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Petrographic Analysis of Belait Sandstone, Onshore Sarawak.

Fathin Nayli binti Ahmad Aezuddin, Nur Shuhadah binti Japperi and Norsyazwani Abdul Jalil

Faculty of Chemical Engineering, Universiti Teknologi MARA

***Abstract*—Petrographic analysis was used to characterize the rock structure sample of sandstone of Belait Formation (Mid-Upper Miocene) in onshore Sarawak. The sample was properly prepared for petrographic analysis that includes Polarizing Light Microscope (PLM) to make observation regarding grain texture and size, X-Ray Fluorescence (XRF) to obtain quantitative evaluation of chemical composition and Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX) to define quantitative compositional and elemental information. On the basis of petrology, the sample is composed mainly of quartz, feldspar, hematite and zircon. The following are the elements that have been determined and identified: Si, O, Zr, Al, Ba, Fe, C, Na, K, Ca and Mn. Hence the results gained from the analysis shown that sandstone sample in Belait Formation has major elemental composition by Si that has higher weight in percentage (41.6Wt.%) as compared to the other element.**

***Keywords*—Elemental composition, grain size and texture, petrography analysis, sandstone.**

I. INTRODUCTION

The study area is located in East Malaysia in the Northwest of Borneo Island (Figure 1). The petrographic analysis is based on the sandstone sample that is collected from Belait Formation (Mid-upper Miocene) (Figure 2) in onshore Sarawak that comprises alternating clays, sand and sandstones. It is believed to have been deposited as tide-dominated fluvial environment due to major deposited structures [1]

One of the major concepts in petrographic analysis is that the grain compositions, sizes and textures are related to depositional processes. Other related studies have predicted that the depositional environments were original derived based on the sand-grain surface textures. In most classifications of minerals, the presence of quartz is considered a major factor when the quartz acts as a basis.

Generally, all the minerals are commonly found in the sandstone in Belait Formation sample, but only a few are likely to be abundant. The most abundant mineral is quartz, which is the chief component of the sandstone (Figure 3). The next on the list is feldspar as the most abundant unstable mineral grains and followed by the less abundant but widely spreads are the hematite and zircon. They are all among those that are stable during diagenesis and in sedimentary environments [2].

Therefore, the aims of this paper are: a) to identify and observe the fine-grained minerals aggregates, grain size and texture of the sandstone sample by using Polarizing Light Microscope (PLM); b) to obtain a quantitative evaluation of chemical composition of the minerals in the sample by using X-Ray Fluorescence (XRF); and c) to define the elemental information and quantitative compositional information of the sample by using Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX) analysis.

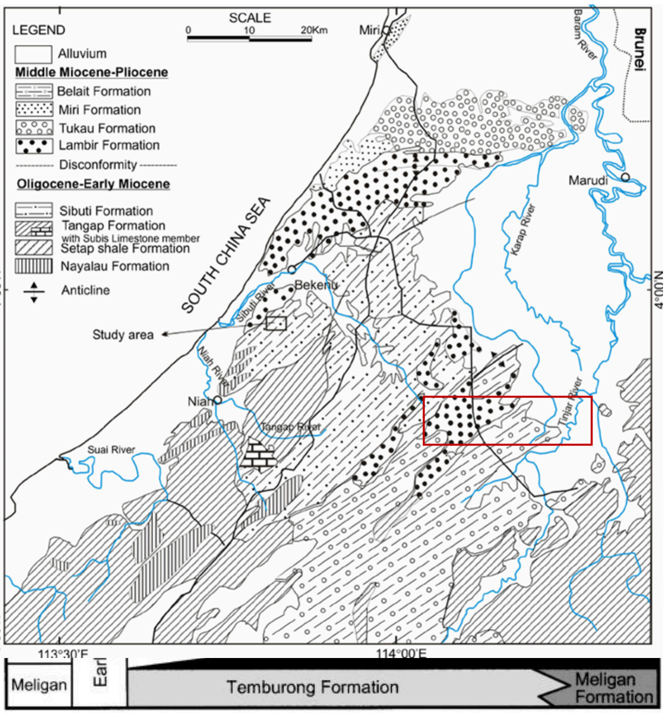
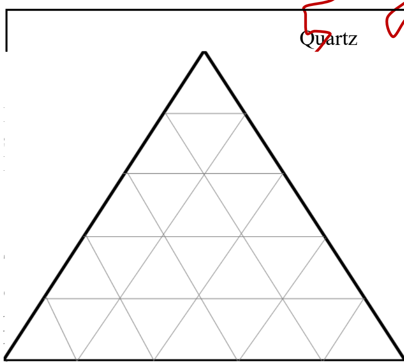


