Fathi Habashi

My Trips in
Scandinavia

2015

My Trips in Scandinavia

Volume derived from

Fathi Habashi

Department of Mining, Metallurgy, and Materials Engineering
Laval University, Quebec City, Canada

2015

The Book

The present volume is derived from *De Re Metallica. A Metallurgist on the Move*, which is a diary of the trips the author has undertaken during his professional career. He visited many industries, universities, research centres, and museums and participated in many conferences. The book therefore reflects the state of extractive metallurgy since he left his home country Egypt and went to study in Vienna. *De Re Metallica* is in seven volumes fully illustrated mainly by coloured photographs. It includes a short history of the place visited and its main sightseeing sites. Volume 1 Egypt, Volume 2 Canada, Volume 3 United States, Volume 4 Latin America, Volume 5 Asia [in two parts], Volume 6 Europe [in two parts], and Volume 7 Russia & other countries. Total number of pages was 5500.

Since these volumes could not be separated and therefore they will not be available to many readers, I decided to split the book into selected 29 small units, each representing one country or a group of countries closely related geographically. The present volume is one of these volumes.

The Author

Fathi Habashi, Professor Emeritus at Laval University in Quebec City. He holds a B.Sc. degree in Chemical Engineering from the University of Cairo, Dr. techn. degree in Inorganic Chemical Technology from the University of Technology in Vienna, Dr. Sc. *honoris causa* from the Saint Petersburg Mining Institute, Dr. *h.c.* from National Technical University in Lima, and Dr. *h.c.* from San Marcos University also in Lima. He held the Canadian Government scholarship at the Mines Branch in Ottawa, taught at Montana College of Mineral Science & Technology, then worked at the Extractive Metallurgical Research Division of Anaconda Company in Tucson, Arizona, before joining Laval in 1970. His research was mainly directed towards organizing the unit operations in extractive metallurgy and putting them into a historical perspective.

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To Nadia,
Hani, and Hatem
with love

Other Books by the Author

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Technical

F. Habashi, *Principles of Extractive Metallurgy*:
- Volume 1: General Principles (422 pages), 1969 (reprinted 1980) (out of print), Gordon & Breach Science Publishers.
- Volume 2: Hydrometallurgy (468 pages), 1970 (reprinted 1980) (out of print), Gordon & Breach Science Publishers.
- Volume 3: Pyrometallurgy (493 pages), 1986 (reprinted 1992) (out of print), Gordon & Breach Science Publishers.
- Volume 4: Amalgam and Electrometallurgy (380 pages), 1998.

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F. Habashi, *Pressure Hydrometallurgy*, 2014, 242 pages.
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F. Habashi (editor), *Gellert's Metallurgic Chymistry*, 1998, 500 pages.
F. Habashi, D. Hendricker, C. Gignac, *Mining and Metallurgy on Postage Stamps*, 1999, 335 pages.
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Preface

De Re Metallica. A Metallurgist on the Move is a diary of the trips the author has undertaken during his professional career. He visited many industries, universities, research centres, and museums and participated in many conferences. The book therefore reflects the state of extractive metallurgy since he left his home country Egypt and went to study in Vienna. The book is in seven volumes fully illustrated mainly by coloured photographs. It includes a short history of the place visited and its main sightseeing sites. Volume 1 Egypt, Volume 2 Canada, Volume 3 United States, Volume 4 Latin America, Volume 5 Asia [in two parts], Volume 6 Europe [in two parts], and Volume 7 Russia & other countries. Total number of pages was 5500.

Since these volumes could not be separated and therefore they will not be available to many readers, I decided to split the book into selected 28 small units each representing one country or a group of countries closely related geographically as shown below.

1	Arab Countries	Jordan, Kuwait, Morocco, Syria, Tunis
2	Austria	
3	Australia & Southeast Asia	Australia, Cambodia, Indonesia, Malaysia, Philippines, Thailand, Vietnam
4	Balkans	Albania, Bosnia, Bulgaria, Croatia, Greece, Romania, Serbia, Slovenia
5	Baltic Countries	Latvia, Lithuania, Poland
6	Brazil	
7	Canada	
8	Caribbean	Cuba, Puerto Rico, Venezuela
9	Caucasus	Armenia, Azerbaijan, Georgia
10	Central Asia	Afghanistan, Kazakhstan, Mongolia, Uzbekistan
11	Central Europe	Czech Republic, Slovakia, Hungary, Switzerland
12	Chile and Argentina	
13	China	
14	Egypt	
15	England and France	
16	Germany	
17	Iberian Peninsula	
18	India	
19	Italy and Vatican	
20	Japan and Korea	
21	Low Countries	

22	Mexico	
23	Middle East	Iran, Turkey
24	Peru and Bolivia	
25	Russia	
26	Scandinavia	
27	South Africa	
28	USA	

I hope in this way the book will available to a large number of readers.

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Historical Introduction

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The history of Denmark, Sweden, Norway, and Finland is so closely related that they are altogether known as Scandinavia (Figure 1.1). They all mainly confess the Lutheran faith and their flags are very similar (Figure 1.2). Russia also played an important role in the history of this region by occupying Finland. Mitsommardag is a common and important holiday for the Scandinavians — the shortest night of the year [June 23]. During the Nazi occupation of Denmark and Norway tens of thousands sought refuge in Sweden.

Figure 1.1: Scandinavian countries.

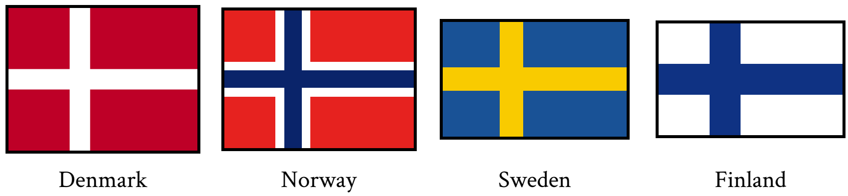

Figure 1.2: Flags of the Scandinavian countries.

Denmark

The Danes are of Teutonic origin. At the time of the Roman Empire, they had a form of clan government. In the 5th century AD, the Angles and Jutes of Denmark invaded England, and the mixture of groups made the composite from which modern Englishmen are descended. During the 9th century the Danes, also known as Norsemen and Vikings, took a leading role in the raids on England, France, and Spain. In France, they concentrated their efforts on the area near the Seine River, which became the Duchy of Normandy, and eventually Normandy was created. Alfred the Great surrendered a portion of eastern and north eastern England to the Danes. Canute II, who reigned from 1014 to 1035, united Denmark, England, and Norway under his rule; the southern part of Sweden was part of Denmark until the 17th century. After his death in 1035, the empire fell.

Norway

The rule of Norway alternated between the Danish and the Swedish kings for many centuries until 1815 when it was transferred to Sweden by the foreign powers at the Congress of Vienna after the fall of Napoleon. However, the Norwegian people did not recognize the Swedish king who was imposed on them. In 1905, they dissolved union with Sweden and invited Prince Christian, son of Frederick VIII, the king of Denmark, to be their king as Håkon VII. He was married to Princess Maud, the daughter of Edward VII, king of Britain.

Håkon's son, Olav, was married to Princess Martha, daughter of Prince Carl, son of Oscar II, king of Sweden. He ascended to the throne as Olav V after the death of his father in 1957. When King Olav died in 1991, he was succeeded by his son, the present King Harald.

Norway produced the playwright Henrik Ibsen (1828–1906), and the composer Edvard Grieg (1843–1907).

SWEDEN

During the reign of Canute IV between 1182 and 1202, Pomerania and Mecklenburg were conquered. Later kings conquered Holstein. When King Waldemar IV died with no male heir, his daughter Margaret, who had married Håkon VI of Norway, ruled as regent for her son, Olaf II. When Olaf died in 1387, Margaret secured her position as a Swedish sovereign, having already been recognized as Queen of Norway and Denmark. In 1397, the kingdom became known as the Union of Kalmar named after the Swedish town where the document was signed.

In 1448, the Danish Diet elected Christian I, Count of Oldenburg, to the throne. His family ruled Denmark for over four centuries. He founded Copenhagen University in 1479. In 1520, Christian II proclaimed himself King of Sweden at Stockholm and ordered the massacre of anti-Danish nobles. This led to the successful uprising of Sweden in 1523 under Gustavus Vasa, who became King Gustav I. The conflict, however, continued for about two centuries but from this time on Sweden rose and became a great power.

When Frederick I (1471–1533) came to the throne in 1523 the first signs of Reformation began to appear. After Frederick's death, Catholic strength in the Danish parliament temporarily increased and an attempt to prevent the accession in 1533 of the protestant Prince Christian (1503–1559) led to civil war. The war ended with the surrender of Copenhagen to Christian's Protestant army in 1536.

