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Geology, resource potential and organic petrography of the Neogene coals in the Miri area of Northwest Sarawak, Malaysia

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Abstract: There are three coal-bearing geological formations in the Miri area, viz. the Belait Formation, the Lambir Formation, and the Liang Formation. Of the three coal-bearing geological formations, only the sub-bituminous B Tutoh coals from the Belait Formation, with an estimated resource of 203 million tonnes, are believed to be of economic potential. The Tutoh coals are dominated by vitrinite group, especially desmocollinite. The sub-bituminous B from the Lambir Formation and the lignite from Liang Formation are of low economic potential due to the limited area of the hosting formations.

Keywords: Coal resource potential, organic petrography, Belait Formation, Lambir Formation, Liang Formation

INTRODUCTION

Despite global efforts to reduce the use of coal as a primary energy source, current and future geopolitics may dictate that countries may require to revert to the use of coal to maintain energy security. This aspect of "return to coal" was recently highlighted by Stanway (2022). Presently Malaysia remains partially dependant on coals within its current energy mix. Nevertheless, Malaysia has reached 23% installation of renewable energy, and there is a plan to hit 40% by 2035 (Bernama, 2022).

Coals in Malaysia are present in the Tertiary basins in all three geographical provinces, viz. Sarawak, Sabah and Peninsular Malaysia, with most of them located in the states of Sabah and Sarawak. As at the end of 2011, 1,468 Mt or 80.7 % of the coal resources, ranging from sub-bituminous to anthracite, were located in Sarawak (Sia & Abdullah, 2012).

Coals are present in three different geological formations at three different localities in Miri, viz. the Belait Formation at Tutoh, the Lambir Formation at Kuala Tutoh, and the Liang Formation at Long Patan (Figure 1). The aim of this study is to assess the resource potential of these coals based on the exploration carried out by Sia & Johari (2004) and Aro *et al.* (2005). Organic petrographic analysis was performed on the Belait Formation coals to complement these published data.

METHODOLOGY

Traversing was conducted along rivers, creeks, valleys, timber tracks and footpaths to scout for coal and rock exposures. All coal outcrops found were either manually trenched or pit to expose the fresh and clean coal, as well as full section of the seam for detailed lithotype description of seam and sampling as described by Sia & Johari (2004).

Samples for petrographic study were progressively polished using finer grades of silicon carbide papers (320, 800 and 1200 grit) and followed by alumina (initially 1 µm, then 0.3 µm and finally 0.05 µm grades). Details of sample preparation prior to polishing were as described by Wan Hasiah (1999). Water was used as lubricant for all the polishing stages. Microscopical examination was performed under oil immersion (with a reflective index of 1.518 at 23 °C) in plane-polarised reflected light using a Leica DM 6000M microscope equipped with fluorescence photometry system.

GEOLOGY, RESOURCE POTENTIAL AND ORGANIC PETROGRAPHY

Belait Formation

At Tutoh, the coal deposit is hosted by the Middle Miocene and possibly also in the Early Pliocene Belait Formation (Wilford, 1961), covering an area of 230 km^2

