The genesis and characteristics of primary kaolinitic clay occurrence at Bukit Lampas, Simpang Pulai, Ipoh

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Abstract — The chemical, mineralogical and textural characteristics of the Lampas kaolin occurrence, near Simpang Pulai Ipoh and its genesis were investigated using X-ray diffraction, scanning electron microscopy and differential thermal, thermo gravimetric, Fourier transform infra-red, X-ray fluorescence, energy dispersive X-ray and granulometric analyses. Properties including particle sizes, moisture content, LOI, chemical composition, plasticity, firing shrinkage, brightness/whiteness and modulus of rupture were used to evaluate its potential as an industrial raw material.
Field evidence supported by mineralogical and chemical analyses suggests that the Lampas kaolin is a product of both hydrothermal alteration and weathering of aplite, leucomicrogranite, pegmatites and medium to coarse-grained porphyritic granite. Numerous quartz-feldspar veins and stockworks, silicification and illite alteration (argillic zone) were evident and characterize the hydrothermal fluid influx system of the area. Kaolinite is the predominant clay mineral of the Lampas kaolin with subordinate quartz, feldspar and illite/muscovite. There is localized occurrence of halloysite. Widespread occurrence of red, orange, or brown more stable lateritic clay saprolite characterizes the near surface overburden. The alumina content of Lampas kaolin is generally between 28 and 34%. Impurities, particularly iron oxide is less than 0.2% and total alkali and titania account for less than 1%. The average total alkali and iron contents are about 0.7% and 0.2% respectively. The average dry powder moisture and LOI is 1.25% and 14.0% respectively. The shrinkage and modulus of rupture values of the Lampas crude clay are moderate at lower temperatures, mainly due to its lower alkali and iron contents with over 45% (D_{45}) below the 2μm fraction and has excellent whiteness/brightness but with a lacking workability index.

Keywords: Kaolin, clay mineral, industrial clay, kaolinite, clay genesis

INTRODUCTION

Kaolinitic clay is a versatile industrial mineral. This clay type is generally used as fillers or raw material in ceramic, paints, plastics, paper, rubber, ink, catalyst, insecticide, pharmaceutical formulation etc. In the paper industry, kaolin is widely used as a pigment both as filler and coating. The physical and chemical characteristics of kaolin determine its ultimate application. Some specific physical and chemical properties of kaolin are dependent on the environment of deposition, geological origin, geographic source and the method of processing (Murray & Kogel, 2005). Presence of impurities, especially iron oxide and hydroxide and titanium-bearing materials impair the quality of kaolin and affect its utility for various industrial requirements. Most of the industrial kaolin in Malaysia was sought from secondary clay deposits. The main high quality kaolin deposits in Peninsular Malaysia are found near Bidor and Tapah Perak, Cheras Selangor; Jemeluang Johore and recently, Sg. Rasau Pahang. Due to rapid exploitation and industrial demand, depletion of such good kaolin is unavoidable, and a concerted effort must be made towards finding new kaolin deposits. Kaolin genesis has a direct bearing on its industrial applications. Sedimentary kaolin generally has a higher economic value compared to primary kaolin. The search for primary and

secondary kaolinitic clay reserves, originating from felsic rocks such as granite, aplite, leucomicrogranite, rhyolite, tonalite and tuff has not been pursued in this country. It is believed that there are some good clays as well as feldspar-rich rocks that were not evaluated such as in Grik, Perak. Economic kaolin deposits in Malaysia are mostly associated with granite intrusives which form the mountain ranges in the peninsula. Assessment of the economic aspects of these deposits is important to determine their suitability for industrial applications and for subsequent exploitation and processing as well as their and value-added potential.

This paper discusses the genesis and characteristics of the Lampas kaolinitic clay with respect to its mineralogy, chemistry, crystal morphology, plasticity, firing properties (modulus of rupture and shrinkage) and other relevant physical properties suitable for ceramic application.

LOCATION AND GENERAL GEOLOGY

This newly-discovered primary kaolin occurrence, located at km 12 to km 13 of the Simpang Pulai-Pos Slim road, Perak, is on the southern side of Bukit Lampas, (507m) the highest peak in the area (Figures 1 and 2). This area is drain by Sg. Anak Ayer China (a tributary of Sg. Raya) and its tributaries. Three main white kaolinized

clay occurrences can be traced along the road cuttings in the hilly area (elevation between 135 m and 180 m). The site is near the former orang asli (aborigines) settlements of Kg. Terasau and Kg. Juang. The area is partly covered by secondary forest and partly cleared for agriculture and road construction.

The detailed geology of the area and neighborhoods was investigated or reviewed by Teh (1969), Tan (1972), Ariffin Suhaidi (1993), Cheong (1990) and Mohd Azamie and Azman (2003). The Lampas area and the neighborhood of Keramat Pulai and Simpang Pulai (Kinta Valley), from west to the east, are underlain by marble, schist and granite. Schist of Paleozoic (Devonian-Permian) age, is the oldest rock. It only occupies a narrow zone between the younger Kinta Limestone comprises recystallized marble and the Slim granite to the east. In places, these rocks are overlain by Recent superficial deposits (Figure 2).

