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LIMESTONE-GRANITE CONTACT ZONE IN THE DAYANG BUNTING & TUBA ISLANDS, MALAYSIA: AN EDUCATIONAL OUTDOOR GEOTOURISM LABORATORY

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Abstract: This paper discusses a research conducted in Dayang Bunting and Tuba Islands, Langkawi, Malaysia, in an effort to promote these islands as educational geosites to explain the process and impact of contact metamorphism to the public. The research activities involves evaluation of microscopic rock samples from the closest to the farthest distance from the metamorphism contact zone. The evaluation involves examining grain size, zonation, shape, and fabric of minerals in rock samples. Pronounced changes were observed from different distances from the contact zone as indicated by the change in grain size, grain shape and zoning in the mineral. These informations are stored in a database that is accessible to the public in the future.

Key words: Dayang Bunting Island, Tuba Island, Langkawi Geopark, contact metamorphism, educational geosites

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INTRODUCTION

The Dayang Bunting and Tuba Islands located at the southern part of the Langkawi main island are rich in geological marvels. These two islands have many areas with exposed rock outcrops that enable studies in different aspects such as engineering geology, geomorphology to geotourism. Being part of the Langkawi archipelago, these islands are not only rich in geological history but are also well-known tourist spots, thanks to the duty free status bestowed on the Langkawi Island which is also listed as

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Global Geopark by UNESCO in 2007. However, some sections of these islands are secluded, hence, their natural settings are still left intact. Apart from offering numerous attractions to tourists, geoheritage conservation practices should have an educational aim (Brocx & Semeniuk, 2007; Palacios et al., 2012) that includes important geological processes with great scientific, aesthetic, and educational values (De Carvalho & Rodriques, 2009). There are several established geosites that have been used for educational purposes elsewhere. The few examples are Ordovician Ichnofossils in Arouca Geopark (Artur, 2009), lava delta geosite (Nunes & Lima, 2009), and river features in Tiete Headwaters Park demarcated by the Brazillian Geography Society (Velaquez et al., 2013). These examples of geosites, can have high potential for scientific studies, use as outdoor classrooms, enhancing public understanding of science, recreational use, and economic support to local communities (Kepalaitè, 2015).

The presence of the contact zone between limestone and granite in these two islands provides an opportunity to the authors to study how this feature can be used to reach out and educated the public on the importance of geology not only locally but also regionally. In this study, an initiative has been taken to explore the possibility of making these two islands a field laboratory for geological studies by examining changes in rock micro-features at various distances from the contact zone. Thus, to achieve the aim mentioned above, two objectives have been designed; the first objective is to determine the type of rocks that are present in both islands and subsequently, analyzes the changes of rock micro-features in terms of grain size, mineral composition, mineral shapes, and rock texture at varying distance from the contact zone. These changes will indicate the intensity level of metamorphism at various distances. This study hopes that by instilling sense of wonders and curiosity, visitors will be motivated to revisit this geosite (Allan et al., 2015).

