資　　料

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Kaolin Deposits of Japan*

By

Noriyuki Fujii**, Takeo Okano** & Yoshihiko Shimazaki**

要　　旨

本年秋にプラハで開催される万国地質学会において，カオリンに関するシンポジウムが行なわれることとなり，日本のカオリン鉱床について大要次のような内容の資料を提出した。なおここでいうカオリンとは，カオリン質粘土のなかで陶磁器原料，紙などに使用され得るものに限ることとし，耐火粘土としてしか利用出来ないものは除外した。

本邦のカオリン鉱床は成因的には次のように分類することが出来る。

(1) 熱水性鉱床

(2) 堆積性鉱床―┬―木節粘土
　　　　　　　├―蛙目粘土
　　　　　　　└―層状白色カオリン

(3) 風化残留性鉱床

これら各種の鉱床について，それぞれ例をあげて地質的な産状の特徴を概説した。（熱水性鉱床……板谷粘土，対州カオリン，堆積性鉱床……愛知・岐阜県下の木節・蛙目粘土，風化残留性鉱床……本宮カオリン）またこれらの粘土の鉱物組成，化学組成を例示し，さらにカオリン粘土の用途，生産統計，輸出入統計をも表示した。

1. Brief summary of the deposits

The kaolin deposits of Japan are classified by their genesis as follows.

Kaolin deposits { Hydrothermal deposits ; Sedimentary deposits …… { "Kibushi-clay" ; "Gaerome-clay" ; Residual deposits ; Bedded white kaolin }

Kaolinic clays used mainly for pottery and white wares, and for paper clay are included in this report, and material used exclusively for fireclay are excluded.

"Kibushi and gaerome-clays" are usually classified as material for fireclay, but since more than 30 percent is used for pottery and white ware, they are included in this paper, also.

Hydrothermal deposits These deposits are vein and massive deposits occurring mostly in volcanic and granitic rocks. There are a large number of these deposits, but only a few are of large scale. Many of the material mined for use in paper industry come from the deposits of this type.

Sedimentary deposits "Kibushi-clay" is a general term designating soft and plastic underclay. "Gaerome-clay" is formed by secondary deposition of decomposed granitic rocks and it contains coarse quartz grains. The clay and quartz are

* この報文は第23回万国地質学会（1968年8月，チェッコスロバキアのプラハで開催される）におけるシンポジウム "The Kaolin Deposits and Their Genesis" に提出されたものと同文である。なお粘土の化学分析値はいずれも「粘土ハンドブック」の資料によったものである。

** Mineral Deposits Department

separated by washing before use. These "kibushi and gaerome-clays" are the most important sources of kaolin in Japan, and they are used mainly for refractories, pottery, and white ware. The bedded kaolin clays occur in Tertiary terrigenous sediments. It is believed to have been formed by the kaolinization of tuffaceous material and is used mainly for pottery and white ware.

Residual deposits In Japan, there are residual deposits formed by in situ weathering of granitic rocks, pegmatites, and of Quaternary volcanic ashes. The clays of granitic and pegmatitic origin are used for pottery and white ware, but the scale of the deposits are small. Those of the volcanic origin are abundant, but many of them contain impurities which makes utilization difficult.

The distribution of the major kaolin deposits of Japan is shown in Fig. 1.

2. Geological conditions

The number of kaolin deposits in Japan is very large, and the geological conditions of the representative deposits of various types are presented below.

(1) **Hydrothermal deposits-I** (in volcanic rocks)

These deposits were formed by the hydrothermal alteration of volcanic and pyroclastic rocks of Cretaceous to Quaternary period. Many of these are closely associated with metallic deposits of gold, mercury, iron sulphides, and others.

Some of these deposits have vein forms such as those of the Seta mine, but most of them are irregular beds or massive deposits. The scale of these deposits are mostly small.

Itaya mine consists of exceptionally large deposits of this type and the monthly production is about 15,000 tons. There are three major deposits, and the largest one has the confirmed dimensions of 350 m east-west, 300 m north - south, and the depth is over 100m. It is probable that the deposits are the hydrothermal alteration product of andesitic lava and pyroclastics of Quaternary eruption. The occurrence is complex as the silicified and kaolinized zones are intricately interwoven. Montmorillonitized zone is developed in the fringes of the deposits. Many parts of the kaolinized zone contain sericite.