The Lampas area is predominantly underlain by the Slim granite, which is part of the Main Range granite batholith. The Slim granite consists of coarse-grained porphyritic biotite granite and medium to coarse granite as well as leucomicrogranite of Late Triassic (Bignell and Snelling, 1977; Ariffin Suhaidi, 1993). The pluton was locally intruded by numerous tourmaline veins, aplite dykes and occasionally pegmatite bodies. The mineral composition of granitic rock in the Bukit Lampas and adjacent areas is shown in Table 1. The granitic rocks were further classified by Tan (1972) and Cheong (1990) as adamellite, which

contains oligoclase and potassium feldspars, quartz, and occasional tourmaline in addition to biotite. The granites are highly sheared in many places and it is cut by three sets of joints. Some of these joints are filled by tourmaline, quartz, calcite and fluorite. The dominant orientations of quartz veins are 270°-280°, 330°-340° and 350°-360°, coinciding with the joint sets (Gobbett, 1971; Ariffin Suhaidi, 1993). They concluded that the veins were deposited by late-phase fluids, upwelling through joint and fracture planes. There are intense koalinisation of feldspars and chloritisation of biotite, as well as widespread tourmalinisation and greisenisation (Tan, 1972).

LAMPAS KAOLIN OCCURRENCE

The cutting of hill slopes between km 12 and km 13 of the Simpang Pulai-Pos Slim road has exposed extensive occurrence of massive white kaolinitic clay. Major occurrences of kaolinised overburden are found in at least 3 cut slopes along a 1-km stretch of the road that cut through part of the Bukit Lampas. Figure 3 shows the extensive formation of kaolinised material on a cut slopes in the vicinity of Bukit Lampas.

The main primary kaolin occurrence is located on a stretch between 04° 33.711" N, 101° 11.555" E and 04° 33.718" N, 101°11.614, about 135 m long in the direction of 085°. This cut slope is covered by massive kaolinised material encompassing an estimated area of 2000 m². The kaolin occurrence lies on a gentle to medium slope between the elevations of 135 m and 180 m. It is bordered on the southern side by Sg. Anak Ayer China, the road and a logging track on the western flank.
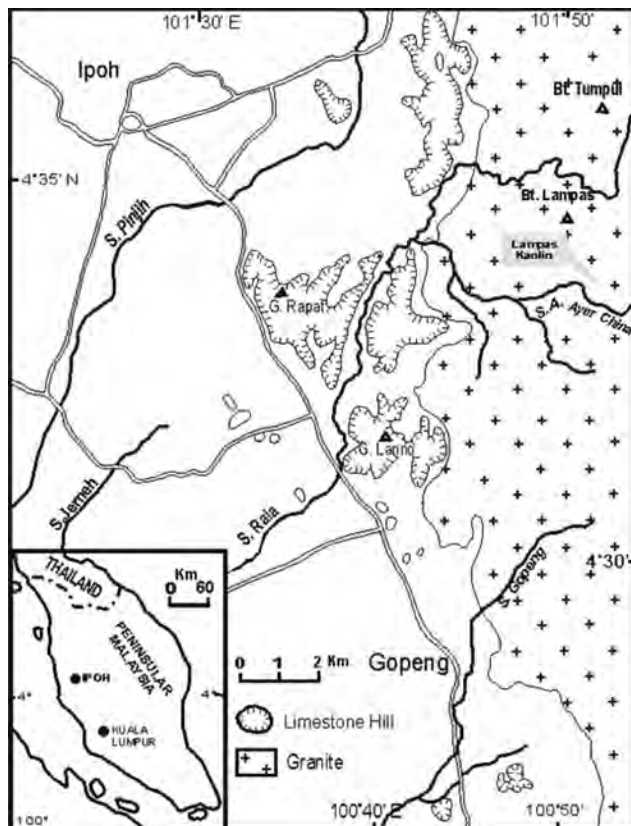

Figure 1: Map showing location of Lampas kaolinitic clay occurrence at km 12 – km13 of Simpang Pulai-Pos Slim road.
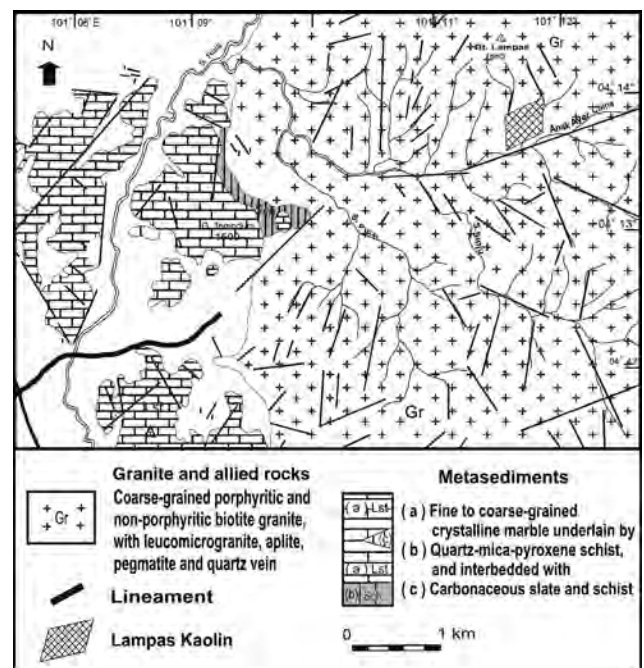

Figure 2: Geology of Bukit Lampas and the Keramat Pulai area, Ipoh, Perak.

