Geological Survey of Finland, Current Research 1995–1996
Edited by Sini Autio.
Geological Survey of Finland, Special Paper 23, 43–54, 1997.

MINING IN FINLAND DURING THE PERIOD 1530—1995

by
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Key words (GeoRef Thesaurus, AGI): economic geology, mining industry, mines, metal ores, industrial minerals, limestone deposits, mining, production, history, Finland

Introduction

Mineral commodities have been utilized in Finland for at least 4500 years. Asbestos from Paakkila served as a binding material for the early Neolithic Comb-Ceramic pottery found in the south of the country. Finds of these thin-sided cooking vessels show what long distances mineral commodities were transported even then (Aurola 1954a, Palomäki & Halonen 1968). Limestone has been burned to make quicklime from time immemorial. The introduction of mortar dates back to the building of medieval stone churches and castles in the 11th and 12th centuries. The oldest information on the quarrying of limestone in Finland is contained in a letter recorded in the Black Book of Turku Cathedral, dated 12 June 1329. We read there about three residents of Kemiö who donate a limestone hill called Krakanäs to the Cathedral. This hill still exists nearby the present Förby mine (Boström 1986).

Over the years, the products mined in Finland have ranged from metallic ores, industrial minerals and industrial rocks to limestone. The first metallic ore mine to have a specific name was probably Remojärvi, in the Mikkeli region in eastern Finland, where small-scale mining had been conducted around 1530 (Hultin 1897). There are records suggesting, however, that there had been an even older mine in the Åland Islands, as it was already in ruins when King Gustav Wasa of Sweden came to the throne in 1496. The first true industrial enterprise was the Ojamo iron ore mine, which went into operation in 1542 (Hultin 1897, Neovius 1911).

The first industrial mineral mine, recorded in 1737, was the Skogsböle pegmatite occurrence at Kemiö, in southwestern Finland (Linder 1737). Feldspar and quartz are still produced in the same area today. The pegmatite quarries at Somero and Tammela, where quartz was extracted as a raw material for the Åvik glass plant at Somero from 1748 to 1830, date from the same year.

Compared with present methods, mining consisted of little more than primitive quarrying in the early years. Mining was nevertheless a very important undertaking, and a decision to start operations could not be taken lightly. Finland's mining history thus starts with small pits and continues in the large underground mines of today.

Finnish mining felt the impact of the industrial revolution around 1860. Coke replaced charcoal in large-scale metallurgical processes, and steam energy became a widely used source of energy. The old-fashioned Finnish mining industry was unable to compete and almost ceased to exist (Laine 1952, Laine 1955, Saltikoff et al. 1994). Many small iron ore mines in southern Finland, for instance, were forced to close down. In the early 20th century the situation changed dramatically. The discovery of the major Outokumpu and Petsamo ore deposits heralded a new era, marked by the introduction of modern mining and dressing methods and the application of sophisticated metallurgical processes.

Reference material

The first true description of economic geology and mines in Finland is the report written by Daniel Tilas after his travels in the south of the country in 1737 and 1738 (Tilas 1738). He was sent to Finland by the King of Sweden to look into the state of mines, both active and closed ones, to undertake exploration, and to make recommendations concerning future operations. During his travels Tilas even discovered a small copper deposit at Tilasinvuori in Tammela and an iron ore occurrence at Ansomäki in Hämeenkyrö. A few years later, around 1794, the iron ore deposit of Haveri was discovered not far from Ansomäki, and some 1 700 tonnes of ore were extracted there between 1794 and 1866. From 1942 to 1960 the new Haveri was in operation as a gold-copper mine.

Tilas's report (1738) deals exclusively with metallic ore mines and occurrences. The same emphasis is apparent in descriptions of economic geology in Finland in the 19th century, those by Bremer (1824, 1825), Holmberg (1858), Furuhjelm (1884a, 1884b, 1886, 1887) and Hultin (1897), for instance. Almost every present-day reference to the economic history of mining in this country draws on these papers in some way.

As the mining superintendents with the Central Board of Industry ceased to produce annual reports after 1885 (Furuhjelm 1887), we have no complete records of mining in Finland between that date and the 1940s. The gap can partly be filled by the figures on the production of mines and mineral commodities recorded in the yearbooks of Industrial Statistics (Teollisuustilasto 1900—1996). In January 1942, the Mining Office was established at the Ministry of Trade and Industry, and in 1944 a new Mining Law entered into force (Kauppa- ja teollisuusministeriö 1950—1995). The authority of the Office extended only to those mineral mentioned in the Law. Since the revision of the mining legislation in 1965, information has been available on most mineral commodities mined in this country, in particular on industrial minerals and limestone.

Many general descriptions of Finnish mines and related subjects have been published in this century, among others, by Eskola (1919), Eskola et al. (1919), Mäkinen (1920), Laine (1952, 1955), Aurola (1954b), Isokangas (1978), Boström (1986) and Saltikoff et al. (1994). The present paper contributes to this and by summarizing the historical data given in the reports of Puustinen (1995, 1996).

Methods of estimating production

The production statistics for metals and industrial minerals given in the present paper are liable to several inaccuracies. Ore recovery, for example, could not be taken into consideration. The figures presented are thus economic geological estimates of the significance of the various mines and commodities. Wherever annual mine statistics (Teollisuustilasto 1900—1996, Kauppa- ja teollisuusministeriö 1950—1995) were available, the production of metallic mines was calculated according to the feed to the concentrator (in tonnes) and the average grade. The total amount of metal estimated is thus the sum of annual recovery. Otherwise, production was estimated from total mine output or even the size of old quarries. The production of industrial mineral mines was calculated following the same principles as in Puustinen (1996).

