Properties and Occurrences of Rock Coatings in Jeli, Kelantan As A Record of Environmental Processes

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Abstract. Rock coatings can be defined as a product material deposition from surroundings. It is resulted from the wide variety of reactions which occur at the interface between the lithosphere and the biosphere. The coatings are biochemically and mineralogically complex and have the potential to record changes in their immediate environment. The changing of the coating gives information about the factors involved during the process which include dissolution and chemical reaction. The range of their activities and their proper significance in the environment as well as their relationship with the microorganisms that inhibit rocks and minerals provide a lot of information of the process involved. Types of coatings that have been identified on the outcrops around Kampung Kalai, Jeli are case hardening, iron film, dust film, rock varnish and lithobiontic coatings. The environmental exposures and inputs to the coatings, determines the coating mineralogy that formed on the parent rock. Scanning Electron Microscope (SEM) was used to analyse the microscopic properties of the coating samples. The presence of iron oxides have been found on the brick orange coating which potentially occurred from chemical weathering such as oxidation and the leaching of iron-bearing minerals. Besides that, geochemical analyses using X-Ray Fluorescence (XRF) on selected samples have shown limited information about the changing elemental composition. Iron, aluminium and silica are the major elements composition in the rock coatings reflecting the similar elemental composition of the existing parent rock.

1. Introduction

Rock coatings are geochemical sediment which deposited on the rock surface after a period of time. The coatings normally resulted from the wide variety of reactions and processes that took place at the interface between lithosphere and biosphere. They are mineralogically, biochemically, and isotopically complex and have the ability to record changes in their immediate environments [1,2,3]. The rock coating components are varied from one locality to another locality which bottom coatings formed from contact minerals. The elements are brought into solution and deposited onto the host rock as a clay cemented and sometimes hardened by silica. Other substances that usually found on rock surface are pollen, organic compound, and soil components [4]. Major sources for accumulated elements may be rainfall or dust [5]. The physical properties of rock varnish are difficult to characterize because the coating is very thin and discontinuous, but the texture of the rock coating surface is varied in terms of deposition [6].

Meanwhile, fungi and lichen are the microorganisms that can be found anywhere and act as the important geoactive agents in the change of geochemical. Fungi are capable to transform the metals and minerals as well as alter the surface structure and chemistry of the rock and their constituent minerals.

Rock coatings also have potential in giving information and evidence of past life in the form of mineralised filaments and others morphological characteristics [7,8,9,10,15].

Besides, lichens are probably the most obvious fungal inhabitants of rock surfaces which intimately associated with elements such as Na, Mg, Fe, K, P, Ca, Al, Si, Ti, and Mn. As a result of lichen bio-weathering, several rock forming minerals exhibit extensive surface alteration, bio-deterioration and chemical transformation [11,12,13]. Fungi also produce variety of other metal oxalates when they interact with minerals that contain metal elements likes Ca, Zn, Pb, Cu, Mg, Mn, and Ni. Many lichens and free-living fungi play a role in silicate dissolution and release important nutrients such as P, K and Fe which then contribute to the genesis of clay minerals as well as soil and sediments [7,10].

The research is mainly focused on rock coatings as a record of environmental processes which has been conducted in Kampung Kalai, Jeli. The objective of this research is to provide information and knowledge regarding rock coatings or geochemical sediment as a record of environmental processes. It is important to gain new knowledge about rock coatings and to understand more about the environmental changes as the earth is getting older day by day. Rock coatings are important in geomorphology as it can stabilize landform surfaces through case hardening. In addition, some types of rock coatings like silica glaze can slow down the rate of chemical weathering.

2. Methodology

2.1 Study area and sampling

The study area is in Kampung Kalai, Batu Melintang, Jeli, Kelantan (Figure 1a). The preliminary study is important to make a detail analysis on study area followed by data collection, data interpretation, analysis, and reporting. The base map was produced using ArcGIS 10.2 and the sampling point was targeted scattered around the study area (Figure 1b). The detail geological mapping was carried out during field observations to identify and determine trend structural geology, geomorphology, lithology and others.

