Bulletin of the Geological Survey of Japan, Vol. 45(3), p. 107–133, 1994

Industrial mineral resources in Japan

Hideo HIRANO* and Sadahisa SUDO*

HIRANO Hideo and SUDO Sadahisa (1994) Industrial mineral resources in Japan. *Bull. Geol. Surv. Japan*, vol.45(3), p. 107–133, 22figs., 11tables.

Abstract: Distribution, production and demand for industrial minerals in Japan are reviewed as well as their characteristic features.

Following industrial minerals are currently produced in Japan:

(1) Silicastone and silica sand: white silicastone (or shirokeiseki in Japanese), loose silicastone (or nankeiseki), silicastone for furnace (or rozaikeiseki), silica sand (natural and artificial) and diatomite.

(2) Feldspar: pegmatite feldspar, aplite feldspar and weathered granite feldspar.

(3) Clay:

(a) Hydrothermal clay: roseki, roseki clay, toseki (porcelain stone or pottery stone), hydrothermal kaolin and sericite.

(b) Sedimentary clay: kibushi clay, gaerome clay and shale clay as refractory clays.

(c) Residual clay: residual kaolin.

(4) Carbonates: limestone and dolomite.

(5) Miscellaneous: talc, peridotite/serpentinite, bentonite, fuller's earth and others.

Among them major commodities are limestone, silicastone, silica sand, roseki and dolomite. Such hydrothermal clays as roseki and toseki formed by Mesozoic to Cenozoic igneous activities are characteristic minerals of Japan.

The industrial minerals are mainly consumed in the cement, steel, ceramic, glass and refractory industries. Domestic industrial minerals consumed large amounts show their low prices. Kaolin, talc and other industrial minerals are imported in considerable amounts due to their high qualities.

In accordance with progress of application technology in Japan, several minerals have been utilized in the fields of new ceramics and composite materials such as glass-fiber reinforced plastics. On the other hand, limestone which is an essential and versatile material for cement, chemical and steelmaking industries has been consumed for civil engineering as aggregates in large amounts due to its low price.

1. Introduction

Industrial minerals, more precisely industrial minerals and rocks, have been used as bulk products (blocks and powder) in various fields of industry. Usually individual industrial minerals have several significant uses depending on their physical and chemical properties. Talc, for example, is used for such various fields as fillers of paint, plastics, rubber and paper, fluxes in glaze and electric welding, carriers in insecticide and fertilizer, electric insulators, foodstuffs, cosmetics and pharmaceuticals.

Industrial mineral mining has expanded closely linked with Japan's economy after World War II, since the industrial minerals have commonly been consumed large amounts by various fields of industries. The domestic production of industrial minerals has constantly increased (Fig.

* Mineral Resources Department

Keywords: Industrial mineral, Non-metallic mineral, Production, Consumption

1). The mine production value of the industrial minerals has exceeded that of petroleum and natural gas since 1950, that of metallic minerals since 1972 and that of coal and lignite since 1988 in Japan. In 1990, the ratios of the domestic production value are: 47.4% for industrial minerals, 26.3% for coal and lignite, 18.7% for petroleum and natural gas and 7.6% for metallic minerals.

In this paper we will review distribution, geology, production and demand for major industrial minerals of Japan as well as their characteristic features. Statistical data on production tonnage and values for domestic minerals of Japan were already presented by Sudo and Hirano (1992) and supply and demand of non-metallic ores were briefly noted by Hirano and Sudo (1992).

2. Industrial minerals

The mine output value of industrial minerals exceeds 1,536 million US dollars or 233 billion yen in 1990. Many kinds of industrial minerals are currently produced from quarries and mines. Limestone, silicastone and silica sand are produced in remarkable amounts and are followed by *roseki* (see 2.3.1), refractory clay, dolomite, peridotite, bentonite and feldspar, in the descending order of the production value (Table 1). The majority of the industrial minerals in Japan rely on the Mesozoic to Paleozoic sediments although the geology of Japan is composed mainly of Cenozoic volcanics and sediments as young islands.

Several major industrial minerals will be described in the following orders:

(1) Silicastone and silica sand: white silicastone (or *shirokeiseki* in Japanese), loose silicastone (or *nankeiseki*), silicastone for furnace (or *rozaikeiseki*), silica sand (natural and artificial) and diatomite.

(2) Feldspar: pegmatite feldspar, aplite feldspar and weathered granite feldspar.

(3) Clay:

(a) Hydrothermal clay: *roseki, roseki clay, toseki* (porcelain stone or pottery stone), hydrothermal kaolin and sericite.

(b) Sedimentary clay: *kibushi clay, gaerome clay* and shale clay as refractory clays.

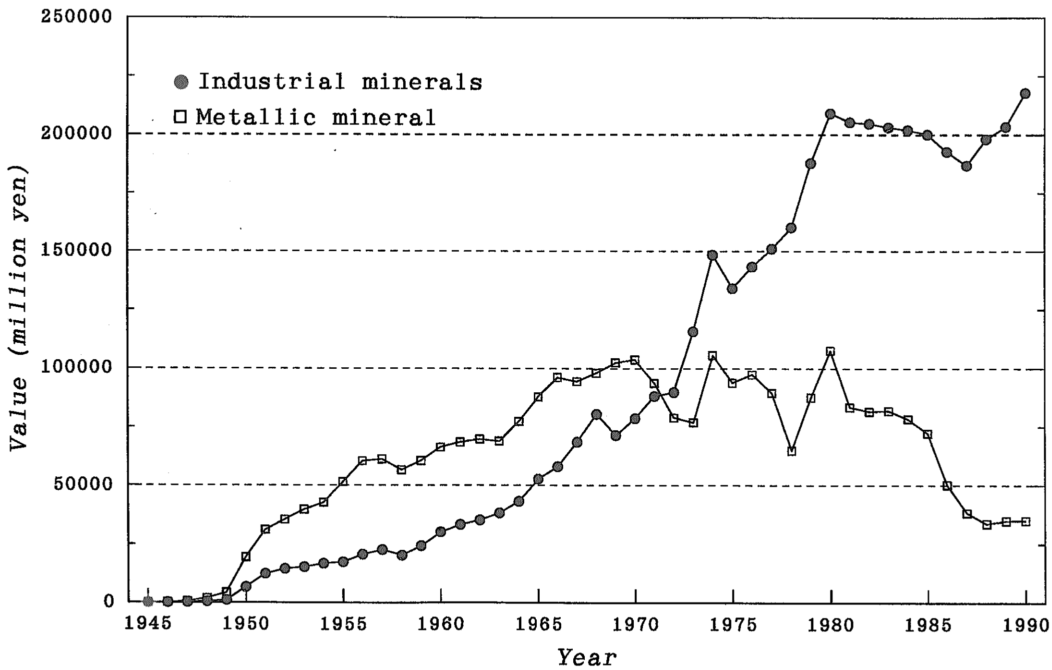


Fig. 1 Variation of domestic mine production values for metallic and industrial minerals.

Table 1 Mine production of industrial minerals of Japan in 1990

Commodity	Number of mine	Production (kt)	Value		
			(¥ million)	(US$ m.)	%
Silicastone	69	16,537.5	16,376.9	112.6	7.5
Silica sand	52	4,235.5	18,636.2	128.2	8.6
Diatomite	17	180.6	792.0	5.4	0.4
Pegmatite feldspar	30	26.0	297.4	2.0	0.1
Aplite feldspar		518.2	1,352.2	9.3	0.6
Granite feldspar		687.8	2,600.5	17.9	1.2
Kibushi clay	86	453.5	1,493.4	10.3	0.7
Gaerome clay		687.5	4,598.1	31.6	2.1
Shale clay*		497.8	583.3	4.0	0.3
Kaolin	13	129.1	640.5	4.4	0.3
Roseki	40	897.8	4,366.0	30.0	2.0
Toseki	17	183.2	1,071.5	7.4	0.5
Sericite		1.0	51.8	0.4	0.0
Bentonite	16	478.5	3,830.2	26.3	1.8
Fuller's earth	9	132.7	591.0	4.1	0.3
Limestone	245	200,444.0	138,804.0	954.6	63.7
marble	12	19.7	150.9	1.0	0.1
Dolomite	9	5,229.0	5,921.0	40.7	2.7
Talc	8	58.1	308.1	2.1	0.1
Peridotite	16	5,323.0	5,132.5	35.3	2.4
Others	10		5,361.0	36.9	4.7
Total	649		223,300.0	1,535.7	100.0

* The production includes that of low-grade clay.

Exchange rate in 1990: ¥145.41/US$

(c) residual clay: residual kaolin.

(4) Carbonates: limestone and dolomite.

(5) Miscellaneous: talc, bentonite, fuller's earth and others.

Names of domestic commodities are defined in the Mining Law of Japan and listed in various statistic tables. These commodity names will be explained in the following sections. The original statistic data on domestic mineral production are from Mining yearbook of Japan (Ministry of International Trade and Industry (MITI), 1950–91) and History of the mining trends of Japan (MITI, 1963) and those on mineral demand (consumption) are from Yearbook of minerals and non-ferrous metals statistics (MITI, 1976–91). The difference between the production tonnage and the consumption is caused mainly by carry-overs from the previous year and to the next year.

To additional understanding the following review papers are useful: Okano (1983) and O'Driscoll (1992) especially on economics, and Sudo (1992) on geologic points of view.

2.1 Silicastone and silica sand

2.1.1 Silicastone

Silicastone is divided into following three classes in accordance with its purity and physical property, mainly hardness: white silicastone, silicastone for furnace and loose silicastone.

White silicastone is lamps of highly pure quartz from pegmatite, vein, quartzite, chert, and

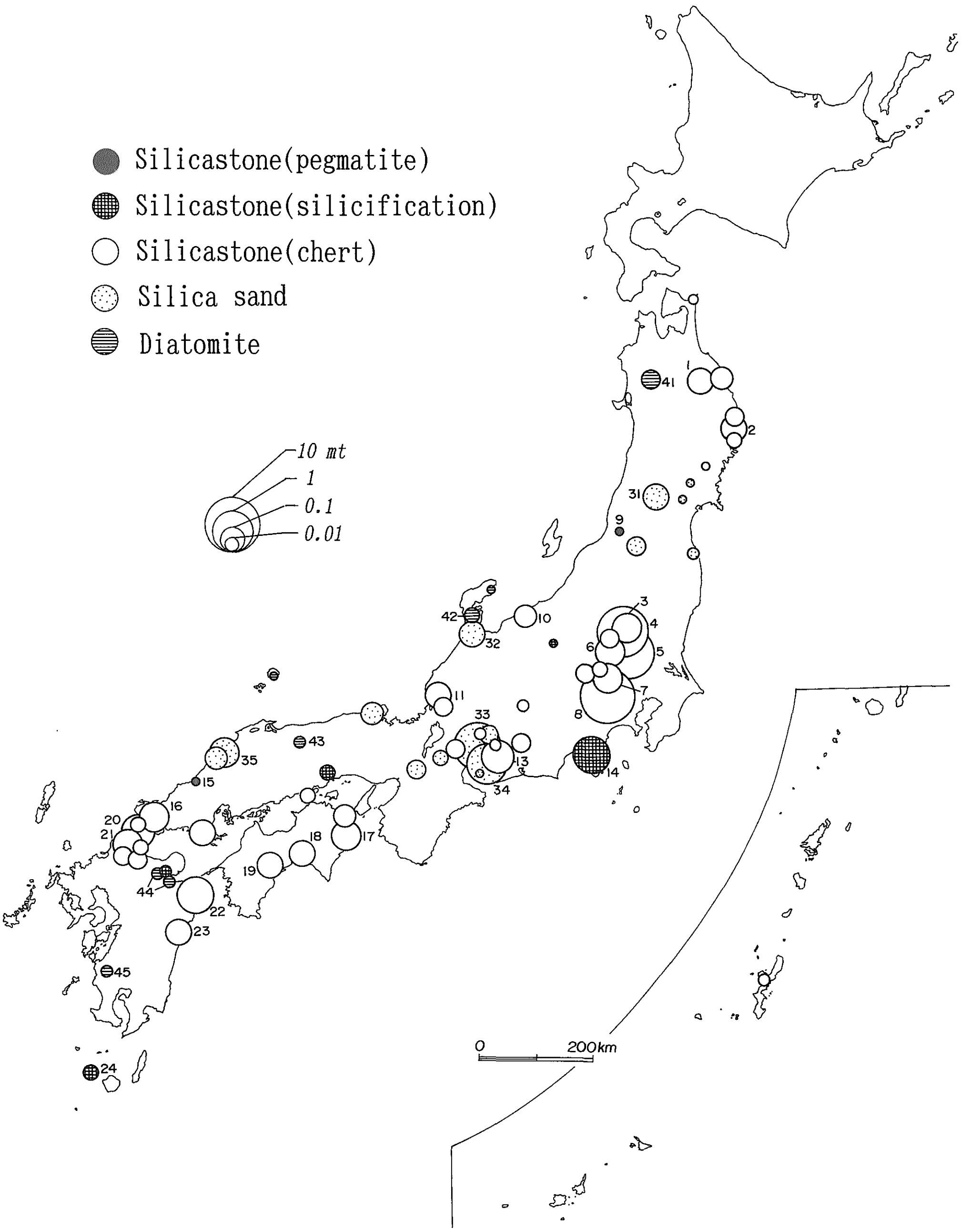


Fig. 2 Distribution map of silicastone, diatomite and silica sand quarries. Numbers in this figure correspond to those in Table 2.

silicified rocks in hydrothermal origin. The major domestic source is the quartzite of the Ryoke metamorphic terranes.

