranite at Kannar Monastery, (Looking-, 65°).

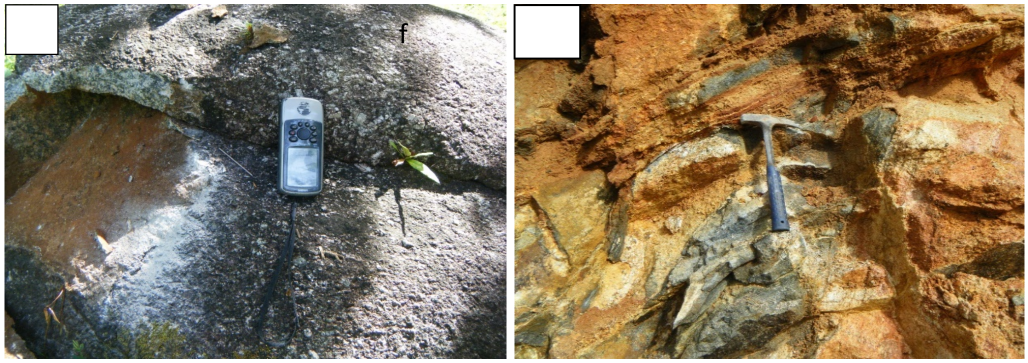


Figure (4-e) Well exposed diorite outcrop at Chaungwa, (Looking-103̊).

Figure (4-f) Outcrop nature of microdiorite dyke at Kyanbid Monastery (Looking- 110̊).

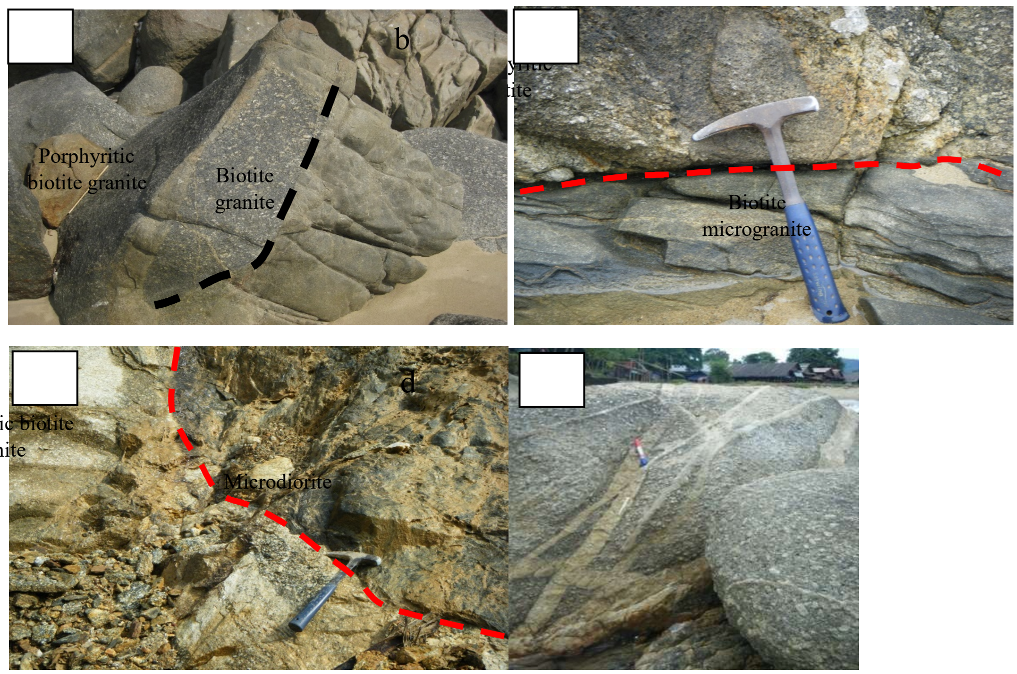


Figure (5-a) Biotite granite intruding porphyritic biotite granite at Phayartaung.

Figure(5-b) Biotitemicrogranite intruding porphyritic biotite granite at Phayartaung.

Figure (5-c) Microdiorite dyke intruding porphyritic biotite granite at Kyainbid Monastery.

Figure (5-d) Quartz veins cutting across porphyritic biotite granite.

Petrography of Igneous Rocks

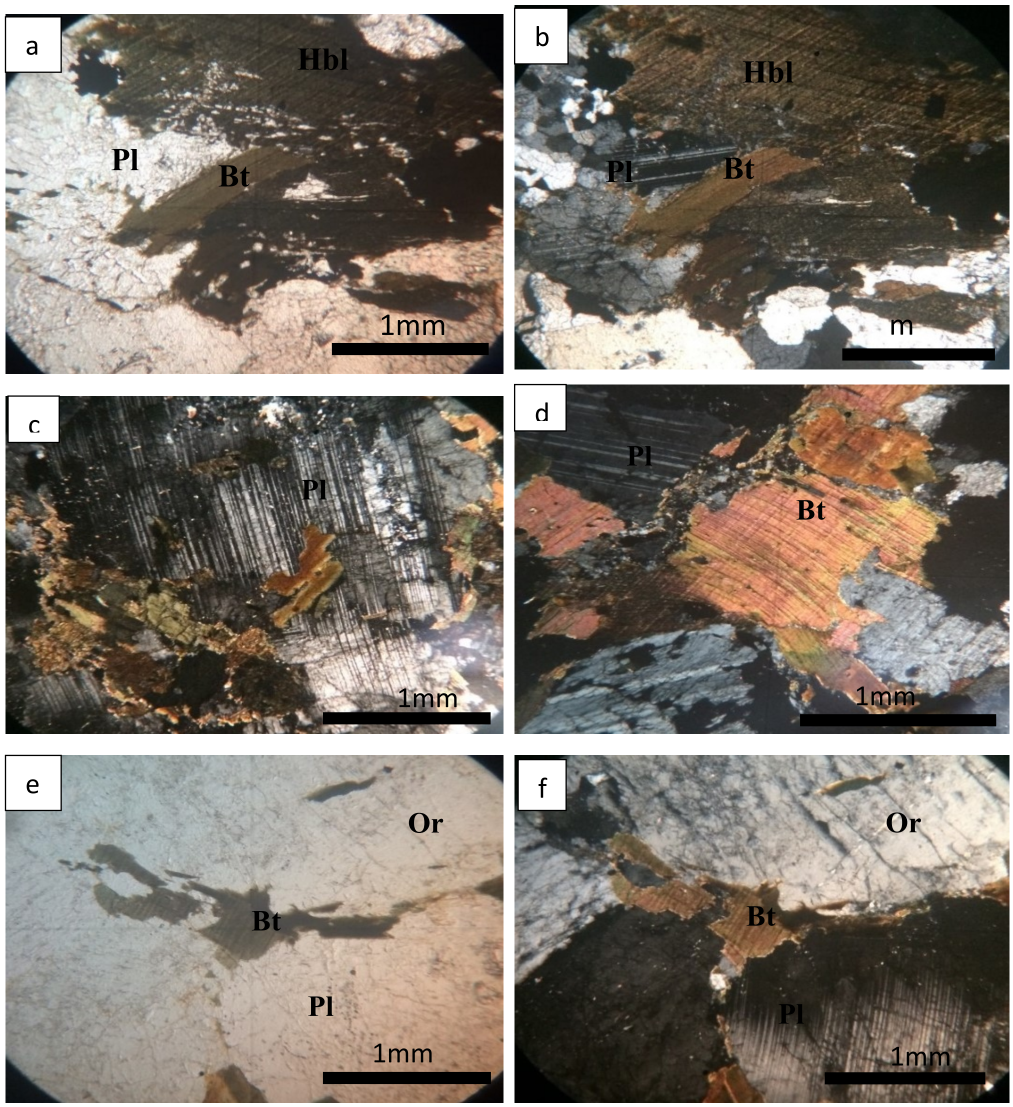
Igneous rocks in the research area are diorite, porphyritic biotite granite, biotite granite and biotite microgranite. Point counting data from the representative samples were plotted in IUGS classification diagram, Table (1) and Figure (9). According to this classification diagram, biotite granite and porphyritic biotite granite fall in syeno-granite and diorite falls in quartz monzodiorite fields.

Diorite is mainly composed of plagioclase, hornblende, biotite and minor amounts of quartz, orthoclase and perthite. Plagioclase occurs in subhederal to euhedral forms with average grain size of 1mm x 2mm. The compositional range of plagioclase is from An_{37} to An_{40}(andesine).Sometime, plagioclase shows the combination of simple contact twin and polysynthetic twin. Hornblende, zircon and opaque minerals occur as inclusion in plagioclase. Hornblende is the chief ferromagnesium mineral and occurs as subhedral to euhedral form with 0.5mm x 3mm. Zircon and opaque minerals also occur as inclusion in hornblende crystals. Biotite shows subhedral to euhedral form and average grain size of 0.5mm x 1mm.Some biotite alters to chlorite. Quartz occurs as anhedral grain and as interstitial fillings between plagioclase, hornblende and biotite, Figue (6-a, b, c, d).

Porphyritic biotite graniteis mainly composed of alkali feldspar (orthoclase, microcline and perthite) pheocrysts, quartz, plagioclase and biotite. In porphyritic biotite granite, perthitic orthoclase shows euhedral form and the average grain size is 4mm x 8mm.Orthoclase occurs as irregular interlocking mosaic. Perthite; flame perthite are present. Microcline shows cross-hatched twinning. Alkali feldspars are very abundant and found as phenocrysts. Some alkali feldspar altered to sericite. Quartz shows anhedral form and wavy extinction. Biotite is pleochroic from light yellow to brown. It is altered to chlorite along the cleavage planes and some are bent due to deformation. Plagioclase occurs in subhedral form and composition of plagioclase is albite An_{9-10}.Some plagioclase are altered to saussurite and muscovite. Myrmekitic texture is observed in it, Figure (6-e, f) (7-a, b, c, d, e, f).

Biotite Granite is mainly composed of quartz, orthoclase, microcline, biotite, and plagioclase and accessory mineral is muscovite. Quartz occurs as anhedral grains with undulose extinction. Myrmekite texture is also found along the margins of quartz and plagioclase. Orthoclase exhibits simple twinning. Some orthoclase altered to sericite. It shows anhedral to subhedral forms and size varies from 0.5mm x 1mm to 1mm x 2mm. Microcline is subhedral and shows cross-hatched twining. Size varies from 1mm x 2mm to 1.5mm x 3mm. Perthitic microcline is also found in some biotite granite. Biotite displays subhedral to anhedral forms and size varies from 0.5mm x 1mm to 1mm x 2mm. It shows light yellow, pale brown to dark brown in pleochroism. It altered to chlorite. And also occurs as inclusion in plagioclase. Plagioclase shows subhedral forms and polysynthetic twinning. Some plagioclase are altered to saussurite. Zoning are present. Some plagioclases twin band are bent due to deformation. The composition of plagioclase is albite An_{8-10}. Muscovite flakes are present in minor amounts and curved cleavages are found due to deformation, Figure (8-a, b, c, d).

Biotite Microgranite is mainly composed of orthoclase, quartz and biotite. Plagioclase and microcline occur in minor amounts. Small quartz grains show undulose extinction and anhedral form. It is also found between interstices of larger grains. Orthoclase is abundant and found as subhedral to euhedral grain. Size of orthoclase varies from 0.2mm x 0.5mm to 0.3mm x 1mm. In biotite microgranite, orthoclase is more abundant than plagioclase. Biotite shows subhedral to anhedral form. It is pleochroic from light brown to dark brown. Some biotite are altered to chlorite. Biotiteis found disseminated. Plagioclase occurs as subhedral form and average grain size varies from 0.2mm x 0.5mm to 0.3mm x 1mm. It is present in small amount and shows polysynthetic twinning. Twin bands are closely spaced and composition of plagioclase is albite An_{8-10}. Normal zoned plagioclase are also found. Microcline occurs in very little amounts as subhedral grains. It shows cross-hatched twinning, Figure (8-e, f).



Figure(6-a and b) Hornblende (Hbl), Plagioclase (Pl) and Biotite (Bt) in diorite, under PPL and between XN.

Figure (6-c) Plagioclase corroded by altered biotite in diorite between XN.

Figure (6-d) Plagioclase (Pl) and bent biotite (Bt) in diorite between XN.

Figure (6-e and f) Orthoclase (Or), Biotite (Bt) and Plagioclase (Pl) in porphyritic biotite granite, under PPL and between XN.

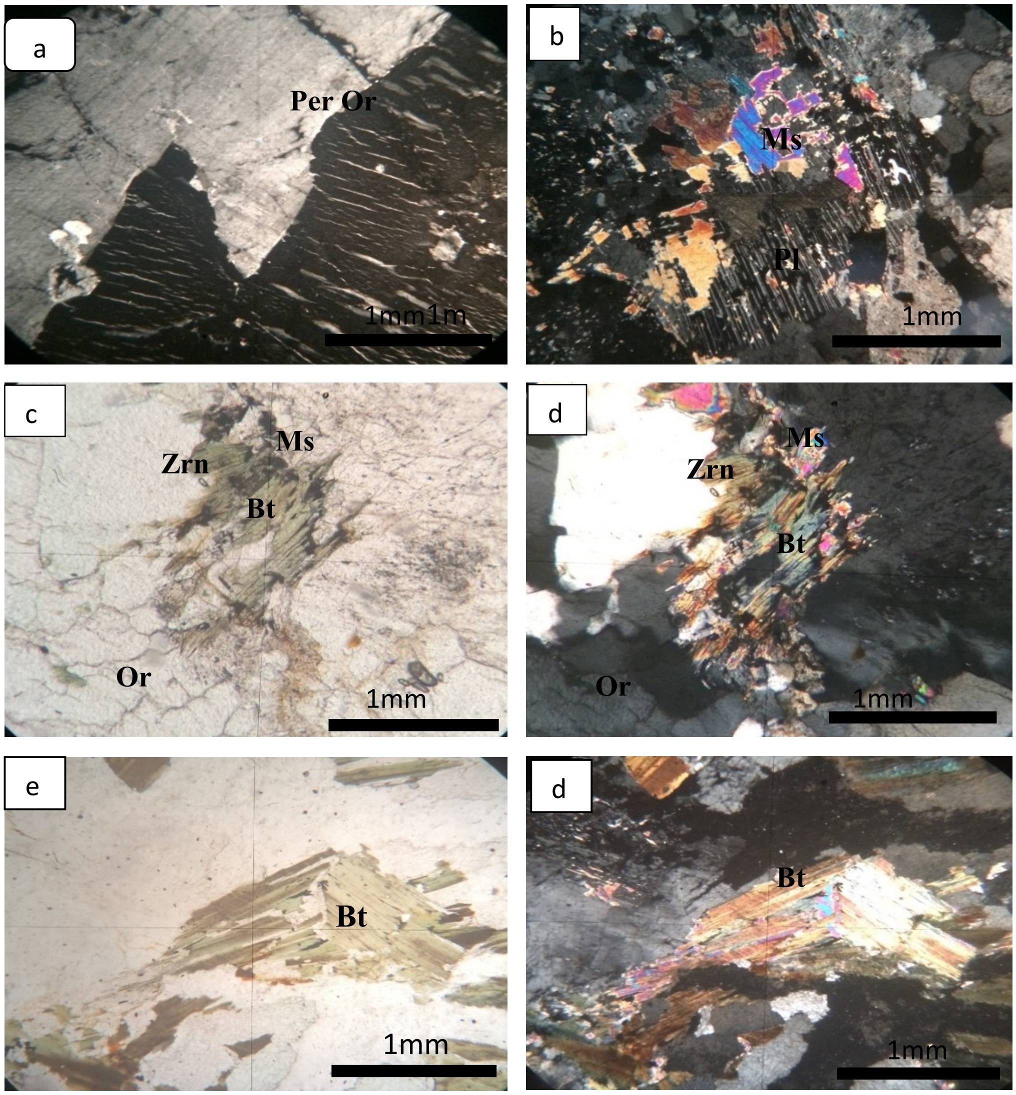


Figure (7-a) Large - grained size of perthitic orthoclase (Per Or) in porphyritic biotite granite, between XN.

Figure (7-b) Plagioclase altered to saussurite, between XN.

Figure (7-c and d) Zircon (Zrn), Orthoclase (Or), Muscovite (Mus) and Biotite (Bt) altered to chlorite in porphyritic biotite granite, under PPL and between XN.

Figure (7-e and F) Biotite (Bt) is bent due to strain effect in porphyritic bioitite granite, under PPL and between XN.

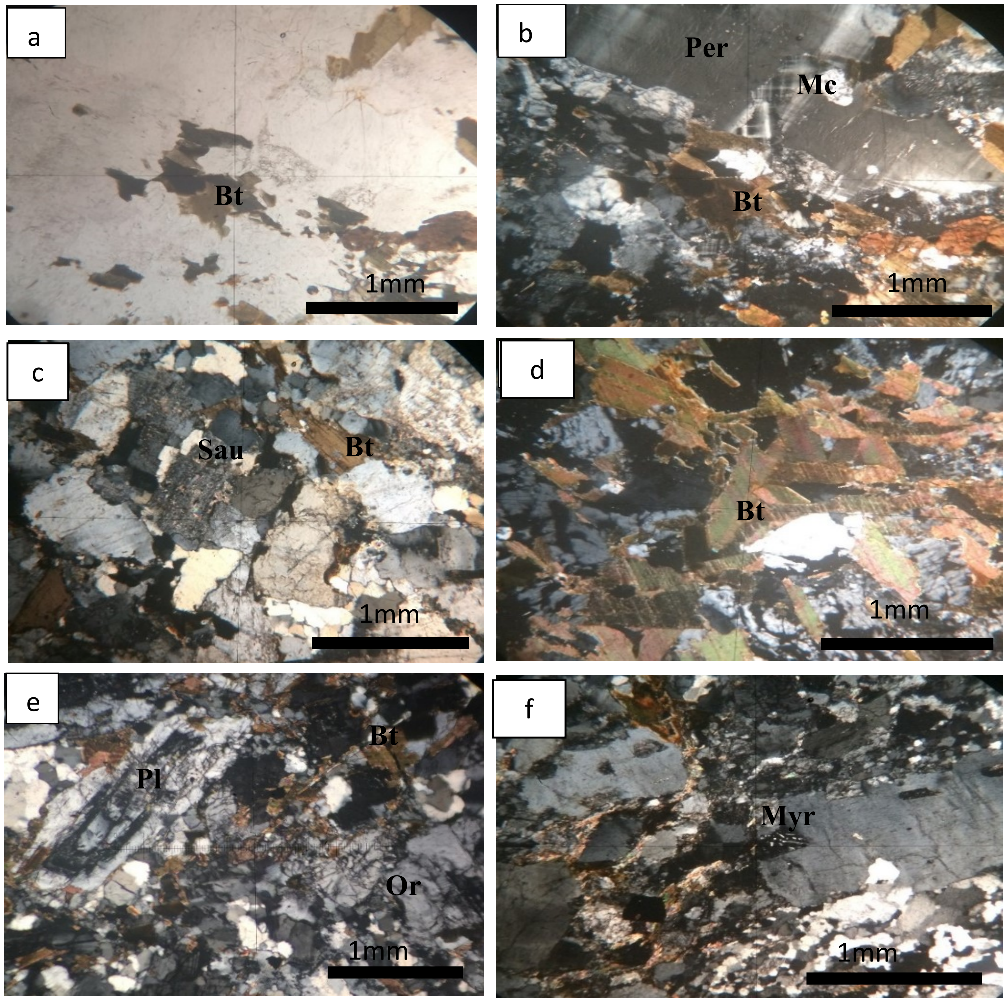


Figure (8-a and b) Biotite (Bt), Microcline (Mc) and Perthite (Per) in biotite granite under PPL and between XN.

Figure (8-c) Plagioclase (Pl) altered to saussurite in biotite granite between XN.

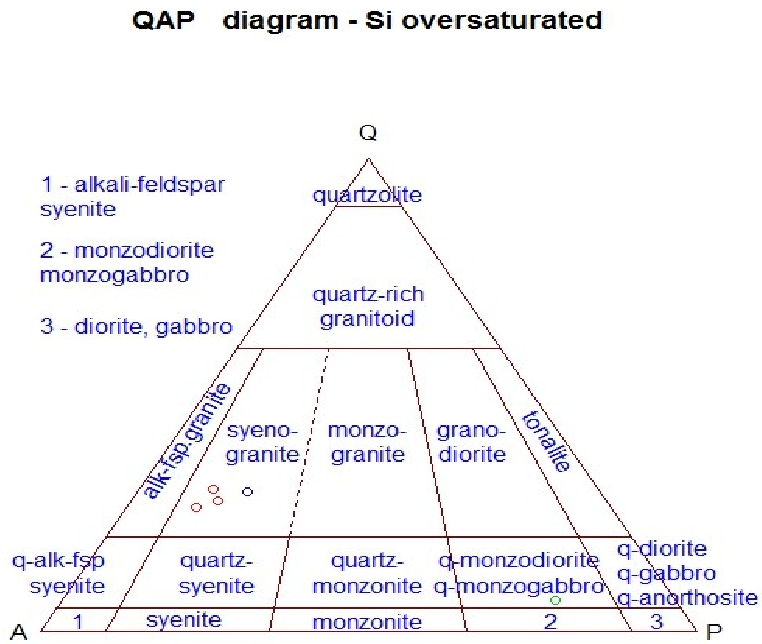
Figure (8-d) Biotite (Bt) altered to chlorite in biotite granite between XN.

Figure (8-e) Zoning and saussurite in the core of zoned plagioclase (Pl) in biotitemicrogranite, between XN.

Figure (8-f) Myrmekitic texture (Myr) in bioitiemicrogranite, between XN.

Table (1) Modal composition of igneous rocks (in volume per cent)

Name	Porphyritic biotite granite	Biotite granite			Diorite
Sample No	29/1	28/1(I)	28/1(II)	28/1(III)	1/3
Location N- E	15°13' 1.08" N	15°14' 13.32"N	15°14' 13.32"N	15° 14' 13.32"N	15°15' 11.4"N
	97°46' 35.34"E	97°45' 43.44"E	97°45' 43.44"E	97°45' 43.44"E	97°44' 57.78"E
Total count	1098	1031	1082	1054	1256
Quartz	23.4	25.08	23.23	25.05	5.1
Al-feldspar	42.25	48.88	49.68	60.15	15.96
Plagioclase	13.29	9.56	11.13	10.5	57.80
Biotite	9.28	8.45	5.5	4.84	7.83
Hornblende	-	-	-	-	10.51
Muscovite	3.18	3.7	4.25	-	0.32
Sphene and Zircon	2.5	-	2.25		1.51
Opaque and others	5.5	4.5	3.65	-	1.86
Total	**99.4**	**100.17**	**99.69**	**100.54**	**100.89**



○ Biotite granite

○ Porphyritic biotite

○ Diorite

Figure 9. Modal composition of the igneous rocks in the research area (in volume percent).

Economic Aspects of Research Area

The important economic minerals are not found in the research area. The granite and diorite can be used as construction materials and road materials. The microgranite can also be used as road materials. The Daminzeik Quarry is situated in the northwestern part of the research area producing large quantities. These granitic rocks are crushed and chipped to be used for highways, railways, construction and road materials. Biotite granite, biotitemicrogranite, diorite and porphyritic biotite granite are used as decorative stones, Figure-28.

Figure 28. Biotite granite is excavated for construction and decorative stones at Daminzeik Quarry.

Summary and Conclusion

The research area is situated around Asin, Ye Township, Mon State. It is located about 9.6 km to the southwest of Ye. Asin area is fairly mountainous and rugged terrain with trending nearly N-S regional trend in general. Biotite granites are the most abundant rock type of the research area. It is well exposed in the rock quarry in the central part of the research area. Porphyritic biotite granite is second widely exposed rock type and occurs in the central part of the research area. Sometimes, it is also found associated with biotite granite. Biotitemicrogranite is common at the Myintmotaung and Phalaingtaung. Diorite is exposed near Chaungwa. Microdiorite is exposed as dyke intruding the porphyritic biotite granite. It is found at Kyanbid Monastery. Quartz veins are common in all rock units of the research area.

Especially, it is found at Phayar Taung. Petrographically, quartz, orthoclase, biotite and plagioclase are major constituents and zircon, sphene, apatite and opaque are minor constituents in porphyritic biotite granite, biotite granite and biotitemicrogranite. Hornblende is the chief mineral in diorite. In IUGS classification, biotite granite and porphyritic biotite granite fall in syeno-granite and diorite falls in quartz monzodiorite fields. Igneous rocks can be used as construction and road materials and decorative stones.

Acknowledgements

The authors would like to express their sincerely thanks to Dr. Day Wa Aung, Professor and Head of the Geology Department, University of Yangon, Dr. Htay Lwin and Dr. Thet Tin Nyunt, Professors, Geology Department, University of Yangon for their permission and valuable administrative supports.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

THE CHEMICAL CHARACTERISTICS OF MAN SIN SPINEL, MOGOK, MYANMAR

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Abstract

Man Sin is located about 5 km to the northeast of Mogok. It is bounded by Latitudes 22 ° 57′ 05″ to 22°58′ 30″ N and Longitudes 96° 32′ 00″ to 96° 33′ 00″ E, in part of UTM Map 47Q KF 2296- 09. Jedi spinel (Hot spinel) was first discovered at Man Sin mine in 2009. This mine produces as varieties of coloured spinel, but most of them are intense red spinel principally Jedi spinel (Hot spinel).Chemical analyses of Man Sin

spinel indicate that Al_2O_3ranges from (71.5 – 60.5 wt %) and MgO from (26.6 – 18.5 wt %). The high concentrations of elements were Cr (3.66 – 0.008 ppm), V (0.633 – 0.005 ppm), Fe (2 – 0.03 ppm), Zn (0.725- 0.038) and Zr (1.103 – 0.219 ppm) respectively. Ti (0.113 – 0.008 ppm) and Ga (0.052 – 0.003 ppm) are generally low in concentration. Fe+TivsV+Cr and Cr+TivsV+Fe plots indicate that they are negatively associated. In Fe-V- Cr Ternary diagram, the red spinel from the Man Sin mine has two population: one is coloured by higher Cr content (> 80 ppm) and V content (> 40 ppm) but Fe content is (12 to < 10 ppm) in red spinel. The other group has average value of Cr and V ranging from (40-60 ppm). In these two groups, one which has higher Cr content shows more attractive red colour. Moreover, pink spinel also shows two groups. One is rich in Cr and other is rich in V. Fe concentration in these two groups is intermediate (35-55 ppm). One sample shows the significantly excessive Fe concentration (nearly 100 ppm) and thus the colour of this spinel is greenish blue. Trace elements (V, Ti and Zr) are positively associated with Cr but other trace elements such as Fe, Ga and Zn are negatively associated with Cr, which display increase of Cr content with decrease of Fe, Ga and Zn contents. Conversely, red spinel from Htayan Sho mine indicates that Fe content is (> 40 ppm) and the amount of V and Cr contents is (< 60 ppm). So, the constraint on the attractive colour of Man Sin Hot spinel is due to the Cr rather than other trace elements such as V and Fe; pink and purple spinel are due to Fe and Cr, V and Ti, and the green spinel is due to the Fe. On the other hand, red spinel from Htanyan Sho is due to the average concentration of Fe and V rather than Cr and the purple spinel is due to higher concentration of Fe than V respectively.

Key words: Man Sin, Htayan Sho, Jedi Spinel, Hot Spinel, Mogok, Myanmar

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Introduction

Spinel has been used as a gemstone and was mistaken for ruby in the past and can be ranked next to ruby and sapphire due to lack of cleavage, higher dispersion and wide range of colour. It mostly occurrs in metamorphosed impure dolomitic limestone where the protolith was partly incorporated with clayey materials. These rocks were later affected by higher temperature regional metamorphism. One of the attractions of spinel is wide range of its elegant colours. For red spinel, the finest colors tend to be similar to ruby. However, Spinel tends to be slightly more bright-red colour than ruby and is called ***'Ruby Spinel'*** (Balas Ruby). Some spinel colours are more rare and valuable than others. In Myanmar, the finest spinels were producedfrom Man Sin mine in Mogok which was operated about 12 years ago, but pocket of ***jedi spinel (hot spinel)*** was first found only in 2009 (Pardieu, 2014). Although it was found in 2009 as famous attractive coloured spinel, the composition of such a beautiful gemstones from Man Sin area has not yet been studied in detail.

Location and Size

The research area is located in Mogok Township, Pyin Oo Lwin District, Mandalay Region. It is situated approximately 205 km to the northeast of Mandalay and 5 km to the northeast of Mogok. It is bounded by latitudes 22 ° 57′ 05″ to 22˚58′ 30″ N and longitudes 96˚ 32′ 00″ to 96˚ 33′ 00″ E. This area also lies between horizontal grids 400 to 425 and vertical grids 470 to 490 in UTM Map 47Q KF 2296- 09.The research area is about 2.5 km in N-S and 2km in E-W and the total area coverage is about 5 square km. Location map of the study area is shown in (Fig. 1).

Methods of Study

Field Work

Field work was carried out with conventional methods together with some modern equipment such as GPS which were plotted on Google Earth Map. Samples were collected from the Man Sin primary deposit as well as secondary deposit. Moreover, spinel samples from Htayan Sho mine were collected for comparative study (Fig. 2 A-D).

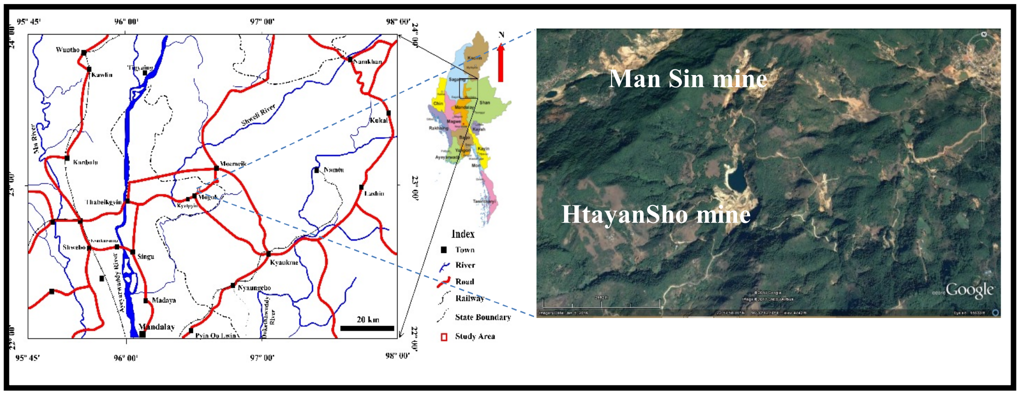


Figure 1. Location map of the Man Sin and its environs.

Figure 2 (A-C) Hot spinel crystals from Man Sin mine and (D) Spinel crystals from Htayan Shomine.

Laboratory Work

Analytical Method

For the present study, sixteen collected spinel were selected for analysis which includes thirteen samples from Man Sin mine and three samples from Htayan Sho mine. They sent to DGSE and MGJEA Labs. The major oxide and trace element concentrations of spinel samples were analyzed by using ED-XRF (X- Ray Fluorescence Spectrometry) method.

Chemical Composition of Man Sin Spinel

Analysed EDXRF results for major oxides and trace element concentrations are shown in Table1. These samples, in general, have Al_2O_3 (71.5 – 60.5 wt %) and MgO (26.6 – 18.5 wt %).The high concentrations of elements were Cr (3.66 – 0.008 ppm), V (0.633 – 0.005 ppm), Fe (2 – 0.03 ppm), Zn (0.725- 0.038) and Zr (1.103 – 0.219 ppm) respectively. Ti (0.113 – 0.008 ppm) and Ga (0.052 – 0.003 ppm) are generally low in concentration. The concentrations of these elements are graphically presented in (Fig. 3). Fe+Ti and V+Crare used to interpret the colour variation in Man Sin spinel and the plot indicates that they are negatively associated (Fig. 4). Moreover, Cr+Ti and V+Feare used to interpret the colour variation in Man Sin spinel and the plot indicates that they are negatively associated (Fig. 5).

In Fe- V- Cr Ternary diagram, the red spinel from the Man Sin mine has two population (Fig. 6). One is coloured by higher Cr content (> 80 ppm) and V content (> 40 ppm) but Fe content is (12 to < 10 ppm)in the red spinel. The other group of red spinel has average value of Cr and V ranging between (40-60 ppm). In these two groups, one which has higher Cr content shows more attractive red colour than the other group which is coloured by average contents of Cr and V. In these two groups, Fe plays a minor role. Moreover, pink spinel also shows two populations. One is rich in Cr and other is rich in V. Fe concentration in these two groups is intermediate (35-55 ppm). One sample shows the significantly excessive Fe concentration (nearly 100 ppm) and thus the colour of this spinel is greenish blue.

Table . Concentration of Major Oxides and Trace Elements of Man Sin Spinel

Sample. No	MS- 3	MS-4	MS- 5	MS- 6	MS- 7	MS- 8	MS- 9	MS- 10	MS- 11	MS- 12	MS- 13	MS- 14	MS- 15
Major Oxide (%)/Colour	Pink	Red	Red	Purple	Red	Pale pink	pink	Deep Red	Deep Red	Deep Red	Deep Red	Red	Greenish Blue
													
Al_2O_3	60.5	63.4	62.1	70.3	68.6	70.1	69.7	71.5	71	70.2	71.1	66.2	66.5
MgO	19.7	18.5	22.7	24.9	25.5	26.6	26	24.2	25	26.2	26.1	23.4	24.8
SiO_2	12.9	12.2	6.97	1.09	1.79	1.13	2.68	0.681	0.978	1.49	0.603	5.76	3.05
SO_3	0.195	0.188	0.119	0.0876	0.23	0.258	0.134	0.0718	0.069	0.0651	0.0533	0.25	0.278
K_2O	0.931	0.0753	0.0759	0.0176	0.0739	0.0481	0.0552	0.0156	0.0223	0.0255	0.0153	0.122	0.123
CaO	0.132	0.149	0.131	0.0213	0.0444	0.306	0.0655	ND	0.0305	0.0222	0.0268	0.108	0.11
MnO	ND	ND	0.0234	ND	ND	0.0036	0.0019	0.0176	ND	ND	ND	0.0106	0.0275
Trace Elements (ppm)													
Cr	1.019	1.82	3.66	0.493	0.985	0.058	0.138	0.666	0.395	0.4	0.442	1.341	0.008
V	0.113	0.633	0.398	0.171	0.248	0.127	0.033	0.543	0.292	0.333	0.315	0.132	0.005
Fe	1.406	0.239	0.317	0.45	0.174	0.233	0.083	0.044	0.234	0.093	0.03	0.124	2
Ti	0.065	0.113	0.058	0.098	0.03	0.014	0.008	0.062	0.016	0.089	0.088	0.105	0.04
Zr	0.444	0.566	0.65	0.547	0.707	0.219	0.399	0.911	0.452	0.37	0.466	1.103	0.473
Ga	0.027	0.012	0.014	0.052	0.031	0.02	0.018	0.004	0.028	0.004	0.003	0.01	0.042
Zn	0.68	0.228	0.204	0.693	0.428	0.092	0.332	0.049	0.619	0.038	0.065	0.056	0.725
Sum	98.112	98.1233	97.4203	98.9205	98.8413	99.2087	99.6476	98.765	99.1358	99.3298	99.3074	98.7216	98.1815

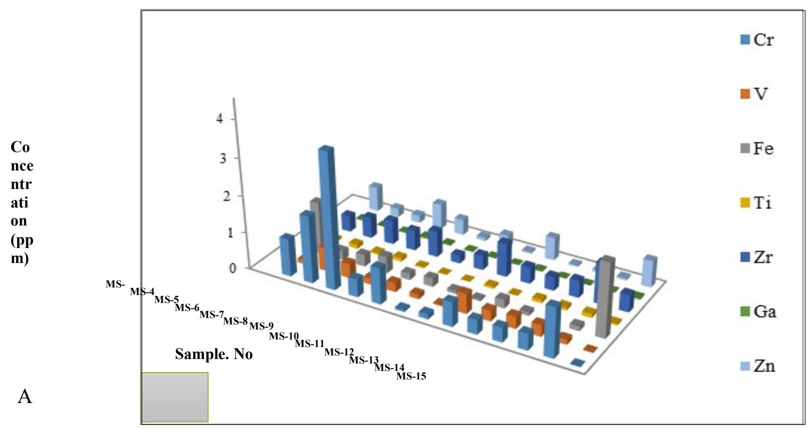


Figure 3. Trace elements variation diagram of spinel from Man Sin mine

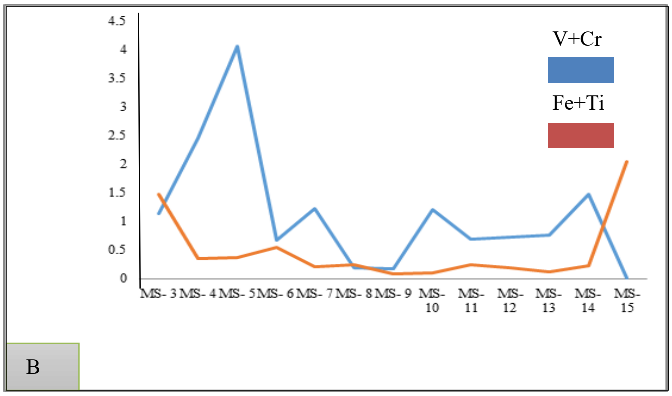


Figure 4. V+Cr and Fe+Ti plot indicates that they are negatively associated for the colour variation in Man Sin spinel

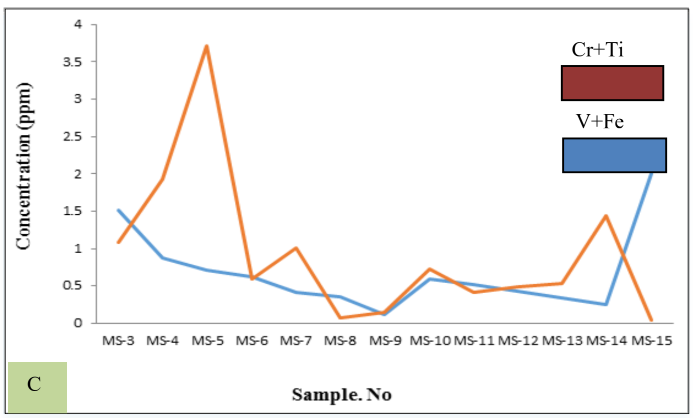


Figure 5. Cr+Ti and V+Feplot indicates that they are negatively associated for the colour variation in Man Sin spinel

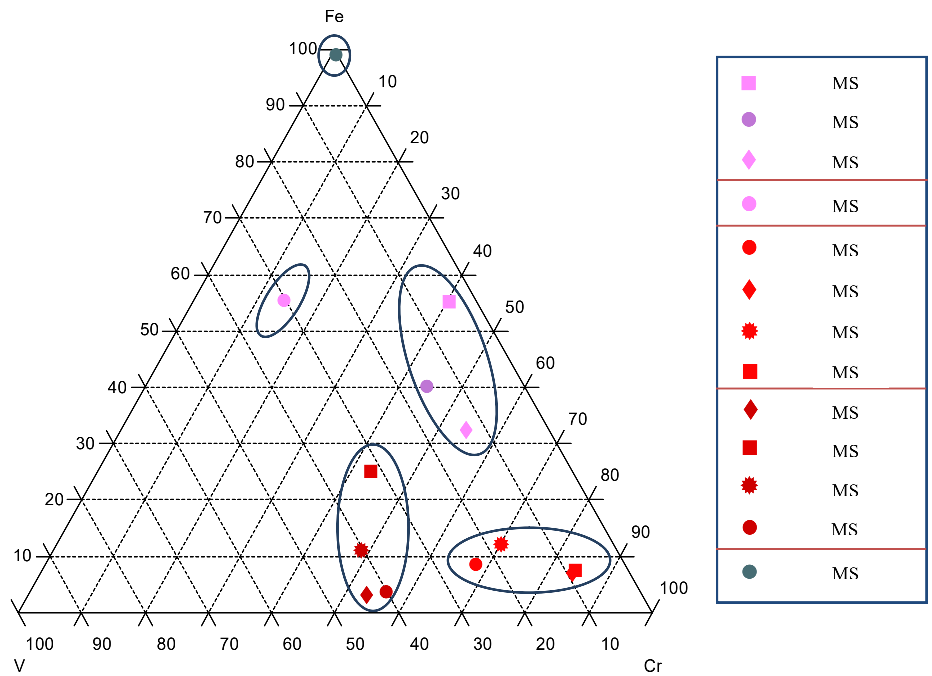


Figure6. Fe- V- Cr Ternary diagram showing increasing Cr contents in red spinel with two groups, and increasing Fe content in pink spinel with Cr rich and V rich groups and higher Fe concentration in greenish blue spinel from Man Sin mine. See also Table 1.

The present study typically indicates that Cr content is higher than V and Fe contents in red to pink spinel, but more Fe content in greenish blue spinel. According to chemical analyses and Ternary diagram, the colour of Man Sin spinel depends on Cr with minor influence of V and Fe.

Moreover, trace elements (V, Fe, Ga, Zr, Zn and Ti) versus Crvariation diagrams also explain the correlation of these elements in the Man Sin spinel (Fig. 7 A-E). In these diagram, trace elements (V, Ti and Zr) are positively associated with Cr but other trace elements such as Fe, Ga and Zn are negatively associated with Cr, which display increase in Cr content with decrease in Fe, Ga and Zn contents.

Comparison of Man Sin Spinel with HtanyanShoSpinel

The comparison of trace elements (Cr, V, Fe and Ti) of spinel from Man Sin with HtayanSho is shown in Table 2.

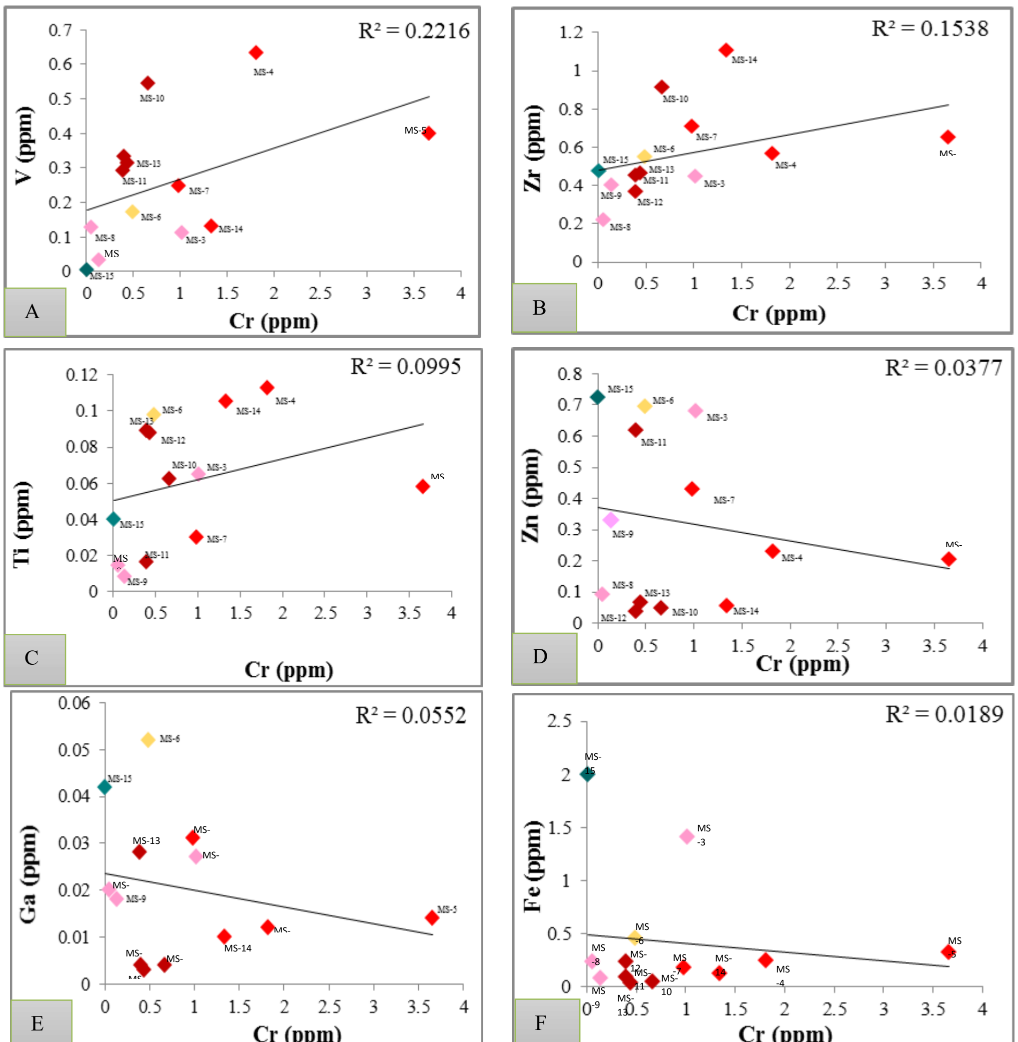


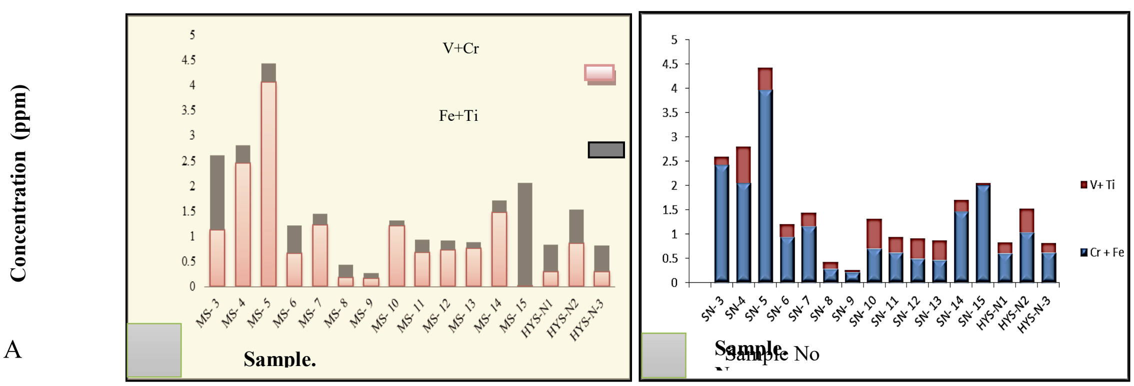
Figure 7. (A-E)Variation diagrams of Cr vstrace elements in Man Sin spinel

In the variation diagram, the concentration of trace elements Fe+Ti and V+Cr are used to interpret the colour variation of spinel from two mine sites(Fig. 8 A, B). This diagram shows that colour variation in Man Sin mine has higher concentration of Cr with V contents than those of HtayanSho mine but the amount Fe with Ti concentrations are less.

Fe- V- Cr Ternary diagram shows that the increasing amount of Cr content with decreasing amount of Fe and V contents in red to pink spinel from Man Sin mine than Htanyan Sho mine (Fig. 9). Spinel from Htayan Sho mine indicates that Fe content is (> 40 ppm) and the amount of V and Cr contents are (< 60 ppm).

Table 2. Comparison of Trace Elements (Cr, V, Fe and Ti) of Man Sin Spinel and Htayan Sho Spinel

Mine Site		Man Sin												Htayan Sho		
Sample. No	MS-4	MS- 5	MS-7	MS-14	MS-10	MS-11	MS-12	MS-13	MS- 3	MS- 8	MS- 9	MS- 6	MS- 15	HYS-N1	HYS-N2	HYS-N3
Location (UTM 47Q KF)	481425													478414		
Colour / Elements (ppm)	Red	Red	Red	Red	Deep Red	Deep Red	Deep Red	Deep Red	Pink	Pale Pink	Pink	Purple	Green-ish Blue	Red	Orange Red	Purple
Cr	1.82	3.66	0.985	1.341	0.666	0.395	0.4	0.442	1.019	0.058	0.138	0.493	0.008	0.413	0.116	0.142
V	0.633	0.398	0.248	0.132	0.543	0.292	0.333	0.315	0.113	0.127	0.033	0.171	0.005	0.449	0.180	0.156
Fe	0.239	0.317	0.174	0.124	0.044	0.234	0.093	0.03	1.406	0.233	0.083	0.45	2	0.625	0.497	0.484
Ti	0.113	0.058	0.03	0.105	0.062	0.016	0.089	0.088	0.065	0.014	0.008	0.098	0.04	0.04	0.034	0.031



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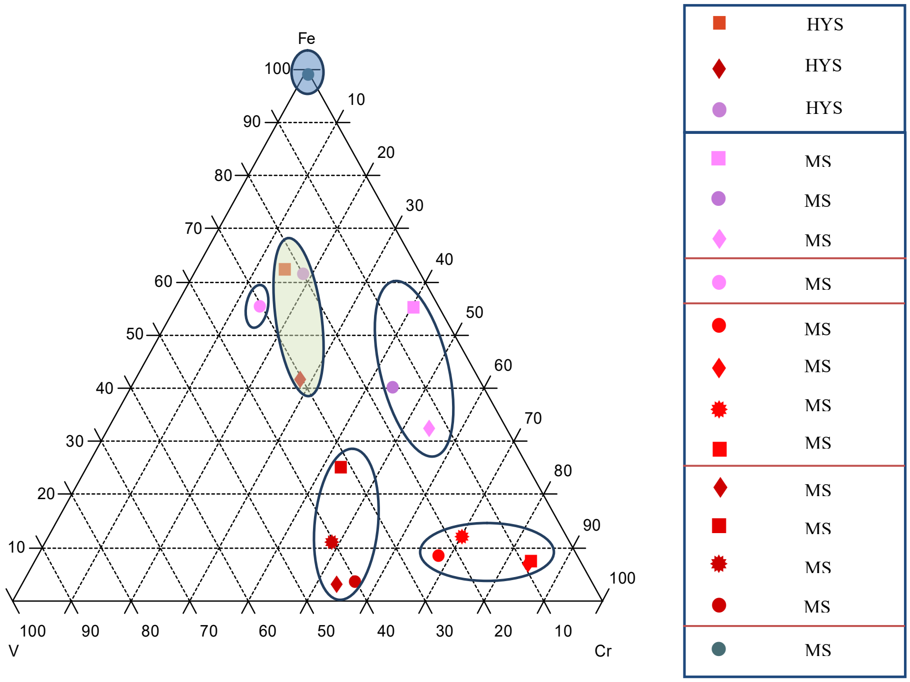

Figure 9. Fe- V- Cr Ternary diagram of Man Sin and HtayanSho spinel. See also Table 2

Conclusions

Spinel deposits are located from central to south east Asia and associated within the Himalayan mountain belt which was formed by continental collision between the India and Eurasia during the Tertiary. Spinel was formed both mafic igneous rocksand metamorphic rocks which occurred in carbonate series and underwent high temperature amphibolite to lower granulite grade regional metamorphism (Malsy & Klemm; 2010). The spinel is formed at temperatures 600˚- 700˚C. Depending on the amount of magnesium which played an important factor for colouring during the genesis of spinel. Spinel would form when magnesium exceeds aluminium (Themelis, 2009).

At Mogok, spinel was formed as a result of contact metamorphism or skarnmetasomatism within regionally metamorphosed basement rocks where the presence of fluids played an important role (Iyer, 1953; Themelis, 2009). Spinel occurs within a relatively narrow aluminium rich layer in the marble. It is very resistant to chemical and physical weathering but its host marble is much less resistant to weathering. Therefore spinel is easily liberated from the marble and transported by streams and occurred as alluvial deposits.

Jedi spinel (Hot spinel) was first discovered at Man Sin mine in 2009. This mine produces varieties coloured spinel, but most of them are intense red spinel and principally Jedi spinel (Hot spinel*)* (Pardieu, 2014). Moreover, it is an only active source for hot spinel in Mogok. At Man Sin, spinel occurs as porphyroblasts in marble as primary deposit and also excavated from gem-bearing gravel in alluvial (secondary deposit). The primary rocks were clayey limestones and calcic limestones. They may become dolomitic limestone by metamorphism (Gübelin & Koivula, 2005) where, high temperature regional metamorphism and then larger- scale transformation of carbonate rocks, high mobilization and migration of many chemical elements containing Al and Cr in the dynamothermal metamorphism of carbonate rocks (Kisin et al., 2016) occurred.

The formation of Man Sin spinel in the marble is due to the presence of certain amount of magnesium in the spinel- graphite marble. Graphite and spinel association in the marble indicates that this marble (limestone for the protolith) was deposited in the carbon and magnesium rich environment.

The chemical analyses indicate that the constraint on the attractive colour of Man Sin Hot spinel is Cr rather than other trace elements such as V and Fe; pink and purple spinel are due to the concentration of both Fe and Cr, V and Ti and the green spinel is due to Fe. Conversely, red spinel from HtanyanShois due to the average concentration of Fe and V rather than Cr and the purple spinel from HtayanSho is due to higher concentration of Fe than V respectively.

Acknowledgement

We are very grateful to Prof. Dr. Daywa Aung, (Head of Geology Department, Yangon University) for his permission to carry out the investigation of this area. We would like to extend our sincere thanks to Prof. Dr. Phyu Phyu Lwin, (Head of Geology Department (Retired), Dagon University) and Prof. Dr. Cho Cho Aye, (Head of Geology Department, East Yangon University) for their encouragement and advice. Thanks are also extended to Major Aung Nyunt Thein, Managing Director, Myanma Gems Enterprise, Nay Pyi Taw, U Hla Aung (Assistant Director), U Win Htay (Deputy Director) and Major Aung Kyaw Moe (Assistant Director), Major Tun Wai (Assistant Director)and all staffs from Myanma Gems Enterprise, Mogok for their help. Dr. Ye Myint Swe, (Director General, DGSE), for his permission on XRF measurement and also thanks are extend to Daw Ye Ye Mon (F.G.A, London), (Former Research Officer, Myanmar Gems and Jewellery Entrepreneur's Association Lab.) for EDXRF Analyses. We are very grateful to U Kyaw Thu and U Si Thu (Directors of “Mani Yadanar Aung” gems and jewellery Co.Ltd.) and UAungNaing Win (Director of “Nanda Aung” Co. Ltd.)and U Than Naing (Chairman, San Taw Win Co.Ltd.)for their kind permission to study in the mine and collected gem samples.

The last author is also grateful to Dr. Kyaw Thu for his advice and deeply thankful to Dr. Kyaw Khaing Win for his help in her field works, providing valuable advice and discussion. She also would like to extend her sincere thanks to Dr. Myat Thuzar Soe, Director, (AGD), Prof. Dr. Ohn Thwin, (Rtd), Dr. Su Su Hlaing and Dr. Aung Zaw Myint (Lecturers, Geology Department, Yangon University) and Dr Tin Myint Oo (Lecturer, Geology Department, AGD), Dr. Win Min Oo, (Lecturer, East Yangon University) and Dr.Mi Paik (Lecturer, Sittway University)for their advice, helpful suggestions and comments. Last, but not least, Mg Zaw Hteik for map preparation and Mg Myo Myint Tun, Mg Min Ye Kyaw, and Ko Phyu Phwe (Mogok) for their indefagtigable help during the field work are acknowledged.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No. 5**

GEOLOGY AND PETROGRAPHY OF IGNEOUS ROCKS IN ANDIN AREA, YE TOWNSHIP

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Abstract

The study area is located in the northwestern part of Ye Township, Mon State. The area coverage is about 35.84 square kilometres in one inch topographic map No. 95 E/15. The igneous rock units are generally trending NNW-SSE. Diorite is found along the shore-line. Porphyritic biotite granite is the most abundant rock type and well exposed in the central part. Biotite granite is second abundant rock type. It occurs in the southern part of the study area. Biotite microgranite exposed at the Phalaing Taung. Microdiorite is found as dyke which intruding the porphyritic biotite granite. Lamprophyre dyke is intruding porphyritic biotite granite and biotite microgranite. Quartzofeldspathic vein and quartz vein are also intruding older rock units. Hypidiomorphic granular texture is found occurs in diorite, porphyritic biotite granite, biotite granite and biotite microgranite. Panidiomorphic granular texture is observed in lamprophyre. Quartz, orthoclase, microcline and biotite are major components in granitic rocks. Muscovite, zircon, apatite, epidote, sphene and magnetite are found as accessory minerals. According to modal analysis of I.U.G.S classification diagram, diorite falls in the quartz-monzodiorite field. Porphyritic biotite granite, and biotite granite, and biotite microgranite falls in the syeno-granite and monzo-granite fields. Igneous rocks can be used as decorative stones, construction and road materials.

Key word:Diorite, porphyritic biotite granite, biotitemicrogranite, microdiorite dyke, lamprophyre dyke

Introduction

The study area is located in the northwestern part of Ye Township, Mon State. The approximate length, east to west is about 6.4 km and width is about 5.6 km from north to south. The area coverage is about 35.84 square kilometres in one inch topographic map No.95 E/15. The location map of the study area is shown in Figure (1). The highest peak is

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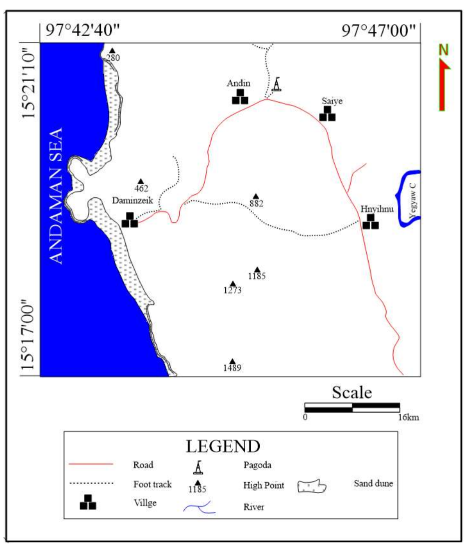
Taungchon Taung (1489m). Physiography of the study area is shown by 3D modelling in Figure (2). The study area is a highly rugged terrain with locally thick soil and dense vegetation. The main stream is Yegyaw Chaung which flows from west to east. Phalein Chaung flows from west to east and finally enters the Andaman Sea. The drainage pattern of the study area is dendritic with medium to coarse texture.

Regional Geologic Setting of the Study Area

The study area lies in the southern continuation of the Shan Tanintharyi Block of Maung Thein (2000). The regional geological map of study area and its environs were taken from Myanmar Geosciences Society, 2014 and is shown in Figure (3). The granitoid plutons intrudedthe metasedimentary rocks of the Mergui Group, Chhibber (1934). These granitoids were possibly emplaced during the Late Mesozoic and Early Eocene (Khin Zaw, 1990). It is mainly composed of granitoid rocks such as granite and granodiorite. These granitoid rocks intruded sedimentary and metasedimentary rocks of Mergui Group which is possibly regarded as the Carboniferous-Late Permian (Win Swe, 2012) according to the stratigraphic correlation and relationship. The general structural trend of the study area is NNW-SSE. Thegranitoid rocks in the study area consist of diorite, porphyritic biotite granite, biotite granite, biotite microgranite, microdiorite dyke, lamprophyre dyke, quartzofeldspathic vein and quartz veins.



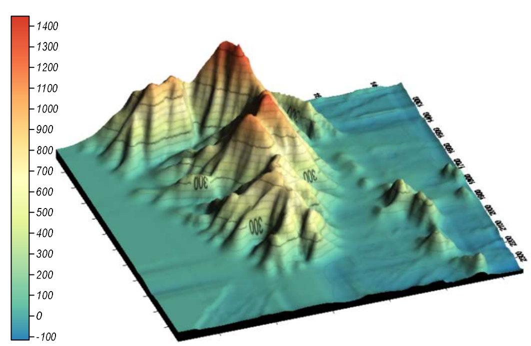


Figure 1. Location map of the study area **Figure 2.** The physiography of the study area

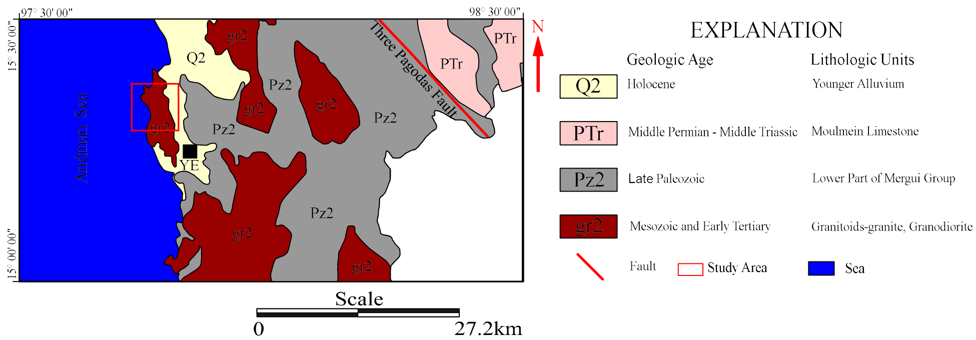


Figure 3. Regional geological map of the study area and its environs (After Geological Map of Myanmar Geosciences Society, 2014)

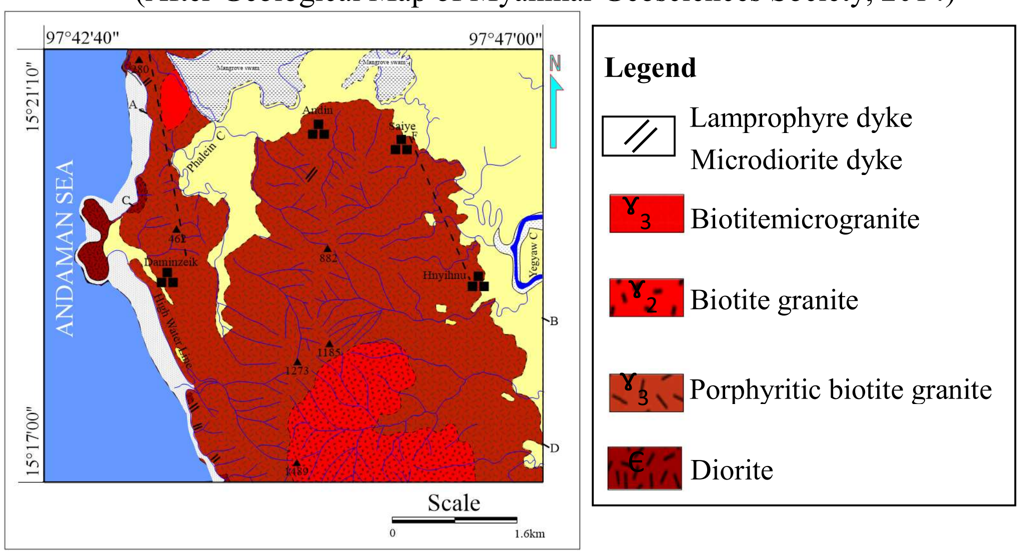


Figure 4. Geological Map of the Andin Area, Ye Township

Geology of Andin Area

The study area is mainly composed of igneous rocks. They are diorite, porphyritic biotite granite, biotite granite and biotite microgranite. Microdiorite dyke, lamprophyre dyke, quartzofeldspathic veins and quartz veins intruded the older granitoid rocks.

Diorite is exposed along the shore-line, especially in the western part of the study area. It is well exposed and minor faults cut across it.

Porphyritic biotite granite is the most abundant and widely distributed in the study area. It is well exposed in the northwestern part of Tharkayan Taung area. Most of the outcrops are highly jointed. It occurs not only as large massive boulders but also as highly weathered outcrops along the shore-line. Randomly oriented feldspar phenocrystsare found in porphyritic biotite granite. Some are gradually transformed into laterite. **Biotite granite** is well exposed in the southern part of the study area. Large massive boulders with exfoliation weathering features are common. **Biotitemicrogranite** is exposed in the northeastern and eastern part of the study area. It shows sheeted joint nature due to tidal wave erosional effect along the shore-line. It also intruded porphyritic biotite granite. **Microdiorite** occurs as dyke intruding porphyritic biotite granite unit. **Lamprophyre dykes** are trending nearly NE-SW. It intruded porphyritic biotite granite. Geological Map of The Andin Area is shown in Figure (4). Outcrop natures of each rock unit are shown in Figure (5).

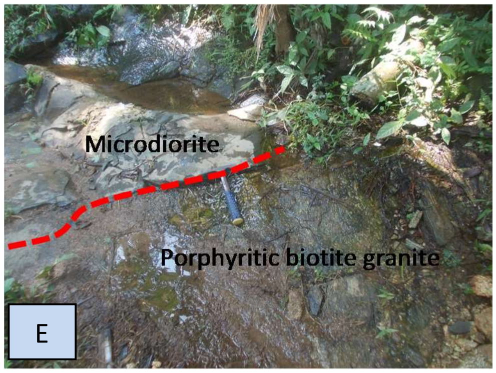


Figure (5) (A) Diorite outcrop along the shore-line (Looking-220°)
(B) Randomly oriented feldspar phenocrysts in porphyritic biotite granite
(C) Exfoliation nature of biotite granite
(D) Sheeted nature of biotitemicrogranite at the shore-line
(E) Contact of microdiorite and porphyritic biotite granite in the northern part of the study area
(F) Lamprophyre dyke intruding porphyritic biotite granite. (15° 20′ 17.0″ N, 97° 45′ 06.5″ E)

Field Relationship of Igneous Rocks in the Study Area

The rock sequence of the study area is recognized from the field relationships of some igneous rocks. Biotite microgranite intruded porphyritic biotite granite in the southeastern part of the study area. It indicates that porphyritic biotite granite is older than biotitemicrogranite, Figure (6) (A). Biotite microgranite intruded diorite in northwestern part of the study area,indicating that diorite is older than biotite mocrogranite, Figure (6) (B). Diorite xenoliths occur in biotite microgranite in the northwestern part of the study area. This indicates that diorite is older than biotite microgranite, Figure (6) (C). Lamprophyre dyke intruded porphyritic biotite granite and diorite in the western part of the study area. This indicates that porphyritic biotite granite and diorite are older than lamprophyre dyke, Figure (6) (D).

