Construction of Parabolic Trough a Solar Collector

Win Khaing[1], Kyaw Wai Oo[2], Myint Naing Soe[3]

Abstract

The parabolic trough solar collector is very important in the study of application of solar energy. The constructed solar collector is 12ft in length and focal length is about 8 inches and it is situated in Monywa University. The diameter of absorber is 2.5 inches and 12ft long. The absorber is constructed with iron pipe. The efficiency of the collector is about 60%

Introduction

Parabolic trough power plants use parabolic trough collectors to concentrate the direct solar radiation onto a tubular receiver. Large collector fields supply the thermal energy, which is used to drive a steam turbine, which, on its part, drives the electric generator. Parabolic trough power plants constitute the biggest share of the installed concentrating solar power technology. Distinguishing between parabolic trough power plants, Fresnel power plants, solar tower power plants and dish/Stirling systems, the parabolic trough power plants provide over 90% of the capacity of concentrating solar power plant technology that is in operation or in construction in September 2010. Among the planned additional capacity (at the same date) more than 50% are constituted by parabolic trough power plants. The following figure shows the absolute numbers and the shares of the four technology types among the plants in operation, in construction, in the planning stage, and, finally, the sum of all of them. The energy flow in a parabolic trough power plant has the following structure: Direct solar radiation is concentrated and converted into thermal energy. The thermal energy is converted into pressure energy of vapour, which is converted into kinetic energy. The kinetic energy is finally transformed into electrical energy, the final product of the power plant.

Materials and Method

Mirror material

The main requirements for appropriate mirror materials are their reflective properties. The reflectivity must be high. The reflectivity of a surface is a number that indicates the fraction of the incident radiation that is reflected by the surface. In general, the reflectivity is different for different wavelengths so that it has to be specified for a given wavelength or a given wavelength range, for instance for the visible light range. In the case of solar applications, the solar spectrum is of interest. Generally, a "solar weighted reflectivity" is indicated that takes into consideration that there are different energy contents at different wavelengths in the solar spectrum. The solar weighted reflectivity indicates, hence, the fraction of solar energy that is reflected on a mirror. Furthermore, reflection can be distinguished in specular reflection and diffuse reflection. Specular reflection means that the light that comes from a single incoming direction is reflected into a single outgoing direction. Specular

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reflection is mirror-like reflection. According to the law of reflection the direction of the incoming light and the direction of the outgoing light have the same angle with respect to the mirror surface normal. At diffuse reflection, on the contrary, the incoming light is reflected in a broad range of directions. In CSP applications, only specular reflectivity is of interest, because the reflected radiation must have a defined direction.

The Absorber

The absorber tube must have a sufficient diameter to permit a high intercept factor. The intercept factor is the ratio of the total reflected radiation to the reflected radiation that hits the absorber surface. On the other hand, the absorber diameter should not be too big in order to maintain the thermal losses low. An absorber tube with a big diameter has a large surface area per meter and loses therefore more heat than an absorber tube with a smaller diameter. In order to estimate the appropriate absorber tube diameter, we will take an absorber, the diameter of which is just sufficient to receive all the radiation reflected by a geometrically perfect parabolic mirror, i.e. by a parabolic mirror that does not have slope errors and that does not widen the beam radiation due to microscopic errors. The necessary absorber diameter to reach an intercept factor of 1 depends, then, on the distance of the absorber tube from the mirror and on the solar beam angle. The solar beam angle is the opening angle of the direct solar radiation. It amounts to 32' (it is not zero because of the extension of the Sun disc). Because of this beam angle the Sun image at an ideal parabolic trough is not a one-dimensional mathematical line but has a two-dimensional extension. The rays that are reflected from the mirror are reflected with a corresponding angular variance of 32'. The distance between the mirror and the absorber is different for the different points of the mirror. The largest distance is between the mirror rim and the absorber. So we take the rim of the parabolic mirror to determine the absorber diameter.

Method

Analytical Model

Parabolic troughs have a focal line, which consists of the focal points of the parabolic cross-sections. Radiation that enters in a plane parallel to the optical plane is reflected in such a way that it passes through the focal line. A proof of the existence of a focal point is presented in the annex. An appropriate analytic representation of a parabola is

$$y = \frac{1}{4f}x^2,$$

where is the focal length, i.e. the distance between the vertex of the parabola and the focal point.

Parameters for the geometrical description of a parabolic trough

In order to describe a parabolic trough geometrically, the parabola has to be determined, the section of the parabola that is covered by the mirrors, and the length of the trough. The path of parallel ray of parabola is shown in figure 2.3.1. to figure 2.3.4.

The following four parameters are commonly used to characterize the form and size of a parabolic trough: **trough length**, **focal length**, **aperture width**, i.e. the distance between one rim and the other, and **rim angle**, i.e. the angle between the

optical axis and the line between the focal point and the mirror rim: The **length of the trough** is an unproblematic measure and does not need any explanation.

The **focal length**, i.e. the distance between the focal point and the vertex of a parabola, is a parameter that determines the parabola completely (in the mentioned mathematical expression of a parabola, the focal length f is the only parameter).

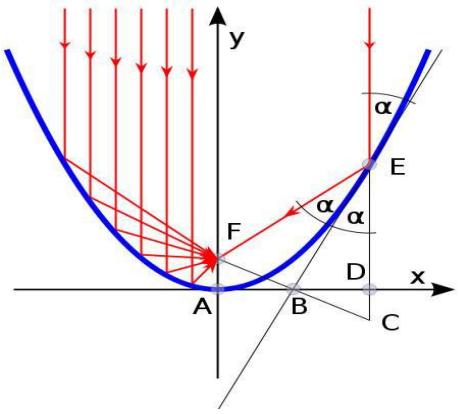

Fig.2.3.1 Path of parallel rays at a parabolic mirror

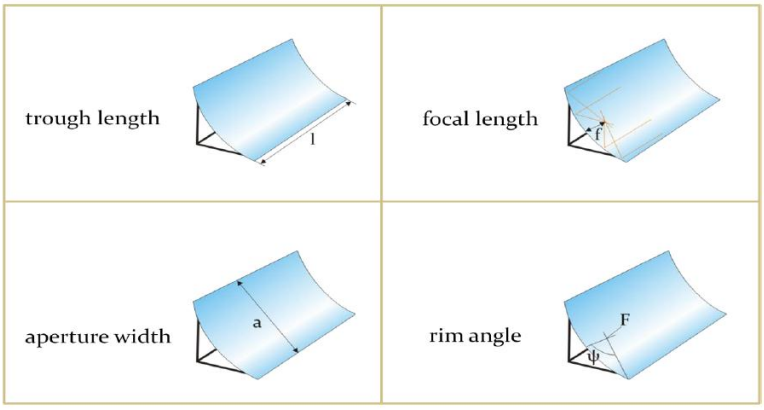

Fig. 2.3.2 Geometrical parabolic trough parameters

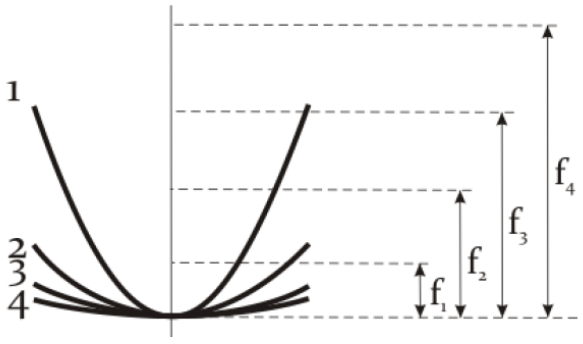

Fig.2.3.3 Relation between the focal length and the rim angle for a constant trough aperture width

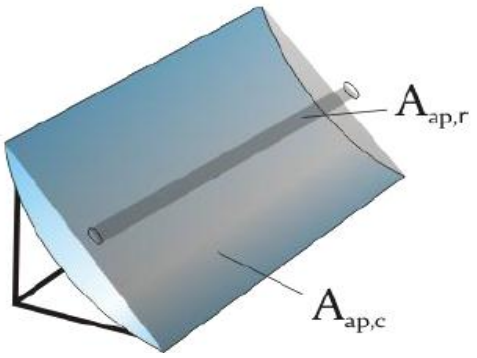

Figure 2.3.4 Collector aperture area and receiver aperture area

Concentration ratio

The concentration ratio is one of the central parameters of the collector. It is decisive for the possible operating temperatures of the parabolic trough power plant. The concentration ratio is defined as the ratio of the radiant flux density at the focal line, or, what is the same, at the Sun image, , to the direct irradiance at the aperture of the collector, $G_{b,\,ap}$:

$$C = \frac{G_{im}}{G_{b,ap}}$$

Now, the irradiance is different in different points of the Sun image. That's why we can consider, first, a punctual concentration ratio. In this case, has to be determined at a point within the focal line in order to determine the concentration ratio in relation to that specific point. Or we can consider, second, a mean concentration ratio taking as the ratio of the mean irradiance at the focal line to the direct normal irradiance. Concerning the mean concentration ratio (contrary to the punctual one) there is an easy way to specify it without any measurement: The **geometrical concentration ratio** is a useful approximation. It is defined as the ratio of the collector aperture area to the receiver aperture area.

$$C_G = \frac{A_{ap,c}}{A_{ap,r}}$$

While it is clear what the collector aperture area is (see above), it is much less clear what has to count as the receiver aperture. In many cases, the projected area of the absorber tube is chosen. In this case the receiver aperture area is a rectangle with the area, where is the absorber tube diameter. The concentration ratio is, then:

$$C_G = \frac{a \cdot l}{d \cdot l} = \frac{a}{d}$$

In the chapter "Solar Radiation" it was demonstrated that the maximal mean concentration ratio in linear focusing collectors, taking the Sun image area in the focal plane, is 107.5. The maximal geometrical concentration ratio in real systems, accepting the projected absorber tube area as, is 82.

Another possibility is to take the irradiated absorber surface area as the receiver aperture area. In real parabolic troughs this would mean that the whole absorber tube surface area is the receiver aperture area16:

$$C_G = \frac{a \cdot l}{\pi \cdot d \cdot l} = \frac{a}{\pi \cdot d} .$$

This definition would lead to a lower geometrical concentration ratio. However, the concentration ratio according to the projected areas is more commonly used.

Construction Of Parabolic Trough Collector Using Thin Zinc Plate

Construction of Reflective Trough Collector

The reflective materials used for this project is thin zinc plate. The thickness of plate is 0.01mm. This particular material was chosen for its high reflectivity and low cost. The step by step construction of skeleton for collector are as shown in Fig.3.1.1(a),(b), (c) and (d) and zinc sheet isplaced on the skeleton of collector as shown in Fig. 3.1.2. The completion of zinc plateon the collector is shown in Fig. 3.1.3.

Frame of Collector

The base structure of trough solar collector is constructed with steel structure. It is 12 ft long and 3ft in bread. 3x2 square hollow tubes are used for frame of structure. To be moveable the collector, two bearing balls are fixed at the bar as shown in figure 3.2.2. Figure 3.2.1 shows the frame for solar collector.

Fig.3.1.1 (a) Cutting and bending iron rods

Fig.3.1.1 (b) Welding the parabolic skeleton of trough and base structure

Fig.3.1.1 (c) Installation of skeleton of trough on base structure

Fig.3.1.1 (d) Painting red oxide

Fig.3.1.2 Arrangement of zinc sheet on the skeleton of collector

Fig.3.1.3. The completion of parabolic trough solar collector

Figure 3.2.1 The frame of solar collector

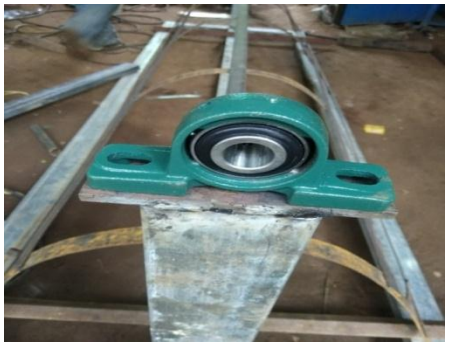

Figure 3.2.2 Setup of ball bearing

Construction of Absorber

Absorber material is very important in construction of solar collector. It can absorb radiation and emits radiation. Heat energy is lost by conduction, convention and radiation. Some metal are good in heat conduction but emit radiation as soon as the temperature is changed. They cannot store the heat for a long time.In construction of absorber, iron metal container is used as absorber. It is cylindrical shape and 2.5 inch in diameter and 10ft long. It consists of one inlet and one outlet as shown in Fig. 3.3.1. The volume of absorber is 377.04inch^3.

Fig.3.3.1 Absorber

Experimental System Design Parameters

Parameter values of constructed system is as shown in Table 3.4.1. . Table

Parameter Value of constructed system

Parameter	Unit	Value
Area of aperture (D)	ft^2	25
Area of absorber	ft^2	4.97
Focal length (f)	inch	9
Dish depth (d)	inch	18
Focal diameter (dF)	inch	2

A focal length of 8 inches was chosen to give the absorber. In the design of all collectors such disturbances as gravity and wind loading need to be considered. This is true for this concept as well. A discussion of active compensation using servo controlled of the tensioning cable or wires and overall stiffness selection to mitigate the effects of such disturbances is the subject of our current studies and beyond the scope of this paper.

Results and discussion

Construction of parabolic trough concentrator using thin sheet of zinc.

There are four main sections in construction of parabolic trough solar concentrator;

(i) Construction of petals in parabolic shape

(ii) Construction of base structure

(iii) Construction of absorber

(iv) Data collection of light intensity and absorber temperature

The skeleton of dish is constructed with flat iron plates (2x0.3) inch in bread and thickness. The length of iron plate is about 4ft. Five iron pla are assembled in parabolic shape. And then, the iron rods are bent to get specified angle and they are placed on the pivot assembly as shown in Fig.3.1.1(b). After that skeleton of iron rods are welded. The completion of skeleton development can be seen in Fig.3.1.1 (c). Major problem of parabolic concentrator is its weight and fabrication of collector. Firstly, thin zinc sheets are installed on the skeleton. Nine zinc metal sheets are used as petals for parabolic concentrator. They are tied to the skeleton rods of parabolar. The installation of zinc petals are as shown in Figure.3.1.2. The parameters of collector is as shown in Table.3.4.1.. The completion of the collector is shown in Fig.3.1.3. The base structure is as shown in figure 3.1.1.(c). The absorber tube is 9.5 ft long and 2.5 inches in diameter. It is as shown in figure 3.3.1.

Experimental Setup and Measurement

"TRIE iLab" is a powerful experimental data processing software, which is developed by Jiangsu Suweier Science Technology Co., Ltd. It supports experimental design, data collection and storage, data analysis and calculation and so on. After installation of TRIE iLab software, we can measure the many parameters by using electronic sensor. In this project, light sensor and temperature sensors are used and; manuals of sensors are also as shown in Fig.3.5.2, Fig.3.5.3and Fig.3.5.4. Experimental setup of temperature is as shown in Fig.4.2.1. Before measurement, water is filled into the absorber. And then the temperature prove is inserted into the absorber and set the time interval of acquisition for five minutes. Surface temperature sensor is placed at the surface of absorber. And then data is collected graphically and stored as excel data. At the same time, surface temperature and light intensity are also measured for five minute. Experiments have been done for four days. The results of measurements are as shown in Table 4.2.1 to Table 4.2.10. It can be concluded the efficiency of the trough solar collector is approximately about 60%. .

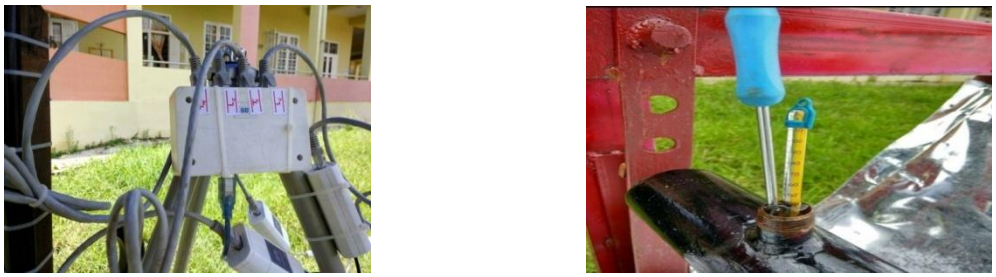

Figure 4.2.1 Experimental setup and measurement of light intensity and temperature measurement

Table (4.2.1) Light intensity and temperature of absorber of Parabolic Collector investigated on 20.1.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding - Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	75.3	105.1	25	42
2	11:00 AM	84.0	112.4	28	45
3	12:00 AM	86.8	167.5	33	49
4	1:00 PM	87.5	196.0	37	54
5	2:00 PM	83.5	208.0	39	60

Table (4.2.2) Light intensity and temperature of absorber of Parabolic Collector investigated on 22.1.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding- Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	75.8	108.1	26	42
2	11:00 AM	83.6	126.0	30	49
3	12:00 AM	86.6	153.1	37	50
4	1:00 PM	84.5	157.3	38	61
5	2:00 PM	80.2	141.6	40	63

Table (4.2.3) Light intensity and temperature of absorber of Parabolic Collector investigated on 24.1.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding-Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	75.5	105.1	28	44
2	11:00 AM	79.3	112.4	35	48
3	12:00 AM	86.5	167.5	38	59
4	1:00 PM	87.1	195.5	40	62
5	2:00 PM	83.7	200.0	40	64

Table (4.2.4) Light intensity and temperature of absorber of Parabolic Collector investigated on 26.1.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding- Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	76.5	114.0	28	30
2	11:00 AM	84.2	125.0	36	48
3	12:00 AM	85.1	190.2	38	49
4	1:00 PM	86.0	230.9	41	57
5	2:00 PM	86.0	210.1	42	61

Table (4.2.5) Light intensity and temperature of absorber of Parabolic Collector investigated on 28.1.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding- Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	67.4	100.5	31	36
2	11:00 AM	79.2	105.5	37	47
3	12:00 AM	83.0	110.2	38	50
4	1:00 PM	87.1	120.1	39	56
5	2:00 PM	86.5	134.2	40	62

Table (4.2.6) Light intensity and temperature of absorber of Parabolic Collector investigated on 14.2.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding-Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	75.5	100.1	33	35
2	11:00 AM	78.6	115.2	34	52
3	12:00 AM	83.2	120.9	36	61
4	1:00 PM	84.4	124.4	37	68
5	2:00 PM	82.2	129.5	38	73

Table (4.2.7) Light intensity and temperature of absorber of Parabolic Collector investigated on 16.2.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding- Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	72.2	82.2	32	36
2	11:00 AM	77.0	106.9	33	49
3	12:00 AM	80.5	125.5	35	60
4	1:00 PM	82.4	131.1	36	65
5	2:00 PM	78.9	139.9	37	72

Table (4.2.8) Light intensity and temperature of absorber of Parabolic Collector investigated on 18.2.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding-Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	68.4	89.1	29	35
2	11:00 AM	79.5	102.5	33	52
3	12:00 AM	79.8	114.3	35	58
4	1:00 PM	80.5	122.5	36	63
5	2:00 PM	81.6	129.4	35	66

Table (4.2.9) Light intensity and temperature of absorber of Parabolic Collector investigated on 20.2.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding- Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	68.4	89.1	29	35
2	11:00 AM	79.5	102.5	33	52
3	12:00 AM	79.8	114.3	35	58
4	1:00 PM	80.5	122.5	36	63
5	2:00 PM	81.6	129.4	35	66

Table (4.2.10) Light intensity and temperature of absorber of Parabolic Collector investigated on 22.2.2019

No.	Time (Hour:min)	Input Intensity (kLux)	Output Intensity (kLux)	Surrounding - Tem (ºC)	Water-Tem (ºC)
1	10:00 AM	77	98.2	29	35
2	11:00 AM	80.5	112.8	30	45
3	12:00 AM	86.2	125.2	32	60
4	1:00 PM	87.5	127.1	33	68
5	2:00 PM	80.5	140.2	34	71

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REFERENCES

Romero. M., Martinez. D and Zarza. E., Terrestrial solar thermal power plants: on the verge of commercialization, 4th Int. Conf. on Sol. Power from Space, Granada, (2004) PP. 81-89.

Aden, Meinel. B and Marjjorie meilen P. (1976), Applied Solar Energy, An Introduction, third edition, Addison-Wesly Publishing Company, Philippines, (document).

Frank Kreith and Jan, Kreider. F. (1978), Principles of Solar Engineering. Hemisphere Publishing Corporation, New York.

Donald Rapp. (1981), Solar Energy. Prentice-Hall, Inc.

Water Quality Analysis of Four Public Wells in Mandalay City

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Abstract

The aim of the research is to give the environmental awareness to the public. Public dug wells are commonly used for drinking, bathing, cleaning and cooking purposes. Four water samples from four dug wells, named Yarma, Coco-plant, Cow Lake and Salty Water (briny) along Shwe-Ta-Chaung Creek in Tampawaddy, Mandalay City were examined with Public Health Laboratory to determine the water quality. The water chemical analysis reports that water from Coco-plant and Salty Water (briny) dug wells is chemically potable and the water from the other two dug wells are chemically unpotable. The results are compared with the World Health Organization (WHO) standard values to identify the existence of contaminants above the acceptable levels. The water supply wells should not be located near the disposal area.

Key words: Yarma Dug Well, Coco-plant Dug Well, Cow Lake Dug Well, Salty Water (briny) Dug Well, Shwe-Ta-Chaung Creek

Introduction

Groundwater is also one of our most important sources of water for irrigation. Unfortunately, groundwater is susceptible to pollutants. Groundwater contamination occurs when man-made products such as gasoline, oil, road salts and chemicals get into the groundwater and cause it to become unsafe and unfit for human use. Water is used at homes for consumption such as drinking, cooking, bathing and cleaning. The important way to access to water is either through a municipal water supply from a major city or through wells. Wells exist in two forms, dug wells and tube wells. These water supplies can be contaminated through different mechanisms. Water can be contaminated with either chemicals or microorganisms through improper installation of wells, or being in close proximity to sources of pollution such as sewage or lands fills. In this research, the water quality of four dug wells beside Shwe-Ta-Chaung Creek was tested for chemical contamination in Public Health Laboratory, Mandalay, Myanmar. The four dug wells are Yarma Dug Well, Coco-plant Dug Well, Cow Lake Dug Well and Salty Water (briny) Dug Well. They are located in Tanpawaddy, Chanmyatharsi Township, Mandalay City, Myanmar and situated beside Mandalay on Sagaing-Shwebo Road. The main focus of this research is to investigate the water quality of four dug wells located adjacent to the Shwe-Ta-Chaung Creek in Mandalay, Myanmar.

Chemical testing of water quality relies on the comparison of the results with WHO drinking water guidelines to identify contaminants. Most of these contaminants are only of concern with chronic exposure (long-term exposure). Some contaminants that occur in water are the matter of concern because of effects arising from acute exposure (short-term exposure). Sewage, garbage and liquid waste of households,

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agricultural lands and factories are discharged into lakes and rivers. Early types of water pollution were usually due to contamination from human and animal waste, which caused major outbreaks of diseases like cholera. The toxic elements effect on human health including organs, damage respiratory tract disorder, lung diseases, skin diseases and other illnesses.

It is suspected that the waste water from the Shwe-Ta-Chaung Creek may be contaminating the dug wells degrading the water quality. Thus, this research is to determine the impact of the Shwe-Ta-Chaung Creek on ground water by the analysis of water samples collected at four sites next to the Shwe-Ta-Chaung Creek in March 2018.

Materials and Methods

Description of Research Area

Yarma Dug Well, Coco-plant Dug Well, Cow Lake Dug Well and Salty Water (briny) Dug Well are located in the Tanpawaddy, Chanmyatharsi Township, Mandalay City, Myanmar and situated beside Mandalay-Sagaing-Shwebo Road.

Sample Location (Sampling Site) and Collection

Yarma Dug Well lies at approximately 21º 55' 46" north latitude and 96º 4' 4" east longitude. It is located in the Yarma quarter, Tanpawaddy Chanmyatharsi Township, Mandalay City, Myanmar and situated beside Mandalay-Sagaing-Shwebo Road. The well was constructed over 100 years ago. Typically, the well-base is about 30 feet away from the Shwe-Ta-Chaung Creek during the dry season. A garbage area is about 75 feet away from the well-base. The diameter of the well is 6.5 feet and the thickness of the well is 1.5 feet, which is constructed with a brick lining. The height of the well base is 1.5 feet above the ground. The depth to water from the top of the well casing is 20.5 feet on 5th March 2018.The photograph of Yarma Dug Well beside the Shwe-Ta-Chaung Creek is shown in Figure (1).The width of Shwe-Ta-Chaung Creek near Yarma Dug Well is about 25 ft and it lies approximately at 21º 55' 45" north latitude and 96º 4' 4" east longitude. Raw sewage from downtown Mandalay flows into the creek. In this area, the creek is not lined by concrete. Waste water is in direct contact with the ground in the creek. Yarma Dug Well region is located adjacent to the rubbish filter site along Shwe-Ta-Chaung Creek. The photograph of trash located near the Yarma Dug Well in the bank of the Shwe-Ta-Chaung Creek is also shown in Figure (2).

Coco-plant Dug Well lies at approximately 21º 56' 13" north latitude and 96º 4' 20" east longitude. It is located in the southern quart of Tanpawaddy Tharmoe, Tanpawaddi Chanmyatharsi Township, Mandalay City, Myanmar and situated beside Mandalay-Sagaing-Shwebo Road. The well was constructed over 100 years ago. Typically, the well-base is about 9.5 feet away from Shwe-Ta-Chaung Creek during the dry season. A garbage area is about 15 feet away from the well-base. The diameter of the well is 4.9 feet and the thickness of the well is 10 inches, which is constructed with a brick lining. The height of the well base is 5 inches above the ground. The depth to water from the top of the well casing is 17 feet on 5th March 2018. The photograph of Coco-plant Dug Well beside the Shwe-Ta-Chaung Creek is shown in Figure (3).The width of Shwe-Ta-Chaung Creek near Coco-plant Dug Well is about 25ft and it lies approximately at 21º 55' 59'' north latitude and 96º 4' 11" east longitude. Raw sewage from downtown Mandalay flows into the creek. In this area,

the creek is not lined by concrete. Waste water is in direct contact with the ground in the creek. The photograph of small trash located near the Coco-plant Dug Well in the bank of the Shwe-Ta-Chaung Creek is also shown in Figure (4).

Cow Lake Dug Well lies at approximately 21º 56' 20'' north latitude and 96º 4' 21" east longitude. It is located in the northern quart of Tanpawaddy Tharmoe, Tanpawaddy Chanmyatharsi Township, Mandalay City, Myanmar and situated beside Mandalay-Sagaing-Shwebo Road. The well was constructed over 100 years ago. Typically, the well-base is about 45 feet away from Shwe-Ta-Chaung Creek during the dry season. A garbage area is about 95 feet away from the well-base. The diameter of the well is 4 feet and the thickness of the well is 11 inches, which is constructed with a brick lining. The height of the well base is 9 inches above the ground. The depth to water from the top of the well casing is 21 feet on 5th March 2018. The photograph of Cow Lake Dug Well beside the Shwe-Ta-Chaung Creek is shown in Figure (5).The width of Shwe-Ta-Chaung Creek near Cow Lake Dug Well is about 20 ft and it lies approximately at 21º 56' 18" north latitude and 96º 4' 22" east longitude. Raw sewage from downtown Mandalay flows into the creek. In this area, the creek is lined by concrete. Waste water is not in direct contact with the ground in the creek. The photograph of trash located near Cow Lake Dug Well in the bank of the Shwe-Ta-Chaung Creek is also shown in Figure (6).

Salty Water (briny) Dug Well lies at approximately 21º 56' 51" north latitude and 96º 4' 34" east longitude. It is located in the No.505, golden pot, Kyung Lone Oat Shaung quarter, Tanpawaddy Chanmyatharsi Township, Mandalay City, Myanmar and situated beside Mandalay-Sagaing-Shwebo Road. The well was constructed over 100 years ago. Typically, the well-base is about 36.5 feet away from Shwe-Ta-Chaung Creek during the dry season. A garbage area is about 65 feet away from the well-base. The diameter of the well is 4 feet and the thickness of the well is 10 inches, which is constructed with a brick lining. The height of the well base is 1 feet above the ground. The depth to water from the top of the well casing is 19 feet on 5th March 2018. The photograph of Salty Water (briny) Dug Well beside the Shwe-Ta-Chaung Creek is shown in Figure (7).The width of Shwe-Ta-Chaung Creek near Salty Water (briny) Dug Well is about 22 ft and it lies approximately at 21º 56' 49" north latitude and 96º 4' 30" east longitude. Raw sewage from downtown Mandalay flows into the creek. In this area, the creek is lined by concrete. Waste water is not in direct contact with the ground in the creek. There is vegetation between the well and the creek. The photograph of small trash located near Salty Water (briny) Dug Well in the bank of the Shwe-Ta-Chaung Creek is also shown in Figure (8). The water samples were collected from each well with one liter bottle. Photograph of location map of four dug wells in Tanpawaddy is represented in Figure (9).

Public Health Laboratory, Ministry of Health and Sports

The water quality parameters (Appearance, Colour, Turbity, pH value, Total Solids, Total Hardness, Total Alkalinity, Ca, Mg, Cl, SO_4 and Fe) in four water samples of Yarma Dug Well Coco-plant Dug Well, Cow Lake Dug Well and Salty Water (briny) Dug Well were tested at Public Health Laboratory, Ministry of Health and Sports, Mandalay City.

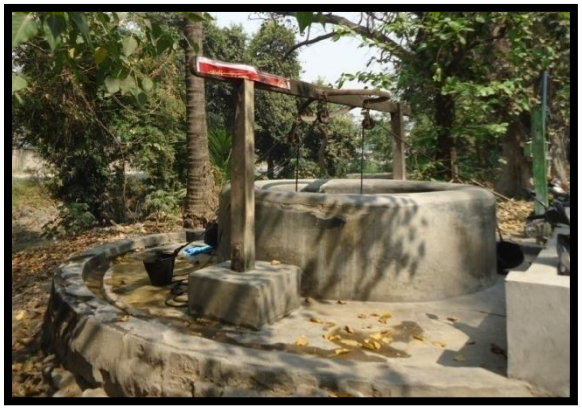

Figure (1) Yarma Dug Well beside the Shwe-Ta-Chaung Creek

Figure (2) Trash located near the Yarma Dug Well on the bank of the Shwe-Ta-Chaung Creek

Figure (3) Coco- plant Dug Well beside the Shwe- Ta-Chaung Creek

Figure (4) Trash located near Coco-plant Dug Well on the bank of Shwe-Ta-Chaung Creek

Figure (5) Cow Lake Dug Well beside the Shwe-Ta-Chaung Creek

Figure (6) Trash located near Cow Lake Dug Well on the bank of Shwe-Ta-Chaung Creek

Figure (7) Salty Water Dug Well beside the Shwe-Ta-Chaung Creek

Figure (8) Trash located near Salty Water Dug Well on the bank of Shwe-Ta-Chaung Creek

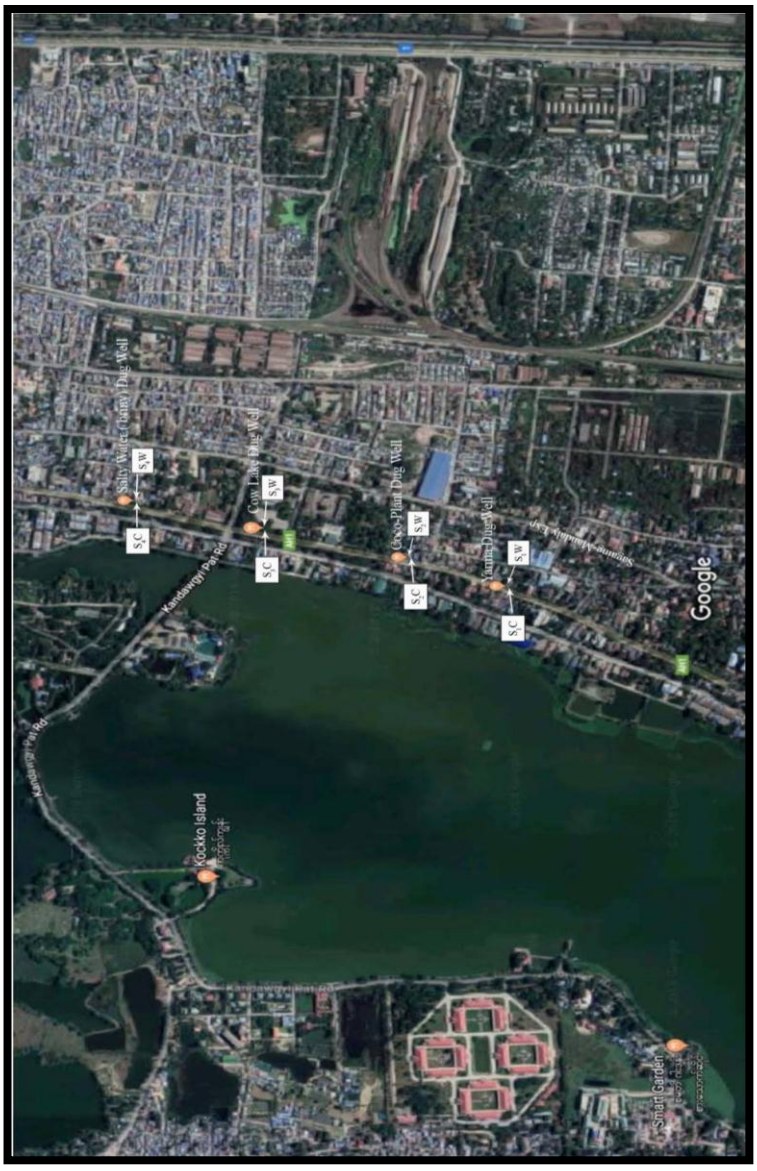

Figure (5) Location Map of four dug wells in Tanpawaddy Township, Mandalay City, Myanmar

Results and Discussions

In the research work, four water samples from Yarma Dug Well, Coco-plant Dug Well, Cow Lake Dug Well and Salty Water (briny) Dug Well were collected and analyzed in Public Health Laboratory, Ministry of Health and Sports. The chemical analysis of the water in Yarma Dug Well is listed in Table (1). The chemical analysis of the water in Coco-plant Dug Well is shown in Table (2). The chemical analysis of the water in Cow Lake Dug Well is also listed in Table (3). The chemical analysis of the water in Salty Water (briny) Dug Well is also shown in Table (4).

The water quality parameters of four dug wells were tested in Public Health Laboratory. According to the results, total solids are greater than maximum permissible level in Yarma Dug Well. Total alkalinity is much greater than maximum permissible level in Yarma Dug Well. Calcium Ca is slightly near to maximum permissible level in the Yarma Dug Well. Other parameters (Colour, pH value, Total Hardness, Magnesium Mg, Chloride C1 and Sulphate SO_4) of Yarma Dug Well are under the maximum permissible level. Total solids and total alkalinity are much greater than maximum permissible level in Cow lake Dug Well. Total iron Fe was found only in Cow Lake Dug Well among the four dug wells but less than maximum permissible level. Other parameters (Colour, pH value, Total Hardness, Calcium Ca, Magnesium Mg, Chloride Cl and Sulphate SO_4) of Cow Lake Dug Well are under the maximum permissible level.

The remarks of water chemical analysis report from Yarma Dug Well and Cow Lake Dug Well are chemically unpotable. The depth to water from the top of the well casing of Yarma Dug Well and Cow Lake Dug Well are greater than the other two dug wells. The water from Yarma Dug Well and Cow Lake Dug Well are used only for taking baths, washing clothes and cleaning dishes. It is not used for drinking purpose.

The water quality parameters of Coco-plant Dug Well and Salty Water (briny) Dug Well are under the maximum permissible level. According to the remarks of water chemical analysis report from Coco- plant Dug Well and Salty Water (briny) Dug Well is chemically potable. The water from Coco-plant Dug Well and Salty Water (briny) Dug Well are now used only for taking baths, washing clothes and cleaning dishes.

Table (1) Chemical Analysis of the water in Yarma Dug Well

No.	Parameter	Result	Maximum Permissible Level[WHO]	Unit
1	Appearance	Slightly Turbid	-	-
2	Colour (Platinum, Cobolot Scale)	7	50	Units
3	Turbidity (Silcoda Scale Unit)	-	25	NTU
4	PH value	7.1	6.5 to 9.2	-
5	Total Solids	1571	1500	mg/l
6	Total Hardness (as $CaCO_3$)	310	500	mg/l
7	Total Alkalinity (as $CaCO_3$)	1105	950	mg/l
8	Calcium as Ca	112	200	mg/l
9	Magnesium as Mg	7	150	mg/l
10	Chloride as Cl	140	600	mg/l
11	Sulphate as SO_4	147	400	mg/l
12	Total Iron as Fe	Nil	1	mg/l

Table (2) Chemical Analysis of the water in Coco-plant Dug Well

No.	Parameter	Result	Maximum Permissible Level [WHO]	Unit
1	Appearance	Slightly Turbid	-	-
2	Colour (Platinum, Cobolot Scale)	6	50	Units
3	Turbidity (Silcoda Scale Unit)	-	25	NTU
4	PH value	7.1	6.5 to 9.2	-
5	Total Solids	1109	1500	mg/l
6	Total Hardness (as $CaCO_3$)	270	500	mg/l
7	Total Alkalinity (as $CaCO_3$)	715	950	mg/l
8	Calcium as Ca	80	200	mg/l
9	Magnesium as Mg	17	150	mg/l
10	Chloride as Cl	100	600	mg/l
11	Sulphate as SO_4	147	400	mg/l
12	Total Iron as Fe	Nil	1	mg/l

Table (3) Chemical Analysis of the water in Cow Lake Dug Well

No.	Parameter	Result	Maximum Permissible Level [WHO]	Unit
1	Appearance	Clear	-	-
2	Colour (Platinum, Cobolot Scale)	6	50	Units
3	Turbidity (Silcoda Scale Unit)	-	25	NTU
4	PH value	7.3	6.5 to 9.2	-
5	Total Solids	1808	1500	mg/l
6	Total Hardness (as $CaCO_3$)	230	500	mg/l
7	Total Alkalinity (as $CaCO_3$)	1495	950	mg/l
8	Calcium as Ca	84	200	mg/l
9	Magnesium as Mg	5	150	mg/l
10	Chloride as Cl	120	600	mg/l
11	Sulphate as SO_4	49	400	mg/l
12	Total Iron as Fe	0.01	< 0.3	mg/l

Table (4) Chemical Analysis of the water in Salty Water (briny) Dug Well

No.	Parameter	Result	Maximum Permissible Level [WHO]	Unit
1	Appearance	Slightly Turbid	-	-
2	Colour (Platinum, Cobolot Scale)	6	50	Units
3	Turbidity (Silcoda Scale Unit)	-	25	NTU
4	PH value	7.3	6.5 to 9.2	-
5	Total Solids	1109	1500	mg/l
6	Total Hardness (as $CaCO_3$)	260	500	mg/l
7	Total Alkalinity (as $CaCO_3$)	780	950	mg/l
8	Calcium as Ca	96	200	mg/l
9	Magnesium as Mg	5	150	mg/l
10	Chloride as Cl	60	600	mg/l
11	Sulphate as SO_4	118	400	mg/l
12	Total Iron as Fe	Nil	1	mg/l

Conclusion

Water treatment will be needed to describe those processes used to make water more acceptable for a desired end-use. These can be used to get drinking water and for industrial processes, medical and many other uses. The goal of all water treatment process is to remove existing contaminants in water. Surface water usually needs to be filtered and disinfected, while ground water often needs to have hardness (Ca and Mg) removed before disinfection. Effective municipal wastewater treatment system to human health, ecosystem stability, and water quality will be needed. The results of water samples indicate that water supply wells should not be located near the disposal area. Moreover, garbage should not be dumped near the wells. Although the canal of Yarma Dug Well and Coco-plant Dug Well are not lined by concrete and the canal of Cow Lake Dug Well and Salty Water (briny) Dug Well are lined by concrete. It is indicated that the water supply wells are impacted by contamination associated with waste water.

The waste water creek should be reconstructed with appropriate protection. The creek should be constructed with concrete. The creek is too shallow so that it is flooded during the rainy season and the waste water reached to the base of the well. So the garbage should not be dumped near the well base. It is indicated that the water supply wells are impacted by contamination associated with waste water. Humans and animals should not use the wells located near the waste water creek for any purpose.

AKNOWLEDGEMENTS

First and foremost I would like to express my gratitude to Dr Aye Aye Han, Pro-Rector of Banmaw University, for her kind permission to carry out this work. I am also grateful to Professor Dr Than Than Lwin., Head of Physics Department, Banmaw University for her valuable suggestions.

References

Lawrence A R et al., (2000), Hydrogeology Journal, 8, 564

Natro J P & Kaper J B, (1998), Clinical Microbiology Reviews, 11, 142

Foster S S D & Chilton P J, (2004), Hydrogeology Journal, 12, 15

World Health Organization, (2006), Guidelines forDrinking Water Quality [electronic resources]

WAITING-LINE MODELS

Khin San Aye*

Abstract

In this paper, we illustrate the basic features of a waiting line model and consider the waiting line situation at the Golden Muffler Shop. We study the part of waiting-line model. Firstly, we study single channel waiting-line and secondly, multiple channel waiting-line with arrivals.

Characteristics of a Waiting-Line System

In this paper, we take a look at the three parts of a waiting-line, or queuing, system:

1. Arrivals or inputs to the system. These have characteristics such as population size, behavior, and a statistical distribution.
2. Queue discipline, or the waiting line itself. Characteristics of the queue include whether it is limited or unlimited in length and the discipline of people or items in it.
3. The service facility. Its characteristics include its design and the statistical distribution of service times.

