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Mineralogical analyses of Belata Black Shale, Perak, Peninsular Malaysia

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Abstract: Although Peninsular Malaysia comprises of 25% Paleozoic black shales, these shales have very little published literatures on their mineralogical content. This study employs the use of X-ray diffraction analyses to characterize the mineralogical composition of the Belata Black shales. The findings of the study indicate that the black shales of Belata Formation are dominated by felsic minerals such as quartz and feldspars. Minerals such as muscovite, calcite, pyrite, kaolinite and chlorite are also present, and this may indicate a felsic source rock for the shales. The study of the source of sediments helps in revealing the processes they have gone through and may together be used with the weathering, transport, deposition and burial history of the sediment to analyze their thermal maturity.

Keywords: Mineralogy, black shales, Belata Formation, Xray diffraction

INTRODUCTION

Shale is by far the most abundant type of sedimentary rocks mostly formed in marine environments close to continents at places where the seafloor falls beneath the storm wave base. Shale is a sedimentary rock formed at quiet parts of rivers, lagoons, lakes, tidal flats, deltas, and open seas (Tourtelot, 1979). Organic shales have been classified as argillaceous, siliceous or calcareous based on their mineralogical content.

Black shales are basically composed of mixtures of non-clay minerals such as microcrystalline quartz, feldspars, pyrite, carbonates and clay minerals of smectites, kaolinite, chlorites, illites and mixed layers of the mentioned clay types.

Sedimentary rocks are composed of both detrital and authigenic minerals. Shales rich in organic matter could be classified as argillaceous, siliceous or calcareous depending on their mineralogical content (Chermak & Schreiber, 2014). Organic shales are mostly referred to as black shales due to their black color incorporated during their deposition and the organic matter present in them. Black shales primarily have a mixed composition of non-clay minerals such as fine-grained quartz, feldspars, pyrite, carbonates and clay minerals of smectites, kaolinite, chlorites, illites and mixed layers of the mentioned clay minerals.

With the rise in the exploration and production of shale gas globally due to the decline in conventional resources, it has become a necessity to explore shale around the globe. Researchers have placed current interest in the study of organic rich shales due to their hydrocarbon potential and their metal concentrations especially in countries with shale deposits such as Argentina, China and the United States of America (Masters *et al*., 1987; Wang *et al*., 2014). Thus, understanding the mineralogy of shales is one of the fundamental information required. Studies into the type of mineral together with other geochemical parameters are useful for the study of the source rock, depositional environment and burial diagenesis of sediments (Niu *et al.,* 2018).

Peninsula Malaysia is made up of 25% scattered Paleozoic black shales from various formations of which the Belata Formation forms a part (Figure 1). Various authors have published the existence of these shales. Burton (1970), Jones (1970), Foo (1983, 1990) extensively studied the shales in the Peninsular for their stratigraphy and geology. Baioumy *et al.* (2016) worked on a wide selection of shales from all over Peninsular Malaysia excluding the Belata Formation amongst a few. Using age, he grouped all the black shale lithology into seven main categories ranging from Cambrian through to Permian and worked on their mineralogy. He discussed the shales to be in the late stage of maturity but recommended other analysis to be conducted to confirm his claim. However, the black shales in the Belata Formation unlike the other shales worked on by Baioumy *et al.* (2016) has been described by Gan (1992) to not have been affected by contact metamorphism and may be found to be economically important due to their distance further away from the granitic intrusion.

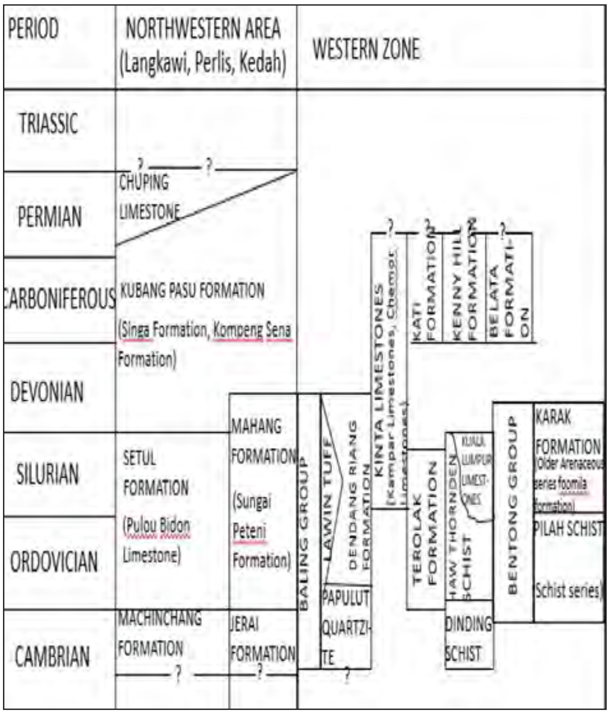

Figure 1: Formations found within Peninsula Malaysia, modified after Foo (1983).