During the reign of Christian IV (1588–1648), the Danish East and West Indies companies were founded, the navy and merchant fleets were modernized, and Denmark started to acquire colonies. The capital city, Oslo, was destroyed by fire in 1624. It was re-built during his reign and called Kristiania until 1925. Christian IV also founded Kristiansand, which became an important port. Under Frederick III (1609–1670) the monarchy was strengthened and made hereditary in 1665. He weakened the nobility by recruiting his immediate advisers from German families.

Denmark was punished for her support of Napoleon by the Treaty of Kiel in 1814 with the loss of the rule of Norway to Sweden. When in 1863, the direct male line of the house of Oldenburg became extinct with the death of King Frederick VII, the crown of Denmark was held by Prince Christian of Schleswig–Holstein. After World War I, northern Schleswig voted for Danish rule while southern Schleswig preferred incorporation with Germany.

FINLAND

A small peaceful country called Suomi by the natives, that is Finnish for Finland, had a turbulent history. However, she was capable of producing the famous chemist Johan Gadolin (1760–1852), the famous composer Jean Sibelius (1865–1957) as well as a large number of distinguished metallurgists.

Until 100 AD, the territory of Finland was sparsely inhabited by the Lapps, a nomadic tribe of Mongolian origin. Between 100 and 800 AD, Finno-Ugric people arrived from the southern shores of the Gulf of Finland and from the Ural. These forced the Lapps to retreat to the north. From the eleventh century onwards, Swedes also began to settle along the western and southern coasts of Finland. During the Napoleonic Wars, Russia seized Finland and in 1809 it became a Grand Duchy of the Russian Empire.

During the Swedish rule, Turku (called Abo in Swedish) was the capital of Finland, and Swedish was the official language. During the Russian domination, the capital was moved to Helsinki (Helsingfors in Swedish) in 1812. Finnish, in addition to Swedish, became an official language in 1863. However, under Nicholas II in 1900, Russian language was imposed, later the autonomy status was dissolved and the country suffered from repression. With German help, a secret liberation force was formed during World War I. After the collapse of the czarist regime in Russia and widespread turmoil, Finland declared its independence on December 6, 1917. Finland had its own civil war in 1918 between those who supported a socialist system such as that emerging in Russia and those who favoured a European style democracy. There was a project to invite a German prince to become a king of Finland but the project was abandoned and a republic was installed when Germany lost the war.

At the beginning of World War II, the Soviets occupied parts of Finland. These, however, were regained a few years later with German help when Finland entered the war as an ally of Germany in 1941. When, however, the Germans were defeated in the war, Finland had to yield the territory she had won back, together with the Petsamo Peninsula (Figure 1.3), and to pay a high war indemnity amounting to nearly half of the country's annual income.

At present, the country has two official languages: 93.6% of Finns speak Finnish as a mother tongue and some 6% are Swedish-speaking. A Western democracy, Finland elects a President every 6 years. The feudal system never existed in Finland, and agriculture has throughout the ages been almost entirely in the hands of independent peasant proprietors. The majority of Finns belong to the Lutheran Church. The Finnish language has been traced to a region beyond the Ural Mountains in Russia. Finnish belongs to the Finno-Ugric language group along with Hungarian. The Estonian language is its closest relative.

Figure 1.3: Map of Finland showing the location of Petsamo in the north.

MINING AND METALLURGY

Table 1.1: Visits to Scandinavian countries.

Dates	Cities	Purpose of visit
October 1977	Helsinki	Helsinki Institute of Technology
	Pori	Outokumpu Research
	Harjavalta	Outokumpu flash smelting
June 1980	Stockholm	Visiting Professor Gotthard Björling at home
May 1981	Stockholm	Short course on hydrometallurgy
	Uppsala	Cultural visit
	Falun	Cultural visit
	Helsingborg	Boliden sulfuric acid plant
	Höganäs	Iron powder production
	Oslo	Cultural visit
	Persegrunn	Norsk Hydro fertilizer plant
	Trondheim	Norwegian Institute of Technology
May–July1990	Copenhagen	Cultural visit
	Stockholm	Lecturing at Royal Technical University
	Ytterby	Cultural visit
	Skelleftehamn	Visit to Boliden's Rönnskär Works

Dates	Cities	Purpose of visit
May 2–June 16, 1993	Helsinki	Helsinki Institute of Technology
	Pori	Outokumpu Research
October 2003	Stockholm	Seminar at Royal Technical University
	Luleä	Visit and seminar at Luleä University

Figure 1.4: Map showing location of important mines and metallurgical plants [E&MJ, 2012].

Chapter 2

Denmark

Copenhagen was the usual stop when flying to Scandinavia. As a result, a three-day sightseeing visit was planned during a trip to Stockholm in 1990. The City was found to be an interesting place with many monuments (Figures 2.1–2.4).

Figure 2.1: A general view of Copenhagen.

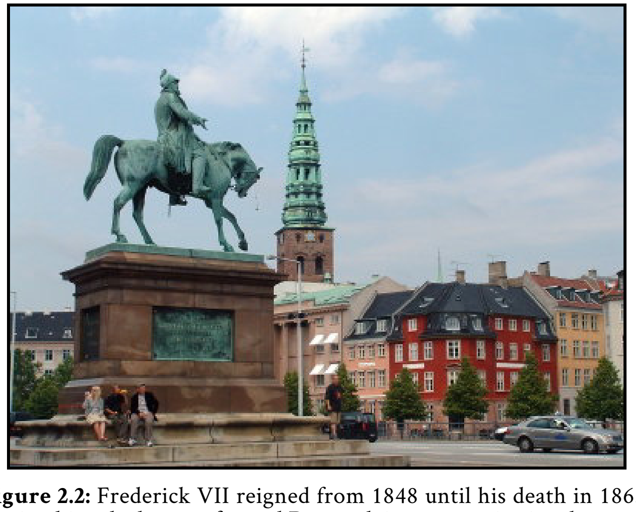

Figure 2.2: Frederick VII reigned from 1848 until his death in 1863. During his rule, he transformed Denmark into a constitutional monarchy. He was the most beloved Danish Kings.

Figure 2.3: The mermaid.

Figure 2.4: Hans Christian Andersen (1805–1875), the story teller.

Chapter 3

Norway

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Mining and Metallurgical Industries

Norway was rich in natural resources. In 1623, masses of native silver weighing over 180 kg were discovered in a locality on the Lagen River south west of Oslo which later became known as Kongsberg (Figure 3.1). In 1757, a mining academy was founded in Kongsberg by Frederick V (1723–1766), king of Denmark and Norway, who ruled from 1746 until his death in 1766. In 1770, Kongsberg became the second largest city in Norway and the first Norwegian centre of academic life, the precursor of today's University of Oslo, which was opened in 1813.

In 1834, an important library and mineral collection was founded. The Library was moved in 1963 to the University of Oslo after closing the mines, while the mineral collection is now part of the Mining Museum in Kongsberg.

Norway was one of the first producers of chromium salts. Chromite ore was mined and exported from 1818 to 1904. The major producer of chromite ore was Feragen near Røros. Vanadium was produced from the iron–titanium–vanadium mine at Rødsand. Molybdenite was produced from 1885 to 1973 from the Knaben deposit located 100 km southeast of Stavanger, the only European source of the mineral. Cobalt ore was mined in the first half of the nineteenth century in the Modum district near Hønefoss, where it was chiefly used for colouring glass and porcelain. The industry, however, was abandoned in 1898 when synthetic ultramarine was discovered.

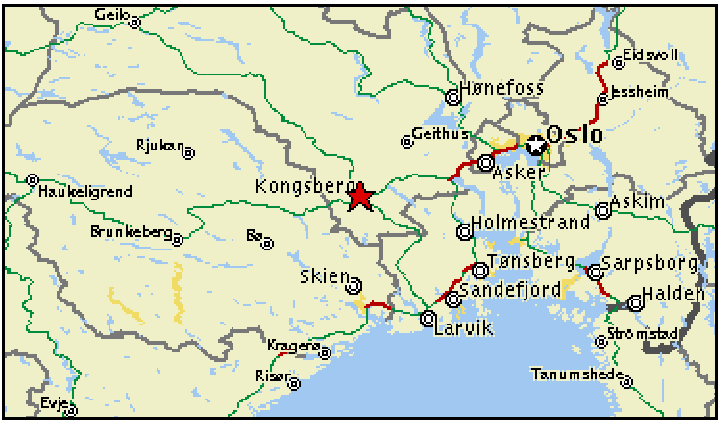

Figure 3.1: Location map of Kongsberg.

In the beginning of the 1860s, the Norwegian chemical industry started using pyrite as a raw material for making sulfuric acid. It has been the most important single factor for the prosperity of the mining industry In 1904, Orkla Grube-Aktiebolag took over the mines, which were initially worked for copper, and developed what became known as the Orkla process for producing elemental sulfur and copper matte in a shaft furnace (Figure 3.2). The process was adopted later in Sweden, Portugal, Spain, and Russia.

