GEOSEA V Proceedings Vol. II, Geol. Soc. Malaysia, Bulletin 20, August 1986; pp. 601–617

Geology and exploitation of kaolin deposits in the Bidor area, Peninsular Malaysia.

P.C. Aw
Geological Survey of Malaysia,
P.O. Box 1015, Ipoh, Perak.

Abstract: The kaolin deposits of more than 50 million tonnes and distributed over 70 sq km occur in the Bidor area, Peninsular Malaysia. They are believed to have been formed hydrothermally. The area is underlain by Paleozoic metasediments which are intruded by the Changkat Rembian granite of Late Triassic age. Argillization is pervasive, affecting both the metasediments and the southern half of the Changkat Rembian granite which is intensely sheared.

The residual kaolin deposits derived from the alteration of granitic and metasedimentary rocks may be distinguished by their field, physical, chemical and mineralogical characteristics. Kaolin of granitic parent rock is generally characterized by relict granitic texture, high grit and lower clay content compared to metasedimentary kaolin. The granitoid kaolin generally has a higher brightness. Quartz, in vein and granular forms, is the most predominant non-clay mineral common to both types of deposits. In the clay mineral fraction, the assemblage consists mainly of kaolinite and trace to small amounts of illite, montmorillonite/vermiculite, quartz and feldspar. However, in places, illite predominates over kaolinite in some residual metasediments to form illite deposits.

It was mining of placer tin which led to the exposure of most of the kaolin deposits. Quartz veins/stringers carrying tourmaline and cassiterite with occasional wolframite and gold have been found in the Changkat Rembian granite and along its contact with the metasediments. Though the genetic relationship between gold, tin and tungsten mineralization and argillization is uncertain, temporally argillization is the youngest.

The Malaysian kaolin industry originated in the 1930s from this area. Currently, there are about a dozen processing plants which produce more than two-thirds of Malaysia's kaolin output of about 50,000 tonnes per annum. Both wet and dry processes are used to produce various grades of kaolin for ceramic, paper, paint, plastics and rubber industries. The most refined kaolin produced is of paper-filler grade.

INTRODUCTION

Bidor, in the state of Perak, is the main kaolin producing area in Malaysia. It is situated about 145 km north of Kuala Lumpur and 70 km south of Ipoh. Kaolin production in the area began on a small scale in the early 1930s, and today accounts for more than two-thirds of Malaysia's kaolin output of about 50,000 tonnes per annum. Both wet and dry processes are used to produce various grades of kaolin for ceramics, paper, paint, plastics and rubber industries. The most refined kaolin produced is of paper-filler grade.

This paper describes the field, chemical, mineralogical and physical characteristics of the kaolin deposits in relation to their origin. Methods of mining and processing of kaolin are also given.

The Bidor area was mapped geologically by Ingham (1938). At that time most of the area, where kaolin was subsequently found, was mined for placer tin. Only one small kaolin working was then in existence.

Permission to publish this paper is given by the Director-General, Geological Survey, Malaysia.