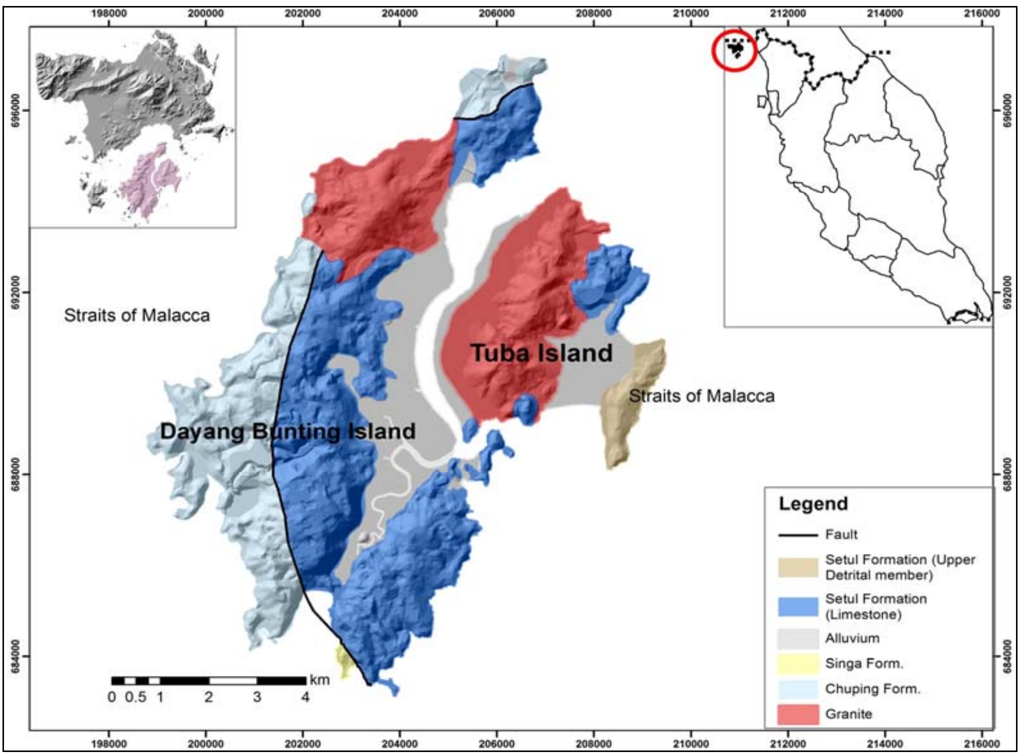


Figure 1. The location of the study area with geological information

GEOLOGY OF THE STUDY AREA

In general, the Dayang Bunting and Tuba Islands are underlain by two main rock formations known as Chuping and Setul Formations, granite bodies and alluvium which covers the coastal plain.

a) Setul Formation

The Setul Formation was named after the Setul Range bordering Malaysia (west of Perlis) and south of Thailand (Jones, 1981). The rock unit was formed in middle Ordovician to Early-Devonian, around 450 million to 410 million years based on the findings of gastropod and cephalopods fossils (Jones, 1978). It consists of two lithologies; limestone and detrital components (Jones, 1981; Jantan et al., 1989) which can be divided into four members, i.e., lower Setul limestone member, lower detrital member, upper Setul limestone, and upper detrital member.

The upper detrital member composed of quartzite and gray subgreywacke, gray, brown and black carbonaceous shale and red shale (Harun et al., 1998), while the lower-detrital member consists of quartzite, limestone, pyhllite, slate, and siliceous mudstone (Jones, 1978). The lower-detrital member also contains fossils of graptolites, trilobites and other old Llandonvery fossils (Harun et al., 1998). Jones (1981) have interpreted that the Setul Formation Setul was deposited in a shallow continental shelf.

b) Chuping Formation

The Chuping Formation which got its name from Chuping hill in Perlis consists of a sedimentary rock sequence that overlain conformably on the Singa Formation. In the Langkawi archipelago, the Chuping Formation is distributed in Dayang Bunting Island, and in the Langkawi main island (Kg Belanga Pecah & Kg Kisap). Chuping Formation consists of white to light gray limestone. At some places, it has undergone metamorphism and turned into marble.

c) Granite Body

Massive granite bodies are found at the northwestern part of the Dayang Bunting Island and in the center of the Tuba Island. These granite bodies are related to the two large granite batoliths known as Gunung Raya and Bukit Sawar in the main island of Langkawi. These granites can also be observed at several other localities such as Kuah and Teluk Apau. The age of these granites ranges from 217 m.a to 209 m.a. (Triassic period) based on radiometric dating done by Bignell & Snelling (1977).

d) Alluvium

Quaternary sediments cover a large area on the island of Langkawi. These deposits were mostly concentrated in the western part of the island and consist of marine and fluvial sediments. They are found mostly at the east on the eastern part of Dayang Bunting and Tuba Islands and with small occurrences along the western coast of the Tuba Island.

METHODOLOGY

Petrographic analysis was conducted to examine changes in composition, grain size and rock fabric from rock samples taken in every station. The analysis involves 50 rock samples collected from various locations around the Dayang Bunting and Tuba Islands. These rock samples were cut into rectangular shape with a dimenstion of 5cm x 2cm x2cm (length x width x height). Subsequently, the samples were placed on a heating element and heated with a temperature of 400°C for an hour and Canada Balsam was applied on each of the samples surface. These samples were left overnight to cool. The surface with Canada Balsam was later affixed to a glass slide with a glue and left for several days so that the glass slide will attached firmly on the samples.

After several days, the samples were polished with carborundum powder until they are translucent with 0.03mm thickness. In the final stage of the preparation, the samples were left to dry overnight before they were washed and cleaned with soapy water and acetone. After these processes, the samples are ready for the next stage of preparation, which is known as 'staining.' Staining is a colouring process used to identify types of minerals or grains in a rock. In this study, the staining process was conducted to distinguish carbonate cement in the rock and to categorize them into calcite, fero-calcite, or dolomite. The colouring process involve mixing two types of solution known as Alizarin Red S and Potassium Ferrycianide.

