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Major Industrial Minerals in Korea : Geological Occurrence and Current Status of Demand/Supply

국내 산업소재광물의 수급 및 부존 특성

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ABSTRACT : The industrial minerals play an important role in mining sector. More than 70 % of total mineral production come from industrial mineral sector.

This paper reviews geological occurrence of kaolin, pyrophyllite and limestone, and current demand-supply status of major industrial minerals in the Republic of Korea.

The kaolin is mainly distributed in the Kyeongsang province, formed by deep weathering of Precambrian anorthosite on mountainside of gentle slope.

The pyrophyllite mainly occurs in the Kyeongsang and Chulla provinces, formed by hydrothermal alteration of late Cretaceous andesitic and rhyolitic rocks. Pyrophyllite comprises massive and lenticular bodies and contains minor amounts of kaolin, alunite and pyrite, in some places andalusite and illite.

The limestone(Great Limestone Series of Cambrian age) is distributed widely in the Kwangwon and Chungcheong provinces. The limestone bodies are approximately 70 km long and 3 km wide, elongated NE-ward, and show high grade of CaO content.

In 1992, the self-sufficiency ratio of 44 nonfuel (metallic and non-metallic) minerels was no more than 30 percent. However, the ratio of 27 industrial minerals (non-metallic) represents high value of about 72 percent.

The export/production ratio of the industrial minerals shows decreasing patterns from 12.2 % in 1983 to 4.2 % in 1992. Also the import/production ratio shows rapidly decreasing pattern from 84 % in 1983 to 38.2 % in 1992.

요약 : 국내 산업에 활용되는 광물은 약 50종으로서 이 중에서 산업소재광물 (비금속광물)은 27종에 이른다. 산업소재광물이 차지하는 생산금액은 모든 광물자원(석탄 제외)이 차지하는 금액의 70 %를 상회한다. 1983년부터 1992년까지 광업 및 제조분야의 성장률은 연평균 11.5 % 그리고 GNP는 14.8 %의 성장률을 보인 반면 광물자원의 수요는 2.7배로서 연평균 12.6 %의 증가율을 나타낸다. 27개 산업소재광물의 자급도는 평균 72.4 %로서 이중 석회석은 생산과 수요에 있어 선두를 차지하며 납석은 수출면에서 수위를 점하고 있다. 생산에 대한 수출비율은 1983년도에 12.2 %에서 1992년도에는 4.2 %로 그리고 수입비율은 84 %에서 38.2 %로 하향되었다.

국내 산업소재 광물자원으로서 중요 역할을 담당하는 것으로 석회석, 납석 그리고 고령토를 들 수 있는 바, 석회석은 캠브리아기의 풍촌석회암층에 고품위가 부존되어 있으며, 납석은 경상 및 전라지역에 발달된 백악기 유천그룹의 화산암 내에, 그리고 고령토는 경상남북도 지역에 분포된 회장암 풍화대에서 발달 양상을 잘 확인할 수 있다.

INTRODUCTION

The economic growth in the Republic of Korea for the last two decades has accelerated mass consumption of mineral commodities. Owing to poorly endowed mineral resources, Korea had to expand imports of raw materials in line with its industrialization. Most of the expansion was led by the metallic mineral sector such as iron ore, copper concentrates and zinc ore, etc, while industrial minerals reveal upward increasing trend reflecting the expansion of industry. In general, local consumption of domestic production has increased.

Currently about fifty minerals are utilized for mineral industry in the Republic of Korea. Twenty-seven of them comprise industrial minerals (non-metallic) among which limestone and kaolin constitute the two most important production commodities. Pyrophyllite is the top-ranking exporting mineral.

The self-sufficiency ratio of domestic demand for industrial minerals was much higher than that of the metallic minerals. The component ratio of mineral industry sector of the gross national production (GNP) in Korea has dropped from 0.77 % in 1988 to 0.36 % in 1992 due to the rapid growth of other industries in the country. The component ratio, 0.27 % in 1992, of industrial mineral sector of the GNP ocupies ranks higher compared with the ratio of mineral industry sector 0.36 %.

GEOLOGICAL OCCURRENCE

Limestone

The limestone bodies in Korea mainly occur in Kwangwon and Chungcheong provinces (Fig. 1).

The limestones in the Kyungbuk and Kyungki provinces are of Precambrian age. These limestones occur in patchy areas in the Preacambrian Yeongnam and Kyunggi metamorphic complex. Generally the limestone bodies are not laterally

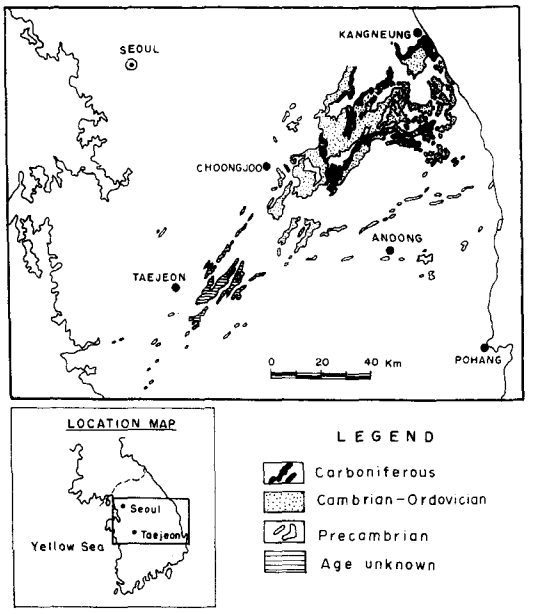

Fig. 1. Distribution map showing different ages of limestones in South Korea.

continuous and corse-grained in some areas. In Andong area, it occurs in a relatively large area, (100 m wide, 800 m long) in gneiss complex and shows high grade of CaO (52~55 %) and SiO_2 (less than 1 %) content. The precambrian limestone covers less than 5 % of the total limestone in Korea.