The size of metallic mines can be expressed by the total metal content mined, and by proportioning the amounts of different metals with given equivalent constants (Kahma et al. 1976, Lafitte 1984, Puustinen 1995). Different types of industrial mineral mines cannot, however, be compared with each other using these principles. Lafitte (1984) has calculated constants for columbotantalite, graphite, kaolin-clay, phosphates and talc, but quartz and feldspar, which are important to Finland's mining industry, are not on his list. Metallic and industrial mineral commodities and the output of individual mines can only be compared on the basis of the production value of the mineral commodity mined, which is equivalent to the gross value. This is different, however, from the commercial value used by mining economists, who express the production value as net present value or net smelter return (e.g., Goldie & Tredger 1991).

Originally for land-planning purposes, Brew et al. (1992) have used a probabilistic method of calculation that is a nonaggregated, individual mineral-resource-tract-oriented assessment. This leads to the use of gross-in-place values (GIPV) of a tract, which is defined in terms of the value of mineral commodities in the ground. It does not take into account the costs of discovering, developing, mining, beneficiating or transporting the resource. Different mineral commodities have thus an equal and consistent measure, regardless of their ore type or geographic location.

The unit prices used here to determine the value of each mineral commodity are shown in Table 2. The majority correspond to world prices in December 1995. The historical production of each mine is

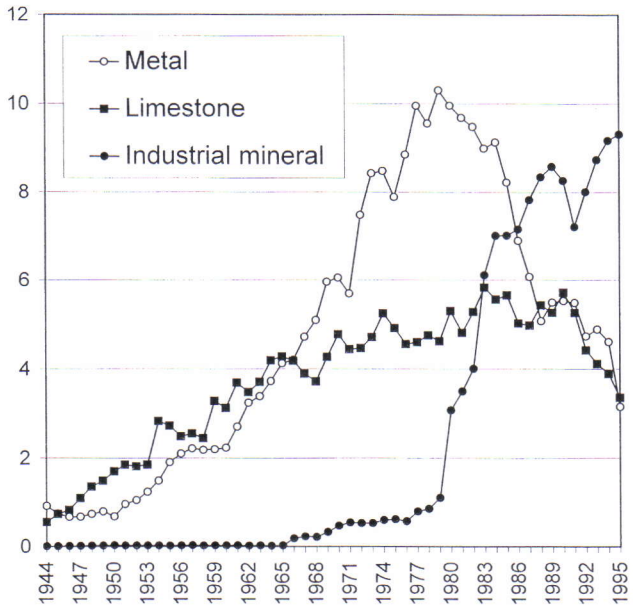

Fig. 1. Ore output (in million tonnes) from mines in Finland during 1944—1995 according to figures given by Ministry of Trade and Industry (Kauppa- ja teollisuusministeriö 1950—1995).

evaluated to correspond to its aggregate present value (in Finnish monetary units, FIM) what could have been paid for the commodities at the mine gate. This method can be applied to all types of mineral commodities, such as metals, industrial minerals, industrial rocks or limestone.

The localities of mines on the maps give here are shown uniformly with symbols, their size proportional to the calculated total value of production. The diameter of the symbols equals the cubic root of the value.

Mine and commodity production

Mining in Finland has expanded since the Second World War (Fig. 1). The production of metallic ore mines reached its peak in 1979, when ore output totalled 10.3 Mt, and thereafter declined to its present level, 3.2 Mt. At the same time the ore output of industrial mineral mines begun to rise, reaching 9.3 Mt in 1995. This is mostly due to the opening of big talc and apatite mines in the 1970s. Since 1987, output has surpassed that of metallic ore mines. Production of limestone has always been in balance with the consumption of cement by the construction industry and of agricultural lime by the farming.

Metallic ore mines

From 1530 to 1995 at least 280 metallic ore mines were in operation; some are still in operation today. Most of these mines have exploited iron ores (52.7 %) or copper ores (23.9 %). In tonnes, however, the total output of the iron ore mines has been only 21.8 % and ore output 24.9 %. This is a consequence of the modest production of the numerous pre-industrial iron ore mines.

As mentioned, the first metallic mine in Finland may have been that at Remojärvi in the Mikkeli area (Hultin 1897), which is believed to have been in operation around 1530. Information on early mines is scarce, and even the precise location of Remojärvi is uncertain. The opening of the Ojamo iron ore mine at Lohja in 1540 marked the real start of mining in Finland. The number of ore deposits discovered since then seems to have varied greatly from time to time. Not many mines were opened before 1650, but after that year, steady progress was made, excluding a possible recession during 1675—1720. From 1850 to 1940, only a few new economically viable ore deposits were discovered. The mines with the longest history of operations were those at Ojamo (323 years) and Orijärvi (197 years). The most recent ore deposit to be brought into production is that at Pahtavaara in Sodankylä, where the development of a gold mine got under way in 1995.

The location of all metallic mines in operation since 1530 is presented in Figure 2. From the distribution of the mines we see that: (1) many small pre-industrial iron and copper ore mines were located in the coastal area of southern Finland. They all belonged to the same metallogenic province with its parallel ore-bearing belts. The concentration of these old mines, such as Vihiniemi, Malmberg and Sillböle, in this area is partly a consequence of the demand for iron in populated areas, where also labour and charcoal were readily available. The copper-zinc-lead deposits in the Orijärvi field will be described later; (2) major nickel mines in the southwest (Vammala) and central parts of the country (Hitura, Kotalahti and Laukunkangas) are associated with the Svecofennian Vammala and Kotalahti nickel belts; (3) major copper-zinc-lead mines (Vihanti, Pyhäsalmi, Luikonlahti and Outokumpu) in central Finland lie in the so-called Main Sulphide Ore Belt; and (4) the Kemi chromium and Mustavaara vanadium mines are hosted by a 2.4 Ga old layered intrusion.

