INTRODUCTION

A review of past literature was carried out prior to conduct the fieldwork. This was followed by field mapping, measurement and sketching of outcrops and sampling. Laboratory analyses of samples were carried out followed by interpretation of the data collected.

Representative samples were collected from the outcrops within the Ransi Member and limestone samples were collected from the Arip area and calcareous sandstone from Lesong Hill. Some samples from the adjacent formations such as the Belaga Formation, Tatau Formation and Nyalau Formation were also collected for comparative studies.

The following studies were undertaken:

(A) Literature review

A study of the part geological review of the area by Wolfenden (1960), Liechti et al. (1960), Ismail (1996 & 2000), published articles and some unpublished reports was undertaken before starting with the fieldwork.

(B) field investigation

Geological mapping, sedimentary logging, collection of conglomerate, sandstone and limestone samples for petrographic studies and coal or lignite samples for organic geochemistry analyses.

(C) Conglomerate petrology study

Comparison and grain-size studies of the clasts was carried out using 1 m X 1 m grid in the field for Ransi Member. The matrix was collected for petrographic study in thin section. Palaeocurrent determination base on pebble orientation was also carried out.

(D) Sandstone petrology study

Thin sections of the sandstone samples from Ransi Member were used for composition and textural studies to determine the provenance of the grains and interpretation of transport history and depositional environment.

(E) Igneous petrology study

Thin sections of igneous samples from Piring Hill were used to determine and characterize the type of the igneous rock for comparison with the igneous clasts in the conglomerate and sandstone in provenance studies.

(F) Coal petrology study

It includes maceral analysis and vitrinite reflectance determination using polished sections of 6 samples from Ransi Member, 4 samples from other parts of Tatau Formation and 3 samples from nearby formations to differentiate them using their burial histories.

(G) Micropaleontology study

Thin sections of the limestone from the Arip area and Lesong block were studied to identify the benthonic foraminifera and calcareous algae. This was used together with carbonate petrology to help interpret the age and depositional environment of Arip Limestone.

(H) Data interpretation

Available data including those from previous works were compiled for statistical analyses and used to discuss, compare and intergrate the depositional setting of the different rocks found to build up a model for the depositional environment and geologic history of the area.

(A) Literature Review

A review of all published and unpublished articles on the geology of the area and adjacent areas was conducted prior to commencement of field work. Most of these publications were found in the Klompe Reading Room, Geology Department, University Malaya and the Main library of University Malaya. The most useful articles were Geology of North-West Borneo – Sarawak, Brunei and Sabah (Hutchison, 2005). Geological setting of Sarawak (Mazlan, 1999), Petrology of sedimentology and stratigraphy (Boggs, 1992) and The geology of Sarawak, Brunei and the western part of North Borneo (Liechti et al., 1960).

(B) Field investigation

Field mapping was done with the aid of a Garmin GPS X-trex to determine the coordinates of localities and mapping of outcrops. It has an accuracy of up to 4m depending to the prevailing satellite positions. The reference datum used is Timbalai.

A major part of this study consisted of fieldwork and mapping in the Ransi Member in the Tatau area from 8.2.2009 to 12.2. 2009, 13.4.2009 to 18.4.2009, 21.9.2009 to 25.9.2009, and 9.8.2010 to 13.8.2010.

Lithostratigraphic sections were measured in most of the localities with information on bed thicknesses, lithologies and field descriptions of grain size and textures, sedimentary structures, clast orientations, pebble counts and occurrence of fossils and trace-fossils.

Strikes and dips of the bedding and main faults or folds were measured at most exposures with a Silva Geological Compass.

(C) Conglomerate petrology study

A detail study was carried out on the conglomerate clasts and matrix from different localities of the Ransi Member exposures to aid in determining provenance.

The finer grained matrix of sufficiently hard specimens were cut for thin section studies. Petrographic studies of the rocks were carried out under transmitted light microscope for identification of their components, grain size distributions and textures. Weakly cemented specimens had to be impregnated with resin mixed with hardener before sectioning. Details of making thin sections are presented in Appendix 1.

