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THE ROLE OF EDUCATION IN THE DEVELOPMENT OF THE MINING SECTOR IN FINLAND

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The Role of Education in the Development of the Mining Sector in Finland

Special paper prepared for the Joint-Meeting of Finland and OECD on the Role of Education in Socio-Economic Development in Hotel Korpilampi Finland, 3-5.11.1986

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Preface

This is the second paper related to the research project "The Rise of Autonomous Technological Capability in the Mining Sector in Finland with Special Reference to the Copper Sector" under the auspices of the Research Institute of the Finnish Economy. The first paper "Kaivos- ja metallituotteiden maailmantalous" (The world economy of mining and basic metal industries) was published in the same publications series earlier this year.

The author owes special thanks to Professor Raimo Matikainen, the Department of Mining Engineering and Metallurgy at the Helsinki University Technology who has provided valuable information about the development of higher education in mining engineering and metallurgy in Finland.

Abstract

In general, insufficient attention has been paid to the role of education in the development of the mining sector in concrete cases. In this study, the role of education in the development of the mining sector in Finland is dealt with.

The Finnish case may be interesting because Finland was a small peripheral country with limited industrial traditions and the traditional mining sector suffered a serious decline at the beginning of the industrialization. The domestic mining resources have been limited and the higher education in the mining engineering and metallurgy started quite late even during the industrialization.

On the other hand, the development of the mining sector has been very successful during this century especially in the case of the copper sector. Domestic mining and basic metal industries, domestic technological capability and domestic supplier industries had been created directly from a backwoods situation. Finnish industries have adopted a kind of an intelligent followers' strategy for technological development.

Domestic higher education in geology started toward the end of the last century and became firmly established at a high level under the guidance of scholars of international reputation during this century. The higher mining engineering and metallurgical education gained a good reputation after the Last World War under a dedicated group of professors educated by practice and in foreign universities.

During the last few years, the exhaustion of the main domestic ore-bodies has provoked a crisis in the mining in Finland with the problems of re-education of miners and the oversupply of geologists and mining engineers from the universities.

1. Introduction

Generally, the studies dealing with the role of the mining sector in economic development mention education and training among basic factors to progressive development. For instance, Rex Bosson and Bension Varon write in their book The Mining Industry and the Developing Countries prepared for The World Bank:

> In their field, in the laboratory, in the administration, and in operations, mineral resource development requires highly specialized personnel. The growth of the industry calls for a continuing flow of geologists: mining, metallurgical and other engineers: and financial and other technical men keyed to the industry. Foreign experts may be hired to train local personnel teach in local universities, and undertake actual field work. Mining, metallurgical and geological education should be started in the country, preferably by a shortened university term followed by a period in the field to provide a blend if theory and practice. Scholars may be sent abroad for post-graduate and specialized studies. A technological institute may be established at far less cost than a university or college to produce in a much shorter time a large number of semiprofessionals for positions of secondary responsibility. Education in specialized fields may be provided with the assistance of multilateral and bilateral agencies (Bosson & Varon 1977 p. 156-57).

However, only a few attention has been paid to education and training in concrete studies on the role of the mining sector on economic development. For example, this dimension seems to be quite peripheral in the studies applying more or less formal linkage approach to the analysis of development problems of the mining sector as concerns the case of Chile, Malaysia or the Province of Quebec in Canada (cf Mamalakis 1971; Thoburn 1977; Paquette 1984).

The only exception where specific attention has been paid to the role of education and training seem to be the studies concerning the mining sector in the context of the research project "Historical Background of Technological Transfer, Transformation and Development in Japan" undertaken under the auspices of UN University in Tokyo (cf. Yoshiki 1979; Hoshino 1982).

Good education and training seems to be a key for a successful technology transfer and a creation of domestic resources, the development of domestic enterprise, and mining and metallurgical expertise, the creation of efficient state-owned companies, and the development of supplier industries to the mining and basic metal industries (cf table 1.)

Theoretical perspective in this study are stemming from diverse sources, such as from theories on the role of the mining sector in economic development, theoretical views on technology transfer and creation and on the role of education in socio-economic development (cf authors quoted above; Rosenberg 1969, 1972; Perrin 1983, 1984; Moisset 1986).

As far as social aspects are concerned, I shall deal with the social background of university students, language conflicts between Finnish language and Swedish language interests, problems of introduction of a Finnish terminology in geology, mining engineering and metallurgy, popular mobilization for geological exploration, decentralization effort of higher education, re-training of miners and the spread of female students to higher education in geology and mining engineering and metallurgy.

Table 1.

TECHNOLOGY TRANSFER AND CREATION

Passive

Active

Means of Acquisition of Foreign Technology

1) Receiving foreign direct investment;

2) Importing foreign machinery and equipment;

3) Acquiring turn key plants;

4) Importing of foreign knowhow: labour force, experts, consulting services;

5) Acquiring foreign patents and licences;

6) Acquiring technical aid from international organizations;

7) Establishing joint-ventures with foreign companies;

8) "Industrial espionage": utilization of foreign publications, education in foreign schools and universities; practice and work abroad;

Means of Creation of Domestic Technological Capability

1) Imitating foreign technology;

2) Learning by doing;

3) Adapting foreign technology to domestic circumstances;

4) Improving foreign technology;

5) Making original inventions and innovations;

Key for Success

1) Good education of workers;

2) Good education of engineers;

3) Development of domestic design capability;

4) Development of domestic R&D capability

In the study, I shall mainly deal with higher education, high school education and professional education in mining and metallurgy. Some attention is also paid to the development of higher commercial and engineering education in general. As it is difficult to distinguish between higher education and research, the development of associated research will be taken into consideration as well.

Because studies about practical learning and knowhow of workers and engineers are inexistent, this crucial aspect cannot be dealt with in the study. Such indicators as efficient energy use, and high labour productivity would offer, of course, some ideas about the state of these hidden dimensions.

In the following, the development of domestic education in geology and mining and metallurgical engineering in Finland is dealt with in the context of the development of the mining sector, and with special reference to its role in the development processes. Finally, the results of this study are confronted, among others, with ideas stemming from the studies on the Japanese example.

2. The Development Based on Transfer on Foreign Technology

2.1. Before 1917

Before industrialization, Finland never had great traditions in mining industry. Because of plentiful forest resources in the country, the Swedish Crown established small-scale iron works in southwestern Finland during the Swedish rule but iron ore was imported from Sweden. After Finland became an autonomous Grand Duchy of the Russian Empire at the beginning of the last century, the Finnish Government and public administration made special efforts to promote mining in order to diminish the traditional dependencies from Sweden. In spite of Government's efforts, no significant iron ore or non-ferrous metal ore bodies were found. The building of the domestic iron industry was mainly based on the exploitation of bog iron ore in eastern Finland. Technological dependency vis-à-vis Sweden was continuosly strong (cf Laine 1948-50).

Toward the end of the last century and at the beginning of this century, the decline of mining was striking in Finland. The traditional iron industry was not able to compete with new large-scale iron and steel industries created in the industrial core ares in the West and in the East. The largest Finnish companies adopted Siemens-Martin technics and shifted to the use of imported raw material and scrap. The exploitation of domestic bog iron ore practically disappeared. Due to the existence of iron works in the country since the centuries, a certain nucleus of domestic capabilities had, in any case, developed in this industry, such as experienced labour force, and a certain engineering and managerial knowhow. The new iron and steel techniques were, of course, imported (cf Herranen 1986).

Table 2.Sources of Technology Transfer to the Mining Sector in Finland

SWEDEN

- mining and metallurgical technology before the industrialization
- exploration technology since the end of the last century
- mining technology since the beginning of the industrialization
- professional workers in mining
- expertise in mining
- education of mining engineers in Stockholm
- iron and steel industry technology since the beginning of industrialization
- engineering expertise in iron and steel industry

GERMANY

- mining technology since the beginning of industrialization
- expertise in mining
- ore processing technology in non-ferrous metal industry
- engineering expertise in non-ferrous metal industry
- iron and steel industry technology

ENGLAND

- mining technology since the beginning of industrialization
- iron and steel industry technology

NORWAY

- mining and metallurgical expertise at the beginning of this century
- electrical process metallurgy during the interwar period

U.S.A.

- mining technology from the beginning of this century
- ore processing technology in non-ferrous metal industry
- process metallurgy in non-ferrous metal industry

CANADA

- process metallurgy in non-ferrous metal industry since the 1930s

SOVIET UNION

- iron and steel industry technology since the 1960s

An effort was made to revitalize the ailing mining industry through direct foreign investment and transfer of new technology, such as electrification, adoption of rail transport and new exploration and drilling methods, and introduction of new concentration methods, e.g. magnetic separation and flotation, but this effort was not successfull. Technology and expertise arrived from Sweden, Denmark, Germany, England and U.S.A. The only positive development took place in the limestone industry based on domestic enterprise (cf appendix 1.).

Taking into consideration the pessimistic mood of the time, the discovery of a large copper deposit in Outokumpu in northern Karelia in 1910 was a kind of a sensation. Because the owner of the ground, the big merchant and sawmill industry company Hackman Ltd, was willing to participate to the exploitation, the Industrial Board and the company established a joint venture to start mining development. The opening of the mine heavily leant on Swedish and Norwegian expertise. Because of the selection of new electrical smelting method still on experimental stage, the operations in Outokumpu met with many difficulties (cf appendix 3).

Turning to the development of education, the rise of the Finnish nationalist movement during the second half of the last century had a considerable impact on this process. Traditionally, Finland had been dominated by a Swedish language administrative and economic elite. Instead, the peasantry kept on speaking the native Finnish tongue. The peasantry and the Lutherian elergy were together the backbone of the Finnish nationalist movement aiming at making the Finnish language into a national language and at the creation of a Finnish speaking

administrative and intellectual elite. The movement was headed by university professors and education was considered to be the key factor in the emancipation process.

As a consequence of a continuous increase in the strength of the Finnish nationalist movement, the percentage of the university students per population became one of the highest in Europe at the beginning of this century. Except the rising middle class, the independent peasantry contributed to the expansion of the student population in Finland. As the dominant language in teaching continued to be Swedish, protestations against this state of affairs became louder, by and by (cf Elovainio 1971).

As far as technical and commercial education is concerned, its foundations were laid during the second half of the last century. Technical education on the university level started in 1908 and the commercial one in 1911. No specific education in mining and metallurgy was given in Finland at that time, except a short interlude in the Kuopio Technical School which was located in the centre of the iron industry using bog iron ore. This education eclipsed with the collapse of domestic bog iron ore exploitation (cf table 3.).

Young Finnish engineers who aimed at acquiring education in mining and metallurgy went to foreign universities, especially to Sweden and Germany to complement their studies. In addition, the most actives among them went also to work abroad, e.g. to Sweden, Russia, Germany and U.S.A. to gain practice in modern mining, basic metal and engineering industries (cf appendix 2.).

As compared with the other countries located in the Northern Coniferous Forest Zone, Finland formed a real vacuum as concerns the mining industry and the education in mining engineering at the beginning of this century. Sweden had long traditions in these fields, and active developments had started in Norway and Russia in eigthteenth century. Education in mining engineering started in such a "new country" endowed with ample natural resources as Canada on the university level in 1893 (cf Falck-Muus 1932; Warrington-Nicholls 1949; Vucinich 1970; Eriksson 1978).

2.2. After the Independence, 1917-1937[1)]

After the outbreak of the Russian Revolution, the Finnish Government declared Finland independent in 1917. The new Republic adopted economic nationalism vis-à-vis the exploitation of principal natural resources of the country. Among others, state-owned companies were created in resource sectors. Because of the importance of the Outokumpu deposit to the national economy, the state took control of the mine and a state-owned company Outokumpu Oy was established to exploit the deposit out of the national interest in 1924.

As the position of political forces supporting Finnish nationalist ideas was strong in the new Republic, special attention was paid to the promotion of Finnish language teaching. Finnish language interests gained control of the University of Helsinki and the Helsinki

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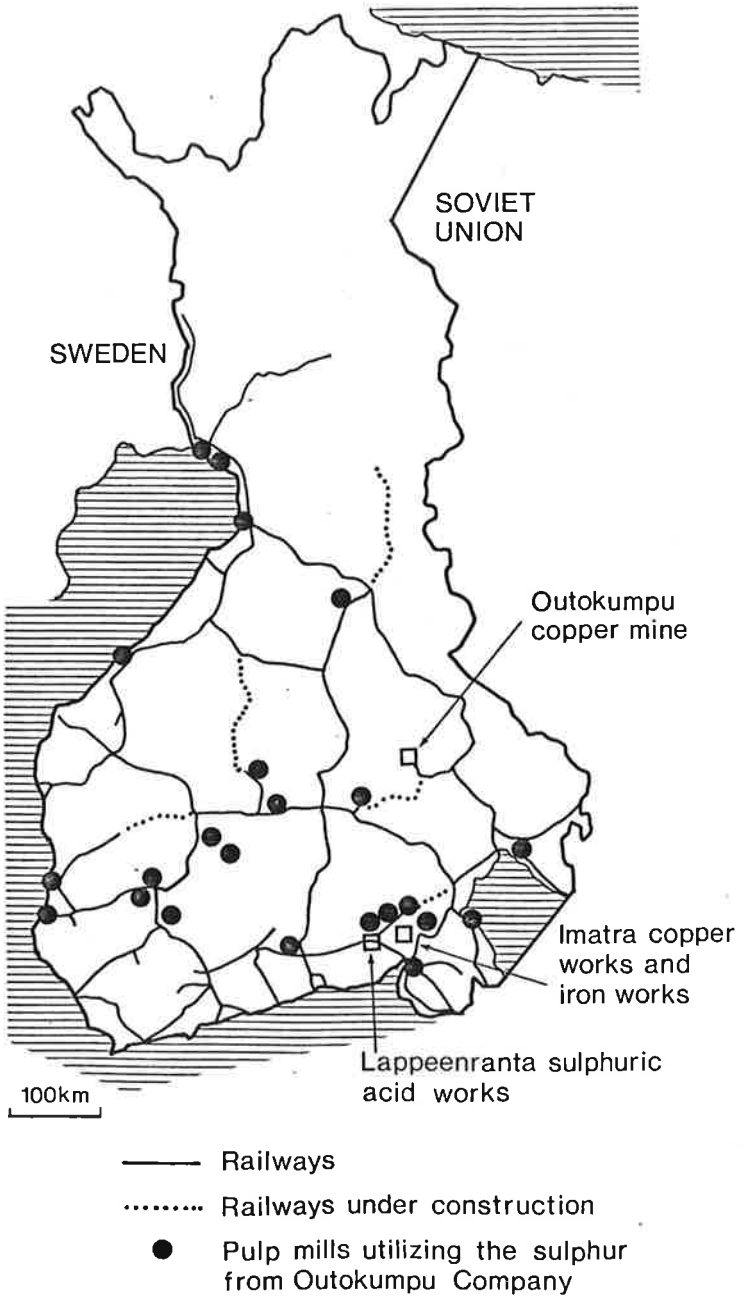
1) The interpretation presented here heavily leans on Raumolin 1984.