We now examine each of these three parts.

Arrival Characteristics

The input source that generates arrivals or customers for a service system has three major characteristics:

(i) Size of the arrival population.

(ii) Behavior of arrivals.

(iii) Pattern of arrivals (statistical distribution).

Size of the Arrival (Source) Population

Population sizes are considered either unlimited (essentially infinite) or limited (finite). When the number of customers or arrivals on hand at any given moment is just a small portion of all potential arrivals, the arrival population is considered unlimited, or infinite. Examples of unlimited populations include cars arriving at a big-city carwash, shoppers arriving at a supermarket, and students arriving to register for classes at a large university. Most queuing models assume such an infinite arrival population. An example of a limited, or finite, population is found in a copying shop that has, say, eight copying machines. Each of the copiers is a potential "customer" that may break down and require service.

Pattern of Arrivals at the System

Customers arrive at a service facility either according to some known schedule (for example, one patient every 15 minutes or one student every half hour) or else they arrive randomly. Arrivals are considered random when they are independent of

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one another and their occurrence cannot be predicted exactly. Frequently in queuing problems, the number of arrivals per unit of time can be estimated by a probability distribution known as the Poisson distribution. For any given arrival time (such as 2 customers per hour or 4 trucks per minute), a discrete Poisson distribution can be established by using the formula

$$P(x) = \frac{e^{-\lambda}\lambda^{x}}{x!} \quad \text{for } x = 0,1,2,3,4,...,$$

where $P(x)$ = probability of x arrivals.

x = number of arrivals per unit of time,

λ = average arrival rate,

$e = 2.7183$ (which is the base of the natural logarithms).

Figure 1 illustrates the Poisson distribution for $\lambda = 2$ and $\lambda = 4$. This means that if the average arrival rate is λ = 2 customers per hour, the probability of 0 customers arriving in any random hour is about 13%, probability of 1 customer is about 27%, 2 customers about 27%, 3 customers about 18%, 4 customers about 9%, and so on. The chances that 9 or more will arrive are virtually nil. Arrivals, of course, are not always Poisson distributed (they may follow some other distribution). Patterns, therefore, should be examined to make certain that they are well approximated by Poisson before that distribution is applied.

$$\text{Probability} = P(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}$$

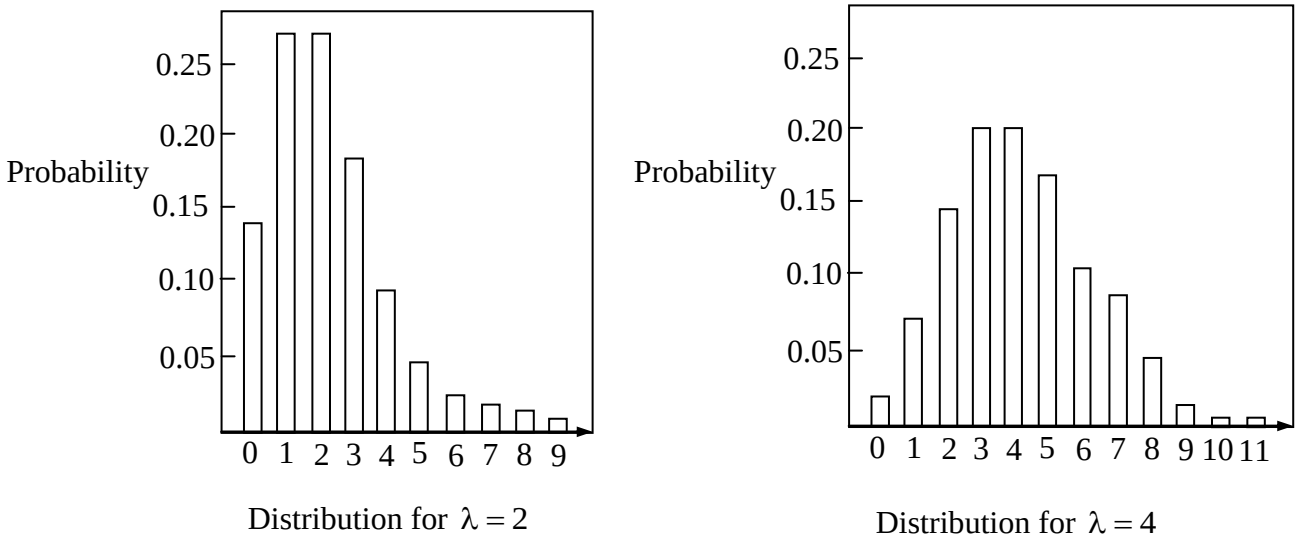

Figure 1

Behavior of Arrivals

Most queuing models assume that an arriving customer is a patient customer. Patient customers are people or machines that wait in the queue until they are served and do not switch between lines. Unfortunately, life is complicated by the fact that people have been known to balk or to renege. Customers who balk refuse to join the waiting line because it is too long to suit their needs or interests. Reneging customers

are those who enter the queue but then become impatient and leave without completing their transaction. Actually, both of these situations just serve to highlight the need for queuing theory and waiting-line analysis.

Waiting-Line Characteristics

The waiting line itself is the second component of a queuing system. The length of a line can be either limited or unlimited. A queue is limited when it cannot, either by law or because of physical restrictions, increase to an infinite length. A small barbershop, for example, will have only a limited number of waiting chairs. Queuing models are treated in this module under an assumption of unlimited queue length. A queue is unlimited when its size is unrestricted, as in the case of the toll booth serving arriving automobiles.

A second waiting-line characteristic deals with queue discipline. This refers to the rule by which customers in the line are to receive service. Most systems use a queue discipline known as the first-in, first-out (FIFO) rule. In a hospital emergency room or an express checkout line at a supermarket, however, various assigned priorities may preempt FIFO. Patients who are critically injured will move ahead intreatment priority over patients with broken fingers or noses. Shoppers with fewer than 10 items may be allowed to enter the express checkout queue. Computer - programming runs also operate under priority scheduling. In most large companies, when computer produced paychecks are due on a specific date, the payroll program gets highest priority.

Service Characteristics

The third part of any queuing system are the service characteristics. Two basic properties are important: (1) design of the service system and (2) the distribution of service times.

Basic Queuing System Designs

Service systems are usually classified in terms of their number of channels (for example, number of servers) and number of phases (for example, number of service stops that must be made). A single-channel queuing system, with one server, is typified by the drive-in bank with only one open teller. If, on the other hand, the bank has several tellers on duty, with each customer waiting in one common line for the first available teller, then we would have a multiple-channel queuing system. Most banks today are multichannel service systems, as are most large barbershops, airline ticket counters, and post offices.

In a single-phase system, the customer receives service from only one station and then exits the system. A fast-food restaurant in which the person who takes your order also brings your food and takes your money is a single-phase system. So is a driver's license agency in which the person taking your application also grades your test and collects your license fee. However, say the restaurant requires you to place your order at one station, pay at a second, and pick up your food at a third. In this case, it is a multiphase system. Likewise, if the driver's license agency is large or busy, you will probably have to wait in one line to complete your application (the first service stop), queue again to have your test graded, and finally go to a third counter to pay your fee. To help you relate the concepts of channels and phases, Figure 2 presents four possible channel configurations.

Service Time Distribution

Service patterns are like arrival patterns in that they may be either constant or random. If service time is constant, it takes the same amount of time to take care of each customer. This is the case in a machine-performed service operation such as an automatic car wash. More often, service times are randomly distributed. In many cases, we can assume that random service times are described by the negative exponential probability distribution.

Figure 3 shows that if service times follow a negative exponential distribution, the probability of any very long service time is low.For example, when an average service time is 20 minutes (or three customers per hour), seldom if ever will a customer require more than 1.5 hours in the service facility. If the mean service time is 1 hour, the probability of spending more than 3 hours in service is quite low.

Measuring the Queue's Performance

Queuing models help managers make decisions that balance service costs with waiting-line costs. Queuing analysis can obtain many measures of a waiting-line system's performance, including the following:

(a) Average time that each customer or object spends in the queue.

(b) Average queue length.

(c) Average time that each customer spends in the system (waiting time plus service time).

(d) Average number of customers in the system.

(e) Probability that the service facility will be idle.

(f) Utilization factor for the system.

(g) Probability of a specific number of customers in the system.

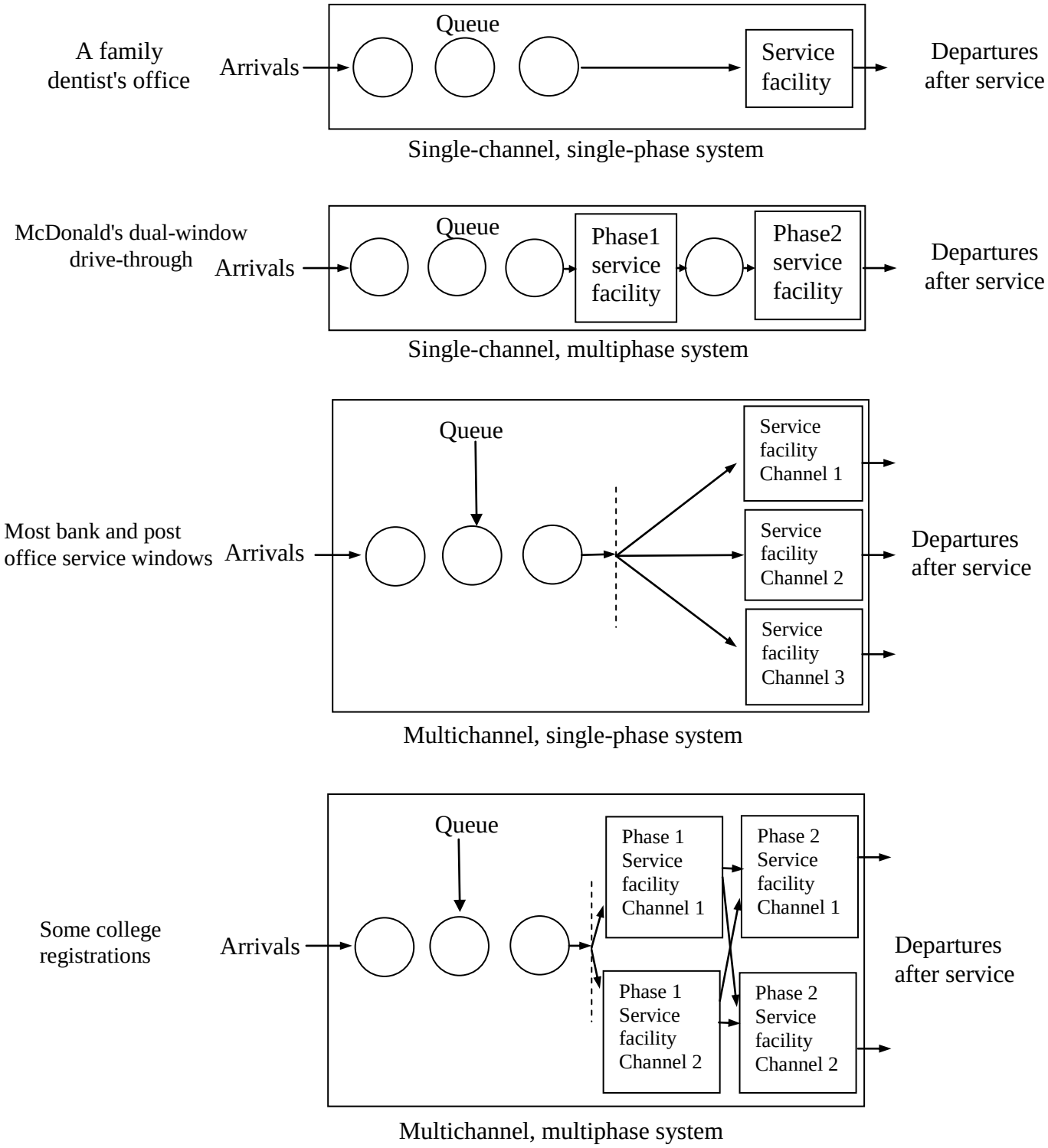
A family dentist's office
Arrivals
Queue
Service facility
Departures after service
Single-channel, single-phase system
McDonald's dual-window drive-through
Arrivals
Queue
Phase1 service facility
Phase2 service facility
Departures after service
Single-channel, multiphase system
Most bank and post office service windows
Arrivals
Queue
Service facility Channel 1
Service facility Channel 2
Service facility Channel 3
Departures after service
Multichannel, single-phase system
Some college registrations
Arrivals
Queue
Phase 1 Service facility Channel 1
Phase 2 Service facility Channel 1
Phase 1 Service facility Channel 2
Phase 2 Service facility Channel 2
Departures after service
Multichannel, multiphase system

Figure 2

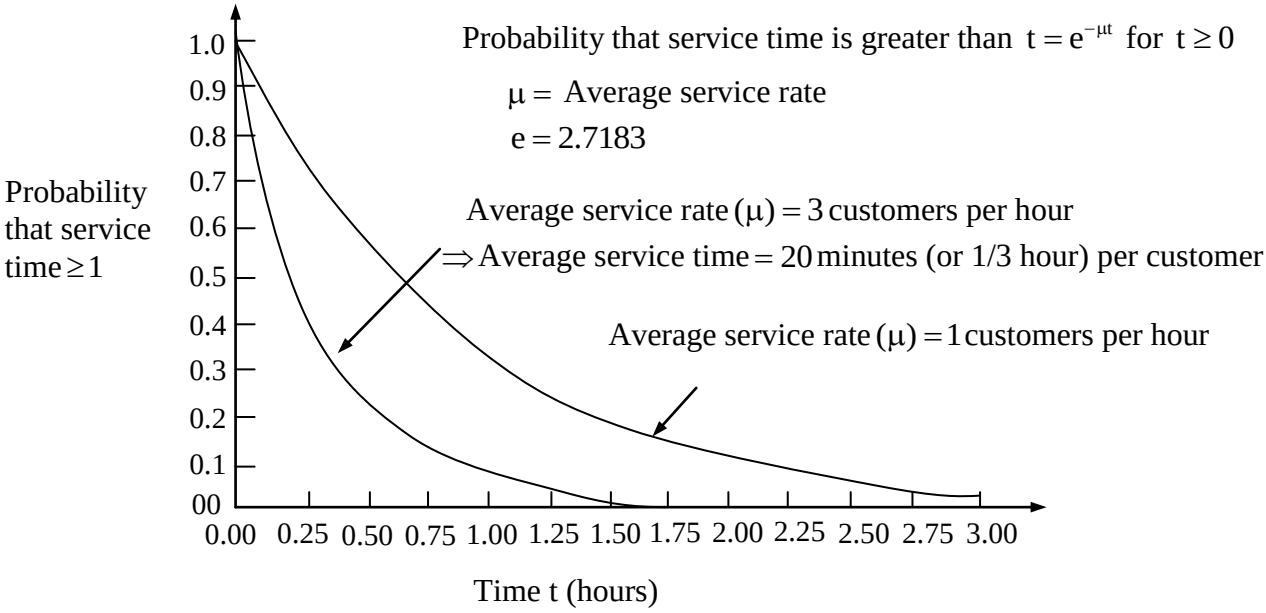

Figure 3

Single-Channel Queuing Model with Poisson Arrivals and Exponential Service Times

The most common case of queuing problems involves the single-channel, or single-server, waiting-line. In this situation, arrivals form a single line to be serviced by a single station. We assume that the following conditions exist in this type of system:

1. Arrivals are served on a first-in, first-out (FIFO) basis, and every arrival waits to be served, regardless of the length of the line or queue.
2. Arrivals are independent of preceding arrivals, but the average number of arrivals (arrivalrate) does not change over time.
3. Arrivals are described by a Poisson probability distribution and come from an infinite (or very, very large) population.
4. Service times vary from one customer to the next and are independent of one another, but their average rate is known.
5. Service times occur according to the negative exponential probability distribution.
6. The service rate is faster than the arrival rate.

When these conditions are met, the series of equations shown in Table 1 can be developed. Examples 1 and 2 illustrate how single-channel queuing model may be used.

λ = mean number of arrivals per time period,

μ = mean number of people or items served per time period,

L_s = average number of units (customers) in the system (waiting and being served)

$$= \frac{\lambda}{\mu - \lambda}.$$

W_s = average time a unit spends in the system (waiting time plus service time)

$$= \frac{1}{\mu - \lambda}.$$

L_q = average number of units waiting in the queue

$$= \frac{\lambda^2}{\mu(\mu - \lambda)}.$$

W_q = average time a unit spends waiting in the queue

$$= \frac{\lambda}{\mu(\mu - \lambda)}.$$

ρ = utilization factor for the system

$$= \frac{\lambda}{\mu}.$$

P_0 = probability of 0 units in the system (that is, the service unit is idle)

$$= 1 - \frac{\lambda}{\mu}.$$

$P_{n>k}$ = probability of more than k units in the system, where n is the number of units in the system

$$= \left(\frac{\lambda}{\mu}\right)^{k+1}.$$

Table 1

Example 1

Tom Jones, the mechanic at Golden Muffler Shop, is able to install new mufflers at an average rate of 3 per hour (or about 1 every 20 minutes), according to a negative exponential distribution. Customers seeking this service arrive at the shop on the average of 2 per hour, following a Poisson distribution. They are served on a first-in, first-out basis and come from a very large (almost infinite) population of possible buyers. From this description, we are able to obtain the operating characteristics of Golden Muffler's queuing system:

$\lambda = 2$ cars arriving per hour

$\mu = 3$ cars serviced per hour

$L_s = \frac{\lambda}{\mu - \lambda} = \frac{2}{3-2} = \frac{2}{1} = 2$ cars in the system, on average.

$W_s = \frac{1}{\mu - \lambda} = \frac{1}{3-2} = 1 = 1$-hour average waiting time in the system.

$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{2^2}{3(3-2)} = \frac{4}{3(1)} = \frac{4}{3} = 1.33$ cars waiting in line, on average.

$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{2}{3(3-2)} = \frac{2}{3}$ hour $= 40$-minute average waiting time per car.

$\rho = \frac{\lambda}{\mu} = \frac{2}{3}$

$= 66.6\%$ of time mechanic is busy

$= 0.33$ probability there are 0 cars in the system.

Probability of more than k cars in the system	
k	$P_{n>k} = (2/3)^{k+1}$
0	0.667
1	0.444
2	0.296
3	0.198
4	0.132
5	0.088
6	0.058
7	0.039

Once we have computed the operating characteristics of a queuing system, it is often important to do an economic analysis of their impact. Although the waiting-line model described above is valuable in predicting potential waiting times, queue lengths, idle times, and so on, it does not identify optimal decisions or consider cost factors. As we saw earlier, the solution to a queuing problem may require management to make a trade-off between the increased cost of providing better service and the decreased waiting costs derived from providing that service. Example 2 examines the costs involved in Example 1.

Example 2

The owner of the Golden Muffler Shop estimates that the cost of customer waiting time, in terms of customer dissatisfaction and lost good will, is \$10 per hour of time spent waiting in line. Because the average car has a $\frac{2}{3}$-hour wait (Wq) and because there are approximately 16 cars serviced per day (2 arrivals per hour times 8 working hours per day), the total number of hours that customers spend waiting each day for mufflers to be installed is $\frac{2}{3}(16) = \frac{32}{3} = 10\frac{2}{3}$ hour.

Hence, in this case,

$$\text{customer waiting-time cost} = \$10(10\tfrac{2}{3}) = \$106.67 \text{ per day.}$$

The only other major cost that Golden's owner can identify in the queuing situation is the salary of Jones, the mechanic, who earns $7 per hour, or $56 per day. Thus,

$$\text{total expected costs} = \$106.67 + \$56$$
$$= \$162.67 \text{ per day.}$$

Multiple-Channel Queuing Model

A multiple-channel queuing system in which two or more servers or channels are available to handle arriving customers. We still assume that customers awaiting service form one single line and then proceed to the first available server. Multichannel, single-phase waiting lines are found in many banks today: A common line is formed, and the customer at the head of the line proceeds to the first free teller.

The multiple-channel system presented in Example 3 again assumes that arrivals follow a Poisson probability distribution and that service times are exponentially distributed. Service is first-come, first-served, and all servers are assumed to perform at the same rate. Other assumptions listed earlier for the single-channel model also apply.The queuing equations for multiple-channel queuing model are shown in Table 2. These equations are obviously more complex than those used in the single-channel model; yet they are used in exactly the same fashion and provide the same type of information as the simpler model.

Queuing Formulas for Multichannel System.

$M =$ number of channels open

$\lambda =$ average arrival rate

$\mu =$ average service rate at each channel

The probability that there are zero people or units in the system is

$$P_0 = \frac{1}{\left[\sum_{n=0}^{M-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right] + \frac{1}{M!}\left(\frac{\lambda}{\mu}\right)^M \frac{M\mu}{M\mu - \lambda}} \quad \text{for } M\mu > \lambda.$$

The average number of people or units in the system is

$$L_s = \frac{\lambda\mu(\lambda/\mu)^M}{(M-1)!(M\mu-\lambda)^2} P_0 + \frac{\lambda}{\mu}.$$

The average time a unit spends in the waiting line and being serviced (namely, in the system) is

$$W_s = \frac{\mu(\lambda/\mu)^M}{(M-1)!(M\mu-\lambda)^2} P_0 + \frac{1}{\mu} = \frac{L_s}{\lambda}.$$

The average number of people or units in line waiting for service is

$$L_q = L_s - \frac{\lambda}{\mu}.$$

The average time a person or unit spends in the queue waiting for service is

$$W_q = W_s - \frac{1}{\mu} = \frac{L_q}{\lambda}.$$

Table 2

Example 3

The Golden Muffler Shop has decided to open a second garage bay and hire a second mechanic to handle installations. Customers, who arrive at the rate of about $\lambda = 2$ per hour, will wait in a single line until 1 of the 2 mechanics is free. Each mechanic installs mufflers at the rate of about $\mu = 3$ per hour. To find out how this system compares with the old single-channel waiting-line system, we will compute several operating characteristics for the $M = 2$ channel system and compare the results with those found in Example 1:

$$P_0 = \frac{1}{\left[\sum_{n=0}^{1} \frac{1}{n!}\left(\frac{2}{3}\right)^n\right] + \frac{1}{2!}\left(\frac{2}{3}\right)^2 \frac{2(3)}{2(3)-2}} = 0.5 \text{ probability of zero cars in the system.}$$

Then,

$$L_s = \frac{(2)(3)(2/3)^2}{1![2(3)-2]^2}\left(\frac{1}{2}\right) + \frac{2}{3} = 0.75 \text{ average number of cars in the system.}$$

$$W_s = \frac{3/4}{2} = \frac{3}{8} \text{ hours.}$$

$$L_q = L_s - \frac{\lambda}{\mu} = \frac{3}{4} - \frac{2}{3} = 0.083 \text{ average number of cars in the queue (waiting).}$$

$$W_q = \frac{L_q}{\lambda} = \frac{0.083}{2} = 0.0415 \text{ hours} = 2.5 \text{ minutes average time a car spends in the queue (waiting).}$$

We can summarize the characteristics of the 2-channel model in Example 3 and compare them to those of the single-channel model in Example 1 as follows:

	SINGLE CHANNEL	**TWO CHANNELS**
P_0	0.33	0.5
L_s	2 cars	0.75 cars
W_s	60 minutes	22.5 minutes
L_q	1.33 cars	0.083 cars
W_q	40 minutes	2.5 minutes

The increased service has a dramatic effect on almost all characteristics. For instance, note that the time spent waiting in line drops from 40 minutes to only 2.5 minutes.

Acknowledgements

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References

Arnold, O. A., "Probability, Statistics, and Queuing Theory with Computer Science Applications", by Academic Press, Inc, New York San Francisco London, (1978).

Palaniammal, S., "Probability and Queuing Theory", PHI Learning Private Limited, New Delhi,(2012).

Finding the Eigenvalues and Eigenvectors of Circulant Matrices

Hnin Oo Lwin*

Abstract

In this paper, Toeplitz matrix and circulant matrix are presented. The eigenvalues and eigenvectors of the circulant matrices are found by using the idea of n^{th} roots of unity and the roots of the polynomial. Two examples are illustrated for the circulant matrix of order 3 and the circulant matrix of order 4.

Key words: n^{th} roots of unity, circulant matrix

Introduction

We begin De Moivre's formula and the n^{th} roots of unitary. We introduce permutation matrix, Toeplitz matrix and circulant matrix. Then we illustrate how eigenvalues and eigenvectors of circulant matrices are found.

Multiplication and Division in Polar Form

Let $z_1 = r_1(\cos\theta_1 + i\sin\theta_1)$ and $z_2 = r_2(\cos\theta_2 + i\sin\theta_2)$.

The product is

$$z_1z_2 = r_1r_2\,[(\cos\theta_1\cos\theta_2 - \sin\theta_1\sin\theta_2) + i(\sin\theta_1\cos\theta_2 + \cos\theta_1\sin\theta_2)].$$

The addition rules for the sine and cosine now yield

$$z_1z_2 = r_1r_2\left[\cos(\theta_1+\theta_2) + i\sin(\theta_1+\theta_2)\right].$$

Taking absolute values on both sides of above equation, we have that the absolute value of a product equals the product of the absolute values of the factors,

$$|z_1z_2| = |z_1||z_2|.$$

De Moivre's Formula

Let $z_1 = z_2 = z$. Then we obtain by induction for n = 0, 1, 2, …,

$$z^n = r^n(\cos n\theta + i\sin n\theta). \qquad (1)$$

For $|z| = r = 1$, Equation (1) becomes De Moivre's formula

$$(\cos\theta + i\sin\theta)^n = \cos n\theta + i\sin n\theta.$$

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Roots

If $z = w^n (n = 1, 2, \ldots)$, then to each value of w there corresponds one value of z. We shall see that, conversely, to a given $z \neq 0$ there corresponds precisely n distinct values of w. Each of these values is called an **n^{th} root** of z, and we write

$$w = \sqrt[n]{z}.$$

The n values of $\sqrt[n]{z}$ can be obtained as follows. We write z and w in polar form

$$z = r(\cos\theta + i\sin\theta) \text{ and } w = R(\cos\phi + i\sin\phi).$$

Then the equation $w^n = z$ becomes, by De Moivre's formula

$$w^n = R^n(\cos n\phi + i\sin n\phi) = r(\cos\theta + i\sin\theta).$$

The absolute values on both sides must be equal; thus

$$R^n = r, \text{ so that } R = \sqrt[n]{r},$$

where $\sqrt[n]{r}$ is positive real and thus uniquely determined. Equating the arguments $n\phi$ and θ, and θ is determined only up to integer multiples of 2π, we obtain

$$n\phi = \theta + 2k\pi,$$

thus $$\phi = \frac{\theta}{n} + \frac{2k\pi}{n},$$

where k is an integer. For $k = 0, 1, 2, \ldots, n-1$ we get n distinct values of w. Further integers of k would give values already obtained. Consequently, $\sqrt[n]{z}$, for $z \neq 0$, has the n distinct values

$$\sqrt[n]{z} = \sqrt[n]{r}\left(\cos\frac{\theta + 2k\pi}{n} + i\sin\frac{\theta + 2k\pi}{n}\right), \qquad (2)$$

where $k = 0, 1, 2, \ldots, n-1$.

These n values lie on a circle of radius $\sqrt[n]{r}$ with center at the origin and constitute the vertices of a regular polygon of n sides. The value of $\sqrt[n]{z}$ obtained by taking the principal value of argument z $(\arg z)$ and k = 0 in Equation (2) is called the **principal value** of $w = \sqrt[n]{z}$.

In particular, taking $z = 1$, we have $|z| = r = 1$ and $\arg z = 0$. Then Equation (2) gives

$$\sqrt[n]{1} = \cos\frac{2k\pi}{n} + i\sin\frac{2k\pi}{n}, \; k = 0, 1, 2, \ldots, n-1. \qquad (3)$$

These n values are called the **n^{th} roots of unity**. If ω denotes the value corresponding to k = 1 in Equation (3), then the n values of $\sqrt[n]{1}$ can be written as $1, \omega, \omega^2, \ldots, \omega^{n-1}$.

Toeplitz Matrix and Circulant Matrix

Permutation Matrix

A **permutation matrix** $P=\left[p_{ij}\right]$ is a matrix with exactly one nonzero element, namely unity, in each row and each column.

For example, permutation matrix of order 4 is

$$P=\begin{bmatrix}0&1&0&0\\0&0&0&1\\0&0&1&0\\1&0&0&0\end{bmatrix}.$$

Toeplitz Matrix

The square matrix $T=\left[t_{ij}\right]$ of order n is said to be **Toeplitz** if

$$t_{ij}=t_{i+1,j+1},\ i,j=1,2,\ldots,n-1.$$

Thus Toeplitz matrices are those that are constant along all diagonals parallel to the principal diagonal.

For example, Toeplitz matrix of order 4 is

$$T=\begin{bmatrix}a&b&c&d\\e&a&b&c\\f&e&a&b\\g&f&e&a\end{bmatrix}$$

Circulant Matrix

A **circulant matrix** of order n is a square matrix of the form

$$C=\begin{bmatrix}c_1&c_2&\cdots&c_n\\c_n&c_1&\cdots&c_{n-1}\\\vdots&\vdots&\ddots&\vdots\\c_2&c_3&\cdots&c_1\end{bmatrix}=\operatorname{circ}\left(c_1,c_2,\ldots,c_n\right).$$

The elements of each row of C are identical to those of the previous row, but are moved one position to the right and wrapped around. The whole circulant is evidently determined by the first row (or column). We may also write a circulant in the form

$$C=\left[c_{ij}\right]=\left[c_{j-i+1}\right],\ \text{subscripts mod n.}$$

For example, circulant matrix of order 4 is

$$C = \begin{bmatrix} a & b & c & d \\ d & a & b & c \\ c & d & a & b \\ b & c & d & a \end{bmatrix}.$$

Properties of Circulant Matrices

Let $A = \text{circ}(a_1, a_2, \ldots, a_n)$ and $B = \text{circ}(b_1, b_2, \ldots, b_n)$. Then

(i) $A+B = \text{circ}(a_1, a_2, \ldots, a_n) + \text{circ}(b_1, b_2, \ldots, b_n)$

$= \text{circ}(a_1 + b_1, a_2 + b_2, \ldots, a_n + b_n)$.

(ii) $\alpha\,\text{circ}(a_1, a_2, \ldots, a_n) = \text{circ}(\alpha a_1, \alpha a_2, \ldots, \alpha a_n)$ where α is a scalar.

Theorem (i)

Let A and B be $n \times n$ circulant matrices. Then the product AB is also a circulant matrix.

Proof

Let $A = \text{circ}(a_1, a_2, \ldots, a_n)$, $B = \text{circ}(b_1, b_2, \ldots, b_n)$ and C = AB. We consider the element c_{ij}.

We know that

$$c_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj} \quad \text{and} \quad c_{(i+1)(j+1)} = \sum_{k=1}^{n} a_{(i+1)k} b_{k(j+1)}.$$

By shifting the index of summation, we get

$$c_{(i+1)(j+1)} = \sum_{k=0}^{n-1} a_{(i+1)(k+1)} b_{(k+1)(j+1)}.$$

Since $a_{(i+1)(k+1)} = a_{ik}$ and $b_{(k+1)(j+1)} = b_{kj}$,

we find that

$$c_{(i+1)(j+1)} = c_{ij}.$$

So C is circulant. □

Theorem (ii)

Let A and B be $n \times n$ circulant matrices. Then AB = BA.

Proof

Let A = $\text{circ}(a_1, a_2, \ldots, a_n)$, B = $\text{circ}(b_1, b_2, \ldots, b_n)$.

We know from Theorem (i) that

C=AB is circulant.

So, we will denote C by $\text{circ}(c_1, c_2, \ldots, c_n)$.

Then for $j = 1, 2, \ldots, n$,

$$c_j = c_{1j} = \sum_{k=1}^{n} a_{1k} b_{kj} .$$

$$= \sum_{k=1}^{n} a_{k-1+1} b_{j-k+1} .$$

$$= \sum_{k=1}^{n} a_k b_{j-k+1}$$

$$= \sum_{k=1}^{n} b_{j-k+1} a_k .$$

The final summation may be recognized as element j of the convolution of the two sequences $\{b_1, b_2, \ldots, b_n\}$ and $\{a_1, a_2, \ldots, a_n\}$. The result then follows from the well-known fact that the convolution is commutative. □

Eigenvalues and Eigenvectors of Circulant Matrices

We study that W is a permutation matrix representing a cyclic permutation of order n. This shows that minimal polynomial for W is

$$p(t) = t^n - 1,$$

and hence that the eigenvalues of W are the n^{th} roots of unity. For each n^{th} roots of unity μ, an associated eigenvector is given by

$$v(\mu) = (1, \mu, \mu^1, \ldots, \mu^{n-1}).$$

For concreteness, we express the n^{th} roots of unity as powers of $\omega = e^{2\pi i/n}$. That gives the eigenvalues of W as $\omega^0, \omega^1, \omega^2, \ldots, \omega^{n-1}$ with associated eigenvectors $v(\omega^0), v(\omega^1), v(\omega^2), \ldots, v(\omega^{n-1})$. Arranging these as the columns of a matrix Q and entering the corresponding eigenvalues ω^k in the diagonal matrix D leads to identity

WQ =QD.

We have to note that $Q^{-1} = \frac{Q^*}{n}$, where Q^* is the conjugate of Q. Therefore $\frac{Q}{\sqrt{n}}$ is unitary.

Consequently, WQ = QD can also be written in the form

$$W = Q\ D\ Q^{-1}$$

$$= Q\ D\ \frac{Q^*}{n}$$

$$W = \frac{Q}{\sqrt{n}}\ D\ \frac{Q^*}{\sqrt{n}},$$

which is a unitary diagonalization of W.Next we extent these results about eigenvalues and eigenvectors for W to general circulant matrices.

We consider that the algebra generated by W, namely, the matrices expressible as polynomials

$$q(W) = a_0 + a_1 W + a_2 W^2 + \cdots + a_{n-1} W^{n-1}.$$

There is a general relationship linking the eigenvalues of a matrix A to those of any polynomial $q(A)$. Indeed, if $Av = \lambda v$, then $q(A)v = q(\lambda)v$. Here, taking A to be W, each $v(\mu)$ is an eigenvector of $q(W)$, with corresponding eigenvalue $q(\mu)$. But the matrices $q(W)$ are precisely the circulant matrices. That is, if C is any $n \times n$ circulant matrix, use its first row $\begin{bmatrix} a_0 & a_1 & a_2 & \cdots & a_{n-1} \end{bmatrix}$ to define a polynomial

$$q(t) = a_0 + a_1 t + a_2 t^2 + \cdots + a_{n-1} t^{n-1}.$$

Then $C = q(W)$, and for any n^{th} root of unity μ, $q(\mu)$ is an eigenvalue of C. Moreover, every circulant $C = q(W)$ is diagonalized by Q. Specifically,

$$q(W)Q = Q\,q(D),$$

with corresponding unitary diagonalization

$$q(W) = \left(\frac{1}{\sqrt{n}}Q\right) q(D) \left(\frac{1}{\sqrt{n}}Q\right)^*.$$

Example for the Circulant Matrix of Order 3

We consider the circulant matrix of order 3,

$$C = \begin{bmatrix} 1 & \sqrt[3]{2} & \sqrt[3]{4} \\ \sqrt[3]{4} & 1 & \sqrt[3]{2} \\ \sqrt[3]{2} & \sqrt[3]{4} & 1 \end{bmatrix}.$$

Here, with n = 3, we use $\sqrt[3]{1} = \cos\frac{2k\pi}{3} + i\sin\frac{2k\pi}{3}$, $k = 0, 1, 2$.

Therefore, the cube roots of unity are

$$1,\ \frac{-1+i\sqrt{3}}{2} \text{ and } \frac{-1-i\sqrt{3}}{2}.$$

We construct the polynomial q from the first row of C:

$$q(t)=1+\sqrt[3]{2}t+\sqrt[3]{4}t^2.$$

The eigenvalues of C are now computed as the following ways:

$$q(1)=1+\sqrt[3]{2}(1)+\sqrt[3]{4}(1)^2$$

$$=1+\sqrt[3]{2}+\sqrt[3]{4},$$

$$q\left(\frac{-1+i\sqrt{3}}{2}\right)=1+\sqrt[3]{2}\left(\frac{-1+i\sqrt{3}}{2}\right)+\sqrt[3]{4}\left(\frac{-1+i\sqrt{3}}{2}\right)^2$$

$$=\frac{2-\sqrt[3]{2}-\sqrt[3]{4}+i\sqrt{3}\left(\sqrt[3]{2}-\sqrt[3]{4}\right)}{2}$$

and

$$q\left(\frac{-1-i\sqrt{3}}{2}\right)=1+\sqrt[3]{2}\left(\frac{-1-i\sqrt{3}}{2}\right)+\sqrt[3]{4}\left(\frac{-1+i\sqrt{3}}{2}\right)^2$$

$$=\frac{2-\sqrt[3]{2}-\sqrt[3]{4}-i\sqrt{3}\left(\sqrt[3]{2}-\sqrt[3]{4}\right)}{2}.$$

Then we get eigenvectors,

$$v(1)=\begin{bmatrix}1\\1\\1\end{bmatrix},\ v\left(\frac{-1+i\sqrt{3}}{2}\right)=\begin{bmatrix}1\\\frac{-1+i\sqrt{3}}{2}\\\frac{1-i\sqrt{3}}{2}\end{bmatrix} \text{ and } v\left(\frac{-1-i\sqrt{3}}{2}\right)=\begin{bmatrix}1\\\frac{-1-i\sqrt{3}}{2}\\\frac{-1+i\sqrt{3}}{2}\end{bmatrix}.$$

Example for the Circulant Matrix of Order 4

We consider the circulant matrix of order 4,

$$C=\begin{bmatrix}1&2&1&3\\3&1&2&1\\1&3&1&2\\2&1&3&1\end{bmatrix}.$$

Here, with n = 4 we use $\sqrt[4]{1}=\cos\frac{2k\pi}{4}+i\sin\frac{2k\pi}{4}$, $k=0,1,2,3$.

Therefore, the fourth roots of unity are ± 1 and $\pm i$.

We construct the polynomial q from the first row of C:

$$q(t) = 1 + 2t + t^2 + 3t^3.$$

The eigenvalues of C are now computed as the following way;

$$q(1) = 1 + 2(1) + (1)^2 + 3(1)^3 = 7,$$

$$q(-1) = 1 + 2(-1) + (-1)^2 + 3(-1)^3 = -3,$$

$$q(i) = 1 + 2(i) + (i)^2 + 3(i)^3 = -i,$$

and $$q(-i) = 1 + 2(-i) + (-i)^2 + 3(-i)^3 = i.$$

Then we get eigenvectors,

$$v(1) = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, \quad v(-1) = \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix}, \quad v(i) = \begin{bmatrix} 1 \\ i \\ -1 \\ -i \end{bmatrix} \text{ and } v(-i) = \begin{bmatrix} 1 \\ -i \\ -1 \\ i \end{bmatrix}.$$

Conclusion

The eigenvalues of a circulant matrix C, can be found by applying the polynomial q from the first row of C to the n^{th} roots of unity. This perspective leads to a method for solving general quadratic, cubic and quartic equations.

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References

Davis, P. J., "**Circulant Matrices**", United States of America, (1994).

Kalman, D. and White, J. E., "***Polynomial Equations and Circulant Matrices***", Mathematical Association of America, Monthly 108, pp 823-840, (2001).

Kreyszig, E., "**Advanced Engineering Mathematics**", John Wiley and Sons, Singapore, (1999).

Some Properties of Line Graphs

Myo Pa Pa Htwe*

Abstract

Let G be a simple graph .We define that the line graph L(G) of G is a graph whose vertices are edges of G and two vertices of L(G) are adjacent whenever the corresponding edges of G are adjacent. In this paper, we study the structures of L(G) for same classes of graphs such as trees, blocks, and connected graphs.

Introduction

The line graph transformation is the interesting of all graph transformation. The line graph concept is natural and has been introduced in several alternative way of describing a graph the edges and their adjacencies are given without reference to the vertex set. In this paper, firstly, some baric terminologies and notations on graph theory are discussed. Then the structures and some properties of L(G) for trees, blocks and connected graphs are presented.

Line Graphs

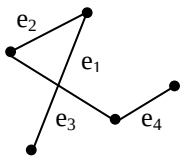
A graph G = (V,E) consists of a finite nonempty set V, called the set of vertices and a set E of unordered pairs of vertices, called the set of edges. The **degree** of a vertex denoted d (v), is the number of edges incident to v, except that each loop at v is counted twice. The two simple graphs G and H are **isomorphic**, written $G \cong H$, if and only if there is a bijection $\theta: V(G) \rightarrow V(H)$ such that $uv \in E(G)$ if and only if $\theta(u)\,\theta(v) \in E(H)$. A **walk** in G is a finite non-null sequence $W = v_0, e_1v_1e_2 \ldots e_kv_k$, whose terms are alternately vertices and edges. A **trail** is a walk with no repeated edge. A **path** is a walk with no repeated vertex. A **cycle** is a closed trail. Two vertices u and v of G are said to be connected if there is a (u,v) - path in G.

The **complete graph** on n vertices, for $n \geq 1$, which we denote K_n, is a graph with n vertices an edge joining every pair of distinct vertices. A graph G' = (V', E ') is a **subgraph** of a graph G = (V, E) if $V' \subseteq V$ and $E' \subseteq E$. A **component** of a graph G is a maximal connected subgraph of G. A **block** of a graph is a maximal non separable subgraph. A **tree** is a connected undirected graph without cycles. A **spanning tree** of a connected graph G is a tree of G having all the vertices of G. A **cut vertex** of a graph is one whose removal increases the number of components.