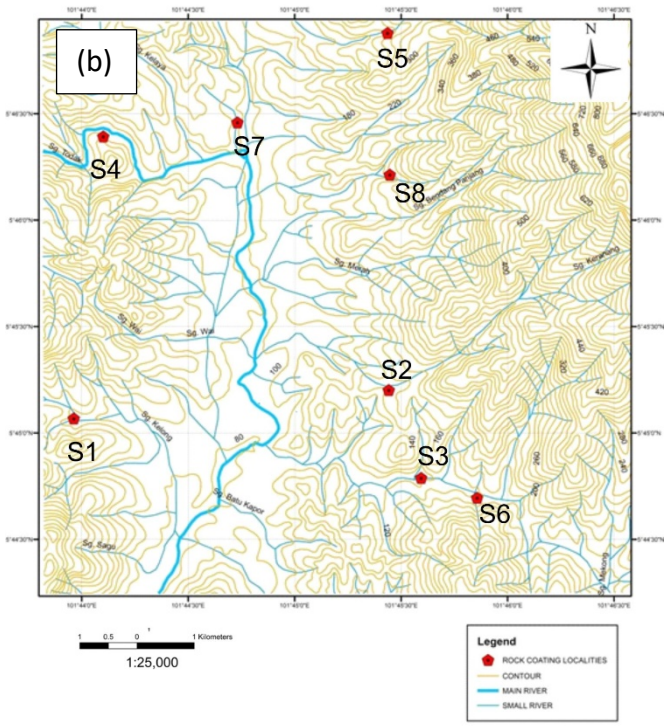

Figure 1. (a) Map of Kelantan, small box in Jeli district represent sampling area in Batu Melintang (b) Sampling locations in selected area in Batu Melintang, Jeli, Kelantan.

The land uses of Kampung Kalai consist dominantly plantation area such as oil palm and rubber plantation, reserved forest and small town. The topography of the area is quite hilly at the left with the highest elevation is about 880 m and the lowest elevation is about 80 m. The average annual temperature in Jeli is 26.7 ˚C with the average amount of rainfall distribution every year is about 256.2 mm of precipitation. For the road connection and accessibility at Kampung Kalai, mostly located at the central and west part of the study area because of the mining activity. Jeli district is granted with attractive geological landform and unique geological phenomena such as caves, rivers, waterfalls, gold deposits and hills.

Rock coating samples were collected from exposed bedrock within the study area, a distance of at least 30m from roads, buildings and water bodies to minimize possible sources of contamination. Soil samples were also collected at similar locations as rock samples to be used for comparison purpose.

2.2 Sample preparation and chemical analyses.

The sampling process includes rock and soil sampling. 100 to 200g soil samples were taken at selected location for further geochemical analysis. The soil sampling normally done close to the outcrop in order to find the correlation between the elements and the types of coatings. The rock samples are taken based on the highest degree and types of rock coatings for composition and petrographic analysis.

The thin sections were prepared and analysed under microscope to investigate the properties of mineral in the rock sample. The rock sample normally were cut to smaller size for detailed observation using Scanning Electron Microscope (SEM) instrument together with Energy-dispersive X-ray (EDX) spectrometer for elements determination. The percentage of elements composition in each sample will help for identifying the element distribution of the rock coatings. Meanwhile, the soil sample is crushed using the mortar and pestle to become powder for X-Ray Fluorescence (XRF) analysis.

3. Results and discussion

3.1 Rock coating properties and occurences.

Rock coatings are part of the near-surface weathering environment where geochemical materials are produced in response to the presence of geochemical and stress environments different from those that prevailed at the location of mineral genesis. The rock coatings terminology that have been classified by Dorn [3] include the following coating types such as iron films, silica glazes, sulphate crusts, alumina glazes and heavy-metal skins. Some of them also have been found in this study.

Eight localities of rock coatings in Kampung Kalai have been characterised based on colour, topography, microscopic images and shape as well as correlate to the types of coating presence. All the characteristics of coating found in Kampung Kalai are represent in Table 1 and Figure 2.