The ore output of all metallic mines until 1995 was 253.7 Mt (Table 1). Of this, sulphide mines accounted for 169.9 Mt (67.0 %) and oxide mines for 83.8 Mt (33.0 %). Although the true historical output of all old mines is not available, the figures

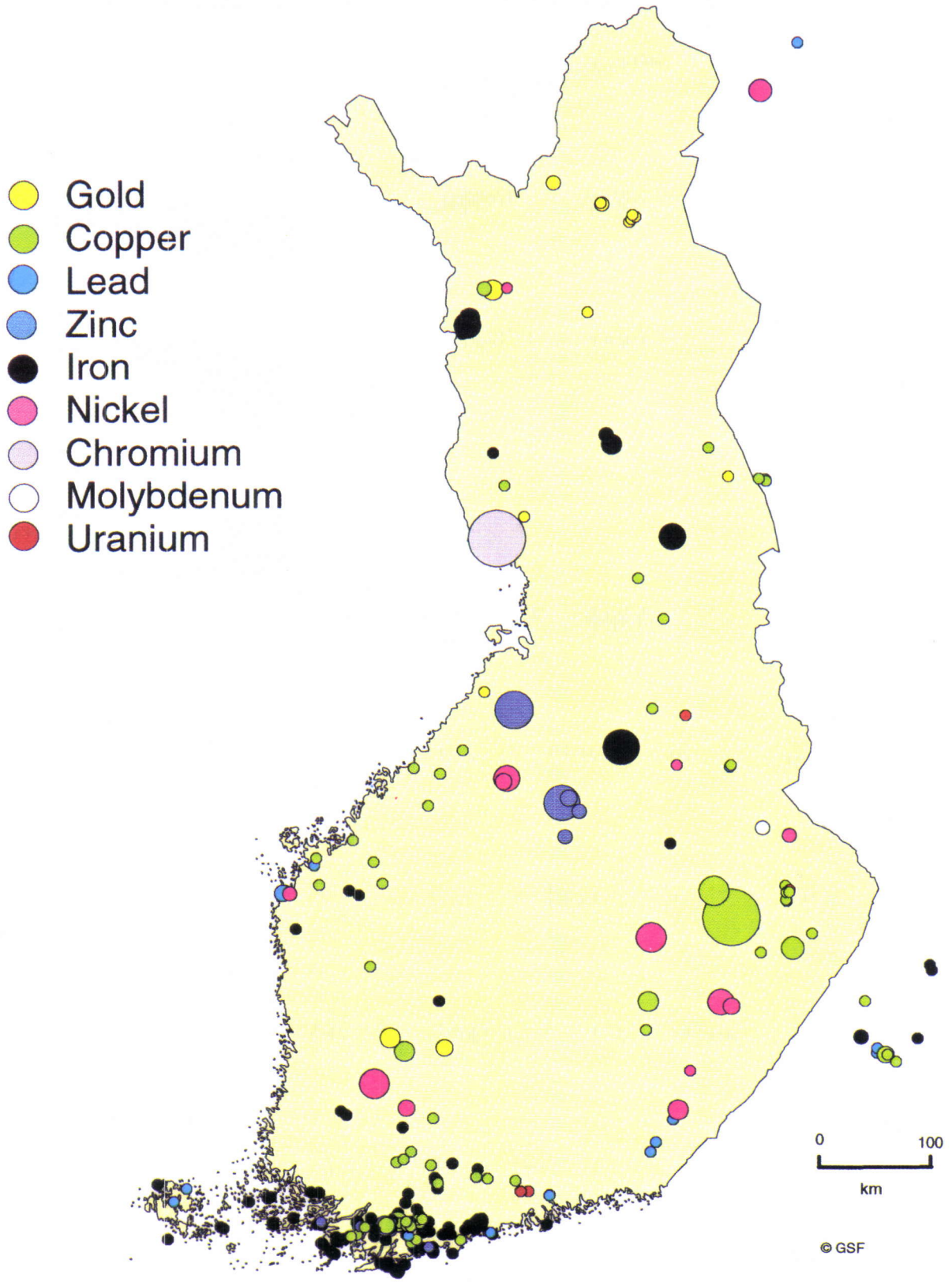

Fig. 2. Location of metallic ore mines in Finland during 1530—1995. The size of the symbols indicates the total value of metals mined. Mines in localities that are no longer part of Finland are also shown.

Table 1. Mines in Finland according to total mine output and ore output.

Main commodity	Mines number	%	Total output 1000 tonnes	%	Ore output 1000 tonnes	%
Metallic ore mines:						
Gold	14	5.0	8 003	2.0	3 912	1.5
Copper	67	23.9	82 168	20.5	66 537	26.2
Lead	20	7.1	1 014	0.3	880	0.3
Zinc	12	4.3	74 240	18.5	59 444	23.4
Iron	147	52.5	87 634	21.8	63 213	24.9
Nickel	14	5.0	55 373	13.8	37 923	14.9
Chromium	1	0.4	91 487	22.8	20 615	8.1
Molybdenum	1	0.4	1 156	0.3	1 154	0.5
Uranium	4	1.4	72	0.0	42	0.0
Total	280	100.0	401 147	100.0	253 720	100.0
Industrial minerals mines:						
Apatite	3	1.6	121 800	69.2	93 688	73.9
Talc	11	5.7	31 859	18.1	16 587	13.1
Asbestos	6	3.1	5 009	2.8	647	0.5
Graphite	23	12.0	6	0.0	3	0.0
Feldspar	60	31.3	6 465	3.7	5 536	4.4
Quartz	47	24.5	6 364	3.6	5 864	4.6
Diatomite	7	3.6	?	?	?	?
Industrial rocks	24	12.5	4 565	2.6	4 437	3.5
Other	11	5.7	8	0.0	5	0.0
Total	192	100.0	176 076	100.0	126 767	100.0
Other mines, only during 1944—1995:						
Carbonate rocks	26		214 295		197 247	
Marble	3		158		60	
Soapstone	6		3 465		762	
Total	35		217 918		198 069	
Grand total	507		795 141		578 556	