Figure 2: The stratigraphy of Upper and Lower Miocene of Belait Formation (in red square), Sarawak where it changes into fully marine from the coastal environment that merges into Lambir and Miri Formations and to the uppermost part of the Setap Formation. (Taken from [4])



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ı from Belait Formation, ucial to determine the ion. The sample has taken h are PLM, XRF and SEM-EDX. Therefore, there were three samples prepared using the same type of sandstone for each different analysis.

A. The Petrographic Analysis

The thin section analysis involves the using of PLM; model OLYMPUS Th4-200, in order to study the optical properties of the sample. This approach is the most effective of investigation of sandstone in the laboratory [5].

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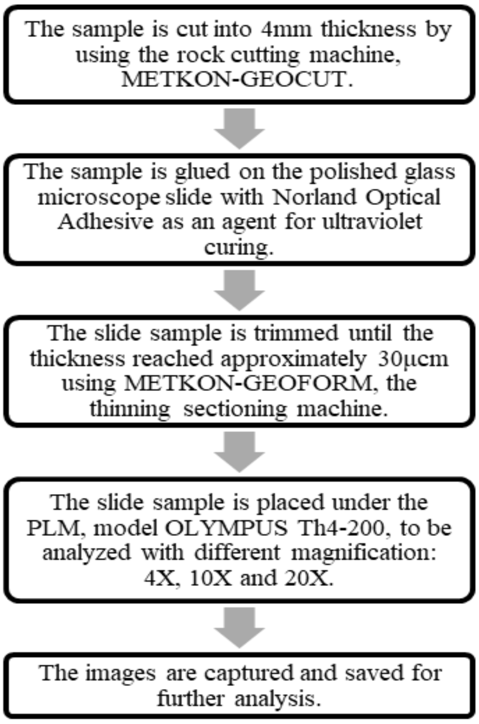


Figure 4: The flow chart of petrographic analysis by using PLM for Belait sandstone sample.

The classification of the minerals composition is based on the Michel-Levy Birefringence Chart that is useful in unlocking many mysterious of microscopic analysis and identification. Basically this chart is utilized by comparing he highest-order interference colors that displaced by the specimen in the plain polarizing microscope.

B. X-Ray Fluorescence (XRF)

Next is the XRF analysis; model Axios, where the elements in the prepared sample is measured with maximum voltage and current is approximately 60kV and 125mA, in a vacuum environment.

The sample must be in a solid state with flat surface, because it will effected the distance from the sample to the x-ray source and will introduce error if the sample is in irregular surface. Also, if the sample has a rough surface, it can cause reabsorption and scattering of linger wavelength elements.

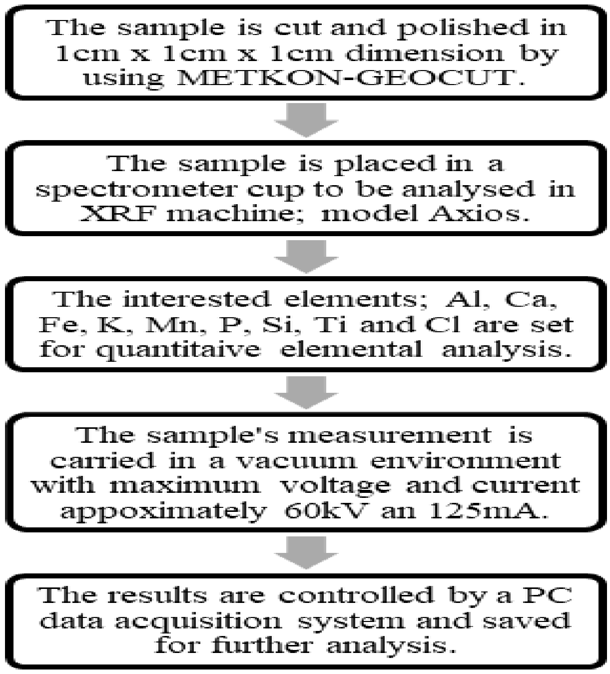


Figure 5: The flow chart of XRF analysis on the Belait sandstone sample.