Figure 2. Different types of rock coatings have been found on the surface of exposed rock within the study area; (a) Case hardening, (b) lithibiontic film (c) iron films (d) rock dust

Table 1. Description on rock coatings at selected localities.

Sample	Coordinate	Types of coating	Sample description
S1	N 05 45 05.5 E 101 44 03.0	Rock varnish	Brown to black colour. Mostly covered by mossed
S2	N 05 45 13.5 E 101 45 31.8	Case hardening	Dark brown to black. Minerals in the rock having a slightly discolouration.
S3	N 05 44 52.0 E 101 44 06.1	Oxalate crust	Thin coating of orange to dark brown in colour.
S4	N 05 46 23.6 E 101 44 06.1	Dust film	Light brown in colour. Poorly graded sand, mix with a little organic matter.
S5	N 05 46 54.1 E 101 45 31.4	Dust film/ Heavy metal skin/ iron film	Slightly weathered. Minerals colour are slightly changed
S6	N 05 44 41.7 E 101 45 51.4	Iron film/ oxalate crust	Slightly weathered and moderately coated. Minerals colour are slightly changed
S7	N 05 46 30.9 E 101 44 45.1	Lithobiontic coatings	Less coating. Poorly graded silty, compacted and light brown in colour.
S8	N 05 46 01.6 E 101 45 32.1	Iron films	Highly weathered. Orange to light brown in colour.

Lichens, moss fungi, algae and cyanobacteria are amongst the organism that moulded the rock coatings. The rock surface usually have a thin layer which can be considered as organic mat as it is comprised of living organism. From SEM observation, it has indicated the abundance of phosphorus (P) and calcium (Ca) elements in microorganism especially from black regions, sometimes also associated with trace elements. The P content may derived from the agriculture activities where the fertilizer have been used for crop.

Iron films (Figure 2b and Figure 3e) composed of primary iron oxides or oxyhydroxides. The iron oxides potentially originated from the process of chemical weathering such as oxidation and the leaching of iron-bearing minerals. The colour at the outcrop is brick orange which indicates that the presence of iron oxides and some of the coating on the rock surface showed the rusted dust represent the iron films.

The rock coating on the schist rock (Figure 2d) is known as rock dust have a light brown colour with thickness of coating around 2 μm. The light brown powder of coatings has very fine-sized particles of clay and silt attached to the rough surface of schist or within the rock fractures. The composition in the dust film is clay mineral which resulted from the chemical weathering process and precipitation process [12,14]. From SEM images (see Figure 4), the characteristics of the coating showed the sheet of clay minerals with irregular shaped of agglomerates and preferred orientation. Latter is very common in soils and fine grained metamorphic rock such as schist.