In 1870, Norway had 40 nickel mines and seven smelters in operation and produced 75% of the world's nickel at the turn of the century. One of the major mines was the Flat mine at Evje at the southern tip of the country near Kristiansand which remained in operation until 1946. Kristiansand was an established trade and industrial centre with close links to markets outside of Norway. In 1910, a small group of businessmen and engineers formed Kristiansand Nikkelraffinerings Verk which was purchased in 1929 by the Canadian mining company Falconbridge Nickel Mines, after the discovery of major nickel deposits in Sudbury, Canada, where the need arose for a refinery to produce pure nickel from the matte.

In 1887, Borgestad Fabrikker was founded by ship owner and later prime minister of Norway, Gunnar Knudsen, as a brick works. A few years later, fire bricks were produced from the rejected material of the Porsgrunn Porcelain Factory. After the turn of the century, the company specialized only in the production of fire bricks and, in 1903, supplied the necessary bricks for the Birkeland-Eyde furnaces. After World War II, the company produced silicon carbide and became a large supplier of refractories world wide.

The winter is said to be reasonable because of the Gulf Stream. Power in Norway is 100% hydroelectric; only in off-shore operations where petroleum is exploited, gases are used as fuel.

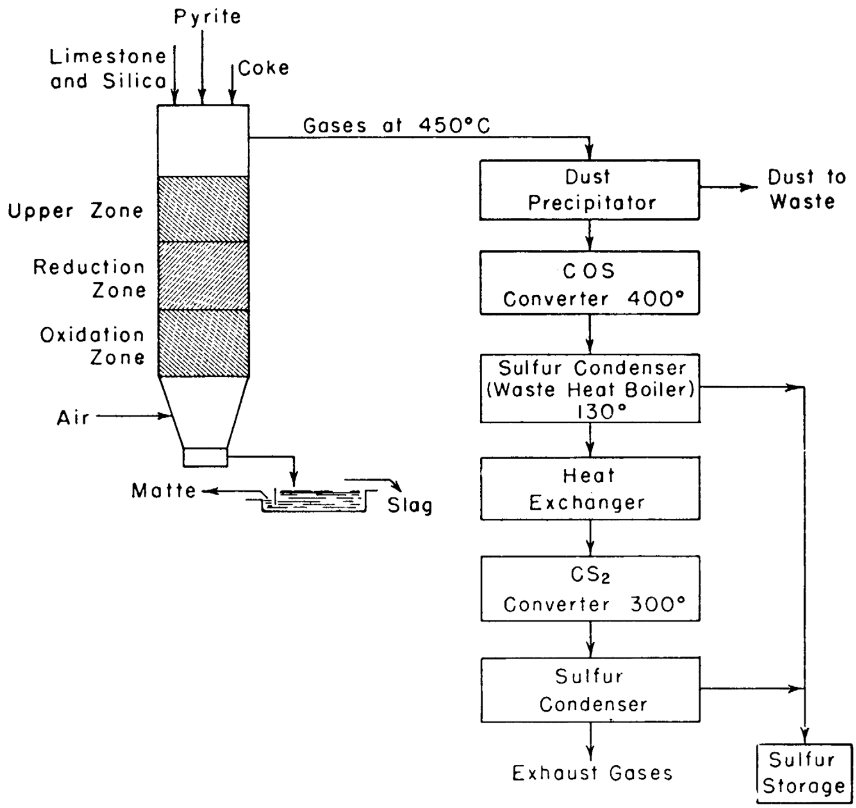

Figure 3.2: Orkla process.

Oslo

After being destroyed by a fire in 1624, Oslo was moved closer to Akershus Castle during the reign of King Christian IV and re-named Christiania in his honour. After independence the original name was restored. The city (Figures 3.3–3.8) has many monuments, parks, and museums. The Nobel Peace Centre celebrates the famous men and women who have won the Nobel Peace Prize.

Figure 3.3: General view of Oslo.

Figure 3.4: Fountain.

Figure 3.5: Oslo City Hall.

Figure 3.6: Statues in front of City Hall.

Figure 3.7: Norwegian Parliament known as Storting is responsible for nominating the Nobel Peace Prize winners. At the time of Alfred Nobel, Norway was part of Sweden.

Figure 3.8: Royal Palace.

History Museum

The History Museum (Figure 3.9) shows Norwegian antiquities from the Stone Age to the Middle Ages including Viking Age and Medieval collections. The Collection of Coins and Medals displays Norwegian coins and bank notes.

Figure 3.9: History Museum, Oslo.

Viking Ship Museum

The Viking Ship Museum was created to display finds that were discovered at the end of the 19th and the beginning of the 20th century. The Viking were the Norse explorers, warriors, merchants, and pirates who raided, traded, explored and settled in wide areas of Europe, Asia and the North Atlantic islands from the late 8th to the mid-11th century. They used special ships (Figures 3.10–3.11) to travel as far east as Constantinople and the Volga River in Russia, and as far west as Iceland, Greenland, and Newfoundland, and as far south as Al-Andalus.

Figure 3.10: Viking ship.

Norway's Resistance Museum

The museum collection focuses on Norwegian resistance during the occupation of Norway by Nazi Germany from 1940 to 1945. The museum displays equipment, photos and documents from the war years. The royal family escaped to Britain while Vidkun Quisling (1887–1945), the Norwegian leader of the Nazi Party, was appointed Prime Minister. At war's end he was condemned to death as a traitor.

Technical Museum

The Norwegian Museum of Science, Technology, and Medicine relates the development of these sectors in the country. Among the interesting stories is the fixation of atmospheric nitrogen in 1903 using the electric arc furnace by the scientist Kristian Olaf Birkeland (1867–1917) and the engineer and industrialist Samuel Eyde (1866–1940) founder of Norsk Hydro and Elkem (Figures 3.12–3.13). The process was displaced by the Haber–Bosch ammonia method in 1929. Incidentally, the 200 Kroner show a picture of Birkeland (Figure 3.14).

In 1917, Elkem purchased the first ferroalloy plant and Søderberg electrodes were introduced to the aluminum industry.

Figure 3.11: Viking ship.

Figure 3.12: Kristian Olaf Birkeland (1867–1917), painting at the Technical Museum.

Figure 3.13: Samuel Eyde (1866 –1940), painting at the Technical Museum.

Figure 3.14: 200 Norwegian Kroner.

Viegland Park

Viegland Park is devoted to the Norwegian sculptor Gustav Vigeland (1869–1943), the most prolific sculptor of all time. He focused on innovative realism and on the human body creating about 1 600 sculptures (Figures 3.15–3.23). He received technical training from the renowned Norwegian sculptor Brynjulf Bergslien. Having won a prize for one of his early works he got a stipend to go to Copenhagen to study under another prominent sculptor Vilheim Bissen. He then took advantage of government funding to go to Paris to continue his studies. There, he often visited the studio of Auguste Rodin and was influenced by his methods and motifs. However, he never met the master sculptor. In 1895 he went to Berlin and then visited the major European capitals.

Figure 3.15: Viegland Park.

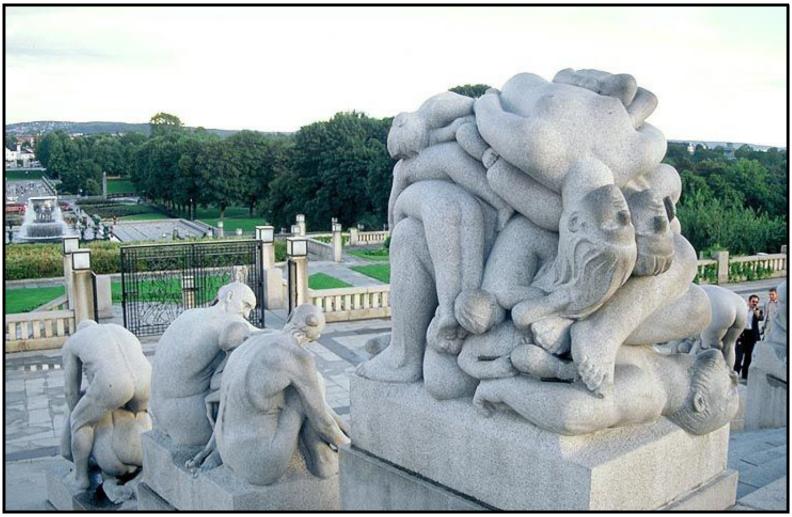

Figure 3.16: Viegland Park.

Figure 3.17: Viegland Park.

Figure 3.18: Viegland Park.

Figure 3.19: Viegland Park.

Figure 3.20: Viegland Park.