Silicastone for furnace coming from relatively high purity chert of the Mesozoic-Paleozoic ages is mainly used as refractories.

Loose silicastone from chert and sandstone of the Mesozoic-Paleozoic age is used a lot of volume as raw materials for cement.

Although white silicastone locally occurs in

Table 2 Quarries of silicastone, silica sand and diatomite in Japan

No.	Locality		Ore type	Genesis	Age	Size
Silicastone						
1	Ninohe Area	二戸地区	SC	Sd	J	M
2	Otsuchi Area	大槌地区	SC	Sd	J	M
3	Kanuma	鹿沼	SC	Sd	J	M
4	Kuzu–Awano	葛生―粟野	SC	Sd	J	L
5	Ashikaga Area	足利地区	SC	Sd	J	L
6	Kiryu	桐生	SC	Sd	J	M
7	Chichibu	秩父	SC	Sd	J	M
8	Tama Area	多摩地区	SC	Sd	K	L
9	Kanamaru	金丸	WS	Pg	K	S
11	Nanjo–Imajo	南条―今庄	WS	Sd	J	M
13	Mikawa Area	三河地区	WS SC	Sd	J	M
14	Ugusu	宇久須	SC AS	Hy	Q	M
15	Shiroyama	城山	WS SC	Pg	K	S
16	Mine Area	美祢地区	WS AS	Sd	J	M
17	Katsuura Area	勝浦地区	SC WS SR AS	Sd	J	M
18	Nangoku Area	南国地区	WS SC	Sd	K	M
19	Sakawa Area	佐川地区	SC	Sd	K	M
20	Moji Area	門司地区	SC	Sd	P	M
21	Kokura Area	小倉地区	SC SR	Sd	P	M
22	Tsukumi Area	津久見地区	SR SC	Sd	J	M
23	Hyuga	日向	SC	Sd	K	M
24	Iojima	硫黄島	WS	Hy	Q	S
Silica sand						
31	Oishida Area	大石田地区	SS	Sd	T	M
32	Oyabe Area	小矢部地区	SS	Sd	T	M
33	Seto Area	瀬戸地区	SS	Sd	T	L
34	Toyota Area	豊田地区	SS	Sd	T	L
35	Yunotsu Area	温泉津地区	SS	Sd	T	M
Diatomite						
41	Takanosu Area	鷹巣地区	DT	Sd	T	S
42	Nanao Area	七尾地区	DT	Sd	T	S
43	Yatsuka Area	八束地区	DT	Sd	Q	S
44	Kuju–Shonai	九重―庄内	DT	Sd	Q	S
45	Hiwaki	樋脇	DT	Sd	Q	S

Ore type: AS = silicastone for artifical silica sand, DT = diatomite, RS = silicastone for refractory, SC = silicastone for cement, SS = silica sand, WS = white silicastone.
Genesis: Hy = hydrothermal, Pg = pegmatitic, Sd = sedimentary.
Age: J = Jurassic, K = Cretaceous, P = Late Paleozoic, Q = Quaternary, T = Tertiary.
Size: L > 1 Mt/y > M > 0.2 Mt/y > S, based on the production in 1990.

the country, loose silicastone (mainly chert) is widely distributed and mined on large scale especially in the Kanto District (Fig. 2, and Table 2). Silicastone for furnace has been mined in Northern Kyushu.

Domestic productions of the silicastone have increased since 1966 (Fig. 3) and those in 1990 are: white silicastone 1.8 million tons (Mt),

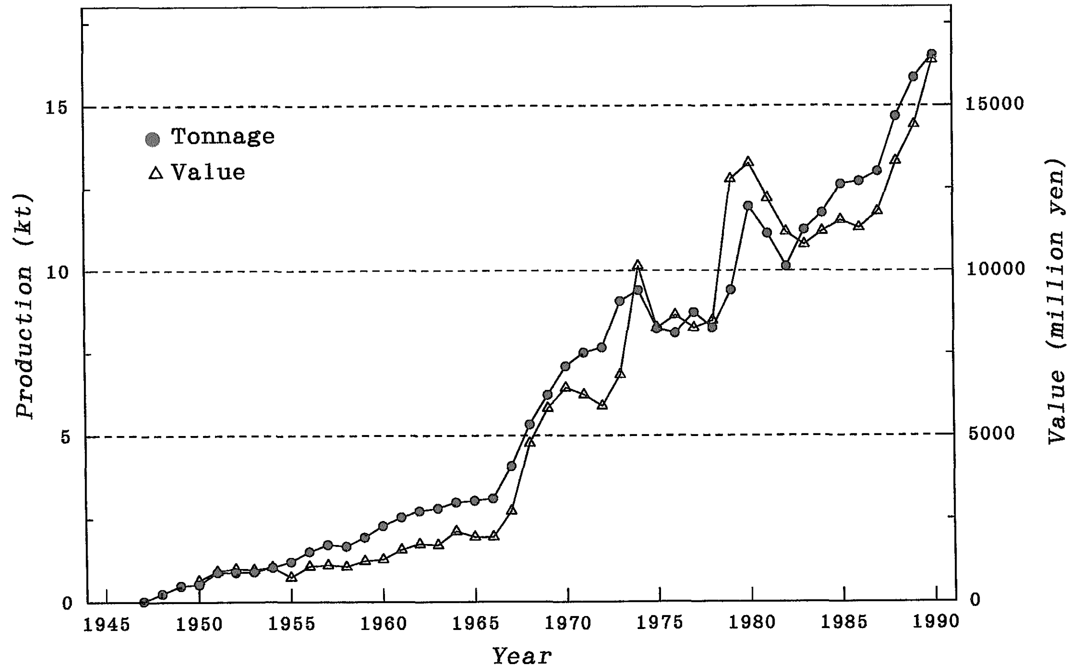


Fig. 3 Variation of domestic mine production for silicastone.

silicastone for furnace 0.5 Mt, and loose silicastone 14.4 Mt with a total of 17 Mt.

In 1990, 47% of the silicastone was consumed by material industries, such as cement (25%), construction materials for autoclaved light-weight concrete (ALC) (10%) and steelmaking (5%) as shown in Fig. 4. From 1980 to the 1990 the silicastone has become much more used for construction materials, especially for ALC boards due to great demand for housing. This trend would be continued in future.

Almost all the white silicastone consumed in Japan is imported. In 1990, it was imported 75 kilotons (kt) for abrasives, lining of mills and furnaces and quartz glass. Exporters of the white silicastone are India, Thailand, China and Sweden.

2.1.2 Silica sand

Silica sand occurs with a lot of clay in lacustrine sediments of the Pliocene age. Majority of the silica sand is produced from the Seto-Tajimi District in Central Japan as shown in Fig. 2. The silica sand of this district is called *gaerome* (frog's eye) sand because the coarse silica grains in clay matrix look like flog-eyes when they get wet. Since domestic silica sand is mixed with clay, feldspar, mafic silicates and iron oxides, the silica sand must be carefully refined by processing such as water elutriation, magnetic separation and flotation.

The silica sand is also artificially produced from Cretaceous pegmatite. Total production of silicasand including the artificial one is 4.2 Mt in 1990. The silica sand is used for glass wares (29%), flat-glass (19%), foundry (16%), sodium silicate, glass fiber and construction materials. Recent demands for silica sand are also remarkable in housing sectors as ALC boards and glass-fiber industries.

Imported silica sand has recently tripled from 0.6 Mt in 1980 to 2.0 Mt in 1990. Almost all the imported silica sand is for glass industries. Exporters of the silica sand are Australia, Malaysia, China and Russia.

2.1.3 Diatomite

Diatomite occurs as sediments of Neogene and Quaternary ages in many places (Fig. 2 and Table 2). Diatomite deposits are usually small in

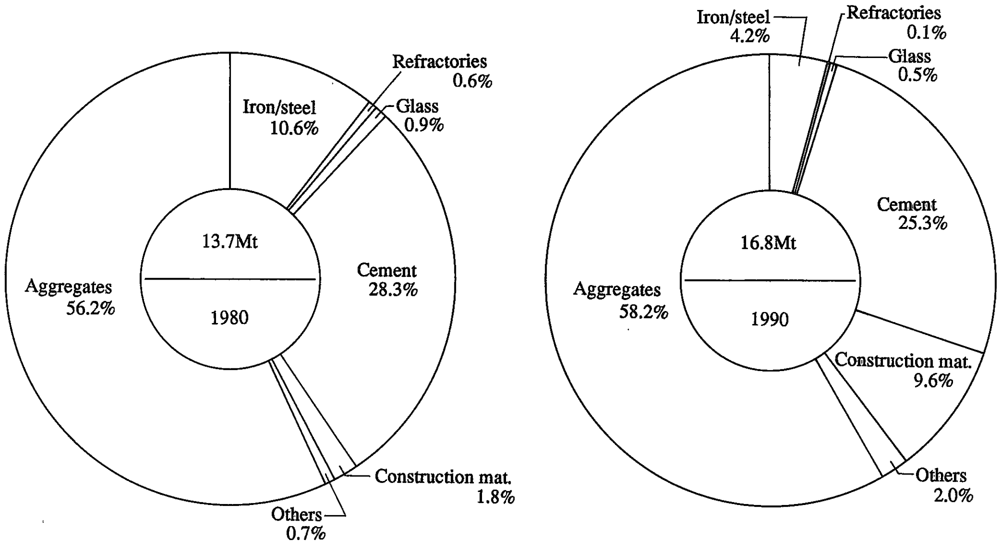


Fig. 4 Use of domestic silicastone in 1980 and 1990.

size. About 180 kt of diatomite was produced in 1990 mainly from Tohoku, Hokuriku, Chugoku and Kyushu.

Diatomite is used mainly for filters of sugar, oil, fat, *sake* and beer (33%), construction materials (21%), refractories (11%), pesticide carrier and fillers of paper, plastics and rubber.

2.2 Feldspar

Feldspar is classified into three groups by their mode of occurrence: Pegmatite feldspar, aplite feldspar and granite feldspar.

Pegmatite feldspar, in this paper, includes metasomatic feldspar from granites by pneumatritic or hydrothermal processes at high temperature. The constituent minerals are soda-rich plagioclase and K-feldspar.

Domestic production of pegmatite feldspar is 28 kt in 1990, of which 80% comes from two of the biggest deposits, Gozairi (metasomatic-type, Katashina Area in Gunma Prefecture) and Shiroyama (pegmatite-type, Shimane Prefecture) as shown in Fig. 5 and Table 3. Main uses of the pegmatite feldspar are ceramics (58%), glass (22%) and tile (17%).

Aplite feldspar is obtained from aplite which includes medium- to fine-grained leucogranite and hydrothermally altered granite of which biotite is disappeared. Almost all production of aplite feldspar (518 kt in 1990) relies on the weakly altered granite of the Late-Cretaceous age in the Shigaraki Area, West Japan.

Crude aplite feldspar is composed mainly of quartz, K-feldspar and albite in nearly the same ratio, associated with small amount of iron. They are mainly used as raw material for tile without any concentration process.

Granite feldspar is obtained from loose granite caused by weathering and/or shearing at shallow depth during the Cenozoic age. About 700 kt of granite feldspar is produced in 1990 mostly from East of Nagoya, where the massive biotite granite of Late-Cretaceous age is widely developed. Recently feldspar in weathered granites has become an important source material for ceramics and tile (Fig. 6) due to great reserve and easy preparation of concentrate with the desirable quality. Granite feldspar is used for ceramics (45%), glass (19%), tile and construction materials.

Production of domestic feldspar meet principally its demand but the present source can last only for several years. If the demand greatly increases, a lot of alaskite, granite without mafic minerals, will possibly be imported as a source of feldspar.

High-quality pegmatite feldspar is imported about 5 kt mainly from Norway and China.

