GEOLOGY OF BUKIT PANAU, TANAH MERAH, KELANTAN

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ABSTRACT

A unique isolated hill of Bukit Panau around a flatland deposits comprise of Jurassic-Cretaceous sedimentary sequence overlying the Triassic granite rock body underneath it. Previous researchers claim that the contact between those two rock units is a nonconformity, but the evidences are insufficient to validate those claims. Therefore, this research studies the type of contact between the rock two rock units and verifies the geological age of the Panau Formation. Several fieldworks were conducted to the study area and petrographic and geochemical studies were performed on selected rock samples retrieved from the fieldwork. As a result, it is believed that Bukit Panau could possibly have two types of unconformities and that the Panau Formation is not the only formation there.

Keywords: formation, unconformities, angular unconformity, nonconformity, granite intrusion, boundary range granite.

INTRODUCTION

The formation of the nonconformity begins with the uplifting of the igneous and metamorphic rocks that are formed deep in the earth crust. An erosion then takes place on the surface of the rocks prior to the final stage of the process where new sediments are deposited on top of the igneous or metamorphic rocks and overtime, layers of sedimentary rocks of the continuous deposited sediments is formed. However, there are cases on what seemed to be a nonconformity contact between the sedimentary layers and the underlying granite, could be a granite intrusion instead as the crust beneath the sedimentary rocks may have been intruded by granite in the form of magma. This means that the granite is younger than the overlying sedimentary rocks as the sedimentary rocks have formed first before the magma intrusion event occurred. Therefore, the boundary contact between the sedimentary rocks and the underlying granite is an intrusive contact instead of a nonconformity contact.

It is identified that the Panau Formation comprises of conglomerate, interbedded sandstone and argillite beds and this formation overlies the granite rock body underneath which is then claimed to be a nonconformity contact according to the conducted geological survey [1]. This particular contact is defined as the deposition of the sedimentary rocks on top of an eroded surface of igneous rock such as granite or metamorphic rocks.

Although the contact between the granite rock body and the sedimentary layers of Panau Formation has been identified by the previous studies, the evidences and justifications are insufficient to verify that the contact is a nonconformity as this matter is not being thoroughly emphasised in the preceding researches. A granite intrusion could possibly be the actual case that explains the origin of the contact boundary between the granite and the overlying sedimentary rock. It is crucial to study the type of granite that Bukit Panau has in order to know the continental setting it was generated. Apart from that, the Panau Formation

is reported to be a Cretaceous age based on the plant fragments found in the fine grained sandstone beds at the foothill of Bukit Panau. However, some of the plant fragments that are similar to the ones in Bukit Panau are also found in Bukit Keluang reported to be of Permian age. Therefore, detailed studies on these arising issues should be conducted and the concerns on the nature of contact between the sedimentary rocks and granite can be specified by starting off with acquiring more in-depth evidences from field studies.

The aims of this research are to establish a detailed geological map of Bukit Panau, investigate the nature of contact between the sedimentary rocks and the underlying granite rock and verify the stratigraphic succession of the Jurassic-Cretaceous sequence in the Bukit Panau area.

This research is focused on several aspects which are identifying the contact between granite rock body and Panau Formation through field observations and structural studies. Then, determining the type of rocks and their minerals through petrographic studies along with determining the depositional environment of Bukit Panau. Lastly, classifying the type of granite that Bukit Panau has by using XRF analysis and QAP diagram.

LITERATURE REVIEW

Geological Settings of Bukit Panau

Bukit Panau is an isolated hill located at approximately 10km north of the Tanah Merah town in Kelantan with Panau Formation cropping out the Bukit Panau area

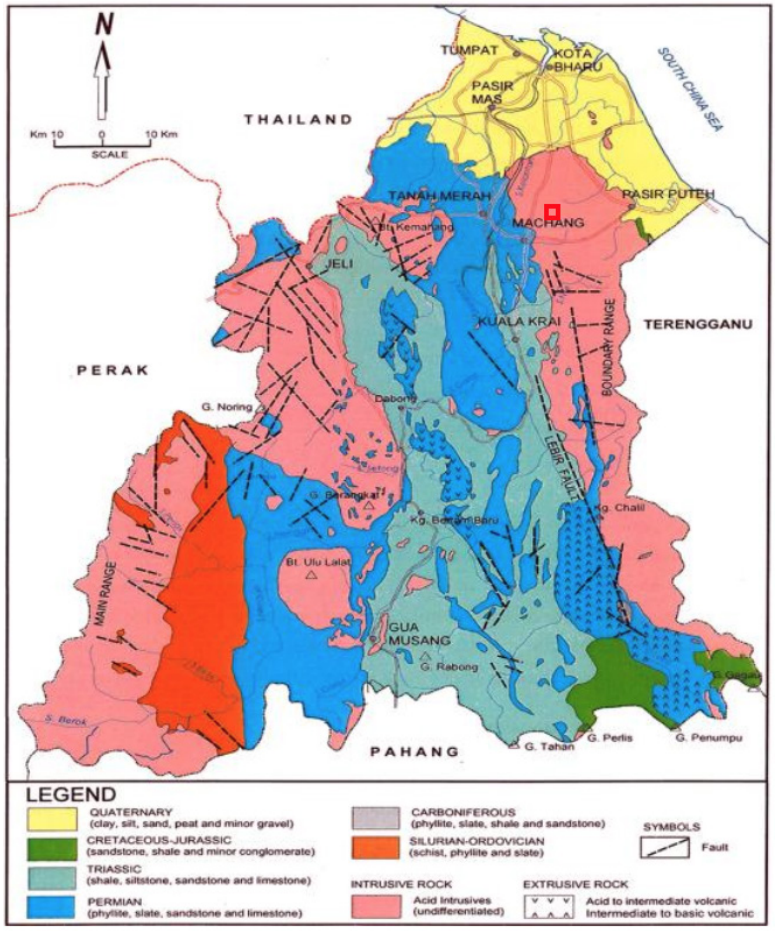

Figure 1 General Geological Map of Kelantan with the estimated study area of 4km^2 situated in the red box [2]