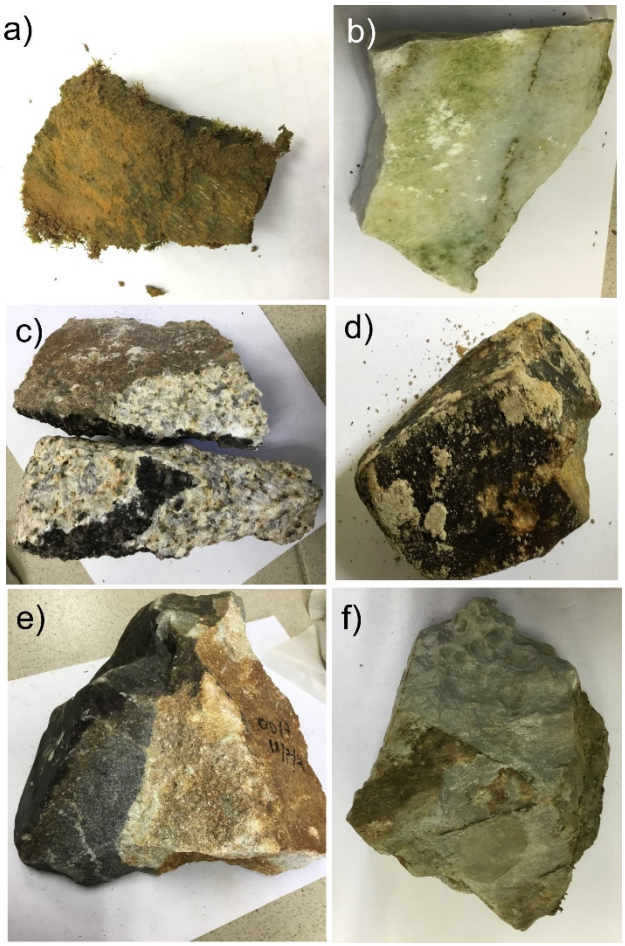

Figure 3. Close-up images of rock coatings at selected locations, (a) & (b) lithobiontic films, (c) & (d) case hardening, (e) iron film, (f) rock varnish.

The types of coatings are resulted from the lithology of the area, the weathering types, intensity, and acidity from precipitation. From these factors the relationship between the petrographic analysis and the percentage of the oxides in the soil samples is inferred. The diversity of the rock coatings are explained

based on the weathering stage of the area which could affected the physical properties of the coatings. The coatings always occurred on the exposed rock surface with mats of coatings such as dust films, iron films, oxalate crust, rock varnish, case hardening and lithobiontic coatings [2,3]. Those are the common types of coating and have been analysed with respect to the lithology and the weathering stage; mostly contain silica (Si), alluminium (Al) and iron (Fe) which are relevant for the formation of coatings. The oxidation and the reduction reactions directly precipitate minerals or produce chemical species which may combine with suitable pairs of ions that exist in the environment to produce another minerals [14].

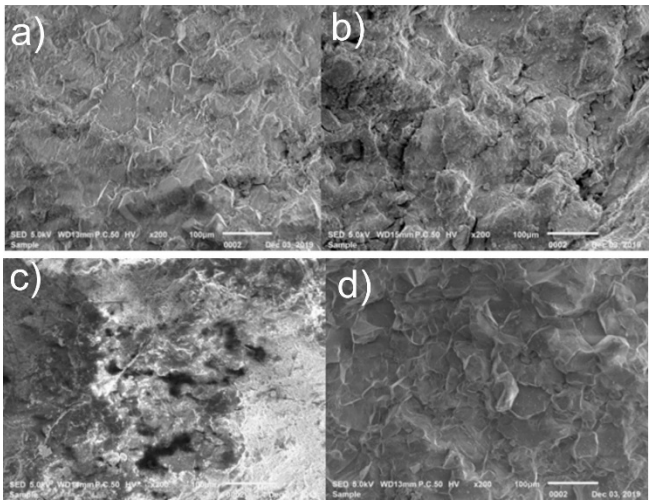

Figure 4. SEM images show varieties textures of rock coating that represent the weathered element from the rock itself and its contact.

The types of the coatings occurred at certain localities is influenced by the percentage of oxides in soil and the weathering types. The dark brown to almost black colour of the coatings layer formed because it is made up of clay particles combined with iron and manganese oxides. This is probably resulted from wind-blown or water transport material that settled on the rock surface because the oxides composition is higher for Fe, Al and Si elements especially within the study area [12,15].

The rock coating may also accrete on the surface where the interaction between rock and the sulphuric acid from the precipitation. The environmental exposures and inputs to these coatings determines the coating mineralogy formed on parent rock. The physical and chemical characteristic of rock coatings shows that there is a change of climate where rock coating can change the surface of the rock. Rock coating is internally layered due to a depositional process resulting from climatic changes. These micro laminations can occur over wide regions and correlate with major paleo-environmental regimes which are alternating dry periods produced orange layers and wet period produces black layers.

Aside that, the coatings contain silica-rich as well as metal sulphate-rich layers on rocks located within the study area. Thickness of coating not only dependant on the distance from the source but also on the lithological composition of the rock.