can be regarded as a good estimate. According to their ore output, the biggest individual mines have been Outokumpu (28.5 Mt of copper, zinc, cobalt and gold ore plus 3.2 Mt of tailings), Pyhäsalmi (29.4 Mt of zinc, copper, silver and gold ore), Vihanti (27.9 Mt of zinc, silver, copper and lead ore), Otanmäki (25.4 Mt of iron ore with titanium and vanadium) and Kemi (20.6 Mt of chromium ore).

Because the production of the various metals cannot be compared by tonnages, a comparison based on their gross-in-place value will be adopted. Historical production figures, unit prices and the value of metals in Finland are presented in Table 2. Until 1995, the most significant metals were chromium (FIM 37 191 million), copper (FIM 22 588 million), cobalt (FIM 22 461 million), zinc (FIM 11 481 million) and nickel (FIM 9 331 million).

Industrial mineral mines

By 1995, a total of 192 industrial mineral or industrial rock mines and quarries had operated in Finland. The oldest mine, that at Skogsböle in Kemiö, has been dated at least to 1737 and is mentioned by Linder (1737) in his treatise on the Skogsböle tin-bearing pegmatite and by Tilas (1738) in his discussion of small-scale mining of the Somero - Tammela pegmatites. The mining area at Kemiö thus has an unbroken history of almost 260 years that continues right up to the present day. Other long-lived operations were those at Hiekkamäki for quartz, from 1914 to 1988 (74 years), and at Paakkila for asbestos, from 1904 to 1975 (71 years).

Table 2. Historical production of metals and industrial minerals in Finland. Unit prices of metals in FIM/kg, industrial minerals and rocks in FIM/ tonne.

Commodity	Production 1000 tonnes	Unit price FIM/ kg-tonne	Value FIM million	%
Metals:				
Gold (kg)	50	54 860.00	2 716	2.3
Silver (kg)	835	750.00	626	0.5
Copper	1 832	12.33	22 588	19.5
Lead	145	3.12	454	0.4
Zinc	2 621	4.38	11 481	9.9
Tin	0	27.12	13	0.0
Iron	19 088	0.16	3 054	2.6
Nickel	282	33.07	9 331	8.1
Chromium	3 519	10.57	37 191	32.1
Cobalt	70	319.09	22 461	19.4
Molybdenum	2	41.10	67	0.1
Tungsten	2	26.44	53	0.0
Vanadium	164	28.96	4 754	4.1
Titanium	3 269	0.33	1 079	0.9
Uranium	0	112.71	6	0.0
Lanthanides	1	1.95	2	0.0
Sulphur	11	0.23	3	0.0
Total			115 879	100.0
Industrial minerals:				
Amblygonite	1	772	1	0.0
Apatite	7 733	210	1 624	11.0
Asbestos	416	718	299	2.0
Beryl	0	3 727	0	0.0
Graphite	1	1 127	2	0.0
Garnet	2	910	1	0.0
Calcite	1 200	100	120	0.8
Kaolin	0	417	0	0.0
Mica	26	975	26	0.2
Quartz	5 631	90	507	3.4
Kyanite	0	568	0	0.0
Feldspar	2 061	215	443	3.0
Diatomite	39	2 328	91	0.6
Talc	7 238	1 467	10 618	71.8
Tantalite	0	19 000	0	0.0
Industrial rocks	4 437	50	222	1.5
Wollastonite	457	1 834	839	5.7
Total			14 793	100.0
Other commodities, only during 1944—1995:				
Carbonate rocks	197 247	100.00	19 725	
Marble	60	4 000.00	242	
Soapstone	762	2 555.00	1 946	
Total			21 913	
Grand total			152 585	

The industrial mineral mines are here grouped according to their main commodities, which also define their genetic types. For instance, ultramafic bodies host asbestos and talc-bearing deposits, and granitic pegmatites feldspar-bearing deposits, in which quartz, beryl or tantalite occur as by-products.

Most industrial mineral mines have produced feldspar and quartz from pegmatites (31.3 %), although in ore tonnages, they make up only 4.4 % of the total number of mines (Table 1). Apatite mines account for 121.8 Mt (69.2 %) and talc mines for 31.9 Mt (18.1 %) of total mine output of 176.1 Mt. The figures express only the output at a specific type of mines.

The total mine output of industrial mineral mines, 176.1 Mt, was divided between Siilinjärvi (121.7 Mt), Ihalainen (34.1 Mt of wollastonite and limestone), Lahnaslampi (20.6 Mt), Horsmanaho (5.4 Mt), Paakkila (4.9 Mt), Kemiö (4.5 Mt mined after the year 1965) and Kinahmi (4.2 Mt) mines.

In ore output and main products, the largest individual mines were again Siilinjärvi (93.6 Mt of apatite), Ihalainen (30.3 Mt of limestone and wollastonite), Lahnaslampi (9.7 Mt of talc), Kemiö (after 1965 4.1 Mt mined of feldspar and quartz), Kinahmi (4.0 Mt of quartz) and Horsmanaho (3.4 Mt of talc).