PETROGRAPHIC ANALYSIS

A petrographic analysis of rock samples taken from various locations (Figure 2) in the study area were conducted to examine the characteristics of rocks in the Setul and Chuping Formations. These petrographic studies were also used to examine changes of rock micro-features brought about by contact metamorphism during the granite intrusion. The microscopic descriptions based on petrographic analysis of selected of rocks samples are as follows.

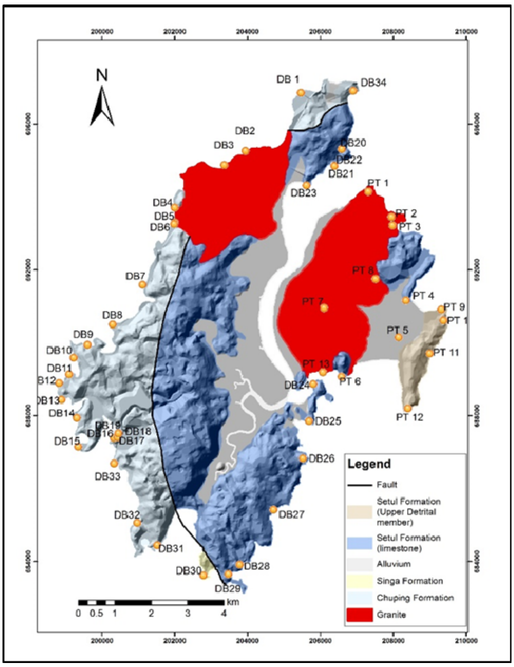
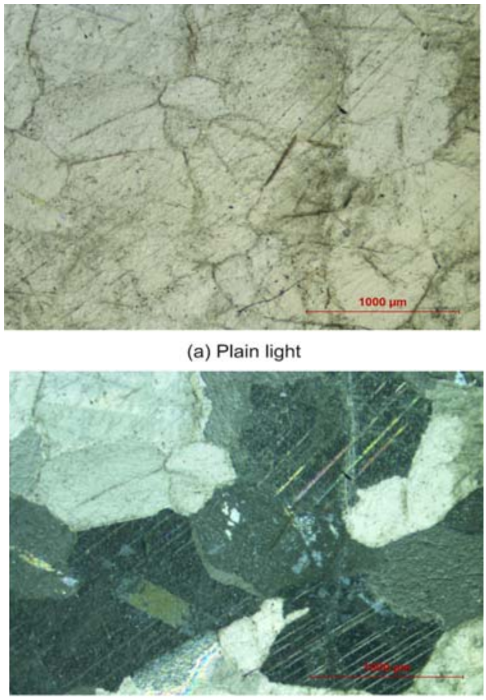


Figure 2. Sampling locations around the Dayang Bunting and Tuba Islands



(a) Plain light

(b) Crossed polarized light

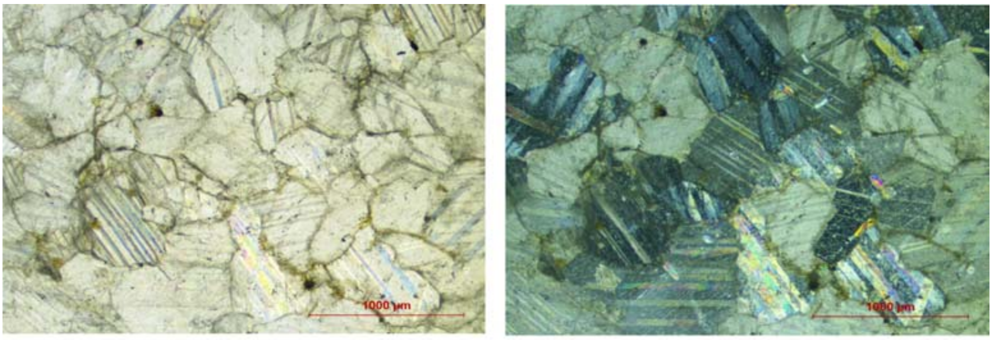
Figure 3. Microscope view of marble (sample DB4) collected next to granite intrusion in the Dayang Bunting Island consists almost entirely of calcite

a) Calcite Marble

Samples of this rock were collected adjacent to the granite intrusion. Based on petrographic observation, the rock has very coarse grain size indicating that recrystallization has occurred. The sample consists of almost 95% calcite showing anhedral texture (Figure 3). Evidently, the presence of granoblast texture is obvious observed in the sample which again shows that the sample rock has has undergone recrystallization from limestone to marble.