In the study of shale as a reservoir, it is necessary to understand the geologic processes by which the sediments in the rock have been through. This begins with the type of source rocks from which the sediments originated from weathering, then transportation to deposition and finally burial. Although it has been recognized that black shales are by far an economic and important rock type for reasons in and beyond geological studies, about twenty five percent of Paleozoic black shales scattered in Peninsular Malaysia have little or no work done on them in terms of their mineralogical characteristics.

In this work, the mineralogy of the black shale of Belata Formation is studied for the first time. The mineralogical composition of the carboniferous black shales of the Belata Formation which lies to the southern part of Tanjung Malim on the borders of Perak state and Selangor state of Peninsular Malaysia is studied to interpret their source rock type (Figure 2). Apart from the interpretation of the source rock of these shales, mineralogy together with a study of the elemental and oxide analysis of the black shales could aid in the determination of the maturity of these shales which could further assist in their shale gas prediction.

MATERIAL AND METHOD

Representative fresh samples from different outcrops and localities of the black shales were taken from the field using geologic instrument such as the geologic hammer. The samples after being ripped of the weathered portion were crushed in an electronic pulverizing machine and then subjected to detail mineralogical analysis at the Centralized Analytical Laboratory (CAL) in Universiti Teknologi PETRONAS. Twenty-two black shale samples

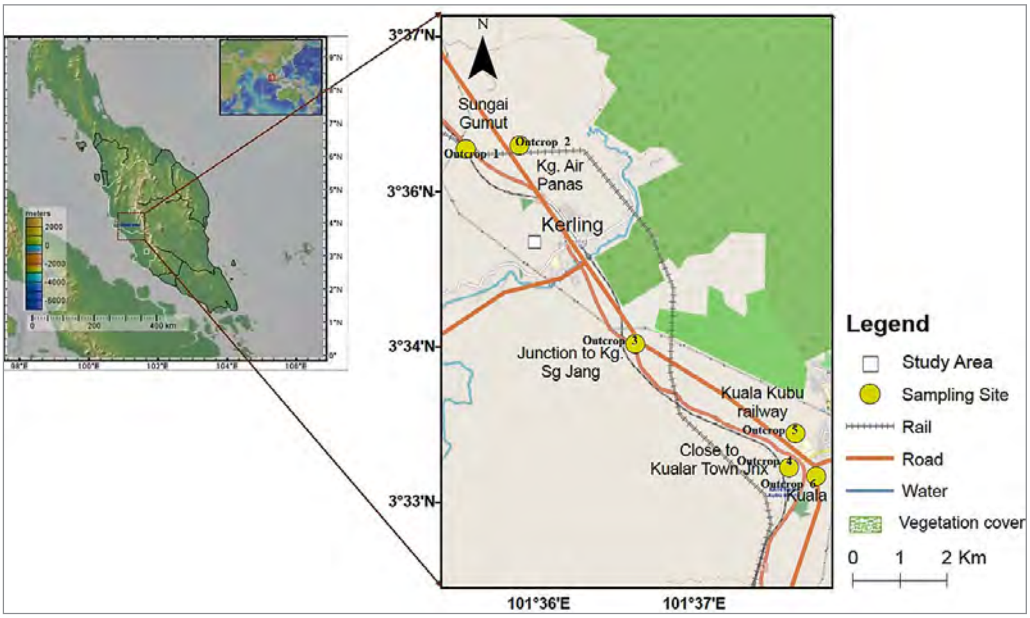

Figure 2: Geology Map of the peninsular showing the study area (Peng *et al.*, 2004).

picked from the field were analyzed for their clay and non-clay fraction using powder X-ray Diffraction (XRD) method.