The location of Finnish industrial mineral mines is shown in Figure 3. Geographically they are divided as follows: (1) feldspar and quartz mines in pegmatites at Kemiö, Somero - Tammela and Orivesi, and in Central Ostrobothnia; (2) small graphite mines extending as a train from Vammala via Mäntyharju to Kuopio; (3) industrial rock mines, mainly in south Finland, between Parainen and Lappeenranta, in the area with the highest demand for rock wool for the construction industry; (4) major talc mines extending from North Karelia to Kainuu, and asbestos mines around Tuusniemi and Outokumpu, immediately to the west of the talc mines; (5) the Lappeenranta limestone mine producing wollastonite, and the Siilinjärvi apatite mine in a carbonatite complex; (6) quartz mines associated with the Savo quartzites; and (7) the Perä-Pohja schist belt, which has produced quartz, mica and industrial rocks. According to this list, almost all industrial mineral mines have been located in the coastal area of the Gulf of Finland or the Gulf of Bothnia. There are practically no mines in the central part of the country or in northern Finland.

The value of the historical production of industrial minerals is presented in Table 2. In decreasing order, the most important minerals have been talc (FIM 10 618 million), apatite (FIM 1 624 million), wollastonite (FIM 839 million), quartz (FIM 507 million), feldspar (FIM 443 million), asbestos (FIM 299 million) and industrial rocks (FIM 222 million).

Limestone mines

Limestone has been mined mainly as a raw ma-

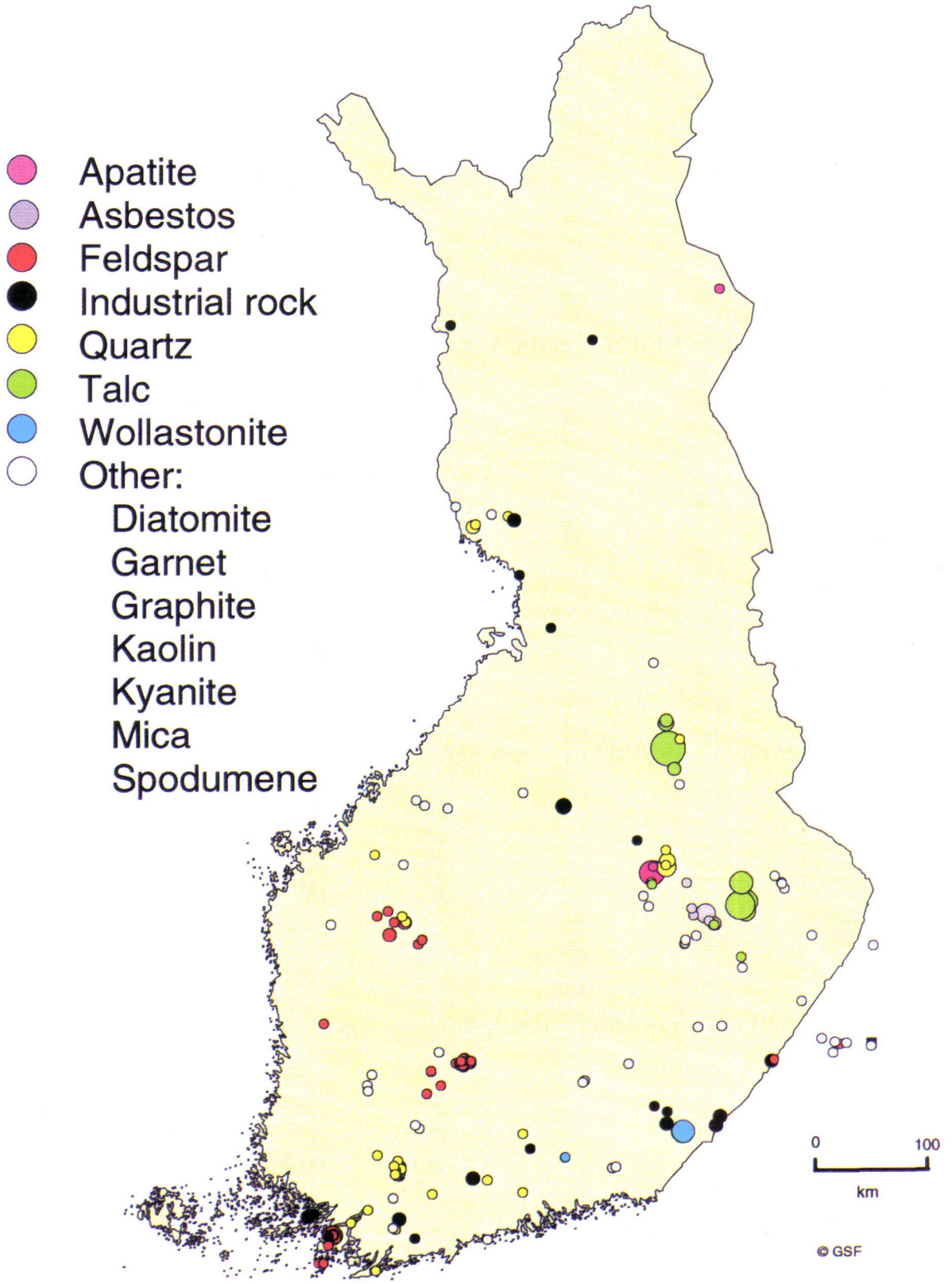

Fig. 3. Location of industrial mineral mines in Finland during 1737—1995. The size of symbols indicates the total value of minerals mined. Mines in localities that are no longer part of Finland are also shown.

terial for burning lime and making cement but also for agricultural lime. Earlier, excavation was largely on a domestic scale. Most of the companies mining limestone today have been in existence since the late 19th century. The location of the limestone mines in production since 1944 is presented in Figure 4, in which a rough distinction is made between limestone- and dolomite-producing mines. The major limestone mines are located in southern Finland, where the demand for cement is heaviest.