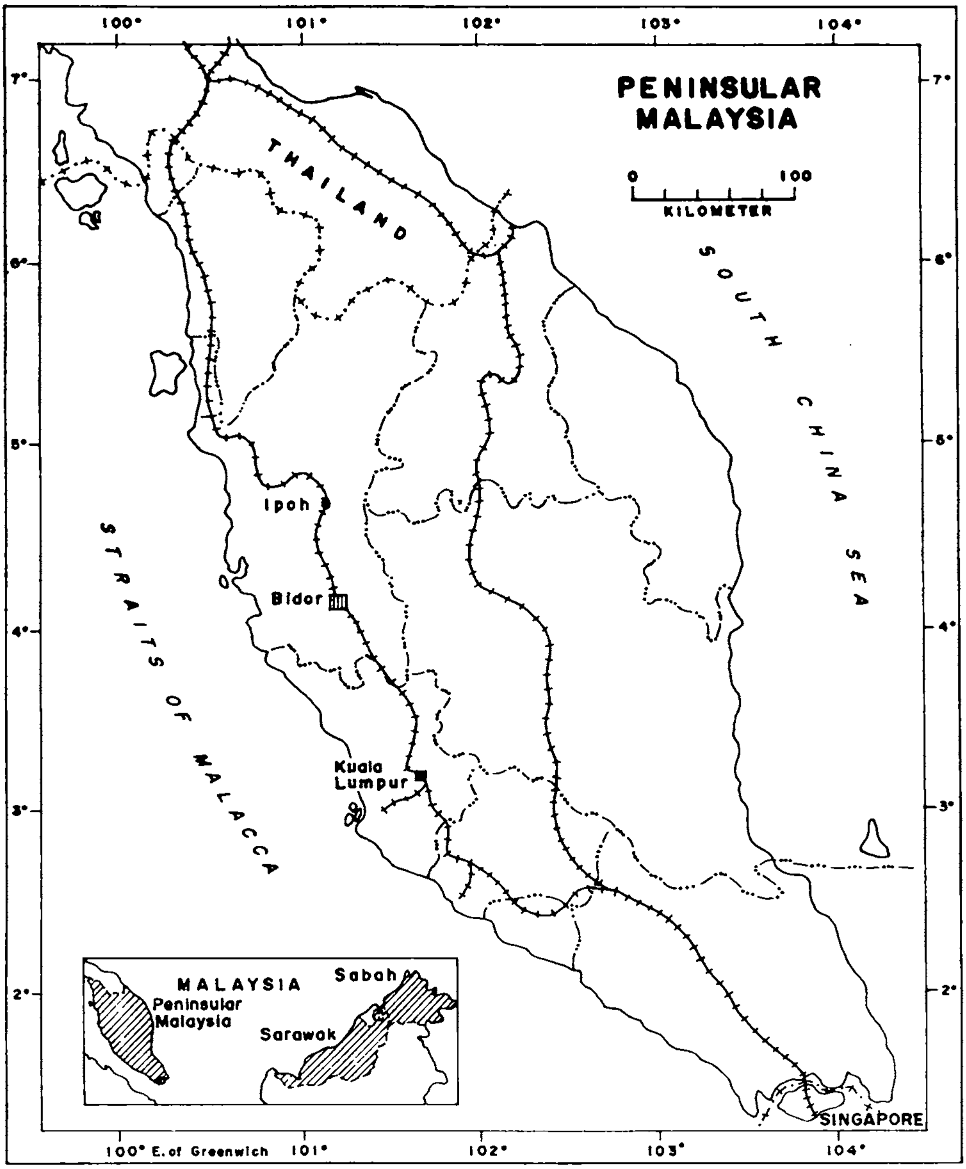

Fig. 1. Locality map of the kaolin deposits in Bidor area

GEOLOGICAL SETTING

The kaolin deposits occur in both the metasediments and Changkat Rembian granite. The metasediments consist of schist and phyllite which are in places, interbedded with marble. Metaquartzite is rare. The age of the metasediments is uncertain. Although Ingham (1938) considered the metasediments to be probably Carboniferous to Permian in age, the lower stratigraphic limit may be as old as Ordovician (Kobayashi *et al.*, 1979).

Fresh outcrops of metasediments are scarce, as nearly all the phyllite and schist observed were strongly altered and/or weathered. Ingham (1938) stated that the most common varieties of schist range from mica schist, mica-quartz schist to quartz schist with subordinate mica partings. Graphite schist, pyroxene schist and amphibole schist are also known to occur. Muscovite is the dominant mica, but biotite occurs occasionally.

The Changkat Rembian granite forms elongated granite stock about 13 km in length in the south-southeast direction. Outcrops are common on the northern half of Changkat Rembian, but the southern half is nearly everywhere covered by alluvium and the presence of granite is only revealed in mines or road cuttings.

The granite is mostly medium-grained, non-porphyritic variety with some fine-grained types in the northern half of Changkat Rembian. In the immediate vicinity of Changkat Rembian, granite porphyry, tourmaline granite and greisen occur. Towards the south the granite is strongly sheared and its weathered equivalent resembles a weathered schist in appearance (Ingham, 1938).

GEOLOGY OF KAOLIN DEPOSITS

General

Nearly all the known kaolin deposits are located along or to the west of Bidor-Tapah road (Figure 2). Most of them were uncovered as a result of past tin mining activity. Some of the kaolin exposures among the old mining ponds and mine tailings as seen looking south from the top of Changkat Rembian (ca 200 m) is shown in (Plate 1). However, there are some known kaolin deposits located on relatively undisturbed areas covered by jungle or planted with rubber.

Metasediment-hosted Deposits

Kaolinization is prevalent in phyllite and schist, except in the graphitic variety (Plate 2). Marble and metaquartzite are not known to be affected by this process.

Kaolin derived from metasediments can generally be recognised in the field by the presence of relict schistosity (Plate 3). The kaolin is homogeneous and soft to the touch. However, sand grains and coarse quartz fragments may be introduced by quartz veins. In some exposures where quartz veining is widespread and relict schistosity is not well defined, the kaolin texture may appear granitic. Besides the quartz veins, there may be some fine kaolin veins in the residual kaolin (Figure 3A).

Size-distribution of kaolin derived from metasediments is shown in Table 1.

TABLE 1

SIZE DISTRIBUTION OF COARSE-FRACTION OF RESIDUAL KAOLIN OF METASEDIMENT HOSTED ROCK (17 SAMPLES).

BSS mesh size	Range (%) Minimum	Range (%) Maximum	Average (%)
+ 4	0	2.1	0.4
+ 8	0	13.8	1.2
+ 16	0.3	15.7	1.8
+ 30	0.5	13.4	2.9
+ 60	0.5	12.6	3.2
+ 120	0.9	9.5	3.6
+ 240	0.6	18.7	9.6
+ 350	0.1	3.1	1.4
Pan	31.7	96.9	75.8

Analyst: Chow Chong

Plate 1. Panoramic view looking south from top of Changkat Rembian showing the ex-mining land with kaolin outcrops, tailings and ponds.