Powder XRD is a robust method for identifying and characterizing crystalline minerals (such as quartz, clays, carbonates and pyrite). A bulk analysis was done by mounting the powdered samples into the X-ray holder for analyzing of mineral peaks. Clay fraction involved 10 g of powdered shale samples mixed with 1 M acetic acid and shook in the beaker till it was completely disaggregated. This procedure removes carbonates (if any) present in the samples and the residue was washed several times with distilled water. After that, the residue was treated with 30% H_2O_2 to get rid of organic matter in the samples and then the residue was rinsed several times to remove the acid before drying. Finally, the suspended clay fraction was pipetted onto glass slides and the water allowed to drain out of it. For each sample, three oriented mounts were prepared. The first slide was dried by air. The second was saturated with ethylene glycol and kept in an oven for an hour at 60°C. The third slide was heated for three hours at 550°C. The analysis determined both the bulk and clay fraction with scans limited to the range from 2 to 80° 2θ for the bulk samples and from 2 to 40° 2θ for the clay fractions. Minerals identification was based on the data produced by International Center for Diffraction Data (ICDD).

RESULT AND DISCUSSION

Minerals present in the Belata black shale includes non-clay minerals (quartz, feldspars and muscovite with traces of calcite and pyrite) and clay minerals (kaolinite and chlorites) as shown in Figure 3.

While minerals such as quartz, feldspars and chlorite are products of detrital components of the Belata black shales, minerals such as carbonates and sulfides may have formed in the shales during burial or most probably as cementing or replacing materials similar to what was described by Boggs (2006).

The minerals present within the shales from all the outcrops are same, represented by the similar trends shown in Figure 4. Also, the shales are dominated by felsic or silicic minerals such as quartz and feldspars and hence could be interpreted as coming from a felsic provenance which is not too distant away from the place of deposition. Thus, feldspars are generally low resistant minerals to weathering as compared to quartz which has high resistance. The K-feldspar presence in the mineralogy indicates a short time exposure to weathering and/or diagenesis. The absence of mafic and ultramafic minerals such as olivine, pyroxenes and amphiboles support the felsic nature of the sediments which formed the black shales. However, for future work and recommendations, the use of higher magnification microscope such as the scanning electron microscope (SEM) and the use of other

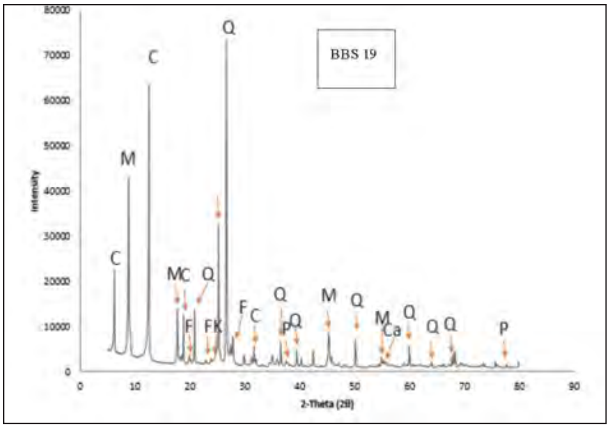

Figure 3: XRD pattern of the various mineral phases. C- Chlorite, M- muscovite mica, K- Kaolinite, Ca- Calcite, Q- Quartz, F- Feldspar (Albite) and P- Pyrite.

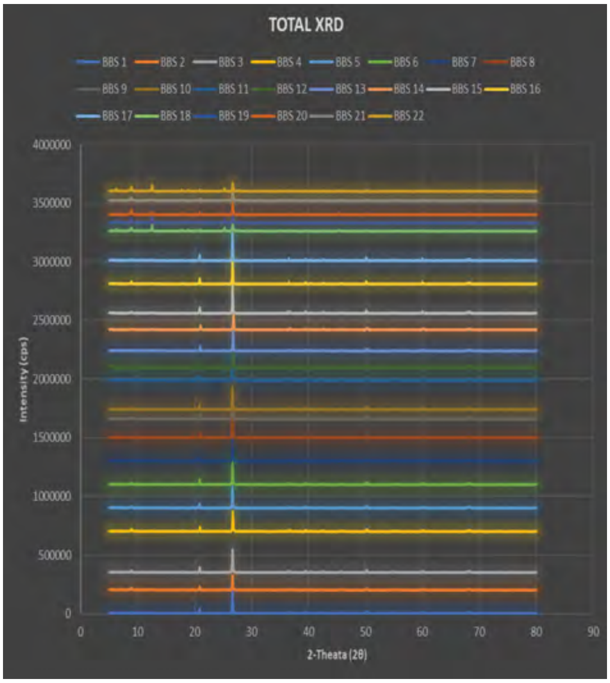

Figure 4: Total XRD patterns for all twenty two black shale samples of the Belata Formation.

geochemical parameters such as major and minor element proxies would be employed to aid in the source rock as well as the depositional environment description of the shales. This is necessary because the minerals present in the shales may have been affected by other conditions such as weathering and burial diagenesis at variable conditions and these methods have been used by various authors (e.g. Morton, 1985; Fralick & Kronberg, 1997; Garzanti *et al.*, 2013; Newport *et al.*, 2016) to tell the conditions. The black shales of the Belata Formation probably originated from the hidden felsic igneous basement rock of Peninsular Malaysia, similar to what was described by Baioumy *et al.* (2016) for the other shales in the Peninsular.

