Bulletin of the Geological Society of Malaysia, Volume 74, November 2022, pp. 169 - 173
DOI: https://doi.org/10.7186/bgsm74202211

Characterization of dikes at Simpang Pulai quarry, Perak

Muhammad 'Izzat 'Irfan Ahmad Tajuddin[1], Teoh Ying Jia[1,*], Choong Chee Meng[2], Benjamin Sautter[2], Haylay Tsegab[2], Muhammad Hatta Roselee[3]

[1] School of Physics, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia
[2] South East Asia Carbonate Research Laboratory, Universiti Teknologi Petronas, Perak, Malaysia
[3] Geology Department, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
* Corresponding author email address: tyj@usm.my

Abstract: Due to dissolution, weathering and erosion, limestone and marble form karstic landscape with precipitous hills, rugged valleys, caves and sinkholes. In the event of an intrusion, the magma, which resides below the limestone bedrock will ascend toward the earth's surface and fill up the fractures within the pre-existing rocks, forming dikes and sills. Dikes and veins can also be formed when minerals precipitate from hydrothermal fluids within a fracture. The objective of this study was to determine the texture and mineralogy of the dikes cutting the marble in the study area. The findings suggest that the mineral composition and physical structure of the dikes differ from the marble host rock based on its mineral, chemical and physical properties. Three samples were collected and analyzed using Scanning Electron Microscopy (SEM), X-ray diffraction analysis (XRD) and petrographic microscope. The results show that there are at least two types of dike, which are quartz and a coarse-grained granite dike at the study area. The presence of these dikes may affect the chemical and mechanical properties of aggregates produced from the quarry, and in turn affect the excavated rocks of its usage.

Keywords: Simpang Pulai quarry, dikes, petrographic, scanning electron microscope

INTRODUCTION

Perak state is the fourth-largest state in Malaysia, and was known for its plentiful mineral resources; hence, the state's main source of income was once mining. In general, mineral resources in the state are found in Kinta Valley which is mainly made up of karstic limestone. Perak was previously one of the main tin producing states in Malaysia. Between 1876 and 1950, Perak was the world's largest tin producer, with 1,200,000 tonnes of tin production annually. Within the state of Perak, Kinta Valley is known to be the main producer of tin, and it is located in the western part of Perak. Kinta Valley is mainly made up of limestone classified as sedimentary rocks that consists of calcium carbonate ($CaCO_3$). The eastern part of Kinta Valley is bordered by the Main Range, which is the backbone of Peninsular Malaysia. The range forms a batholithic body in a north-south direction and extends more than 400 km in length. The western part of the valley, meanwhile, is connected to the Kledang Range.

Dike formation is a rare geological feature that can be found in the Simpang Pulai area, in the Kinta Valley. Magmatic dikes are formed when magma flows into a cracked rock and solidifies to form a sheet intrusion, and sedimentary dikes are formed when sediments fill an open fracture of a pre-existing crack (Ingham & Bradford, 1960). Quartz dike refers to masses of quartz that was formed by the crystallization of an igneous melt series that described how magma minerals change as they cool on the surface. Quartz is one of the minerals formed during the crystallization of molten rock (Miyashiro, 1975). Highly organized atoms and structures are created during crystallization. The structures can be analysed through a microscope using thin sections and can help to categorize different types of igneous rocks (MacKenzie *et al*., 1982).

STUDY AREA

The study was conducted at the Imerys Mineral Sdn. Bhd. quarry at Simpang Pulai, within Kinta Valley, Perak. There are several pits within the study area as shown in Figure 1. The area is within Kinta Limestone where different geological features due to weathering and erosion of the exposed karst formation are commonly seen. The limestone formation in Kinta Valley is aged between the Lower Paleozoic (Ordovician) and the Upper Paleozoic (Permian) periods (Henri & Amnan, 1995).

METHODOLOGY

Field observation

The main aim of the field observation was to locate and identify the dikes in the quarry. Samples A and B were collected from dikes, while sample C was collected from the host rock. The rock samples were labelled and stored inside sealed bags for further testing in the laboratory.