Figure 6 (A) Biotite microgranite intruding porphyritic biotite granite

(B) Biotite microgranite intruding diorite

(C) Diorite xenoliths in porphyritic biotite granite

(D) Lamprophyre dyke intruding diorite

Rock Sequence of the Study Area

The rock sequence of the study area is established on the basis of the field relationship and lithologic characters.

Rock Type	**Possible Age**
	(After Su Su Hlaing, 2014)
alluvium	- Quaternary

Veins and dykes

Quartzofeldspathic vein and Quartz vein

Lamprophyre dyke

Microdiorite dyke

Igneous Rock

Biotitemicrogranite

Biotite granite

Porphyritic biotite granite

Diorite

Paleocene

- Older thanPaleocene

Petrography of Igneous Rocks

Diorite has coarse-grained, hypidiomorphic granular texture. It is mainly composed of hornblende, plagioclase and subordinate amount of biotite, orthoclase and quartz. Sphene, zircon, apatite, epidote and magnetite occur as accessory minerals. The grain size of plagioclase is about 0.3mm to 1mm in diameter. The composition range of plagioclase is An_{34} to An_{45} (andesine). Plagioclase feldspar is altered to clay minerals at the core, Figure (7) (A). Twin bands are slightly bent due to deformation, Figure (7) (C). Apatite occurs as inclusion in plagioclase, Figure (7) (B). Hornblende occurs as subhedral to anhedral grains and the grain size varies from 0.3mm to 2mm in diameter. It is the chief ferromagnesium mineral in diorite. Sometimes, it shows simple contact twinning. Zircon and opaque minerals also occur as inclusios in hornblende crystals. Biotite occurs as small flakes and displays light yellow, pale brown to dark brown pleochroic colours. Quartz occurs as interstitial grains within hornblende and plagioclase. Some biotite are altered to chlorite. Orthoclase and microcline are present in small amounts and occur as anhedral grains. Sphene displays subhedral form and high relief. Myrmekitic worm-like bodies of quartz are found along the edge of plagioclase. Zircon, sphene, apatite, and magnetite occur as accessory minerals, Figure (7) (D).

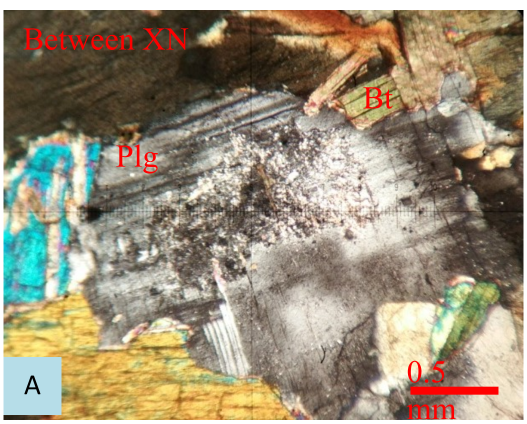
Porphyritic biotitegranite is coarse-grained with hypidiomorphic granular texture and porphyritic texture. It is mainly composed of alkalifeldspar as phenocrysts, orthoclase, microcline, perthite, quartz, plagioclase and biotite. The accessory minerals consist of zircon, muscovite, apatite, sericite and magnetite. Alkalifeldspar comprise orthoclase, perthitic orthoclase, Figure (7) (E) and microcline. The grain size varies from 3mm to 6mm in diameter. Orthoclase is subhedral in form and shows simple contact twin. Most of orthoclase is altered to sericite, Figure (7) (F). Perthitic texture is formed by the intergrowth of alkalifeldspar and albite. Some microcline arefound as large phenocrysts. The grain size of plagioclase feldspar varies from 2mm to 5mm in diameter. The composition range of plagioclase is An_{10-12} (albite to oligoclase). Quartz usually occurs as anhedralgrains and shows undulatory extinction. The aggregates of very small anhedral grains along the margin of large grains are found as garland. It is the characteristic effect of stress. Biotite occurs in subhedral form and the grain size varies from 0.2mm to 1mm. It shows strong pleochroism from yellow to dark brown. Zircon occurs as inclusions in orthoclase. Hornblende occurs insubhedral form and shows pleochroism from dark green to yellow. Sphene shows neutral colour, subhedral and very high relief under PPL. Myrmekitic texture is the intergrowth of quartz and alkalifeldspar. Zircon, sphene and magnetite occur as accessory minerals.

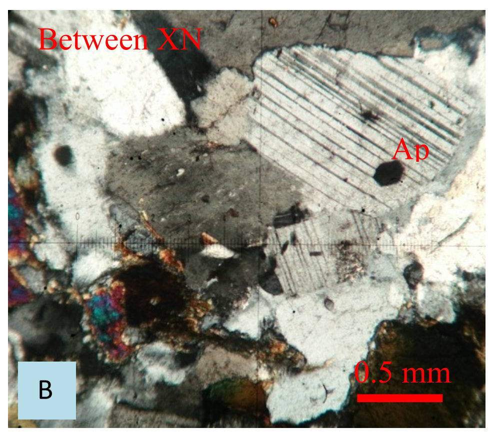
Biotite granite is coarse-grained with hypidiomorphic granular texture. It is mainly composed of orthoclase, microcline, quartz, plagioclase and biotite. The accessory minerals consist of zircon, apatite, hornblende and magnetite. Most of the alkali feldspar is represented by orthoclase and microcline. Orthoclase shows simple contact twin, Figure (8) (A). Microcline is in subhedral form and displays cross-hatched twin. Quartz is found inanhedral form and the grain size varies from 2mm to 6mm in diameter. It shows wavy extinction and sometimes displays suture contact. Plagioclase feldspar displays good polysynthetic twinning and twin bands are closely spaced. The composition range of plagioclase is An_{9-10} (Albite). Some twin bands are bent due to deformation, Figure (8) (B). Biotite is in subhedral form and shows light yellow and pale brown and dark brown pleochroiccolours. Biotite occurs insubhedral flaky form having 0.5mm to 2mm in diameter. In some sections, it commonly altered to chlorite along the cleavage planes.

Zircon displays high relief and pleochroic haloes and occurs as inclusions in biotite, Figure (8) (C). Accessory minerals comprise zircon, apatite, sphene and magnetite.

Biotite microgranite is medium-grained with allotriomorphic granular texture, Figure (8) (D) and equigranular in nature. It is mainly composed of quartz, orthoclase, plagioclase, microcline and biotite. Accessory minerals consist of sphene, zircon and muscovite. Quartz grains show undulose extinction and anhedral form. Alkali feldspar is represented by orthoclase, microcline and perthite. It shows subhedral to anhedral form and the grain size varies from 1mm in diameter. Biotite displays subhedral flaky form and 0.2mm to 0.5mm in diameter. It shows yellowish to dark brown in pleochroism. Plagioclase showssubhedral form and the grain size varies from 0.2mm to 1mm in diameter, Figure (8) (E). The composition range of plagioclase is An_{8-10} (Albite). Myrmekite texture is formed by the intergrowth of quartz and alkalifeldspar. Zircon occurs as inclusions in alkalifeldspar, Figure (8) (F).

Microdiorite has medium-grained, hypidiomorphic granular texture. It is composed of plagioclase, hornblende, biotite, quartz, orthoclase and magnetite. Plagioclase occurs in subhedral form and grain size varies from 0.1mm to 1mm in diameter. The composition range of plagioclase is An_{32} (oligoclase to andesine). Euhedral zoned plagioclase is found in





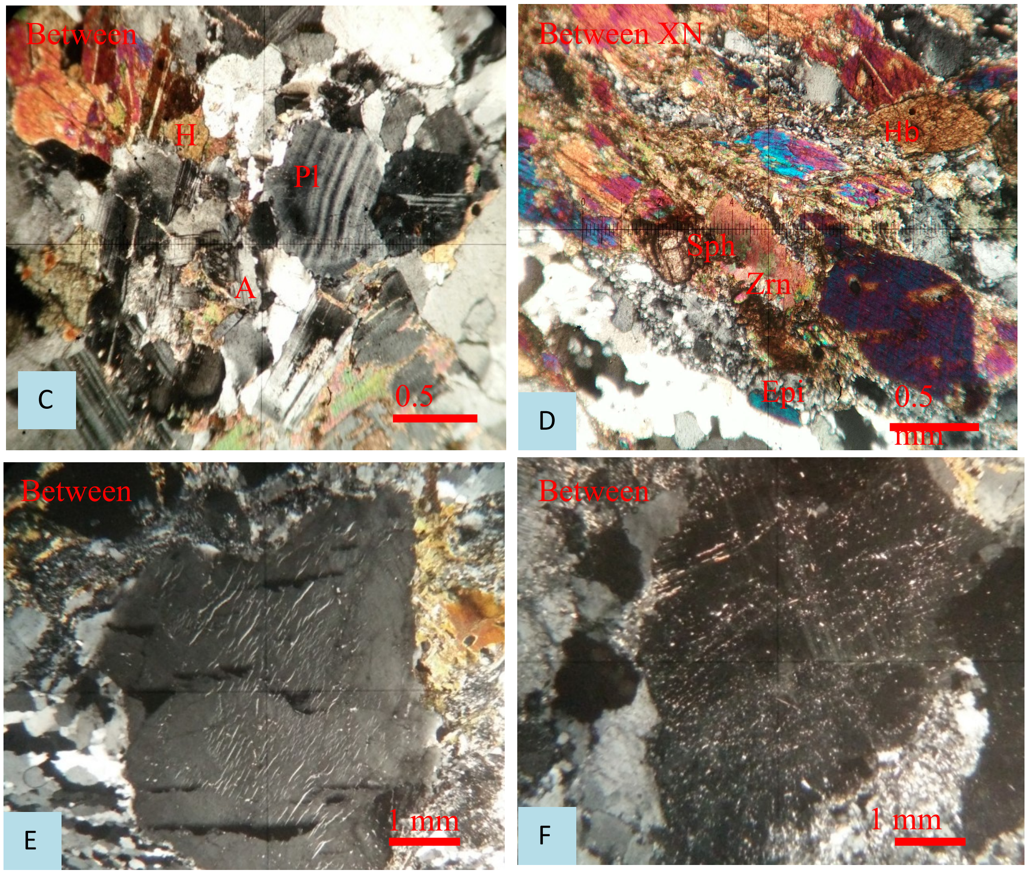


Figure 7: (A) Plagioclase altered to clay minerals in diorite

(B) Apatite inclusions in plagioclase in diorite

(C) Plagioclase twins bent due to deformation in diorite

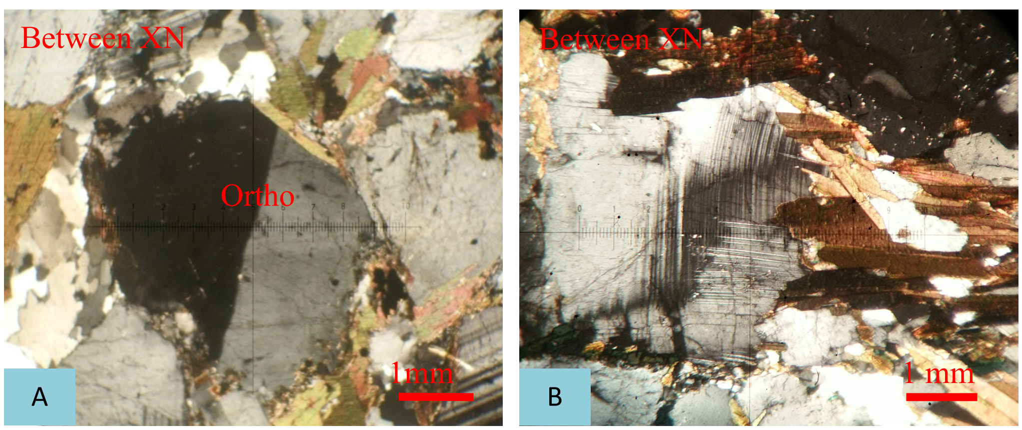
(D) Sphene, zircon, hornblende occurring in diorite

(E) Perthite in porphyritic biotite granite

(F) Orthoclase altered to sericite in porphyritic biotite granite.

Figure (9) (A). Hornblende occurs as anhedral, Figure (9) (B) and showing strong pleochroism from yellowish brown to yellowish green in color. Biotite occurs as subhedral form and grain size varies from 0.1mm to 0.3mm in diameter. It shows pleochroic from yellowish brown to greenish brown. Quartz grains occur as anhedral crystals and wavy extinction. Zircon, sphene and magnetite occur as accessory minerals.

Lamprophyre is medium-grained, panidiomorphic granular texture and porphyritic texture. It is mainly composed of hornblende and plagioclase. Epidote, zircon, apatite and pyrite occur as accessory minerals. Euhedral hornblende occurs as phenocryst in fine to medium-grained groundmass. Six-sided basal hornblende crystals are also found in Figure (9) (C, D). Some hornblende shows simple contact twin and as long prismatic crystals. Euhedral plagioclase occurs as lath-shaped and as phenocrysts in Figure (9) (E). Zircon occurs as sub-rounded form and very high relief. It has second-order interference color and pleochroic haloes. Pyrite occurs as four-sided euhedral crystals, Figure (9) (F).



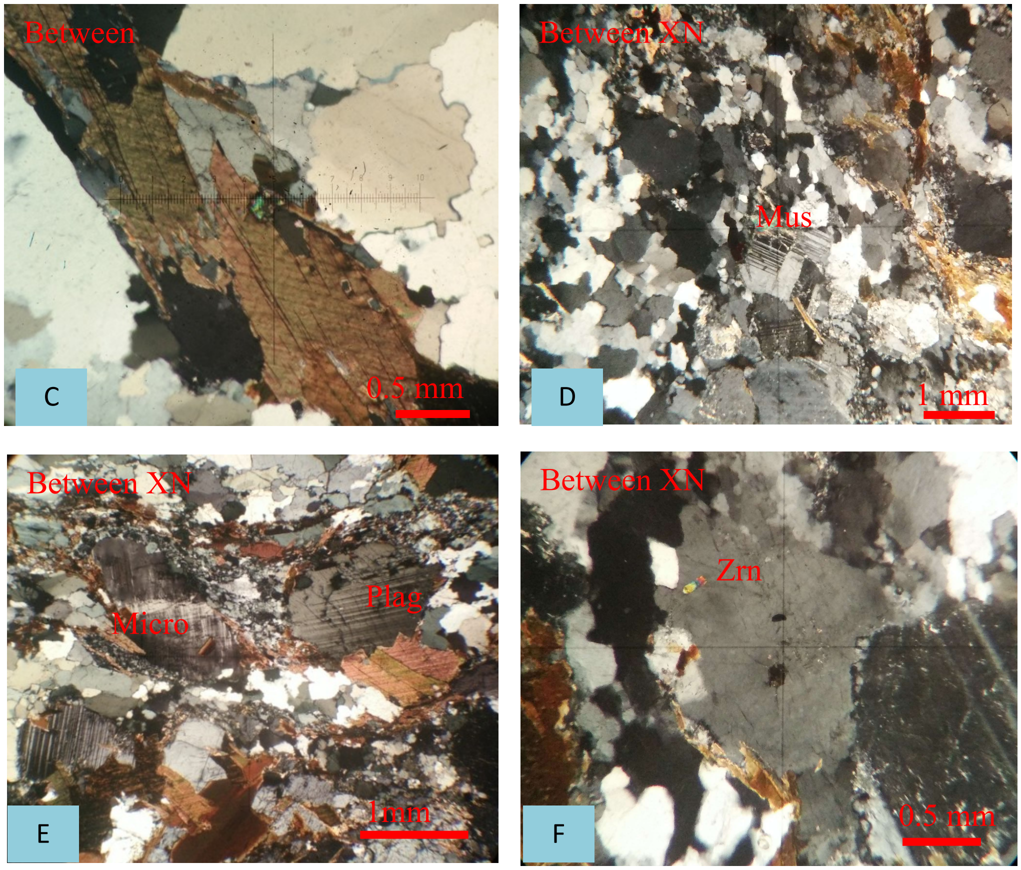


Figure 8: (A) Simple twin orthoclase in biotite granite.

(B) Plagioclase in biotite granite.

(C) Zircon inclusionsbiotite in biotite granite.

(D) Allotriomorphic granular texture in biotitemicrogranite.

(E) Plagioclase, microcline and biotite in biotitemicrogranite.

(F) Zircon inclusions in alkalifeldspar in biotitemicrogranite.

Figure 9: (A) Biotite and plagioclase in microdiorite
(B) Anhedral hornblende in microdiorite
(C, D) Euhedral and twinned basal section hornblende in lamprophyre
(E) Euhedral zoned plagioclase in lamprophyre
(F) Euhedral four-sided pyrite mineral in lamprophyre

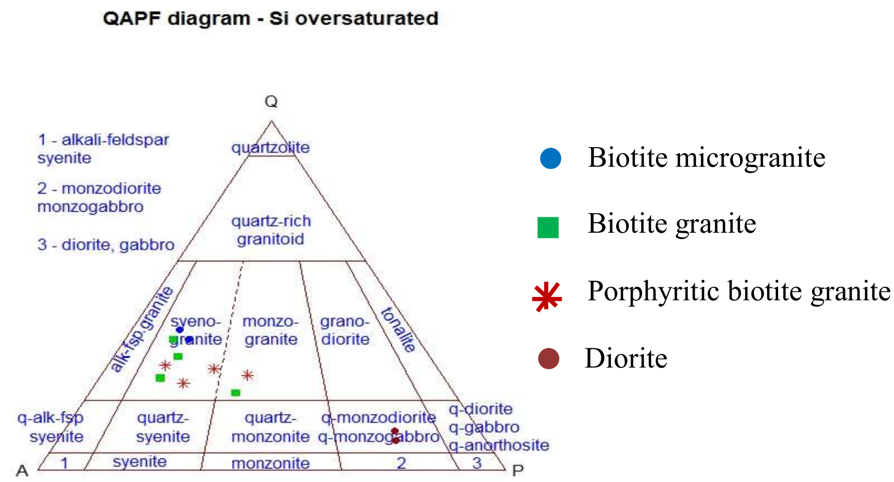


Figure 10: Plotted data of the igneous rocks of the study area (Source; IUGS Classification, Streekeisen, 1974)

Summary and Conclusion

The study area is mainly underlain by of igneous rocks. The igneous rock units consist of diorite, porphyritic biotite granite, biotite granite, biotite microgranite, microdiorite dykes, lamprophyre dykes, quartzofeldspathic veins and quartz veins. The modal composition of granitoid rocks in the study area are plotted on the IUGS classification diagram as shown in Figure (10). According this diagram, diorite falls in the quarz-monzodiorite field. Porphyritic biotite granite, biotite granite and biotite microgranite falls in the syeno-granite field and monzo-granite field. Diorite is found in the western part of the study area and mainly composed of hornblende, plagioclase and biotite. Porphyritic biotite granite is widely distributed in the northern part of the study area. It is mainly composed of quartz, orthoclase, plagioclase and biotite. Biotite granite is found in the southern part of the study area. It is mainly composed of orthoclase, quartz, plagioclase and biotite. Microdiorite dykes intruded porphyritic biotite granite. Lamprophyre dykes are mostly fine-grained and mainly composed of plagioclase and hornblende. Lamprophyre dykes intruded porphyritic biotite granite and diorite. They are mainly composed of hornblende and plagioclase. Quartzofeldspathic veins and quartz veins intruded the older rock units. Petrographically, hypidiomorphic granular texture in porphyritic biotite granite and biotite granite, allotriomorphic granular texture in biotite microgranite and panidiomorphic granular texture in lamprophyre are encountered in the study area. Granites from the study area can be used as decorative stones, dimension stones, construction and road materials.

Acknowledgements

The author would like to express her sincere thanks to Dr. Day Wa Aung, Professor and Head of the Geology Department, University of Yangon, Dr. Htay Lwin and Dr. Thet Tin Nyunt, Professors, Geology Department, University of Yangon for their permission and valuable administrative supports.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

STUDY ON MORPHOLOGICAL CHANGE OF AYEYARWADY RIVER FROM PYAY TO HINTHADA

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Abstract

River morphology has been a subject of great challenge to scientists. It is based on a proper understanding of the morphological features and changes. In this paper, an overview of river morphology is presented from the geomorphic viewpoint. The main aim is to describe river channels shape and how they change overtime. This study examines the morphological change of Ayeyarwady River from Pyay to Hinthada segment by using Geographic Information Systems (GIS) technique. Channel pattern and channel movement, channel bar formation and morphology of point-bar have been identified using a time series images from Google Earth Engine (2015, 2011, 2006, 2001, 1996 and 1991). Settlement areas are also extracted from topographic maps of 1945 and 2002. ArcGIS is used for visual screen digitizing and to obtain accurate information about river channel movement.

Key words: Ayeyarwady River, channel pattern, channel movement, channel bar formation

Introduction

The Ayeyarwady River is the major drainage basin and course life artery of the Union of Myanmar, running generally north-south reflecting the trend of the mountain ranges of the country. According to F. Bender (1983), the Ayeyarwady has a length of 2010 kilometers (1246.2 miles) and a catchment area covering 415700 sq.km (162123 sq-ml).In this paper, study area defines from Pyay to Hinthada along the Ayeyarwady River course. It is about over 205 km long.

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Aim and Objectives

The main aim of this paper is to describe river channels shape and how they change over time. Major objectives are to identify channel pattern and channel movement, to examine the formation of channel-bar within the river course and to assess channel bank erosion within the study area.

Materials and Methods

Based on satellite image quality and availability the primary data were used TM and ETM+ sensor of Landsat satellite for four and five different years. Settlement areas are extracted from topographic maps of 1945 and 2002.

Satellite	Sensor	Month/Year
Landsat 5	TM	March, 1991 March, 1996 March, 2001
Landsat 7	ETM+	March, 2006 March, 2011
Landsat 8	OLI	March, 2015
Topographic Map		1945 and 2002

Main channel, channel-bar and channel bank erosion data is derived from Google Earth Engine (GEE) by using the Normalized Differenced Water Index (NDWI).The NDWI maximizes reflectance of water by using green band wavelengths and minimizes low reflectance of NIR by absorbing maximum of wavelength. As a result, water features are enhanced owing to having positive values and vegetation and soil are suppressed due to having zero or negative values. ArcGIS is used for visual screen digitizing and to obtain accurate information about river channel movement. Our Space eye product uses the near-infrared and green spectral bands from **various satellites** (Landsat 8 OLI, Landsat 7 ETM+ and Landsat 5 TM) to calculate the NDWI with the following formulas:

$$NDWI_{L8} = \frac{Band_3 - Band_5}{Band_3 + Band_5} \quad \text{Landsat 8 OLI}$$

$$NDWI_{L5} = \frac{Band_2 - Band_4}{Band_2 + Band_4} \quad \text{Landsat 5 TM}$$

Results and Discussion

1. Classification of Channel Pattern along the Course

Channel morphology is three-dimensional, cross-section; plan-form and long-profile properties constituting the complete morphology are closely interrelated: to emphasize one dimension alone is to achieve only a particular understanding. Wide, shallow cross-sections are associated with braided patterns, and meandering streams have lower gradient than straight channels between the same two end points.

Theoretically, morphological variables of alluvial channel are: Cross-section (width, mean depth, maximum depth, channel capacity, wetted parameter and hydraulic radius, form ratio, selection asymmetry, and selection roughness), Plan –form (axial wavelength, arc wavelength, bend amplitude, arc height, radius of curvature, radius: width ratio, sinuosity, index, index and braided intensity), long-profile: (profile gradient, Taylor-Schwartz slope, profile concavity, bed slope, water surface slope, floodplain wavelength, and bed-form amplitude) (Richard, K., 1982).

In this paper the emphasis is on the plan-form especially on sinuosity along the Pyay to Hinthada segment of Ayeyarwady River course. These parameter exhibits shape and lateral development of band of alluvial channel.

The ratio between the measured length of a stream channel and that of the thalweg of its valley is measure of its sinuosity. Sinuosity ratio P is 1.0 for straight channel, 1.2 for transitional between straight and regular, 1.5 for regular channel, 1.7 for irregular channel and 2.1 for tortuous (Chorley, R.J., 1984).

From Pyay to Hinthada segment of Ayeyarwady River's straight line length of main channel is 165.44 km and thalweg line length is 205.97 km for the year 1991. Therefore sinuosity ratio is 1.24. In 1996, thalweg line length becomes 209.29 km and sinuosity ratio is 1.26. In 2001, 2006, 2011 and 2015 thalweg line length is 205.61 km, 214.69 km, 213.66 km and 220.82 km respectively. So, sinuosity ratio is 1.24, 1.29, 1.29 and 1.33. Generally, channel pattern between Pyay to Hinthada segment is transitional between straight and regular as shown in Table 1.

Table 1. Sinuosity ratio and channel pattern along Pyay to Hinthada segment

Year	Straight channel length (km)	Thalweg line length (km)	Sinuosity ratio	Channel pattern
1991	165.44	205.97	1.24	transitional
1996	165.44	209.29	1.26	transitional
2001	165.44	205.61	1.24	transitional
2006	165.44	214.69	1.29	transitional
2011	165.44	213.66	1.29	transitional
2015	165.44	220.92	1.33	transitional

Source: Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

For more detail study, Pyay to Hinthada segment is subdivided into four segments from north to south, namely such as segment 1, 2, 3 and 4. Length of segment 1, 2 and 3 are 50km and segment 4 is 55.619 km respectively as shown in Figure 1.

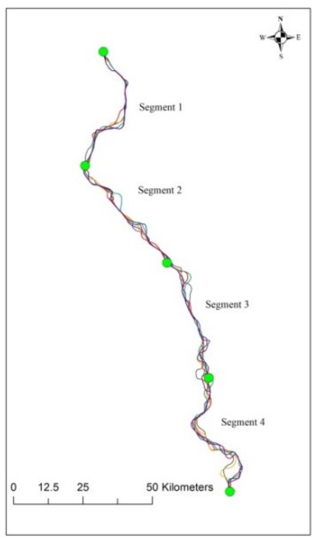


Figure1 Channel segment of study area
Source: Lansat 5, 7 and 8 satellite imagery

According to Table 2, channel pattern of segment 1 is transitional between straight and regular. Sinuosity ratio is gradually increased within 25 years as shown in Figure 2.

Table 2. Sinuosity ratio and channel pattern of segment 1

Year	Straight channel length (km)	Thalweg line length (km)	Sinuosity ratio	Channel pattern
1991	41.70	51.12	1.22	transitional
1996	41.70	51.98	1.24	transitional
2001	41.70	50.09	1.20	transitional
2006	41.70	52.34	1.25	transitional
2011	41.70	53.81	1.29	transitional
2015	41.70	55.63	1.33	transitional

Source: Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

According to Table 3, sinuosity ratio of segment 2 are 1.06 in 1991, 1.04 in 1996 and 1.06 in 2001. The channel pattern of the first three years is nearly straight. But, sinuosity ratios of second three years are 1.10, 1.13 and 1.08. The channel patterns of these years are nearly transitional. See Figure 3.

Table 3. Sinuosity ratio and channel pattern of segment 2

Year	Straight channel length (km)	Thalweg line length (km)	Sinuosity ratio	Channel pattern
1991	47.31	50.58	1.06	nearly straight
1996	47.31	49.48	1.04	nearly straight
2001	47.31	50.43	1.06	nearly straight
2006	47.31	52.25	1.10	nearly transitional
2011	47.31	53.72	1.13	nearly transitional
2015	47.31	51.47	1.08	nearly transitional

Source: Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

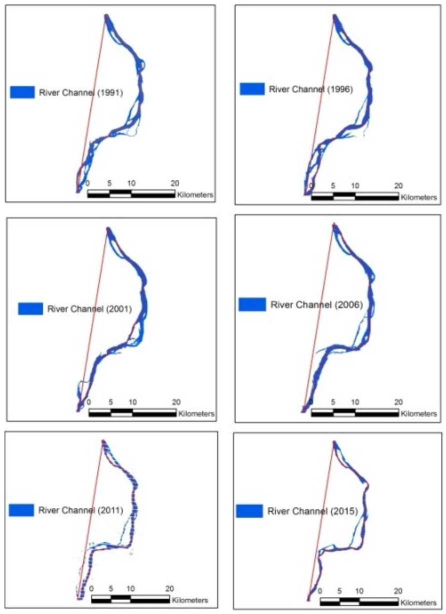


Figure 2. Channel plan-form of segment 1
Source: Lands at 5,7 and 8 satellite imagery

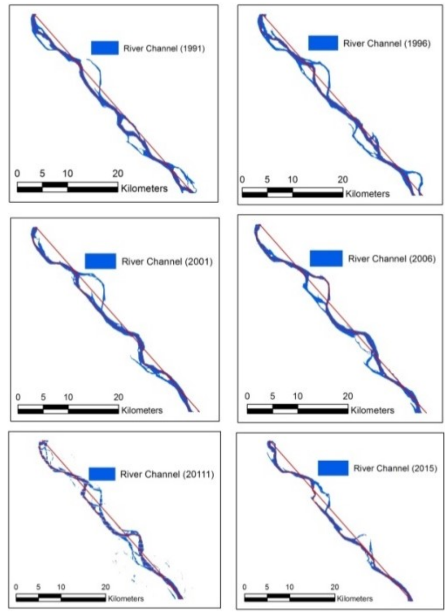


Figure 3. Channel plan-form of segment 2
Source: Lands at 5, 7 and 8 satellite imagery

In segment 3, sinuosity ratio for the years 1991, 1996, 2001, 2006, 2011 and 2015 are 1.15, 1.14, 1.17, 1.24, 1.11 and 1.24. Channel patterns of segment 3 are gradually changed from nearly transitional to transitional as shown in Table 4 and Figure 4.

The last segment's (segment 4) sinuosity ratio for the years 1991,1996,2001, 2006, 2011 and 2015 are 1.29, 1.39, 1.29, 1.35, 1.37 and 1.42. Channel patterns of that segment are progressively changed for transitional to nearly regular. See Table 5 and Figure 5.

Table 4. Sinuosity ratio and channel pattern of segment 3

Year	Straight channel length (km)	Thalweg line length (km)	Sinuosity ratio	Channel pattern
1991	42.23	48.86	1.15	nearly transitional
1996	42.23	48.24	1.14	nearly transitional
2001	42.23	49.60	1.17	nearly transitional
2006	42.23	52.38	1.24	transitional
2011	42.23	47.16	1.11	nearly transitional
2015	42.23	52.75	1.24	transitional

Source: Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

Table 5. Sinuosity ratio and channel pattern of segment 4

Year	Straight channel length (km)	Thalweg line length (km)	Sinuosity ratio	Channel pattern
1991	42.72	55.28	1.29	transitional
1996	42.72	59.42	1.39	nearly regular
2001	42.72	55.48	1.29	transitional
2006	42.72	57.71	1.35	nearly regular
2011	42.72	58.95	1.37	nearly regular
2015	42.72	60.95	1.42	nearly regular

Source: Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

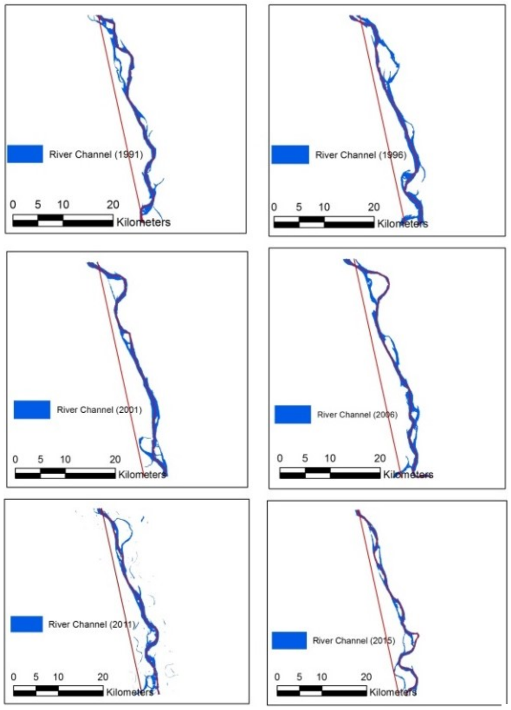


Figure 4. Channel plan-form of segment 3
Source: Landsat 5, 7 and 8 satellite imagery

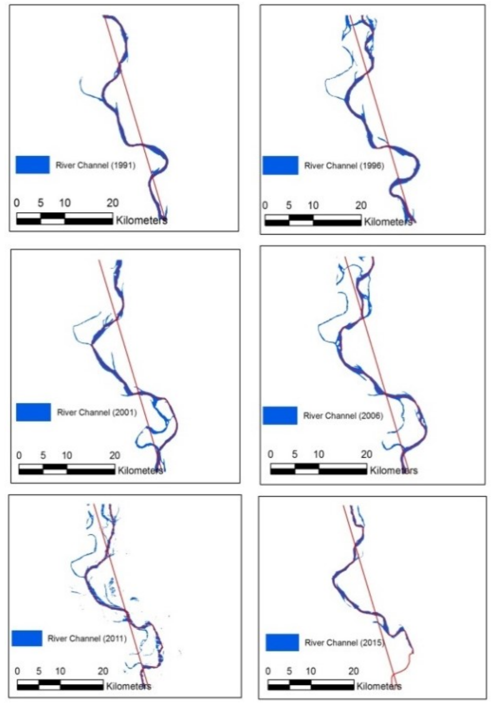


Figure 5 Channel plan-form of segment 4
Source: Landsat 5, 7 and 8 satellite imagery

2. Channel Bar Formation along the Course

The nature and distribution of alluvial instream geomorphic units is fashioned by the interaction between unit stream power along a river reach and sediment calibre and availability.

The most common instream geomorphic units are accumulations of deposits referred to as bars. These areas of net sedimentation of comparable size to the channels in which they occur are key indicators of within-channel processes. Interpretation of bar type is often critical in elucidation of river character and behaviour. There are two main components in bar form. The basal feature, or platform, is made up of coarse material and is overlain by supraplatform deposits of varying forms which is subject to removal and replacement during floods. Bars are readily reworked as channels shift position over the valley floor. Bank attached features are much less likely to be reworked than mid-channel forms. The long-term preservation of bars is conditioned by factors such as the aggradational regime and the manner of channel movement.

Bars adopt many varied morphologies, ranging from simple unit bars (Smith 1970) to complex compound features (Briefly 1991, 1996). Bar character is controlled primarily by local-scale flow and grain size characteristics. Unit bars are simple features composed of one depositional style. The sediments of a unit bar (whether they be sand or gravel in composition) tend to be fine in a downstream direction. As unit bars are found at characteristic locations along long profiles under particular sets of flow energy (stream power) and bed material texture relationships, a ‘typical’ down-valley transition in forms can be discerned (Church and Jones1982). Bed material character, and the competence of flow to transport it, determines formation of longitudinal bars as flow divides around a tear-drop shaped feature. When flow is oriented obliquely to the long axis of the bar, a diagonal feature is produced. This is commonly associated with a dissected riffle. In highly sediment-charged sandy conditions, flow divergence results in transverse or linguoid bars, which extend across rather than down the channel (Collinson 1970; Cant and Walker 1978). Alternatively, the entire channel bed may comprise a homogenous sandsheet.

Instances in which patterns of sedimentation are dominated by within-channel bars reflect situations in which the material on the channel bed is either too coarse to be transported or the volume of material is too great to be transported. These scenarios are generally associated with gravel and sand bed systems respectively, such that competence and capacity limits are exceeded and flow divides around sediment stored in the channel zone.

In contrast to various mid-channel sedimentation features, rivers that are more readily able to accommodate their sediment load or have lower available energy are commonly characterized by bank-attached bars. Dependent on channel/flow alignment, lateral and point bars are found at channel margins under both sand and gravel conditions. These features record sediment accretion on the convex slopes of river bends. Lateral bars tend to occur along straighter river reaches, while point bars are formed on bends. Scroll bars on the inside of bends may form a distinct element in themselves, while former positions of the channel may be recorded by a series of accretionary ridges and intervening swales (Nanson 1980). A range of bar forms have also been characterized for laterally constrained sinuous channels, such as point dunes (Hickin1969), gravel counterpoint bars (Smith 1987) and convex bar deposits (Goodwin and Steidtmann 1981).

In this paper, emphasise is given to the area of channel bar, in channel bar and total area of bar in the channel along the river course from Pyay to Hinthada segment. According to Table 6, total channel bar area is 291.5963 sq-km, 257.2957 sq-km, 336.1158 sq-km, 307.3269 sq-km, 313.47.5 sq-km and 335.7910 sq-km respectively. Channel bar area in 1991 was 234.2458 sq-km (80.33% of the total bar area) and in channel bar area was 57.3505 sq-km (19.67% of the total channel bar area). In 1996 channel bar area was decreased to the 174.0022 sq-km (67.63% of the total bar area, while in channel bar area was increased to 89.2937sq-km (32.37% of the total bar area). Channel bar area was increased again in 2001 with the area of 285.61 sq-km (84.97% of the total), while the area of in channel bar was decreased again with the area of 50.5058 sq-km (15.03% of the total) in 2001.Channel bar area was decreased again in 2006 with the area of 244.0008 sq-km (79.39% of the total), while the area of in channel bar was increased again with the area of 63.3261 sq-km (20.61% of the total) in 2006. Between 2006 to 2011, within five years period, percentage area of channel bar and in channel bar are nearly the same, but channel bar area became 267.7123 sq-km (80.32% of the total) and in channel bar area became 66.0787 sq-km in 2015 respectively.

Table 6. Channel bar, in channel bar and total bar area along the river course

Year	Channel Bar Area (sq-km)	Channel Bar Area (%)	In Channel Bar Area (sq-km)	In Channel Bar Area (%)	Total Bar Area (sq-km)	Total Bar Area (%)
1991	234.2458	80.33	57.3505	19.67	291.5963	100
1996	174.0022	67.63	83.2937	32.37	257.2959	100
2001	285.61	84.97	50.5058	15.03	336.1158	100
2006	244.0008	79.39	63.3261	20.61	307.3269	100
2011	247.6315	79.00	65.84	21.00	313.4715	100
2015	269.7123	80.32	66.0787	19.68	335.7910	100

Source: Calculated by author

3. Channel Movement along the Course

River course changes can be quantified by superimposing early maps, aerial photographs and satellite imagery (e.g. Hooke and Redmond 1989; Lewin 1987), often using analytical photogrammetry and GIS (e.g. Lane *et al.* 1993). In this paper, channel movement and erosion data are derived from the topographic maps and satellite imagery by using screen digitizing and auto data extraction methods.

For channel movement and bank erosion studies, there are eight selected channel movement sites along the study river course as shown in Figure 6. Absolute location of selected channel movement sites are as follows:

Absolute location

Channel movement site 1: North Latitude 18˚ 29′ 40.98" and
East Longitude 95˚ 07′ 48.72"
(Thauk Kyar Du village tract, Kyangin township, west bank of the Ayeyarwady River)
Channel movement site 2: North Latitude 18˚ 23′ 39.56" and
East Longitude 95˚ 12′ 29.23"
(Sonle village tract, Kyangin township, west bank of Ayeyarwady River)
Channel movement site 3: North Latitude 18˚ 13′ 1.25" and
East Longitude 95˚ 22′ 3.12"
(Ka Zun Khon village tract, Myanaung township, east bank of Ayeyarwady River)
Channel movement site 4 :North Latitude 18˚ 00′ 6.40" and
East Longitude 95˚ 28′ 7.87"
(Nyaung Waing village tract, Monyo township, esat bank of Ayeyarwady River)
Channel movement site 5: North Latitude 17˚ 56′ 39.28" and
East Longitude 95˚ 27′ 4.33"
(Gway Tauk Chaung village tract, Ingapu township, west bank of Ayeyarwady River)
Channel movement site 6: North Latitude 17˚ 52′ 22.69" and
East Longitude 95˚ 28′ 0.50"
(Sitkone village tract, Ingapu township, east bank of Ayeyarwady River)

Channel movement site 7: North Latitude 17˚ 43′ 2.66" and
East Longitude 95˚ 26′ 34.51"
(Aing Ta Loke village tract, Letpadan township, west bank of Ayeyarwady River)
Channel movement site 8: North Latitude 17˚ 39′ 10.14" and
East Longitude 95˚ 28′ 37.17"
(Gaung Say Kyun village tract, Hinthada township, west bank of Ayeyarwady River)

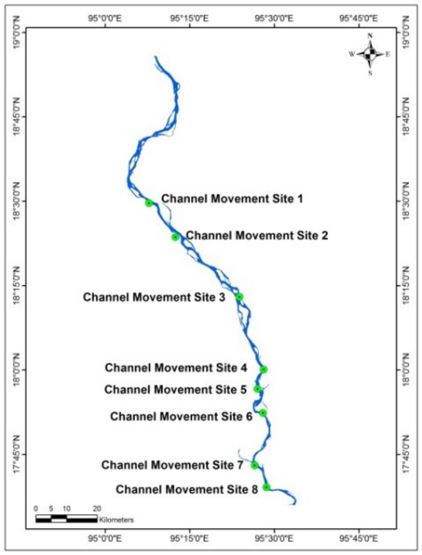


Figure 6. Channel movement sites along the course
Source: Landsat 5, 7 and 8 satellite imagery

Channel movement data for all selected channel movement sites for the year 1996, 2001, 2006, 2011, and 2015 are measured based on the 1991 active channel. Selected site number 1, which is Thauk Kyar Du village tract, Kyangin township, is located on the west bank of the Ayeyarwady River. No channel movement was seen in 1996, and channel shift to the eastward direction with the distance of 0.5567 km in 2001, 1.2117 km in 2006, 1.6624 km in 2011, and 2.4269 km in 2015 from the reference point. In this site, channel shifts to the eastward direction within 25 years as shown in Figure 7 and Table 7.

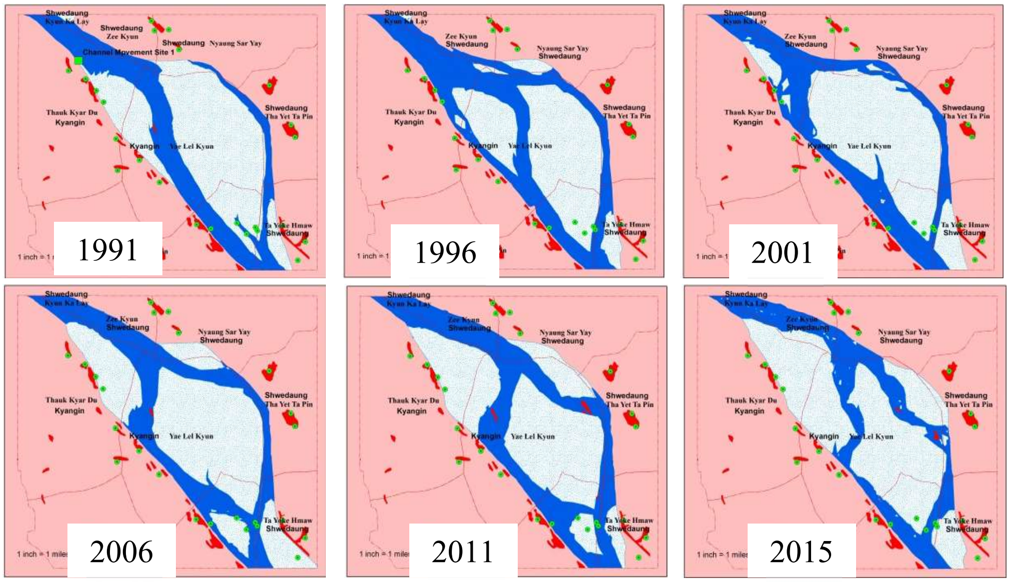


Figure 7. Channel movement of site 1
Source: Landsat 5, 7 and 8 satellite imagery

Site number 2,which is Gway Tauk Chaung village tract, Ingapu township, is located on the west bank of the Ayeyarwady River. Channel shifts in westward direction from the reference point with the distance of 0.635 km in 2001, 1.3106 km in 2006, 1.5539 km in 2011 and 1.548 kmin 2015 (figure 8).

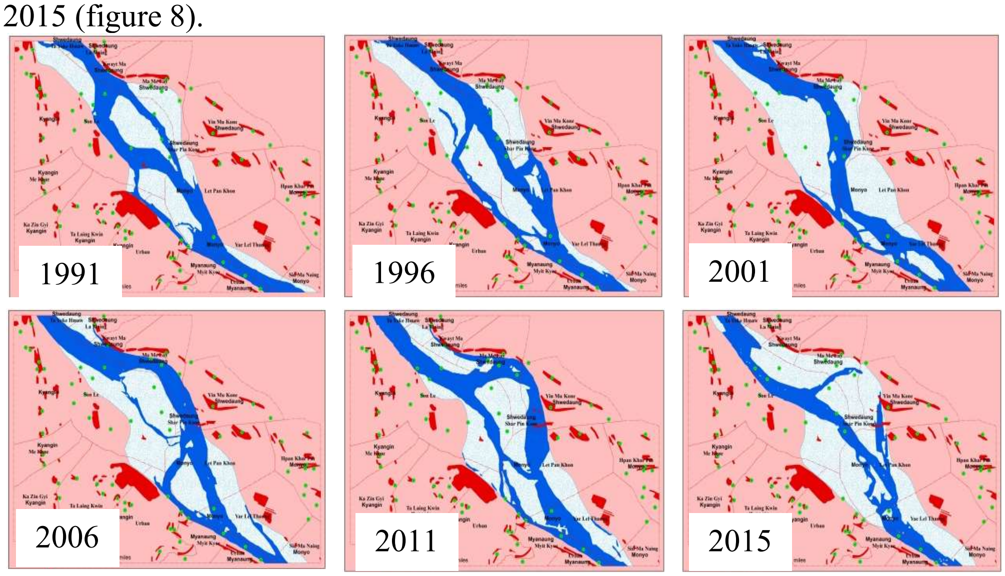


Figure 8. Channel movement of site 2
Source: Landsat 5, 7 and 8 satellite imagery

Table 7. Channel Movement of Ayeyarwady River from Pyay to Hinthada

Channel Movement Site	Referenced Point Location	Year	Distance of Channel Movement from Referenced Point to West (km)	Referenced Point (km)	Distance of Channel Movement from Referenced Point to East (km)
1	18° 13′ 1.25"N, 95° 07′ 48.72"E	1991		0	
		1996			0
		2001			0.5667
		2006			1.2177
		2011			1.6624
		2015			2.4269
2	18° 23′ 39.56"N, 95° 12′ 29.23"E	1991		0	
		1996	0		
		2001	0.635		
		2006	1.3106		
		2011	1.5539		
		2015	1.548		
3	18° 13′ 1.25"N, 95° 22′ 3.12"E	1991		0	
		1996			0.1061
		2001			2.0232
		2006			2.9015
		2011			2.5911
		2015	0.3108		
4	18° 00′ 6.40"N, 95° 28′ 7.87"E	1991		0	
		1996			0
		2001			0.1793
		2006			0.1754
		2011			0.7632
		2015			0.7451
5	17° 56′ 39.28"N, 95° 27′ 4.33"E	1991		0	
		1996	1.4236		
		2001			1.0014
		2006			0.4267
		2011			0.3824
		2015	1.2019		

Channel Movement Site	Referenced Point Location	Year	Distance of Channel Movement from Referenced Point to West (km)	Referenced Point (km)	Distance of Channel Movement from Referenced Point to East (km)
6	17˚ 52′ 22.69"N, 95˚ 28′ 0.50"E	1991		0	
		1996			1.3380
		2001			2.1398
		2006			3.2224
		2011			1.0717
		2015			1.0985
7	17˚ 43′ 2.66"N, 95˚ 26′ 34.51"E	1991		0	
		1996	0.8273		
		2001	1.1851		
		2006	1.7039		
		2011	1.8592		
		2015	2.3740		
8	17˚ 39′ 10.14"N, 95˚ 28′ 37.17"E	1991		0	
		1996			0
		2001			1.2250
		2006			1.9592
		2011			3.4468
		2015			5.2292

Source: Calculated by author

Site number 3, which lies in Ka Zun Khon village tract, Myanaung township, is located on the east bank of the Ayeyarwady River. Channel shifts to the eastward direction from the reference point with the distance of 0.1061 km in 1996, 2.0232 km in 2001, 2.9019 km in 2006 and 2.5911 km in 2011. The channel shifts again to the westward direction with the distance of 0.3108 km in 2015 (figure 9).

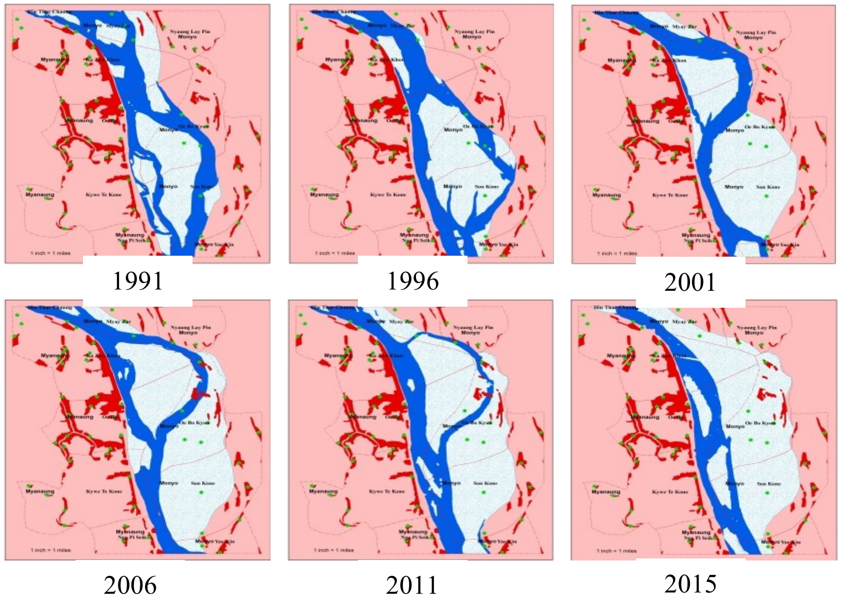


Figure 9. Channel movement of site 3
Source: Landsat 5, 7 and 8 satellite imagery

At selected site number 4, which is Nyaung Waing village tract, Monyo township, is located on the east bank of the Ayeyaewady River. Channel movement is absent in 1996, and channel shifts to the eastward direction with the distance of 0.1793 km in 2001, 0.1754 km in 2006, 0.7632 km in 2011, and 0.7451 km in 2015 from the reference point.

Site number 5, which is Gway Tauk Chaung village tract, Ingapu township, is located on the west bank of the Ayeyarwady River. Channel shift to the westward direction from the reference point with the distance of 1.4236 km in 1996, and then channel is moved eastward direction with the distance of 1.0014 km in 2001, 0.4267 km in 2006 and 0.3824 km in 2011. And then channel shifts again to the westward direction with the distance of 1.2019 km in 2015 as shown in figure 10.

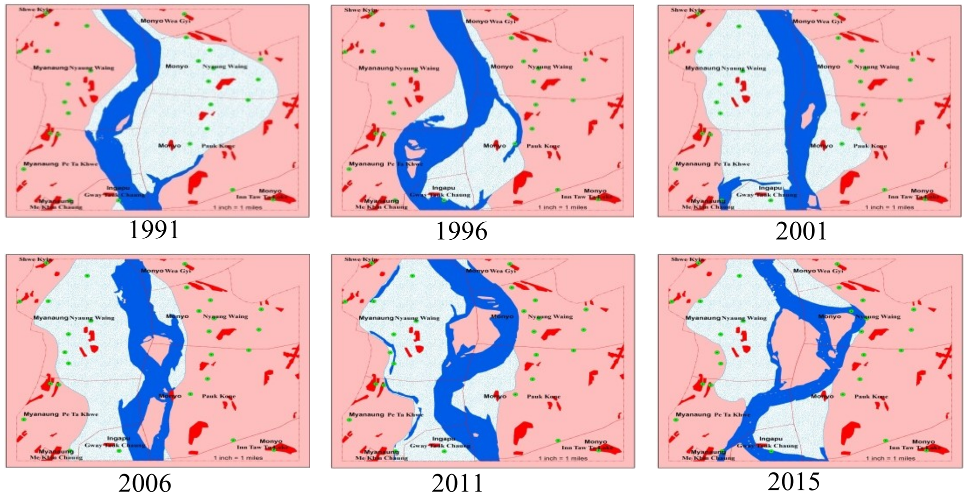


Figure 10. Channel movement of site 4 and 5
Source: Landsat 5, 7 and 8 satellite imagery

Site number 6, which is situated in Sitkone village tract, Ingapu township, is located on the east bank of Ayeyarwady River. Channel shifts to the eastward direction from the reference point with the distance of 1.3380 km in 1996, 2.1398 km in 2001, 3.2224 km in 2006, 1.0717 km in 2011, and 1.0985 km in 2015 (figure 11).

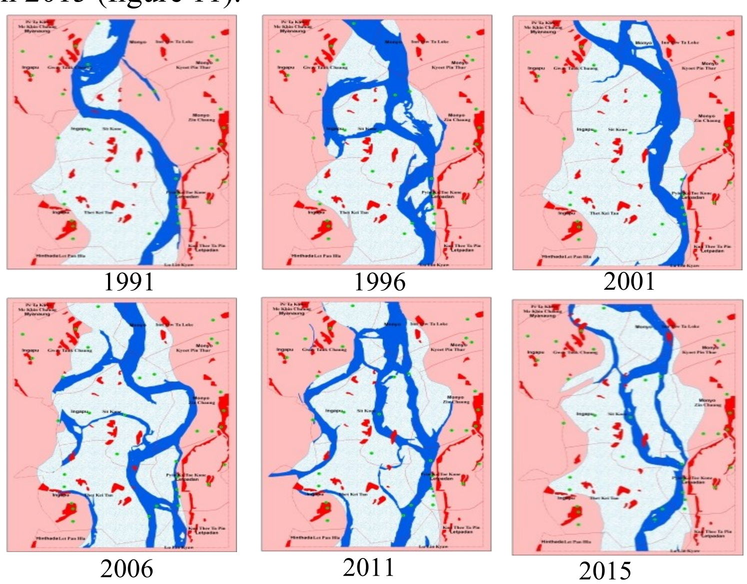


Figure 11. Channel movement of site 6
Source: Landsat 5, 7 and 8 satellite imagery

Site number 7, which lies the Aing Ta Loke village tract, Letpadan township, is located on the west bank of Ayeyarwady River. Channel shifts to the westward direction from the reference point with the distance of 0.8237 km in 1996, 1.1851 km in 2001, 1.7039 km in 2006, 1.8592 km in 2011, and 2.3740 km in 2015 (figure 12).

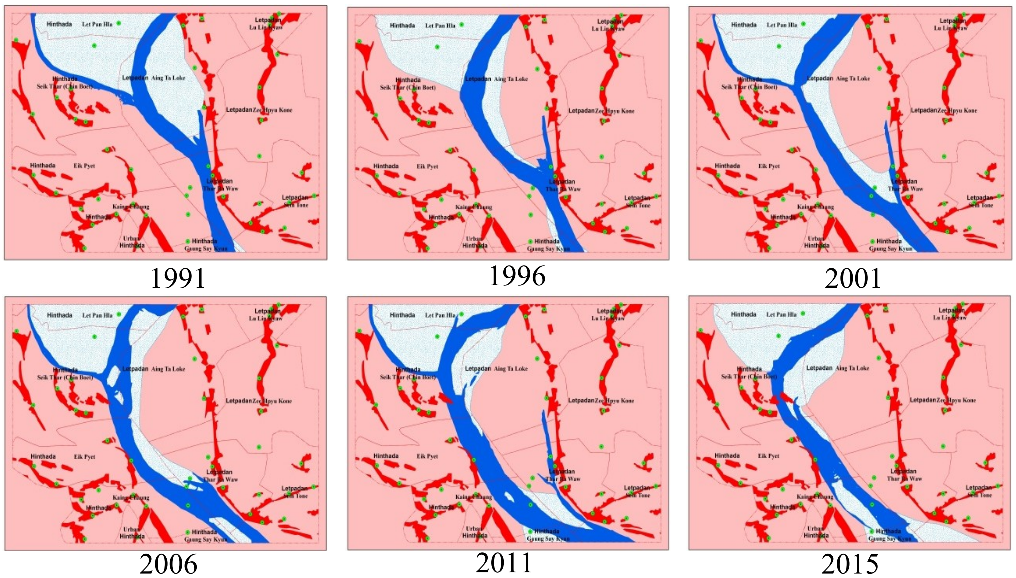
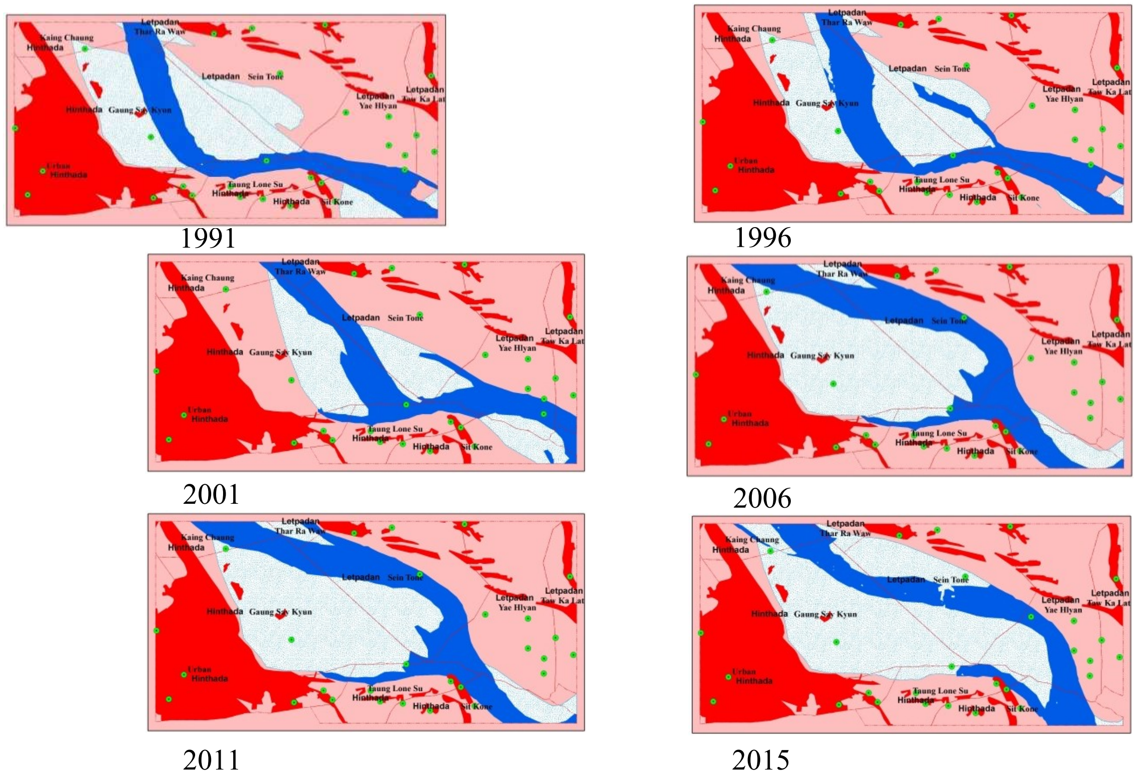


Figure 12 .Channel movement of site 7

Source: Landsat 5, 7 and 8 satellite imagery

At selected site number 8, which lies the Gaung Say Kyun village tract, Hinthada township, is located on the west bank of Ayeyarwady River. No channel movement in 1996, and channel shift to the eastward direction with the distance of 1.2250 km in 2001, 1.9592 km in 2006, 3.4468 km in 2011, and 5.2292 km in 2015 from the reference point. In this site, channel shifts to the eastward direction within 25 years as shown in figure 13.



2011

Figure 13. Channel movement of site 8
Source: Landsat 5, 7 and 8 satellite imagery

Conclusion

The study demonstrates efficient way to determine river channel pattern and understanding river erosion and siltation and how it has trended on settlement alongside the study area channel using GIS from medium resolution Landsat images and topographic maps. This type of study is appropriate for further planning of river and river adjacent to settlement management an effective manner as it could be incorporated in the long time changes of the river morphology. GIS analysis result shows in form 1991 to 2015 as a little bit change along the river course.

Acknowledgements

I would like to gratefully acknowledge to U Thein Naing, Township General Administration Department, Hinthada Township, U Than Soe, Officer, Relief and Resettlement Department, Hinthada Township and Daw Aye Aye Htay, Assistant Engineer, Directorate of Water Resources and Improvement of River Systems, Hinthada Township for their help throughout the field work.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

TOURISM AS A DRIVER FOR SOCIO-ECONOMIC DEVELOPMENT POTENTIALS OF PYAY AREA, MYANMAR

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Abstract

This Paper attempts to analyse the contributions of the tourism sector in Pyay Area, Myanmar. Pyay and its surrounding areas originally posses a wide range of unique potentials for a diversified tourism development. Tourism has positive socio-economic impacts on the livelihoods of the local people. Recommendations are suggested for the provision of knowledge and skills related to the tourism business to the community in order to improve the well-being of locals from which the entire area and many parts of the society can benefit. In this study, primary data as field observations and expert interviews were conducted and secondary data and GIS analysis mapping explores for the touristic locations in the Pyay Area. The paper identifies the contributions of the tourism sector of cultural potentials and attempts to analyse socio-economic benefits of the tourism industry.

Key words: potential of long history images, regional improvement factors, potential economic factors

Introduction

Tourism development is currently a key issue for many developing countries including Myanmar. Many governments and development practitioners increasingly consider tourism as a driver for potentials development of socio-economic strategy in Less Developed Countries (LDCs). With proper interventions, socio-economic benefits brought about by tourism can play an important role. In general, tourism has become a significant tourism industry in both poor and rich economies, because of its important impacts on socio-economic, livelihoods and socio-cultural development (Shah, 2000).

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Now, tourism becomes one of the Myanmar's most important sectors that benefit the communities, if it is properly managed and developed as a driver. Development of a tourism industry plays an important role in the contribution of foreign income sources and creation of many jobs. However, to understand the relationship between tourism and socio-economic development processes, empirical analysis is required. Tourism development and its impacts on socio-economic conditions in Myanmar has not yet been explored. Therefore, this paper intends to find out the tourism effects on socio-economic development in Pyay Area. The effect of tourism employment on development potential on socio-economic activities in Pyay Area and in the ways, in which tourism can improve the well beings of the locals in Pyay.

Tourism provides income for local people, in particular Pyay area (*Sri Kestra*) profits substantially from tourism through employment in the production of goods and services. For instance, rising demands on agriculture through industrial crop products, handicrafts and human resources with tourism. However tourism also has negative impacts on environmental degradation and social impacts. To lessen these, special care in tourism development planning is needed. Thus, the Ministry of Hotel and Tourism of Myanmar is trying to develop the tourism sector by adapting new policies, such as "Responsible Tourism Policy" or "Community Involvement Policy". These policies operate especially in the main touristic areas.

A key to resolve negative impacts is to make the tourism business aware of the importance of incorporation sustainable development principles into planning and operations. The world Tourism Organization defines sustainable tourism as:

"Sustainable tourism development meets the needs of present tourists and host regions while protecting and enhancing opportunities for the future. It is envisaged as leading to management of all resources in such a way that economic, social and aesthetics needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity and life support systems" (United Nations, 2001).

Against this background, the overarching aim of the study is to contribute to a more sustainable touristic development by applying basic principles of international sustainable tourism development .Therefore, the research based on present situation of tourism business in the Pyay Area and its controlling factors and impacts, the article is seeking for better tourism planning and management in future. (Frauke Kraas, 2015).

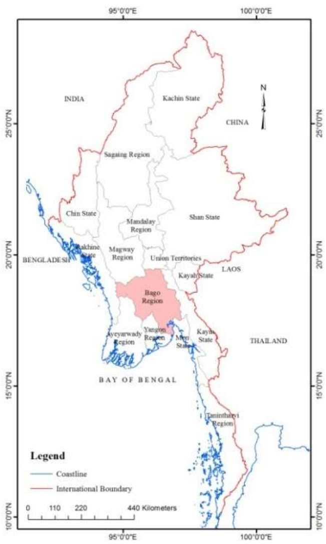
The study will serve as a reference for further research in these dynamic areas of the tourism industry. The research results will also contribute to the anti-poverty policy formulation on development of socio-economic conditions of their Civilian Government of Myanmar and the Ministry of Hotels and Tourism through review and formulation of policies and strategies that can reduce the poverty level on potential development of socio-economic activities in the study area and Myanmar as well.

What is Tourism?

To understand the linkage between tourism, poverty and development of socio-economic conditions it is important to define what tourism is. Although the definition is problematic, this study adapted the tourism defined by World Tourism Organization (WTO), which states that tourism is the set of activities engaged in by persons temporarily away from their usual environment, for a period not more than one year, and for a broad range of leisure, business, religious, health and personal reasons, excluding the pursuit of remuneration from within the place visited or long–term change of residence (WTO).

Study Area

Pyay Area lies in the western Bago Region and is located on the eastern bank of Ayeyarwady River. It lies between north latitudes 18 º 23′ - 19º 6′ and also between east longitudes 90º 40′ - 99º 50′. The Pyay Area is about 788.41 sq- kilometer. The area is roughly a square shape. Pyay Area is bounded by Bago Region in the east, Ayeyarwady Region in the south, Rakhine State in the west, Magway Region in the north. Generally Pyay Area is a flat lowland area. Average temperature is (28°C), and the annual rainfall within 20 years of 1995-2015 was 1147.6 mm. Therefore, Pyay Township experiences the Tropical Savanna Climate (Aw) type. It is a Transitional Zone situated between Central Myanmar and the Wet Deltaic Zone. An urban area of 14 wards and 55 village tracts are composed of Pyay Township Figure (1),(2) and (3).