Figure 1.

The Outokumpu Copper Mine and Related Production in Finland in 1938.



Source: J. Raumolin: The Impact of Forest Sector on Economic Development in Finland and Eastern Canada: in J. Raumolin (ed.): Natural Resources Explanation and Problems of Staples - Based Industrialization in Finland and Canada. Fennia 163:2, 1985, p. 417.

University of Technology, by and by. In addition, a new Finnish language university was established in Turku. The Swedish language interests responded to this challenge by creating parallel institutions of higher education with special reference to reproduction needs of the traditional economic elite (cf. table 3.).

As the expansion of higher education took place in the context of a favourable economic development based on the exports of forest products and the growth of home market production, the democratisation of education continued. The social background of the students extended to workers and the share of female students became the highest in Europe (cf Elovainio op. cit.).

Starting in the 1920s, the development of the Outokumpu Mine was rapid. A large copper smelter using electrical methods was established in southeastern Finland in the early 1930s. Most of the copper concentrate and blister copper produced by Outokumpu Oy was exported to Germany. Except copper, raw materials for chemical industry, pulp industry and iron and steel industry was extracted from the Outokumpu ore (cf figure 1.).

Except the Outokumpu Mine, no major metal mining development took place in Finland in 1917-1937. A large nickel deposit was discovered in northern Finland in the 1920s but, due to depressed market conditions and the quasi-monopoly position enjoyed by International Nickel Company, a concession was given to its British subsidiary Mond Nickel Ltd to start the exploitation in 1934. Instead, domestic extraction of limestone strongly expanded. Typical of the domestic iron and steel industry was horizontal and vertical integration to large concerns (cf appendix 3).

Table 3. Parallel Swedish-Language and Finnish-Language Higher Education Institutions in Finland, 1890-1939 With Special Reference to the Mining Sector

Swedish-language	Finnish-language
Geology	
University of Helsinki Department of Geology 1877-1928	University of Helsinki Department of Geology 1924-
Åbo Akademi in Turku Department of Geology 1918-	
Engineering	
Polytechnical Institute in Helsinki 1879-1908	
New Swedish Technical High School in Helsinki 1916-	Helsinki University of Technology 1908-
Faculty of Chemistry and Technology in Åbo Akademi in Turku 1920-	Technical High School in Tampere 1911-
Business	
Swedish Business High School in Helsinki 1909-	Helsinki School of Economics and Business Administration in 1911-
Swedish School of Economics and Business Administration in Helsinki in 1927-	
School of Economics and Business Administration associated to Åbo Akademi in Turku 1927-	
Societies	
Society for Advancement of Sciences in Finland 1828-	Finnish Association of Engineers 1896-
Association of Engineers in Finland 1886-	Finnish Academy of Sciences 1908-
Association of Chemists in Finland 1891-	Finnish Association of Chemists 1924-
Swedish Technical-Scientific Academy in Finland 1921-	Association of Geology Students in University of Helsinki Vasara 1937-

The development of mining and basic metal industry in Finland was continuously characterized by imports of foreign technology, stemming mainly from Sweden, Germany, Norway and U.S.A. A nucleus of the domestic production of machinery and equipment started anyway to develop in the context of the imports substituting industrialization in the country. A pool of domestic engineers and managers was also available so as to assume the main leading technical and managerial position in enterprises. Since most of the private enterprises were controlled by the Swedish language economic elite, the state-owned companies were almost the only chance to young Finnish speaking engineers to enter leading technical functions in the industry (cf table 2.; appendix 2.).

No special education in mining and metallurgical engineering was, however, available in Finland. Young engineers had still to go abroad to acquire the special education in the field. The Royal University of Technology in Stockholm continuously played an important role in this respect. The possibilities of gaining practical experience abroad somewhat diminished after the closure of the Russian border and the adoption of strict immigration laws in U.S.A. and Canada (cf Helenius 1930).

The managing director of Outokumpu Oy, Eero Mäkinen adopted a consistent strategy as regards the building of processing chain around the Outokumpu Mine. He sent young engineers abroad to continue their studies in view of future tasks in the company. So the need fo foreign experts was kept in minimum although there was no experience of building of a large-scale copper industry in the country.

In general, the expansion of copper mining and limestone mining together with that of basic metal industries created new job opportunities in Finland so that the need of acquiring foreign practical experience somewhat diminished.

A small nucleus of education of mining engineering developed at the Helsinki University of Technology in the early 1930s. Lectures in this topic were given in the Department of Chemistry. Eero Mäkinen accomplished a pioneer task by publishing a handbook in mining technology and metallurgy in Finnish in 1933. As most of technology was foreign and education still took place abroad, the creation of a Finnish vocabulary in mining technology and metallurgy was a great challenge (cf Mäkinen 1933).

After the erection of the large-scale copper smelter based on new process technology by Outokumpu Oy in Imatra was proven a success, the direction and the engineers of the company could be content with. The company was pioneering as a state-owned copper industry company outside the Soviet Union. The copper industry was the first large-scale industry among the basic metal and engineering industries in Finland that was led by Finnish speaking managers and engineers.

Before the establishment of Outokumpu Oy, it was said that it was impossible build a large-scale copper industry in a small peripheral country with limited industrial experience and lacking traditions of national independence. In addition, unexperienced Finnish nationalist engineers would not be able to create an efficient state-owned company.

Mäkinen himself was originally university teacher, doctor in geology and researcher in the Geological Survey in Finland before acquiring education in mining engineering in Stockholm. He was learning mining practice by doing as other engineers in the company. This "learning by doing" aspect was important also for workers in the Outokumpu mine and in other works of the company because specialized professional schooling was still lacking in Finland.

3. The Rise of Domestic Education in Geology, 1890-1930[2)]

An important factor contributing to the rise of self-confidence and initiative especially among Finnish nationalist "mining entrepreneurs" was the ascendancy of domestic geology toward the end of the last century and at the beginning of this century.

Along with the reorganization of the public administration in Finland, the former Mining Board was incorporated to the Industrial Board which became the chief agency of mineral propecting, mining and basic metal in 1884. The Geological Survey of Finland started its activities under the auspices of this Board in 1885. The principal task of the Survey was to undertake geological mapping of the country. In this context, the Geological Society of Finland was founded in 1886.

The first chair in mineralogy and geology was set up at the University of Helsinki in 1852. Since there were no qualified scholars in the field in Finland the chair rested vacant up to 1877. The first professor F.J. Wiik was not open to new dynamic ideas and was mainly interested in mineralogy. In the stratigraphical classification of the Finnish bedrock, he borrowed foreign ideas such as Canadian terminology.

It was only in 1890 when a new generation of geologists which had adopted uniformitarian ideas, started an active and creative period in

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2) As regards general surveys on history of geology during the period in question cf. Eskola 1959; Hausen 1968. The interpretation presented here heavily leans on Raumolin 1984.

the Finnish geology. Except in Helsinki, these scholars had studied abroad among the prominent scientists in Sweden and Germany.

Wilhelm Ramsay who became professor after Wiik in 1899 was a creative and dynamic scholar. He took part in many expeditions to Kola Peninsula and paid special attention to petrology and Quaternary geology. He introduced the term Fennoscandia as a regional concept which became soon accepted also among the geological profession abroad. Fennoscandia contains a geological entity of norther Europe dominated by a very ancient bedrock.

Ramsay was able to attract talented students to geology. He published a large textbook in geology in Swedish in 1909 which, among others, included the first comprehensive description of the geology of Fennoscandia. This textbook became largely used in Nordic universities.

J.J. Sederholm who was appointed to the head of the Geological Survey in 1893 became, for his part, heavily involved in the studies on Precambrian bedrocks. He was able to develop original classifications of the Finnish bedrock. The work of the Survey gained a clear scientific emphasis and Sederholm established special scientific publication series in connection.

Sederholm actively participated into international geological congresses and travelled largely abroad, especially in North America. He became a well known scholar in the studies on the problems of Precambrian stratigraphy and correlation and of origin of granites and gneisses. He paid special attention to the comparison of the geology of Fennoscandia with that of the Canadian Shield in his effort to

correlate and unify knowledge about geological histories of different Precambrian regions of the world.

Thanks to Ramsay's and Sederholm's work, geology in Finland shifted form the very periphery close to the centre in the international research in a couple of decades. These scholars undertook studies on typical Finnish geological formations by new appropriate conceptual tools, created new ideas and were able to extend their studies abroad as well. As almost all ideas and theories had traditionally stemmed from abroad, a certain reversion of centre-periphery relations in the scientific world took place in Finland. This state of affairs, of course, provoked new self-confidence among the rising profession of geologists in the country.

Did these scientific accomplishments have any impact on mineral prospecting in Finland? The new ideas about classification of course contributed to the advance of geological mapping. The discovery of the Outokumpu ore was based on the use of scientific methods of exploration. No other significant deposit was, however, discovered at the beginning of this century.

The leading geologists, especially Sederholm, participated to the undertakings in mineral industry but their success was ephemeral. Sederholm was active in social and economic discussion as well: he even wrote the first book on Taylorism in the Nordic countries and participated to the organizations of the Swedish language business elite promoting ideas of economic liberalism (cf Sederholm 1915).

The advance of Finnish-language geologists at the University of Helsinki started in the 1910s. Eero Mäkinen presented a doctoral dissertation as the first Finnish-language scholar in 1913 and Pentti Eskola followed the example in 1914. Eskola established his position as the leading petrologist in the country by presenting a new facies theory in the study on metamorphic rocks in 1915.

Eskola wrote the first textbook in geology in Finnish and started to lecture in Finnish at the University. Aarne Laitakari who was made responsible of reorganization of the mineralogical collections of the Department of Geology and Mineralogy relabeled them in Finnish. Eskola had studied mining engineering in Germany and Mäkinen left for Stockholm to attend courses in mining engineering in 1916. Mäkinen, Eskola and Laitakari were Finnish-language nationalists who aimed at creating a geology in Finnish, developing practical geology and using domestic natural resources to promote economic advance of the nation.

The optimism raised by the discovery of the Outokumpu ore and the achievement of national independence increased resources allocated to geological education, research and prospecting in Finland. A well-known mineralogist L.H. Borgström became extraordinary professor at the University of Helsinki. A new chair was established for Pentti Eskola in the Department of Geology. Aarne Laitakori occupied the permanent lectureship in geology established at the Helsinki University of Technology. The Swedish-language university Åbo Akademi in Turku created a chair of geology as well (cf appendix 4).

In the late 1920s, Wilhelm Ramsay's advanced pupils started to colonize new chairs in geography established at the University of

Helsinki. The dominance of geomorphological school of thought in the Finnish academic geography made this shift quite easy to geologists specialized in Quaternary studies. Among three chairs of the Department of Geography, two were occupied by geologists at the beginning of 1930s. So the real number of "professors of geology" had raised from one to seven in the course of thirteen years.

The Geological Survey of Finland increased its staff as well in the 1920s. Finnish geologists undertook experitions to Canada and Argentina to find out comparative materials for their studies on Quaternary developments. The period seemed to be that of a great expansion of the Finnish geological research.

Turning to language issue, the teaching of geology at the University of Helsinki became predominantly Finnish when a Finnish-speaking scholar gained the chair of Ramsay after the latter's death in 1928. Both of full professors in the Department of Geology were now Finnish nationalists aiming at the creation of the geology of Finland in Finnish. Geology teaching in Swedish took place in Åbo Akademi. J.J. Sederholm, for his part, was an ardent defensor of the Swedish language and his aristocratic attitude had a definite impact on the work of the Geological Survey.

The attitudes of geologists vis-à-vis the development of mining enterprise had much to with the language issue and interests. Swedish speaking geologists defended the virtues of private enterprise whereas Finnish speaking geologists identified themselves with Outokumpu Oy. Pentti Eskola became, for instance, a member of the board of this

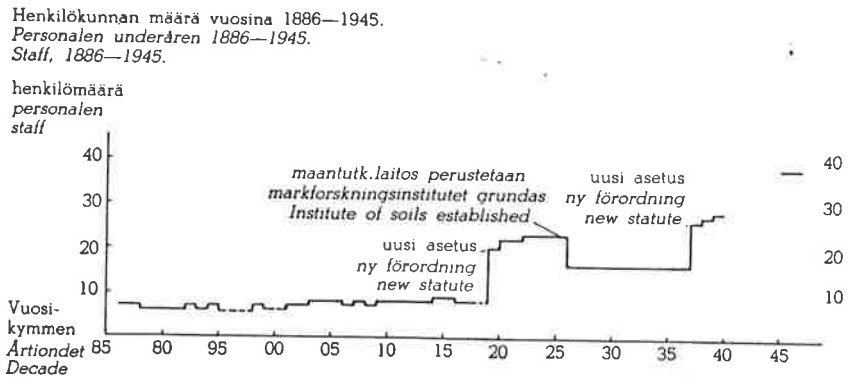
state-owned company and closely collaborated with Eero Mäkinen. He was also lecturing at Workers' Academy established by Social Democratic intellectuals.