Thin section analysis

Thin section study was carried out to observe the mineralogy and petrography of rock samples to determine rock types. Images were taken using a microscope to identify and

0126-6187; 2637-109X / Published by the Geological Society of Malaysia.

Figure 1: Satellite image showing the location of the of the study area which conists of several quarry pits owned by Imerys Sdn. Bhd. Picture at bottom right shows the location of dikes.

analyze the optical properties. This analysis was conducted using Toupview software connected to a BX43F-CCD Olympus Digital microscope to capture thin section images. The magnification powers of 2.5X and 4X were used to obtain a clearer view of the crystal structures while using the microscope. Images of rock samples were taken with polarizing and non-polarizing effects. Each rock sample was first crushed into tiny pieces and placed on transparent glasses. Each piece has to be as tiny as possible to ensure the images received are clear and precise. Different features observed in the thin section analysis represent a different type of mineral composition. The images were analyzed and categorized based on their features, including mineral shapes and colors.

X-ray diffractometer (XRD) analysis

Identifying different mineral composition was done by undertaking XRD experiment for phase identification of crystalline materials that make up the rock samples. In order to run the experiment with minimal error, a few steps during sample preparation were taken before proceeding with the experiment.

Each of the rock sample taken from the study area was dried for at least 12 hours before grinding to ensure no contaminations which may cause error in reading. Next, the rock sample was ground using a grinding machine to obtain a powder sample. The powder sample of each rock was stored and placed in a glass bottle with appropriate labels. The powder sample was next transferred onto a plastic sample holder in a small quantity before being gently pressed using a glass slide. Excess powder at the edges of the sample holder has to be removed to ensure the sample holder is smooth before it is placed in the appropriate XRD slot. The XRD machine used for the experiment is the PANalytical X'Pert Pro machine.

The experiment began by scanning the sample, and the data obtained from the machine was stored in a computer. The data was analyzed and interpreted using X'Pert Highscore software after the appropriate instrument settings were selected. The settings were chosen to obtain data such as the mineral composition and intensity of minerals. All information on crystallography is stored in a PDF file for further interpretation. After the first round of testing has been completed, the sample holder is replaced with another holder containing a different rock sample, and similar steps are repeated for each of the powder samples. Safety operating procedures were adhered to to avoid any injuries or damage to the machine.

Scanning electron microscopy (SEM) analysis

Images produced by SEM when the rock sample surfaces are scanned with a focused beam of electrons show the objects' microcrystalline structures. Each of the rock samples has its own crystalline group that helps to indicate and classify the rock types. The collected samples were first broken to expose fresh surfaces. Each chip is about 2-10 mm in size, and they were then cemented and bound on the plate and dried before being placed in the SEM machine. The images generated by the electron emission interact with atoms in the samples and produce signals containing information about the composition and surface topography of the samples. The images provide detailed three-dimensional viewing that enables interpretation of the samples' surface structure (Janssen, 2015).

The geotechnical information from the SEM analysis can also be used to describe the characteristics of rock surfaces. Porosity and grain size, which affect the hardness and surface properties of a rock, are important features required in construction and manufacturing. SEM is thus an effective tool to obtain precise measurements from small features in rocks (Bowles, 1979).

RESULTS

Field observation

From the field observation, sample A (from a dike) is noted to consist of quartz mineral entirely which intruded the host rock that is made up of coarse grain granite and limestone. The dike intrusion is almost vertical across the marble host, with irregular boundaries (Figure 2). The color of the dike (sample A) differs from the host rock: it is milky white while the host rock is more light orange with some dark colors. Rocks from the coarse-grained granite dike (sample B) display a phaneritic texture and contain feldspar and quartz with minor biotite as the main mineral composition. The texture and mineralogy of sample B are similar to the Main Range Granite of Peninsular Malaysia. The width of both dikes is about 1.5 meters and they extend vertically up to 10 to 15 meters. Both sides of the first dike show mixing colors of quartz and the host rock as was also mentioned by Lin *et al.* (2020).