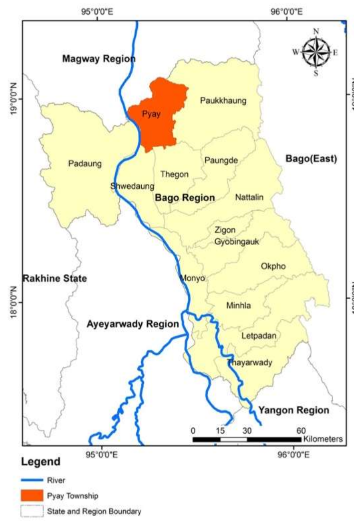


Figure 1. Location of Bago Region **Figure 2.** Location of Pyay Township

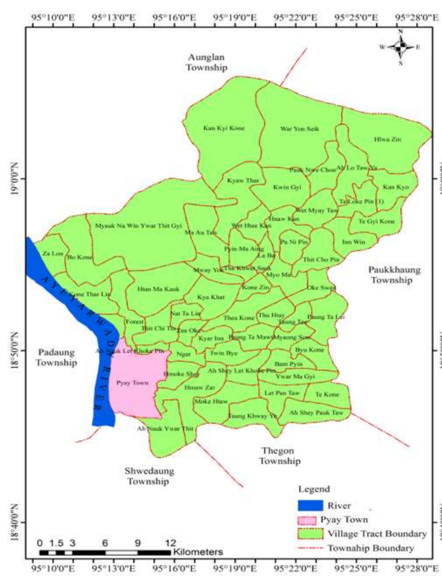


Figure 3 .Location of Village Tracts in Pyay Township

Source: Topographic Maps No.85 N/5, 85N/6

Research Questions

The guiding research questions are:

(a) Which socio-economic potential driver benefits on tourism sector in Pyay Area?

(b) How can these potentials be developed as sustainable tourism in a practical way?

(c) Which socio-economic potential driver can be chosen in achieving a more sustainable tourism development?

(d) Which economic factors can benefits for many societies as a driver?

Aim and Objectives

The aim of the paper is:

-to give suggestions that support tourism sector of the study area.

The objectives of the paper are:

-To access tourism conditions for Pyay Area

-To reduce the poverty level on potential development of socio-economic activities

-To encourage potentials drivers of tourisms

-To support needs of tourisms related the business development

-To search for the best way of sustainable economic development in Pyay, Myanmar

-To examine how socio-economic factors are related to those driving of tourism factors in Pyay Township

Sources of Data and Methods

Primary data was derived from field observations, participant observations and interviews conducted in December 2014, May 2015, June 2016 and March 2017. Perceptions of various stakeholders and local people on tourism were collected. The secondary data were gathered from publications of tourism statistics and township records. The research is conceptualized based on a mixed - methods approach, combining and triangulating different kinds of data in order to gain a complete overview on the topic from the perspectives of quantitative and qualitative socio-economic research.

The analysis and assessment of the tourism development of the Pyay Areas is based on six basic requirements, known as “6As context” namely attraction, accessibility, amenities, administration, awareness and attitude (actual field observations). On the other hand, the supply components of tourism in the Pyay Areas and its potentials of socio-economic conditions to sustainable tourism development is assessed by a “classical” of SWOT (Strength, weakness, opportunities and threats) analysis.

Results and Findings

Indicators of Attraction Sites (Ancient Historical Images) in Pyay Area

Generally Pyay Area is a flat lowland area. The boundaries of Pyay Area are administrative and physical boundaries. In the west, the Ayeyarwady River forms as the natural or physical boundary between Padaung and Kanma townships. In the north and west, Bago *Yoma* (mountain range) and Ayeyarwady River are used as physical boundaries. In Pyay Township, an urban area is composed of one city and one town, and rural area includes 55 village tracts (Khin Sandar Moe, 2016).

Pyay Township is located on Yangon- Pyay Railway and Road 288.0727 (kilometer) far away from Yangon. Therefore, the products from Pyay Township are easily carried to Yangon, the most densely populated area of Myanmar. In Pyay Township, the economic opportunities and population increased in the study period due to its locational advantage and government policy and then as the ancient city of *Sri Kestra*, which has been recently inscribed on the list of World Heritage by UNESCO. Total population is also increased from 185621 in 1990 to 222856 in 2016. As the consequence, there will be potential development of socio- economic conditions in Pyay Township in respect to tourism.

The most important tourist attraction is ancient city of Sri-ksetra, which has been recently inscribed on the list of World Heritage by UNESCO (June 22,2014) , about 8.0467 (kilometer) far away from Pyay Township. It has a long history of ancient pagodas in Pyay and near Pyay Area. The local people are known as Pyu, whose economy is based on agriculture, traditionally on handicrafts like weaving, bamboo and wood production. Moreover, the cultural attractions of Pyay areas are its historical famous pagodas and monasteries, such as Pyay Shwe San Daw Pagoda and Shwe Bone Thar Muni Pagoda with their pagoda festival.

The second most famous tourist attraction area is A Kaunk Taung Mounatin. It has mountainous surrounding with attractive views, favourable climatic conditions, hills resort and some hiking trails. Besides, there are urban profile attractions and major cultural heritages such as Shwe San Daw Pagoda, with its breath –taking view over the whole City and Nawaday Bridge, cultural museum, Sal Htat Gyi Pagoda, Myo Ma Market which mainly attracts domestic tourists and where ethnic people from the vicinity sell their agricultural products.

Thirdly, the ancient historical hill station and resort in Pyay Areas are Phoe Oo Taung, Yone Phyu Taung, Kyet Kin Taung and Other mountainous area. Its surrounding offers not only favourable climatic and environmental conditions but also famous for its hiking tourism. The mountainous terrain with its natural scenic beauty, the traditional settlement, green areas of agricultural patterns, the traditional life style of the local people make it attractive to domestic and international tourists. In addition, Shwe San Daw, Shwe Bone Thar Muni pagoda and Sal Htet Gyi pagoda festivals are famous from field observation in 2015 and 2016. Moreover, other mountainous areas are attractions of growing importance with about 200 pagodas from the 16th century of the Pyay Area and natural forests ranges and slopes Figure (4,5,6,7).

Figure 4. Location of Akauk Taung Area

Figure 5. Location of Shwe Taung Area

Figure 6. Location of Padaung Area

Figure 7. Location of Pyay Area (Sri-ksetra & Mountainous)

Source: Image 2017CNES/Airbus, Digital Globe, Landsat/Copemicus

Indicators of Tourists Arrival in the Pyay Area

The characteristic of tourist arrivals in Pyay Area is regionally and seasonally imbalanced, as well as a clear distinction between a strong domestics and relatively stable international tourism at medium level- compared to other Southeast Asian destinations. Even though international and domestic tourist arrivals in Pyay area has already been expected to rise since five years ago. See table (1) 5524 tourists arrived in 2011-12, 6502 tourists in 2012-13 (15.04%), 9951 tourists in 2013-14 (34.66%), 29348 tourists increased in 2014-15 (66.09%). International and domestics tourist arrivals in Pyay area is expanded substantially and risen – up, according to the data from Ministry of Hotel and Tourism. This caused high level income during the peak tourism season from October to March. See table (1) as a consequences the rising rates in hotel and guesthouses and subsequent construction of new accommodation capacities lead to touristic impacts.

Table 1. Arrival of International and Domestic tourists to the Pyay Area

Year	Tourists	Income Level
2011-12	5524	1044100
2012-13	6502 9(15.04%)	1213100
2013-14	9951(34.66%)	1873500
2014-15	29348(66.09%)	5586900

Source: Myanmar Hotel and Tourism Enterprises, Pyay (June, 2016)

The ancient city of Sri - ksetra, A Kauk Taung area and Pyay City are not connected with each other and also with other tourist destinations. Until today, high number of domestic and international tourists are attracted and visited Pyay and surrounding area. Among the domestic tourists, their activities are mostly connected with the capital function of Pyay, because many government staff often visit offices and attend the meetings. Beyond this limit, Pyay has an attractive location like Myoma market place for the people of adjacent villages and thus it functions as a regional trade centre for domestic tourism. Moreover, there are many religious sites, local festivals and cultural centres, where organizations are visited, therefore making Pyay Area an important cultural destination.

Indicators of Accommodation for Tourists in Pyay Area

The accommodations for tourists, The Ministry of Hotel and Tourism adopted clear rules and regulations for hotels and guest houses of the area. A hotel must have 20 rooms at least and permission (license) is given, based on six recommendations from different government departments, including the Township's Health Department and the Fire Brigade. Incomplete recommendations, hotel and guesthouse licenses are not permitted. There is also a regular check of the quality of hotels and guesthouses, Proper rules on ratings of "star" on hotels and regular checks are strictly followed.

The total number of hotels and guest houses in the Pyay Area adds up to 40 with the total number of rooms of over 1200 in 2016. Within the Pyay area, only one three stars hotel can be found, which has about 35 rooms. Also, the highest number of hotels concentrates in Pyay Township. In Pyay, the highest standard of two stars hotels is available with total number of 45 rooms.

In respect to the quality standards, according to own interviews, private hotels and guest houses became improved much during the last four years. Generally, hotel facilities, service provision and touristic offers were upgraded. However, WiFi and internet connection are still difficult and unreliable which hinders a further expansion of the tourism business.

According to employment opportunities due to high and rising arrival of domestic and international tourists the ancient city of Sriksetra, faces rising income generation opportunities, within the transportation and hotel construction sectors. So also food and beverages supply and services within the hotels. The opportunities are still comparatively weak. Partly, this is connected with the facts that local festivals create seasonal and events-oriented demand only. For instance, in Pyay , local festivals such as Shwe San Daw pagoda and Sal Htet Gyi pagoda and Shwe Bone Thar Muni pagoda festivals, attract many domestic arrivals. Moreover, international tourists visit the area during the tourist season between October and March. Beyond the peak season, a few amount of international tourist visit the area.

Indicators of Accessibility in the Pyay Area

Pyay Area can be accessed by road and railway. Due to the increased arrivals, particularly international tourists, the regional and local roads have been upgraded and improved in recent years. Also, the connectivity via highway bus connections has much increased and improved with a number of high class bus lines with air-conditioned transportation for relatively reasonable prices. Only the railway connections has not been upgraded yet. As one can reach from Yangon to Pyay and from Mandalay and Magway to Pyay via Aunglan, with the daily commuting connections by roads, the beautiful natural landscape between Lower Myanmar and Central Myanmar plains and Bago highlands can be appreciated via road and railway.

Discussion

For further development of domestic and international tourist in Pyay Area, two ways of growth are needed to be considered: (a) to increase long stay visitors and (b) to increase short stay visitors. Thus, in order to provide a sound baseline for decision making processes, an in - depth supply and demand analysis was undertaken. The tourism potential is evaluated by the "6As context approach" and a ***SWOT*** analysis as follows.

Potential Driver for New Attractions

Pyay area has high potential for new tourist attractions of various types, Unlike other areas, many places within the area can be created and upgraded as popular tourist destinations without much effort as almost all potential attraction sites have already been within an accessible distance from Pyay. Because of these attractive natural and environmental scenes, ancient historical images can further be developed. But it is not yet well developed. Many environmental areas are suitable for highland tourism, including those based on hiking and bicycle trails within the forest areas. The Ayeyarwady river and green highland ridges can be created into new tourist destinations, although the climate is favourable in Pyay, sometimes flood condition occurs in the rainy season.

Moreover, ethnics settlement offers unique potential, different agricultural patterns, traditional housing style, local nunneries and monasteries, village culture can be associated with tourism sites. These are attractive potentials to tourists. And after the construction of Nawaday bridge , Pyay Area became important node of north-south corridor as well as to the west. Furthermore, unique traditional foods and products such as souvenirs ,*Taw La Phat, Daw Oo* rice package, fruits specifically *Mya Kyauk* mango, preserved fruit jams and Milk sticks and Milk balls are well known. But there is weakness of promotion on unique products.

Moreover, due to its favourable climatic conditions, environmental situation and the special functions connected with Pyay as regional capital can be developed as a centre of tourist destination, both for domestics and foreign visitors. Sufficient investment on infrastructure is needed by private sector.

Pyay also has the potential to become the national trading centre of Myanmar, because of its business facilities, favourable climatic conditions for cultivation of diverse crops. Tourism education needs to be upgraded e.g. providing training on special language courses (e.g. English, Chinese, Thai, Japanese, France, German) to the government offices and the private sector. Health facilities, particularly toilets and dispensaries should be established for Pyay's Tourism development. Today, the existing health facilities offer better services than other destinations learnt from structured interview in 2014.

Potential Driver for Better Accessibility

Compared with other areas in Bago Region, Pyay Area offers better transport facilities. However, further improvement is needed, especially in the railway transport. The existing railway and road conditions are rather inferior. If it is more comfortable, reliable and faster, tourist arrival will be increased such as day trips from Yangon to Pyay, from Mandalay to Pyay. If the transport sector is improved, people, trade and commodity flow will be enhanced. In the study area railway tourism with renovated coaches has gradually increased to become a specialized segment of international tourism.

Potential Driver for Amenities

The above mentioned tourist attraction sites are located in quite a short distance from Pyay, but well developed connections are needed. For example, attractive hotel, motel, guesthouse, restaurants and cafes, ethnic markets and bus terminals are necessary. Moreover, an urban image campaign, coupled with better information about Pyay's long historic sites and its facilities and attractions can attract more tourists.

Potential Driver for Better Administration (Planning and Management)

Although the government has adapted the general tourism laws and regulations since 1992, on the regional and local level, tourism related management and planning are less integrated for further tourism improvement. Although headquarters of all government institutions are developed, overall planning is weak for regional development. On the other hand, local people want to establish hotel & motel in the heritage zone, the government restricts it not to spoil ancient historic treasure. Tourism related local governance and management thus requires systematic investigations for the improvement in Pyay Area.

Potential Driver for Awareness

The local inhabitants of Pyay Area offer good perception on places, cultural values and knowledge on conservation of heritage sites. However, further improvement is needed. The locals want their culture to be recognized by the tourists but they do not have enough potential to commercialize their culture. On the other hand, they are afraid of being influenced by other culture with the development of tourism.

Another factor is the locals are worried about relocation if tourism develops. The locals want foreign support in establishing hotel and motel on their own farm lands that are located in heritage zone, which is not allowed by the government.

Potential Driver for Attitudes

Pyay area has high potential concerning attitudes of the local people on their native place. Many locals have good attitudes on tourism sites including active connections with ethnics' settlement. Today, children and old people of the area are hospitable and offer helping hand to any tourist, which is a unique character. But if tourism develops further, their hospitality and attitude may be changed in future.

Analysis of SWOT Assessment on Perceptions of Tourism development: the SWOT analysis is a structured planning method to evaluate the strengths, weaknesses, opportunities, and threats in social and economical changes to competitive position. The SWOT analysis is based on the favourable and unfavourable factors to achieve for the purpose..

The SWOT analyze is based on internal factors for strengths and weaknesses. Internal and external factors are included for opportunities and threats. That generate meaningful information for each category (strengths, weaknesses, opportunities, and threats) depends upon their effect on the organization's objectives. They are divided into six groups, as Attractions, Accessibility, Amenities and Administration, Awareness and Attitude. The above mentioned criteria designate actual field observation for their purpose. These are: (1) Strength, (2) Weakness, (3) Opportunities and(4) Threats.

Of these, strength and opportunities potential for new attraction on tourism toward potential development of socio-economic conditions of Pyay Area, but the weakness and threats somehow should be managed to reduce.

As shown in table (2), the conditions for tourism development are Attractions, Accessibility, Amenities and Administration, Awareness and Attitude.

Table 2. Rapid appraisal on tourism business of Pyay Area in the "6As" context

6 As	Strength	Weakness	Opportunities	Threats
Attractions	Hill environments	Not yet well developed	Hiking, Biking	Deterioration of environments
	Ayeyarwady River	Silting up	Jetty, Natural Scenic beauty	Lost of water way (esp; Transport) because of sedimentation on route
	Favourable Climate	Sometime flood condition in rainy season	Resort tourism	Pollution
	Surround by many attractive sites	Weak of interest on attractive sites	Possibility to create new attraction sites in order to extend long stay	Improper provision of infrastructures and maintenance
	Many Long history and Cultural value	Weakness of promote on souvenirs for culture value	Local area more attractive to tourists	Lost of originality
	Local Handicrafts	Quality Skill-labour shortage	Attraction/ Employment	Competition with foreign products,
Accessibility	West corridor	Bad road conditions	Trade and Connectivity	Informal Trading
	Easy access by roads and railways	upgrading necessary	Increasing trade and commodity flow	Security issue, Foreign migrants
	Trade centre of Bago Region	Growing population density , narrow place of urban area	Employment in tourism related business conference and business tourism	Over congestion of existing infrastructures
Amenities	Hotel, Guesthouse,	Not sufficiently maintain	Job opportunity	Create casual labour force

6 As	Strength	Weakness	Opportunities	Threats
	Restaurants Bus Terminal			
	Mountain environment	Insufficient maintenance, lack of funds	Walking and Hiking trails from urban and rural areas	Transformation to urban land use, threat to natural ecosystems
	Compact shape	Lack of urban infrastructures & public transportation	-	Increased investment needed
Administration	Being capital town at the western part of Bago Range	Poor overall planning to regional development	Under transformation. Introduce to better management of tourism issues	Weak in Gov. setting
	Headquarters of all government institution	Poor tourism management and Plan	local ethnic communities	Poor planning of tourism sector
Awareness	-Good perception on places and culture value -Knowledge conservation on heritages	not have enough potential to commercialize their culture.	- Hopes on supporting of investments form NGOs & foreign - Create & Promotion of local products and souvenirs	-influence of other culture - Want to establish hotel & motel in heritage zone
Attitude	Today Children and Old people hospitality	-	-	- Their attitude will be change if tourism development in future

Source: Own field observations and interviews 2014 to 2017

Conclusions and Suggestions

The high potential for sustainable tourism development in the Pyay Areas has not been systematically developed yet. Tourist sites currently exist in a spot- like manner and thus not yet integrated in an overarching regional concept. Degradation, pollution, declining functionality of ecosystem services threaten to destroy the natural environments. Although there are driver of economic potential on interesting handicrafts , unique food products, e. g. *Taw la phat*, *Daw Oo* rice package, mango of (*Mya Kyauk*) , fruits jams , milk sticks & balls and other tradition foods these are not yet systematically package for sales. Locals are already active and hospitable in the native place for tourism development. But their attitude will be changed if tourism develops in the future, leading to threat for tourism development.

High local land prices make to destabilize existing socio-economic balances. But domestic tourist increases more than favored international tourist. Therefore, further sustainable development is required for the improvement of international tourism.

The capacities of infrastructures have already been upgraded during the last decade, but the administrative relations between the private sector, public institutions and civil society are also required for improvement of tourism sector.

Many potential locations, opportunities for the promotion of tourism driving factors and analysis of systematic regular supply and demand are required for an improved planning and management. And then the regular consultation needs between government and universities for the development of tourism sector. Moreover, the good research findings should be applied in the economic sectors, particularly in tourism.

Suggestion to further development of tourism business in the Pyay Area if potential economic factors such as hotel, motel, guesthouse, restaurants, handicrafts, traditional foods & products and natural beauty of hilly will exist in the "Mountain Park of Pyay Area", there can be sustainable tourism development. Moreover, destination management organizations (Public, Private and Partnership) bring together the tourism related business. These organizations allowed as independent bodies and the process should be allowed monitored and reviewed and checked regularly by the government. Ancient monuments and natural beauty of mountainous views should be maintained (sports- related and hiking tourism) for avoiding further environmental degradation with improved citizen's knowledge and awareness to sustainable tourism development.

Moreover, tourism - related events and natural resources, traditional ethnic culture can have enhanced with its authentic and rich diversity and then Strand Road as a walk-way can be integrated as a walk-way by the government. Improvement of internal roads within Pyay, Cleanness of the city (wastes, spitting, etc.), provision of bus lines within areas of Pyay should be also integrated. On the other hand, Pyay Area can be established as one of Myanmar's leading cultural heritage centre with its long history of culture (arts, literature, customs) of ethnic groups, Creation of museum on culture value and heritage supported by open air museums, handicrafts centre and cultural events. Pyay City can be integrated into a highly attractive tourism site with the existing assets. English language course to youth groups and Summer school camp for school children, medical and wellness tourism should be introduced. Training courses on tourism for skill development of labors which also offers new opportunities for small and medium enterprises have been provided. Specialized on handicrafts, traditional foods and local products are being upgraded.

Therefore, that enhancement of tourism related events can be fulfilled for tourism development in Pyay by distribution of pamphlet and information, establishment of tourist information centre in peak tour season, keeping tourist police in tour season, proper town map which is easily available to tourists. Proper sign-board for street names in Pyay, better services from hotels, motels and guesthouses and restaurants with reasonable price. Private sectors and public sectors as provision of infrastructure (electricity and water supply), Proper and clean toilets in main touristic sites are also needed. Creation of events/activities (local food cooking, special pagoda festival), Provision of taxi and motor cycle services and creation of more attraction sites need to be checked from based integrated tourism development plan should be developed with different government institutions as a long-term plan in Pyay to attract tourists. Then A hotel proper zoning for the further construction of new and high-quality hotels and related facilities is required with improvement of the basic IT infrastructure and telecommunication (Wi-Fi and Internet) which is inevitable.

From the above facts if that can be fulfilled for tourism development in Pyay Area, a regional integration of a "systematic tourism system" can grow gradually, which can lead to the best potential development of socio-economic conditions in Pyay Area.

Acknowledgement

I am greatly indebted to Pro Rector Dr. Nyunt Soe, Pyay University for his permission on this research. I would like to express my special thank to Professor Dr. Frauke Kraas, Department of Geography, Cologne University and Head of Professor Dr. Mi Mi Kyi (Retired) , Department of Geography, University of Yangon for their valuable advices. I am deeply indebted to Dr. Aung Kyaw, Pro. Rector, University of Yangon. I would like to express Dr. Tun Ko, Head of Department of Geography, University of Yangon for his valuable advices and guidance in preparing this research. Moreover, I also like to thank various stakeholders and local people in Pyay Township, for their important advices and information. Last but does not the least, I would like to express my special thank to Collages in my Department for their greatly help in preparing this research.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

ASSESSMENT OF RURAL ROAD NETWORK ON SOCIO-ECONOMIC DEVELOPMENT OF PYAY TOWNSHIP: THE CASE STUDY OF WETHTIKAN AREA

Nwe Yin Min[1], ThidaNaing[2], Thi Thi Khine[3]

Abstract

This research work emphasizes on the assessment of rural road network on socio-economic development of Pyay Township: the case study of Wethtikan Area. Inadequate road investment results in road network not being able to be developed and expanded and it is also difficult to maintain existing roads. The consequence is deterioration of the road network that not only limits accessibility, mobility and regional connectivity of a country, but also results in increased production and transport cost. Rural transport depends on appropriate infrastructure, where rural infrastructure consists mainly of rural road, tracks, and footpaths. Wethtikan Area is situated in Pyay Township of Bago Region (West). It is 28.97 km (18 miles) away from Pyay. It is composed of 21 village tracts and 101 villages. An increased interest in rural roads investment potential has developed in recent years. This is mainly due to the need for development of rural as well as the advantageous that road investment could generate on rural communities. The aim of this paper is to discuss the assessment of rural road network on socio-economic development. To present this paper, field observation was systematically done for the purpose of presenting rural road network on socio-economic development of Wethtikan Area. In methodology, primary source (field survey and interviews with department concerned and local peoples) and secondary sources on types of roads and network, education and health care etc. are collected from departments concerned.

Keywords: *road network, socio-economic development, infrastructure.*

Introduction

Rural areas had relatively large agricultural sector compared to urban areas. Transportation infrastructure is often mentioned as a key to promoting growth and development. Rural road is one of the main priorities of

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Government in Myanmar as a mechanism towards upgrading socio-economic condition and reducing poverty.

Currently several factors, including the lack of adequate road network, are hampering socio-economic development and subsequent economic growth in Wethtikan Area. Roads are the primary mode of transport in the study area for both passengers and freight.

This study has focused on temporal changes and spatial changes of rural road network on socio-economic development in Wethtikan Area. Temporal changes were emphasized before 1988 and between 1988- 2017, and spatial changes were measured for 21 village tracts of Wethtikan Area. This study, therefore, has mainly emphasized on rural road network on socio-economic development of Wethtikan Area.

Problem

Wethtikan is located on the road leading to North Nawin Dam. The road is concrete road that has been constructed since 1972. Road density increased and travel time decreased by establishing the roads connecting villages in the rural area. Travel time decreased due to better accessibility. Well connected areas differ in socio-economic conditions from less connected areas. The paper presents effects of road development on socio-economic condition of the area and points out the different socio-economic condition of accessible areas and less accessible areas. Therefore, the research problem is -

The spatial variation of socio-economic condition is uneven in the study area.

Objectives

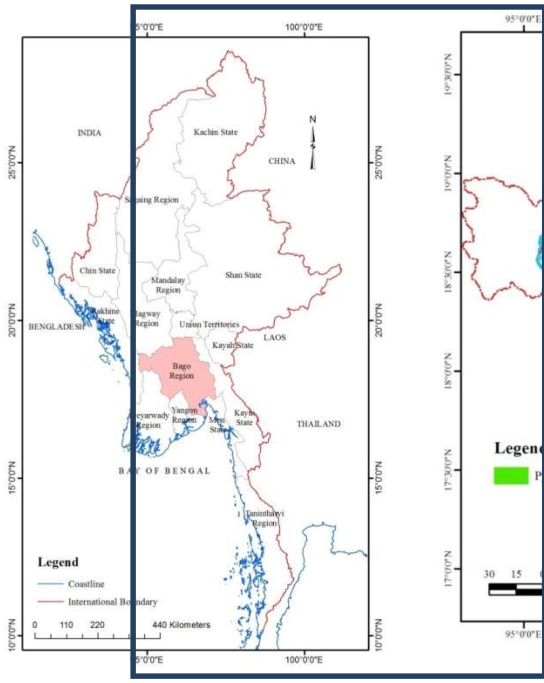
- to assess the quality of roads within the study area,
- to analyse the existing density of the rural road network
- to investigate the level of social and economic infrastructure provisioning
- to explain the effects of rural road network on socio-economic development in the study area.

The background of the study area

To materialize the new economic system, infrastructure development projects has been carried out by construction of many new bridges and roads on the one hand and new motor vehicles are imported both for passenger and freight transport. This infrastructure improvement and permission of private participation have cause changes in nature of rural economy. Both private participation and transportation development, especially "Trailer-Jeep and Motor cycle" seem to have caused distinguished changes in rural area. With increasing economic status social welfare condition gradually increased. These socio-economic changes, however, do not occur equally in all rural areas. Some geographically favoring area seems to have more chances for socio-economic development while others have less. Variation of socio-economic condition could be distinguished within the study area.

Wethtikan Area is located at the northeastern part of Pyay Township in Bago Region (West). The distance from Pyay is 28.97 km (18 miles). It is located between North Latitudes 18°54' and 19°06' and East Longitudes 95° 19' and 95°27'. It has an area of 201.04 square kilometers (124.92 square miles). It has 21 village tracts which comprise of 101 villages. (Fig 1,2,3) The total population of Wethtikan Area was 40345 persons (18 % of population in Pyay Township) in 2017. In Wethtikan Area, physical resources are suitable for agriculture and other agro-related economic activities located in rural areas. Development of rural areas supported the development of urban area by means of allowing establishment of industries, services and trade (buying and selling).

After economic policy change, the government has extended services including health, education, agriculture, communication, construction of the main roads at the township level. The local development processes have changed due to the economic growth which leads to changes in social conditions. But the development processes are not balanced in all places. Socio-economic conditions could vary according to geographical locations and efforts of the local people. Thus, Wethtikan Area is selected as a study area to analyze its socio-economic variation.



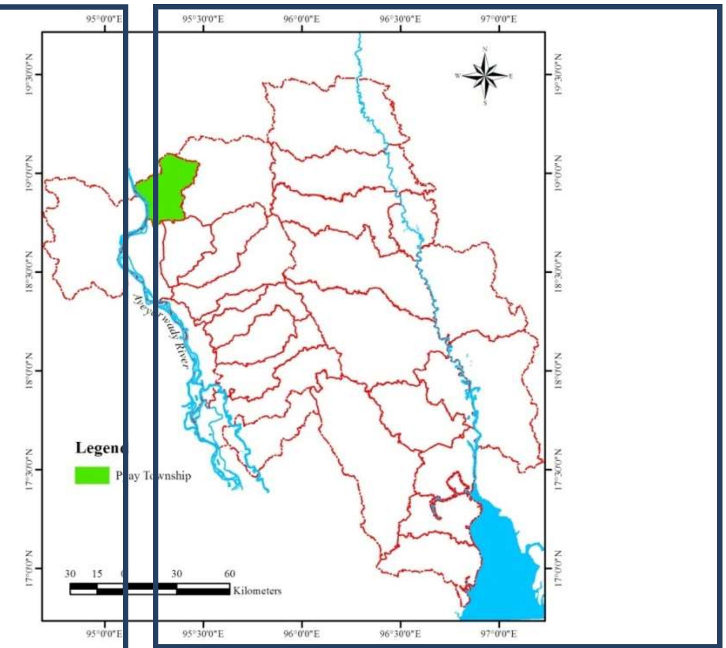


Figure 1. Bago Region in Myanmar
Source: Agricultural Atlas (2002)

Figure 2. Pyay Township in Bago Region
Source: GAD, Pyay Township

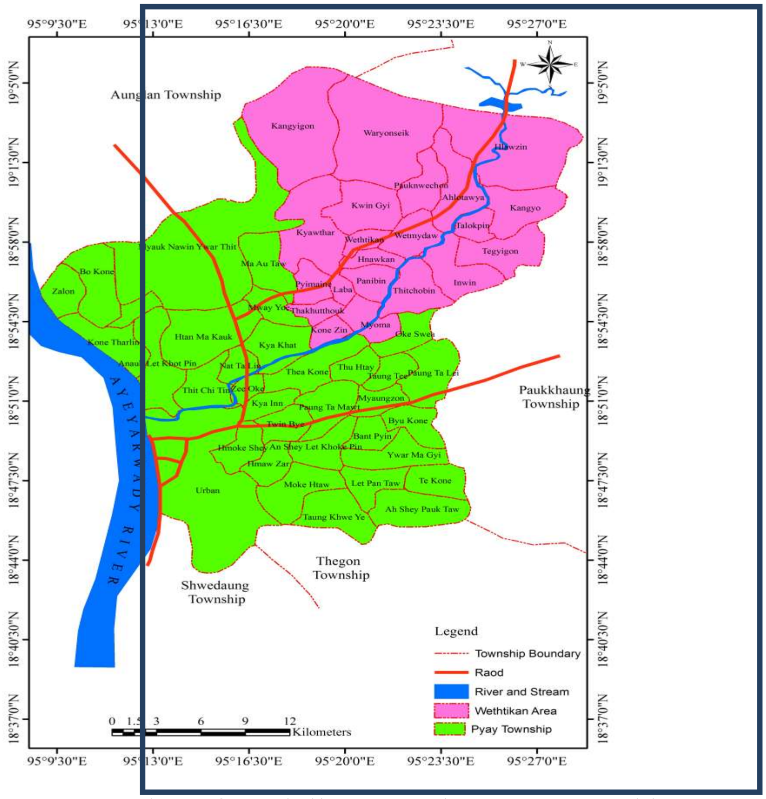


Figure 3. Location of Wethtikan Area in Pyay Township
Source: UTM map (1:50000)

Material and Method

The primary and the secondary data were used to present the paper and they are collected through interviews with local people, local authorities and authorities concerned. The interview questions concerning the difference in socio-economic condition of the people in the area caused by upgrading and opening rural roads. The well connected and less connected village tracts have been chosen to study the effect of transportation network on socioeconomic development and the growth of social and economic conditions were studied from the geographical point of view. The primary data were also collected from field observation, informal talks with local peoples and focus group discussion. The secondary data were mainly collected from the department concerned. Mapping, data linkages, and analysis were done by using GIS, with the help of UTM map (1:50000)(Survey Department).

Results and Findings

Rural Road Network in Wethtikan Area

Road infrastructure is a factor providing links between rural and urban areas and among the villages. The relationship between the socio-economic conditions and transportation infrastructure development leads to the development as well as the uplifting of the socio-economic condition of a location. Economic activity is closely related to progress in transportation which leads to development of economic activities. Transportation routes were built primarily for the purpose of moving commodities and are also used by people.

Transportation development could generate economic development and economic development also forces to construct new transportation infrastructures(Aung Kyaw, Mya Thaung, Nay Win Oo and Associates).

In Wethtikan Area, the length of rural roads was 91kilometers (56/6.1miles) in 2017. This is 33.53 % of the total mileages of the rural roads in Pyay Township.

At present the Ministry of Agriculture, Livestock and Irrigation (Department of Rural Development), local authorities concerns and native people accelerate momentum in constructing new roads, upgrading, maintaining and repairing the existed roads in the study area.

The Wethtikan Area has the length of 76.12 km (47/3.59 miles) of roads in before1988, 91 km (56/6.1 miles) in between 1988 and 2017. These roads are grouped into five categories: such as concrete, crushed stone road, hill gravel road and hard soil roads (Table.1and Fig. 4). Most of the roads are aligned from east to west and from north to south, because of its compact shape of the area.

Network density had increased as the numbers and mileages of the roads had increased. Road network density was 0.23% in 1988 and it increased to 0.28% in 2017.

Table1: Types of Roads in the Wethtikan Area in periods before 1988, and between 1988 and 2017 (in km)

Length of Roads (Miles)	Before 1988	Between 1988 and 2017
Concrete Road	14.48	14.48
Gravel Road	-	8.64
Lateritic Road	48.48	57.56
Hard Road	13.24	10.08
Total	**76.12**	**91**

Source: Yin Min Htut (2005) and Department of Rural Development, Pyay Township

Pyay-Wethtikan Road-It secedes from the milepost of (187/6) of Pyay-Taungdwingyi-Magway Road to north-east direction. It was built in 1970, during the construction year of North Nawin Dam (1966-1975). The distance between Pyay and North Nawin Dam is 43.45km (27 miles). It is 28.97 km (18 miles) from Pyay to Wethtikan. From Pyay to Tetut to Wethtikan is 14.48 km (9miles) and the breadth of the road is 0.004 km (12 ft) concrete road. From Wethtikan to Hsisankone is 9.66 km (6 miles) lateritic road.

Former earth roads were upgraded to lateritic roads. Hence, the transportation system has greatly expanded and upgraded, which accounts for the socio-economic development in Wethtikan Area. Due to the development of road transportation facilities, the socio-economic conditions also improved more than before. Transportation facilities support the development of the socio-economic conditions.

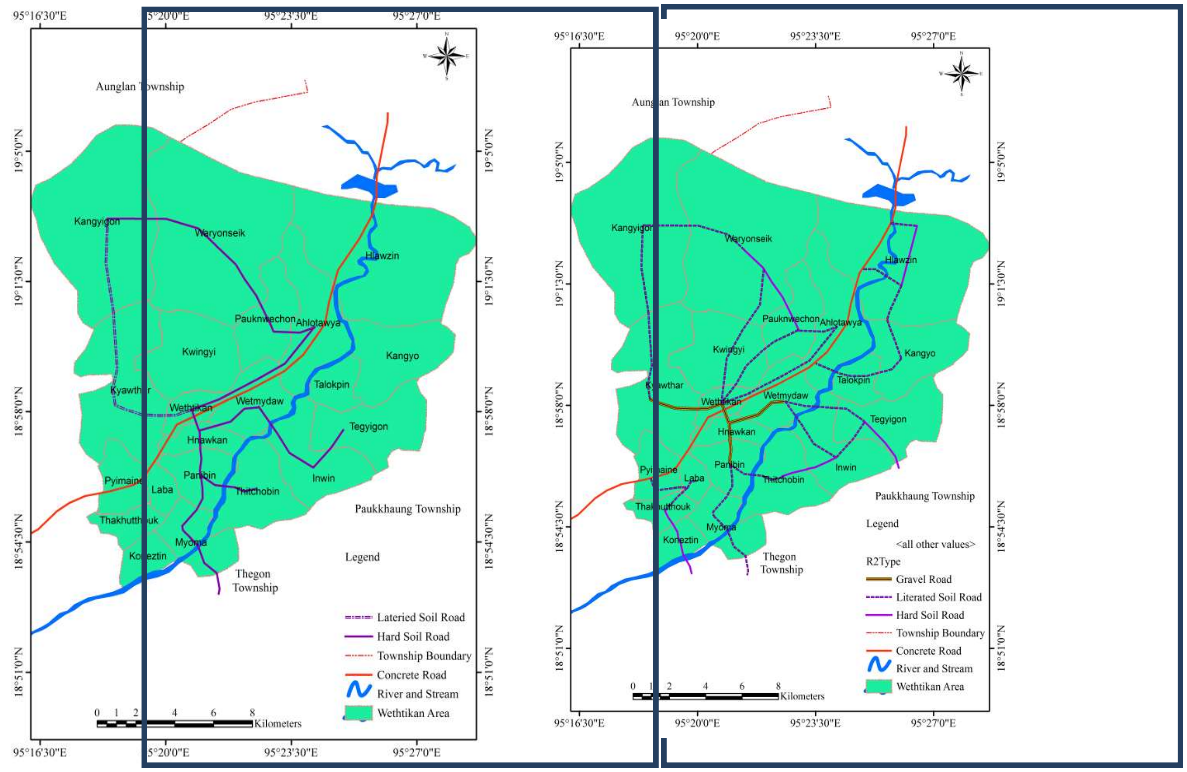


Figure 4. Type of Roads and Road Network in Wethtikan Area (before 1988 and Between 1988 and 2017)

Source: Based on Department of Rural Development, Pyay Township

Social Factors of the Study Area

The population distribution is uneven because it is influenced by the topography, transportation and communication. Population distribution is more concentrated along part of the main roads (Pyay-Wethtikan-Hsisankone) in this area. Wethtikan Area consists of 21 village tracts and total population was 24520 persons in 1992 and increase to 40345 persons in 2017. As the Wethtikan Area is not far from Pyay City, the change was due to natural growth and migration from other nearby places to the study area.

According to Figure 5, growths of population and population distribution are related to road network in the study area. As the rural roads was upgraded and extended, socio-economic condition developed and population density increased in the area.

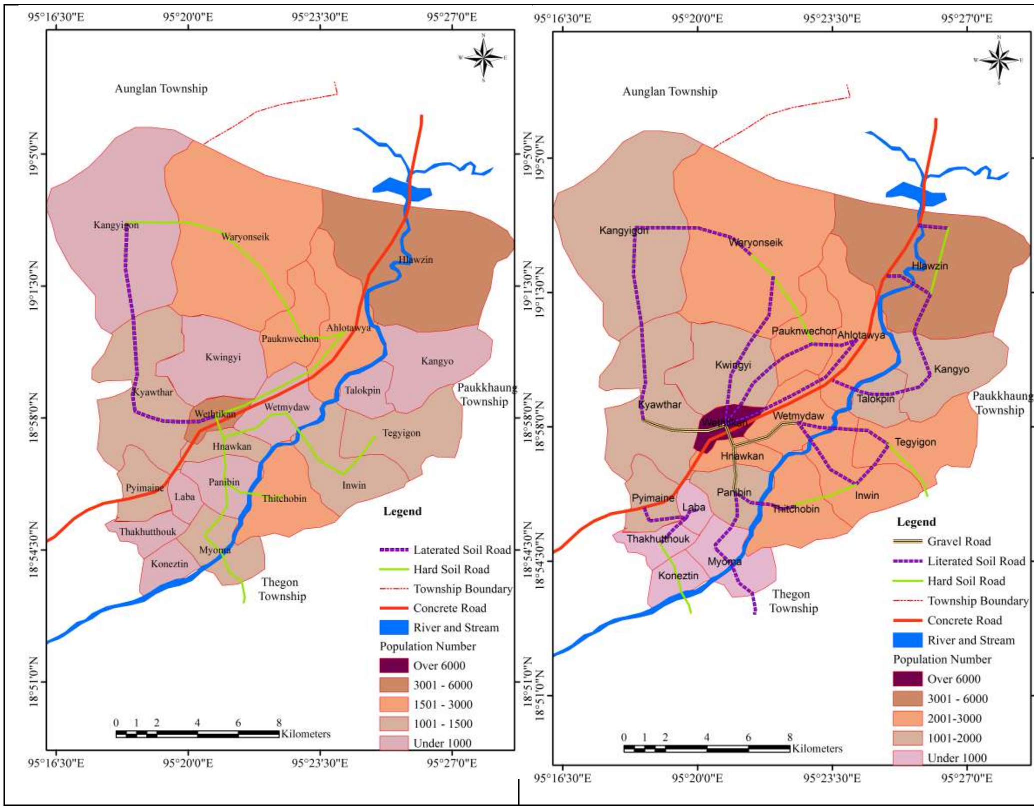


Figure 5. Distribution of Population in Wethtikan Area (1992 and 2017)
Source: Draw based on Population and National Registration Department

Education Sector

In 1988, there were few roads between urban and rural area in the Pyay Township. Social status especially in education sector was lower in that period. At present, road infrastructure development is one of the main pillars to develop educational sector due to better road and easy access to the rural areas. Therefore, upgrading the school level and an increase in number of schools were found in Wethtikan Area.

Education sector is one of the pillars that force to develop a nation, there were one high school and 14 primary schools in 1988 and the number of school increased to two high schools, one middle school and 21 primary schools in 2017 (Table 3). Most of them are situated in the rural areas especially along the new roads and its feeders. Because of better transportation system in the area, students can go to schools and it takes less time.

Table 3 Progress in the Basic Education Sector of the Wethtikan Area Between 1988 and 2017

Subject	Count	1988	2017	Increase
High School	**School**	**1**	**2**	**1**
-State School	School	-	1	Upgrading
-Branch School	School	1	1	1
-Affiliated School	School	-	-	
Middle School	**School**	**-**	**1**	**1**
-State School	School	-	-	
-Branch School	School	-	1	1
-Affiliated School	School	-	-	
Primary School	**School**	**14**	**21**	**7**
-Post Primary School	School	-	4	Upgrading
-State School	School	14	16	2
-Branch School	School	-	1	1
-Affiliated School	School	-	-	-

Source: Interviews and Education Department, Pyay Township

Poverty Reduction

Mya Seinn Yaung Rural Development Programme has been started since 2014-15 under the guidance and help of Ministry of Agriculture, Livestock and Irrigation, Pyay Township Rural Development Department and Pyay District Rural Development. One of the four objectives of Mya Seinn Yaung Rural Development Programme is to reduce poverty in the rural areas by increasing job opportunity and family income and it is carried out in 29 villages of Pyay Township. Of these, Ahlotawya, Myoma, Waryonseik, Kangyigon and Inwin villages of Wethtikan Area are included.

Socio-economic Pattern of Well Connected and Less Connected Area

Transport itself is not a sufficient condition for development; however the lack of transport infrastructures is a constraining factor for development. The development of any area depends largely on good communications and transport. All modes of transportation are vital not only for the development of the economy of the Wethtikan Area but also for the improvement of the cultural and social well-being.

To understand the impact of rural road network on socio-economic development, it would be necessary to examine the various socio-economic aspects and the relationship between socio-economic sectors and road network development. All transportation links affect not only regional development but also the socio-economic conditions of local people. Moreover, road network development leads to the emergence of new locations at which economic activities can successfully be undertaken.

Socio-economic activities and the development of transportation facilities usually go hand in hand. The government is constructing new roads and upgrading existing roads including unpaved rural feeder roads, which could actually improve the lives of the rural population, increase accessibility of the area including easy access to clinics, schools and markets, and indirectly create higher standard of living of the areas.

Well connected village tracts and less connected village tracts have been compared to study the growth of socio-economic condition of Wethtikan Area after constructing rural roads.

To compare the village tracts, Wethtikan and Hlwazin village tracts located on Pyay-Wethtikan-Hsisankone concrete road that has been constructed since the North Nawin Dam was established were selected as well connected village tracts. Waryonesik village tract included in Mya Seinn Yaung Rural Development Program and Tegyigon village tract were selected as less connected village tracts.

Well connected Wethtikan Village Tract is situated at the western part of the study area. Wethtikan Village Tract was upgraded as Town in 2000. It has an area of 7.16sq/km (2.7703 sq/miles). Wethtikan Town is composed of six wards. Before 1988, Wethtikan area had Police Training Camp, police station, affiliated high school and 25 bedded hospitals. As animal husbandry was mainly done in Wethtikan area, agriculture ranked second in economic activities of the area. Total paddy cultivated area was only 206.79 hectare (511 acres) and area of garden land was 8.09 hectare (20 acres). Area of agriculture land decreased to 81.34 hectare (201acres) and garden land to

4.45 hectare (11acres) in 2017. In the study period, population density increased from 171,423 per sq.km (66340 persons per sq. mile) to 321,036 per sq.km (124, 240 persons per sq.mile) because of better transportation. As it was upgraded as a town, socio-economic activities were also changed. In 1990, a high school was opened and a post primary school was established. Although Wethtikan Area has Wethtikan High School and affiliated high school at Hlwazin Village Tract, most students attend Wethtikan High School due to easy accessibility. Few years ago, students from remote areas had to stay in Wethtikan to attend the classes. At present, these children go to Wethtikan daily as commuters, because of better accessibility.

Well connected Hlwazin village tract is located in the northeast of Wethtikan Area. Hlwazin, Lebe, Inntawtha, Thaphaykhoun and Hsisankone villages are included in this village tract. Basic Education Primary School Lebe was established in 1966-67 and gradually upgraded to Affiliated Basic Education Middle School in 1971, and Branch Basic Education High School in 1996. Before 1988, students depended on ferry of Irrigation Department to go to Wethtikan. Parents planned for their children to stay in Wethtikan. At present, students can go as commuters and it only take 30 minutes on foot and 15 minutes by bicycles to attend at the Lebe Branch Basic Education High School. Green gram and groundnut are cultivated on the alluvial land. Agriculture produces of the area are sent to Aunglan Township because of easy accessibility.

Less connected Waryoneseik Village Tract is located in the northern partof Wethtikan and it possessed earth road, but it was upgraded as Laterite road leading to Kyawthar in 2005. Last two or three years, it took one hour to go to Wethtikan by bicycle and at present, it only takes 20 minutes. Therefore, travel time reduces for 40 minutes. Because of better road transportation, local people go to Aunglan Township to sell paddy to get higher income. After 1988, the number of graduate increased to 40 and Rural Clinic is established.

Less connected Tegyigon Village Tract is situated in the south-eastern part of study area. It includes 5 village tracts in which Tegyigon, Kantharyar and Sinde villages have state primary schools. After passing the primary school, students living in the area went to the state high school located in Gyoegone Village of Paukkhaung Township on foot to attend the middle school level literature and it took about an hour before 1988 as the students had to cross North Nawin Stream. In the flooding period, it was difficult to go to the school and low accessibility affects the education of the students in the area. The areas near the North Nawin Stream produce much agricultural products because of alluvial soils. But, it was difficult to sell out the crops produced in the area to other area because of low accessibility. Moreover, students living in the area also encounter difficulties on education because of poor roads.

In 2012, Township Development Committee contracted earth road and it was upgraded by self-help basis. At present, students go to State High School, Wethtikan Township and it takes only 30 minutes by bicycles and 15 minutes by bikes. In that area, education level become higher and number of graduate was 30. The number of government employee increased to 25 and socio-economic conditions of the area became higher due to better accessibility.

As better accessibility affects economic growth of the area, number of economic activities increased in the area. The young adults go to Yamethin and Meikhtila and work there as seasonal or migrant workers because they can easily come back to the study area in time of emergency due to better accessibility. It somehow show the effects of better transportation on socio-economic conditions of the area.

To reduce the poverty, Cooperative organization lends the loan to the local people but it is lent only for 6 months. Local people want to lend the loan for long term. They also lend the loan from private source but interest rate is high with 6 percent.

Findings

The main findings of this research are as follows:

Development of road transport affects the growth of rural area and the development of rural areas supported the development of urban area by means of allowing establishment of industries, services and trade (buying and selling).

Total length of the road was 76.12 km (47/3.59 miles) before 1948 period and it increased to 91 km (56/6.1) miles in 2017. Generally, travel time is reduced. Network density had increased as the numbers and mileages of the roads had increased. Before1988, road network density was 0.23% and it increased to 0.28% in 2017.

In education sector, number of school increased distinctly so that all rural children will have access to a basic education. Although students in the area encountered to continue their education after finishing primary education, students have a chance to learn higher education because of accessibility.

As the transportation sector develops, economic activities of the area somewhat increased and well-being of local people become higher.

Number of population has been increased due to natural increase and establishing boarding schools, upgrading governmental schools and the growth of connection among Yangon, Wethtikan and Nay Pyi Taw caused by better accessibility.

As consequences of the better accessibility, population growth is distinct, area of settlement area increased and number of job opportunities increased. Therefore, it is needed to maintain and upgrade existing road for the purpose of using and supporting local people. On the other hand, to get easy accessibility in education, health care and economic activities, it is necessary to plan public transports that help local people.

Conclusion

Wethtikan Area is located at the northeastern part of Pyay Township in Bago Region (West). The distance from Pyay is28.97 km (18 miles). It is located between North Latitudes 18°54' and 19°06' and East Longitudes 95° 19' and 95°27'. It has an area of 201.04 square kilometers (124.92 square miles). It has 21 village tracts which comprise of 101 villages. The total population of Wethtikan Area was 40345 persons (18 % of population in Pyay Township) in 2017. In Wethtikan Area, physical resources are suitable for agriculture and other agro-related economic activities located in rural areas.

After upgrading existing roads and establishing new roads, education of the student became higher and trade on agriculture products increased. Effects of transportation on socioeconomic conditions of the local people are district and number of economic activities also increased owing to transportation sector development.

By fulfilling the needs on transportation steadily, socio-economic condition of the area will be gradually higher in the near future.

Acknowledgement

We would like to express our deep gratitude to Dr Win Naing, Professor and Head, Department of Geography, Pyay University and Dr Le Le Win Professor, Department of Geography, Pyay University and for they kind permission to conduct this research paper and proper guidance. We are greatly indebted to Sayamagyi Dr Mi Mi Kyi (E.C member, Myanmar Academy Arts and Science) for her encouraging advice and guidance on this paper. Finally, we deeply thank to our colleagues for their eager and willing help and supports in field observation and data collection.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

CAUSES OF IN-MIGRATION IN HLAINGTHARYAR TOWNSHIP, YANGON CITY

Htay Htay Naing*

Abstract

According to the 1973 census, the population of Yangon City was just a little over 2 million (2,015,230) and it increased to 2.26 millions in the next 10 years in 1983. When the latest population census was taken in August, 2014, the population of Yangon City rose to over 5 million (5,209,541) with 1,093,200 households representing 10.13 percent of the total population of the country (Immigration and Manpower Department of Yangon, 2014). The increase of population in Yangon City was largely due to in-migration from different parts of the country for seeking higher income and better job, being the largest commercial city of the country. Out of 33 townships of Yangon City, migration is highest in Hlaingtharyar Township. The main aim of this study is to give suggestions for solving problems related to migration in Hlaingtharyar Township. The objectives are to understand the factors that cause migration and to inquire the push and pull factors of migration in Hlaingtharyar Township. Primary data collected from the field observation through structured questionnaires have been used in this study. A number of variables causing migration have been identified. To assess the strength and weakness which can bring about opportunities and threats due to in-migration SWOT analysis is applied.

Key words: migration, push and pull factors, SWOT Analysis

Introduction

Population growth rate of a country or a place basically depends on the birth rate and death rate, but it is also affected by the migration of people. The abrupt change in the number of population is usually related to migration. If anyone wishes to leave one's own homeland and relocate in other place, one can try to accomplish it. However, only a small proportion of the population usually migrate and settle in other places, mostly young men and women, educated persons and skilled workers. Migration can affect the number of population in an area. In examining the population change of a certain area, it is necessary to analyze the migration change component. Migration also

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influences population growth and structure of the population. There are two main factors that cause migration and these are push factor and pull factor.

The increase of population in Yangon City was largely due to in-migration from different parts of the country for seeking higher income and better job, being the largest commercial city of the country. In-migration rate to Yangon Region was 194.7 persons per thousand, out-migration rate 56.3, net migration 138.4, gross migration 250.9 and return migration 41.2 per thousand people. With the rapidly increasing population, the number of squatters have also increased. To allocate the squatters and provide living space for the fire victims, new towns have been extended, including Hlaingtharyar (686,827), Shwepyithar (343,270), Dagon Myothit (north) (203,883), Dagon Myothit (South) (371,579), Dagon Myothit (East) (165,518) and Dagon Myothit (Seikkan) (167,346). Among the new towns, Hlaingtharyar has the largest population. The township population was 686,827 persons in 2014 with a density of 26,406 persons per square mile with a growth rate of 14.24 percent per annum. A large number of people are still moving into the township which in turn increases the number of squatter settlement units.

Migration can be found in some townships of Yangon Region including Hlaingtharyar Township. As a result, the growth of population increased in the study area. Migration is a fundamental element determining population growth and structure in an area. Push and pull factors encourage people to migrate. This study focuses on the causes of migration into Hlaingtharyar Township in Yangon Region.

Research questions

Why migration is higher in Hlaingtharyar Township?
What are the causes of migration in Hlaingtharyar Township?

- **Aim**
- The main aim of this study is to give suggestions for solving problems related to migration in Hlaingtharyar Township.
- **Objectives**
- To examine the migration pattern of Hlaingtharyar Townshipto understand the factors that cause migration and to inquire the push and pull factors of migration in Hlaingtharyar Township.

Data and Method

According to the population census taken in 2014, Hlaingtharyar Township had 148,736 households in which 686,827 persons were living. Instead of calculating by certain formula, about one percent of the households were purposively taken to be included in the sample size. For selecting samples among the households, stratified sampling method is used, dividing the urban and rural areas. The wards are selected based on the number of squatters recorded in the Township General Administration Office. Ward No. 2, 3 and 5 with greater number of squatters, Ward No. (10) that has no squatters, Ward No. 13 and 18 with small number of squatters, Ward No. 4 with FMI Housing Project and Ward No.6 that has Nawaday Housing Project and Kyansitthar Housing Project are selected. The reason why the wards with squatters are selected is on the conception that though all migrants are not squatters, but all squatters are migrants. The choice of village tracts for sampling is based on Random Table. The township has 9 village tracts of which Yeokkan, Apyinpadanand Kasin are selected (Table 1).To get detailed information and primary data, field survey were conducted by questionnaires during the period from 30-6-2016 to 7-8-2016.

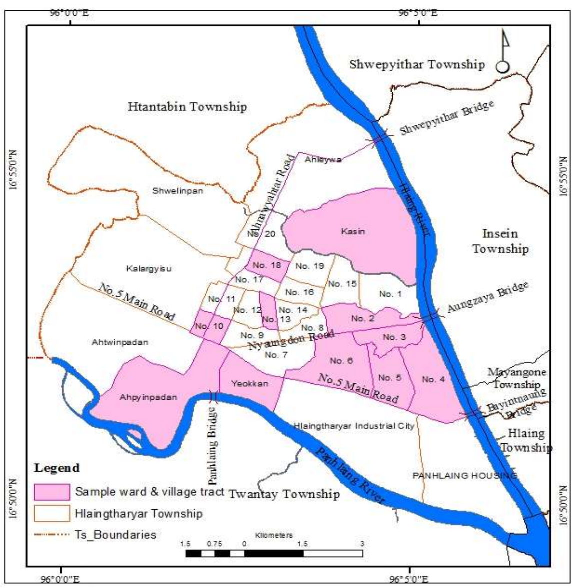

Figure 1. Location of sample wards and village tracts in Hlaingtharyar Township

Source: Survey Department and General Administrative Department, Hlaingtharyar Township

Household Heads for sampling are identified by the help of heads/ chairmen of the wards and village tracts who are supposed to know heads of each migrant family settling along the different roads and different sections of the wards or village tracts.

Heads of households as identified by the chairmen of ward/village tract are asked the questions mentioned in the questionnaires. Some male household heads were absent, being occupied at their respective worksites. Under such situation, housewives are asked to answer the questions.

Study Area

Hlaingtharyar Township occupies the western suburb of Yangon City between the Panhlaing and Hlaing Rivers. It is located between north latitude 16˚ 49' 30"and 16˚54' and between east longitudes 95˚59'30" and 96˚06' 45". The township comprises 20 wards and nine village tracts, and shares borders with Htantabin Township on the north and west, Shwepyithar Township on the northeast, Insein Township, Mayangon Township and Hlaing Township on the east across the Yangon River, and Twante Township on the south.

Hlaingtharyar is the most developed among new satellite towns founded in the 1985. Hlaingtharyar Industrial Zone is one of the largest industrial areas in the country established in 1995. There were 13 industrial zones and 918 factories in 2014. The total area of industrial land uses was 1879.84 hectares in 2015. After Cyclone Nargis, the township experienced a jump increase in population due to storm victims. The total population was 374,698 persons in 2010 and 686,827 persons in 2014. The population growth rate was (141.56) percent during the four-year period.

Results and Findings

Demographic Characteristics of Migrants in Hlaingtharyar Township

Among the 1500 heads of household, 1448 (96.53%) are not native; they came from different parts of the country including Yangon Region. Only 52 (3.47%) are natives of Hlaingtharyar. Therefore, the migrants outnumber than the natives in every ward and village tract of Hlaingtharyar.

Occupation of Migrants

Occupations by which the migrants earn their living are classified into 11 categories. Generally the distribution pattern of migrants in each work category corresponds to the distribution pattern of the 1500 family heads. The majority of migrants are engaged in random jobs, construction work and factories for industrial production.

Table 1. Occupation of Migrants in Hlaingtharyar Township

Type of job	Number	Percent
Government employees	18	1.24
Retired	21	1.45
Agriculture	5	0.35
Manufacturing industry	200	13.81
Company	81	5.59
Transportation	144	9.94
Construction	222	15.33
Commercial	94	6.49
Services	100	6.91
Random / informal	385	26.59
Dependent	178	12.29
Total	**1448**	**100**

Source: Field Observations, (30/6/2016 - 7/8/2016)

Education Standard of Migrants

The education standards of the majority of migrants are of basic education level, greatest in number with basic middle school level which represented a little over one-third (37.22%). Those with monastery education and basic primary school level accounts for 26.93 percent, followed by those with basic high school level (21.96%). Generally, the education level of the heads of most migrant families is lower than basic high school level. The number of migrant family heads with graduate or diploma or post-graduate level represents only 7.73 percent of the head total.

Table 2. Education Standard of Migrants in Hlaingtharyar Township

Type	Number	%
Illiteracy	13	0.90
Monastery Education	76	5.25
Primary School	390	26.93
Middle School	539	37.22
High School	318	21.96
University	30	2.07
University graduate	75	5.18
Post-graduate	7	0.48
Total	**1448**	**100.00**

Source: Field Observations, (30/6/2016 - 7/8/2016)

Household Size

Merriam-Webster Dictionary defines 'household' as 'the people in a family or other group that are living together in one house. In the 1448 sample households, some households have more than one family living together in one residential unit. The households that have 1 to 3 members are considered as small size, 4 to 6 members as median size and 7 and above as large size. The sample households include 652 (45.03%) small size households, 704 (48.62%) medium size households and 92 (6.35%) large size households. The average household size is 4 persons and the total population of the 1448 sample household is 5,616. Generally the median household size is the most common.

Table 3. Household Size of Migrants in Hlaingtharyar Township

Household Size	Number of Household	%
Small size households (1 - 3 persons)	652	45.03
Medium size households (4 - 6 persons)	704	48.62
Large size households (≥7 persons)	92	6.35
Total	1448	100

Source: Field Observations, (30/6/2016 - 7/8/2016)

Working Population

Generally one or two family members are engaged in certain jobs. The number of households with 3 or more than 3 workers is small representing only 26.59 percent of the total migrant households.

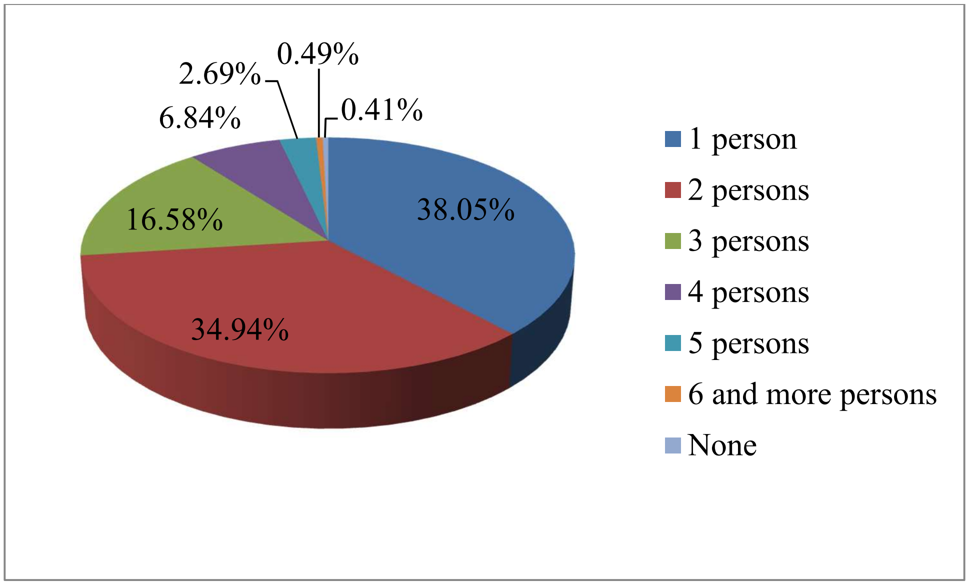

Figure 2. Working population in a migrant household
Source: Field Observations, (30/6/2016 - 7/8/2016)

House Ownership

The majority of the migrant households have no own house. Only 12.64 percent of the heads of household have their own house. Among the 1448 households, 1232 households (85.08%) have to live in the rented house or apartment for shelter. There are a few families that live together with their relatives and some few families built their own house or hut on the empty space belong to someone by renting the vacant land. In the long run, such type of living is more economical than by renting house or apartment. The current house/apartment rent is between Ks 30000 and Ks 65000 per month and the rent for land is Ks 15000 to Ks 20000 per month.

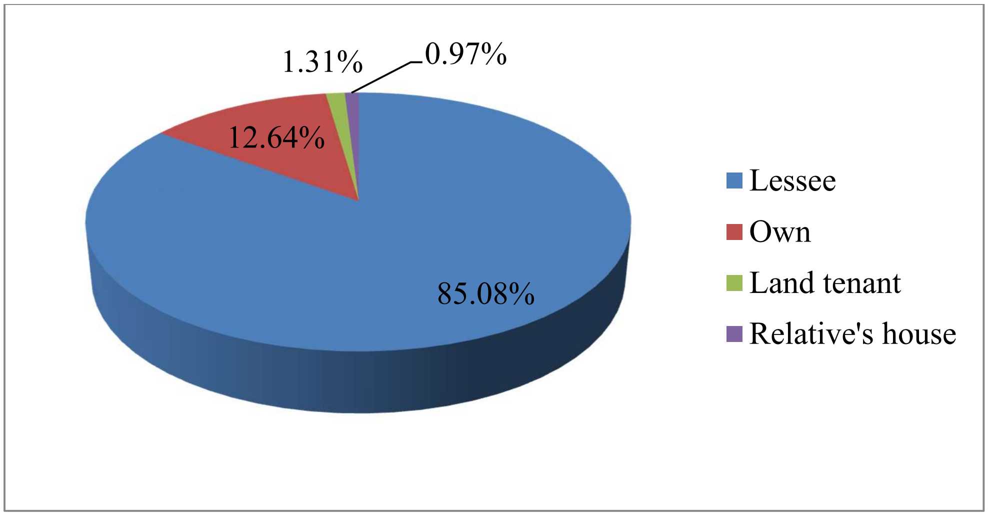

Figure 3. Ownership of House of migrants
Source: Field Observations, (30/6/2016 - 7/8/2016)

Pattern of Migrant Movement

Migrants to Hlaingtharyar lived for a certain period in the native land or other places before moving to Hlaingtharyar. Some came from the urban areas, but the greater proportion came from the rural areas. The migrants include that came from Yangon Region, other states and regions as well as from abroad.

Among the 1500 sample households 96.53 percent are migrants and only 3.47 percent are natives of Hlaingtharyar. The number of the migrant family heads that came from certain urban areas was 606 (41.85%) and the remaining 842 (58.15%) came from different places of the rural areas.

Among the 842 families that came from rural areas 549 (65.20 %) lived in Ayeyarwady Region before they moved to Hlaingtharyar, 85(10.10%) in Bago Region, 80 (9.50%) in Magway region and 67 (7.96 %) in Yangon Region. The number of migrants from other regions and states are very limited. For instance, there are only 18 (2.14%) that moved from Rakhine State and the number of migrants is even smaller from other states. No people have ever migrated from Kachin and Kayah States to Hlaingtharyar.