(Figure 1). The Panau Formation is characterised by the sequence of continental sediments [3], channel lag deposit and sedimentary rocks cropping out at Bukit Panau, Tanah Merah, Kelantan. The sequence is termed as Panau Formation after the Malaysian Working Group discovered a sedimentary sequence at an abandoned quarry at the foothill and peak of Bukit Panau. Bukit Panau is said to be a unique hill as only Panau Formation is cropped out at that area and surrounding the hill is a flat surface land.

granite with the age of Jurassic-Cretaceous based on the presence of plant fragments in the fine-grained sandstone beds at the Bukit Panau foothill. The discovered plant fragments identified as Frenelopsis sp., Otozamites sp., Calamites sp., and Pecopteris sp are predicted to be of the Cretaceous age. However, similar plant fossils like Calamites sp., and Pecopteris sp are discovered in Bukit Keluang and these plant fossils indicate that the sediments in Bukit Keluang are of Late Permian age [4]. Based on the previous

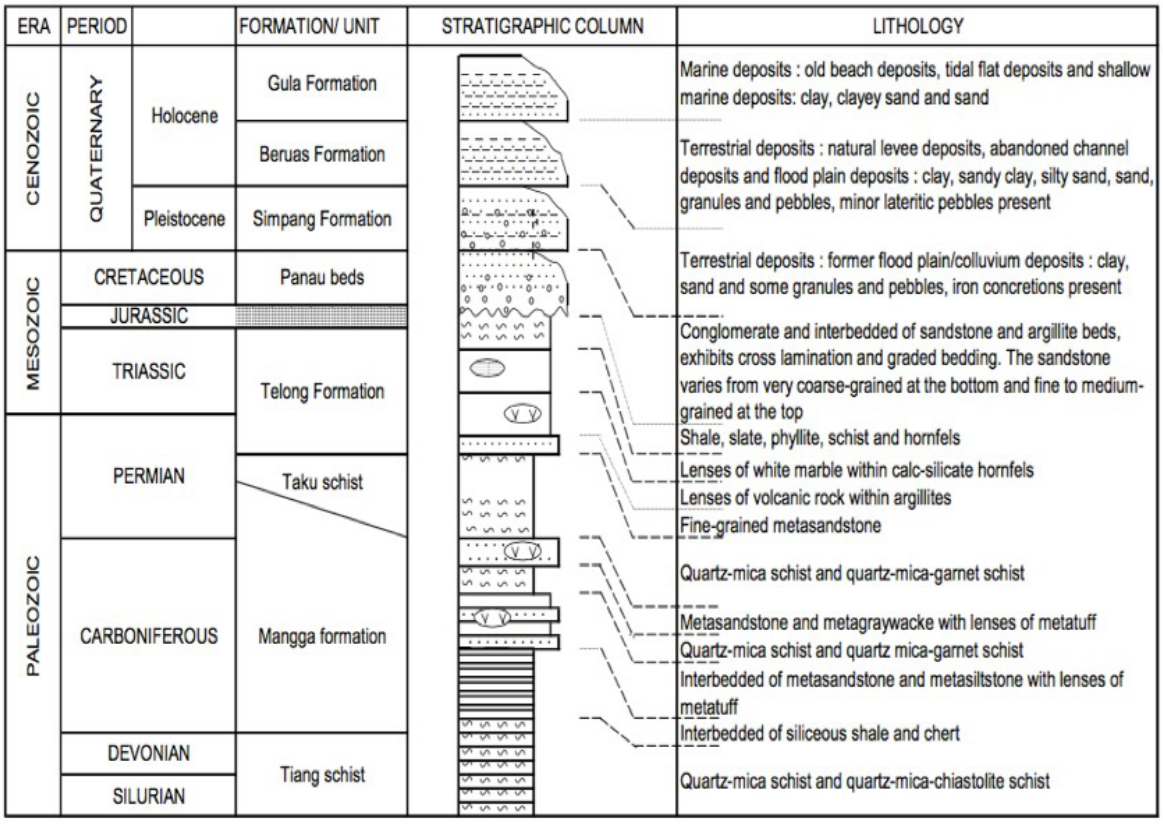

Figure 2 Batu Melintang-Sungai Kolok Transect area Schematic Stratigraphic Column [1]

Based on the previous studies of the Bukit Panau area [1] and [3], a nonconformity between the granite of Triassic age and the overlying sandstone of Panau Formation is discovered at the abandoned rock quarry at Bukit Panau foothill. It is believed by both studies that the Panau Formation is younger than the Triassic

studies conducted on the Bukit Panau area, it is discovered that there is limited emphasis on the study of the nature of contact between the granite and the sedimentary sequence resulting in insufficient and indistinct information about the contact and their geological age.