Plate 2. Outcrop of kaolinized metasediment with dark patches of unaltered graphite schist.

Plate 3. Close-up of kaolinized metasediment, showing relict schistosity.

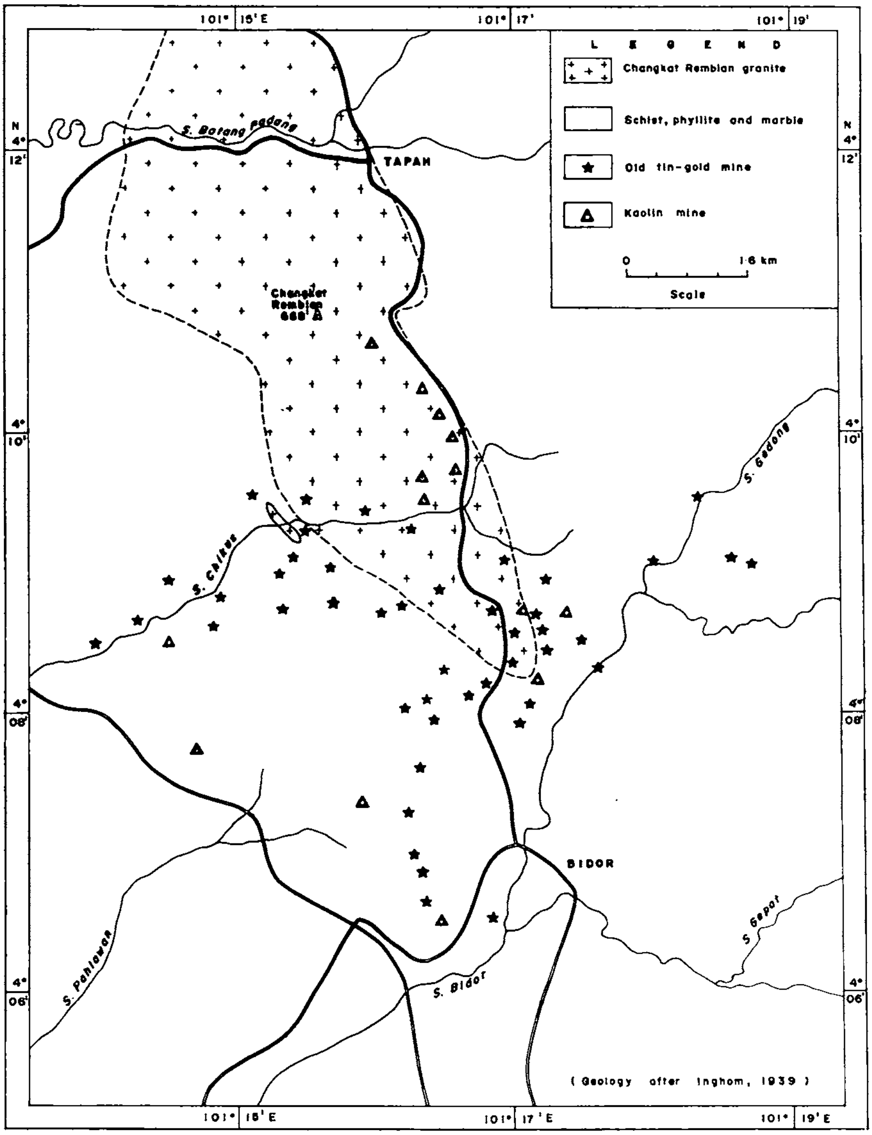

Fig. 2. General geology and distribution of kaolin and old tin-gold mines in Bidor area

The percentage of the coarse fraction is erratic where the percentage is high, it is generally contributed by the quartz veins.

Size distribution of the clay fraction of kaolin derived from metasediments is shown in Table 2.

TABLE 2

SIZE DISTRIBUTION OF CLAY FRACTION OF RESIDUAL KAOLIN OF METASEDIMENT-HOSTED ROCK (19 SAMPLES)

Size	Range (%) Minimum	Maximum	Average (%)
+ 350 # BSS	2.6	20.3	9.8
+ 30µm e.s.d.	1.1	14.0	5.3
+ 20µm e.s.d.	1.8	7.6	5.0
+ 10µm e.s.d.	5.3	15.7	11.6
+ 5µm e.s.d.	9.1	25.1	17.5
+ 2µm e.s.d.	14.5	32.5	23.9
– 2µm e.s.d.	7.5	53.4	26.9

e.s.d. = equivalent spherical diameter Analyst: Chow Chong

The clay-size fraction (- 2µm) constitutes slightly more than a quarter by weight. Tables 1 and 2 are compiled from data obtained from different samples, hence the discrepancy in the average values of plus 350 mesh fraction.