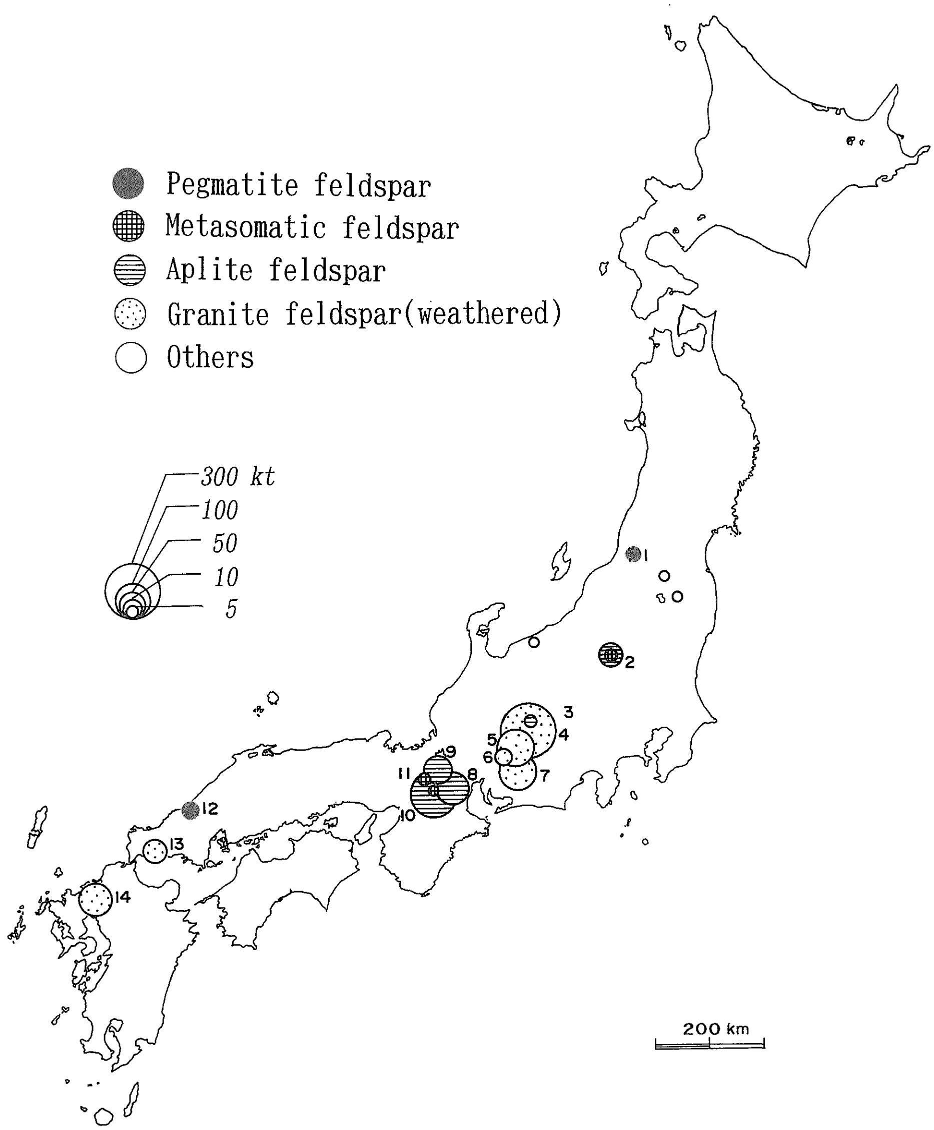


Fig. 5 Distribution map of various types of feldspar quarries. Numbers in this figure correspond to those in Table 3.

2.3 Clay

Clay comprises *roseki, toseki*, hydrothermal kaolin, residual kaolin, sericite, *kibushi* clay, *gaerome* clay and shale clay. They are grouped together by their genesis as follows: hydrothermal clay (*roseki, toseki*, hydrothermal kaolin and sericite), sedimentary clay (*kibushi* clay, *gaerome* clay and shale clay) and residual clay (Table 4). Clay deposits are widely distributed in East Asia as one of the characteristic mineral resources in this region (Fig. 7).

Hydrothermal clay deposits of older than 25 Ma are distributed along a narrow zone such as southeast edge of China, southern part of Korean Peninsula and West Japan. They are associated with terrestrial felsic volcanics of Mesozoic age. Hydrothermal clay deposits younger than 25 Ma

Table 3　Feldspar quarries in Japan

No.	Locality		Ore type	Size
1	Kanamaru	金丸	PF	S
2	Katashina	片品	AF MF	M
3	Yabuhara	藪原	AF	S
4	Nagiso Area	南木曾地区	WG	L
5	Azuma Area	吾妻地区	WG	M
6	Mizunami Area	瑞浪地区	WG	S
7	Togo Area	東郷地区	WG	M
8	Ayama	阿山	AF	M
9	Mikumo	三雲	AF	M
10	Shigaraki Area	信楽地区	AF	L
11	Ishiyama Area	石山地区	MF	S
12	Shiroyama	城山	PF	S
13	Ube	宇部	WG	M
14	Sugiyama	杉山	WG	M

Ore type: AF=aplite feldspar, MF=metasomatic feldspar, PF=pegmatite feldspar, WG=feldspar from weathered granite.
Size: L>200 kt/y>M>10 kt/y>S, based on the production in 1990.

are restricted to the island arcs, where andesitic volcanics occurred mainly in Miocene age.

Sedimentary clay deposits for ceramics and refractories are developed widely. The older ones (more than 25 Ma) are distributed in the continents and the younger ones are along the continental margin and the island arcs. They are associated with coal beds or organic materials.

Residual clay deposits are concentrated in South China. Most of them are developed on the surface of granitic rocks.

2.3.1 Hydrothermal clay

Hydrothermal clay in Japan comprises *roseki*, *toseki* (porcelain stone), hydrothermal kaolin and sericite.

Roseki is a waxy compact stone in hydrothermal origin from felsic volcanics, and is composed of pyrophyllite, kaolinite, with or without sericite and quartz. Powdered and well-prepared *roseki* is called *roseki clay*. It is accounted separately from domestic *roseki* in statistic tables.

Roseki deposits are generally irregular or composite-funnel shapes. The deposits usually show zoned alteration from the center to the margin: the corundum plus diaspore zone, the

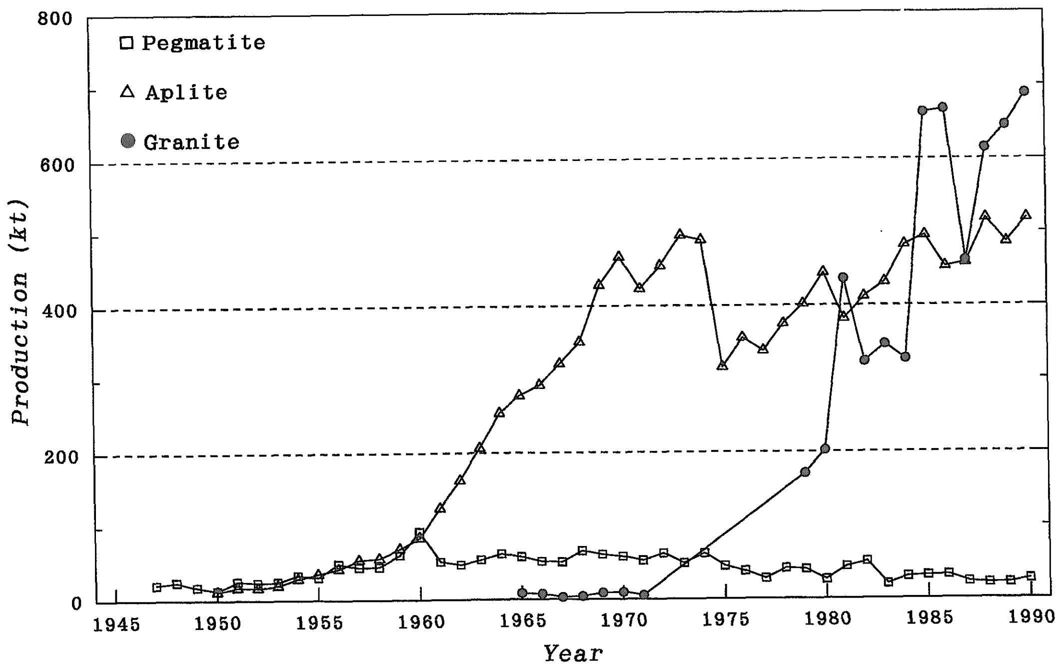


Fig. 6　Variation of domestic mine production for feldspar.

Table 4 Classification of clay deposits based on their mode of occurrence

	Occurrence	Commodity in Japan (age)
Hydrothermal clay	Derived mainly from felsic volcanic rocks which erupted along the continental margin of island arcs.	Roseki (Mesozoic–Paleogene>Neogene) Toseki (Mesozoic–Paleogene>Neogene) Hydrothermal kaolin (Neogene) Sericite (Neogene)
Sedimentary clay (<25 Ma)	Derived from well-weathered surface of continents and settred as lacustrine and lagoon sediments.	Kibushi clay (Neogene) Gaerome clay (Neogene)
(>25 Ma)	Usually associated with coal beds.	Shale clay (Mesozoic)
Residual clay	Weathered products mainly from granites and felsic gneiss. Stable continent without surface erosion.	Residual kaolin (Neogene to Quaternary)

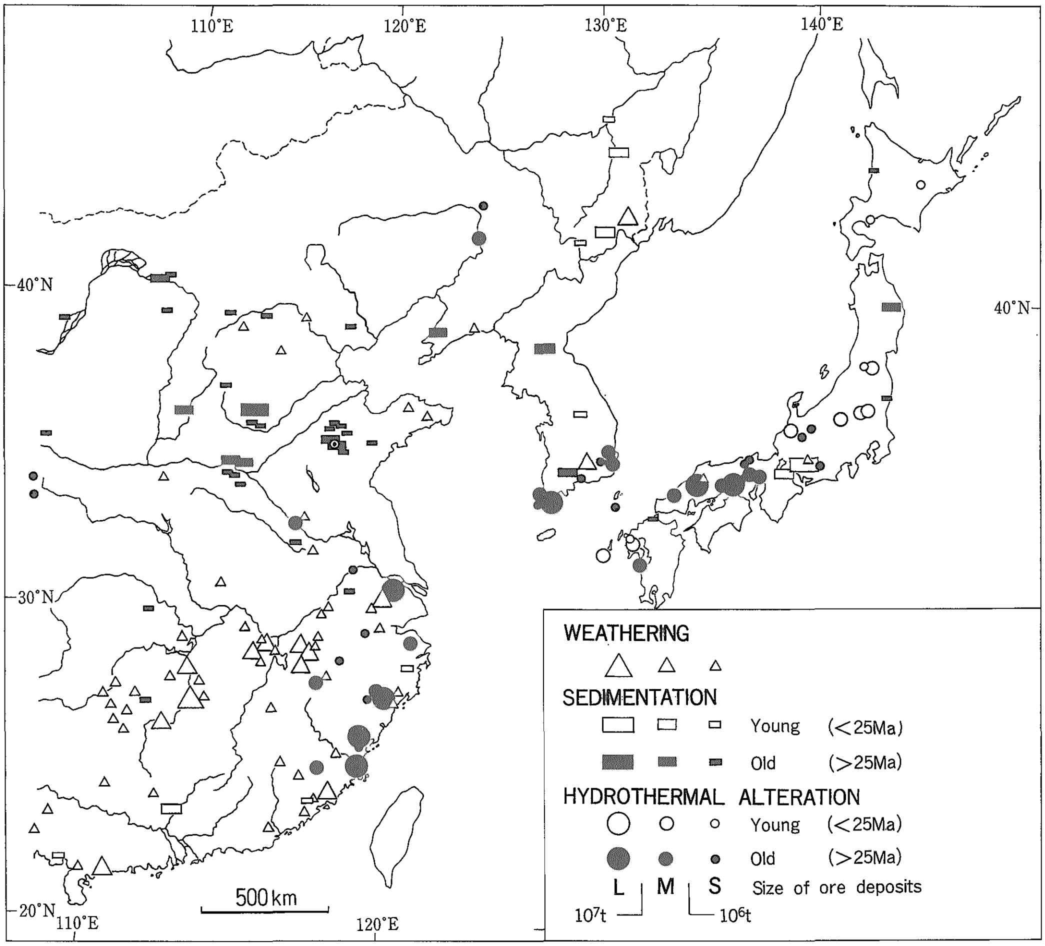


Fig. 7 Distribution map for various origins of clay deposits in East Asia.

Table 5 Hydrothermal and residual clay deposits in Japan

No.	Locality		Ore type	Genesis	Age	Size
1	Otoge	大峠	Po Ka	Hy	TN	M
2	Itaya	板谷	Ka Rk	Hy	TN	M
3	Kampaku	関白	Ka	Hy	TN	M
4	Onuki	大貫	Rp	Hy	TN	M
5	Shin'yo	信陽	Rp	Hy	TN	M
6	Ina Area	伊那地区	Ka	Rs	Q	M
7	Kamioka	上岡	Po	Hy	K	M
8	Hattori-Kawai	服部—河合地区	Rs	Hy	TN	M
9	Furikusa	振草	Ser	Hy	TN	S
10	Kanzaki	神崎地区	Rk	Hy	K	M
11	Hiraki	平木	Rk	Hy	K	M
12	Mitoya Area	三刀屋地区	Ser	Hy	TP	S
13	Iwaya	岩屋	Ser	Hy	TP	S
14	Mitsuishi Area	三石地区	Rp	Hy	K	L
15	Wake Area	和気地区	Rp	Hy	K	M
16	Shokozan Area	勝光山地区	Rp	Hy	K	L
17	Kamagamine	釜ヶ峰	Rp	Hy	K	M
18	Namera	滑	Rs	Hy	K	M
19	Tobe Area	砥部地区	Po	Hy	TN	S
20	Arita Area	有田地区	Po	Hy	TN	S
21	Taishu	対州	Po Ka	Hy	TN	M
22	Goto	五島	Rp	Hy	TN	L
23	Omura	大村	Ka	Hy	TN	S
24	Amakusa Area	天草地区	Po	Hy	TN	M
25	Okuchi	大口	Ka	Rs	Q	S
26	Iriki	入来	Ka	Hy	TN	M
27	Sendai	川内	Ka	Rs	Q	M

Ore type: Ka=kaolin, Po=toseki, Rk=kaolinic roseki, Rp=pyrophyllitic roseki, Rs=sericitic roseki, Ser=sericite.
Genesis: Hy=hydrothermal, Rs=residual.
Age: K=Cretaceous, Q=Quaternary, TN=Neogene, TP=Paleogene.
Size: L>300 kt/y>M>100 kt/y>S>10 kt/y, based on the production in 1990.

pyrophyllite zone, the kaolinite zone, the sericite zone, and the weakly altered zone in which igneous feldspar remains (*e.g.* Fujii *et al.*, 1979). These deposits are thought to be formed near the surface. Lenticular-shaped deposits rarely occur with a simple and homogeneous mineral composition of kaolinite and quartz with small amounts of dickite. The Hiraki *roseki* deposit is an example (Taninami, 1991).