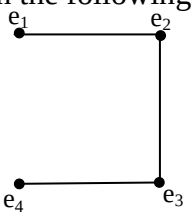
The **line graph** L (G) of a graph G is a graph whose vertices are edges of G and joining two vertices whenever the corresponding edges in G are adjacent

Example

Graphs and their line graphs are given in the following Figure 1.



G_1



$L(G_1)$

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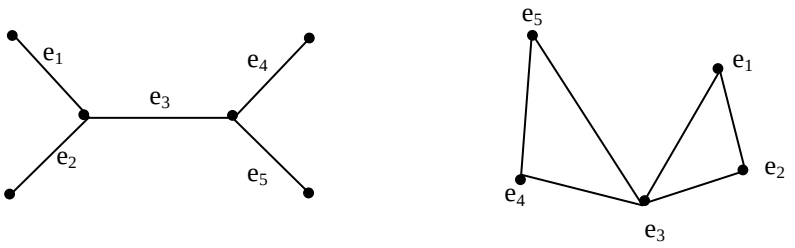


G_2 $L(G_2)$

Figure 1

Theorem

If G(V,E) is a graph with n vertices and ε edges and each vertex has degree d_i, then L(G) has ε vertices and ε_L edges, where $\varepsilon_L = -\varepsilon + \frac{1}{2}\sum d_i^2$.

Proof

By the definition of line graph, L(G) has ε vertices. Then d_i edges incident with a vertex v_i contribute $\binom{d_i}{2}$ to ε_L.

So $\varepsilon_L = \sum\binom{d_i}{2}$

$= \frac{1}{2}\sum d_i (d_i - 1) = \frac{1}{2}\sum d_i^2 - \varepsilon$.

Line Graphs of Connected Graphs

A graph is said to be **connected graph** if every two of its vertices are connected; otherwise it is disconnected.

Lemma

If G is a connected graph and $|V(G)| = |E(G)|$, then G contains exactly one cycle.

Proof

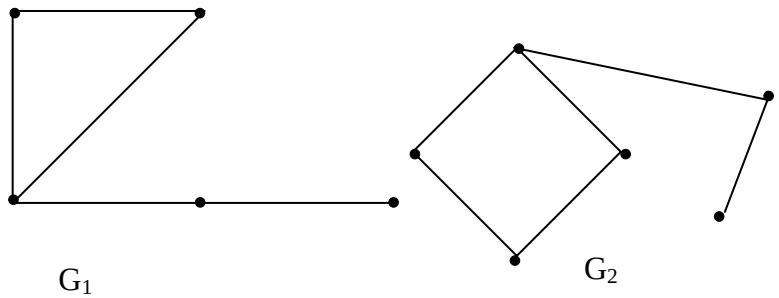
Let T be a spanning tree of G. Then

$|E(T)| = |V(T)| - 1 = |V(G)| - 1 = |V(G)| - 1$.

There exists only edge in G which is not in T. Let e be the only edge of G which is not in T. Therefore T+e = G. T+e consists exactly one cycle. Hence G contains exactly one cycle.

Example

Figure 2 shows connected graphs with V(G) = E(G).



G_1 G_2

Figure 2

Theorem

A connected graph is isomorphic to its line graph if and only if it is a cycle.

Proof

Let G be a connected graph which is isomorphics to its line graph L(G). Since G ≅ L(G), $|V(G)| = |V(L(G))|$ and $|E(G)| = |E(L(G))|$. By the definition of line graph, E(G) = $|V(L(G))|$. Therefore $|E(G)| = |V(G)|$. By lemma, G contains exactly one cycle. G contains the cycle C = {v_1, v_2, …, v_i, v_1} and assume i ≠ n = $|V(G)|$. There exists a vertex $v_j \in V(G) - \{v_1, v_2, \ldots, v_i\}$ such that the edge $v_jv_k \in E(G)$ for some k = 1,2, …, i. Suppose k = 1 and then the edge $v_jv_i \in E(G)$. Then the edges $x_1 = v_jv_1$, $x_2 = v_1v_2$, $x_3=v_iv_1$ form a triangle in L(G). Since G ≅ L(G) and G contains exactly one cycle, L(G) contains exactly one cycle. So the only cycle in L(G) must be the triangle (x_i,x_2,x_3,x_1). Since G ≅ L(G) and G contains a triangle. But G contains exactly one cycle. Therefore, the only cycle in G is a triangle. Hence i = 3 and v_1,v_2 and v_3 form a triangle in G. Let the edge $v_2v_3 = x_4$. Then it is clearly seen that (x_2, x_3, x_4, x_2) form another triangle in L(G). It contradicts to Lemma. Therefore, our assumption that i≠n = $|V(G)|$ is impossible. Hence i = n and G itself is a cycle.

Conversely, suppose that G be a cycle. We now show that G≅ L(G). Since G is a cycle, every vertex of G has degree two and $|V(G)| = |E(G)|$. By the definition of line graph $|V(L(G))| = |E(G)|$ and every edge of G is considered as a vertex in L(G). Since every edge of G is adjacent with exactly two edges, every vertex of L(G) has degree two. So L(G) is also a cycle. G as well as L(G) is a cycle and $|V(G)| = |E(G)| = |V(L(G))| = |E(L(G))|$. Then G = L(G). Therefore, G ≅ L(G).

Theorem

Let G be a graph.

(i) If x = vw is an edge of G then the degree of x in L(G) is d(v) + d(w) – 2.

(ii) G and L(G) have the same number of connected components if G has no isolated vertices.

(iii) $L(P_n) \cong P_{n-1}$, for n ≥ 1.

(iv) $L(K_3) \cong L(K_{1,3})$.

(v) If G is connected and n ≥4, then L(G) ≅ K_n if and only if G ≅ $K_{1,n}$.

Proof

(i) Since x = vw is an edge of G, vertex x in L(G) is adjacent to all vertices which are adjacent as edges of G at v and w except itself. Therefore d(x) = d(v)+d(w) − 2.

(ii) By the definition of the line graph, the two vertices in each component C in L(G) are adjacent if and only if they are adjacent as edge of G. So G and L(G) have the same number of connected components.

(iii) Let $P_n = x_1e_1x_2e_2\ldots x_{n-1}e_{n-1}x_n$. Then P_n has n−1 edges and in L(P_n), e_i adjacent only e_{i-1} and e_{i+1} for i = 2,3,…, n−2. Therefore L(P_n) has n−1 vertices and each vertex has degree d_i = 2 (i = 2,3,…, n−2) and d_i = 1, for i = 1 and n −1. So $L(P_n) \cong P_{n-1}$.

(iv)

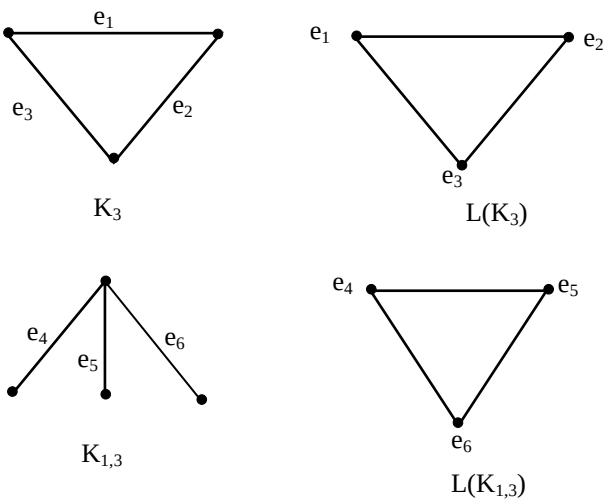


Figure 3

From the Figure 3, $L(K_3) \cong L(K_{1,3})$.

(v) Suppose $G \cong K_{1,n}$. All the edges in G adjacent to each other, so the vertices in L(G) adjacent to each other and L(G) has n vertices. Therefore $L(G) \cong K_n$. Conversely, suppose that $L(G) \cong K_n$. Then G must have n edges and all edges in G adjacent each other. Therefore $G \cong K_{1,n}$.

Definitions

The **subdivision graph** S(G) of a graph is the graph resulting from G by subdividing every edge of G. The **iterated line graph** $L^k(G)$ is defined recursively as $L^0(G) = G$, and $L^k(G) = L(L^{k-1}(G))$ for $k \geq 1$.

Example

Figure 4 shows a graph G and its $L^2(G)$ graph.

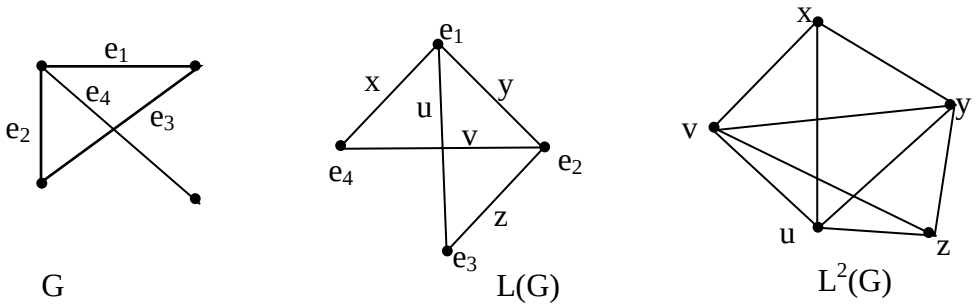


Figure 4

Line Graphs of Trees and Block Graphs

Definitions

Let S be a set and $F = \{S_1, S_2, \ldots, S_p\}$ be a nonempty family of distinct nonempty subsets of S whose union is S. The **intersection graph** of F is denoted by $\Omega(F)$ and defined by $V(\Omega(F)) = F$, with S_i and S_j are adjacent wherever $i \neq j$ and $S_i \cap S_j = \emptyset$. Then a graph G is an intersection graph on S if there exists a family F of subsets of S for which $G \cong \Omega(F)$. If we take the blocks of G as the family F of sets, then the intersection graph $\Omega(F)$ is the **block graph** of G, denoted by B(G). The blocks of G

correspond to the vertices of B (G) and two these vertices are adjacent whenever the corresponding blocks contain a common cutvertex of G. A graph G is a **line graph** if it is isomorphic to the line graph L(H) of some graph H.

Theorem

If a graph H is the block graph of some graph, then every block of H is complete.

Proof

Let H $\cong$ B(G) and assume there is a block H_i of H which is not complete. Then there are two vertices in H_i which are nonadjacent and lie on a shortest common cycle Z of length at least 4. But the union of the blocks of G corresponding to the vertices of H_i which lie on Z is then connected and has no cutvertex, so it is itself contained in a block, contradicting the maximality property of a block of a graph.

Example

Figure 5 shows a graph G and its block graph B(G).

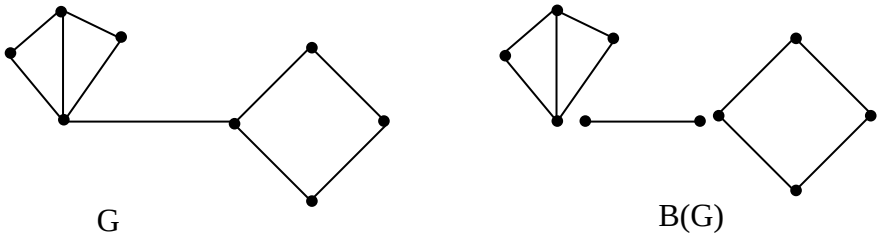


Figure 5

Theorem

The following statements are equivalent.

(i) G is a line graph.

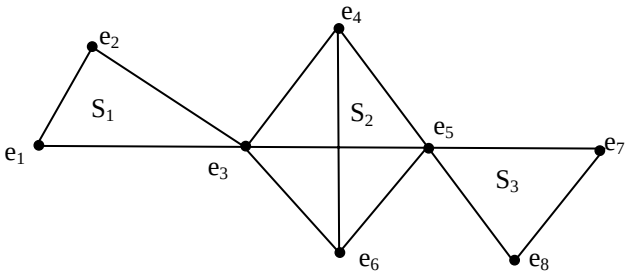
(ii) The edges G can be partitioned into complete subgraphs in such a way that no vertex lies in more than two of the subgraphs.

Proof

(i) implies (ii) Let G be the line graph of H. Without loss of generality we assume that H has no isolated vertices. Then the edges in the star at each vertex of H induce a complete subgraph of G, and every edges of G lies in exactly one such subgraph. Since each edges of H belongs to the stars of exactly two vertices of H, no vertex of G is in more than two of these complete subgraphs. (ii)implies (i). Given a decomposition of the edges of a graph G into complete subgraphs S_1, S_2, …, S_n satisfying (ii), we indicate the construction of a graph H whose line graph is G. The vertices of H correspond to the set S of subgraphs of the decomposition together with the set U of vertices of G belonging to only one of the subgraphs S_i. Thus S$\cup$U is the set of vertices of H and two of these vertices are adjacent whenever they have a nonempty intersection; that is, H is the intersection graph Ω(S$\cup$U).

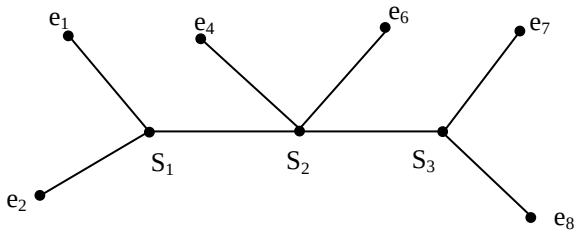
Example

In this example, we construct an intersection graph H = Ω(S∪U) from its line graph G.



G = L(H)

U = {e_1,e_2,e_4,e_6,e_7,e_8}, S = {S_1,S_2,S_3}



H = Ω(S∪U)

Figure 6

Theorem

A graph is the line graph of a tree if and only if it is a connected block graph in which each cutvertex is on exactly two blocks.

Proof

Suppose G ≅ L(T), T some tree. Then G is also block tree B(T) since the edges and blocks of a tree coincide. Each cutvertex x of G corresponds to a bridge uv of T, and is an exactly those two blocks of G which correspond to the stars at u and v.

Conversely, suppose that G be a block graph in which each cutvertex is on exactly two blocks. Since each block of a block graph is complete by theorem, there exists a graph H such that L(H) ≅ G by theorem. If G = K_3, we can take H = $K_{1,3}$. If G is any other block graph, then we show that H must be a tree. Assume that H is not a tree so that it contains a cycle. If H is itself a cycle, then by theorem, L(H) ≅ H. Hence H must property contain a cycle, there by implying that H has a cycle Z and an edge x adjacent to two edges of Z, but not adjacent to some edge y of Z. The vertices x and y of L(H) lie on a cycle of L(H) and they are not adjacent. This contradicts to the fact that L(H) is a block graph. Hence, H is a tree, and the theorem is proved.

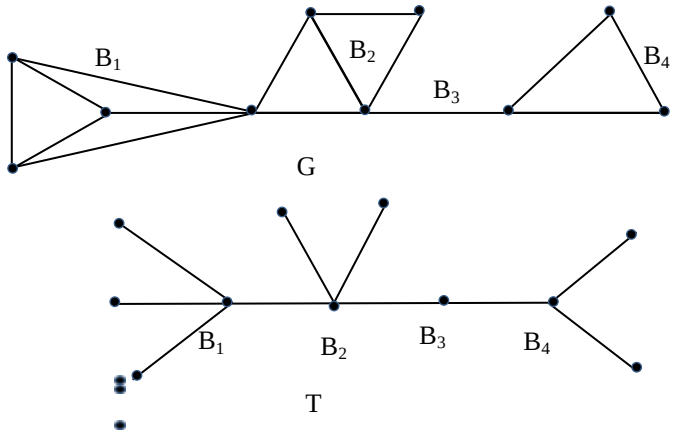


Figure 7 The tree T of a line graph G.

In Figure7, a block graph G is shown in which each cutvertex lies on just two blocks. The tree T of which G is the line graph is constructed by first forming the block graph B(G) and then adding new vertices for the noncutvertices of G and the edges joining each block with its noncutvertices.

Acknowledgements

I am greatly submit the paper for thankful to Dr Aung Kyaw Thin, Rector and Dr Aye Aye Han, Pro-Rector of Banmaw University for the permission to the journal. I would like to express my thanks to Dr Khin San Aye, Professor and Head, Department of Mathematics, Banmaw University for her kind encouragement to submit this paper. I would like to thank Professor Dr Hnin Oo Lwin, Department of Mathematics, Banmaw University for her helpful advice to do this paper.

References

Beineke, L.W., and R.J.,Wilson, “Selected Topics in Graph Theory”, Academic Press, London, (1978).

Bondy, J.A.and U.S.R.,Murty“Graph Theory with Application”, Macmillan Press Ltd, London, (1976).

Grossman, J.W., “ Discrete Mathematics”, Macmillan Publishing Company, New York, (1990).

Harry. F., “Graph Theory”, Addison Wesley, Publishing Company, London, (1969).

Ray-Chaudhuri, D.K.,“Characterization of Line Graphs”,J. Combinatorial Theory 3, P.210-214, (1969).

Some Application of Permutations and Combinations

Mar Mar Than*

Abstract

The principles of permutation and combination in mathematics are stated. Then the circular and necklace permutations which have beads of several colors, and count the related combinational number are enumerated.

Key words: permutation, combination, circular and necklace permutations

Introduction

We often compose new sets, systems, or sequences from the elements of a given set, in a certain way. Depending on the way we do it, we get the notion of permutation, combination and arrangement. The basic problem of combinatorics is to determine how many different choices or arrangements are possible with the given elements.

Fundamental Principle

Multiplication Principle

If an activity can be constructed in t successive steps and step1 can be done in n_1 ways: step 2 can then be done in n_2 ways; … ; and step t can then be done in n_t ways, then the number of different possible activities is $n_1 \times n_2 \times ... \times n_t$.

Addition Principle

Suppose that $X_1, X_2, ..., X_t$ are sets and that the i^{th} set X_i has n_i elements. If $\{X_1, X_2, ..., X_t\}$ is a pairwise disjoint family of sets (i.e., $i \neq j, X_i \cap X_j = \phi$), then the number of possible elements that can be selected from X_1 or X_2 or … or X_t is $n_1 + n_2 + ... + n_t$.

Permutations

A permutation of *n* elements is an ordering of the *n* elements.

Number of Permutations without Repetition

The number of different permutations of *n* different elements is

$$P_n = n! = n(n-1) \ldots 3 \times 2 \times 1 .$$

■ In a classroom, 13 students are seated on 13 places. There are 13! different possible arrangements.

Number of Permutations with Repetitions

The number $P_n^{(k)}$ of different permutations of *n* elements containing *k* identical elements ($k \leq n$) is

$$P_n^{(k)} = \frac{n!}{k!} .$$

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■ In a classroom, 13 schoolbags of 13 students are placed on 13 chairs. Four of them are identical. There are $\frac{13!}{4!}$ different arrangements of the schoolbags.

Generalization

The number $P_n^{(k_1,k_2,\ldots,k_m)}$ of different permutations of n elements containing m different types of elements with multiplicities k_1, k_2, …, k_m respectively $(k_1 + k_2 + \ldots + k_m = n)$ is

$$P_n^{(k_1,k_2,\ldots,k_m)} = \frac{n!}{k_1!k_2!\ldots k_m!} .$$

■ Suppose we compose five-digit numbers from the digits 4, 4, 7, 7, 7. We have $P_5^{(2,3)} = \frac{5!}{2!3!} = 10$ different numbers.

Circular and Necklace Permutations

Circular permutation is the number of ways to set up n distinct objects beside a fixed circle.

The number of circular permutations of n distinct things taken all together is $(n-1)!$ or $\frac{(n-1)!}{2}$ according as clockwise and counter-clockwise order distinguished nor not.

■ 

There are 7! = 5 040 different arrangements.

■ 

There are $\frac{7!}{2} = 2\ 520$ different arrangements.

■ 

There are $9 \times 7! = 45\ 360$ different arrangements.

Combinations

A combination is a choice of k elements from n different elements not considering the order of them.

Number of Combinations without Repetition

The number $C_n^{(k)}$ of different possibilities to choose k elements from n different elements not considering the order is

$$C_n^{(k)} = \binom{n}{k} = \frac{n!}{k!(n-k)!} \text{ with } 0 \le k \le n,$$

if we choose any element at most once. We call this a combination without repetition.

■ There are $\binom{25}{4} = 12\ 650$ possibilities to choose an electoral board of four persons from 25 participants.

Number of Combinations with Repetition

The number of possibilities to choose k elements from n different ones, repeating each element arbitrarily times and not considering the order is

$$C_n^{(k)} = \binom{n+k-1}{k}.$$

In other words, we consider the number of different selections of k elements chosen from n different elements, where the selected ones must not be different.

■ Rolling k dice, we can get $C_6^{(k)} = \binom{k+6-1}{k}$ different results. Consequently, we can get $C_6^{(2)} = \binom{7}{2} = 21$ different results with two dice.

Arrangements

An arrangement is an ordering of k elements selected from n different ones, that is, arrangements are combinations considering the order.

Number of Arrangements without Repetition

The number $V_n^{(k)}$ of different ordering of *k* different elements selected from *n* different ones is

$$V_n^{(k)} = k!\binom{n}{k} = n(n-1)(n-2)...(n-k+1),\ 0 \le k \le n.$$

■ We may choose a chairman, his deputy, and a first and a second assistant from 25 participants at an election meeting, the answer is $4!\binom{25}{4} = 303\,600$.

Number of Arrangement with Repetition

An ordering of *k* elements selected from *n* different ones, where any of the elements can be selected arbitrarily many times, is called and arrangement with repetition. Their number is

$$V_n^{(k)} = n^k.$$

■ We can represent 2^8 = 256 different symbols with the digital unit called a byte which contains 8 bits.

Collection of the Formulas of Combinatiorics

Type of choice or selection of *k* from *n* elements	Number of possibilities	
	without repetition ($k \le n$)	with repetition ($k \le n$)
Permutations	$P_n = n!(n = k)$	$P_n^{(k)} = \frac{n!}{k!}$
Combinations	$C_n^{(k)} = \binom{n}{k}$	$C_n^{(k)} = \binom{n+k-1}{k}$
Arrangements	$V_n^{(k)} = k!\binom{n}{k}$	$V_n^{(k)} = n^k$

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I would like to express my heartfelt gratitude to Dr Aung Kyaw Thin, Rector and Dr Aye Aye Han, Pro-Rector Banmaw University for their permission to carry out the research and their encouragement. And then, I would like to thank Dr Khin San Aye, Professor and Head of Department of Mathematics and Dr Hnin Oo Lwin, Professor, Department of Mathematics, Banmaw University, for their exhortation and helpful comments on this research.

References

Johnsonbaugh, R., *Discrete Mathematics*, Macmillan Publishing Company, (1990).

Grossman, J.W., *Discrete Mathematics*, An Introduction to Concepts, Methods, and Applications, Macmillan Publishing Company, (1990).

Comparative Study on the Alimentary Tracts of Some Bony Fishes in Hlaing River

Kyi Kyi San[1], Le Le Naing[2] and Ohnmar Myint[3]

Abstract

This study described the determination of feeding habits of some bony fishes on the basis of the relative length of the alimentary tracts. The specimens were taken form Hlaing River.Studied species were recorded by photographs and also tabulated the measurements.The results suggested that these species have different alimentary tract length.The finding of this study are compared and discussed.

Key words; feeding habits, alimentary tracts, bony fishes.

Introduction

The study of the food and feeding habits of freshwater fish species is a subject of continuous research because it constitutes the basis for the development of a successful fisheries management program on fish capture and culture (Oronsaye and Kakpodia, 2005).

Fishes are carnivorous, herbivorous, or omnivorous, but most of them are highly adaptable in their feeding habits and utilize the most readily available food. In fishes, alimentary tract length is often an indicator of diet. Species that eat only algae or higher plants (herbivores) tend to have longer alimentary tract than species that eat both plant and animal material (omnivores), and these in turn tend to have longer alimentary tract than species that eat only other animals (carnivores, e.g. Al-Hussaini, 1947, 1949; Fryer and Iles 1972; Kapoor et al., 1975). Relative alimentary tract length (the ratio of alimentary tract length to standard length) is usually used to compare species, but is highly variable within dietary categories.

Based on Suyehiro (1942) Kafuku (1958), Kiener (1963), Cited from Taki, 1978), fishes having an alimentary tract length shorter than 1.5 times of the standard length were judged to be carnivores, and those with an alimentary tract length longer than 3 times of the standard length were regarded as herbivores. Tentatively, fishes that were intermediate in the relative alimentary tract length and showed no other evidence to determine their food habits were considered as omnivores.

Objectives

The objectives of this study are as follows:

To determine the feeding habits of some bony fishes on the basis of the relative alimentary tract lengths

To compare the alimentary tract of some bony fishes

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[3] Dr., Lecturer, Department of Zoology, Banmaw University

Materials and methods

The fish species were obtained from the Hlaing River.Ten specimens for each species were collected and preserved in 10 percent formalin.The collected fish species were identified according to standard references namely Day (1878) and Jayaram (1981). The identified species were classified according to the system of classification given in Talwar and Jhingran (1991).

Measurements in length of the alimentary tract have been taken in fresh condition.The standard length of the fish was measured to the nearest centimeter (cm). Standard length was taken from the snout to the nearest centimeter (cm).

The determination of feeding habit was made on the basis of the ratio of the alimentary tract length to the standard length (Taki, 1978). The ratio of the alimentary tract length (AL) to standard length (SL) was calculated using the equation.

Relative alimentary tract length = AL/SL

According to Suyehio (1942), Kafuku (1958), Kiener (1963) Cited from Taki, 1978), fishes having an alimentary tract length shorter than 1.5 times of the standard length were judged to be carnivores (AL/SL <1.5), and those with an alimentary tract length longer than 3 times of the standard length were regarded as herbivores (AL/SL > 3).Tentatively, fishes that were intermediate in the relative alimentary tract length were considered as omnivores (1.5 < AL/SL < 3).

Results

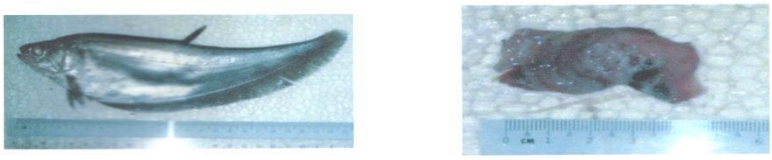
Scientific Classification

Phylum	-	Chordata
Superclass	-	Gnathostomata
Class	-	Osteichthyes
Order	-	Osteoglossifomes
Family	-	Notopteridae
Genus	-	*Notopterus* (Lacepede, 1800)
Species	-	(i) *Notopterusnotopterus* (Pallas, 1769)
Order	-	Cypriniformes
Family	-	Cyprinidae
Subfamily	-	Cyprininae
Genus	-	*Cirrhinus* (Oken, 1817)
Species	-	(ii) *Cirrhinusmrigala* (Hamilton, 1822)
Genus	-	*Labeo* (Cuvier, 1817)
Species	-	(iii) *Labeorohita* (Hamilton, 1822)
Order	-	Siluriformes
Family	-	Bagridae
Genus	-	*Mystus* (Scopoli, 1777)
Species	-	(iv) *Mystusgulio* (Hamilton, 1822)

Order - Perciformes
Family - Anabantidae
Genus - *Anabas* (Cuvier and Cloquet, 1816)
Species - (v) *Anabastestudineus* (Bloch, 1792)
Family - Channidae
Genus - *Channa* (Scopoli, 1777)
Species - (vi) *Channastriatus* (Bloch, 1793)

Table.1 The recorded fish species in Hlaing River

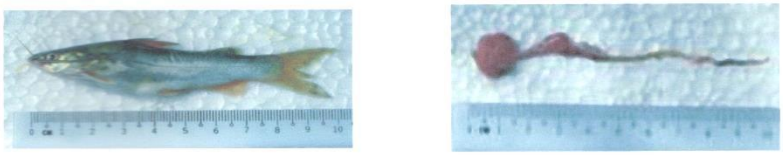
No.	Order	Family	Scientific Name	Common Name	Local Name
1	Osteoglossiformes	Notopteridae	*Notopterusnotopterus* (Pallas, 1769)	Featherback	Nga-phe
2	Cypriniformes	Cyprinidae	*Cirrhinusmrigala* (Hamilton, 1822)	Mrigal	Nga-gyinn
3			*Labeorohita*(Hamilton, 1822)	Rohu	Nga-myit-chin
4	Siluriformes	Bagridae	*Mystusgulio* (Hamilton, 1822)	Long-whiskered catfish	Nga-zin-yaing
5	Perciformes	Anabantidae	*Anabas restudineus* (Bloch, 1792)	Climbing perch	Nga-byay-ma
6		Channidae	*Channastriatus* (Bloch, 1793)	Striped (or) banded snakehead	Nga-yant



A. *Notopterus notopterus* (Nga-phe)

B. *Cirrhinus mrigala* (Nga-gyinn)

C. *Labeo rohita* (Nga-myit-chin)



D. *Mystus gulio* (Nga-zin-yaing)

E. *Anabas testudineus* (Nga-byay-ma)

F. *Channa striatus* (Nga-yant)

Plate.1 Recorded fish species and their alimentary tract

Descriptive accounts of the studied species

Notopterusnotopterus (Pallas, 1769) Plate. IA)

Common name - Grey featherback

Local name - Nga-phe

Fin formula - D7-9; A +C 100-100; V 5-6

Body oblong and strongly compressed. Head compressed, its length about 4-5 times in standard length; preorbital serrated. Mouth moderate, maxilla extends to midorbit. Dorsal fin inserted nearer snout-tip than to base of caudal fin. Pectoral fins

moderate, extend beyond anal fin origin.Scale minute; considerably larger on opercles than on body.

Colour; in life, silvery-white with numerous fine grey spots on body and head which are dark along the narrow back.

Found in clear streams and enters brackish water sluggish water of lakes, floodplains, canals and ponds.Feeds on insects, fish and crustaceans.

A total of ten specimens having the standard length of 17.2 cm to 27.2 cm and the alimentary tract length of 10 cm to 12 cm were observed. The relative alimentary tract length was shorter than 1.5. *N.notopterus*was determined as carnivore.

Table.2 Standard length and alimentary tract length of *Notopterusnotopterus*

No.	SL (cm)	AL (cm)	AL/SL
1	17.2	10	0.58
2	18.5	10.5	0.57
3	18.7	10.5	0.56
4	19.2	10.8	0.56
5	19.6	11	0.56
6	21.5	11.3	0.53
7	23.6	11.5	0.49
8	24.4	11.5	0.47
9	26.1	11.8	0.45
10	27.2	12	0.44
Average	21.6 ± 3.51	11.09± 0.64	0.52 ±0.05

SL = standard length, AL = alimentary tract length

Cirrhinusmrigala (Hamilton, 1822) (Plate. IB)

Common name - Mrigal

Local name - Nga-gyinn

Fin formula - D iii-iv 12-13; A iii 5; P i17; V i 8

Body streamlined, its depth about equal to length of head. Snout blunt, often with pores. Mouth broad; upper lip entire, lower lip most indistinct.Dorsal fin as highs body. Pectoral fins shorter than head. Caudal fin deeply forked.

Colour; in life, dark grey along back often with a coppery tinge, flanks silvery with a yellowish tinge, and belly silvery-white; eyes golden. Pectoral, pelvic and anal fins orange-tipped; dorsal and caudal fins dusky.

Inhibits fast following streams and rivers. Feeds on plankton, but also grazes on algae.

A total of ten specimens having the standard length of 17.8 cm to 27.8 cm and the alimentary tract length of 210.8 cm to 480.6 cm were observed. The relative alimentary tract length was 15.10 ±1.96.the average relative alimentary tract length was longer than 3. C.mrigala was determined as herbivore.

Table.3 Standard length and alimentary tract length of *Cirrhinusmrigala*

No.	SL (cm)	AL (cm)	AL/SL
1	17.8	210.8	11.84
2	18.2	235.5	12.94
3	19.6	260.6	13.30
4	19.8	270.1	13.64
5	19.9	320.7	16.12
6	20.1	326.5	16.24
7	21.5	350.4	16.30
8	24.3	392.3	16.14
9	24.5	420.6	17.17
10	27.8	480.6	17.29
Average	21.35±3.20	326.81± 86.1	15.1 ±1.96

SL = standard length, AL = alimentary tract length

Labeorohita (Hamilton, 1822) (Plate. IC)

Common name - Rohu

Local name - Nga-myit-chin

Fin formula - D iii-iv 12-14; A ii-iii 5; P i 16-18; V i 8

Body moderately elongate, its dorsal profile more arched than the ventral profile.Snout fairly depressed, projects beyond mouth, devoid of lateral lobe.Eyes large, not visible from underside of head, the diameter 4 to 6 times in head.Mouth small and inferior; lips thick and fringed, with a distinct inner fold to each lip.Dorsal fin inserted midway between snout-tip and base of caudal fin. Pectoral fins shorter than head.Caudal fin deeply forked.

Colour; in life, bluish along back, becoming silvery on the flanks and beneath; eyes reddish. Fins grayish or dark; pectoral fins dusky.The body colour tends to vary in fishes living among weeds, exhibiting greenish black on back.

Inhibits rivers. Feeds on plans.

A total of ten specimens having the standard length of 15.4 cm to 20.2 cm and the alimentary tract length of 141.2 cm to 198.6 cm were observed. The relative alimentary tract length was 10.28±0.59. The average relative alimentary tract length was longer than 3.The feeding habits of *L. rohita* was determined as herbivore.

Table.4 Standard length and alimentary tract length of *Labeorohita*

No.	SL (cm)	AL (cm)	AL/SL
1	15.4	141.2	9.17
2	15.7	166.9	10.63
3	16.5	178.3	10.81
4	16.5	179.6	10.88
5	16.7	180.2	10.79
6	17.3	185.3	10.71
7	18.3	189.9	10.38
8	19.2	190.6	9.93
9	19.8	192.3	9.71
10	20.2	198.6	9.83
Average	17.56±1.71	180.29±16.38	10.28±0.59

SL = standard length, AL = alimentary tract length

Mystusgulio (Hamilton, 1822) (Plate. ID)

Common name - Long-whiskered catfish

Local name - Nga-zin-yaing

Fin formula - D 17; A iii-iv 9-11; P i 8-9; V i 5

Body elongate and compressed, its depth 3.8 to 4.1 in standard length.Head depressed, its upper surface rough and granulated.Mouth terminal; dorsal spine strong. Caudal fin forked.

Colour; in life, bluish-brown on head and back, dull white below.Fins, especially outer half, usually black.

Inhibits estuaries and tidal rivers and lakes, ascending to freshwater. Feeds on fish, shrimp and insect.

A total of ten specimens having the standard length of 4.8 cm to 7.1 cm and the alimentary tract length of 6 cm to 8.1 cm were observed. The relative alimentary tract length was 1.18±0.04. The average relative alimentary tract length was longer than 1.5. *M. gulio* was determined as herbivore.

Table.5 Standard length and alimentary tract length of *Mystusgulio*

No.	SL (cm)	AL (cm)	AL/SL
1	4.8	6	1.25
2	5	6.1	1.22
3	5.2	6.2	1.19
4	5.6	6.8	1.21
5	5.9	6.8	1.15
6	6.2	7.1	1.15
7	6.3	7.3	1.16
8	6.5	7.6	1.17
9	6.6	7.8	1.18
10	7.1	8.1	1.14
Average	5.92±0.76	6.98±0.73	1.18±0.04

SL = standard length, AL = alimentary tract length

Anabas testudineus (Bloch, 1972) (Plate. IE)

Common name - Climbing perch

Local name - Nga-byay-ma

Fin formula - D xvi-xviii 8-10; A viii-xi 9-11; P i 13-14; V i 5

Body elongate and moderately deep, its depth 3 to 3.5 times in standard length. Mouth fairly large.

Colour; in life, adults greenish to dark grey on dorsal side and flanks, fading to pale-yellow on belly, a distinct dark spot at base of caudal fin; usually a black spot at base of pectoral fin. Dorsal and caudal fins dark grey; pectoral and anal fins pale yellow, and pelvic fins pale orange.

Inhibits fresh and brackish waters; mostly in canals, lakes, ponds, and swamps.Feeds on macrophytic vegetation, shrimps and fish fry.

A total of ten specimens having the standard length of 9.6 cm to 12.3 cm and the alimentary tract length of 16 cm to 20 cm were observed. The relative alimentary tract length was 1.61 ± 0.05. The average relative alimentary tract length was intermediate between 1.5 and 3. *A. testudineus* was determined as herbivore.

Table.6 Standard length and alimentary tract length of *Anabas testudineus*

No.	SL (cm)	AL (cm)	AL/SL
1	9.6	16	1.67
2	9.8	16.5	1.68
3	10.6	16.9	1.59
4	11.2	17	1.52
5	11.3	18	1.59
6	11.5	18.5	1.61
7	11.8	18.8	1.59
8	11.8	19.3	1.64
9	12	19.5	1.63
10	12.3	20	1.63
Average	11.19±0.92	18.05±1.39	1.61±0.05

SL = standard length, AL = alimentary tract length

Channastriatus (Bloch, 1973) (Plate. IF)

Common name - Striped or Banded Snakehead

Local name - Nga-yant

Fin formula - D 37-46; A 23-29; P i 5-17; V 6

Body elongate and fairly rounded in cross-section. Eyes moderate, its diameter 6 to 7 times in head length.Mouth large.Pectoral fin about 2 times in head length. Caudal fin rounded.

Colour; in life, adults grey-green to black-green on upper side; from middle of side upwards very pale, yellow to silvery, belly usually pure white.Dorsal and anal fins slightly darker in colour than body; caudal fin dark; pectoral and pelvic fins pale; dorsal fin in young with a black blotch at hind end.

Inhibits freshwater ponds, streams and tanks of plains; prefers stagnant muddy waters and grassy tanks.Feeds on other fishes, mollusks and insects.

A total of ten specimens having the standard length of 14.7 cm to 19.2 cm and the alimentary tract length of 9.8 cm to 13.4 cm were observed. The relative alimentary tract length was 0.72 ± 0.02. The average relative alimentary tract length was shorter than 1.5. The feeding *habits fo C. striatus* was determined as herbivore.

Table.7 Standard length and alimentary tract length of *Channastriatus*

No.	SL (cm)	AL (cm)	AL/SL
1	14.7	9.8	0.67
2	15.2	10.8	0.71
3	15.7	11.3	0.72
4	16.6	11.9	0.72
5	17.1	12.9	0.75
6	17.5	12.9	0.74
7	17.6	13	0.74
8	18.2	13	0.71
9	18.6	13.1	0.70
10	19.2	13.4	0.70
Average	17.04±1.48	12.21±1.21	0.72±0.02

SL = standard length, AL = alimentary tract length

Discussion

Fishes have different diet which varies with food habits for their growth. Six species of fishes included in this work are grouped as carnivores, herbivores and omnivores according to determination of their food habits. Determinations of feeding habits of some bony fishes were based on the relative alimentary tract length.

Of six species, three species were determined as carnivores, two species as herbivores and one species as omnivores.

The average relative alimentary tract length was 0.52±0.05 in *N notopterus* (see table.2); 0.72±0.02 in *Cstriatus* (see Table.7) and 1.18±0.04 in *M gulio* (see Table.5). The relative alimentary tract lengths of carnivorous species determined in this study were observed to be shorter than 1.5. *Notopterusnotopterus*, *Channastriatus*and *Mystusgulio* were regarded as carnivorous fishes.

The average relative alimentary tract length was 15.10±1.96, in C mrigala (see Table.3); 10.28±0.59 in L rohita (see Table.4). The relative alimentary tract lengths of herbivorous species determined in this study were observed to be longer than 3. *Cirrhinusmrigala* and *Labeorohita* were regarded as herbivorous fishes.

The average relative alimentary tract length was 1.61±0.05 in *A. testudineus* (see Table.6). The relative alimentary tract lengths of omnivorous species determined in this study was observed to be intermediate between 1.5 and 3. *Anabas testudineus* was regarded as omnivorous fish.

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References

AL-Hussaini,A.H.,(1947).The feeding habits and the morphology of the alimentary tract of some teleosts living in the neighbor-hood of the Marine Biological Station,Ghardaqa,Red Sea.Publications of the Marine Biological Station, Ghardaqa,(Red Sea) 5:1-61.

Day ,F.,1875-78.The fishes of India,being anatural history of the fishes knownto inhabit the sea and freshwater of India, Burma and Ceylon.Vol .1 and 11(Repsrinted,1967).today and tomorrow's book Agency ,New Dalhi.

Fryer,G.,Iles,T.D.,(1972).the cichlid fishes of the Great Lakes of Africa:their biology and evolution . T.F.H.Publications, Neptune City. 647pp.

Jayaram,K.C.,(1981).the fresh water fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka.Zoological survey of India.

Kafuku, T.,(1658).Speciation in Cyprinid Fishes on the Basis of Intestinal Differentiation.BULL.Fresh water fish.Res.Lab.Tokyo.8(1):45-78.

Kapoor,B.G.,Smit,H., and Verighina, A.I., (1975).The alimentary canal and digestion in teleosts. Adv. Mar Biol. 13: 109-239.

Kiener, A., (1963).Poisons.Pisciculture.Madagascar. Centre Tech Forest.Tropic. Publ. No. 4: 244.Pp. 99.

Oronsaye, C.G., Nakpoida, F.A., (2005).A comparative study of the food and feeding habits of Chrysichthysnigrodigitatus and Brycinus nurse in a tropical River. Pak. J. Sci. Ind. Res., 48: 118-121.