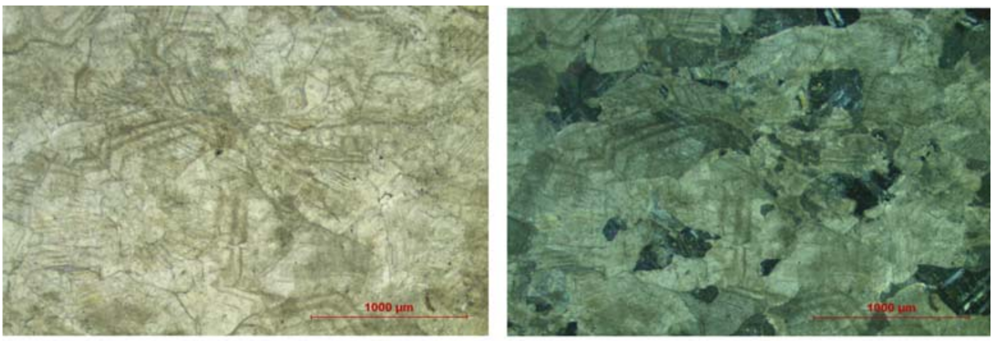
Dolomite Marble

This rock is well exposed in the western part of Pulau Dayang Bunting and southwestern tip of Tuba Island. The rock consisting of 95% dolomite. The presence of granoblas texture in this rock indicates that the parent rock has undergone metamorphism. Figure 4 shows the sample of this rock type taken from Pulau Tuba under a microscopic view. Medium to coarse grain dolomites with xenotopic texture are distributed unevenly in the sample. Zoning- like appearance was also observed in other sample taken from other locations (Figure 5).



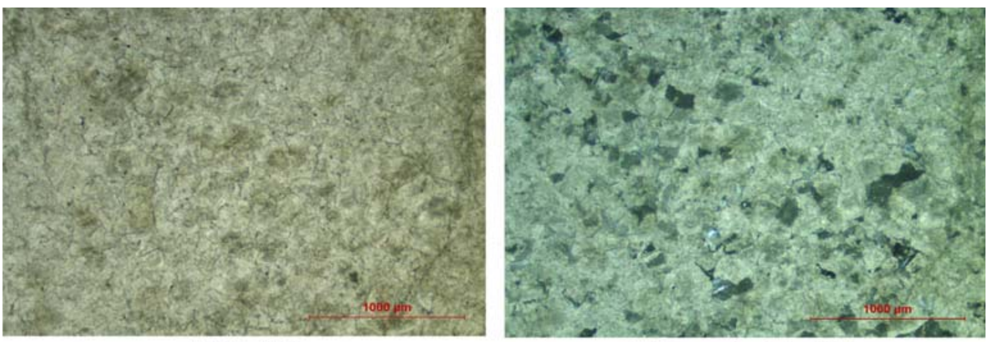
(a) Plain light (b) Crossed polarized light

Figure 4. Dolomite marble (sample PT13) collected from Tuba Island showing xenotopic texture



(a) Plain light (b) Crossed polarized light

Figure 5. Dolomite marble (sample DB12) collected from Dayang Bunting Island shows zoning in crystals

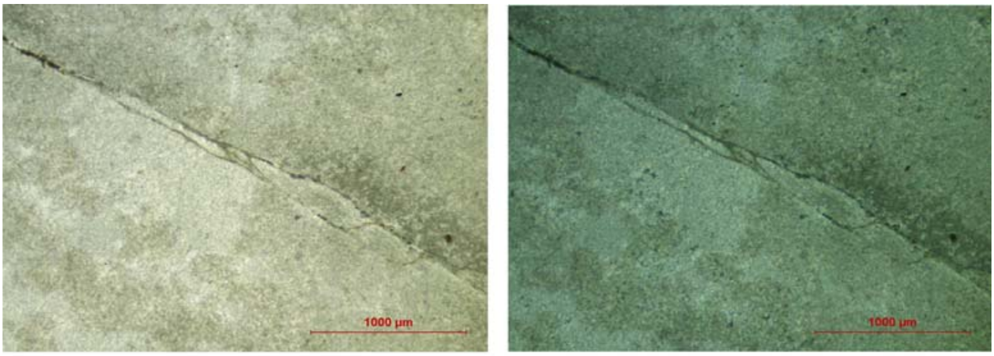


(a) Plain light (b) Crossed polarized light

Figure 6. Microscope view of fine grain dolomicrite rock (sample DB17) collected from Dayang Bunting Island

