Heavy Minerals Analysis of the Irrawaddy Formation in Kuga- Palaung Area, Pauk Township

Khaing Zin Nwe

Abstract

The study area is located between North latitude 21° 19′ to 21° 29′ and East longitude 94° 22′ to 94° 30′. It is situated on the western part of the Yaw River. The study area is situated in the Central Cenozoic Belt of Myanmar. Geologically, the study area is located near the north-south trending axis of the Salin Syncline. The research objective is to interpret the heavy minerals analysis of Irrawaddy Formation of the study area and relative source area. The nature and occurrence of heavy minerals were used for the determination of source area weathering, significant gravity separation during transportation, deposition and diagenetic alteration and tectonic activities of the provenance. The quantitative analyses of heavy minerals were made for source area associated with the deposition of the Irrawaddy Formation. There a total set of 16 different types of heavy minerals and opaque varieties. The representative non-opaque heavy minerals of present area are zircon, tourmaline, rutile, garnet, kyanite, staurolite, epidote, diopside, augite, hornblende, olivine, hypersthenes, sillimanite, topaz, allanite and apatite. The opaque minerals are magnetite, chromite and hematite. On the basic of the suite of light and heavy minerals and their characteristics, the source rocks of the study area may be interpreted as follows;(a) the presence of rounded zircon, tourmaline and rutile indicate that the sediments were derived from pre-existing sedimentary rocks, (b) euhedral crystal of zircon, tourmaline, hornblende and topaz were derived from acid igneous rock, (c) augite, chromite, diopside, hypersthenes, magnetite and olivine may indicate basic igneous source and (d) the presence of epidote, garnet, kyanite, sillimanite and staurolite may indicate the high grade metamorphic rocks.

Keywords: Irrawaddy Formation, heavy minerals, source

Introduction

The study area is located between North latitude 21° 19′ to 21° 29′ and East longitude 94° 22′ to 94° 30′. It is situated on the western part of the Yaw River, falling in 2194-07 (84 k/7) refer to UTM topographic map. The present area is ten miles (16km) long from north to south and eight miles (13km) from east to west, covering approximately 80 square miles (208 sqkm) of flat and low lying terrain. The Pakokku-Pauk-Kyaukhtu car road cut across the northern part of the area and, most part of the area is accessible through the year (Figs. 1 & 2).

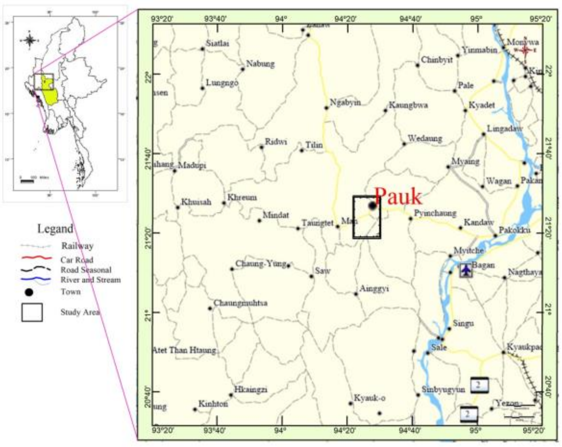


Figure (1). Location Map of the Kuga - Palaung area

Department of Geology, Pakokku University, Magway Region, Myanmar

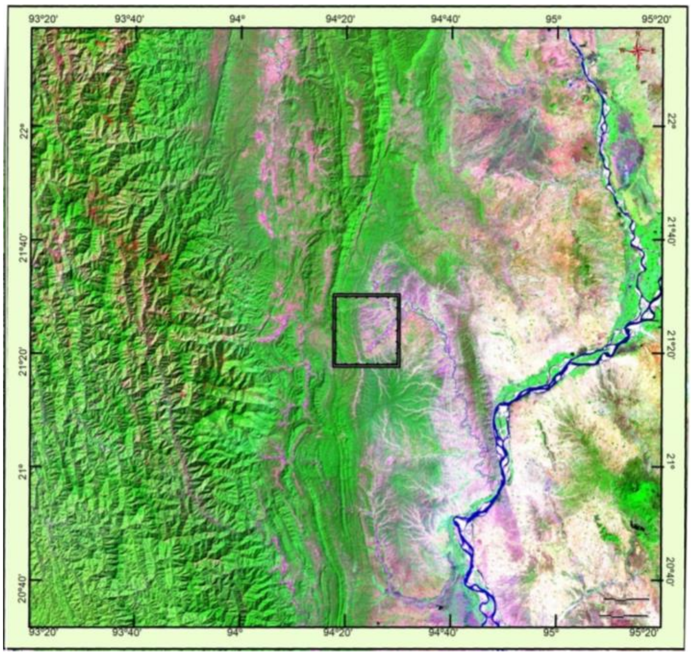


Figure (2). Satellite image of the Kuga - Palaung area (Source; Google earth, 2014)