Suyehiro, Y., (1942).A Study of Digestive System and Feeding Habit of Fish. Japan. Jour. Zool. 10 (1): 1-303.

Taki, Y., (1978).An analytical study of the fish fauna of the Mekong basin as a biological production system in nature. Res. Ins.Of Evo.Bio. Special Publications No.1, Tokyo.

Tawlar, P.K., Jhingran, A.G., (1991). Inland Fishes of India and Adjacent Countries.Volume I and II. Oxford and IBH Publishing Co. PVT Ltd., New Delhi, Bombay, Calcutta.

STUDY ON CRAB SPECIES IN SOME MARKETS OF YANGON ENVIRONS

San San Myaing[1], Soe Than[2]

Abstract

A total of six species of crabs belonging to four general under two families was recorded from three markets in Yangon environs.Of these species, two species of the genus *Portunus*, two species of the genus *Scylla* and only one species of the genus *Charybdis* belonging to the family Portunidae were recorded. Only one species of the genus *Eurycarcinus* of the family Xanthidae was also recorded. Most of the edible crabs caught from marine and brackish water environments belong to the family Portunidae. Among the recorded crabs species, the two species of *Scylla tranquebarica* and *Portunus sanguinolentus* were found as predominant species while two of the species, *Portunus pelagicus* and *S. olivaceae* were second most abundant in these markets. *Charybdis feriatus* and *Eurycarcinus orientialis* were least abundant in all the Market combined.

Key words; Family Portunidae and Xanthidae, edible crabs, marine and brackish water

Introduction

The decapods are divided into two suborders, the Natantia including shrimps and prawns, and the Reptantia containing the lobsters, crayfish and crabs. Decapods are higher forms of crustaceans in which one of the most important characters is constancy in number of body segments. Most of the decapods are relished as delicacy in many countries. The family Portunidae is a distinctive group of marine crabs which are well represented in Southeast Asia. Portunids, better known as swimming crabs, are so-named as the last pair of legs are paddle-like, and make them good swimmers. The carapaces of most swimming crabs are somewhat hexagonal, and the margin of the front half is often lined with sharp teeth. The various species live in a variety of habitats, from soft substrates like mudflats and sand flats to harder bottoms like coral reefs and rubble.

The crabs of both inland and marine forms are one of the main staple protein resources and are highly favoured by the people consumed in various methods. Hence, crabs play an important role in economy in many ways. Most crabs are marine forms, but many can tolerate brackish water. Some entirely live in freshwaters while a considerable number live partly on land and partly in water, but others live in waters off shores.

Like other true crabs, swimming crabs have a broad carapace, and a very short flattened abdomen which is usually folded underneath the body. The diet varies between the species as well, ranging from slow-moving prey such as snails and annelids to fast-moving ones such as fish and shrimps. Portunid crabs and mud crabs are a highly priced delicacy in both local and export markets throughout Southeast Asia and Australia. The objectives of the present study are:

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- to identify the recorded crab species from various markets in Yangon Region.
- to study the morphological characters of the recorded species
- to observe the species composition in various markets as commercial products

Materials and Methods

Study sites

All specimens were collected from Pazundaung Market in Pazundaung Township. Central Sanpya Fish Market in Kyeemyindaing Township and Yadana Theingyi Market in North Okkalapa Township of Yangon Region.

Study period

The study period lasted from June, 2015 to August, 2015.

Specimen collection and preservation

The collection of fresh and live crab species was conducted weekly in the selected markets. The coloration of specimens were noted and recorded by digital photographs. The specimens were then washed and thoroughly cleaned in water and preserved in 10 percent formalin. To study the preserved specimens, they were first washed in tap water.

Morphometric analysis

Morphometric measurements of the collected species were systematically examined. Six measurements were taken from ten specimens (N=5) of each species. Carapace length (CL1), carapace width (CW), merus length (ML), carpus length (CL2), propodus length (PL) and dactyluslength (DL) were measured and recorded.

Identification

Identification of the collected crab species were followed after Alcock, 1898, 1899; Chhapgas, 1956; Keenan *et al*., 1998.

A. Pazundaung Market

B. Central Sanpya Fish Market

C. Yadana Theigyi Market

Plate 1.The study sites of the present study in Yangon Region

Results

The systematic classification was done after Alcock, 1898 and 1899; Chhapgas, 1956; Keenan *et al*., 1998.

Descriptive account of the observed crab species

***Scylla olivacea* (Herbst, 1796) (Plate A, B, C, D)**

Carapace oval and convex in shape, carapace surface smooth and glabrous, H-shaped groove prominently carved in the centre of the carapace front ornamented with 4 subequal and equally spaced teeth. The last teeth are the smallest, anterolateral tooth broad with convex outer margin.

Chelipeds massive and unequal in size, merus ornamented with 3 spines and 2 spines on the anterior and posterior region respectively, no spines present on the inner and outer of the carpus, two blunt spines present on the distal upper part near the insertation of finger.

The coloration of carapace brownish green, with palm orange to yellow, tips of chelae bright orange and distal segments of legs orange.

***Scylla tranquebarica* (Fabricius, 1798) (Plate E, F, G, H)**

Carapace oval and convex in shape, carapace surface smooth and glabrous. H-shaped groove moderately carved in the centre on the carapace front ornamented with 4 subequal and equally spaced teeth. Front teeth moderately high in height and rounded in shape, the interspaces between front teeth rounded, anterolateral borders ornamented with 9 subequal teeth, the last teeth are the smallest, anterolateral tooth broad with convex outer margin.

Chelipeds massive and unequal in size, merus ornamented with 3 spines and 2 spines on the anterior and posterior region respectively, carpus with strong spine on inner part and small spine on the outer part, two distinct spines present on the distal upper part near the insertion of finger. Strong patterning observed on female abdomen and last two pairs of walking legs, finger straight with slightly rounded claw shape tip.

The coloration of carapace dark grayish green, with palm purplish to green, tips of chelae orange and distal segments of legs pale orange.

***Portunus pelagicus* (Linnaeus, 1766) (Plate I,J,K,L)**

Carapace broad, little convex, its length a little more than half its breath without the great lateral spines, covered with largish military granules. Anterolateral borders very long and oblique, cut into nine teeth, including the outer orbital angle, the last is about four times as long as any of the others. Posterior border, smooth, forms a common curve with the posterolateral borders.

Chelipeds are more than three times at length of the carapace the hand on the most massive segments. Leg smooth, a spinule near the far end of the posterior border of the carpus of the first two pairs. The fifth pair of legs paddle shaped. The second pair of leg is the longest and the fifth the shortest.

The coloration of carapace pinkish purple, with extensive irregular, white spot, tips of chelae and distal segments of legs bluish and purplish green.

Portunus sanguinolentus **(Herbst, 1796) (Plate M,N,O,P)**

Carapace was very broad, little convex, its length in the middle line half its breadth excluding the great lateral spine.The presence of conspicuously marked three large blood red spots on the carapace posteriorly. Anterolateral borders are very long and oblique, cut into nine teeth of which the last is the longest. The posterolateral border smooth, forming a common curve with the posterolateral borders.

Chelipeds about two times the length of the carapace.Arm with three or four large spines on the anterior border, none on the posterior border. The walking legs smooth, the first two pairs with a spinule near the distal end of the posterior border of the carpus.

The coloration of carapace dark yellowish green, three blood-red spots ringed with while posteriorly.Chelipeds and the last walking leg greenish grey with white patches.

Charybdis feriatus **(Linnaeus, 1758) (Plate Q,R,S,T)**

Carapace not distinctly pilose, about two-thirds as long as broad, slightly convex, nearly smooth, the regions ill-defined. The posterior border of the dorsal surface of the carapace forms a curve with the posterolateral borders.The teeth in between are broad anteriorly acuminate lobes.

Chelipeds nearly two and a half times the length of the carapace, smooth and definitely placed costae and spines. Hands a little unequal in size, tumid but not inflated, with five costae and four spines on the upper surface fingers strongly toothed, as long as the palm. Fifth legs paddle-liked, has a spine at the distal end of the posterior border.

The coloration of carapace was orange brown with a large yellow cross. Chelipeds yellow, purple with spotted, the tips pink and light brown.

Eurycarcinu sorientialis **(Milne Edwards, 1867) (Plate U,V,W,X)**

Carapace rather over two as long as broad, perfectly smooth and somewhat quadrilateral. Front cut quite straight and square. Antero-lateral border being cut into five sharply teeth including the outer orbital angle and being less than the length of the postero-lateral borders.

Chelipeds are of unequal size. Arm with serrated upper margin, smooth lower margin and having a sharp spine on it, wrist with one sharp spine on each margin. The thumb of the largercheliped with an enlarged tooth at its base. Walking legs have sharp spiny claws at the tip. The second walking leg is the longest and the last one the shortest.

The coloration of carapace and all the appendages are purplish. Dorsally the tip of the cheliped is purple in color and eye black.

A. Male (Dorsal view)

B. Male (Ventral view)

C. Female (Dorsal view)

D. Female (Ventral view)

E. Male (Dorsal view)

F. Male (Ventral view)

G. Female (Dorsal view)

H. Female (Ventral view)

I. Male (Dorsal view)

J. Male (Ventral view)

K. Female (Dorsal view)

L. Female (Ventralview)

M. Male (Dorsal view)

N. Male (Ventral view)

O. Female (Dorsal view)

P. Female (Ventral view)

Q. Male (Dorsal view)

R. Male (Ventralview)

S. Female (Dorsal view)

T. Female (Ventral view)

U. Male (Dorsal view)

V. Male (Ventral view)

W. Female (Dorsal view)

X. Female (Ventral view)

Table 1. List of the recorded crab species from the studied three markets

Family	Genus	Scientific name	Common name	Local name
Portunidae	*Scylla*	1. *S.olivacea*	Red crab, Orange mud crab,	Shunt-ga-nan, Sar-ga-nan,
		2.*S.tranquebarica*	Purple mud crab	Shunt-ga-nan
	Portunus	3. *P.pelagicus*	Flower crab, Blue swimming crab	Pann-ga-nann, Ah-eho-gyi-ga-nan
		4. *P.sanguinolentus*	Three-spot swimming crab	Wa-thone-lone-ga-nan
	Charybdis	5. *C.feriatus*	Crucifix crab, Musk crab	The'-ga-nan, Myae-pone-ga-nan
Xanthidae	*Eurycarcinus*	6. *E.orientialis*	crab	Pa-zun-lone, Paik-ga-nan

Table 2. Genera and species occurrences of the two families of the recorded crab species from the three markets

Sr. no.	Family	No. of genus	No. of species	Species no. (% of total)
1.	Portunidae	3	5	83.33%
2.	Xanthidae	1	1	16.67%
Total		4	6	100.00%

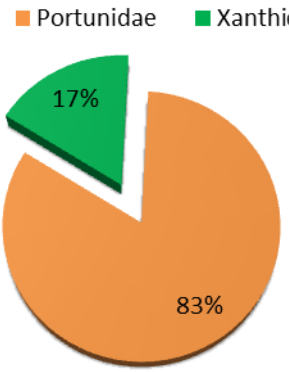

Fig.1 Number of species (% of total) of the two families of the recorded crab species from the three markets

Table 3. Range of morphomertric measurements of the recorded crab species

Sr. no.	Recorded species	Sex	Parameters					
			CW (cm)	CL1 (cm)	ML (cm)	CL2 (cm)	PL (cm)	DL (cm)
1.	*Scylla olivacea*	Male	8.0-8.6	6.2-6.6	2.9-3.0	2.1-2.3	5.6-5.7	2.1-2.9
		Female	8.0-9.5	5.6-6.3	2.2-3.0	1.8-3.0	5.0-5.5	2.5-2.9
2.	*Scylla tranquebaricaa*	Male	4.3-5.0	4.2-4.5	1.2-1.9	1.3-1.5	3.1-4.0	1.6-2.2
		Female	4.5-5.0	3.3-4.3	1.2-1.5	1.2-1.5	2.2-3.0	1.3-1.7
3.	*Portunus pelagicus*	Male	13.0-13.9	6.9-7.8	4.5-6.0	2.1-2.4	8.4-8.3	3.5-3.8
		Female	10.0-11.5	6.0-6.5	2.2-2.4	2.0-2.3	6.9-7.8	2.4-3.5
4.	*Portunus sanguinolentus*	Male	13.2-13.5	5.7-6.5	5.0-5.3	2.3-2.5	7.4-8.0	3.2-3.7
		Female	13.5-14.3	6.1-6.5	3.4-4.4	2.0-2.3	6.5-7.0	3.2-3.7
5.	*Charbdis feriatus*	Male	11.0-11.5	7.6-7.9	5.0-5.5	2.4-2.9	8.2-9.3	3.9-4.1
		Female	95-10.2	6.2-6.3	4.0-4.3	2.2-2.4	6.3-7.4	3.0-3.2
6.	*Eurycarcinus orientialis*	Male	2.7-2.9	3.0-3.7	0.9-1.1	1.2-1.5	1.8-2.1	1.1-1.6
		Female	2.9-3.2	3.2-3.9	0.8-1.0	1.0-1.2	1.6-1.9	1.0-1.4

CW = Carapace width CL1 = Carapace length ML = Merus length

CL2 = Carpus length PL = Propodus CL = Dactylus length

Table 4. Number of individuals of the recorded species in the three markets during the study period

Sr. no.	Recorded species	Number of individuals			Total
		Pazundaung Market	Central Sanpya Fish Market	Yadana Theingyi Market	
1.	*Scylla olivacea*	50	250	30	330
2.	*Scylla tranquebarica*	80	260	40	380*
3.	*Portunus pelagicus*	140	200	-	340
4.	*Portunus sanguinolentus*	60	250	60	370
5.	*Charybdis feriatus*	35	150	-	185
6.	*Eurycarcinus orientialis*	-	-	80	80
Total		365	1110*	210	1685

*Maximum

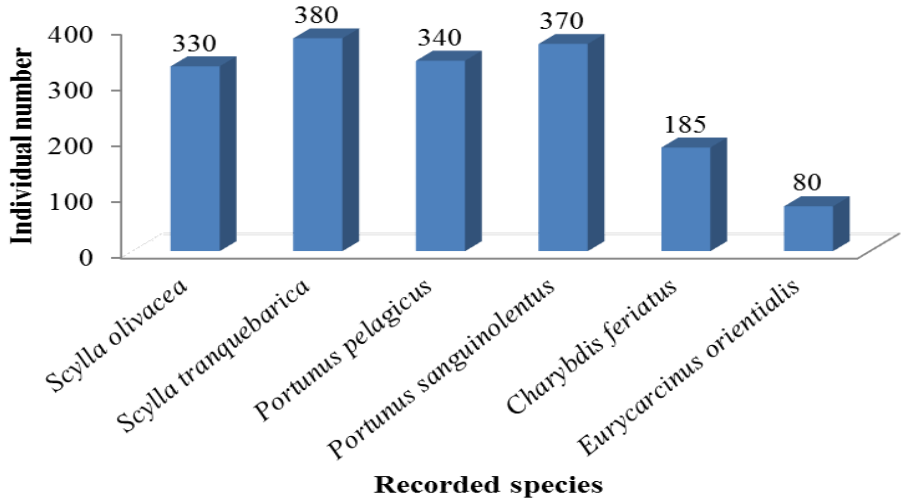

Fig. 2 Abundance of crab species in all three markets combined

Discussion

A checklist of brachyuran crabs of the world, reported 6,793 species, 1,271 genera and 93 families (Ng *et al*., 2008). Brachyuran crabs are comprised of about 700 genera and 5000 to 10,000 species worldwide, out of which 2,600 are present in Indo-West.Pacific region (Serene,1968). In India, 705 brachyuran crabs species, and 270 genera from 28 families have been reported (Venkataraman and Wafar, 2005)

In Myanmar, a total of 115 crab species of 50 genera belonging to the 12 families was reported by previous researchers with taxonomic point of views from the various coastal regions. Of these reported species, 20 species of six genera are from the family Portunidae and 24 species of 14 genera are from Xanthidae. Forty species of brachyuran crabs were found in vicinity of the mouth of Pathein river(MyintMyint Aye, 1996).

Among the recorded species of crabs, *Scylla olivacea* and *S. tranquebarica* were reported for the first time from these markets. Mud crabs of genus *Scylla* are very important part of marine fisheries resources for aquaculture purposes in many countries including Myanmar.

In Myanmar, the two species, *Portunus pelagicus* and *P. sanguenolentus* were recorded from the vicinity of Hpa- an Township by Nan KyiThein (2012). Taxonomy of *P. pelagicus* had been reported by San San Lwin (1986), KhinKhin Thant (1986), and Khin Mar Wai (1995).

In the present work, four species of the edible commercial crab species, *Scylla olivacea, S. tranquebarica, Portunuspelagicus, and P. sanguinolentus* were found as the abundant species in the studied markets of Yangon Region.

In the recent study, only one species of the genus *Charybdis* was found in the studied markets but not in Yadana Theingi Market. Out of the recorded species, only one species *Eurycarcinus orientialis* was found in relatively small amount only at Yadana Theingi Market, *Eurycarcinus orientialis* had been reported from mud flats of rivers in Hpa-an Township by Nan Kyi Thein (2012) but this species was not recorded by previous researchers from Myanmar Coastal waters.

Conclusion

A total of six species belonging to four genera under two families of Order Decapoda was recorded from Pazundaung Market in Pazundaung Township, Central Sanpya Market in Kyeemyindaing Township and Yadana Theingyi Market in North Okkalapa Township of Yangon Region. Among the recorded species, *Scylla olivacea*, *S. tranquebarica, Portunus pelagicus, P. sanguenolentus and Charybdis feriata* were the most commercially important exportable species during the study period (June to September, 2015), *Eurycarcinus orientalis* was marketed only for local consumption

In this present study, four species (*Scylla olivacea, S. tranquebarica, Portunus pelagicus, P. sanguenolentus*) of portunid crabs were abundantly encountered during the study period (*C. feriatus*) and one Xanthid species (*E. orientalis*) were less abundant in the studied markets.

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References

Alcock,A.,(1898). *Materials for a Carinological Fauna of India*.No.2.Bracyura Cyclometopa.Part1. The family Xanthidae.*Ibid*., Vol.67, Part 2, No.1.

Alcock, A., (1899). *Materials for a CarinologicalFauna of India*.No.4.Brachyura Cyclometopa. Part.2. The family Portunidae and Corystidae.*Ibid*., Vol.68, Part2. No.1.

Chhapgar, B.F. (1956). Marine Crabs (Decapoda: Brachyura) of Bombay State.*Jaurnal Bombay Natural Hist.Society*. Vol.54. Part, 2.

Khin Khin Thant, (1986). Taxonomy and distribution of Myanmar marine crabs (Decapoda: Branchyura) *MSc Thesis*.Department of Zoology, University of Yangon, Myanmar.

Khin Mar Wai, (1995). The taxonomic study of crabs in Gwa Area.*MSc Thesis*, Department of Zoology, University of Yangon, Myanmar.

MyintMyint Aye, (1996). The systematic study of some crabs from the mouth of Pathein River Ayeyarwady Division.*MSc Thesis*, Department of Zoology, University of Yangon, Myanmar.

Nan KyiThein, (2012). Occurrence of some crab species around Hpa-an Township, Kayin State.*MSc Thesis*, Department of Zoology, University of Hpa-an, Myanmar.

Ng. P.K.L.,Guinot, D, and Daie, P.J.F., (2008).Systemabrachyurorum; Part 1.An annotated checklist of extant brachyuran crabs of the world.*The Raffles Buttetin of Zoology*, 17:1-286.

San SanLwin, (1986).The taxonomy study of marine crabs of Chaungtha Area.*MSc Thesis*, Department of Zoology, University of Yangon, Myanmar.

Serence, R.(1968).The Brachyura of the Indo-Pacific region. In: Prodromus for a Check List of the Non-planktonic Marine Fauna of South East Asia. *National Academy of Sciences* Special Publication, 1:33-112.

Venkataraman, K., and Wafar, M., (2005).Coastal and marine biodiversity of India. *Indian Journal of Marine Science*, 34:57-75.

OCCURRENCE OF BUTTERFLY SPECIES IN NAMPHA VILLAGE, BANMAW ENVIRONS

Pan Ei Phyu*

Abstract

The distribution of butterflies was studied in Nampha Village, Banmaw Environs from June, 2017 to January, 2018. A total of 18 butterfly species including 14 genera and four families were recorded. The four families of butterflies recorded were Papilionidae, Pieridae, Nymphalidae and Lycaenidae. Among them, the highest number of species was Nymphalidae followed by Pieridae, Papilionidae and the lowest family in Lycaenidae. Regarding species composition, family Nymphalidae represented the highest percentage (44.44%) with 8 species and the lowest composition in family Lycaenidae (11.11%) with 2 species representative.

Introduction

Butterflies are beautiful flying insects with large wings. Like all insects, they have six jointed legs, three parts of body and a pair of antennae and compound eyes. The three parts of body are head, thorax and abdomen. The butterfly's body is covered by tiny hairs. Therefore, their wings are covered with thousands of tiny scales.

Butterflies belong to order Lepidoptera, the literal meaning of which is "scale-winged". Lepidoptera is a very large group; there are many types of butterflies than there are of any other types of insects except beetles.Approximately 17,200 species of butterflies throughout the world. The distribution of butterflies depends upon the availability of their host plants (Arya *et al*., 2014).

Butterflies have evolved in complex feeding relationship with plants since the development of both larvae and adults. Their larvae are typically host specific while adults often show a high degree of generalization. Most butterflies prefer flower nectar. Nectar provides energy and pollen is responsible for providing proteins, lipid and vitamins (Faegri and Van-Der-Puji, 1979) (cited by Sajjad *et al*., 2012).

Butterflies are very important group of insects because they transfer pollen from one flower to the next and thus serving as agents for pollination (Sajjad, *et al*., 2012). Healthy biological communities depend on insects as pollinators, seed dispersers, herbivores, predators and prey.(Tiple and Khurad, 2009).

Nowaday, increasing in urban feature such as building, road and over population give results decreasing in butterfly species richness, diversity and abundance (Stefaneseu, 2004: Dover and Settele, 2009).

Banmaw Environs is suitable for butterflies because this area has a subtropical humid climate and spread over with trees and flowering plants, crops, paddy fields and some vegetables plants that provide shelter and breeding sites for the butterflies.

So, Nampha Village from Banmaw Environs was selected as the study area to complete the entire fauna of this area and thus add to the survey of the butterflies in Myanmar. Therefore, the present study is intended to add more information with

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respect to the butterfly occurrence depended on the plants. The present study has been undertaken with the following objectives;

- to record and identify the species of butterflies from Nampha Village

- to investigate the species composition of butterflies

Materials and methods

The specimens were collected at once in every weekends of each month by hand and hand net. They were searched at day between 8:00 -12:00 am and 2:00 - 4:00 pm. After catching, the butterflies were killed by squeezing between the thumb and index finger on the thorax of the butterflies while still in the net. Next, the spreading specimens and the photographs were taken to obtain a natural color and to identify the specimen. The dead specimen was placed into triangular folded envelopes of various sizes made of translucent tracing paper with its wings folded together, and the antennae in their natural position. The translucent tracing paper with dead specimens was kept with naphthalene balls in a plastic box to prevent for entering and destroying the ants. These specimens were identified according to Talbot (1939), Bingham (1905) and Corbet and Pendlebury (1992).

Results

A total of 1351 individuals of 18 species belonging to 14 genera under four families were recorded during the study period. The recorded species were included under four families, Papilionidae, Pieridae, Nymphalidae and Lycaenidae;

(1) Species –*Papilio polytes romulus*(Cramer, 1775)

Above black tailed, forewing with terminal series of white spots, decreasing in size towards the apex. Hindwing with complete discal band of elongate white spot (Plate 1, A).

(2) Species –*Papilio demolus* Linnaeus,1758

On a black ground the wings present numerious creamy coloured markings. One band made up of irregular patches starts in the discal region of the forewing (Plate 1, B).

(3) Species – *Papilio memnon agenor* Linnaeus, 1758

Upperside of the wing is black dusted with blue. Upperside of the hindwing with indistinct gray-blue stripes and no tail (Plate 1, C).

(4) Species – *Graphium agamemnon*(Linnaeus,1758)

On the upperside of the wings, brownish black with apple green spots. The hindwing has short tail at vein which is longer in the female (Plate 1, D).

(5) Species –*Delias hyparete* (Linnaeus,1758)

Upperside of the white forewing with a black apical area and the vein black. Above the wings are white, with the veins black dusted in the outer areas (Plate 1, E).

(6) Species–*Appias libythe aolferna* Swinhoe,1890

Upperside of the forewing is cream-white in color. Forewing has no pale spots, in the black border (Plate 1, F).

(7) Species –*Catopsilia pomona pomona* Cramer, [1777]

Upperside of the wings are pale greenish yellow.Basal part yellowish green. Forewing marginal apex black (Plate 1, G).

(8) Species - *Catopsilia pyranthe* (Linnaeus,1758)

Ground colour of both wings are white. Upperside of the forewing is costa black and extended towards the outer marginal border and a black cell end spot (Plate 1, H).

(9) Species – *Danaus genutia* (Cramer,[1779])

Both wings are reddish-brown with all veins broadly black. The margins of the wings are black with two series of white spots, two, in each area in each row (Plate 1, I).

(10) Species – *Tirumala limniace* (Cramer,[1775])

Dark-brown with bluish white spots and streaks. Upperside of forewing is banded spots and streak. Upperside hindwings cell are entirely blue (Plate 1, J).

(11) Species – *Parantica aglea melanoides* Moore, 1883

Upperside of the forewing, color fuliginous black with bluish-white streaks and spots,

cell with a very broad, elevate streak transverse by two fine black lines (Plate 1, K).

(12) Species – *Euploea tulliolus* Fabricius,1793

The wings are ferruginous brown, and the apical portion of the forewing is shot with deep blue and bears a few pale blue. (Plate 1, L).

(13) Species–*Ethope himachala* (Moore,1857)

Forewing with 7 white pupilled black ocelli. Hindwing similar to forewing with 6 ocelli and submarginal lines in upperside (Plate 1, M).

(14) Species –*Cethosia cyane euanthes*(Drury,1770)

Upperside of the forewing, brown to basal region, white board from mid costa to sub-termen the extent of black on forewing larger (Plate 1, N).

(15) Species – *Junonia hierta* (Fabricius, 1789)

It is predominantly yellow. It forewing apex is black with yellow spots. The hindwings have a large blue spot (Plate 1, O).

(16) Species – *Athyma perius* (Linnaeus, 1758)

Upperside of the forewing, black with white markings. Upperside of the hindwing, subbasal white band broader (Plate 1, P).

(17) Species – *Castalius rosimon* (Fabricius, 1775)

Upperside white with black borders and black spots, wing bases blue. On the upperside, the bases of the wings are metallic green (Plate 1, Q).

(18) Species – *Cheritra freja* (Fabricius, 1793)

The upperside of the wings have a brown with white bands. The hindwings consist of a tail (Plate 1, R).

A total of 18 butterfly species under the order Lepidoptera were recorded from the study area of Banmaw Environs. During the study period, four species, *Papilio polytes romulus, P. demolus, P. memnon agenor, Graphium agamemn*on in family

Papilionidae; four species, *Delias hyparete, Appias libythea olferna, Catopsilia pomona pomona, C. pyranthe* in family Pieridae; eight species, *Danaus genutia, Tirumala limniace, Parantica aglea melanoides, Euploea tulliolus, Ethope himachala, Cethosia cyane euanthes, Junonia hierta, Athyma perius* in family Nymphalidae and two species, *Castalius resimon* and *Cheritra freja* in family Lycaenidae were recorded (Table, 1).

Among the recorded families, the highest species percent was recorded in Nymphalidae 8 species (44.44%) followed by Pieridae and Papilionidae each of 4 species (22.22%) and the lowest species percent was founded in Lycaenidae 2 species (11.11%) (Fig.1).

According to data collection, the highest individual numbers collected was *J. hierta* (207) and the lower individual number was *G.agamemnon* from study site. Therefore, the highest number of 8 species and 652 individuals in Nymphalidae and the lowest individual number of 2 species and 160 also were found throughout the study period (Fig.2, Table, 2).

A. *Papilio polytes romulus*

B. *Papilio demoleus*

C. *Papilio memnon agenor*

D. *Graphium agamemnon*

E. *Delias hyparete*

F. *Appias libythea olferna*

Plate 1 Butterfly species recorded under family Papilionidae and Pieridae

G. *Catopsilia pomona pomona*

H. *Catopsilia pyranthe*

I. *Danaus genutia*

J. *Tirumala limniace*

K. *Parantica aglea melanoides*

L. *Euploea tulliolus*

Plate 2 Butterfly species recorded under family Pieridae and Nymphalidae

M. *Ethope himachala*

N. *Cethosia cyane euanthes*

O. *Junonia hierta*

P. *Athyma perius*

Q. *Castalius rosimon*

R. *Cheritra freja*

Plate 3 Butterfly species recorded under family Nymphalidae and Lycaenidae

Table1. Butterfly species recorded in the study area

Sr. No	Order	Family	Species name	Common name
1	Lepidoptera	Papilionidae	*Papilio polytes romulus*	Common Mormon
2			*Papilio demolus*	Lime butterfly
3			*Papilio memnon agenor*	Great Mormon
4			*Graphium agamemnon*	Tailed jay
5		Pieridae	*Delias hyparete*	Painted Jezebel
6			*Appias libythea olferna*	Striped Albatross
7			*Catopsilia pomona pomona*	Lemon Emigrant
8			*Catopsilia pyranthe*	Mottled Emigrant
9		Nymphalidae	*Danaus genutia*	Common Tiger
10			*Tirumala limniace*	Blue tiger
11			*Parantica aglea melanoides*	Glassy tiger
12			*Euploea tulliolus*	Dwarf crow
13			*Ethope himachala*	Dusky diadem
14			*Cethosia cyane euanthes*	Leopard lacewing
15			*Junonia hierta*	Yellow pansy
16			*Athyma perius*	Commom sergeant
17		Lycaenidae	*Castalius rosimon*	Common pierrot
18			*Cherita freja*	Commom lmperial

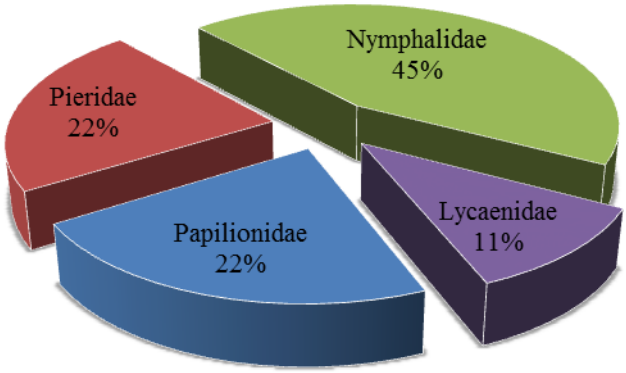

Fig. 1 Composition of butterflies in different families from study site during June, 2017 to January, 2018

Table2. Monthly collected butterfly species from study area

Sr No.	Species Name	June	July	August	September	October	November	December	January	Total
1	*Papilio polytes romulus*	4	19	20	15	17	10	1	3	89
2	*Papilio demolus*	22	26	19	21	17	24	10	10	149
3	*Papilio memnon agenor*	9	11	6	7	4	5	3	2	47
4	*Graphium agamemnon*	0	1	2	0	1	1	0	0	5
5	*Delias hyparete*	12	22	18	15	10	8	1	3	89
6	*Appias libythea olferna*	14	17	10	22	16	20	10	17	126
7	*Catopsilia pomona pomona*	10	5	0	1	3	5	0	0	24
8	*Catopsilia pyranthe*	1	0	2	4	0	1	0	2	10
9	*Danaus genutia*	3	18	11	19	15	2	6	1	75
10	*Tirumala limniace*	11	10	19	18	9	7	1	0	75
11	*Parantica aglea melanoides*	12	23	27	25	22	11	0	1	121
12	*Euploea tulliolus*	9	6	11	10	2	5	0	0	43
13	*Ethope himachala*	0	4	7	0	2	1	0	0	14
14	*Cethosia cyane euanthes*	1	2	1	9	0	2	0	0	15
15	*Junonia hierta*	20	33	17	39	41	28	19	10	207
16	*Athyma perius*	11	16	19	14	17	13	10	2	102
17	*Castalius rosimon*	21	11	15	9	10	18	7	3	94
18	*Cherita freja*	10	17	7	18	10	3	0	1	66

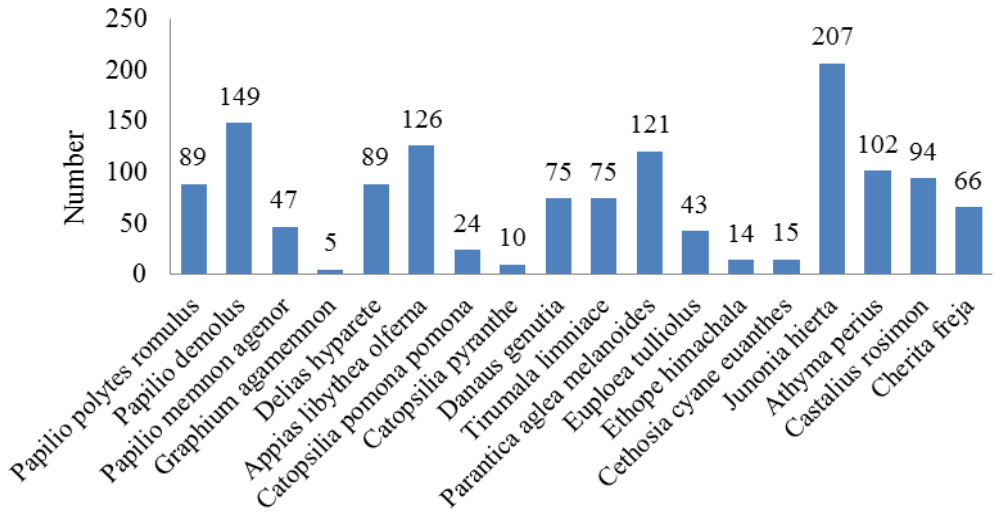

Fig.2 Recorded individual numbers of butterflies in study area

Discussion

During the study period (June, 2017 – January, 2018), a total of 18 butterfly species belong to 14 genera four families including 6 subspecies were recorded from Nampha Village in Banmaw Environs. Out of these families, Nymphalidae revealed the highest species composition (8 species, 44.44%) and Lycaenidae (2 species, 11.11%) were recorded. Members of the family Nymphalidae were always dominant in the region because they constitute the largest group of diurnal Lepidoptera. They also seem to be very susceptible to change in the environment and tend to produce a great number of local races and forms (Pinratana, 1979).

Naw Cillia Lin Bert (2010) described 11 species of Papilionidae in Winemaw Township, Kachin State. In the present work, four species of the family Papilionidae were recorded. Among them *Papilio demoleus* was collected in the largest number in study area. It is assumed that the occurrence of butterflies may depend on the presence of host plants.

When comparison is made with previous local worker, Khin Soe Win (2003) reported 55 species of distributed under 5 families, 43 subspecies in Banmaw area. In this research, 18 species, 14 genera, four families including 6 subspecies were recorded. The difference of butterfly species between present work and previous local researchers may depend on factors such as environmental condition, collection time and food sources.

Khin Thandar Latt (2016) reported 60 species and 43 genera and five families in Monywa Environs, Sagaing Region and 14 species and 9 genera are the same with present work. But, family Hesperidae didn't found in this site. Hesperidae includes butterflies which are known as skippers are of jungle butterflies and reach their greatest numbers in the hilly region in Burma (Myanmar) (Blyth, 1857).

During this research, species composition of family Nymphalidae was recorded as the largest family containing 8 species. This finding of the present study agreed with the statements of Khin Thandar Latt (2016), Kinyon (2004) and Mail *et al*. (2014). According to the previous authors and present study, family Nymphalidae is the most dominant family among butterfly families in all localities of Myanmar and worldwide.

On the whole, the results of the present study indicated the importance of habitat area on the butterfly community, resource availability happened to be a critical factor in determining the occurrence of butterfly species. In conclusion, this research work does not claim complete but it would give information for further researchers.

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References

Arya, M.K., (2014). Species richness and diversity of Butterflies in and around Kumaun University, Nainital, Uttarakhand, India. *Journal of Entomology and Zoology Studies*. 2(3): 153-159.

Bingham, C.T., (1905). *The Fauna of British India Including Ceylon and Burma. Butterflies. Volume I.* Taylor and Francis Company, London.

Corbet, S.A. and Pendlebury, H.M., (1992). *The Butterflies of the Malay Peninsula*. Malayan Nature Society, Kuala Lumpur. Malaysia.

Khin Soe Win, (2003). Systematic Study on the Butterflies of Ba Maw Area. Banmaw Uinversity.

Kinyon, S., (2004). *A field Guide to the Butterflies of Myanmar*. Sponsored by: Smithsonian Institution, Zoology Department. University of Yangon

Khin Thandar Latt, (2016). Species Composition, Abundance, and Density of Butterfly Fauna in Monywa Environs, Sagaing Region with Emphasis on Food Plants Nectared by Adult Butterflies. *PhD Dissertation*. Department of Zoology. University of Mandalay.

Mail, M., Khokhariya, B.P and Dabgar, Y.B., 2014. Biotic Interrelationship of Plants and Butterflies in Surrounding of Gandhinagar, Guijarat. *International Journal of Scientific Research*.

Naw Cillia Lin Bert, (2010). Species Diversity and Seasonal Abundance of Some Butterfly Species in Nay Pyi Taw Environs. *PhD Dissertation.* Department of Zoology. University of Mandalay.

Stefanescu, C., Roland, J., (2006). Moth diversity in a fragmented habitat: importance of functional groups and landscape scale in the boreal forest. Ann Entomol Soc Am. 99(6): 1110-1120.

Sajjad, A., Saeed, S. and Burhan-u-din, S., 2012. Yearlong association of butterfly populations with flowering plants in Multan, Pakistan. *Pak. Entomol*, 34(2): 105-110.

Talbot, G., (1939). *The Fauna of British India including Ceylon and Burma. Butterflies Vol.I*. Taylor and Francis Company, London.

Tiple, A.D. and Khurad, A.M., (2009). Butterflies Species Diversity, Habitats and Seasonal Distribution in and around Nahpur City, Central India. *World Journal of Zoology*, 4(3): 153-162.

Study on Nutritional and Phytochemical Analysis of *Mucuna pruriens* L. Seeds (Khwaylaya)

Pyone Yi[1], Kyaw Lwin[2], and Hnin Yu Maw[3]

Abstract

A medicinal plant *Mucuna pruriens* L. (Velvet bean) is commonly known as Khwaylaya in Myanmar, belong to the family Fabaceae which has been collected from Patheingyi Township, Mandalay Division. In this research, the morphological characters, phytochemical constituents and nutritional values of *Mucuna pruriens* L. were conducted. The morphological character was done by available literatures. According to this, *Mucuna pruriens* L. is perennial climber, inflorescence pendulus, flower dark purple, fruits with velvet hairs. Phytochemical investigation revealed that thirteen tests, among them, the exception of tannin, steroid, cyanogenic glycosides, the others compound were found in sample seeds. A nutritional analysis of the powdered seeds was conducted and the results indicated that the seed contain carbohydrate (48.6 %), protein (24.17 %), fat (3.62 %), moisture content (10.73 %), ash (4.93%) and fibre content (7.95 %). Medicinal uses of sample seeds were described according to the interviewing information. This research aims to inform the medicinal properties and nutritional values of (Khwaylaya) seeds for local people.

Key words: *Mucuna pruriens* L., Fabaceae, morphological, phytochemical, nutritional value.

Introduction

All plants contain a large number of bio-active compounds and possess medicinal value that can be used to treat many diseases in humans and animals. Medicinal plants are greatly important to the health of the individuals and communities. There are many thousands of medicinal plants throughout Myanmar, with a tremendous of actions and degree of potency. For people in developing countries, medicinal plants are popular because their products are safe and widely available at low cost. Some compounds *Clerodendrum, Mentha, Ocimum, Leucus and Coleus*, etc (Nyo Maung et al., 2012) extracted from medicinal plants already play an important role against infectious diseases. In Myanmar, the use of most medicinal plant is usually based on folklore.In this paper, carried out the chemical constituents and nutritional values of *Mucuna pruriens* L. seed in family Fabaceae.

Mucuna pruriens L. is a tropical legume belongs to the family Fabaceae. It is native to Africa and tropical Asia and widely naturalized and cultivated. Its English common names include Velvet bean, Bengal velvet, Florida velvet bean, cowage, cowitch, and lacuna bean. In Myanmar, this plant commonly known as khwaylaya. The plant is an annual climbing shrub with long vines that can reach over 15 meters in length. The leaves are tripinnate, ovate to obovate. The inflorescences are axillary panicles, 15-32 cm long with many flowers. *Mucuna pruriens* L. bear white lavender or purple flowers. Its pods are about 10 cm long and are covered in loose, orange hairs. The seeds are shiny black or brown.

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The phytochemical investigation of a plant may thus involve the authentication and extraction of the plant materials for quantitative evaluations (Evens, 2002). In present research, except of the tannin, steroid, cyanogenic glycosides the other compounds were found in sample seeds. Minerals are inorganic substance, present in all body tissues and fluids. Their presence is necessary for the maintenance of certain physicochemical processes which are essential to life.

The nutritional value of moisture, protein, ash, fat, crude fibre, carbohydrate give the benefits for human being. Foods provide nutrients such as vitamins, minerals, proteins, carbohydrates and fats and a host of other non-essential nutrients that may confer health benefits (Gershwin and Belay, 2008). In present research, protein 24.17%, carbohydrate 48.6 %, fiber 7.95 %, fat 3.62%, ash 4.93%, moisture 1.73% respectively were contained in sample seeds.