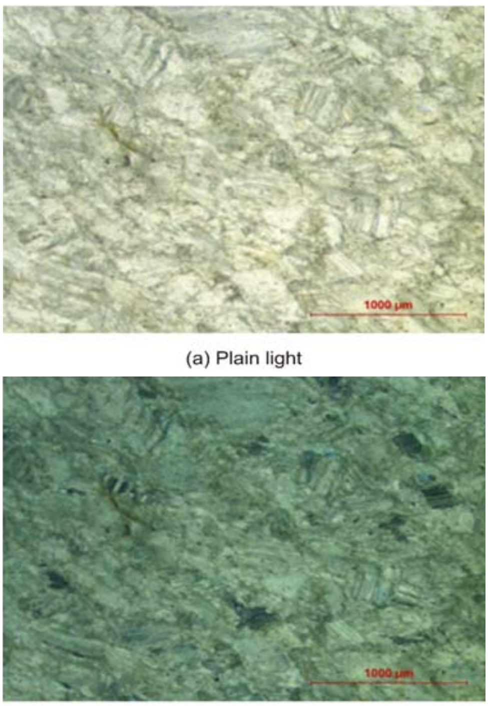
a) Dolomicrite

The difference between this rock with the calcite and dolomite marbles is its grains size and its mineral content in which the dolomite mineral approaching 90 - 95%, with subordinate occurrence of calcite (0-10%). Based on the petrographic investigation, this rock type consists of very fine grain size that are not evenly distributed. Apart from its grains distribution, granoblast texture of euhedral to anhedral crystals were also observed in the rock sample DB17 (Figure 6).



(a) Plain light (b) Crossed polarized light

Figure 7. Fine-grained dolomitic mudstone (DB33) dominantly distributed in the south of Dayang Bunting Island



(a) Plain light

(b) Crossed polarized light

Figure 8. Ferroan Dolomite Marble collected at location DB20 in Dayang Bunting Island

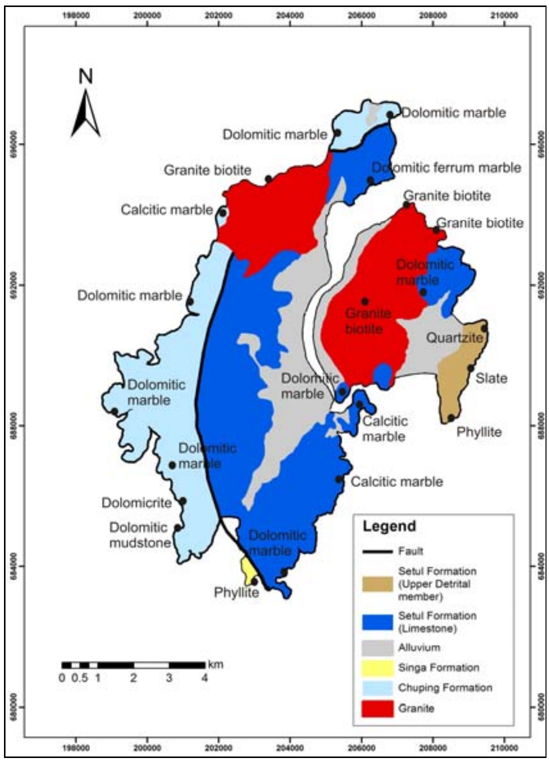


Figure 9. The type of lithologies found in both islands

a) Dolomitic Mudstone

This rock is characterized by the presence of 80 % micrite and mainly distributed in the southern part of Dayang Bunting Island. Its matrix comprises mainly of dolomicrite. The distribution of dolomite minerals in the sample are random and have no specific arrangement and fabric (Figure 7).

b) Ferroan Dolomite Marble

This lithology is part of the Setul Formation and widely exposed in the northern part of the Dayang Bunting Island. Staining method using Alizarin Red S and potassium ferricyanide produces blue colour,due to the presence of ferrum in the rock samples. The sample observed consists of 85% to 90% dolomite and 3% to 10% calcite with grain size ranges from medium to fine (Figure 8). In addition, the rock shows anhedral minerals with xenotopic texture, which could be associated with metamorphism.

c) Type of lithologies

Based on field observation and petrographic investigation, the distribution of rock types in the Dayang Bunting and Tuba Islands can be identified (Figure 9). The type of lithologies observed in both islands are dolomitic marble, dolomicrite, dolomitic mudstone, calcitic marble, dolomitic ferum marble, biotite granite, quartzite, slate, and phyllite.