Regional Geologic Setting

Myanmar can be divided into four north-south trending geotectonic regions: Eastern Highlands (Sino-Burman Ranges); Central Cenozoic Belt (Central Myanmar Tertiary Basin); Western Ranges (Indo-Burman Ranges); Rakhine Coastal Plain (Arakan Coastal Area) (Stamp, 1922; Chhibber, 1934; Maung Thein, 1973; Bender, 1983; Kyi Khin and Myitta, 1999). Neogene freshwater sediments mainly derived from the Eastern Highlands (Shan Plateau), Eastern Himalayas and Western Ranges are mostly exposed in central Myanmar, and consist of two units of freshwater sediments: Fresh Water Pegu Beds (middle Miocene) and Irrawaddy Formation (late Miocene to the early Pleistocene). These units are constituted as Neogene continental sediments of Myanmar yielding remains of terrestrial and aquatic vertebrates.

The study area is situated in the Central Cenozoic Belt of Myanmar which is relatively a low-lying province between the Eastern Highlands to the east and the Western Ranges to the west (Fig. 3). In Myanmar, most of the Neogene mammalian fossils have been discovered from Central Burma Basin (CBB) along its nearly 1100km length the Central Cenozoic Belt is divided into several sedimentary basins (Bender, 1983). From north to south, these basins are Hukaung, Chindwin, Shwebo, Salin, Prome and Irrawaddy Delta. These basins may have form as a series of pull-apart basins in the early Eocene as the Myanmar Plate moved northward relative to Asia plate (Tankard et al., 1994).

Geologically, the study area is located near the north-south trending axis of the Salin Syncline in the western part of central Myanmar. The late Miocene to early Pleistocene massive sandstone and gravels of the Irrawaddy Formation are exposed in the central part, while the Eocene to Miocene deposits are cropped out in the eastern and western flank of the syncline (Trevena et al., 1991).

Previous Works

Pilgrim (1939) carried out the systematic analysis of a small sized bovid from the study area based on the horn core and dental materials. Colbert (1942) reported a fossil tooth of primitive horse (*Hipparion* sp.) from the Pauk area. Thaung Htike (2008) carried out systematic paleontology of hippopotamus and wild boar fossils from the study area. Zin Maung Maung Thein et al. (2010) carried out the systematic analysis of the rhinoceros fossils from the Irrawaddy Formation of Myanmar.

Purpose of Study

The proposed research will focus on carry out the provenance of the study area on the basis of heavy minerals

Method of Study

During the field survey, outcrop mapping and traverses were taken along the stream courses, cart tracks and car-roads where good exposures of rocks were observed. The representative sand samples were systematically collected and taken for the purpose of making heavy mineral analysis.

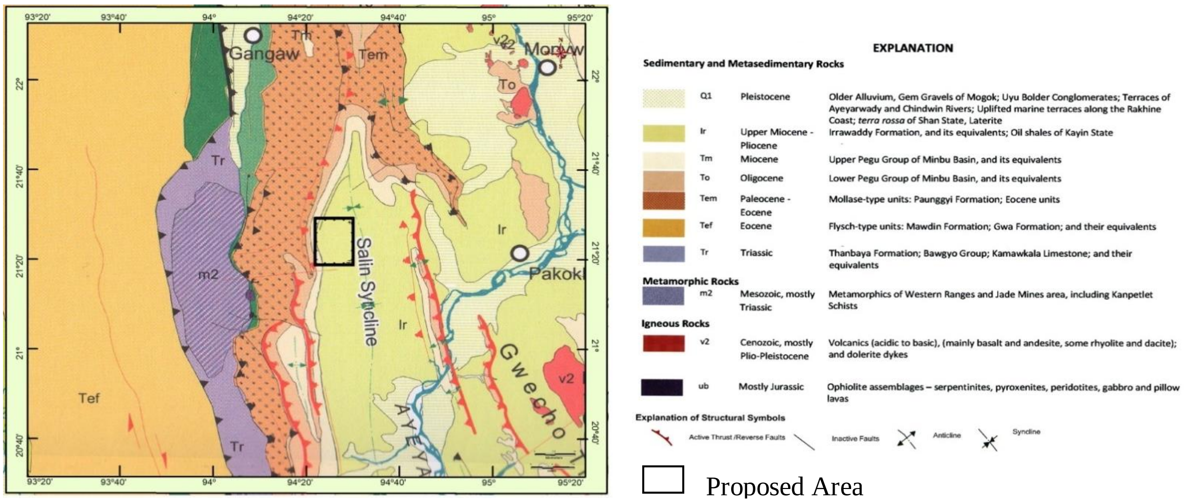


Figure (3). Map showing the regional geologic setting of the proposed area

Heavy mineral analysis

General Statement

This chapter describes the heavy minerals analysis of Irrawaddy Formation of the study area and relative source area. The nature and occurrence of heavy minerals were used for the determination of source area weathering, significant gravity separation during transportation, deposition and diagenetic alteration, and tectonic activities of the provenance (Pettijon *et al*., 1973).The quantitative analyses of heavy minerals were made for source area associated with the deposition of the Irrawaddy Formation. Heavy minerals are accessory minerals in sandstone containing about 1-3% and which have specific gravity (>2.89 g/cm^3). They were eroded from the source area and mechanical separating during transportation, and deposited in the present area. The diversity of heavy minerals suite is found in study area. The controlling factors for the distributions of heavy minerals in sediments are temporal change in sediments from the source area, weathering, in transit and post depositional alterations (Morton and Hallsworth 1999 in Biernacka J, 2004). Examinations of the heavy minerals in friable sand contain non-opaque and opaque heavy mineral species. The relative abundance of heavy minerals and their maturity reflect the weathering, depositional conditions, stratigraphic changes and their provenance.