The migrants who came from the urban areas lived in different regions and states, except Kachin and Kayah states. There are 606 families that migrated from the urban areas of which 284 (46.86 %) are from Yangon Region, 168 (27.72 %) from Ayeyarwady Region, 56 (9.24 %) from Bago Region, 28 (4.62 %) from Mandalay Region, 23 (3.80 %) from Magway Region and one each (0.17 %) from Chin State and Naypyidaw, but nil from Kayah State.

The number of migrants is largest from Ayeyarwady Region with 717 (49.52 %), followed by Yangon Region with 351 (24.24%), Bago Region with 141 (9.74 %) and Magway Region with 103 (7.11%). Only 5 (0.35%) migrants came from Tanintharyi Region, the least among the regions of the country. Among the 7 states, Rakhine State ranks first in the number of migrants to Hlaingtharyar with 33 (2.28%) and Napyidaw is at the bottom with only one (0.07%) migrant. There is no migrant that moved to Hlaingtharyar from Kayah State. The number of migrants from the remaining states is very limited (1.04%). For the whole Union, the number of migrants to Hlaingtharyar is least from Naypyidaw and Chin State and nil from Kayah State.

Table 4. Migrants from regions and states to Hlaingtharyar Township

No.	Region / State	From Urban		From Rural		Total	
		Family	%	Family	%	Family	%
1	Ayeyarwady Region	168	27.72	549	65.20	717	49.52
2	Yangon Region	284	47.36	67	7.96	351	24.24
3	Bago Region	56	9.24	85	10.10	141	9.74
4	Magway Region	23	3.80	80	9.50	103	7.11
5	Mandalay Region	28	4.62	29	3.44	57	3.94
6	Sagaing Region	7	1.16	1	0.12	8	0.55
7	Tanintaryi Region	4	0.66	1	0.12	5	0.34
8	Rakhine State	15	2.48	18	2.14	33	2.28
9	Mon State	8	1.32	7	0.83	15	1.04

No.	Region / State	From Urban		From Rural		Total	
		Family	%	Family	%	Family	%
10	Kachin State	4	0.66	0	0.00	4	0.27
11	Kayin State	0	0.00	3	0.36	3	0.21
12	Kayah State	0	0.00	0	0.00	0	0.00
13	Shan State	7	1.16	1	0.12	8	0.55
14	Chin State	1	0.17	1	0.12	2	0.14
15	Nay Pyi Taw	1	0.17	0	0.00	1	0.07
	Total	**606**	100.00	**842**	100.00	**1448**	100.00

Source: Field Observations, (30/6/2016 - 7/8/2016)

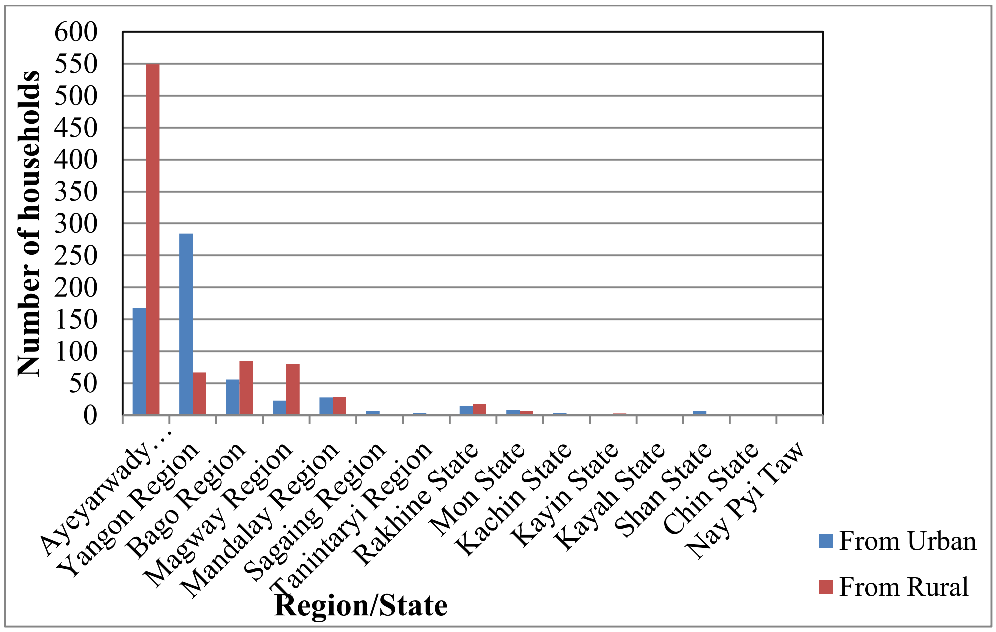

Figure 4. Migrants from regions and states to Hlaingtharyar Township
Source: Field Observations, (30/6/2016 - 7/8/2016)

Generally the greater proportion of migrants to Hlaingtharyar came from the rural areas, but as for Yangon Region, three-fourths of the migrants are from the urban areas. There is no migrants that moved from the rural areas of Kachin State and Naypyidaw. In contrast, there is no migrant from the urban area of Kayin State to Hlaingtharyar.

Times of Migration

When the heads of sample households were asked the time of migration to Hlaingtharyar Township, they could not respond the month and year of migration from their natives. However, most household heads could answer to the question how many years have they been living Hlaingtharyar Township. Based on the answers, the period from 1985-86 when the township was established to 2016 were divided into 6 shorter periods for comparative study.

In the beginning of sampling, 1500 households were included in the sample. As 52 households had been occupying the area since before the constitution of the new township, these households were excluded in this analysis. Households from other places have gradually migrated to Hlaingtharyar Township, since after the establishment of the township. The influx of migrants escalated in the 1997-2001 period, after the establishment of industrial zones in the township. The number of households that migrated were 173 (16.78%) in the 2002-2006 period, 348 (24.03%) in the 2007-2011 period and 511 (35.29%) in the 2012-2016 period. The increasing number of migrant people in the later years indicates that the township has more jobs and space to offer to the migrants.

The coastal area of Ayeyarwady deltaic region was hard hit by the storm Nargis in May 2008, flattening a great number of households and damaging widespread cropland. As such a number of people left their natives to the places where they could survive. Hlaingtharyar Township has been one of their targets. Of the 1448 sample households, 632 (43.65%) had migrated to Hlaingtharyar Township before the storm Nargis battered the southern part of Ayeyarwady Delta. The number of sample households that migrated to Hlaingtharyar Township was 816 (56.35%) after the storm. Therefore, it can be said that the migration of people to Hlaingtharyar Township was somehow related to the destructive Storm Nargis.

Changes in Occupation before and after Migrating to Hlaingtharyar

Occupation before Migration

Most family's heads of the migrants to Hlaingtharyar earned their living by engaging in farm work or fishery in their native land. Out of 1448 migrants, 490 (33.84%) were engaged in the farm work or fishery. Their main livelihoods were growing crops on 'Le' and 'Kaingkyun' lands, livestock breeding and fishing. The second most important group includes those involved in random jobs before leaving their homeland. This group accounts for 23.0 percent of the total migrants to Hlaingtharyar. The third group comprises jobless dependents, including who had no job, students and other types of dependents, representing 18.44 percent of the total migrants. Among the migrants, there were only a few engaged in government services, transportation, construction, trade and service businesses. The number of migrants involved in private companies and factories was the least. No one was a pensioner among the migrants before moving to Hlaingtharyar.

Present Occupation

Among the heads of sample households of the migrants, 385(26.59%) are engaged in various random jobs in Hlaingtharyar. This group is the largest in proportion among the migrants, followed by the group engaged in construction work with 15.33 percent. Those who engaged in private mills and factories rank third in number with 13.81 percent, followed by those who have no job or dependents with 12.29 percent, in transportation sector with 9.95 percent, in services with 6.91 percent, in small-scale trading with 6.49 percent and in private companies with 5.59 percent. A little over one percent each are government service personnel and pensioners. Only less than one percent (0.35%) earns their living on agriculture. (Table 3.1)

Table 5. Changes in Occupation before and after Migrating to Hlaingtharyar

Type of job	Dependent	Agriculture	Random job	Manufacturing industry	Company	Government servants	Retired	Transportation	Construction	Commercial	Services	Before HTY (Total)	%
Dependent	30	0	51	42	20	6	4	48	35	14	17	267	18.44
Agriculture	52	4	144	67	39	5	0	34	86	32	27	490	33.84
Random job	48	0	131	51	3	1	0	27	42	10	20	333	23.00
Manufacturing i	1	0	4	7	3	0	0	1	2	0	2	20	1.38
Company	2	0	1	2	4	0	0	1	3	2	4	19	1.31
Government ser	6	0	2	4	2	5	14	2	3	3	3	44	3.04
Retired	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Transportation	4	0	4	5	1	0	1	22	6	0	1	44	3.04
Construction	4	0	10	2	0	0	0	0	37	1	1	55	3.80
Commercial	23	0	27	12	4	0	1	5	1	3	25	101	6.98
Services	8	1	11	8	5	1	1	4	7	29	0	75	5.18
Total (Current)	178	5	385	200	81	18	21	144	222	94	100	1448	100.00
%	12.29	0.35	26.59	13.81	5.59	1.24	1.45	9.94	15.33	6.49	6.91	100.00	

Source: Field Observations, (30/6/2016 - 7/8/2016)

The Changes in Occupation

Before migration, 33.84 percent of the total migrants earned their living on agriculture and fishery, but only 0.35 percent are new engaging in such activities. Of the people, the majority (60.61 %) are now involved in random jobs, construction work and in factories and manufacturing plants. This implies that it is relatively easier in seeking job at Hlaingtharyar Township. Of the remaining some 40 percent, 7.96 percent are now engaged in private companies, 6.94 percent in transportation, 6.53 percent in trading and 5.51 percent in services activities. A very small proportion (1.02 %) becomes government service personnel. There is no one who has become dependent or retired person.

The migrants, who were dependents in their respective homeland which represent 18.44 percent of the migrant total, now share only 12.29 percent. Of the total dependents and jobless persons before migrating to Hlaingtharyar 19.10 percent are now engaged in random jobs, 17.89 percent in transportation, 15.73 percent in factories and mills, 13.11 percent in construction work, 7.49 percent in private companies, 6.37 percent in services, 5.24 percent in commercial activities and 2.25 percent become government service personnel and 1.50 percent pensioners. For various reasons, 11.24 percent have become dependents, but no one is engaged in farm work.

Among the migrants, 23.0 percent were random job workers before migration and the proportion has slightly increased to 26.59 percent after migration. Of the total former random job workers, 39.34 percent are now involved in random jobs in Hlaingtharyar, 15.32 percent in private factories and mills, 12.61 percent in construction work, 8.11 percent in transportation, 6.01 percent in service activities, 3.0 percent in trade, 0.90 percent in private companies, and 0.3 percent in government services. Among the former random job workers, 14.41 percent have now become dependents, but no one has turned to become pensioner or farm worker.

The number of migrants who earned their living by trading before migration accounted for 6.98 percent of the migrant total. Among the migrants in Hlaingtharyar Township, 6.49 percent are now involved in commercial activities, decreasing slightly in proportion. According to questionnaire survey, 3 (2.97%) out of 101 former traders now continue their former occupation. Most of them (27 or 26.73%) have become daily wage earners in random jobs, followed by services activities with 25 (24.75%), private factory or mill workers with 12 (11.88%), transportation workers with 5 (4.95%), company workers 4 (3.96 %), each pensioner and construction worker 1(0.99%) each. There is no one who get involved in government service and farm work, but 23 (22.77%) have become jobless persons or dependents.

The former number of migrants who earned on service activities shares 5.18 percent of the total migrants, currently 6.91 percent of the migrants in Hlaingtharyar Township are engaged in services for their livelihood. However, no former services workers continue the same occupation in Hlaingtharyar Township. The majority 29 (38.67%) have become small traders while 11 (14.67%) are engaged in random jobs, 8 (10.67%) in private factories and mills, 7 (9.33%) in construction work, 5 (6.67%) in private companies, 4 (5.33%) in transportation, and each one in farm work and government service. Another one is retired and 8 (10.67%) has to depend on the income of others.

Among the migrants to Hlaingtharyar Township, 3.80% were construction workers before they left their native land. Now, in Hlaingtharyar Township, 15.33 percent are engaged in construction work, increasing by fourfold. Among the former construction workers 67.27% continue their old occupation in Hlaingtharyar Township, and 18.18 percent are engaged in random jobs, 3.64 percent in factories and mills, and 1.82 percent each in commercial and services activities, and nil in government service, farm work, company and transportation. No one has become retired person, but 7.27 percent have become dependents.

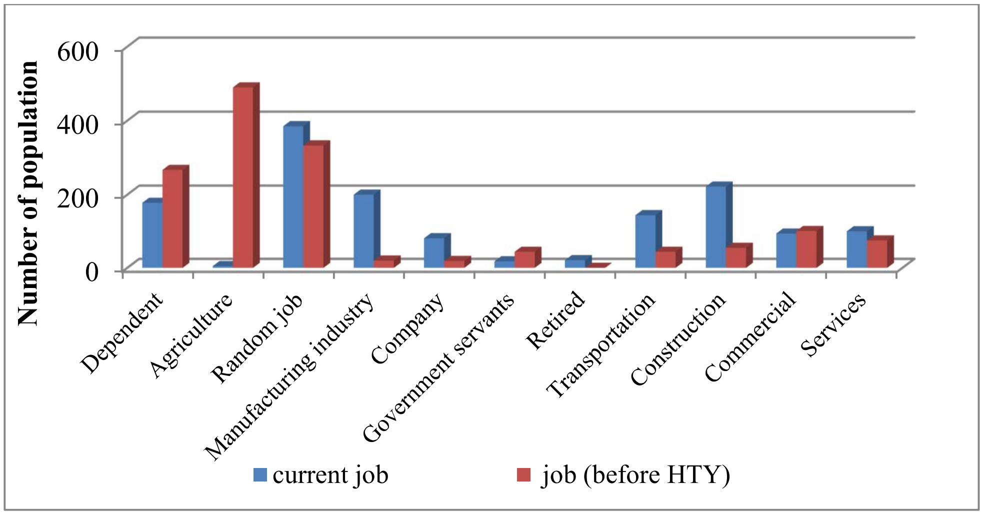

Figure 5. Changes in occupation of household heads in Hlaingtharyar Township

There were 3.04 percent of the total migrants whose occupation was transportation before they migrated to Hlaingtharyar Township. At present 9.95 percent of the total migrants are engaged in transportation. The number of former transportation workers was 44 of which 22 (50%) are now carrying on their old job whereas 13.64 percent are now engaged in construction, 11.36 percent in private factories and mills, 9.09 percent in random jobs, 2.27 percent each in companies and services, and another 2.27 percent are retired. Those who have become dependents or jobless persons account for 9.09 percent. No one of this group has become farm worker, government service personnel and sellers or buyers.

The number of migrants those who were engaged in government service share 3.04 percent of the total migrants. After migration only 1.24 percent is working in government services. Before migration 44 were government service personnel of which 11.36 percent continue to work in government departments while 31.82 percent have retired and 6 (13.64%) have no job or become dependents. Among the remainder, 4 (9.09%) are now engaged in private factories and mills, 3 (6.82%) each in construction work, commercial activities and services, and 2 (4.55%) each in transportation, company and random jobs, but nil in farm work and fishery.

Before migration to Hlaingtharyar Township, 1.38 percent of the total migrants were involved in private factories and mills. Now the number of migrants those who are engaged in the same occupation accounts for 13.81 percent of the total migrants, increasing ten-fold. Of the former factory or mill workers 35 percent now continue to work the same job in Hlaingtharyar Township, while 20 percent are engaged in random jobs, 15 percent in private company, 10 percent each in construction work and services and one in transportation. The remaining one has become dependent.

Before migration to Hlaingtharyar Township, 1.31 percent had their employment in private companies, the least occupation category in the migrant workers. In Hlaingtharyar Township, 5.59 percent of the total migrants are now company workers, increasing by about four-fold. Of the total former company workers, 21.05 percent continue to work the same job in Hlaingtharyar Township, while another 21.05 percent are engaged in service activities, 15.79 percent in construction work, 10.53 percent each in commercial activities and factories and mills, 5.26 percent each in transportation and random jobs, but 10.53 percent have become jobless dependents. There is no one who earns living on farm work, government service or is retired.

No one was pensioner among the migrants before they left their native, but 1.45 percent of the total migrants are now retired persons.

Push Factors and Pull Factors

Out of 1500 sample households, 1448 (96.53%) are migrants. The migrants have left their native lands for various reasons which can be differentiated as push factors and pull factors. Some migrated because of push factors and some due to pull factors or both. Push factors can be categorized as economic factor, social factor, environmental factor and governmental factor, while pull factors constitute economic factor, social factor and environmental factor. According to the responses by heads of sample households, there is no migrant migrated due to governmental factor relating to pulling effect the government policy.

Push Factors

Economic factor is concerned with low job opportunity, difficulty to make both ends meet, lack of shelter and being government service personnel. Among the heads of migrant households 24 (1.7%) had no regular job and not sufficient income to support the family. They can get random job easily in Hlaingtharyar Township and the income is fairly sufficient for their livelihood. There are 22 heads of households (1.5%) who have been transferred to Hlaingtharyar Township as government service personnel. Among this category, those who could not support their families with their income share the largest proportion with 28 households (1.8%). with a limited income they could hardly resist the hardship of being poor. That is why they have migrated to Hlaingtharyar Township with the expecion of getting better job and more income. There are 4 households (0.3%) with no shelter to live in and sufficient food for survival. This type of households is the least among the migrants.

Table 6. Push and pull factors of immigration in Hlaingtharyar Township

Reasons			Frequency	Percent	Total
Push	Economic Factor	Under employment	24	1.7	386 (26.66%)
		Job transfer	22	1.5	
		Survival	30	2.1	
	Social Factor	Family migrate	50	3.5	
		Married	72	5	
		Demise parents	9	0.7	
	Environmental Factor	Natural disaster	84	5.8	
		Worry for fire hazard	10	0.7	
	Governmental Factor	Government Policy	85	5.9	
Pull	Economic Factor	In search of job	958	66.2	1062 (73.34%)
		better shelter	32	2.2	
	Social Factor	To live with parents	60	4.1	
		better educational opportunities	7	0.5	
	Environmental Factor	more convenience in life	5	0.3	
Total			**1448**	**100**	**1448**

Source: Field Observations, (30/6/2016 - 7/8/2016)

Migrants due to social factor can be differentiated into 4 types: migration of all family members, migration due to marriage, migration due to the demise of family member or members and migration due to lack of effective healthcare services, of which migration due marriage are the largest in number with 72 households which represented 5.0 percent of total migrant households. The newly wedded couples believed that if they persisted on living in the rural area they could not overcome the vicious circle of poverty. They wanted to improve their living condition. They had good images of urban area, particularly Hlaingtharyar with high accessibility, high employment opportunity, fairly low house rent, easy access to the downtown and they also considered the education of their coming offspring. There are 50 households (3.5%) whose all members of families have migrated to Hlaingtharyar Township, the second largest group due to social factor. Some members were still young when they migrated together with their parents. After living several years in HTY, they got married and now become heads of the migrant households in HTY. In HTY Township, although their living standard is fairly low, they do not want to go back to their homeland where job opportunity is low. A few migrated due to the demise of their close relatives. Such types of migrants constitute a few, only 8 (0.6%) households. Having no kinship in their respective villages and they ventured to migrate as the Myanmar saying goes 'One cannot prosper unless one move to another place (village)'. Among the migrants who moved HTY Township on the ground that the rural area had no effective health care service include only one household (0.1%).

Migration related to environmental factor includes mainly due to disastrous effect of powerful and destructive Storm Nargis. Some lost their land; some could not continue fishing because of serious habitat changes, while others had no job even as a daily wage earner. A few migrated due to being afraid of fire that might break out at anytime among the rural huts.

The Storm Nargis battered the Ayeyarwady Region on 2nd May 2008, killing over 100,000 and a greater number of those living in the coastal area became homeless; a wide tract of farmland was heavily inundated; the invasion of saline water destroyed the planted crops. Losses of family members and draught animals, serious destruction of home, damage of planted crop caused depression to many a local inhabitant to start their live again in their rural homeland. As a result 84 (5.8%) out of 1448 sample households migrated to HTY Township. There are 10 households (0.7%) that moved from their native due to anxiety over the possibility of fire breakout.

Government factor over migration is solely related to rehabilitation of fire victims of Mayangone, South Okkalapa, Thingangyun and Kamaryut townships as well as squatters from other townships of Yangon City. This type of migration includes 85 (5.9%) out of 1448 sample migrant households.

Among the 4 types of migrants related to push factors, the number of households is largest due to social factor with 131 households which account for 9.2 percent of the total sample households, followed by on account of environmental factor with 94 (6.5%) and of governmental factor with 85 (5.9%). The number of households migrated due to economic factor is the least with 76 households (5.3%). Table (1)

Pull Factors

Pull factors of HTY Township over migrants includes economic, social factor and environmental factor. The most important is economic factor, the availability of job in HTY Township. The majority, 958 out of 1448, migrated to HTY due to better chance of job availability which account for 66.2 percent of the total migrants. This clearly shows that the migration of a greater number of people to HTY Township is mainly due to job availability. According to the responses of heads of sample households, there are many factories and mills in HTY and they can easily engage in certain job. The cost of living is relatively lower than in the inner part of Yangon City. There are 32 households (2.2%) that migrated to HTY due to having better shelter.

As regard with social factor, some migrated to live together with their relatives, while some expected better educational opportunities for their off springs. Among the sample households 60 (4.1%) migrated to live together with their kins while 7 households (0.5%) decided to move to HTY Township with the expectation of better educational opportunity for their children.

Environmental factor is concerned with the privileged who want to shun away for the stress of urban congestion and decided to settle at an apartment or house in FMI compound. Therefore such migrants are limited in number, only 5 (0.3%) among the sample households. Only the upper class can afford to purchase an apartment or a house in FMI. The existence of high-price residential buildings in the study area together with mostly low-price ones shows explicit economic polarization and class distinction, essentially the outcome of free economic system.

Summing up the pull factors, the greater proportion (958 or 66.2%) of the migrant households made decision to move to HTY Township on the fact that they could get certain job there which can solve their basic essentials. Other pull factors such as for living together with their close relatives, availability of better educational opportunity and living in stress-free area with high-prize modern style building are less effective in decision making for migration to HTY Township. Those households migrated due to pull factors highly outnumber the households that moved by the push factors with 1062 (77.3%) and 386 (26.7%) respectively. These figures clearly indicate that the pull factors are more powerful and important in the migration of people to HTY Township.

Table 7. SWOT Analysis on in-migration of Hlaingtharyar Township

Strength	**Weakness**
- Large human (manual) resource - Cheap shelter - Can seek job easily for basic livelihood than in the native	- Low skill labour; the nature of job is different from the native - Causing housing shortage problem - Housing and drains are not in systematic pattern - No systematic plan for the in-migrants as well as administration
Opportunities	**Threats**
- High job opportunity - Investment opportunity for new economic activities (e. g house renting, selling certain items) -More incoming of migrants having industrial zones; can reap the benefit of agglomeration - Unskilled labour can be trained to become skilled lobour	- Labour shortage in their origin - Emergence of squatter settlements - Can increase crime rate - Low wage, unemployment and underemployment may increase squatter settlements

Source: Field observations and interviews (30/6/2016 - 7/8/2016)

Discussion and Conclusion

This paper analyzes the causes of in-migration to Hlaingtharyar Township, Yangon City. To have comprehensive understanding of pull factors and push factors, open and structured interviews (questionnaires) are conducted on 1500 sample households. The data and information from the respondents are analyzed, essentially including demographic characteristics, causes of migration, profile of the household members and employment status.

Among the sample households 96.53 percent are migrants to Hlaingtharyar Township. The education status of most migrants is of basic primary or basic middle school levels. They came to Hlaingtharyar Township mostly from the rural areas than from other urban areas. The rural migrants include a greater number from Ayeyarwady Region and the urban migrants mostly from Yangon Region. Generally most migrants are from Ayeyarwady, Yangon and Bago regions. Among the remaining regions and states, those who came from Rakhine State are greatest in number, as the state is vulnerable to natural hazard and economic hardship.

Being hard hit by Storm Nargis in May, 2008, and serious flooding, some rural people of the Ayeyarwady deltaic region lost their farmlands and property leading to more difficulty to persist on living at their rural natives. Such effect of natural disaster and scarcity of job to earn a living drove them to move to other places, particularly to Hlaingtharyar Township. The negative impact of Storm Nargis has been the strongest push factor for migration. According to the responses of heads of sample households, 816 (56.35%) were migrated to Hlaingtharyar Township after the Storm Nargis.

Therefore, the main cause of migration to Hlaingtharyar Township is the scarcity of job in the rural area to make both ends meet. Among the heads of sample households 66.2 percent have migrated to Hlaingtharyar to get a job with fairly high income. Due to the pull factor of high job opportunity, the township population has been increasing rapidly.

There are 490 (33.84%) heads of households who were engaged in the farmwork before shifting to Hlaingtharyar Township. The nature of available job in Hlaingtharyar Township is unlike that of farmwork and thus they are mere unskilled labour in Hlaingtharyar.

Before moving to Hlaingtharyar, 18.44 percent of the heads of households were dependents. The proportion of dependent slightly decreased to 12.29 percent. Those who were engaged in farmwork in their natives, the majority (98.97%) are now working in different work categories, particularly in random jobs, but 0.35 percent remains as farmers in the new place.

Among the heads of sample households 183 (12.64%) have own house while the majority (1232 or 84.41%) have to live in the rented houses or small apartment, indicating high housing requirement for the migrants.

According to responses of the household heads, 74 (5.11%) want to move to other better place. Half of them want to migrate due to economic reason, and another half to social reason, particularly to the place where their relatives are residing. Among them 50 percent want to resettle in their natives. One of the heads cannot make decision whether to stay on in Hlaingtharyar Township or go back to his natives. However, the large majority (1373 or 94.82%) have decided to settle forever in Hlaingtharyar Township.

Migration of people in greater number to Hlaingtharyar Township results in scarcity of labour in the rural area to carry out farmwork. On the other hand, the rapid increase of population in Hlaingtharyar Township enhances housing problem and the emergence of squatter settlements. By establishing agricultural trading centres in the rural area, the inertia of push factor can somehow be reduced. As the great majority of in-migrants are not willing to go back to their natives, more job opportunity should be created with reasonable wage or salary. At present, the government of Yangon Region is collecting data of the squatter houses to relocate at a suitable place with low-cost housing or apartment. Such undertaking is highly welcome to the squatters as well as to the townships concerned. According to field survey, not all the squatters are so poor. As they do not need to pay house rent, some could have saved extra money and ever built a strong semi-brick house. However, as the majority have to live in rented room, the number of squatter units is likely to increase over time, unless the authority concerned can solve the problem. Therefore, the government should also take consideration for the migrants who are currently living in rented houses.

Acknowledgements

I would like to express my special thanks to supervisor Dr. Zin Nwe Myint, Associate Professor, Department of Geography, University of Yangon, for her encouragement and valuable suggestions. I also would like to recognize the gratitude indebted to the editors of Myanmar Academy of Arts and Science who give me permission to publish this paper.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

GEOGRAPHIC ASSESSMENT ON SPATIAL VARIATION OF LAND SURFACE TEMPERATURES IN YANGON CITY

Khin Kay Khaing*

Abstract

Biophysical attributes of earth surface in non-evaporating and impervious materials cause the solar energy to raise Land Surface Temperature (LST). At present, LST obtained by satellite technology can furnish effective assessment of surface temperatures variation than thermometer network based assessments. The main aim of this study is to evaluate the use of Thermal Infrared Remote Sensing for assessing temperature differences in Yangon City area. The estimation of surface temperature variation and areas of high temperature is the major objectives of this study. Local studies of LST need to use a sensor with high resolution, therefore, Thermal data of Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 with resolution of 30 meter for 1994, 2003, and 2014 are used respectively in this study. The output LSTs are classified into only two classes between low and high temperature areas according to the temperature ranges. Again the total area of Yangon City is divided into five categories from high temperature to low temperature for clear distinguishing. The obtained output images of LST are exported to present as layout maps for better understanding of the temperature variation in the area. It was observed that areas having built up surfaces contain high temperatures compared to the areas having vegetation cover. The thermal energy responses of different structures of the City indicate the variations in surface temperature. Ground-based observations reflect only thermal condition around the station. However, by using remote sensing thermal bands in this study enable to get the thermal condition for each pixel and assess the spatial variation of temperatures on the whole area of city.

Keywords: LST, thermal infrared remote sensing data (TIR), spatial variation

Introduction

The study of surface temperature, on local climate condition, has been important work in present days since global temperatures are increasing. The earth surface and all substances on it releases temperatures, but the urban centres are releasing much more heat than other places due to the large

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number of industries, the use of automobiles, dense settlement, uses of air conditioners and the lack of trees and other vegetation there. Urbanization refers to general increase in population and the amount of industrialization of a settlement (K. Sundara Kumar et al., 2015). The built-up area is generally considered as the parameter for quantifying urban sprawl (J. S.Yang et al., 2004). Urban sprawls have several environmental impacts and the extension of built up area that cause the increase in surface temperature and development of urban heat island is one of significant impact of climate on urban structure.

The climatic elements have been observed by climate stations and almost each city has at least one climatic station. In many cases, however, station based observations do not express actual climate variability and microclimate conditions. These observations reflect only thermal local condition around the station. At present, by using remote sensing thermal bands the researcher is enable to get the thermal condition for each pixel in the image. Remotely sensed thermal infrared (TIR) data have been widely used to retrieve land surface temperature (LST) since satellite sensor data provides a dense grid of almost instantaneous temperature measurements over a city by permitting spatial relationships between temperature patterns and land surface features. This study analyzes the surface temperature variation in terms of both temporal and spatial extent with the application of remote sensing data.

Study Area

Yangon City, a total area of 796.4 square kilometer, located between north latitudes 16° 30′ and 17° 11′ and 17° 31′, East longitudes between 92° 11′ and 92° 30′ is taken as study area (Figure 1). It is the most populated area in Myanmar.

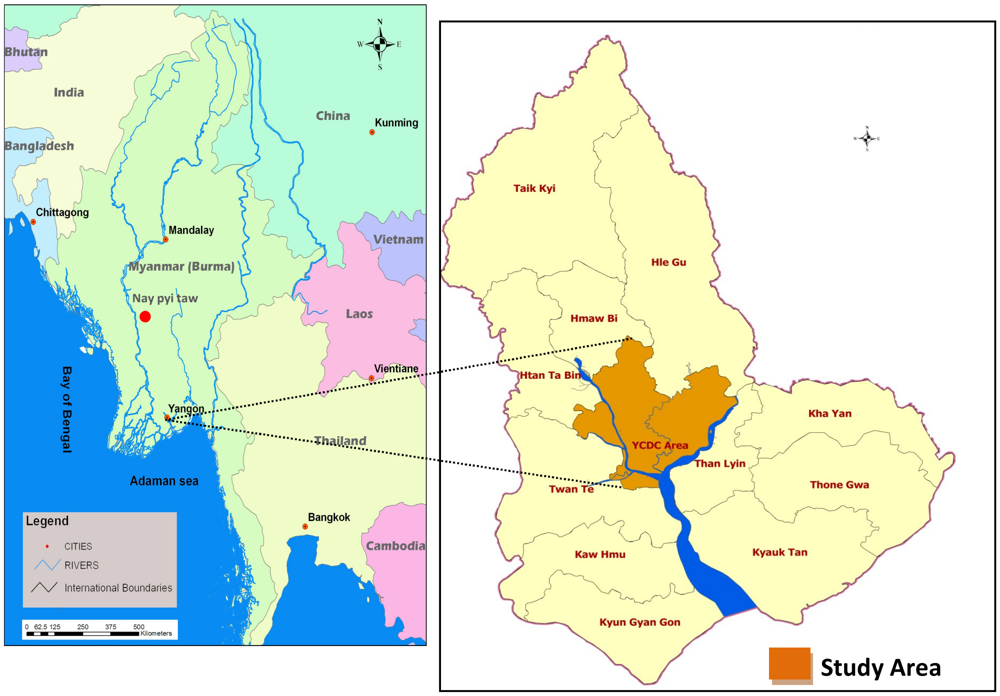


Figure 1. Location of Yangon City

Population of the study areas has increased rapidly within the past two decades mostly due to migration from the rural sites towards urban areas. In accordance with increasing population about, 2.99 million in 1994 to about 5 million in 2014, the surface structure of the city is changed significantly. Replacing natural land cover with pavements, buildings and other infrastructures takes away the natural cooling effect. According to YCDC, land use categories in Yangon City in 2013 are presented in figure 2.

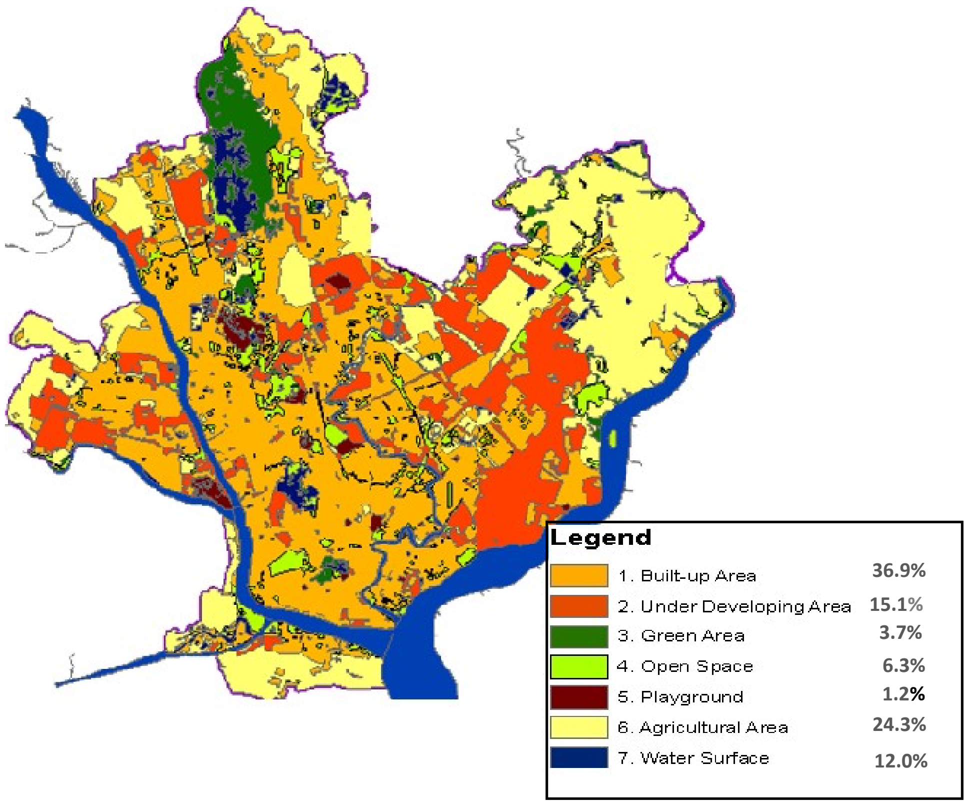


Figure 2. Land cover classification of Yangon City in 2013
Source: Khine Moe Nyunt and YCDC, 2013

Purpose

The main purpose is to evaluate the usefulness of remotely sensed thermal infrared (TIR) data in retrieving land surface temperature (LST). The major objectives are the estimation of land surface temperature variation during two decades and detection of area of high and low temperatures.

Materials

Satellite TIR sensors measure radiances at the top of the atmosphere (TOA), from which brightness temperatures (also known as blackbody temperatures) can be derived by using Plank's law (Dash et al., 2002). It is assumed that the water vapour content of the atmosphere is constant for a relatively small region, so that the atmospheric condition could be considered as uniform, and the influence of atmosphere on radiance temperature could be neglected (Xiao_ling Chen et al., 2006). To get pixel wise surface temperature in this study, satellite images are used as the main materials in this study. Landsat 5 (MSS TM) image, Landsat 7 (ETM+) image, and Landsat 8 (OLI-TIRS) image for Path 132 and Row 48 WGS 1984, Zone 47 used in the study are downloaded from USGS earth explorer website. The details of the Landsat satellite images selected for the present work are given in the table below.

Table 1. Details of satellite images downloaded from US Geological Survey

No	Types of Landsat sensor	Reference system, Path/Row	Bands used in this study	Date of Image acquisition	Spatial Resolution
1	Landsat 5	WRS-II/132/48	Band 6	4 March1994	30 m
2	Landsat 7(ETM+)	WRS-II/132/48	Band 6.1	5 March 2003	30 m
3	Landsat8(OLI-TIRS)	WRS-II/132/48	Band 10	11March 2014	30 m

Each satellite has several sensors and each sensor captures the data on the specific wavelength of the electromagnetic spectrum which is called the band. Among these several bands, some have been captured in the thermal spectrum, which can be used to find out the land surface temperature. For example, the bands 6 in TM sensor, 6.1 in ETM+, and, band 10 in LC 8 TIRS are thermal bands which were used for the present study.

Methodology

During this research work many research papers (K. Sundara Kumar et al, (2015), B mahalingam, (2013), J.S. Y and et al., (2004), P.V August et al. (2006) P. Dash, et al. (2002), Xiao_ling Chen, et al. (2006) etc.) concerning with the retrievals of surface temperature from satellite images and remote sensing data are studied in detail. By reviewing these papers, it is found that the formulas to convert digital number (DNs) to spectral radiance are slightly differing in some papers. This is may be due partly to the improvement of data processing technique and partly by periodically refreshing the global data achievement in landsat. After a comprehensive study of these papers, the input values in the computation are compiled. For the precision of formulas, calibration constants, and metadata of these images are checked with those of landsat 7 science data user handbook and landsat 8 data user guide book (Version 1.0, 2015). The following equations are used to convert DN's in a 1G product back to radiance Units and then to effective at-satellite temperature (Landsat 7 user handbook, 2010 and landsat 8 user guide book, 2013).

The equation 1 is used for landsat 5 TM and land 7 ETM+ and the equation 2 is used for landsat 8. The last equation, equation 3 is used to convert the radiance values to effective at-satellite temperature in Kelvin. And then the temperature in Kelvin is change to temperature in Celsius by subtracting 273.15°C. The calibration constants and scale factors needed are obtained from metadata files of respective images. The equations are given below and the methodological consideration as a flow chart is shown in figure 3.

$$L\lambda = Grescale * QCAL + Brescale$$

which is also expressed as

$$L\lambda = ((LMAX\lambda - LMIN\lambda)/(QCALMAX-QCALMIN))*(QCAL-QCALMIN) + LMIN\lambda \quad \text{----------} \; 1$$

where: $L\lambda$ = Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * μm)

Grescale = Rescaled gain in watts/(meter squared * ster * μm)/DN

Brescale = Rescaled bias in watts/(meter squared * ster * μm)

QCAL = the quantized calibrated pixel value in DN

$LMIN\lambda$ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * μm)

$LMAX\lambda$ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * μm)

QCALMIN = the minimum quantized calibrated pixel value (corresponding to $LMIN\lambda$) in DN

= 1 for LPGS products, 1 for NLAPS products processed after 4/4/2004

= 0 for NLAPS products processed before 4/5/2004

QCALMAX = the maximum quantized calibrated pixel value (corresponding to $LMAX\lambda$) in DN= 255

$$L\lambda = ML*Qcal + AL \text{-------------------------} 2$$

where:

$L\lambda$ = Spectral radiance (W/(m2 * sr * µm))

ML = Radiance multiplicative scaling factor for the band from meta data

AL = Radiance additive scaling factor for the band from meta data

Qcal = Level 1 pixel value in DN

T = K2 / 1n ((K1 / Ll) + 1) ------------------- 3

T = Effective at-satellite temperature in Kelvin

K2 = Calibration constant 2 from meta data of respective image

K1 = Calibration constant 1 from respective image

L = Spectral radiance in watts/(meter squared * ster * µm)

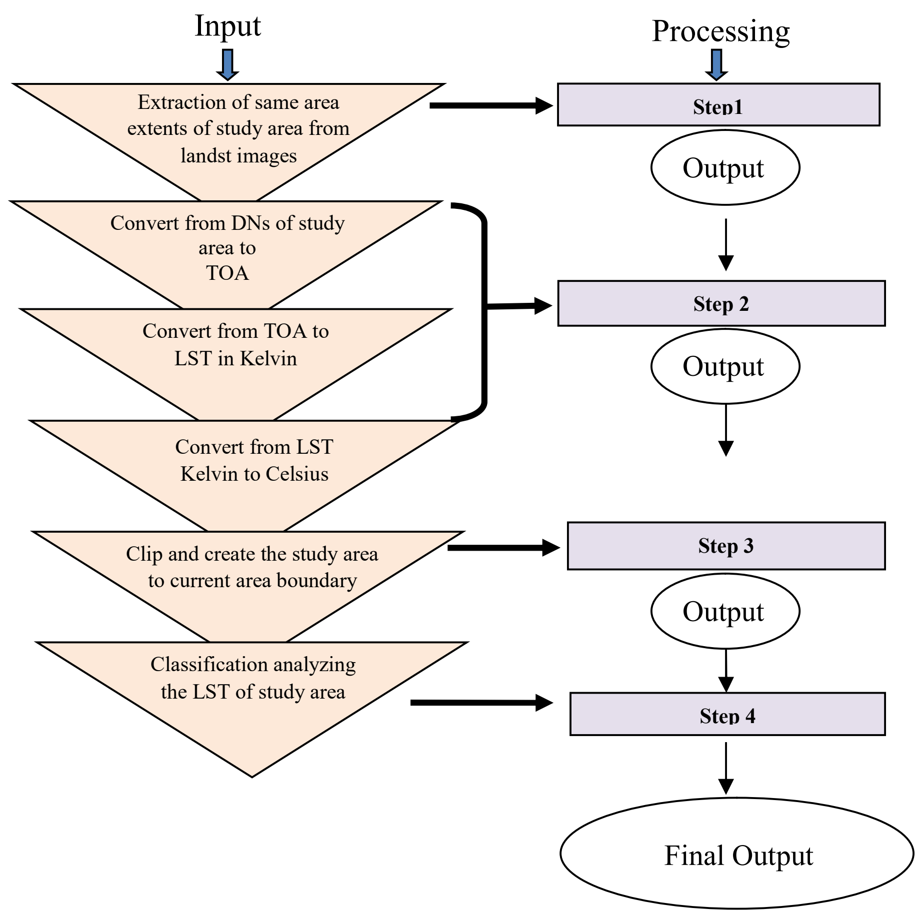


Figure 3. Flow chart of Land Surface Temperature (LST) estimation from landsat images

Step by step procedure for Estimation of LST

After the compilation of data needed, as the first step, the same area extent of images are extracted from thermal band images of landsat 5, 7 and 8 by using spatial analyst tools of ArcGIS.

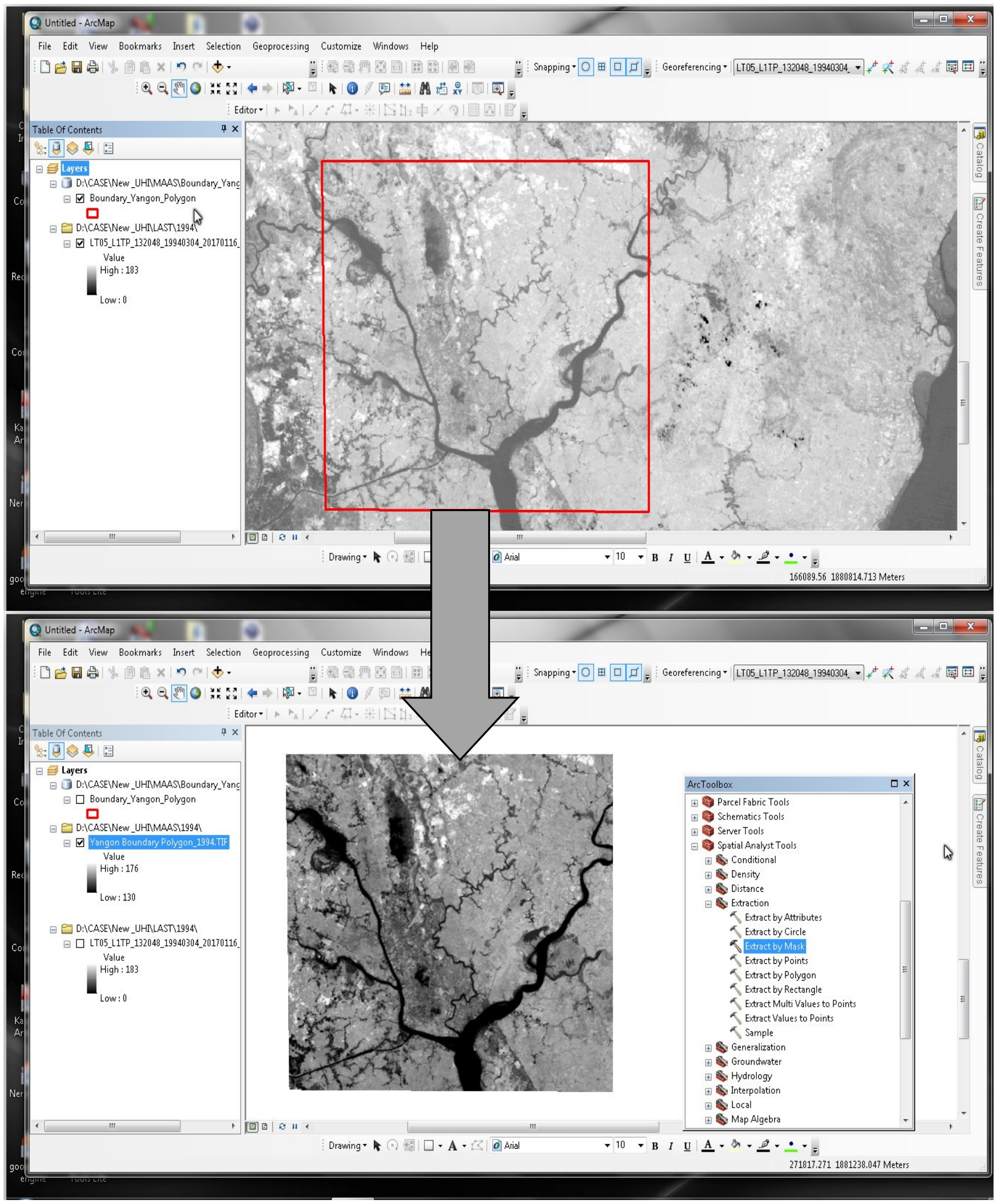


Figure 4. Window for Step 1, the extraction from raw image to study area.

After the first step, the extraction of same area extent from three satellite images under study, the different digital numbers of different images for study area are available. As a next step, the computation of TOA, at-satellite temperature in Kelvin, and changes to the temperature in Celsius is made by using Raster Calculator tool from the Map Algebra tool box of spatial analyst tool set (Step 2). It is shown by the following window of figure 5.

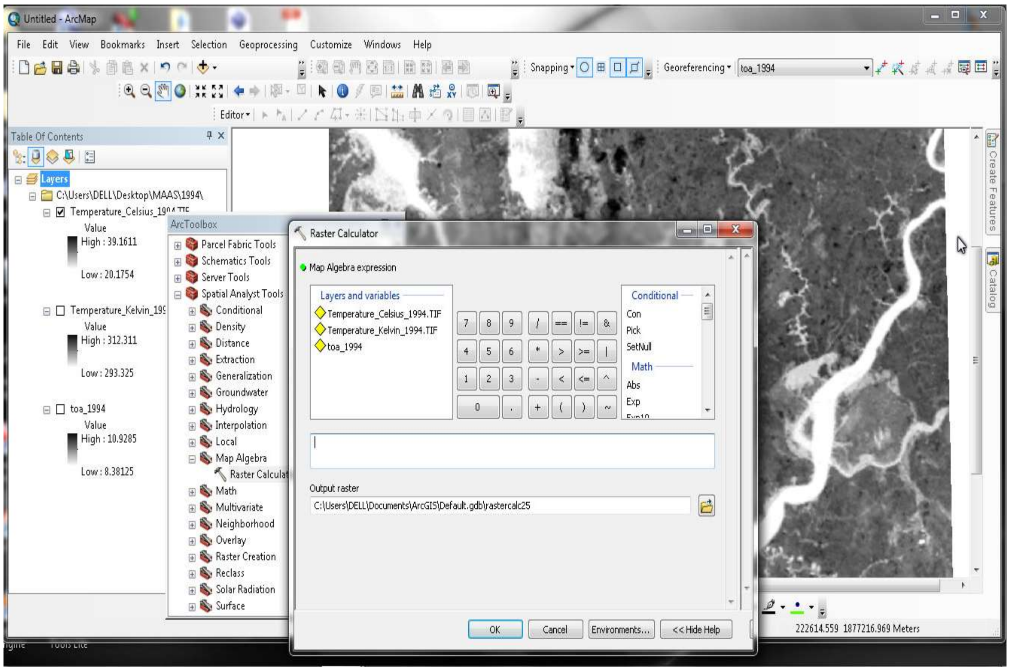


Figure 5. Window for Step 2, Raster calculator window and change from DNs to land surface temperatures

All of temperature values (LST) in Kelvin convert to LST in Celsius. After finishing the converting of DN values to land surface temperature LST) for 1994, 2003, and 2014 images, it is needed to specify the boundary of study area to get more precise data on temperature of study area. Therefore these images are clipped into boundary of YCDC area in Step 3. At the end of Step 3, processing the imagery, classifying, re classifying, analyzing, and evaluating the values of LST are conducted at Step 4 (Figure 6).

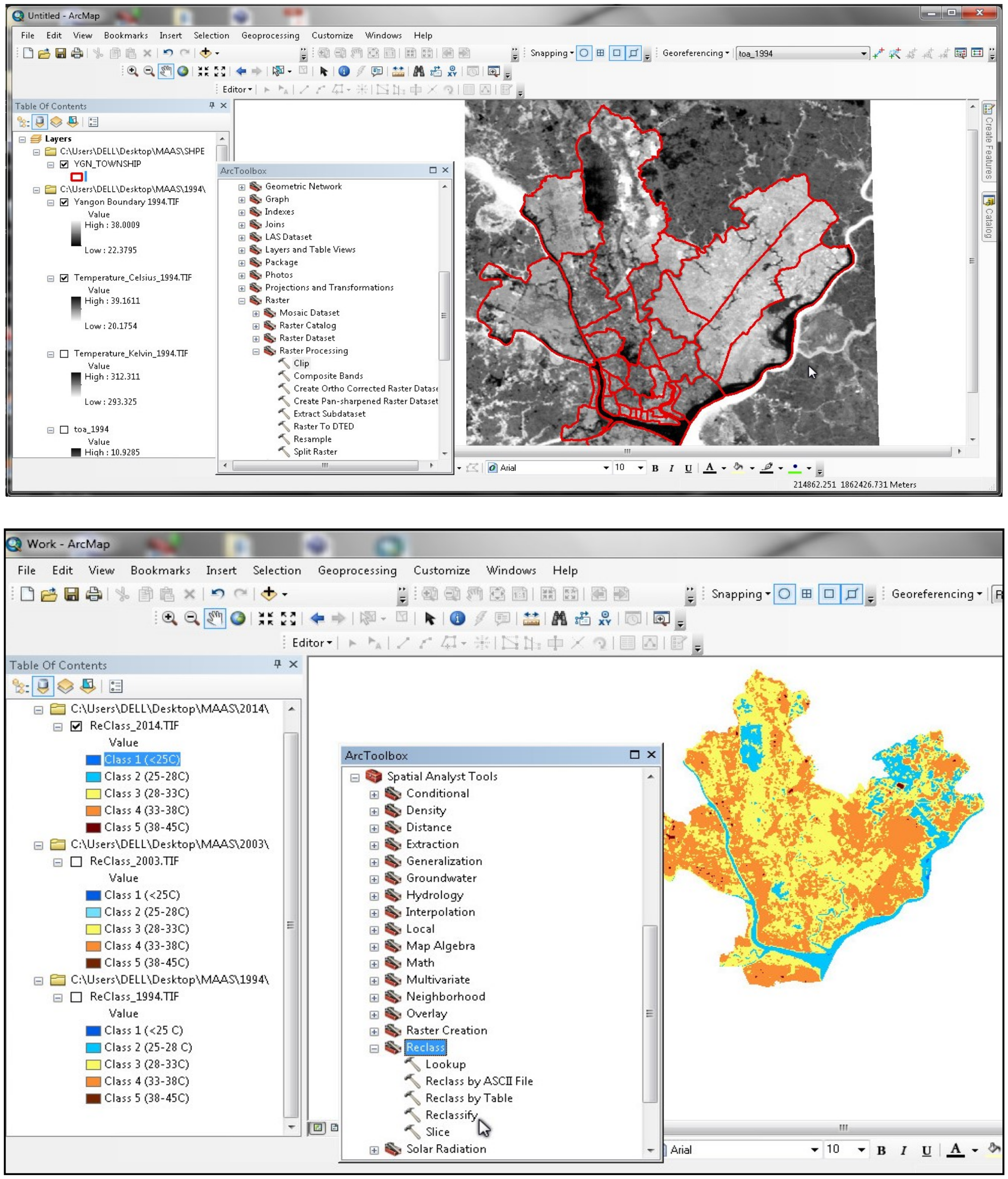


Figure 6. windows showing clip into YCDC boundary and Re-classifying and analyzing LST

Result and discussion

After completion of Step 3 and at the beginning of Step 4, LST surface form of study area can clearly be seen for 1994, 2003, and 2014. LST for these three periods are shown in table 2. In the whole study area, LST ranged from 22.4° C to 38.0° C in 1994, 22.3° C to 38.7° C in 2003, and 24.7° C to 44.1° C in 2014. Therefore LST variations in both form of spatial and temporal can clearly be examined.

Table 2. The LST results from selected landsat images of three periods

	1994 TM 5	**2003 ETM^{+} 7**	**2014 LC 8**
Count	884893	884893	884893
Minimum	22.4° C	22.3° C	24.7° C
Maximum	38.0° C	38.7° C	44.1° C
Mean	29.6° C	30.4° C	32.1°C
SD	2.7° C	2.3° C	2.8° C

For the reliability of results, temperature data of the ground stations is used to compare these LST values. The following table 3 shows the LST of satellite data and station based observed data.

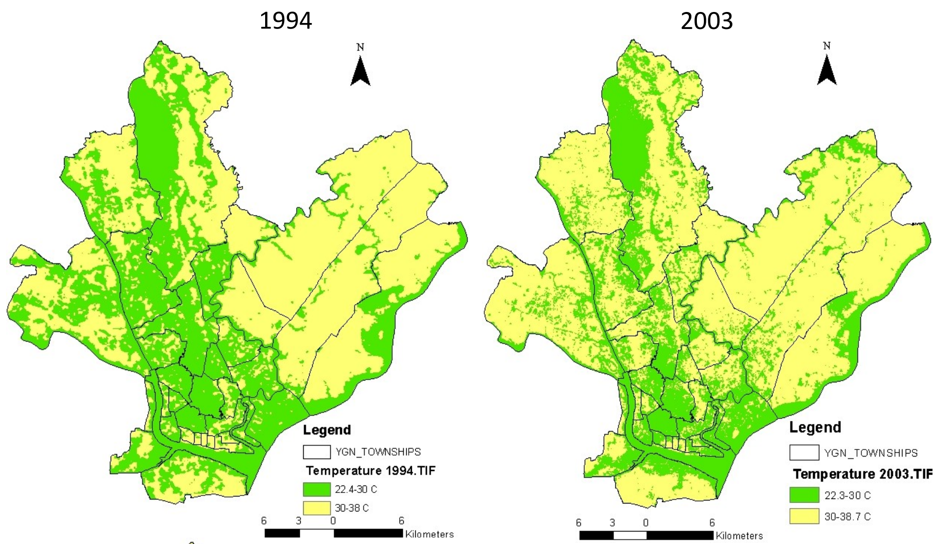
Table 3. LST from satellite data and recorded observed air temperature from Mingaladon

Mingaladon (North Latitude 16.9036°, East Longitude 96.1349°)			
	Station based Observed Data*		Satellite Data**
Date	Mini (06:30 a.m.)	Maxi (06:30 p.m.)	11:00 a.m.
4 March 1994	19.3° C	35.5° C	31.23° C
March 2003	20.9° C	36.5° C	33.12° C
March 2014	21.4° C	36.8° C	34.68° C

Data source: * are from DMH, Myanmar, ** is from calculated LST

06:30 a.m. and 06:30 p.m. are recorded time for observed data and 11:00 a.m. is saltllite passing time over study area. According to diurnal temperature cycle, the calculated LST are consistent with station based observed data.

According to the results in table 2, the mean values of LST become higher from 29.6° C in 1994 to 30.4° C in 2003 and 32.1° C in 2014. The standard deviation value between highest LST value and lowest LST value for the whole city is highest in 2014. It can be stated that LST of the area significantly increase throughout the study area over time. This is due to the increase in population, building density, concrete area and decrease of vegetation cover. In order to clear the spatial and temporal change of LST, the output LST images are classified into only two classes by using a threshold value of 30°C. The corresponding areas are also calculated. Hence below 30° C areas are classified as low temperature areas and above 30°C are classified as high temperature area. The area of low temperature in 1994 was 55.3% of total study area and it decreased to 34.4% in 2003 and to 20.5% in 2014. Therefore the area of high temperature was increased from 44.7% in 1994 to 79.5% in 2014. The area changes from low to high temperature can clearly be seen in figure 7.



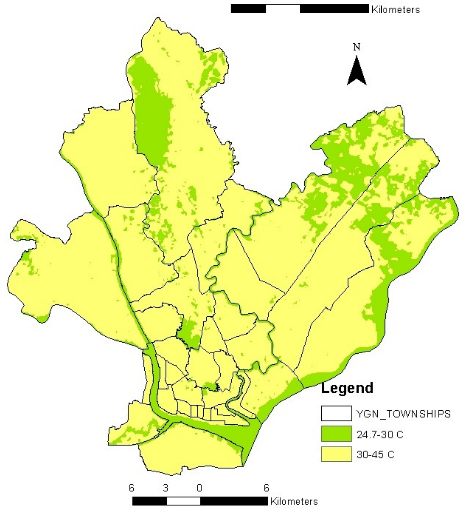


Table 4. percentage of total area under low LST value and high LST values in different time

	1994	2003	2014
Low area of LST	55.3%	34.4%	20.5%
High area of LST	44.7%	65.7%	79.5%

Figure 7. The low and high surface temperature area of Yangon City

This process coincides with settlement area expansion and landuse change of YCDC. The Yangon City area was faced with the remarkable development under the rule of State Law and Order Restoration Council (SLORC) during the two decades of study period. Most land area under cultivation also changes to residential plots and more roads are converted to concrete which are non-absorbing materials of sunlight and emit heat to the atmosphere. The increase number of vehicles and large trees removal of

Nagis, devastated storm of 2008, is also the contributors of the increase of LST in study area.

The output results of the LST are classified into 5 groups again from lowest to highest value of during study period, such as, Class 1- very low (< 25°C), Class 2- low (25°C - 28°C), Class3- moderate (28°C - 33°C), Class 4- high (33°C - 38°C), Class 5- very high (38C° - 45°C). ArcGIS was used to classify the raster layer into these classes and each class of spatial extent is also calculated and these are presented in figure 8.

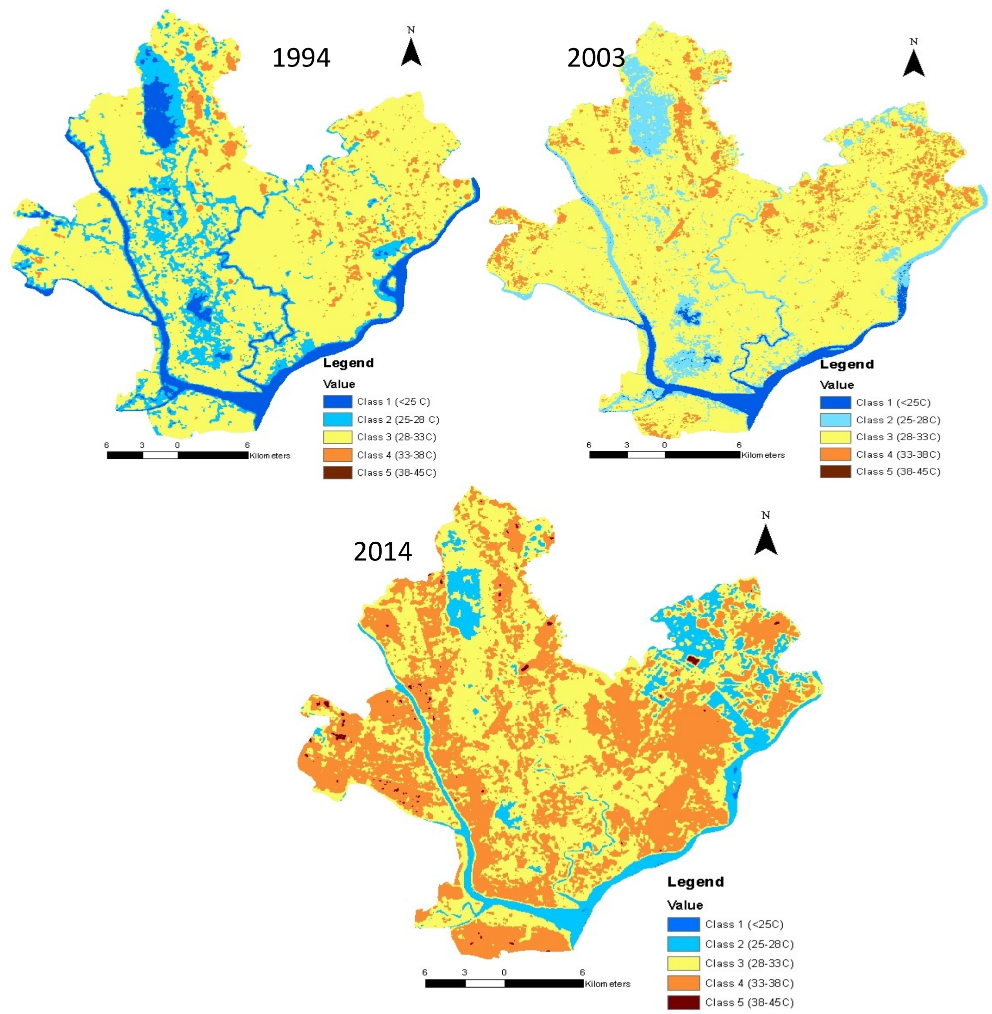


Figure 8. Spatial variations in land surface temperature of Yangon City

In 1994, the area under Class 1 was 8.7% of total area but it was nearly absent in 2014. The area under Class 2 was also decreasing from 16.2% in 1994 to 11.5 % of total area in 2014. Although the area under Class 3 was increased from 1994 to 2003, from 70.7% to 76.3% of total area, it decreased to 45.4% in 2014. This is due to significant increase in Class 4. Therefore, the relatively moderate to high surface temperature area of Yangon City is increasing during the last two decades (Figure 9 and Table 5).

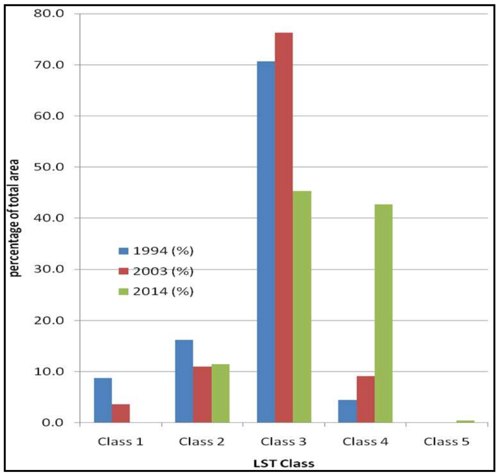
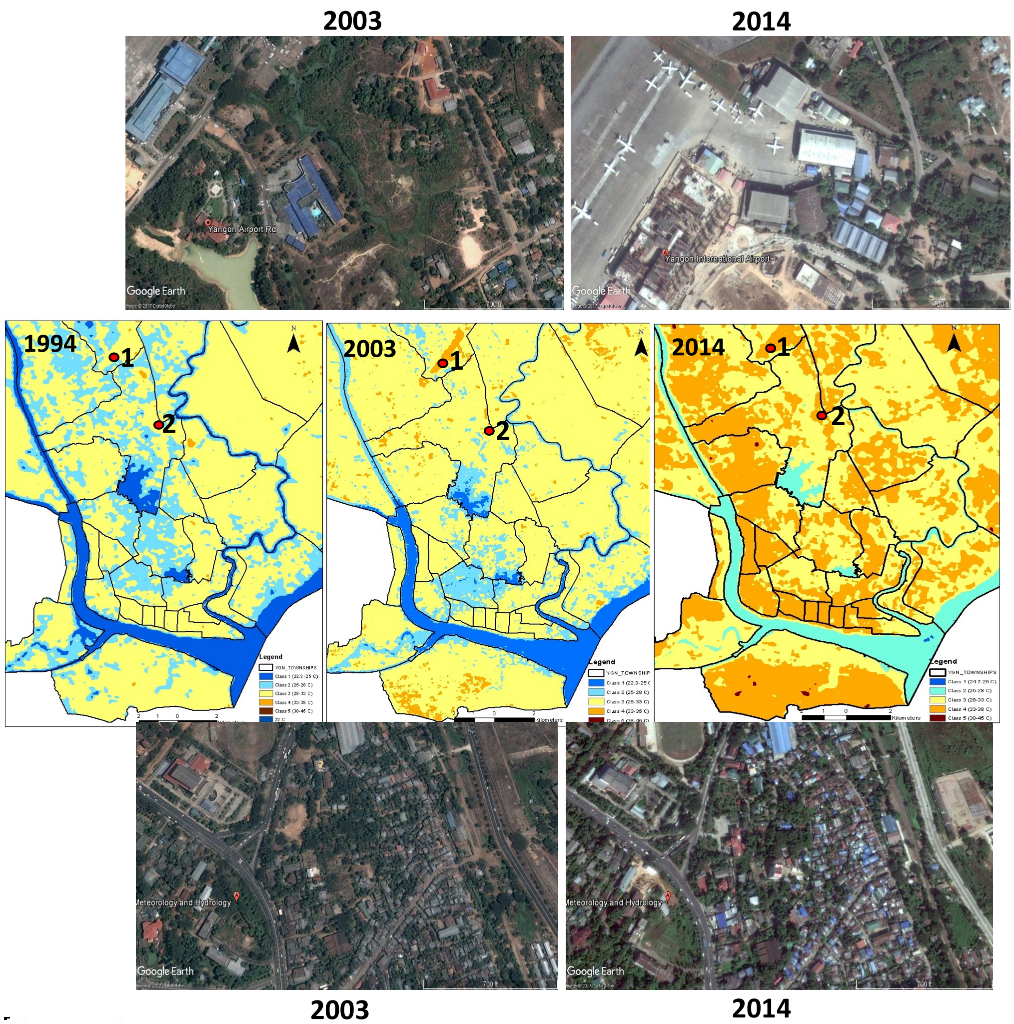


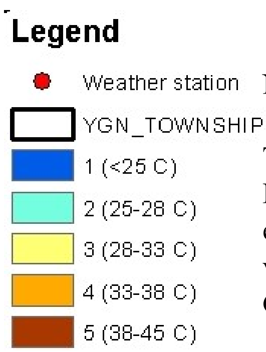
Figure 9. Graph showing the LST in different period

Table 5. Percentage of total area of land under different class of LST

Year	1994(%)	2003(%)	2014 (%)
Class 1	8.7	3.6	0.1
Class 2	16.2	11.0	11.5
Class 3	70.7	76.3	45.3
Class 4	4.4	9.1	42.7
Class 5	0.0	0.0	0.4

Where are these changes and why do they change? It is the most important question need to be answered. The LST changes can be seen especially on water surface area, downtown area, the areas of Dagon Myothit area, Thanlyin, Seikkyi Khanaungto. The example of significant change in part of the area under study is shown in figure 10. The figure clearly shows the increasing changes of LST of from one class to another during the period from 1994 to 2014. These changes are mainly due to the landuse changes especially to dense, tall, and concrete buildings. The changing landuse and the processes under these changes are interesting to do further study.