SAMPLING AND TEST METHODS

The geology, mineralization, mineralogical and chemical characteristics of the kaolinitic clay occurrence were investigated in order to understand its genesis and its suitability for utilization in industrial applications, particularly the ceramic industry. The initial field investigation involved geological mapping and sampling. Observation and sampling of rocks and kaolin clay were made based on two auger holes as well as on a 130 m x 1.5 m west-east trending trench and grab samples (Figures 3 and 4). Depth of auger holes AU1 and AU2 is about 1.8 m and 3.6 m, respectively. Samples were obtained and recorded for every 24 cm interval. AU1 is located over thick red-yellow-brown soil, whereas AU2 penetrating the lower part with the kaolin clay occurrence has a thick white clay exceeding 3.6 m. Along the trench T2, samples were collected at bottom (SA) and top (SB) of the wall. A hand-held GPS was used to determine the sample locations.

Petrography and mineralogy of rock and kaolin samples were studied using powder X-ray diffraction (XRD), chemical analysis using X-ray fluorescence (XRF) and polarized microscope. An infrared (FTIR) spectrophotometer was used to identify and confirm the composition as well as the degree of crystallinity and structure of the kaolin clay minerals. Powder samples of crude kaolin were also analyzed by thermogravimetric analysis (TGA) and differential thermal analysis (DTA) in order to investigate the thermal reactions during the heating process from ambient up to 1200°C at a rate of 5°C/minute under atmospheric pressure. The TGA/DTA analyses were also used for purity determination. Particle size analysis and classification of kaolin were performed by using pre-determined size range sedimentation device (Cyclosizer) and a laser beam particle size analyzer (Malvern Mastersizer). Most analyses were carried out for particle size of less than 75 μm. Particle size, crystal morphology and composition of the kaolin clay were also determined using scanning electron microscope (SEM) and energy dispersive X-ray (EDX).

The industrial characterization of the crude kaolin, particularly as raw material for ceramic grade and other uses,
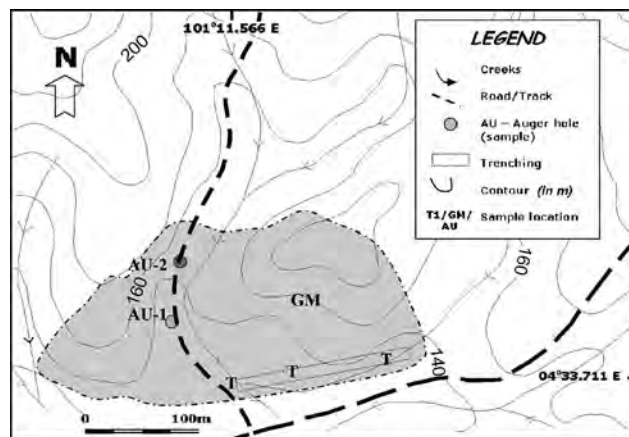

Figure 3: Map showing the Lampas kaolinitic clay occurrence area and sampling locations.

was also performed. The tests included moisture content, iron content, loss on ignition (LOI), pH, moisture, plasticity and specific gravity. Other specific tests for ceramic requirement involving firing test (color before and after) and shrinkage test, as well as modulus of rupture (MOR) conducted at various firing temperature levels in a laboratory electrical muffle furnace. Shrinkage tests were conducted for particle size < 75 μm, whereas MOR tests were conducted for samples with top-cut size of < 45μm. The plasticity test was carried out to determine the plastic limit (PI), liquid limit (LL) and plastic index (PI) using Atterberg apparatus. These tests were conducted in accordance to relevant British Geological Survey (BGS) procedure for kaolin (Bloodworth *et al.*, 1993) and other relevant procedures.