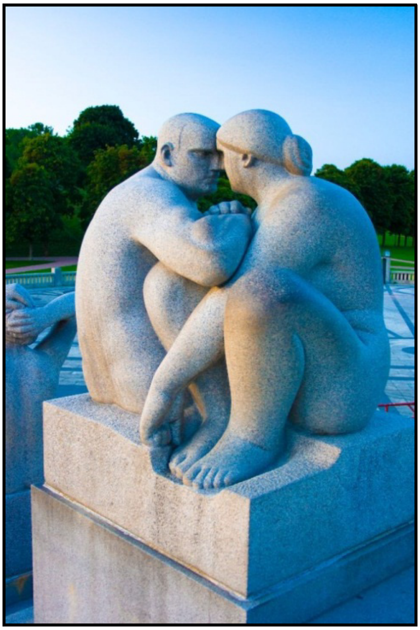

Figure 3.21: Viegland Park.

Figure 3.22: Viegland Park.

TRONDHEIM

The settlement founded in 997 as a trading post was the capital of Norway during the Viking Age until 1217. Today it is the third most populous municipality in Norway after Oslo and Bergen (Figure 3.24).

Figure 3.23: Viegland Park.

Figure 3.24: View of Trondheim.

Norwegian Institute of Technology

The Norwegian Institute of Technology (Figure 3.25) was founded in 1910. It is well known to extractive metallurgists through the works of Prof. Terkel Rosenqvist at the Department of Metallurgy (Pyrometallurgy), Prof. Grjotheim at the Chemistry Department (Electrometallurgy), and Prof. Gunnar Thorsen at the Chemical Engineering Department (Hydrometallurgy). Prof. Thorsen is studying the dissolution of zinc oxide in a kerosene solution of the carboxylic acid, versatic acid. Zinc is then stripped from the organic phase by H_2SO_4 and the resulting $ZnSO_4$ is electrolysed.

PORSGRUNN

Porsgrunn is nearly half way between Oslo and Kristiansand (where Falconbridge Nickel Refinery is situated). It is home to one of the main Norsk Hydro plants (Figure 3.26). The visit to the plant was in company of Hans Rosendahl (Licensing Department, Head Office in Oslo).

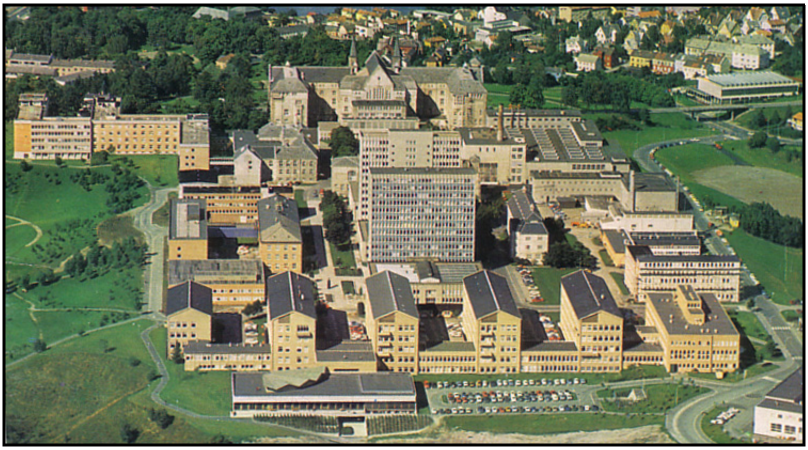

Figure 3.25: Norwegian Institute of Technology.

Norsk Hydro

Norsk hydro-elektrisk Kvælstofaktieselskab (Norwegian hydro-electric Nitrogen Limited) is Norway's largest chemical and metallurgical enterprise. It was founded by Samuel Eyde in 1905 to exploit the novel technology for fixing nitrogen from air developed by the Norwegian scientist Kristian Birkeland. The process, known as the Birkeland–Eyde process, required large amounts of electric energy. For this reason hydroelectric power plants were built. The largest was at Rjukan waterfalls (Figure 3.27).

Norsk Hydro

Bygdøy allé 2
Oslo 2

TERMS OF VISIT

1. The visitor shall at all times be accompanied by a guide and follow his instruction as to the visit.

2. The visitor agrees to keep secret and not to use without Norsk Hydro's written permission, any information disclosed to him during the visit, directly or indirectly (e.g. by demonstration of machines, process equipment, etc.) including the visitor's visual observations.

3. The visitor is not allowed to:
   - come close to or touch machines, appliances and installments;
   - carry cameras without prior authorization:
   - take photographs or films or make measurements, drawings or sketches.

4. The visit is on the visitor's full responsibility.

-------o-------

The undersigned visitor: F. Habash
Name of employer: Laval University, Quebec City CANADA

hereby accept the above terms for a visit to

visit nitrophosphate plant Date of visit: 25/5/1981
Object of visit.

Oslo, ____________________
Place and date of signature.

____
Visitor.

Figure 3.26: Protocol of the visit to Norsk Hydro plant in Porsgrunn on May 25, 1981.

Figure 3.27: Norsk Hydro Rjukan hydroelectric power plant with a statue of Samuel Eyde.

However, by 1920s, the technology was no longer able to compete with the newly developed Haber–Bosch process, and in 1927 the company formed a partnership with the German company IG Farben to produce synthetic ammonia by Haber–Bosch process. The plant used Pelton wheel to recover energy from the pressurized solutions (Figures 3.28–3.29). Hydrogen was produced by the electrolysis of water. In 1934, Norsk Hydro built the first commercial heavy water plant with a capacity of 12 tons per year as a by-product of the water electrolysis.

Norsk Hydro produces aluminum, magnesium, acids, fertilizers, plastics, and other products (Figure 3.30). The magnesium plant is tied to polyvinyl chloride plant: HCl from polyvinyl chloride is used to dissolve MgO, and Cl_2 formed during electrolysis of $MgCl_2$ is used to chlorinate ethylene to form polyvinyl chloride and HCl. Nitric acid made by oxidation of NH_3 is used to dissolve phosphate rock to make nitrophosphate fertilizers (Figure 3.31).

Figure 3.28: Ammonia synthesis plant showing the pipes carrying the pressurized solution to the top of the mountain then descending to drive the Pelton wheel to recover the energy.

Figure 3.29: Model of a Pelton wheel.

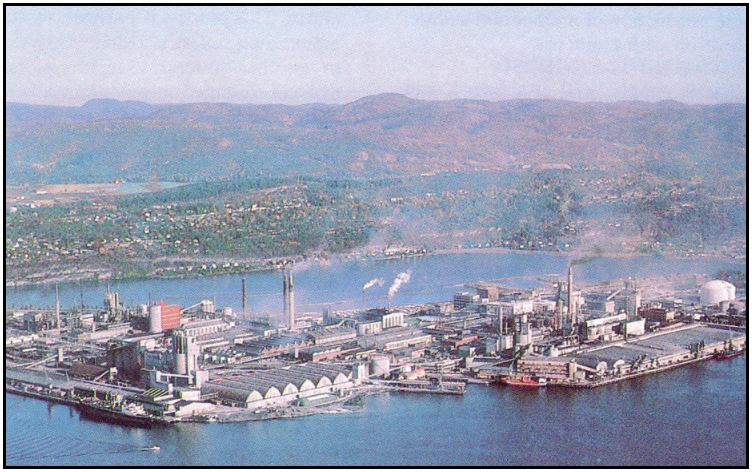

Figure 3.30: View of Porsgrunn Norsk Hydro plant.

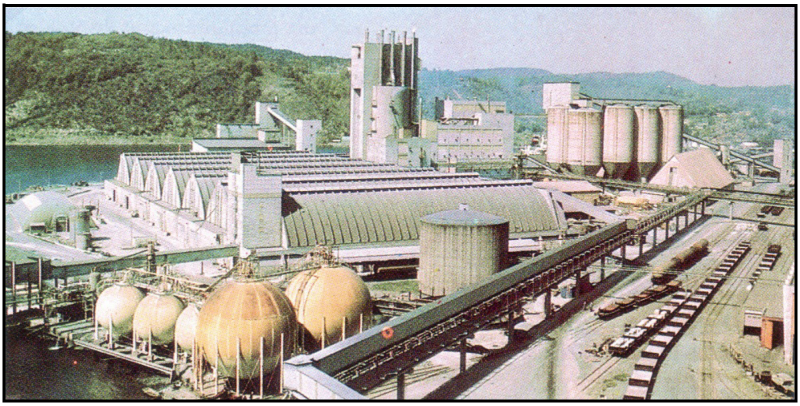

Figure 3.31: Norsk Hydro fertilizer plant.

In this process (Figure 3.32), phosphate rock is dissolved in concentrated nitric acid. After filtration to remove undissolved sand, the solution is cooled to crystallize calcium nitrate tetrahydrate, which is then filtered off (Figures 3.33–3.34). It is treated with ammonium carbonate to form calcium carbonate and ammonium nitrate. This step is necessary because calcium nitrate is hygroscopic and is difficult to handle. The nitrophosphate solution is then treated by ammonia to produce ammonium phosphate fertilizer.