There are two geologic ages of *roseki* mineralization in Japan: Late Cretaceous and Neogene Tertiary. Mesozoic *roseki* deposits are widely distributed in West Japan being associated with terrestrial felsic volcanics (Fig. 8 and Table 5). The Mesozoic *roseki* deposits are traceable from southeast margin of China to Sikhote-Alin of Russia by way of southern end of Korea Peninsula. Their mineralization ages are from Jurassic (Southeast China) to Paleogene (Sikhote-Alin). *Roseki* deposits in Japan are concentrated at Mitsuishi, Shokozan and Hiraki in West Japan.

The Neogene *roseki* deposits occur as small orebodies in the felsic volcanic areas, in the Green-tuff Region. The deposits are Onuki and Shin'yo in Central Japan, and Goto in Kyushu.

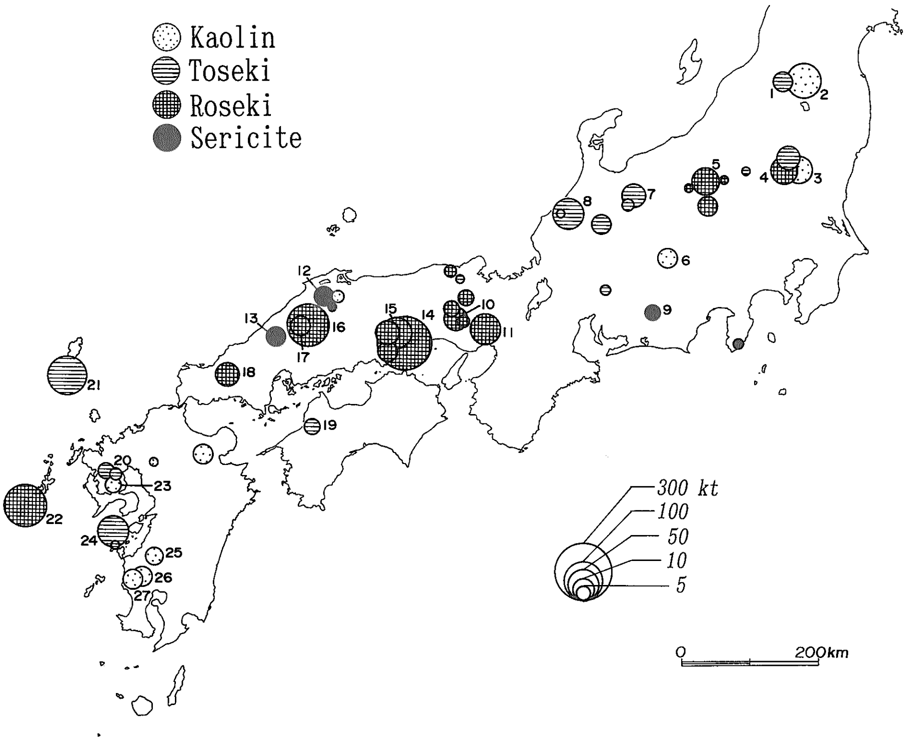


Fig. 8 Distribution map of hydrothermal clay deposits. Numbers in the figure correspond to those in Table 5.

Domestic output of *roseki* is 898 kt in 1990. It is utilized for refractories (39%), ceramics (20%), tile (13%), pesticide carrier (10%) and cement (8%) (Fig. 9). Recently domestic production of *roseki* has decreased due to continuous decline of demand from refractories and paper industries (Fig. 10).

In 1990, *roseki* (mainly pyrophyllite) was imported 100 kt from China and Korea mainly for ceramics and glass-fiber industries. They are blended with several domestic *roseki* in order to improve the quality, especially decreasing iron and alkali contents.

Toseki (porcelain stone) is a white compact ore composed mainly of sericite, kaolinite and quartz. It is derived from Neogene felsic volcanics. *Toseki* has traditionally been utilized for tableware in Japan. The *toseki* is unique in the world and is characterized by excellent nature for ceramic raw materials. It can be used without any blending of other clays.

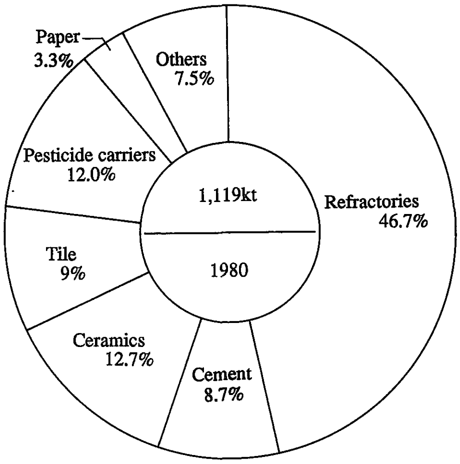
Toseki deposits show several modes of occurrence: Altered rhyo-dacite dikes (Amakusa), an irregular mass in altered lavas and tuffs in rhyo-dacite composition (Hattori-Kawai, Taishu), etc.

Production of domestic *toseki* is 183 kt in 1990 and almost all of them are consumed for traditional tableware (Arita-ware or Imari-ware), electric insulators and sanitary ware.

Since *toseki* runs short in the country, a large amount of low-quality *toseki* has been mined. The ore is refined with washing by acid solution to eliminate iron and carbonates. Domestic reserves of *toseki* are misgivings to reach a crisis point.

Hydrothermal kaolin is a white fragile ore with rough surface composed of kaolinite, halloysite and dickite.

This type of kaolin were formed by hydrothermal alteration of rhyo-andesite in Late Cretaceous and Neogene ages (Table 5). The Cretaceous ore with waxy surface is usually classified as *roseki* in Japan, although it contains a lot of kaolinite (*e.g.* the Hiraki Mine, Taninami, 1991).



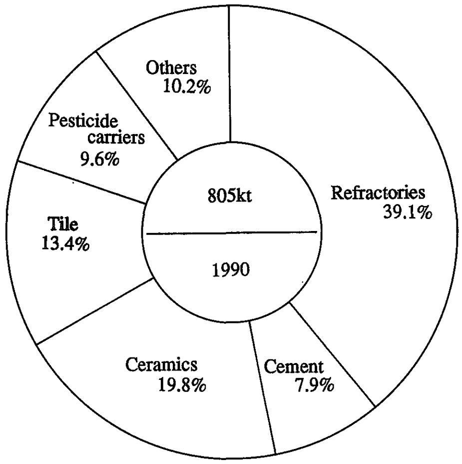


Fig. 9 Use of domestic roseki in 1980 and 1990.

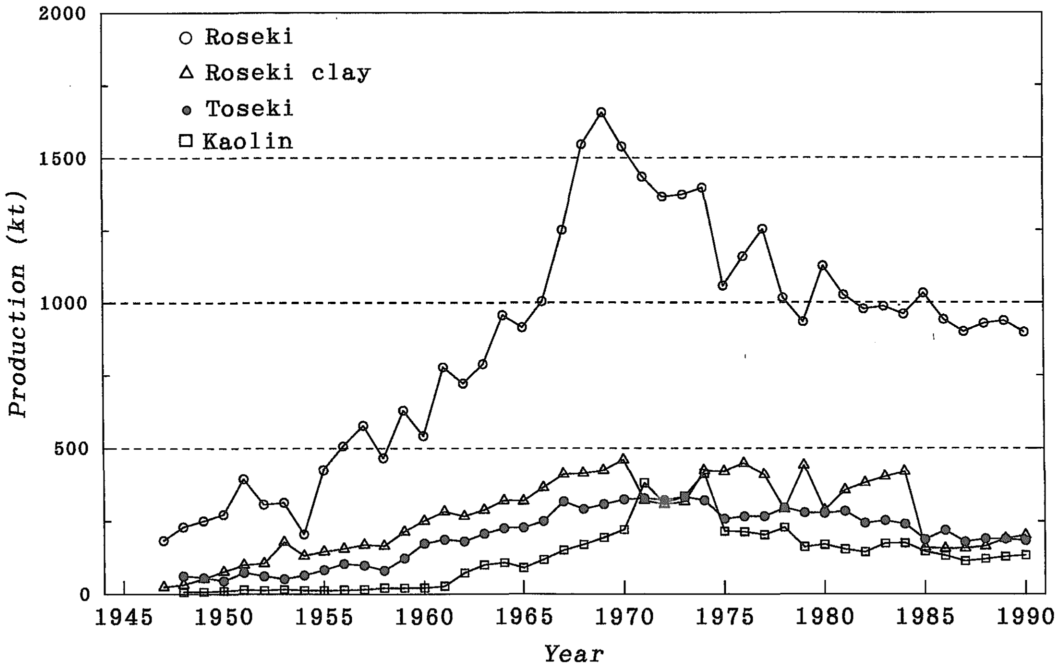


Fig. 10 Variation of domestic mine production for hydrothermal clay.

Domestic kaolin is produced by 129 kt in 1990. This figure includes the production of a small amount of residual kaolin. Domestic kaolin is used for paper (38%), pesticide carrier (25%), ceramics (10%), cement (7%) and fiber-glass industries (Fig. 11).

Sericite can be classified into two types: high-crystalline sericite and low-crystalline sericite.

High-crystalline sericite is formed at high temperature. It has hexagonal platy crystals with strong flaky cleavage, high electric insulation, high brilliance and significant hardness. Main uses of this sericite are of fillers for paints,

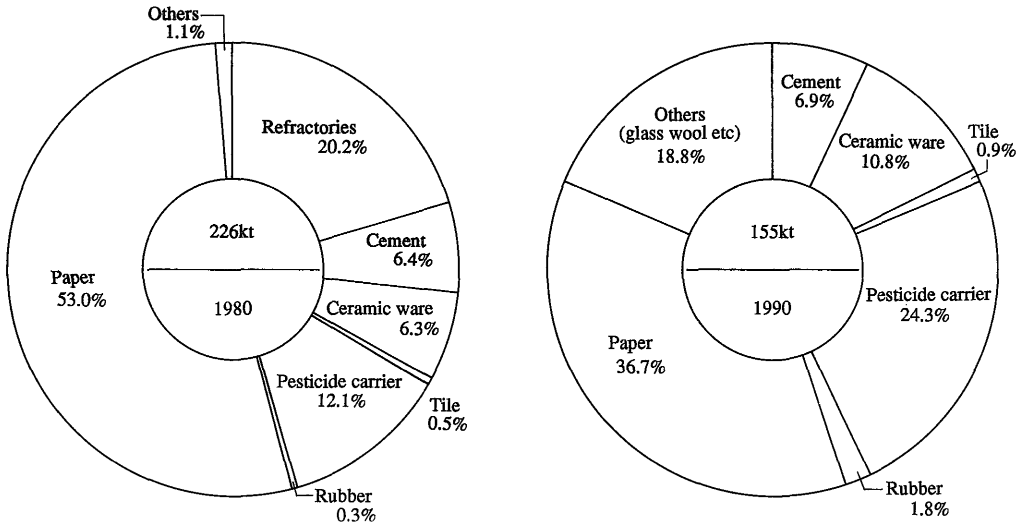


Fig. 11 Use of domestic kaolin in 1980 and 1990.

plastics, rubber and welding and electromagnetic shield.

Low-crystalline sericite shows higher plasticity and excellent behavior for calcination. This type of sericite is used for ceramics.

Both types of the sericite are produced totally several hundred tons a year. Utilization of both types of sericite have considerably expanded with improvement of processing and manufacturing technology in Japan.

2.3.2 Sedimentary clay

Sedimentary clay of Japan can be classified into two types based on their thermal property: high-refractory clay (more than SK26 of the pyrometric cone equivalent) and low-refractory clay.

2.3.2.1 High-refractory clay

High-refractory clay is composed mainly of kaolinite and it is subdivided into *kibushi* clay, *gaerome* clay and shale clay based on their apparent features. The distribution of high-refractory clay is shown in Fig. 12 and Table 6. *Kibushi* and *gaerome* clay deposits are concentrated in Pliocene terrigenous sediments at the Seto-Tajimi Area, Central Japan.