Materials and Methods

Poorly consolidated fine to medium-grained samples were collected from the Irrawaddy Formation of the study area. To obtain mechanical composition and heavy mineral grains, every sample were weighted in 100g at first. These samples are placed in 2mm mesh size. And then, the sieves were agitated for 10 minutes using a electromagnetic shaker. The samples containing heavy minerals were obtained in sieve opening size 0.125mm. To remove iron coating on grains, the particles were boiled and washed by using hydrochloric acid and oxalic acid until the grains are clear. The considerable differences in density between heavy and light minerals were determined by high density liquid bromoform (2.89sp.gr) within 30 minutes in a separating funnel. After sinking the heavy minerals, the pinch clip was open slowly in beaker and washed with oxialic acid and dried. Thin sprays of heavy minerals, grains were mounted on glass slide in Canada balsam. The heavy slides were identified under petrographic microscope and the type of heavy minerals were interpreted by their respective properties.

Description of Heavy Minerals

In this study, there are a total set of 19 different types of heavy minerals and opaque varieties. The representative non-opaque heavy minerals of present area are zircon, rutile, garnet, epidote, kyanite, staurolite, diopside, augite, hornblende, olivine, hypersthenes, sillimanite and minor constiturents of tourmaline, allanite, apatite and topaz . The abundant opaque minerals are magnetite, chromite and hematite. Heavy minerals can be classified as three groups according to the resistance of weathering, transportation abrasion and reaction with chemical solution. There are the most resistant stable minerals (tourmaline, zircon, rutile), metastable minerals (garnet, epidote, kyanite, staurolite) and unstable minerals (olivine, pyroxene, amphibole). The opaque group is composed of magnetite, chromite, hematite. In the study area, the opaque group is remarkably abundant.

Zircon

Zircon is the most stable minerals found in the study area. It can resist erosion, long distance transportation, deposition and diagenesis processes. The mineral is colourless, pale pink, grey and the grain shape is characterized by subhedral, subrounded and well rounded form (Fig. 4). Rounded zircon is more common than sub-euhedral form. Some grains have thick marginal zoning and other contain gas, fluid and small sub-euhedral zircon inclusions. The particle size of zircon varies from 0.1mm to 0.15mm. Surface etching is found in some grains. Zircon is the most common accessory minerals in granitic rocks. It represented by the early liquid magmatic crystallization in albite bearing acidic rocks, their metamorphic derivative and recycled sedimentary rocks. Zircon may reach high concentration in some beach sands and placers.

Tourmaline

Tourmaline is the stable minerals of the present area. It can be found as elongated, prismatic, triangular and rounded grains with green, bluish-green, yellowish green, black, dark brown and light brown in color varieties. The particle size varies from 0.1 mm to 0.15mm. Tourmaline show strongly paleochroism, low relief and parallel extinction (Fig. 5). Sharp edge splinters of tourmaline are also found. Stration parallel to long axis traversed by distinct partings are found in large prismatic tourmaline. Some of grains show corrosion effect and fractured and are filled with iron. Tourmaline occurs in granites, granite-pegmatites and in contact or regionally metamorphosed rocks (Mange *et al*., 1992).

Rutile

Rutile occur as subangular, subrounded, prismatic grains of deep red to yellow color grain figure (6). Blood-red color in the center of the grain is a marked feature. The crystal shows brilliant luster. Some grains show etched border by corrosion of chemical solutions. The particle size varies from 0.05mm to 0.1mm. Rutile is a widespread accessory mineral in metamorphic rocks particularly in schist, gneiss and amphibolites. It is less significant in igneous rocks and pegmatite. It can be found in high temperature-pressure metamorphic minerals of granulite and elongite facies.

Garnet

Garnet occurs as colourless to grey, pale reddish brown, light green varieties with subangular 6 sided (Fig. 7). Some are subrounded to rounded grains. The particles of garnet vary from 0.15mm to 0.2mm. It is the metastable minerals and the abundance of all heavy minerals. It shows high relief, uneven fracture. The morphological features of garnet show brittle nature. Some of grain surface show pitted nature and etched border by transportation abrasion and chemical reaction with intrastratal solution. The abundance of garnet may have been caused by the peculiar provence of the sediments with effective hydraulic sorting. Garnet is the typical mineral in metamorphic gneiss, schist and contact metamorphic rocks.