The success of Outokumpu Oy, the discovery of nickel in Petsamo and the needs of the industrializing national economy contributed to an upsurge of prospecting effort in the middle of 1930s. The Government created a new state-owned prospecting company, Suomen Malmi Oy in 1935. Private limestone and iron and steel companies increased their prospecting effort as well and new companies were created for this purpose. It was maybe no accident that the first chair of economic geography established in Finland at the Swedish School of Economics and Business Administration in Helsinki was occupied by a geologist in 1937.

After J.J. Sederholm retired in 1933, the question of reorganization of the work of the Geological Survey became actual. Aarne Laitakari was appointed to the new Director of the Survey in 1935. He started to engage Finnish speaking staff and to direct the work of the Survey to serve the practical needs of mineral and ore prospecting. A popular mobilization of the Finnish peasantry for the search of useful metals and minerals was initiated and Finnish-speaking students from University of Helsinki were engaged to extension work, among others. Special training courses were organized for the students engaged to field work.

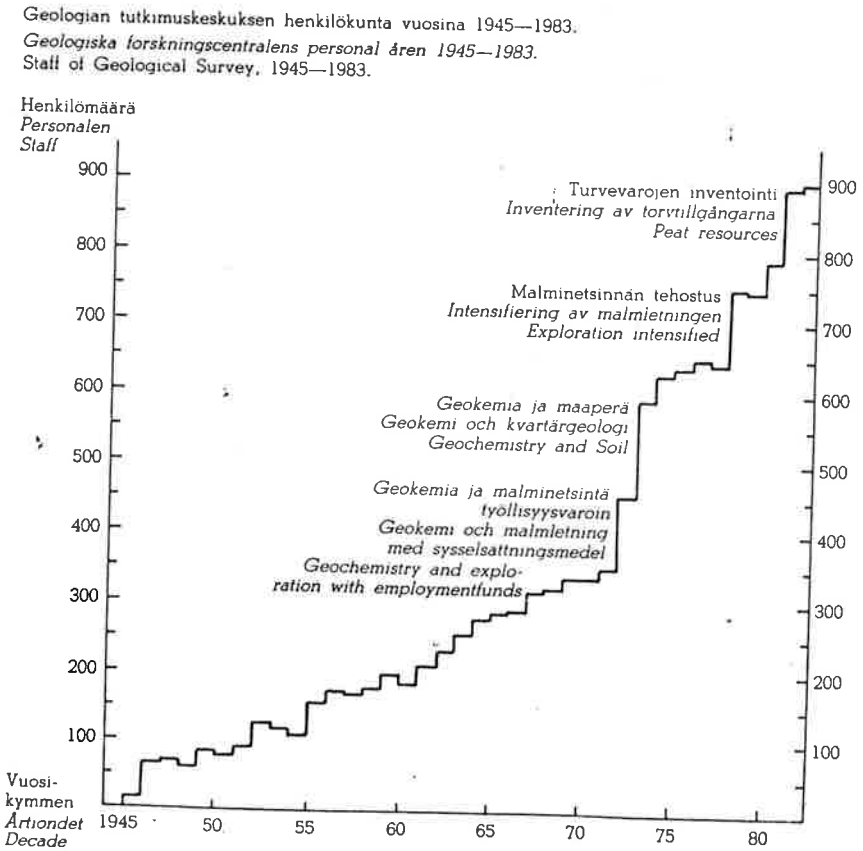
Pentti Eskola presented a new classification of mineral associations and ore types in Finland in view of future prospecting work. His theory of ore types was based on an idea very similar to A.K. Cajander's theory of forest types which formed the basis for

Figure 2. Staff of Geological Survey, 1886-1945.



Source: K. Virkkala: Geologisen Tutkimuskeskuksen 100-vuotishistoriikki (The history of the Finnish Geological Survey 1886-1986). Helsinki 1986, p. 47.

Figure 3. Staff of Geological Survey, 1945-1983



Source: K. Virkkala: Geologisen Tutkimuskeskuksen 100-vuotishistoriikki (The history of the Finnish Geological Survey 1886-1986). Helsinki 1986, p. 47.

practical forestry in Finland. The expansion of prospecting led to growth of number of students in the Department of Geology at University of Helsinki and the students established a special student association in 1937. Eskola engaged a female assistent to the Department at the same time.

The basic structures of labour market of geologists in Finland formed during the 1930s. There were some Academic jobs and some jobs in enterprises whereas the Geological Survey and prospecting organizations were becoming great employers. As the labour market of Finnish speaking geologists concentrated to the public sector, the pressure for the creation of a public prospecting organization and the acquisition of control of the Geological Survey was strong in the Finnish nationalist side.

As a conclusion for this section it can be stated that geological research and education had attained a mature stage in Finland up to the 1930s. Education in geology was given in three universities and on a bilingual basis. Academic geology had gained an international stature. A pool of geologists was available for domestic and international tasks.

The three leading young Finnish nationalist geologists at the University in the 1910s; Eero Mäkinen, Pentti Eskola and Aarne Laitakari could be content with the state of affairs in the late 1930s. A Finnish language geology of Finland and a geological terminology in Finnish had been created. Mäkinen was managing-director of the large and successfull copper industry company, Eskola the leading professor in geology in the country with an international

stature and Laitakari Director of the Geological Survey. Geology and mining industry were clearly contributing to national development of independent Finland.

Theoretical basis of the geology of Finland was becoming more solid, geological mapping more precise and mineral prospecting had got a new impetus. New discoveries in the late 1930s included a promising iron ore deposit in northern Finland.

4. The Rise of Domestic Education in Mining Engineering and Metallurgy, 1937-1960[3)]

Dynamic developments took place in the mining sector in Finland in the late 1930s. Outokumpu Oy was planning the building of a copper refinery and metal works. Mining development was opened in the Petsamo District by the Finnish subsidiary of Mond Nickel Ltd. Vuoksenniska Oy established new iron and steel works on the basis of roasting scraps of the Outokumpu ore. Typical of Finland was the use of new electrical process methods based on Norwegian knowhow. Finland even played a pioneering role in the application of these processes.

In addition, the limestone industry experienced a strong expansion and a new phase started in mineral prospecting. The Finnish Governments considered the mining sector vital for the national economy in the late 1930s and paid special attention to the promotion of its development.

A new section of mining engineering was set up in the Department of Chemistry at the Helsinki University of Technology in 1937. At the beginning, two full chairs, the first in geology and mineralogy and the second in mining engineering together with a permanent lectureship in metallurgy were established in the section. A mining laboratory and a metallurgical laboratory were established in this context as well. Because of a shortage of domestic expertise, Swedish and German experts were invited to take charge of teaching in mining engineering and metallurgy.

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3) The basic sources for this section are Lehto 1958 and articles published in the review Vuoriteollisuus since 1943.

Outokumpu Oy created the Outokumpu Foundation for the Promotion of Education and Research in Mining Engineering, Metallurgy and Geology in 1938. The Board of the Foundation consisted of a group of prominent experts and builders of independent Finland including Eero Mäkinen, Pentti Eskola, Aarne Laitakari and A.K. Cajander. The Foundation supported the organization of education at the University of Technology and granted scholarships to promising former young engineers for studies abroad. In a way, it institutionalized the former practices of the direction of the company.

The involvement of Finland in the World War 1939-1945 put heavy strain both on the mining sector and the education in connection. Outokumpu Oy had to expand strongly the copper production and new marginal mines were opened. After British, American and Canadian experts engaged in the nickel industry left the country, Finnish engineers had to assume the task of nickel production as well. Since it was difficult to keep foreign teaching personnel in Helsinki during the War, a special agreement was negotiated with the Royal University of Technology in Stockholm concerning the organization of teaching of mining engineering to Finnish students in Sweden. An effort to initiate professional schooling in mining engineering and metallurgy again in Kuopio was not successfull.

The Government established the State Technical Research Institute in close collaboration with the Helsinki University of Technology in order to strengthen domestic technological capability in 1942. A new Bureau of Mines was set up to the Ministry of Trade and Industry to increase the efficiency of mining administration in the same year. Finnish mining and metallurgical engineers established, for their

part, a special professional association in 1943 which started to publish the first Finnish mining review.

As the result of the War, Finland lost, among others, the District of Petsamo to the Soviet Union and she had to pay heavy war reparations to her eastern neighbour as well. The heavy strain on the mining sector continued as the main part of the war reparations asked by the Soviet Union consisted of engineering industry products and the industrialization of the country got a new impetus. A shortage situation with regard of energy and raw materials was typical of afterwar Finland.

After the most critical afterwar period was over, the Government introduced a couple of reforms in research and education policy. The Academy of Finland was founded to promote top level scientific research in 1947. The reorganization of the Helsinki University of Technology included the foundation of the new Department of Mining and Metallurgy in 1947. The Department included the chairs of geology and mining engineering established in the 1930s, and the chairs of process metallurgy and physical metallurgy created in the early 1940s. In addition, a new chair of concentration technics was founded. So the whole processing chain from the mine to metal works was incorporated to the curriculum. The education included practical training periods in the industry (cf appendix 5.).

The chairs of geology, mining engineering and concentration technics were occupied by Finnish scholars whereas Swedish experts were still invited to take charge of education in metallurgy. Finally, all the chairs were occupied by Finnish scholars at the beginning of the

1950s. New laboratory facilities were developed in a close collaboration with the State Technical Research Institute. The students in the new Department created a special student association in 1947.

Turning to the development of Outokumpu Oy, it had established the copper refinery and works during the War and started to produce nickel and zink as well. The copper smelter had been transferred from southeastern to southwestern Finland. Because of serious energy shortage the company started to develop a new energy saving furnace. Chief Metallurgist Petri Bryk and Chief Engineer John Ryselin were able to develop a new flash smelting method during 1947-1949 which made possible to use the copper concentrate's own caloric value during 1947-1949. The company established a Metallurgical Research Centre to carry on the research and development effort in 1949.

The role of Outokumpu as a significant education instrument for young engineers became evident in the afterwar situation. Both Ryselin and Bryk had been sent to study metallurgy to U.S.A. in the 1930s. Among the four new professors of the Department of Mining and Metallurgy, three had either the work experience on or had been sent to study abroad by the company (cf table 4).

Eero Mäkinen could be very content with his accomplishments at the beginning of the 1950s. An integral copper industry had been created in Finland. This industry had exerted a great influence on the economic structure of the country. An integral higher education in mining and metallurgy given by Finnish professors was available. Finnish engineers had been able to make pathbreaking innovations in process metallurgy. He died exhausted in 1953.

Table 4. The Background of the New Finnish Professor in the Department of Mining and Metallurgy Established in the Helsinki University of Technology in 1947.

Kauko Järvinen: Degree from the Helsinki University of Technology in 1929. Study of mining engineering in the Royal University of Technology in Stockholm in 1929-1931. Mining engineer in the Outokumpu mine of Outokumpu Oy in 1931-1942. Director of the Bureau of Mines in the Ministry of Trade and Industry in 1942-1946. Professor of Mining Engineering in the Helsinki University of Technology in 1946.

Risto Hukki: Degree from the Helsinki University of Technology in 1939. Scholarship from the Outokumpu Foundation to study mining engineering in the Queen's University Kingston Ont.Canada in 1939. Degree from this university in 1941. Worked as mining engineer in several mines in North America and as researcher in M.I.T. in U.S.A. in 1941-1945. Doctor from the M.I.T. in 1944. Teacher in the Helsinki University of Technology in 1945-1946. Professor of Concentration Technics in 1946.

Matti Tikkanen: Degree in engineering from the Åbo Akademi in 1938. Worked in the State Aircraft Works in 1940-1946. Research engineer in Husqvarna Vapenfabriks Ab in Sweden in 1946-1948. The first doctor from the new Department of Mining and Metallurgy in Helsinki University of Technology in 1949. Professor of Process Metallurgy in 1949.

Heikki Miekk-oja: Degree in physics from the University of Helsinki in 1932. Worked in the Weights and Measures Office in Ministry of Agriculture in 1933-1939. Special tasks under the General Staff of the Finnish Army during the World War 1939-1944. Doctor from the University of Helsinki 1941. Well-known expert in reading secret messages, among others. Director of Research Laboratory of the copper refinery of Outokumpu Oy in Pori in 1945-1950. Teacher in the Helsinki University of Technology 1950-1954. Professor of Physical Metallurgy in 1954.

As the intensity of mineral prospecting had diminished during the War, the new Bureau of Mines started to promote prospecting after the War. The number of the staff of the Geological Survey and the resources at the disposal of Suomen Malmi Oy were increased. In addition, companies like Outokumpu Oy created prospecting organizations of their own. In fact, some small copper and zink deposits were discovered in the late 1940s.

The Government established a new state-owned mining company to start the exploitation of the promising iron ore deposit which had been discovered in northern Finland before the War. Because of the experience accumulated by Outokumpu Oy and nickel mining in Petsamo, it was much easier to create a new state-owned mining company in the 1950s than it had been in the 1920s. For instance, the principal adviser of this project was former mining engineer of the Outokumpu Mine and Professor of Mining Engineering Kauko Järvinen and the Managing-Director of the new company was Ilmari Harki, former Director of the copper works of Outokumpu Oy.