The study of medicinal plants and their therapeutic properties play a very important role in the health care system of the country. In Myanmar, most of the populations have been using traditional medicine for centuries. Myanmar traditional practitioners use a variety of effective medicines mostly based on plant materials available. The seeds of *Mucuna pruriens* L.mostly used for parkinson's disease in Myanmar. It caused tonic and lactation to woman and then sperms production increases to man. (Myanmar's medicinal plants, Vol. 2, Medical Research Centre, Upper Myanmar, Health Ministry). The seeds of *Mucuna pruriens* L. are considered a tonic specific to neurons and then it is often taken with milk and honey to enhance its restorative nature. The seeds of velvet bean are reversed as one of the best reproductive tonics for men and women alike. It also supports normal fertility, healthy sperm and ova.(Chaung Oo clinic, Monywa). A typical dose of the powder is ¼ - ½ teaspoon, once or twice daily. This powder can be taken with water, milk, ghee, honey and acts as tonic (Yoma Hein clinic, Mandalay).

Objectives

The present research aimed to identify this *Mucuna pruriens* L. plant and to know the chemical composition of *Mucuna pruriens* L. as well as to evaluation of its nutritional values.And then to inform the medicinal properties of *Mucuna pruriens* L. plant.

Materials and Methods

Collection and Identification of Plant

Mucuna pruriens L. plants family Fabaceae were collected from Patheingyi township area, growing as cultivated during flowering times (February to May) 2017. Collected specimens were identified according to Hooker (1879), Kirtikar and Basu (1933), Backer (1963), Hutchinson (1967), and Dassanayake (1987) and Flora of China (1994). The morphology and taxonomical studies were made from the fresh specimens of both the vegetative and reproductive parts.

Preparation of sample seed powders

The collected sample seeds were sun-dried until crisp and easy to bundle (about 3 days). The seeds were ground into powder with an aid of a mechanical grinder and stored in an air tight container for throughout the studies.

Methods for Preliminary phytochemical screening

The chemical analysis of sample seeds (*Mucuna pruriens* L.) was conducted in the Biochemistry Laboratory, Department of Biochemistry, Institute of Medicine, Mandalay. The qualitative chemical constituents of methanol extract of the seeds using commonly employed precipitation and coloration to identify the major natural chemical groups such as alkaloids, carbohydrates, glycoside, phenol, α- amino acid, saponin, tannin, flavonoid, steroid, terpenoid, reducing sugar, starch, cyanogenic glycoside compounds were performed by the standard methods (Harborne JP, 1973). General reactions in these analyses revealed the presence or absence of these compounds in the crude extracts tested.

Methods for analysis of general nutritional values

Determination of moisture content

The percentages of loss of water on drying of weighted of seeds sample were determined by the Automatic Moisture Analyzer, MAC Series 110, Taiwan. The moisture in a weight sample is removed by heating in an oven in water specified conditions. The weight loss is calculated and taken as the content of moisture.

Apparatus –Electronic balance, Moisture basin, Oven, Air – tight desiccator

$$\text{Calculation - Moisture content \%} = \frac{\text{Loss in weight (g)}}{\text{Weight of sample (g)}} \times 100$$

Determination of ash

Five grams of the dried powdered of seeds were weighed in a crucibles and placed in a muffle furnace at 600˚C until the substance turned into ash. After this, the crucibles were cooled in a desicator and weighed. The procedure was repeated until a constant weight was obtained and the percentage of the total ash was calculated. The ash content is determined by weighing the dry mineral residue of organic material heated at elevated temperature.

Apparatus – Electronic balance, Porcelain crucible, Muffle furnace (600^{o} C)

Air – tight desiccator

$$\text{Calculation - Ash content \%} = \frac{\text{Weight of residues (g)}}{\text{Weight of sample (g)}} \times 100$$

Determination of fat

The content of fat is determined by solvent extraction method by using Soxhlet apparatus.

Apparatus – Electronic balance, Thimble, Oven, Soxhlet apparatus

Reagent - Petroleum ether (bpt. 60-80^{o}C)

$$\text{Calculation - Fat content \%} = \frac{\text{Weight of fat (g)}}{\text{Weight of sample (g)}} \times 100$$

Determination of fibre

The crude fibre is determined as the organic residue that is left after the other carbohydrates and proteins have been removed by successive treatment with boiling acid and alkali.

Apparatus – Electronic balance, Condenser, Filtering cloth, Buchner fannel,

Muffle furnace (600^{o} C), Desiccator, Water section pump

Reagents - 1.25 % Sodium hydroxide solution (w/v), 1.25 % Sulphuric

acid solution(w/v), 95 % Ethanol

$$\text{Calculation - Fibre content \%} = \frac{\text{Weight of fibre (g)}}{\text{Weight of sample (g)}} \times 100$$

Determination of carbohydrate

The carbohydrate content is determined by phenol-slphuric colorimetric methods. This method is sensitive, rapid, accurate, specific for carbohydrates and widely applicable. Besides, the reagents are unexpensive, readily available, and stable.

Apparatus –Test tube, PYE UNICAM SP 6/450 UV VIS Spectrophotometer

Reagents - 5 % phenol solution, Sulphuric acid solution (96%)

Determination of crude protein

The crude protein content is determined by Micro-Kjeldahl's method. In this method, the estimation of crude protein in food is based on the assumption that the percentage of protein in food is equal to 6.25 times percent nitrogen.

Apparatus – Kjeldahl digestion flask (30 ml), Kjeldahl distillation

apparatus, Digestion rack, Conical flask, Micro-burette

Reagents - Concentrated sulphuric acid

- Kjeldahl mixture ($K_2 SO_4$: $CuSO_4$. $5H_2O$ = 100: 10)
- 40% Sodium hydroxide solution
- 0.1 M Sodium hydroxide solution
- 0.5 M Sulphuric acid solution

$$\text{Calculation - Nitrogen content \%} = \frac{0.014 \times 100 \times (x-v)\, M}{W}$$

0.014 = Milliequivalent weight of the Nitrogen

x = vol (mol) of Sodium hydroxide solution used in blank

v = vol (mol) of Sodium hydroxide solution used in test

M = Molarity of Sodium hydroxide solution

W = weight of defatted powder of sample

Protein content % = 6.25 x Nitrogen %

Results

Morphological Characters

***Mucuna pruriens* (L.) DC.**

Family - Fabaceae
English name - Velvet Bean
Myanmar name - Khwaylaya
Flowering period - November to February
Part Used - Seeds

Outstanding Characters - Annual twining herbs; stems and branches terete or angular, densely clothed with patent brown stinging hairs. Leaves trifoliolate-compound; stipules linear-lanceolate, caducous; petioles 7.0-9.0 cm long, canaliculated above; rachis 1.0 to 2.0 cm long, wtih stinging hairs; leaflets ovate or ovate-rhomboid, 7.0-10.0 cm by 3.5-5.0 cm, entire along the margin, acute apex, densely brown-hairy on both surfaces.Inflorescences axillary racemes; peduncles 10.0-12.0 cm long, with brown hairy. Flowers bisexual, zygomorphic, pentamerous, dark violet;bracts lanceolate.Calyx campanulate, 4- to 5- lobed.Corolla papilionaceous, exserted; standard ovate, dark violet, glabrous; wings oblique-oblong, dark purple, glabrous; keels oblong, purple, glabrous.Stamens 10, diadelphous; filaments free; anthers unifrom.Ovary superior, oblong, densely oranged brown hairs, unilocular, with many ovules on the marginal placentae; style filiform; stigma small, capitate, hairy. Pods dehiscent, oblong, 5.0-8.0 cm long, slightly curved at the top, densely orange brown hairs, 8 - to 10 - seeded.Seeds oblong, about 1.0 cm long, black. These characters were shown in Figure 1.


Habit


Plant with Inflorescences


Inflorescences


Fruiting Plant


Fleshing Fruits

Fig.(1):*Mucuna pruriens* L. (Khwaylaya)

Preliminary phytochemical Tests

The preliminary investigations were analysed for the determination of chemical constituents from the seeds of *Mucuna pruriens* L. (Khwaylaya). The results are shown in Table 1.

Tabel(1) Preliminary Phytochemical examination of the seeds of *Mucuna pruriens*L.

No.	Type of compound	Extract	Reagents used	Observation	Results
1	Alkaloid	1% HCL	Mayer's reagent	White ppt.	+
			Wagner's reagent	Deep blue ppt.	+
			Dragendorff's reagent	Brown ppt.	+
			Hager's reagent	Yellow ppt.	+
2	Carbohydrate	D/W	10% α –naphthol& H_2SO_4 (Conc:)	Red ring	+
3	Glycoside	D/W	10% Lead acetate solution	White ppt.	+
4	Phenol	D/W	5% $FeCL_3$ solution	Greenish black ppt.	+
5	α – amino acid	D/W	Ninhydrin reagent	Purple colour	+
6	Saponin	D/W	-	Persistent foam	+
7	Tannin	D/W	1% Gelatin & 10% NaCL solution	No ppt.	-
8	Flavonoid	70% EtOH	Mg ribbon &Conc; HCL	Pink colour	+
9	Steriod	Pet-ether	Acetic anhydrite &Conc; H_2SO_4	-	-
10	Terpenoid	Pet-ether	Acetic anhydrite &Conc; H_2SO_4	Pink	+
11	Reducing sugar	D/W	Fehling's solution	Orange ppt.	+
12	Starch	D/W	Iodine solution	Brownish blue colour	+
13	Cyanogenic glycoside	Powder	H_2O, Conc; H_2SO_4,	No colour change	-

(+) = presence (-) = absence

In present study, the exception of tannin, steriod and cyanogenic glycoside, the remaining compounds; alkaloids, carbohydrate, glycoside, phenol, α – amino acid, saponin, flavonoid, starch, terpenoid, reducing sugar compounds were found in the specimen.

Analysis of General Nutritional Values

The determination of percentage of the fats, protein, fibres, carbohydrate, ash, moisture contents of sample seeds of *Mucuna pruriens* L. were carried out at Food Industries Development Supporting Laboratory (FDSL), Myanmar Food Processors and Exporters Association (MFPEA), Yangon. The results were shown in Table (2) and Figure (2).

Table (2): The nutritional values of *Mucuna pruriens* L.

No.	Constituents	Nutritional values (%)
1	Protein	24.17 %
2	Carbohydrate	48.60 %
3	Fibre	7.95 %
4	Fat	3.62 %
5	Moisture	10.73%
6	Ash	4.93%

In the nutritional value, the seed of *Mucuna pruriens* L. contained nutritional values such as carbohydrate (48.60%), protein (24.17%), fat (3.62%), fibre (7.95%), moisture (10.73%) and ash (4.93%) respectively.

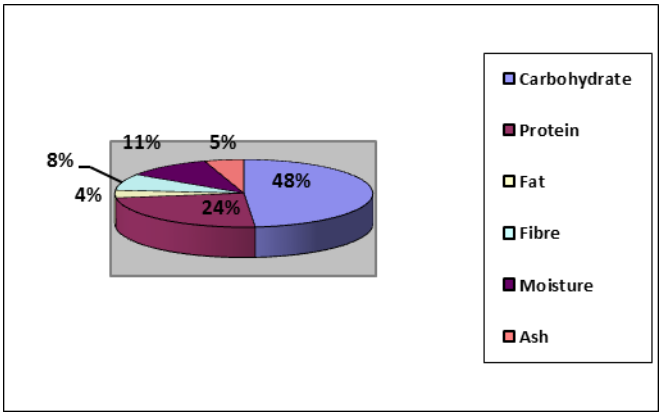

Fig.(2): Nutritional values of *Mucuna pruriens* L.

Discussion and Conclusion

Plants used in traditional medicine contain a wide range of ingredients that can be used to treat chronic as well as infectious diseases. The medicinal value of plants lies in some chemical substances that produce a definite physiological action on the human body. According to the WHO, medicinal plants would be the best source for obtaining variety of drugs. Plants are rich in a wide variety of secondary metabolites such as tannins, alkaloids and flavonoids, which have been found in vitro to have antimicrobial properties. A number of phytotherapy manuals have mentioned various medicinal plants for treating infectious diseases due to their availability, fewer side effects and reduced toxicity. In the present research, morphological characters of *Mucuna pruriens* L., phytochemical constituents, and nutritional values of selected medicinal plant have been described.

Mucuna pruriens L. is a medicinal plant, belonging to the family Fabaceae. This plant is annual climbing herb. Stems and branches terete or angular, densely clothed with patent brown stinging hairs. Leaves trifoliolate-compound; leaflets ovate or ovate-rhomboid, densely brown-hairy on both surfaces.Inflorescences axillary racemes, pendulous, brown hairy.Flowers bisexual, zygomorphic, pentamerous, dark

violet.Stamens 10, diadelphous; filaments free; anthers unifrom.Ovary superior, oblong, densely oranged brown hairs, unilocular, with many ovules on the marginal placentae; style filiform; stigma small, capitate, hairy. Pods dehiscent, oblong, slightly curved at the top, densely oranged brown hairs.Seeds oblong, black. These characters were in agreement with those given by literatures (Hooker, 1879; Hutchinson, 1964; Hooker (1879), Hutchinson (1967), and Dassanayake (1987) and Flora of China (1994). In this research, preliminary phytochemical test was investigated to determine the presence of various phytoconstituents. The nutritional values such as protein, fibre, fat, carbohydrates were found in various percentage.

Phytochemical screening of *Mucuna pruriens*L.extracts revealed that the plants contain several secondary metabolites. This study shows that the exception of tannin, starch and cyanogenic glycoside, the remaining compounds; alkaloids, carbohydrate, glycoside, phenol, α – amino acid, saponin, flavonoid, steroid, terpenoid, reducing sugar compounds were present in the specimen. Pharmacological study of *Mucuna pruriens* L. has not still been systematically reported until now in Myanmar.

In nutritional values, the seeds of *Mucuna pruriens* L. were contained protein 24.17%, carbohydrate 48.6%, fiber 7.95%, fat 3.62%, ash 4.93%, moisture 10.73% respectively. These constituents were agreed with (Faridah Hanum, 1997). *Mucuna pruriens* L. seeds are used traditionally for various diseases including human cancers. Its medicinal uses, however, have not been scientifically validated. Thus, the current study has provided a information of the medicinal properties of the seeds of *Mucuna pruriens* L. in Myanmar.

The present study suggests that the seeds of *Mucuna pruriens* L. have bioactive components and nutritional values. However it is obvious that less information was available further in order to explore this plant more researchers should be carried out. This study will provide medicinal and nutritional values from the seeds of *Mucuna pruriens* L. as to contribute to human health.

Mucuna pruriens L. seeds are used traditionally for various diseases including parkison’s disease and rapid sperm production in man at some regions in Myanmar. But its medicinal uses have not been scientifically validated. Thus, the current research has provided information of the medicinal properties of the seeds of *Mucuna pruriens* L. in Myanmar. Furthermore, the outcome results can be used in upgrading the future traditional medicine to level up with the modern medicines.

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References

Baker, C.A & R.C Bakhunzen Van Brink Jr. (1963) **Flora of Java**, Vol.1-3, Noordhoff. Graningen, Nethrlands.

Dassanayake, M.D. (1987) **A Revised Handbook to the Flora of Ceylon**, Vol 1-13, University of Peradeniya.Department of Agriculture, Washington DC

Harborne JB. (1984) **Phytochemical methods: A guide to modern techniques of plant analysis**. London: Chapman and Hall.

Hooker, J.D (1879) **Flora of British India**, Vol. 1-6, L. Reev& Co. Ltd., London.

Hutchinson, J. (1967) **The families and flowering plants.** Vol. 1,2, 2st Edition, Oxford University Press.

Kapoor, L.D. (2001) **Hand Book of Ayruvedic Medicinal Plants.** Press.Boca Raton. London New York Washington DC.

Kirtikar KR, Basu BD. (1933) **Indian medicinal plants.** 2nd Edition, Dehradun; International Book distributors.

Trease, G.E and Evans, W.C (2002) **Text book of Pharmacognosy.** 15th Edition, Harcourt Publishers Limited, New York.

FaridahHanum. I, (1997) **Plant Resources of South-East Asia, No.11, "Axillary Plants",** Backhugs Publishers, Leiden.

TiwariP.B.Kumar (2011). **Phytochemical screening andextraction**, A review International Pharmaceutical Sciencia

Pavenden P.C.S. Rajasekaran, & V.A. Gideon (**2011**). **Pharmacognostic standardization and physic-chemical evaluations of leaves of endangered species.** International Journal of Pharma and Bio Sciences

Kunle, Oluyemise F., Egharevba, Ahmadu and Peter Ochogy (2012). **Standaridization of herbal medicines.** A review Int.J.Biodvers

Sermakkani M, Radha (2011). **Evaluation of preliminary phytochemical and antimicrobial activity.** In. J. P. Sci

Roy, J. S. B. (1922). **Flora of China,** vol.1.p.435 in Flora of China @ Efloras. Org.Asiat.Willam, H. (1980).**Official Methods of Analysis of the Association of official analytical chemists.** 13th ed., Washinton, DC

Internet sources:

http:// www.*Mucuna pruriens* L. (Dc.) Benefits for Dopamine, Testosterone and Better Sleep, superfood profiles.com

http// www. Ali Kuoppala, Testosterone and *Mucuna pruriens* : The Amazing Benefits

http// www. Tropicalforages. Info, Forages

http// www. Globalhealingcenter.com, The Benefits of *Mucuna pruriens*

http// www. Banyanbotanicals.com, Health Benefits of *Mucuna pruriens*

A Study on Elemental and Phytochemical Analysis of *Zingiber cassumunar* Roxb. Rhizome

Ni Ni Htun*

Abstract

Zingiber cassumunar Roxb.(Meik-tha-lin) is found to be the most important aromatic medicinal herb in South East Asia including Myanmar. So, an attempt was made to investigate its elemental and phytochemical analysis in the present research. Collection of specimens was carried out during the flowering time of this plant, from July to November. After the collection, all parts of the fresh specimens were studied and measured in detail and recorded for taxonomic description. Identification of plants was done based on new findings and previous literatures. The fresh rhizomes were cut into small pieces and dried and powdered. The dried rhizome powder was tested to determine the phytochemical characters and physicochemical properties. Terpene, resin, carbohydrate, saponin, tannin and starch were present dominantly and more soluble in water and chloroform. Elemental analysis of rhizome was conducted by using energy dispersive X-ray fluorescence (EDXRF) spectrometer. Potassium was found to be dominant.

Key words: *Zingiber cassumunar,* elemental and phytochemical analysis

Introduction

The plants provided food, clothing, shelter and medicine. Much of the medicinal use of plants seems to have been developed through observations of wild animals. Indeed, well into the 20th century, much of the pharmacopoeia of scientific medicine was derived from the herbal lore of native people. Many drugs commonly used today are of herbal origin (Website. 1).

Herbal medicine refers to the use of any plant parts, such as seeds, roots, rhizomes, leaves, barks and flowers, for medicinal purposes. Recently, the World Health Organization estimated that 80 % of people worldwide rely on herbal medicines for some aspect of their primary healthcare (Website. 2).

The species of *Zingiber* arouse interest among people as these could have possessed new natural sources and most of their aromatic rhizomes are used as traditional medicine and spices by local people. The essential oil in these rhizomes has been of great interest for people as the sources of health promotion, food preservation, food flavoring and cosmetics.

The *Zingiber cassumunar* Roxb.belongs to the family Zingiberaceae which is a tropical group of monocotyledons. This family usually consists of aromatic herbs that are useful in medicine. Aromatic herbs have been utilized by man since very ancient times in food, cosmetics and medicinal preparations. Due to their characteristic of aroma and flavour, they should naturally be among the first plants that attracted man's attention.

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In the performing the phytochemical tests and physicochemical properties of *Z. cassumunar* Roxb., terpene, resin, carbohydrate, saponin, tannin and starch were present dominantly and more soluble in water and chloroform.

Harborne (1984) stated that potassium (K) is needed for growth, building muscle, transmission of nerve impulses and heart activity. Deficiency of potassium (K) in human body may result in fatigue, leg cramp, muscle weakness, slow reflexes, dry skin, mood changes and irregular heartbeat. Calcium (Ca) is the principal supporting material of the skeleton, bone and teeth. Deficiency of calcium (Ca) in the body may cause osteoporosis. Iron (Fe) is necessary for the oxygenation of red blood cells, a healthy immune system and energy production. High iron content in our body has been linked to cancer and heart disease. As these elements contained more or less in rhizome of *Z. cassumunar* Roxb. it can be used as medicine for man.

The aim of present research is to find out the medicinal properties of *Zingiber cassumunar* Roxb. (Meik-tha-lin). To fulfill this aim, the research was carried out according to such objectives as collection and identification of this plant, performing of the preliminary phytochemical tests in order to find out the presence or absence of organic constituents, investigating of physicochemical properties on the collected plants, observing the elemental analysis.

Materials and Methods

Collection, identification and preparation

In this investigation, *Z.cassumunar* Roxb.was collected during flowering period (July to November) from different locations. After the collection, all the vegetative and reproductive parts of the fresh specimens were studied, measured in detail and recorded. The relevant data for taxonomic description of the species were also recorded. Based on the resulting data, the plants were identified with the help of literatures (Backer; 1963, Hooker; 1875, Kirtikar & Basu; 1935). All the necessities were documented by photographs. The rhizomes of the collected plant were thoroughly washed with water and cut into small pieces. Then these samples were dried in shade for 5 – 7 days and crushed and powdered with a grinding machine. This powder was stored in the airtight container for further study.

Preliminary phytochemical investigation

The rhizome powder were tested qualitatively for the presence or absence of alkaloids, flavonoids, carbohydrate, glycoside, polyphenol, steroid, terpene, saponin, tannin, resin, protein, starch and cyanogenic glycosides according to the methods of Central Council for Research in Unani Formulation (1989), and Trease and Evans (2002).

Physicochemical properties

Determination of moisture content

The moisture content of the rhizome powder was determined by using Ultra X-030-infra-red high speed moisture tester. It is an infra-red drier provided with a built-in balance, particularly suitable for rapid determination of the moisture content. The aluminium foil was placed on the pan of tester and the sample was put into the foil until the pointer of the balance indicates 0%. The voltmeter pointer was set at 137, which was equivalent to temperature of 105°C. 10g of sample was being

determined. As moisture of the sample was decreased by means of infra-red light, the pointer showing the percentage of moisture loss of the sample gradually increases. After about 30 minutes of heating, when the pointer representing the moisture percentage value became constant, the moisture content shown by the scale on the dial was recorded. The result was shown in Table 2.

Determination of total ash content

The determination of total ash content was carried out according to the procedure described in the British Pharmacopoeia (1973).

5 g of sample powder was weighed and transferred into the previously weighed crucible and placed in a muffle furnace and heated up to 500°C until it turned into ash. After ashing, the crucible was removed from the muffle furnace and cooled and weighed. The procedure was repeated until a constant weight was obtained and the percentage of total ash was calculated. The result was shown in Table 2.

Determination of acid-insoluble ash

Acid-insoluble ash was determined by the method given in the British Pharmacopoeia (1973).

The ash sample (1gm) was boiled for 5 mins with 25 ml of 10% dilute hydrochloric acid. The acid insoluble matter was collected on ashless filter paper, washed with hot water until free of acid and placed in a previously weighed container (W_1) and ignited at a low temperature and weighed again (W_2). The difference in weight (W2 – W1) represented the weight of acid-insoluble ash. The percentage of the acid-insoluble ash was then calculated. The result was shown in Table 2.

Determination of water-soluble ash

The method used for the determination of water-soluble ash was the method given in British Pharmacopoeia (1973).

The ash sample (1gm) was boiled for 5 mins with 25 ml of water. The water insoluble matter was collected on filter paper. The filtrate was collected in previously weighed crucible (W_1) and was dried in an oven at 105°C and weighed again. The weight of the crucible (W_1) was subtracted from the weight of water-soluble matter together with the crucible (W_2). The difference in weight (W_2-W_1) represented the water-soluble ash. The percentage of water-soluble ash was calculated. The result was shown in Table 2.

Determination of alcohol–soluble matter

Alcohol-soluble matter content of sample powder was determined by the methods given in Physicochemical Standards of Unani Formulation (1987).

5 g of the air-dried powder was macerated with 100 ml of absolute alcohol in a closed flask for 24 hrs (shaking frequently during 6 hrs and allowing standing for 18 hrs). The mixture was filtered rapidly through the filter paper taking precautions against loss of alcohol. 25 ml of the filtrate was evaporated in a weighed petridish (W_1) on a boiling water-bath, until it was completely dry. The evaporated residue together with the petridish was weighed (W_2). The procedure was repeated until a constant weight was obtained. The difference in weight ($W_2 – W_1$) gave the alcohol soluble extractive value. The percentage of alcohol-soluble matter was calculated. The result was shown in Table 2.

Determination of water-soluble matter

Determination of water-soluble matter was conducted in the same way as the determination of alcohol-soluble matter using 100 ml of distilled water instead of alcohol. The yield % of water-soluble matter was shown in Table 2.

Determination of petroleum–ether soluble matter

Determination of Petroleum-ether soluble matter was conducted in the same way as the determination of alcohol-soluble matter using 100 ml of petroleum-ether instead of alcohol. The yield % of petroleum-ether soluble matter was shown in Table 2.

Determination of chloroform soluble matter

Determination of Chloroform soluble matter was conducted in the same way as determination of alcohol soluble matter using 100 ml chloroform instead of alcohol. The yield % of chloroform soluble matter was shown in Table 2.

Determination of pH value

Determination of pH value was carried out according to the method given in Physicochemical Standards of Unani Formulation (1987).

1 g and 10 g of aqueous extracts and 95% ethanol extracts were dissolved in 100 ml of distilled water, filtered and the pH of filtrate was checked with a standardized glass electrode pH meter. The results were shown in Table 3.

Elemental analysis of *Z. cassumunar* Roxb. by using EDXRF.

The experimental work for the analysis of elemental concentrations was carried out by using EDXRF (Energy Dispersive X-ray Fluorescence) at University Research Centre, Yangon.

First of all, rhizome of *Z.cassumunar* Roxb were ground in order to get a fine powder using a grinding machine.Then the powdered sample was pressed into pellet and was used in the EDX 700 spectrometer as specimens.The spectrometer produced the characteristic X-rays spectrum of sample, consisting of the respective elements, and the spectrum evaluation was carried out by the use of the built-in elemental analysis software.The quantitative results of EDXRF are shown in Table 4 and Figure6.

Results

Morphological characters of *Zingiber cassumunar* Roxb.

Perennial rhizomatous herbs; the rhizomes thick, ovoid with fleshy roots, bright yellow inside, with palebrown scale leaves at each node and a strong camphoraceous odour. Aerial stems herbaceous, 4 – 6 ft high, cylindrical, glabrous, reddish green. Leaves alternate, simple; the leaf-blades oblong-lanceolate, 23.0 – 35.0 x 2.5 – 4.0 cm, the bases obtuse, the margins entire, the tips acuminate, the upper surfaces glabrous, the lower ones pubescent; the petioles subsessile, 2.0 – 4.0 mm long; the leaf sheaths oblong, reddish green, the margins pubescent; the ligules small, triangular, 2-clefted, whitish, membranous, glabrous. Inflorescences terminal cone-like spike, the spikes oblong-ellipsoid, 9.0 – 18.0 x 3.5 – 5.0 cm, red, the peduncles terete, 10 to 30 cm long, enveloped by bladeless leaf-sheaths, pinkish, glabrous; bracts broadly ovate, 2.5 – 3.5 x 2.5 – 3.5 cm, the tips subacute, brightly red, pubescent,

persistent; bracteoles lanceolate, 2.5 – 3.5 x 0.8 – 1.0 cm, whitish, glabrous, persistent. Flowers infundibuliform, creamy color, 4.0 – 4.5 x 2.5 – 3.5 cm, complete, bisexual, zygomorphic, 3-merous, sessile epigynous; calyx 3-dentate, fused, tubular, valvate, white, glabrous, deciduous; corolla 3-lobed, fused, corolla tubes cylindrical, 2.5 – 3.0 x 0.3 – 0.5 cm, glabrous, deciduous, the lobes lanceolate, posterior lobes 3.0 – 3.5 x 1.3 – 1.5 cm, concave, lateral lobes 2.2-2.5 x 0.8 – 1.0 cm, deflexed, yellowish white, glabrous; fertile stamens inserted, epipetalous, the filaments very short, the anthers oblongoid, about 1.3 – 1.5 x 0.5 – 0.8 cm, dithecous, basifixed, introrse, longitudinal dehiscence, yellowish white, the connective appendix or beaks or crests curved, 1.3 – 1.5 cm long, yellowish white; lips or labellum shorter than the corolla segments, 3-lobed, the middle lobes orbicular, 2.0 – 2.5 x 2.5 – 3.0 cm, yellowish white, unspotted, the tips obtuse, the margins wavy, the two lateral lobes or basal auricles obovate, 1.5 – 2.0 x 1.0 – 1.3 cm, yellowish white with red streak below, the tips obtuse, the margins entire; ovaries inferior, oblongoid, 0.4 – 0.6 x 0.2 – 0.3 cm, 3-carpelled, syncarpous, 3-loculed, the posterior lobes compressed, the placentation axile, the styles simple, white, the stigmas infundibuliform, white, with a whorl of cilia on mouth. These above characters were shown in Figure 1.

Habit

Rhizome

Leaf

Spike

Flower

Figure 1 *Zingiber cassumunar* Roxb.

Preliminary phytochemical investigation

Preliminary phytochemical test on the *Zingiber cassumunar* Roxb. was investigated and the presence or absence of constituents in each plant were presented in Table 1.

Table 1 phytochemical test on the rhizome of *Zingiber cassumunar* Roxb.

No.	Constituents	Extract	Test Reagent	Observation	Result
1.	Alkaloid	3% HCL	Dragendroff's reagent Mayer's reagent Wagner's reagent.	Orange ppt. White ppt. Brown ppt.	-
2.	Flavonoid	EtOH extract	HCL, Mg turning	Pink colour	-
3.	Steroid	Pet-ether Extract	acetic anhydride+ conc. H_2SO_4	Blue-green colour	-
4.	Terpenoid	Pet-ether Extract	acetic anhydride+ conc. H_2SO_4	Pink colour	+
5.	Glycoside	EtOH extract	NaOH sol:	Yellow colour	-
6.	Carbonhydrate	H_2O extract	Fehling sol: A+B	Red colour ppt.	+
7.	Saponin	H_2O extract	Distilled water	Frothing	+
8.	Tannin	H_2O extract	5% ferric chloride sol:+ dil H_2SO_4	Yellowish-brown ppt.	+
9.	Resin	$CHCl_3$ extract	Acetic anhydride+ H_2SO_4	Violet colour	+
10.	Polyphenol	H_2O extract	3% ferric chloride sol:	Blue or green colour	-
11.	Protein	H_2O extract	Sodium hydroxide sol:+3 % copper sulphate sol:	Red or violet colour	-
12.	Starch	H_2O extract	I_2 solution	blue-black ppt.	-
13.	Cyanogenic glycosides	H_2O extract	Cons: H_2SO_4 Sodium picrate	No colour	-

+ = Present – = Absent

In the present study, test for terpenoid and resin using acetic anhydride and sulphuric acid and test for starch using iodine solution all gave positive results. Similarly, the water extracts of tested plants reveal the frothing and red colour precipitate when tested with Fehling solution A + B, indicating the presence of saponin and carbohydrate. The phytochemical test concerning the presence of steroid, cyanogenic glycoside and polyphenol gaves negative results. When the ethanol extract was tested with NaOH solution, it gave the negative results. The positive results for tannin were recorded. This tests were shown in Figure 2.

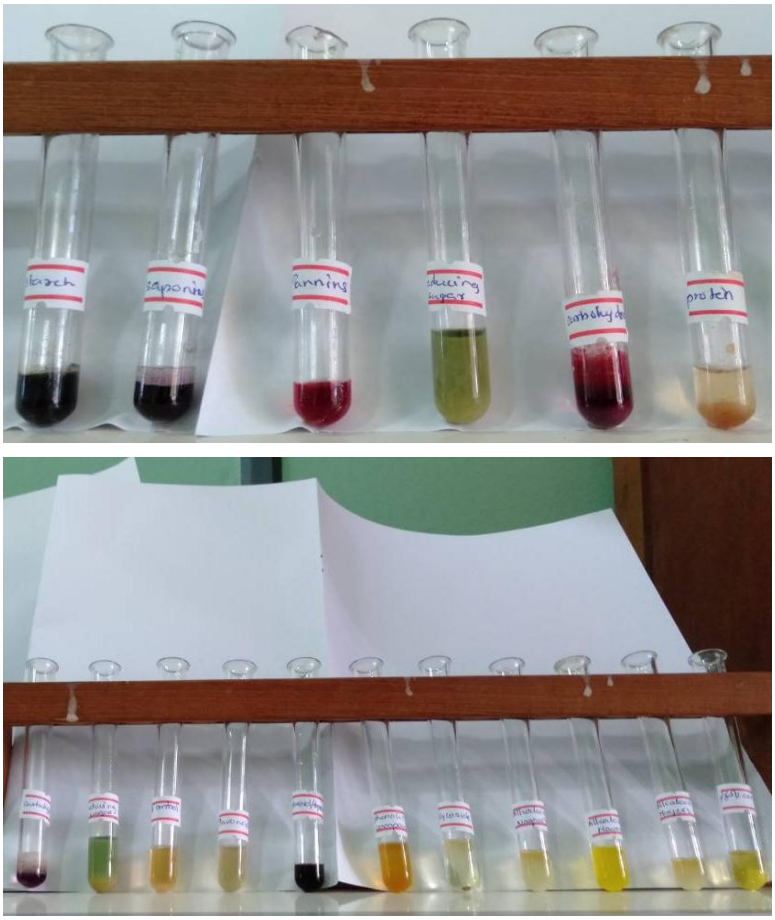


Fig. 2 Phytochemical investigation on *Zingiber cassumunar* Roxb.

Physicochemical properties

Moisture content is usually determined by drying to constant weight and taking the loss in weight as moisture. All these values are useful for the quality control system regarding the impurity when it is used for medicinal purposes. The solubility tests were carried out to find the amount of total solids soluble in solvents.

The results of the moisture content, total ash, acid-insoluble ash and water-soluble ash, solubility in different solvents were recorded in Table 2.

Table 2. Physicochemical properties of *Zingiber cassumunar* Roxb.

	Quantity Determined Percent (%)
Moisture content	14.0
Total ash	9.8
Acid-insoluble ash	6.7
Water-soluble ash	20.0
Solubility in alcohol	5.4
Solubility in water	9.2
Solubility in pet-ether	0.6
Solubility in chloroform	6.9

According to above results, it is found that minimum solubility was in pet-ether and maximum solubility was in water.

pH value

pH value of aqueous extract and 95% ethanolic extract of rhizome of *Z. cassumunar* Roxb.was also determined and recorded in Table 3.

These values are useful as the standard quality criteria in the quality control tests when rhizome of *Z. cassumunar* Roxb. is used as drug.

Table 3. pH value of rhizome of *Z. cassumunar* Roxb.

Rhizome *Z. cassumunar* Roxb.	Solution %	pH value
aqueous extract	1	7.1
aqueous extract	10	6.8
95% ethanol extract	1	6.1
95% ethanol extract	10	5.9

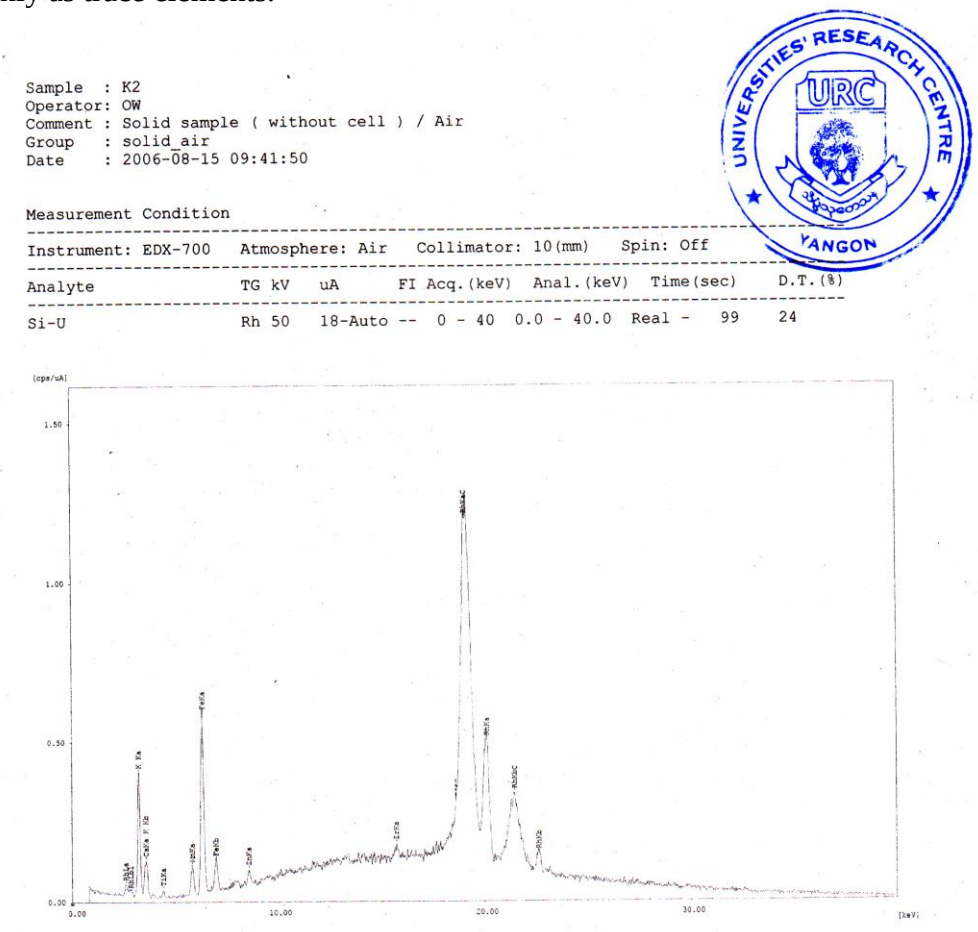
Elemental analysis of rhizome of *Z. cassumunar* Roxb. by using EDXRF

The experimental data were shown in Table 4 and Figure 3.

Table 4. Elemental concentration (%) in rhizome of *Z. cassumunar* Roxb.

No.	Elements	Results %
1	Potassium	0.649
2	Calcium	0.083
3	Iron	0.072
4	Manganese	0.016
5	Titanium	0.009
6	Zinc	0.003
7	Zirconium	0.002

According to the table, Potassium (K) is found to be predominant in powdered rhizome. Calcium (Ca), Irom (Fe), Manganese (Mn) Titanium (Ti), Zinc (Zn) and Zirconium (Zr) are found to be of moderate quantity and other elements are found only as trace elements.



Sample : K2
Operator: OW
Comment : Solid sample (without cell) / Air
Group : solid_air
Date : 2006-08-15 09:41:50

Measurement Condition

Instrument: EDX-700	Atmosphere: Air	Collimator: 10(mm)	Spin: Off

Analyte	TG kV	uA	FI Acq.(keV)	Anal.(keV)	Time(sec)	D.T.(%)
Si-U	Rh 50	18-Auto --	0 - 40	0.0 - 40.0	Real - 99	24

Quantitative Result

Analyte	Result	Std.Dev.	Proc.-Calc.	Line	Int.(cps/uA)
K	0.649 %	0.011	Quan-FP	K Ka	2.798
Ca	0.083 %	0.003	Quan-FP	CaKa	0.680
Fe	0.072 %	0.001	Quan-FP	FeKa	4.984
Mn	0.016 %	0.000	Quan-FP	MnKa	0.825
Ti	0.009 %	0.001	Quan-FP	TiKa	0.155
Zn	0.003 %	0.000	Quan-FP	ZnKa	0.512
Zr	0.002 %	0.000	Quan-FP	ZrKa	0.790
C H	99.166 %	--------	Balance	--------	--------

Figure 3. EDXRF spectrum of powdered rhizome of *Z. cassumunar* Roxb.

Discussion and Conclusion

Zingiber cassumunar Roxb. was usually found growing wild throughout the country during the rainy season. This was perennial rhizomatous herbs and they could be easily propagated by means of rhizome cuttings.

The main rhizome was ovoid in shape. The aerial stem was cylindrical, solid, erect and was enclosed within the overlapping sheathing bases. The leaf-sheath was reddish-green. The leaves of *Z. cassumunar* Roxb.was oblong lanceolate to lanceolate and pubescent beneath. Ligules was membranous. The inflorescences was radical and their spikes were produced from the rootstock either on elongated peduncles. The

spikes was oblong or fusiform with broadly ovate reddish outer bracts. The flowers were conspicuous, infundibuliform. The posterior corolla segments were largest and all broadly lanceolate in shape. They were all white or yellowish-white. The labellum had 3-lobes, in which middle lobes were largest, while the two lateral lobes (basal auricles) were smaller. The lips were orbicular and emarginated. The colour of the lips was wholly yellowish white. The stamens were composed of short and broad filament and anther cell opening with a slit together with a curved crest clasping the upper part of the style. All anther cells were yellowish-white to yellow in colour. The ovaries were all tangentially compressed.

All morphological and taxonomical characters of the plants studied were in accordance with those decribed by Backer (1968), Bailey (1930), Burkill (1935), Hooker (1885), Kirtikar Basu (1933), Purseglove (1976) and Ridley (1924).