The Nitrophosphate Plant and the Research Department were visited. Discussions were held with the following: Trygve Heggebø (Manager, Fertilizer R & D), Gløt Mejdell (Manager, Chemical Engineering R & D), and Arne Sletholt (Manager, Complex Fertilizer Section).

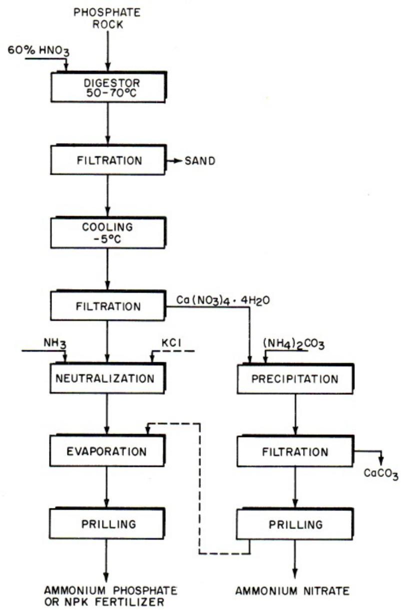

Figure 3.32: Flowsheet for the production of ammonium phosphate fertilizers by nitric acid.

Figure 3.33: Cooling vessels to crystallize calcium nitrate tetrahydrate.

Figure 3.34: Filtration of calcium carbonate.

Chapter 4

Sweden

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Swedish chemists were the most active chemists in Europe in the 18th and 19th centuries. They discovered 22 elements — the largest number ever discovered in a single country (Table 4.1). Two of the most well known figures are Carl Wilhelm Scheele (1742 –1786) (Figure 4.1) and Jöns Jacob Berzelius (1779 –1848) (Figure 4.2).

Alfred Nobel (1833–1896) (Figure 4.3), the inventor of dynamite, accumulated great wealth. His will directed his fortunes to be used to establish a foundation that awards a yearly prize in the areas Physics, Chemistry, Physiology and Medicine, Literature, and Peace. The Nobel Prize ceremonies are held in Stockholm on December 10 each year the date of his death. The ceremony for the for peace prize is held is, however, held in Oslo — at that time Norway was united with Sweden. The king of Sweden in person hands over the prize to the winners while the Norwegian parliament is in charge of the Peace Prize.

Nobel once wrote, "My dynamite will sooner lead to peace than a thousand world conventions. As soon as men will find that in one instant, whole armies can be utterly destroyed, they surely will abide by golden peace." This seems that this prediction did not materialize.

Table 4.1: Elements discovered by Swedish chemists.

Year	Discoverer	Element	Remarks
1730	Brandt	Cobalt	
1751	Cronstedt	Nickel	
1771	Scheele	Fluor	Isolated by the French chemist Henri Moissan in 1801.
1772	Scheele	Oxygen	Independently discovered by the British chemist Joseph Priestley in 1774.
1774	Scheele	Chlorine	
1774	Gahn	Manganese	
1778	Scheele	Molybdenum	Isolated by Swedish chemist P. J. Hjelm in 1782.
1781	Scheele	Tungsten	
1802	Ekeberg	Tantalum	
1803	Berzelius	Cerium	Independently discovered by the German chemist Heinrich Klaproth in the same year.
1817	Berzelius	Selenium	
1817	Arfwedson	Lithium	
1829	Berzelius	Thorium	
1830	Sefström	Vanadium	Independently discovered by Emmanuel del Río in Mexico and was called erythronium.
1839	Mosander	Lanthanum	
1842	Mosander	Didymium	Split into praseodymium and neodymium by the Austrian chemist Auer von Welsbach in 1885.
1843	Mosander	Erbium	Split into erbium and ytterbium by Marignac in 1878. Cleve in 1879 separated holmium and thulium from it.
1843	Mosander	Terbium	
1843	Mosander	Yttrium	(Gadolin 1794).
1879	Nilson	Scandium	Predicted by Mendeleev.
1879	Cleve	Holmium	
1879	Cleve	Thulium	

Figure 4.1: Monument to Scheele.

Figure 4.2: Monument to Berzelius [Photo by Nadia Habashi, 2003].

Figure 4.3: Alfred Nobel (1833–1896).

STOCKHOLM

Stockholm (Figures 4.4–4.9), the capital of Sweden, is said to have been founded by Birger Jarl in the 13th century as a centre for iron trade (Figure 4.10). This name is widely used in the city. Stockholm is built on a number of islands connected together (Figure 4.11). Gamla Stan is the old district (Figure 4.12).

Figure 4.4: View of Stockholm.

Figure 4.5: Grand Hotel where Nobel Prize winners are accommodated.

Figure 4.6: Concert Hall where Nobel Prize ceremonies take place.

Figure 4.7: Stockholm City Hall where the dinner takes place after the ceremony of Nobel Prizes.

Figure 4.8: A relief in the City Hall about the five Nobel Prizes.

Figure 4.9: Opera House.

Figure 4.10: A monument to Birger Jarl, founder of Stockholm.

Figure 4.11: Map of Stockholm.

Figure 4.12: The narrow street of Gamla Stan [Old Town].

Vasa Museum

The Vasa Museum (Figure 4.13) displays the only almost fully intact warship that sank on her maiden voyage in 1628 because of the heavy 64 guns that she carried and has ever been salvaged.

Figure 4.13: Vasa Museum.

Royal Institute of Technology in Stockholm

Gotthard Björling (1909–2003) (Figure 4.14) was a well known hydrometallurgist in Sweden with whom I established contact in the early 1970s. He graduated from the University of Lund in 1932 then worked in the Swedish metallurgical industry before joining the Royal Institute of Technology in Stockholm (Figure 4.15) in 1949 as assistant professor. After obtaining his doctorate in 1955 under Lars Gunnar Sillen (1916–1970) he became Head of Department of Nonferrous Metallurgy in 1957 succeeding Otto Barth and later elected Dean of the Faculty. He retired in 1975 at the age of 66.

My first meeting with Prof. Björling took place in June 1980 during "Midsommartagen" when, unfortunately, everybody was away on holidays. However, he managed to show me around the Metallurgy Department [headed by Prof. L. I. Staffensen] and the Chemistry Department [headed by Prof. Ingmar Grenthe]. At the Metallurgy Department I met Ivo Toromanoff of Bulgarian origin and a long time assistant to Prof. Björling (Figures 4.16–4.17). At the Chemistry Department work was conducted on the purification of iron ore from its phosphorus content by Mamoun Mohammed, a young researcher of Egyptian origin.

Figure 4.14: With Professor Gotthard Björling (1909–2003) at the Royal Institute of Technology in 1990 [Photo by Nadia Habashi].

Figure 4.15: A typical view of the buildings at the Royal Institute of Technology, now named Kunglica Tekniska Högsklan.

Figure 4.16: With Dipl. Ing. Ivo Toromanoff in Stockholm, 1980.

Few years after Björling's retirement many changes took place at the Institute. The name was changed to Technical University of Stockholm. The Department of Nonferrous Metallurgy became Department of Theoretical Metallurgy dealing mainly with certain aspects of slags. Ivo Toromanoff was moved to Department of Ferrous Metallurgy headed by Professor Sven Eketorp (Figure 4.18) who was interested only in steelmaking.

He was assisted by Dipl. Ing. Stefan Gustavson and Dipl. Ing. Carl Lennart Axelsson. Professor Edstöm, well known by his work on the reduction of iron ores became Head, Department of Production Technology. In general, the main fields of research in metallurgy at the Technical University were directed towards iron and steel making because Sweden possessed large deposits of iron ore and was a leader in steelmaking since the Industrial Revolution. Swedish engineers used to visit Les Forges du Saint-Maurice in Quebec during the era of New France and give advice on iron making. But, hydrometallurgy was completely ignored although it was the speciality of Prof. Björling.

Figure 4.17: Boat excursion in Stockholm. Photo by Toromanoff, 1980.

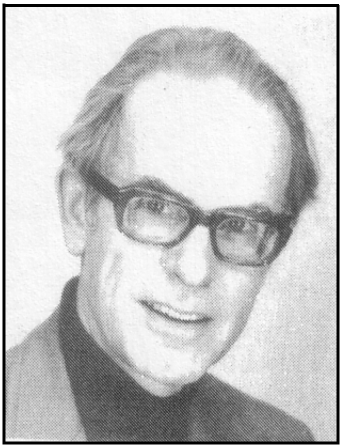

Figure 4.18: Professor Sven Eketorp in 1981.

Ivo Toromanoff persuaded his new Department Head to invite me to give a short course on hydrometallurgy. This was accepted and a short course was held at the Royal Institute of Technology in May 1981 (Figures 4.19–4.20). Now faced with Toromanoff's doctor's thesis, Eketorp asked me if I would supervise his work. Accepting this responsibility, Toromanoff came to Laval University and finished successfully his doctorate in December 1981.