The Great Limestone Series (Cambro-Ordovician) are widely distributed in the Kwangwon and Chungcheongbuk provinces. It occupies more than 85 % of the total limestone and is most important raw materials for the limestone industry in Korea. The Great Limestone Series is dominated with limestone and dolomitic limestone, interbeded with sandstone, sandy shale and calcareous shale. These Limestone bodies are elongated northeastward (about 90 km long on NE and 30 to 40 km wide on SW direction) (Fig. 2). Pooncheon, Heungwolri, Samtaisan, Yeongheung, Magdong and Jeongseon limestone formations belong to these series (Fig. 2).

The Poongcheon limestone Formation of middle Cambrian age overlies Myobong slate of the

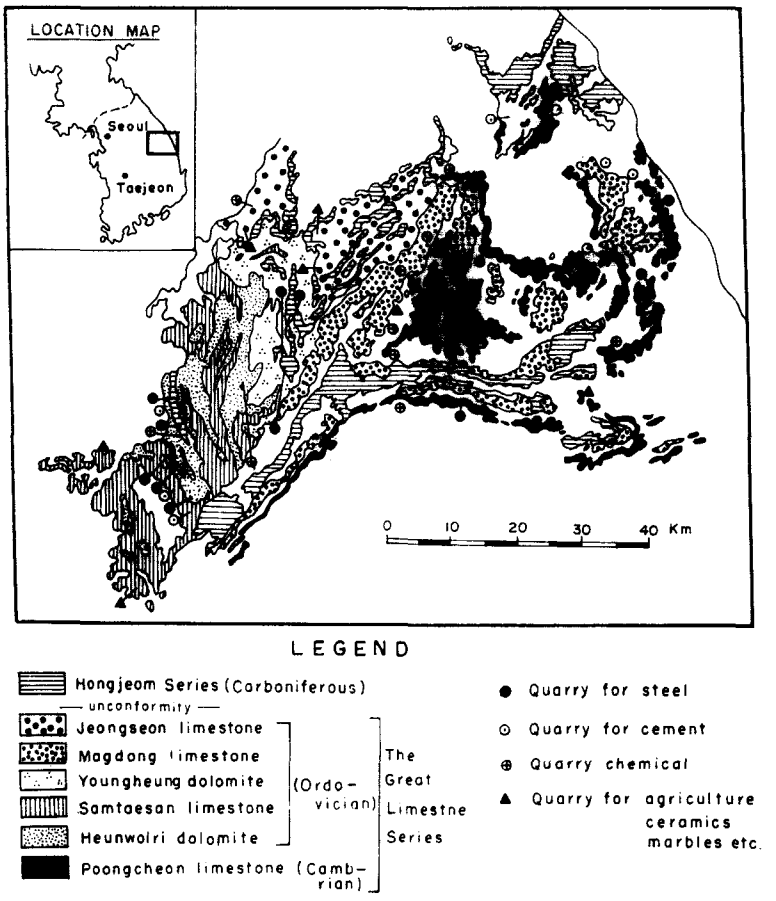

Fig. 2. Distribution map of limestones (Cambrian, Ordovician and Carboniferous) and quarries.

Yangdok series comformably, and consists mainly of milky white, thinly interbeded light to dark grey massive limestones with intraformational limebreccia, oolitic limestone and dolomitic limestone. It is estimated to be 150 to 400 m in thickness. In some places, small amounts of dark grey shale and marl are associated with in its lower and middle parts. The limestone is generally poorly bedded and mostly pure in composition. The formation is subdivided into three zones by its color, grain size and CaO content of the limestone. The upper zone is characterized by milky white fine to very fine-grained and high value of CaO (52~55 %) and SiO_2 (1~2 %) contents. The middle zone is chracterized by grey fine to medium-grained with the values of CaO (50~52 %) and SiO_2 (4~8 %) contents. The lower zone is characterized by dark greyish medium-grained and low value of CaO (less then 50 %) and SiO_2 (more than 4 %) contents. In the upper and lower zones, dolomitic limestone is intercalated with about 10m in thickness. The high quality limestones in the upper zone are utilized as raw materials for steel and chemical industry.

The Heungwolri Limestone Formation of early Ordovician age is the lower most part of the Great Limestone Series. It conformably overlies Machari Formation and consists mainly of light

grey to grey crystalline dolomitic limestones and thinly intercalated grey to bluish grey limestone. The crystalline dolomitic limestone is generally massive and poorly bedded with dark green weathered surface.

The Samtaisan Formation conformably overlies the Heungwolri Formation and consists mainly of bluish grey well bedded limestone, greeish grey shale, dark yellow marl, dolomitic limestone and thinly interbedded vermicular limestone. The bluish grey limestone is generally well laminated owing to the clay layers parallel to bedding plane. The formation is divided into three lithologic parts; the upper part, 70 to 100 m thick, consists generally of alternations of bluish grey limestone, marl, greenish grey shale and platy limestone. The lower part, 40 to 100 m thick, is chiefly composed of grey massive dolomitic limestone and reddish sandy limestone intercalated with thin layers of black chert. The basal 10~20 m includes mainly bluish grey limestones, greenish grey shales and dark yellow marl-vermicular limestone.

The Yeongheung Formation, the uppermost of the Choseon Supergroup in the Yeongwol area, conformably overlies the Samtaisan formation and is, in turn, overlain by the Cambrian-Triassic Pyeongan Supergroup with unconformity. The formation consists mainly of dark grey dolomitic limestone and grey to bluish grey limestone intercalated in places with several thin beds of shale and argillite. Especially in the lower and middle parts of the formation dark grey dolomitic limestone predominates, whereas limestone is dominent in the upper part.