Chemical composition of three varieties of schist and minus 350 mesh fraction of kaolin is shown in Table 3. Owing to the diverse composition of the schist, little comparison can be made with the kaolin. However, partial chemical analyses of 6 kaolin fraction samples given in Table 4, shows only an increase in the alumina content.

Granitoid-hosted Deposits

All the known granitoid-hosted kaolin deposits are found to the south of Changkat Rembian (Figure 2). In general, the kaolin derived from the granitoid can be recognised by its residual texture of random distribution of relict quartz (Plate 4). However, in highly sheared granitoid, the shearing may be mistaken for relict schistosity. On close observation it will be noted that the kaolinized granitoid is criss-crossed by quartz and kaolin veins (Figure 3B).

Size-distribution of the coarse fraction of kaolin derived from the granitoid is shown in Table 5. The coarse fraction (plus 350 mesh) constitutes about 30 percent by weight.

Size distribution of the clay fraction of kaolin derived from granitoid is shown in Table 6.

The average clay-size fraction (- 2µm) is about 15 percent which is slightly more than half that of kaolin derived from metasediment.

Partial chemical composition of some granitoid-derived kaolin is shown in Table 7.

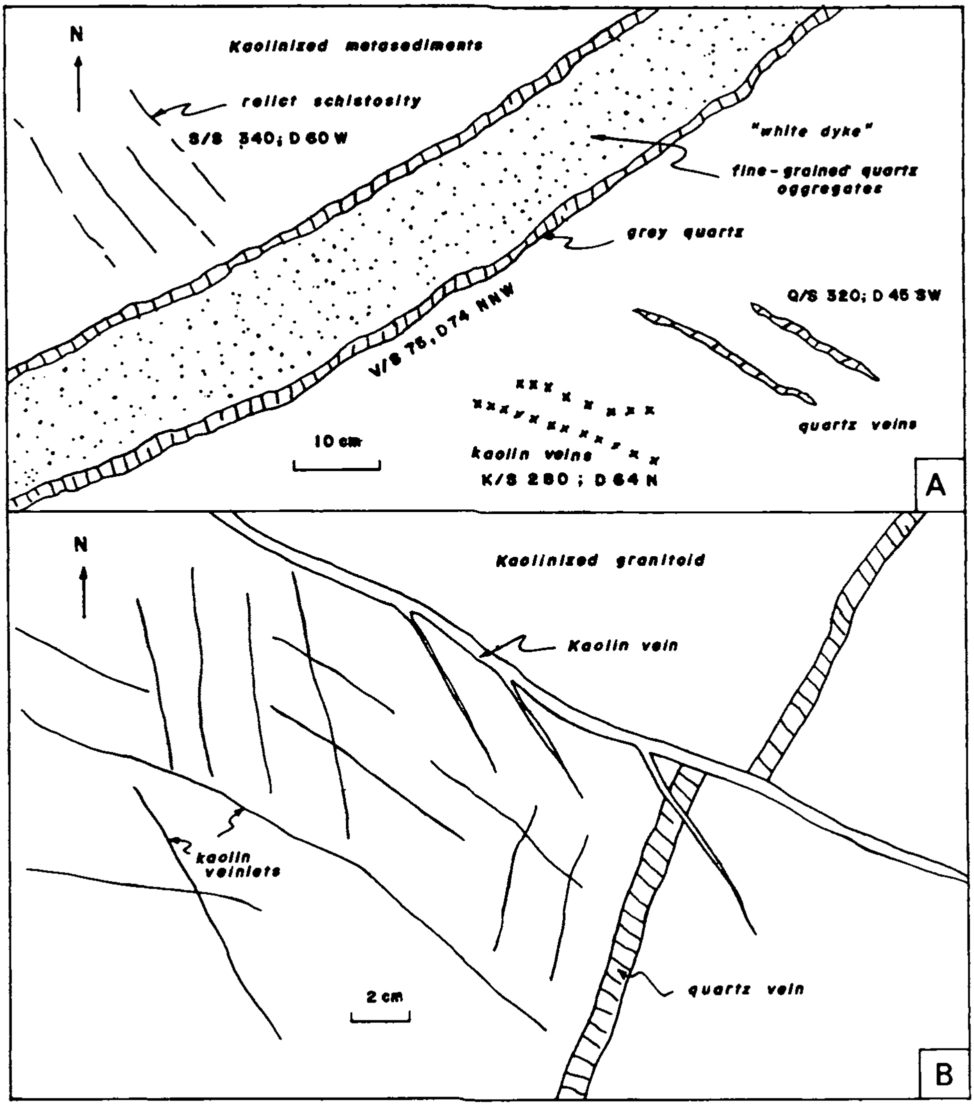

Fig. 3. Relationship between quartz and kaolin veins in kaolinized metasediments and granitoid.

In general, kaolin derived from granitoid is higher in alumina and lower in iron and potash than kaolin derived from metasediments.