Later visits to the Royal Technical University were at the Chemistry Department at the invitation of Professor Mamoun Mohammed (Figures 4.21–4.23).

ROYAL INSTITUTE OF TECHNOLOGY

Date
January 22, 1981

Department
Ferrous Metallurgy
Information circular

ADVANCES IN HYDROMETALLURGY
Seminar on 12-13th May 1981

At Royal Institute of Technology, Stockholm organized by Division of Applied Process Metallurgy (Ferrous Metallurgy). This seminar is part of the graduade course in Hydrometallurgy.

This seminar will be held by

PROFESSOR **FAHTI HABASHI**

Dr FATHI HABASHI is presently professor at the Department of Mining and Metallurgy, Laval University in Quebec City, Canada. Previously, he was with the Research Division of Anaconda at Tuscon, Arizona. Habashi authored "Principles of Extractive Metallurgy" in two volumes, "Chalcopyrite, its Chemistry and Metallurgy" and is editing a series entitled "Progress in Extractive Metallurgy".

Contact person for this seminar is:
Dipl.ing. Ivo Toromanoff
Institutionen för Järnets Metallurgi
Brinellvägen 23
Tekniska Högskolan
S-100 44 STOCKHOLM
Tel. 08/787 83 03, 08/787 83 76

Figure 4.19: Announcement for the short course.

Figure 4.20: Preparation for the hydrometallurgy short course at the apartment on Villagatan donated to the Royal Institute of Technology by a former mining professor [1981].

ROYAL INSTITUTE OF TECHNOLOGY

Inst f Oorganisk Kemi

SEMINARIUM

Professor Fathi Habashi, Department of Metallurgy, Laval University, besöker institutionen för Oorganisk Kemi, KTH, under vecka 25 och ämnar hålla två seminarier enligt följande.

Seminarium 1:

Titel **Changing Technology in the Metallurgical Industry**
Tid: Onsdag 20, kl 13:15
Plats: Inst f oorg kemi, biblioteket. (Teknikringen 30).

Seminarium 2:

Titel **Dissolution and Precipitation Processes in Chemical Metallurgy**
Tid Torsdag 21, kl 14:15
Plats: Inst f Oorg kemi, biblioteket.

Alla är välkomna!

Mamoun Muhammed　　　Ingmar Grenthe

Dr. Habashi is the professor of Metallurgy at Laval University, Québec, Canada. Dr. Habashi has a Dr. Techn. degree in Inorganic Chemical Technology (Univ of Tech Vienna) and held several positions in Europe, USA and Canada before he was appointed prof at Quebec Univ in 1972. Professor Habashi has published the well known monograph "Principles of extraction Metallurgy" in three volumes. The first two were translated in Russian and Chinese. Dr. Habashi has recently published an audio-course for the American Chemical Society.

Address	Telephone	Cable	Telex	Postgiro
Royal Institute of Technology	Nat. Vx 08-790 60 00	Technology	103 89 KTHB Stockholm	1 56 53 - 9
S-100 44 STOCKHOLM	Int. + 46 8 790 60 00			

Figure 4.21: Announcement for two seminars at the Royal Institute of Technology, 1990.

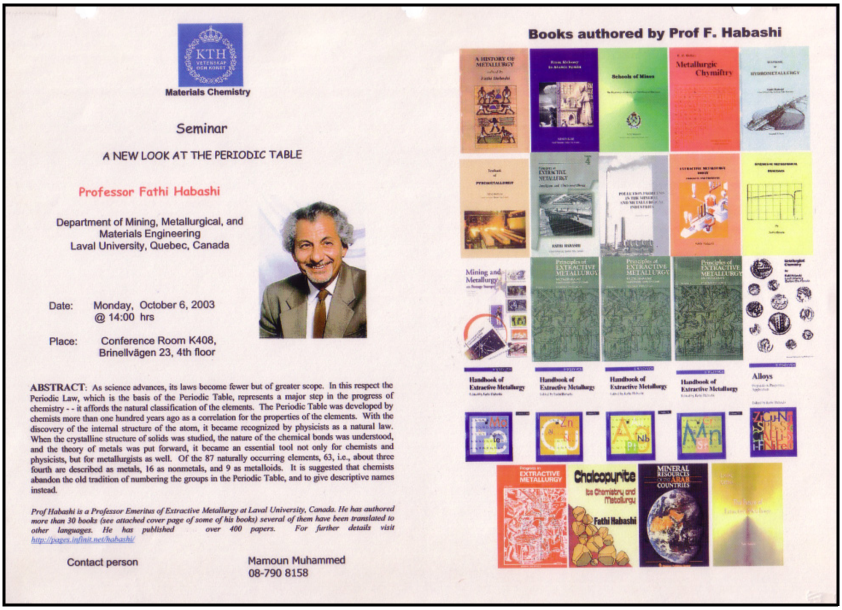

Figure 4.22: Announcement for seminar at Royal University of Technology in 2003.

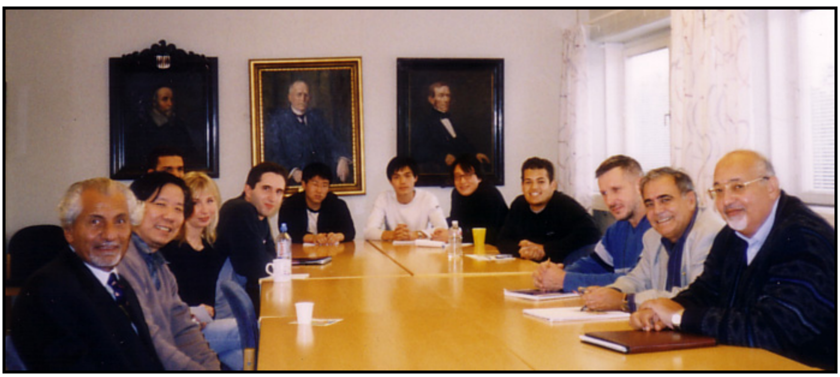

Figure 4.23: With Professor Mamoun Muhammed (extreme right) and his students at the Royal University of Technology [Photo by Nadia Habashi, 2003].

Swedish Museum of Natural History

The Museum has an impressive building (Figure 4.24). An important item in the collection are the large blocks weighing many tons of native iron from Uiffaq on the south coast of Disko Island in Baffin Bay off the west coast of Greenland. These blocks were discovered where a basalt dyke is exposed on a beach by the Swedish professor Adolf Nordenskiöld (1832–1901) in 1870 during his arctic exploration. They were lifted aboard a ship from the Swedish Navy and carried to Sweden. Geologists first believed the blocks to be iron meteorites but later it was proved that the iron formed by reaction between basalt magma and organic carbon from sediments and became known as telluric iron.

Figure 4.24: Swedish Museum of Natural History.

Berzelius Museum

Jöns Jacob Berzelius (1779–1848) (Figure 4.25), the famous Swedish chemist, not only made important discoveries in chemistry (selenium, thorium, and cerium), but also introduced the way known today for writing chemical equations. The museum is maintained by the Academy of Sciences; it houses his personal effects, books, chemicals, glassware, etc. (Figure 4.26).

Ytterby

Ytterby, a suburb of Stockholm on Resarö island (Figure 4.27), is famous in the history of chemistry because the rare earth metals yttrium, ytterbium, terbium, and erbium were discovered from a mineral found there and the first two were named after this locality where a feldspar quarry was in operation. In fact, the rare earths history started from this mine when the army officer Carl Axel Arrhenius (1757–1820) (Figure 4.28) who was an amateur mineralogist found a heavy black mineral (Figure 4.29) in the quarry and gave it to Professor Johan Gadolin at Abo University to analyse. Gadolin concluded that the mineral contained a new unknown metal.

Figure 4.25: Jöns Jacob Berzelius (1779–1848).

Figure 4.26: Some of the chemicals saved by Berzelius in his laboratory.

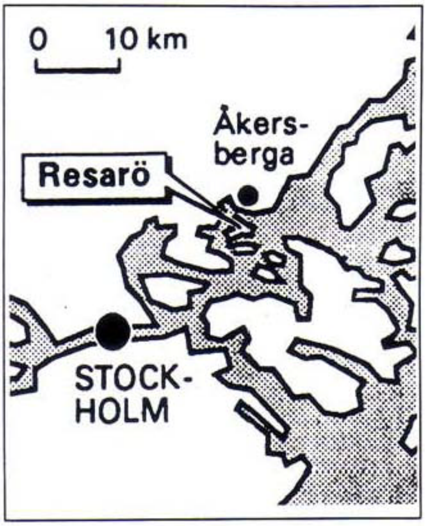

Figure 4.27: Ytterby mine is located on Resarö island near Stockholm.

Figure 4.28: Carl Axel Arrhenius (1757–1824).

Figure 4.29: The black mineral gadolinite named after Prof. Gadolin who first examined it.