Lithology and Stratigraphy of Panau Formation

According to The Malaysian and Thai Working Groups [1], the lithology in Panau formation comprises of interbedded thin argillite beds, laminated fine-grained sandstone, poorly sorted pebbly sandstone and paraconglomerate as shown in Figure 2. However, there is an absence of rock stratigraphy during the age of Jurassic identified just beneath the Panau Beds in the Figure 2. It is discovered that the Panau Formation is stratigraphically divided into two lithofacies which are arenaceous and argillaceous facies [3]. The arenaceous facies is mainly made up of fine to coarse poorly sorted graded sandstone that is grey to maroon colour with subordinate graded grit, maroon paraconglomerate and very thin to thin bedded maroon shale, mudstone and siltstone. As for the argillaceous facies, it consists of light grey to grey plant fragment bearing shale, siliceous shale, mudstone and thin-bed of fine-grained sandstone and siltstone.

The maroon colour in the Panau Formation is predicted to be the result of oxidation from the continental deposit or also known as mollase. In terms of mineralogy, it was agreed that the sandstones are classified as arkosic due to the high feldspar content where the end product of the alteration in chemical composition is kaolinite [1,3]. This indication leads to the suggestion that the origin of this rock unit is from the nearby Boundary Range Granite.

Nonconformity Contact in Bukit Panau

The concerns on the nature of contact between the Panau Formation and granite can be specified by acquiring more in-depth evidences from field studies. If the evidences of the rock fragments from the Panau Formation sedimentary rocks found in the granite body and the sedimentary layers have been contact metamorphosed when it is adjacent to the granite body, these indicate that the granite has intruded the older sedimentary layers making the granite body younger than the layers. The presence of the rock fragments from the sedimentary rocks in the host rock which are older than the host rock is known as the principle of inclusion. As for the nonconformity contact, it is identified when there is presence of rounded granite pebbles in the sedimentary rocks, it proves that the granite body has been uplifted and the surface has eroded prior to the deposition of the new sediments and therefore, making the granite older than the overlying rocks.

Boundary Range Granite

The Boundary Range Granite is widely distributed in the northern part of the Eastern Belt granite. Based on the studies conducted, the Boundary Range Granite is identified as I-type granite due to the presence of high Na_2O content, comprises of sphene and amphibole, increasing ACNK values with SiO_2 and abundance of mafic microgranular enclaves [5]. The Boundary Range Granite is the granite pluton that is exposed at Bukit Panau with the composition of granite to granodiorite [1]. This granite is described to have a fine- to medium-grained megacrystic biotite granite with pink K-feldspar phenocrysts. The presence of the pink K-feldspar in this granite fits one of the important parameter of granitic rocks from the Eastern Belt Granite that could indicate the emplacement of the Boundary Range Granite to be an epizonal where the level of intrusion is high. Reference [6] stated that the Eastern Belt Granite has a property of a good contact metamorphic aureoles in the deformed sedimentary formations and its high level granite intrusion that occurred during Triassic is now still exposed and not eroded away. If the Boundary Range Granite is proven to have the similar granite emplacement like the Eastern Belt Granite, the Boundary Range Granite in Bukit Panau can be classified as epizonal granite. The granites at Bukit Panau are estimated to comprise of quartz (30-35%), K-feldspar (20-30%), plagioclase (20-35%), biotite (5-10%) and/or muscovite with occasionally hornblende. The accessory minerals in these granites are allanite and sphene. There are abundant of zircon and apatite inclusions in the biotite. The presence of chlorite, sericite, and magnetite in Bukit Panau granites are the secondary alteration products.

METHODOLOGY

Fieldworks to the study area of Bukit Panau is conducted in order to witness first-hand geology of the study area and gather the relevant data. There are several geological activities are carried out during this fieldwork. From this fieldwork, it is expected that the nature of contact between the granite rocks and the overlying Panau Formation can be validated along with their age by observing the boundary between the granite rocks and the Panau Formation whether there is a sharp contact of metamorphism or a distinct contact.

The structural geology of Bukit Panau is studied as well where the azimuth or strike and dip reading for the fractured system such as joint and fault are obtained in order to construct the Schmidt net or also known as the Lambert equal-area net for analysing the direction and the vectors of structural forces and also construct the Rose diagram for determining the orientation of the fractured system.

Petrographic testing is utilized for identification of minerals and determinining their compositions by using the polarizing microscope. The minerals' percentages in the granite and other 4 rock samples can be roughly estimated from the thin section through the petrographic testing. The detailed analysis of the minerals, micro-texture and structure in the thin section is crucial to understand the origin of the granite rock.

The whole rock chemical analysis is carried out by utilising the X-ray fluorescence (XRF) which is used to determine the percentage of the chemical composition in granites such as SiO_2, $Al2O_3$, K_2O, Na_2O, MgO, etc. The result of the chemical analyses of rocks are expressed as weight percentages of oxides like SiO_2 and MgO instead of separate elements like Si and Mg. Based on the percentage of chemical composition obtained, the CIPW Normative Mineralogy of the granite rock is then calculated by using the simplified mineral formulas to determine the precise percentage of the minerals in the granites like Quartz, K-Feldspar, Albite, Anorthite and Biotite. The calculated percentage of minerals are transferred to the QAP diagram for granite classification.