RESULTS AND DISCUSSION

Genesis of the Lampas Kaolin

Due to intense and prolong weathering and oxidation, the overburden of this occurrence is covered by 1 m to 3 m thick of red, orange or brown color lateritic soil (saprolite). This is due to intense oxidation and hydrolysis of iron-bearing mineral silicates (biotite). This has resulted in the formation of more stable iron oxide minerals such as limonite, hematite and goethite, and to some extent gibbsite.
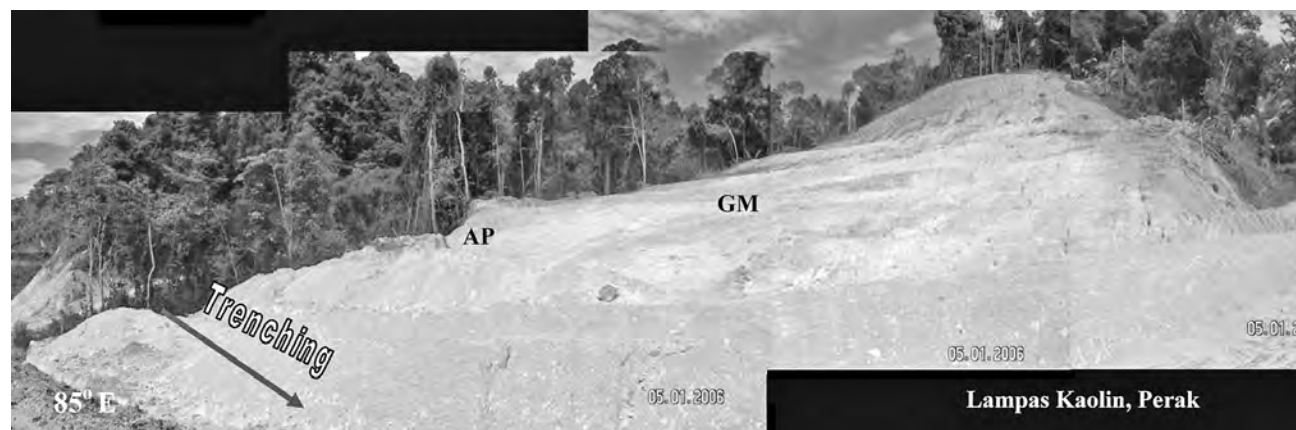

Figure 4: Lampas kaolinitic clay occurrence covered by red orange, or brown in color lateritic saprolite between 04° 33.711" N, 101° 11.555" E and 04° 33.718" N, 101°11.614 (135 m) along direction of 85°E.

Table 1: Mineral composition of major felsic rocks of the Lampas area and neighborhoods (after Tan, 1972, Cheong, 1990 and Ariffin Suhaidi, 1993).

Rock types / Mineral	CGPB 1	CGPB 2	CGPB 3 (GA)	CGPB 4 (GS4)	MGBG 1	MGBG 2 (GB)	MGBG 3 (G2)	PBMG	LM-1	LM-2
Quartz	25.3	20.5	25.8	20.9	25.2	22.7	22.2	40.2	50.2	49.6
Potash-feldspar	40.3	36.4	34.9	35.6	38.4	37.1	37.5	25.8	20.8	21.8
Plagioclase	26.1	38.5	30.4	33.6	35.2	35.2	36.8	30.2	28.9	28.5
Accessory minerals	8.10	4.50	8.70	9.60	1.00	4.90	3.20	3.50	< 1	< 1
Total			99.8	99.7	99.8	99.9	99.7	99.7	99.9	99.9

Accessory minerals= biotite, muscovite/illite, tourmaline and others; CGPB= coarse-grained porphyritic biotite granite/ adamelite; MGBG= medium-grained non-porphyritic biotite granite/adamelite; PBMG= porphyritic biotite microgranite/adamelite and LM=leucomicrogranite.

Feldspars are not stable at temperatures and pressures near the earth's surface and when in contact with acidic hydrothermal fluid, waters and high temperature environment they decomposed to other stable forms with almost similar composition. Hydrothermal alteration (hypogene process) of the granite that involved extensive koalinisation is the main process that contributes to kaolinitic clay formation of the area. Feldspar minerals of the granite and allied rocks, especially aplite and leucomicrogranite were weathered by hydrolysis resulting in alteration to kaolinite plus dissolved materials (K^+ and Na^+ ions). Further leaching will removed these K^+ and Na^+ ions from kaolin. Equigranular, angular to subangular quartz remain as resistant mineral that form residual mineral together with other weathered rock fragments within the kaolinitic clay occurrence. In the area, newly formed kaolinitic clay is often found as interlocked masses within interstices of hard, grayish to clear quartz crystals in highly weathered granite and aplite, or as feldspar pseudomorph in places. It is also locally found in-situ as whitish clay bordering quartz veins in granite.

The presence of numerous quartz veinlet stockworks within the kaolin occurrence indicates that active hydrothermal activities contributed to the kaolin formation. Hydrothermal activities are also indicated by outcrops of resistant silicified rocks (Figure 5). Silicification in the form of stockwork vein swarms can be seen near the western flank of the cut slope (Figure 4). Yellow-green patches consisting of a low-grade alteration mineral assemblage (GM, Figure 5) are also evident, especially near the centre of the slope, and restricted to fractured zones. Hydrothermal activities are evident from the nearby occurrence of a hot water spring near the confluence of Sg. Anak Ayer China and Sg. Pulai and tin-quartz mineralized veins within the vicinity of Keramat Pulai (Tan, 1972). Other features that influenced the Lampas kaolin formation are the presence of fractures or joints in the rock which enabled free flow of meteoric and hydrothermal waters that increased the rate of kaolin formation, and the prolonged chemical weathering in the warm humid tropical climate. The occurrence is considered as a part of the Bukit Lampas system, where leucomicrogranite and late phase aplitic dykes and hydrothermal quartz-vein were ascendant or prevailing. This late phase felsic rocks and allied dyke and vein systems had intruded into the Late Triassic Slim granite pluton. The model of late-phase leucomicrogranite intrusion and (aplite) dykes into older granite phase has been described by Clarke (1972) and Ariffin Suhaidi (1993).