Kibushi clay is a soft dark-brown underclay containing a lot of fossil wood. The term "Kibushi" means woody chips in Japanese. This clay corresponds to the Ball Clay of European

Table 6 Sedimentary clay deposits in Japan

No.	Locality		Ore type (Size)	Age
1	Iwate	岩手	SC(M)	K
2	Nakatsugawa Area	中津川地区	GC(S)	TN
3	Mizunami Area	瑞浪地区	KC(S) GC(M)	TN
4	Yamaoka Area	山岡地区	KC(M) GC(L)	TN
5	Toki Area	土岐地区	KC(L) GC(M) OC(S)	TN
6	Tajimi Area	多治見地区	KC(M)	TN
7	Seto Area	瀬戸地区	KC(M) GC(L) OC(L)	TN
8	Fujioka Area	藤岡地区	GC(M)	TN
9	Toyota Area	豊田地区	KC(M) GC(S) OC(L)	TN
10	Shigaraki Area	信楽地区	KC(S) GC(S) OC(S)	TN
11	Ayama Area	阿山地区	GC(S)	TN
12	Ueno Area	上野地区	KC(S) GC(S)	TN
13	Shimagahara Area	島が原地区	KC(S) GC(M)	TN
14	Tsukigase Area	月が瀬地区	KC(S) GC(M)	TN
15	Tagawa	田川	SC(S)	TP

Ore type: GC=gaerome clay, KC=kibushi clay, SC=shale clay, OC=others (low-grade clay associated with Kibushi clay and gaerome clay).
Size: L>100 kt/y>M>10 kt/y>S, based on the production in 1990.
Age: K=Cretaceous, TN=Neogene, TP=Paleogene.

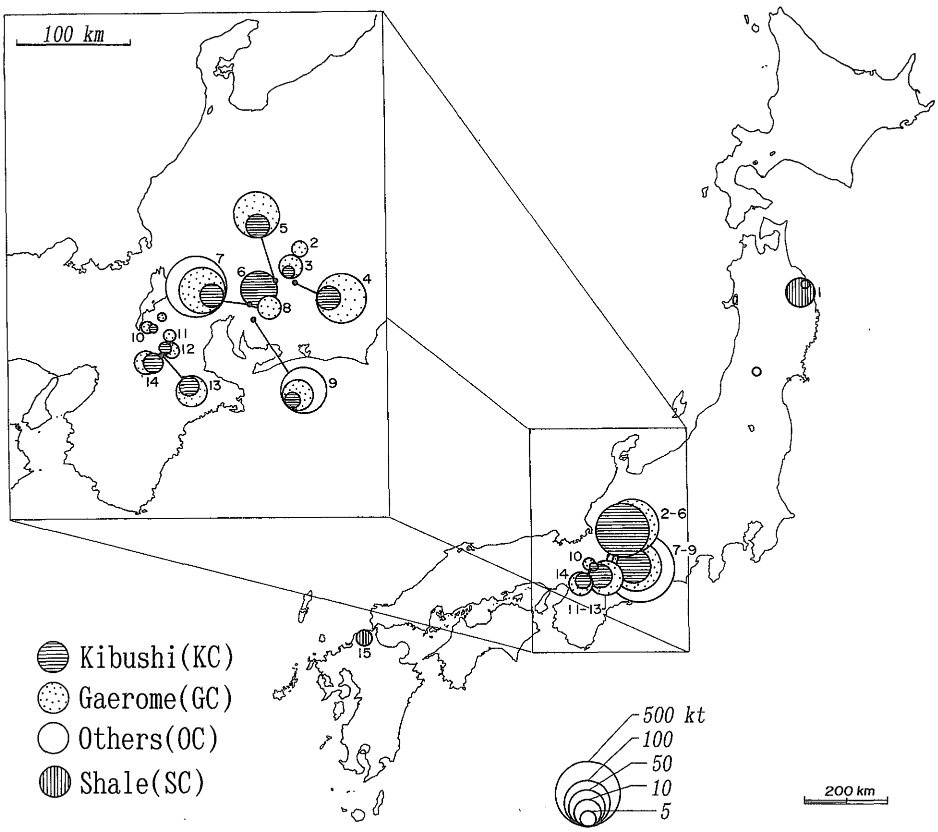


Fig. 12 Distribution map of sedimentary clay deposits. Clay deposits of high refractories are plotted. Numbers in this figure correspond to those in Table 6.

countries. The main minerals of the kibushi clay are kaolinite associated with small amounts of quartz, illite, feldspar and organic materials.

Gaerome clay is light-colored unsorted clay with silica sand, which is formed by rapid deposition of materials derived from decomposed granitic rocks. *Gaerome* clay often develops on weathered granitic rocks and is covered by *kibushi* clay beds in Central Japan. Crude *gaerome* clay is composed of silica sand (40–60% in volume), clay (15–30%) and micaceous minerals. The clay part of the *gaerome* clay is similar to *kibushi* clay in mineral composition. The clay is separated from silica grains by washing and used for ceramic and tile industries.

Shale clay is hard and its main constituent is kaolinite associated with small amounts of quartz, feldspar, illite and siderite. This clay occurs in clayey sediments associated with Cretaceous to Paleogene coal beds. Shale clay corresponds to the Fire Clay of the European countries, though the geologic age is different between them.

Total production of sedimentary clay has doubled in the past ten years (Fig. 13). Although *kibushi* and *gaerome* clays are important domestic raw materials for ceramic industries, their production has significantly declined during the two decades (618 kt in 1970, 456 kt in 1980 and 453 kt in 1990 for crude *kibushi* clay and 1,500 kt in 1970, 1,386 kt in 1980 and 688 kt in 1990 for crude *gaerome* clay). Reserves of these clays are estimated to run out by next 25–40 years. To keep supplies of the high quality clay, several milling factories have carried out following research and development activities:

a. Improvement of processing technology especially for clay of low quality.

b. Exploration of overseas clay deposits and its assistance.

c. Synthesis of high quality clay and modification of natural clay in low quality.

Shale clay was produced by 50 kt in 1990 mainly from Iwate and Fukuoka. It is used for ceramic ware, tile and refractories.

A great quantity of sedimentary clay is imported from U.S.A. (761 kt), Australia (112 kt), Brazil (99 kt), etc. The majority is Georgia Kaolin of U.S.A. About 50 percent (635 kt) of imported sedimentary clay is used for paper industries. It is used also for ceramics, glass-fiber, refractories, paint and rubber as fillers and medicines as carriers.

In 1990, 20 kt of refractory clay and 137 kt of aluminous shale are also imported mainly from China as a chamotte in refractories.

2.3.2.2 Low-refractory clay

Low-refractory clay occurs anywhere in Quaternary sediments along rivers, ponds and lakes in this country. The clay is used for roofingtiles, bricks and plant pots.

2.3.3 Residual kaolin

Residual kaolin formed by weathering is limited in Japan (Table 5). It is derived from glassy volcanics, such as obsidian and pumice tuff. The kaolin mineral is composed mainly of halloysite with small amount of kaolinite. This type of kaolin is used mainly for paper-filler.

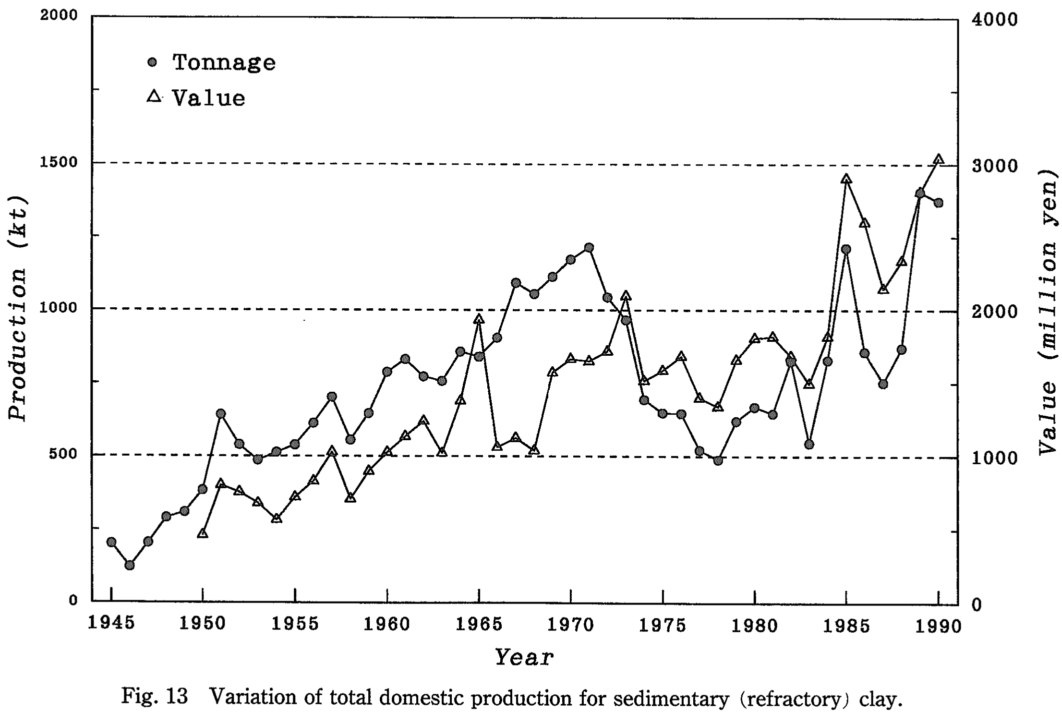


Fig. 13 Variation of total domestic production for sedimentary (refractory) clay.

2.4 Carbonates

2.4.1 Limestone

Limestone is the biggest domestic mineral resources in Japan. The value of mine production of limestone occupies more than 60% of that of total industrial minerals as already shown in Table 1.

The limestone occurs in many places as geologic bodies in accretion terranes of Late Paleozoic to Early Mesozoic ages (Fig. 14 and Table 7). The limestone bodies are not so huge compared with those in continents. Chemically they are extremely pure since they are organic in origin.

Production of domestic limestone has in-

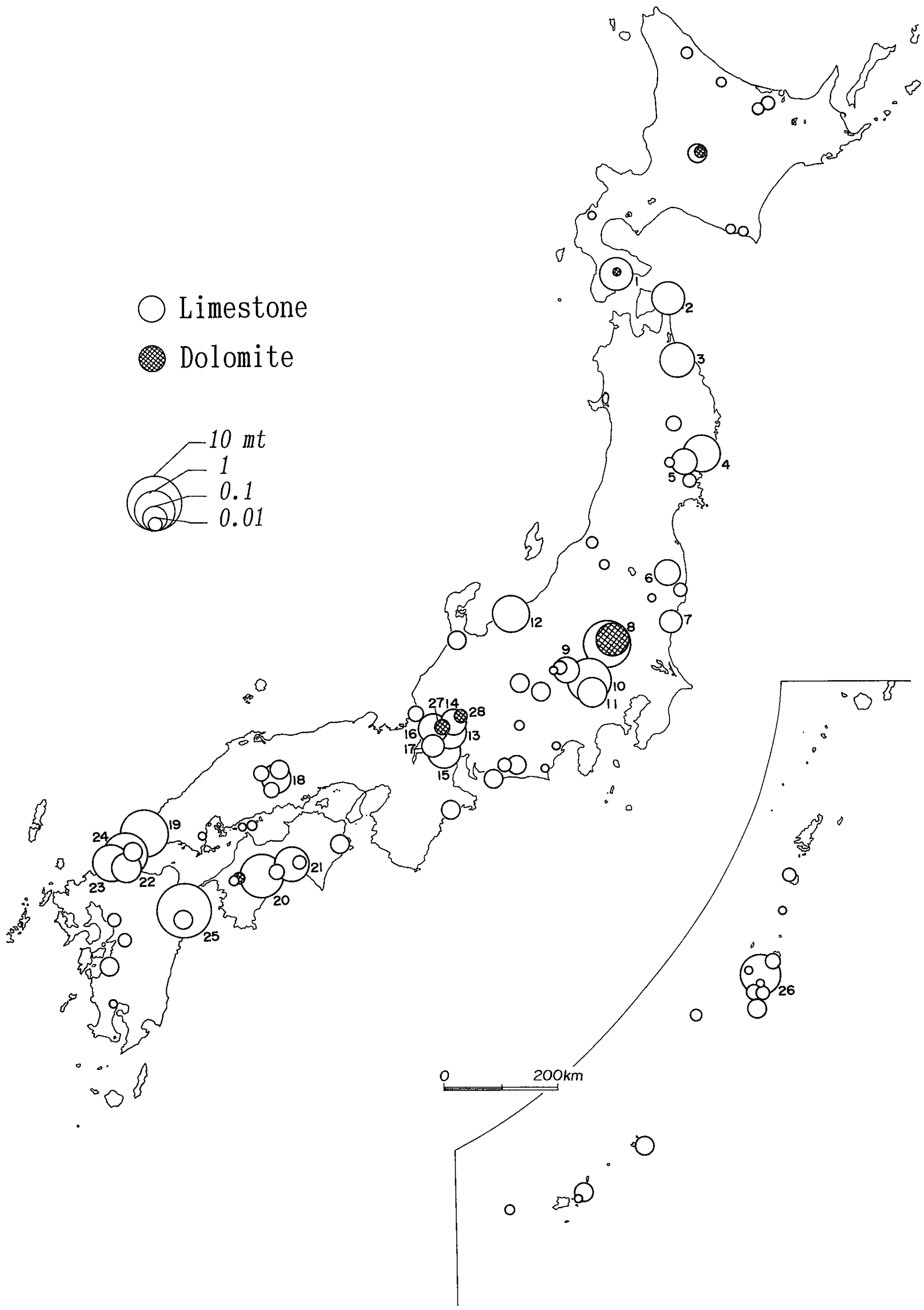


Fig. 14 Distribution map of limestone and dolomite quarries. Numbers in the figure correspond to those in Table 7.