The Magtong limestone overlies the Tumugol shale conformably, and consists mainly of well bedded bluish grey platy limestone with the association of grey calcareous shale beds and intraformational breccias. Generally the bluish grey platy limestones are predominent in the lower and upper parts, whereas the massive limestone is predominant in the middle part of the formation interbedded with the lenticular dolomitic limestone beds.

The Cheongseon limestone is unconformably overlain by the Carboniferous Pyeongan Supergroup. The lower limit of the limestone is obscure due to the faults in most contacts. It consists mainly of grey to bluish grey microcrystalline limestone. Several light grey to dark grey dolomitic limestone beds are intercalated. The main grey limestones are well bedded and generally laminated.

The Carboneferous limestone, the lowermost part of the Pyeongan Supergroup with reddish sediments has been correlated with the Hongjeom Series. The Hongjeom Series consists mainly of light colored limestone, red shale, white to light green or red sandstone, and white, light green, mottled fine pebble conglomerate. Lateral and vertical facies of the rock sequence and amounts of each rock type change in short distance. The base of the Homjeom Series lies disconfomably on the Ordovician sequence. The upper limit of the Series has been defined by the uppermost white limestone bed. The Series is 200~300 m in thickness.

The limestone of age unknown occurs in small scale in part of the Okcheon metamorphic zone (Okcheon Group). The Okcheon Group consist mainly of shist, dolomite, limestone, quartzite, phyllite, slate and pebble-bearing phyllite, limestone and slate partly with chert. The limestone covers less than 10 % of the total limestone surface in Korea. Small amounts are utilized for filler in chemical industry.

Kaolin

The Sancheong-Okchong area in Kyeongsang province consists mainly of Precambrian gneiss complex, anorthositic rocks, Jurassic plutons and Cretaceous sedimentary rocks (Fig. 3).

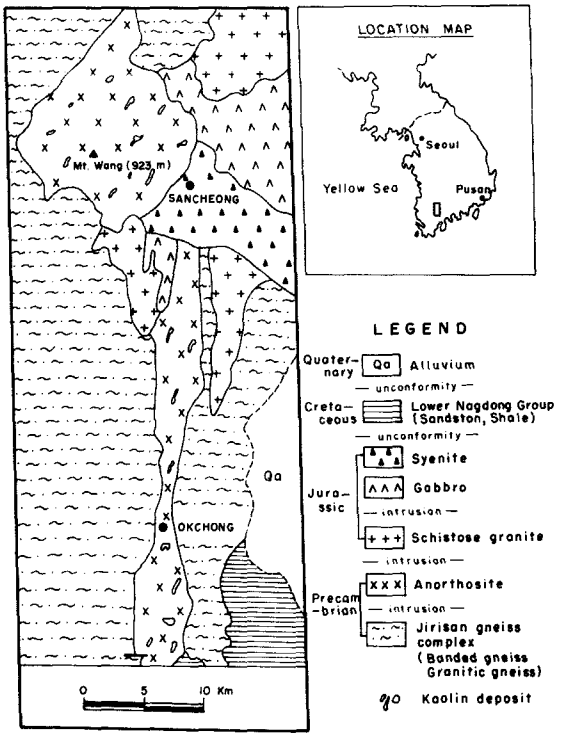

Fig. 3. Geologic map of the Sancheong-Okchong area in Kyeongsang province, showing the distribution of kaolin deposits.

The kaolin was formed by supergene weathering of Precambrian anorthosite that has undergone regional metamorphism. The anorthosite intruded the Precambrian gneiss complex and crop out as a belt, 2~12 km long in E-W direction and about 50 km long north-southward. The age of anorthosite has not been known, althouth the preliminary study on Sm-Nd isotopes gives 1678+90 Ma (Kwon and Jeong, 1990). The anorthosite consists almost of labradorite plagioclase with minor amphiboles, chlorites, biotite, epidote, muscovite, ilmenite and titanite. The anorthosite are characterized by laminations and spots of mafic minerals. The color of mafic laminations and spots vary with the mineral constituent: deep green (amphiboles and chlorite) to dark brown (biotite and chloritized biotite). Many mafic dykes (generally less than 1m in thickness) intrude anorthosites.

The kaolin deposits are developed in the anorthosite and shows a circular distributional pattern around Mt. Wang (923 m) near Sancheong area. The kaolin consists chiefly of halloysite with minor kaolinite, vermiculite, mixed-layer chlorite-vermiculite, mixed-layer biotite-vermiculite, gibbsite, smectite, goethite, Ti-oxide and Mn-oxide. Many open-pits of kaolin mine are mainly on gentle slope. Most of the deposits near Sancheong area occur between the mountainsides with slope up to 27° and the riverside with slope less than 5°(Jeong, 1992). Deep kaolinic weathering profiles are exposed in the open-pits. The weathering profiles are divided into four units; fresh rock, coherent rock, friable rock and kaolin (Jeong, 1992). The depth of the weathering profiles varies broadly from place to place, and it appears to be related with the topography of the area. The deeper part (maximum 30 m) of the kaolin profile are white, gray or pale pink in color. However, the shallower part in contact with the soil are stained with yellowish, yellowish brown, red, reddish brown, dark pink colors. These stains depend on the mineral constituent and the degree of weathering.

Pyrophyllite

The pyrophyllite is largely distributed in the Kyeongsang and Chulla provinces in the southern part of the Korean peninsula.

Fig. 4 shows distribution of pyrophyllite deposits in the Tongnai-Milyang area in the Kyeongsang province.