During 1944—1995, total mine output was 214.3 Mt and limestone output 197.2 Mt (Table 1). For comparison, total output from industrial mineral mines was 176.1 Mt and ore output 126.7 Mt. In respect of ore output, the most prominent mines were Parainen (66.4 Mt), Ihalainen (35.6 Mt), Tytyri (32.5 Mt), Ruokojärvi (10.4 Mt) and Mustio (8.4 Mt). The value of the total production of limestone is estimated to have been FIM 19 724 million (Table 2).

Case mines

The following looks at some mines as examples of the production of certain mineral commodities or because of the special position they hold in the mining history of Finland. Included are the well documented metallic ore fields of Orijärvi and Outokumpu. As Finland's first proper mine, the iron ore deposit at Ojamo is discussed in detail. Examples of industrial mineral mines include the pegmatite mines in the Somero-Tammela area and at Kaatiala. All asbestos and talc mines are genetically associated with similar ultramafic intrusions in North Karelia and Kainuu. In total mine output, the Siilinjärvi apatite mine is the biggest in operation in Finland today. Several metallic and industrial mineral mines have been in operation in localities that are no longer part of Finland, for example, the well-known copper-tin-iron ore mine at Pitkäranta and, above all, the large nickel-copper ore mine at Petsamo.

Ojamo

The Ojamo estate was first mentioned in 1384. The next time it appears it is already an iron ore mine (Bremer 1825, Holmberg 1858, Hultin 1897, Neovius 1911). Erik Fleming, the powerful Counsilor of State in Finland, obtained the area of Lohja as a fief on 15 October 1538. Soon afterwards he applied to King Gustav Wasa for "the authorization to begin mining, because he had recently discovered an iron or steel hill, for the test mining of which he had already spent money, but had not ventured to spend more before he had made a humble plea to the King to permit him to engage in mining operations for the benefit of himself and his descendants". The request was granted on 5 September 1542 that "for the good of the country, such gifts given by God could be utilized, and that Lord Erik, who was the discoverer and originator of the ore, was granted the privilege to mine and smelt rock without let or hindrance, and whatever the Lord Almighty would give him for this work, iron or steel, he could keep it for himself and his descendants, although on condition that the Crown should be given every 12th kippunta (170 kg) of pure iron, were it soft iron, cast iron or pig iron". As to the mine or coal wood, "Lord Erik had to agree with the owners of the forests, and moreover the King should be informed about how mining advanced, so that other honest people, land proprietors and townsmen or the like would also be able to take part in this Crown mining operation". Finally the King forbids his bailiffs and sheriffs or any other person to harm or hinder the aforementioned mining.

The quoted correspondence between King Gustav and Erik Fleming constitutes one of the first exploration licences and mining concessions granted in Finland. It also gives orders for the taxes, concession fees and royalties collected by the Crown. The Ojamo mine was probably closed from 1562 to 1610, because no records remain of those years. In 1615, King Gustav II Adolf ordered that the mine should be opened once more. Then in 1657, it was suddenly almost half filled with water from the adjacent lake, and a large amount of hoisted ore fell into the shaft. The miners were in imminent danger of life and could not rescue their tools. The ruined shaft was some 53 m deep and 4—5 m wide. The ore layer had been 1—1.2 m wide, and in total some 32 m of adits had been excavated.

Although Ojamo is an authentically recorded mine, statistics on it are very sparse and difficult to decipher. Unambiguous figures are not available until the period 1826—1863, when Ojamo was once again in operation and the total hoist was 1 563 tonnes of ore. The average grade is said to have been relatively high, so much so that the aim throughout all the years it was operational was to extract ore with more than 50 % Fe.

Somero and Tammela

During his travels in 1737 and 1738 Daniel Tilas discovered, among other things, the small Hopiavuori sulphide-bearing deposit in Somero (Tilas