Note: 1- Mingaladon Weather Station on map
2- DMH, Kaba-Aye Weather Station
The upper images are the surrounding area view of Mingaladon weather station from 2003 and 2014 Google earth images and the lower images are the surrounding area view of Kaba-Aye weather station from 2003 and 2014 Google earth images

Figure 10. The LST changes in part of Yangon City from 1994 to 2014

Conclusion

Temperatures are retrieved from landsat images to analyze the changes of temperature distributions for the past 20 years. The results in the study suggest that the spatial temperatures are High buildings densities result large LST effect and uneven distribution of surface materials create the variation in LST. The temperature variations may be attributable to greater absorbency of man-made materials. Landsat satellite is one of the longest running programs for global change research and has been applied for agriculture, geology, regional planning and urban environment.

It has been observed that the surface temperature is higher in urban areas than vegetation and water body areas, because of lower contributions of evaporation and transpiration in non-vegetation areas. It is noted that occasionally vegetation areas might show higher temperature when the area is covered with relatively shorter plants such as shrubs or dried paddy fields. This increase of high temperature area is posing a serious threat to the urban thermal environment. Because of this heating with high temperature may cause discomfort to the city dwellers. Consumption of energy for artificial cooling of buildings and other work places will increase enormously. These high temperature urban heat islands may cause increase in death rate of old age people due to heat waves. Towards a solution the city planners must take into account the loss of green cover and propose social forestry and other community greenery development to mitigate the development of high temperatures. This study can clearly show the usefulness of remotely sensed thermal infrared (TIR) data in retrieving land surface temperature (LST) that can make the estimation of land surface temperature variation for both temporal and spatial, and the detection of area of high and low temperatures over a given area.

Acknowledgement

I would like to acknowledge my gratitude to express my special thanks to Dr. Kay thwe Hlaing, Professor, Department of Geography, YU, for her guideline to download the satellite images from USGS website for this paper. I would like to thank my Professor Dr. May Myat Thu, Head of Department of Geography, Pathein University, for his kind permission to carry out this study. Last but not least, I am greatly indebted to U Zaw Win, MIMU, for his solutions of my difficulties.

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CHANGE ANALYSIS OF INDICES (NDWI, NDVI,NDBI) FOR MAWLAMYINE CITY AREA USING GOOGLE EARTH ENGINE

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Abstract

Until last year, most of the scholars in Geography face many problems to get fine resolution satellite images, to have small knowledge for geo-spatial techniques and difficult the use of GIS analysis as professional. To overcome the above said limitations, Google Earth Engine (GEE) can be able to get a lot of satellite images easily, easy access to data, online platform with scientific algorithms, computational power and etc. This research is analyzedusing GEE platform for temporal and spatial change of urban area which is based on satellite imagery from Landsat 5and Landsat 8 Top of Atmosphere (TOA) as inputs for Mawlamyine City, Mon State. The analysis of indices: normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and normalized difference built-up index (NDBI) produce fine-quality of vegetation, water and built-up values. Although the dataset can facilitate these three indices in any platform, this paper highlight its potential use in GEE for temporal scale analysis of the urbanization process. The main aim is to evaluate the extracted values from three indices that can be applied to GEE platform for urban area analysis. The results show that the reflected values of vegetation, water and built-up in Mawlamyine City during the three time periods (1997, 2007 and 2017). This process requires reliable and comprehensive checked with field survey data for build up to validate of these products. Actually the result of built-up area comprises with the mixture of built up and bare land. It can also be reclassified with the positive and negative Digital Numbers (DNs) for built-up and bare areas. Thermal Infrared Sensor(TIRS) can only classify as an indicator to separate built-up from non-built-up areas (bare land) but this paper cannot calculated this processes to preparing for further study.

Key Words: Google Earth Engine, TOA, NDVI, NDWI, NDBI, algorithms, built up, bare land

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Introduction

Understanding the spatial distribution and growth of urban areas is essential for urban planning and resource management, and one of the basic activities required for this purpose is mapping the built-up areas (Bertrand-Krajewski, Barraud, and Chocat, 2000).Google Earth Engine is a cloud based geospatial remote sensing processing platform, complete with an extensive public data catalog (www.adpc.net). Another factor is that the encroachment of people living in slums and squatters are forced to the extended urban area. The often rapid urban expansion also makes the task of a timely and accurate mapping of urban built-up areas quite difficult (Small, 2003; Perepechko *et al.*, 2005; Lein, 2006). Acceleration rates of population growth and expansion of urban areas in the most countries focus on economic development, activities and transportation accessibility. The rapid urbanization is caused by population growth as well as by people migrating from rural areas to towns in search of a better life. Establishing industrial zone in 2002 was also one of the factors that attracted immigrants from nearby towns and other places in southern Myanmar to Mawlamyine City. Therefore, population increases noticeably in this city as well as results from economic growth and job opportunities.

GEE can restore multi-temporal images without involving ancillary data and benefit from products already available in GEE. It also provides a cloud-based platform to access and seamlessly process large amount of freely available satellite imagery. Hence, it provides a set of the state of the art classifiers for pixel-based classification. Though these methods are well-documented in the literature, there were no previous studies to compare all these methods for classification. Only fine resolution imagery (30m spatial resolution) has been utilized to derive urban built up area extent. While enhancing the spatial characteristics, resolution merging methods should preserve the equally useful spectral properties of original multispectral data.

Each method has its own set of advantages and limitations; however, indices have a certain edge over other classification methods in terms of time needed to generate results. A variety of indices have been developed for the extraction of features of interest from satellite imagery. It can explore efficiency of using the GEE platform when classifying multi-temporal satellite imagery for built up area with a larger scale (e.g., town level), time duration (e.g., 1997, 2007 and 2017) and multiple sensors (e.g., Landsat-5 and Landsat-8 TOA).The normalized difference vegetation index (NDVI) is the most commonly used for the extraction of vegetation. Other indices include the normalized difference water index (NDWI) and normalized difference built-up index (NDBI) for water and built-up area extraction, respectively. These three indicate that spectral indices can be safely applied to resolution-merged imagery if the resolution ratio between the merged bands is small. The calculations of these indices are based on the specific properties of the features of interest in terms of strong absorption or reflection in different spectral bands of multispectral imagery (Jensen, 2006). However, such mapping is still challenging due to spatial, spectral and temporal variability in built-up areas for the study area.

Aim and Objectives

The main aim is to explore efficiency of using the Google Earth Engine platform when using normalized difference indices for Urban Area with spatial, spectral and temporal analysis. The objectives of this study comprise: (1) to learn about Google Earth Engine data structures and methods, functions, and algorithms(2) to compare spectral responses of the three indices within three decadal periods and (3) to evaluate the extracted values from indices for urban area analysis.

Study Area

Mawlamyine City is located at latitude 16º29' N and longitude 97^0 38' E. Covering an area of around 106.79sq-km (41.23sq-miles)with the ranges of surface elevation from5.5 meters to 61 meters above mean sea level. It is characterized as a flat terrain. It was the administrative headquarters of the Tanintharyi pan-handle part of the country. The city became the capital of Mon State in 1974. The city occupies the left bank of the Thanlwin River where it branches off into the Gulf of Mottama. The Yankin Ridge is steeper than the surrounding area of study area. The long axis is about 11.3 kilometers from north to south. Originally the urban area was on the west of the central ridge but at present urban expanded to the east and south of the range. The low central Yankin Ridge and the scenic coastline with Bilugyun Island on the west give a beautiful natural setting to the city. The surface is not flat but is a rolling topography. At present, the shape of urban area in Mawlamyine City is nearly compact shape. Thanlwin, Attaran and Gyaing are the three important rivers for Mawlamyine City. The Attaran and Gyaing join the Thanlwin in north and northeast. The Thanlwin branches off into two and empties into the sea from "Darebauk('&,fayguf)" River in the south and Mawlamyine River in the south which is 45.1 kilometers apart as the crow flies. The location of study area in Mon State is shown in Figure1.

Before 1826, Mawlamyine, one of the riverside towns, has about 2500 residents on the alluvial plain locating the junction of Thanlwin River and Attaran River. After 1989, the State Law and Order Restoration Council faces the problem of increasing population and migrating people from rural area. It had renovated and expanded the cities to meet the required standard of a progressing nation. Thus, new urban areas of Mawlamyine were also established in urban-rural fringe areas. The urban areas were extended only in the eastern and southern parts because western boundary of Mawlamyine City is Thanlwin River and Central part in higher Yankin Ridge. Therefore, urban area extension can be found eastern and southern part(Myint Thida, Myo Myo Khine, Khin Maung Zaw, 2011).

In 1993, the total population of the city was 239,683. The city has a total population of around 289,388with about 87.7% residing inurban and the rest in peri-urban and rural areas (Census Report Volume 3-J (Mon), 2014). The city is administratively divided into twenty-one in 1993 and gradually increased into twenty-nine wards in 2017.For the purpose of this research, these areas were selected as they extracted areas having built-up densities with the periods of 1997, 2007 and 2017.

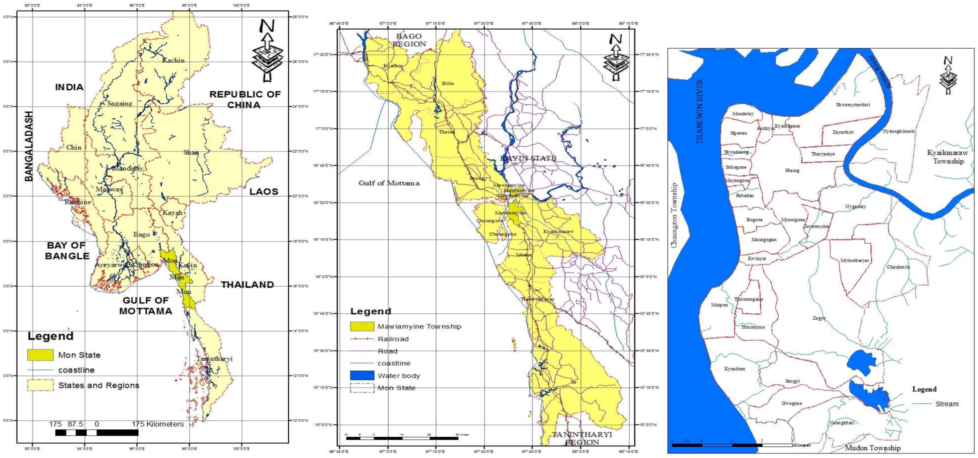


Figure1: Location of the Mawlamyine City, Mon State and Myanmar
Source: Myanmar Information Management Unit 2014

Methodology

Mawlamyine City image collection referred to a set of Google Earth Engine. It is a cloud based geospatial remote sensing processing platform, complete with an extensive public data catalog. It is available via a web-based Application Program Interface (API) called the Code Editor. In this study, Landsat satellites images from Landsat Thematic Mapper (TM)and Operational Land Imager (OLI)are used to interpret features analysis. The proposed method for extraction of spectral indices areas using GEE comprised four major steps: preprocessing of satellite data, image enhancement through resolution merging, calculation and extraction of three spectral indices and change areas assessment.

(a) Preprocessing of Satellite Data

In the study, classification of imagery is performed at per-pixel basis. Multiple imagery collection techniques are constructed a java script in GEE. One way to create a Feature Collection is to provide the constructor with a list of features for region of interest (roi). The features do not need to have the same geometry type or the same properties.

```
// Get a collection.
var L8_collection = ee.ImageCollection('LANDSAT/LC8_L1T_TOA');
var l5_collection = ee.ImageCollection('LANDSAT/LT5_L1T_TOA');
```

And then, collections more than 500 images is needed to be filtered for the region of interest (roi) (path: 131, row: 49) before printing. Earth Engine provides a variety of convenience methods for filtering image collections. To decrease an impact of atmosphere to the image quality conversion from the TOA reflectance to the surface reflectance (SR) has been done using the Simplified Model for Atmospheric Correction. In order to avoid the influence of cloud, most of images are acquired from February to April within 1997, 2007 and 2017. The World Geodetic System of 1984 (WGS84) wasset as coordinate systems.

```
var temporalFiltered = spatialFiltered.filterDate('2017-03-15','2017-04-15');
```

Then, the Mawlamyine City called as region of interest (roi) in GEE was created a rectangle feature geometry on java script and defined area.

```
// Make a list of Features.
 varroi= ee.Geometry.Rectangle([97.59,16.53,97.67,16.38])
```

This research uses two multispectral satellite imageries: Landsat-5 Thematic Mapper (TM) imagery and Landsat-8 Top of Atmosphere (TOA) imagery of Mawlamyine City which are acquired and mainly used to analyze urban expansion in City (Table-1). These images are resampled to 30 m resolution, and all reflective bands are applied in image classification excluding the thermal band. Landsat-7 Enhanced Thematic Mapper Plus (ETM+) has caused a problem by failure of the Scan Line Corrector (SLC).

Table 1: Two Multispectral Satellites and Acquired Date

Name of Satellite	Acquired Date	Resolution (meters)	Path/Row and specification
Landsat-5 (TM)	From 01-02-1997 To 31-04-1997	30/120 thermal (7 Spectral Bands)	LANDSAT/LT5-L1T/ LT51310491997112BKT01
Landsat-5 (TM)	From 01-02-2007 To 30-04-2007	30/120 thermal (7 Spectral Bands)	LANDSAT/LT5-L1T/ LT51310492007108BKT00
Landsat-8(TOA)	From 15-3-2017 To 15-4-2017	30/100 thermal (11Spectral Bands)	LANDSAT/LC8-L1T-TOA/ LC81310492017119LGN00

http://landsat.usgs.gov/tools_specialViewer

(b) Image Enhancement through Resolution Merging

Enhancement are used to make it easier for visual interpretation and understanding on imagery. For scoring Landsat pixels by their relative cloudiness, Earth Engine provides a rudimentary cloud scoring algorithm in the method. To create a median value image from a collection of the multi band, the names of the reducer has been appended to the band names. At the study location in the output image with each year, the pixel value is the median of all unmasked pixels in the input imagery. `Median ()` is a convenience method for the calculation:

```
//reduce to median value per pixel
var median_1997 = toa_1997_noCloud.median();
var median_2007 = toa_2007_noCloud.median();
var median_2017 = toa_2017_noCloud.median();
```

Figure 2(A) and (B) illustrate the difference between spatially enhanced image and median filter to reduce noise image, respectively, at a sample location in the study area. Image enhancement is the process of adjusting digital images so that the result are more suitable for display or further image analysis.

A. LANDSAT/LC8-L1T-TOA/ LC81310492017119LGN00

B. LANDSAT/LC8-L1T-TOA- Median

Figure 2: Landsat-8 TOA False Colour Composite (A) spatially enhanced image and (B) Median filterimage of Mawlayine Area

After enhanced images, the images are displayed with the default visualization: first three bands map to RGB and stretched to [0, 1] since the bands are float data type. To render the image as true colour composite, Earth Engine is displayed both the Landsat 5 bands B3, B2 and B1and the Landsat 8 bands B4, B3 and B2 band combination for R, G, and B. In contrast, false colour composite for land cover extraction, GEE is create the Landsat 5 bands B4, B7 and B3and the Landsat 8 bands B5, B7 and B4 for RGB, respectively. Specify which bands to use with the `bands` property of the `visParams` objects applied the scrip. Learn more about Landsat band combinations for visualization at this reference.

```
//add True and False Color Composite for Annual Median Reflectance
layers
Map.addLayer(median_1997,
{ min:0.05, max: 0.4, bands: ['B3, B2, B1']}, 'median_2007');
{ min:0.05, max: 0.4, bands: ['B4, B7, B3']}, 'median_2017');
```

The result of true and false colour composite were showed in Figure 3 for visualization analysis. Note that this code assigns the object of visualization parameters to a variable for possible future use.

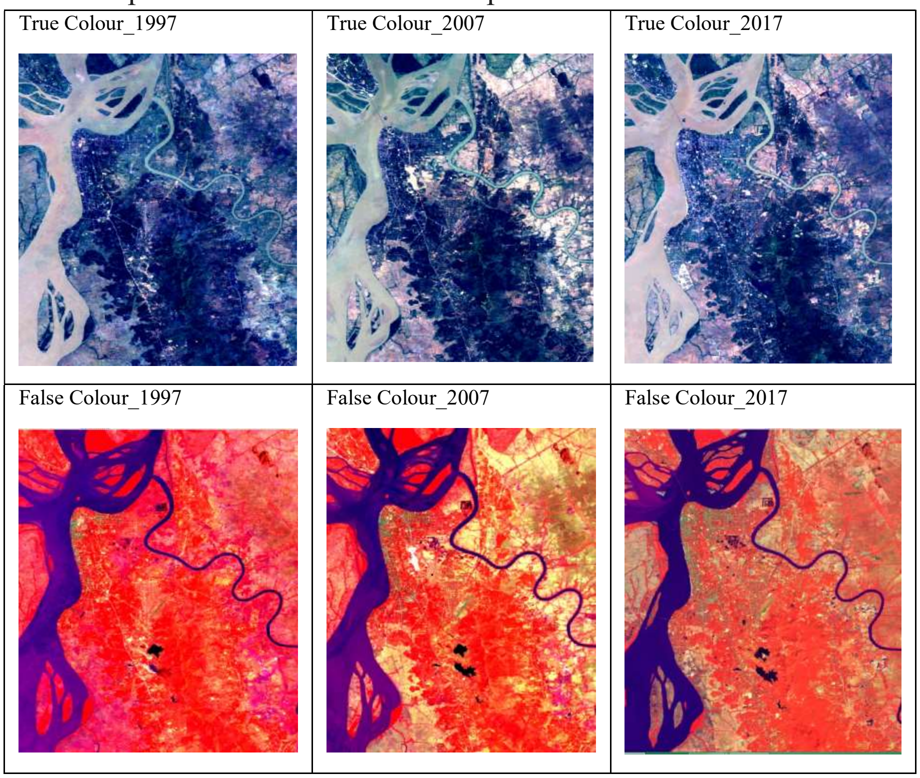


Figure 3: True and False Colour Composite for Mawlamyine City (1997, 2007 and 2017)

(https://code.earthengine.google.com)

(c) Calculation and Extraction of Three Spectral Indices

To extract three spectral indices: multispectral bands are calculated for Mawlamyine City. The positive values of NDBI, NDWI and NDVI represented built-up areas, water and vegetation, respectively. The methodology comprises three arithmetic computations or GEE algorithm. Vegetation reflects light in the near-infrared (NIR) part of the electromagnetic spectrum and absorbs light in the red part. NDVI uses this to create a single value roughly reflecting the photosynthetic activity occurring at a pixel. This results in a number between 1 and -1, where pixels with high photosynthetic activity have a high NDVI. This image was obtained using Equation (1)

$$NDVI = \frac{TOA\ Band\ 4 - TOA\ Band\ 3}{TOA\ Band\ 4 + TOA\ Band\ 3} \text{ (OR) } NDVI = \frac{TOA\ Band\ 5 - TOA\ Band\ 4}{TOA\ Band\ 5 + TOA\ Band\ 4} \text{ ---- (1)}$$

To write Java script,

```
// NDVI calculation
varndvi_97= median_1997.normalizedDifference(['B4','B3']).rename('nd_97');
var ndvi_07 = median_2007.normalizedDifference(['B4','B3']).rename('nd_07');
var ndvi_17 = median_2017.normalizedDifference(['B5','B4']).rename('nd_17');
```

Second, the NDWI to delineate open water features was calculate Equation (2). Water uses in conjunction with vegetated cover (green) to access context of apparent change area.

$$\mathrm{NDW}I = \frac{TOA\ Band\ 2 - TOA\ Band\ 4}{TOA\ Band\ 2 + TOA\ Band\ 4} \text{ (OR) } NDWI = \frac{TOA\ Band\ 3 - TOA\ Band\ 5}{TOA\ Band\ 3 + TOA\ Band\ 5} \text{-----(2)}$$

```
// NDWI calculation
var ndwi_97 = median_1997.normalizedDifference(['B2','B4']).rename('nd_97');
var ndwi_07 = median_2007.normalizedDifference(['B2','B4']).rename('nd_07');
var ndwi_17 = median_2017.normalizedDifference(['B3','B5']).rename('nd_17');
```

Thirdly, Built-up is typically a higher reflectance in the shortwave-IR, compared to NIR. Based on the high reflectance in the 1.55–1.75 µm and their low reflectance in the 0.76–0.90 µm wavelength range, NDBI was computed using Equation (3)

$$\mathrm{NDB}I = \frac{TOA\ Band\ 5 - TOA\ Band\ 4}{TOA\ Band\ 5 + TOA\ Band\ 4} \text{ (OR) } NDBI = \frac{TOA\ Band\ 6 - TOA\ Band\ 5}{TOA\ Band\ 6 + TOA\ Band\ 5} \text{------(3)}$$

```
// NDBI calculation // builtup index
var ndbi_97 = median_1997.normalizedDifference(['B5','B4']).rename('nd_97');
var ndbi_07 = median_2007.normalizedDifference(['B5','B4']).rename('nd_07');
var ndbi_17 = median_2017.normalizedDifference(['B6','B5']).rename('nd_17');
```

(d) Change Areas Assessment

The performance of the proposed spatial indices extraction method in Mawlamyine City was tested through accuracy assessment at 30 point locations (pixels) using a stratified random sampling technique. Three strata, vegetation, water and built-up including non-built-up were formed and taken from each of them based on their proportion in the output image. And also checked with the Google Earth 2017 population/household data from 2014 census data, field survey and some literature reviews. These difference data were compared to assess their efficiency in terms of segregating built-up areas from other land uses. Different areas were visually examined by change detection method in detail.

Results and Discussion

GEE platform offers powerful capabilities in handling large volumes of remote sensing imagery that a set of classificational gorithms to be used for spatial analysis purposes. In order to deal with irregular observation and missing values due to clouds-based and shadows, a compositing approach was applied. Also, using the JavaScript APIs, it is possible to fill missing values of Landsat images. Spectral responses of built-up areas including bare land, vegetation and water areas were examined in Landsat multispectral bands. All three types had a unique signature in optical bands which indicated that they can be segregated from their respective indices. The analysis of indices is the function of the visible bands of multispectral data and the near infrared bands. Likewise, there are other indices using different spectral bands that may be calculated to allow more efficient interpretation of features. The overall spatial distribution of vegetation, water and built-up including bare land areas obtained from the NDVI, NDWI and NDBI indices using Google Earth Engine data are shown in Figure 4.

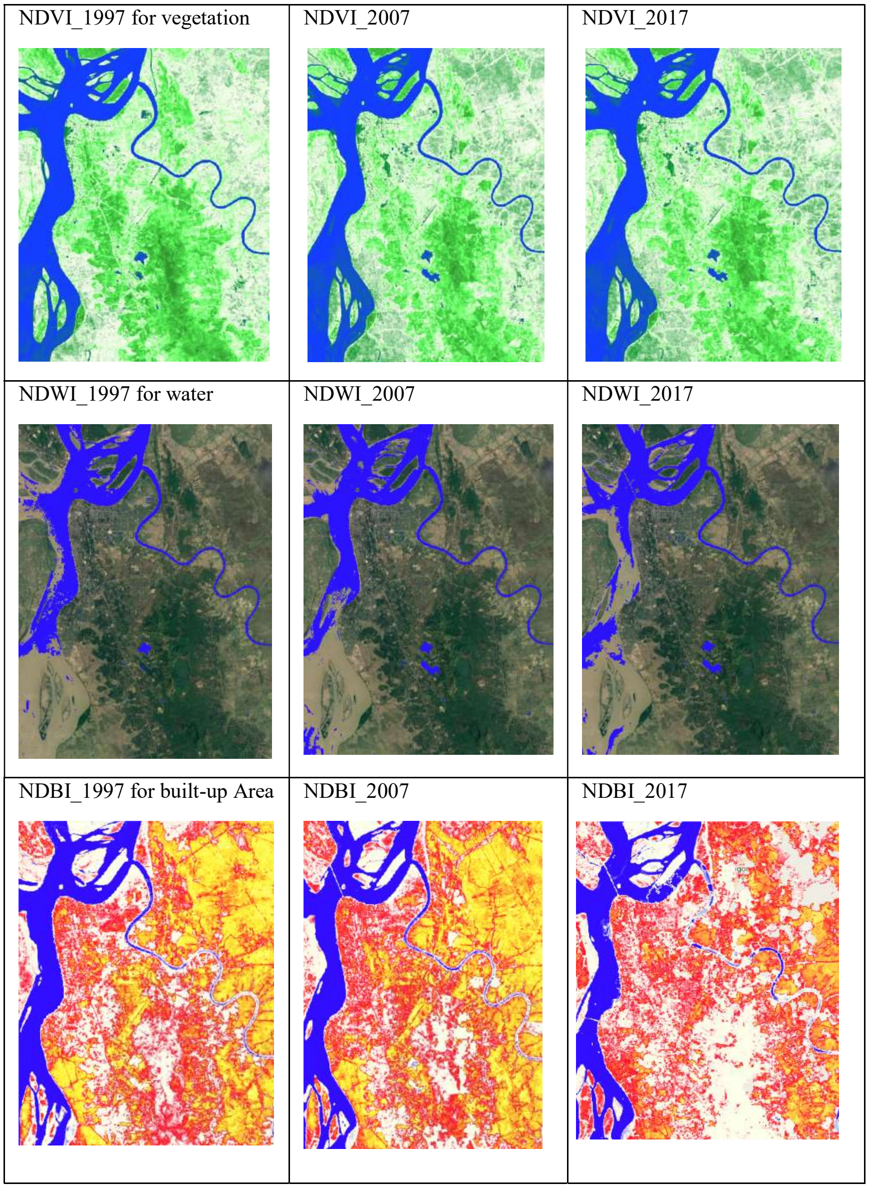
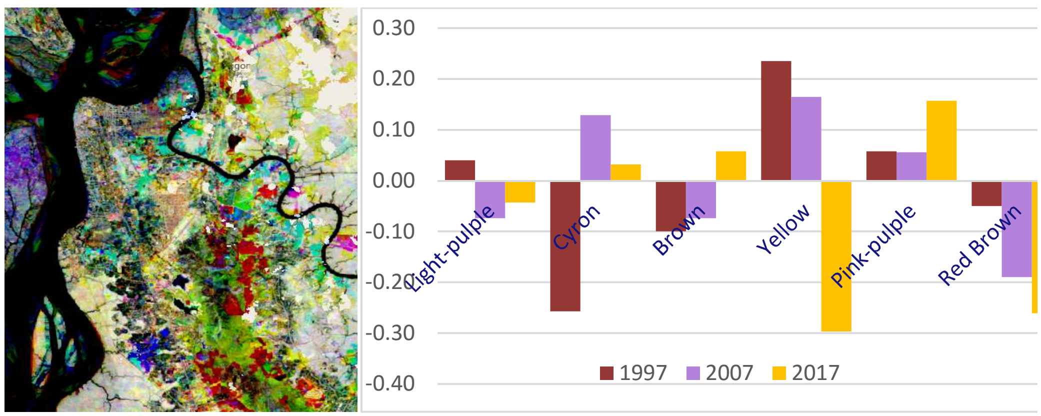


Figure 4: Comparative of NDVI, NDWI and NDBI indices

The Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Built-up Index (NDBI) are selected in this study to compares for three periods. Mawlamyine city consists of urban built-up land features, water bodies and water courses imbedded in vegetation. Another relevant finding was the difference between temperatures of the three land-cover types. NDVI has been determined that the changing vegetated areas give a very simple and fast interpretation of Landsat satellite data. It expresses the relation between red visible light (from 0.4 to 0.7 μm) (which is typically absorbed by a plant's chlorophyll) and near-infrared wavelength (from 0.7 to 1.1 μm)(which is scattered by the leaf's mesophyll structure).The values of NDVI (0.2 to 0.5) represent shrub and grassland if high value (0.6 to 0.9)also indicate tropical rainforest. Negative value correspond to water, value close to zero (-0.1 to 0.1)correspond to barren areas of rock or sand. Figure 4shows that the changing vegetated areas using three decadal period. Dense vegetation cover can be found over the Yankin range and its surrounding area in 1997 but some areas near the waterfront area and the southern part are a change to thinly vegetated area in 2007. During 2017, the eastern and southeastern part of study area is becoming vegetated areas which may be replanted near the new Kimmonchom and Shwe Nattaung reservoirs for soil conservation.

Another interesting finding was found that NDWI can supply the extracting water as non-built-up area. NDWI is sensitive to atmospheric effects than NDVI. The Attaran and Gyaing join the Thanlwin in north and northeast. After the construction of Thanlwin Bridge (Mawlamyine) in 2004, the drainage pattern was changed from DarePauk, in the north and Kyaikkame in the south. The positive values of NDWI represent water content while the range between (-1) and (0) represent bright surface with no vegetation or water content. Thanlwin estuary, being two distributaries Darebauk in the north and Mawlammyine River in the south, flows entering into the gulf of Moattama. During 1997, Darebauk(N) and Mawlammyine (S) drainage pattern were same with developing fishery resources. After the construction of Thanlwin Bridge in 2007 which crosses at the center point of the distributaries, had created high sediment accumulation in the Darebauk. This effect on Mawlammyine River may be changed to the alteration of the water course. After construction of embankment along the strand road and Chaungzone Bridge in 2007, Mawlammyine River drainage system begins to flow retarding and course changing of this area.

Besides, vegetation and water were very well separated from built-up areas indicating that both NDVI and NDWI were correctly processed. NDBI was able to extract built-up areas with reasonable accuracy when applied to Landsat data. Thus, the reason for the high commission error may be attributed to spectral mixing of built-up areas with land-cover types other than transportation or vegetation or water. Figure 4presents the three changing of built up areas: built-up (red) and bare land (yellow) are mixed in 1997, built-up land are dense along the transportation rivers and roads in 2007 and bare land can be found scarcely in the study area in 2017. Actually higher temperature readings of built-up areas in the thermal bands can be used as an aiding factor to separate built-up areas from vegetation and water. This paper cannot separate urban area purely from mixture of bare land or non-built up areas but this calculation may be used for further study.



https://code.earthengine.google.com

Figure 5: Changes Areas of spatial, spectral and temporal in Mawlamyine City

Band combination of three spectral indices: (NDVI), (NDWI) and (NDBI) pixels value is calculated for accuracy assessment of changing patterns. The changing detective values also indicate a clear separation in spectral responses. As illustrated in Figure 5,change area of three spectral indices pixels value with seven colour tones show built-up areas, whereas light purple show urban areas since 1997and pink and grey purple tones are urban areas as the downtown of Mawlamyine City. And also light brown tone in urban area is interrupting the transport construction with concretes' reflectance. Cyan and light blue among the urban area which was the bare land until 1997has been changed the new urban extension areas since 2007. Densely vegetated areas appear dark and light green in this image, whereas vegetation and a few areas with less dense vegetation are shown in bright tones. Near the vegetation green area can be found urban area with dark purple again which is existing with the less transportation road since 1997. Yellow mixture with the built up with transportation road and bare land since 1997.A very clear separation between vegetation and other land-cover types is evident in this output. Water is shown as black pixels in this image, whereas other land-cover types are depicted in the tones of grey and light brown. Areas with dense vegetation appeared-brown whereas atmospheric cloud intervention.

The result of change areas' image values is verified with the Google Earth 2017, population/ household data from 2014 census data, field survey data in April, 2017 and historical recorded data. Figure 6 shows the three changes of urban area according to the urban development plan. These factors are the focus of economic development, activities and transportation accessibility. It increased to 53,107 persons in 1881, to 102,777 in 1953 and to 203,214 in 1973. According to the census data, the population of Mawlamyine City was 219,961 persons in 1983 and it increased to 289,388persons in 2014. During 1959-1960, squatter huts were moved out to wards such as Shwemyinethiri and Thirimyine wards. To meet the basic need for growing population in Mawlamyine City, urban area extension had been conducted and people are created and allocated new urban wards. In 1971, the administrative authorities put forward the "Greater Mawlamyine Project" with an aim to expand the town to the east of Yankin Ridge. And downtown urban areas have been established on the eastern and western side of the Yankin Ridge. In 2015, seven new wards was established due to accelerate rates of population growth in this area and upgraded from former rural village to urban areas. Urban area extension has been found in southeastern and southern part of Mawlamyine City. The verification for ground survey check for urban area growth is major requirement for regional development planning in Mawlamyine City.

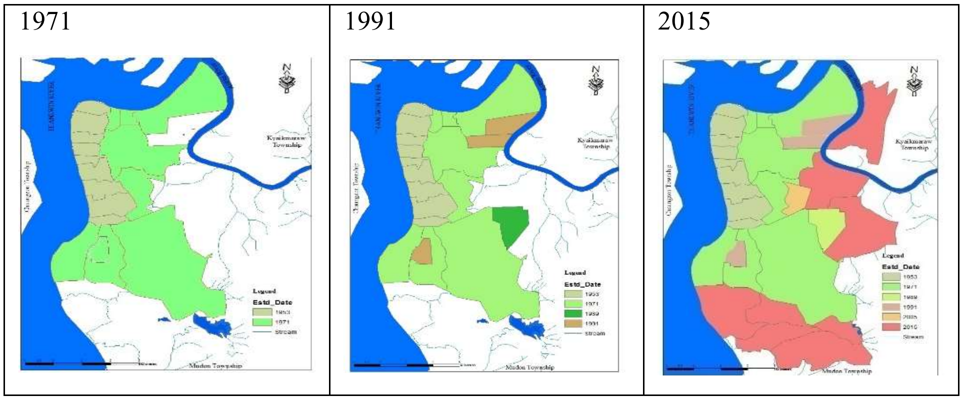


Figure 6: Urban Expansion of Mawlamyine City
Source: Township Administrated Office, 2016

Conclusion

Most of the cities are facing urbanization as more and more people are migrating to urban areas. In order to have a proper control on urbanization, it is necessary for an urban planner to have accurate information on current landuse practices and should able to know how landuse changes over the years. The basic foundation of indices discussed above is the spectral response of vegetation, water and built up areas in different bands of Landsat-5and Landsat-8 TOA data. In the present study, Mawlamyine City is explained not only for the temporal and spatial changes within the three decadal periods (1997, 2007 and 2017) but also for the spectral differences between spectral wavelength ranges of the bands for the three indices (NDVI, NDWI and NDBI). Therefore, this study is proposed for extracting built-up areas using NDBI, for vegetation using NDVI and for water using NDWI.

The output image was later segmented into a binary image (1 and 0) using an optimal threshold value. Actually the built-up areas can be reclassified with the positive for built-up and bare areas. Another important characteristic suggests that temperature can be used as an indicator to separate built-up from non-built-up areas (bare land) but this paper cannot calculated here to preparing for further study. Until the last decades, the researchers in education sector faces the many difficulties to get lower resolution image with low cost, impossible to get the latest image, very expensive to get latest high resolution satellite image and how to mosaic and clip to facilitate onscreen digitizing using GIS software. The use of GEE consequently helped in capturing the variance and comprehending a broader range of useful dataif you got good facilitated internet access.

Acknowledgements

First and foremost, we would like to thank Prof. Dr. Mi Mi Kyi one of the members of Myanmar Academic of Arts and Science (MAAS) for her editorial suggestions, and to give her encouragement to complete the research. We have a deeply gratitude to Pro-rector Dr. Win Tint for his modern guidance, valuable advices and encouragement to conduct this research work.

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IMPACTS OF FLOODING AND RIVER BANK EROSION ON LOCAL PEOPLE OF HINTHADA TOWNSHIP, AYEYARWADY REGION

OhnmarThein[1], Myint Thida[2], Nyi Nyi Aung[3], Mya NyeinNyein[4], Thin Thin Oo[5], Nwe Ni Oo[6], Ei Ei Phyo[7]

Abstract

Flooding and River bank erosion have emerged as one of the environmental problems in Hinthada Township. Hinthada Township is located on Ayeyarwady Deltaic Area known as Myanmar Granary and is located on the western Bank of Ayeyarwady River. As the study area is located on the bank of Ayeyarwady River in the deltaic area, flooding and bank erosion occur every year. At present, flooding and bank erosion are more severe in the area due to climate change and agricultural land was eroded yearly. Because of flooding and bank erosion, status of education, health and economy of the local people are low. Existing fertile kaing land support crop cultivation and local farmers cultivate seasonal crops especially kaing crops in flood free period. To get higher income through crop cultivation, farmers practice adaptable ways in crop cultivation. The objectives of the paper are to understand flooding and bank erosion in the area, to study loss of agriculture land, to assess the socio economic impacts of river bank erosion and to find the perception on adaptability and resilience of the inhabitants. Field observation was thoroughly done to get detail understanding on impacts of flooding and river bank erosion. To illustrate local people perspectives on bank erosion, focus group discussion was done. To present the paper, qualitative quantitative mixed method will be applied.

Key words: flooding, bank erosion, socio-economic conditions of local people

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Introduction

The Republic of the Union of Myanmar is prone to multiple natural hazards including cyclones, floods, drought, landslides and earthquakes (FAO,2015). Natural hazards cannot be prevented from occurring, but their impacts can be reduced. Flood and Riverbank erosion are dynamic and natural processes which have an adverse impact on livelihood of the local people. River bank erosion is the wearing away of bank materials of a river and a dynamic process causing the loss of agricultural land.

In Myanmar, Ayeyarwady Region is known as Myanmar's Granary and it possesses *Le* land, *Ya*, *Kaing Kyun, Garden* and *Dhani* Land. Most population of the Hinthada Township lives in rural areas and they absolutely depend on agriculture. In the dry season, farmers lived near the bank of Ayeyarwady River cultivate crops such as chili, vegetables, flowers, maize and etc on Kaingland. Ayeyarwady is the most affected region in terms of destroyed crops with more than 100,000 hectares (247100 acre) of cultivated land washed away due to floods and a total loss of crops (FAO,2015).

Drainage condition of Ayeyarwady River at Hinthada Township is poor because of flood plain and deltaic area (Lwin Lwin Cho, 2017).

River erosion means current of the river hit the banks of rivers and broken the banks, which create most sensitive and dangerous situation in river areas (Khan,2012).At the lower course, the river overflows its banks and its velocity decreases outside the river channel. River deposits and there is shallower water on the inside of a river. It is one of the factors forcing flooding and bank erosion.

Flood and River bank erosion are dynamic and natural processes which have an adverse impact on livelihood as homesteads are destroyed, cultivatable lands are wiped out and employment opportunities are reduced (Acharjee, 2013). Flooding is more severe in the study area and recorded flood occurred in 2015. Water level reached more than 2.1 meter(7 ft)in August, 2015. At present, flooding and bank erosion became worse and local people lost their farm land. In Hinthada Township, the impacts of flooding and erosion on the socio economic lives of the poor villagers are distinct.

Severe flooding caused bank erosion and area of cultivated land owned by the local people decreased distinctly.

In the study area, Pegyikyun, Letpanhla, Kywetkyun, Theyoe, Kyaukye, Tarngote, Phaunghteik, Tharyaraye and Shwegukyun villages are severely affected by flooding and river bank erosion. Kyaukye Village possessing more than 200 households and cultivated area of more than 800 hectares (2000 acres) on Kaing land is nearly being disappeared during 2 year period.

When Hinthada is at danger level, water level at these village tracts is 0.9 meter 993ft high. But water level usually reaches more than 1.5 meter (5 ft) and water level reached to 2.1 meter (7 ft) in August, 2015.In the rainy season, crops cannot be cultivated in Tarngote, Pegyikyun, Letpanhla and Kywetkyun village tracts in the rainy season to flooding and young adults in the area move to other place as migrant workers to get income. The river bank erosion causes huge destruction of agriculture land and loss of house, schools, etc. Flooding and river bank erosion is important because river erosion leads to huge socio-economic losses and has been great impact on eroded villages.

Study Area

Hinthada Town is located in the Northern portion of the Ayeyarwady Region. It lies between North latitudes 17 °15′ and 17° 39′and also between East longitudes 95°13′ - 95° 30′. It is situated on the deltaic area of Ayeyarwady Region and Southeastern part of Hinthada Township. As it is situated between Ayeyarwady and Ngawun rivers, the area suffers flooding and bank erosion badly.

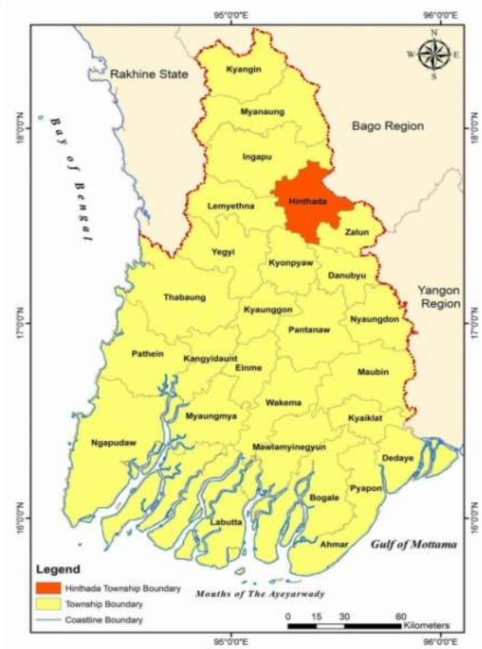

Figure 1: Hinthada Township in Ayeyarwady Region
Source: Agriculture Atlas (2002)

Objectives

Objectives of the paper are:

- to understand flooding and bank erosion in the area,
- to study loss of agriculture land,
- to assess the socio economic impacts of river bank erosion and
- to find the perception on adaptability and resilience of the inhabitants

Methodology

Both primary and secondary data were collected in order to understand socio-economic conditions of local people and reach clear results and conclusion. For examining the effect of flooding and river bank erosion on the local people of Hinthada Township, 10 village tracts were mainly chosen as samples from affected village tracts. These areas located on the southern bank of Ayeyarwady River are now actively witnessing flooding and bank erosion and effects on the local people are more severe. Questionnaires were distributed to 10 households in each village tracts and questions were mainly concerned with education, health, the loss of their property and their copping mechanism. The patterns of rehabilitation and their perception about the causes of erosion and the way they continuously try to adapt were observed.

Discussion and focused interviews were conducted with authorities, heads of village tracts, old aged person lived in the area to gain insight into the problems related to bank erosion and its impacts on the socio economic conditions of the local people.

Results and Findings

Flooding and River Bank Erosion

River bank erosion is a natural process influenced largely by rainfall, soil structure, river morphology, topography of the river and adjacent areas, and floods; it can also be influenced by human activities such as intensive agriculture, settlement expansion, deforestation, etc (Yousifet al, 2015). But, in the study area, erosion processes are mainly caused main by the continuous run-off over a slope.

Hinthada Township has been affected by massive floods almost every year. Flooding became severe due to change in amount and distribution of rainfall caused by climate change and shallow river channel of Ayeyarwady caused by deposition. Local people lost their agricultural land and flooding and river bank erosion have negative impacts on local people.

Plate 1: Bank erosion at Theyoe Village (27.6.17)

Plate 2: Bank erosion at KywetKyun Village (27.6.17)

Plate 3: allocation the Monastery by Bank erosion at Kyaukye Village (27.6.17)

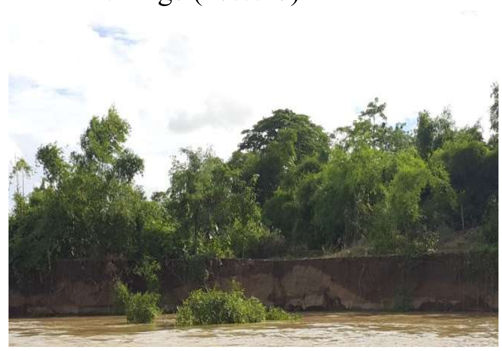

Plate 4: Bank erosion at Kyaukye Village (27.6.17)

In Hinthada Township, Pegyikyun, Letpanhla, Kywetkyun, Theyoe, Kyaukye, Tarngote, Phaunghteik, Tharyaraye, and Shwegukyun villages located western part of Ngawun and Ayeyarwady rivers suffer severe floods and bank erosion. In these villages, the erosion rates varies from 1.8 meter (6 ft)to 77 meter (264 ft)per year (Wint Wint Htun, 2016). Among them, Kyaukye Village suffered most severe bank erosion and nearly the whole village was eroded.

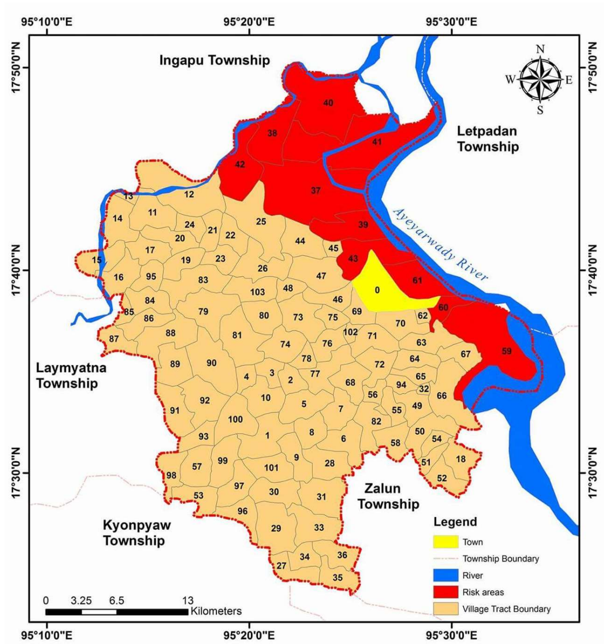

Figure 2: Village Tracts affected by flood and river bank erosion

Source: Field survey (June, 2017)

Total distance of erosion at Hinthada Town in western river bank between2009 and 2015 was 720.4 m (1714.55ft). Erosion rates in the front flood land area of Hinthada Town are still increasing (WintWint Htun, 2016).

Figure 2: Bank erosion at Kyaukye Village

Source: Ye Khaung Htun (2016)

The study area is topographically flood plain areas and affected by river bank erosion. In the study area, bank erosion occurs frequently and affects local people and their property in the region.

Impacts on Socio-economic Conditions of Local people

In order to understand socio economic conditions of local people affected by bank erosion, a questionnaire survey and semi-structured interview were conducted.

According to questionnaire results, 62 percent of the respondents suffer the flooding period of between 45 and 50 days and 38 percent less than 20 days. The high flood period is the end of July, August and September locally called as mid and the end of the rainy season. Local people know that flooding and bank erosion became more severe and it is due to shallow river channel of Ayeyarwady River.

Local people get supports during the flood periods from the monks such as Sayadaw Ashin Nyanaissara, etc and philanthropic social organizations like Gayunar Alindan.

According to structured-interview, 83 percent of the local people do not move to the places instructed by local authorities and only 17 percent to monastery that is designed as temporal shelter for flood victims.

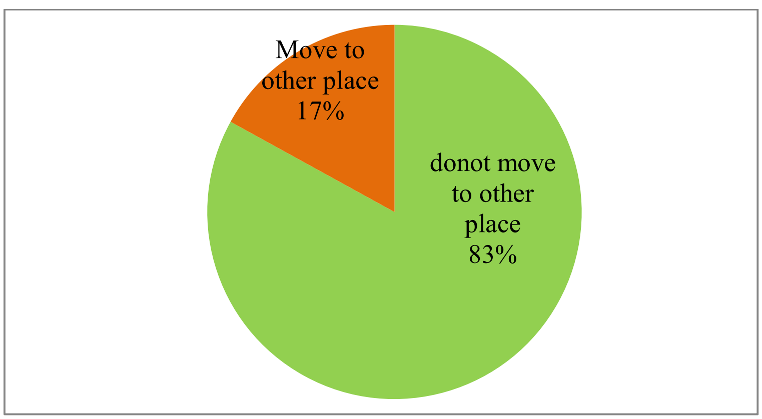

Figure 3: Respondents' answer on movement to other places
Source: Questionnaires' results(June, 2017)

Allocation of Houses

According to questionnaire's results, 33 percent of the population allocate their home once during 10 years period, 19 percent twice and 48 percent three times.

Aung Chan Tha village no longer exists and people live in the village move to Kyaukye and The Yoe villages. In Let Pan Hla Village, people allocate their home on pasture as their former places were eroded.

Loss of Property and the Economic Stress

People lived in Kyaukye, Tarngote, Phaunghteik, Tharyaraye, and Shwegukyun villages lose their agricultural land because of bank erosion. Bank erosion caused decrease in agricultural land and the income became low.

River bank erosion and flooding also have very serious psychological effect on local people due to loss of home, property, land and etc. Because of bank erosion, people buy land plots on Kaing Land of other villages that are away from bank erosion. It is found that about 5 or 6 households collectively buy 0.25 hectare (an acre) of Kaing land and it is again divided into small plots on which new houses were built. The price of 0.25 hectare (an acre) of Kaing land is about 2,000,000 ks. After allocation their homes to new places and some people are in debt.

Loss of Agricultural Land

Most people cultivate Kaing crops in their Kaing land and it has been eroded at the rate of 0.4 km (0.25 miles) per year. Therefore, they lost their agriculture land and area of cultivated land decreased. Loss of agricultural land is a very common effect of flood and erosion in the area. Due to bank erosion, local people have been losing a vast area of land every year. Therefore, cultivated area is more limited and income is getting low. In the area, kaing crops are mainly grown after receding river water. Cultivation period was shorter than other areas that are free from flooding. Local people highly depend on the land to get income and the loss of land is a major problem affecting socioeconomic condition of the area.

Poor Transport System

As the area is annually affected by floods, the earth-roads in the villages are poor in condition. While the villages are flooded, local people use boats to go one place to another. When the flood water retreats, these roads are muddy and it affects socioeconomic condition of the local people. Every household possesses a boat for the purpose of using in the flood period.

Plate 5: Poor Road at Gaungsaykyun Village (24.6.17)

Plate 6: House and boat at Gaungsaykyun Village (24.6.17)

Problems on Education

Most villages have a primary school and most of schools are attached with monasteries. But inundation is annual phenomena and it is difficult for children to go to school in the flooding. Problems on the class irregularity, low accessibility, insecurity, etc hamper the education of the children.

Plate 7: School at Gaungsaykyun Village (24.6.17)

Plate 8: Monastry at Gaungsaykyun Village (24.6.17)

According to questionnaire survey, 20 percent of the local people said that they do not allow the children to go to school because of insecurity caused by flooding, 32 percent said because of low accessibility and 48 percent said because of lack of teachers and school closing due to severe flooding.

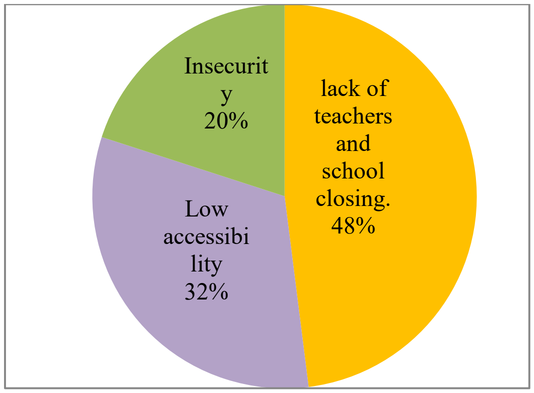

Figure 4: Respondents' answer on Education

Source: Questionnaires' results (June, 2017)

Medical Problems

During the flooding period, authorities announced that to shift to other for the purpose of protecting the local people because these areas do not have adequate medical facilities and staff. But, local people do not move to other areas.

According to field survey, there is no problem on snakes in villages such as Gaungsaykyunin flooding period and the problem is found in Pegyikyun, Letpanhla, Kywetkyun, Theyoe, Kyaukye and Tarngote villages. For that case, there is no sufficient medicine and staff in the flooding period.

Survival Strategies

As flood and bank erosion are natural processes, therefore it is not possible to provide complete protection from these hazards. Local people can minimize the adverse effect of flood and erosion by adopting various household techniques. Household's ability to adapt with flood and river erosion depends on people's socioeconomic and environmental conditions, such as education, income and occupation. Though, flood and river erosion cause the loss of land and properties, people's indigenous coping techniques could significantly reduce their vulnerability without outside assistance. Most of the houses raised the floor above the possible flood level (Plate 9). Moreover, most people possess boats to be used in flood period (Plate10).

Plate 9: house at Gaungsaykyun Village (24.6.17)

Plate 10: house at Gaungsaykyun Village (24.6.17)

According to questionnaires' results, they get information on flooding and bank erosion from radio. According to interviews, some adults get information on face books.

Adaptation Strategies for Crop Cultivation

As the local people depend on agriculture for their income, pulses, black gram, tomato, Accra, cucumber, chilli, pulses and tomatoes are grown Kaing land in flood free period.

Cropping Calendar

M	A	M	J	J	A	S	O	N	D	J	F
		Accra/Cucumber		flooding period		Tomatoes / Pulses			Chili		

Source: Interview (15.7.17)

According to interviews, accra and cucumber are widely grown in May and June before monsoon sets in and early monsoon period (Plate 12). Because of severe flooding in July and August, farmers do not grow in these period and young adults move to other towns and Yangon Region to get income in the rainy season.

In August, the people germinate the tomatoes seeds on the temporary buildings in the rivers and in front of their houses. In September, they grow these nurseries on the Kaing land. Therefore, their tomatoes flower and fruit early and the price of tomatoes is high when they sell them to the market due to low supply (Plate 12).

At the end of the rainy periods, growers cultivate tomatoes and pulses. In summer, chili is widely grown on Kaingland due to high market demand.

Plate 11: Accra cultivation on Kaing Land (8.7.17)

Plate 12: temporarily building to germinate tomatoes seeds in August (21.8.17)

Machinery Use in Cultivation

The Kaing lands in the area are fertile and crops can be grown successfully. It is necessary to get long cropping period for the intention of getting income from agriculture by practicing double or triple cropping. To get long cropping period, the farmers use agriculture machinery in ploughing for the purpose of reducing time for tillage. Growers do not have sufficient amount of investment to buy agriculture machinery and these are rent from private owners and it is difficult to get in time. The farmers want to apply agriculture machinery to get long time span for crop cultivation.

Local People's Perception on Rivers

The extent of loss to the bank erosion becomes worse in the area. According to interviews, Aung Chan Thar Village having more than 250 households was located near Kyaukye Village. Last 20 years ago, it was disappeared due to bank erosion and people moved from Aung Chan Thar Village established Kyaukye and Ngareindan villages west of Aung Chan Thar Village. At present, Kyaukye Village is being severely eroded and disappeared quickly.

According to questionnaires' results, 19 percent of the respondents said that river gives disadvantages to them, 68 percent advantages and 13 both advantages and disadvantages.

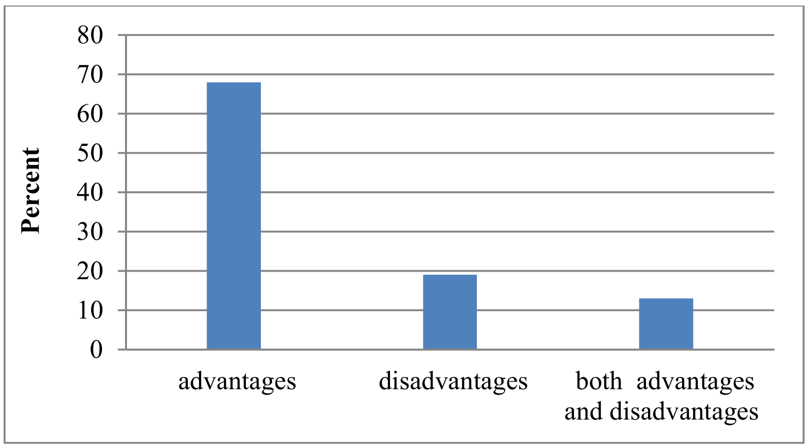

Figure 5: Perception of Local people on migration
Source: Questionnaires' results (June, 2017)

Conclusion

Floods and river bank erosion are common problems for the people living in coastal and deltaic areas. Like other people lived in coastal and deltaic areas, people in Hinthada Township encounter the problems on floods and river bank erosion. As effects of flooding and erosion increased in the area due to rainfall irregularity caused by climate change and shallow river channel caused by deposition, local people encountered socio-economic problems and their socio-economic conditions are low. They lost their agriculture land that is major pillar to their economy and bank erosion reduces their income through the reducing agriculture land for crop cultivation. Because of flooding, education and health care level of the study area is somehow low.

It is needed to raise local peoples' awareness for the purpose of protecting their areas from bank erosion. It is necessary to do environmental researches in the risk areas. Regional hazard and risk assessments should be done and local people will have to be persuaded in protecting their land. Moreover, permanent settlement should be avoided in risk are as and it is needed to do mitigation practices and contributing to the community base level. It is needed to lend long term loan to farmers for the intention of buying agriculture machineries to get more income from crop cultivation, major economy of the area.

On the other hand, local authorities should plan to pay flood insurance for local people. It is needed to do flood and bank erosion mitigation, installation of floods warning system and Mass education to protect bank erosion and to upgrade socio-economic conditions of the local people.

Acknowledgement

We would like to thank Dr. Kyaw Kyaw, Professor and Head, Department of Geography, Mawlamyine University for his permission to do the research paper and encouragement. We would like to thank Sayamagyi Dr. Mi Mi Kyi (E.C member, Myanmar Academy Arts and Science) for her valuable advice and kind guidance on this paper. We also thank to our friends for their helping hands.

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COMPARATIVE ANALYSIS OF RETAIL SHOPS ALONG BOHMU PHOKUN AND TAUNGOO UNIVERSITY ROADS

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Than Than Nu[4], Zar Li Win[5], Khin Than Nwe[6], Eh Mwe Paw[7]

Abstract

This paper analyse the retail shops of Bohmu Phokun and Taungoo University roads between 2007 and 2017. As the population increasein Myanmar, development process occur in every sector. Taungoo city either increased in total population or urban area. Taungoo lies within northern part of eastern Bago Region. It is also second largest district city after Bago city. It is located in southern part of Taungoo Township which is composed of 38 village tracts. These village tracts serve as hinterland of Taungoo city economy. Moreover, the development of educational centre such as Taungoo University, Teacher Training College, Computer University and GTC (Government Technology College) are established in Taungoo city environment. New Teacher Training College and Taungoo University are situated in western part of Taungoo city. The purpose of this paper is to investigate the influencing factors for the temporal changes of the pattern, types and style of retail shops. This paper is represented by the comparative study of retail shops for the years 2007 and 2017 along the Bohmu Phokun and Taungoo University roads which connect Taungoo and Taungoo University and Teacher Training College. Data was collected by field survey and structured interview for 2017 and comparative study was made based on 2007. Spatial analysis of retail shops is conducted by using GIS (Geographic Information System). The changes of the pattern, types and style of retail shops can be found year by year according to many background influencing factors especially Taungoo University and Teacher Training College. It is noted that the landuse pattern has been changed from agricultural landuse and residential landuse to commercial landuse along these roads especially between Taungoo and Taungoo University.

Key words: Retail shops, Taungoo University, Comparative study, spatial analysis

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Introduction

Taungoo is located in the northeastern part of Bago Region. Bago Region itself is divided into east and west parts by Bago Yoma. As a result, development of urban areas in the region is dominated by many nodes rather than single node as a capital. Although Bago is the capital town of Bago Region, Pyay is thriving as a major node of western part while Taungoo become a major node in the eastern part. Taungoo is located on the Yangon-Mandalay Highway and Yangon-Mandalay Railroad. It is also connected with Taungoo-Loikaw Road which connects between Bago Region and Kayah State, and Taungoo-Thandaunggyi Road which connects Kayin State. Oktwin is located on the Yangon-Mandalay Road at a 14.5 km (9 miles) distance from Taungoo. It is connected to Pyay with Taungoo-Paukkhaung Road. Therefore, Taungoo becomes a junction between western and eastern part of Myanmar and northern and southern parts of Myanmar.

Since it is a junction and having many hinterlands, both wholesale and retail activities are developed in Taungoo. Wholesale activities are developed since it is an exchange place for commodities produced in different parts of Myanmar under different physical conditions. Retail activities are developed to supply the Taungoo and neighbouring towns and villages. Most of the retail activities serving the town itself and its neighbouring towns and villages are concentrated near the municipal market (Central Business District). Other retail activities serving the town populations are distributed throughout the town.(Figure. 1)

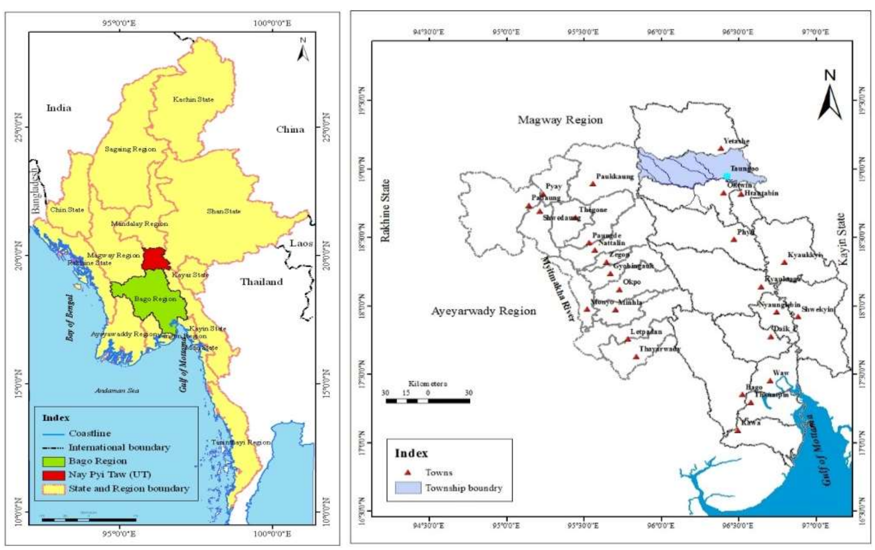


Figure 1.(a) Bago Region within Myanmar and (b) Taungoo in Bago Region
Source: Land Records Department

Research Questions

In this paper comparative analysis of retail shops are conducted to answer following questions.

(1) How retail shops are developed along the Bohmu Phokun and Taungoo University Roads for the year 2007 and 2017?

(2) How retail shops are spatially distributed along the Bohmu Phokun and Taungoo University Roads in 2017?

(3) What are the controlling factors for the spatial-temporal development and the style of the retail shops?

Data and Methods

Data were collected in two ways to understand the temporal development and spatial variations of retails shops. Location of retail shops were recorded on the base map before digitizing on the computer. By means of digitizing the location of retail shops, spatial database of the study area was constructed. At the same time, retail shops were interviewed to understand the temporal development. The reasons to be able to explain the spatial and temporal development patterns of retail shops were also asked in the structure interview. Then, interview results were compiled by using Microsoft Excel Database.

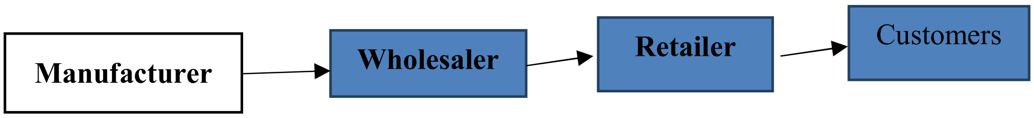
Above two databases were combined by using ArcMap software to analyze the spatio-temporal development of retail shops for these two years according to answer above research questions.