Kyanite

The grains show well distinct bladed forms and sub-rounded elongated grains, pale blue and yellow in color (Fig. 8). It contains one set of perfect cleavage with transverse fractures and high relief. The particles are ranged from 0.5 to 0.25mm in size. Kyanite is distinct metamorphic grains of AL bearing rocks and their sedimentary particles. Some large kyanite grains are source of pegmatite.

Staurolite

Staurolite is subangular, subrounded and irregular grains. It is represented by yellowish brown to pale reddish brown color (Fig. 9). Inclusions of quartz and carbonaceous matter are found in some grains. The particles range from 0.2mm to 0.25mm in size. Staurolite is almost exclusively a product of medium-grade regional metamorphism and it forms in mica schist, derived from argillaceous sediments and less frequently in gneisses. It is associated with kyanite and garnet (Mange *et al*., 1992).

Figure (4). Subhedral, subrounded and well rounded zircon occurring in Irrawaddy Formation.

Figure (5). Elongated and prismatic form of tourmaline in Irrawaddy Formation.

Figure (6). Red rutile in Irrawaddy Formation.

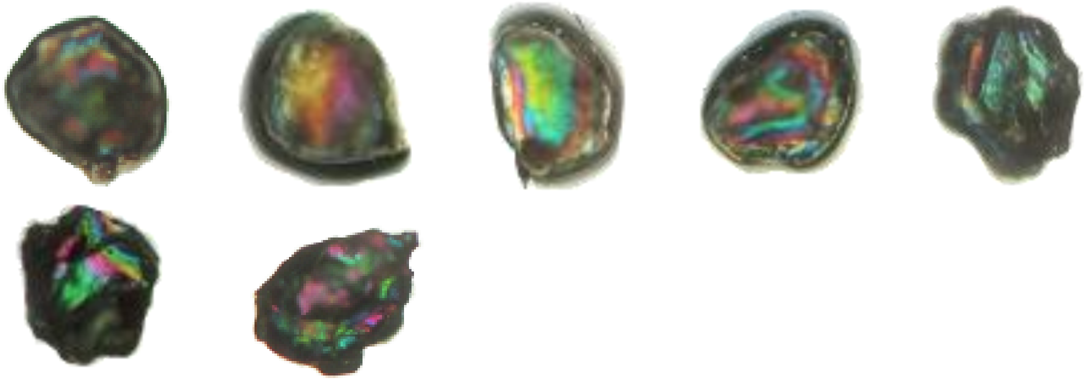


Figure (7). Rounded and corroded garnet in Irrawaddy Formation.

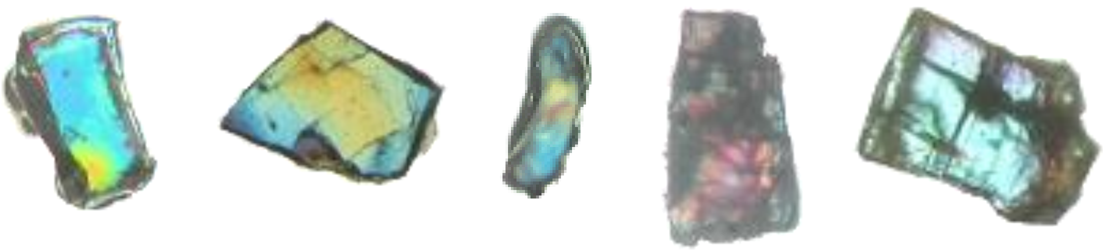


Figure (8). Kyanite in Irrawaddy Formation

Scale 0 0.1 0.2 0.3mm

Epidote

Epidote displays yellowish green to colorless and grass green, subrounded to pseudohexagonal grains. Some of the grains show yellowish green spongy apparence and other show corroded boundaries (Fig. 10). Epidote shows high relief with faint paleochrosim. Some of the grains have corroded edge. The grain size varies from 0.15mm to 0.25mm. Although epidote and garnet have similar chemical stability, epidote was destroyed before garnet (Friss, 1974 in Biernacka, 2004). So, it is less stable than garnet. Epidote is the index mineral of the albite-actinolite-epidote chlorite zones of the greenschist facies regional metamorphism. It is also present in contact metamorphic rocks and in hornfels. In igneous rocks, epidote is more common in the basic types, but may occur in granites (Mange *et al.*, 1992).

Diopside

It is characterized by colorless to light green. Diopside grains are dominantly prismatic and appear either as stubby prism or less frequently, long slender grain. The grains are mostly subangular four sided and subrounded grains. It shows 2 sets of cleavage and fairly high relief (Fig. 11). The particle size varies from 0.12mm to 0.3mm. Diopside is common in regional and contact metamorphic rocks and basic igneous rocks.

Augite

Augite appears in various shades of green, yellow and sometime brown or yellowish brown. They occur as subangular to subrounded and prismatic grains (Fig. 12). Augite is the second most abundance of all heavy minerals. The typical source of for augite is intermediate and basic igneous rocks.