In general, it can be stated that there was a critical mass of experienced engineers available in Finland for new mining, mining industry and basic metal industry projects at the beginning of the 1950s. In addition to the academic education and work experience, many people had an additional and compulsory schooling by war experience. After a short period of oversupply of mining engineers and metallurgists in the late 1940s, the expanding labour market could absorb all new entrants in the 1950s.

The pioneers of academic education in mining engineering and metallurgy in Finland were a dedicated and talented group od professors. They participated to the development of established and new mining and basic metal enterprises and of supplier industries developed new ideas and solutions, were capable to attract talented students and wrote new textbooks in Finnish. Their work was supported by a couple of other qualified professors of the Helsinki University of Technology, especially that of geodetics, inorganic chemistry, and technical physics (cf table 4).

The basic structures of professional education in the mining sector are stemming from the afterwar period as well. Due to the growing importance of labour unions and the acceleration of mechanization new attention was paid to miner's work. Outokumpu Oy founded a Mining School in Outokumpu in 1951 and special consideration was given to education in accident prevention, among others. The education in mining technology started in the Technical School in Lappeenranta in 1958. Education in metallurgy was given in the Swedish Technical High School in Helsinki and in the Technical High School in Tampere.

The number of students in the Department of Mining Engineering and Metallurgy was among the smallest at the Helsinki University of Technology in the 1950s. This kind of situation produced a small and cohesive group of engineers united by the common student association, excursions, professional association, and professional review. The people knew each other eventhough the occupations could be various in mining industry, basic metal industry, engineering industry, public administration or higher education and research (cf table 5.).

Table 5.

The Number of Students in the Department of Mining and Metallurgy, at the Helsinki University of Technology, 1947-1986

Student Enrolment		M.Sc. Degrees	
1947	11	1947	4
1948	13	1948	16
1949	6	1949	26
1950	9	1950	10
1951	8	1951	4
1952	12	1952	10
1953	15	1953	11
1954	15	1954	9
1955	16	1955	4
1956	17	1956	14
1957	15	1957	6
1958	15	1958	6
1959	16	1959	12
1960	23	1960	14
1961	30	1961	14
1962	30	1962	17
1963	35	1963	9
1964	48	1964	19
1965	62	1965	10
1966	52	1966	22
1967	59	1967	30
1968	60	1968	22
1969	57	1969	41
1970	82	1970	42
1971	91	1971	41
1972	88	1972	47
1973	78	1973	55
1974	82	1974	49
1975	88	1975	47
1976	98	1976	69
1977	98	1977	56
1978	60	1978	46
1979	60	1979	48
1980	79	1980	57
1981	83	1981	52
1982	89	1982	63
1983	96	1983	53
1984	107	1984	36
1985	115	1985	37
1986	115		

Source: Satu Sarkola, Department of Mining and Metallurgy. Helsinki University of Technology. Research Note 30.9.1986.

There were certain advantages of smallness in this situation which made a contribution of its own to an integrated mining sector development. It was quite easy to find out a synergy between different elements. For example, contacts between domestic industries and suppliers could be established via diverse informal means. The language issue had become peripheral during the War and after the War when the adoption of new recruiting policies was necessary for private companies and the access to the private sector became open to Finnish speaking engineers as well.

As far as the development of higher education in geology is concerned, a new post of associated professor was founded at the University of Helsinki during the War. In addition, two new extraordinary professors were appointed during the 1940s. There were together five professors in the Department of Geology at University of Helsinki at the early 1950s: by this criteria it was one of the largest in the University (cf appendix 4.).

Finnish scholars T.G. Sahama and Kalevi Rankama gained international reputation by their studies and textbooks in geochemistry. A couple of new international expeditions were undertaken in Finland in the 1950s. The development of new capital intensive research methods made it, however, difficult to follow international frontiers in geological research in a small peripheral country with limited research budget after the War.

Due to the increase in prospecting activities and new mine developments in the 1950s, new jobs were available for geologists and the number of students consequently increased. Finnish geologists

Table 6. The Number of Mining and Metallurgical Engineers in Finland, 1950-1965*

	1950	1955	1960	1965	shortage in 1965
Mining engineers	30	43	62	71	9
Concentration engineers	8	10	19	28	4
Metallurgists	36	51	70	104	14
	74	104	151	203	27

* including engineers graduated from Åbo Akademi.

Source: J. Porkka: Vuorimiesyhdistyksen insinööritarpeen ennustekomitean mietintö (The report of the forecasting committee on the demand of mining and metallurgical engineers in Finland). Vuoriteollisuus 23, 1965:2, 50-51.

Table 7. The Number of Geologists Awarded a Master's (M.A.) Degree, by Decade

	Univ.Helsinki		Univ. Turku		Univ. Oulu		Åbo Akad.	
Decade	geol.& min.	geol.&	geol.& min.	Quat. geol.	geol.& min.	Qaut. geol.	geol.& min.	total
1850-59	1							1
60-69	1							1
70-79	0							0
80-89	4							4
90-99	3							3
1900-09	3							3
10-19	5							5
20-29	3							3
30-39	4							4
40-49	30	1					3	34
50-59	67	8					7	82
60-69	60	48	11		8		13	140
70-79	48	35	25	26	23	13	20	190
80-84	29	18	19	17	17	15	16	131
total	258	110	55	43	48	28	59	601

Geology and mineralogy, total		420
Geology and palaeontology and Quaternary geology, total		181
	total	601

Source: I. Haapala: The history of geology teaching at Finnish universities. Geological Survey of Finland, Bulletin 336, 1986 p. 342.

became professionally organized after the War and started to publish professional review in 1948 (cf table 7.).

Summa summarum, the gaps in education inherited from the prewar period became filled after the War. Both professional and higher education in mining and metallurgy became established in Finland. This education was close to practice. The invention of flash smelting was a reflection of the rise of domestic capability in knowhow. This capability to innovate raised self-confidence among Finnish metallurgists.

Typical of the afterwar development was the rise of domestic supplier capability as well. Eero Mäkinen had a consistent aim at creating domestic backward linkages by means of procuring policy of Outokumpu Oy and dynamic developments in the Finnish engineering industry after the War strengthened these linkages (cf Mäkinen 1942).

Finland was not any more a mining vacuum in the Northern Coniferous Zone whereas she was becoming a small-scale mining nation. The rise of domestic mining industry, basic metal industry, education, expertise, supplier capacity together with accumulated geological knowledge, and official and popular mobilization for prospecting created opportunities to cumulative developments.

5. The Expansion of Education in the 1960s and 1970[4)]

Many new valuable ore and mineral deposits were discovered in Finland under the period extending from the early 1950s up to late 1960s. The growth of the number of geologists, the growing public support on prospecting, and the adoption of new exploration methods all together contributed to this accomplishment. For instance, the Geological Survey started the first systematic countrywide airborne geophysical survey in the world at the beginning of the 1950s.

These discoveries led to an exponential growth of the production of the mines in Finland and to the rise of great optimism with regard of prospects of mining in the country. Good market conditions and high price level in the international markets of non-ferrous metals created favourable conditions for this expansion. Outokumpu Oy diversified its operations to the production and exports of nickel, cobolt, zink, and ferro-chrome and established a stainless steel plant in the middle of the 1970s. The company continued its active research and development effort in process metallurgy and developed new process control equipment and systems as well.

The opening up of the exploitation of iron deposits in northern Finland led to the creation of the state-owned steel industry in the 1960s. The builders of the state-owned steel industry manifested a great skill by adopting new oxygen converter and continuous casting

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4) Basic sources for the period in question are as regards ore prospecting cf. Papunen 1986; the Geological Survey cf. Virkkala 1986; geological education cf. Haapala 1986; geology in general Geologi 1960-1980; education in mining engineering and metallurgy cf. Vuoriteollisuus 1960-1980; Outokumpu Oy cf. Kuisma 1985 and the Finnish steel industry cf. Haavisto 1985.

methods. The traditional private steel industry likewise adopted new and efficient steel making processes. The Finnish steel industry was able to cover a major part of the domestic need of steel products.

A technologically advanced mining industry and basic metal industry was created in Finland in the 1960s and 1970s. Dynamic development in the mining sector during the afterwar period exerted a decisive impact on this process. On the other hand, the current development of the education system supported it as well.

Special attention was paid to the role of education as means of democratisation of the society, and as an important factor in economic growth in the afterwar public discussion in the West. These ideas received an enthusiastic response in Finland where the attitudes about the emancipatory role of education were deep-rooted and considerable practical realizations had already taken place. As elsewhere, the creation of a consistent education and research policy was considered pertinent. The idea of promoting balanced regional development by means of education policy was especially strong in the country.

Both basic and professional education were greatly expanded and reformed starting from the late 1950s. The expansion of higher education was large enough to keep the share of university students among the population one of the highest in Europe. The social background of university students was also more democratic in Finland than in other countries in Western Europe. The share of female students of the total student population in universities was the highest in Europe in the country in the late 1960s (cf Elovainio op.cit.).

Turning to research policy, the system of the state science councils created after the War was expanded and state research institutes, included the Geological Survey of Finland, had more resource at disposal. Generally seen, the share of research and development expenditures per GNP kept, however, on a very low level in Finland among the industrialized countries in the West.

A basic problem of this expansionary policy was the overdimensioned attention paid to the extension of number of students and university departments at the expense of intensive aspects of education and research.

Turning to the development of education in the mining sector, education in geology greatly expanded. New departments of geology were established at the University of Turku and the University of Oulu. Outokumpu Oy donated a chair in geology and mineralogy to the University of Turku already in 1958. The second chair, that of Quarternary geology, was established in 1966. In addition, two posts of associate professors were set up in the early 1970s. The students in geology at the University of Turku and the Åbo Akademi founded a common student association in 1960 which clearly pointed out that the period of language conflicts in higher education was passing to the history (cf appendix 4.).

Table 8. The Distribution of Labour Market of Geologists in Finland in 1969.

	number of jobs	per cent
Research	81	39
Education and research	42	20
Mining industry and exploration	60	29
Geotechnics	26	12
	209	100

Source: A.J. Laitakari: Geologien ammatillinen jakaantuminen ja työmarkkinatilanne syksyllä 1968 (The occupational distribution and the labour market situation of geologists in the autumn 1969). Geologi 22, 1970, p. 49.

Table 9. The Development of the Labour Market of the Geologists in Finland in the 1960s.

	1963	1969	increase
Geological survey	45	73	28
Universities	22	42	20
Mining industry and exploration	44	60	16
Engineering geology	10	26	16
	121	201	80

Source: ibid

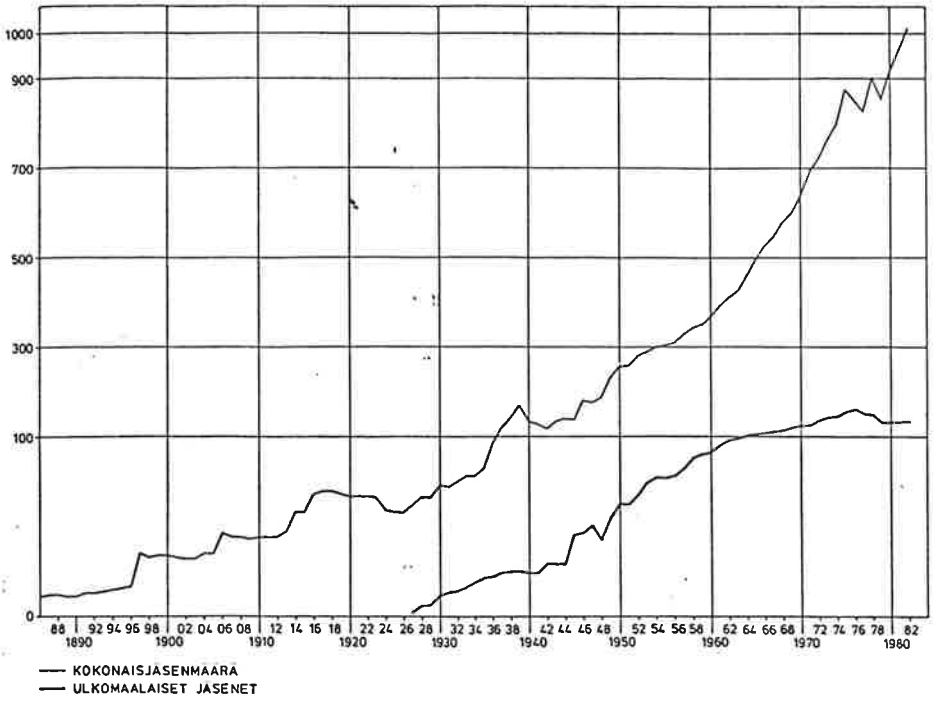
The University of Oulu was founded in 1958 as the first new university outside the traditional university centres in Turku and Helsinki. It was located in northern Finland. The first chair in geology and mineralogy was established in 1961. The rise of the new Department of Geology was rapid. Up to 1970, there were together two full chairs and to posts of associate professors at the University which surpassed the number of permanent professors at the Department of Geology at the University of Helsinki.

In addition, the post of associate professor of engineering geology was established in 1967 in the new University of Technology in Tampere founded in 1965. This post became closely associated to the Department of Civil Engineering, a major department in the new university.

The old departments of geology at the University of Helsinki and the Åbo Akademi together with the geology teaching at the Department of Mining Engineering and Metallurgy at the Helsinki University of Technology did not get any new posts of professors in the 1960s. The protestations from the side of the University of Helsinki led to the establishment of a couple of new posts of associate professors at the early 1970s but the number of students started to decline there (cf table 7.).

The number of geologists in Finland doubled in the 1960s and a strong expansion continued in the 1970s. Since the labour market was expansive, new entrants could quite easily find jobs. The Geological Survey, universities, and engineering geology were the fastest growing labour market sectors in the 1960s (cf table 7; table 8; table 9; figure 3; figure 4.).