In the first section of the paper deals with the physical factor of the study area. In the next section the development of retail shops along the Bohmu Pokhun and Taungoo University Roads for the two years are described. Then, spatial variation of retail shops by type, size and conditions are analyzed in section three. Section four discusses the controlling factors of retail shops distribution and development in the study area based on the interview results.

What is retail?

A retail sale occurs when a business sells a product or service to an individual consumer for his or her own use.

The role of Retail Function



Source: Based on retail definition

2. Physical Bases of Study Area

Taungoo is located in the northeastern part of Bago Region. It also lies in the southern part of Taungoo Township. It lies between 18° 54'and 18° 57'north latitudes and between 96° 24' and 96° 28'east longitudes. It is situated on the Yangon-Mandalay railroad and highway road.

Taungoo has an area of about 14.82 square kilometer(5.72 square miles) or about 0.86 percent of Taungoo Township. It also comprises 23 wards of Taungoo Myoma. Its boundary is demarcated by Kanyoe village tract on the north, on the east by Thahpapin and Mogaung village tracts, Ziedaine and Putsu village tracts on the south and Lebu is bounded on the west. Bohmu Phokun road is located in the ancient city boundary and trending east-west direction and connected with Taungoo University and Teacher Training College.(Figure 2)

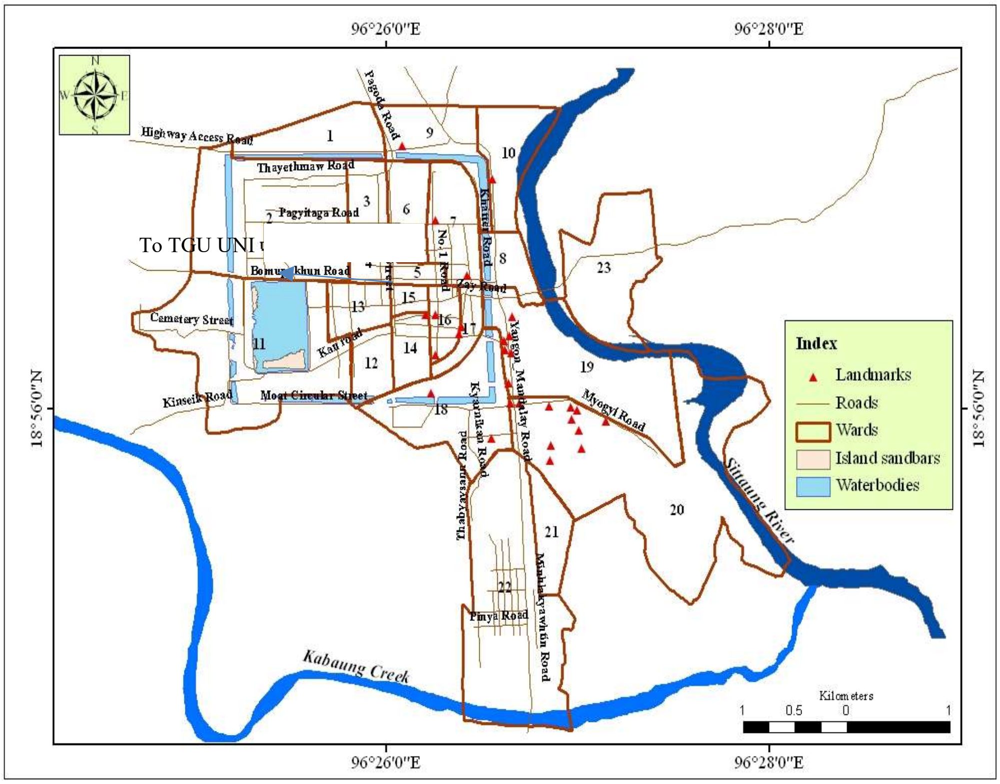


Figure 2. Taungoo Myoma Wards

Source: Land Records Department and Google Earth Pro

3. Development of Retail Shops

The development of retail shops depends on many factors: market economic activity, establishment of Taungoo University and Teacher Training College on the western part of Taungoo, urban growth of Taungoo itself. Development of Taungoo depends on hinterland or neigh bouring villages. Development of retail shops are varying within 11 years between 2007 and 2017. (Table 1)

Types of retail shops are represented with their respective symbols:

1. ***Personal goods shops (PeG)*** **–**Personal Goods Shops including grocery shops, stores, and various kinds of bakeries.

2. Specialized services (SpS) – Specialized services including beauty parlor, video tape and VCD rental, TV game, photo studio, sewing services, electrical goods shop and their repair work.

3. Daily consumption goods shops (DaC)-Fast food shops like tea shop, rice noddle (mohhinkha) shops, Chinese Restaurant.

4. Betel and cigarette shops (Ft)

5. Transport services (TrS) – Transport Services shops like motorcycle repair shop, bicycle repair shops, car repair shops, gasoline shops.

6. School services (ScS) - School Services likes hostels, tuitions, guest house.

7. Specialized shops related to University (SpU) – Specialized shops related to University such as compurterizing and copier shops, stationary shops, medicine shops.

8. BL-billiards houses

9. Others (Ot)

Table 1. Types of retail shops for the years 2007 and 2017

Types of Retail shops	2007	2017
PeG	59	91
SpS	47	74
DaC	26	38
Ft	25	18
TrS	21	23
ScS	19	7
SpU	10	22
BL	5	0
Ot	18	7
Total	**230**	**280**

Source: Field observation (December, 2006 and February, 2017)

According to table 1, personal goods shops (PeG) increased from 59 in 2007 to 91 in 2017. This types includes daily consumer goods such as grocery shops, shoes, stores and wearing. Specialized services(SpS) also increased from 47 in 2007 to 74 in 2017 including beauty parlor, video tape and VCD rental, book rental, TV game, photo studio, sewing services, electrical goods shop, mobile phone selling and services, internet cafe. Fast food shops (DaC) like tea shops, rice noodle (mohhinkha) shops, Chinese restaurant are also increased 26 in 2007 to 38 in 2017.Specialized shops related to University (SpU) includes computerizing and copier shops and medicine shops increased from 10 to 22. Betel and cigarette shops (Ft), School services (ScS) includes hostels, tuitions, guest house, billiards (BL) and others (Ot) decreased between 2007 and 2017. The total number of retail shops increased from 230 in 2007 and 280 in 2017 which the net total is 50 shops. (Figure 3)

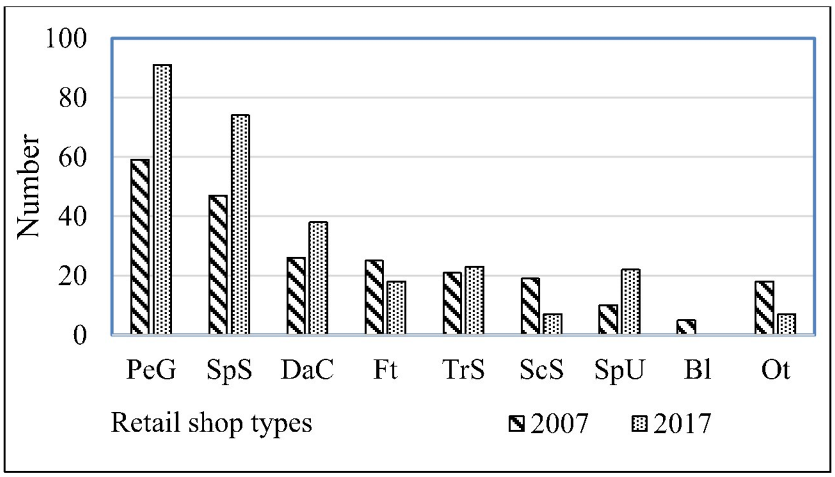


Figure 3. Types of Retail shops development for the years 2007 and 2017
Source: Based on table 1.

The development of retail shops are studied in detail for the year2017 especially in four different periods: before 1988, between 1989 and 2000, between 2001 and 2010, and after 2010. The first period the development of retail shops under the state economy, the second period represent under the establishment of the market economy, the third and the fourth period depend the establishment of Taungoo University and others supporting factors. (Figure 4)

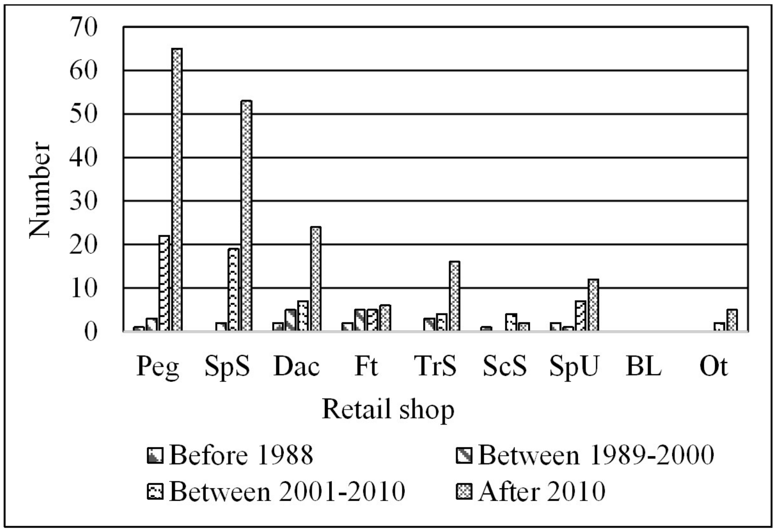


Figure 4. Development of retail shops in different period
Source: Field observation (February, 2017)

Share percentage or number of retail shops are presented in table 2 and figures5 and 6. According to this table some types of retail shops like PeG, SpS, DaC, and SpU are markedly increased but some are such as Ft, ScS, and Ot decreased with their role of importance on customer.

Table 2. Development conditions of retail shops (2007 and 2017)

Types	2007	%	2017	%	Increase / Decrease Number
PeG	59	25.65	91	32.50	32.00
SpS	47	20.43	74	26.43	27.00
DaC	26	11.30	38	13.57	12.00
Ft	25	10.87	18	6.43	-7.00
TrS	21	9.13	23	8.21	2.00
ScS	19	8.26	7	2.50	-12.00
SpU	10	4.35	22	7.86	12.00
Bl	5	2.17	0	0.00	-5.00
Ot	18	7.83	7	2.50	-11.00
Total	**230**	**100.00**	**280**	**100.00**	**50**

Source: Field observation

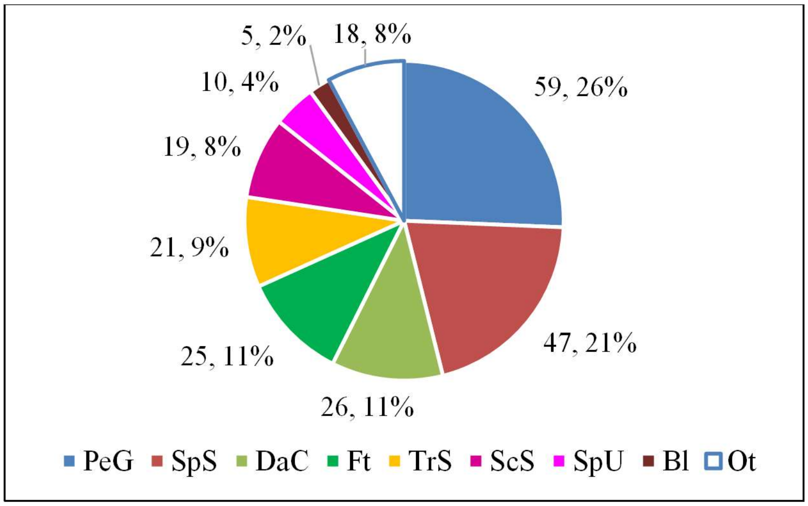


Figure 5. Share percentage of retail shops for the year 2007
Source: Field observation (December, 2007)

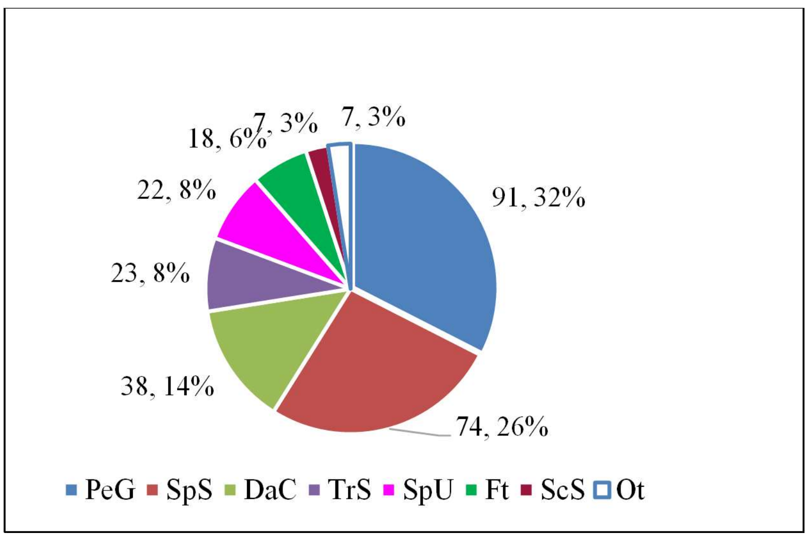


Figure 6. Share percentage of retail shops for the year 2017
Source: Field observation (February, 2017)

According to the above comparative study of retail shops for the years 2007 and 2017, number of retail shops and share percentage are varying with their respective types. Moreover some retails totally disappeared and are replaced with other types, apparel specially 5 billiard game centres in 2007 disappeared. Some retail shops especially apparel for men, women and children are more than others. Retail shops concerned with mobile phone selling and service centreis new type of retail shops in 2017 which increased dramatically with the number of 28 shops.

4. Spatial Distribution of Retail Shops

Retail function is one of the factor of urbanization process in every city and towns. Most of the retail shops are found along either side of the streets or roads. In this study all the retail are unevenly distributed along both sides of Bohmu Phokun and Taungoo University roads. Their distribution are classified into 3 clusters (1) Taungoo urban area, (2) Lebu model village and (3) in front of Taungoo University campus. Moreover some retail shops are under construction replaced on the paddy fields near Taungoo University campus (Figure 4). Thus their future linear distribution pattern may be filled with retail shops along either sides of these roads between Taungoo Myoma and Taungoo University (Figure 5). Therefore the agricultural landuse pattern is gradually filled with commercial landuse between Taungoo University and Taungoo Myoma. Then, along this road many retails are still under construction.

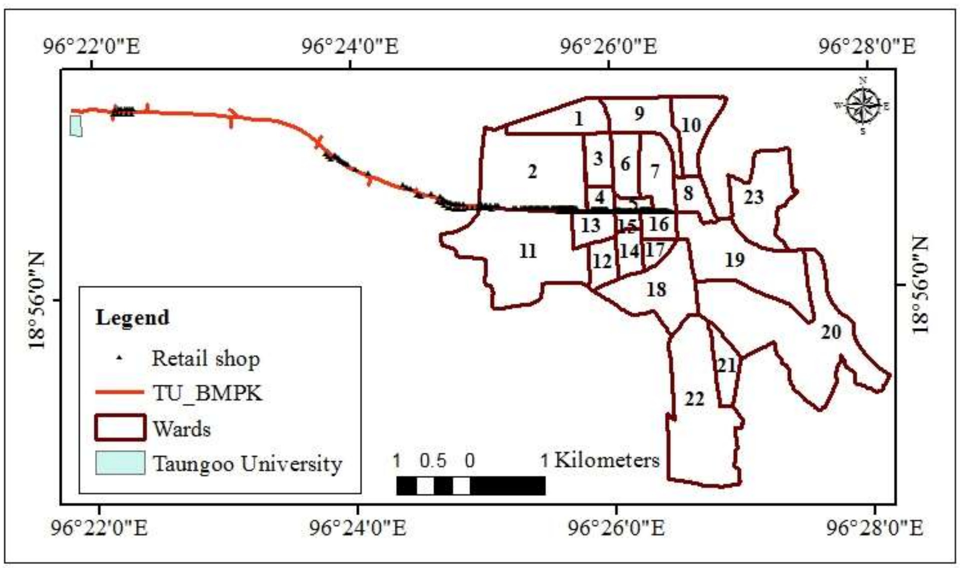


Figure 7. Distribution of retail shops along Bohmu Phokun and Taungoo University Roads

Source: Field observation (February, 2017)

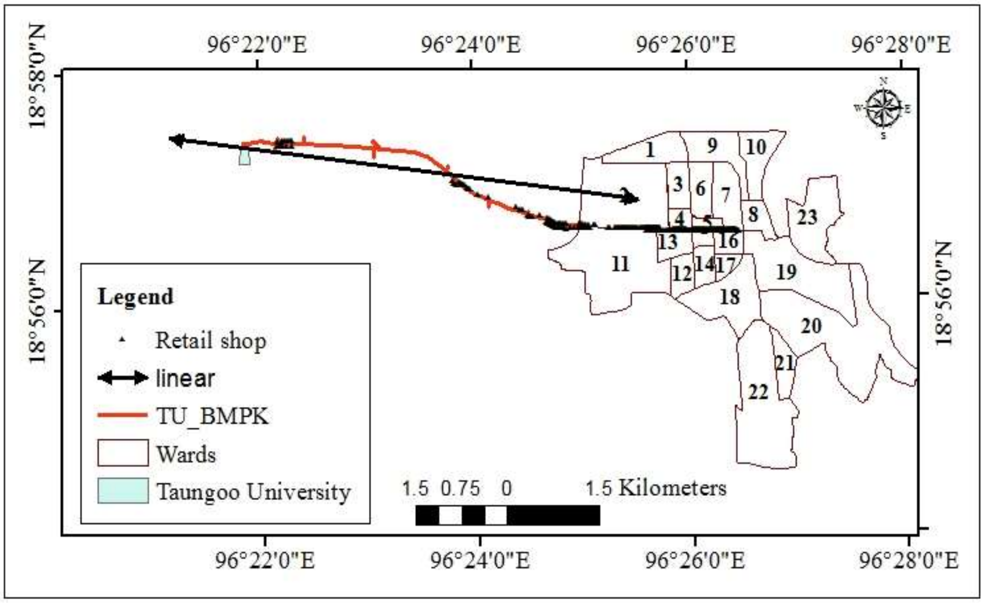


Figure 8. Linear directional mean of retail distribution
Source: Field observation (February, 2017)

Table 3. Locational characteristics of retail shops

	2007	%	2017	%
Owner	124	53.91	120	42.86
Rent	106	46.09	160	57.14
Total	**230**	**100**	**280**	**100**

Source: Field observation (February, 2017)

From table 3, the total retail shops along this road are increased within 11 years in relation to many factors in particularly establishment of Taungoo University. In 2007, the total retail shops 230, of which 53.91% are owner while 46.09 % are rental, in construct, in 2017, 42.86 % of the total retail shops are owner and 57.14% are rental. Therefore, the percentage of the owner and rent for the two years are quite different this is because some retail shops migrated from other lane or streets. (Figure 9)

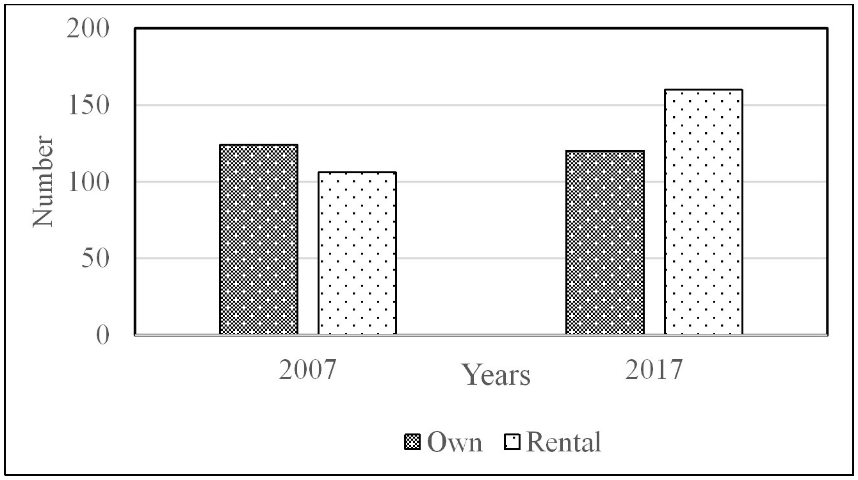


Figure 9.The number of rental /ownerships of retail shops
Source: Field observation

Level of retail shops

The level of retail shops in this study represent size, conditions, and style of retail shops along Bohmu Phohun and Taungoo University roads. The former type of retail in Taungoo is very simple style and small (Plate a and b) but according to this observation the types of retail activities are changed into modern styles. In 2017 interview result, some company and bank which are special kind of retail shops along this road. Moreover some retail shops like Win Mart is constructed as super market like Yangon style (Plate. e).The reason for this variation of retail level is the nearness of Yangon capital also called economic capital of Myanmar.

Table 4. The level of retail shops

Level	Number	%
Very Large	21	7.50
Large	112	40.00
Medium	4	1.43
Small	135	48.21
Very Small	8	2.86
Total	**280**	**100.00**

Source: Field observation (February, 2017)

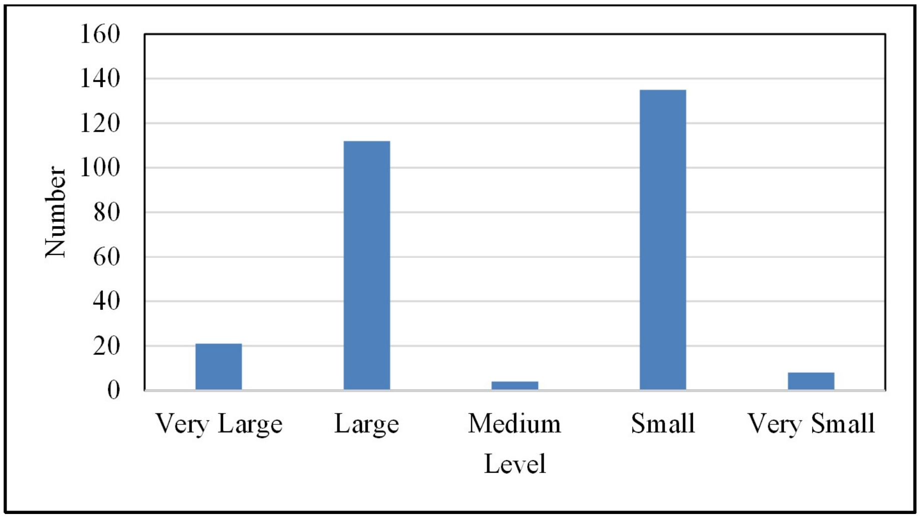


Figure 10. Level of retail shops (2017)
Source: Based on table 4.

Style of retail shops

In this paper, the style of retail shops are represented by the size because the size, and style of retail shops are related. The larger the size of retail shops can sell more types of goods which is one of the most attractive side for customers. The style of retail shops describe the urban growth and development of economic activities. In the past situation, the retail shops along this road are very simple in structure but current situation very modernized. Some retail shops are company function such as Honda cycle, T.Com mobile services, OPPO mobile sales and services center. Red Rose is very popular store and also the style is modernized. (Plates c, d, f, g, h, i)

(a)

(b)

Plate 1. Former retail shop styles (a, b)
Source: Photo taken by February, 2017

(c)

(d)

Plate 2. Present styles of retail shop (c, d, e, f, g, h, i)
Source: Photo taken by February, 2017.

(e)

(f)

(g)

(h)

(i)

Conclusion and discussion

The urban growth of any towns and cities describes with economic activity including whole sales and retail functions. This research studies the comparative analysis of retail shops along Bohmu Phokun and Taungoo University roads for the years 2007 and 2017 as the presented three questions. The increased number of retail shops within 11 years is 50 but the styles and the types are very different, because the distance between Taungoo and Yangon is 234.96 km (146 miles) which is capital city of Myanmar and only four hours for time travel. Therefore the modern styles of retail shops are diffused to Taungoo. The spatial variation of retail shops along this road differ between 2007 and 2017 according to the consumers need as the modern fashion of students and local people. The landuse pattern along either sides of this roads continuously changed from agricultural landuse to commercial landuse as the natural population increased of Taungoo and the students of Taungoo University, Teacher Training College, Computer University and Government Technology College (GTC).The development of retail shops causes some adverse effects on transportation of Bohmu Phokun road that sometimes traffic jam and accident. Therefore, the systematic management of retail function and transportation facilities need to be practiced along this road.

Acknowledgement

We wish to express our sincere thanks to Dr Win Myint Oo, Professor and Head of the Department of Geography, Taungoo University for allowing us to go to field trip. We are deeply indebted to Dr Khin Naing Myint, Professor, Department of Geography, Taungoo University.

We would like to express our special thanks to the responsible persons of the administrative office for their help during our field observation. We acknowledge to the owner and salespersons of the retail shops along the Bohmu Phokun and Taungoo University roads.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

AGRICULTURAL TRANSFORMATION PROCESSES IN MYANMAR : FARMING OF INDUSTRIAL CROPS IN BAGO REGION (WEST)

Swe Zin Theik*

ABSTRACT

Major economic policy of Myanmar changed since the introduction of the market- oriented economy in 1988 carried out in the agriculture sector. Industrial crop farming of Bago Region(West) changed after 1988 in the transformation of agriculture. Spatial impacts of government policy on input costs, farm size, land tenure systems, labour supply, farmer decision-making and market opportunities were observed during the transformation processes. In this research, the controlling factors that caused changes of industrial crop farming are studied by using qualitative and quantitative methods. This research attempts to analyze the agricultural land use and changes in agriculture pattern in Bago Region (West) area by the case study on industrial crop farming villages of Pyay Township, Paukkhaung Township and Monyo Township .Better and more feasible means for industrial crop farming are searched and recommended for further development .

Key words : Industrial Crop Farming , Policy Change , Market-oriented Economy

Introduction

Agricultural practices are in the process of transformation as a consequence of increasing population pressure, decreasing agricultural land, environmental constraints increasing market demand and globalization processes. Agricultural transformation is the process by which individual farms shift from a highly diversified, subsistence-oriented production towards a more specialized production oriented market or other systems of exchange (e.g., long-term contracts).The process involves a greater reliance on input and output delivery systems and increased integration of agriculture with other sectors of the domestic and international economies (Staatz, 1998).

Agriculture is the key sector of Myanmar's economy, contributing 40.2 per cent of the GDP, 12.14 per cent of the total export earnings in 2005-06

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and employing 69 per cent of the active labour force (Soe Soe Aye, 2006). Myanmar has laid down 12 political, economic and social objectives in its endeavours to establish a peaceful, modern and developed nation. One of the major economic objectives is development of agriculture as a base and all round development of other sectors of the economy. Since 1992-93, the Economic Development Year an integrated development strategy has been applied for agricultural development, with specific sector-objectives and policies. The main strategies of the plan relating to agricultural and agro-processing sectors are to increase production of the staple food crops to achieve regional self-sufficiency, to extend cultivation of industrial crops to fulfil domestic raw material requirements, to promote the diversification and expansion of exports, to achieve effective mobilization and utilization of productive resources, to increase the efficiency of investments and to improve production efficiency and cost effectiveness.

Major economic policies changed with the introduction of market-oriented economy in 1988. Private companies were allowed to import pesticides, insecticides and chemical fertilizers .Many land development permissions were given to private companies. Farm products were allowed to more free trade. Changes in agricultural policy could also generate some patterns of agriculture in the industrial crop farming areas. This research paper attempts to analyze the land use and agricultural pattern changes in Bago Region (West) area by the case studies of each industrial crop farming village.

Research Questions

The role of industrial crop farming in the process of agricultural transformation is empirically investigated for Bago Region (West). The research questions are:

(1) How have industrial crop farming in Bago Region (West) changed in the transformation of agriculture?

(2) What are the controlling factors of industrial crop farming?

Data and Methodology

Secondary data and factual materials are collected from respective Government Departments. Based on those data, representative villages are selected for each crop and interviews are conducted with crop cultivators .The above research questions, some villages located in Bago Region (West) where most villagers cultivated the industrial crops of sugarcane, jute and kenaf and cotton are selected as case studies .The farmers cultivating the industrial crops were interviewed. Open talks as well as structured interviews were conducted to obtain data on the controlling factors on industrial crop farming.

Geographical Background of Study Area

Industrial crop farming mainly depends on physical features such as relief, drainage, climate, geology and soils of the study area. The Bago Region (West) is located between north latitudes 17° 2' and 19° 1' and east longitudes 94° and 96° 10'.There are 14 townships in the Bago Region (West).The whole area is divided into two districts, Pyay and Thayarwady. The total area of the Bago Region(West) is 14384.43 sq-km (5553.86 sq miles).The study area is wide in the north and narrow in the south. It is 120.70 km (75 miles) from east to west in the widest part, about 80.47 km (50 miles) in the central part and about 64.37 km (40 miles) in the extreme south. It extends for 228.53 km (142 miles) from north to south. Therefore the north-south alignment of the study area is longer than the east-west alignment. The Bago Region (West) bordered by Magway Region in the north, Bago Yoma in the east, Yangon Region in the south, and Ayeyarwady Region and Rakhine State in the west (Figure .1).

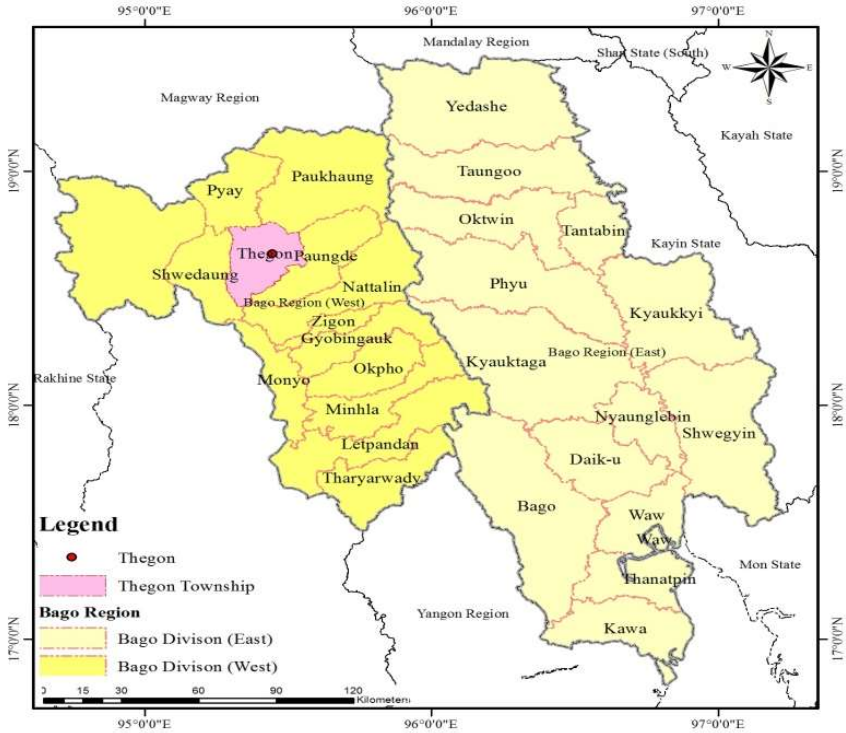


Figure 1. Location of Bago Region (West)
Source: Survey Department , Thegon Township

Industrial crop farming in Bago Region (West) is closely related to its relief. It lies between the Bago Yoma in the east and Rakhine Yoma in the west. The Ayeyarwady River is flowing through the area from north to south. It is gently sloping towards the south. Many streams and rivers originate on the Rakhine Yoma and Bago Yoma and flows into the Ayeyarwady River. The central part of the Bago Region (West) between Ayeyarwady River and Bago Yoma is flat land except Pyaytaungtan (Pyay Range) and Ayeyarwady uplands in the north .The rivers and streams take their sources on the Bago Yoma and flow from east to west into the Ayeyarwady River . Myitmakha an important river takes its source in the Inma-In extends 12.87km (8 miles) from north to south and about 3.21km (2 miles) from east to west, Myitmakha river flows parallel to the Ayeyarwady River course from north to south. Many streams that originated on the Bago Yoma, flow into Myitmakha River.

Agriculture is also dependent upon climate. Climatic conditions of Bago Region (West) is directly related to selection of crops and pattern of cropping .According to the 29 year average data (1988-2017), April is the hottest month with maximum temperature of 40°C in Pyay and 41°C in Thayarwady. The minimum temperature of the coldest month of January was 32° C and 35° C in Pyay and Thayarwady respectively. The annual rainfall is 116.84 mm (46.00 inches) at Pyay and 219.96 mm (86.60 inches) at Thayarwady. On the other hand, the rainfall of Pyay varies greatly from that of Thayarwady in amount. The study area, thus, experiences the Tropical Monsoon Climate type (Am) in the south, and Tropical Savanna Climate type(Aw) in the west and in the north. Soils consist of alluvium and sandstones at the foothills of the Rakhine Yoma. Alluvial soils occur along the Ayeyarwady River and streams. The Light Forest soils and Lateritic soils develop on the eastern uplands between the Bago Yoma and alluvial plain. Yellow Brown Forest Soils, Light Forest soils are developed in the Pyay Range area. The total population of Bago Region (West) in 2017 was 4,964,487 persons, the increase of 728,896 persons than that of 1983. The average rate of increase was 1.41 percent per year. Rural population of Bago Region (West) has gradually increased. The increase in rural area is greater than that of urban area. The relatively higher growth rate was due to the development of road network and road infrastructure, and increased economic activities (such as industries) which are favourable for immigration of population from outside of the study area. Bago is the Branch office of the Region.

Results and Findings

Agricultural Transformation Processes in Industrial Crop Farming in Bago Region (West)

Industrial Crop Farming

The main economy of Bago Region (West) is agriculture. Bago Region is the second most producer of rice. The other crops are oilseeds such as groundnut, sesame, sunflower and industrial crops such as sugarcane ,cotton and jute. According to the agricultural census taken in 2001-2002, Bago Region as a whole, has the highest sugarcane net sown area(25%)

(while Bago Region (West) has 11% of net sown area). For cotton farming, Bago Region (West) ranks fourth, after Magway, Mandalay and Sagaing regions .Jute is cultivated mainly in the deltaic region. Ayeyarwady Region, currently, accounts for 85 per cent of the total crop production, with Bago and Yangon Regions contributing around 14 per cent and 1 per cent respectively (Soe Soe Aye, 2006). Sugarcane currently, accounts for some 45 percent of the total net sown area of industrial crops, with cotton and jute contributing around 33 percent and 22 percent respectively .Industrial crops are cultivated in Bago Region (West). Among these, Pyay District boasts the highest cultivated area for sugarcane and cotton, while Tharyarwaddy District mainly grow jute and kenaf crops.

Changes in sugarcane farming

Record of earliest sugarcane cultivation in Myanmar dates back to AD 800 and the art of manufacture of jaggery became well established during Inn-wa era in the 15th century. Crude sugar was manufactured in the 18th century and the first white sugar mill was established in Kyaik-kha-me in 1840. After subsequent attempts, modern sugar factories were firmly set from the year 1926 onwards. With the aim of scrutinizing both the sugarcane production and sugar processing by one sole agency, the Myanma Sugarcane Enterprise (MSE) was organized in 1994 under the Ministry of Agriculture and Irrigation (MOAI) and it took over all the responsibilities involved in sugar industry.

Changes in Cultivated Area and Yield

According to the Myanma Sugarcane Enterprise, Pyay data, sugarcane was grown in all townships. Paukkhaung, Thegon and Pyay Townships have large cultivated areas. Paukkhaung Township had the largest in acreage in Bago Region (West) (Figure 4). Within the period from 1988 to 2006, Paukkhaung Township occupied 40-60 per cent of the Region's net sown acreage. There were fluctuations in the net sown acreage during the period from 1988 to 1994 that increased due to high price of jaggery. Sugarcane need not compete with other crops. It is less infected by diseases. In 1994-95, Paukkhaung Township cultivated more than 90 per cent of the Region’s acreage because of policy factors, replacement of other crops areas and the other townships could not grow sugarcane in the irrigated area. After 1999, establishment of sugar mill, there was an increase of 19622.81 hectares in the region .In 2016-2017,the cultivated areas of sugarcane decreased 5958.59 hectares due to high price of crops, the soil was exhausted and lack of the interest of farmers who are more interested in other cash crops such as pulses.(fig(4)).

Figure (4) indicates the fluctuation in of yield per hectare changing from 1988 to 2017. According to the figure, there is a slight increase in production between 1988-89 and 1996-97. To compare with the yield per hectare it shows 19.40 tonne per hectare between 1988-89 and 19.57 tonne in 1996-97.In 2003-2004, the yield fell dramatically from 19.40 tonne to 14.99 tonne per hectare .In 2016-2017, the yield per hectare increases gradually up to 18.25 tonne per hectare. Generally, the yield was decreasing because the soil was exhausted and lack of the interest of farmer who are more interested in other cash crops such as pulses. Within the Paukkaung Township, 22 village tracts were cultivating sugarcane. In those village tracts, Dha-ma-thaw village tract covers large hectare as 20-25 per cent of the township net sown area .Therefore, Dha-ma-thaw village has long history and it is suitable for studying the sugarcane farming in the transformation process of agriculture.

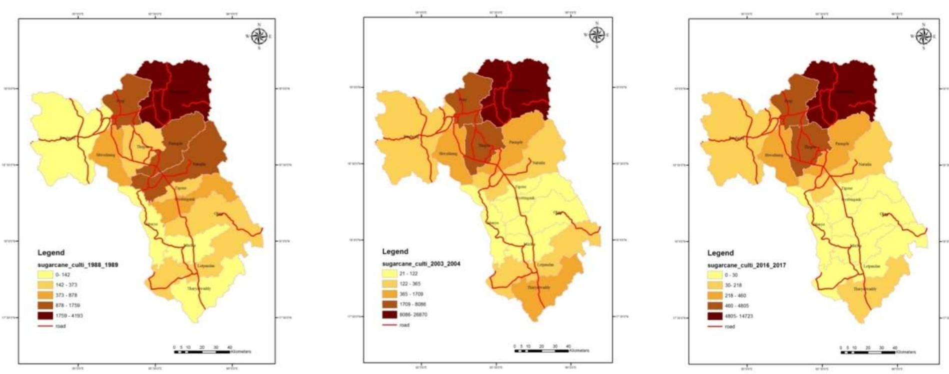


Figure 4. Sugarcane Cultivation in Bago Region (West) in 1988-89 , 2003-04 and 2016-2017

Source : Department of Settlement and Land Records, Pyay Township

The Case of Dha-ma-thaw Village Tract

Dha-ma-thaw village tract is located on the north of Paukkhaung Town.The terrain is mostly flat with nearly 40 years experiences of sugarcane growing the average annual rainfall is 1206.5 mm and the average maximum temperature is 34.9°C and minimum temperature is 21.6°C. Most of the area have silt, alluvial, cinnamon and dark brown savanna soils. Dha-ma-thaw village tract has an area of 3548.29 hectares. This village tract has six villages. There are 923.08 hectares of arable land. Sugarcane is mainly cultivated as 48 per cent in this village tract. Within the six villages, Dha-ma-thaw village was chosen to study the controlling factors in the transformation process of agriculture. In Dha-ma-thaw Village, there were 290 households living in this area and population was 1450 in 2006. There are 467 hectares of Le land, 456.08 hectares of Ya land and the main crops are paddy, groundnut, green gram, sesame, sunflower, long-staple cotton, sugarcane and vegetables. Prior to1988, there were about 32.37 hectares under sugarcane. After 1989, the village tract had more than 242.81 hectares under sugarcane. Although sugarcane growing population is changing from over 100 farmers prior to 1988, 60 farmers in 2004-05,86 farmers in 2006-2007 and 76 farmers in 2016-2017. Farm size for a farmer is divided into four stratums which are shown in table Table(1).Since sugarcane is a perennial crop, sugarcane cultivators grow not only sugarcane but also other crops for their subsistence. Only about fifty percent of their farms is devoted to sugarcane and other crops are cultivated on the remaining part of the farm. .Until 1999, most of the farmers made jaggery, sugarcane syrup and alchohol .After the sugar mills came to be established in the villages (In-nga-gwa and Nawaday) farmers have to send their cane to the mills beginning from 2000-2001. Since Myanmar Sugar Enterprise (MSE) was established in 1994, MSE operated 17 sugar mills in Myanmar .Today 12 sugar mills are operation (Table.2) . All sugar mills are private-owned.

Table 1. Stratum of farm size in Dha-ma-thaw Village Tract (2016-2017)

Stratum	Farm-size hectares	No.of.farmers 2003-2004	No.of.farmers 2004-2005	No.of.farmers 2006-2007	No.of.farmers 2016-2017
1	>8.09	3	7	1	1
2	4.45-8.09	4	17	3	2
3	0.8-4.04	55	50	61	51
4	< 0.8	35	12	21	22

Source : Village Administrative Office, Dha-ma-thaw Village Tract

Table 2. Operation of sugar mills under Myanma Sugarcane Enterprise (MSE)

Sr.	Name	Township	Capacity (ton/day)	Year of Commission
1	Pyinmana-3	Pyinmana	1500	1957
2	Shwe-Nyaung	Nyaung Shwe	300	1983
3	Pyinmana-2	Pyinmana	1500	1984
4	Kyauk Taw	Kyauk Taw	300	1985
5	Yedashe	Yedashe	1500	1991
6	Dahatkone	Takkone	1500	1999
7	Myo Hla	Yedashe	2000	1999
8	Oaktwin	Oaktwin	2000	1999
9	Yonzeik	Aung Lan	2000	1999
10	Duyingabo	Aung Lan	2000	1999
11	In-nga-gwa	Pauk Khaung	2000	1999
12	Nawaday	Pyay	2000	1999

Source : Myanma Sugarcane Enterprise

In-nga-gwa mill and Nawaday mill (JVC with Thailand) separately collected the cane from Pauk-khaung Township. The areas for collection of cane are demarcated by authorities. Although Dha- ma-thaw village is located near In-nga-gwa mill, (at a distance of 13 km) the farmers must transport their sugarcane to Nawaday mill (at a distance of 64 km) that is located in Pyay Township. Thus, cane growers faced high production costs in addition to transportation problems. Net profit from sugarcane is lower than that from other crops especially groundnut. Labour for harvesting season is not sufficient because it coincides with the growing season of other crops. Thus, labour cost is also higher than that for other crops (Table 3.). Reduction of small farm size is caused by high production cost and they stopped growing sugarcane .Yield per hectare is 30000-75000kg/ha, because of land condition, lesser utilization of expensive inputs and decreasing soil fertility. Furthermore, availability of water for irrigation during hot season is not easily accessible. Government and private companies' assistance, price incentives and subsidies or credit system becomes a paramount importance to boost sugarcane production .In 2016-2017 cultivated area increased, resulting in higher yields and more income earnings, but they still faced many problems particularly labour shortage. The profit of 1 hectare of sugarcane was kyats138, 500 and that of groundnut was kyats 220,000 in 2006-2007. In 2016-2017, a farmer who has 1 hectare of sugarcane in Da-ma-thaw village received about kyats 622,500 per year. A farmer received kyats 294,000 from groundnut area within three months. Farmers were interested in cropping groundnut, which gain more profit (Table 3). Moreover, market price of sugarcane in the year 2000 was kyats 5275-6100 per ton but farmers had to sell their products to the government at a fixed price of kyats 2500 per ton. After 2014, private entrepreneurs owned all sugar mills and farmers can sell their products freely. Market prices changed yearly during the period from 2007 to 2010.It was kyats 13500 per ton. In 2014-2015 prices increased to kyats 30000 and prices reached a peak of kyats 45000 per ton in 2016-2017.

Table 3. Differences between returns from Sugarcane and that of other crops in 2006-07 and 2016-2017 (in kyats) (assuming an average yield of 25 tonnes/ hectare for sugarcane and 50 baskets/hectare for groundnut)

	Sugarcane (2006-07)	Groundnut (2006-07)	Sugarcane (2016-17)	Groundnut (2016-17)
Costs of input materials	77600	14400	210000	114500
Labour costs	71400	15600	292500	155000
Total estimated costs	149000	30000	502500	269500
Selling price	287500	250000	1125000	563500
Projected returns	138500	220000	622500	294000
Benefit-cost ratio	0.93	7.33	1.24	1.09

Source : Based on interviewed data, 2016-2017

Changes in Cotton Farming

In Bago Region (West), there are two cotton growing zones; Pyay District and Tharyarwady District. The former has more cotton growing areas than the latter .This is because Pyay District gets a mean annual rainfall of 1270 mm , and being irrigated areas of North Nawin Dam and South Nawin Dam .On the other hand, Thayarwady District has a mean annual rainfall of 2286 mm. Thus cotton cannot thrive there. Cotton can only be grown on Ya lands.

Changes in cultivated area, seed, crop pattern and yield

Cotton cultivated areas in Pyay District have been increasing from 1988-89 to 2016-17. In 1989-90 the cotton cultivated areas were 4869 hectare and in 1995-96 these areas more than doubled to12128 hectares. The Government projected a policy to grow cotton in cultivable land. At that time, farmers received a government subsidy including fertilizers, good quality seeds, pesticides ,and technology as well as methods for growing cotton by the staff members of responsible departments .Therefore ,the farmers were interested in long-staple cotton cultivation. In that year, cotton production was 9841.25 tons. The cultivated areas dropped to 4980 hectares in 1996-97 as a result of irregular rains. The cultivated area increased to12043 hectares in 2016-17 as a result of the replacement of long-staple cotton and mixed farming with groundnut, sesame and pulses.(see fig (5)). Wagyi (short-staple cotton) need long growing season and thus double cropping cannot be practiced. Long-staple cotton can be cultivated by irrigation in the pre-monsoon period before paddy and other crops are grown in the rainy season. Besides, it can be cultivated as a double crop with sesame, pedisein and other crops which need only a short growing season.

In 1988-89, the cotton yield was 1946.68 tons and the yield per hectare was 449 kg. The highest cotton production was in 1995-96 with 9841.24 tons and the yield per hectare was 820.96 kg. It was the result of the selection of good quality seeds, using the fertilizers, pesticides and good agricultural practices (GAP). Yield per hectare was changing during the period from 1988-89 to 2016-17. Although the cotton yield in 1988-89 was 178 kg ,in 2016-17 the data showed a dramatic rise to 711 kg .The townships which had high cotton yields in Pyay District are Pyay, Paukkhaung and Pandaung townships while those in Tharyarwady District are Nattalin and Minhla townships.

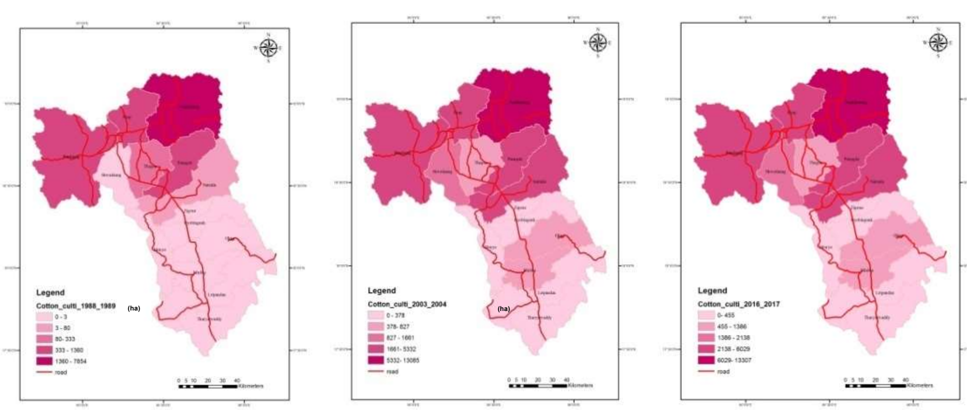


Figure 5. Cultivation of Cotton in Bago Region (West) in 1988-89, 2003-04 and 2016-17

Source: Department of Land Records, Pyay

The case of Thit-cho-pin Village Tract

Based on data obtained from the Myanma Cotton and Sericulture Enterprise, at Pyay the representative village was chosen to study of agriculture and controlling factors. The selection was based on the cultivated area of 40.46 hectares and more village tracts. In Bago Region (West), Thit-cho-pin village tract grows nearly 202.34 hectares and it received the government award for high production (Figure 6)

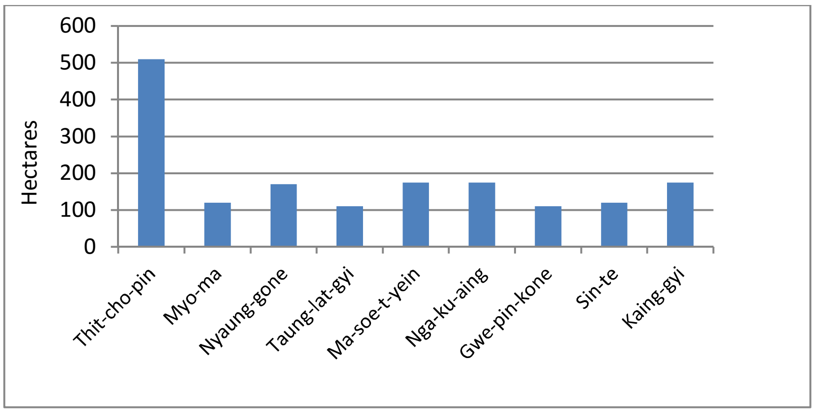


Figure 6. Cotton cultivation by village tracts in Bago Region (West) with 100 and more hectares of net sown area

Source: Myanma Cotton and Sericulture Enterprise(MCSE) Pyay

Thit-cho-pin village tract is located between North Nawin and South Nawin drainage area and within the Pyay Township. It receives an average annual rainfall of 1206.5 mm. The average maximum temperature is 34.9°C and minimum is 21.6°C .The soils are silt, alluvium, cinnamon and dark brown savanna. Thus, the soils and climate of this village tract are suitable for cotton cultivation. It consists of 6 villages. In those villages, Kan-su and Ein-kone villages are most favourable for cotton. The main crop of these villages is cotton and the secondary crop is pulses. Thit-cho-pin village tract has experienced cotton cultivation since 1978-79. Farmers have grown cotton as planned crop since 1977.At that time, farm- size was 4 hectares and yield was 1155 kg/ha. Farmers received the supply of loans, fertilizers, good quality seeds and pesticides from the government. The common fertilizers are Urea, T-Super and Phosphate. After 1988, the use fertilizers was changed to compound and pesticides from private companies. Farmers cannot use high cost agro-input materials so the yield of cotton had dropped to about 660 kg /ha.

The size of farm was reduced from 4 hectares to 2.4 hectares as large farm size, from 2.02hectares to 1.21hectares as middle farm size and from 1.21hectares to 0.8 hectares in small farm size. In this situation, beans and sesame replaced cotton growing areas and most of the cotton areas changed to pulses growing which get high profit (Table 4). A serious issue is that impure seeds are procured from farmers and imported seeds cannot be used easily. After 2002-03, cotton came to be traded freely in the domestic market. Since then, supply by the government is reduced and the private sector is emerging. In 2016-2017sown hectares and yield (1141kg) increased and growers get high benefits but they still encounter many problems. In 2006-2007, the profits gained from 1hectare of cotton (pure) area was kyats 113850 while kyats 329050 was received from cotton (mixed with groundnut). In 2016-2017, farmers who worked on 1 hectare of cotton in Thit-cho-pin village tract received about kyats 283000 and about kyats 712250 received from cotton(mixed with groundnut). Therefore, farmers were interested in the cultivation of cotton mixed with groundnut because the projected return is high and transformed to intensive cultivation of other cash crops. (table 4).Moreover, market price of cotton had changed from (1.63 kg) kyats 188 in1988-89 to (1.63 kg) kyats 1000 in 2007-2010.The highest price was kyats 1300-1500 for 1.63kg in 2016-2017.Therefore, farmers were interested in growing mixed crops and changed to cotton mixed with groundnut which get high returns.

Table 4. Differences between returns of cotton (pure) and cotton mixed with groundnut in 2006-2007 and 2016-2017 (in kyats) (assuming an average yield of 400 viss /hectare for cotton (pure), 300 viss /hectare for cotton mixed with groundnut and 50 baskets/hectare for groundnut)

	Cotton(pure) 2006-2007	Cotton (mixed with groundnut) 2006-2007	Cotton(pure) 2016-2017	Cotton (mixed with groundnut) 2016-2017
Input material costs	26150	13450	72000	54000
Labour costs	60000	27500	165000	123750
Total estimated costs	86150	40950	237000	177750
Selling Price	200000	400000	520000	890000
Projected returns	113850	329050	283000	712250
Benefit-cost-ratio	1.32	8.04	1.19	4.0

Source: data obtained from open-talks and structured interviews

Since 1977, cotton became the planned crop and cotton had to be sold government procurement centres at Wethtikan, Pyay and Paungtale. In 1988, private merchants registered at Myanma Cotton and Sericulture Enterprise (MCSE) and they were permitted to procurement of cotton and 50 per cent of their cotton must be sold to the government and the rest must be traded in the domestic market. In 2002-03, cotton was liberalized as a free trade commodity in the domestic market. Cotton growers gained higher since then MCSE must also change their procurement price with competition of private merchants (Figure 7). After 2002-03, the supply of inputs such as fertilizers and pesticides was reduced and irregular.

Therefore cotton growers came to rely on private companies.

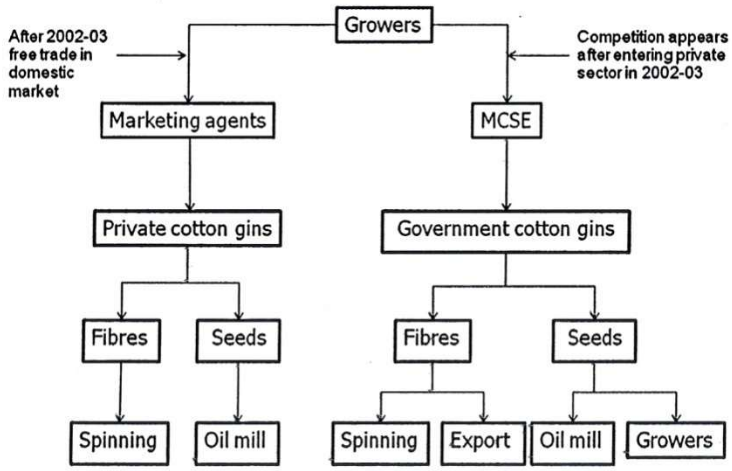


Figure 7. Marketing Chain of Cotton

At present, farmers faced the competition with other crops and difficulties in the availability of pure seeds. Some farmers obtained pure seeds and increased in yield per hectare. If farmers in Thit-cho-pin village tract can get pure seeds, high price of cotton and government supply, they are keen to grow cotton. Formerly , the harvested cotton are collected by brokers and sent to Pyay and Shwedaung (textile factory and oil mills).At present ,textile factory and oil mill in Pyay and Shwedaung townships are not operating .As such ,brokers stayed in the cotton growing areas , collected the harvested cotton and sent it to Aunglan and Mandalay.

Changes in Jute and Kenaf Farming

Myanmar is an agrarian country and its economy is largely dependent on agricultural products such as rice, pulses, etc. In order to export them, the farmers and producers need packaging materials such as gunny bags, hessian and twine .In the past, these packaging materials were all imported from India and East Pakistan (now Bangladesh). Market research reveals that it would be more beneficial to cultivate jute and to establish a jute mill in Myanmar.

Jute is cultivated mainly in the deltaic areas. Ayeyarwady Region, currently, accounts for about 85 per cent of total jute production, with Bago and Yangon regions contributing around 14 per cent and 1 per cent respectively. Paddy is the primary crop in the deltaic area, with jute cultivated as one of the secondary crops. It is commonly sown as pre-monsoon and monsoon crop. There are two varieties of Jute. These are *Corchorus capsularis* (White Jute) (Thelonpu/short-pod) and *Corchorus olitorius* (Tossa Jute) (Thedaungshe/long-pod), C. *capsularis* is mainly grown in low-land areas while C. *olitorius* is cultivated in up-land areas. The maximum Jute production recorded in 1988 was 98643.16 tons.

In Bago Region (West), two kinds of jute are grown as pre-monsoon jute and monsoon jute. Thayarwady District has more jute growing areas than Pyay District. Jute requires a total annual rainfall of 2286 mm. *Kaing land* areas in Tharyarwady District get more annual rainfall than Pyay District. Although both Thelonpu and Thedaungshe varieties are grown in Bago Region (West), Thedaungshe which can tolerate waterlogged conditions is mostly cultivated during the monsoon is in the lowlands.

Changes in cultivated area and yield

The cultivated area of Tharyarwady District was mainly analyzed. The jute growing areas in Tharyarwady District was 7386.32 hectares in 1988-89 .It increased to 8458.74 hectares in 1995-96 .Due to pump irrigation with the support of the government. However ,it dropped to 6001.89 hectares in 1999-2000 as a result of less interest of farmers and the competition of other cash crops such as corn, sesame, pulses and etc. In 2003-2004, jute cultivation further dropped to 4711.35 hectares as a consequence of river flooding .In 2016-2017, the cultivated areas again dropped to 4118.89 hectares because farmers came to be more interested in other cash crops (Fig 8).

In 1989-90, the production of jute was 8112.32 tons and yield was 1142 kg/ha. The production and yield dropped to 3739.12 tons and 255 kg/ha in 2016-2017.The yield of jute and kenaf had dropped 211.9 kg/ha in 2016-2017. The rate of yield per hectare, the total production and the quality of jute depend on the use of fertilizers and pesticides, harvesting and retting of jute. In Tharyarwady District, jute cultivated area is found in every township. Among these townships, Monyo Township has the largest cultivated area. This is accounted for by the facts that this township gets enough rainfall for jute cultivation and has favourable meadow soils, meadow clay soils and meadow alluvial soils.

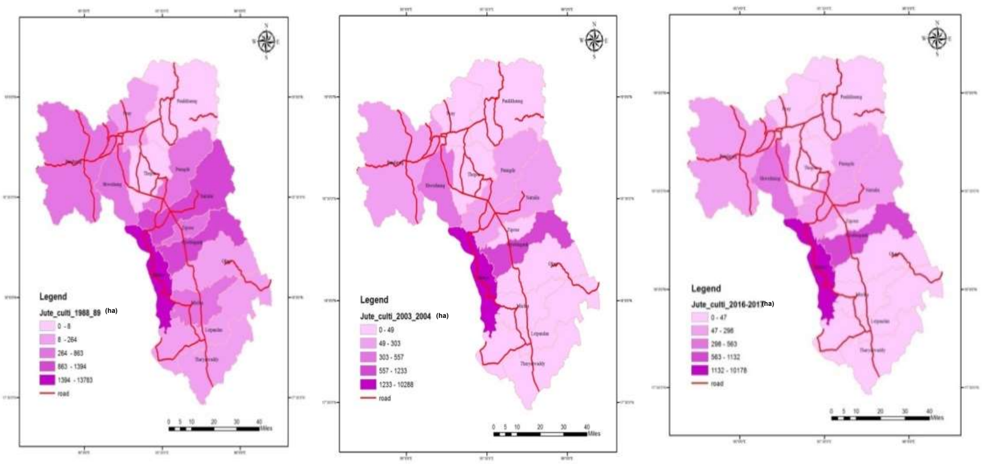


Figure 8. Jute Cultivation in Bago Region (West) in 1988-89, 2003-04 and 2016-17

Source; Myanma Jute Industries, Tharyarwady

The case of Pat-taw Village Tract

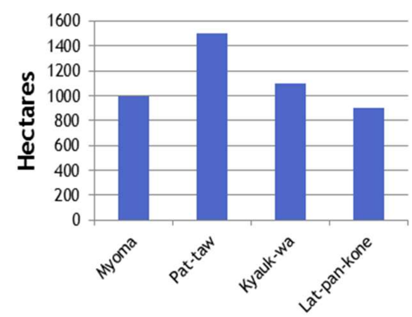
In Monyo Township, with 404.686 hectares and more cultivated village tracts,Pat-taw Village Tract is analyzed for investigation of the changes in agriculture and the controlling factors. Pat-taw village tract has experienced jute cultivation since 1963. This village tract is composed of 6 villages. It is located in Myintmakha river basin area and rich alluvial soils and cinnamon soils. The average annual rainfall is 2133.6 mm and the average maximum and minimum temperatures are 38.8°C and 17.5°C respectively. In Pat-taw village, there are 800 households with the total population of 3500. Jute cultivation area is 809.372 hectares, and that of sesame is 283.28 hectares. There are 300 jute growers. Thedaungshe is cultivated in pre-monsoon while Thelonpu is cultivated in the monsoon period. Large farm-size area was 7.28 hectares prior to 1988. The current size of farms are 3.23 hectares. This reduction is to result of less government support, high cost of production, especially after harvesting and construction of levees for protection from flooding. Ten acres are changed to other crops such as sesame and paddy. After the year 2000, jute area declined because of the lack of support by the government. In 2016-17, jute growing areas are replaced by sesame.

Table 5. Condition of Jute/Kenaf cultivation in Pat-taw Village Tract in 2016- 2017

	2005-2006			2016-2017		
	Number of Farmers	**Pre-Monsoon (hectares)**	**Monson (hectares)**	**Number of Farmers**	**Pre-Monsoon (hectares)**	**Monsoon (hectares)**
Pat-taw	74	222	278	61	216	23
Gyo-kone	53	181	188	53	138	37
Payagyi-tan	44	118	137	42	104	36
Le-won-kwin	30	51	87	30	96	15
Htan-taw-kone	24	48	70	24	80	17
Payagyi-kone	44	55	184	44	95	12
San-pya	19	0	76	19	26	20

Number of jute farmers and cultivated area in Pat-taw village were decreasing. All villages from Pat-taw Village Tract's monsoon jute area has dramatically declined in 2015-16. This is the result of the construction of embankments for prevention of flooding and profits from jute is relatively less than that of other cash crops.(Table 5). Therefore, Jute/Kenaf area had declined .It is a critical issue for the study area. The major problem is the imbalance in the relative advantages of other competitive cash crops. The cost and returns of jute and that of other major crops are compared in **Table 6**. For the crop season 2007-2008, purchasing prices of Jute and Kenaf encouraged farmers to produce more quantity as well as high quality.

Table 6. Benefit-Cost Ratio of Jute / Kenaf and other competitive crops



Fig(9) Jute and Kenaf cultivated village tracts with 1000 and more net sown hectares in 2016-2017
Source : Myanma Jute Industries , Tharyarwady

Source: Soe Soe Aye, MJI, 2007

Crops	Benefit-Cost Ratio
Paddy	1.85
Black gram	4.17
Green gram	1.94
Maize	1.60
Sesame	1.69
Chilli	8.97
Pre-monsoon jute	0.91
Monsoon kenaf	1.13
Kenaf (Bast fibre)	0.98
Jute (Whole plant)	1.10

Due to higher wages of labour, farmers can hardly offer to hire labour for cultivation and post-harvesting. This consequently resulted in shrinkage of cultivation areas. The remaining smaller plots could be managed by family members. This situation could have been better, if yield per unit area had improved. Pat-taw's Jute is collected from Myanma Jute Industries (MJI) and transported to Okkyin Jute Mill until 1972. Since them, harvested jute is transported to Pyay Jute Grading and Baling Factory. All of the markets for jute are controlled by government enterprise. After the introduction of summer paddy in1992, the area under jute declined. Even if the farmers should get an incentive of high price, they would still force the quality issue.

Table 6. Differences between returns of jute/kenaf and other crops in 2006-2007 and 2016-2017 (in kyats) (assuming an average yield of 450 visses /hectare for jute/kenaf and 10 baskets/hectare for sesame)

	Jute and Kenaf 2006-2007	Seasame 2006-2007	Jute and Kenaf 2016-2017	Seasame 2016-2017
Input material costs	13000	19400	23000	58500
Labour costs	56700	28900	100000	148000
Total estimated costs	68700	48300	123000	206500
Selling Price	45000	200000	67500	400000
Projected returns	24700	151700	55500	193500
Benefit-cost-ratio	0.35	3.14	0.45	0.94

Source: interviewed data

Discussion and Conclusion

After 1988, the changes in cultivation of the industrial crops in Bago Region (West) depend on agricultural policy, kinds of crop, situation of markets and the decision- making of farmers. After 2002, industrial crops are replaced by other crops according tomarket-oriented economy. Prior to 1988, double cropping was practiced in this region, for example, the farmers grew cotton after paddy. The farmers gained profit in this period as a result of natural fertilizer use and labour costs were less than that after 2002 price. After 1988, pattern of agriculture was changed in accordance with the changing market economy of the country. Therefore, the industrial crops are substituted with other cash crops such as pulses. In addition, after 2002 the fertility of soils is degraded. Thus, the farmers use more chemical fertilizers for high yield. In addition, the farmers were faced with high labour costs, high input material costs (fertilizer, pesticides), problem of seeds and difficulties in transportation. The Sugar Mill No.12 (Nawaday) was constructed in 1997 in Pyay Township and Sugar Mill No.(11) (In- nga-gwa) was constructed in 1998 in Paukkhaung Township. The farmers were faced with many problems. The major problems were related to transportation and the higher the labour changes. The shortage of labour is one of the problems because the growing season of summer paddy and harvesting period of sugarcane coincided.