Table 7 Limestone and dolomite quarries in Japan

No.	Locality		Commodity	Age	Size
1	Kamiiso Area	上磯地区	Ls Dl	J	M S
2	Shiriya	尻屋	Ls	J	M
3	Hachinohe Area	八戸地区	Ls	J	M
4	Ofunato Area	大船渡地区	Ls	P	M
5	Higashiyama	東山地区	Ls	P	M
6	Abukuma Area	阿武隈地区	Ls	J	M
7	Hitachi Area	日立地区	Ls	J	M
8	Kuzu Area	葛生地区	Ls Dl	J	L M
9	Kanozan	叶山	Ls	J	M
10	Chichibu Area	秩父地区	Ls	J	L
11	Okutama Area	奥多摩地区	Ls	J	M
12	Omi Area	青海地区	Ls	P	M
13	Akasaka Area	赤坂地区	Ls	J	M
14	Mugi Area	武儀地区	Ls	J	M
15	Fujiwara Area	藤原地区	Ls	J	M
16	Ibuki Area	伊吹地区	Ls	J	M
17	Taga Area	多賀地区	Ls	J	M
18	Niimi Area	新見地区	Ls	P	M
19	Akiyoshi Area	秋吉地区	Ls	P	L
20	Torigatayama	鳥形山	Ls	J	L
21	Kochi Area	高知地区	Ls	J	M
22	Kawara Area	香春地区	Ls	P	M
23	Kokura Area	小倉地区	Ls	P	L
24	Tagawa Area	田川地区	Ls	P	M
25	Tsukumi Area	津久見地区	Ls	J	LL
26	Motobu-Nago	本部一名護	Ls	K	M
27	Kasuga	春日	Dl	J	S
28	Miyama	美山	Dl	J	S

Commodity: Ls=limestone, Dl=dolomite.
Size: LL>25 Mt/y>L>10 Mt/y>M>1 Mt/y>S, based on the production in 1990.
Age: Limestone block in the sediments of: P=Late Paleozoic, J=Jurassic, K=Cretaceous.

creased year by year (Fig. 15) and is produced by 200 Mt from 250 quarries in 1990. It is consumed for cement (46%), aggregates for civil engineering (33%), steel (11%), lime (6%) and calcium carbonate (3%) (Fig. 16).

Limestone is essential and versatile raw-materials for cement, steel and chemical industries. New demand for the limestone is now accelerated accompanied by the improvement of manufacturing technology, e.g. micronized milling for paper-filler, fiber-crystal synthesis for new composite materials.

2.4.2 Dolomite

Domestic dolomite occurs as lenticular bodies associated with limestone in the Mesozoic to Paleozoic terranes, as shown in Fig. 14. The largest body of the dolomite is in the Kuzu Area, Tochigi Prefecture, and small ones are distributed in several areas such as Gifu, Ehime and Hokkaido. The chemical composition of the domestic dolomite is characterized by low contents of iron, alumina and silica as well as magnesia compared with those in continents.

Production of the dolomite is 5 Mt. The main producer of it is the Kuzu Area. Almost all the dolomite quarries are located in deep inlands of the country.

Domestic dolomite is used for aggregates (48%), steel (28%), lime and carbonate (6%) and glass (4%). Consumption of the dolomite has recently increased in the sector of civil engineering as aggregates.

The domestic dolomite has become expensive in freight charge so that imported dolomite has taken the place of the domestic one for steelmaking industries as flux. In 1990, 1.4 Mt of dolomite was imported from Korea, Thailand, Philippines and Australia.

2.5 Others

2.5.1 Talc

Domestic talc includes soft chlorite-schist. The talc often contains antigorite, tremolite-actinolite, chlorite, magnesite, dolomite and iron oxides as accessory minerals.

The demestic talc deposits occur in metamorphic terranes as small bodies associated with serpentinite. They are located in South Hokkaido, Ibaraki, Gunma and Hyogo Prefectures in Honshu, and Kumamoto Prefecture in Kyushu (Fig. 17 and Table 8). The deposits were formed by metamorphism and hydrothermal alteration.

About 60 kt of domestic talc is produced in 1990. The talc is used for housing materials (35%), pesticide carrier (29%) and paper-filler (15%). Recently fine powder products of chlorite schist are used for filler in plastics as reinforced composite-materials.

Talc is imported mainly from China (80%), Australia (16%) and U.S.A. Huge deposits of high-quality talc occur in Liaoning Sheng, Northeast China. The imported talc is used for

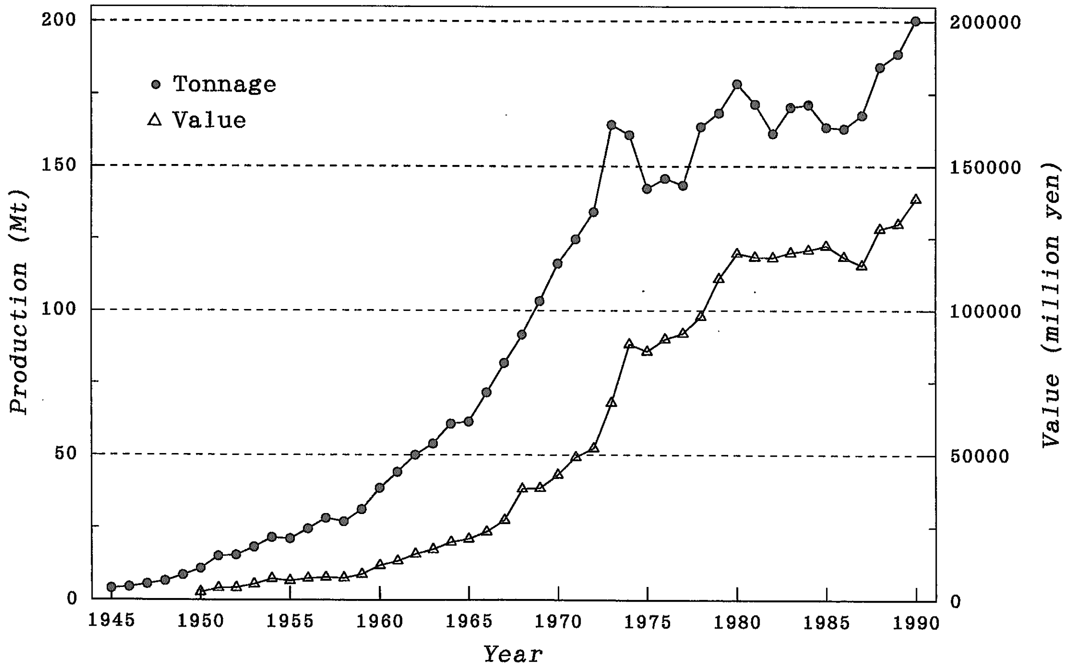


Fig. 15 Variation of domestic mine production for limestone.

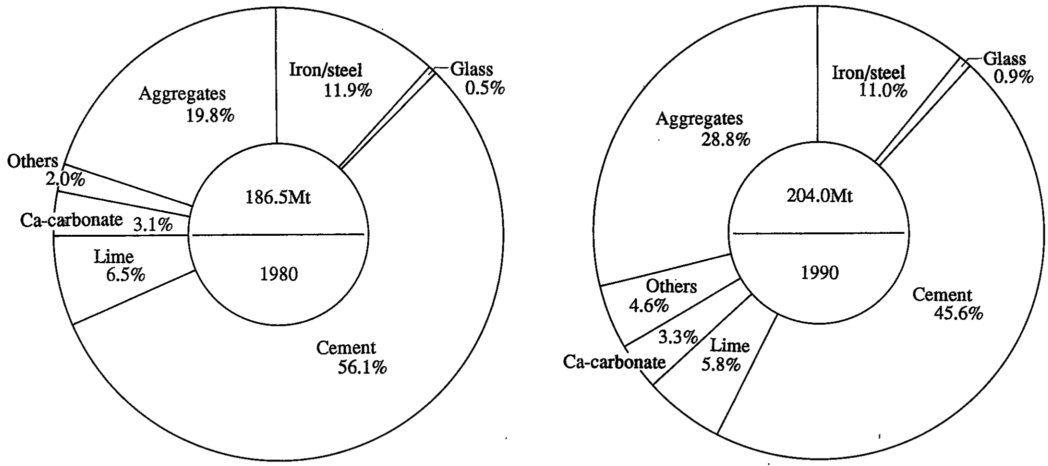


Fig. 16 Use of domestic limestone in 1980 and 1990.

fillers of paper, cosmetics, medicines, plastics, paint and rubber and for coating paper and for electric insulators.

2.5.2 Peridotite

Peridotite and serpentinite are distributed as small bodies with metamorphic rocks in Hokkaido, Northeast Japan, Central Japan, Shikoku and North Kyushu as shown in Fig. 17 and Table 8. The peridotite is produced 5.3 Mt in 1990 and is consumed mainly for civil engineering as aggregates (55%), for steelmaking as refractories and flux (32%), and also for foundry, abrasive and fertilizer in small amounts.

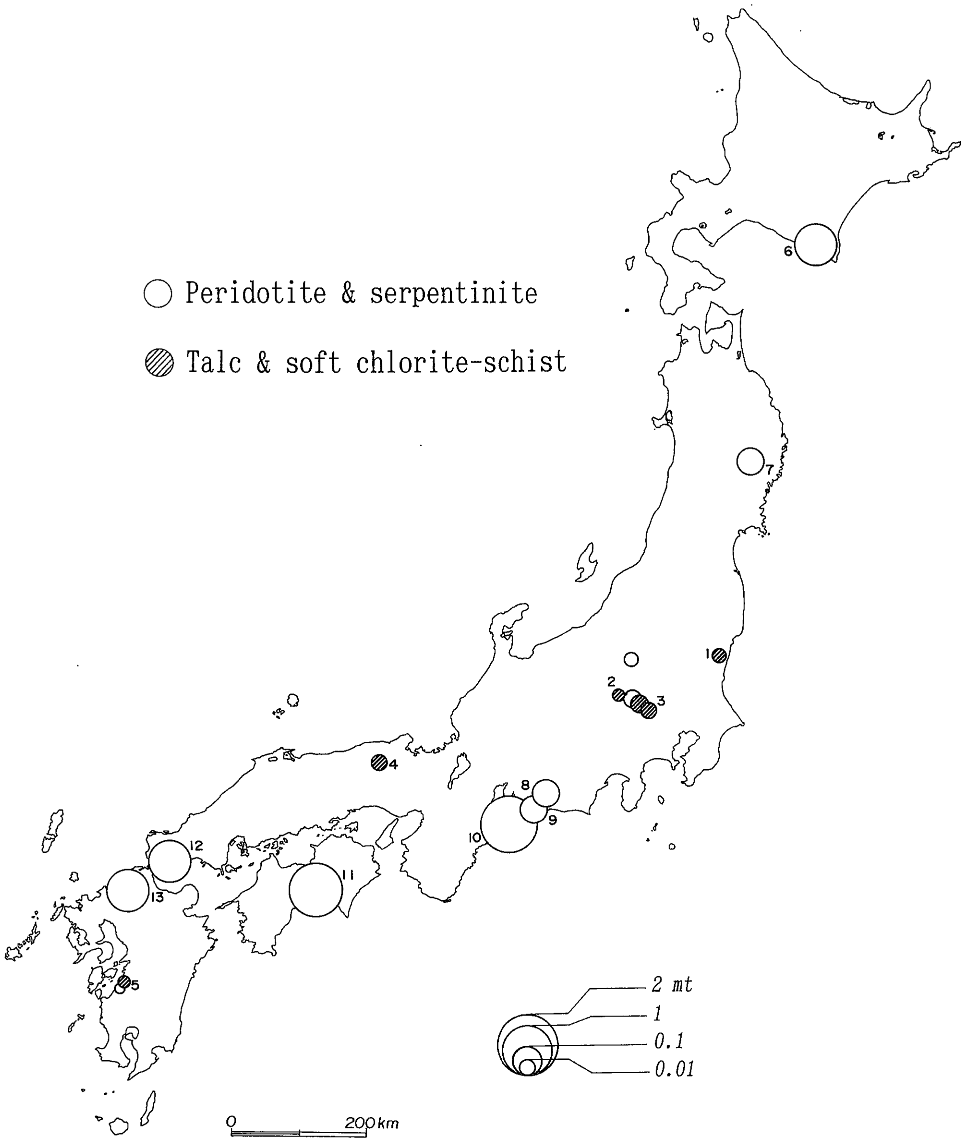


Fig. 17 Distribution map of talc and peridotite/serpentinite quarries. Numbers in the figure correspond to those in Table 8.