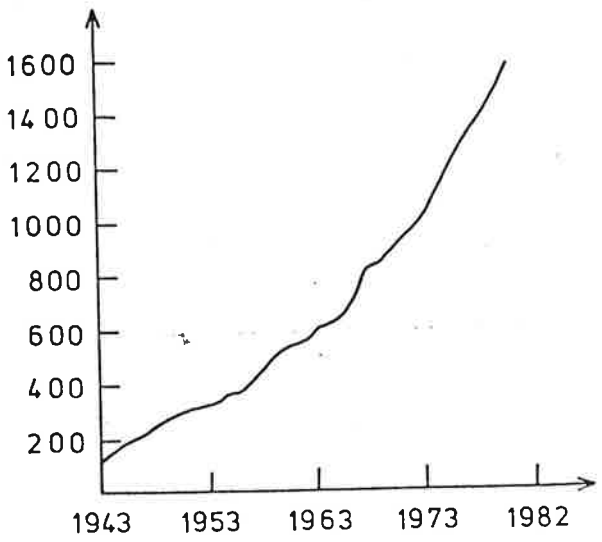
Figure 4. The Progress of the Number of the Members of the Geological Society of Finland, 1886-1982



Seuran kokonaisjäsenmäärän kehitys 1886—1982. Progress of the number of members of the Society 1886—1982. The upper line: total membership; the lower line: foreign members.

Source: K. Virkkala: Suomen Geologisen Seuran historiikki 1886-1986 (The history of the Geological Society of Finland, 1886-1986). Bulletin of the Geological Society of Finland 58:1, 1986 p. 5.

Figure 5. The Growth of Membership of the Finnish Association of Mining and Metallurgical Engineers



Source: M. Aulanko: Historiikkia ja muistelmia Vuorimiesyhdistyksen 40-vuotistaipaleelta (Pages from the 40 years' annals of the Finnish Association of Mining and Metallurgical Engineers). Vuoriteollisuus 41, 1983:1, 11-17.

As concerns professional education, education given in the Mining School in Outokumpu and in the Lappeenranta Technical School expanded and the latter one acquired the status of Technical High School. Another mining school was established in Otanmäki by the state-owned mining company Otanmäki Oy. The education in metallurgy in professional schools was changed into that of process technology in 1963. New schools were built close to the growing centres of basic metal industry, such as the Technical School in Kokkola which was founded in 1960 and acquired the status of high school in 1972.

The number of professors in the Department of Mining Engineering and Metallurgy at the Helsinki University of Technology increased only by one in the 1960s but the general conditions of education improved after the shift of the Department together with the laboratories of the State Technical Research Institute to the new university and research institute complex in Otaniemi outside Helsinki in 1963-1964. The new facilities of the Geological Survey of Finland were located there as well (cf appendix 5.).

The teaching was continuously given by the same group of professors who had started their academic career with the foundation of the Department. The only major change concerned the teaching in geology. The new professor in geology since 1958, Aimo Mikkola redirected the teaching toward economic geology. In spite of the tiny permanent staff at disposal, he was able to create a dynamic teaching and research unit in geology at the Department in the 1960s.

Because of the relative small increase in the number of students at the early 1960s, there were talks about coming shortage of engineers in the middle of the decade but, among others, the availability of

better facilities after the shift to Otaniemi considerably increased the supply of engineers in the late 1960s (cf table 5; table 6; figure 5.).

The rapid rise of the University of Oulu provided with the Faculty of Technology contributed to the growth of the supply of metallurgists in the late 1960s. Special consideration was given to the teaching of process technology at the Faculty and a chair of physical metallurgy was established there in 1963. Higher education in metallurgy started in the new Tampere University of Technology as well. The building of engineering education in new universities demanded so much resources that new chairs could be established at the Helsinki University of Technology only at the early 1970s (cf appendix 5.).

Since most of the mines and potential mining reserves were located in the northern and eastern peripheral regions whereas the smelters and basic metal works were located in southern Finland after the War, the Government paid special attention to the possibilities of the mining sector to contribute regional development policy. The new basic metal works erected by the state-owned mining companies were located on the north-west coast during the 1960s. The stainless steel works of Outokumpu Oy were located against the will of the direction of the company close to the ferrochrome mines in northern Finland in the 1970s.

The activities of the Geological Survey were decentralized. It established new reserch units in eastern Finland and in northern Finland. The building of a strong department of geology at the University of Oulu also served the interests of intensifying ore

prospecting in the national peripheries. The Ministry of Trade and Industry established, for instance, a special delegation to coordinate the use of public research funding to ore prospecting in northern Finland in 1971. Its members included representatives of the University, the Geological Survey and the state-owned mining companies.

Because professional education in the mining sector became already quite decentralized in the 1950s, few changes took place in this field except the establishment of new schools for metal workers close to the new basic metal work on the north-west coast.

The keeping of the higher education in mining engineering and metallurgy intact at the Helsinki University of Technology seemed to be a kind of exception from the rule. The close contacts between the Department of Mining Engineering and Metallurgy and the laboratories of the State Technical Research Institute made it very difficult to change the location or to establish a new comparable teaching unit elsewhere. On the other hand, the need of university engineers in the mining sector was not great in Finland.

The establishment of the Faculty of Technology provided with the chair of metallurgy in the University of Oulu signified anyway a decentralization of the higher education toward the north. The Department of Geology and other departments, such as Geophysics, and Faculty of Technology at the University of Oulu were together able to give a certain basic teaching as regards the higher education serving the needs of the mining sector.

As far as the development impact of decentralization of the education in the mining sector is concerned, the establishment of the Department of Geology at the University of Oulu signified that the knowledge of the geology of northern Finland became better. Secondly, the students from northern Finland could have an access to higher education closer to their homes than formerly. Thirdly, some new jobs were created at the University and in ore prospecting. In addition, geologists of local origin could be hired to new tasks opened up in northern Finland. On the other hand, no significant new discovery was made in spite of the increase in prospecting activities since the late 1960s.

Generally seen, the decentralization of education in geology led to the formation of too many small-sized university department in Finland. These departments suffered from a relative shortage of staff, facilities, and research funding. In the 1950s, the Department of Geology at the University of Helsinki had chances to become an education and research establishment which would be significant on the international level. Its development prospects were, however, cut down by the creation of new departments of geology elsewhere.

On the other hand, the great emphasis on applied geology in universities led to a neglect of basic research. For example, both Departments of Geology in Turku and the Department of Geology in Oulu mostly concentrated to applied geology. In technical universities, economic geology and engineering geology were teached. Since the Geological Survey concentrated its activities to ore prospecting as well few chances were really left for basic research. It is maybe no wonder that no new great geologists of theoretical and synthetical nature, such as Sederholm, Ramsay, or Eskola grew up in Finland in the 1960s and 1970s.

The establishment of professional education close to mines and basic metal works certainly had a positive impact on the formation of labour force. As to the higher education in mining engineering and metallurgy, the establishment of new universities of technology since the late 1960s started to provoke a relative shortage of staff, facilities and research resources at the Helsinki University of Technology in the 1970s. Money earned by research contracts and some donations from the side of companies could only a little alleviate this problem.

As regards of development of new universities, the foundation of the Tampere University of Technology, of course, strengthened education and research basis of the old industrial centre Tampere. It certainly contributed to the development of a couple supplier companies to the mining sector located in the region (cf. figure 9.).

The foundation of the University of Oulu in northern Finland created, for its part, a dynamic university establishment there. This University had the chance of being the first new university and therefore, it had ten years time to grow up before the decentralization effort of higher education really started which squeezed the resources of all established universities. This university has always enjoyed significant political preferences in the Government. It became an integral university with several faculties and approaching of the size of the University of Turku and the Helsinki University of Technology. The university has been able to create dynamic contact with local enterprises, such as the basic metal works in northern Finland. It has become a kind of development pole for northern Finland, by and by (cf Raumolin 1985).

Turning to the interaction between higher education in mining engineering and metallurgy and enterprise in general in Finland, it has already been stated in the former section that the professors in the Department of Mining Engineering and Metallurgy at the Helsinki University of Technology were active in this field. Since many of them acted as director of laboratory in the State Technical Research Institute at the same time, the link between university, technical research and enterprise was well established.

In this context, an example of the link between university and enterprise in the mining sector is given which is not directly related to the Department of Mining Engineering and Metallurgy. Professor of Technical Physics at the Helsinki University of Technology and Director of the Laboratory of Technical Physics of the State Technical Research Institute Erkki Laurila was one of the most influental professors in Finland from the 1940s up to 1970s. He taught, among others, geophysics at the Department of Mining Engineering and Metallurgy.

Laurila sold his prototypes of instruments to Outokumpu Oy in 1964 which led to the foundation of the Institute of Physics of the company. The new Institute was headed by his former research associates. This was the origin of the company's success in instrument fabrication and process control. Laurila held also patents in magnetic separation which he sold to a Finnish company fabricating concentration machinery and equipment (cf Laurila 1982).

The exhaustion of mines and rapid advance in technics started to pose new challenges to the education in the mining sector in Finland in the

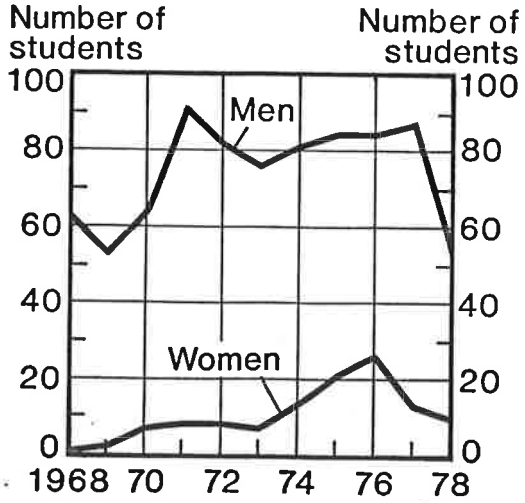
1960s and 1970s. Outokumpu Oy adopted the policy according to which the exhaustion of a mine should not lead to unemployment of miners. The miners who accepted the work in another mine or in a metal works of the company were transferred and retrained to new occupations. Because the opening up fo the mines was continuous and new metal works were constructed in the 1960s and in the 1970s this policy did not cause any major problem to the company.

The Finnish Association of Mining Engineers and Metallurgists adopted an active role in education and training of its members starting from the late 1950s. It edited, among others, a new handbook in mining technology, organized research concerning the introduction of new technics, and started a complementary schooling of its members.

The profession of geologists and that of mining engineers and metallurgists have traditionally been typically very masculin by character. As the female students traditionally for their part concentrated in humanities, social sciences, teachers' training colleges and alike, their entry to studies in geology, mining engineering, and metallurgy was quite late, especially as concerns universities of technology. The share of female students in geology raised to one third of total number of students up to the late 1970s. Their entry to mining engineering and metallurgical studies took principally place in the 1970s (cf figure 6.).

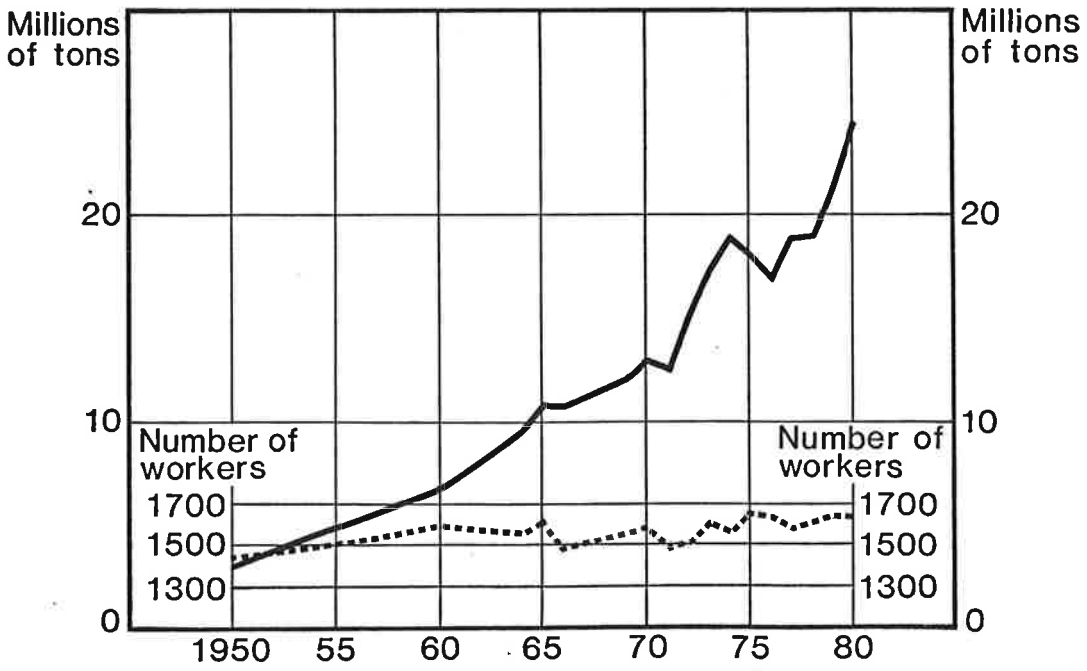
Seen from an international perspective, the change in the higher education in mining engineering and metallurgy had been really fundamental from the beginning of this century up to the 1970s in Finland. Young Finnish mining engineers and metallurgists did not have

Figure6. The Structure of Students in the Department of Mining and Metallurgy at the Helsinki University of Technology, 1968-1978.



Source: Opiskelijarakenteen muuttuminen 1970-luvulla (The change in the structure of students in the 1970s). Vuoriteollisuus 37, 1979:1, 9.