METAMORPHIC GRADE

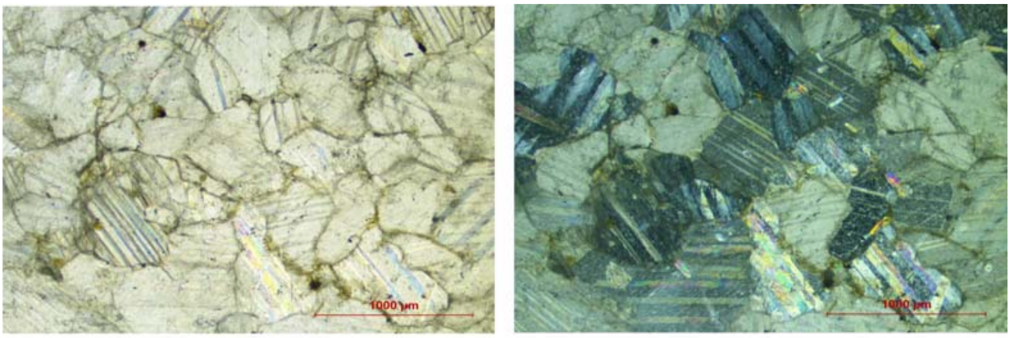
Petrographic studies were conducted to examine changes in the micro-features of limestone due to the effect of different metamorphism intensity experienced by both the Chuping and Setul Formations. In order for a rock to adapt to temperatures and pressures that are relatively higher than its initial formation, changes in minerals, texture and structure need to occur. Its microphysical features will be altered at different levels in accordance to the different metamorphism intensity the rock is exposed to. Petrographic studies show that the limestone in the study area has experienced contact metamorphism from granite intrusion with high heat from this intrusion has metamorphosed its surrounding rocks. To examine changes in microphysical appearance of these limestones, the changes in mineral composition and size, texture and crystal arrangement of limestones taken from various distances from the granite intrusion have been analyzed. This study found that there are significant differences of rock microphysical features from farthest to the closest distance to the boundary of the granite intrusion. The metamorphism grades were determined based on field observation and through detail petrographic studies. For the purpose of discussion, this section divides the metamorphic grade into three level; high, medium, and low.

a) High Grade Metamorphism

Samples representing rocks with high grade metamorphism were collected at very close proximity to the granite intrusion, which is around the contact between limestone and the granite body (Figure 10). These rock samples display clean polished white color marble. One of the sampling area was a former marble quarry where marbles with the aforementioned feature is abundant. In addition, limestones from the Chuping Formation that are located around the border of the limestone-granite contact zone contain a subtle greenish colour mineral, which is identified as wolastonite. This mineral was formed as a result of chemical interaction between calcite and silica at high temperatures. Jones (1981) recorded an almost 3 inches wide of this mineral in the study area. Based on the petrographic examination, the grain size of the mineral is around 1000 µm in average, which indicate that the rock forming minerals; dolomite & calcite had undergone high level of recrystallization.

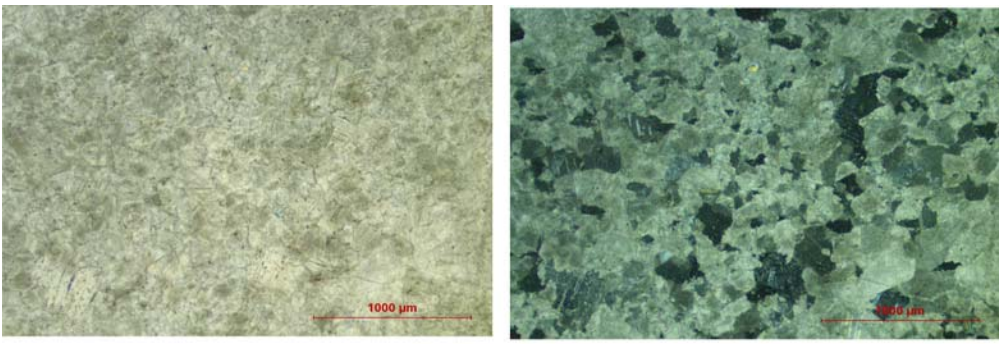
b) Medium Grade Metamorphism

Samples to represent this group were collected approximately 3 to 6 km from the granite intrusions. The field samples display white to bright greyish colour. From the petrographic analysis, sample with medium-grade metamorphism show finer grain size than the high-grade metamorphic rock, which shows the intensity of the process occurred at a lower temperature than the rock in high-grade metamorphism group. Based on the composition, dolomite crystal with anhedral shape and xenotopic texture is also present in the sample. The crystals size are finer as compared to the high grade metamorphism rock (Figure 11).