2.5.3 Bentonite and fuller's earth

Bentonite is light-colored soft clay showing high swelling ability in water. Bentonite is composed of sodium-based montmorillonite associated with cristobalite, zeolite, feldspar, quartz and calcite. Bentonite deposits occur in the Green-tuff Region in which Neogene submarine volcanics are widely distributed (Fig. 18 and Table 9). Bentonite deposits were formed by diagenesis of andesitic to rhyolitic tuffs.

Output of natural bentonite is 478 kt in 1990, mainly from Tohoku, Kanto and Chugoku (Fig. 19). Bentonite is utilized in various fields: stabilizer for soft soil in civil engineering (36%), steel casting and foundry (32%), pesticide carrier (7%), drilling mud (6%) and fertilizer. Granular bentonite is used especially for pet litter. Demand for natural bentonite increases remarkably in civil engineering.

Bentonite was imported by 203 kt from U.S.A., China, India and Australia in 1990.

Fuller's earth called *sansei-hakudo* in Japanese is a hydrogen-based variety of bentonite showing weakly acid nature without swelling in wet condition. The fuller's earth consists of montmorillonite with small amounts of cristobalite, quartz and halloysite. The fuller's earth is derived from bentonite through weathering process and is mainly produced in Niigata Prefecture, Central Japan. Output of fuller's earth in 1990 is: crude clay 104 kt and refined clay 29 kt. Japan exports 25 kt of acid activated bentonite to Belgium, United Kingdom, Taiwan and Thailand.

Fuller's earth is used for deodorant or decolorizing agent of oil and fat, as raw materials for ceramics, silica gels and detergent builders for water treatment.

2.5.4 Other minerals

Mine production of sulfur and gypsum has been ceased since 1973 and 1978 respectively (Figs. 20 and 21), because they are supplied excessively as by-products from the petroleum refining industry.

Table 8 Talc and peridotite/serpentinite deposits in Japan

No.	Locality		Ore type	Size
Talc and chlorite schist				
1	Hitachiota	常陸太田	T	S
2	Kanra Area	甘楽	CS T	S
3	Minano-Ogawa	皆野—小川	CS T	M
4	Seicho	聖長	T	M
5	Akamatsu	赤松	Sp	S
Peridotite and serpentinite				
6	Horoman	幌満	Pd	M
7	Miyamori	宮守	Sp	S
8	Shinshiro	新城	Sp	M
9	Tawara	田原	Sp	M
10	Toba	鳥羽	Pd	L
11	Engyoji	円行寺	Sp	L
12	Ube	宇部	Sp	M
13	Sasaguri	篠栗	Sp	M

Ore type: CS=chlorite schist, Pd=peridotite, Sp=serpentinite, T=talc.
Size: L>100 kt/y>M>10 kt/y>S, based on the production in 1990.

Table 9 Bentonite and fuller's earth deposits in Japan

No.	Locality		Ore type	Size
1	Aomori	青森	Bt	S
2	Odate	大館	F	M
3	Tsukinuno	月布	Bt	L
4	Kawasaki	川崎	Bt F	M
5	Shibata	新発田	F	M
6	Mikawa Area	三川地区	Bt	M
7	Nakajo	中条	F	M
8	Itoigawa	糸魚川	F	S
9	Matsuida	松井田	Bt	L
10	Seto Area	瀬戸地区	F	M
11	Izumo Area	出雲地区	Bt	M
12	Kasaoka	笠岡地区	Bt	M

Commodity: Bt=bentonite, Fe=fuller's earth (sansei-hakudo).
Size: L>100 kt/y>M>10 kt/y>S, based on the production in 1990.

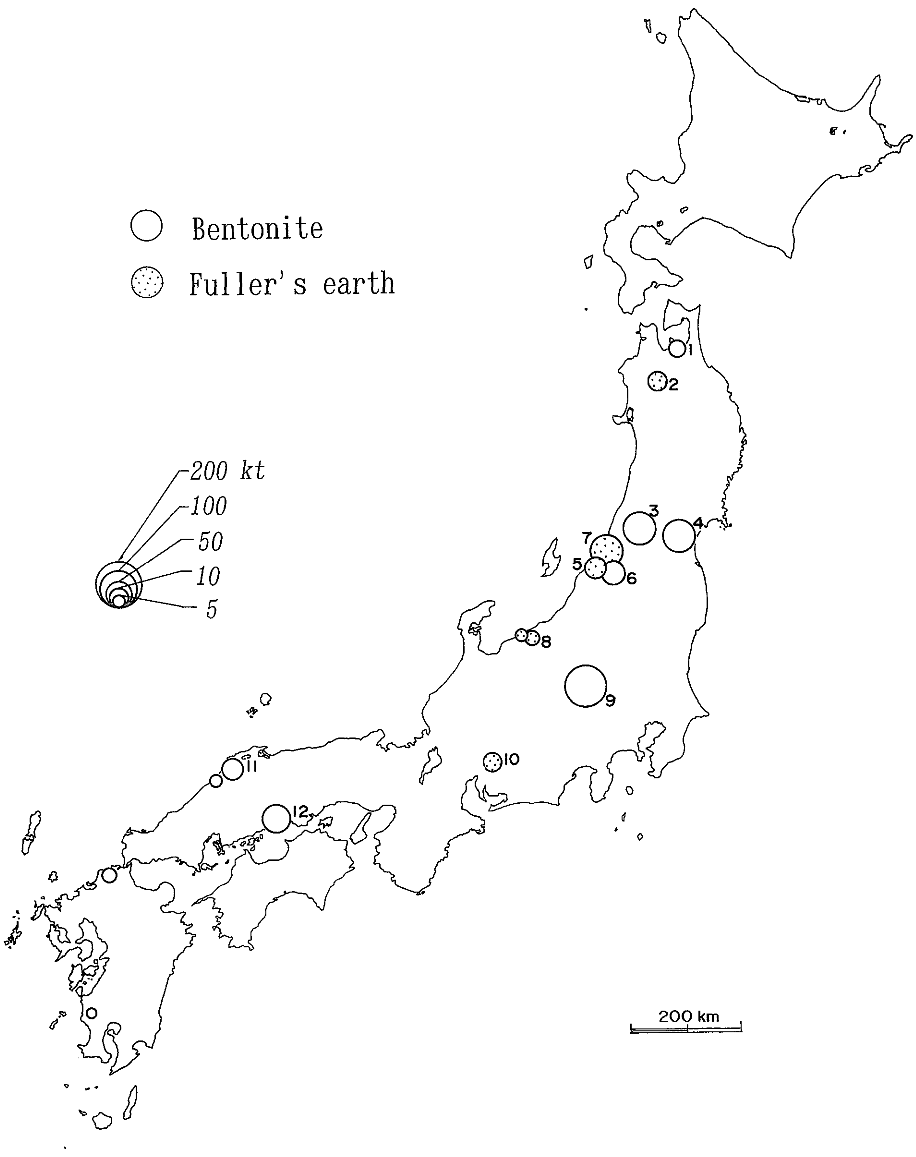


Fig. 18 Distribution map of bentonite and fuller's earth quarries. Numbers in the figure correspond to those in Table 9.

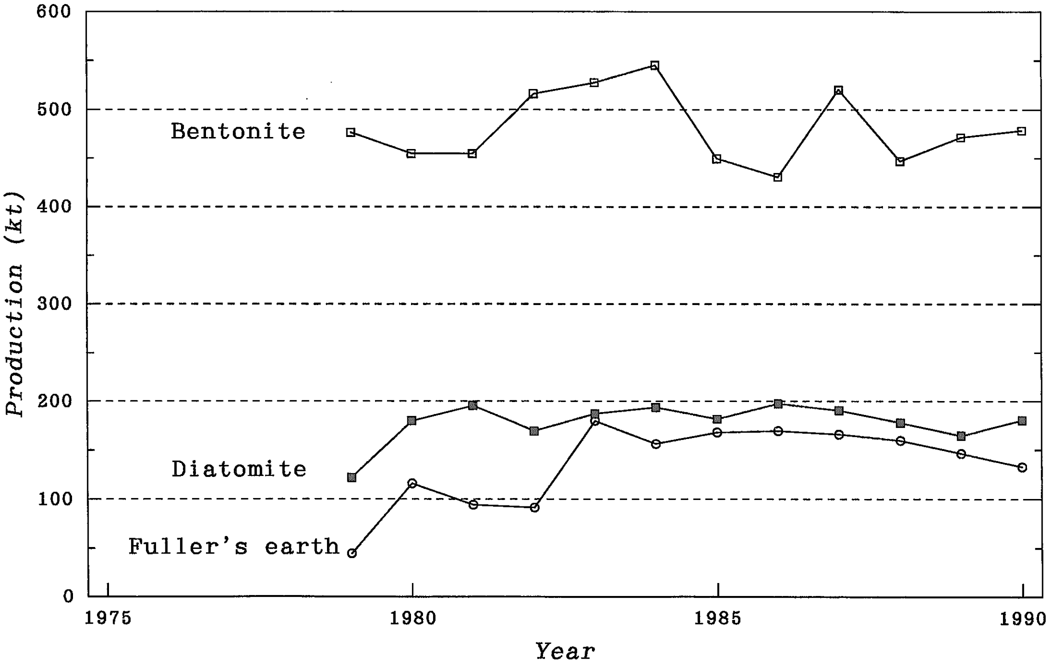


Fig. 19 Variation of domestic mine production of bentonite, fuller's earth and diatomite.

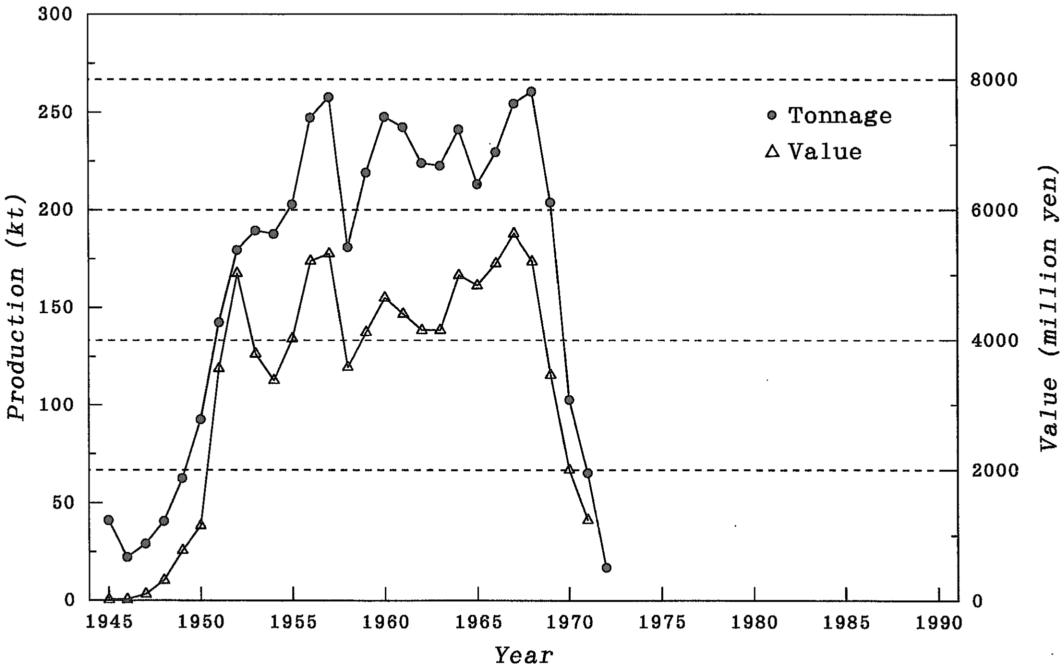


Fig. 20 Variation of domestic mine production for sulfur.