Figure 7. The Output, Employment and Number of the Finnish Mines, 1950-1980



Ore mines	6	8	13	15	16	16	15
Limestone mines	11	11	12	14	12	12	15
Others	3	3	3	7	6	15	20
	20	22	28	33	34	43	50

Source: R. Matikainen: Suomen kaivostoiminta (Mining in Finland): in Kaivos- ja louhintatekniikan käsikirja (Handbook of mining technics). Helsinki 1982 p. 10.

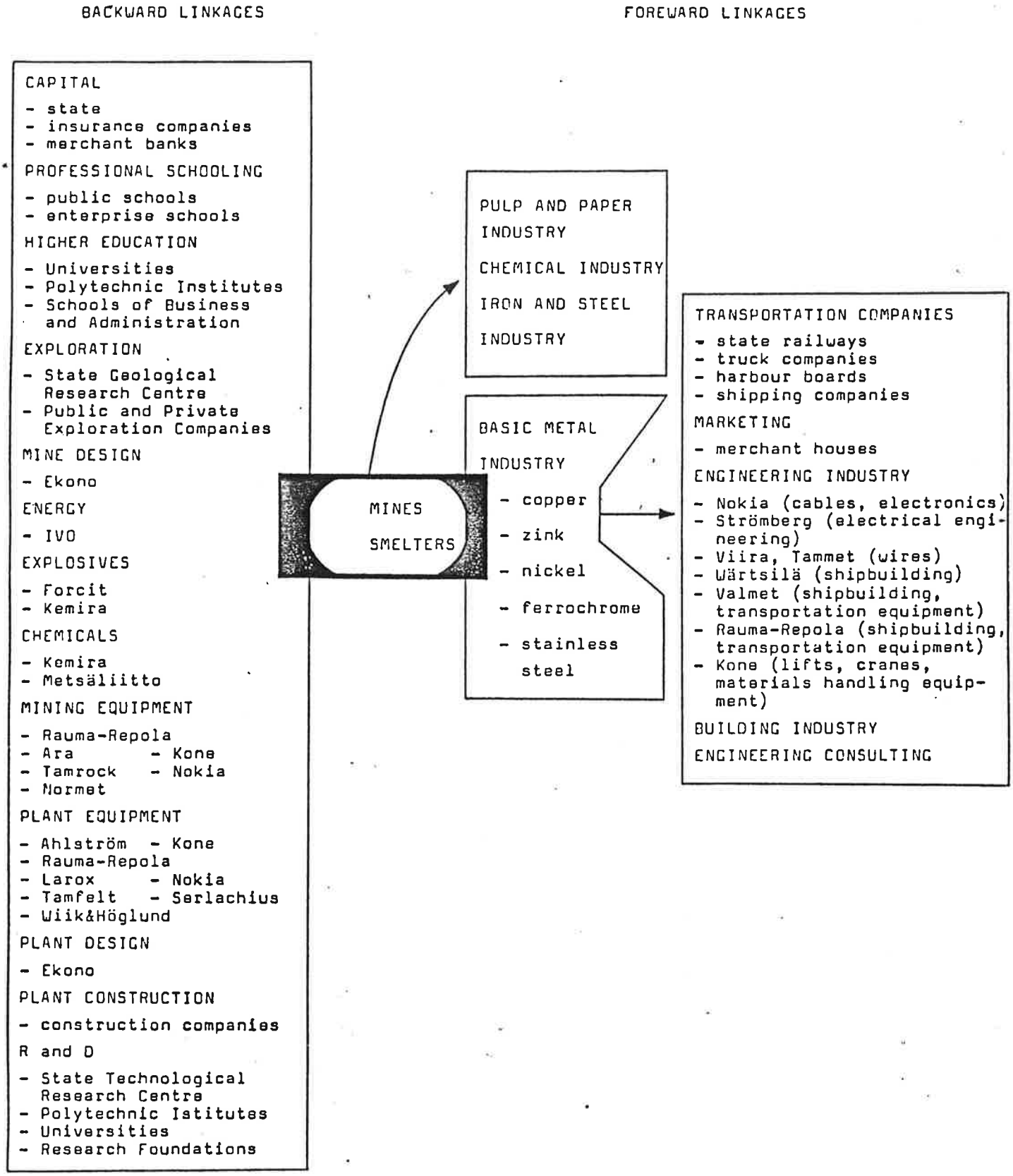
any more large education and work experience from abroad. As students they normally had a training period in Finnish enterprises. After graduation there were many challenges, such as new mine developments and construction of basic metal works available in Finland. In addition, the Finnish mining sector was becoming from technological point of view, one of the most advanced in the world.

In fact, Finland developed an exporter of knowhow, by and by. Finnish geologists started to work abroad as experts already at the beginning of this century. Now Outokumpu Oy and Finnish consulting companies were able to sell Finnish engineering knowhow abroad. A couple of Finnish mining engineers and metallurgists worked as UN experts in the developing countries as well.

On the other hand, the number of students in geology, mining engineering, and metallurgy from the developing countries kept on a low level in Finland. Limited number of scholarships, difficult language problem, and harsh Nordic winter did not attract many students from the South to Finland. A larger project as regards the education of students from the developing countries is the building of the Department of Geology of the University of Dar-es-Salaam in Tanzania undertaken by the Finnish International Development Agency in collaboration with the Department of Geology at the University of Helsinki together with other departments of geology in Finnish universities. This project started in the late 1970s.

Typical of the development of the Finnish technological capability in the mining sector was its appropriateness to the Finnish conditions. Finnish technology is energy saving, capable of operating in harsh

Figure 8. The Linkages of Outokumpu Oy in the Finnish Economy in 1982

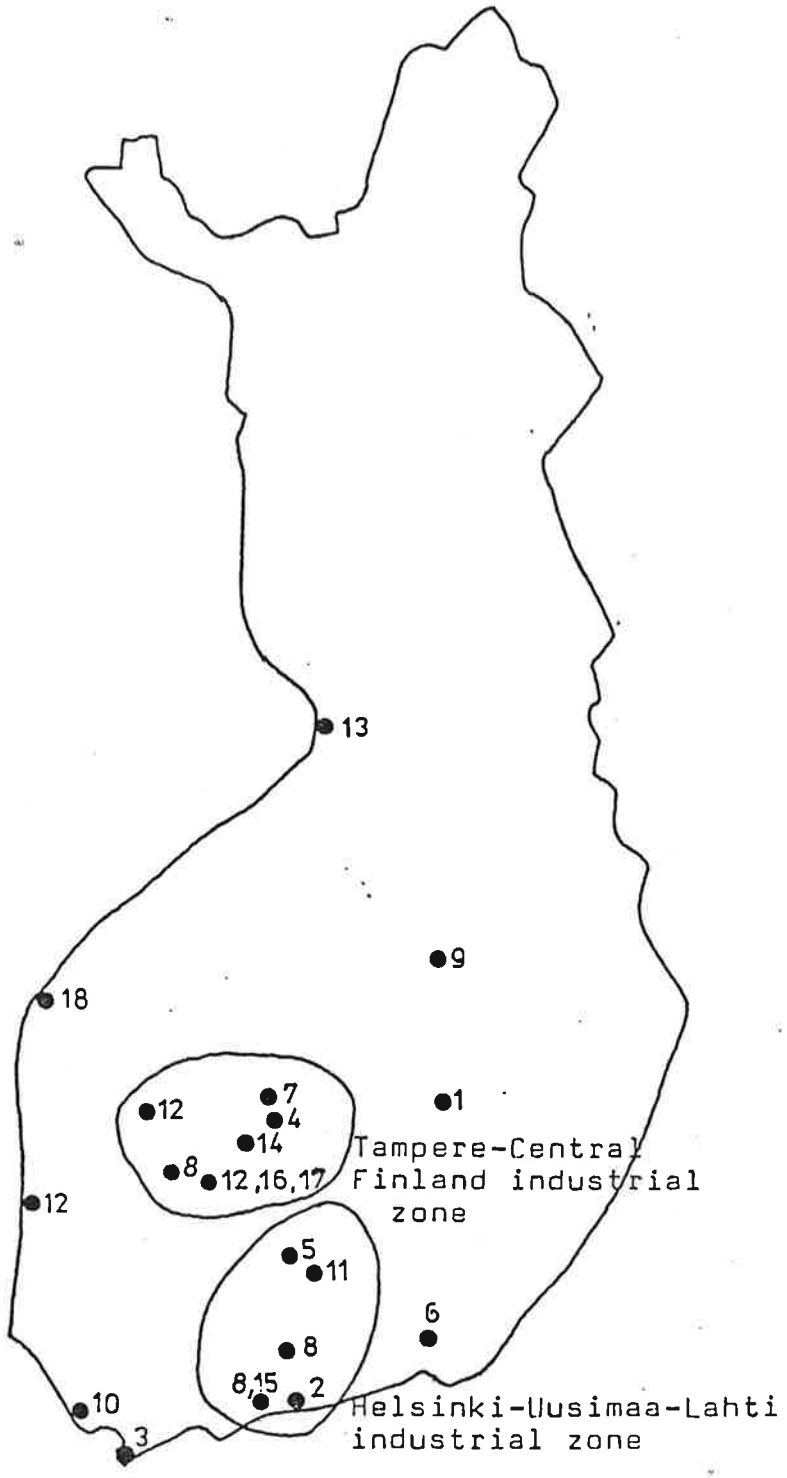


Originally in J. Raumolin: The Formation of Autonomous Scientific and Technological Capability in the Resource-based Peripheral Economy, Finland: the Case of Copper Industry. Paper for the IV EADI. General Conference in Madrid, 3-7 September 1984, Mimeo 64 p.

winter conditions, capable of exploiting economically low grade, small sized, and polymetallic deposits and it is also paying attention to diminishing environmental damage.

The rise of dynamic domestic supplier industry was a part of the dynamic development processes in the mining sector in Finland during the 1960s and 1970s. The advantages of smallness i.e. close contacts between universities of technology, state research institutes, mining companies, and basic metal companies all together contributed to the development of Finnish drilling equipment, crushers, materials handling equipment, concentration equipment, machinery and equipment for smelters, process control equipment etc. Finland became a significant exporter of the mining sector machinery and equipment in the 1970s. Among Finnish companies, Tamrock Oy gained a prominent share in the world market of drilling equipment (cf figure 8; figure 9.).

Figure 9. The Location of Main Domestic Suppliers of Machinery, Equipment and Other Supplies to the Mining Sector in Finland in 1982.



1. Ahlström (Varkaus Engineering Works)
   - boilers, converters
2. Ekono (Helsinki)
   - design of mining, metallurgical, cement and industrial mineral plants
3. Forcit (Hanko)
   - explosives
4. Kemira (Vihtavuori Works)
   - explosives
5. Kone (Salpakangas Engineering Division)
   - crushing and concentration equipment
   - materials handling and conveyor equipment
6. Larox (Lappeenranta)
   - classifying, concentration and filtration equipment
7. Metsäliiton teollisuus (Chemicals Division, Äänekoski)
   - chemicals
8. Nokia (Industrial Rubber, Kerava; Tyre Division, Nokia; Airam-Kometa, Espoo)
   - industrial rubber and tyres
   - drilling equipment
9. Orion (Normet, Peltosalmi)
   - mine vehicles
10. Perusyhtymä (Ara, Turku)
    - mine vehicles
11. Rammer (Lahti)
    - hydraulic hammers, breaker booms
12. Rauma-Repola (Lokomo Division, Tampere; Parkano Engineering Works)
    - crushing equipment, mine trains,
    - concentration equipment
    - grinding mill equipment
    - furnaces, converters dryers and other metallurgical machinery and equipment
13. Rautaruukki (Central Office, Oulu)
    - geophysical measurement instruments
14. Serlachius (Pump Factory, Mänttä)
    - pumps
15. Suomen Malmi-Finnexploration (Espoo)
    - geology, geophysics, drilling and mine services
16. Tamfelt (Tampere)
    - industrial textiles
17. Tampella (Tamrock, Tampere)
    - drilling equipment
18. Wiik&Höglund (Vaasa)
    - pipes

Data based on Finnminers 1982 (Outokumpu Oy not included).

Originally in J. Raumolin: The Formation of Autonomous etc.

6. Problems Since the Late 1970s[5)]

The so-called energy crisis in the middle of the 1970s provoked a depression in the international economy. At the same time, the exports of a couple of newly industrialized countries begun to penetrate the markets of the West. In the late 1970s, the breakthrough of new production technics, such as microelectronics, started to take place in the West. This all together provoked a heavy restructuration of industries.

This depression hit hard the mining and basic metal industries of the West. The decline of consumption of metals and the new competition from the South led to a severe decline of price level, problems of overcapacity and low profitability overall. In addition, the rise of new technics started to produce new materials which substituted traditional uses of metals and the growing public concern on environment increased production costs. This all together provoked automatisation and rationalization of production, capacity cuts, and closing of mines in the West (cf Raumolin 1986a).

As far as the Finnish case is concerned, some specific national problems appeared in addition to these general development problems of the mining sector in the West. The exhaustion of the mines opened up during this century, including the Outokumpu Mine, progressed further whereas only a few new ore deposits of minor economic value were discovered. Finland seemed to be facing again with the spectre of the

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5) Basic sources for this period are Vuoriteollisuus 1976-1986; Geologi 1976-1986; Helsingin Sanomat 1980-1986.

decline of the mining industry toward the end of the century. The mining of minerals is anyway still expanding (cf figure 7.).

Turning to the development of higher education in Finland in the late 1970s the establishment of new universities continued. There were alltogether seventeen universities in the country at the beginning of the 1980s! Although the impact of the depression on Finland was not as deep as elsewhere the growth of education budgets did not continue as before. Since the promotion of new universities was continued in spite of the change of economic conditions the old universities experienced a veritable squeeze of resources. In addition, the restrictions imposed by the Ministry of Education vis-à-vis research contracts limited opportunities to increase resources by other means than state budget.