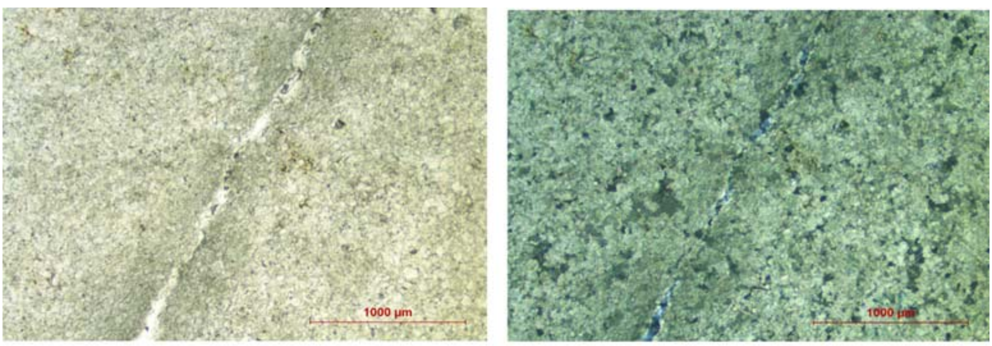
(a) Plain light (b) Crossed polarized light

Figure 10. Microscopic view of calcite and dolomite marble with coarse-grained mineral due to recrystallization. Sample was collected at station PT13



(a) Plain light (b) Crossed polarized light

Figure 11. Microscopic view of medium-grained with anhedral crystal shape metamorphic rock in DB19



(a) Plain light (b) Crossed polarized light

Figure 12. Fine-grained low-grade metamorphic rock collected at station DB31 in the Dayang Bunting Island

c) Low-grade Metamorphism

The samples representing low-grade metamorphic rocks was collected around 6 to 8 km from the limestone-granite contact zone. The samples are characterized by bright to dark gray in colour. At this distance, the rocks also show clear characteristics of carbonate sediment layers. Based on petrographic studies, the low-grade metamorphic rocks consist of very fine-grained crystals compared to the medium and high-grade metamorphic rocks (Figure 12). The result also shows that the limestone characteristics are still pronounced.

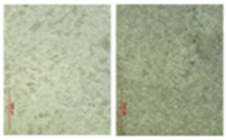
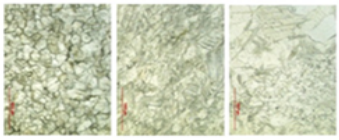
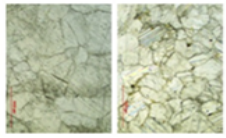
Metamorphism	Low-grade	Medium-grade	High-grade
Microscopic view			
Grain size	Fine	Medium	Coarse
Crystal form	Not clear	Subhedral to anhedral	Anhedral
Fabric	Fabric is unclear and minerals are in random arrangement	Xenotopic and hidiotopic	Xenotopic & compact
Mineral composition	Fine-grain dolomite	Dolomite & calcite	Dolomite & calcite
Rock type	Dolomitic mudstone & dolomicrite	Dolomitic marble	Calcitic & dolomitic marble

Figure 13. Fine-grained low-grade metamorphic rock collected at station DB31 in the Dayang Bunting Island