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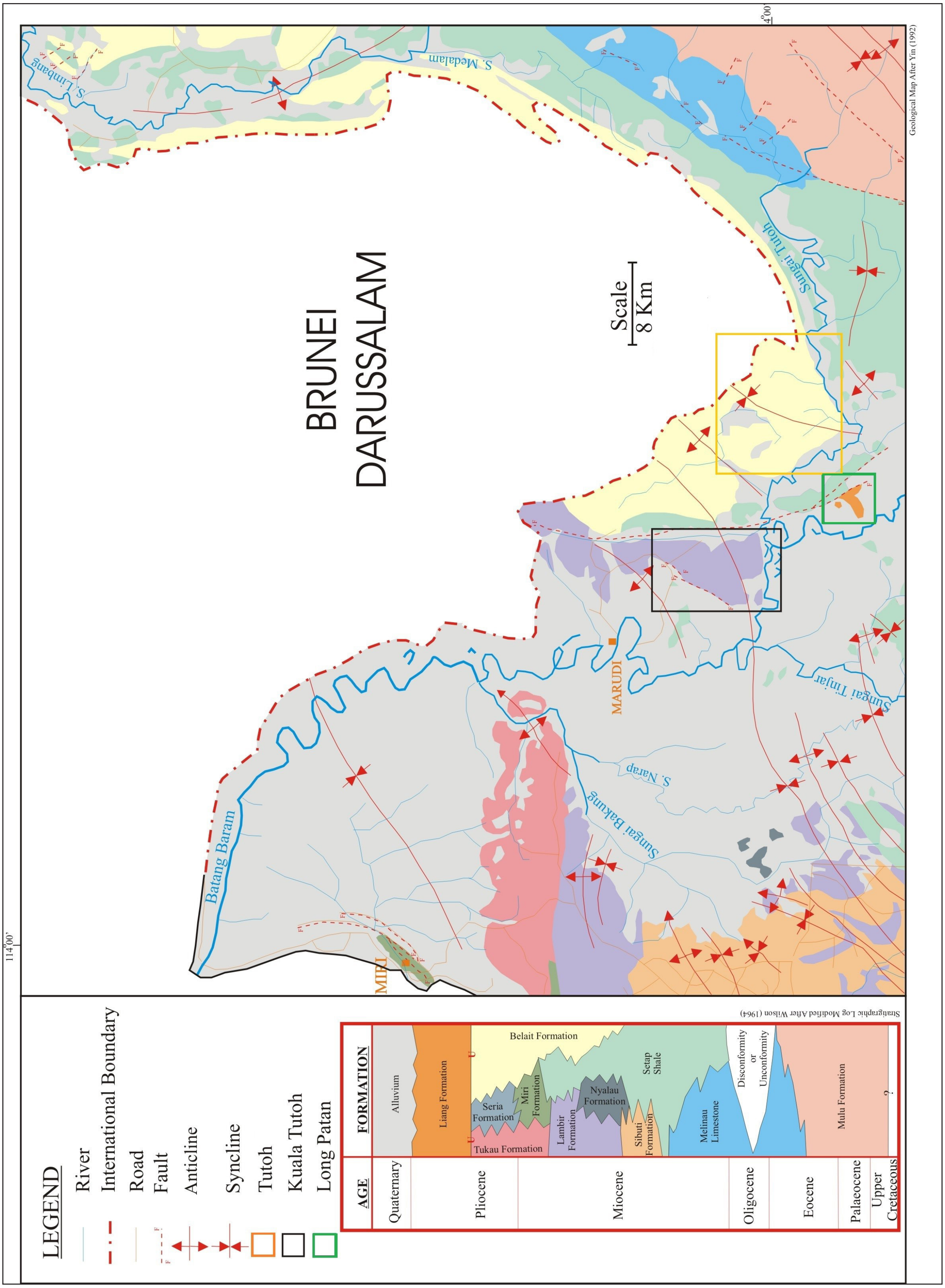

Figure 1: Geological map of the Miri area (modified after Yin, 1992).

(Figure 1). Sediments at the eastern part dip at 35°–50° towards NW while sediments at the western part dip 10°–30° towards NE, forming a northeast plunging syncline. The coal deposits extend beyond the international boundary into Brunei Darussalam. On the Malaysian side, six main coal seams, ranging in thickness from 0.65 m to 3.20 m, have been identified (Aro *et al.*, 2005; Figure 2). Total moisture of Tutoh coals varies from 8.5% to 23.2%, ash yield from 1.1% to 35.7% but generally below 10%, and total sulphur varies from 0.43% to 7.00%. The volatile matter content (dry) varies between 30.7% and 54.5% with an average of 45.5%. The heat value for coal with ash yields less than 10% ranges from 24.67 MJ/kg to 30.05 MJ/kg, indicating a sub-bituminous B coal rank (Aro *et al.*, 2005) and generally of good quality. Aro *et al.* (2005) reported the Tutoh coal field hosted an estimated reserve of 203 million tonnes and recommended drilling and geophysical logging to better correlate with the mapped sections.

The analysed sub-bituminous coals from Belait Formation were studied petrographically using a reflected light microscope under oil immersion as described in the Methodology section above. An example of the observed maceral association is shown in Figure 3. The Tutoh coal is dominated by vitrinite maceral group (Figure 3A and 3C); the most dominant maceral being desmocollinite (also known as collodetrinite after ICCP, 1998). Liptinite (also referred to as exinite) macerals occur in significant amount, the most common being cutinite, resinite and suberinite. Under UV (ultra violet) light excitation, these liptinites show greenish yellow to dull yellow fluorescence (Figure 3B and 3D). Inertinite is fairly common with presence of sclerotinite (also known as funginite after ICCP, 2001) being most distinct. Mineral matter such as pyrite and clay minerals were often observed although their abundance is generally low to fairly common.

