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Mineralogical Variation of Sedimentary Clay Deposit at Mae Than Mine, Ban Mae Than, Amphoe Mae Tha, Lampang Province, Thailand

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Abstract: *The sedimentary deposit is a part of the south of Lampang basin with the age of Tertiary to present. Clays in this deposit was divided into three layers covered with red clay. Clay layers were overburden which was the clay overlying on top of coal seam; interburden was the clays lie between coal seams; and underburden was the clay lie under coal seam. The basement rock was rhyolitic tuff. Major minerals found were quartz, kaolinite, illite, potassium feldspar and montmorillonite, respectively. There was no distinct relationship of quartz content in each clay layers. However, kaolinite and illite contents slightly increased in deeper clay layers. Additionally, montmorillonite presented in basement rock sample and some of overburden clay.*
Keywords: *ceramic, clays, Lampang, mineralogical, sedimentary*

I. Introduction

Ceramic clays deposits in Thailand have been found widely distributed, especially in the northern and southern part of Thailand. Department of Mineral Resources (2003)[1] assessed that the reserves of Thailand were about 182.79 million tonnes. The important sources were Had Som Pan, Amphoe Muang, Ranong Province, Khao Pang Kha and Huai Pan, Amphoe Jae Hom, Lampang Province. Later, ball clays at Ban Mae Than, Amphoe Mae Tha was also exploited, made the ceramic clays reserves up to approximately 68 million tonnes in Lampang province. In northern Thailand, the largest deposit and widely scatter number of mines are in Lampang Province. The second largest is in Uttaradit Province with a few mines are operated. The other smaller deposits are found in Chiang Mai, Sukhothai, Chiang Rai, Lamphun, Phrae and Nan. Presently, the important ceramic clays deposits are in Ban Sa, Amphoe Jae Hom, Ban Mae Than, Amphoe Mae Tha, Lampang Province and Ban Ngu Ngam, Uttaradit Province.

The study of mineralogy was based on three techniques namely X – Ray Diffraction method, petrographic study and Scanning Electron Microscope (SEM). Additionally, Differential Thermal Analysis – Thermogravimetric analysis was applied to investigate the thermal properties.

II. Geologic Setting

The study area is situated in the mining area of MRD – ECC Co., Ltd., Amphoe Mae Tha, Lampang Province. This mine is located in Mae Than Deposit. The reference topographic map ofthescale 1:50,000 series L7018 is 4844 I (Amphoe Sop Prab). The area covers about 2 square kilometers and lies approximately between the latitude of 17°57 ′ N to 18°02 ′ N and longitude 99°25′ E to 99°32′ E (Fig.1). It can be access by the Sop Prab - Mae Tha local road from Paholyothin (No.1), 7 kilometers north of Amphoe Sop Prab.

The Mae Than area is a small sub-basin located in the southern part of the Lampang basin. The geologic units of the area are composed mainly of Silurian-Devonian meta-sedimentary rocks of Don Chai Group, Permian-Carboniferous undifferentiated unit, Permian rocks of Ratburi Group, and marine Triassic sequence of the Lampang Group. Tertiary and recent sediments cover almost all the Mae Than intermontane basin. Igneous rocks including Permo-Triassic volcanics, Mesozoic granites and Cenozoic basalts are also exposed within this area (Thowanich, 1997)[2].

According to site survey, on the upper most was reddish brown topsoil with the thickness about 4 to 10 meters overlain the unit of siltstone and sandstone. The lower unit consisted ofhigh plasticity ball clay and clay layers interbedded with coal seam. Rhyolitic tuff was found to be basement rock (Fig. 2).