Hornblende

Hornblende displays short or long prisms, irregular or rectangular fragments to long thin flakes. They are green and brown color varieties with elongated, bladed prisms (Fig. 13). The particle size varies from 0.1mm to 0.15mm. Hornblende is the most unstable minerals and exhibit the saw-teeth marked by intrastratal solution. The typical source for hornblende is acid, intermediate igneous rocks and their older metamorphic rocks

Olivine

Olivine is found as colorless, light green, honey yellow, angular and irregular or rounded, often attaining a high sphericity. The grain size may range 0.2-0.25 mm (Fig. 14). It is the most abundant of all heavy minerals. Some grains are corroded and altered. The interference color is high. Olivine is common in basic igneous rocks.

Hypersthene

Hypersthene is very common in the sediments of the study area. They are characterized by angular shape fragments of larger crystals (Fig. 15). They show shades of pink, pale green or colorless with faint paleochrosim. Hypersthene is common in both extrusive and intrusive basic to intermediate igneous rocks (Mange *et al*., 1992).

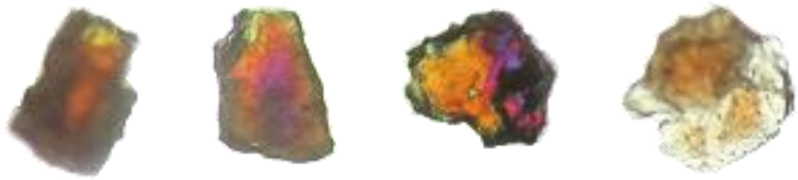


Figure (9). Yellowish brown to pale reddish brown color staurolite in Irrawaddy Formation.

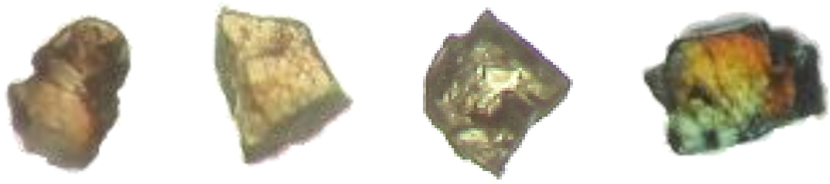


Figure (10). Epidote in Irrawaddy Formation.

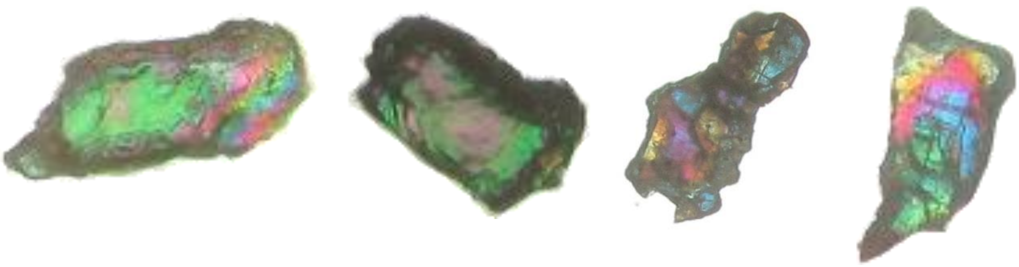


Figure (11). Light green color of diopside in Irrawaddy Formation.

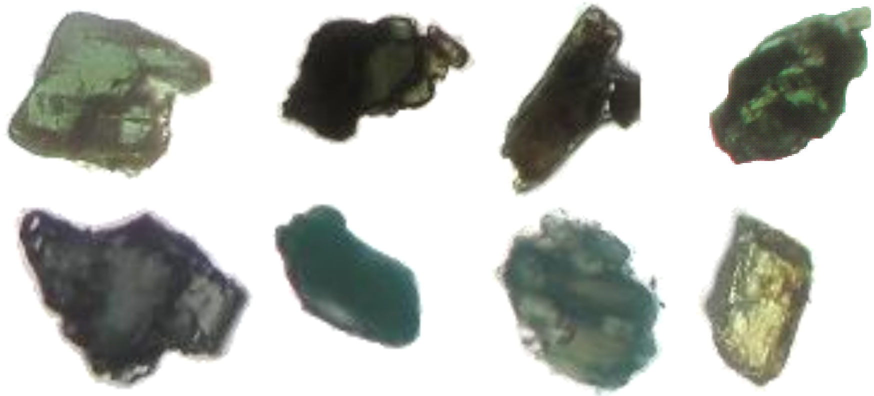


Figure (12). Various shades colors of augite in Irrawaddy Formation.

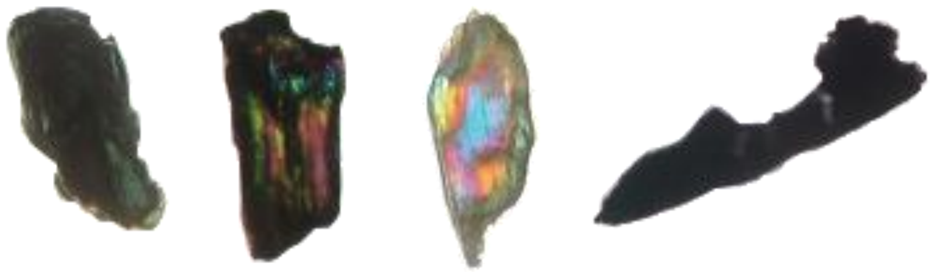


Figure (13). Hornblende showing fibrous in Irrawaddy Formation.