The Quartz-K-feldspar-Plagioclase (QAP) diagram is used to classify the type of granite rocks. The QAP diagram can only be plotted when the percentage of the mineral composition of the granite rock is known derived from calculating the CIPW Normative Mineralogy. This diagram is utilized in this study to verify the type of granite in the Boundary Range Granite whether it is a granite or granodiorite or consists of both.

After undergoing the fieldwork and performing stratigraphic log and structural study on the area of study, the ArcGIS software is used to produce the base map and geological map of Bukit Panau.

RESULT AND DISCUSSION

Geological Map

According to the generated geological map of Bukit Panau in Figure 3, there are three lithologies identified which are granite, sandstone and schist and gneiss. Granite is the most dominant lithology in the map and covering almost the entire area of Bukit Panau. The sandstone is overlying the granite rock body and there is another sandstone located at the southeast of Bukit Panau near the Sungai Kelantan.

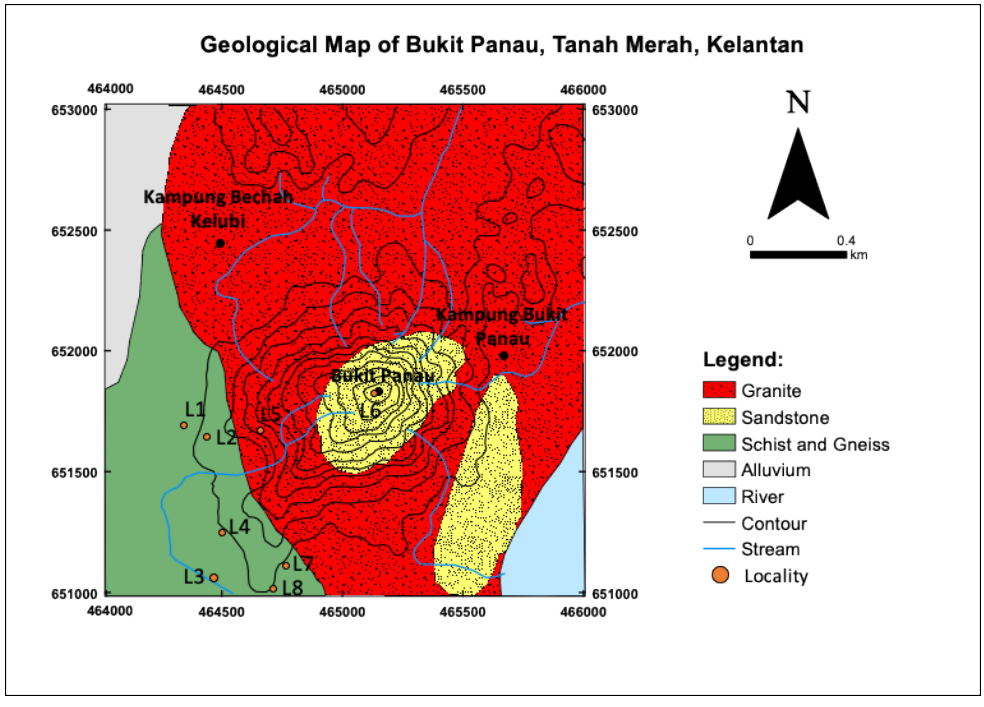

Figure 3 The geological map of Bukit Panau, Tanah Merah, Kelantan which is adapted from [7] and marked on this map is the localities where the fieldworks were conducted

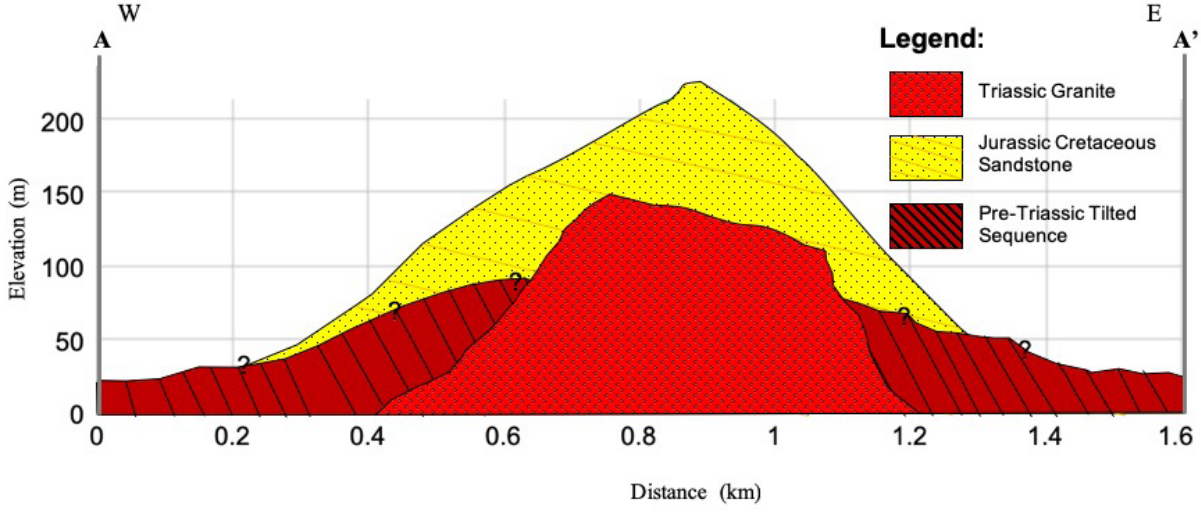

Figure 4 The proposed geological cross section of Bukit Panau from west to east of the hill

Proposed Geological Cross Section

The proposed geological cross section shown in Figure 4 is constructed from west to east direction based on the field observation on the study area and geological map of Bukit Panau. The beddings in Locality 3 situated at the southwest of Bukit Panau are observed to be tilting at almost vertical angle with the dipping range between 70° to 89° as shown in Figure 5.