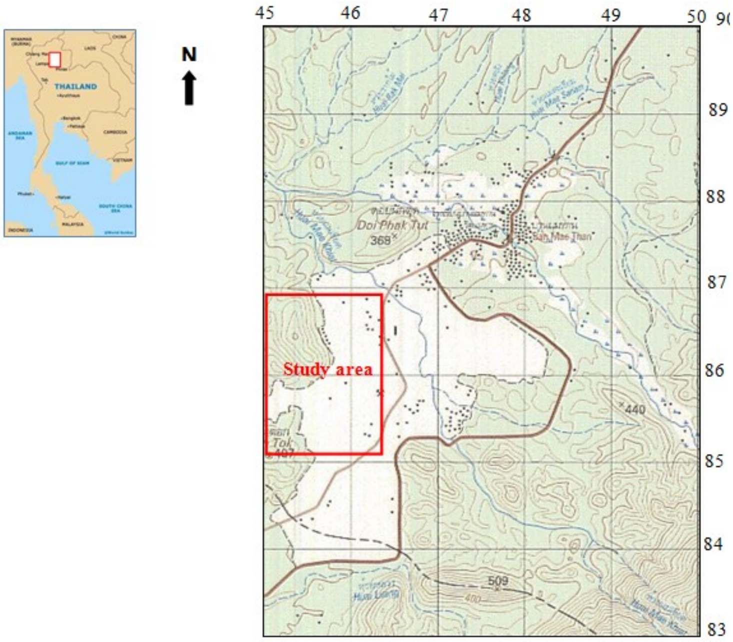

Figure 1 Topographic map of the second study area, Mae Than Deposit, Mae Tha, Lampang Province, Thailand,WGS 84 Amphoe Sob Prab, edition 1-RTSD, series L7018, sheet 4844 I(after Royal Thai Survey Department, 1999)[3].

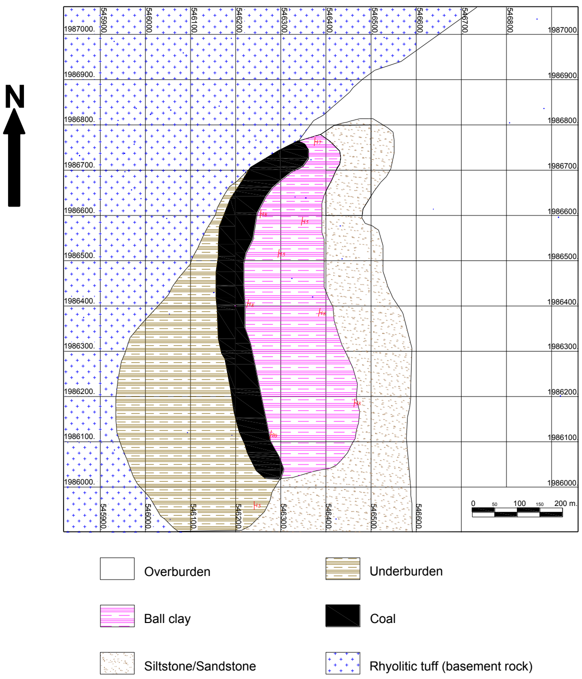

Figure 2 Geologic map of the study area (modified after MRD-ECC, 2001)[4].

The clay layers of the mine were classified to three units namely OB, IB and UB (Fig.3). OB is overburden clay which lies on top of the coal seam. The thickness is about 11 meters. IB is interburden clay with the thickness of 3 to 5 meters lies between upper coal seam and lower coal seam. UB is underburden clay which lies under the lower coal seam. The maximum thickness of this layer is about 26 meters. Siderite nodules commonly show in fine grained sediment beds both OB and IB. This mine uses stockpile layering in order to control the clay quality.

Figure 3 Looking NW on the opening mine face, clay layers of the mine classified to 3 units: OB (overburden), IB (interburden) and UB (underburden)(source: MRD-ECC, 2001).