The pyrophyllite is mainly distributed in the area of the Yucheon Group. The Yucheon Group, 2,000 to 3,000 m thick, consists of volcanic and associated sedimentary rocks. It is characterized by the dominance of volcanic rocks in contrast to the unconfomably underlying Hayang Group that consists mostly of sedimentary rocks and comprises only a trivial amount of volcanic rocks. In Kyeongju-Yucheon area, the group is divided into the lower Chusasan Andesitic Sub

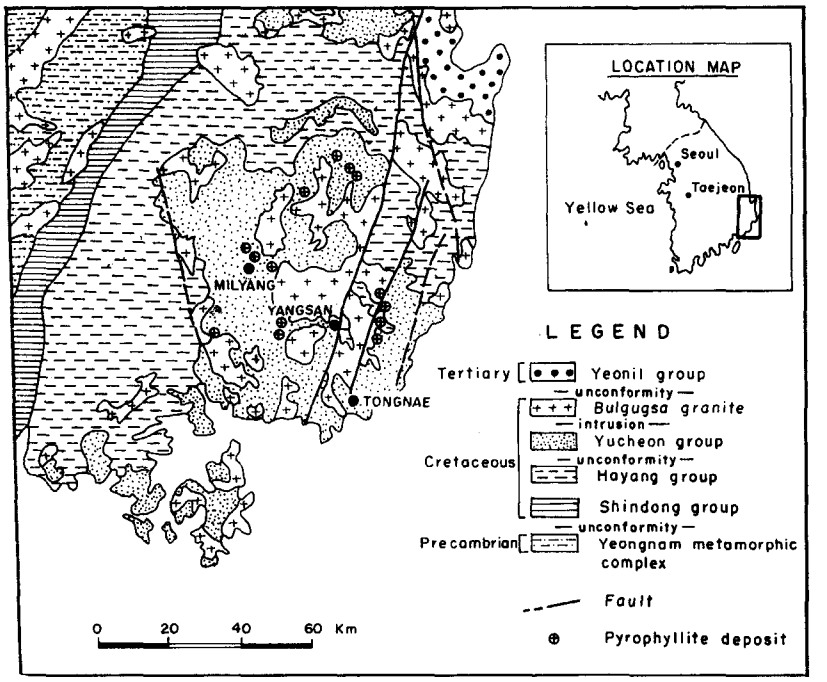

Fig. 4. Geologic map of the Tongnae-Milyang area in Kyeongsang province, showing the distribution of pyrophyllite deposits.

group and the upper Unmunsa Rhyolitic Subgroup. The Yucheon Group is intruded by the Bulguksa Granite, around 85 Ma and 70 Ma of the isotopic ages.

The pyrophyllite deposits are widely distributed in southern part from Tongnae, Yangsan and Milyang area in the Kyeonsang province. The pyropyllite deposits were formed by hydrothermal alteration of andesitic rocks, rhyolite and rhyolitic welded tuff covered in this area.

In the Milyang area, the altered rock in the rhyolitic welded tuff can be classified into pyrophyllite, pyrophyllite-kaolin, pyrophyllite-kaolin-sericite and silicified zone from the center part. The pyrophyllite ores occur as irregular massive, layer and funnel type, about 5~30 m in width, and are accompanied by thin diaspore beds outside of ore shoot. The pyrophyllite ores consist mainly of pyrophyllite, kaolinite and sericite, and a little amount of diaspore, alunite, dumortierite, corundum, toumaline, andalusite and pyrite.

In Tongnai-Yangsan area, the altered rocks in the welded rhyolitic tuff and andesitic rocks can be classified into pyrophyllite-kaolin-quartz, pyrophyllite-sericite-quartz, and kaolin-chlorite-quartz-feldspar zones by mineral assemblages. The pyrophyllite deposits are mainly distributed in sea level 30 to 200 m area, and developed irregularly along the minor fault and fissures. The ores occur as irregular massive, about 5~10 m in width, and accompanied by sericite, kaolin quartz, feldspar and a little amount of diaspore, alunite, corundum, chlorite, dumortierite, andalusite and disseminated pyrite. Generally the occurrence of the pyrophyllite in this area is similar to that of Milyang area, but the accompanied sericite is more abundant than that of Milyang area whereas kaolin is less.

Pyrophyllite and dickite deposits are widely ditributed in the Hainam-Jindo area in the Chulla province. The Hainam-Jindo area consists mainly of Precambrian metamorphic complex,

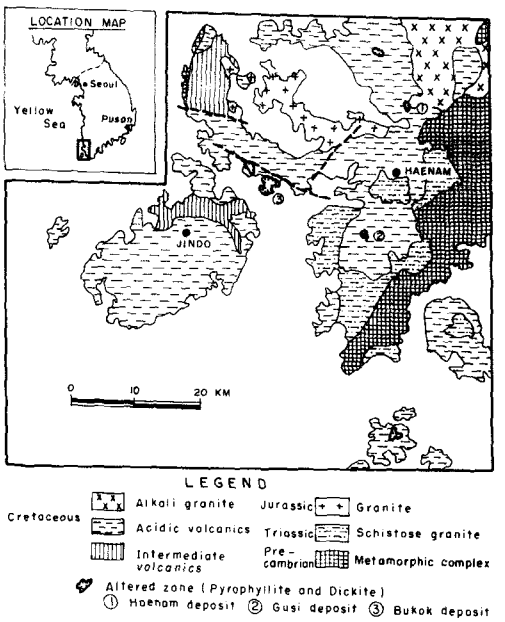

Fig. 5. Geologic map of the Haenam-Jindo area in Chulla province, showing the pyrophyllite deposits.

Triassic shistose granite, Jurassic granite, Cretaceous intermediate and acidic volcanics and Cretaceous alkali granite (Fig. 5). The Cretaceous intermediate acidic volcanics belong to the Hainam Group. Pyrophyllite and dickite deposits were formed by hydrothermal alteration of Cretaceous acidic volcanics which composed mainly of rhyolite and rhyolitic tuff.