(2) **Hydrothermal deposits-II** (in granitic rocks)

There are hydrothermal kaolin deposits formed in the acidic intrusives such as granite and quartz porphyry of Cretaceous to early Tertiary age. Most of them are of massive or vein form.

The deposits of the Taishu mine is well known in this group. The deposits of this mine were formed by halloysitization of quartz porphyry which intruded almost concordantly into Paleogene strata. There are scores of deposits of this type with various dimensions and the largest ones are in the order of 100 m × 200 m. Similar deposits are Kanpaku, Okutsu, Komaki and others.

(3) **Sedimentary deposits** ("kibushi-clay", "gaerome-clay", and bedded white

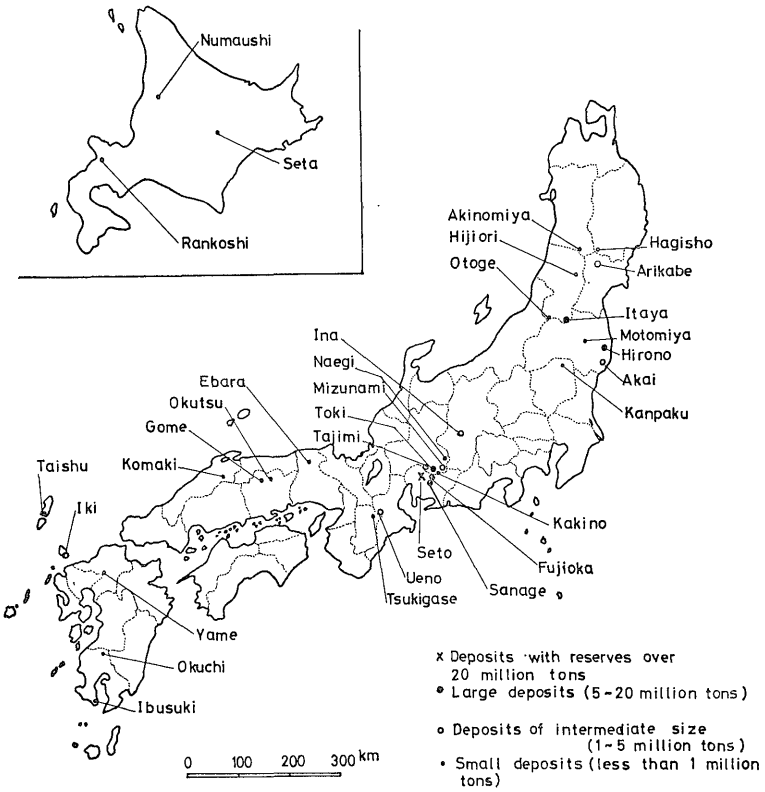

Fig. 1 Kaolin Deposits in Japan

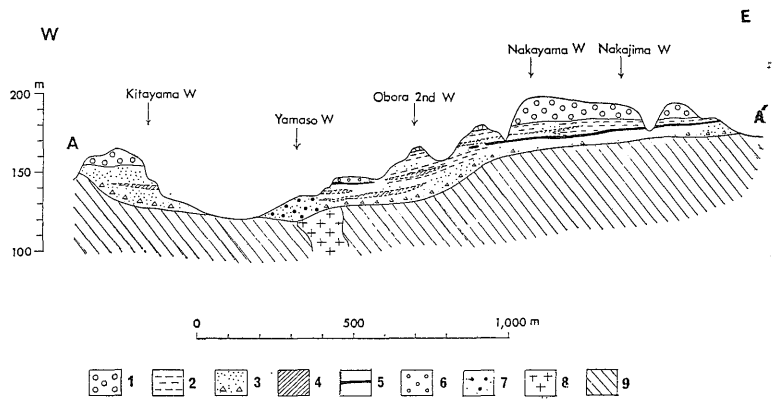

Fig. 2 Geological Profile of Clay-bearing Beds at Obora Area, Toki-shi, Gifu Prefecture

1.	sand and gravel	Upper Pliocene formation
2.	clay and silt	Lower Pliocene formation
3.	sand and breccia	
4.	"kibushi-clay" and lignite	
5.	tuff and/or white "kaolin"	
6.	chert gravel	
7.	"gaerome-clay"	
8.	granitic rocks	Mesozoic
9.	chert, shale and sandstone	Upper Paleozoic

kaolin deposits).