The preliminary phytochemical investigation was carried out on the rhizome powder. *Z. cassumunar* Roxb. contains carbonhydrate, resin, saponin, terpene, tannin, steroid, polyphenol and starch.

Physicochemical tests showed that the powdered samples were mostly soluble in water depending on which it can be calculated for the percentage of soluble matters to estimate the percentage of solubility of different solvents. These values are usually used for preparation of crude plant drugs in all the pharmacopoeia. Therefore, for the dried rhizome powder of *Z. cassumunar* Roxb. to be used as crude vegetable drug, it was also necessary to determine the above mentioned physicochemical characteristics. Moisture content is determined by drying to constant weight and taking the loss in weight as moisture content. This information indicated to how avoid the contaminations due to moisture in plant materials.

It is generally known that there are eight principal elements in human body. They are calcium (Ca), phosphorous (P), potassium (K), sulfur (S), sodium (Na), chlorine (Cl), magnisum (Mn) and iron (Fe). In addition to these, there are small quantities of other trace elements many of which are essential to life.

In the study of elemental concentration of Meik-tha-lin rhizome, potassium (K) is found to be highest in percentage content and following second and third in percentage are calcium (Ca) and iron (Fe). Manganese (Mn), titanium (Ti), zinc (Zn) and zirconium (Zr) are present only in small quantities. Other elements were found as trace elements.

According to elemental analysis, *Zingiber cassumunar* Roxb. can be used in medicinal processes because it mostly contained potassium, calcium and iron which principal elements in human body.

In conclusion, it is deemed appropriate for mentioning in a nut-shell some vital aspects and processes involved in making this research or investigative study of *Zingiber cassumunar* Roxb.(Meik-tha-lin). It is considered imperative to include in the conclusion some suggestions for furtherance of this study up to the stage where theory can be put into practice meaning production of useful materials based on the research findings.

It is hoped that further and more detailed study of these aspects will make a great contribution to the improvement of the indigenous medicines.

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References

Backer, C.A. (1968) Flora of Java. Vol. III, Noordhoof-Groninen Co., Netherland.

British Pharmacopoeia. (1973). to the published on the recommendation commission, London.

Central Council for Research in Unani Medicine (1987) Physicochemical Standards of Unani Formulation Part 2, Ministry of Health and Family Welfare, Govt. of India, New Delhi.

Chopra, R.N. (1956) Glossary of Indian Medicinal plants. Council of Scientific Industrial Research, New Delhi.

Ertel, D. (1991) X-ray Flurorescence Analysis. Nuclear Research Centre, Karlsruhe, Germany.

Harborne, J.B (1984) Phytochemical Methods. 2nd Ed, Chapman and Hall, London.

Hooker, J.D. (1881) Flora of British India. Vol. VI, Reeve & Co., Ltd., London.

Hundley, H.G and Chit Ko Ko (1987) Trees, Shrubs, Herbs and Principal Climbers, etc. Government Printing Press, Yangon, Myanmar.

Kirtikar and Basu (1935) Indian Medicinal Plants. Vol III. The Calnerdan Press. Oxford.

Kress, W.J., Robert A. Defilipps, Ellen Farr and Daw Yin Yin Kyi (2003) A Checklist of the Trees, Shrubs, Herbs and Climbers of Myanmar.

Lawrence H.M. (1968) Taxonomy of Vascular Plants. The Macmillan company, New York.

Trease and Evans (2002) Pharmacognosy. 11th edition, 15th edition, Bailliere Tindall, London.

Vogel (2000) Textbook of Quantitative Chemical Analysis. University of Greenwich, London.

Websites

1. http://www.holisticonline.com/Herbal-Med/hol-herb-intro.htm

2. http://www.umm.edu/altmed /cons Modalities/ Herbal Medicine com.html

Anatomical Characters and Phytochemical Analysis on Leaves of *Clerodendrum thomsonae* Balf.

Sandar Sann*

Abstract

A medicinal plant *Clerodendrum thomsonace* Balf.was selected for the present study. Myanmar name Taik-pan-gyi that belongs to the family Lamiaceae. The specimens were collected from Hlegu Township, Yangomn Division during the year 2015. The collected plant was identified by the literature references to confirm its identity. The present research was conducted to study the anatomical characters and photochemical analysis of the leaves. In morphological and anatomical studies, inflorescences were axillary or terminal cymes and flowers were 5-lobed.Anomocytic type of stomata were present only in the lower surface of lamina. The vascular bundles of lamina, midrib and petiole were collateral and closed types. The numerous unicellular and simple trichomes were present in lamina, midrib and petiole. In phytochemical analysis, glycosides, phenolic compounds, α-amino acids, carbohydrates, saponins, tannins, alkaloids, steroids and terpenoids were found to be present in leaves of *Clerodendrum thomsonae* Balf.

Key words: *Clerodendrum thomsonae*, anatomical characters, phytochemicals

Introduction

Clerodendrum is a genus of flowering plants in the family Lamiaceae. Its common names include glory bower, bag flower and bleeding-heart. It is currently classified in the subfamily Ajugoideae, being one of the several genera transferred from Verbenaceae to Lamiaceae in the 1990 based on phylogenetic analysis of morphological and molecular data (Steven J.Wagstaff, 1998).The plants *Cleodendrum thomsonae* Balf.belongs to the family Lamiaceae. There are about 251 genera and 6700 species in this family. The family is cosmopolitan, ranging from tropical forest to arctic tundra and from sea level to high altitude. In our country the family is represented by several important genera such as, *Tectona, Vitex, Gmelina, Clerodendrum, Mentha, Ocimum, Leucus and Coleus*, etc (Nyo Maung et al., 2012)

According to Hundley and Chit Ko Ko (1987), the family has 21 genera and 100 species are attributed to Myanmar. The genus is native to tropical and warm temperate regions of the world, with most of the species occurring in tropical Africa and southern Asia, but with a few in the tropical America and northern Australasia, and a few extending north into the temperate zone in eastern Asia (David J.Mabberley, 2008). The genus has been reported in various indigenous systems of medicines and as folk medicines. The genus is being used as medicine specifically in Indian, Chinese, Thai, Korean, Japanese system of medicine for the treatment of various life.Treating diseases such as syphilis, typhoid, cancer, jaundice and hypertensions (Patel, 2007). In Myanmar, the leaves, stem and root are used in asthma, pyreticosis, cataract malaria, diseases of blood, skin and lung.

Clerodendrum thomsonae Balf. is commonly known as Taik-pan-gyi in Myanmar and bleeding glory-bower or bleeding-heart vine in English. It is also grown as an ornamental plant for its decorative two-colored flowers (Dorling kindersley,

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2008). The powder or paste form and the various extracted of root, stem and leaves are reported to be used as medicine for the treatment of asthma, pyreticosis, cataract, malaria, and diseases of blood, skin and lung (Patel, 2007).

Thus the aims and objectives of this study were to investigate the morphological characters, to record the anatomical characters of the leaves, to find the medicinal plant scientifically which have effective medicinal values and to perform the screening of phytochemicals of leaves of *C.thomsonae* Balf.

Materials and Methods

Botanical Studies

The specimens of *Cleodendrum thomsonae* Balf. used in this study were collected from Hlegu Township, Yangon Division, especially during the flowering and fruiting periods.

After the collection, specimens were identified with the help of available literatures (Dassanayake, 1981; Dutta, 1983, Kirtikar and Basu, 1935; Pandey, 2004; Rendle, 1967; Sen Gupta, 1985). Both the vegetative and reproductive parts of the fresh specimens were used for the morphological and taxonomical studies.

For anatomical studies, lamina, midrib and petiole were examined by preparing free hand sections from the fresh specimens. The according to the methods is given by Trease and Evans (2002). The specimens cleared in chloral hydrate solution on a glass slide and observed under the microscope. Chloral hydrate solution was used as clearing reagent. The present of calcium oxalate crystals were confirmed by 80% sulphuric acid and acetic acid (BP).

Chemical Studies

The preliminary phytochemical investigation on the leaves of *C. thomsonae* Balf. was carried out to determine the presence or absence of alkaloids, glycosides, saponins, steroids, terpenoids, phenolic compound, α-amino acid, carbohydrates, tannins and flavonoids. The method of Marini Bettalo G.B. et.al, (1981) and Trease and Evans (2002) were applied for investigation of phytochemical studies.

Results

Morphological Characters of *Clerodendrum thomsonae* Balf.

Myanmar name : Taik-pan-gyi

Local name : Unknown

English name : Bleeding heart; glory-bower; white bleeding heart

Flowering period : September to December

Parts used : Leaves, stem, root

The plant was perennial, high-climbing herbaceous or woody vine or liana; stems and branches were slender, obtusely tetragonal, brown or purplish, densely puberulent. Leaves were simple, opposite and decussate, exstipulate; petioles slender, 8-35 mm long, minutely puberulent with purplish hairs; blades elliptic or elliptic-ovate, 6-14 cm by 3-7 cm, rounded or subacute at the base, entire along the margin

short-accuminate at the apex, green above and paler beneath, glabrous on both surfaces. Inflorescences were axillary or terminal cymes with 8 to 20 flowers; penduncles slender, 2.6-6.5 cm long, densely puberulent. Flowers were red, about 1.5 cm in diameter; bracts linear or subulate, 5 mm long, puberulent. Calyx was deeply 5-partite, combined into an ovoid, sharply, quinquangular, involucre pale yellowish-green, changing to cream-colour and then pure white during anthesis, fading to yellow or pink. Corolla was hypocrateriform, 5-lobed, dark red; tube slender, 2.5 cm long; lobes elliptic-oblong, 7 mm by 4 mm, reflexed. Stamens were 4, free, didynamous, exserted; filaments filiform, about 2.2 cm long, red, glabrous; anther dithecous, oblong, 1.5 mm long. Ovary was globoid, 3 mm long, tetralocular, with one ovule in each locule on the axile placetae; style filiform, 2.5-3.5 cm long: stigma bifid. Drupes were globoid, glossy-black, with a brilliant red aril uniting the 4 pyrenes. These morphological characters were shown in Fig.1.

Figure 1. Morpholocigical Characters of *Clerodendrum thomsonae* Balf.

(A) Plant in natural habit (B) Upper surfaces of leaves

(C) Lower surfaces of leaves ` (D) Inflorescence

(E) Flowers (F) L.S of flower

Anatomical characters of *Clerodendrum thomsonae* Balf.

Lamina

In surface view, the epidermal cells of both surfaces were parenchymatous and thin walled. The cell walls of the upper and lower surfaces were wavy. Stomata were present only in the lower epidermis. They were ranunculaceous or anomocytic types. The guard cells were reniform in shape and contain abundant chloroplast. Trichomes were present on both surfaces.

In transverse section, the upper cuticle layer was slightly thicker than the lower one. The upper and lower epidermal cells were mostly rectangular in shape. Epidermal cells with straight or sinuous anticlinal walls of varying thickness. The mesophyll consisted of palisade and spongy parenchyma. The palisade mesophyll was made up of one layer of vertically elongated cylindrical cells, which were closely packed with one another. The spongy mesophyll consisted of 3-5 layers of cells, which were irregular in shape and losely arranged towards the lower epidermis, enclosing numberous large intercellular spaces and air cavity. Solitary and prismatic calcium oxalate crystals were present.

The vascular bundle of lateral veins consisted of xylem always lying towards the inner side and phloem always towards the outer. This arrangement was collateral and closed type. The phloem tissue consisted of sieve tube elements and companion cells. The phloem cells were very small. The xylem consisted of vessels, tracheids, fibers and xylem parenchymatous cells. The vessels have simple perforations and simple pitted. The fiber cells were long with tapering pointed.

Midrib

In surface view, the epidermal cells were parenchymatous and compactly arranged and irregular. Stomata were absent and trichomes were present.

In transverse section, nearly circular in the lower surface and concave in the upper surfaces were covered with very thin cuticle. The upper epidermal cells were rounded-shaped. The lower epidermal cells were similar in shape and size to the upper epidermal cells. The cuticle layers of both upper and lower surfaces were the same. Both surfaces consisted of unicellular, uniseriate trichomes.

The cortex was made up of collenchyma and thin-walled parenchyma cells. The collenchyma cells were 2-4 layers in thinkness towards the upper surface and 2-5 layers in thickness towards the lower surface. They were rounded to isodiametric in shape. The parenchyma cells were 1 to 2 layers in thickness above the vascular bundle and 3 to 5 layers in thickness below the vascular bundle. They were thin-walled and oval in shape. Intercellular spaces were numerous among them and, solitary and prismatic crystals of calcium oxalate were present in both parenchymatous cells and collenchymatous cells.

The vascular bundle was oval-shaped in outline; collateral closed type. The phloem tissues consisted of sieve tube elements and companion cells. The xylem consisted of vessels, tracheids, fibers and xylem parenchyma cells. The vessels have simple perforatin and simple pitted. The fiber cells were long with tapering pointed.

Petiole

In surface view, the epidermal cells were parenchymatous thin-walled and mostly rectangular in shape and elongated along the length of petiole. Trichomes were

abundant and stomata were absent. In transverse section, the petiole was circular in outline and slightly concave in the upper side and prominently convex in the lower side. The cuticle layer was very thin. The epidermal cells were rounded-shaped. Unicellular, uniseriate trichomes were present.

The cortex was made up of two different types of tissues, collenchymatous and thin walled parenchymatous tissues. The collenchymatous tissues consisted of 3 to 7 layers in thickness. The parenchymatous tissues consisted of about 3 to 6 layers in thickness. The parenchyma cells were oval to isodiametric in shape. Intercellular spaces were numerous among the cells. Prismatic and solitary crystals of the calcium oxalate were present in the cells.

The vascular bundles were more or less rounded in outline and embedded in the parenchymatous tissues. The arrangement was collateral and closed types. The xylem was present in the inner region and the phloem was present in the outer region. The xylem cells were lignified, thick-walled and polygonal to isodiametric in shape. The phloem consisted of sieve tube and companion cells. The xylem consisted of vessels, fibers, tracheids and xylem parenchyma cells. The vessels have simple perforation plate. The fiber cells were long and the end walls were pointed. These above anatomical characters were shown in Fig. 2, 3, and 4.

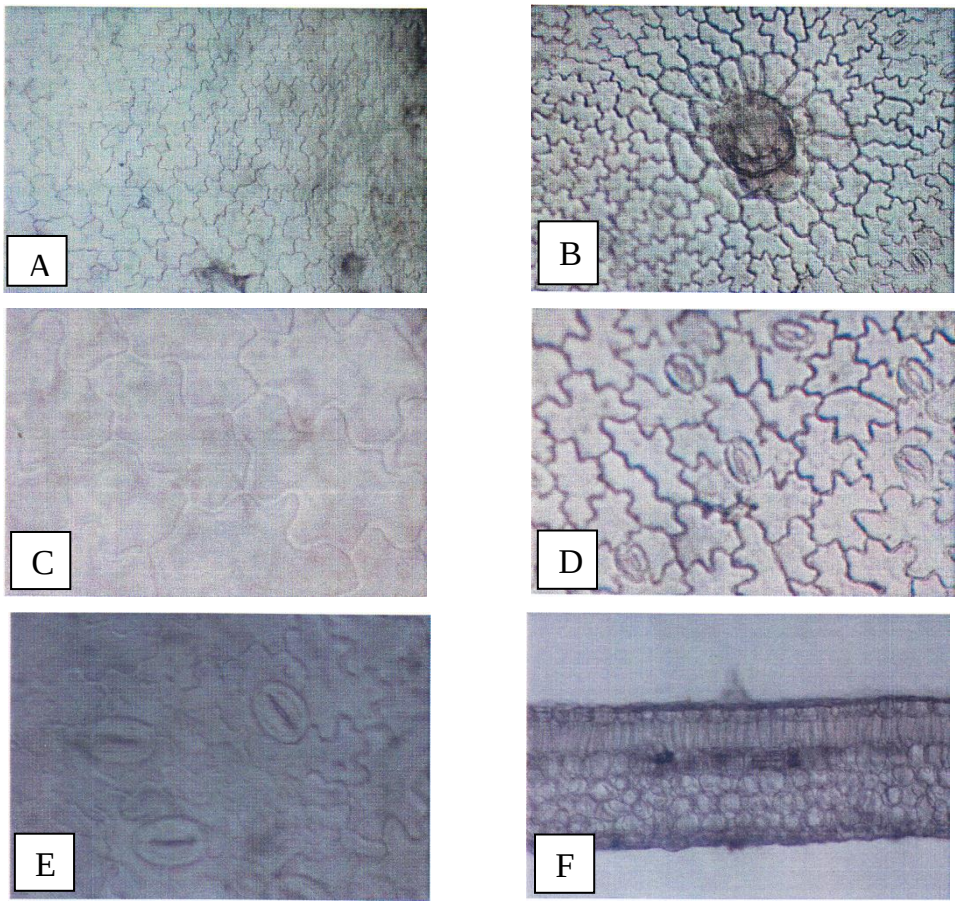

Figure 2. Anatomical characters of lamina of *Cledendrum thomsonae* Balf.

(A) Surface view of upper epidermis
(B) Surface view of upper epidermis with trichome base
(C) Closed up view of upper epidermis
(D) Surface view of lower epidermis with stomata
(E) Closed up view of lower epidermis with stomata
(F) T.S of Lamina with trichomes

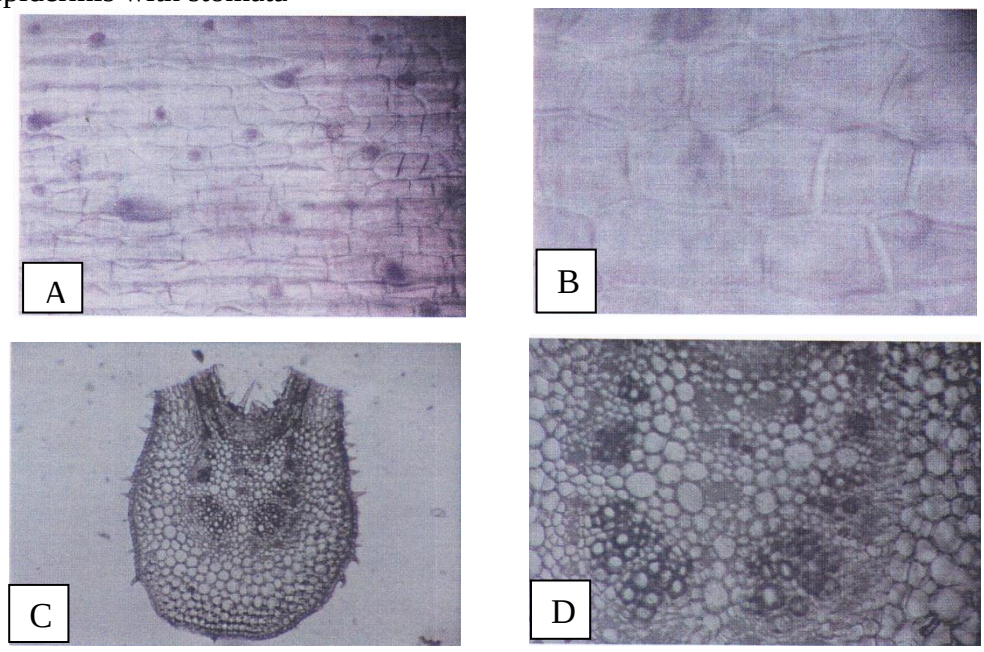

Figure 3. Anatomical characters of Midrib of *Cledendrum thomsonae* Balf.

(A) Surface view of midrib with trichomes trace
(B) Closed up view of surface of midrib
(C) T.S of midrib in outline
(D) Colsed up view of vascular bundle in midrib

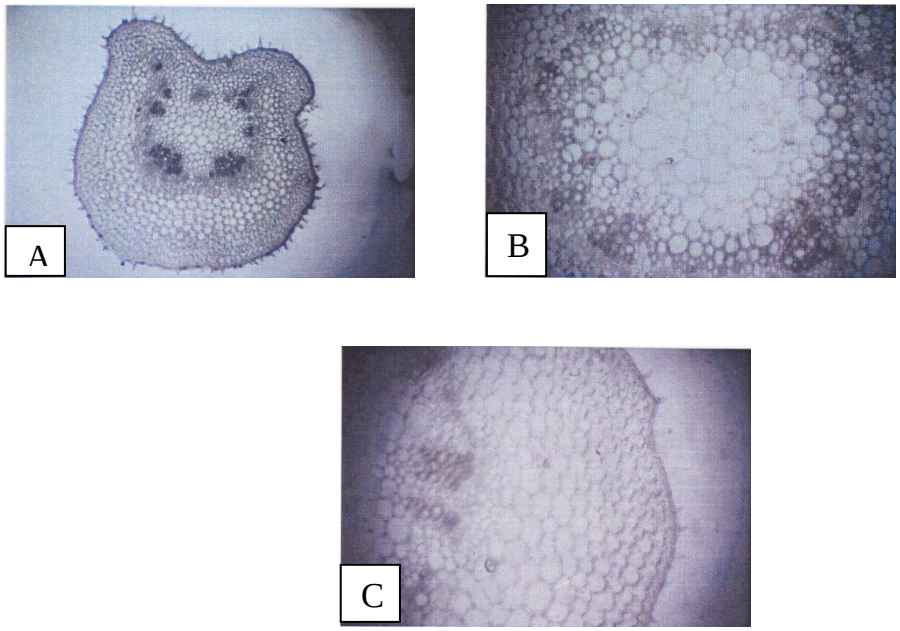

Figure 4. Anatomical characters of Petiole of *Cledendrum thomsonae* Balf.

(A) T.S of petiole in outline (B) Closed up view of vascular bundle in petiole

(C) Closed up view of margin of petiole with trichomes

Chemical Studies

Preliminary Phytochemical investigation on leaves of *Clerodendrum thomsonae* Balf.

The preliminary photochemical investigation was carried out on the powdered leaves. The tests indicated that glycosides, phenolic compound, α-amino acids, carbohydrates, saponins, tannins, alkaloids, steroids and tepernoids were found to be present and starch and flavonoids was absent in *Clerodendrum thomsonae* Balf.

The results of phytochemical tests were shown in Table 1 and Fig. 5.

Table (1) Preliminary Phytochemical Test of Leaves of *Cledendrum thomsonae* Balf.

No	Constituents	Extracts	Test Reagents	Observation	Remark
1.	Glycosides	EtOH	10% lead acetate	White ppt	+
2.	Phenolic compounds	H_2O	1% $FeCl_3$, $K_3F_e(CN)_6$	Deep blue	+
3.	α-amino acids	H_2O	Ninhydrin	Pink colour	+
4.	Carbohydrates	H_2O	10% α-Naphthol & H_2SO_4 (conc:)	Red ring	+
5.	Starch	H_2O	I_2 solution	Blue	No ppt
6.	Saponins	H_2O	Shake	Forthing	+
7.	Flavonoids	EtOH	Mg ribbon and HCl (conc:)	Pale-pink	-
8.	Tannins	EtOH	5% $FeCL_3$	Green ppt	+
9.	Alkaloids	1%HCl	Mayer' reagent Dragendroff's reagent Soidum picrate Wagner's reagent	Buff colour ppt Orange ppt Yellow ppt Red ppt	+ + + +
10.	Steroids	PE	Acetic anhydride, conc. H_2SO_4	Greenish Yellow	+
11.	Terpenoids	PE	Acetic anhydride, conc. H_2SO_4	Pink colour	+

+ = presnece **- = absence**

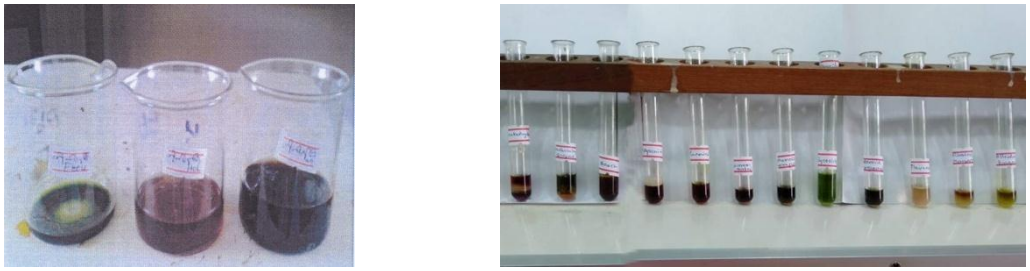

Figure 5. Preliminary Phytochemical Test of Leaves of *Clerodendrum thomsonae* Balf.

Discussion and Conclusion

The medicinal plant *Clerodendurm thomsonae* Balf. belongs to the family Lamiaceae. The species of *Clerodendrum* was found in Hlegu Township, Yangon Region.

In the present investigation, the morphological studies on both vegetative and reproductive parts of the species of the plant were carried out. In the preliminary phytochemical studies, the dried powered of leaves had been undertaken.

As a result of morphological study, the plant of C. *thomosonae* Balf. was perennial, high-climbing herbaceous or woody vine or liana; stems and branches were slender, obtusely tetragonal, densely puberulent. Leaves were simple with purplish hairs; blades elliptic or elliptic- ovate, entire along the margin, short-accuminate at the apex, glabrous on both surfaces. Inflorescences were axillary or terminal cymes; peduncles slender, densely puberulent. Flowers were red, bracts linear or subulate, puberulent. Sepals were deeply 5- partite. Petals were hypocrateriform, 5-lobed; tube slender; lobes elliptic- oblong. Stamens were 4, free didynamous, exserted; filaments filiform, glabrours; anther dithecous. Ovary was globoid, tetralocular, axile placentae; style filiform; stigma bifid. Drupes were globoid, glossy-black, with a brilliant red aril uniting the 4 pyrenes. These characters are in agreement with those mentioned by Dutta (1983), Hong Kong Herbarium (2009), Hundley and Chit Ko Ko (1987) and Kirtikar and Basu (1935).

In anatomical study, the leaves were dorsiventral type. The mesophyll consists of palisade and spongy parenchyma cells in laminae. In the plant *C. thomsonae* Balf., stomata were present only in the lower surface. They were ranunculaceous or anomocytic types. Trichomes were present on both surfaces. These characters are in agreement with those describe by Metcalfe and Chalk (1950) and Watson and Dallwitz (1992). In the surface view of midrib, the epidermal cells of this plant were parenchymatous and compactly arranged and mostly irregular. In transverse section, the vascular bundles of this plant were oval or rounded in shaped; collateral and closed type. These characters are in agreement with those described by Metcalfe and Chalk (1950) and Waston and Dallwitz (1992).

In surface view of petiole, the epidermal cells were parenchymatous, thin walled and mostly rectangular in shaped and elongated along the length of the petiole. Trichomes were abundant and stomata were absent in *C. thomsonae* Balf. In transverse section, the vascular bundles were more or less rounded in outline and embedded in the parenchymatous tissues. the arrangement was collateral and closed type. These characters are in agreement with those described by Metcalfe and Chalk (1950) and Watsn and Dallwitz 1992).

Phytochemicals are any of various biologically active compounds found in plants. They are found in fruits, vegetables, grains, beans, and other plants. Some of these phytochemicals are believed to protect cells from damage that could lead to cancer and help to step carcinogens from attacking cells (Website 1).

Terpene and terpenoids are the primary constituents of the essential oil of many type of medicinal plants and flowers (Eberhard Breitmaier 2000). Glycosides are medicines for treating heart failure and certain irregular heartbeats (Brito-Arias, Marco, 2007). Saponins exhibit antimicrobial properties, guarding the body against fungi, bacteria and viruses (Hostettmann, k; A-Marston, 1995). Steroids are used as the main treatment for certain inflammatory conditions, such as, inflammation of blood vessels and myositis (inflammation of muscle), rheumatoid, arthritis, lupus and gout. Phenolic compounds play an important role in cancer prevention and treatment. Reducing sugar intake and eating a healthful diet may help people: lose weight and prevent obesity (leung, David, A-1984). Carbohydrates are body's main source of energy. They help fuel your brain, kidneys, heart, muscles and central nervous system (Davidson Eugene A-2015).

In preliminary phytochemical tests, the leaves of the C. *thomsonae* Balf. showed that glycosides, phenolic compounds, α-amino acids, carbohydrates, saponins, tannins, alkaloids, steroids and terpenoids were found to be present; starch and flavonoids were absent in *C. thomsonae* Balf.

Many taxa of this family are aromatic and are often used as herb spices, folk medicines and fragrances (Werker et al., 1985). Many species are used as raw material in the cosmetic industry. Some species are traditionally used as medicinal plants. In addition to this, Lamiaceae has great importance due to its economic value and its variety of species. (Baytop,1984). *C. thomsonae* Balf. is used in asthma, pyreticosis, malaria, diseases of blood, skin and lung (Kirtikar and Basu, 1935; Cheng-hwai Tzeng et al., 1987; Patel, 2007).

Therefore, aims of this present study on taxonomy and anatomy can give a few information on the systematic study on members of the family Lamiaceae. It is sincerely hoped that this present study can help the future researchers. Moreover, the species of *Clerodendrum* includes many chemical constituents. They are employed for medicinal purposes. Therefore, *C. thomsonae* Balf. inclusive in the family lamiaceae is a valuable medicinal plant.

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References

Baytop T, (1984). **Turkiye'de bitkiler ile tedavi. ist. Univ. Yay**. No.3255, Istanbul.

Brito-Arias, Marco (2007).Synthesis and Characterization of Glycosis. Springer. ISBN 978-387-262512.

Central Council Research in Unani Medicine, (1989). **Phytochemical standards of Unani fromation**. Ministery of Health, Government of India, New Delhi.

Cheng-hwai Tzeng, et.al, (1987). **Section of Medicinal Oncology**, Department of Medicine, Veterans General Hospital and National Yang-Ming Medicinal College, Taipei, Taiwan.

Dassananyake, M.D and W.D. Claylon, (1981). **Flora of Cyelon**, vol.iii, A.A. Balkema/ Rotterdam/ Brookfield.

David J.Mabberley. (2008). **Mabberley's Plant-Book third edition (2008).** Cambridge University Press.

Davidson, Eugene A. (2015). "**Carbohydrate**". Encyclopaedia Britannica.

Dutta, A.C.(1983). **Botany for degree students**. (5th ed). New Delhi: Oxford University Press.

Eberhard Breitmaier (2006). **Terpenes: Flavors, Fragrance, Pharmaca, Pheromones**. Wiley-VCH. dol: 10. 100219783527609949. ISBN 9783527609949.

Hong Kong Herbarium, (2009). **Flora of Hong Kong** vol.3, Agriculture, Fisheries Conserval on Department.

Hostettmann. K;A. Marston (1995). **Saponins**. **Cambredge:** Cambridge University Press. P.sff. ISBN 0-521-32970-1. OCLC 29670810.

Hundley and Chit Ko Ko, (1987), **List of Trees, Shrubs, Herbs and Principal Climbers, etc**, Government Printing Press, Yangon.

Kirtikar, K.B and Basu, B.D, (1935). **Indian Medicinal Plants**, vol.iii. Lalit Mohan Basu, M.B.49, leader Road, Allahabad, India.

Leung, David W.M; Thhorpe, Trevor A. April (1984). **"Intrference by edta and calcium ions of the 3, 5 dimitrosalicylate reducing sugar assay"**. Phytochemistry. Pergaman Press. 23(12): 2949-2950. dol: 10.1016/0031-9422 (84)83048-4. ISSN 0031-9422.

Marini-Bettolo, G.B, (1981). **Plant Screening by chemical and Chromatographic procedure under field condition**. Journal of Chromatography, 31, 14-17.

Metcalfe C.R and L.Chalk, (1950). **Anatomy of the Dicotyledons Leaves**, Stemand Wood in relation to Taxonomy with Notes on Economic Uses, vol-ii Oxford, at the Clarend on Press.

Nyo Maung U., et al., (2012), **Taxonomy of Angiosperms**, Department of Botany, University of Mandalay.

Pandey, S.N., (2004). **Plant Anatomy and Embryology**, Vikas Publishing House PVT LTD 576 Masjid Road, Jangpura, New Delli.

Patel. B. (2007). **Medicinal and Aromatic Plant Science and Biotechnology**.

Rendle, Alfred Bartan, (1967). **The Classification of Flowering Plants**, vol-ii, Cambridge at the University Press.

Sen Gupta, J.C. (1985). **Botanical Survey of India**, Calcutta.

Steven J. Wagstaff, laura Hickerson, Russ Spangler. Patrick A. Reeves, and Richard G.Olmstead. (1998).**"Phylogeny in Labiatae** 5.1., Inferred from cpDNA sequences", Plant systematics and evolution 209 (3-4); 265-279.

Trease, G.E and Evans, W.C, (2002). **Pharacognosy**. (11th ed.). London; Cassell and Collier Macmillan Publishers ltd.

Waston, L., and Dallwitz, M.J., (1992). **The families of flowering plants**: descriptions, illustrations, identification, and information retrieval.

Werker E, Ravid U, Putievsky E, (1985). **Structure of glandular hairs and identification of the main components of their secreted material in some species of the labiatae**. Israel J. Bot 34:31-45.

Websites

http://www.breastcancer.org>photochem.

Petrographic Criteria and Petrogenetic Significance of Metamorphic rocks of Pinbaw Area, Mogaung Township, Kachin State

Ni Ni Win*

Abstract

The study area, Pinbaw, is situated in the southern part of the Mogaung Township, Mohyin Disrtict, Kachin State. The main lithology of the study area is medium-to high-grade regionally metamorphic rocks. Based on the texture and constituent mineral assemblag02es, the metamorphic rocks can be subdivided into metapsammite, metapelites and metaigneous. Occurrences of mineral assemblages in metapelites indicate that the metamorphism of the study area falls within the greenschist facies to amphibolite facies. Three metamorphic zones for metapelitic rocks are defined, namely, garnet zone, staurolite zone and kyanite zones. The peak of metamorphic temperature reaches up to 700℃. The metamorphic rock in the study area is primarly derived from the pelitic and psammitic rocks of possibly Ngapyawdaw Chaung Formation of Late Jurassic to Early Cretaceous.

Key words: Petrography, petrogenesis, metapelites, metapsammite

Introduction

The study area is situated in Mogaung Township, Mohyin District, Kachin State. It is located about 118 km from south of Myitkyina. The study area belongs to N Latitude 25° 4' to 25° 10' and E Longitudes 96° 38' to 96° 43' in one inch toprographic map 92 C/12. It covers approximately 126 square kilometer. It can be easily reached by car or railway road from Myitkyina to Mandalay. The present area was dominated by metamorphic rocks (Schist, quartzite and some serpentinites) and sedimentary rocks (Pleistocene gravels). The present work emphasizes with the petrography and petrogenesis of the metamorphic rocks. Based on their mineral paragenesis, the metamorphic rocks are grouped into metapelites and metapsammites. More than thirty thin sections were cut from various representative rock sample for the petrographic criteria. Petrogenesis of metamorphic rocks is studied on the basis of mineral assemblages, mineral chemistry, textural and field relationships. The location map of the study area is shown in figure (1).

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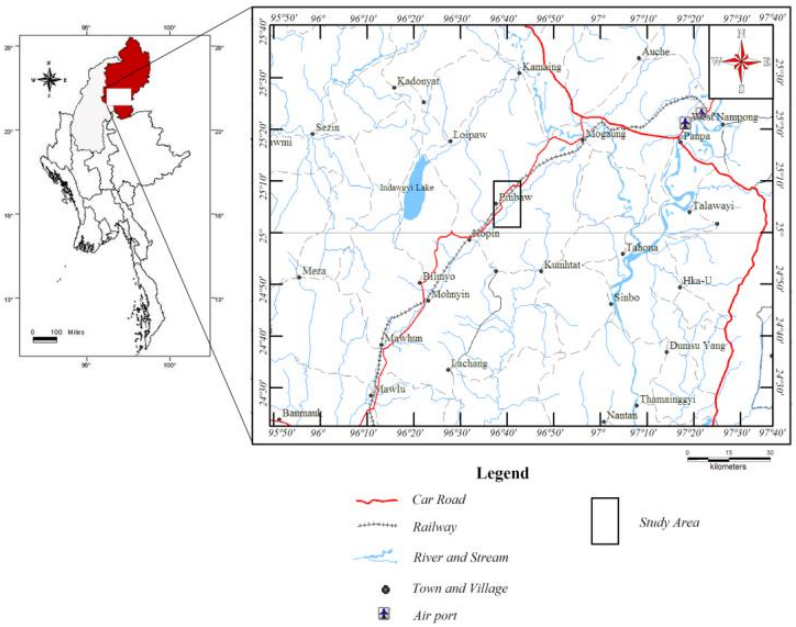

Fig.(1) Location map of thePinbaw area

Regional Geologic Setting

The study area falls in the northern part of Sagaing Fault (West Kachin Unit of Bender, 1983). Where it branches in various splays terminates in Jade Mine Belt into a compressive horse tail structure, 200 km wide from east to west. Regionally large part of nothern Myanmar is composed mainly of ultrabasic, igneous rock and sedimentary and metamorphic rock and all are ranging in age from Precambrian to Quaternary. The present area is partly included in Katha-Gangaw Range of Upper Irrawaddy Province which consists of three belts.Tagaung Myitkyina belt, Katha-Gangaw Range and Kumon Range (United Nation Team, 1978). Regional geological map of the study area is shown in Fig.(2).

Katha- Gangaw Range including present area, forms narrow mountain ranges immediately west of the Tagaung- Myitkyina belt and bounded on the west by the Namyin Fault (Sagaing Fault). The western part of the range consists largely of quartzites and quartz-mica garnet schists. These pass eastward into greenschist and minor amphibolites, tremolite-talc schist and mica schist. The intrusive rocks are absent. The compositional layering mostly dips east, although in place tight small scale east facing folds are present. The eastern flank of the range is occupied by phyllites and marbles.

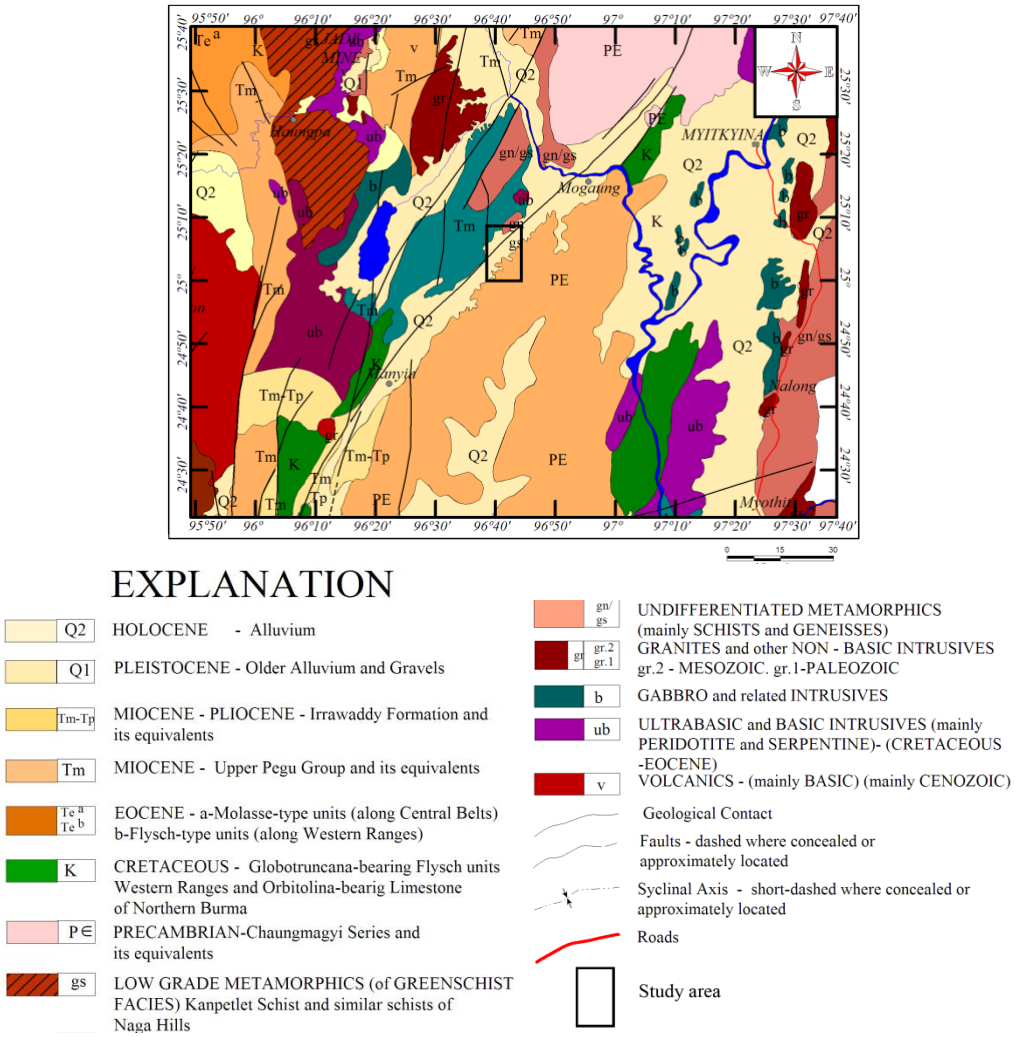

Fig.(2) Regional geologic setting of the Pinbaw area

(After the Geological Map of Burma, 1: 1000000 scale map; Earth Sciences Research Division, 1977)

Tagaung-Myitkyina Belt, eastern part of the area, is a poorly mapped belt characterized by basic and ultrabasic rocks of ophiolite suites mostly forming inliers within Late Tertiary sediments and alluvium, extend from Tagaung Taung, east of the Ayeyawaddy, northwards through Myitkyina to Sumprabum. The Tagaung-Myitkyina Belt narrows northwards between the converging Mogok belt and Kumon range.