Hainam pyrophyllite is alteration production of the rhyolitic tuff and the ore is predominantly composed of pyrophyllite and illite accompaning such clay minerals as kaolinite and smectite. Pyrophyllite ores at the center of altered mass are associated with high temperature minerals of corundom, andalusite and diaspore. On the basis of mineral assemblages, the altered rocks can be divided into three alteration zones from the center to the margin; pyrophyllite zone, kaolin zone and illite zone. The ores in the pyrophllite zone occur as irregular massive or layered, and show grey white, pale green and dark green in color.

Table 1. Industrial mineral sufficiency in 1992.

condition	industrial minerals
self-sufficiency	limestone, pyrophyllite, zeolite, silica stone, alunite (>99 %)
partial-sufficiency	feldspar (96.8 %), diatomite (93.5 %) kaolin (89.2 %), silica sand (63.9 %) marble (74.2 %), mica (57.5 %), talc (42.5 %) amorphous graphite (20.8 %), asbestos (2.4 %), kyanite (1.6 %)
whole or almost import	phosphate rock, sulfur, wollastonite, andalusite, magnesite, gypsum, barite crystalline graphite, fluorite, boron (<0.1 %)

*(%): The ratio of self-sufficiency = $\frac{\text{produciton}}{\text{pfoduction}+\text{import}}$

Source: Ministry of Energy and resources (1993)

The ores contain small amounts of quartz, diaspore, sericite and dis-seminated pyrite.

Gusi Pyrophyllite was formed by hydrothermal alteration of rhyolitic tuff. The pyrophyllite ores occur as irregular massive, layer and oval, and show fine compact pink gray and light greenish gray in color. On the basis of mineral assemblages, the altered rocks can be divided into four zones; pyrophyllite zone, dickite zone, illite-smectite zone and silicified zone. The ores in the pyrop hyllite zone consist mainly of pyrophyllite and little amounts of quartz, kaolinite, smectite, illite, alunite, andalusite and pyrite.

Bukok dickite was formed by hydrothermal alteration of rhyolite and rhyolitic tuff. The altered rocks can be divided into five zones: quartz, alunite, dickite, illite and quartz zone. The ores in the dickitd zone consist of dickite with minor kaolinite, nacrite, alunite, illitic materials and pyrite.

OVERVIEW OF MINERAL INDUSTRY

During th period of 1983~1992, the average growth rate of mining & manufacturing sector marked 11.5 % per annum and that of GNP was

Table 2. Rank of industrial minerals in 1992.

Rank Production	%	Export	%	Import	%	Consumption	%
1. limestone	77	pyrophyllite	32	phosphate rock	31	limestone	57
2. clay	5	limestone	27	clay	16	phosphate	9
3. silica stone	5	claly	21	sulfur	12	clay	8
4. silica sand	4	amorphous graphite	5	asbestos	12	silica sand	4
5. pyropyllite	3	talc	5	silica sand	6	silica stone	4
6. talc	2	feldspar	2	talc	5	sulfur	3
7. feldspar	1			gypsum	4	asbestos	3
8. serpentine	1			magnesite	3	talc	3
9.				graphite	2	pyrophyllite	1
10.				fluorite	2	gypsum	1

Source : Ministry of Energy and Resource (1993)

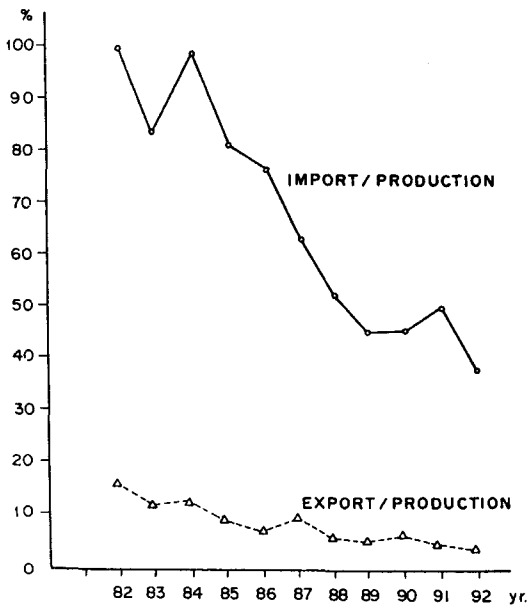

Fig. 6. The export/production and import/production trend of the industrial minerals.

14.8 %. However, the consumption of mineral commodities increased 2.7 times with an average growth rate of 12.6 % per annum. Most expansion was led by the metallic sector such as iron ore, copper concentrates, zinc ore etc. Industrial mineral (non-metallic) sector also reveals upward trend reflecting the expansion of industry. Thus, in general, the local consumption of domestic production has increased.

When coal mining is excluded, mining is led by the industrial mineral sector. Production of industrial mineral sector in 1992 is 3.7 times as great as that in 1983 and it shared more than 70 % of total mineral production in 1992. Korea, though it can supply lots of needed industrial minerals by itself, has to depend on imports of major raw materials for chemical industry due to the lack of endowment.

Among 27 industrial minerals consumed in the Republic of Korea, it produces 17 kinds, of which 5 kinds are self-sufficiency (Table 1).

The self-sufficiency ratio of 27 industrial minerals represents high value of average 72.4 %. Table 2 shows the leading industrial minerals in production, export, import and consumption. Limestone ranks the top position in production and consumption. Among the top 10 industrial mineral commodities consumed in 1992, 3 commotities such as phosphate, sulfur and magnesite are entirely imported. More than 75 % of imports are due to the lack of endowment. There is a tendency to import some high grade ores because it is more economic to import.