X-ray diffraction of clay-size fraction of both granitoid and metasediment derived kaolin shows the assemblage consists of mainly kaolinite and small to trace amount of illite,

TABLE 3

CHEMICAL COMPOSITION OF SCHIST AND KAOLIN FRACTION

%	1 Graphite schist	2 Quartz-sericite schist	3 Biotite schist	4 Kaolin (-350 #)
SiO_2	72.98	93.85	52.39	56.42
Al_2O_3	6.1	2.04	13.76	28.35
Fe_2O_3	0.32	0.23	0.76	0.75
FeO	Tr	0.14	9.61	Tr
TiO_2	0.19	0.32	1.50	1.00
P_2O_5	0.03	0.05	–	–
CaO	0.38	1.22	5.72	0.22
MgO.	0.81	0.50	7.28	0.83
Na_2O	0.05	0.05	2.05	0.44
K_2O	1.28	1.11	4.08	4.21
H_2O^+	0.63	0.26	1.44	7.18
H_2O^-	3.43	0.53	–	0.76
CO_2	–	–	0.32	–
ZrO_2	–	–	0.04	–
F	–	–	0.34	–
S	–	–	0.62	–
MnO	–	–	0.04	–
			99.95	
Less $O = S + F_2$			0.45	
	99.61	99.08	99.50	100.22

Sample 1, Analyst : Tong Yik Lum
Sample 2, Analyst : Lee Kim Hock
Sample 3, Analyst : Harral (in Ingham, 1938)
Sample 4, Analyst : Chow Chong

montmorillonite/vermiculite, quartz and feldspar (Teoh & Leong, personal communication). However, in deposits derived from certain metasediments, illite predominates over kaolinite.

Generally, the granitoid-derived kaolin is brighter than those derived from metasediments. The comparative brightness of the kaolin, measured by means of the Carl Zeiss Elrepho spectrophotometer at 457 nm is shown in Table 8.

COMMERCIAL EXPLOITATION OF KAOLIN

There are about a dozen kaolin producers in Bidor area who produce semi-refined and refined kaolin. Except for 2 producers who use modern processing machinery, the rest of them utilize simple equipment to separate the coarse impurities from the kaolin (Aw, in

TABLE 4

PARTIAL CHEMICAL COMPOSITION OF KAOLIN FRACTION (MINUS 350 MESH) FROM METASEDIMENT-HOSTED ROCK (6 SAMPLES)

	Range (%)		Average
	Minimum	Maximum	
SiO_2	44.98	64.72	55.25
Al_2O_3	18.55	38.45	38.65
Fe_2O_3	0.49	1.99	1.12
Na_2O	Tr	0.03	Tr
K_2O	0.11	5.85	3.46
LOI	4.40	13.98	8.81

Analyst: Chow Chong

TABLE 5

SIZE DISTRIBUTION OF COARSE-FRACTION OF RESIDUAL KAOLIN OF GRANITOID-HOSTED ROCK (11 SAMPLES)

BSS	Range (%)		Average (%)
mesh size	Minimum	Maximum	
+ 4	0	3.2	0.8
+ 8	0.5	3.4	1.7
+ 16	1.8	10.1	4.7
+ 30	1.9	9.8	5.1
+ 60	1.3	8.0	4.3
+ 120	0.8	12.2	3.8
+ 240	2.2	10.7	5.3
+ 350	1.3	3.1	2.2
Pan	58.8	89.0	72.1

Analyst: Chow Chong

TABLE 6

SIZE DISTRIBUTION OF CLAY FRACTION OF RESIDUAL KAOLIN BY GRANITOID-HOSTED ROCK (17 SAMPLES)

Size	Range (%)		Average (%)
	Minimum	Maximum	
+ 350 # BSS	14.6	61.7	32.0
+ 30μm e.s.d.	2.4	18.5	11.0
+ 20μm e.s.d.	1.9	14.5	6.1
+ 10μm e.s.d.	2.0	19.5	12.1
+ 5μm e.s.d.	2.0	19.3	12.8
+ 2μm e.s.d.	5.0	19.1	11.1
− 2μm e.s.d.	6.7	32.9	15.0

Analyst: Chow Chong

TABLE 7

PARTIAL CHEMICAL COMPOSITION OF MINUS 350 MESH KAOLIN DERIVED FROM GRANITOID (4 SAMPLES)

%	Range %		Average %
	Minimum	Maximum	
SiO_2	54.98	58.52	56.82
Al_2O_3	28.76	30.18	29.20
Fe_2O_3 (total Fe)	0.50	1.62	0.94
Na_2O	tr	tr	tr
K_2O	1.42	4.02	2.42
L.O.I.	8.94	11.46	10.33

Analyst: Chow Chong

TABLE 8

Comparative brightness of granitoid and metasediment-derived kaolin

	No. samples	Range %	Average %
"Granitoid" kaolin	10	74.5 - 84.7	79.3
"Metasediment" kaolin	12	63.4 - 84.3	75.4