The Kumon Range is structurally part of the western Trough, consisting of Upper Cretaceous to Tertiary sedimentary rocks. The range is bordered in the east and west by Oligocene and younger sediments and in the northeast bounded by Miju Thrust (United Nation Team, 1978).

Purpose of study

Previous workers researched regionally on geology of the Pinbaw area. There is no detail research on mineralogical, petrographical and petrogenesis. So, the present research mainly focuses on petrography and petrogenesis of the study area.

Sequence and Distribution of the Petrographic Units

Sequence of the Petrographic Units

The main lithology of the study area is medium to high grade regionally metamorphosed schists, quartzites and some serpentinites. The metamorphic rocks in the study area are primarily derived from the pelitic and psammitic rocks of possibly Ngapyawdaw Chaung Formation of Late Jurassic to Early Cretaceous.

Depending upon the previous works, the available structural and stratigraphical evidence, seven major rocks types have been recognized in the present area which is shown in table (1).

Table (1) Rock sequence of the Pinbaw area

	Lithologic Unit	Age
	Sedimentary Unit	
	Alluvium	Recent
	^^^^^^^^^^^^^^^^	
	Pebbly sandstone	Pleistocene
	Metamorphic Rocks	
Metaigneous	Serpentinites	
Metapsammite and metapelite	Kyanite quartzite	
	Granet-staurolite schist	Late Jurassic to
	Garnet-mica schist	Early Cretaceous
	Quartz-mica schist	
	Garnet -graphite schist	
	Micaceous quartzite	

Distribution of the Petrographic Units

The most abundant metamorphic rocks occupied in the study area is metapelitic rocks such as garnet-mica schist, micaceous quartzite, garnet-staurolite schist, quartz-mica schist, kyanite quartzite and graphite schist. This unit occupies in the southeastern part of the study area. The metaigneous rocks, serpentinites cropped out in the northwestern part of the study area. The sedimentary rocks, pebbly sandstone are found in western part of the study area. The geological map of the study area is shown in figure (3).

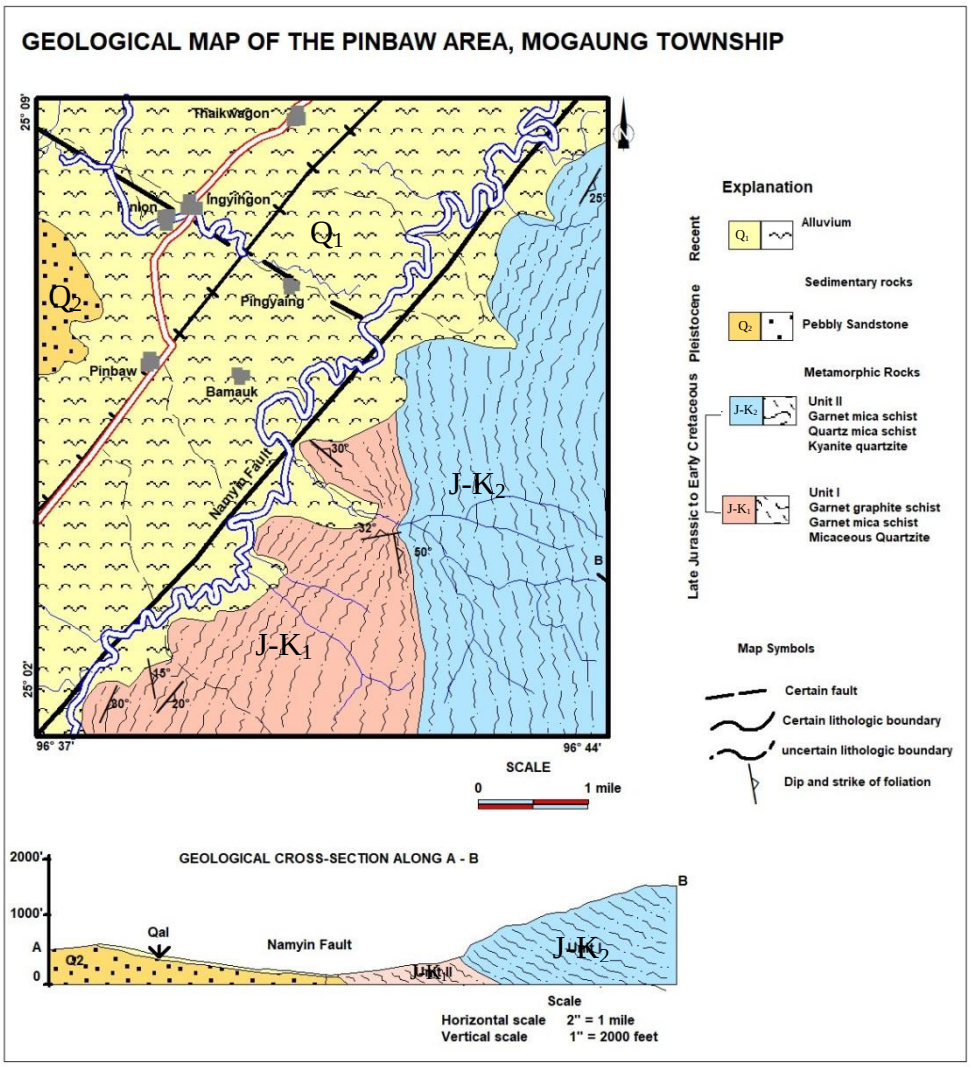

Fig.(3) Geological map of the Pinbaw area
(Modifies after Moe Kyaw Naing, 2010)

Petrography

More than thirty thin sections were cut from various representative rock samples collected from the study area for the petrographic studies.

Based on the constituent mineral assemblages, the metamorphic rocks can be grouped into metapelitic rocks, metapsammitic rocks. The metapelitic rocks are garnet-mica schist, micaceous quartzite, garnet-staurolite schist, quartz-mica schist, kyanite quartzite and garnet-graphite schist.

Micaceous quartzite

It is mainly composed of quartz and mica. It shows fine-grained, granoblastic texture. Quartz occurs as anhedral interstitial grains occupying irregular spaces between the other constituents. The grain size of quartz ranges from 0.1 mm to 0.3 mm. Some quartz grains show undulose extinction whereas the others are partially granulated and crushed. Suture contact of the grain boundaries is also observed. This may be as a result of strain effect (Fig.4). Mica is generally muscovite. It occurs as tabular form, pink or green color. Its grain size varies from 0.01 mm to 0.2 mm.

Garnet-graphite schist

The rock comprises of garnet, muscovite, quartz and graphite. This rock is fine-grained schistose texture. Slightly rotated nature of garnet grains can be observed in this rock (Fig.5). The grain size ranges from 0.1 mm to 0.5 mm. It is dark brown in colour and often include quartz inclusion. They can be easily recognizable in hand specimen which show reddish brown colour. Muscovite occurs as tabular form, almost all of them show scaly aggregates. Parallel alignment of muscovite flakes are marked by foliation. String of graphite and fine-grained muscovite flakes are parallel and aligned with schistosity. Quartz occurs as anhedral grains and xenoblastic texture.

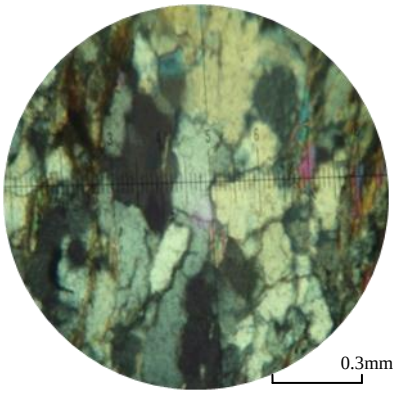

Fig.(4) Suture contact observed along the quartz grain boundaries in micaceous quartzite, between XN.

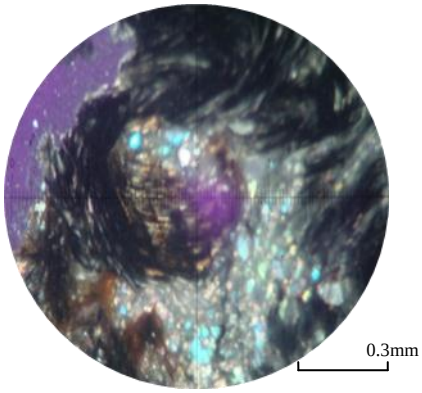

Fig.(5) Slightly rotated garnet grain in garnet-graphite schist, between XN.

Quartz-mica schist

It is mainly composed of muscovite and quartz. This rock is medium-grained, schistose texture due to parallel alignment of small muscovite flakes. Quartz crystal displays medium-to coarse-grained, anhedral grains and moderate to strongly sutured grains. Its grain size ranges from 0.1 mm to 0.3 mm. Some quartz crystals show undulatory extinction resulting from post crystalline deformation. Muscovite occur as tabular form. The crystal ranges from 0.1mm to 0.2mm in length. It shows pink or pale green colour. Schistosity is marked by strongly preferred orientation of mica-rich layered and quartz- rich layered (Fig.6).

Garnet-mica schist

Garnet-mica schist is mainly composed of quartz, feldspar, muscovite, garnet, and opaque minerals.

Muscovite occurs as tabular nature. The grain size ranges from 0.05 to 0.2 mm. Garnet occurs as subhedral to anhedral form. The garnet porphyroblast shown here has curved trails of small opaque inclusions of ilmenite which apparently indicate about 90̊ rotation (S-shape) of the garnet during growth (Fig.7). This may be as a result of faster strain rates. Quartz and feldspar occurs as mosaic of shapeless grains in the matrix.

Roughtly parallel alignment of muscovite flakes and quartz and feldspar grains shows schistose texture.

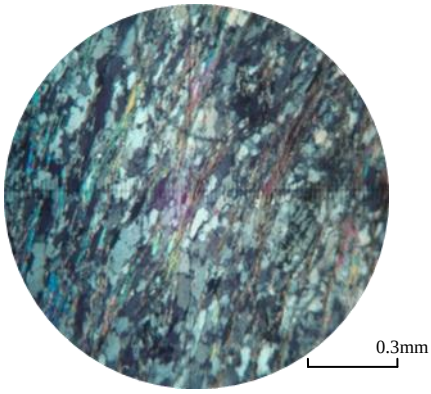

Fig.(6) Parallel alignment of mica - rich and quartz – rich layer in quartz-mica schist, between XN.

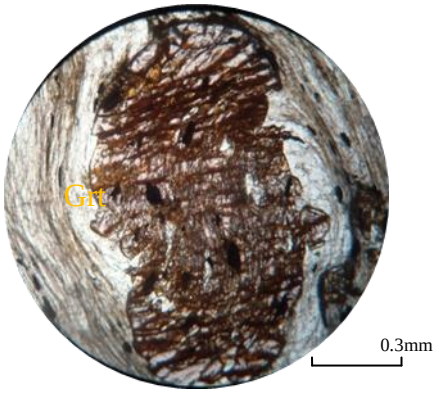

Fig.(7) S-shape inclusion trails of garnet mineral in garnet-mica schist, between XN

Garnet-Staurolite schist

This rock is mainly composed of muscovite, garnet, staurolite, muscovite and quartz. This rock shows coarse-grained porphyroblastic texture.

Staurolite occurs as large porphyroblast. The penetrated twin, the characteristic of staurolite, is common in hand specimen as well as in thin section. It exhibit lozened-shape and reaction rims and unidentifiable inclusions are common (Fig 8). Cracks and parting in staurolite crystals are also commom in this rock.

Garnet occurs as large porphyroblast. Their size ranges from 0.5mm to 2 mm in diameter. Many of them are in contact with staurolite crystals (Fig.9). Muscovite can be observed along the margin of the garnet crystal. The foliation of the rock is well defined by alignment of the muscovite flakes. Quartz occurs as anhedral crystal, suture contact and undulose extinction. Their size ranges from 0.01 mm to 0.5 mm in diameter.

Kyanite Quartzite

It is mainly composed of muscovite, quartz and kyanite. It is medium- to coarse-grained, porphyroblastic schistose texture. Kyanite occurs as large porphyroblast and shows flaky or bladed crystal in quartz matrix (Fig.10). Quartz in this rock is mostly found as equidimensional euhedral grains. It displays granoblastic polygonal texture which is characteristic of very high grade metamorphism. The size ranges from 0.01 mm to 0.05 mm in diameter. It shows undulose extinction and suture contact. Muscovite occur as small flakes.

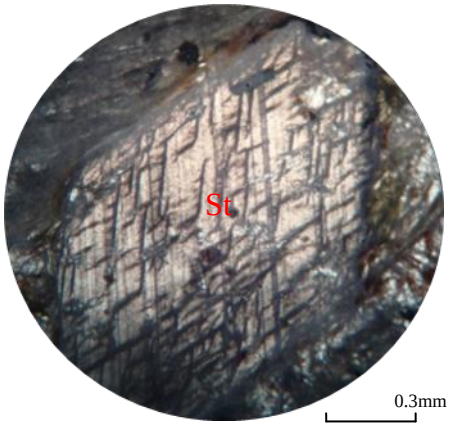

Fig.(8)Lozenge-shaped porphyroblast of staurolite in garnet staurolite schist, between XN.

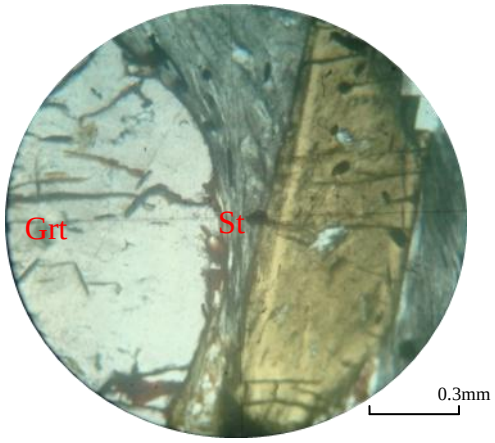

Fig.(9) The contact between garnet and staurolite in garnet staurolite schist, between XN.

Serpentinite

The rock is almost entirely made up of serpentine minerals such as, chrysotile, and antigorite together with some opaque iron oxide. Chrysotile occurs in long flexible, or rod like forms. Large masses of minute matted fibers are found in serpentine. Antigorite exhibits a flat, lathlike form, light green color and randomly oriented. The rocks show mesh structure in which very low birefringence (Fig.11)

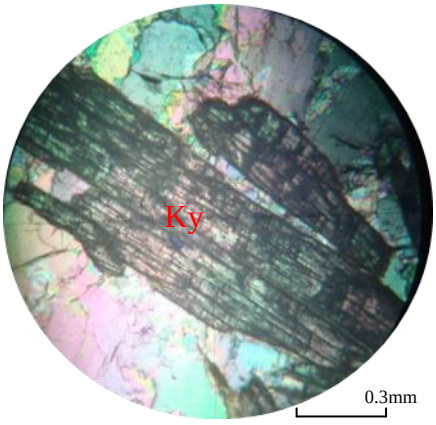

Fig.(10) Bladed crystal of kyanite in kyanite quartzite between XN.

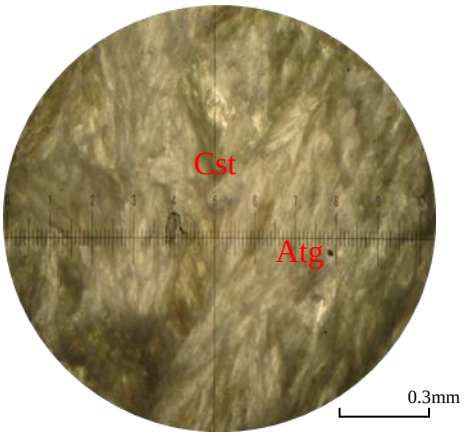

Fig.(11)A distinctive mesh texture in serpentinite, between XN.

Petrogenesis

Petrogenesis of metasedimentary rocks is interpreted on the basis of constituents' mineral assemblages, textural and field evidence.

Type of metamorphism

Based on the textural, mineralogical and field criteria, the study area possesses regional metamorphism. The regional metamorphism in the study area is indicated by

the occurrence of foliation, recrystallization, metamorphic differentiation and neomineralization products such as garnet, staurolite, and kyanite.

In the study area, presence of deformation features, such as sutured grain boundary, undulose extinction. This fact points out dynamic metamorphism.

Metamorphic facies

The identification of metamorphic facies is based on the diagnostic mineral assemblages. The presence of prominent mineral assemblages in metapelitic rocks of the study area are as follows:

(1) Quartz, muscovite

(2) Quartz, muscovite, garnet, graphite

(3) Quartz, muscovite, garnet

(4) Quartz, muscovite, garnet, staurolite

(5) Quartz, muscovite, kyanite

The occurrence of mineral assemblage quartz, muscovite in quartz-mica schist represents greenschist facies.

The garnet-graphite schist and garnet-mica schist may be characterized by the presence of assemblage quartz, muscovite, garnet, graphite and quartz, muscovite, garnet. This assemblage is the characteristic of garnet zone of lower- to middle-amphibolite facies.

Bucher and Grapes (2011) pointed that the first occurrence of staurolite in garnet-staurolite schist marks the transition from greenschist facies to amphibolite facies in pelitic rocks.

The assemblages muscovite, quartz, kyanite is typical assemblage of kyanite quartzite and, the occurrence of this mineral assemblage represents kyanite zone of upper amphibolites facies and at a temperature close to 700° C. Therefore, it can be assumed that the study area falls within the greenschist facies to amphibolite facies.

Metamorphic Grade and Zone

Metamorphic grade in the study area is characterized by the occurrence of garnet, stauroite and kyanite. Bucher and Frey (1994) point out the first occurrence of garnet in garnet-mica schist, garnet-graphite schist represent garnet zone and coincides with temperature 450° C. The first occurrence of staurolite in garnet-staurolie schist defining staurolite zone and its temperature indicates about 470° C. The first occurrence of kyanite in kyanite quartzite represent kyanite zone. This mineral assemblages indicate high grade metamorphism and its temperature close to 700° C.

Based on the previous author's comments and field criteria, it is inferred that metapelitic rocks of the study area show three distinctive metamorphic zones: garnet zone, staurolite zone and kyanite zone and the metamorphic grade is medium-to high grade.

Protolith

In the study area, the metamorphic rocks may be assumed to be derivatives of two types of protoliths: pelitic and psammitic on the basis of mineral paragenesis and textural criteria.

In metapelitic rocks, mica plays an important role. The principal micas in metaplites are muscovite. Abundance of garnet, graphite, staurolite and kyanite show high aluminous nature, indicating the original pelitic rock.

Graphite schist probably derived from organic rich sediment. The presence of graphite suggests the precursor was black shale and marls (Winkler, 1979).

Micaceous quartzite mainly composed of quartz and mica suggests the precursor was arenitic. In some quartzites, feldspars are rare, and mainly composed of crystalline quartz and a few flakes of muscovite. These types of quartzite suggest the protolith was chert (Willam et al., 1953).

Myint Thein et al., (1982) documented Katha Metamorphics are derived from the rocks of the Ngapyawdaw Chaung Formation (Middle to Upper Triassic?). Maung Thein (1983) proposed that metamorphic rocks of the Katha-Gangaw Range may be correlated with that of Tagaung-Kyaukphyu area where the premetamorphic rocks of the Katha Metamorphics were well exposed (Myint Thein et al., 1982). It is suggested that ophiolite associated with metamorphosed sediments along Alpine Himalaya Chain give a range of radiometric dates from Mid-Jurassic to Middle Cretaceous (Yardley, 1998).

Laja (1985) and Aung Kyaw Thin (2006) described the age of microfossil, radiolarian, from chert of Ngapyawdaw Chaung Formation at Tagaung area as Late Jurassic to Early Cretaceous.

Based on the previous works and present observations, the metamorphic rocks of the study area have been metamorphosed from Late Jurassic to Early Cretaceous.

Time of metamorphism

M.O.G.E (1998) mentioned that schists of the Katha-Gangaw Range are the offset continuation of the Kanpetlet schist and that of Naga-Chin Hills. Uplift of the Arakan-Chin-Naga and the Katha-Gangaw Ranges to form a geanticline probably took place in Oligocene, perhaps accompanied by extensional movements.

Mitchell, 1993, suggested that the metamorphic rocks in the Katha-Gangaw Range may be Pre-Triassic rocks equivalent to the lower part of the Mergui Nappe, or Chaungmagyi Turbidites to the east.

Mitchell et al., 2007, also considered that the Katha-Gangaw Range is thought to be the northern continuation of the Mogok Metamorphic Belt.

G.I.A.C, 1999, described that the ages of metamorphis rocks of the Katha and Kumon Ranges ranging from 37 to 32 Ma by $^{39}Ar/^{40}Ar$ dating method.

Therefore, the time of metamorphism of the study area may be assigned to Oligocene.

Conclusion

The research area was dominated by metamorphic (metapelite, metapsammite and some metaigneous). The present work deals with the petrographic features of the mineral assemblages of metapelitic rocks. Existence of garnet, staurolite and kyanite indicates medium- to- high grade regional metamorphism. The prominent mineral assemblages in garnet-mica schist, garnet- staurolite schist and kyanite quartzite in the study area points out the greenschist to amphibolite facies. In addition, the peak of metamorphic temperature reaches up to 700° C.

Acknowledgements

I would like to express my sincere gratitude to Dr Aung Kyaw Thin, Acting Rector and Dr Aye Aye Han, Pro-Rector, Banmaw University, for their kind permission and encourangement to carry out this work.

References

Aung Kyaw Thin, (2006), Petrogenetic Study on Igneous and Metamorphic rocks of the Tagaung - Twingge area, Thabeikkyin Township. Unpublished Ph.D Thesis, MU .

Bender, F., (1983), *Geology of Burma*, Berlin, stuttgart, 293p.

Bucher, K. and Grapes, R., (2011), *Petrogenesis of MetamorphicRocks*. 8th ed. Springer Verlag Berlin Heidelberg, printed in Germany.

Bucher, K., and Frey, M., (1994), *Petrogenesis of Metamorphic Rocks*. 6th ed., Springer Verlag.

Earth Sciences Research Division, (1977), Geological Map of the Socialist Republic of the Union of Burma, 1:1,000,000 scale. Rangoon.

G. I. A. C Project, (1999), *Tectonic of Myanmar*; Final report.

Laja, L., (1983). Geology and Mineral Resources of Tagaung Taung Area, Thabeikkyin Township. M.Sc. Thesis. MU.

M.O.G.E, (1998), Myanmar as a nappe stack and relationship to plate collisions and the Himalayas. M.O.G.E Seminar- March 10, (1998).

Maung Thein, (1983), The Geological Evolution of Burma, Geological Association, Mandalay University, *Unpublished paper*.

Mitchell, A.H.G, (1993), Cretaceous-Cenozoic tectonic events in the western Myanmar (Burma)-Assam region. *Journal of the Geological Society of London*.V.150.pp.1090-1102.

Mitchell, A.H.G, Myint Thein Hlay, Kyaw Min Htun, Myint Naing Win, Thura Oo and Tin Hlaing, (2007), Rock relationships in the Mogok Belt, Tatkon to Mandalay, Central Myanmar, *Jour. of Asian Earth Sciences*.

Moe Kyaw Naing, (2010), Geology of the Pinbaw area, Mogaung Township. Unpublished MSc Thesis, MU .

Myint Thein, Kyaw Tint and Kan Saw, (1982), *Geology of the part of the eastern margin of the central Burma (Myanmar) Belt between Sagaing and Tagaung.* Research titles, Geoscience Group, Policy Directing Committee on Research Projects, Burma, pp.295-303.

United Nation Team, (1978), Preliminary results of regional geological mapping and reconnaissance geochemical exploration in Manst - Manhton, Indaw - Tigyaing, Kyindwe - Longyi, Patachaung - Yeni and Yesin Area, Burma, Tech. Report no. 8, *Geot, Surv. & Expl. Proj.* U.N (restricted).

Willian, H., Turner, F. J., and Gilbert, C., (1953), Petrography. Freeman and Co., Sanfransisco. 626p.

Winkler, H.G.F., (1979), *Petrogenesis of metamorphic rocks*, 5th ed., Springer -verlag, Berlin, New York, 348p.

Yardley, B.W.D., (1998), *An Introduction to Metamorphic petrology.* Addison Wesley, Longman Singapore pte Ltd.

Stratigraphy of Monywa Area and its Environs, Monywa Township, Sagaing Region

Yee Myo Oo*

Abstract

The study area is situated in Monywa Township, Sagaing Region. It lies between Latitude 21˚55'45″N to 22˚18' N and Longitude 95˚05'E to 95˚23'E of one-inch topographic maps 84-N/4 and 84- N/8. It lies geographically in the Central Lowland. It is situated tectonically in the Lower Chindwin Basin which is in the western part of the Central Volcanic Line (CVL). The study area is mainly composed of sedimentary and volcanic rocks. The sedimentary strata consist of Upper Pegu Group (Miocene) and Irrawaddy Formation (Late Miocene-Pliocene). Volcanic occurrence at Kyaukka Taung and Taungtalone Taung lying N-S trending is very distinct and in which the igneous rocks are mostly basic rocks (basalt). There were three recognized stratigraphic units in the Upper Pegu Group, namely; Taungtalone Sandstone, which is composed of dark grey, medium to coarse-grained, hard and compact sandstones, Moza Formation which is mainly made up of alternation of sand and shale and Khabo Sandstone which is mainly composed of medium to coarse-grained, buff color, thick bedded to massive sandstone. Irrawaddy Formation is composed of thick bedded to massive, coarse-grained, light yellow and soft to friable sandstones.

Key words: Central Lowland, Central Volcanic Line, Lower Chindwin Basin, Upper Pegu Group, Taungtalone Formation, Moza Formation, Khabo Formation, Irrawaddy Formation

Introduction

The study area is situated in Monywa Township, Sagaing Region. It lies between Latitude 21˚55'45″N to 22˚18' N and Longitude 95˚05'E to 95˚23'E of one-inch topographic maps 84-N/4 and 84- N/8 (Figure 1). It lies geographically in the Central Lowland. It is situated tectonically in the Lower Chindwin Basin which is in the western part of the Central Volcanic Line (CVL) (Figure 2). Structurally, the major anticline is generally striking NNW-SSE. Volcanic occurrence at Kyaukka Taung and Taungtalone Taung lying N-S trending is very distinct and in which the igneous rocks are mostly basic rocks (basalt). Kyaukka Taung is located between the Chindwin basin and Minbu Basin and west of the Central Volcanic Line. The height of Kyaukka Taung peak is 1262 feet. Taungtalone Taung is isolated volcanic hill. The height of Taungtalone Taung peak is 822 feet. The various geological investigators of the proposed area had been done by many geologists. Stamp (1922) and Chhibber described the late Tertiary igneous rocks of the Lower Chindwin region in 1927. General geology of the Kyaukka-Thazi Area has been worked by Ba Maw (1968). Aung Win (1986) studied the geology of the Okhpo-Kyaunggon Area, Monywa and Budalin Townships. Win Myint (1986) studied sedimentological data were provided for the rock sequences in the Kadetkan-Nwegwe Area.

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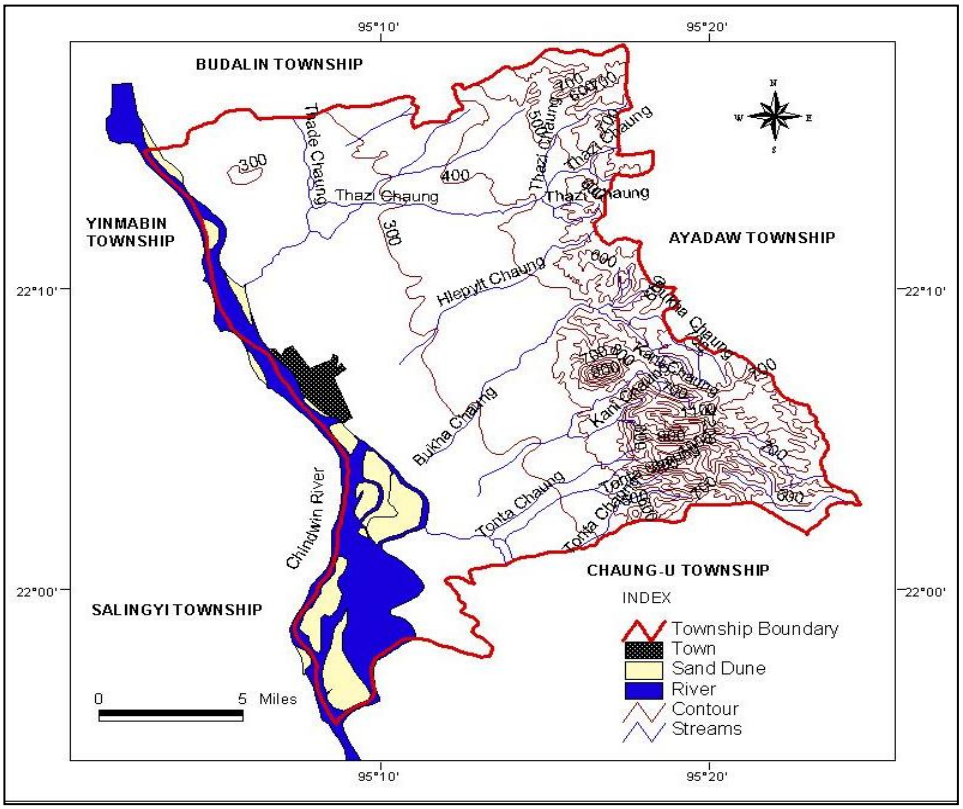

Figure (1) Location map of the study area

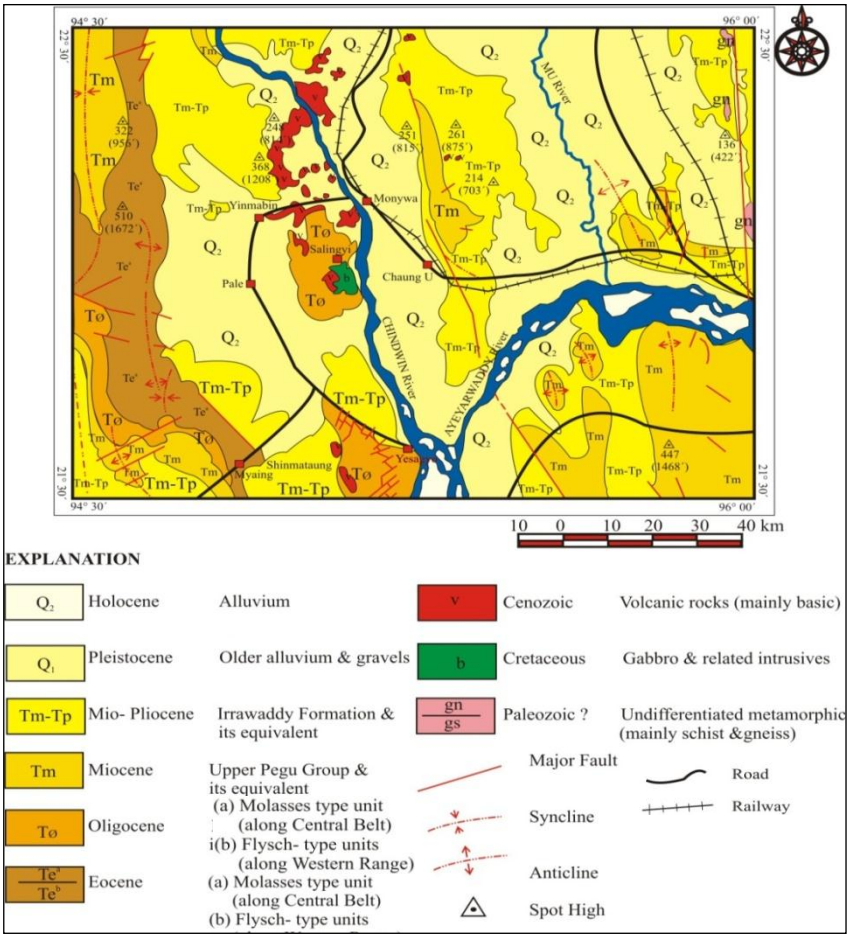

Figure (2) Regional geological map of the study area and its environs

Stratigraphy

General Statement

The study area is composed mainly of igneous rocks, clastic sedimentary rocks of Upper Pegu Group and Irrawaddy Formation. There were three recognized stratigraphic units in the Upper Pegu Group, namely; Taungtalone Sandstone, Moza Formation and Khabo Sandstone. These sedimentary sequences are capped by the basalts. The rock sequence of the study area is divided into, from older to younger; Taungtalone Sandstone, Moza Formation, Khabo Sandstone, Irrawaddy Formation and the recent igneous rocks. The stratigraphic correlation chart of the study area is shown in Table (1).Geological map of the study area is shown in (Figure 3).

Sedimentary Rocks

Taungtalone Sandstone

Name Derivation

The term Taungtalone Sandstone was first defined by Myint Thein (1966) for a unit of sandstone exposed in the core of the Taungtalone anticline, in Kyaukse Township.

Distribution

It is best exposed in the Kyaunggon Chaung, Nyaungdawdon Chaung as the core of the major anticline, Buga Chaung and Kanni Chaung.

Lithology

The Taungtalone Sandstone is composed mainly of light to dark grey, medium to coarse-grained, hard and compact, thick-bedded to massive sandstones (Figure 4). They are also interlayered with light grey siltstones and blue grey shale. The primary sedimentary structures are ripple marks, parting lineations, planar cross bedding (Figure 5). Sandstone concretions (Figure 6) and horizontal laminations (Figure 7) are found. Convolute laminations are also occurred (Figure 8). The lower boundary is not exposed in the area. This formation is conformably overlain by the Moza Formation (Figure 9).

Fauna, Age and Correlation

According to the previous workers, the fauna such as *Pecten* sp., *Ostrea* sp., *Turritella* sp., *Cyrena* sp., are indicated that the Taungtalone Sandstone was deposited during Middle Miocene. This formation can be tentatively correlated with the Taungtalone Sandstone of Taungtalone area, Kyaukse Township (Myint Thein, 1966).

Figure (4) Thick bedded to massive sandstone of the Taungtalone Sandstone (Nyaungdawdon Chaung, Lat. 22˚11′48.7″N, Long. 95˚15′25.8″E)

Figure (5) Planar cross-bedded sandstone in the Taungtalone Sandstone (Nyaungdawdon Chaung, Lat. 22˚11′48.7″N, Long. 95˚15′30″E)

Table (1) The stratigraphic correlation table of the study area

Age	Taungtalone Area Myint Thein (1966)	Kyaukka-Thazi Area Ba Maw(1968)	Standard Minbu Basin		Kadetkan-Nwegwe Area Win Myint (1986)	Monywa Aera Yee Myo Oo (2015)
Pleistocene	Alluvium	Alluvium	Alluvium		Alluvium	Alluvium
Pliocene	Thittawpya Sandstone	Pyawbon Sandstone	Irrawaddy Formation		Irrawaddy Formation	Irrawaddy Formation
		Nyaungbinde Sandatone				
		Yinmabin Sandstone				
		Nagu Sandstone				
Miocene	Khabo Sandstone	Htantaloke Sandstone	Upper Pegu Group	Obogon Formation	Khabo Sandstone	Khabo Sandstone
	Moza Formation	Kanbauk Sandatone Kanbauk Clay			Moza Formation	Moza Formation
	Taungtalone Sandstone	Hletpyit Chaung Sandstone		Kyaukkok Formation	Taungtalone Sandstone	Taungtalone Sandstone
	Shwetaung Clay			Pyawbwe Formation		

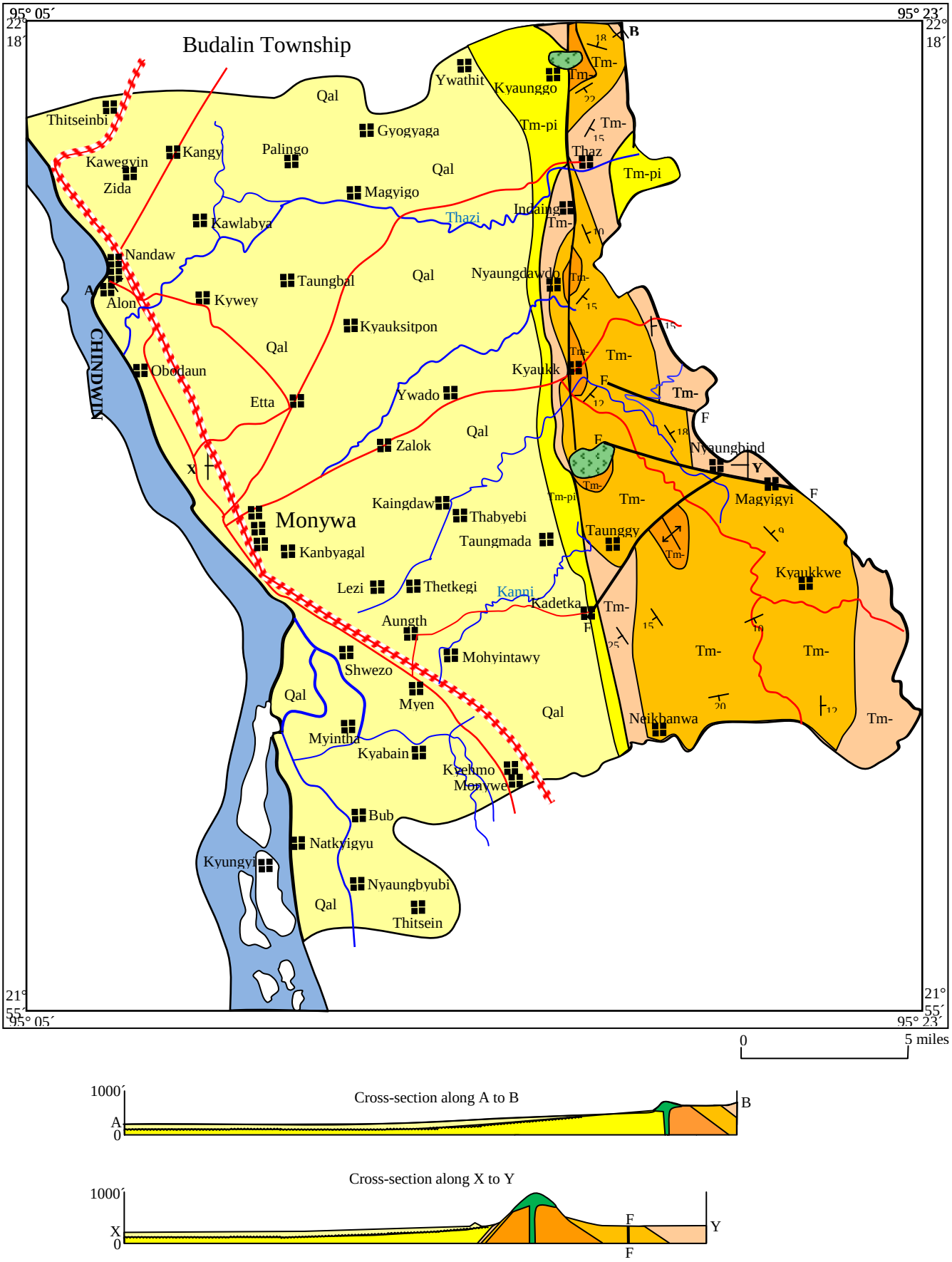

Figure (3) Geological map of the study area

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY	Qal	ALLUVIUM
LATE MIOCENE TO PLIOCENE	Tm-pi	IRRAWADDY FORMATION
MIDDLE MIOCENE	Tmk	KHABO SANDSTONE
MIDDLE MIOCENE	Tmm	MOZA FORMATION
MIDDLE MIOCENE	Tmt	TAUNGTALONE SANDATONE

IGNEOUS ROCKS

QUATERNARY		BASALT

SYMBOLS

contact

axis of plunging anticline

15°

F F dip and strike of bedding

fault

town and village

stream

rail road

car road

After Bamaw, 1886

Figure (6) Sandstone concretion in the Taungtalone Sandstone (Nyaungdawdon Chaung,Lat. 22˚11′47″N, Long. 95˚15′31.5″E)

Figure (7) Fine to medium-grained sandstone with horizontal laminations in the Taungtalone Sandstone (Nyaungdawdon Chaung, Lat. 22˚11′49.3″N, Long. 95˚15′35″E)

Figure (8) Sandston e with convolute laminations of the Taungtalone Sandstone (Nyaungdawdon Chaung, Lat. 22˚11′50″N, Long. 95˚15′48.2″E)

Figure (9) Contact between the Taungtalone Sandstone and Lower Member of the Moza Formation (Nyaungdawdon Chaung, Lat. 22˚11′48″N, Long. 95˚16′E)

Moza Formation

Name Derivation

The term Moza Formation was firstly defined by Myint Thein (1966) for a unit of interbedded sequence of sandstone, siltstone and shale that is well exposed in the Taungtalone area, Kyaukse Township.

Distribution

The Moza Formation is widely distributed in the most parts of the study area. Good exposures occur along the stream sections of Kyaunggon Chaung, Kyauktan Chaung, Thazi Chaung, Buga Chaung and Kanni Chaung.

Lithology

The Moza Formation is mainly made up of alternation of sand and shale. This formation can be divided into the Lower Member and the Upper Member. The Lower Member is composed of interbedded sandstone, siltstone and shale. Sandstone with rib and furrow structure is occurred (Figure 10). Sandstones are yellowish grey, fine to medium-grained, thin to thick bedded, and indurated. The sedimentary structures are small current ripples (Figure 12), small to medium scale wedge- shaped planar cross-laminations (Figure 13). Siltstone and shale are bluish grey and thin to medium

beddded. The hard calcareous clay bands frequently present in the lower part of this member. Interbedded layers of sandstone, siltstone, clay and shale are present in the Upper Member (Figure 11). In this member shales are more common than the Lower Member. Sandstones are light grey to buff colored. Shale and clay are bluish grey 2cm to 15cm thick. The individual layers of sandstone vary from 5cm to 20cm in thickness. The sedimentary structures are small current ripples, small to medium scale cross beddings, parallel laminations, lenticular and flaser beddings (Figure 14), and convolute bedding (Figure 15). Wavy laminated sandstone and shale alternation are observed in the Moza Formation (Figure 16). The Moza Formation is conformably by the Khabo Sandstone (Figure 17).