There are two types of deposits of this category, one is those consisting mainly of detrital origin minerals and the other is those composed mainly of authigenic kaolin minerals. Majority of these deposits occur in post-Miocene terrigenous sediments. The important deposits of this type are intercalated in lower Pliocene strata and the major localities are Seto, Sanage, and Fujioka of Aichi Prefecture, Tajimi, Toki, and Mizunami of Gifu Prefecture.

The lower Pliocene series of these areas consist of lacustrine sedimentary rocks and the size of the individual sedimentary basins which are scattered in the region is in the order of 2-5 km. "Kibushi and gaerome clays" are believed to have originated from detrital minerals while the bedded white kaolin clays were mostly formed authigenously.

"Kibushi-clay" occurs in the mother rocks of brown coal. The maximum thickness of individual beds is about 3 m. The clay consists mostly of disordered kaolinite and quartz grains are contained as impurity in most cases. In areas where Miocene series are distributed below the Pliocene beds, montmorillonite which is believed to be an alteration product of the Miocene strata is mixed in the kaolin deposits.

"Gaerome-clay" occurs at the base of the lower Pliocene series and the maximum thickness is 20 m. It is believed to have been deposited from weathered and decomposed granitic rocks without sorting. It contains many coarse grains of quartz, unaltered feldspars, and mica minerals. Normally, the major constituent minerals are disordered kaolinite and partially dehydrated halloysite. These "gaerome-clays" are developed only in sedimentary basins where the basement consists of granitic rocks such as Seto, Toki, and Fujioka.

The bedded white kaolin usually occurs in thin beds of 20 - 30 cm. They are distinguished from other clays in the lower Pliocene by the fresh white color. It is believed to be the product of alteration of tuffaceous material after deposition. The major clay minerals are halloysite and meta-halloysite with small amount of quartz. The occurrence of this clay is limited to the basins of Tajimi, Toki, and Naegi. Similar clay is distributed in the post-Miocene sediments of Hokkaido (Numaushi) and Northeast Japan (Hagisho, Arikabe, etc.).

(4) **Residual deposits**

There are many small scale kaolin deposits within the granitic basement below the lower Pliocene which contains "kibushi and gaerome-clays". These deposits in the granitic rocks seem to have been formed by in situ weathering. Kakino and Mitsukuri kaolin deposits are the representative deposits of this type. Most of the deposits have thickness of several meters.

The deposits of the Motomiya mine is the only case of kaolin formed by the weathering of feldspars in pegmatites in Japan. On the other hand, Ina kaolin is an example of the deposits formed by the weathering of Quaternary volcanic ashes. It is used for paper clay and the thickness of the deposits is in the order of 2 meters.

3. Mineralogical and geochemical conditions

The mineral compositions and the kinds of kaolin minerals are shown below according to the types of the deposits.

(1) Mineral composition

Type of Deposit	Name of Deposit	Main	Accessories
Hydrothermal Deposit In volcanic rocks	Itaya	K, (S), q	py
	Iki	K, c	K, q
	Seta	K, q	py
	Ebara	K, (D)	dias, q, B
In granitic rocks	Taishu	H	q, f, S
	Kanpaku	K	H, dias, G, py
Sedimentary Deposit "Kibushi-clay"	Tajimi	K, (q)	M, I
	Seto	K, (q)	I
	Ueno	K	q, f, I
"Bedded white kaolin" clay	Tajimi	H	q
	Arikabe	H, (q)	
Residual Deposit Weathered granite	Kakino	H, mH, q	I, f
	Motomiya	K, H	I, q, pl
Weathered volcanic ash	Ina	H, mH, q	pl
	Yame	H, mH, q	pl, h, limo

B : boehmite
dias : diaspore
H : halloysite
I : illite
M : montmorillonite
py : pyrite
c : α-crystoballite
f : feldspar
mH : metahalloysite
K : kaolinite
S : sericite
D : dickite
G : gibbsite
h : hornblende
limo : limonite
q : quartz