As for the contact between the granite rock and the overlying sedimentary sequence, the contact metamorphism was not present in between those two lithologies during the field observation in Locality 4 and due to the horizontality of the sedimentary sequence overlying the granite rock, it indicates that there is absence of structural deformation occurred to the sedimentary sequence. Therefore, it is believed that the contact between the sedimentary sequence and the underlying granite is a nonconformity.

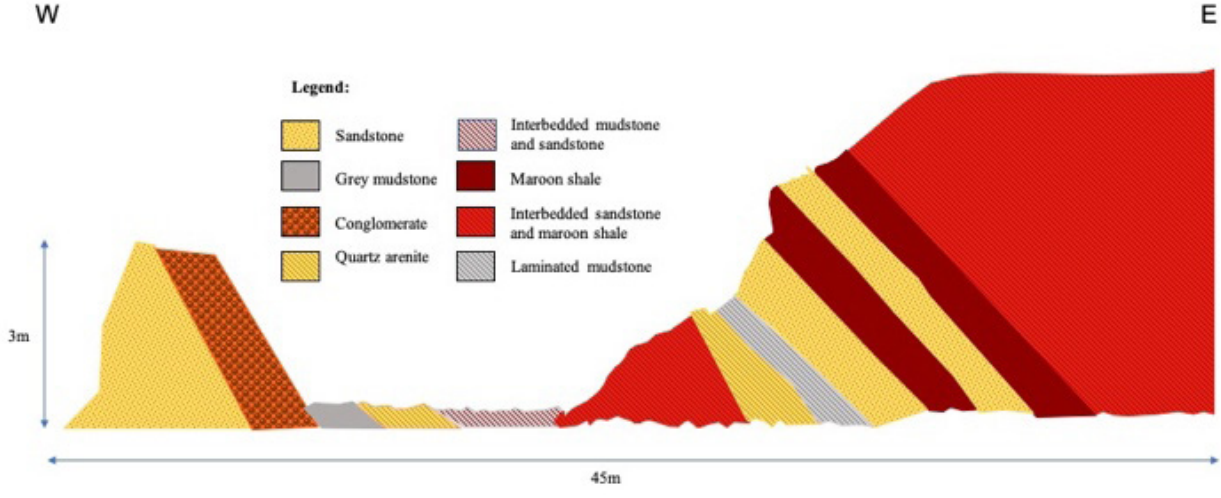

Figure 5 Lithology cross section of Locality 3 [7]

Figure 6 The granite rock body underlying the sedimentary rocks above it in Locality 4

As all the relevant geological information is assembled together to form the geological cross section as shown in Figure 4, it is convinced that there are two possible types of unconformities discovered which are the angular unconformity and nonconformity. The rock layers in Locality 3 existed first and then, tilted due to thrust fault or uplifting prior to the intrusion of granite in the pre-existed tilted rock layers afterwards. Overtime, the surface of the granite eroded away and new sediment sequence deposited on top of the granite and emulating its surface shape. With this, it can be said that the tilted sequence at the foothill of Bukit Panau belongs to a different formation due to the different sequence structure and geological age compared to the Panau Formation. In addition, the tilted sequence is older than the granite rock of Triassic age and the Jurassic Cretaceous Panau Formation.

Depositional Environment

Based on the field observation made in Bukit Panau, it can be observed that the hill is mainly comprises of red to maroon beds which are usually the sandstone and shale successions. The origin of the red to maroon beds are due to the presence of iron into the sediments during the detrital burial and the iron converted to hematite during the early diagenesis where such events are most likely to occur in non-marine environment and it is most likely the case for Bukit Panau. The sediments in Bukit Panau indicates that its depositional environment is fluvial due to the presence of cross bedding in the sandstone and graded bedding fining upwards [7]. The Bukit Panau was once a floodplain depositional due to the presence of parallel lamination in the sandstone and mudstone. Apart from that, the sequence at the foothill of Bukit Panau could possibly once in a transitional environment like the beach for a period of time due to the presence of quartz arenite bedrock where this rock is known to be the repeated reworked sediments and become a new rock. There are several graded beddings in the Panau Formation with sediments fining upwards and some with coarsening upwards which indicates that this formation has undergone several cycles of rising and falling sea level and the level of depositional energy has influenced the deposition of sediments [3]. The coarsening upward sequence could possibly indicate a coastal area or delta environment and as for the fining upward sequence, it is dominant in meandering, point-bar or tidal channel deposits as there is an upward decrease in fluid velocity within a channel.

Petrographic Analysis

Quartz Arenite

It can be observed that the quartz arenite has overgrowth quartz grains that are well-developed and they are coated with possibly red hematite or iron oxide. The main mineral of this rock is monocrystalline quartz of subhedral and euhedral crystal form. There is absence of twinning in this rock. It is predicted that the feldspar grains exhibit effects of dissolution (Figure 7).