Swedish chemists later analysed the mineral and were able to separate four new elements closely related to each other: yttrium, ytterbium, erbium, and terbium. That is why the American Society of Metals recognized the site of this former quarry as a historic landmark (Figure 4.30). The streets in this locality are named after many metals (Figure 4.31).

Figure 4.30: Plaque at the Ytterby mine by ASM International.

Figure 4.31: At Ytterby mine [Photo by Prof. Mamoun Mohammed, 1990].

UPPSALA

Uppsala (Figure 4.32) is 67 km north of Stockholm, it is the seat of the Archbishop of the Church of Sweden which professes the Lutheran faith and the home Sweden's most famous scientist Carl Linnaeus (1717–1778) (Figure 4.33) who classified the plant kingdom and the Hammarskjöld family. Uppsala University (Figures 4.34–4.35) is the oldest centre of higher education in Scandinavia, it was founded in 1477. Among her professors were Georg Brandt (1694–1768) the discoverer of cobalt, Anders Celsius (1701–1744) who proposed the temperature scale now known after him, Torbern Bergman (1735–1784) who clarified the role of carbon in steel, and many others.

Figure 4.32: View of Uppsala.

Figure 4.33: Carl Linnaeus (1717–1778).

Figure 4.34: Main building of the Uppsala University.

Linnaeus Garden

Linnaeus Garden (Figure 4.37) is the oldest botanical garden belonging to Uppsala University. Linnaeus became responsible for the garden in 1741 and had it rearranged according to his own ideas.

Figure 4.35: The hall in the main building of Uppsala University.

FALUN

Falun is an old mining town has its reputation for the copper mine that has been in continuous operation for over 1000 years (Figure 4.38). Beside the Mining Museum near-by, parts of the mine are open to visitors with guided tours to show the ancient methods of mining (Figures 4.39–4.42). In the 17th century, the Falun Mine supplied two-thirds of the world's copper and was the main source of wealth of the Swedish Empire. Many smelters were at one time scattered around the mine. Now modern houses are build on the large slag piles that accumulated over the centuries.

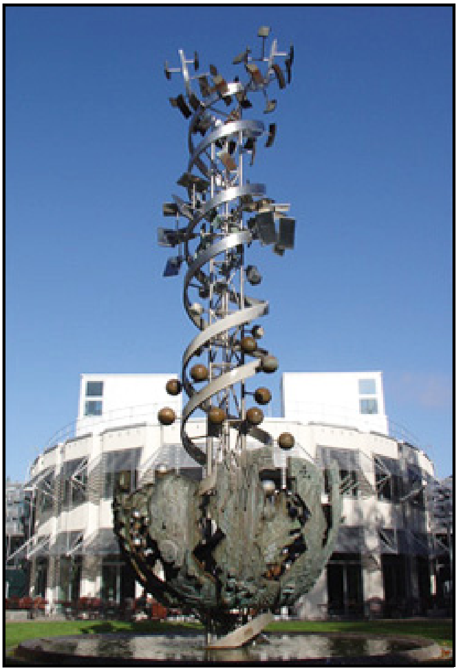

Figure 4.36: Model of deoxyribonucleic acid known as DNA at the University of Uppsala.

Figure 4.37: Linnaeus Garden.

Figure 4.38: The Falun mine and museum.

Figure 4.39: With Dipl. Ing. Ivo Toromanoff examining minerals at the Falun open pit mine.

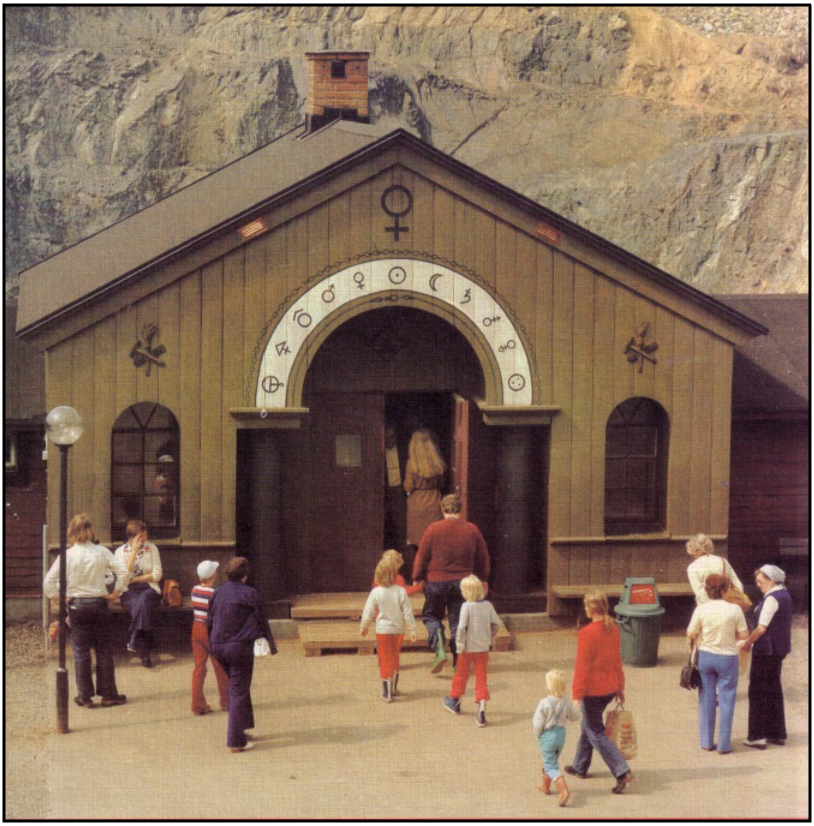

Figure 4.40: Entrance to the Falun underground mine.

HÖGANÄS

Höganäs was a small fishing village in the south of Sweden (Figure 4.43) when, in the middle of the 17th century, coal and clay deposits were found in the area, and mining started in 1797 by Höganäs AB (Figure 4.44). During the 19th century a ceramic industry was founded. The coal mines, however, were closed in the 1960s. Today, Höganäs AB has four divisions: iron powder, refractories, building materials, and abrasives.

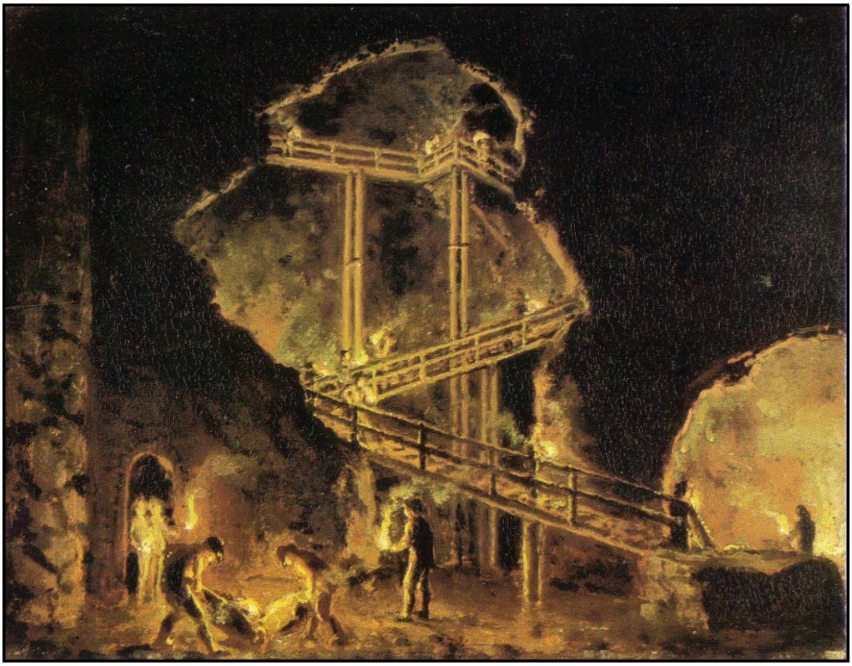

Figure 4.41: A historic picture of the mine underground.

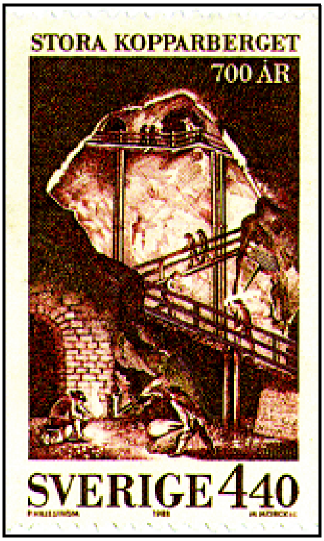

Figure 4.42: Falun on a postage stamp.