The mineral matter content is often associated with ash yield determined by proximate analysis and is a parameter used in determining coal quality. The composition of the ash depends on the composition of the mineral precursors (Diessel, 1998). He described that in combustion process, after injection into the furnace, mineral matter particles may decompose, whereby the majority of flyash particles are the thermal transformation products of the minerals contained in the feed coal. Coals rich in reactive macerals such as vitrinite and exinite from low rank coals of Batu Arang, Selangor have been reported to have a high coal conversion and oil+gas yields and thus can be considered as a potential alternative energy resource for liquid fuel (Abdullah *et*

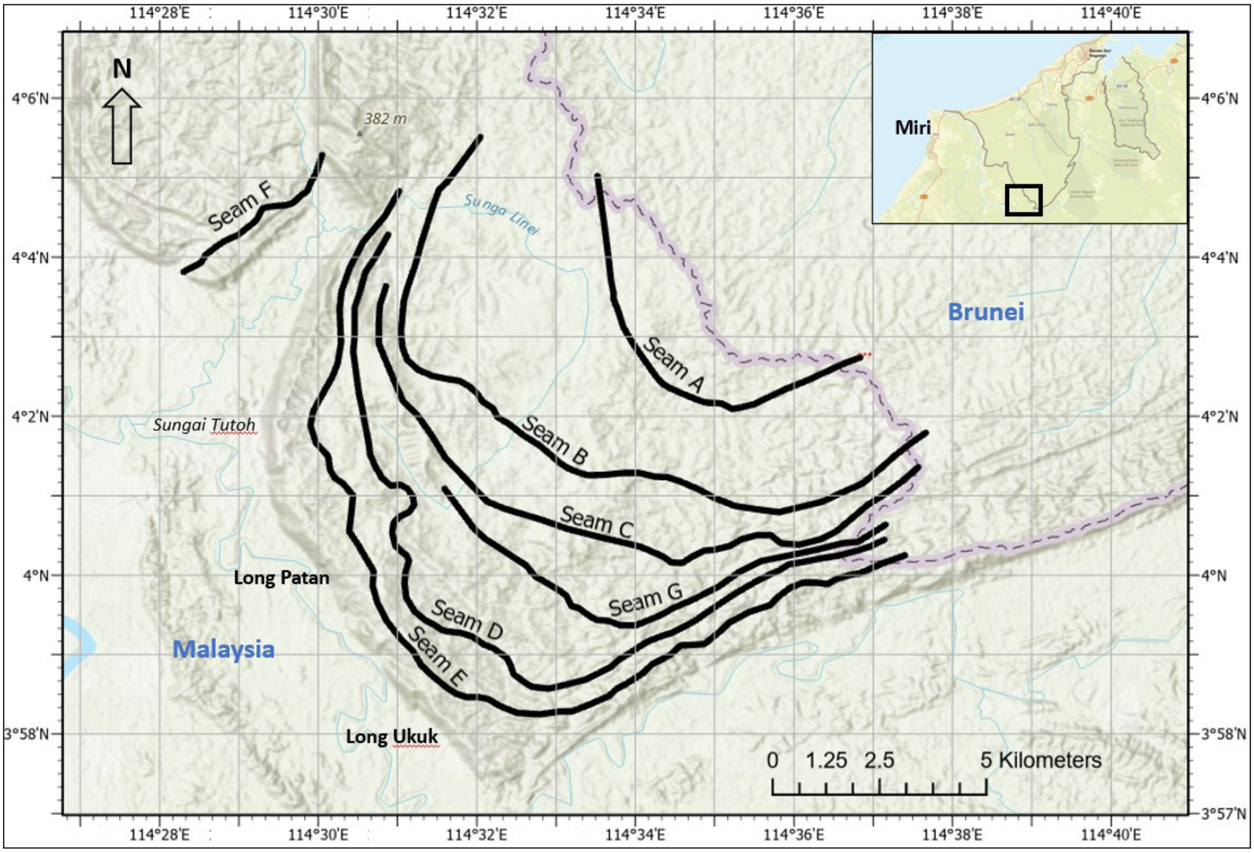

Figure 2: Coal seams occurrences at Tutoh (modified after Aro *et al.*, 2005).