Mineralogy

X-ray diffraction for mineral phase identification was carried out for selected samples of kaolin, aplite (leucomicrogranite) and the green alteration mineral (Figure 6). XRD analyses confirmed the presence of kaolinite in L-T1 and L-SB (T2). Two types of kaolinite crystal system and class (H-M) were identified, i.e. triclinic 1A and monoclinic 2M, however with kaolinite 1A being more dominant. The green alteration mineral assemblage generally consist of muscovite $[KAl_2(Si_3Al)O_{10}(OH)_2]$, quartz and kaolinite 1A $[Al_2(Si_2O_5)(OH)_4]$. Occurrence of muscovite indicates the presence of fine sericite/illite as a low grade alteration (argillic) product accompanying kaolinisation. The presence of illite in sample L-GA was traceable by FTIR (Figure 8) as well as kaolinite in LS-A (T2). Results of XRD analyses show that microcline, albite and quartz are the major mineral constituents of the aplite (leucomicrogranite). The chemical composition data (L-AP2) showed that the rock contained trace amounts of accessory minerals such as apatite, titanium-bearing and chromium-bearing minerals. SEM examination revealed the occurrence of halloysite (tabular, tube-like structure) locally, especially for kaolinised clay bordering the quartz veins (Figure 7).

FTIR patterns of the crude kaolinitic clay (< 45μm) and L-GM are shown in Figure 8. A typical spectrum characteristic of peaks at 3694, 3621, 3654, 1106, 1020, 918 and 974 cm^{-1} proved presence of kaolinitic clay and quartz at 1160 cm^{-1}. The spectrum for L-GM generally resembles kaolinite pattern, but with the absence of quartz peak. Presence of muscovite and quartz shown by XRD analyses was not apparent in FTIR, and may be due to poor representative sample use (5 mg). The DTA pattern (Figure 9) exhibits characteristics of endothermic and exothermic peaks of kaolinite at 537°C and 976°C, respectively and a peak inflexion near 432.6°C in the TGA curve (Fentaw *et al.*, 1998; Hajjaji *et al.*, 2002).

Chemistry

Table 2 gives the XRF chemical composition data of selected crude clay samples (AU1-6, AU-24, LS-A (T2) and L-KL (washed crude clay). L-AP-2 is a white aplite rock, whilst L-GM and L-GA are samples of green-alteration minerals.

The alumina content of crude kaolin clay ranges from 28% to 34%. Total alkali content (K_2O and Na_2O) and

iron content are about 0.7% and 0.2%, respectively. The maximum total iron and titanium-bearing oxides is 0.29%, with average of around 0.19%. The washed crude clay seemed to have lower iron oxide. An unusual high SiO_2 content in L-AP reflects the abundant quartz together with feldspars (microcline and albite). Evidence of the presence of trace apatite, ilmenite and zircon is indicated by the significant P_2O_5, TiO_2 and ZrO_2 contents. Exceptionally high K_2O, Fe_2O_3 and MgO contents of L-GM sample differentiates it from typical kaolinite composition. MgO is absent in L-GA. MgO might have been contributed by biotite.

Industrial Technical Properties

Some of the typical physical properties of crude kaolin samples from Lampas are shown in Table 3. Typical pH values of the raw Lampas kaolin are about 4.4. Moisture content of the raw kaolin and in the dry form is 28.10% and 1.25%, respectively. The dry powder moisture content is exceptionally low and is suitable for use as paint fillers (< 2%). Average specific gravity is 2.63.
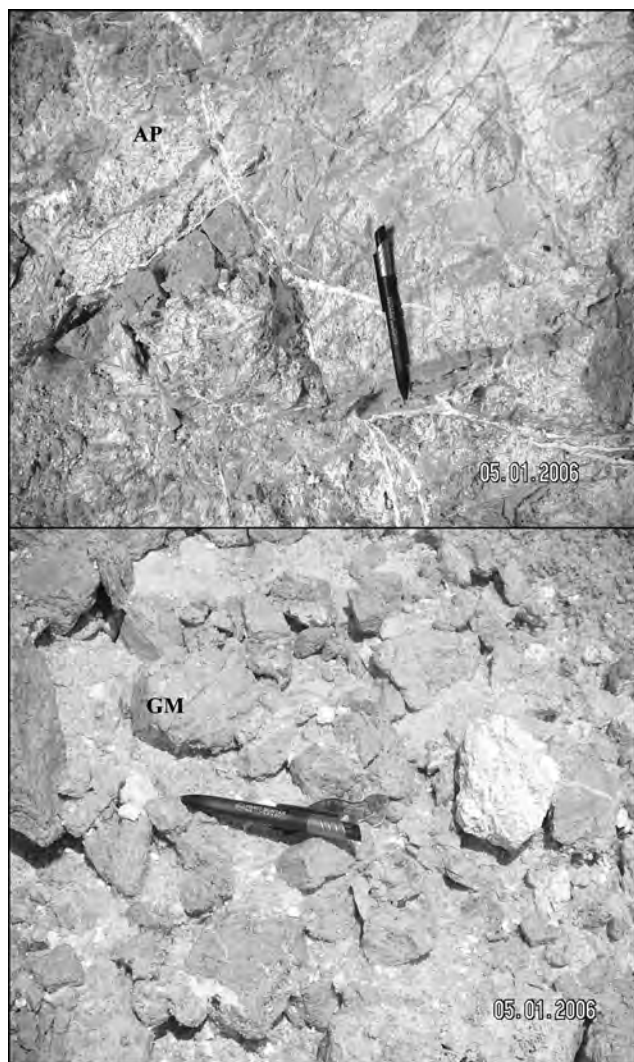
Particle size distribution of the crude kaolin bulk samples are generally 100% under 30 μm (by cyclosizer classifier), with the size fraction below 10 μm at around 41%. Particle size measured using the Malvern Mastersizer shows cumulative undersize of 100% below 20 μm and approximately 45% below 2 μm (LS-A (T2) and L-TA). Poor disintegration of individual kaolinite crystals, as observed under SEM (Figure 6) could be one of the reasons for the difference in the particle size measured.