After the state of the mining and basic metal industries deteriorated in Finland in the late 1970s the Department of Mining Engineering and Metallurgy of the Helsinki University of Technology cut down the enrolement of new students by one third in 1978. On the other hand, the share of practical training was increased in order to provide better employment prospects for the students (cf table 5).

The Ministry of Trade and Industry set up a Committee to study the problems of declining mining communities. The Report of the Committee proposed, among others, the creation of alternative occupations in the largest mining communities, such as Outokumpu, and retraining of miners to new occupations. New single-industry mining communities should not be established in the future. The Government should adopt a special policy measures for the development of declining mining communities (cf Kaivospaikkakuntien... 1979).

Taking into consideration the exhaustion of the existing mines and the spectre of the decline of the mining industry, the Government increased the resources of the Geological Survey in ore prospecting. As new resources were allocated to the Survey for the inventary of peat resources in view of energy production almost simultaneously, the Survey became a kind of "mammoth research institution" in the Finnish conditions provided with the staff of almost a thousend people (cf figure 3.).

The optimism among the geologists did not seem to be shaken in the late 1970s since the number of students was growing all the time especially in the new departments of geology. The boom in peat inventary and the prospects of intensification of ore prospecting kept the labour market situation still rosy (cf table 7.).

It was only at the early 1980s that a more pessimistic mode of thinking vis-à-vis the chances of ore prospecting started to spread in Finland. Both of the state-owned mining and basic metal companies, Outokumpu Oy and Rautaruukki Oy, which had created prospecting organizations of their own at the beginning of the 1950s, stated that the investments in ore prospecting did not seem to be justifiable any more. Rautaruukki Oy cut down of its prospecting activities alltogether.

In spite of the increased effort, no new ore discoveries of significant economic value was made in Finland in the late 1970s and at the early 1980s. The established view on ore prospecting was facing with a crisis. Now, the discussion started among the experts about the neglect of basic research and the need of new paradigmas. Since many

Table 10.

The Distribution of Occupations of the Members of the Finnish Association of Geologists in 1981

Public sector	
Geological Survey	169
Other Central Boards	20
Universities	30
Communes	2
	221
State companies	
Outokumpu Ltd	26
Rautaruukki Ltd	8
Other companies	6
	40
Private companies	
Geotek Ltd	4
Soil and Water Ltd	4
Lohja Ltd	3
Partek Ltd	3
Other companies	8
	22
Others	
Abroad	10
Unemployed	3
No information	7
	20
Together	303

Note: Number of geology students at the universities 449 (excluding universities of technology).

Source: V. Suominen: Romahtaako geologien työllisyystilanne? (Will the employment of the geologists collapse in the future?). Geologi 33, 1981: 9-10, 136-38.

of the existing teachers have passed first a bureaucratic career in the Geological Survey before getting an university chair, the possibilities of creating a dynamic basic research in universities do not seem, however, to be the greatest. In fact, some people have even proposed that Finnish geologists should go abroad to learn basic research.

After limits have been set to the expansion of the staff in the Geological Survey and due to the decline of the peat boom, and the cutting down of prospecting activities of the companies, the labour market situation of the students in geology radically deteriorated. The number of students in geology in universities was greater than the number of the all occupied members of the Finnish Association of Geologists at the beginning of the 1980s (cf table 10)!

Since major part of the research and education staff in the public sector are relatively young and the labour markets prospects in the private sector are neither good, the situation of young geologists and students of geology in Finland are not enviable. Chances in finding a permanent job are not at all great.

In the context of the shortage of facilities in the late 1970s, a discussion about the need of concentrating resources into two or three larger departments of geology began in Finland. The initiative stemmed from the University of Oulu whereas voices defending small departments of geology were heard from Turku. This discussion has well reflected the stakes of the issue: if a concentration will take place, Turku will be the obvious loser.

The exhaustion of mines has already started to reduce education facilities in Finland. Both mining schools have been closed. The education in mining engineering is facing with difficulties. The search for new labour markets for young mining engineers is paying special attention to such new fields such as rock caving, tunnelling, and construction and and engineering industry producing mining equipment. Because of pessimistic prospects of the mining industry, the Department of Mining and Metallurgy at the Helsinki University of Technology is experiencing certain difficulties in engaging new students.

The good shape of the basic metal industry thanks to its modern and efficient technology and qualified labour force is still keeping labour market prospects of metallurgists better than that of mining engineers. Again, the need to concentrate academic education and research in metallurgy has been stressed from the part of the University of Oulu, among others. The evident loser would be the Tampere University of Technology.

The extension of female students to the academic studies in geology, mining engineering and metallurgy did happen under unfavourable circumstances. Female geologists and engineers have experienced difficulties because of the traditional attitudes and labour market structures and, now, the cutthroat competition in the declining labour market is making their chances of advance still worse. The situation of young female engineers will be especially difficult.

The only sub-division in the mining sector which is still dynamic in Finland is the supplier sector. A good example of a recent dynamic interaction between university and enterprise is Larox Oy, a prominent producer of classification, concentration, and filtration equipment in Lappeenranta. When it was established in 1977 it used, among others, patents in concentration technics by R.T. Hukki, Professor of Concentration Technics at the Helsinki University of Technology and later on, it has entered in collaboration with the local Lappeenranta University of Technology (cf Raumolin 1986b).

As a response to new challenges, Outokumpu Oy has started a strong internationalization drive during the last few years by acquiring mines, basic metal works and electronics companies abroad. The leading supplier companies in Finland, such as Tamrock Oy or Larox Oy, are internationalizing their activities as well. This process is raising a need of qualified labour force capable of working abroad in Finland.

As the other governments in the West, the Finnish Government has started to promote research and development as means of preserving the competitiveness of the Finnish economy in the international markets in the 1980s. The possibilities of universities to engage research contracts have liberalized. One of the principal aims of the public research policy is promote new technics and new industries.

The ideas about the future of the education in the mining sector in Finland should of course depend on the development strategy selected for the sector. In the following, it has been taken for granted that the mining industry, the basic metal industry and the connected technological capability in Finland are worth of preserving and developing further.

The discussion about the prospects of geological education and research has mainly taken place among the profession itself. Professors in geology have generally shared the opinion according to which the reduction of the number of students would lead to loss of resources allocated to the departments and, consequently, to that of staff as well. A balance in the labour market will be found by itself in the long run. Tasks abroad, engineering geology, and environmental administration have presented as alternative occupations. In view of the competitive situation in the labour market in Finland and abroad these alternatives do not offer much for geologists provided with a normal education package.

The existence of several small departments and the competitive position among them make the idea of achieving good results by an academic self-regulation a little irrealistic. In view of rationalizing the higher education in geology, the need of creating strong centres of basic research should be taken into consideration as well.

The formation of two large departments would make the reduction of students as well as the organization of basic research much easier than the preservation of existing structures. The reorganization of higher education and research in geology should pay special attention of the establishment of a division of labour between the university departments and the Geological Survey as regards basic research and applied research. Sufficient resources and facilities to undertake basic research should be quaranteed to these "new" departments.

The Ministry of Education should establish a special committee to prepare alternative plans for reorganization of geological education and research in Finland. On the other hand, a complementary education and training programme should be established to train young geologists to alternative tasks in the labour market. If the closing of a mine leads to a retraining of miners, why not to apply the same principle to the case of geologists?

After the proposals of the Committee for Development of Declining Mining Communities have been put into action, few new ideas are needed in this sub-section. Alternative occupations have been created in the largest declining mining communities, and in general, miners have trained to new occupations.

Since the education and research in mining engineering should be preserved the Department of Mining Engineering and Metallurgy at the Helsinki University of Technology in spite of declining domestic job opportunities, a possibility to keep a stable student population would be the considerable increase of students from the developing countries. Special resources and facilities for this purpose should be organized. The adoption of English as a teaching language would also give to the Finnish students better chances to interntional tasks as before.

As the only possibility to preserve the competitiveness of the Finnish basic metal industry is the highly qualified labour force, technological sophistication and innovativeness, new "centres of excellence" in materials processing and metallurgy should be created

in Finland. A nucleus for the creation of such centres already exists in universities of technology especially in the Helsinki region.

In general, learning of foreign languages, studies abroad, and practice abroad should be stressed in the organization of future education in geology, mining engineering and metallurgy. Special resources and facilities should be offered to the universities for this purpose.

7. Conclusions

The fact that Finland provided with limited traditions in the mining industry and limited mining opportunities, has become a prominent nation in many fields of mining and metallurgical technics is a good indicator about the success of the education system in the mining sector in Finland.

The successfull adoptation of foreign technology and the creation of an appropriate domestic technology have been dependent on qualified labour force and expertise in Finland. The creation of appropriate domestic education system in geology took place at the beginning of this century whereas education in mining engineering and metallurgy took place abroad or by "learning by doing" up to end of the 1920s. A higher education in mining engineering and metallurgy was established in a decade a little later on. Professional education in mining engineering and metallurgy became appropriately organized after the War as well.

In the 1960s and 1970s, the strong expansion of universities started to provoke a certain conflict between intensive and extensive factors of higher education. On the other hand, the excessive stress on applied aspects of education and research led to a neglect of basic research in universities. In spite of resource limitations, especially the education in mining engineering and metallurgy kept on a high level, mainly due to the dedication of professors.

In the last few years, the exhaustion of mines and the lack of new ore discoveries of economic value as well as defavourable trends in the

international markets have posed new challenges to the education in the mining sector in Finland. New strong measures are necessary so as to preserve the positions that Finland had gained in the mining industry and the basic metal industries.

The development strategists of the Finnish education system, such as Eero Mäkinen, had a clear integrated vision on the development of the Finnish mining sector. Therefore, they were able to link the development of the education system consistently with the development needs of the mining sector. In fact, the practical realizations in Finland are quite similar as the models proposed by the development theorists an experts to the developing countries after the last World War (cf Raumolin 1984; 1986c).

Especially, the linkages between higher education and research in mining engineering and metallurgy, and the mining industries and the basic metal industries have been well established both on the national and on the regional level.

The importance of the symbolic values attached to the development of geology and metallurgy, such as nationalism and self-confidence, should not be underestimated in any analysis of the development of the mining sector in Finland. The mobilization of the population for ore hunting has had deep nationalist resonances as well.

Turning to a comparison between the Finnish case and the Japanese case, common to both has been a kind of intelligent followers' strategy for technological development in the mining sector including a pragmatic use of foreign expertise, the formation of high level

domestic expertise through education and practice abroad, the adoption of the most advances technology in building the basic metals industries, the building of the domestic education and research system and technological capability closely linked with the progress of the domestic mining and basic metal industries, by and by (cf Sen 1979).

Some further examples may illuminate parallel development characteristics. The copper industry has been directly linked to the advance of domestic electronics industry in Japan and in Finland. Japan was the first to adopt the Finnish flash-smelting method and has developed it further. Both countries were the first to adapt the advanced steel making methods in the 1960s. Both Japan and Finland started to penetrate to the world market of machinery and equipment to the mining industry, which had traditionally been dominated by British, German, American, and Swedish producers, in the 1960s (cf Raumolin 1986a; 1986c).

Since Japan has had great mining traditions and is a large country as compared with the small peripheral country Finland, the development of the Finnish mining sector seems to be a real miracle in the world economy of mining and basic metal products.

It was established at the beginning of this study, that minor attention has been paid to the role of education in the development of the mining sector in concrete case studies. The situation is the same as concerns some theories of decline of the mine. The Finnish case may be a good experiment field for the creation of a theoretical view on connections between the education and the decline of mining in the future (cf Aschmann 1970).

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Appendix 1.

The Decline of Mining in Finland at the Beginning of This Century

Metals

Iron Ore

The copper-iron ore in Pitkäranta was found in 1810. The business interest in St Petersburg started to exploit the copper in 1847. The company E.M. Meyer & Co from St Petersburg took control of mine in 1875. In the 1880s, new German and Swedish mining technology was introduced and exploitation of iron ore started. Another company from St Petersburg, Torgopromyslennoje Obsestvo Ladoga took control of the mine in 1896 and the company Aleksandrovskaja Staleliteinija continued the operations 1899. In this phase, a blast furnace was constructed in Pitkäranta. The operations were not, however, very profitable and the Imperial Russian Bank took control of the mine in 1903 closing it next year. The mine was sold to the British company United Mining and Financial Corporation Ltd in 1908 but it did not start exploitation and the mine was returned to the Imperial Bank in 1910.

The iron ore in Välimäki was found in 1885 and the Russian company with several interests in the iron industry in Finland, Putilovin Ruukkiyhtiö Oy started exploitation in 1889. Though modern German and Swedish mining technology was taken into operation, the mining was not very profitable and the mine was closed in 1907.

Non-Ferrous Metals

Finnish business interests established the gold mining company Ab Prospector in 1901 but, after some unsuccessful experiences in northern Finland, the company ceased its activities in 1903.

American businessmen of Finnish origin established the Finnish-American Mining Company in 1906 in order to exploit the old Orijärvi copper-zink-lead deposit by using modern British and American mining technology. They were, however, obliged to close operations in 1912.

Minerals

Limestone

The Finnish entrepreneur Karl Forsström created Förby Kalkbruks Ab in 1882 which started to exploit limestone deposits in Förby. He established a branch in Lohja which became a separated company Lojo Kalk Ab in 1897. He was involved with the creation of the company Ruskealan Marmori Oy which started large-scale limestone mining in Ruskeala in 1896. The Finnish company Pargas Kalkbergs Ab was established in Parainen in 1898.

Other Minerals

Suomen Asbesti Oy was founded in 1899 in order to exploit the asbestos deposits in Tuusniemi. This Finnish company was not, however, able to start production. Therefore, the mining rights were sold to the Danish multi-national engineering contractor and machine builder F.L. Smidth Co in 1907 but this company closed its operations in Finland in 1910.