Granite

The petrography of granite is shown in Figure 8 where the granite sample was obtained at Locality 4 displayed in the geological map of Bukit Panau. This granite consists of phenocrysts orthoclase and large plagioclase crystals among the smaller grain size subhedral to euhedral quartz which intergrows with feldspar grains. Orthoclase has a subhedral crystal for and plagioclase occurs as laths in anhedral crystal with polynthetic twinning, perfect cleavage and triclinic crystal system.

Greywacke

Based on the minerals in the petrography shown in Figure 9, the rock is classified as a greywacke where the grains comprise of various size range and they are very poorly sorted. The greywacke comprises of angular quartz grains, feldspar and lithic grains in the possibly silt-grade quartz. The clear angular grains are mainly quartz whereas feldspar is represented by the cloudy grains. It can be observed that there is presence of irregular fractures on the quartz grains. Such fractures usually occur in minerals with poor or no cleavage which could possibly due to the exposure from the external mechanical or internal stress during the rapid cooling of minerals.

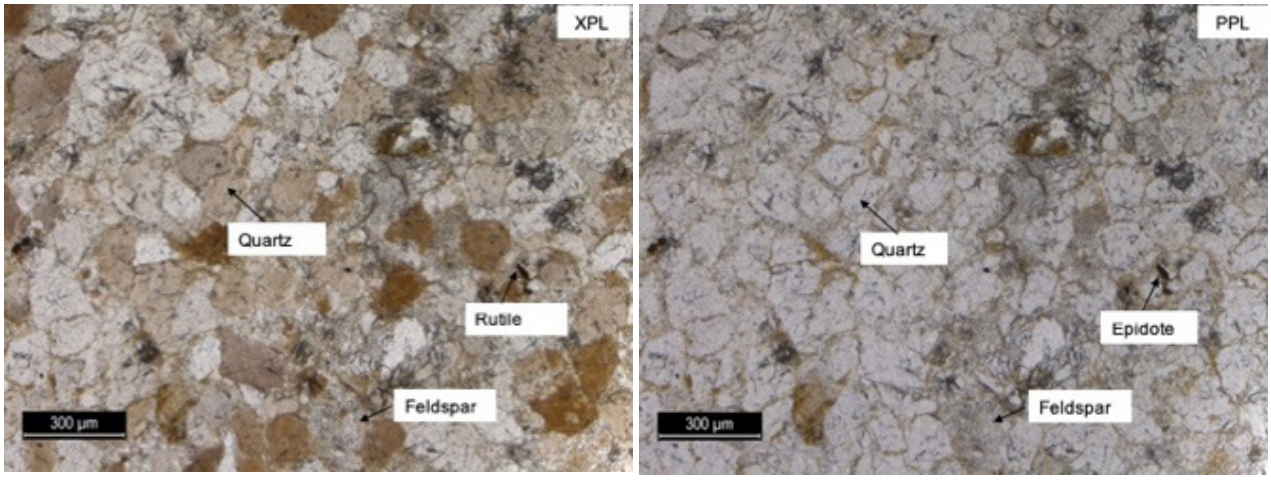

Figure 7 Quartz arenite in crossed polarized (XPL) and plane polarized (PPL)

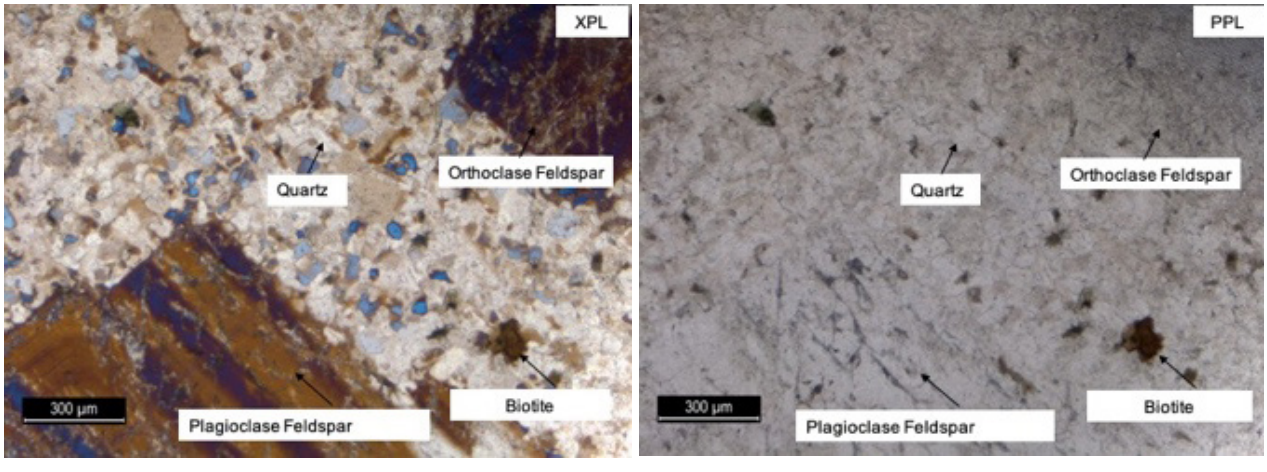

Figure 8 The minerals in granite rock under crossed polarized (XPL) and plane polarized (PPL)