Plasticity changes the shape of a clay-water mass in a non-elastic non-reversible manner. As almost all the clay materials are used in the plastic state, significant parameters include the Atterberg limits (liquid limit, LL and plastic
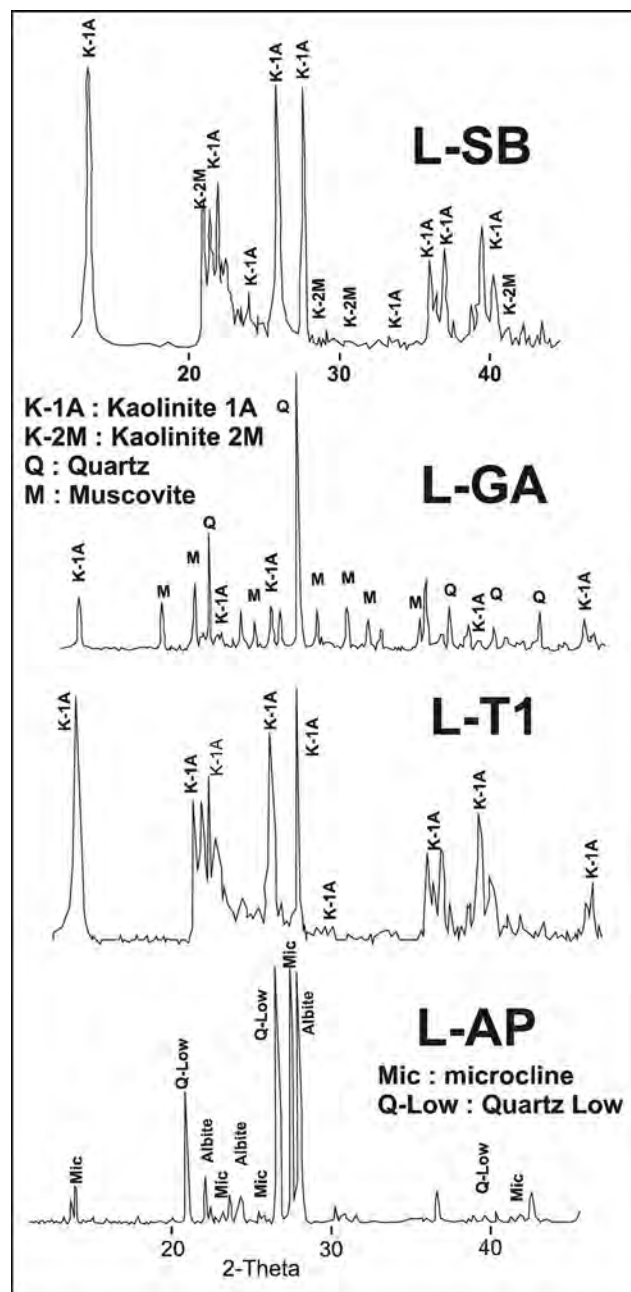

Figure 5: Top) Silicified aplite and quartz vein stockworks AP). Bottom) Assemblage of (L-GM) green chloritic/illite alteration minerals within the kaolinitic clay occurrence.