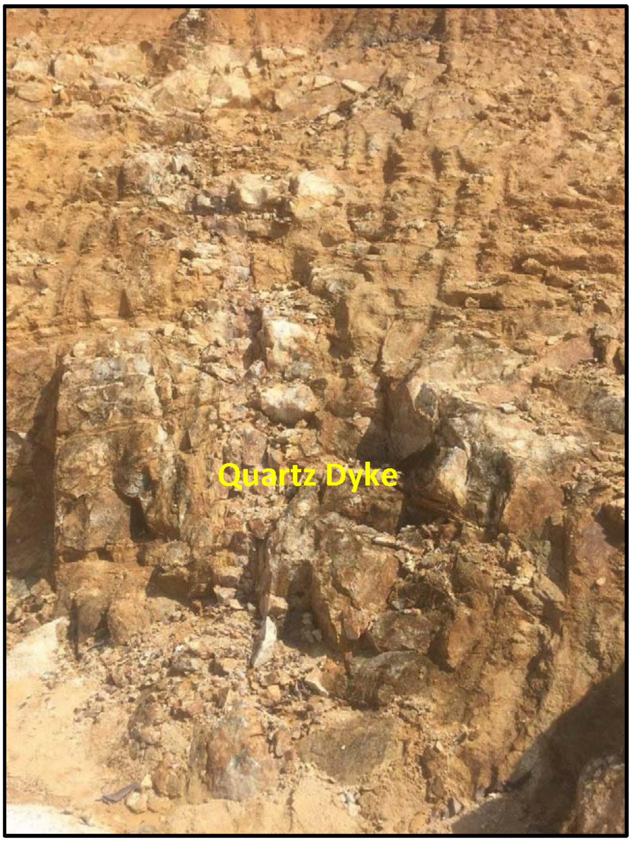

Figure 2: Intrusion of quartz dike into the host rock marble. Note that quartz shows white colour on non-wearthered surfaces.

Petrographic analysis

Thin section study of sample from quartz dike

Based on microscopic observation, the quartz dike (sample A) is generally entirely composed of quartz mineral where the chemical composition is silica oxide. The crystal shape of the quartz is generally irregular or fairly equant as a block cemented together. The quartz exhibits first-order grey interference colour, low relief, and no pleochroism. There is no evidence of alteration within the quartz grains.

Thin section study of coarse grained granite

Based on microscopic observation, the granite that was marked as sample B is mostly dominated by quartz (30%), plagioclase feldspar (30%), and alkali feldspar (40%). Albite-oligoclase is the main plagioclase solid-solution mineral formed in the rock. Plagioclase often shows albite twinning. The twins form a polysynthetic set of parallel lines on certain crystal or cleavage surfaces (Li & Knowles, 2013). The type of the plagioclase can be determined by measuring the extinction angle of the twins following the Michel Levy method.

Thin section study of host rock

From the thin section analysis of sample C, parallel extinctions are clearly shown by the minerals due to the aligned cleavages. The detected rhombohedral cleavages and double refraction phenomenon show that the sample is made up of calcite. Moreover, parallel polysynthetic twinning, which commonly happens during the deformation of calcite because of changing temperatures (Bauer *et al.*, 2018), was also observed.

The host rock that is intruded by the dikes can be classified as marble based on the texture and mineralogy analysis. Marble in the study area is typically massive, with very few thin layered textures. It consists purely of medium grained calcite aggregates with a mosaic texture. Some of the calcite grains show distinct rhombohedral cleavage system. The presence of twinning lamellae calcites in the sample is fairly common. The double refraction characteristic of calcite, where the intensity of the cleavage relief appears dull and sharp when the microscope stage is rotated, can also be observed.