Korea exported 13 industrial minerals in 1992,

Table 3. Supply/demand index of industrial minerals.

year	Production	Consumption	Import	Export
1983	100	100	100	100
1984	98.7	102.4	116.7	103.1
1985	141.5	136.3	139.2	112.7
1986	149.5	139.8	139.1	105.9
1987	157.3	135.1	119.1	128.4
1988	211.5	170.4	130.3	129.4
1989	237.5	181.8	130.5	128.5
1990	245.0	191.0	137.4	144.4
1991	316.9	256.1	188.6	136.1
1992	367.4	274.1	167.2	126.0

Source : Ministry of Energy and Resource
Note : Based on actual price

the top five minerals listed above shared 89.4 %. Table 3 shows supply/dement index of industral minerals. Consumption and production have expanded 2.7 and 3.7 times respectively, and import increased 1.7 times during the last 9 years.

The export/production ratio of the industrial minerals shows a decreasing trend from 12.2 % in 1983 to 4.2 % in 1992. Also the import/production ratio shows a rapidly decreasing trend from 84 % in 1983 to 38.2 % in 1992 (Fig. 6). Although consumption of industrial mineral shows an increasing trend, the ratio of industrial minerals to total mineral consumption decreased 41.4 % in 1983 to 37.4 % in 1992 due to the relatively rapid increase of metallic sector. Therefore, the self-sufficiency ratio of total mineral sector dropped from 41.3 % in 1983 to 29.7 % in 1992 while industrial mineral sector is maintaining 72.4 %.

SUPPLY/DEMAND STATUS OF MAJOR INDUSTRIAL MINERALS

Limestone

The demand of limestone is as follows : cement industry, 83 %; steel industry, 11 %; chemical industry, 3 % and others 3 %.

The Republic of Korea has more than 42 billion tons of limestone resources and these are distributed within relatively confined area. These abundant resources strongly support its cement industry. The Production increased 32,992 thousand tons in 1983 to 65,446 thousand tons in 1992.

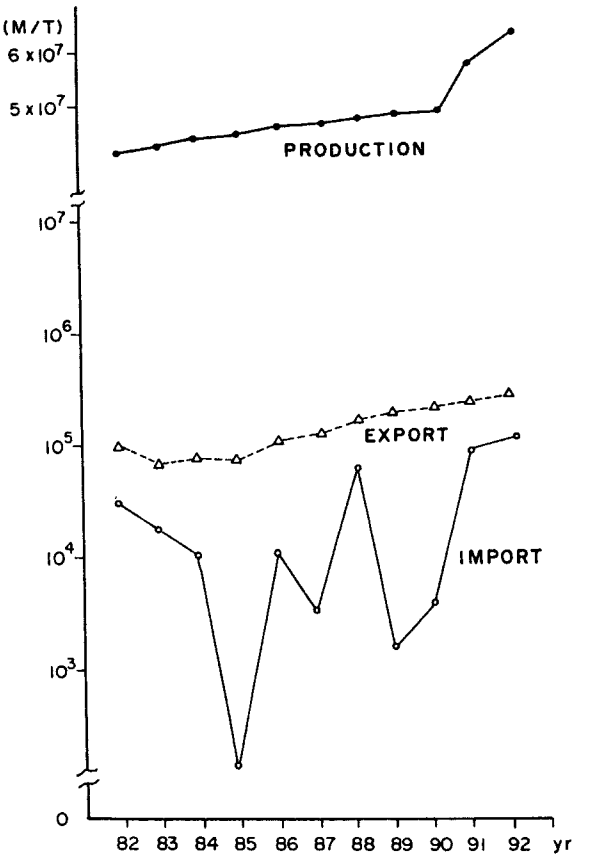

Fig. 7. Production, export and import trend of limstone in 1982~1992.

Table 4. Supply-demanded data of talc.

(unit : 10^3M/T)

Year	Demand	Production	Export	Import
1983	126.3	171.2	45.9	5.2
1984	178.6	192.2	40.7	21.0
1985	184.9	194.2	38.0	29.7
1986	210.9	210.6	42.5	41.9
1987	186.1	161.1	36.6	63.9
1988	210.2	146.5	36.1	96.3
1989	249.3	162.1	34.2	123.4
1990	238.0	181.7	33.1	121.6
1991	332.7	170.6	21.4	177.2
1992	347.1	149.9	9.0	203.0

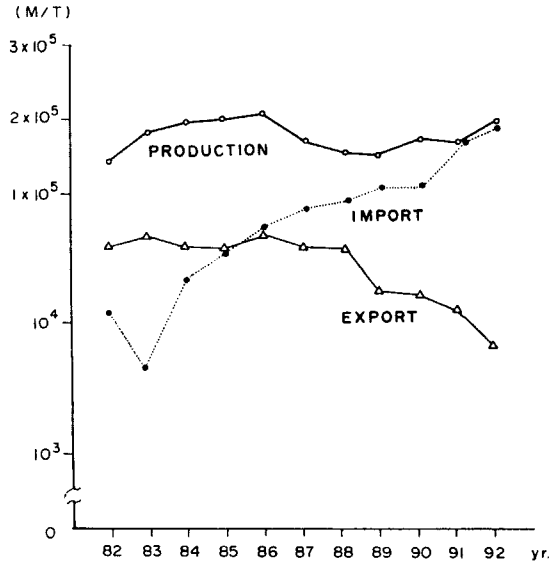

Fig. 8. Production, export and import trend of talc in 1982~1992.

Export has also increased from 60,000 tons in 1983 to 354,300 tons in 1992 (Fig. 7). Import has very fluctuated until 1988 due to the increase in construction, especially for the '86 Asian and '88 Seoul Olympic Games. However the import gradually increased since 1989.

Talc

About 70 % of talc is used as a filler in paper industry. Korea has about 37 million tons of talc ore reserves which can cover more than 100 years based on present demend. However, only 15 % of resources are suitable for the required quality of paper industry and production cost becomes higher due to the deep seated mining.