The analysis will be controlled by a PC data acquisition system. Each spectrum is collected for the specified time and will be saved for self-analysis.

C. Scanning Electron Microscope – Energy Dispersive X-ray (SEM-EDX)

Last but not least, the last sample is analyzed with SEM-EDX, model Hitachi SU-3500 series to determine and quantify the texture details and mineralogical composition of the sample with extremely high magnifications.

The SEM-EDX method involve the use of backscattered electron imaging, image analysis and x-ray analysis [6] to visualize and investigate the surface of small pieces of sample under fully automated operation. It is strongly advice to turn off the automatic control of brightness and contrast for easy image interpretation during the analysis.

The mechanism to measure the x-ray energy spectrum shows the energy and intensity of the x-ray generated by the interaction of the electron and the sample. In addition, the number of x-rays emitted by each element is related to the concentration of that particular element at that specified spot for analysis and the characteristics of the x-ray lines enables the elements to be specifically identify [7].

Later, the elements in the sample will be recognized and at this moment the x-rays will be generated.

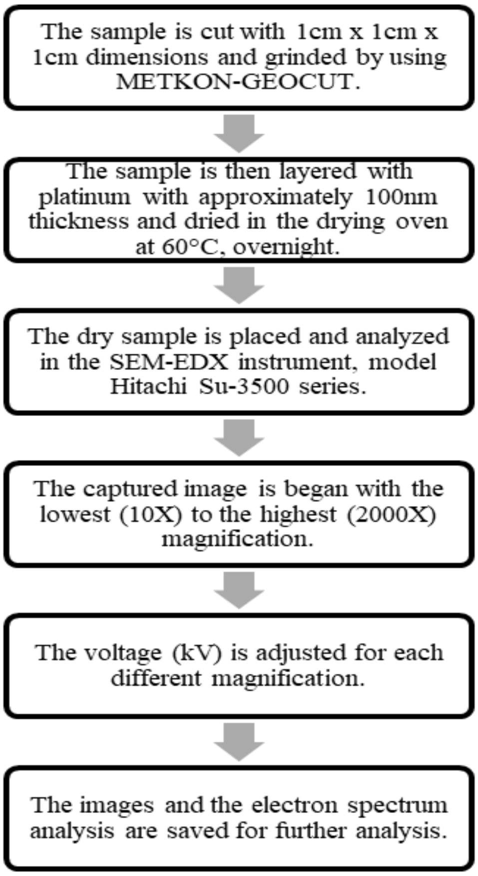


Figure 6: The flow chart of SEM-EDX analysis of Belait sandstone sample.

III. RESULTS AND DISCUSSION

A. The Petrographic Analysis

Thin section of the sample was analyzed under PLM. It has been traditionally applied to establish the mineral composition, texture information of sandstone. Other than that, the thin section analysis can interpret the origin and history of sample, which is suitable to analyze the petrography for the sample.

The images showed green, a little bit of red and orange, brownish and yellowish colors (Figure 5) that indicates specific elements in the sample. The images also showed the texture of the grain which are moderately well-sorted fine to medium-grained sand. The minerals and framework compositions that had been identified are quartz, feldspar, hematite and zircon that based on the Michel-Levy Birefringence Chart.

First and foremost, quartz (SiO_2) is the most dominant framework grain in the Belait sandstone, onshore Sarawak. It compromised almost 79.6% of the total framework composition that is compressed and cemented together. The quartz grains are colorless (show first-order grey-white interference color) and mainly shown as angular to sub-angular in shape as viewed. If it appears in brownish-white shades, the polarizers are not precisely adjusted and oriented.