(D) Sandstone petrology study

Thin sections were prepared from the sandstone and calcareous sandstone from different localities of the Ransi Member to trace the sources of sediment supply. The weakly cemented sandstone grains are easily disaggregated so the sandstone samples had to be hardened by the resin mixed with hardener before thin sectioning. The thin sections were studied using under transmitted light microscope. The petrography of the rocks was used to interpret the sedimentary sources and aid in interpretation of the transport histories and depositional environments.

The sandstone were classified using Mc Bride's (1963) classification based on proportions of quartz-feldspar-lithic fragments found as the fine-grained matrix was less than 15% in all samples.

The frequency distributions of the grain-size data are displayed in histograms as they provide an easily visualized pictorial representation of the grain-size distributions. Their distribution patterns are affected by the grain-size interval selected for plotting.

Three mathematical measures can be used to describe the average size of grains in each sample (Boggs, 1992). The mode is the most frequently occurring particle size in a population of grains. The median size represents the mid-point of the grain-size distribution corresponding to the 50% diameter on the cumulative curve. The mean size is the arithmetic average of all the particle sizes in a sample.

$$\text{Mean, } m = \frac{S_{16} + S_{50} + S_{84}}{3}$$

The mathematical expression of sorting is the standard deviation. The formula below yields the standard deviation expressed in mm units. The verbal terms for sorting corresponding to the various values of graphic grain size of standard deviation are given below (Simon & Kenneth, 2001):

$$\text{Standard deviation} = \exp\left(\frac{\ln P_{16} - \ln P_{84}}{4} + \frac{\ln P_{5} - \ln P_{95}}{6.6}\right)$$

Very well sorted	<1.27
Well sorted	1.27 – 1.41
Moderately well sorted	1.41 – 1.62
Moderately sorted	1.62 – 2.00
Poorly sorted	2.00 – 4.00
Very poorly sorted	4.00 – 16.00
Extremely poorly sorted	>16.00

Skewness is an additional measure of grain-size distribution that accounts for sorting in the tails of the distribution (Boggs, 1992). When plotted as a frequency curve, the grain-size distributions of most natural sediments do not yield a perfect bell-shaped curve but will exhibit a log-normal grain-size distribution displaying an asymmetrical or skewed distribution.

For the texture study, the shape and roundness of the grains are important in describing sedimentary textures. The grain shape and roundness classification by Pettijohn et al. (1973) was applied to describe the geometry of the grains.

(E) Igneous petrology study

Thin sections were prepared from the igneous samples of different localities within the Piring Hill igneous body. For petrographic studies a transmitted light microscope was used to identifiy the rocks. This was used to compare with the igneous sedimentary clasts for provenance studies.

(F) Coal petrology study

Coal samples for microscopic assessment were crushed and mounted in slow-setting resin which had been mix with a few drops of hardener. The samples took around 2 days to harden and after that it underwent several stages of polishing to produce the polished samples for petrologic study. The detail procedure on polished block preparation is shown in Appendix II.

The polished coal samples were studied using a Leica DMRCP microscope photometry system equipped with fluorescence illuminators. Microscopic examination was carried out principally in oil immersion under normal reflected light and blue light excitation. A Window-based MPVGEOR package software was used for vitrinite reflectance (%Ro) analysis.

(G) Micropaleontology study

Microfossils in limestone samples were studied in thin section under a transmitted light microscope. Those in loose samples such as shales and siltstones were soaked, washed, sieved, dried and picked under a binocular microscope for study. Details on the methodology of sample preparation for micropalentological analysis of the microfossils in shale are given in Appendix III.

There are two methods for nannoplankton sample preparation carried out in the Shell Laboratory namely the SSB-in-house method and smear method. The details of sample preparation and microscopic analyses are given in Appendix IV and V. Unfortunately no nannoplankton was recovered from the samples processed.

A total of 25 samples were processed for nannoplanktons at Sarawak Shell Berhad Laboratory but did not yield any results. This might due to the samples were highly weathered.

(H) Data interpreatation

Data from the field studies, laboratory analyses which include petrology, micropaleontology were compiled and analysed statistically to interpret the depositional subenvironments and produce a depositional model for the Ransi Member. It was also used to build up a more complete geological history of the formation of the rocks in the Tatau area.