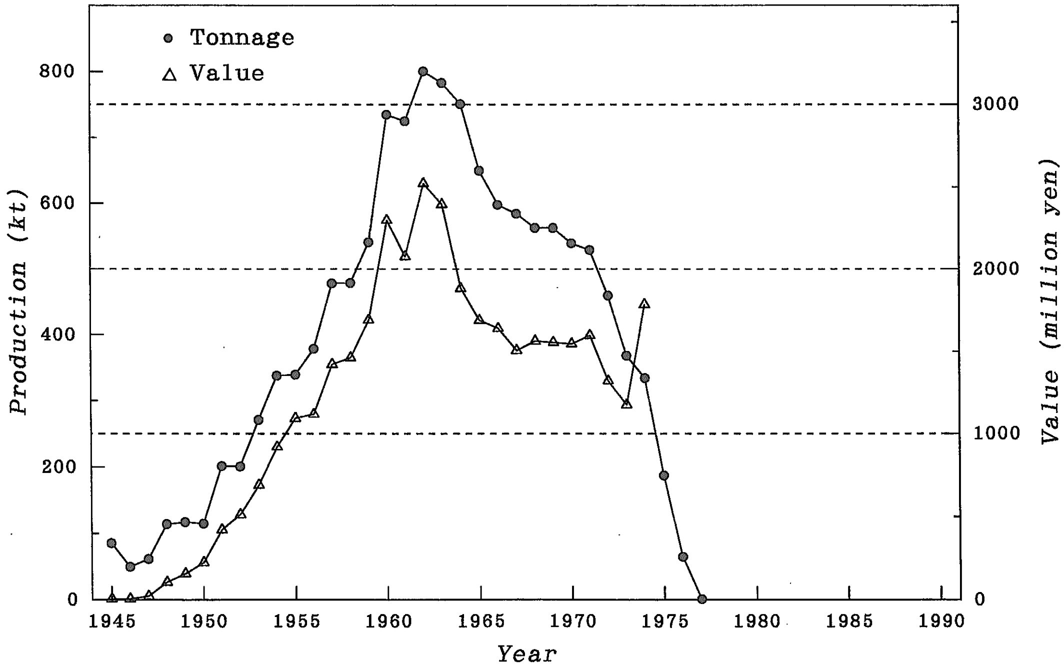


Fig. 21 Variation of domestic mine production for gypsum.

3. Price, demand and supply of industrial minerals

3.1 Production price

The average price of domestic minerals is shown in Fig. 22. In the figure, mineral names are arranged in the descending order of the price.

Most of industrial minerals show low prices and are valued US$10 to 100 per ton. Industrial minerals are so cheap and used so much that their transportation costs can not be ignored. This is the reason why the production of industrial minerals has constantly increased with the development of Japan's economy in spite of decline of the other resource production as already shown in Fig. 1.

3.2 Self-sufficiency index

Some of major industrial minerals are essentially imported into Japan (O'Driscoll, 1992). The domestic production, imports and indices of self-sufficiency (self-sufficiency index) of the industrial minerals are shown in Table 10. Silicastone, *roseki* as hydrothermal clay and limestone are supplied domestically, and their self-sufficiency indices keep high values (93 to 100%). Kaolin and talc for paper industries are mostly imported. Silica sand for glass industries and dolomite for steelmaking industries are also imported although they are not listed separately in Table 10.

Japanese manufacturing industries can be classified into three groups based on the contribution of local raw materials (Table 11) as noticed by Fujii (1981).

In the class 1, the industry depends totally on local raw materials. Cement industry established near limestone quarries is an example of this class.

In the class 2, industries use about half of raw materials from remote areas. Glass and most ceramic industries are in this class.

The class 3 industries are essentially independent of domestic raw materials. Steelmaking industry is the case. Almost all iron ores and cokingcoal come from overseas. Fine-ceramic industries also depend on imported raw materials of high quality.

Table 10 Mine production and imports of industrial minerals

Commodity	Domestic products (kt)		Imports (kt)		S.S.I.**		Exporter country
	Fy 1980	Fy 1990	Fy 1980	Fy 1990	Fy 1980	Fy 1990	
Silicastone	14,408	18,039	103	74	99.3	99.6	India, Thailand
Silica sand	4,654	4,449	634	1,970	88.0	69.3	Australia, Malaysia
Pegmatite feldspar	28.3	57.2	5.6	10.6	83.5	84.4	Australia, China, India
Roseki	1,262	894	110	65	92.0	93.2	Indonesia, China, Korea
Kaolin	229.9	157.6	565.4	1,153	28.9	12.0	USA, Australia, Brazil
Refractory clay	1,493	1,172	236	246	86.4	82.7	USA, China
Limestone	181,816	200,767	0	0	100	100	
Doromite	6,084	5,407	197	1,404	96.9	79.4	Korea, Philippines
Talc	123.1	63	441.8	397.3	21.8	13.7	China, Australia, USA
Fluorite	0	0	481	573.9	0	0	China, South Africa
Barite	56.4	0	43.8	106	56.3	0	China
Gypsum	6,105*	5,466*	43	3,774	99.3	59.2	Thailand, Mexico
Sulfer	1,132*	1,267*	0	0	100	100	

Fy: Fiscal year (April to March of the next year). *By-products, **Self-Sufficiency Index.

Most industries in Japan which consume non-metallic minerals belong to the class 1 or 2. In this context, they can be called local industries.

4. Concluding remarks

The domestic production of industrial minerals has steadily grown in Japan, but most of the industrial minerals have run short and the mine products have been decreasing in quality. It becomes a problem that a lot of limestone is consumed as aggregates for civil engineering (Kasai, 1990). Low price of the limestone has caused an easy manner of consumption of the limestone. Since the limestone can not be taken the place of other minerals so far, today's industries would not be able to survive without supply of the limestone and its products.

Nowadays raw material industries of Japan require not only considerable volume, but also high quality of industrial minerals in order to make new products with high functions. Therefore, following efforts may be necessary for stable supply of industrial minerals:

(1) Well-organized exploration and exploitation for working quarries. This type of activities has already been carried out in the field of the metallic exploration by subgovernmental companies.

(2) Development of technology for blending of minerals and for improving characteristics. Several private milling-factories have already prepared suitable quality of raw materials for glass-fiber from domestic clays blending with small amounts of imported clays in high-quality. This kind of technology is highly requested also for other industrial minerals.

Table 11 Classification of Japanese industries based on role of indigenous minerals

Class	Contribution from local raw materials	Example in Japan
1	Essential	Traditional pottery, Cement
2	Important	Sanitary ceramics, Glass
3	Insignificant	Fine ceramics, Steelmaking

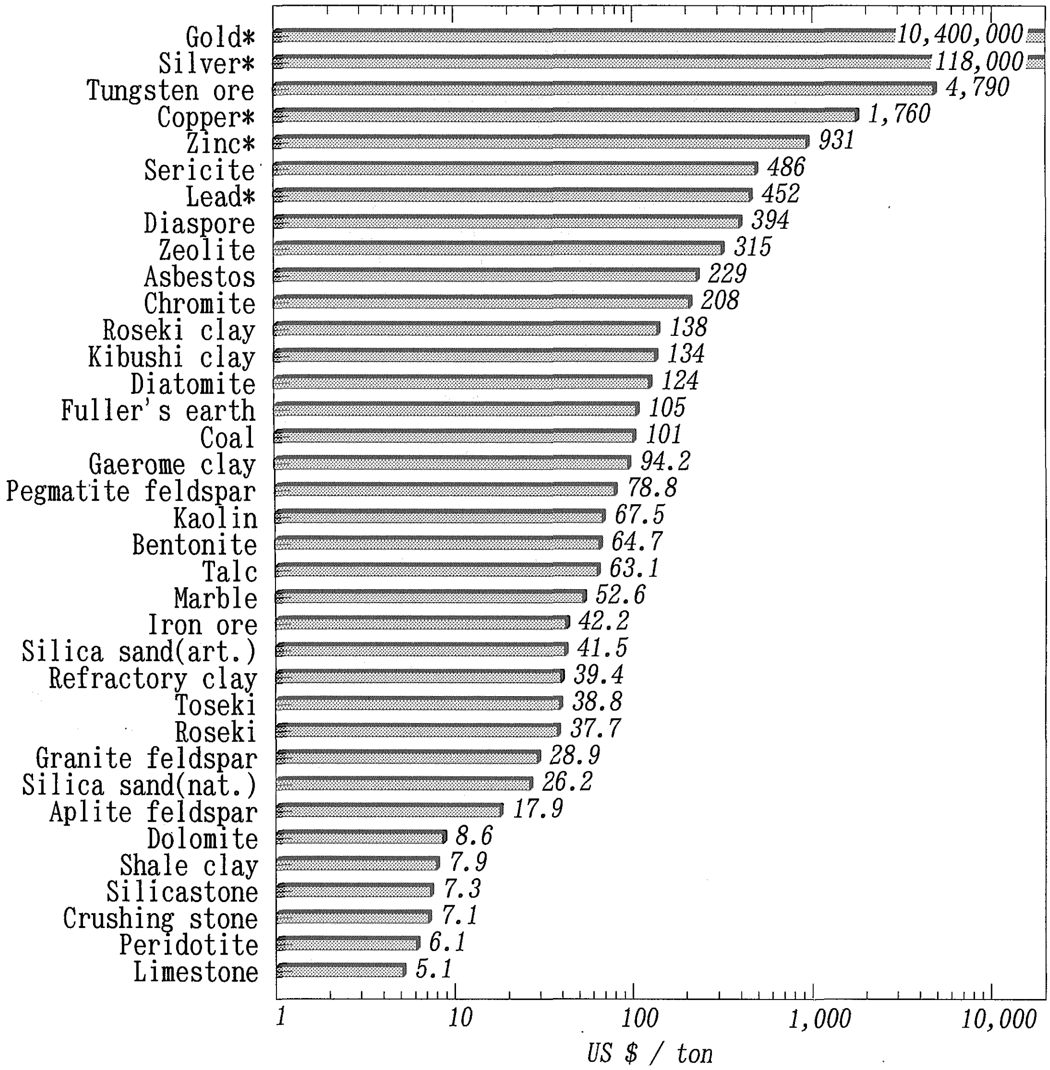


Fig. 22 Average price of domestic minerals (concentrates) in Japan. Mineral names are arranged in the order of their prices in 1990.
*Expressed in terms of metal content in concentrates.

References

Fujii, N. (1981) The industrial minerals of Japan. Industrial Minerals (London). No. 170, p. 21–25.

Fujii, N., Hirano, H., Sudo, S., Kamitani, M., and Togashi, Y. (1979) Geologic features related to formation of the pyrophyllite and sericite clay (roseki) deposits in the Mitsuishi Area, Southwest Japan. Mining Geology (Tokyo). Vol. 29, (2), p. 83–95. (Japanese with English abstract)

Hirano, H. and Sudo, S. (1992) Industrial minerals in Japan. ESCAP workshop-cum-study tour on Industrial minerals development, held on 29 Aug.–3 Sept., 1992 (Nagoya, Hyogo).

Kasai, Y. (1990) Limestone—A valuable resources. Lime (Tokyo). No. 416, p.1–8.

Japan Lime Association. (in Japanese)

MITI Research and Statistics Dept. (1950–1991) Mining Yearbook of Japan (*Honpo Kogyo no Susei*) —1945 to 1990—. Tsusho Sangyo Chosakai, Tokyo. (in Japanese)

——— (1976–1991) Yearbook of minerals and non-ferrous metals statistics (*Shigen Tokei Nempo*)–1975 to 1990. Tsusho Sangyo Chosakai, Tokyo. (in Japanese)

——— (1963) History of the mining trends of Japan (for 1905–1960). 787p. Tsusho Sangyo Chosakai, Tokyo. (in Japanese and English)

O'Driscoll, M. (1992) Industrial minerals of Japan, Bowing to recession reality. Industrial minerals (London). No. 295, p. 19–43.

Okano, T. (1983) Non-metallic industrial raw materials of Japan. Journal of Geography. Vol.92, p. 344–364, 392–408. Tokyo. (in Japanese with English abstract)

Sudo, S. (1992) Review on ceramic raw materials in Japan. p. 1–30. In ed. by Subcommittee for Ceramic Engineering, Industrial Technology Committee, Japan, "Ceramic Raw Materials in Japan—1992", 919p. TIC Co. Osaka. (in Japanese)

——— and Hirano, H. (1992) Some mining statistics of Japan, 1945–1990. In "Resource geology, the year 2000". Resource geology special issue. No. 13, p.196–208. Society of Resource Geology, Tokyo. (in Japanese with English abstract)

Taninami, S. (1991) Exploration and development of the Hiraki kaolin Mine, Hyogo Prefecture, Japan. Mining Geology (Tokyo). Vol. 41, (5), p. 269–278. (in Japanese with English abstract)

日本の工業原料鉱物資源

平野英雄・須藤定久

要　旨

日本の工業原料鉱物の分布，需給の現状について概要をとりまとめた．現在生産されている工業原料鉱物には以下のものがある．

① けい石類：白けい石，軟けい石，炉材けい石，けい砂，けい藻土
② 長石類：長石(ペグマタイト長石)，半花崗岩(アプライト長石)，風化花崗岩(花崗岩長石)
③ 粘土類：ろう石，陶石，カオリン，セリサイト，木節粘土，蛙目粘土，頁岩粘土
④ 炭酸塩岩類：石灰石，ドロマイト
⑤ その他：タルク，かんらん岩(蛇紋岩)，ベントナイト，酸性白土等

これらのうち主要なものは，石灰石，けい石，けい砂，ろう石，木節粘土，蛙目粘土，ドロマイトなどであり，それらはセメント，鉄鋼，セラミックス，ガラス，耐火物など基幹的産業の基礎原材料として供給されている．低価格で需要量の多い工業原料鉱物は国内依存度が高いものの，カオリン，タルク，けい砂等の高品位鉱の輸入が一層増加する傾向にある．

また鉱石の選鉱・改質技術が進み，工業原料鉱物のより高度の利用や新用途が開拓される一方，石灰石やけい石の土木用などへの流用も増加傾向にある．

(受付：1993年7月9日；受理：1993年11月22日)