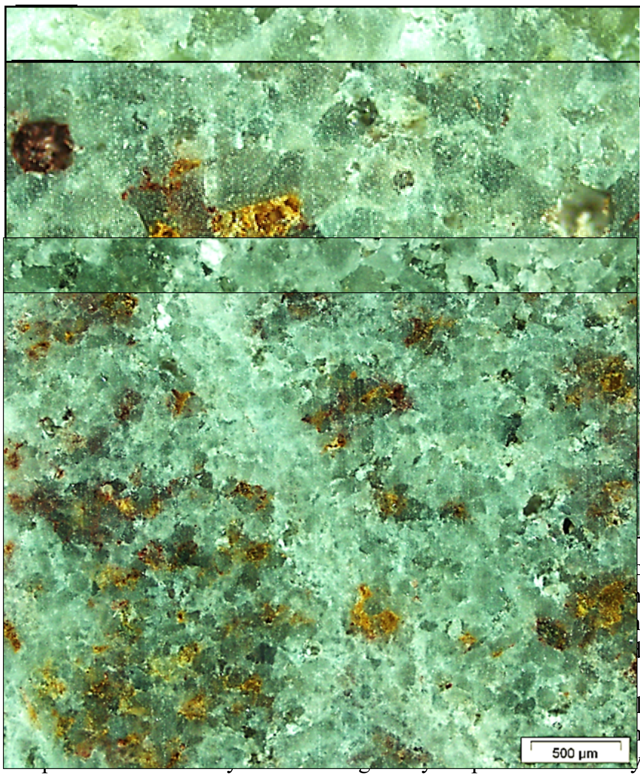
Next is the feldspar (AlSi3O8), it has appeared in 15 to 18% of the total composition, might be because of the feldspars had included in clay minerals or weathered beyond the maximum of recognition. However, plagioclase (CaAlSi3O8) which is a member of the feldspar mineral family was observed in the image. It appeared as white to grey and a glassy surface.

Since both quartz and feldspar were appeared white to grey color in polarizing light microscope as shown in Figure 5a), the best clues that can differentiate the both is depending on how the minerals grow and then break. As for feldspar, it will show two directions of cleavage that look just like a stairway under the microscope and will sparkles when the light is reflecting off the cleavage on the spot. Unlike the quartz, it has no cleavage and no sparkles in all light directions.

Next dominant framework that can be identified is hematite cement or can be so called as iron oxide (Fe2O3) that will show red, black and steel blue in reflected light in the thin section method. It is a common mineral in many kinds of rocks that may be form as an alteration product after just about any Fe-bearing mineral.

As for the zircon (ZnSiO2) is referring to the presence of detrital heavy minerals that may occur as adsorbed coatings on diagenetic clay minerals (Nicholls and Loring 1962). In plain polarized microscope, it reflected pale brownish color that usually coated hematite.

These minerals show anhedral grain shape that caused by the thermally induced annealing that creates poly-crystalline grains aggregates (Figure 6) that the minerals have dissolved or melted and lead to "rounding" of crystal edges in the framework. The grain size distribution however, is seen to have moderately well-sorted fine to medium-grained sand under the microscope. The framework grains are roughly seen as sub-rounded to rounded, however, the roundness is very difficult to estimate.



emission, as the sample can be used for other types of testing or another analysis. The XRF analysis also fast and easy to use as the x-ray spectrometry enables chemical compositions to be determined in seconds that run under effective software for measurement and results calculation.

The result of elemental analysis for the studied sample is given in Table 1. Generally the established result has shown the Si element (67.8%) is the highest concentration and followed by the Fe element (26.7%) content. This is reflected that the sample is majorly presence of quartz and hematite.

Table 1: The value in percentage of each interested major elements (on average) in sample of Belait Formation.

Element	Si	Fe	Al	Mn	K	Ca
Value, %	**67.8**	**26.7**	**3.8**	**0.9**	**0.5**	**0.3**
Raw, kcps	**2402.1**	**332.2**	**73.9**	**11.2**	**3.3**	**0.5**

However, since there are some minor elements that cannot be detected by XRF, the sample is brought to advanced equipment which is the EDX for further analysis (Table 2). This is because the major component in the XRF machine is crystal that bombards the light reflecting to the absorber that will determine the element of the sample, which is unfortunately, is not clean and cracked.

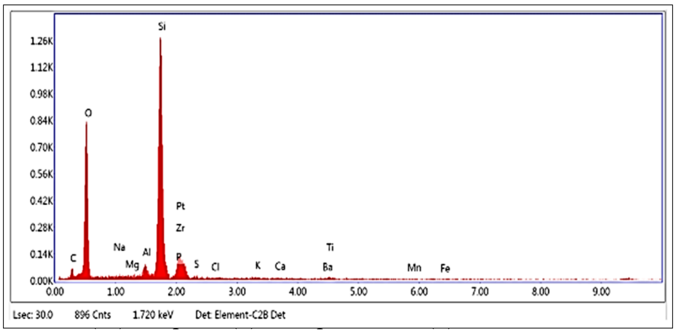
C. The SEM-EDX analysis

The SEM-EDX method involve the use of backscattered electron imaging, image analysis and x-ray analysis [6] to visualize and investigate the surface of small pieces of sample under fully automated operation.