Grower condition

Small farm- size grower

Large farm-size grower

Due to high input
long growing period
other cash crops

Seed

Prior to 2004 –China , Phillippiines

After 2004-Thailand

2016-17- Thailand

Crop change

Sugarcane → groundnut

Market

Prior to1999 → Paungde ,Nattalin , Mandalay ,China

1999-2000 → Inngagwa Mill (Paukkhaung Tsp)

After 2005 → Nawaday Mill (Pyay Tsp)

2016-2017 → Nawady Mill ((Pyay Tsp)-Transport and labour issue

Figure 1. Changes in sugarcane farming and controlling factors

Cotton is permitted to free trade in the domestic market since the year 2002-2003. The cotton was procured by Myanma Cotton and Sericulture Enterprise and transported to the cotton mill in Aunglan. These were recontributed to Meikhtila. After 2002-2003, private merchants send the products to Mandalay, Meikhtila, Pakokku and Shwedaung. Cotton growing farmers grow cotton intensively on the fallowed land. Should the government contributing the pure seeds and necessary inputs, the acreage of cotton will be increased again.

In the growing of sugarcane, the contribution of high yield species, new method of growing and harvesting, the solving the labour shortage and transportation for sugarcane, are the ways to more interesting in sugarcane and more successful.

Grower condition

High benefit 1997-2002 ←

Low benefit 2002- present ←

High benefit 2016-2017

Seed

Prior to 1988 – Lunkyaw } MCSE

After 1988 – Ngwechi

From 2005 – Bounty, Magic (India)

2016-2017 - Magic (India)

Crop change

Prior to 1978-79 → Lablab , Penauk

1979-2007 → Cotton

From 2002 → Mixed with groundnut , Lablab ←

2016-2017 → Long staple cotton ,mixed with groundnut

Market

Prior to 2002 → is procured by the government

After 2002 → free trade in the domestic market → More incentives

2016-2017 → sent to Aunglun and Mandalay textile factories

Government support
Low input cost
Relatively high fertile soil

Irregular government support
High input cost Relatively exhausted fertile soil Impure seed

Figure 2 . Changing cotton farming and controlling factors

Jute ranks as the second highest production cost after sugarcane. The price of industrial crops is subject to yearly fluctuation. Prior to 1988, the government provided the necessary inputs for agriculture. At present, the inputs are more necessary since most of the farmers practice double-cropping and the degradation of soils for longer growing period of crops. Contribution of government support is decreasing and the ·role of private shops becomes more important. After the year 2000, the farmers changed to grow pulses, sesame and groundnut which give good returns. The decision of farmers for production of crops depend on the labour price and input for industrial crops. In jute cultivation, the first problem is higher labour price, second is less contribution of fertilizer, third is the difficulty of diesel for pump, and the last is decreasing of cultivated area since some areas are constructed as embankments to prevent flooding. If the necessities for jute cultivation are well provided well, the farmers will try to increase the cultivated areas for jute.

Grower condition

Jute grower

Due to high production cost after harvested
High income from cash crops

Other cash crop grower

Seed

Prior to 2002-2003 – Thelonpu , Thelonshe (Bangladesh) via MIJ

After 2002-2003 – kenaf (Japan)

2016-2017 – Kenaf (Japan)

Crop changes

Jute → Sesame , paddy ← Embankment construction

Paddy and Sesame → (flooding)

Market

Have to sell to the government → Pyay

Fixed price

Figure 3. Changing jute and kenaf farming and controlling factors

If the government serves carefully to gain profits, to get high yield and to raise the production, the areas for industrial crops in Bago Region (West) will rise as in other regions. Similarly, the control of government on price should change and modify according to modern system and modern living standard.

From the study on the constraints in the development of the industrial crop farming in Bago Region (West), as well as other relevant issues affecting the agricultural sector, it is necessary to push for production of high-demand and high- value crops, to liberalize trade, to allow the state-owned enterprises to compete freely with the private enterprises, to upgrade the administrative and institutional efficiency and to raise capacity building.

Acknowledgements

I am greatly indebted to U Mya Win (Retired Rector), U Win Myint (Pro-Rector) and Dr. Tin Maung Hla (Pro-Rector) of Pyay University and Prof. U Kyi (Retired Professor and Head of Geography Department) for their permission and guidance on this research work .I would like to express my special thanks to Prof . Daw Than Than Htay , Professor and Head of the Department for allowing me to do this research and her invaluable advice and encouragement. I am deeply indebted to my supervisor , Dr Nay Win Oo ,Lecturer, Department of Geography, University of Pyay, for giving me valuable advices and guidance in preparing this research .I also wish to express my thanks to Dr. Saw Pyone Naing ,Associate Professor, Department of Geography, University of Yangon, for their valuable suggestions after reading through my research paper. Thanks are extended to all the members of the academic staff of Geography Department, University of Pyay and especially to Daw Khin Sandar Aye (Associate Professor), Daw Mar Mar Khin (Associate Professor) and Daw Myint Myint Thein (Associate Professor) who helped me by providing support and information on this study. Moreover, I am also grateful to Departmental personnel for their help in the collection of data and also many thanks to villagers and my friends in the study area for their help .Last but not the least, I would like to express my heartfelt thanks to my parents who brought me up, educated and provided assistance in my life.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

A GEOGRAPHICAL STUDY ON THE SPATIAL DISTRIBUTION OF BASIC EDUCATION SCHOOLS IN SINGAING TOWNSHIP, MANDALAY REGION

Thwe Thwe Aye*

Abstract

This research work emphasizes on the spatial distribution of basic education schools in Singaing Township. It is focused on the facts of topographic conditions, age structure, the distribution of population, number of students and basic education schools. Although the western two-thirds of Singaing Township is flat plain, the rest located in the eastern part is the continuation of Shan Highland. Moreover, the study area is an agricultural region, and *inns*, lakes, weirs and canals are mostly found. For these conditions, there are many physical barriers that can impact on students. So, the followings were laid down as the research questions. (1) What is the spatial distribution pattern of basic education schools in Singaing Township? (2) How far the students have taken to travel to attend for their basic education? (3) Where is it necessary to allocate new school or to upgrade the existing school? To answer the above questions, both spatial (location) and attribute (function) data with regard to basic education schools are collected by field survey. Necessary data are obtained from various government offices. In this study, the numbers of basic education schools with their respective students are recognized in (2016-17) Academic Year. Then, their spatial distribution patterns are analyzed by using spatial statistical analysis, especially point density analysis and buffer analysis. As a result, the villages which have no primary school (BEPS) and the middle schools (BEMS) that need to upgrade into high school (BEHS) could be observed.

***Key words*:** spatial distribution, basic education school, physical barrier, spatial statistical analysis, point density, buffer analysis.

Introduction

Education is a basic human need. Only when people are well educated and skillful in modern technologies, they can gain their life struggle for food, clothing and shelter. Being a developing country, Myanmar cannot bewell-developed with human resources into a high quality of life. In fact, child

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labour is applied in various parts of the country instead of educating the children. Early leaving of school education for child labour is particularly true for rural areas where basic infrastructures were poorly provided for the majority of rural population due to a number of reasons, such as cost, consideration, lower population, rugged terrain, etc. It is estimated that over one million children are still out of school in Myanmar. Primarily, there are two types of education in Myanmar: Basic Education and Higher Education. This paper intends to analyze the condition of Basic Education only in the study area.

Basic Education

Primary education is the first stage of basic education and is compulsory. Primary education lasts five years, including the reception year (kindergarten or grade 1); it is organized in two cycles; lower primary (Grades 1 to 3), and upper primary (Grades 4 and 5). Although the admission age is 5+, many children are entering to grade 1 at over 6 years of age. At the end of primary education, pupils have to sit for an examination.

Secondary education is the second stage of basic education and comprises of two cycles; lower secondary or middle school lasting four years (Grades 6 to 9), and upper secondary or high school (Grades 10 and 11).

Research Questions

Following research questions are tried to answer in this paper.

(1) What is the spatial distribution pattern of basic education schools in Singaing Township?

(2) How far the students have taken to travel to attend for their basic education?

(3) Where is it necessary to allocate new school or to upgrade the existing school?

Data and Methods

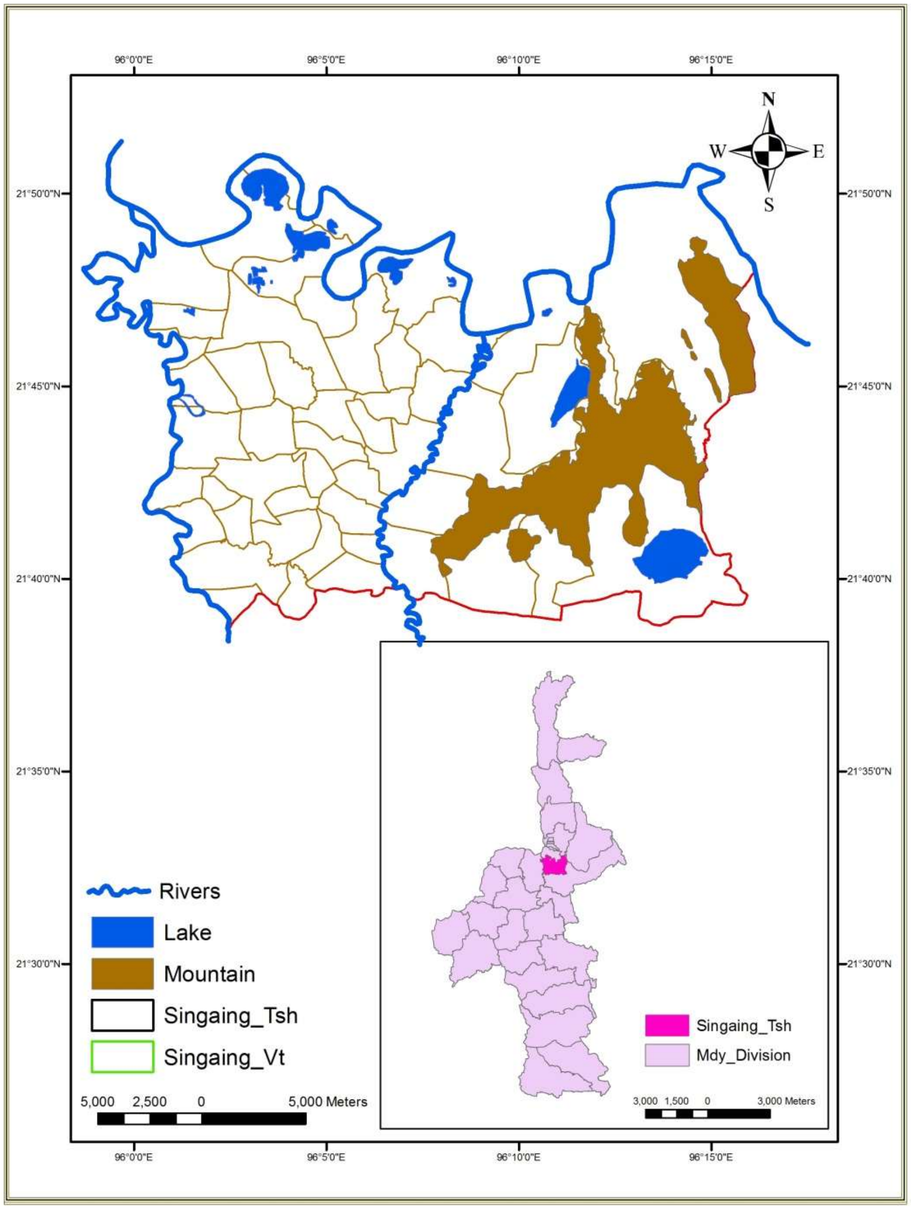
Firstly, primary data were collected by field survey. And then, secondary data were collected from various government offices such as Township Land Records Department, Immigration and National Registration Department, Township General Administration Department and Township Education Office (TEO). Based on the data collected from both primary and secondary sources, the processing and analytical patterns are conducted by means of GIS Techniques. Point density analysis, buffer analysis and spatial statistical method in this study.

Physical Factors of Study Area

Singaing Township is located in Kyaukse District, Mandalay Region, in the Central Lowland of Myanmar. It lies on the Mandalay-Kyaukse Plain. It is located between the North Latitude 21° 39' to 21° 51' and the East Longitude of 95° 59' to 96° 17'. Singaing Township is composed of 5 urban wards and 48 village tracts (163 villages). It has an area of 448.65 square kilometers (173.18 square miles). It is nearly compact shape. The township is bounded on the north by Amarapura and Patheingyi townships, on the east and south by Kyaukse Township and on the west by Tada-U Township. In the north and west, Myitnge River and Panlaung River serve as natural boundary, respectively. The eastern boundary is defined by the Nattabin *taungdan* (range) and further south by Dattaw *taung* (mountain).

A large portion in the western part of the study area lies in the 250' to 76-152 m (500' feet) above sea level. But its eastern part is the continuation of Shan Highland. Here, the low ranges rise to 609 m (2,000 feet) and mountains are 152 m (500 feet) to 305 m(1,000 feet)high above sea level. Myitnge, Zawgyi and Panlaung Rivers and their tributaries drain in this area. There is also an irrigation network system (weirs and canals) along Zawgyi and Panlaung Rivers for agriculture. There are some well-known *Inns* (lakes) such as Sunye, Paleik, Inhlya, Taon, Minhla *Kan* and Nyaunbintha *Kan*.

Map(1). Location of Study Area



Source: Township Land Records Department, Singaing Township

Social Factors of Study Area

Population

In2016, total population of Singaing Township is 144,410. The average population density of Singaing Township was 448 persons per square mile (173 persons per square kilometer) in 1973; it rose to 684 persons per square mile (264 persons per square kilometer) in 1993 and again to 834 persons per square mile(322 persons per square kilometer) in 2016.

Table 1. Average Population Density of Singaing Township

Year	Total Population	Population Density	
		per sq.miles	per sq. kilometer
1973	77,641	448	173
1983	99,729	576	222
1993	118,530	684	264
2003	139,515	806	311
2016	144,410	834	322

Source: Immigration and National Registration Department, Singaing Township

Table 2. Age Groups of Singaing Township (2016)

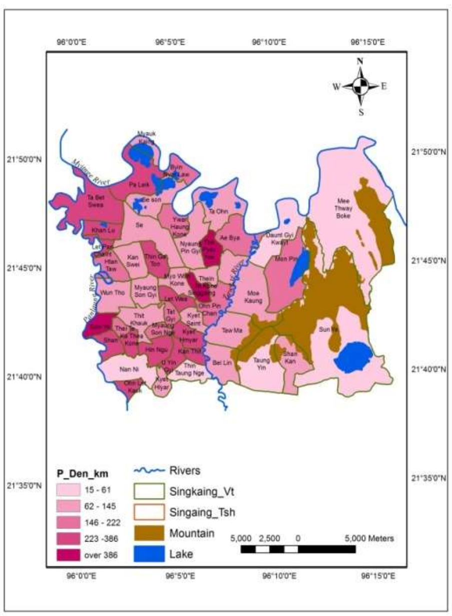
No.	Ward & village tract	Total Population	Age		Remark
			< 18 years	>18 years	
1	Myoma	2,085	687	1,398	Wards
2	Myothit	1,325	478	847	
3	Yannaing	1,247	417	830	
4	Tayokesu	1,781	557	1,224	
5	Yanaungmyin	1,713	559	1154	
6	Katheakone	606	190	416	Village Tracts
7	Kanswe	778	244	534	
8	Kanthit	836	288	548	
9	Kyetseint	1,080	339	741	
10	Kyethmyar	1,208	379	829	
11	Kyetsha	691	217	474	

No.	Ward & village tract	Total Population	Age		Remark
			< 18 years	>18 years	
12	Khanlu	2,616	821	1,795	Village Tracts
13	Sawye	1,984	623	1,361	
14	Sunye	6,349	1,768	4,581	
15	Sisone	2,740	1108	1,632	
16	Seywa	5,300	1,901	3,399	
17	Nyaungbingyi	3,096	973	2,123	
18	Tabetswe	7,679	2,123	5,556	
19	Ta ohn	2,247	707	1,540	
20	Tawma	3,298	1,035	2,263	
21	Taungyin	2,253	845	1408	
22	Tatkyi	463	145	318	
23	Htandaw	1,686	605	1,081	
24	Daunggyigway	2,859	915	1,944	
25	Nanni	2,809	863	1,946	
26	Paleik	21,710	6,042	15,668	
27	Byinnyarlaw	1,345	422	923	
28	Belin	4,885	1,337	3,548	
29	Moekaung	5,113	1,629	3,484	
30	Mithwayboke	8,285	2,631	5,654	
31	Monbaung	858	269	589	
32	Monbin	5,000	1,593	3,407	
33	Myowungone	2,088	625	1,463	
34	Myaukkaing	2,587	813	1,774	
35	Shanywa	918	288	630	
36	Myaungzongyi	1,028	323	705	
37	Myaungzonnge	564	178	386	
38	Ywahaunggone	1,933	607	1326	
39	Shangan	3,107	976	2131	
40	Letpangyaing	930	293	637	
41	Letwe	1,749	550	1,199	
42	Wuntho	2,569	807	1,762	
43	Thabyeyo	2,964	931	2,033	

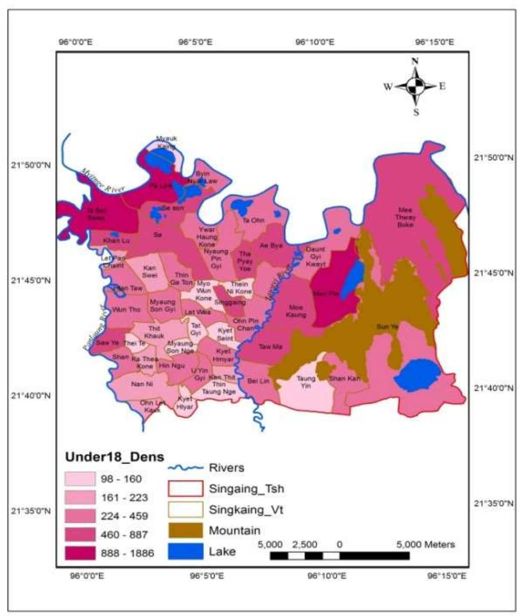
No.	**Ward & village tract**	**Total Population**	**Age**		**Remark**
			< 18 years	**>18 years**	
44	Thindaung	988	313	685	
45	Thitkhauk	3,563	1,120	2,443	
46	Thingadon	1,285	404	881	
47	Thede	333	105	228	
48	Theinnigone	1,419	498	921	
49	Hinngu	2,892	916	1,983	
50	U yingyi	975	306	699	
51	E bya	2,927	890	2,037	
52	Ohnbinchan	2,775	871	1,904	
53	Ohnletkauk	891	280	611	
	Total	144,410	44,787	99,623	

Source: Immigration and National Registration Department, Singaing Township

Map 2. Population Density of Village Tracts in Singaing Township (2016)



Map 3. Population Density (< 18 years) of Village Tracts in Singaing Township (2016)

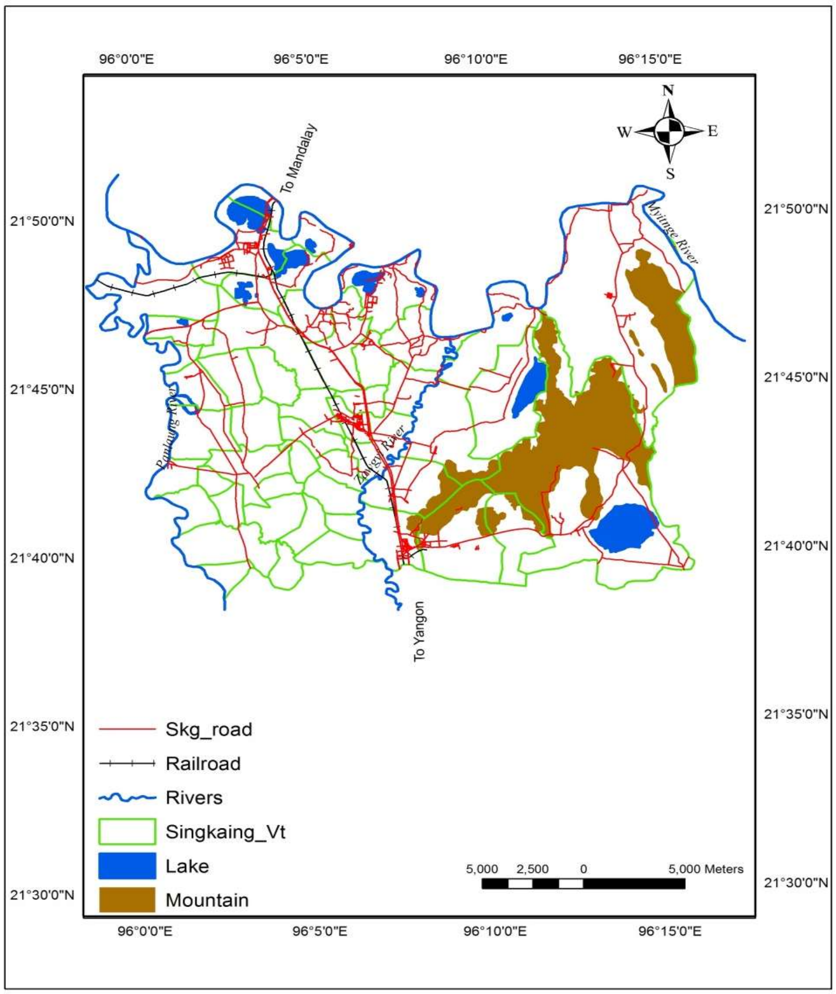


Source: Immigration and National Registration Department, Singaing Township

Transportation

Yangon–Mandalay Highway (old) passes through central portion of Singaing Township. Likewise, Yangon–Mandalay and Mandalay–Nyaung U railroads pass through it. About one third of all roads in Singaing Township are tar roads and can travel in all seasons. The remainings are earthern and macadam roads and they are seasonal roads only. They are used by motor-cycles, trawlergies, bicycles and carts or as footpath.

Map (4) Transportation Map of Study Area



Source: Land Records Department, Singaing Township

Education

Singaing Township has four high schools (BEHS), seven branch (affiliated) high schools (Sub BEHS), one middle school (BEMS), sixteen branch middle schools (Sub BEMS), one post primary school (Post BEPS), eighty primary schools (BEPS) and three branch primary schools (Sub BEPS) totally with 22,927 students in (2016-2017) Academic Year. There are totally 112 government basic education schools and 4private schools(Paleik-1, Ohnbinchan-1 and Singaing-2). The total numbers of students at these private schools were 2017 (High school students – 986, Middle school students – 578, Primary school students – 453) in this Academic Year. In (2017-18) Academic Year, 16 of all schools were upgraded to the next level from existing level.

Table 3. Numbers of Basic Education School

Level	**Type**	**Number of Schools**		**Number of Students (2016-17) Academic Year**
		(2016-17) Academic Year	**(2017-18) Academic Year**	
High School	BEHS	4	5	2,103
	Sub - BEHS	7	6	
Middle School	BEMS	1	12	7,919
	Sub - BEMS	16	5	
	Post BEPS	1	3	
Primary School	BEPS	80	81	12,905
	Sub - BEPS	3	-	
Total		**112**	**112**	**22,927**

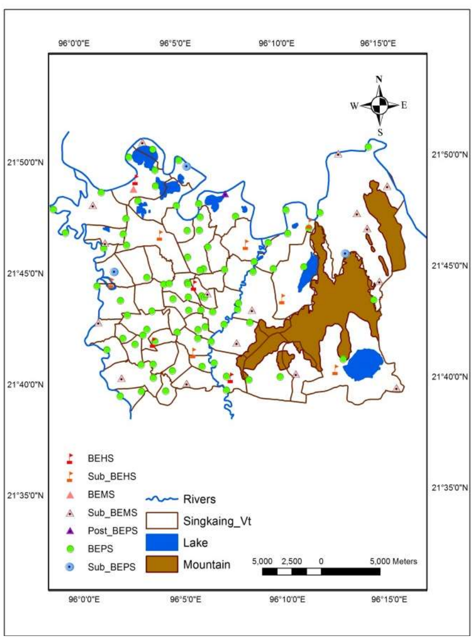
Source: Township Education Office, Singaing

Spatial Analysis

In 2016, there are 112 study points (schools) in Singaing Township. The respective distances among primary, middle and high schools were analyzed. Generally, the students will choose the nearest school to attend for the next level. The distribution of basic education schools in Singaing Township is shown in Map (4).

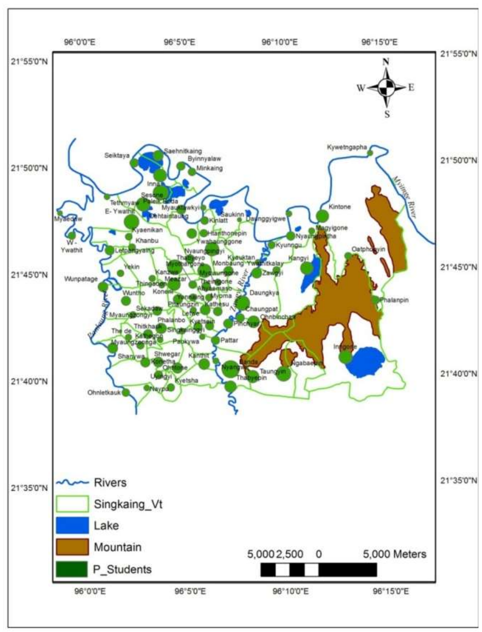
Firstly, basic education primary schools were studied. The study area is mainly composed of rural areas and primary level students can walk about one mile distance only. So one mile radius buffer zones are the most convenient roughly for the present study. Therefore, one mile buffer zones were formed based on all schools. From this study, 10 areas were distinctively emerged out of these buffer zones, including Chanthargone village (Sisone village tract), Amatgyigone village (Kanswe village tract), Seikpyoye village (Mithweboke village tract) and the remaining are uninhibited agricultural areas and mountain ranges (Map 8).

Map (5). Spatial Distribution of Basic Education Schools in Singaing Township



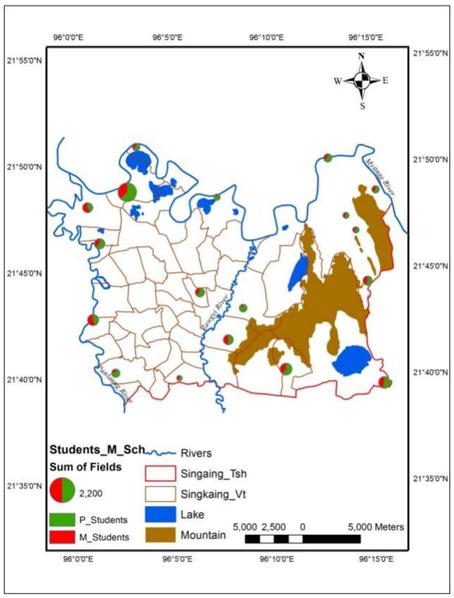
Source: Field survey data

Map (6). Student Population of Primary Schools in Singaing Township

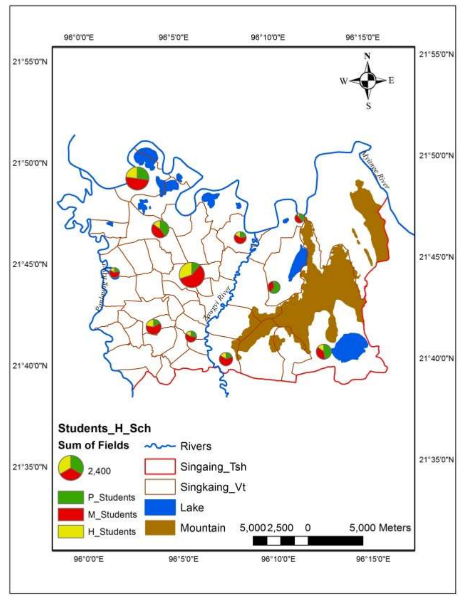


Source: Township Education Office, Singaing

Map (7). Student Population (with their respective grade) of Middle Schools in Singaing Township

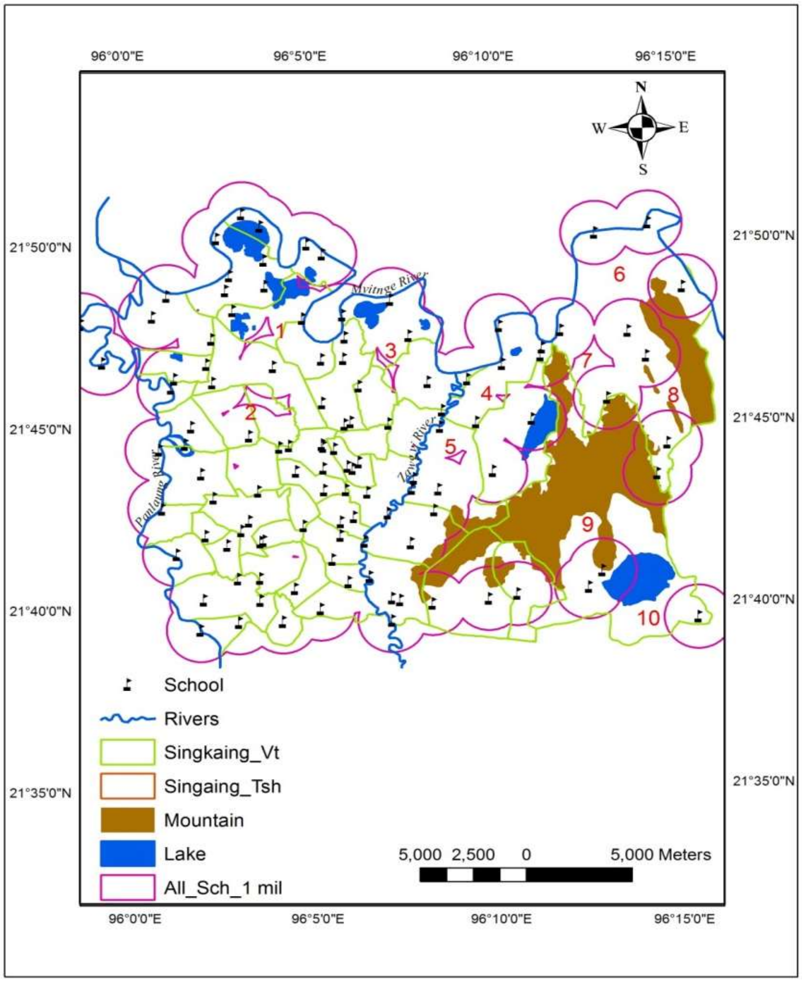


Map (8). Student Population (with their respective grade) of High Schools in Singaing Township



Source: Township Education Office, Singaing

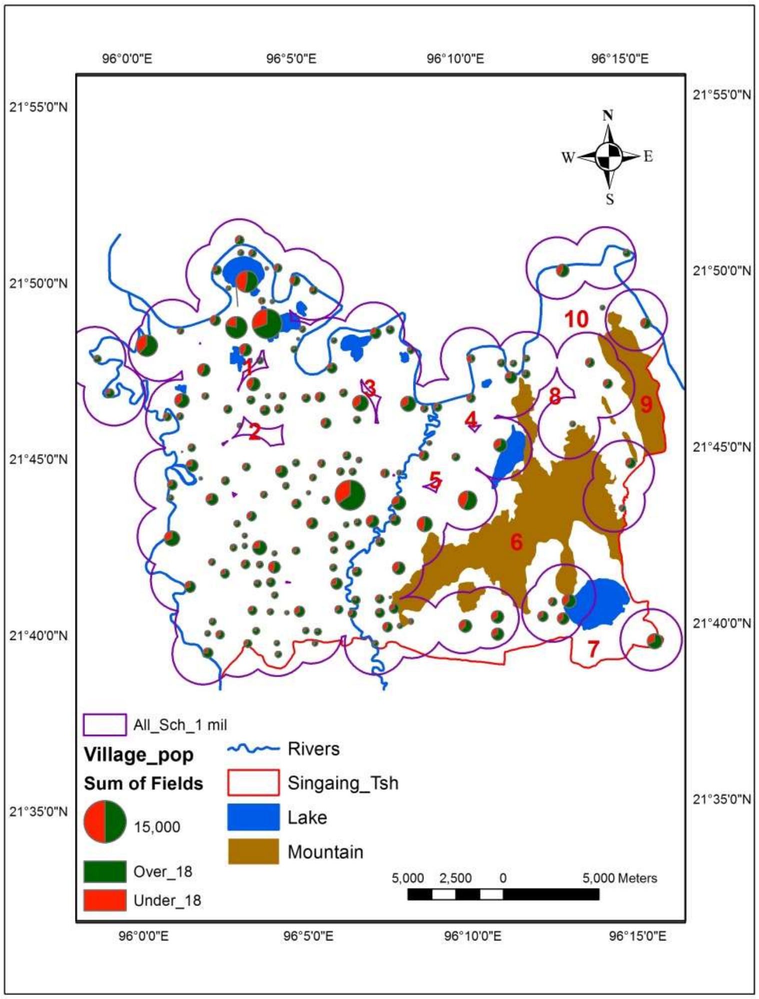
Map(9). New sites for Primary School



Source: compiled by researcher

For this reason, these localities are the most suitable areas to establish and open new primary schools, where 363 people live in Chanthargone village, 224 people in Amatgyigone village and 203 people in Seikpyoye village. The school-age children (under 18 years) of these villages amounts to 91 people, 71 people and 57 people respectively (Map 10).

Map(10). New Sites for Primary School and Total Population of each Village in Singaing Township

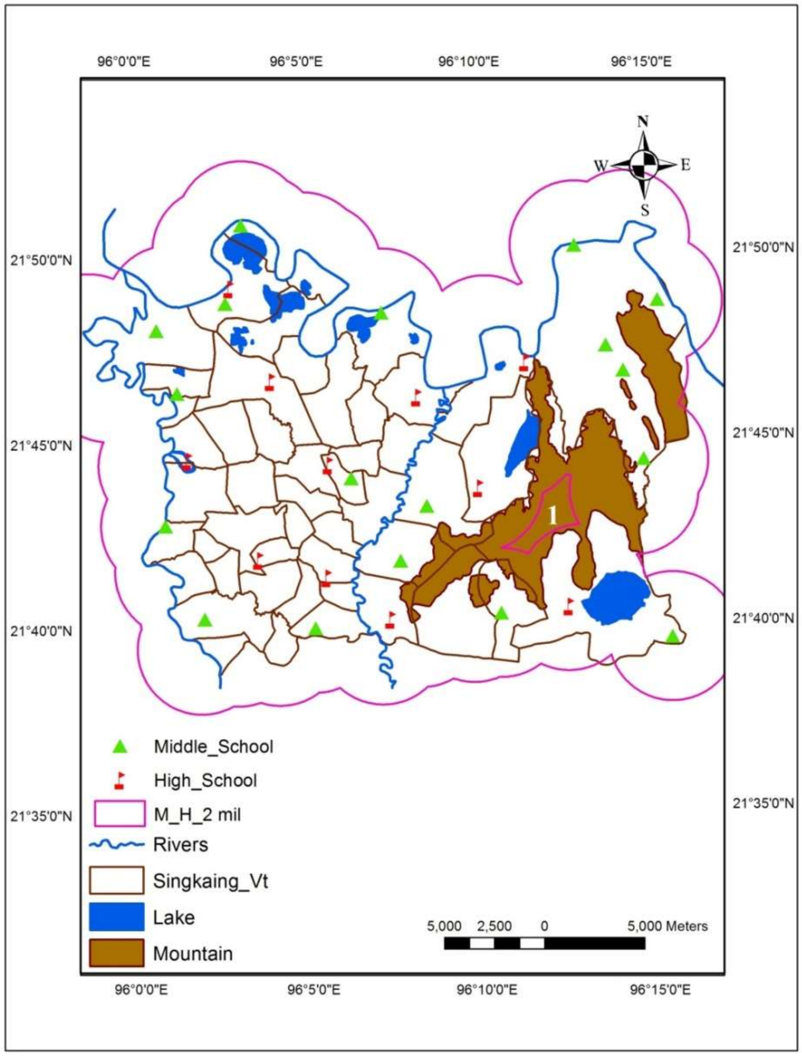


Source: compiled by researcher based on Table (2) and Map (9)

In the second phase of the study, localities of the middle schools were analyzed. As most of the middle school students have to go to their schools by bicycles, their travelling capacities to go to school are 2 or 3 miles. Therefore, the buffer zones were established as a radius of 2 miles. In this case, there is only one area outside of these zones. However, it is located on the Keinnayar

Range and it can be considered that the middle school is sufficient for the whole township (Map 11).

Map (11).Location to be needed to upgrade to Middle school



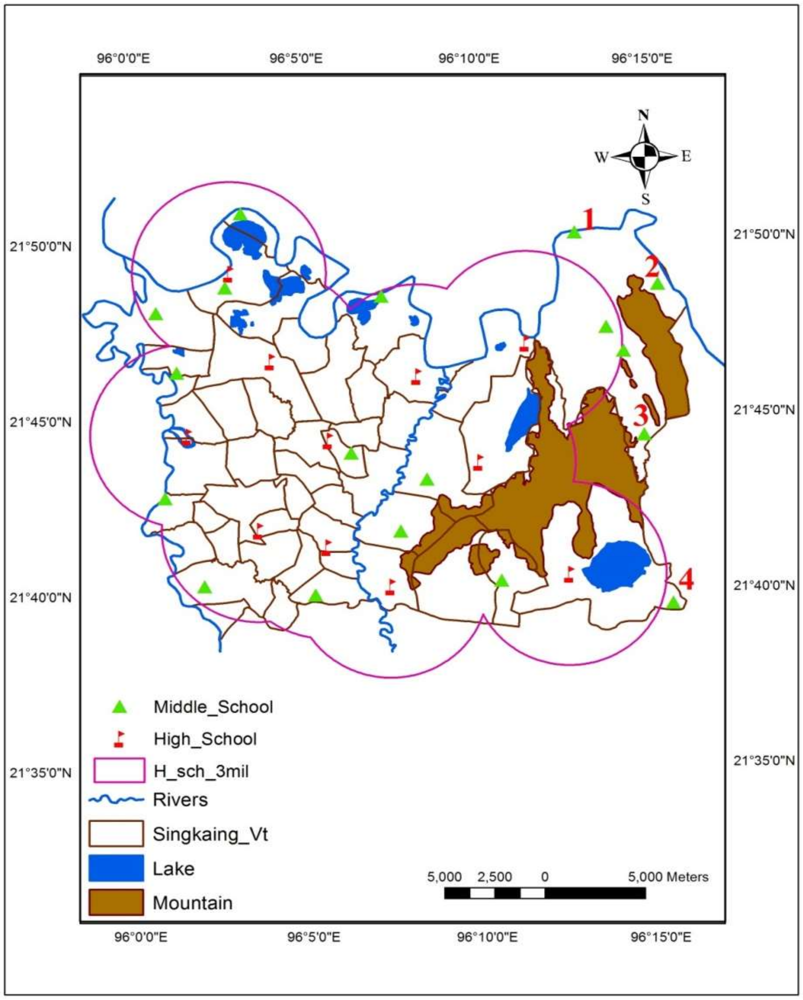
Source: compiled by researcher

Finally, the need for the locations of the State High Schools is examined. In this case, 3 miles radius buffer zones are established. By the examination of 3 miles buffer zones, the localities lying outside the range of the distance to travel to the school were found to be the middle school of Mithweboke, Ywathaya, Natyekan and Kado village tracts (Map 12).

In the first two village tracts of Mithweboke and Ywathaya, the students from these State Middle Schools have to go to Ywabo BEHS for their high school education. By comparison, the student numbers of both schools are nearly the same. However, the students from Ywethaya BEMS have to take a length of their route to go Ywabo BEHS because the route around the mountains has to be taken. Therefore, it can be considered that Ywathaya BEMS is more suitable site than Mithweboke BEMS to be upgraded into the State High School.

In the last two village tracts, the students from Natyekan and Kado State Middle Schools have to go to Sunye State High School for their next level education. By comparison, Kado and Natyekan State Middle Schools are nearly away from BEHS Sunye. However, the Dattaw Hill is between BEMS Natyekan and BEHS Sunye as a physical barrier. Therefore, it can be assumed that the BEMS Natyekan is the most suitable site to be upgraded from BEMS to BEHS in spite of having lower student population than BEMS Kado.

Map(12). Location of Middle Schools (to be needed to upgrade to High school)



Source: compiled by researcher

Findings and suggestions

In studying Basic Education Schools in Singaing Township, three groups can be analyzed such as Basic Education Primary Schools (BEPS), Basic Education Middle Schools (BEMS), and Basic Education High Schools (BEHS).

In examining the first group of Basic Education Primary Schools (BEPS), 10 areas were distinctively emerged out of one mile buffer zones including three villages and the remaining are uninhibited agricultural areas and mountain ranges. For this reason, these three villages (Chanthargone, Amatgyigone, Seikpyoye)are the most suitable areas to establish and open new primary schools.

In studying the second group of Basic Education Middle Schools (BEMS), there is only one area outside of two-mile buffer zones. However, it is on the Keinnayar Range and thus it can be considered that the middle school is sufficient for the whole township.

In analyzing the third group of Basic Education High Schools (BEHS), four middle schools (Mithweboke, Ywathaya, Natyekan and Kado) were found outside the range of three-mile buffer zones. Among these four schools, Basic Education Middle Schools in Ywathaya and Natyekanare needed to be upgrade into Basic Education High Schools because of their physical barriers.

Conclusion

Education is a basic human need. Only when people are well educated and skillful in modern technologies, they can gain their life struggle for food, clothing and shelter. This paper intends to analyze the condition of Basic Education Schools in Singaing Township. In this study of Basic Education Schools, three groups can be analyzed such as Basic Education Primary Schools (BEPS), Basic Education Middle Schools (BEMS), and Basic Education High Schools (BEHS).

In (2016-17) Academic Year, four high schools (BEHS), seven branch(affiliated) high schools (Sub BEHS), one middle school (BEMS), sixteen branch middle schools (Sub BEMS), one post primary school (Post BEPS), eighty primary schools (BEPS) and three branch primary schools (Sub BEPS) totally with 22,927 students. There are totally 112 government basic education schools and 4private schools. The total numbers of students at these private schools were 2017 in this Academic Year.

Based on the data being collected from both primary and secondary sources, the processing and analytical patterns are conducted by means of GIS Techniques. Spatial distribution pattern of education school is analyzed by using

In examining the first group of Basic Education Primary Schools (BEPS), it is found that the three villages such as Chanthargone, Amatgyigone, Seikpyoye are the most suitable areas to establish and open new primary schools.

In studying the second group of Basic Education Middle Schools (BEMS), there is only one area which is on the Keinnayar Range to establish and upgrade to the new middle school. Therefore, it can be considered that the middle school is sufficient for the whole township.

In analyzing the third group of Basic Education High Schools (BEHS) such as the four middle schools of Mithweboke, Ywathaya, Natyekan and Kado were found outside the range of three-mile buffer zones. Among them, Basic Education Middle Schools in Ywathaya and Natyekanare more needed to upgrade into the next level because of physical barriers in those areas.

Acknowledgement

First and foremost, I would like to pay my deep respects to my parents, who give birth and look after with great kindness to me. I am greatly indebted to all my teachers from my schooling age to the present for their teachings, proper guidance and instruction in my life. Secondly, I would like to express my special thanks to Dr Win Min Thein, Professor and Head, Department of Geography, Kyaukse University, for her permission to submit this research paper. Finally, my deep thanks and gratitude are due to the personnel who were concerned at the various governmental offices of Singaing Township for their allowances to collect and use their official data.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

CONSTRAINTS AND OPPORTUNITIES OF RICE-BASED FARMING SYSTEM IN THE AYEYARWADY DELTA: A CASE OF PANTANAW TOWNSHIP, AYEYARWADY REGION, MYANMAR

Yi Yi Cho[1], Phyu Phyu Win[2], Cho Cho Lwin[3], Nan Hla Thuzar[4]

Abstract

Myanmar's economy is predominantly based on agriculture. The study area is located in Ayeyarwady Delta, the rice bowl of Myanmar which produces most of the rice requirements of the country. This area is naturally provided with deltaic alluvial soil and abundant monsoon rainfall. Thus, rice-based farming system in the study area is the most important farming system covering about 40000 hectares. Rice in the study area has reached self-sufficiency for local consumption and surplus is being exported. However rice-based farming system faces a number of constraints at the farm level due to yearly flooding. Opportunities exist for one or more new rice cultivation techniques and varieties to be adopted in farming system. The objectives of this study are to present rice cultivation practices and farming system employed by the local farmers and to present the constraints encountered in their rice-based farming system and opportunities resulted from RBFS. Focus group discussion, in-depth interviews, and field observations are the key techniques for this research. Deep water field is the largest sown area with 57.92 percent of the total rice cultivated area in the township. The results show that constraints encountered in RBFS of study area is related to flooding. Opportunities can be also resulted for this farming system in future.

Key wards: *Farming System, Constraints, and Opportunities*

Introduction

The Ayeyarwady Delta is a key agricultural production zone located on the southern part of Myanmar. The Delta as a large flat alluvial plain is uniquely suitable for rice cultivation. Ayeyarwady Delta known as the rice bowl of Myanmar is naturally provided with deltaic alluvial soil and abundant monsoon rainfall. This region produces most of the rice requirements of the country. However, the delta is flooded each year from July to October by flow

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from the Ayeyarwady river system. Therefore, most areas are favourable for rice cultivation while some are prone to flooding in the monsoon. As the study area is located in this region, rice-based farming system (RBFS) in the study area faces a number of constraints at the farm level. Opportunities exist for one or more new rice cultivation techniques and varieties to be adopted in farming system. This paper presents constraints and opportunities of rice-based farming system in the study area. Therefore this study will focus on the research question "how do constraints faced in rice cultivation affect the high productivity of rice and what are the opportunities involved in RBFS for local farmers?" Based on these research questions the objectives of this study are to present rice cultivation types and farming system employed by the local farmers and to present the constraints encountered in their rice farming system and opportunities resulted from RBFS.

Sources of Data and Methodology

Pantanaw Township is included in Maubin District of Ayeyarwady Region. It lies in the central part of Ayeyarwady Delta which is known as the rice bowl. It extends from north latitudes 16° 48' to 17° 13' and from east longitudes 95°16' to 95° 34'.The neighbouring townships are Danubyu in north and northeast, Nyaungdon in east and northeast, Maubin in east and south east, Wakema in south, Einme in southwest and Kyaunggon and Kyonepyaw in west and northwest.

Most of the boundaries are rivers and creeks. Southern boundary is defined by Shwelaung and Ayeyarwady rivers. Southeast boundary is also formed by Ayeyarwady River (24.1 kilometres or 15 miles long). Eastern boundary (27.4 kilometres or 17 miles long) is limited by Ayeyarwady River. The northeast boundary which is demarcated along Danubyu for 17.9 kilometres (8 miles) is defined by Bawdichaung. The western boundary is 16 miles long and it is demarcated along the paddy fields. The northwest boundary is formed by Kawthaline creek. The western boundary serve as boundary of Pantanaw and Kyaunggon (32.2 kilometres or 20 miles long). Southwest boundary serve as boundary between Patanaw and Einme Township (19.3 kilometres or 12 miles long). Nearly all the boundaries are made of rivers and creeks.

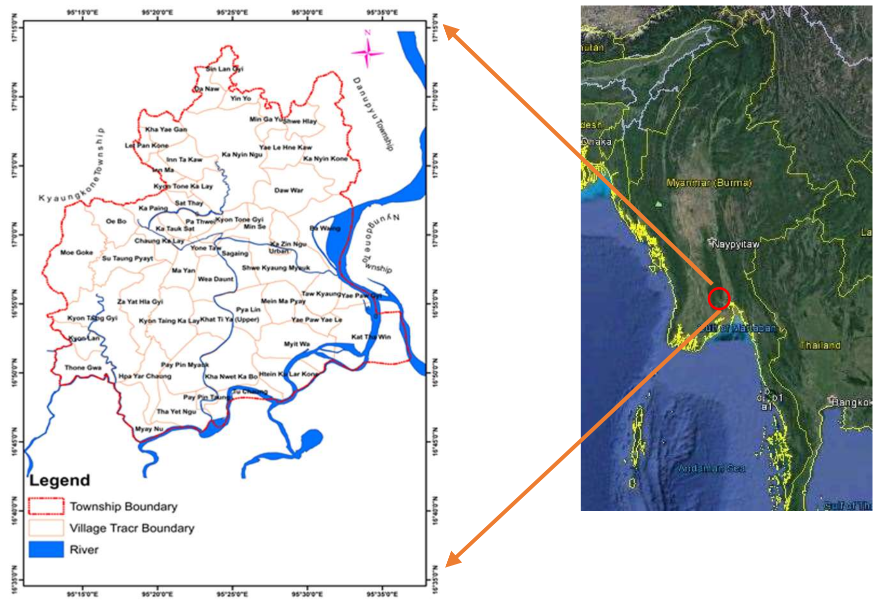

Figure 1 . Location of Pantanaw Township in Ayeyarwady Region
Source : Settlement and Land Records Department, Pantanaw

Data Collection

Primary data was conducted from the duration of fieldwork through data-gathering methods such as interviews and group discussions with key persons and local farmers. In order to investigate the responses of local people to farming system and practices, floods, irrigation, several kinds of data and information needed to be collected as methodologies. Both qualitative and quantitative data comprise information on the impacts of flood conditions, cultivation practices, local experiences and knowledge on their rice farming systems, their adaptive strategies to reduce flood damage, and the attitudes of different groups of farmers to dyke construction.

Secondary data includes the various published and unpublished documents from governmental concerned, and research institutes. Historical documents concerning with the history of the township, land use, farming system and water management from the annual reports. Besides, official records are collected. The statistical data about area, land use, and production were also collected. The interview was supplementary to the group discussion.

Selected households did not follow statistics samples but households represented based on the different farm size.

Results and Findings

Physical Factors affecting rice farming

The study area is a flat region of central part of Ayeyarwady delta. There is regular flooding in the township during the monsoon season. Thus, the cropping cultivation protected is from flooding by dyke construction. Rivers and creeks are frequently crossed by bridge of new highway roads namely Pathein-Yangon roads and Wakema-Yangon road. As a series of branches of Ayeyarwady River, small rivers and creeks flow from north to south. The general elevation of the study area is under 15m (50 feet) above sea-level and the land is flat, favourable for the cultivation of rice crops.

Pantanaw Townshiup is covered by flood water during the monsoon period. But those water retreat back into the river in summer season. So, this region gains good fertilizer from the deposition of silt. They are much suitable for crop cultivation. But the banks are frequently broken by floods and it leads to the loss of agricultural lands and villages.

The township records an average annual rainfall of 2000mm-3 000mm. The major precipitation occurs between June and September but rainy season commences from May onwards. From this, long dry period (November-April) inhibits efficient cultivation. This situation can overcome through irrigation. The average annual temperature is about 27.11° C°(80.8°F) which is the optimum condition for the growth of rice. This land receives tropical monsoon type of climate. The climate is governed by the monsoon and dry seasons according to rice growing period.

The three main soil groups that are important for rice cultivation in the township are meadow alluvial soils, brown meadow soils and meadow gley soils. The general characteristic soil types of this township are meadow gley soils. These soil types are most suited for the rice cultivation.

Socio-economic factors affecting rice farming

As the study area is located in Ayeyarwady deltaic region, the township has broad tract of flat alluvial land suitable for successful growing of rice. Moreover, the township lies on Yangon-Pathein Highway. Combined with easy accessibility, it has become an area of moderately dense population, particularly rice based farming. In 2016, total population was 168561 persons which represented 2.7 percent of the Ayeyarwady Region's total. Of these, 45188 persons are farmers with 27 percent of township's total population. Land use is one of the important factors for agricultural development in any area. The areal extent of the township is 1291.16 sq km (129116 hectares or 498.52 sq mi), taking up 3.68 percent of Ayeyarwady Region. There are five types of land use in the study area. Of these, agricultural land is largest land use type in the township. After 1995, government reclaimed deep water areas and extended as the agricultural land.

Table 1. General Land Use of Study Area (2016)

Type of Land Use	Area (square kilometer)	Percent of township areas
Agricultural Land	933.61	72.31
Fallow Land	3.44	0.27
Pasture	73.25	5.67
Waste Land	43.48	3.37
Uncultivated Land	237.38	18.39
Township Total	**1291.16**	**100**

Source : Settlement and Land Records Department, Pantanaw Township

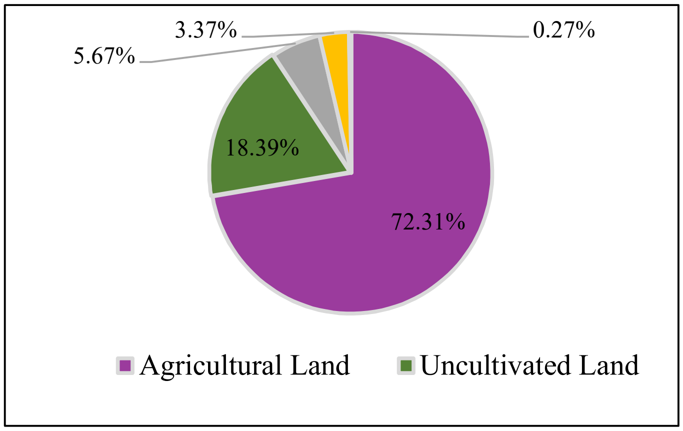

Figure 2. Type of Land Use in Study Area (2016)
Source : Based on table (1)

Rice is grown in the study area during the monsoon (June to November) and summer (November to March) seasons. As the study area enjoys a monsoon climate with abundant rainfall, rice is grown throughout the year. There are two dominant rice production systems in the study area: rainfed rice in monsoon season and irrigated rice in summer season. During the monsoon season, study area's rainfall is sufficient for growing rice without supplemental irrigation from dams, river and stream. On the basis of rainfall, flooding patterns and topography, rice cultivated fields in monsoon season can be categorized further into suitable water and rain field, flood water field and deep water field. Of these, deep water field is the largest sown area with 57.92 percent of the total rice cultivated area in the township (Table 3). Matured area is decreased over 1500 hect (3706.5 acres) due to the effect of flooding in 2016-17.

Farmers in deep water and flood-prone areas cope with the high risk of production by using dry seeding. Direct seed broadcasting is a common practice in areas where the accumulated water level can reach more than 100 cm, since the water in these areas is not likely to subside to a level suitable for transplanting during the monsoon period. Rice establishment by direct seed broadcasting, however, requires dry land preparation before the monsoon.

Deep water and flood water rice are cultivated in the same areas as suitable water and rain rice, but is found mainly near the rivers and streams where the water is deep or flooded. As the study area is located in Ayeyarwady Delta, most of the rice field are subject to flooding ranging in duration from a few days to 2 or 3 months, resulting for significant risks to farmers. More frequent and prolonged submergence events may be a consequence of climate change. Therefore, some areas are suitable only for deep water rice and flood water rice, a low yielding rice type that elongates to stay above the rising water. Therefore, these types of rice are called floating rice in other word. Rice cultivated in these area are the same varieties such as Taunghti, Sitpwar, and Thaiyenet. In 2016-17, rainfed rice in monsoon season account for 40.67 percent of total agricultural land in the township and 19.59 percent of irrigated rice in summer. According to interview monsoon season rice are grown mainly during June to November. Summer season rice is cultivated in the main cropping period of November to March with full or supplementary irrigation or in receding floodwaters.

Table 2. Cropping Calendar of Rice Farming System in the Study Area

Production System	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Rainfed rice												
Irrigated rice												

Source: Based on Interview Survey, July 2017

Table 3. Types of rice cultivated field in monsoon season (2016-17)

Types of Rice Field	Sown Area (Hect)	Matured Area(Hect)	Yield/ Hect(Ton)
Suitable water and rain field	12307	12307	4.71
Deep water field	22638	21104	3.11
Flood water field	3024	3024	3.22
Total/Avg	**37970**	**36435**	**3.68**

Source : Based on Data of Agricultural Department, Pantanaw Township

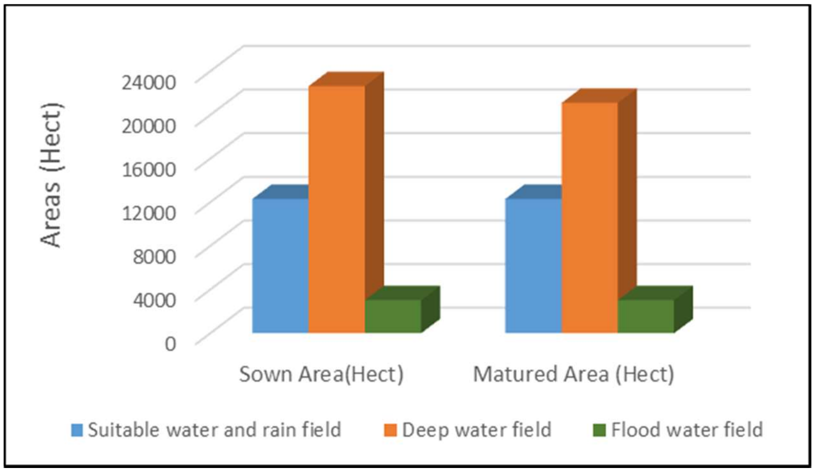

Figure 3. Types of Rice Field in the Study Area (2016-17)
Source: Based on table (3)

Western part of the township was highest in monsoon rice area with more than 1000 hectares (over 2500 acres). Small areas (under 500 hectares) of monsoon rice in that year are found in eastern part of the township. In the study area, rainfed rice is cultivated in the whole township.

More than 2,000 different rice varieties have been used in Myanmar. Many varieties are identical although they are called various names in different areas of the country (Young et al, 1998).Young, 1998). Likewise, many varieties of rice in the monsoon season were cultivated in the study area (table 4). Of these varieties, Sinthukha is the largest cultivated area and yield (except Palethwe) in the study area with 16904.49 hectares in 2016-17. Palethwe are costly to cultivate due to high input cost and labour charges. On the other hand, climate is not adaptable to this variety because of their early maturity and existing harvesting and drying methods.

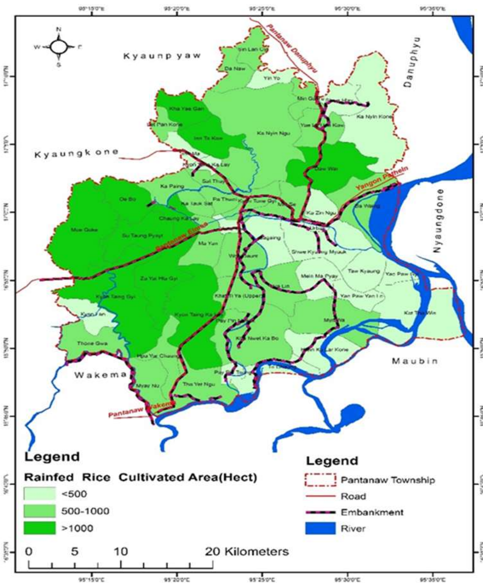

Figure 4. Rainfed Rice Cultivated Areas of the Study Area (2016-17)
Source : Based on Data of Agricultural Department, Pantanaw Township

Therefore, this variety is not highly cultivated area in the township. Taungti and Sitpwer are very low yield with 1.65 to 1.67 ton/hect and cultivated in flooded area. There are risks of submergence and stagnant water, both of which can sharply reduce yields. The average yield in rainfed rice ranges from 1 to 6 mt /hect. Therefore, Maung et al., (1990) also mentioned that the major production constraint in deep-water areas and poorly drained, rain-fed lowlands is the excessive floodwater during the monsoon season.

After the monsoon crop rice was irrigated as second crops in the dry season with 18296.24 ha in 2016-17. Some deep water and flood water rice areas in the monsoon season were used to produce a dry-season crop as the water level receded. As rainfall is highly seasonal in the study area, the dry period lasts for about six months. Rice grow only in flooded field and thus, rice cultivation in the dry period cannot be done successfully without irrigation water sources.

Table 4. Rice Varieties Cultivated in Study Area

Varieties	Matured Area (Hect)	Yield/Hect(Ton)
Parlethwe	48.16	5.95
Manawthuka	4864.02	4.24
Sinthukha	16904.49	4.39
Yatanatoe	1342.78	4.40
Sinthwelat	619.99	4.51
Thihtatyin	1312.02	3.42
Ayeyarmin	2277.22	3.42
Kyauknyin	97.94	2.87
Yatanawin	743.02	2.55
Taungti	4062.32	1.67
Sitpwer	4163.09	1.65

Source : Based on Data of Agricultural Department, Pantanaw Township

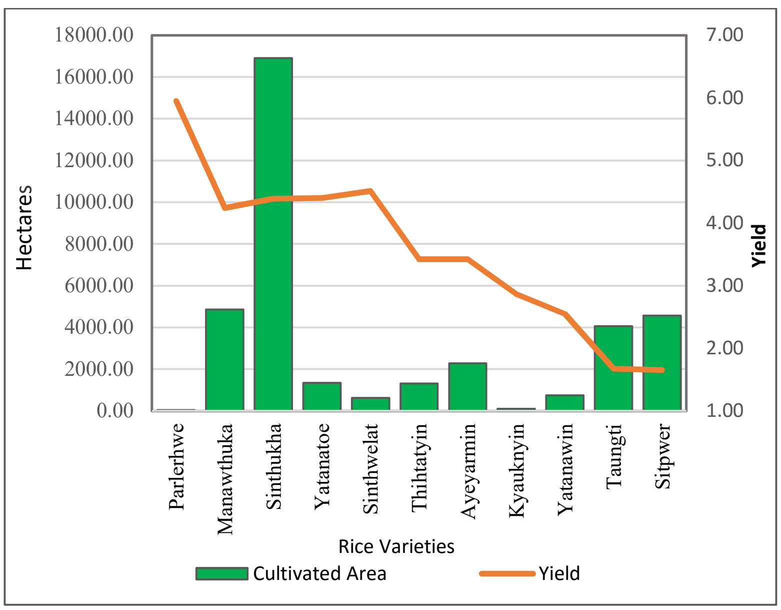

Figure 5. Matured Area and Yield/Hect by Varieties

Source: Based on table (3)

In 2016-17, irrigated rice was mostly grown in the northern part of the township, as they are located near the Ayeyarwady River, and its tributries from which water is pumped into the fields. For the southeastern part of the township, irrrigated rice is slightly cultivated owing to lack of canal that can deliver large amount of irrigation water. However, Naing (2005) reported that there are high potential for groundwater development in the Ayeyarwady River Basin. Therefore, the freshwater from these sources also is pumped by some farmers into the fields to grow summer rice. Rice yields in summer season are more than monsoon season that cultivated traditional varieties with low yield are more suitable to tolerate flooding. This point largely affected the total production of rice farming in the study area.

Prior to the 1995, the majority of the area was cultivated for one crop of long-term floating rice over the monsoon season from June to November in a year. Since the introduction of high yield variety rice at some sections in the country have been modified to provide flood protection by the construction of high embankments exceeding peak flood levels.

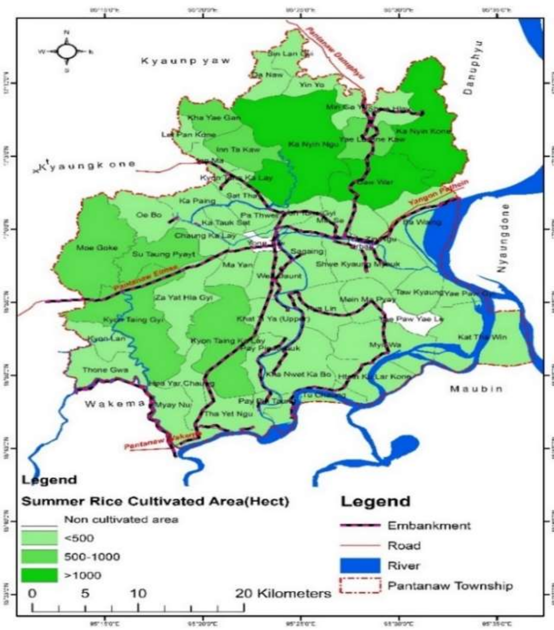

Figure 6. Irrigated Rice Cultivated Areas of the Study Area (2016-17)

Source : Based on Data of Agricultural Department, Pantanaw Township

Embankments are essential to prevent agricultural land and settlement area. Then these are joined to form compartments with sluice gates installed to exclude floodwater but allow water in and out of the compartment as required. In 1995, there are four embankments in the township and beneficial area is 14381.63 hectares (35537 acres). Currently, there are 11 embankments to protect flooded water in the study area and beneficial areas of 42355.32 hectares (104660 acres).

Table 5. Varieties cultivated and Yield/Hectare in Summer Season

Varieties	Cultivated Areas(hect)	Yield/Hect(Ton)
Sinthukha	7588.02	4.89
Thihtatyin	7918.25	5.03
Manawthuka	2316.88	4.93
Yatanatoe	382.44	5.08
90 days	91.06	5.07
Total/Avg	**18296.64**	**5.00**

Source : Based on Data of Agricultural Department, Pantanaw Township

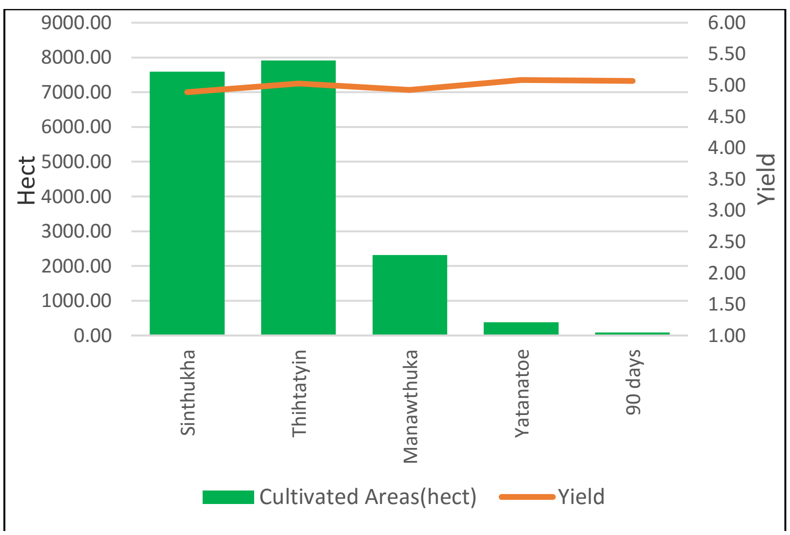

Figure 7. Yield /Hect by Varieties Cultivated in Summer Season
Source: Based on table(5)

Constraints and Opportunities related to Rice Farming

Flood

According to interviews with key informants and group discussion with farmers, the major constraints to rice production in the study area are flooding in monsoon season. The increased productivity of rice-based farming systems remains the primary goals of the national plan, with a focus on short duration varieties for irrigated areas.