Analyst: Chow Chong & Fan Choon Meng

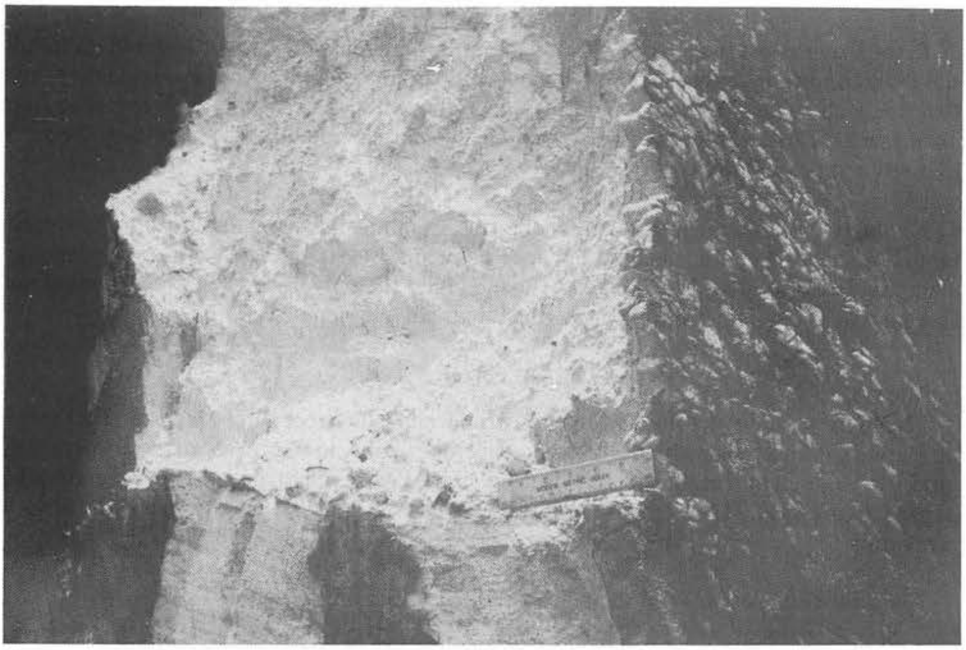

Plate 4. A column of kaolinized granitoid with a quartz vein on the right.

press). Kaolin produced by the latter are of low quality, generally suitable for ceramics and low-grade filler industries. Whereas kaolin of consistent quality which meets the specifications for paper filler grade is produced by the two major processing plants.

Kaolin is mined by open cuts. In most areas, kaolin was exposed by previous tin mining. Any overburden that remained is removed by front end loader. The exposed kaolin is extracted from the ground in two ways. One way is by digging the kaolin either with a dragline or front-end loader. The kaolin is then loaded on to lorries before transporting it to the processing plant or stock-piled in the sheds. The second method is analogous to the first stage of gravel pump tin mining. Kaolin is disintegrated by water under high-pressure jets, the slurry formed is pumped from the bottom of the pit either through a sluice box to a sedimentation tank or direct to the processing plant.

Processing is mainly aimed at removing coarse-grained impurities, concentrating the clay-size fraction and rendering the product as white as possible. There are two methods of processing, the wet process and the dry process or air floatation. The wet process is generally more efficient than the dry process (Fan & Aw, in press).

The various methods of processing are shown schematically in Figure 4.

Kaolin which is used for the manufacture of white cement, does not need processing. The clay is sent direct to the stock pile from the kaolin pit.

In the dry process, the crude kaolin is first dried by air under open sheds, then by heat, using either firewood or fuel-oil. The coarse-grained impurities are removed either manually, mechanically or by air separators.

In the wet process, the coarse-grained impurities are removed by wet screening, through sluice box and sedimentation tank or by hydroseparators or hydrocyclones. In some plants, the clay is chemically treated to improve its brightness. The excess water is removed from the refined kaolin by filter press. The kaolin is then dried either by air under open sheds, or by firewood or fuel oil.

Kaolin is sold either in lump or powder forms. Ceramic industry generally purchase moist lump form. The filler grade kaolin for paper, paint, plastics, rubber, adhesives and pesticides is in powder form. This is produced by using either the pulverizer or simple grinding and sieving machines. The kaolin is packed in 25 kg polyethylene bags.

QUALITY OF KAOLIN

The highest quality kaolin that is being produced is the paper filler grade. So far there is no known kaolin deposit which is of sufficient crude quality to be processed to paper coating-grade. In general, the brightness and viscosity of the kaolin fail to meet the specifications for paper-coating clay. Traces of montmorillonite are responsible for the poor rheological properties.

The analytical details on 2 samples of refined kaolin are shown in Table 8.