III. Materials And Methods

The raw materials were collected vertically in each beds/benches of the mine (Fig. 4). Country rock samples were collected from the western part of the study area and no fresh rock was found. The samples collected were weathered rock samples. Clay samples collected consisted of representative samples of three layers: underburden (UB), interburden (IB), and overburden (OB). Topsoil sample was also collected. Vertical relationship is an important aspect to consider. All samples were analyzed for mineralogical composition. Sample preparation procedure was based on the strength of the samples. Samples with no strength or low strength were dried at 110 °C in an electric oven for 24 hours. Then, the samples were taken out from the oven and cooled down to room temperature. Finally, the samples were grinded to pass through 200 mesh testing sieve and analyzed for mineral composition. Mineralogical analysis was done by drying bulk samples at 110 °C for 24 hours in an electric oven and cooled down before grinding into 200 mesh size or 44 micron. The clay fraction was separated from the bulk sample by sedimentation and mounted as an oriented aggregate for clay-mineral identification. The treatments included air drying, glycolation with ethylene glycol, and heating to 550 °C were used for this analysis (Poppe et al., 2012)[5].

IV. Results And Discussion

X – Ray Diffractometer (XRD), Scanning Electron Microscope (SEM) and Thermal analysis by Differential Thermal Analysis –Thermogravimetry (DTA/TG) techniques were applied for identifying mineral phases of collected raw materials. Most of raw materials are clays samples.

According to XRD analysis, there were five mineral phases found in these raw materials. There were quartz, kaolinite, illite, montmorillonite and potassium feldspar. Quartz was a major mineral and minor mineral was kaolinite (Fig. 4). The content of quartz in the raw materials was more than 75 %. Kaolinite in this deposit was about 15 % at the maximum. Illite was found as accessory mineral with less than 10% and minor content of montmorillonite at about 2% as the highest. Feldspar was detected only in sample no. MT13 with less than 2 %.

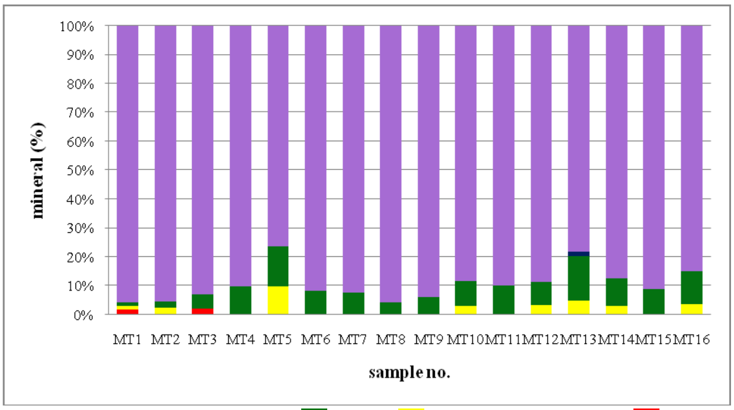

Figure 4 The amount of quartz, kaolinite, illite, montmorillonite and potassium feldspar of raw materials in Mae Than Deposit.

Clay sample was done for SEM to observe mineral crystal forms. SEM of the sample shows aggregate of irregular border kaolinite (Fig. 5).

Figure 5 SEM of MT4 showing irregular border kaolinite and kaolinite aggregate.

To investigate the change of raw materials when heating up to 1250 °C, thermal analysis by DTA/TG was applied. DTA curve shows an endothermic reaction at about 550 °C which is for kaolinite decomposition. Additionally, the second peak is an exothermic reaction at 974 °C where mullite was formed (Fig. 6). TG curve presents total weight loss from starting point to end temperature.