Korea could balance its demand with own production until 1986 (Talbe 4). The imports are expanded rapidly so as to match the local demand (Fig. 8)

Recently, talc is used for paper industry, paint industry and others by 70 %, 20 % and 10 % respectively and this pattern is expected to last for the present.

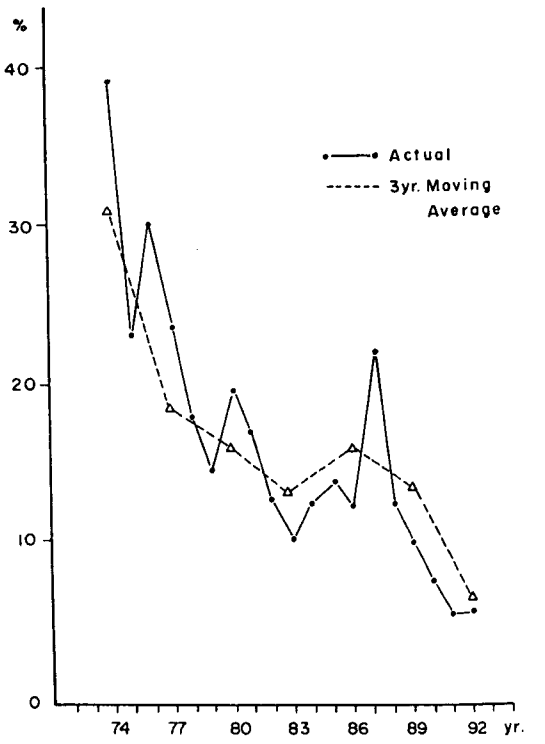

Fig. 9. Trend of export per production ratio of clay minerals.

Table 5. Supply-demand data of pyrophyllite.

(unit : 10^3M/T)

Year	Production	Export	Damand	Exp./Prod.(%)
1983	460.9	213.2	266.9	46.3
1984	656.4	252.3	363.8	38.4
1985	738.5	225.2	516.3	30.5
1986	587	203.8	303.7	34.7
1987	690.8	257.3	456.4	37.2
1988	673.8	221.9	443.3	32.9
1989	770.3	259.6	460.2	33.7
1990	657.6	256.1	426	38.9
1991	573.2	257.3	331.3	44.9
1992	602.5	216.8	373.1	36.0

Pyrophyllite

In Korea, about 73 million tons of pyrophyllite ore are reported as a resources base. Though those are plentiful to produce more than 100 years, a lot of them are not good in quality due to

Table 6. Usages structure of clay minerals.

(unit : %)

Year	Ceramics	Paper	Others
1988	82.4	10.1	5.3
1989	84	9	5.4
1990	85.9	9.5	4.6
1991	85.4	9.6	5

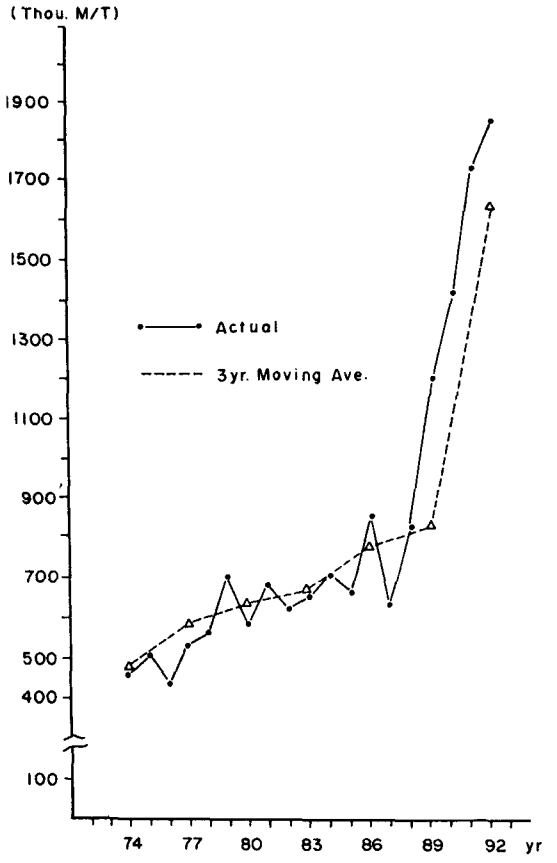

Fig. 10. Production trend of clay minerals.

the high content of iron oxide. The production of pyrophyllite was accerlerated for exports, mainly to Japan. In 1983, the ratio of export per production reached 46.3 %, but in 1992 the ratio dropped to 36 % owing to the expansion of local market (Table 5).

Pyrophyllite is used as a raw material for the refractory bricks, and ceramics like tile, sanitary ware, etc. Thus demand has changed in close

Table 7. Supply-demand data of silica stpne and silica sand.

(unit : thousand M/T)

		1986	1987	1988	1989	1990	1991	1992
Silica stone	Production	885	1235	1379	1554	1452	1627	1870
	Demand	842	1182	1398	1565	1459	1656	1788
	Export	6.7	4.9	7.9	5.5	3.0	2.3	1.4
	Import	0.8	1.1	1.9	2.5	3.6	5.3	8.5
Silica sand	Production	1233	1350	1487	1358	1408	1354	1266
	Demand	1386	1598	1906	1787	1920	2042	1958
	Export	2.0	1.8	–	–	1.4	0.4	2.2
	Import	199	261	389	467	519	648	716