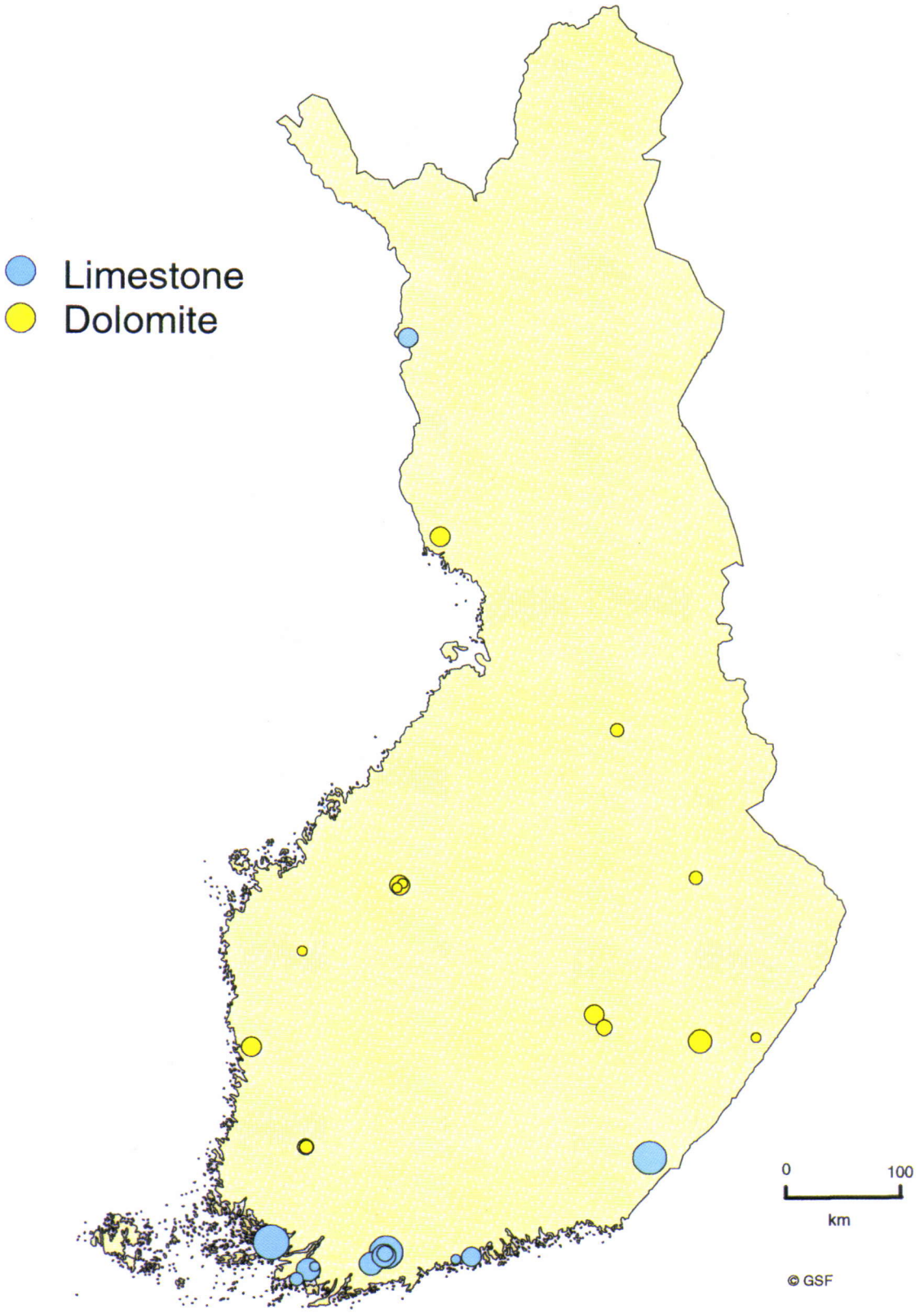

Fig. 4. Location of limestone mines operating in Finland during 1944—1995. The size of the symbols indicates the total value of limestone mined.

1738, Holmberg 1858, Virkkunen 1962). As a result of later exploration in the area several pegmatite bodies were also found in the Torro area. J.R. Pont and Jacob Bremer, two businessmen from Turku, established the Åvik glassworks, which obtained its raw material from these pegmatites. Quartz was taken from almost 30 separate places, probably still during 1824—1825. When E.J. Westling visited these places in 1839, the mines were already filled with water.

Orijärvi field

The Orijärvi copper deposit was discovered by Juhana Iisakinpoika, owner of the Orijärvi estate, in 1757 (Bremer 1824, Holmberg 1858, Hultin 1897, Trüstedt 1909, Nikander 1929, Laine 1952, Laine 1955, Turunen 1957, Warma 1975). After coming to an agreement with the discoverer, J.A. Liljeqvist, a bailiff from the Koski iron smelter, started mining the next year. With only minor interruptions, about 211 200 tonnes of copper ore were extracted, possibly at an average grade of 3.01 % Cu, between 1758 and 1882. The mine was later in operation once again between 1932 and 1955. During that time 699 400 tonnes of ore were mined at an average grade of 0.82 % Cu, 3.32 % Zn, 1.03 % Pb, 40 g/t Ag and 0.4 g/t Au. The total mine output is estimated to have been in the region of 1.3 Mt.

In the vicinity of Orijärvi, iron ore was also mined at Orijärvi and Granaattinokka (18th century), Pahalahti - Loviseberg (1826—1866), Aitsaari (1829 and 1842), and Perkiö (probably in 1842). There were copper mines at Iilijärvi (18th century, 1833 and 1852—1853) and Paavonholma (18th century and 1851—1855). The Orijärvi field is a good example of a polymetallic metallogenic district. Together with the nearby Aijala copper-zinc mine (1948—1960), the Metsämonttu zinc-lead-copper mine (1951—1974) and the Malmberg (or Leila) iron ore mine (1670—1707 and 1813—1866), it was probably the most significant and active mining district in Finland of all time.

Pitkäranta and Lupikko

There were at least 35 separate copper-tin-silver and iron ore bodies in operation from 1813 to 1904 within a small area at Impilahti on Lake Ladoga (Holmberg 1858, Trüstedt 1907, Trüstedt 1914, Palmunen 1939, Laine 1955). Total ore output was about 1.1 Mt at an estimated average grade of 1.5 % Cu, 0.1 % Sn, 40 g/t Ag and 50 % Fe. The Pitkäranta ores contained cassiterite in such abundance that tin was also recovered. The genesis of the ores has still not been established, mainly because the effect of the rapakivi granite on the ore-forming processes is not fully understood.