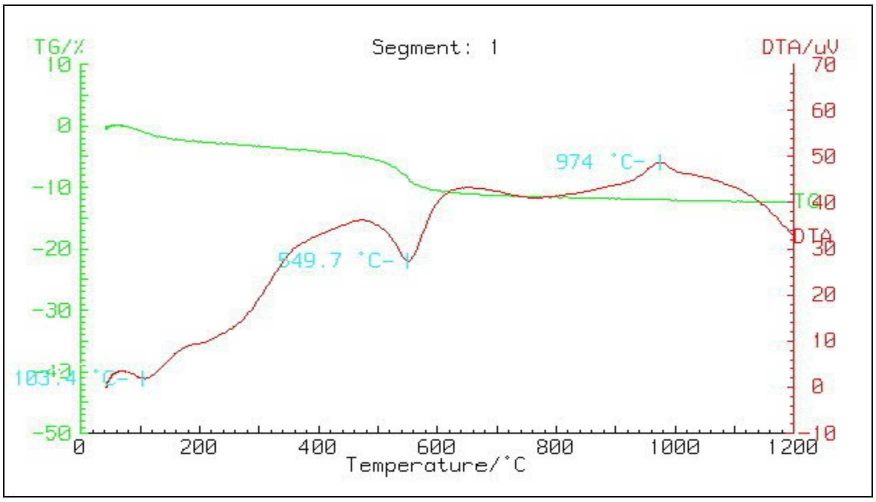

Figure 6 DTA of sample no. MT4 showing endothermic peak of kaolinite at about 550 °C.

4.1 Mineralogical Variation Of Sedimentary Clays At Mae Than Mine

The samples were collected and analyzed for mineral compositions by X – Ray Diffractometer. The X – Ray intensities of major minerals were calculated and adjusted to 100 %. Then, they were merged with the sample location map and observe for mineral variation within the study areas. The raw materials in Mae Than Deposit clearly showed different layers of deposition. Therefore, collecting of the samples was vertically distributed by different clay layers to find out any mineral variation of the deposit. The mineral distribution and sample grouping based on the depositional structure as Overburden, Interburden and Underburden layers are shown in Fig. 7.

The formation of kaolinite and quartz in Mae Than Deposit is believed to be a reaction under chemical weathering. Accumulation of siderite nodule in clays layer at Mae Than basin suggested that the rocks in this basin undergoing chemical weathering. Breaking down of minerals by weathering can be explained by the reverse of Bowen's reaction. Clays is a mineral principally formed under chemical weathering.

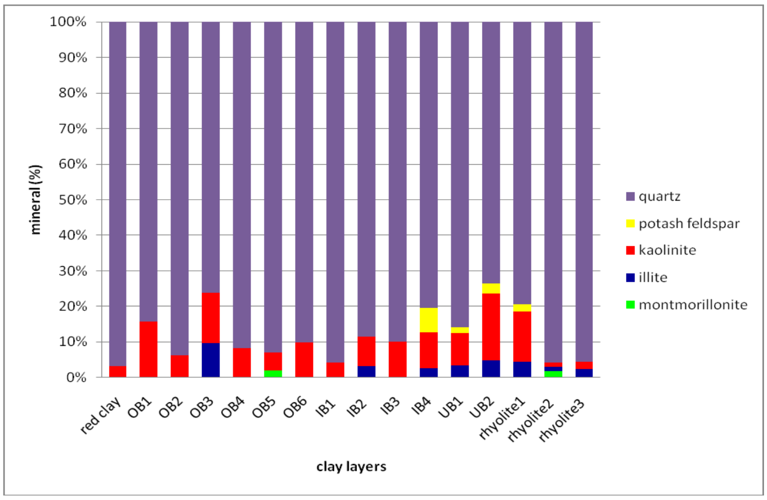

Figure 7 Mineral distributions of raw materials from different layers of Mae Than Deposit.