Water in the monsoon season cannot usually be controlled due to poor drainage and insufficient embankments along the river banks. As the rainfall during six months of monsoon is heavy, the accumulated water level can rise gradually or abruptly, depending on the drainage system, location and amount of rainfall received. The cultivated rice crop can be lost in some deep water and flood water areas due to an abrupt rise of water and lasting. Communication and transport facilities are often hampered during flood periods, preventing the timely application of inputs, such as fertilizer especially in suitable water and rain rice field.

The rice system that would be best adapted to climate conditions projected for the coming decades is to utilize floating rice varieties, which are able to withstand prolonged inundations and floods. Most rice varieties can survive complete submergence for only 3 or 4 days, but submergence-tolerant varieties can survive for about 12 days. Deepwater and floating rice are sown before the floodwaters rise and flower about the time of maximum water depth. Deepwater rice varieties can grow in maximum water depths of around 100 cm. Floating rice are those that grow very rapidly under submergence.

Despite its relatively low yield compared to high yielding varieties (HYV), floating rice (FR) has been seen to have a range of other advantages. According to interview survey, farmers in the study area have not applied to chemical fertilizers in FR cultivation. FR fields have abundant biodiversity compared with other rice field and contain substantial fish and other aquatic animals which can be harvested as valuable food protein sources for local peoples.

The floating rice yields are low at only 1.6 t/ha compared to HYV of rice at over 4 t/ha. There is significant variation in productivity from different farming systems, reflected in differences in yield. Moreover, the price of floating rice is low at only 4000 kyats in 20.86 kg (one basket) compared to HYV of rice at over 6000 kyats.

Although summer season needs irrigated water available to cultivate rice, generally, crops are rarely fully irrigated. In most areas, they are planted to take advantage of the receding floodwaters or of residual soil moisture. For the central part of the township, rice is cultivated very low owing to lack of canals, and other water avalivible conditions. Therefore, farmers are more willing to irrigate into their fields by canals.

Groundwater provides significant advantages over formal surface water irrigation systems in terms of lower infrastructure costs. The potential for expansion of groundwater use is high in the study area particularly in the large alluvial systems of the region's major rivers. Groundwater is seasonally recharged by the annual flood. Therefore, the study area has opportunities for enhancing surface water and groundwater availability through managed irrigation system.

Yield during the dry season can be increased more than during the wet season because farmers potentially have control of the water input. Yield can be increased by up to over 5 t/ha. The Government and local people have placed a strong emphasis on irrigation development.

Varieties

Rice varieties cultivated in the study area are mainly controlled by cost of cultivation and adaptation to local. Farmers want commonly to cultivate their own seed that do not require to buy from year to year. Varieties cultivated in the township are used up to 3 or 4 generations by farmer. After these generations the seeds are no longer usable because of low yield and quality. Then, farmers bought new seeds from local agricultural department or other farmers. Sinthukha as high yield varieties (HYV) is the most cultivated variety in the township. Farmers do not gain potential yield from the cultivation of these varieties due to flooding, low inputs and weak effort in cultivation. Yield per ha has not improved since the early days due to restrictions on chemical fertilizer supply. The yield currently under rice varieties in monsoon and summer season has fairly high, but the floating rice yields are low under 2 t/ha compared to HYV varieties of rice over 3 t/ha. Currently, rice researchers in Myanmar noted that they need a floating rice variety that can elongate more than 50 centimetres/day. They expected to exchange floating rice seed as in Cambodia (Nguyen and Pittock, 2016). Therefore, local farmer's seed selection and genetic exchange is one of the key components for gaining high yield and conserving floating rice systems.

Fertilizer

Rice cultivation in the township used only a small amount of fertilizer due to the high cost. According to interview survey, the current fertilizer use in rice cultivation by farmers is low the quantity actually used for one hectare than township agriculture department standard. For example, instead of three and half bag of Urea fertilizer for one hectare (2.471 acres) in rice cultivation, farmer commonly use two and half bag/hectare. Therefore, insufficient use of chemical fertilizer is one of the low yield production factors in the study area. Fertilizer supply has improved since the government has allowed private imports, but the private market price has been steeply higher. Most of the chemical fertilizer use is for HYVs and in irrigated areas.

Labour

Labour is an important factor in any type of cultivation. Farm labourers are indispensable for the high productivity of rice. Today, the young adults of working age take little interest in the local work to enhance the agriculture activities such as rice farming. The considerably working age-group migrate to other region such as Yangon and the neighbouring countries, mostly to Thailand to get better job opportunities and earn more money. Therefore, labour shortage is also a major constraint in rice cultivation of the township. However, the wages of a worker/day is between 3500 and 4000 kyats in the township. This rate is very expensive for farmer.

Agricultural Loan, Land Tenure and Machinery

According to interview survey poor farmers with a small land holding of less than 2 ha want to maximize the output of his land. It is this category of farmers who are most inspired by the marvels of HYV rice. The most essential input they need is some money to start with. Most of the available money was used in paying compensation to former lenders, instead of being used for agricultural credits. In 2017, farmers are able to borrow a total amount of K 150000/ acres (0.404 hectares) from the Agricultural Bank. However, farmers do not have sufficient amount in cultivation. In study area, some farmers are land tenure. Such farmers do not get agriculture loan. Therefore. They want to get it. Such farmers are not willing to invest in machinery because they do not have secure land tenure.

Lack of domestic and international markets for floating rice (FR)

Although HYV rice has a domestic and international market acceptability, FR has no market. FR can available low prices due to low quality. It is also perceived as hard to eat. Farmers grow floating rice for home consumption or animal feed. Nguyen and Pittock (2016) reported that floating rice is perceived as safe, chemical free and nutritious. Therefore, FR may be market acceptability due to contribute the health of people in the future.

Conclusion

As the study area is located in a flat region of central part of Ayeyarwady delta, there is regular flooding in the township during the monsoon season. Thus, rice farming system of the study area largely affected flooding. The yield currently under rice varieties in monsoon and summer season has fairly high, but the floating rice yields are low under 2 t/ha. The variety that would be best adapted to flood affected areas projected for the coming decades is to utilize floating rice varieties, which are able to withstand prolonged inundations and floods. Some varieties can survive complete submergence for only 3 or 4 days, but floating rice varieties can survive for about 12 days. The floating rice must be improved for changed conditions to increase yield and quality, as they are currently quite low. There is little public policy for recognizing the importance of climate change in rice cultivation in the study area. Therefore, there is no emphasis on developing higher yield floating rice varieties.

Farmers must keep up with the adoption new technologies as they become commercially available. The costs and benefits of rice based farming system in the study area remain an important aspect for further research.

Acknowledgements

I am greatly indebted to Sayamagyi Dr Mi Mi Kyi, Myanmar Academy of Arts and Science. I am also grateful to Dr. Htun Ko (Professor &Head) and Dr. Nilar Aung (Professor) of Yangon University, for their permission to work on this research. My heartfelt thanks are due to my first, foremost teachers and my parents.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

ASSESSMENT OF INTERNAL OR EXTERNAL MIGRATION PATTERNS OF THITTOKAN VILLAGE TRACT, CHAUK TOWNSHIP, MAGWAY REGION (MYANMAR)

Thin Thin Myat*

Abstract

This study intends primarily to investigate the socio-economic activities and migration patterns of Thittokan Village Tract, Chauk Township, Magway Region (Myanmar). Furthermore, migrant incomes will be studied. The objectives of the study are (1) to study the social-economic activities of rural residents, (2) to investigate the rural migration that can influence income of rural families, and (3) to examine internal and external migration patterns of rural families, and (4) to suggest ways of reducing rural migration in the study area. Relevant data will be elicited from both the primary and secondary information, which will be analyzed by using sampling methods and qualitative assessment. The results of the findings show that internal migration is higher than external migration in the study area.Moreover, the villagers believe that both internal and external migration contribute to the reduction of poverty in various ways, with some newly emerging studies revealing that migration helps poor families to cope with risk and to smooth incomes.

Keywords: Internal Migration, External Migration, Migration Patterns

Introduction

Globalization and migration are rapidly transforming traditional spheres of human activity. The work of rural families is no longer confined to farming activities, and rural people are increasingly being diversified through internal migration (rural-to-urban) and external migration (international or other countries). This study intends primarily to investigate the relationship between rural socio-economic activities and migration in Thittokan Village Tract, Chauk Township in Magway Region.

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Study Area

Thittokan Village Tract is a Village Tract in Chauk Township of Magway District, Magway Region, Myanmar. Thittokan Village Tract is subdivided into 4 Villages including Thittokan Village, Suutat Village, Sankan Village and Sanni Village. It lies between latitude 20.77364' and longitude 94.96774' Figure (1).

The research is conducted from the perspective of migrant remittance earnings rural families of Thittokan Village Tract in the case of Chauk Township, Magway Region.

Research Question

"To which extent and through which migration patterns, channel and conditions does rural migration affect the income of rural families?"

Research Hypothesis

- Rural migration positively affects farm and total income of rural families through remittances
- Rural migration is a rational decision to maximize total family income of migrant sending rural households

The specific objectives of the research are;

- to study the socio-economic activities in rural residents,
- to investigate the rural migration that can influence income of rural families,
- to examine internal and external migration patterns of rural families,
- to suggest that the ways of reducing rural migration in the study area

Methodology and Sources of Data

This study analyzed physical conditions, human factors and economic conditions within the village. Physical conditions and human factors are investigated by using secondary data. Major sources of secondary data collection are from the Settlement and Land Records Department, Immigration and Man Power Department, Township Peace and Development

Council. The migration data and socio-economic conditions of the villagers are emphasized by using primary data, which are gathered by using questionnaires, open interviews and field observations.

For data analysis, quantitative analysis and qualitative assessment are used to express the local people socio-economic conditions in Thittokan Village Tract. After that, Geographic Information System is applied for drawing maps and analyzing land use and distribution of economic activities. The discussion on sampling methods also includes the different producers that were used for section of households and research sites.

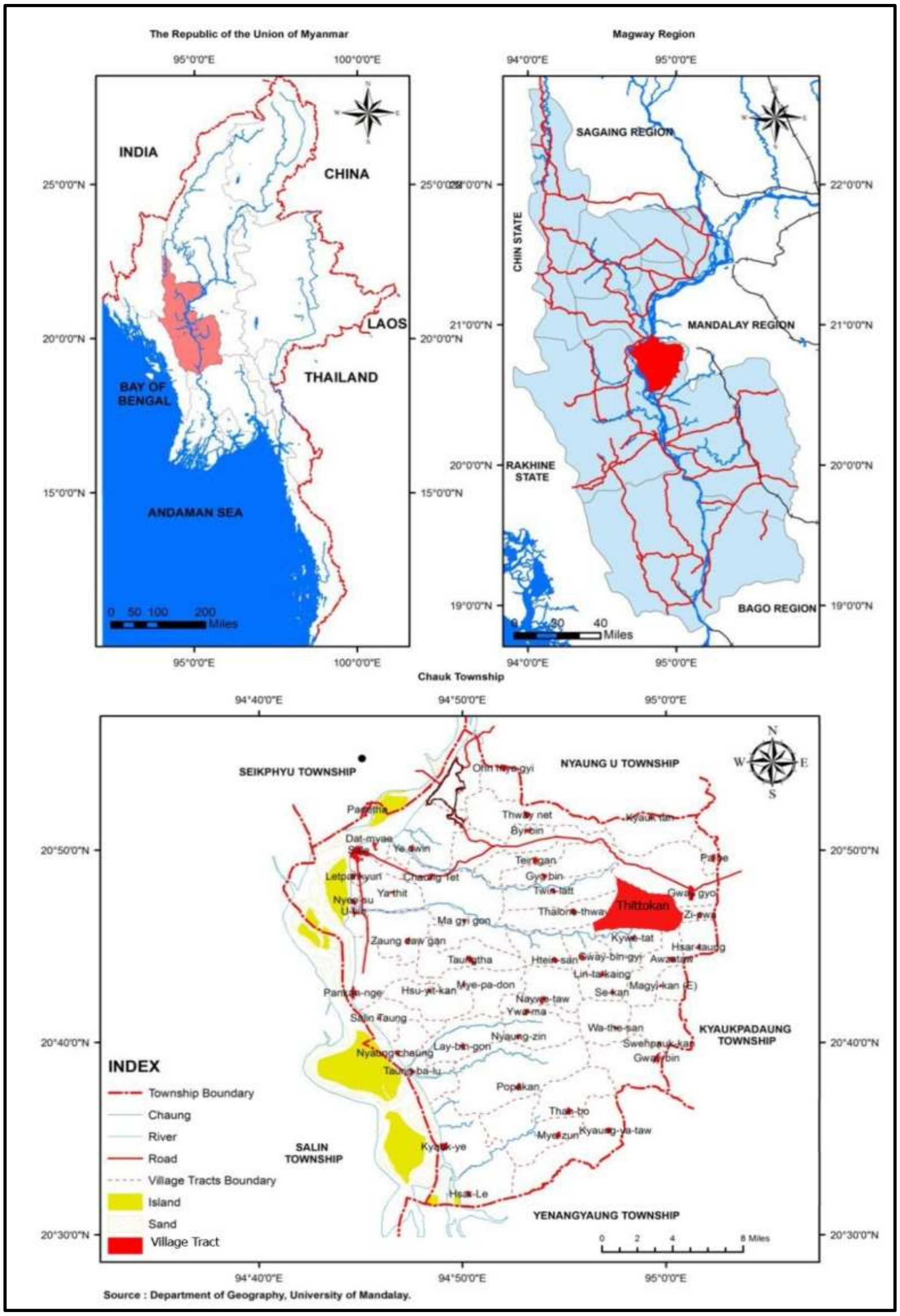

Figure 1. Location of Study Area

Source: Department of Geography, University of Mandalay

Population Background and Source of Labour

Human Factors

Human factors are very important in the geographical study of a region. Generally, the population distribution and density depend on relief, transportation facilities and water supply for agriculture. Magway Region is an administrative region in central Myanmar. It is the second largest of Myanmar's seven regions, with an area of 44,820 square kilometers. Magway Region is made up of the districts of Magway, Minbu, Thatyet, Pakokku and Gangaw comprising 25 townships and 1,696 ward and village tracts. Chauk Township is one of the Townships in Magway District and it has 5 Village Circles which are Salay, Pakannge, Gwaypin, Kwinlat and Gwaycho Village Circle. Thittokan Village Tract lie Gwaycho Village Circle.

Thittokan Village Tract is a Village Tract in Chauk Township of Magway District, Magway Region in Myanmar. It is subdivided into 4 villages including Thittokan Village, Suutat Village, Sankan Village, and Sanni Village. Thittokan Village has the highest population in Thittokan Village Tract. According to 2016 population data Thittokan Village Tract was 3,573 persons with 1,624 males and 1,949 females and the total population was 3,451 persons with 1,539 males and 1,912 females in 2015.

Population Distribution

Thittokan Village Tract is located far from the Kyaukpataung-Chauk main road. Thittokan Village Tract has 755 households and total population of 3,573 in 2016. In the study area, physiographic conditions influence the distribution of population. The large number of population is concentrated in the central village area. Other areas are sparsely populated. Most of people are Bamars. Some are other ethnic groups, also Indians and Chinese. The majority of people are Buddhists. Some are Christians. According to the data available, the total population of the study area was 3,573 persons in 2016, 2,518 or 70 percent were above 18 years of age and the remaining 1,055or 30 percent below 18 years Figure (2).

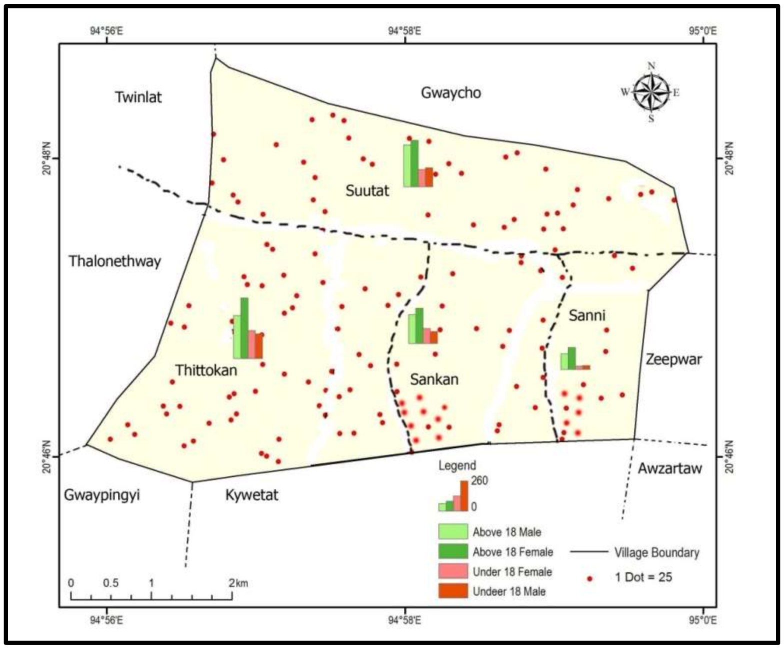

Figure 2. Population Distribution of Thittokan Village Tract
Source: Based on Table 7

Table 2. Population Condition of Thittokan Village Tract, Magway Region (2016)

No	Village	House hold	Above 18 Year Population			Below 18 Year Population			Total Population		
			Male	Female	Total	Male	Female	Total	Male	Female	Total
1	Thittokan	270	369	517	886	211	238	449	580	755	1,335
2	Suutat	245	360	398	758	163	148	311	523	546	1,069
3	Sankan	175	249	303	552	103	129	232	352	432	784
4	Sanni	65	134	188	322	35	28	63	169	216	385
	Total	**755**	**1,112**	**1,406**	**2,518**	**512**	**543**	**1,055**	**1,624**	**1,949**	**3,573**

Source: Land Records Department in Chauk Township

Ethnic Groups and Types of Occupation

Chauk Township is situated in Central Myanmar, and the majority of the population is Bamar. According to 2015-2016 census, 98.96 percent of the total population is Bamar, about 1 percent of the population was other ethnic groups, 0.02percent the total population was Kayin, 0.01percent the total population was Shan, and 0.02percent, 0.01percent, and 0.003percent of the total population were Kachin, Rakhine and Mon respectively. The mixed population, mostly Bamars and foreigners, amounted to 0.97 percent in 2015-2016 Table (2).

Table 3. Population of Chauk Township by Ethnic Groups in 2015-2016

Races Group	Total Population	Percent	Ethnic Groups	Total Population	Percent
Bamars	208488	98.96	Rakhine	30	0.01
Chin	35	0.02	Mon	7	0.003
Kayin	52	0.02	Kayah	3	0.001
Shan	23	0.01	China	148	0.07
Kachin	9	0.02	India	1,886	0.90

Source: Immigration and Man Power Department of Chauk Township

As the majority of the population is Bamar, Buddhists made up the greatest number with 98.96 percent of the total population. The Chins also strongly believe in Buddhism. There are different religious buildings such as Pagodas, Monasteries, Chinese Temples, Christian Churches, and Hindu Temples within the township. Most of these Pagodas, Monasteries, Temples and Churches are found in the urban area of Chauk Township. Thittokan Village Tract has 3,573 persons of the total population in 2016 Table (3). They were mainly engaged in agriculture, livestock breeding, manufacturing, and professionals such as doctors, teachers and nurses. Total workforce was made up of 1,624 males and 1,949 females. The second and third most important economic activity of the township was out migration, manufacturing and government staff. The numbers of male workers were much greater than that of female workers in the out migration and manufacturing sector. In Thittokan Village Tract, workers engaged in agriculture are the highest population. Therefore, agricultural development of Thittokan Village Tract is very important for the economic growth of the area, because about 70 percent of workers are employed in the agricultural sector.

Assessment of Internal or External Migration Patterns of Thittokan Village Tract

Basic Concepts of Migration

Migration has become an integral part of the current rural economy. Both internal (rural to urban with the state) and external migration (international migration) can have major rural development and poverty implications for individuals and their families' economies. Rural poor people migrate internally, but also externally. Short-term contract external migration has greater potential to reduce poverty than internal migration, because of the size of remittances received per household.

Their migration leads to an increase in both employment opportunities and income. Although the internal or external migrants are often essential for the economic activities in receiving areas, their living spaces are not typically allocated in national economic development or urban planning, especially in cases of rural-urban migration.

Internal Migration is moving to a new home within a state, country, or continent. And also internal migration refers to people within a country moving to another location within its borders, also known as external migration, refers to the act of migration across borders from one country to another. Usually, the motivations for internal and external migration differ.

Movement of internal migration includes rural to rural, rural to urban flows. The migration duration can be both short and long term. A particular section of internal migrants circulate repetitively between origin and destination areas based on their respective seasonal conditions and labour demands. These groups are referred to as seasonal and circular internal labour migrants. The most contemporary research is on rural to urban internal migration. From the perspective of poverty reduction, seasonal and circular migration may provide important insights, as these types of migration appear to be more prevalent among the poor. External Migration is moving to a new home in a different state, country or continent.

(* http://family.jrank.org/pages/1169/Migration-Types-Migration.html)

External migration is mostly taken up by medium to high land holding households to improve their livelihood situations but rarely by landless or near landless households. The major reasons for external migration are the high income, better job opportunity and to improve their experience. As compared to internal migration, international migration has higher costs and risks as well as returns.

Migration Channels in Thittokan Village Tract

In the study area, labour migration channels are diverse. In all the four surveyed villages, internal migration to Mandalay Region especially in Pyin Oo Lwin, Yangon, Nay Pyi Taw, Shan State and also external migration to Thailand, China, Singapore, Japan and Malaysia is an important livelihood strategy undertaken by rural household members. Though there is lack of data and studies on internal migration in the study area, various surveys shows that there is a lot of internal mobility for income generation.

Depending on the nature of work and the distance between the work and the origin village, all three types of internal migration – seasonal, year-round temporary and permanent - were observed. The major reason for internal migration is employment. Lack of year-round and sufficient employment in the origin location is the major cause for people to migrate. In general, there seems to be a reduction in seasonal labour migration, with the traditional seasonal migrants preferring to make more temporary and permanent migration to other locations with the entire family. Internal seasonal labour migration is prevalent when the origin and other locations are not very distant. In certain regions, migration is highly complex, both sending and receiving migrants at the same time.

Migration Patterns in Thittokan Village Tract

Permanent, temporary, seasonal and shuttle internal migration patterns are observed in the study area. These types of migration aim at securing often precarious livelihood strategy. There is no universally accepted definition for the various patterns or types of migration. The various patterns of migration, as observed, are defined as follows:

Permanent Migration – Migration is considered to be permanent when migrants or households have left their origin place for good and settled in the destination place indefinitely (with or without registering with the authorities). These migrant or households do not intend to return to their original place of residence.

Temporary Migration – Migration is considered to be temporary, when an individual or household (fully or partly) settles in the destination location throughout the year, but still has the intention to return to the original place of residence.

Seasonal Migration – Migration is considered to be seasonal, when it takes place only in a certain time of the year or when the migrant returns to his/her place of origin at least once a year.

Shuttle Migration – Migration is defined as shuttle migration when the migrant's place of residence and place of work is different but there is no actual change of residence. Thus, the migrant commutes from place of residence to the place of work on daily basis.

According to 2016, total population data of Thittokan Village Tract has 3,573 persons and the total population is 3,451 persons in 2015. Representatives of key informants and officials in each sample village were selected to gather general information about the research area. According to survey data results are as follows;

Internal migration is more a survival strategy, external migration, when successful, has a clear wealth accumulation objective. The most important factor for progressing from internal migration to external is the existence of social networks to support the migration process. According to the study conducted by surveying in 2015, 6.22 percent of villagers migrate to other countries (external migration) and 2.85 percent of villagers migrants in within country (internal migration) are migrants from the Thittokan Village Table (4), Figure (3, 4). And also, in 2016 surveying data, 6.97 percent of villagers migrate to other countries (international or external migration) and 3.30 percent of villagers migrants within country (internal migration) are migrants from the Thittokan Village Table (5), Figure (5, 6). However, there is a recent tendency among young migrants from the Thittokan Village going for cross-border or external migration to Thailand, China, and Malaysia.

Table 4. Internal Migration of Thittokan Village Tract, Magway Region, Myanmar (2014-2016)

Name	2014			2015			2016		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
Thittokan	32	31	63	47	36	83	51	42	93
Suutat	59	46	105	76	51	127	82	60	142
Sankan	27	21	48	29	26	55	27	21	48
Sanni	19	12	31	20	12	32	19	8	27
Grand Total	**137**	**110**	**247**	**172**	**125**	**297**	**179**	**131**	**310**

Source: Survey Results in 2014-2016

Gender in Migration in Thittokan Village Tract

In Thittokan Village Tract, migration is not gender neutral. Internal migration, both men and women migrate, while external migration is mostly male dominated. Most internal seasonal male migrants are either single or married the distance to the origin village is not very huge, so that they can regularly visit back to their home. Similarly, most female seasonal migrants are single and migrate to nearby areas as dependent of the spouse or family members. Therefore, the sector of work has a clear gender division with women being higher demanded in tea plantations, flower plantations and other agriculture work, services, and various factories.

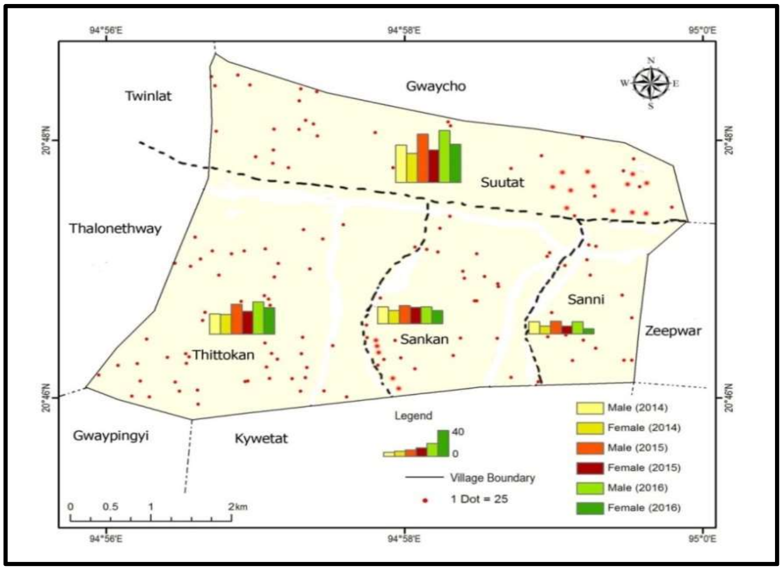

Figure 3. Internal Migration (Gender) of Thittokan Village Tract (2014-2016)

Source: Based on Table 8

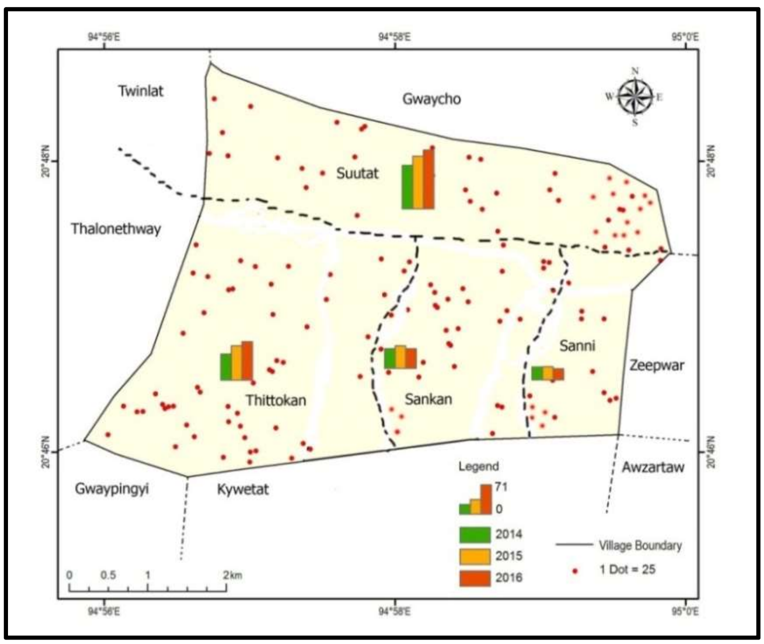

Figure 4. Internal Migration (Total) of Thittokan Village Tract (2014-2016)

Source: Based on Table 8

Table 5. External Migration of Thittokan Village Tract, Magway Region, Myanmar (2014-2016)

Name	2014			2015			2016		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Thittokan	32	1	33	37	1	38	43	1	44
Suutat	21	0	21	24	0	24	36	1	37
Sankan	19	0	19	23	0	23	26	0	26
Sanni	6	0	6	9	0	9	12	0	12
Grand Total	78	1	79	93	1	94	117	2	119

Source: Survey Results in 2014-2016

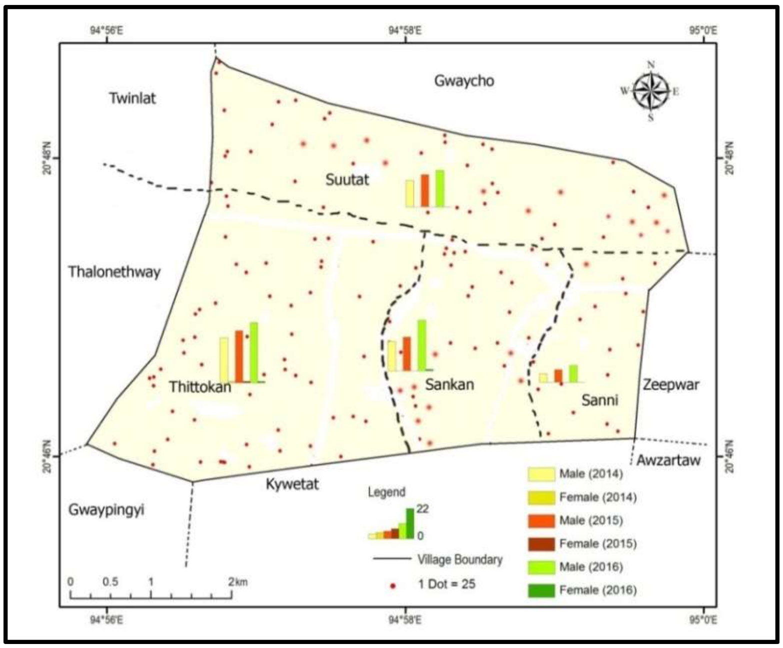

Figure 5. External Migration (Gender)of Thittokan Village Tract (2014-2016)

Source: Based on Table 9

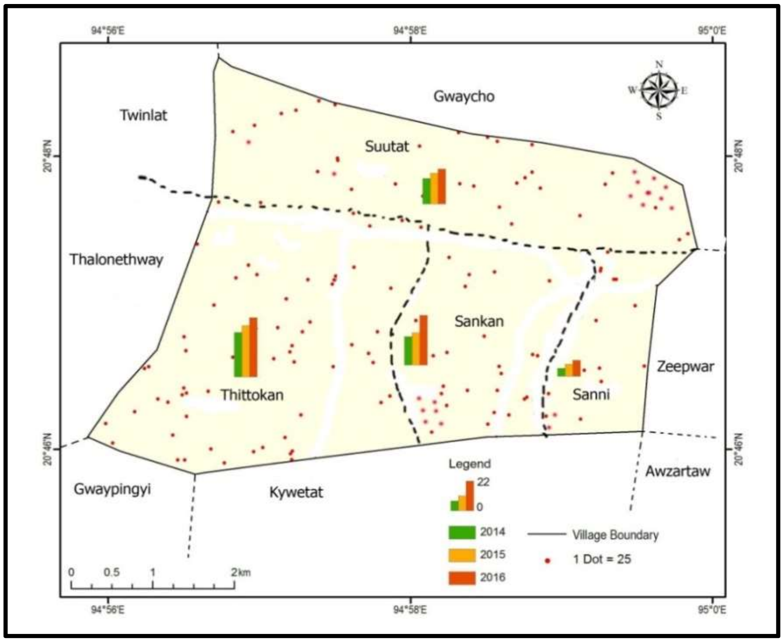

Figure 6. External Migration (Total) of Thittokan Village Tract (2014-2016)
Source: Based on Table 9

Reasons for Migration in Thittokan Village Tract

The reasons for migration (internal and external) are complex and vary from area to area. Migration may be mainly pushed by major economic, demographic and social status. As they mainly depend on agricultural activity, almost all of family members work at this work as household labour. However, in recent years, because of unpredictability of agricultural activity due to climate change, especially youth from households go outside to find other income opportunities which lead to decreased work force in agriculture. Moreover, the area is suitable for Ya cultivation, and the growing seasons is lengthy. But yield potential decrease when it is dry (few amount of rainfall) in growing season. The most common reason for migration is high income generation, year-round employment opportunity, better paying employment and improve skills. Thittokan Village Tract constitutes the largest proportion about 95 percent of migrants to Malaysia.

In Thittokan Village Tract, most migrants reported that lack of sufficient employment in the local community is the major reason for migration (internal and external). Also, mass migration movements are expected as a result of climate change, while agricultural production, including access to food. Episodes of low rainfall and drought are likely to become more frequent and severe, thus triggering further migration of those already living under difficult conditions. However, the reasons for migration also vary according to gender, age, skills and socio-economic situations. Based on such reasons and conditions, patterns of migration (internal and external) also vary. Such migrants are mostly temporary or seasonal migrants, depending on opportunities and family situations. For such households, migration is a livelihood and survival strategy with little wealth accumulation.

In internal migration, depending on the labour needs on the family farm, these migrants also usually visit their native village during the major agriculture season. The migrants' households and migrants are inter-dependent for mutual support during extreme events, such as crop failure in the native village and migrants failing in the migration process. The case takes place in a village with about 755households in Thittokan Village Tract, where some villagers are landless or near-landless. The livelihood of the entire village is dependent on the Ya crops. The income was not even sufficient to pay the costs of inputs. Thus, villagers were forced to sell their house to pay the debt incurred in Ya crops loss and, together with their family, they left the village for good. Among the remaining households, most youths have migrated to Yangon, Nay Pyi Taw and Mandalay cities to work in restaurants or flower or coffee/tea shops to supplement their household incomes.

Findings and Conclusions

Findings

The preferred destination areas for internal labour migrants from the Thittokan Village Tract are: (1) Yangon, Nay Pyi Taw and Mandalay for work in industrial zones, tea shops, restaurants, constructions, workshops, services and seasonal plantations (flowers & fruits); (2) Shan State and Tanintharyi Region to work in tea, sugarcane, rubber plantations, and mines; (3) North Kachin for work in gold and jade mines. Internal migration can be seasonal, temporary and permanent. Work in cities and mines are temporary or permanent in nature. While work in the agriculture sector and plantation sector is seasonal in nature. The type of migration depends on the existing social network, experiences and the socio-economic status of the households.

Most young males with slightly higher education (up to 8-15 years of schooling) find jobs in restaurants, workshops and as sales personnel in shops. The salary for such jobs ranges between 35,000-150,000Kyat per month with free food and accommodation.

The jobs in restaurants, also earn service tips and the work has certain career growth potential. Youth with lower level of education (up to grade 4) find work in the construction sector. Construction workers earn between 3,500-10,000 Kyat per day depending on the experience level with free food and accommodation. However, this sector reports high rates of work related accidents for which workers do not have any insurance cover. The traditional seasonal migration routes such as to flower plantations in Pyin Oo Lwin, tea plantations in Shan State and rubber plantation in Mon State are losing attraction, with mines and construction work getting more attraction. Also, there is increase in temporary and permanent migration with entire families. Seasonal migration is high in the case of Thittokan Village Tract, inter-region migration in the Village is more temporary in nature. Work is seasonal in nature from January to April. Workers return home during off-season to work in their farms. Most internal migrants are males of 8-40 years of age.

For instance, our migrant worker is a young man of 12 years with an up to grade 5 education level. He had little interest in study and was struggling with his exams. As many young men in his village had been, he wanted to drop studying and start working. He was eager to explore city life away from the village. Thus, though there was no economic reason, he decided to migrate to Yangon, Mandalay city to work in an auto spare parts shop. This job earned him 35,000 Kyat to 150,000 Kyat per month with free food and accommodation. They visited their village during the main planting and harvesting season to help their family within farming.

All of young males find jobs in restaurants, tea shops and as sales personnel in shops. The salary for such jobs ranges between 35,000-150,000Kyats per month with free food and accommodation. Jobs in restaurants are preferred as, apart from salary, they also earn service tips and the work has certain career growth potential. Youth with lower level of education (up to grade 4) find work in the construction sector. Construction workers earn between 3500-10,000 Kyat per day depending on their experience level with free food and accommodation. However, this sector reports high rates of work related accidents for which workers do not have any insurance cover Table (6).

As in another instance, migrant worker is a young woman and she is 22 years old and comes from Thittokan Village Tract. She has been working in a restaurant in Nay Pyi Taw since last 4 years as a waiter. She got the job through a friend. She completed grade 9 of schooling but failed in grade 10, and so decided to find job instead of repeating the exam. From her village, very few people migrate, and now she wishes to return back as well. However, she does not want to return back empty handed. Rather she wishes to be self-employed as well as to create jobs for others. She wishes to use the skills (technical, financial and other life skills) that she has learnt to open up her own restaurant in neighbouring village. About 2 years ago, the government has established a factory which employs a lot of work force both from outside the village as well as from cities. She has been saving a part of her salary to fulfil her dream. Apart from working as a waitress, she has been learning financial book keeping, cost calculations, kitchen handling etc. about the restaurant business and is now confident to succeed in her business.

Table 6. Wages in various sectors of employment in the Thittokan Village Tract **(**Internal**)**

Sector	Daily Wages	Month Pays	Food	Accommodations
Agriculture	3,000-5,000	90,000-150,000	Free	Mixed
Construction	3,500-10,000	105,000-300,000	Free	Free
Plantations	-	35,000-150,000	Mixed/ Free	Mixed
Sales person	-	50,000-200,000	Free	Free
Restaurant	-	100,000-200,000	Mixed/ Free	Mixed
Tea Shop	-	35,000-150,000	Mixed	Mixed

Source: Survey Results in 2014-2016

Table 7. Wages in various sectors of employment in the Thittokan Village Tract **(**External Migration**)**

Sector	Daily Wages	Month Pays	Food	Accommodations
Agriculture/ Plantation	-	350,000-450,000	Mixed	Free
Construction	-	350,000-500,000	Mixed/ Free	Free
Decoration	-	350,000-500,000	Mixed	Free
Sales person	-	200,000-450,000	Mixed	Free
Restaurant	-	350,000-450,000	Mixed/ Free	Free
Factories	-	350,000-450,000	Mixed/ Free	Free

Source: Survey Results in 2014-2016

There is also an increase in external migration to Thailand, Singapore, China, Malaysia, though it is still much lower compared to the Southeast. Most of villagers from the Thittokan Village Tract are reported to migrate to Malaysia to work in factories, constructions, decoration and as service workers Table (7). As this migration trend is already established, social networks are used to migrate and find jobs in destination locations. This external migrant is a 32 year old man from Thittokan Village Tract in Chauk Township. In April 2009, he and his wife started working in the plantation in Malaysia. Earlier she used to work in plantation which is far from the village. The decision to move to the plantation was due to its closer proximity to the village. Working in plantation, the couple could save 500,000 to 1000,000 Kyat per month. This money was used for consumption, education of children and a small portion invested in cattle and agriculture land. In 2010, he purchased a farm land for 2,500,000 Kyat and a cow for 250,000 kyat. In 2013, he made one more investment on cattle; purchasing 2 cattle for 3.5 lakhs each. After one year, he sold them for 6 lakhs each. He wants to invest in purchasing more cattle and farm land, because one day, wishes to have his own small livestock enterprise in the village Table (7).

Conclusions

Migration patterns in the study area are mainly diverse: internal migration, and external migration. Internal migration is higher than external migration in the study area. Within internal migration, again diverse patterns are observed – seasonal, shuttle, temporary and permanent migration. Internal migration within the study area is very high in summer. Reasons for migration from Thittokan Village Tract include relative poverty, lack of jobs, inability to earn enough money to survive. Thus, external migration is more a wealth accumulation strategy, whereas internal migration is more a survival strategy. Migrants are mostly employed in flower and vegetable plantations, factories, construction, restaurants, tea shops, services, and etc.Thittokan Village Tract is situated at Chauk Township, Magway District in Magway Region. There are 755 households and the population is 3,573. Special attention is paid to the development of agriculture, which is not only the backbone of economy but also the main occupation of the villagers. The study of case area based on natural environment factors, social factors and economic factors.

The aim of this paper is to review existing literature, and find evidence on linkages between internal and external migrations and poverty. It draws attention to many types of migration including internal migration, short-term external contract labour, cross-border mobility and regional migration and the different impacts that they having at the household level and beyond. The findings show the impact of migration on individual migrants; left behind family members; community; local economies; and national economies of origin. Villagers believed that both internal and external migration, contributes to the reduction of poverty in various ways, with some newly emerging studies revealing that migration helps poor families to cope with risk and to smooth incomes. Moreover, migration is an important livelihood strategy undertaken by poor rural populations to increase their income and employment security and options. The major reason for migration is the lack of year-round and sufficient income opportunities in the source locations and the demand for the labour in destination locations. However, there is a gradual trend in internal migration to progress from seasonal to year round temporary migration and permanent migration, and eventually to external migration. The transition from seasonal to temporary and permanent is particularly seen in the case of landless or near landless farmers and in case of smallholder farmers to external migration. Not only internal but also external migration is seasonal in nature at times. During surveys, most migrants expressed their wish to return to their native village provided there were sufficient work and income opportunities. Thus, it is also important to explore employment and income generation in native villages. Internal migration is mostly used as a survival strategy rather than external migration.

In the study area, more than wage difference, the lack of availability of off-farm work and seasonality of agriculture sector is the major cause of migration. Among the various sectors in which migrants are found working is construction sector that provides higher wages for poor rural villagers. The earning capacity is much higher for international migration compared to internal migration, when migration is successful. While a successful external migration can lead to accumulation of land, small business, a successful internal migration is still limited to bridging gaps in consumption demands of the household members.

Remittance earnings from internal migration is relatively small and mostly used to smoothen family consumption with little saving. On the other hand, remittance earnings external migration is higher savings and enough to undertake a small enterprise.

Future Prospects

1. Rural residents migrate as they do not have good opportunities near their home. Good schools, jobs, business opportunities, technology, etc. if made available can curb migration.
2. Better job prospects within rural areas will surely reduce the rate of migration.
3. Rural area needs to be developed to accommodate the migrant population with sufficient income opportunities for rural residents.
4. Agricultural materials will support rural farming system.

Acknowledgements

I am greatly indebted to Acting-Rector Dr. Nyunt Soe and Pro-Rector Dr. Ni Lar Myint Pyay University for their kind encouragement. Furthermore, the financial support for research project received from my parent is highly acknowledged. I would like to thank all my teachers who have taught me throughout my student life. Finally, I would also like to thank my colleagues and those who helped me throughout my work.

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J. Myanmar Acad. Arts Sci. 2018 **Vol. XVI. No.5**

URBAN DEVELOPMENT IN LASHIO, NORTHERN SHAN STATE/MYANMAR: TRADE FLOWS AND TRADE CONNECTIONS

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Abstract

Lashio is a largest trading town of northern Shan State. It is located on the main trading road connecting with China and Central Myanmar. Most of the traded commodities come from China, Yangon, Mandalay, Thailand and near townships. Most customers are from Lashio town and nearby village tracts. The paper investigates the main trade flows and connections, including seven main commodities: rice, corn, vegetables, grocery, clothes, electronic goods and car accessories. As the urban area expands, trading activities gradually expand from the town centre into urban expansion areas. Small shops and wholesale centres and their connections have been investigated.The paper is based on quantitative and qualitative fieldwork in Lashio. First a literature review took place and secondary data (numbers and types of shops) was collected from General Administrative Department of Lashio, Lashio City Development Committee and Lashio Trade Organization. Then key actors were asked in qualitative open interviews with local experts (retailers and wholesalers). Finally, a SWOT analysis comes to a comprehensive assessment.

Keyword: trade flows, trade connections, wholesalers, retailers, Lashio town, urban development, SWOT analysis

Introduction

Lashio as administrative, political, economic and cultural centre of Northern Shan State is located in key position on the major trade route from Myanmar to China. Its strategic linkage position in respect to its economic and geopolitical importance has developed during the last decades in connection with the gradual upgrading process of road infrastructure (especially the National Highway No. 3 (NR3) = Asian Highway No. 14 (NH14)) and in conjunction with the growing trade volume between Myanmar and China.

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Lashio Town is embedded in a large administrative area in the northeast of Shan State, south of the border between Myanmar and China. Northern Shan State comprises seven districts, namely Kyaukme District (in the west), Muse District (in the north), Laukkaing, Hopang and Matman Districts (in the east) and Lashio District (in the centre). Lashio District is composed of four townships, namely: Lashio (in the west), Theinni (in the north, also written: Hseni), Mineye (in the southwest, also written: Mongyai) and Tantyan (in the southeast, also written: Tangyan). Lashio Town comprises twelve wards: Lashio Gyi, Myanmar Khayo, Nampachi, Myowan, Aungthidar, Aungmyitta, Shwebonthar, Shweli, Thanlwin, Thirimahar, Aryondaw and Aungmingalar Wards.

Recent transformation processes in Northern Shan State

The recent political and economic processes in Northern Shan State have to be judged upon the long, distinctively different and very complicated history of Shan State (in terms of area the biggest amongst Myanmar's States and Regions, covering 23.2% of Myanmar's territory). Shan State is amongst the areas in Myanmar with the greatest ethnic diversity: Of the officially recognised 135 ethnic groups, 33 different groups reside in Shan State. In respect to the diversity of languages, at least eight different languages from different language families can be found, adding upon the ethnic diversity.

Lashio Township and Town

As statistical data on Lashio Township and Lashio Town are scarce, it is not possible to analyse comprehensively the current state of their demographic, economic and social development in detail, but based on the results of the 2014 Myanmar Population and Housing Census, at least an analysis of the general state of development on township basis is possible.

The entire Shan State comprises in total 5,824,432 inhabitants (MoIP 2015: 10); 76% of the persons live in rural areas. So the level of urbanisation in Shan State is still relatively low – which implies that Lashio Town is of relatively high importance within the urban and settlement network of Northern Shan State, being the only larger town with a surplus of urban centrality.

The ***demographic situation*** can be characterised as follows: Lashio Township is by far the most populous within Lashio District, which holds true also for its centrality and urban functionality. Lashio Township has 174,335 urban population (84,331 male and 90,004 female; sex ratio: 93.7) and 149,070 rural population; thus 53.9% are urban (MoIP 2015: 25). The total dependency ratio of Lashio Township is 57.5 (child dependency ratio: 50.4, old dependency ratio: 7.1) (MoIP 2015: 48). The substantial female surplus gives indication to the fact that the government and service sector is more developed here than in the neighbouring townships (i.e. government, education and trade sectors are comparatively active).

Table 1: Total population, sex and sex ratio in Lashio District (2014)

	Total population				**Population in conventional households**			**Population in institutions**		
	Both sexes	**Male**	**Female**	**Sex ratio**	**Both sexes**	**Male**	**Female**	**Both sexes**	**Male**	**Female**
LASHIO District	612,248	299,530	312,718	95.8	583,342	276,528	306,814	28,906	23,002	5,904
Lashio Township	323,405	158,512	164,893	96.1	305,923	145,840	160,083	17,482	12,672	4,810
Theinni Township	56,662	28,604	28,058	101.9	54,190	26,414	27,776	2,472	2,190	282
Mineye Township	59,376	28,391	30,985	91.6	56,768	25,914	30,854	2,608	2,477	131
Tantyan Township	172,805	84,023	88,782	94.6	166,461	78,360	88,101	6,344	5,663	681

Source: MoIP 2015: 16

Lashio Township is subject to certain, but not yet larger migration flows, partly in-migration, partly out-migration (see Table 2). Obviously, labour migration at least contributes to increased food security for the respective households. Even though the contribution from remittances from labour migrants does not seem to be significant, it contribute to improve the food security of the households. About 23% of the households asked in a study reported at least one household member was working outside the community. Compared to other townships, labour out-migration is not so common in Lashio (all figures: WFP 2011: 14). About 11% of the labour migrants chose Myanmar, 12.6% other countries as destination (WFP 2011: 15).

Table 2: Former conventional household members of Lashio Township living abroad by country of residence (2014)

	Total	Thailand	Malaysia	Singa-pore	China	Japan	Korea	India	USA	Other
LASHIO	23,713	14,939	1,146	597	6,325	72	18	19	161	436
Male	11,472	7,591	587	173	2,786	30	13	8	84	200
Female	12,241	7,348	559	424	3,539	42	5	11	77	236

Source: MoIP 2015: 73

The ***economic situation*** in and around Lashio Town is, first, based on local agriculture which produces mainly rice and maize; crop yields in the flat areas near Shweli River are higher than in the mountainous areas. Maize comprised about 31% of the yields in the larger area of Lashio Township and the townships north of Lashio to the Chinese border (2008/9; WPF 2011: 5). Local agricultural products and minerals are mostly exported to Yunnan Province/China. Commodities from other parts of Myanmar - e.g. timer, fish and sea foods, rise, pulses and rubber as well as non-food items - are transported through Lashio to China (WPF 2011: 5). Second, the economy is based on trade, which flourishes particularly within Lashio Town. In recent years, with rising trade volumes and values, trade activities on the international and national scale has grown substantially – which is reflected on local level in the growing numbers of retail and individual shops of different sizes. The trade flows are obviously multidirectional, depending on the type of goods, but cannot be further quantified due to the lack of reliable statistical data on trade. As Shan State is belonging to the so-called Golden Triangle, an important, yet illegal and not quantifiable contribution to the state's economy is generated by the production and trade of opium, heroin and meth-amphetamine (yaba) synthetic drugs (UNDP 2015: 7).

In respect to labour force and thus the economic basis for the households, Lashio Township shows the typical characteristics of a regionally important centre, as town with higher administrative, educational and health-related functions and economic powerhouse for a wider area. This becomes obvious in regards to the usual activity status: Relatively high amounts of people are working as government employees. Also the numbers of private employees (i.e. those owning and running own businesses) and the numbers of full-time students are comparatively high.

Table 3: Usual Activity Status in Lashio Township (2014)

	Total	Employee (government)	Employee (private)	Employer	Own account worker	Unpaid family worker	Sought work	Did not seek work
Lashio	261,728	10,358	36,640	3,308	68,953	22,130	4,488	1,378
Male	127,228	6,522	25,332	2,317	41,888	9,990	2,834	895
Female	134,500	3,836	11,308	991	27,065	12,140	1,654	483

	Total	Full time student	Household worker	Pensioner, retired, elderly	Ill, disabled	Other
Lashio	261,728	43,102	43,874	16,784	1,725	8,988
Male	127,228	20,704	3.096	6,813	931	5,904
Female	134,500	22,398	40,776	9,971	794	3,084

Source: MoIP 2015: 194

Indirect indication about the economic prosperity of Lashio Township can be drawn from the level of available infrastructure. First and foremost the existing road network and it upgrade level are a key indicator: As the National Highway No. 3 has been frequently and recently upgraded and widened over the last years, this reflects the status of economic prioritisation for the country (*here we should in detail describe its state of development). Second, the statistical indicator 'source of lighting' for the households in Lashio Township are a strong indicator for the level of available infrastructure supply: From 64,932 households in total, 34,468 used electricity, 1,501 kerosene, 8,572 candles, 1,822 battery, 447 private generators, 1,991 private water mills, 15,548 solar systems/energy and 583 other sources (MoIP 2015: 275); this indirectly reflects a high urban standard in comparison with other regional cities.

Lashio as trade town: Trade connections between Central Myanmar and China

As reliable figures on the trade volume and flows are yet lacking.

Research Questions

Against this background, which illustrates the importance of Lashio as trade town between Central Myanmar, Northern Shan State and China, the aim of the study is to look deeper into the trade flows and trade connectivity of Lashio within the frame of the recent socio-economic development of Myanmar and Northern Shan State. The guiding research questions are:

(a) How did the general situation of trade in Northern Shan State and Lashio develop and which are the challenges and prospects of local, regional and international trade connections?

(b) Which are the major trade flows in Lashio and how does trade develop for selected commodities?

(c) How can the major challenges and future prospects of trade in Lashio be evaluated?

(d) Which suggestions can be given in order to support an improved development of trade from which the entire area and society can benefit?

Material and Methods

The research project is part of the joint Myanmar-German research project '81+ Urban Network System of Myanmar'; fieldwork was conducted in February/March 2017. The research design is based on a mixed-methods approach which used systematic literature search, secondary data collection, unsystematic talks, in-depth interviews, mapping methodologies and field observations in Lashio in order to understand and evaluate the local, regional and international trade flows and connections. Literature search included reviewed articles, published documents and unpublished studies, as far as it could be retrieved from international libraries. Secondary data include statistical data from the local administration. During the empirical fieldwork, mapping and field observation, 3 unsystematic talks, 19 in-depth qualitative talks with shop owners and wholesale shops and 6 in-depth interviews with experts on the general socio-economic development of Lashio were conducted. Based on the findings, a synthesising SWOT analysis allowed to assess the trade situation.

Trade and Economic Development

In the study area Trade sector is becoming more developed recently. According to Win Maung et al 2005, Myanmar has always been trade - oriented. This was the case in the colonial period, but it is equally true of the present. The commodities composition of Myanmar exports was changed during the last two decades. Rice has become relatively less significant over time. The decline in the relative importance of rice has been eclipsed by the emergence of other exports, especially different kinds of pulses.

Nowadays the trade comes out of peoples or governments sector is compared to private sector since there is open market economy. There are six people's corporations in Northern Shan State that take the responsibility of trade and commerce for both wholesale and retail provided by the Ministry of Trade.

The Township Co-operative Society also carries out the distribution and sale of the consumer goods, textile goods, garments, agricultural implements and tools, domestic household good, medicine and drugs, and electrical appliances (Mya Min, 2010).

Trade flows and markets in Lashio Town

There is one big market under the Lashio administration serve the town, namely Myoma Zaygyi .There are 18 blocs and 1860 shops. Three medium bazaars: Mansu, railway station (Butaryone) and Aungmingalar bazaars and 11 small bazaars are opening in Lashio Town. But there are only small bazaars that open in the morning only. Within the Mansu bazaar has 143 shops (Lashio City Development Committee, 2017). Within the big market foodstuff, edibles and clothes are mainly sold. The exports of Lashio Township are mostly agricultural products and the main imports are consumer's goods, medicine, electrical appliances, agricultural implements and tools and building and construction materials.

Transportation is an important factor for trade flows and regional development. Padauk, Shwe Kankaw and Cherry blocs are near main roads which Lanmataw, Hanthawaddy, Theinni and Bogyoke roads. Thus, well accessible trade facilities for buyers and sellers (Table 4).

Table 4: Number of blocs and shops in Myoma Zaygyi, Lashio town, 2017

Sr No.	Bloc	Shop
1	**Padauk**	**258**
2	**Shwe Kankaw**	**349**
3	**Cherry**	**382**
4	Aung Thapye	**182**
5	Shwe Withmone	**48**
6	Shwe Bontha	**25**
7	Myat Lay	**84**
8	Kan Baw Za	**8**
9	Nay Yee Yee (Thazin)	**139**
10	Bogyoke Lane Zayyone	**41**
11	Han Thar Waddy Lane Zayyone	**14**
12	Swel Taw Yone	**22**
13	Grocery block	**176**
14	Near grocery block	**9**
15	Hnin Si	**49**
16	No. 2 Bank Lane	**18**
17	Inn Waa Bank	**13**
18	Fish and Meat	**43**
Total		**1860**

Source: Lashio City Development Committee, 2017

Major trade flows in Lashio and connections

There are numerous influencing factors on trade flows. These are: price of goods, population, fluctuation of price, infrastructure, and changes of climatic conditions, transport cost and the nature of town (depends on Chinese customers).

Lashio is the largest city in Northern Shan State of Myanmar and being as a trade town. It is located on the main trading road connecting China and Central Myanmar.

The distribution of goods and services between wholesalers, retailers and consumers is one of the major economic activities of the any town. Growing economic activities due to improved connectivity to central Myanmar and the China border area invests in trade sector. New infrastructural developments are supporting, including the upgrading of the transportation, connecting different parts of the town. Transportation Committee is raised to district status and thus it carries out the transportation and distribute of Trade's Corporation merchandize goods and army foodstuff.

On the other hand, in the central part of the town around the Myoma Zaygyi Area and Lashio University emerge stores, minimart, small food shops and services. Consequently, economic power and trade sector growing not only within the urban area but also in border areas. Trade flows and volume of maize increased from 140,069tons in 2007-08 to 455,240tons in 2015-16. This is due to increase demand from China. Some maize cultivated area were replaced in former poppy cultivated land (Table 5).

Table 5: Increase Trade Volume of Maize by Township (Metric Ton)

Sr. No.	Township	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
1	Lashio	33000	34261	53415	41846	92919	100781	116570	138832	150010
2	Tan Yan	10520	12625	15876	17985	19853	20985	22893	24956	25515
3	Mime Yae	3658	3725	3956	4012	4900	4983	5007	5160	5200
4	Thein Ni	7213	7520	7783	7856	7922	8017	8250	8900	9400
5	Kyaukme	10658	12760	14010	13507	14810	21520	42150	53050	61520
6	Thi Paw	48972	49856	54993	79112	60369	61265	62369	62967	63691
7	Naung Cho	24063	25182	26916	58412	42520	49885	50267	98264	120031
8	Nan Ma Tu	1985	2005	2737	3535	1879	5290	17968	18006	19873
	Total	140069	147868	179686	226265	245172	272726	325474	410135	455240

Source: Trade Organization, Mansu Bazar, Lashio 2017

The major trade flows and connections, including seven main commodities: rice, corn, vegetables, grocery, clothes, electronic goods and car accessories. Mapping Categories of Lashio in Figure (1).

Figure 1: Location Map of interviewees regarding trade in Lashio
Source: Own fieldwork, base map: General Administrative, Lashio,2017

The numbers of selected commodities in nine big blocs in (Table 6). Within this nine blocs the number of grocery shops are 74 and located in Padauk bloc. The number of clothes and shores shops are 127 in Shwe Kan Kaw and 301 shops in Cheery blocs. The number of shops more than others blocs. Consequently, most of the sellers depend on grocery, clothes and shoes goods.

Table 6: The numbers of selected commodities in nine big blocs

Sr. no	Name of bloc	rice, corn and beans	vegetables (green-grocery)	grocery	clothes and shoes	electrical goods	car accessories
1	Padauk	3	-	74	61	-	
2	Shwe Kant Kaw	2	-	47	127	3	
3	Cheery	-	-	2	301	8	
4	Aung Thapye	14	-	10	98	10	
5	Hnin Si	-	1	-	46	-	
6	Nay Yee Yee (Thazin)	-	4	2	81	-	
7	Western part of Innwa	3	-	2	1	-	
8	Bank street		4	14	-	-	
9	Grocery bloc	7	2	37	24	1	
	Total	**29**	**11**	**188**	**239**	**22**	

Source: Data derived from LCDC, 2017 and data modified by researchers

The pattern of the trade flows aremultidirectional and it's depend on type of goods. Among them,clothes, shoes and grocery shops are more than others. Most of sellers depend on clothes, shoes and grocery goods.

The major trade flows of riceand corn:

The exports of Lashio Township are mostly agricultural products especially, rice and corn. Rice and corn depots are about 30 in Lashio township. Most of the export area is China and others are Tantyan, Naunmon, Nanmatu, Kyaukme and Nantlan.

The imports areas are Yangon, Daik Oo, Pyay, Shwe Bo, Mataya, Oaktwin and Kwanloan area (villages of northern Shan State). These are Myanmar species. Shan species imports from Loikaw, Nyaung Shwe, Lashio, Maiyal, Kyaukme and Maikaw.

The major trade flows of vegetables:

There are six vegetables shops in Myoma Zaygyi and three vegetables shops are in outside of market. The exports area of vegetables shops are neighboring villages of Lashio township.

The major imports areas are China, Mandalay, Kyaukse, Bhamaw, Kathar, Kyaukme and Chaung Oo.

The major trade flows of Grocery:

The major exports areas are Tantyan, Thepaw, Naungmon and nearly villages**.** The major imports areas are Muse, Mawthaung and Yemathin.

The following table 7 gives a summery and overview of current weaknesses and strenghts as well as future opportunities and threats as they have pointed out and discussed.

Table 7. Comprehensive SWOT analysis on local interviewees (regarding on selected commodities)

		Present		Future	
Sr No.	**Commodities**	**S**trength	**W**eakness	**O**pportunities	**T**hreat
1	Rice	-high experiences -depends on local Products -interested on their jobs -can live together with families	-difficulty in beginning -long time high invest -giving loans	- job opportunities for local people -difference between export price and local price	-depends on Chinese customers
2	Corn	-local products -home economy -can export by public transport -replace in pops land	-export problem -reduce selling	-job opportunities for local people -become owner	-needs peaceful -to live
3	Vegetables	-traditional business -regular income -more sale to Chinese customers	-political issue -irregular climatic conditions -needs cold storage -can sell only 6 months	-more sale in special occasion -better chance for family	-transportation problems in Goudetwin area
4	Grocery	-	- even buy expire goods -depends on Kwegaung -needs to grow in local	-can support to family	-don't worry
5	Clothes	-traditional businesses -more sale in winter -skilled	-can sell only Thedingut and water festival -clothes shortage problems -labour shortage	- job opportunity for family -preserve on inherent	-high price for shop -worry for security
6	Electronic Goods	- responsible in concerning company - interested	-unskilled -technological difficult to sell -more competition than others	-more widely society	-don't worry for next 3 years -depends on politics
7	Car accessories	-traditional business	-delay to delivery -narrow street -unsystematic car park	-job opportunities for local people	-don't worry

Source: Khin Khin Soe, Mya Min, Min Mnin Aye, Frauke Kraas, 2017

The major trade flows of Clothes:

The major exports areas are Lashio, Nanmatu, Theinni, Tantyan, Maiyal, Kautkhaing and Mai Shu. The major imports areas are Muse, Mandalay, Yangon, Taunggyi, Kachin (Moehnyi), Thailand and China.

The major trade flows of of Electronic goods:

The major export areas are neighbourings villages of Lashio, Theinni, Namlan, Maiyal and Maiyaw. The major imports areas are Yangon, Mandalay and China.

The major trade flows of of Car accessories:

The major export areas are Yangon, Thailand, India and China. The major imports area are Namlan, kyaukme, Nanpaung and Lashio.

Suggestions for improved development (interview answers):

- Clear rules and regulations – and consequent implementation
- Modernisation of shops and trade areas, but no high rise buildings (as already second floor is not accepted by customers)
- More car and motor cycle parking space
- Cleaner markets and solving of waste problem
- Space for expansion of businesses
- Better education for and better work morale of workers
- Relocation of passenger busses from centre to other place
- Improved roads from/to villages in order to foster trade opportunities
- Improvement of internet connections to support digital trade orders

Discussion: future prospects

- Traders **know very well their situation** and are very responsible and engaged in local economy
- Many traders are **content with the general facilities** (no complaints about water, electricity, little on infrastructure) and with the **administration**

(many underline the improvements in recent years, but sometimes hint lack of participation)#

- Traders **do not worry for labour force** (but complain about high turn-over, frequent drop-outs) and **not for future development**
- **Connection** (information flow, support, exchange) between traders and administration seems good ("they care well")
- High and **growing international competition** hinders local development (Lashio as transit town only, no benefits)

As currently labour out-migration is not so common: measures for **keeping that important labour force** should be taken

Conclusion and Recommendations

Improvement for trade conditions

- Improvement of **general investment** climate: **real market economic conditions, support for small/medium traders**
- **Diversification** of and **economic support** for local agricultural and handicraft products from the city and its hinterlands
- Improvement of **financing sector**: capital support, longer loans
- Improvement of **transportation**, solving of problems in Goktwin area (currently: delays for trade flows)
- Infrastructure: **cheaper** costs for **transportation**
- Communication: improvement of communication and internet lines
- Establishment of international **product standard system**
- Marketing: establishment of local product and country **brands**
- Implementation of **quality control**
- **Negotiation**: reliable bilateral and multilateral trade agreements

Acknowledgement

This research project was possible because of the strong support by many institutions, experts and citizens. In Lashio, the Township General Administrative Office (GAD), members of the Lashio City Development Committee and the Department of Urban and Housing Development (Ministry of Construction) were extraordinarily helpful. Numerous vendors and citizens shared their experience and views. The project was part of joint Myanmar-German research fieldwork conducted by the Institute of Geography, University of Cologne/Germany, the Department for Urban and Housing Development (DUHD), Ministry of Construction, the Departments of Geography at the University of Yangon, the University of Mandalay and Lashio University and the Centre of Excellence (CoE) for Urban and Regional Development at the University of Yangon. Intensive Fieldwork was undertaken in February/March 2017.

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