(2) Chemical composition

	Hydrothermal Dep.			Sedimentary Dep.				Residual Dep.
	Itaya (*)	Iki (washed)	Kanpaku	Tajimi (K) (**)	Seto (K)	Toki (G) (washed)	Tajimi (Shinmei) (W)	Motomiya (washed)
SiO_2	46.50	44.60	41.55	47.69	45.48	47.51	44.51	57.00
TiO_2	0.10	0.23	0.67	0.94	0.62	0.46	0.11	—
Al_2O_3	37.01	36.86	41.50	30.60	32.15	36.60	35.48	32.55
Fe_2O_3	0.69	3.11	0.46	1.28	0.74	1.24	0.11	0.54
FeO	—	tr	—	—	—	—	—	—
CaO	0.43	0.09	0.11	0.60	0.29	0.22	0.99	1.10
MgO	0.95	0.03	0.36	0.66	0.24	0.21	tr	tr
Na_2O	0.54	0.26	0.02	0.10	0.19	0.04	tr	1.94
K_2O	5.83	0.20	0.00	1.12	0.54	0.60	tr	tr
$H_2O(+)$	7.30	—	—	10.62	—	—	13.28	5.17
$H_2O(-)$	0.46	—	—	4.64	—	—	5.74	2.00
Ig. loss	—	14.50	15.30	—	19.91	13.44	—	—
Total	100.27	99.88	99.97	98.25	100.16	100.32	100.22	100.30

(K) "Kibushi-clay" (G) "Gaerome-clay" (W) "Bedded white kaolin" clay
(*) sericitic clay (**) including organic materials

4. Utilization of kaolin

The major uses of kaolin clays are as follows.

Various properties of the clays are omitted from the table.

Kinds of clay		Use
Hydrothermal kaolin	In volcanic rocks	Paper clay.
	In granitic rocks	Pottery, white ware, paper clay.
Sedimentary kaolin	Kibushi-clay	Refractories, pottery, white ware.
	Gaerome-clay	Pottery, white ware, refractories.
Residual kaolin	Weathered granite	Pottery, white ware.
	Weathered volcanic ash	Paper clay.

5. Economic evaluation of deposits

The reserves of the kaolin deposits are evaluated as follows.

Gaerome-clay approximately 31 million tons

Fireclay and kaolin approximately 88 million tons

The demand and supply of kaolin is more or less balanced, but the kaolin for white wares is insufficient in quantity and the import from Korea, Hongkong and other countries is increasing every year. Also Georgia kaolin and others are being imported as paper clay.

Most of the hydrothermal and residual deposits are mined by open pit methods. However, in about a third of the mines, underground cutting is employed.

6. Statistic data

a) Output of kaolin clay (unit 1,000 m tons)

Year	Hydrothermal kaolin clay	Sedimentary kaolin clay				Residual kaolin clay
		"Kibushi-clay"	"Gaerome-clay"		Bedded white kaolin	
			crude	washed		
1952	24	358	109		3.4	0.3
53	27	316	110		6.6	0.1
54	32	294	356		4.1	0.1
55	35	330	397		4.9	0.7
56	45	399	449		5.5	1.1
57	54	469	479		4.8	2.2
58	57	321	469		5.9	3.8
59	76	405	485		5.7	1.4
60	82	456	627		3.2	0.9
61	96	534	715		5.3	0.7
62	134	439	696	183	9.4	0.6
63	169	369	774	219	13.0	8.4
64	180	393	838	260	14.8	9.6
65	169	427	846	262	16.5	9.6

As mentioned earlier, "kibushi and gaerome-clays" are usually classified as fireclay, and thus the statistical figures of other sources such as the Minerals Yearbook may not agree completely.

b) Export and import of kaolin clay (unit m. tons)

Year	1952	1953	1954	1955	1956	1957	1958
Exports	1	2	21	539	422	208	1, 185
Imports	4, 438	7, 313	10, 127	11, 071	12, 368	15, 906	14, 506
Year	1959	1960	1961	1962	1963	1964	1965
Exports	199	1, 407	2, 428	5, 225	3, 046	2, 780	2, 835
Imports	15, 049	32, 195	36, 759	35, 975	49, 066	53, 769	60, 068

7. History of investigation and exploitation

It is believed that the use of kaolinic clay for earthen wares began more than a thousand years ago. The active use of the material for refractories and pottery and white ware, however, began about 1880. It is after the second world war that kaolin became used in large quantities for paper clays, pyrophyllite was mostly used before that.

The first systematic investigation of kaolin deposits was carried out by the Geological Survey of Japan during the period of 1920–1925, large scale investigations are being carried out actively after the war and various data on the distribution, mineral composition and others are being accumulated. Also geological and geochemical studies on the geneses of various types of deposits are in progress.

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