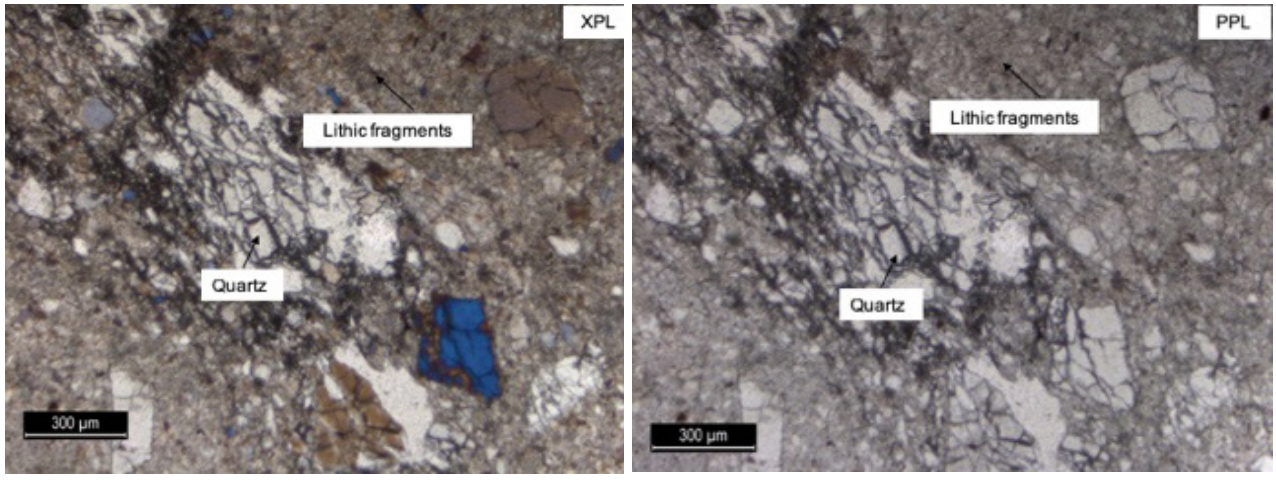

Figure 9 The minerals that are contained in greywacke rock under crossed polarized (XPL) and plane polarized (PPL)