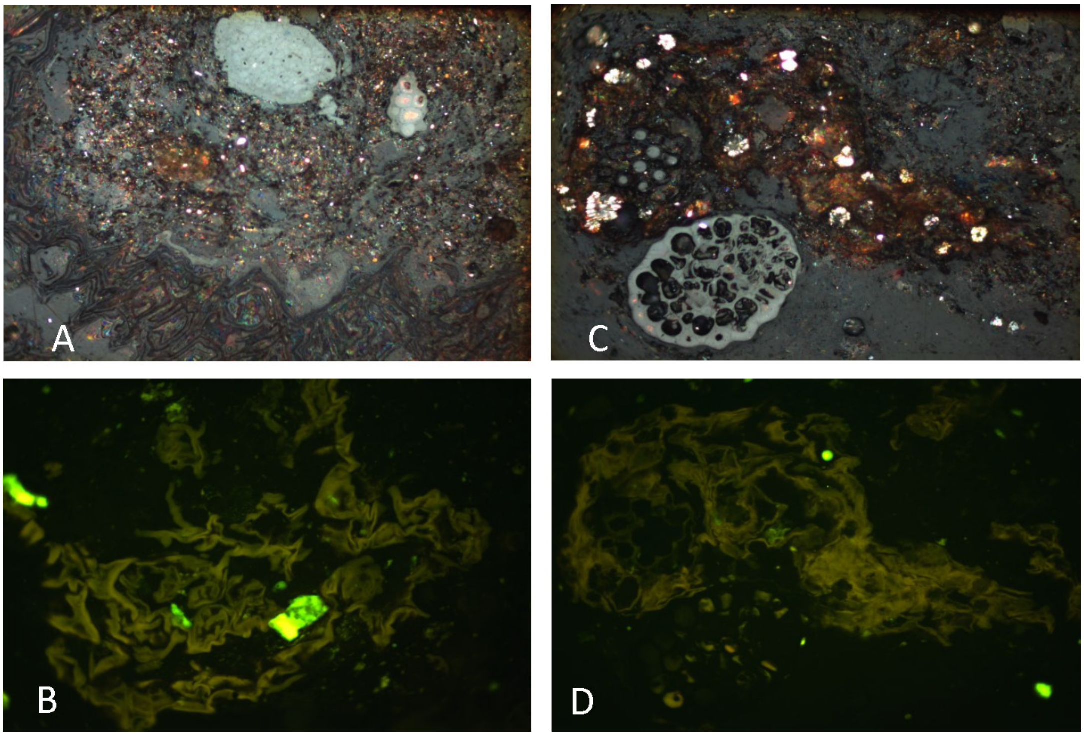

Figure 3: A: High reflecting sclerotinite (top and to the right) embedded in low reflecting desmocollinite matrix and fine-grained clay minerals with the occurrence of colourful oil smear associated with suberinite (band at bottom of phomicrograph) under normal reflected white light. B: Fairly well preserved yellow fluorescing cutinite with minor occurrence of intense greenish yellow resinite as observed under UV light excitation. C: Association of vitrinitic coal constituents with common occurrence of sclerotinite (lower southwest corner of photomicrograph) and some very highly reflecting framboidal pyrite under normal reflected white light. D: Same view as C observed under UV light excitation showing poorly preserved cutinite maceral fluorescing dull yellow and some fluorescing resinite in the cell lumen of the sclerotinite. All photomicrographs were taken on polished surfaces under oil immersion and field width is 0.25 mm

al., 2014) instead of using raw coal feedstock as it would be more environmentally friendly. The analysed Tutoh sub-bituminous coals, similar to the Batu Arang coals, in that they also contain a high abundance of structureless vitrinite, namely desmocollinite, therefore could also possess similar energy resource potential. However, the presented petrographic data here is insufficient to provide conclusive findings as other relevant experimental data is not available in this study. Nevertheless, the encouraging results of similar liquefaction experiments that were performed on a coal dominated by vitrinite with significant liptinite content (from Mukah Balingian, Sarawak) also indicated high coal conversion and high oil yield (Ishak *et al*., 2005). Details on the application of coals and other organic-derived materials for industrial purposes are presented by Speight (2017).

Lambir Formation

Lambir Formation is present in many areas in Miri, but only at Kuala Tutoh it is coal-bearing (Figure 1). The Kuala Tutoh area is a tilted horst block, bounded to the east by the NNW-SSE trending Kalijau Fault and to the west by the NE-SW trending Muam Fault (Sia & Johari, 2004), covering an area of 73 km^2. The horst is underlain mainly by the coal-bearing Middle to Late Miocene Lambir Formation, with patches of Oligocene to Late Miocene Setap Shale and the Pleistocene Old Alluvium Deposits covering the low undulating hills in the west, as well as the recent alluvium deposits covering the floodplains in the east. Coal exposures are seen only at the southern part of Kuala Tutoh, viz. Tebaboi Lake and S. Belasoi areas (Figure 4). The coal exposures are believed to be of the same seam, with thickness up to 0.65 m (Sia & Johari, 2004). The coals are of sub-bituminous B in rank, with high ash yield and total sulphur. Since there is only one coal seam, and this seam has a high ash yield and total sulphur and is restricted to an area of not more than 30 km^2, it is believed that coal in the Kuala Tutoh vicinity is of low economic potential.