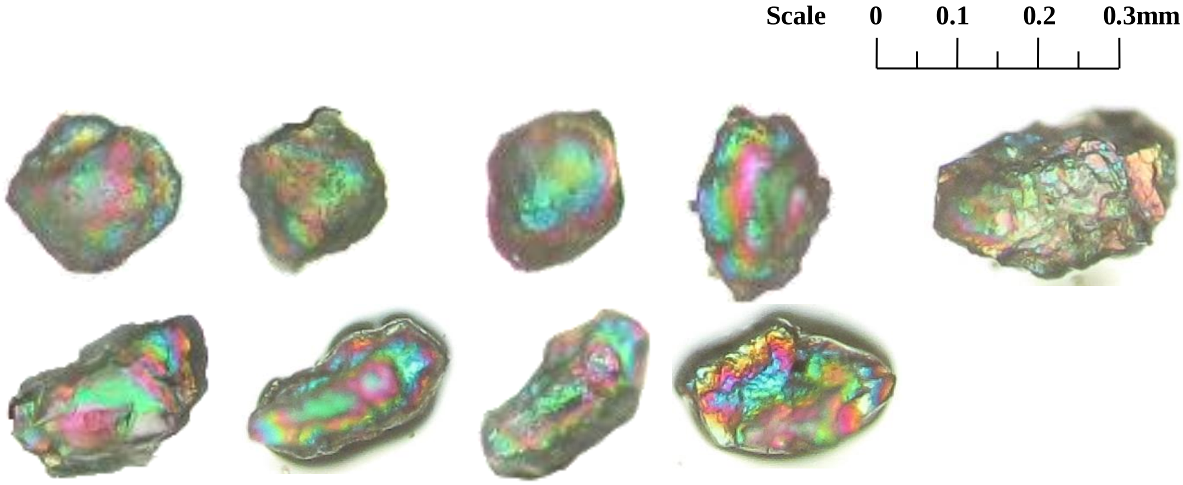


Figure (14). Olivine in Irrawaddy Formation.

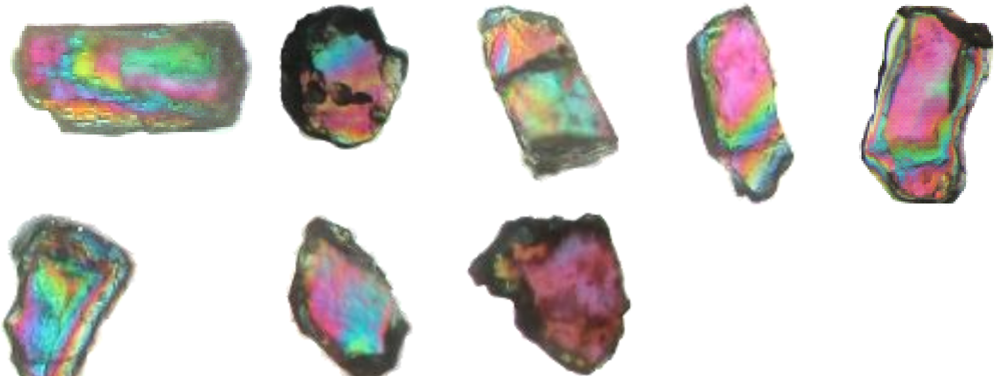


Figure (15). Various shades of pink color of hypersthenes in Irrawaddy Formation.

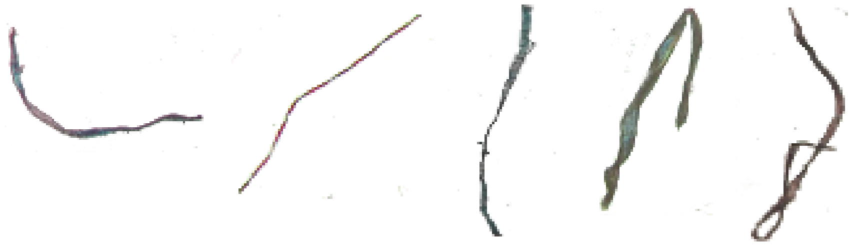
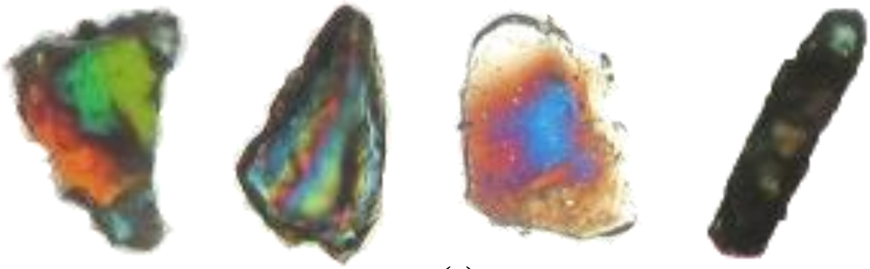


Figure (16). Colorless or blue color and thin slender form of Sillimanite.