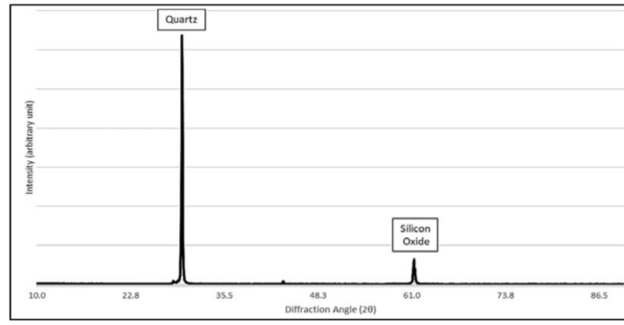

Figure 3: Intensity of mineral composition for rock sample A (Quartz dike). The chemical compound for quartz is silicon oxide. Note that there are two distinct intensity peaks in the diffractogram.

X-ray diffractometer (XRD) analysis

Based on the diffractogram of sample A, there are two major peaks of intensity identified at about 27° and 61° 2θ diffraction angle (Figure 3). The homogeneity of the rock sample is approximately 98% quartz and minor minerals, which is confirmed by the small unidentified peaks. The highest quartz intensity peak for this sample is 6374 cps, and the crystalline size of the mineral is 115nm. Sample B (coarse-grained granite) which was taken in the middle of the dike show high intensities of quartz, plagioclase, and K-felspar (Figure 4). These minerals have high intensities with diffraction angles of 24°, 27°, 35°, and 47°, respectively. The crystalline size value of each mineral is 106nm, 107nm, 218nm, and 171nm, respectively. The marble host rock (sample C) which hosted the coarse-grained granite dike exhibits high intensity of calcite, as demonstrated by the XRD analysis (Figure 5). The intensity of the calcite obtained from this rock sample is approximately 3826 cps with a diffraction angle of 30°. This indicates that the rock sample is 99% calcite (Figure 5). This rock sample has a high intensity of calcite but a low intensity of other minerals.

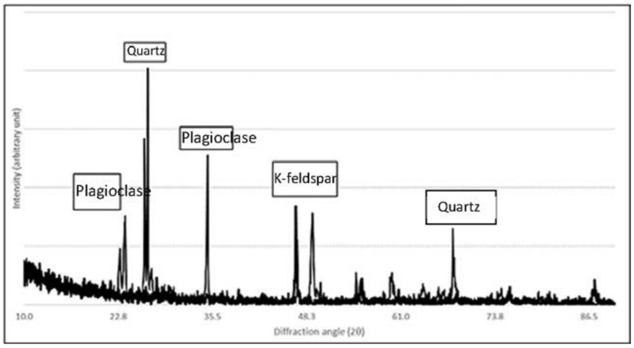

Figure 4: Intensity of mineral composition for rock sample B (coarse grained granite). The notable intensity peaks are for quartz, plagioclase feldspar and K-feldspar, the main mineral constituents.

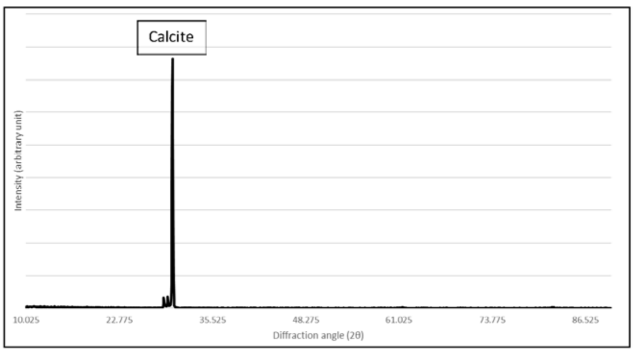

Figure 5: Intensity of mineral composition for rock sample C (marble). There is one clear intensity peak shown in the diffractogram which belong to calcite or also known as calcium carbonate mineral.

Scanning electron microscopy (SEM) analysis

Conchoidal fractures are typical smooth curves of fine-grained material, especially quartz, which does not have a planar surface, no internal weakness, or cleavage directions that occur on minerals lacking cleavage directions (Udayaganesan *et al.*, 2011). This property of quartz is clearly visible in the SEM image as shown in Figure 6.