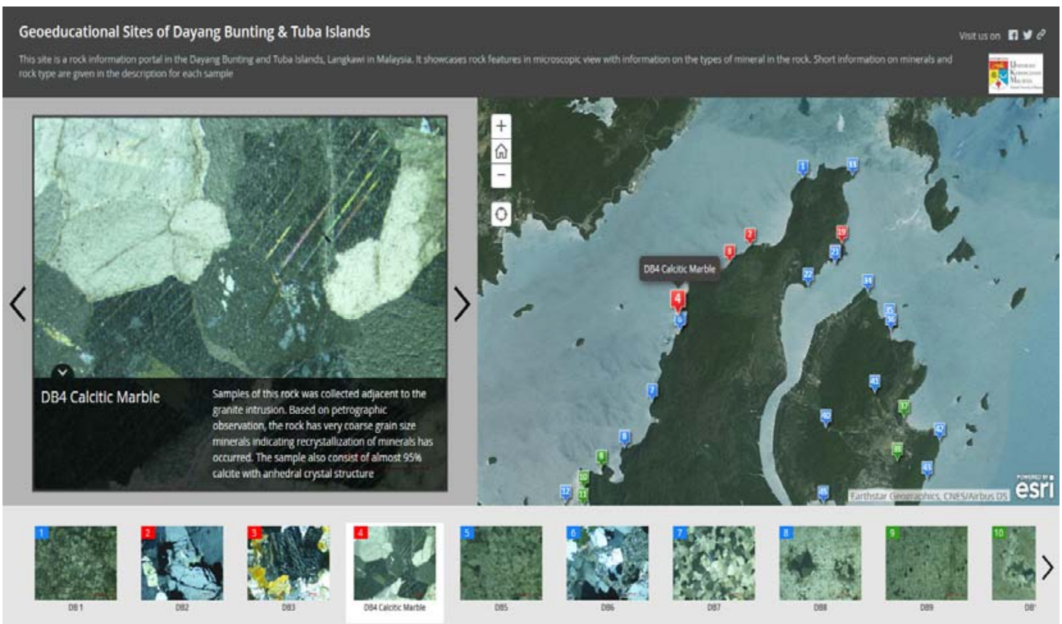


Figure 14. The findings of this research are stored in a database which can be viewed by the public once the website for the geosites completed

COMPARISON OF ROCK MICRO-FEATURES IN DIFFERENT GRADE OF METAMORPHISM

The micro-features of the three different grade metamorphic rocks are summarized in Figure 13. It is evident that the grain size of minerals found in the high-grade metamorphic rock is coarser than the low to medium-grade metamorphic rocks.

The crystal form is not visible in the low-grade metamorphic rock due to its fine-grained size mineral, however, minerals in the medium-grade metamorphic rock display subhedral to anhedral shapes, while in the high-grade group, anhedral crystals are evident.

In terms of fabric, the arrangement in the low-grade group is indistinct, while the medium-grade display xenotopic and hidiotopic textures. The high-grade rock exhibits xenotopic and compact mineral texture. The dominant minerals presence in all groups are similar; namely dolomite and calcite with impurities such as mud can be found in the low-grade metamorphic rock. Apart from the differences shown in Figure 13, the minerals in the high-grade metamorphic rocks appear to be much brighter and have smoother border between minerals than other metamorphism grade rocks.

Based on the petrographic analysis, the lithologies for the low-, medium-, and high-grade metamorphic rocks are dolomitic mudstone & dolomicrite, calcite marble, and dolomite marble accordingly.

DATABASE ON GEOEDUCATIONAL SITES OF DAYANG BUNTING & TUBA ISLANDS

The geoeducational sites consisting of the study samples and their locations were plotted on a satellite image, described and displayed to the public using ESRI services 'map tour' (Figure 14). This is one of the efforts that can be employed to provide an appropriate educational settings to raise awareness of the importance of geological conservation and also as one of a special form of tourism for tourists seeking new destinations (Bâca, 2015; Mrkša, 2015). Currently, information on locations and descriptions of rock micro-features are still under construction. Efforts to gather information on the geomorphology and some other sites that can be used as geoeducational sites are still on-going and will be uploaded to the website once completed. The partially function website is shown in Figure 14.

CONCLUSION

Based on the field observation and petrographic analyses of rock samples from various locations and distances from the limestone-granite contact zone, it can be summarized that the limestones in the study area display significant changes in terms of texture, types and conditions of mineral and grain size when the distance to the contact zone differ. The limestone member of the Chuping Formation demonstrates changes in terms of grain size, shape of the crystal structure and composition when it gets closer to the contact zone. Similarly, whilst the limestone in the Setul Formation shows changes in grain size, shape and mineral compositions at varying distance from the contact zone found in Pulau Tuba.

From the overall result, it can be concluded that the limestone in the study area has undergone a process of contact metamorphism as a result of granite intrusion. However, the level of metamorphism intensity experienced by the surrounding rocks is influenced by the distance of the rock from the contact zone. This is evident based on the changes of grain size and shape, mineral composition and the characteristics of the minerals under the microscope.

Apart from the effort to make the Dayang Bunting and Tuba Islands as field laboratory based on scientific finding, the authors hope that the effort and results from this study will benefit not just the scientific communities, but also to authorities and the public on sustainable development in the future for both islands so that areas identified as suitable for geosites in these islands can be conserved.

Acknowledgement

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