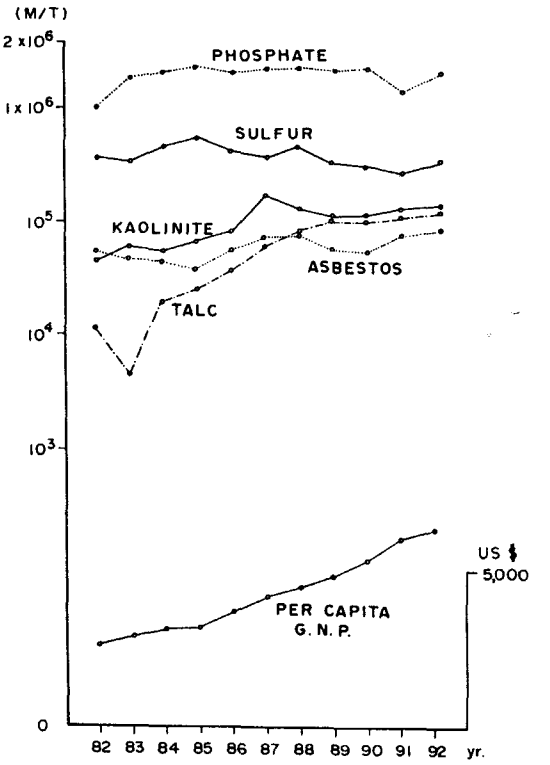

Fig. 11. Import trend of some industrial minerals in 1982~1992.

relationship with the manufacturing activities of industrial minerals.

Clay Minerals

In Korea, there are many small-scale mines producing clays. Clay minerals are composed of

Table 8. Supply-demand data of feldspar.

(unit : 10^3M/t)

Year	Demand	Production	Export	Import
1983	77	110	32	0.01
1984	101	127	22	0.04
1985	123	145	23	0.8
1986	110	131	17	0.8
1987	157	180	19	1.9
1988	214	242	24	2.8
1989	200	233	30	2.3
1990	212	237	25	8.7
1991	233	248	21	6.2
1992	278	282	24	9.4

halloysitic clay, ball clay, bentonite, fuller's earth, alluminous shale and dickitic clay. As shown in Table 2, clay minerals play an important role in industry. It ranks 3rd in consumption, 2nd in produciton, 3rd and 2nd in export and import, respectively. More than 70 % of clay production in Korea are halloysite and ball clay, which are suitable for ceramics. However, as Korea has no high quality deposits of kaolinite, it used to import lots of them for paper industry. More than 80% of clay minerals are used in ceramic industry, half of the rest are used in paper industry. About 5 % are used in rubber, plastics, civil engineering, drilling and others (Table 6).

The ratio of exports per production shows a decreasing trend since 1987. The 3-year moving average curve indicates that the ratio will approach to less than 5 % afterward(Fig. 9).

Figure 10 shows the trend of production since 1974. Although the actual data show volatile patterns until 1989, the smoothed curve since 1989 indicates the rapid upward trend.

Since kaolinite shares 88 % of imported clay minerals and the ratio shows a upward trend recently, it can also be expected that the portion of kaolinite in impoprted clay minerals will be more than now afterwards.

Silica Stone and Silica Sand

The demand for silica stone exceeds local production since 1988. Reflecting this, export of silica stone began to drop and import increased afterwards. Table 7 shows the previous demand and supply data of silica stone and silica sand.

Feldspar

Most feldspar resources in Korea are suitable for ceramic basis grade. In 1983, 28.8 % of production was exported but the ratio dropped to 8.5 % in 1992 since the local demand for ceramic industry increased steadly. The demand of feldspar was increased at 16.7 % per year from 1983 to 1992(Table 8).

Other Imported Industrial Minerals

Korea imports phosphate, sulfur, asbestos, kaolinite, talc and the others. The quantities of imported minerals in 1992 are as follows : phosphate 1,671,025 tons, sulfur 532,189 tons, asbestos 95,476tons, kaolin 224,253 tons and talc 202,962 tons. It is continuously increased since 1983, especially the talc is rapidly increased (Fig. 11).

SUMMARY

1. The kaolin deposit mainly distributed in the Kyeongsang province has been formed by weathering of Precambrian anorthosite. This anorthosite was highly kaolinized developing deep weathering profiles on the mountainsides of gentle slope.

2. The pyrophyllite concentrated in the Kyeongsang and Chulla provinces was formed by hydrothermal alteration of late Cretaceous rhyolitic tuff. The pyrophyllite body contains minor minerals of kaolin, alunite, diaspore, illite, andalusite and pyrite ect..

3. The Cambrian limestone belongs to the Great Limestone Series and is distributed widely in the Kwangwon and Chungcheong provinces. These limestone bodies show high grade of CaO content.

4. The industrial minerls play an important role in mining sector. More than 70 % of total mineral production come from industrial mineral sector.

5. The self-sufficiency ratio of 27 industrial minerals represents high value of average 72.4 %.

6. The export/production ratio of the industrial minerals shows decreasing patterns from 12.2 % in 1883 to 4.2 % in 1992. Also the import/production ratio shows rapidly decreasing patterns from 84 % in 1883. to 38.2 % in 1992.

7. The limestone ranks top position in production and consumption. Among top 10 industrial mineral commodities consumed in 1992, 3 commodities such as phosphate rock, sulfur and magnesite are fully imported.

8. The producition cost of talc becomes higher due to the deep seated mining, whereas imports are expanded rapidly so as to match the local demand.

9. The production of pyrophyllite was accelerated for exports, mainly to Japan. In 1983, the ratio of export per production reached 46.3 %, but in 1992 the ratio dropped to 36 % owing to the expansion of local market.

10. Clay minerals rank 3rd in consumption, 2nd in production, 3rd and 2nd in export and import, respectively. More than 70 % of claly production are halloysite and ball clay.

11. The quantities of imported minerals such as phosphate, sulfur, asbestos and kaolinite are continuously increased since 1983, especially talc is rapidly increased.

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