Paakkila

As mentioned earlier, the anthophyllite asbestos from the ultramafic intrusions at Paakkila has been known since the Stone Age (Aurola 1954a, Aurola & Vesasalo 1954, Palomäki & Halonen 1968). Interest focused on the asbestos deposit as an industrial target in the late 1890s. Samples containing this mineral were sent to Johan Fabritius, an engineering colonel in St. Petersburg, who immediately contacted the civil and military authorities in Kuopio. A company named Suomen Asbesti Oy was founded and it obtained the concession in 1900. During the period 1904—1910, the deposit was leased to a Danish company, I.L.Smith & Co., that mined asbestos-bearing rock and built the first concentrating plant. The mine was short-lived, however, as production was not profitable. Suomen Mineraali Oy began operations at Tuusniemi in summer 1918. Things got off to a good start and even during that first summer a lot of 1 307 777 kg of raw asbestos rock was sent to Helsinki and from there to Germany. The company built a new grinding plant in 1919, and continued mining until 1975, when demand for asbestos slumped. It is estimated here that some 0.65 Mt of asbestos rock was mined from at least six major sites in North Karelia, including Paakkila. The total amount of different types of asbestos products recovered may have been 416 000 tonnes.

Outokumpu field

The Outokumpu copper-zinc-cobalt deposit (Kuisma 1985, Häkli 1987) was discovered in 1908 during exploration conducted by Otto Trüstedt of the Geological Survey of Finland. From 1910 to 1989, 28.50 Mt of ore was hoisted at an average grade of 3.36 % Cu, 0.88 % Zn, 0.23 % Co and 0.8 g/t Au. Some 3.18 Mt of tailings at an average grade of 0.52 % Cu, 0.52 % Zn and 0.11 % Co was reprocessed during the period 1955—1980. The Vuonos deposit was discovered in 1965 in the eastern extension of the Outokumpu deposit. From 1967 to 1986, some 11.00 Mt of ore was extracted at an average grade of 2.14 % Cu, 1.31 % Zn and 0.14 % Co. The roughly 5 Mt of nickel ore mined at Vuonos between 1972 and 1985 assayed about 0.16 % Ni.

The Luikonlahti deposit (Eskelinen et al. 1983) is part of the same ore district as the Outokumpu -

Vuonos deposits. There 6.87 Mt of ore at an average grade of 0.94 % Cu, 0.89 % Zn and 0.11 % Co was extracted between 1958 and 1983.

Petsamo

The extensive nickel-copper deposit in the Petsamo (Pechenga) area is associated with a major ultramafic belt (Haapala et al. 1945, Autere & Liede 1989) and was discovered by the Geological Survey of Finland in 1921. The Kaulatunturi ore body was already in operation from 1936 to 1944, and some 0.46 Mt of ore was extracted at an average grade of 3.87 % Ni and 1.96 % Cu. The deposits have later been exploited by the Russians.

Kaatiala

The Kaatiala pegmatite (Holmberg 1858, Nieminen 1978) had been known long before Suomen Mineraali Oy started to quarry feldspar and quartz from it in 1942. From 1942 to 1968, 516 000 tonnes of pegmatite and 136 000 tonnes of wall rock were mined, which means a total mine output of 652 000 tonnes. Around 160 000 tonnes of potassium feldspar, 30 000 tonnes of quartz, 700 tonnes of mica, 18 tonnes of beryl, 5 tonnes of columbite and 5 tonnes of löllingite were produced.

Talc mines

The ultramafic intrusions in North Karelia and Kainuu have been known since the end of the 19th century (Aurola & Nieminen 1954, Vesasalo 1965, Boström 1986). Suomen Mineraali Oy had mined talc at Jormua from 1952 to 1971, but large-scale mining did not get under way until 1969 when Suomen Talkki Oy started its operations at Lahnaslampi. Talc from all deposits in Finland has been an important domestic raw material for filler and coating material in paper, and also as an export commodity. Talc mines have been operated by several companies, for instance, Suomen Mineraali Oy, Suomen Talkki Oy (owned by Yhtyneet Paperitehtaat Oy and Lohjan Kalkkitehdas Oy), Yhtyneet Paperitehtaat Oy, Oy Lohja Ab, Myllykoski Oy and, most recently, Finnminerals Oy. As of 1950, the total output of all 11 talc mines has been 16.6 Mt and ore output 10.6 Mt, and some 7.2 Mt of talc has been produced. Besides talc, small amounts of nickel concentrate has been recovered annually as a by-product.

Siilinjärvi

The first hint of the existence of apatite at Siilinjärvi was given by an amateur prospector in 1950 (Puustinen & Kauppinen 1989). Between 1958 and 1960, Lohjan Kalkkitehdas Oy located apatite-bearing glimmerite, silicocarbonatite and sövite, all of which appeared to be a part of a carbonatite complex, within a distance of 10 km. Exploration was continued by Typpi Oy from 1964 to 1967 and then by Apatiitti Oy until 1968. In 1966, small-scale test mining was carried out at Saarinen in the north of the complex and at the site of the present mine. The mine area is now in the possession of Kemira Oy, which after a development stage started the beneficiation of the apatite ore. Since 1975 the total output at Siilinjärvi has been 121.7 Mt and the ore output 93.6 Mt. Approximately 7.7 Mt of apatite has been produced as raw material for the nearby fertilizer plant, together with some 1.2 Mt of calcite and 25 000 tonnes of mica as by-products.

Conclusions

By 1995, the total output of Finland's 507 or so mines was 795 Mt and the ore output 579 Mt. The estimated historical value of Finnish mining products is FIM 152 587 million. Of this, metals account for FIM 115 881 million (75.9 %), limestone (including marble and soapstone) FIM 21 913 million (14.3 %) and industrial minerals FIM 14 793 million (9.8 %). The most significant commodities in decreasing order have been chromium, copper, cobalt, limestone, zinc, nickel, vanadium and iron.

All in all then, Finland's total mine output has been quite small compared with that of other countries. Nevertheless, for almost 500 years, the production of metallic concentrates, industrial minerals, industrial rocks and limestone has provided a basis for this country's mining and metal industries, and also material for export.

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