The presence of various types of minerals in sample A can be recognized in the SEM image. Sample A has more electron charge on the right side compared to the left side (Figure 6), as shown by the different brightness. The existence of elements such as aluminium that contain a high number of electrons will produce a high charging electron effect (Kim *et al.*, 2010). Feldspar has aluminium in its chemical structure. Both feldspars commonly form as elongated lath-like crystals and prismatic crystals (Figure 7). Besides that, the smallest range size observed on the surface of the quartz rock sample is between 2 µm – 4 µm with a depth less than 1 µm. The irregular shapes formed on the rock surfaces and the small fraction of quartz grains indicate that the hydrothermal activity took place in a subaqueous environment (Peterknecht & Tietz, 2011).

DISCUSSION AND CONCLUSION

Results from fieldwork and laboratory data (petrographic, XRD and SEM imaging) show that there

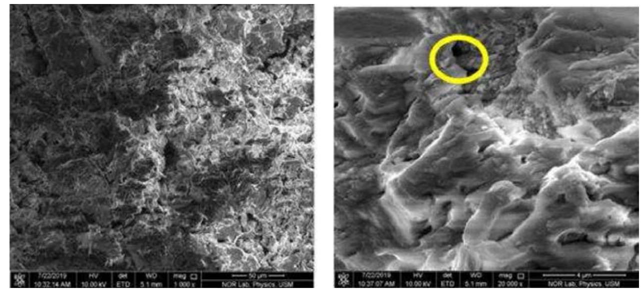

Figure 6: SEM images of sample A (quartz) with different magnification power. The images show quartz is generally anhedral and interlocking with other quartz grains.

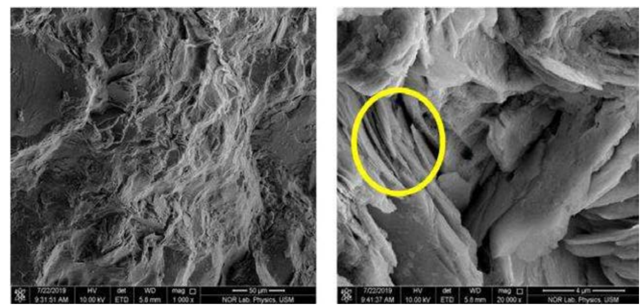

Figure 7: SEM images of sample B (granite) consisting of feldspar, shown with different magnification power.

are at least two dikes of different lithologies within the study area. The first dike is dominated by quartz minerals with minor unidentified impurities. The occurrence of quartz dike indicates that there was a large hydrothermal circulation enriched by silica within the subsurface prior to the formation of the dike. The timing of the hydrothermal circulation could be similar to the formation of the East-West quartz ridge north of Kuala Lumpur which also consists of purely quartz minerals with minor impurities. The other type of dike is dominantly coarse grained granite dominated by quartz-feldspathic and minor biotite minerals. The sample displayed a phaneritic texture with some larger feldspar grains which indicates that the magma that formed the rock had undergone slow crystallization at below-surface depths within the earth's crust (Harker, 2011). The colour of the granite dike is light grey to white. The texture and mineralogy of the coarse-grained dike are similar to the Main Range Granite, which may indicate the timing of the coarse-grained granite formation is almost the same as the granite of the Main Range.

The host rock consists of mainly calcite minerals, as shown by the rhombohedral shaped grains under the microscope, while conchoidal fractures can be seen in the hand specimen. With a low value on the Mohs hardness scale, the rock is breakable with little force to form a smooth and clean surface. SEM images show rhombohedral and scalenohedral morphology grains as well as lath-shaped structures (Figure 8).