Figure 6: X-ray diffractograms of samples within the Lampas kaolin occurrence. LS-B (T2) and L-T1 = kaolin; L-GA = green alteration; L-AP= aplite/leucomicrogranite.
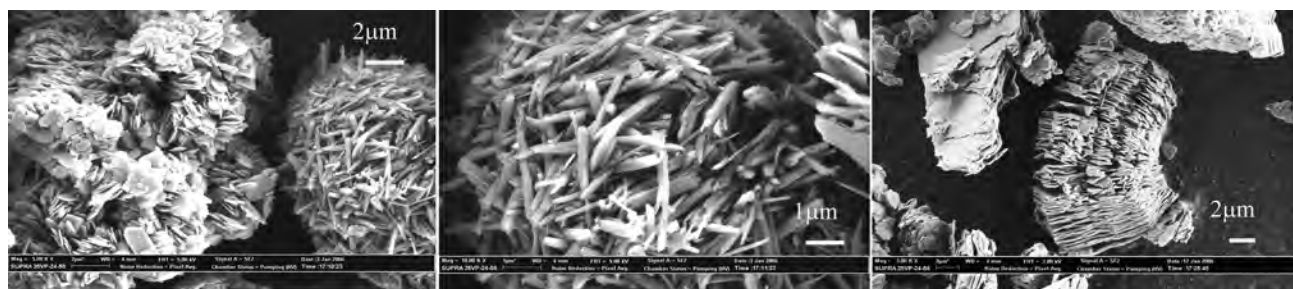
Figure 7: SEM photographs showing the Lampas kaolin crystal morphology. Assemblage of plate-like hexagonal kaolinite and elongated tabular halloysite (center) crystals of Lampas kaolin. Book-like kaolinite stacks are common (left and right).

Table 2 : Chemical composition of kaolin and allied rocks of Lampas kaolin determined by XRF.

Sample	AU1-6	AU2-24	LS-A (T2)	L-KL	L-AP2	L-GM	L-GA	Ceramics
Depth/Type (%)	0.6 - 0.9 m	3.0 - 3.3 m	Trench bottom (2 m)	Washed	Aplite	Green alteration	Green alteration	Prasad *et al.,* 1991 (-53µm)
SiO_2	54.00	52.00	50.00	60.00	78.00	55.00	59.00	51.27
Al_2O_3	28.00	34.00	34.00	28.00	15.00	29.00	28.00	26.31
Fe_2O_3	0.16	0.14	0.12	0.073	0.19	1.30	1.10	1.23
CaO	0.018	0.017	0.012	0.021	0.19	0.015	0.023	-
MgO	0.069	-	-	0.078	-	0.55	-	
Na_2O	-	-	-	-	2.3	0.099	-	
K_2O	0.35	0.42	1.30	0.91	4.30	7.30	6.20	
MnO	-	-	-	-	-	0.016	-	
TiO_2	0.041	0.067	0.13	0.13	0.11	0.044	0.034	1.52
P_2O_5	-	0.026	-	-	0.034	-	0.016	
$Cr2O_3$	-	-	-	-	0.031	0.023	-	
NiO	0.011	0.011	0.010	0.012	0.012	-	0.011	
CuO	-	-	-	-	-	-	Trace	
ZrO_2	Traces	0.018	0.017	0.035	0.022	Trace	Trace	
SrO	-	-	-	-	Trace	-	-	
Rb_2O	Traces	0.013	0.035	0.023	0.045	0.17	0.150	
Y_2O	-	-	-	-	-	0.050	-	
LOI	16.00	13.0	15.0	10.00	2.5	5.90	5.50	9.08

limit, PL) and Plasticity Index, PI. The LL and PL values of Lampas kaolin sample (< 45µm) are between 63% and 56%, with PI of 7%. This indicates that Lampas kaolin sample at this top-cut particle size falls outside of the "acceptable" moulding property fields and in the region of poor cohesion.

Shrinkage on firing at various temperatures was determined for the crude Lampas kaolin samples. Firing induces no color change in the crude of Lampas kaolin. The firing behavior of the Lampas kaolin at 1200°C exhibits similarities to that of commercial kaolin. The Lampas kaolin seems to have significantly high firing shrinkage at about 12% for size fraction < 45 µm at the firing temperature of 1200°C. However, shrinkage values could be lower for the finer size fraction. The modulus of rupture was considerably increased after firing from 800°C to 1200°C, from 1.91N/mm² to 12.01N/mm² at the firing temperature of 1200°C. The increasing shrinkage may be due to higher plastic limit (LL > 56%) and the coarser size fraction used (Siddiqui *et*

al., 2005). The crude Lampas kaolin also has acceptable oil absorption.

The average brightness of the Lampas kaolin as compared to commercially processed kaolin clay samples from Bidor, Perak, is excellent (higher than 80%). This may be due to the low content of ferruginous and titanium oxides. If the particle size fraction of the this primary kaolin is less than 63µm, the resource could be used for tiles manufacturing, and other ceramic applications due to the very low iron and total alkali contents providing that the firing shrinkage is improved.