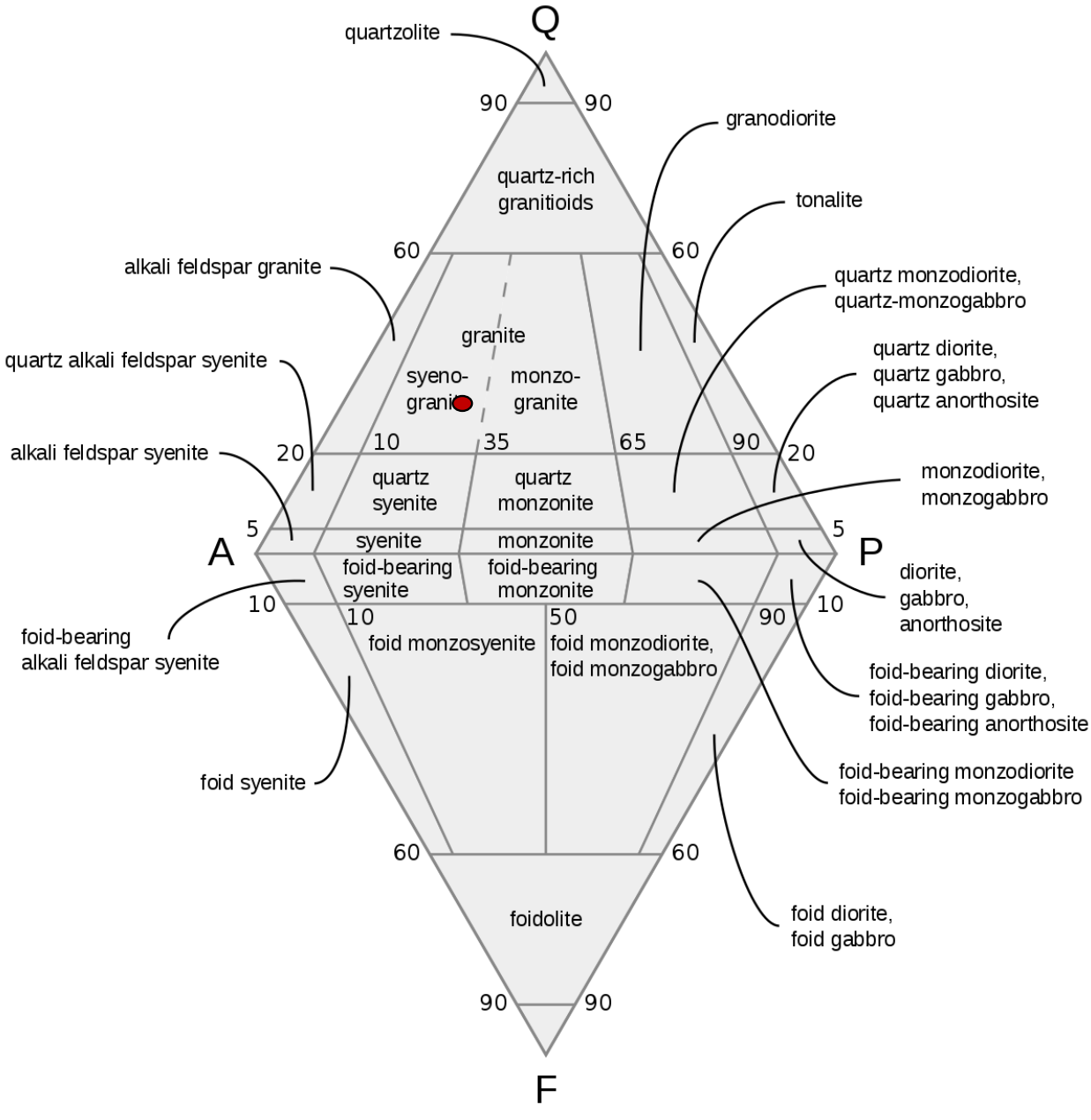

Figure 10 Plotting of the normalized quartz, alkali feldspar and plagioclase minerals that fall under the syenogranite in the QAPF diagram

Granite Identification in Bukit Panau

In order to identify the type of granite that Bukit Panau has, the granite sample obtained from the study area has been sent for XRF analysis and the obtained percentage of the chemical compositions are then used to calculate the exact percentage of quartz, k-feldspar and plagioclase by utilizing the CIPW Normative calculation. Based on the calculations, the weight percentage norm for quartz is 26.31%, plagioclase is 15.46% and orthoclase is 42.02%. The weight percentage norm obtained for the three minerals have to be normalized first prior to construct the QAPF diagram in order to obtain a total of 100% for those three minerals. Based on the normalization of these minerals, the calculated quartz is 31%, alkali feldspar is 50% and plagioclase is 19%.

However, alkali feldspar and plagioclase have to be normalized again to obtain a total of 100% for those two minerals in order to plot the three minerals in the QAPF diagram. After the second normalization, the final percentages for all three minerals are plotted in the QAPF diagram as shown in Figure 10. Based on the plotting on the QAPF diagram, the type of granite that Bukit Panau has is the syenogranite. This type of granite is an intrusive igneous rock with fine to course grain size and has the same general composition as granite. The syenogranite is felsic as it has high content of alkali feldspar. This type of granite is still in the granitoid range and can be found in Boundary Range Granite [8].

CONCLUSION & RECOMMENDATION

Bukit Panau is remarked as a unique hill due to it being an isolated hill surrounded by a flat land and based on the other previous studies conducted on that area, there are loopholes identified which have been further investigated and justified in this research such as the type of contact the granite rock and the overlying sedimentary rocks and the stratigraphic succession of the Jurassic-Cretaceous sequence. The objectives of this project has been achieved by utilizing and implementing the mentioned methodologies. From this study, it can be concluded that there could potentially be two types of unconformities in Bukit Panau which are the angular unconformity and non-conformity. However, both unconformity contacts are unable to be found due to highly weathered rocks in Bukit Panau. It is believed that the tilted sequence at the foothill of Bukit Panau occurred first prior to the intrusion of granite which is then, followed by the deposition of Panau Formation. With this, the pre-Triassic tilted sequence is believed to belong to a different formation due to its different sequence structure and geological age with the Jurassic Cretaceous Panau Formation. Apart from that, the identified granite in Bukit Panau is a syenogranite which is known as a felsic intrusive igneous rock based on the geochemical studies conducted and this type granite can be found in the Boundary Range Granite in Peninsular Malaysia.

Based on the studies and analysis conducted on this project, it is believed that the studies on this solitaire hill of Bukit Panau should be continued in order to find out more on the unconformity contacts and identify the actual geological age of the tilted sequence at the foothill of Bukit Panau and to which formation it belongs to as it is believed that Bukit Panau has more than one formation. The continuation of this study is suggested to be conduct in the North-East of Bukit Panau as that part of Bukit Panau has yet to be discovered and studied.

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AUTHORS' INFORMATION

Nur Farrina binti Asshari holds a Bachelor degree Honours in Petroleum Geoscience from Universiti Teknologi Petronas. Before her graduation from her prestigious alma mater, she did her industrial training as a Well Engineer in Petronas Carigali Sdn Bhd where she was involved in various tasks and jobs related to the integrity, intervention and workover of the wells in Malaysia. She did her industrial project on the plug and abandonment of a well in Malaysia which involved the design and preliminary stages of plugging and abandoning the well. Her final year project titled Geology of Bukit Panau has earned her a place in the esteemed Science & Engineering Design Exhibition (SEDEX) that has acted as a platform for her to showcase her remarkable discoveries on the uniquely isolated hill in Kelantan. Her high adaptability to be in a different field is driven by her strong passion for gaining new knowledge, and she has vowed never to stop learning.

Askury Abd Kadir is a former associate professor who completed his BSc (Hons) in Geology major in Economic Geology from UKM and obtained MSc in Engineering Geology from Leeds University. His MSc research topic was "The determination of shrinkage limit for clay soils using a travelling microscope with a comparison to the established definitive method (TRRL)". After 24.5 years served as a Government Servant in the Minerals and Geoscience Department, he decided to join UTP for sharing his vast experience with students as a field geologist. Associate Professor in Geoscience Department, he involved with teaching and research on geomechanical properties of rocks, structural geology and engineering geology. He is also actively involved in AAPG-UTP-Student Chapter as an Advisor on students' activities and Council Member of Geological Society of Malaysia.