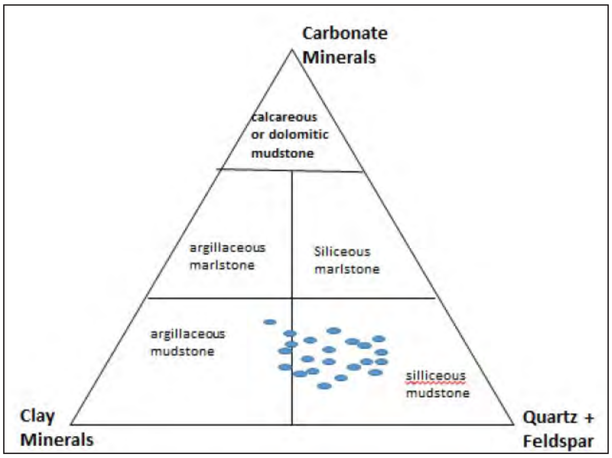

Figure 5: Classification of Belata black shales (after Allix *et al*., 2010).

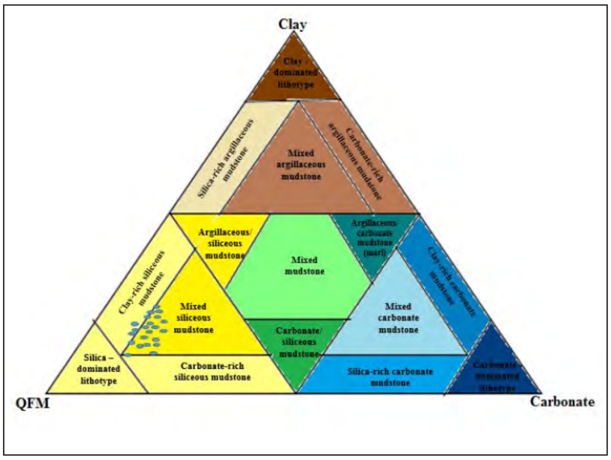

Figure 7: Ternary plot of the black shales of Belata Formation. Q- quartz, F- feldspar, M- muscovite (after Gamero *et al*., 2012).

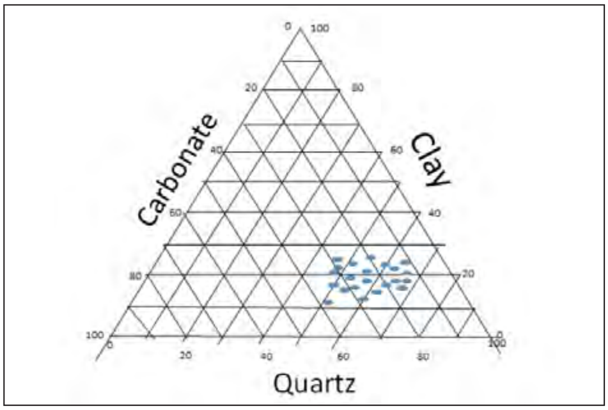

Figure 6: Simple classification of organic mudstone using ternary plot from Dunn *et al.* (2012).

Ternary diagrams have been proposed by various authors and used to describe the mineralogy and source rock of fine organic rich mudstones like shales. From the diagrams introduced by Allix *et al.* (2010); Dunn *et al.* (2012); Gamero *et al.* (2012) as seen in Figures 5, 6 and 7, the Belata black shales are dominant in quartz compared to the carbonates and clays hence are siliceous mudstones as they are plotted in the Mixed siliceous mudstone quadrant.

CONCLUSION

The Belata black shales are rich in felsic minerals such as quartz and feldspars. Minerals such as muscovite, calcite, pyrite, kaolinite and chlorite are also present, and this may indicate a felsic source of sediment. Therefore, it could be concluded that the Belata black shales have siliceous source of sediment. However, other analyses such as the use of the energy dispersive X-ray scanning electron microscopy (EDX/SEM) and other geochemical studies can aid in this study.

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