(a) (b) (c) (d)

Figure (17). (a) and (b) Allanite, (c) Topaz and (d) Apatite in Irrawaddy Formaton.

Scale 0 0.1 0.2 0.3mm

Other accessory heavy minerals

The accessory minerals are sillimanite, topaz, allanite, apatite. Sillimanite shows colorless, pink or blue color (Fig. 16) and thin slender form and bent. Sillimanite is high grade metamorphic derivatives. Topaz is rare (Fig. 17). It shows subrounded colorless with a noticeable bluish-white tinge. Allanite shows irregular, angular fragments of long euhedral tablet and light to dark brown or reddish brown, irregular color variation. Allanite is an accessory mineral of granite, granodiorite and syenite, some pegmatites, schists and gneises and rarely in volcanic rocks. Apatite grains are usually colourless, but because of the presence of manganese, ferrous or ferric irons, that some apatite may have reddish brown tints with broken short stubby or long slender forms (Fig. 17). Apatite is a common accessory mineral of almost all types of igneous rocks.

Opaque minerals

Opaque minerals (Fig. 18) were identified as magnetite, chromite and hematite. Magnetite is the most common kind of opaque minerals in the sediments in the study area. The magnetite shows subangular to subrounded black color. Magnetite is formed by the magmatic segregation processes. Chromite shows 6-sided subangular prism and dark color with purplish blue color reflectance at the border of grains. It occur abundantly ultrabasic igneous rocks. Hematite gives euhedral tabular to irregular form, brilliant metallic luster and deep cherry-red color under transmitted light. Hematite is the alternation product of primary iron. Some of the grain are corroded. Opaque minerals are remarkably present in the study area.

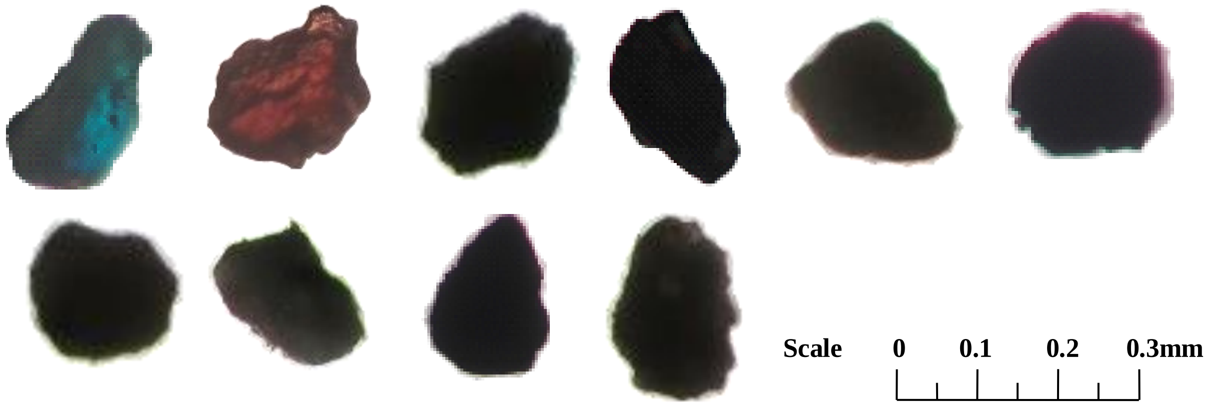


Figure (18). Opaque minerals in Irrawaddy Formation.

Table (1). Distribution of heavy minerals in volume percent of Kuga-Palaung Area

Mineral	**Irrawaddy Formation**					
	Lower		**Middle**		**Upper**	
	1	**2**	**1**	**2**	**1**	**2**
Zircon	11.4	8.3	10	5.4	17.6	7.1
Tourmaline	5.7	1.6	2.5	2.7	5.8	14.2
Rutile	14.2	6.6	7.5	16.2	5.8	21.4
Garnet	2.8	8.3	10	24.3	11.7	-
Kyanite	5.7	3.3	2.5	-	-	-
Staurolite	2.8	5	2.5	2.7	-	-
Epidote	-	5	-	5.4	-	21.4
Diopside	14.2	10	5	-	-	-
Augite	-	5	7.5	8.1	11.7	-
Hornblende	2.8	1.6	2.5	-	5.8	-
Olivine	17.1	13.3	15	-	-	-
Hypersthene	5.7	15	12.5	13.5	-	7.1
Allanite	-	3.3	-	-	-	-
Topaz	5.7	-	-	-	-	-
Apatite	-	1.6	-	2.7	-	-
Sillimanite	8.5	8.3	5	10.8	23.5	-
Opaque	2.8	3.3	17.5	8.1	17.6	28.5

Table (2). Percentage of Zircon (Z), Tourmaline (T) and Rutile (R), ZTR maturity and maturity index

Mineral	**Irrawaddy Formation**					
	Lower		Middle		Upper	
	1	2	1	2	1	2
Zircon (Z)	11.8	8.6	12.3	5.9	21.5	9.9
Tourmaline (T)	5.9	1.7	3	2.9	7.1	19.9
Rutile (R)	14.7	6.9	9.1	17.6	7.1	30
ZTR Maturity	32.4	17.2	24.4	26.4	35.7	59.8
(r) rest of other heavy minerals	65.3	79.7	62.5	67.5	52.7	28.5
Maturity Index ZTR/r	0.5	0.2	0.4	0.4	0.7	2.1

Note-Opaque minerals are omitted.