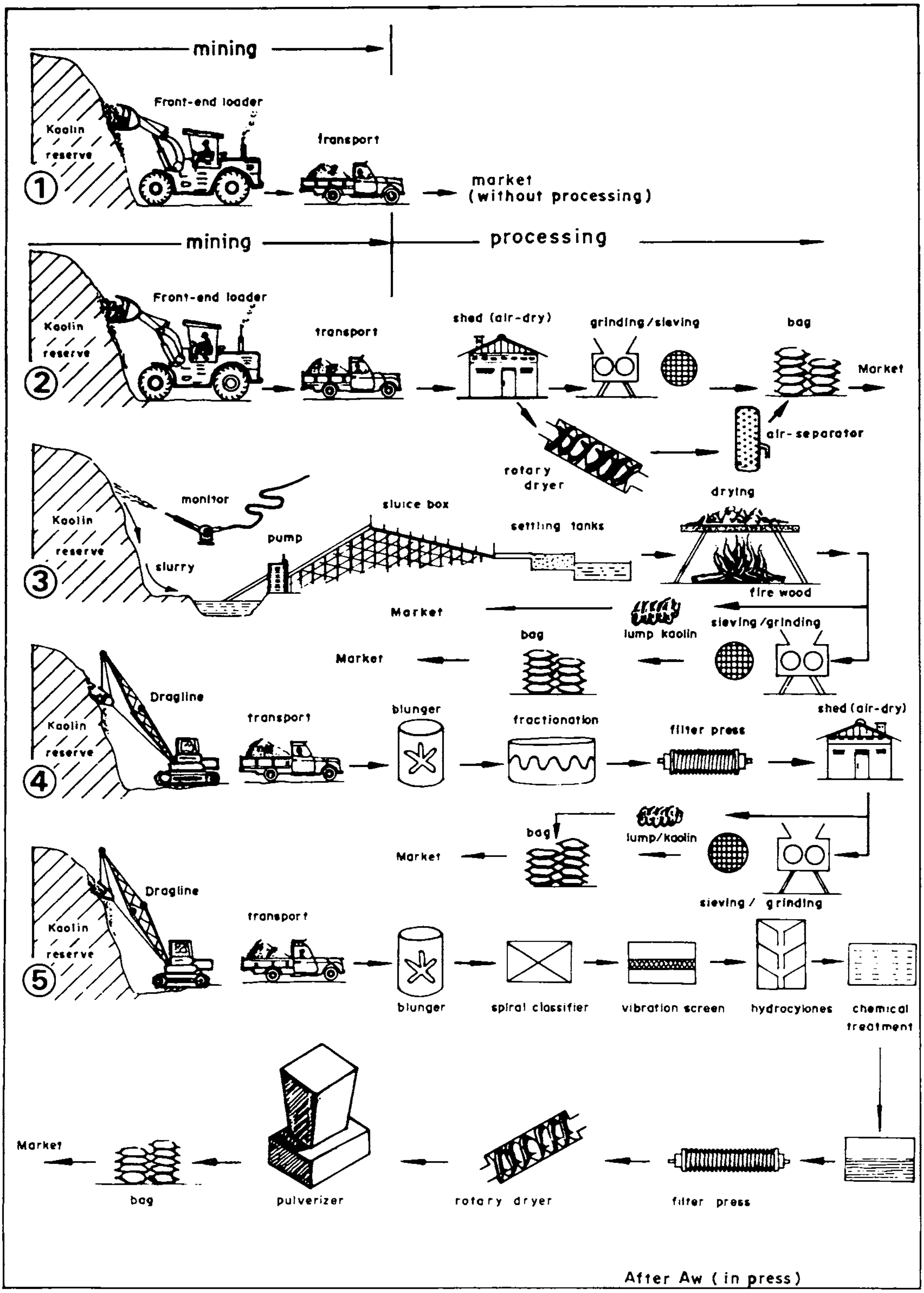

Fig. 4. Schematic diagram showing various methods of kaolin processing in Bidor area.

TABLE 8

SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF 2 REFINED KAOLIN SAMPLES

	J/M	A/133
+ 350 # BSS	0.02	0.01
+ 30μm e.s.d.	tr	tr
+ 20μm e.s.d.	tr	tr
+ 10μm e.s.d.	0.20	2.80
+ 5μm e.s.d.	11.3	22.6
+ 2μm e.s.d.	31.3	35.1
– 2μm e.s.d.	57.2	39.5
	100.0	100.0
SiO_2 %	45.9	46.9
Al_2O_3	37.6	36.5
Fe_2O_3	0.74	0.94
TiO_2	0.26	0.32
CaO	tr	tr
MgO	0.15	0.28
Na_2O	0.02	0.03
K_2O	0.98	1.44
L.O.I.	14.1	13.3
Brightness	84.7	81.8

Analyst: Fan Choon Meng

TABLE 9

SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF A PROCESSED ILLITE SAMPLE

Size distribution		Chemical composition	
+ 350 # BSS	0.1 %	SiO_2	48.42 %
+ 30μm e.s.d.	8.2	Al_2O_3	29.85
+ 20μm e.s.d.	5.7	Fe_2O_3	3.23
+ 10μm e.s.d.	5.9	TiO_2	1.02
+ 5μm e.s.d.	6.1	CaO	0.40
+ 2μm e.s.d.	26.0	MgO	3.13
– 2μm e.s.d.	48.0	Na_2O	0.23
	100.0	K_2O	6.58
		MnO	0.02
		P_2O_5	0.33
		L.O.I.	7.10
			100.31

Analyst: Fan Choon Meng

The analytical details on a processed illite sample are shown in Table 9.