Sources: E. Laine: Neljännesvuosisata maamme kaivostoimintaa 1885-1910 (Quarter of century of mining in Finland 1885-1910). Historiallinen Arkisto 55, 1955; E. Turunen: Orijärven kaivos 1757-1957 (The Orijärvi Mine 1757-1957). Vuoriteollisuus 15, 1957:2, 13-24; Y. Grönros: Suomen Mineraali Oy:n toiminnasta asbestialalla (The operations of Suomen Mineraali Ltd in asbestos industry). Vuoriteollisuus 14, 1956:1, 16-21.

Appendix 2.

Examples of Finnish Engineers with Foreign Education and Working Experience the Finnish Mining and Metallurgical Industry, 1900-1937

Albert Lindsay von Julin (1871-1944). Degree from Polytechnical Institute in Helsinki in 1894. Study of mining engineering in Royal University of Technology in Stockholm 1894-1896. Worked in the oil fields and plants of Nobel Brothers in Baku, Russia in 1896-1900. Engaged with the mechanical engineering company Fiskars Ab in Finland in 1900. Managing Director of the company since 1906.

Emil Sarlin (1875-1956). Degree from Polytechnical Institute in Helsinki in 1898. Study of mining engineering in Royal University of Technology in Stockholm 1898-1899. Worked in Geological Survey of Finland in 1900-1902. Chief engineer of the Finnish gold mining company Ab Prospector in 1902-1903. Engaged with Pargas Kalkbergs Ab in 1904. Managing Director of the company since 1906.

Georg Andersson (1885-1940). Degree from Polytechnical Institute in Helsinki in 1908. Designer in engineering industry in Finland and Russia in 1909-1911. Worked in steel industry in U.S.A. in 1911-1913. Technical Director of the French-Belgian steel company Société Russe de Fabrication de Tubes in Jekaterinoslov in Russia in 1914-1919. Technical Director of iron and steel company S:te A:me d'Escaut&Meuse in France in 1919-1921. Technical Director the mechanical engineering company of Åbo Järnmanufaktur och Vaggonfabrik Ab and the iron and steel company Ab Dalsbruk in Finland in 1921-1927. Associate Managing Director of the mechanical engineering company Ab Crichton-Vulcan in Turku in 1927-1930. Managing Director of Oy Vuoksenniska Ab since 1930.

Max Candelin (1886-1976). Degree from Polytechnical Institute in Helsinki in 1908. Worked in the mining industry in Kiiruna, Sweden in 1908-1912. Worked in the oil fields and works of Nobel Brothers in Baku and elsewhere in Russia in 1912-1921. Engaged with Pargas Kalkbergs Ab in Finland since 1922. Technical Director of the Parainen Works of the company a little later on.

Eero Mäkinen (1886-1953).Degree in geology from University of Helsinki in 1909. Assistent in Department of Chemistry and Department of Geology in Helsinki University and work in Geological Survey in Finland in 1909-1917. Doctor in geology in 1912. Study of mining engineering in Royal University of Technology in Stockholm in 1917-1918. State Geologist in Geological Survey of Finland in 1919-1921. Managing Director of Outokumpu Oy since 1921.

Gustav Wrede (1889-1958). Degree from University of Technology in Darmstadt, Germany in 1909. Work in the car industry in U.S.A. in 1910-1914. Technical Director in Åbo Järnmanufaktur och Vaggonfabrik Ab in Turku, Finland in 1914-1920. Managing Director of the mechanical engineering company Tykö Bruk Ab 1920-1922 and Ab Dalsbruk in 1922.

Eskil Strandström (1892-1971). Degree from Helsinki University of Technology in 1914. Worked in the mining industry in Russia in 1914-1923. Director of the Ojamo Mine of Lojo Kalkverk Ab in 1924.

K.I. Levanto (1895-1971). Degree from Helsinki University of Technology in 1919. Worked in General Electric Company in U.S.A. in 1921-1924. Electrical engineer of the pulp and paper company G.A. Serlachius Ab in Mänttä in Finland in 1924-26. Engaged with Outokumpu Oy since 1926. Director of the Outokumpu Mine in 1932.

Robert Alander	(1901-1978). Degree from Helsinki University of Technology in 1924. Worked in electrical power companies in Canada in 1925-1930. Process engineer in the Lappeenranta Works of Pargas Kalkbergs Ab in Finland in 1931.
John Ryselin	Degree from Helsinki University of Technology in 1930. Studies in metallurgy in U.S.A. in 1930-1932. Engaged with Outokumpu Oy since 1932. Assistent Technical Director of the Imatra Copper Refinery in 1935.
Kauko Järvinen	(1903-1980). Degree from Helsinki University of Technology in 1930. Study of mining engineering in Royal University of Technology in Stockholm in 1930-1931. Mining engineer of the Outokumpu Mine of Outokumpu Oy in 1931.

Sources: Anniversaries and obituaries in Teknologiska Föreningens Föredrag och Förhandlingar; Svenska Tekniska Vetenskapsakademi in Finland Föredrag och Förhandlingar and Vuoriteollisuus.

Appendix 3.

Main Mining Companies in Finland, 1918-1939

Non-ferrous Metals

Outokumpu Oy

Rich copper ore deposit was found in Outokumpu in 1910. The state which was responsible for exploration work and the owner of the ground, the private sawmill company Hackman & Co, established a joint company Ab Outokumpu Kopparverk to exploit the deposit in 1914. A new hydrometallurgical concentration method and a new electrical smelting method were adopted. This exploitation met, however, with many difficulties. Therefore, the owner of the patents of the new processes adopted, the Swedish engineer V. N. Hybinette in collaboration with Norwegian interests leased the mine in 1917-1918. Neither this experience was successfull. The Finnish state and Hackman & Co continued the operations of the mine 1918-1924 whereupon the Finnish state acquired the assets of Hackman & Co in Ab Outokumpu Kopparverk. A new state-owned company Outokumpu Oy started its activities in 1924. A rapid expansion of mining began in the late 1920s and a large copper smelter using electrical smelting method was constructed in Imatra at the beginning of the 1930s. The planning of the erection of a copper refinery and metal works in Pori was initiated in 1938.

Orijärvi Gruvaktie-bolag

The Swedish company Centralgruppens Emissionsaktiebolag in Stockholm took control of the Orijärvi mine in 1928 and established Orijärvi Gruvaktiebolag to carry on the exploitation. The exploitation started only in 1926 and, a little later, Ab Zinkgruvor from Falun, Sweden took control of the company. The introduction of new concentration technics, such as selective flotation, made it possible to carry on operations during all the 1930s.

Petsamon Nikkeli Oy

A considerable nickel deposit was detected in the Petsamo District in Finnish Lapland in 1921. The Finnish Government allotted a concession to exploit the deposit to Mond Nickel Co from London, a subsidiary of International Nickel Co from Toronto in 1934. A subsidiary company Petsamon Nikkeli Oy was established to carry on mining in Finland in 1936. After intensive geological investigations, mining development on a large scale was set up in 1938. The construction of a smelter destined to use new electrical furnace technics started in 1939.

Limestone and Minerals

Pargas Kalkbergs Ab - Paraisten Kalkkivuori Oy

The company erected the first cement factory in Parainen in 1913 and both the production of lime and cement expanded strongly during the interwar period. New mines were opened, for example, in eastern Finland.

Lojo Kalk Ab - Lohjan Kalkkitehdas Oy

The company built its first concrete factory in Lohja in 1918 and diversified the production to the direction of construction materials.

Karl Forsström Ab Förby Kalkbruks Ab became Karl Forsström Ab in 1915. The company specialized in the production of high quality lime and adopted, among others, underground mining methods.

Ruskealan Marmori Oy

Karl Forsström sold the company to the businessmen from Helsinki in 1910. A rapid expansion of mining of limestone started in 1920s mainly to supply the needs of the expanding pulp industry.

Suomen Mineraali Oy

Finnish businessmen established the company in 1917 to exploit feldspar and quartz resources in Finland. It also exploited pyrite ores to supply sulphur in the 1920s before Outokumpu Oy strongly expanded the production of the Outokumpu Mine. It took control of Suomen Asbesti Oy in 1917 and started to exploit asbestos deposit in Tuusniemi in the 1920s. An asbestos industry was created in Helsinki.

Sources: E. Turunen: Orijärven kaivos 1757-1957 (The Orijärvi Mine 1757-1957) Vuoriteollisuus 15, 1957:2, 13-24; Petsamon Nikkeli Oy: Special Issue. Vuoriteollisuus 3, 1945:1-2; Markku Kuisma: Kuparikaivoksesta suuryhtiöksi. Outokumpu 1910-1985. (From the copper mine to a big enterprise. Outokumpu Oy 1910-1985). Helsinki 1985; P. Nyström: Paraisten Kalkkivuori Oy 1898-1948. Helsinki 1951; V. Hoving: Lohjan Kalkkitehdas 1897-1950. Helsinki 1952; B. Saarmaa: Karl Forsström Ab - 100 vuotta. Vuoriteollisuus 31, 1983,2, 120-23; P. Suoninen (ed.). Ruskeala. Ruskealan pitäjän muistokirja. Joensuu 1964; Y. Grönros: Suomen Mineraali Oy:n toiminnasta asbestialalla (The operations of Suomen Mineraali Ltd in asbestos industry). Vuoriteollisuus 14, 1966:1, 16-21.

Appendix 4.

The Development of Higher Education in Geology in Finland:

Chairs in Universities

University of Helsinki (UoH).	University of Turku (UoT)
Helsinki University of Technology (HUoT)	University of Oulu (UoO)
Åbo Akademi (ÅA)	Tampere University of Technology (TUoT)

Chair in geology and mineralogy established at UoH in 1852 (1).

L.H. Borgström appointed to extraordinary professor of mineralogy at UoH in 1918. He retired in 1946.

Chair in geology and mineralogy established at ÅA in 1918 (1).

Permanent lecturship in geology and mineralogy established at HUoT in 1922.

Post of nonpermanent professor in geology and mineralogy established at UoH in 1924.

Lecturship in geology and mineralogy at HUoT changed into full chair in 1937. Changed into chair in economic geology in 1968. (1).

Post of nonpermanent professor in geology and mineralogy changed into full chair at UoH in 1940 (2).

G.E. Pehrman appointed to extraordinary professor of crystallography and mineralogy at ÅA in 1941. He became full professor in geology and mineralogy at ÅA in 1953.

Post of associate professor of geology and mineralogy established at UoH in 1942 (3).

T.G. Sahama appointed to extraordinary professor of geochemistry at UoH in 1946. He retired in 1977.

K. Rankama appointed to extraordinary professor in mineral chemistry at UoH in 1950. He retired in 1980.

A. Metzger appointed to extraordinary professor of general and applied geology at ÅA in 1953. He retired in 1965.

Chair in geology and mineralogy established at UoT in 1958 (1).

Chair in geology and mineralogy established at UoO in 1961 (1).

Post of associate professor of geology and palaeontology established at UoO in 1962 (2).

Post of extraordinary professor of general and applied geology changed into full professor of applied geology and mineralogy in ÅA in 1966 (2).

Chair in Quaternary geology established at UoT in 1966 (2).

Post of associate professor of geology and mineralogy established at UoO in in 1967 (3).

Post of associate professor of engineering geology established at TUoT in 1967 (1).

Chair in geology and mineralogy changed into that of economic geology at HUoT in 1968.

Chair in Quaternary geology established at UoO in 1970 (4). Post of associate professor in geology and palaeontology changed into that of Quaternary geology.

Post of associate professor of geology and mineralogy established at UoT in 1971(3).

B. Kurtén appointed to extraordinary professor of palaeontology at UoH in 1972.

Post of associate professor of geology and palaeontology established at UoH in 1972 (4).

Post of associate professor of Quaternary geology established at UoT in 1973 (4).

Post of associate professor of geology and mineralogy established at UoH in 1974 (5).

Post of full professor of applied geology and mineralogy changed into that of associate professor of geology and mineralogy at ÅA in 1978.

Post of associate professor of geochemistry established at UoO in 1981 (5).

Post of associate professor of geophysics established at HUoT in 1982 (2).

Source: Data based on I. Haapala : The history of geology teaching at Finnish universities. Geological Survey of Finland. Bulletin 336, 1986,299-343.

Appendix 5.

The Development of Higher Education in Mining Engineering and Metallurgy in Finland: Chairs in Universities

Helsinki University of Technology	University of Oulu (UoO) Tampere University of Technology (TUoT)
Permanent lectureship in geology and mineralogy established in 1922.	
Permanent education in mining engineering and metallurgy started in 1937.	
Lectureship in geology and mineralogy changed into full chair in 1937 (1).	
Chair in mining engineering established in 1937 (2).	
Permanent lectureship in metallurgy established in 1937.	
Lectureship in metallurgy changed into full chair in 1940 (3).	
Chair in physical metallurgy established in 1945 (4).	
Chair in concentration technics established in 1945. Changed into that of mineral processing in 1977 (5).	
Department of Mining and Metallurgy established in 1947.	
Chair in physical metallurgy established in 1963. Changed into that of metal working and heat tratment in 1972 (6).	Chair in physical in physical metallurgy established in UoO in 1963 (1).
Chair in applied process metallurgy established in 1969 (7).	Chair in materials science established in TUoT in 1969 (1).
Post of associate professor in physical metallurgy established in 1970 (8).	

Post of associate professor of corrosion prevention established in 1972. Changed into full professor of corrosion engineering in 1984 (9).

Post of associate professor of process metallurgy established in 1973 (10).

Post of associate professor of physical metallurgy established in UoO in 1977 (2).

Post of associate professor of geophysics established in 1982 (11).

Post of associate professor of materials science established in TUoT in 1982 (2).

Sources: Satu Sarkola: Research Note. Department of Mining Engineering and Metallurgy. Helsinki University of Technology 3.10.1986; interviews.

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