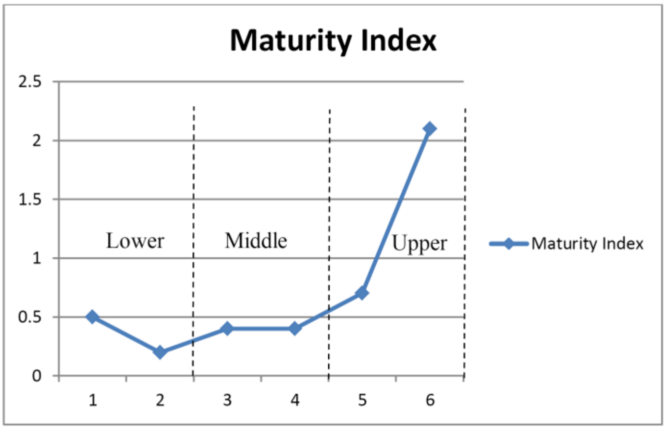


Figure (19). Variation in ZTR maturity index of Irrawaddy Formation exposed in Kuga-Palaung Area

Result and Discussion

In the present study area, comparative studies of lower, middle and upper of Irrawaddy Formation have relatively abundance in heavy minerals. The nature and relative abundance of grains, establishing index minerals and maturity index are analysed for the source rock, depositional history, stratigraphic relationship and tectonic activities. The study of the heavy minerals reveals the following characteristics:

(1) The association of heavy minerals is slightly different in each sample number.
(2) Stable minerals such as zircon, tourmaline, rutile, epidote, garnet and unstanble grains such as hornblende grains are found together in Irrawaddy Formation.
(3) Hack-saw termination, indicative of intrastratal solution, was commonly seen in hornblende.
(4) The boundaries and surface etching in rutile, tourmaline, garnet, epidote and hornblende are observed.
(5) Euhedral and well-rounded zircon, garnet, tourmaline and rutile are associated together.

The above characteristics may indicate the following:

The unstable minerals have no resistant to weathering and diagenetic process. But, the presence of such minerals indicates that the sediments were derived from the near source area rapidly or from the area which consisted of mass of such minerals. Higher maturity index is the evidences of the longer transport or source rock abundance. Subrounded to rounded grains show longer distance transportation or recycled orogen.

Heavy mineral association of euhedral and well-rounded grains indicates that they may be at least two sources for the sediments. Euhedral grains may be from the primary sources and the rounded grains may be from the older sedimentary units or the source was influence of intrastratal solution on the heavy minerals.

On the basic of the suite of light and heavy minerals and their characteristics, the source rocks of the study area may be interpreted as follows:

- The association of augite, chromite, diopside, hypersthenes, magnetite and olivine may indicate basic igneous source.
- Euhedral crystal of zircon, tourmaline and hornblende of the study area were derived from acid igneous rock
- The presence of euhedral and rounded tourmaline, zircon, rutile indicate that the sediments were derived from pre-existing sedimentary rocks.

- The occurrence of metamorphic rock exposures at the source rock is indicated by recognition of garnet, diopside, kyanite, staurolite, silliminite, bule green hornblende and epidote (Milner et.al., 1962).

  On the basic of these above factors, the source of the study area may be plutonic igneous rock, low and high-grade metamorphic rocks and pre-existing sedimentary rocks.

Summary and Conclusion

The present area is ten miles (16km) long from north to south and eight miles (13km) from east to west, covering approximately 80 square miles (208 sqkm) of flat and low lying terrain. It is situated on the western part of the Yaw River. The study area is situated in the Central Cenozoic Belt of Myanmar. The nature and occurrence of heavy minerals were used for the determination of source area weathering, significant gravity separation during transportation, deposition, diagenetic alteration and tectonic activities of the provenance. The quantitative analyses of heavy minerals were made for source area associated with the deposition of the Irrawaddy Formation. There a total set of 16 different types of heavy minerals and opaque varieties. Heavy mineral association of euhedral and well rounded grains indicates that they may be at least two sources for the sediments. Euhedral grains may be from the primary sources and the rounded grains may be from the older sedimentary units or the source was influence of intrastratal solution on the heavy minerals. The source of the study area may be plutonic igneous rock, low and high-grade metamorphic rocks and pre-existing sedimentary rocks.

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