V. Conclusion

Kaolinite is formed under humid conditions by acid hydrolysis of feldspar bearing rock, whereas illite forms under more alkaline conditions by weathering of feldspar and micas (Robb, 2005)[6]. It was believed that kaolinite in the clay of Mae Than Deposit mainly originated under the intensed chemical weathering and decomposition of plagioclase, potassium feldspar and muscovite, under hot and humid condition of the pre – existing rhyolitic tuff, exposed in the western area. Eventually, the kaolinite was eroded and transported to be deposited under the organic rish fresh – water lake environment in the Mae Than basin (Thowanich, 1997). Based on the hydrolysis in feldspar, kaolinite hydrolysis is orthoclase reacts with 22 molecules of H_2O and gives kaolinite, while micaceous minerals hydrolysis is potassium feldspar reacts with 12 molecules of H_2O and gives mica. This may imply that clays of Mae Than Deposit genesis under humid or high rainfall. This can also be one of the reasons why the clays in the southern part of Thailand dominated in kaolinite than clays in Lampang. The depositional process was also different as the location of Mae Than Deposit is basin. Consequently, the grain size of clays from Mae Than will reasonably fine. Mineralogical variation of sedimentary deposit is much less complicated than hydrothermal deposit, since the clay - forming process due to the transportation and deposition. Therefore, the minerals are dominated by kaolinite and the clay properties considerably depends the size and amount of kaolinite and quartz. The depositional process tends to be concern with rate of water flow during the depositional. The stronger water flow is possible to bring larger sized quartz to be deposited and that will lead to clay properties. Because for sedimentary clay, the property of clays is much relevant to grain size, finer grain sized gives higher plasticity. XRD patterns by preferred orientation treatment of kaolinite presented in raw materials of Mae Than Deposit shows broad and low peak.DTA/TG of the same sample shows considerable difference at about 100 °C, endothermic and exothermic reactions of sample from Mae Than Deposit shows broad peaks. According to field observation, there were minerals observed but do not present in XRD analysis for example siderite and pyrite. These minerals are quite trouble for mining and processing. Siderite that found is considerably large and can be separated, but sometimes it is a problem for mining process and also can damage the processing machine. Pyrite may also lead to a decrease of whiteness when it is decomposed to iron oxides. Nevertheless, the results show that the color of clays may not be the result of minerals, but is more likely the result of geochemical of the clay itself.

Mae Than Deposit is one of coal deposit in Lampang Province. This deposit is mining and processing for both coal and ball clay. The clays are separated into three layers: OB clay, IB clay and UB clay. OB clay is clay overlying coal seam. IB clay is clay inter layering coal seam. UB clay is clay underlying coal seam. The samples were collected from all layers. The mineralogical investigation shows variation of quartz, kaolinite and illite. OB clay and IB clay are quite similar in mineralogical composition, but there was slight variation in mineralogical composition with UB clay. The variation of illite and kaolinite tend to increase with deeper layers. Illite and kaolinite contents rise up from OB to IB clay layer and UB clay layer as the highest. In contrast, quartz content slightly decreases with the deeper layer. The deposition may be resulted in the amount of quartz. Since under the process of deposition, quartz is supposed to deposit at the early stage of deposition during the stronger current and clay particles are able to float and deposit later in more quiet condition. However, there were fluctuations in both physical and chemical properties of the raw materials. The major oxides content varies with depth. There was no clear trend of decreasing or increasing of any values related to depth. It can be concluded that there was no relationship between depth and ceramic properties changes (Donmuang and Asnachinda, 2008)[7]. These may support the idea of the depositional environment which based on the strong of current at the moment of deposition. Thowanich (1997) proposed that depositional environment of this deposit was lacustrine origin. Iron compound which occasionally found in the deposit are pyrite (FeS_2) and siderite ($FeCO_3$). Siderite occurs in a form of nodular iron with varied sizes. It generally forms under organic-rich, highly reducing conditions where there is high carbonate and low sulfide. The most favorable environments for siderite formation are organic-rich, reducing fresh water systems. In contrast, siderite formation by sea water is limited by the stronger affinity of Fe^{2+} for HS^- ions rather than HCO_3^- ions (Lim et al., 2004)[8]. Evaporite and carbonate sediments are subcategories of the chemical sediment. Carbonate sediments also form in evaporative lacustrine basins and result from chemical precipitation resulting from pH shifts induced by biological activity or physical changes in the lake water (Schnurrenberger, 2003)[9].

The sedimentary deposit exhibits less complexity in mineral composition. Major minerals found were quartz and kaolinite. The characteristic of raw materials depend on depositional process and stratigraphy of the deposit. The high percentage of quartz could imply the transportation energy was stronger than the higher kaolinite content, which could have been deposited in stagnant water. In Mae Than Deposit, they are distinctively different in grain sizes, layer by layer, and lead to selective mining are process accordingly.

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