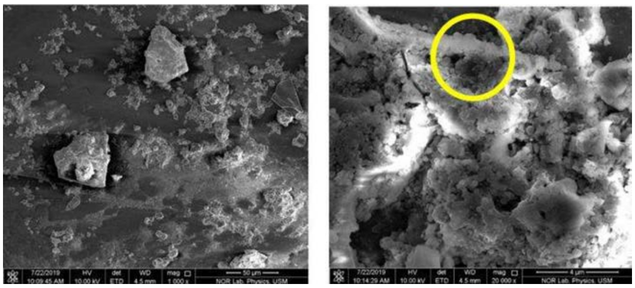

Figure 8: SEM images of Sample C (limestone) showing rhombohedral shaped grains which is one of the characteristics of calcite.

In conclusion, these three types of rocks have different minerals in their compositions. Rock sample A is mainly composed of quartz; rock sample B is a mixture of K-feldspar, plagioclase, and quartz with minor micas; while rock sample C is dominated by calcite based on the XRD and SEM analyses. The colors and textures observed in the experiments can be used to classify the rocks as igneous, sedimentary or metamorphic.

ACKNOWLEDGEMENTS

Special thanks and appreciation to the Universiti Sains Malaysia and South East Carbonate Laboratory (SEACARL) in Universiti Teknologi Petronas for their enormous support, and short-term grant (304/PFIZIK/6315230). The reviewers of this paper are also thanked for their comments.

AUTHOR CONTRIBUTIONS

MIAAT conceptualized and wrote the paper, and performed the laboratory analysis. TYJ, CCM, BS, HT and MHR contributed ideas to improve the paper.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

REFERENCES

Bauer, H., Rogowitz, A., Grasemann, B., & Decker, K., 2018. Intracrystalline deformation of calcite in the upper brittle crust. Geology, 46(4), 375–378.

Bowles, J.E., 1979. Physical and geotechnical properties of soils. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 18(6), 109.

Harker, A., 2011. The natural history of igneous rocks. Published online by Cambridge University Press. 408 p.

Henri, F. & Amnan, I., 1995. Biostratigraphy of the Kinta Valley, Perak. Bulletin of the Geological Society of Malaysia, 38, 159–172.

Ingham, F.T., & Bradford, E.P., 1960. Geology and mineral resources of the Kinta Valley, Perak. Federation of Malaya Geological Survey District Memoir 9, Goverment Press, Malaya. 347 p.

Janssen, G.-J., 2015. Information on the FESEM (Field-emission Scanning Electron Microscope). Radboud University Nijmegen, 1–5.

Kim, K.H., Akase, Z., Suzuki, T., & Shindo, D., 2010. Charging effects on SEM/SIM contrast of metal/insulator system in various metallic coating conditions. Materials Transactions, 51(6), 1080–1083.

Li, B., & Knowles, K.M., 2013. Molecular dynamics simulation of albite twinning and pericline twinning in low albite. Modelling and Simulation in Materials Science and Engineering, 21(5). Doi: https://doi.org/10.1088/0965-0393/21/5/055012.

Lin, Z., Wu, Q., Li, H., Xi, X., Kong, H., Tang, Y. & Liu, B., 2020. The genesis of two types of quartz veins in Banxi Antimony Deposit and their prospecting significance. Earth Science, 45(5), 1503–1516.

MacKenzie, W.S., Donaldson, C.H., & Guilford, C., 1982. Atlas of igneous rock and their textures. Longman, London, New York. 148 p.

Miyashiro, A., 1975. Volcanic rock series and tectonic setting. Annual Review of Earth and Planetary Sciences, 3(1), 251–269.

Peterknecht, K.M., & Tietz, G.F., 2011. Chattermark trails: Surface features on detrital quartz grains indicative of a tropical climate. Journal of Sedimentary Research, 81(2), 153–158.

Udayaganesan, P., Angusamy, N., Gujar, A.R. & Rajamanickam, G.V., 2011. Surface microtextures of quartz grains from the central coast of Tamil Nadu. Journal of the Geological Society of India, 77(1), 26–34.

Manuscript received 20 July 2020;
Received in revised form 21 January 2021;
Accepted 22 January 2021
Available online 30 November 2022