CONCLUSION

There is widespread occurrence of kaolinitic clay in the Lampas area. Field evidence supported by mineralogical and chemical analyses suggests that the Lampas kaolin is a product of both hydrothermal and in-situ weathering of aplite, leucomicrogranite, pegmatite and medium to coarse-grained porphyritic granites. Numerous occurrences
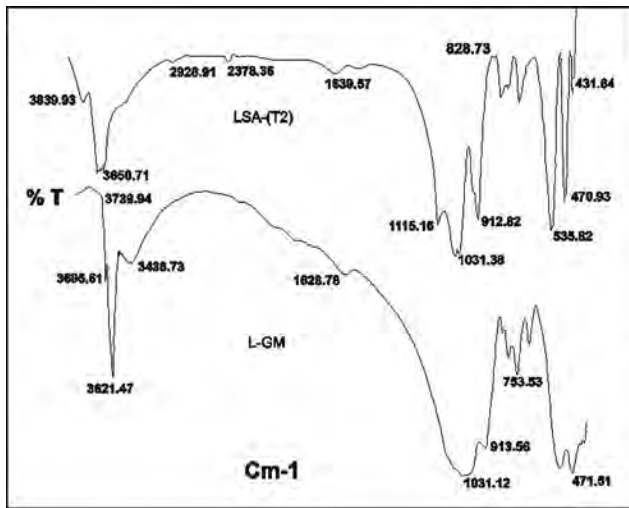
Figure 8: Infrared spectrum of the < 45 µm Lampas kaolinitic clay (L-SA(T2) and green alteration mineral (L-GM).
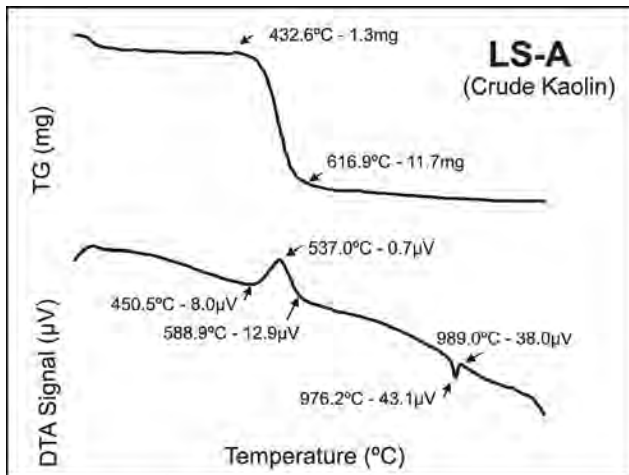

Figure 9: Typical thermogram (DTA/TGA) curve of the < 45µm kaolin of sample LS-A (T2).

Table 3: Technical and physical characteristics of Lampas kaolin.

No	Type of test	Size fraction, µm (sieving)	Typical values
1	Moisture		
	-Crude sample	Various	28.10%
	-Wash powder sample (L-KL)	75	1.25%
2	LOI	75	10.31%
3	pH	75	4.41
4	SG	75	2.63
5	Colour	75	
	-Before fired		White
	-After fired		White
6	Fired shrinkage	45	
	- 800°C		11.73%
	- 900°C		11.93%
	- 1000°C		11.96%
	- 1100°C		11.99%
	- 1200°C		12.01%
7	Plastic limit	45	56.30%
8	Liquid limit	45	62.80%
9	Oil absorption	45	46.5g/100g
10	Modulus of rupture	45	
	• Before fired		1.91N/mm^2
	• After fired		
	- 800°C		6.17N/mm^2
	- 900°C		6.53 N/mm^2
	- 1000°C		8.57 N/mm^2
	- 1100°C		9.32 N/mm^2
	- 1200°C		11.83 N/mm^2
11	Particle size distribution	<30	99.75%
	• (Cyclosizer sedimentation method classification)	<20	80.46%
		<10	40.22%
	• Malvern Mastersizer (laser beam)	< 20	100.00%
		< 2	45.00%

of quartz-feldspar veins stokworks, silicification and illite alteration (argillic zone) are evident and characterize the hydrothermal fluid influx system of the area. Kaolinite is the predominant clay mineral of the Lampas kaolin occurrence, while quartz, feldspar and illite/muscovite occur subordinately and halloysite occurs locally.

Physically and chemically, the crude Lampas kaolin clay has good technical properties and quality, which can meet the specification and requirements of various industrial applications. This crude kaolin clay proved to have low levels of iron oxide, titania, total alkali content and has excellent brightness/whiteness before and after firing. The kaolinitic clay below 75 µm appeared to be less plastic (lacking workability index), has moderate fired shrinkage and MOR values and acceptable oil absorption. However, these properties could be improved with the finer size fraction. Over 90% and 45% of crude Lampas clay size fractions are below 20 µm and 2 µm, respectively with a recovery rate estimated at around 30 to 50%. The Lampas kaolin is generally suitable for many applications provided that the required size fraction comply with the minimal requirements.

For ceramic grade < 63µm, the required ISO brightness is 91.87 with chemical purity as shown in Table 2 (Prasad *et al.*, 1991). Further tests, such as dry and fired shrinkage and MOR test for finer size fraction as stipulated in many standards like the MS standard, IS standard (Saikia, 2003; Prasad *et al.*, 1991) should be considered in order to have a better insight into the clay's technical properties in relation to commercial products. Other tests include viscosity and abrasiveness test and particle size distribution analysis. The quality, consistency, distribution pattern and extent of the Lampas kaolin occurrence should be further explored and investigated. Closely spaced borehole or augerhole and trenching investigation and systematic sampling are needed to evaluate the kaolin occurrence for commercial scale exploitation.

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