3.2 Correlation rock coating to the mineralogy and geochemistry of the rock

The rock types and grain size are normally contribute to the occurrence of rock coatings such as dust film, case hardening and iron film. The mineralogy of rock which consist varieties of minerals are depending on the rock types ultimately, as it reflected the coatings type and its characteristic. Figure 5 represents thin section images of the selected rock samples such as granitoid, sandstone, schist and marble that have been sampled near to the coatings. The samples have shown fine to coarse-grained size and mostly fine-grained rock tend to produce dust film coating as it is easily resulted from weathering and geochemical reaction in nature compared to the coarse-grained rocks which preferred to form in case hardening and iron films [12,15].

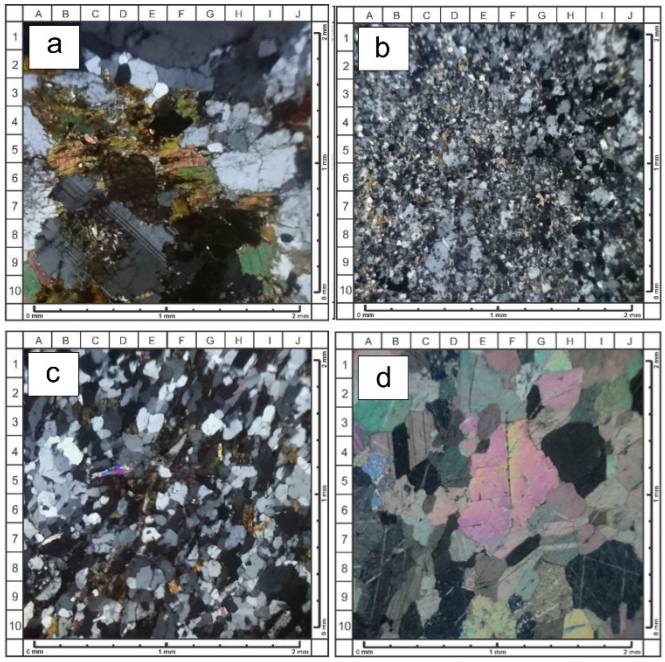

Figure 5. Thin section images of rock samples under cross-polar (XPL) view of optical microscope, (a) Quartz-rich granitoids consists mineral of feldspar, epidote, pyroxene (b) small grains of mixed biotite-quartz in sandstone, (c) schist texture (d) calcite grains in marble.

In terms of geochemistry, silica comprised a major portion of oxides ranged between 65 to 79% of SiO_2 followed by Al_2O_3 ranging from 8 to 30wt% based on XRF analyses (refer Table 2). This suggests that the rapid weathering process such as oxidation, leaching of feldspar as well as the hydrolysis, could control the percentage of oxides composition for Si, Al and Fe. Clay is commonly resulted from typical weathering of feldspar mineral, also may contribute to the formation of coatings on the rock surface.

The minor elements such calcium (Ca), and magnesium (Mg) exist in the range less than 5 wt% or in average 1wt% of oxides association (Table 2) which represented the existence of the accessory minerals in the parent rock within the study area.

Table 2: XRF analysis of selected rock coating samples (notes: XRF result for sample S3 is not available)

SAMPLE	SiO2	Al2O3	CaO	Fe2O3	K2O	MgO	TiO
S1	65.20	17.10	1.19	5.26	8.34	1.18	0.80
S2	74.90	15.10	1.43	2.60	4.26	0.90	0.50
S4	69.70	14.30	0.53	4.13	8.46	1.13	0.92
S5	58.50	31.30		5.23	3.12	0.60	0.76
S6	69.70	15.90	0.80	3.36	8.11	0.79	0.58
S7	70.00	17.70	0.43	3.77	5.81	1.19	0.68
S8	78.50	8.74	0.19	0.70	11.20	0.27	0.17

4.0 Conclusion

Types of coating that covered the study area in Kampung Kalai, Batu Melintang are rock varnish, dust film, iron film, case hardening and lithobiontic coatings. The properties of rock coating in term of petrography analysis, colour and shape have relationship with the elements composition of the rock. These properties offer an evidence or as a record of environmental process that may involve during the formation for example like weathering and other chemical reaction.

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