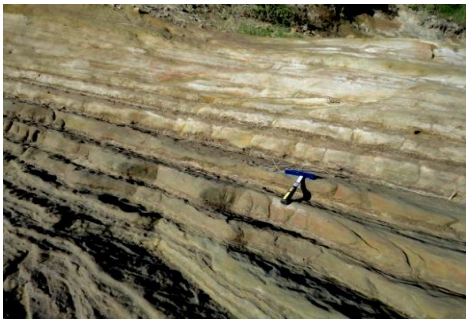

Figure (10) Interbedded sandstone, siltstone and shale showing rib and furrow structure in the Lower Member of the Moza Formation (Kanni Chaung, Lat. 22˚05′ 45.8″N, Long. 95˚16′31.8″E)

Figure (11) Interbedded layers of sandstone, siltstone, clay and shale in the Upper Member (Kanni Chaung, Lat. 22˚05′ 47.2″N, Long. 95˚16′31.8″E)

Figure (12) Small current ripples in fine-grained sandstone of the Lower Member of the Moza Formation (Kanni Chaung, Lat. 22˚05′ 47.2″N, Long. 95˚16′31.8″E)

Figure (13) Small to medium scale wedge-shaped planar cross-laminations in the Lower Member of the Moza Formation (Kanni Chaung, Lat. 22˚05′ 47.2″N, Long. 95˚16′31.8″E)

Figure (14) Lenticular and flaser beddings of the Moza Formation (Kanni Chaung, Lat. 22˚05′ 47.2″N, Long. 95˚16′31.8″E)

Figure (15) Convolute bedding in the Moza Formation (Kyauktan Chaung, Lat. 22˚15′ 50.1″N, Long. 95˚15′25.5″E)

Figure (16) Wavy laminated sandstone and shale alternation of the Moza Formation (Nyaungdawdon Chaung, Lat. 22˚11′50″N, Long. 95˚15′48.2″E)

Fig (17) Contact between the Moza Formation and the Khabo Sandstone (Kyauktan Chaung, Lat. 22˚15′ 52.7″N, Long. 95˚15′28.6″E)

Fauna, Age and Correlation

According to the previous workers, it was deposited during Middle Miocene. On the basis of stratigraphic position and faunal assemblages, it can be correlated with the Moza Formation of Taungtalone area, Kyaukse Township (Myint Thein, 1966).

Khabo Sandstone

Name Derivation

The term Khabo Sandstone was first described by Myint Thein (1966) for a group of sandstones exposed in the Taungtalone area, Kyaukse Township.

Distribution

The Khabo Sandstone crops out in the Kanni Chaung, Nyaungdawdon Chaung, Thazi Chaung, Kyauktan Chaung, and Kyaunggon Chaung.

Lithology

This unit is mainly composed of medium to coarse-grained, yellowish brown to buff color, massive and generally thick bedded sandstone (Figure 18). Shale and

clay are thinly intercalated within the massive sandstone units. Medium scale planar cross-laminations (Figure 19) and large scale trough cross-beddings (Figure 20), parallel laminations (Figure 21), wavy bedding (Figure 22) and convolute bedding. Sandstone concretions are of various sizes ranging from 10cm to 90cm in diameter and shapes (Figure 23). Sole markings (Figure 24, a, b) (Figure 25, a, b) are observed at the base of sandstone bed of the Khabo Formation. The Khabo Sandstone is conformably underlain by the Moza Formation and unconformably overlain by the Irrawaddy Formation.

Figure (18) Thick bedded to massive sandstone of the Khabo Sandstone (Thazi Chaung, Lat. 22˚14′ 01.1″N, Long. 95˚16′46.7″E)

Figure (19) Planar cross-laminations in thick bedded sandstone of the Khabo Sandstone (Thazi Chaung, Lat. 22˚14′ 01.7″N, Long. 95˚16′48.7″E)

Figure (20) Large scale trough cross-beddings in thick bedded sandstone of the Khabo Sandstone (Thazi Chaung, Lat. 22˚14′ 01.7″N, Long. 95˚16′48.7″E)

Figure (21) Horizontally laminated sandstone in the Khabo Sandstone (Kyauktan Chaung, Lat. 22˚15′ 53.7″N, Long. 95˚15′28.8″E)

Figure (22) Wavy laminated sandstone of the Khabo Sandstone (Thazi Chaung, Lat. 22˚13′ 30.7″N, Long. 95˚16′50.2″E)

Figure (23) Disc shaped sandstone concretions in the Khabo Sandstone (Thazi Chaung, Lat. 22˚14′ 03.7″N, Long. 95˚16′49.7″E)

Figure (24) (a) Flute casts observed at the base of sandstone bed of the Khabo Sandstone (Kyauktan Chaung, Lat. 22˚15′56.8″N, Long. 95˚15′33.2″E)

Figure (24) (b) Flute casts observed at the base of sandstone bed of the Khabo Sandstone (Kyauktan Chaung, Lat. 22˚15′56.8″N, Long. 95˚15′33.2″E)

Fauna, Age and Correlation

According to the previous workers, it may be Middle Miocene age. On the basis of lithologic characters and faunal assemblages, this formation can be correlated with the Khabo Sandstone of Taungtalone area, Kyaukse Township (Myint Thein, 1966).

Figure (25) (a) Load casts observed at the base of sandstone bed of the Khabo Sandstone (Kyauktan Chaung, Lat. 22˚15′ 56.8″N, Long. 95˚15′33.2″E)

Figure (25) (b) Load casts observed at the base of sandstone bed of the Khabo Sandstone (Kyauktan Chaung, Lat. 22˚15′ 56.7″N, Long. 95˚15′33.6″E)

Irrawaddy Formation

Name Derivation

The Irrawaddy Formation was first termed Fossil Wood Group by Theobald. But later the Irrawaddy Series was described by Noetling (1900). Pascose (1912) described this unit under the name Irrawaddy Sandstone. Nowadays, the Irrawaddy Formation was defined by Aung Khin and Kyaw Win (1969).

Distribution

The Irrawaddy Formation is widely distributed in the study area. It is well exposed near the Taungtalone Taung (Figure 26).

Lithology

This formation is composed of thick bedded to massive, coarse-grained, light yellow to buff color, and soft to friable sandstones and by the occurrence of fossil wood. After the deposition of Upper Pegu Group then follow the Irrawaddy sediments overlying in the basal conglomerate (Figure 27).

Fauna, Age and Correlation

The Irrawaddy Formation can be regarded that Late Miocene to Pliocene age. It can be correlated with Thittawpya Sandstone of Taungtalone area, Kyaukse Township (Myint Thein, 1966).

Figure (26) Loosely cemented, whitish grey to buff color massive sandstone of the Irrawaddy Formation (Lat. 22˚16′ 37.9″N, Long. 95˚15′00.2″E)

Figure (27) Conglomerate bands showing boundary between the Khabo Sandstone and Irrawaddy Formation (Thazi Chaung, Lat. 22˚13′ 32.7″N, Long. 95˚16′50.3″E)

Igneous Rocks

The igneous occurrences of the Monywa area are found on both banks of Chindwin. The one on the west bank is continuous, stretching between Popa in the south and Wuntho in the north. It appears the line of occurrences on the east bank of the Chindwin forms a subsidiary parallel accompaniment to the main line. In the study area, the igneous rocks occur at, from north to south are; Taungtalone Taung and Kyaukka Taung.

Taungtalone Taung

The Taungtalone Taung is an isolated volcanic hill. It is situated about 3 miles north of Thazi Village. Moreover, Kyaunggon Village is situated on the southern foot of the hill. The hill lies of the main fault on the west edge of the Pegu inlier. The Taungtalone Taung is contact zone between Thazi anticline and Irrawaddy Formation. The Taungtalone Peak is 822 feet and steep slope. The basaltic boulders occur all around the Taungtalone Hill. These are dark grey, fine-grained picrite basalt with vesicular (Figure 28).The basalts of the Taungtalone Taung are supposed to be formed by fissure eruption after the deposition of Irrawaddy Formation.

Figure (28) Dark grey, fine-grained picrite basalts at the Taungtalone Taung (Lat. 22˚16′ 44.9″N, Long.95˚15′04.2″E)

Kyaukka Taung

Looking eastwards from the Chindwin River at Monywa, the peculiarly shaped mound call the Kyaukka Taung can be found. The Kyaukka Taung is near the plane of unconformity as a cap on the top of the hill (Figure 31). Flow direction is more in the direction of S-E of the hill. The high of the Kyaukka Taung is 1262 feet. It is the highest point of the study area. The northwestern and the southern margin of this hill form steep cliff. The mass of basic lava, picrite basalts (Figure 2.30) are capped on the top of the hill. The host rocks may be Peguan and Irrawaddian sandstones. Therefore, eruption has taken after the deposition of sediments.

Figure (29) Fine-grained, dark picritic basalts at the Kyaukka Taung (Lat. 22˚07′ 29.7″N,

Summary

1. The study area is situated in Monywa Township, Sagaing Region. It lies between Latitude 21˚55'45″N to 22˚18' N and Longitude 95˚05'E and 95˚23'E of one-inch topographic maps 84-N/4 and 84- N/8. The study area lies geographically in the Central Lowlands. It is situated tectonically in the Lower Chindwin Basin which is in the western part of the Central Volcanic Line (CVL). Structurally, the major anticline is generally striking NNW-SSE. Volcanic occurrence at Kyaukka Taung and Taungtalone Taung lying N-S trending is very distinct and in which the igneous rocks are mostly basic rocks (basalt).

2. The study area is composed mainly of igneous rocks, clastic sedimentary rocks of Upper Pegu Group (Miocene) and Irrawaddy Formation (Late Miocene-Pliocene). There were three recognized stratigraphic units in the Upper Pegu Group, namely; Taungtalone Sandstone, Moza Formation and Khabo Sandstone. These sedimentary sequences are capped by the basalts. The Taungtalone Sandstone is composed mainly of light to dark grey, medium to coarse-grained, hard and compact, thick-bedded to massive sandstones. The Moza Formation can be divided into two members. The components of the Lower Member are interbedded sandstone, siltstone and shale. Sandstones are more abundant than the Upper Member. Interbedded layers of sandstone, siltstone, clay and shale are also present in the Upper Member. In this member shales are more common than the Lower Member. The Khabo Sandstone is mainly composed of medium to coarse-grained, yellowish brown to buff color, slightly micaceous, massive and generally thick bedded sandstone. The Irrawaddy Formation is composed of thick bedded to massive, coarse-grained, light yellow to buff color, and soft to friable sandstones. The basaltic boulders occur all around the Taungtalone Hill. These are dark grey, fine-grained picrite basalt with vesicular. The basalts of the Taungtalone Taung are supposed to be formed by fissure eruption after the deposition of Irrawaddy Formation. The mass of basic lava, picrite basalts are capped on the top of the Kyaukka hill.

Acknowledgements

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References

Aung Khin and Kyaw Win, (1969). Geology and Hydrocarbon Prospect of the Burma Tertiary Geosyncline. *Journal. Union of Burma, Sci. Tech*., 2.

Aung Win, (1986). Geology of the Okhpo-Kyaunggon Area, Monywa and Budalin Townships, M.Sc Thesis, University of Mandalay, unpub.

Bender, F., (1983). Geology of Burma, Gebruder Brontraeger, Berlin.

Ba Maw, (1968). Geology of the Kyaukka-Thazi Area, Monywa Township, M.Sc Thesis, Art and Science University, unpub.

Blatt, H., Middleton, G.V., Murray, R.C., (1980). Origin of Sedimentary Rocks, 2nd edition. New Jersey: Prentice Hall.

Chhibber, H.L., (1934). The Geology of Burma. Macmillan, London.

Collinson, J.D., and Thompson, D. B., (1987). Sedimentary Structures, 2nd edition. Unwin Hyman, Landon.

Myint Thein, (1966). Stratigraphy and Structure of Taungtalone Area, Kyaukse Township, M.Sc Thesis, unpub, University of Mandalay.

Pettijohn, F.J., (1975). Sedimentary Rocks. 3rd edition. Harper and Raw Press, New York.

Raymond, L.A.,(1993). Petrology*:* the Study of Igneous, Sedimentary and Metamorphic Rocks. Appalachian State, University.

Tucker, M.E., (1988). Techniques in Sedimentology. Blackwell Science.

Tucker, M.E., (2001). Sedimentary Petrology: An Introduction to the Origin of Sedimentary Rocks, 3rd edition, Blackwell Science Ltd.

Tucker, M.E., (2003). Sedimentary Rocks in the Field. 3rd edition. Department of Geological Sciences, University of Durham, UK, Wiley.

Win Myint, (1986). Geology of Kadetkan-Nwegwe Area, Monywa and Chaung U Townships, M.Sc Thesis, unpub, University of Mandalay.

The Study of Geomorphologic Features in Magway Area, Magway Township, Magway Region

Kyi San Lin*

Abstract

The research area occupies the eastern bank of Ayeyarwady River, Magway Township. It is situated between latitude 19˚ 50′ to 20˚ 20′ and longitude 94˚ 54′ 10″ to 95˚ 25′ 00″.The topographic map of this area are 84 L/6 and 84 O/4. The research area is constituted of a small segment of the western margin of the Central Belt of Myanmar and it comprises on almost complete Cenozoic succession. The study area is composed of sedimentary rocks belonging to the Irrawaddy Formation (Miocene-Pliocene) and Alluvium of Quaternary deposits (Pleistocene-Holocene). The topographic features of the study area are characterized by mostly flat valley plain and some of rolling-hills. Myathalum hill and Panyit Taung are the most conspicuous physiographic features of the study area. The Landforms of the present study area are figured by fluvio and glacio denudational processes. Small to medium sized low denudational hills are distributed on the denudational plain. The hill is associated with distinct gully erosion on the slope and less eroded on gentle slope of covered by grass and sparse natural vegetation and bad-land topography.Five terrace levels are also developed within the study area (T1 to T5). Higher level channel bar (Cb2) is covered by cultivated land during the dry season and lower level channel bars (Cb1) are really active flood plain composed of loose sand and silt.

Key words; Stratigraphy, Irrawaddy Formation, Landforms

Introduction

The research area is situated on the eastern bank of the Ayeyarwaddy River. It is located in the area bounded between latitude 19˚ 50′ to 20˚ 20′ and longitude 94˚ 54′ 10″ to 95˚ 25′ 00″. The topographic maps of this area are 84 L/6 and 84 O/4. Myathalun Pagoda, a famous pagoda of Central Myanmar is located in the study area. Therefore, the study area can be readily accessible all the year around (Fig-1).

The topographic features of the study area can roughly be said as a mostly flat valley plain and some of rolling-hills. The study area is characterized by a long and wide conspicuously alluvial and land form. Myathalun hill and Panyit Taung are the most conspicuous physiographic features of the study area. The elevation of the ranges is about 250 feet to 500 feet above sea level. The study area is falling within the western part of the Central Volcanic Line. The present study area is underlined by the sediments of Late Mio-Pliocene and Recent age.

The eastern part of the area consists of alluvial flat plain. It is composed of plateau gravel and red earth. The drainage pattern is less common in the study area. Dendritic pattern is locally noted in the northern part of the area where Wardaw Chaung and Alechaung flow into the Ayeyarwady River. These are drought streamlets and have water in the rainy season. The topography and drainage of the study area reflect the underlying major rock type and geological structures.

The western part of the area is covered by the sedimentary rocks of the Irrawaddy Formation. The western part of the study area is near the eastern bank of the Ayeyarwady River and well developed by the Irrawaddy Formation.

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The present area is known as one of the driest areas in Myanmar. The average temperature of January, the coldest month of Magway, accounts for 69.42˚ F and the hottest month is May with 102.4˚ F. The soil is thin and vegetation is generally sparse. The flat plain of the recent sediments is cultivated for plantations. Thorny bush forests are well developed on the Irrawaddy Formation of the study area land use on this soil, Ya crops are cultivated under rain fed conditions.

Nature of Exposure

Because of the climate conditions that cause chemical weathering due to low rainfall, luxuriant growth of plants, rock units are poorly exposed throughout the area. The Irrawaddy Formation crops out only in deeply dissected stream sections and road cutting and on locally uplifted ridges.

Methods of Study

By studying the topographic map and photographic interpretation, some notably features such as primary sedimentary structures, outcrops nature, prominent landforms, distribution of hill and valley, agricultural lands and natural vegetation and drainage patterns are known.

And the, MAGEUAN, SporTrak Pro, G.P.S is used for the determination of altitude and position of the selected location points. On the basic of the G.P.S data, the different level of landforms are recognized and classified.The field works were carried out on weekend and holidays. Lithology, nature of contact, sedimentary structures are carefully observed and noted. The research was done by observation, use of data comparisons and interpretation.

STRATIGRAPHY

General Statement

The study area occupies a small segment in the Minbu Basin of the Central Cenozoic Belt. The exposed Tertiary deposit in the study area is Irrawaddy Formation (Late Miocene-Pliocene) and the post Tertiary deposits are Plateau Gravel, Red Earth (Pleistocene) and Alluvium (Holocene) (Fig-2). Stratigraphic succession is shown in Table (1).

The sediments in the present area belong exclusively to the molasses sediments. They are composed mainly of sandstone, clay, intraformational conglomerates containing quartz pebbles. The various types of lithological, paleontological and sedimentlogical studies conclusively suggested that these molasses sediments were deposited under fluvial conditions. The Irrawaddy Formation and Plateau Gravel were deposited under fluviatile environments.

Age	Rock Units	Lithology
Holocene to Recent	Alluvium	Soil covers and sand rock
Pleistocene	Plateau Gravel and Red Earth	Gravel, pebble to cobble sized clasts of various rock types, sand, silt and clay
Late Miocene to Pliocene	Irrawaddy Formation	Massive, white to buff coloured, fine to pebble sandstones with clay, ferruginous conglomerates and containing fossil-woods

Table-1 Generalized Stratigraphic Succession of the Research Area

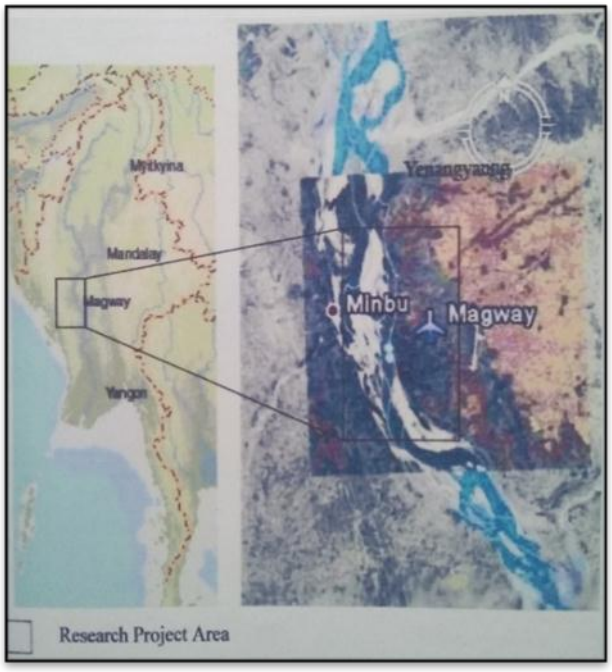


Fig (1) Location Map of the Study area

Irrawaddy Formation

Name Derivation

Irrawaddy Formation was first designated by F.Noteling (1895) as Irrawaddy system including a series of beds overlying the Pegu Series at Magway and Yenangyaung in Upper Myanmar. He regarded this as equivalent to W.Theobald's (1973) Fossil-wood series in Lower Myanmar.

A unit of fine to coarse-grained, loosely cemented sandstone with silicified wood fossils, occupying the south-western part of the area is lithologically and structurally similar to the **Fossil Wood Group** of Theobald (1973), and the **Irrawaddy Series** of Noetling (1895), the **Irrawaddy Sandstone** of Paescoe (1912)

and The **Irrawaddy Formation** of AungKhin and Kyaw Win (1969). Nowadays, the term Irrawaddy Formation is widely used as a lithostratigraphic nomenclature in the literature on Myanmar Geology. Therefore, the above sandstone unit is referred to as the **Irrawaddy Formation**.

Distribution

The Irrawaddy Formation is well exposed along the eastern bank of Ayeyarwady River including the base of Myathalun Pagoda, eastern part of the study area, Alegyaung and Tagugan village.

The thickness of the Irrawaddy Formation has varied from one place to another since early days. In the study area, the exposed part of the Irrawaddy Formation is irregular, so that its actual thickness cannot be certainly computed. However, its thickness recorded in the Alegyaung Chaung is about 300 feet above the ground level.

Lithology

The Irrawaddy Formation is characterized by the abundance of fossil woods and consists of thick-bedded to massive sandstone with a few thin clay bands. The sandstones are pale yellow (buff-coloured, yellowish brown) to reddish brown or light gray, soft, friable, medium to coarse-grained and occasionally ferruginous. Hard calcareous sandstone concretions and slabs are abounded and root-like calcareous concretions and nodules are mostly present along the joint planes.

In Magway area, the Irrawaddy Formation is found along the eastern bank of Ayeyarwady River. At the base of Myathalun Pagoda, the moderately jointed massive sandstone is intercalated with ferruginous sandstone having large-scale trough type cross-bedding (Fig-3) and it is underlain by the yellowish brown ferruginous massive sandstone with disc-shaped concretion along the bedding plane (Fig-4).

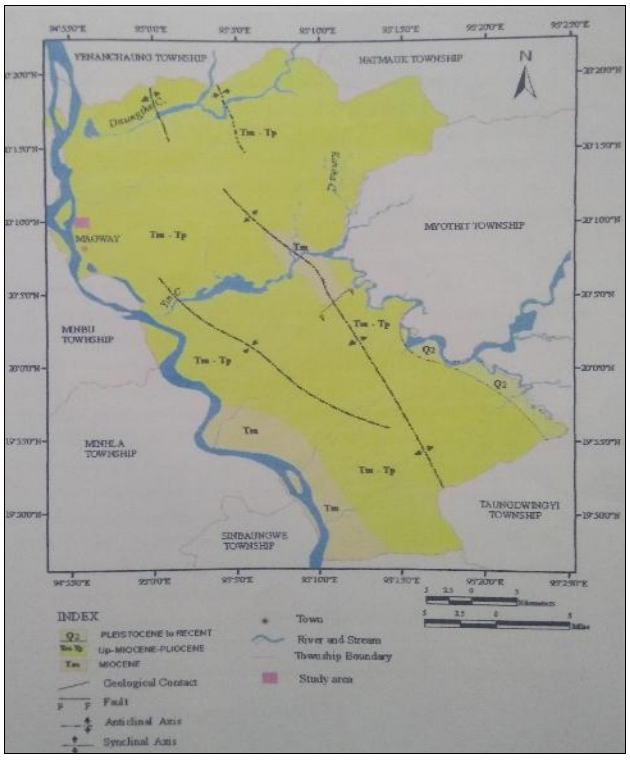


Fig-2 Geological Map of the Magway Area

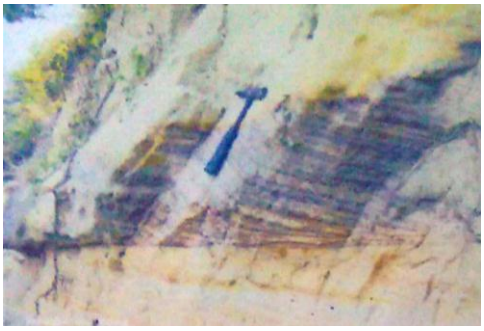


Fig-3The ferruginous sandstone having large-scale cross bedding in the Irrawaddy Formation

Fig-4 The ferruginous sandstone with dish-shape concretion in the Irrawaddy Formation

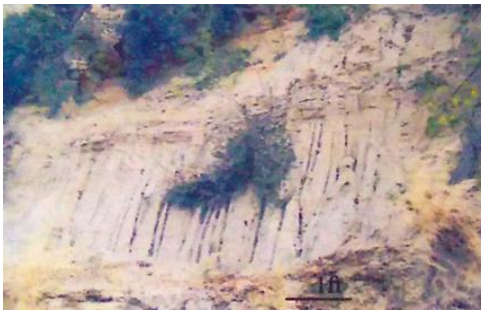


Fig-5 Pillar structure and compound Buttresses

Fig-6 Root-like calcareous concretion in the Irrawaddy Formation

In some places, ferruginous conglomerate bands exist at the top of yellowish brown coloured quartz pebbly laminated sandstone bed about 5 feet in thickness. It is overlying the friable white sandstones bed with earth pillar structure (Fig-5). Here, two types of conglomerates are found; one is clast-supported ferruginous conglomerate and another is calcareous conglomerate. The pebbles vary from 4 to 5 mm in diameter. The thickness of conglomerate bands is about 5 feet and some are slumped on the bank of Ayeyarwady River due to erosion.

Near the Wadawgyaung Village about the 0.5 miles north of Myathlun Pagoda, the ferruginous gritty sandstone bands are overlain by friable sandstone bed.

Root-like calcareous nodules and concretions (Fig-6) and polyparthite concretion (Fig-7) are common throughout the study area. Giant fossil woods are also present near the Alegyaung Village and along the Alegyaung Chaung (Fig-8).

Faunal Assemblages and Age

The Irrawaddies are characterized by the abundance of silicified wood fossils and consist of coarse-grained, soft, yellowish sandstones with occasional ferruginous conglomerates. Clay is present, but mostly in pocket.

This formation contains vertebrate fossils, such as *Rhinoceras, Crocodilus, Cervussp, Hippotanus irravaticus, Stegodon clifit.*

This fossils indicate as Pliocene age for the Irrawaddy Formation.

Fig-7 Polypartite concretion in the Irrawaddy Formation

Fig-8 Large size of fossil-wood in the Irrawaddy Formation

Plateau Gravel

Name Derivation

The term "Plateau Gravel" was first designated by F.Noetling (1900) for a unit overlying uncomformably the Pegus and Irrawaddies. This unit is composed mainly of deep red ferruginous sand and clay. According to Pasecoe (1912), the Plateau Gravel is a kind of deposit which also consists of Plateau Red Earth. Later works confirm that the Plateau Gravel passes laterally into Plateau Red Earth. These gravels have been derived from the ferruginous conglomerates of the Irrawaddy Series. The pebbles are indentical with those found in the Irrawaddy conglomerates and are mostly composed of quartz.

Distribution and Thickness

In the study area, the plateau Gravel is found in the vicinity of the Computer Colleague about 0.5 mile from Myathalum Pagoda. The Plateau Gravel is overlying the thick-bedded Irrawaddy sandstones. The boundary between the Irrawaddy Formation and Plateau Gravel is sharp contact (Fig.9). Its thickness is about 10 feet and it consists of ferruginous nodules and concretions. The Plateau Gravel is associated with Red Earth sands and pebbles.

Lithology

The Plateau Gravel is composed mainly of quartz pebble aggregated loosely in a deep-red, ferruginous sand and clay. The size of fragment varies from 4 mm to 12 cm in diameter. According to Wentworth's grade scale, the primary mode is represented by cobble size and gravel pertaining that size may be classified as cobble gravel.

The vast majority of pebble is of quartz and quartzite. The Plateau Gravel is nearly horizontal and resting on the Irrawaddy Formation. The Plateau Gravel is sometimes difficult to differentiate from the red bed of Irrawaddy Formation due to the lithologic similirity between them. However, the deeply dissected stream sections exhibit the angular relationship between the Plateau Gravel and the order rock.

The occurrence of vertebrate remains and pieces of silicified fossil woods in the Plateau Gravel is noteworthy.

Plateau Red Earth

Distribution

The deposits occur wide-spread in the area. Especially, they are well exposed near the Computer College (20˙10′ 31″ N and 94˙55′ 39″ E). The Plateau Red Earth is derived from the older Plateau Gravel. In the middle of the area, the Plateua Red Earth is found on the top of numerous rolling hills (fig. 10).

The color of Red Earth varies from one place to another. In some places, the color is brick-red and in other the color is bright vermilion to deep-chocolate. It is of sub-aerial origin, judging from the absence of any bedding and the complete absence of fossils and its deeeply ferruginous nature.

The Plateau Red Earth is generally unstratified and is characterized by the occurrence of fine gravels, coarser sand or more clayey materials. The upper portion of the Plateau Red Earth which is bright red in color, is soil of lateritic nature, and the low-lying portions have been derived from this, either by the action of floods or by that of run off.

The Plateau Red Earth has generally the average thickness of 3 to 4 feet. The Plateau Red Earth is especially found in the tropical region of dry zone.

Fig (9) Sharp contact between Irrawaddy Formation and Quaternary Deposits

Fig-10 The top of numerous rolling hills of Red Earth

Fig-11 Denudational hill and alluvial plain

Fig-12 Crops growing land in alluvial plain

Fig-13 Distinct gully erosion on the slope of low –denudational hill

Fig-14 Bad-land topography caused by highly dissected gully erosion

Fig-15 Low denudational plain by lower part of alluvial fan

Alluvium

The alluvium deposits are found in the eastern part of the area. They mainly occur near the Dehatkan village. They cover widely the several places and form flat plain. They include the red sandy soil and black cotton soil. The cultivated fields are well developed on the alluvium plains.(fig.11)

The alluvium deposit overlap the Plateau Red Earth. Fossils are not found in this unit. The color is usually dull grey. In the eastern part of the study area, the river alluvium gives rise to fertilizer for the crops growing land along the bank of the Ayeyarwady River (Fig.12). In the Okpo and Chaungbyu villages the alluvium is clayey, it is used for brick-making.

GEOMORPHOLOGY

General Statement

Being located in the Central Cenozoic Belt, the landforms of the present study area are figured by fluvio and glacio denudational processes. The observed landforms are river terraces, low denudational hill, low denudational plain and recent fluvial deposits of sand alluvial bars. On the basic of aerial photograph and field works, the most common terrain units are recognized and classified (Table-2). In this paper some notable terrain characteristics for classified terrain units are described as follows.

River Terraces

The river terraces in the Ayeyawady valley were studied and described by Leicester (1932), Morris (1935) and De Terra (1943). Five terrace levels are recognized. The complete river terraces are present on the eastern side of the river.

Therefore, five terrace levels are also developed within the study area (T_1- T_5).

(1) Terrace 1 (T_1) is found in the eastern part of the study area near the Dahatkan village.

(2) Terrace 2 (T_2) is situated near the Nagu village.

(3) Terrace 3 (T_3) is located near the Thitsar road.

(4) Terrace 4 (T_4) is found in the Myoma market road and

(5) Terrace 5 (T_5) is found in the Kannar road, near the E bank of Ayeyarwady river.

The outstanding characteristics of each terrace are as follows:

Terrace 5 (T_5)– This terrace (T_5) is the lowest terrace near the Kannar and (20˙ 08′ 45″ N 94˙ 55′ 04″ E). It is about 130 feet above sea level and 40 feet above river bed/ level. It is composed of alluvial soil, plateau gravel and red earth and ferruginous sandstones occupying the recent Ayeyarwady sediments. The absenc of coarse material and red coloring matter is typical. It is banked up againt a steep slope below the next highest level. Accordingly it represents a stage of stream aggregation.

Terracd 4 (T_4)– This terrace more frequenty preserved than T_5 is located in the magway markey road (20˙ 08′ 54″ N and 94˙ 55′ 12″ E). It is about 150 feet sea level and 60 to 70 feet above river level. It is underlain by a red gravels (4 feet thick) and above red sands of 10 feet. The sand-size is medium-grained and the pebbles are lithologically quartz, sandstones, marbles and gneisses ect. All of which are stained with limonite and hemitite associated with lateritic soils. The total thickness does not exceed 30 feet. The implemnts of Late Paleolithic age were discovered in the gravels of Terrace 4 (**T_4**).

Terracd 3 (T_3) – This terrace is the widest and most conspicuous one of all levels and is situated near the Thitsar Road (20˙ 09′ 00″N and 94˙ 56′ 06″E). This surface is about 210 feet above sea level and 100 to 120 feet above river level. Its erosional origin is apparent from the varying thickness of the deposits. It is characterized by red gravels and red earth, resembling to that of Plateau Red Earth of Pascoe (1912). The ferruginous conglomerate bands are also found in this terrace. The gravels are of cobble size consisting of quartz and quartzite. This level is important due to the abundance of fossil wood and vertebrate bone fragments.

Terrace 2 (T_2) – It is developed near the Nagu village (20˙ 09′ 13″ N to 94˙ 56′ 56″E), about 254 feet above sea level and 180 to 200 feet above river level. It is presented only in the form of wide and isolated rolling hills. It is recognized by thick alluvial soils of pale gray color and characterized by red gravels of quartz, quartzite and red clays. The gravel size is finer than that of other terraces. In some places, this terrace occurs in the form of bad land topography.

Terrace 1 (T_1) – It is well developed near the Dahatkan Village in the eastern part of the study area (20˙ 10′ 37″ N to 94˙ 58′ 20″E). It is about 350 feet above sea level and 250 feet above river bed. This terrace is constituted of the alluvial flat plain. It

includes the red sandy soil and black cotton soil. This terrace is fertile for the crop growing and so the cultivated fields are well developed on this terrace.

Low Denudational Hills

These are small to medium-sized low denudational hill with average altitude of 380 feet. The whole terrains are covered by loosely cemented very friable sandy to silty rocks, gravels and reddish brown to buff colored soil. Thinly laminated siltstone and calcareous shales or marly components are locally exposed on the moderately steep slope hills and eroded section formed by land sliding and rock falls. Low denudational hills with rill and gully erosion are recognized in the eastern part of the area. These are sparsely distributed as isolated hills on the denudational plain. The hill is associated with distinct gully erosion on the slope (Fig-13) and less-eroded gentle slope is covered by grass and sparse natural vegetation and bad-land topography (Fig-14).

As the very low amount of rainfall (< 40 inches per year) and highly porous sandy soil cover, very poor drainage system is developed and mostly found as dendritic, subtrellic or sub-parallel patterns. Some other hills and low ridges are retained very locally in the low denudational flat terrain composed of gravels and gritty deposits.

Low Denudational Plains

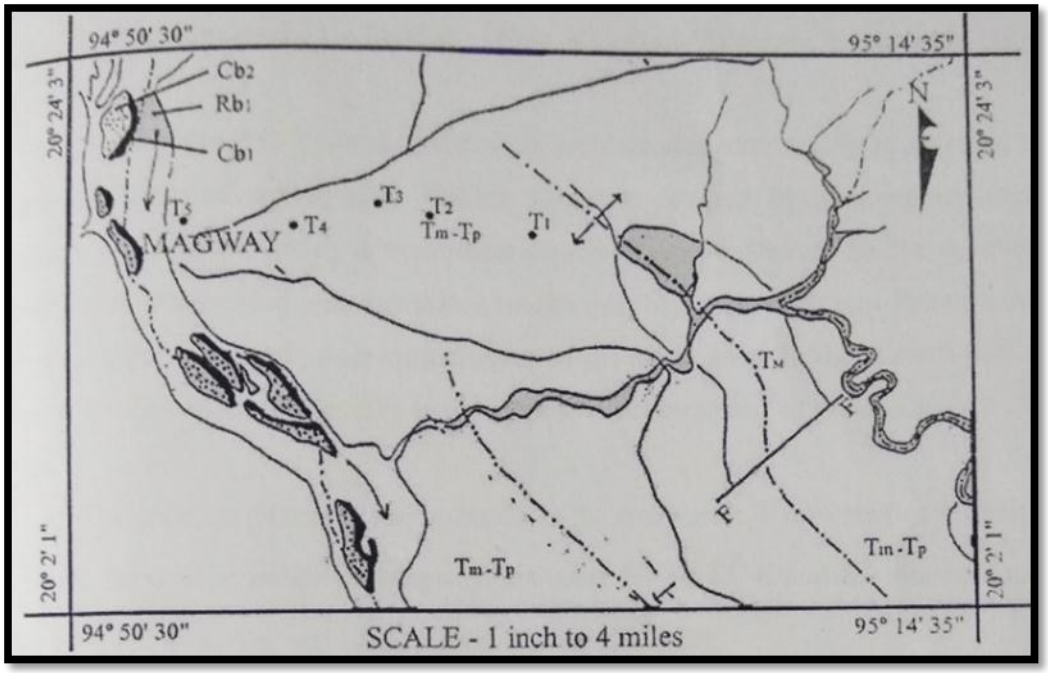
This type of terrain extensively covers the present area, especially in the eastern part of the area. They possess very gently inclined slopes and these slopes are locally covered by lower part of alluvial fan and debris and natural vegetation (Fig-15).

Channel Bars

As the mighty Ayeyarwady flows on the gentle slope gradient, the overall drainage pattern gives the network of meandered to braided channel types. Higher level channel bar (Cb2) is covered by cultivated land during the dry season. As the fertile soil covers this bar, high yield cultivation is possible. The lower level channel bars (Cb1) are really active flood plain composed of loose sand and silt. The generalized geomorphological map of the study area is shown in (Fig-16).

Main Process	Landform Type	Code	Terrain Unit	General Characteristics
River	River bed	Rb 1	River	Present river channel, now running water through the year.
River	Channel bar	C.b 1	Low level channel bar	Sand flat, active flood plain, composed of loose sand and silt.
		C.b 2	Higher level channel bar	Occasionally submerged into the water during high flood, cultivated land during dry season.
Fluvial	River terrace	T5	Lower level younger terrace	40 feet above river level, composed essentially of alluvial soil, plateau gravel and red earth, average elevation above sea level is about 130 feet.
		T4	Higher level younger terrace	60-70 feet above river level, composed of red gravels (4 feet in thickness) and red sand (10 feet in thickness), lithologically containing pebbles of quartz, sandstones, marbles, gneiss etc…and general elevation is 150 feet above sea level.
		T3	Lower level moderately terrace	100-120 feet above river level, composed of red gravel and red earth, ferruginous bands and pebbles of quartz and quartzites, general elevation is 210 feet above sea level.
		T2	Lower level older terrace	About 180-200 feet above river level, preserved only in the form of rolling hills, composed of alluvial soil, gravels of quartz, quartzite and red clay with bad land topography, general elevation is 254 feet above sea level.
		T1	Higher level older terrace	About 250 feet above river level, composed of alluvial flat plain, red sandy soil and black cotton soil, general elevation is about 350 feet above sea level.
Denudation	Hill and flat	Dp	Low denudation plain	Locally covered by lower part of alluvial fan and debris, commonly convered by cultivated lands.
		Dh	Low denudation hill	Locally covered by higher or mid-part of alluvial fan, composed of sandstone and shale layer with abundant fossil wood and mammalian remains.

Table-2 Various terrain units generally observed in Magway and its environs



Geological Explanation		**Geomorphological Index**
Tm	Late Miocene-Pliocene Irrawaddy Formation and its equivalents	Rb 1 = River bed (1)
		Cb 1 = Channel bar (1)
Tm-Tp	Miocene-Upper Pegu Group and its equivalents	Cb 2 = Channel bar (2)
		T1 = Terrace (1)
	Geological Contact	T2 = Terrace (2)
	Fault	T3 = Terrace (3)
	Anticlinal Axis	T4 = Terrace (4)
	Synclinal Axis	T5 = Terrace (5)

Fig-16 Geomorphological Map of Magway Area

SUMMARY AND CONCLUSION

The study area is situated in north-western part of Magway Township, Magway Region. Myathalun Pagoda, a famous pagoda of Central Myanmar, is located in the study area.

The topographic features of the study area are characterized by mostly flat valley plain and some of rolling-hills. Rolling hills are covered by sedimentary rocks of Irrawaddy Formation.Myathalun hill and Panyit Taung are the most conspicuous physiographic feature of the study area. In the eastern part of the area, flat valley plain topography is developed. It is composed of plateau gravel and red earth.

The research area is located in a small segment of the eastern part of Minbu Basin. The Miocene-Pleistocene succession with apparent unconformity within the sequence is exposed in the present area.

Irrawaddy Formation consolidated with occasional thin beds of grey clay and various type of conglomerates. Cross bedding, calcareous concretion and silicified fossil logs are common. All the higher level of the study area are capped by thin veneer of Plateau Gravel. The Plateau Gravel is composed of quartz pebbles and they are loosely aggregated in the deep-red ferruginous sand.

The Plateau Red Earth is generally unstratified and is characterized by the occurrence of thin courses of the fine gravel, coarser sand, or more clayey materials. The sediments of the research area are poorly-graded soil. So, the sediments may be derived form channel sediments of terrigenous condition.The Irrawaddy Formation of the research area may be considered to be deposited in fluviatile environment.

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REFERENCES

Bender, F, (1983).*Geology of Burma*.Berlin. Gebruder. Borntaraeger.

Chibber.H.L, (1934). *The Geology of Burma*. Macmillan London.

Mya Maw, (2008). *Waste Deposal of Magway*. Research paper.

Soe Soe Aye, (2008). *Uses and Exploration of Construction Materials in Magway Area*. Research paper.

Thant Zaw Moe, (2005). *Geology of the Magway Myathalun Area*. M.Sc. Thesis. Magway University.

Yi Yi Moe, (2009). *Stratigraphy and Sedimentary Environment of the Nagottama-Panyit Taung of Magway Township, Magway Division*. Research paper.

Thant Zaw Moe, (2010). *Geomorphology of Minbu Area*. Research paper.