Liang Formation

Accumulation of coal at Long Patan (Figure 5) took place in the Pliocene and is part of the Liang Formation. The area is transacted by the south-eastward extension of the NW-SE trending Kelijau Fault, which serves as the

Figure 4: A sixty-five centimeter coal bed at the S. Belasoi area which is transected by a fault.

contact for the Liang Formation with Setap Shale (Figure 1). The coal is dark brown, dull with matt lustre (Figure 6), disintegrates easily when exposed, and its woody structure is still recognizable in hand specimens. Two coal seams have been identified, viz. the 0.29 m Upper Patan seam and the 1.67 m Lower Patan seam; they are of Lignite A and Lignite B rank. The coal is high in total moisture, carbon and volatile matter, but is low in ash yield and total sulphur. Even though two coal seams have been identified with the Lower Patan reaching 1.67 m, it is believed that coal in Long Patan is of low economical potential owing to its low coal rank and the limited area of not more than 4.5 km^2 covered by the Liang Formation.

CONCLUDING REMARKS

In summary, among the three coal-bearing formations in the studied Miri area, only the sub-bituminous B Tutoh coals from the Belait Formation with an estimated resource of 203 million tonnes, seems to possess resource potential, but further detailed exploration would be required to evaluate the commercial value.

The Belait Formation Tutoh coals are dominated by structureless vitrinite with common liptinite macerals. In addition, the coals that are generally low in mineral matter content may indicate good quality coals suitable for industrial purposes including for application in the energy sector, if ever required.

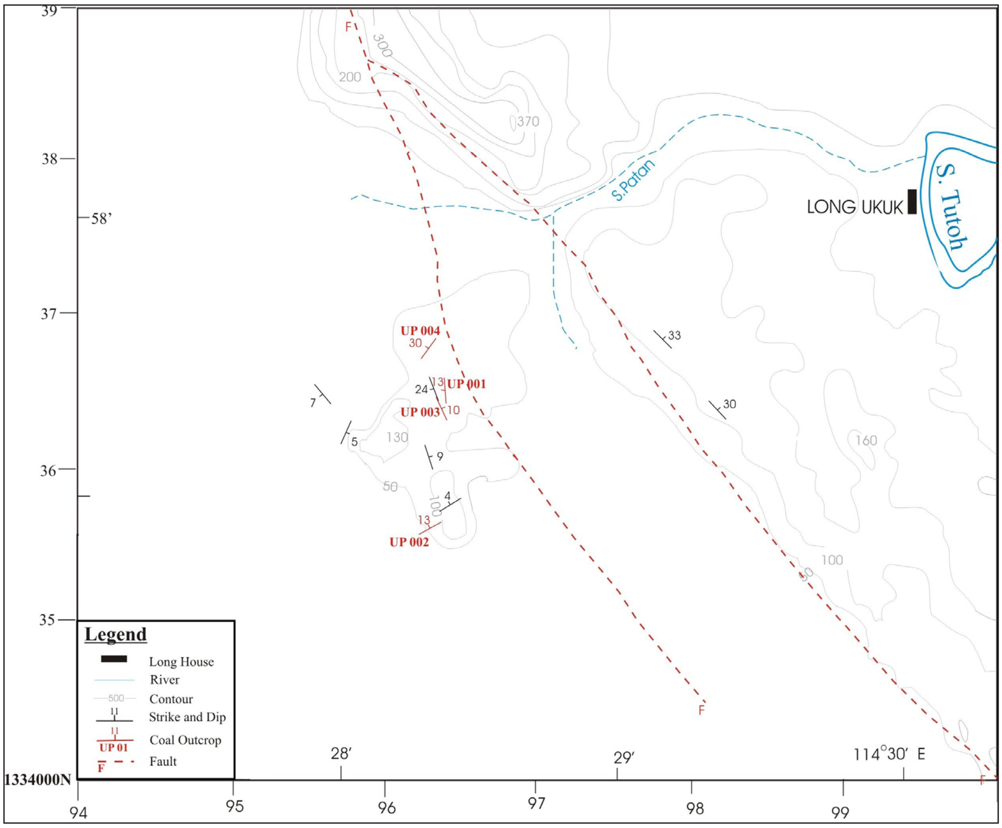

Figure 5: Coal occurrences at Long Patan (after Sia & Johari, 2004).

Figure 6: The dark brown, dull with matt lustre coal at Long Patan.

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AUTHOR CONTRIBUTIONS

The authors confirm their contribution to the paper as follows:

- Study conception and design: WHA and SSG.
- Data collection and interpretation: SSG and WHA.
- Petrographic analysis and description: WHA.
- Draft manuscript preparation: SSG and WHA.
- Both authors reviewed the results and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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