Table 2: The weight in percentage, net color intensity and K-ratio of all the elements that presence in the sample which is detected by SEM-EDX.

Element	Weight, Wt.%	Net intensity	K-ratio
Si	41.6	322.5	0.359
O	38	153.4	0.159
Al	1.7	12.7	0.013
Zr	3.2	8.6	0.02
Ti	0.7	1.9	0.006
Fe	1.4	1.8	0.012
Ba	1.6	1.6	0.011
K	0.4	1.5	0.003
Ca	0.3	1	0.003
Mn	0.5	0.7	0.004

From the Table 1 from XRF analysis and Table 2 from EDX analysis, it proves that Si has a higher concentration with 41.6Wt.% and followed by O with 38Wt.%. As for the moderate concentration, it involves element Zr (3.2Wt.%) while the lowest concentration refers to element Ca with 0.3Wt.%. These heavy minerals chemistry indicates sedimentary environments that associated with a relatively fluvial [3] or large delta environment [8].



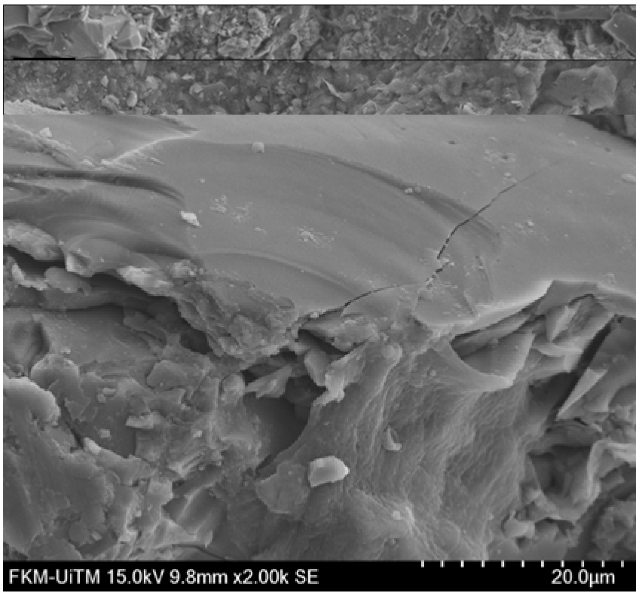
using the XRF and EDX.

The surface of the Belait sandstone revealed the quartz crystals exhibit regular grain surface and the other minerals are loosely attached to the grain. They also appeared to rest on the surface of the quartz as it suggested that the quartz was first deposited (Figure 7-a).

The big overview of the whole sample is shown in Figure 15 where the surface is consists of angular sub-rounded quartz grains. The observed micro-features on the quartz surface are conchoidal fracture (CF) with straight striation (SS), cleavage plane (CP), linear fracture (F), notches (N) and striations (S). All of these features are based on the [9].

The genesis of micro-structure on quartz surface textures is observed as in figure 7 (b-c) will be used to analyze the depositional environment of Belait Formation in onshore Sarawak. The fractures and striations are present in the sample as they reflected the process of mechanical abrasion during weathering, or the impact from the movement between grains or the increment concentrations of crystalline quartz [10].

Next is the mineral's cleavage. Many minerals split preferentially along one or many directions. The planar fractures can be formed and generated through mechanical force that happened during either thin section sample preparation or during geological processes. However, the number and quality of the cleavage is depending on the mechanical stress that indicates some of the features of minerals like feldspar.



sediments.

IV. CONCLUSION

The study of petrographic analysis of Belait sandstone, onshore Sarawak was analyzed by PLM, XRF and SEM-EDX. From the study outcomes, we can conclude that:

- Belait sandstone consists of major abundant of quartz in grain framework due to the high concentration of Si element in all results from PLM, XRF and SEM-EDX.
- Belait sandstone also has moderate abundant of Al and Fe that reflecting other minerals like feldspar and hematite are presence in the sample.
- The interactions between quartz, feldspar and hematite play significant roles in sandstone structure.
- Overall, the results are most closed enough with the other findings as quartz is acting as a basis in Belait sandstone.

It is recommending that the results of this study to be integrated and the outcomes would have a significant impact for a better understanding on the overall petrographic analysis concepts.

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