RESERVE

As the area has not been fully explored, the total kaolin reserve is not known. However, a conservative estimate places the reserve as more than 50 million tonnes. The biggest kaolin pit in operation (Plate 5) is estimated to have more than 10 million tonnes.

MODE OF FORMATION

The kaolin deposits in Bidor are residual, derived from the alteration of granitoid and metasediments *in-situ*. Texture and structure of the kaolin deposits are similar to their unaltered parent rocks. In places, the kaolin deposits are in gradational contact with the parent rocks.

However, the genesis of the kaolin deposits is still controversial. Weathering has been implied to be the cause of kaolinization by Ingham (1938). K.K. Cheang (personal communication) is also of the opinion that the kaolin is of supergene origin. The writer, however, believes the deposits were formed hydrothermally.

Argillization is widespread in the Bidor area. Ingham's observation that shearing is intense in the southern half of Changkat Rembian granite may be relevant to the process. The occurrences of major kaolin deposits in this area may be related to this structural feature.

Plate 5. Kaolin exposures in a kaolin mine.

TABLE 10

SIZE ANALYSIS AND CHEMICAL COMPOSITION OF A SAMPLE FROM THE WHITE DYKE

BSS mesh size	%	Chemical composition	
+ 30 #	2.7	% SiO_2	95.5
+ 52 #	2.5	Al_2O_3	2.38
+ 60 #	0.6	FeO	0.03
+ 85 #	1.3	Fe_2O_3	0.07
+ 100 #	0.9	TiO_2	0.01
+ 120 #	1.4	P_2O_5	0.05
+ 150 #	2.4	MnO	Tr
+ 170 #	5.1	CaO	0.11
+ 200 #	10.8	MgO	0.01
Pan	72.3	Na_2O	0.03
		K_2O	0.06
	100.0	H_2O^+	0.99
		H_2O^-	0.43

Analyst: Fan Choon Meng

Network of kaolin veinlets is common in both types of kaolin deposits. The kaolin veinlets are closely associated with quartz veins. In one outcrop (Figure 3A), a white dyke is bordered on either side by grey columnar quartz. The white dyke is found on analysis (Table 10) to contain mainly fine-grained quartz and minor kaolin. The columnar quartz bordering the dyke may represent the deposition of the expelled silica from the argillization of the dyke. Secondary quartz is prevalent in hydrothermal clay deposits (Keller & Hanson, 1969).

Argillization is common in the primary tin mineralized granitoid in Perak. The author's observation in the mines along the foothills of the Keledang and Main ranges, show that the kaolin veins invariably postdate the quartz-tourmaline-cassiterite veins. However, in most of these areas argillization appears to be less intense, as supergene weathering has largely masked its product. The iron oxide discolouration due to weathering has contaminated the kaolin and rendered it useless as an industrial mineral.

If the supergene process indeed plays a major role in the formation of kaolin deposits, one would expect kaolin deposits to be ubiquitous in Malaysia. The fact is that kaolin deposits are of restricted occurrences. In each case, the kaolin deposit is spatially related to some granitoid plutons. Hence it is likely hydrothermal solution emanating from the pluton, together with that syntectonic activity, is responsible for the formation of kaolin deposits, as in Bidor.

Illite occurs in trace to minor amounts except in two known areas. In these two areas, illite predominates over kaolinite to form deposits which are being exploited. The parent rocks are metasediments. It is probable that the original composition of the parent rocks may be partly responsible for the formation of illite deposits.

ACKNOWLEDGEMENTS

The writer thanks his colleague, Mr. S.S. Rajah for reading the original draft of this paper.

REFERENCES

AW P.C. (in press). Mining and production of kaolin in Malaysia. *Geological Survey Malaysia, Annual Report 1982.*

FAN, C.M. & AW, P.C. (in press). Dry processing of kaolin in Bidor, Perak - a study of the physical and chemical characteristics of the products. *Geological Survey Malaysia, Annual Report 1983.*

INGHAM, F.T., 1938 The geology of the neighbourhood of Tapah and Telok Anson, Perak. Federated Malay States, with an account of the mineral deposits. *Geological Survey Malaysia, Memoir 2*, 1 - 72.

KELLER, W.D. & HANSON, R.T. 1969. Classification and problems of hydrothermal refractory clay deposits in Mexico. *Proceedings of the International clay conference, Tokyo, Japan 1969, Volume 1*, 305-312, Israel Universities Press, Jerusalem.

KOBAYASHI, T., GAN, A.S., & MURTHY, K.N., 1979. On the geological age of the Tanjong Malim Limestone in Peninsular Malaysia. *Proceedings of the Japan Academy, Volume 55. Series B*, 259-263.

Manuscript received 25th September 1984