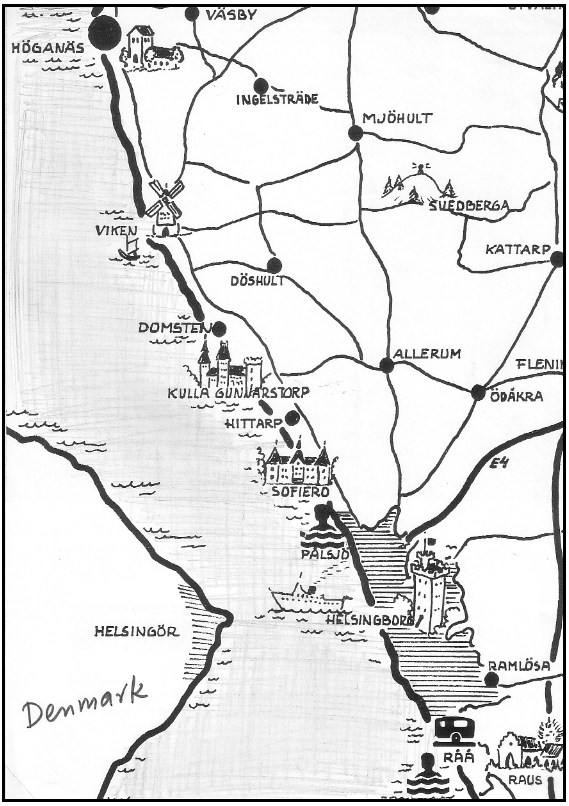

Figure 4.43: Map of southern Sweden showing Höganäs at the top and Helsingborg at the lower part. Facing Helsingborg on the Danish side is Helsingör and the ferry transporting passengers.

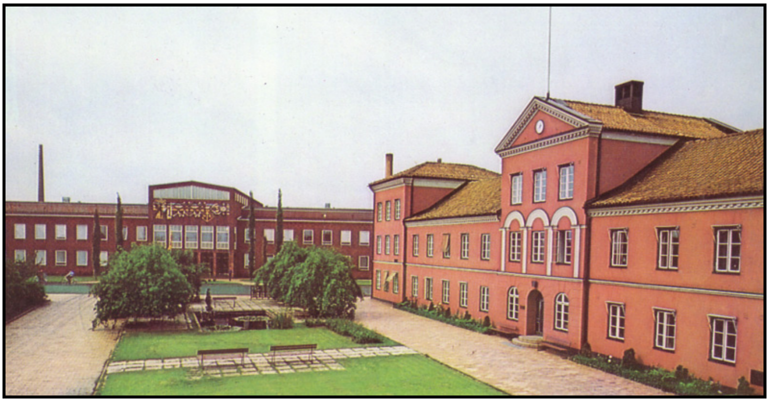

Figure 4.44: Höganäs AB Works in Höganäs.

Iron powder production started at the beginning of the 20th century to exploit a high grade iron ore from northern Sweden which is transported to Höganäs by sea. This was the first company in the world to produce iron from an ore outside the blast furnace. Today, Höganäs AB is one of the largest producer of iron powder in the world, and exports about 90% of its output. She has an excellent Research Department. Some areas of interest are:

1. Production of Co–Ni based powders for surface hardening and corrosion resistance. The powder is mechanically sprayed with a flame directed towards the piece of metal to be treated which is in continuous rotation. When enough powder has accumulated on the surface, the impinging flame sinters the outer layer rendering the piece hard and corrosion resistant.
2. Incorporation of iron powder in the flux layer of the welding rod to increase the rate of welding when such rods are used.
3. Cold-pressed powder samples are heated then forged to produce desired shapes.
4. Production of silicon carbide bricks and segars (the tubes used for reducing iron ore by the Höganäs silicon carbide powder is pressed into shapes, dried, then fired at 1 400–1 700 °C. During use there is an increase in volume because SiC is partially transformed to SiO_2. Used segars are regenerated usually 50 to 100 times.
5. Sponge iron plant (new process started in 1970). The magnetite ore contains 71.5% Fe and 1.1% gangue minerals, is dried to effect magnetic separation so that the gangue is decreased to 0.8%. The powder is charged in SiC sagers to form a specially-shaped cylindrical shell. Coke and limestone are then added inside and outside this shell. The sagers then enter on wheeled cars in a tunnel furnace 265 m long where maximum temperature is 1 200 °C; time inside furnace 50 hours; 80% of the heat comes from the coke in the sagers and the rest from the burner in the kiln. The cooled sponge coming out of the kiln is lifted from the sagers, crushed, screened, then separated magnetically; it contains 0.5% oxygen, 0.2% C, and 0.2% SiO_2, is used directly for metallurgical application. A part is melted and atomized.

The Iron Reduction Plant and the Silicon Carbide Plant were visited; discussions were held with: P. G. Arbstedt (Research Director), Jan Tengzelius (Research Metallurgist), Mats Strömgren (Research Department), Svenn Erik Larssen (Metallurgist, Product Control).

BOLIDEN

Boliden (Figure 4.45) is a group of mining, metallurgical, and chemical companies — the largest in Sweden. It derives its name from the first mine exploited.

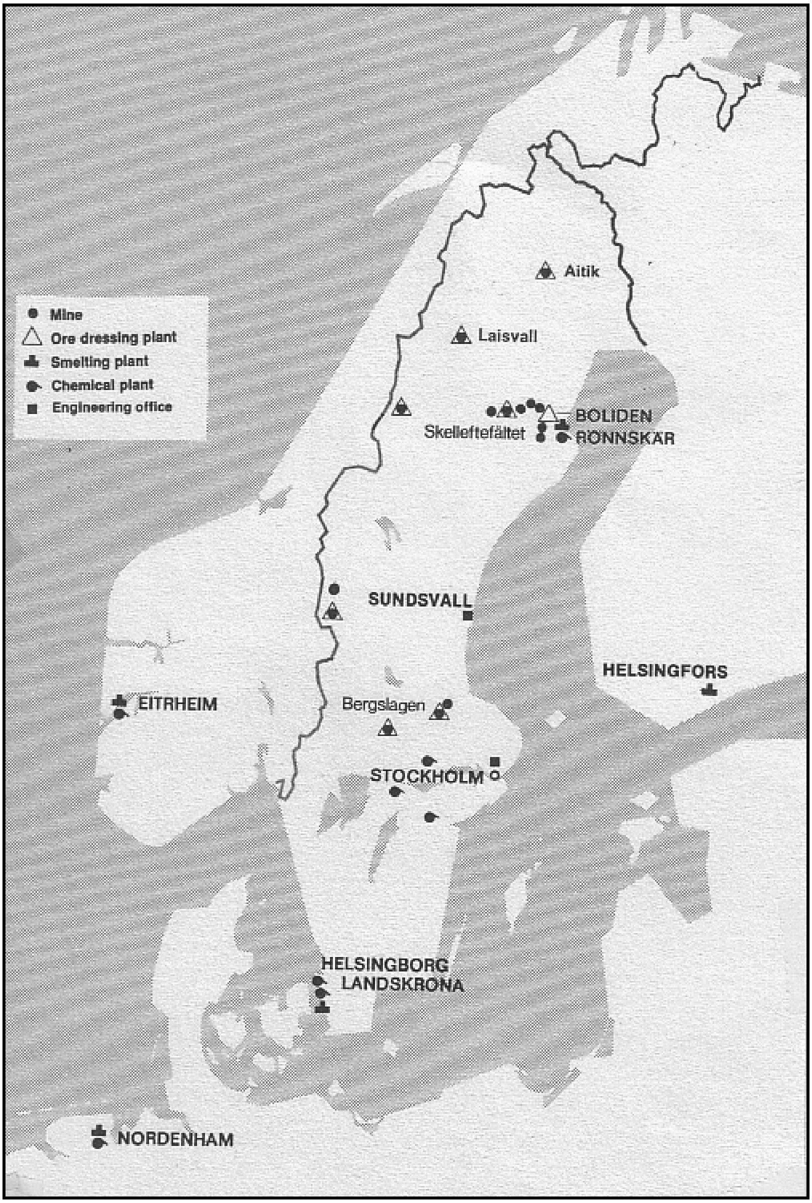

Figure 4.45: Map showing the Boliden operations. Helsingborg in the south and Skelleftehamn in the north of Sweden.

Helsingborg

Helsingborg (Figure 4.46) is Sweden's closest point to Denmark, with the Danish city Helsingør clearly visible on the other side of the Øresund about 4 km to the west. A ferry is available to transport passengers from Sweden to Denmark.

Figure 4.46: A view of Helsingborg.

Boliden's plant at Helsingborg is based on pyrite to make H_2SO_4 the largest in the world (1 million tons H_2SO_4/year) and use the acid to make phosphatic fertilizers. The pyrite cinder plant using HCl gas to volatilize the nonferrous metals operated for two years then dismantled.

Divisions of particular interest: Research Department, recovery of mercury from SO_2 gas produced from pyrite, production of sodium phosphates. Discussion was conducted with the following: Bo Hedenas, Research Director; Elof Wiklund, General Manager for Technology Marketing; Torkel Allgulin, Plant Manager; and Rune Lindström, Superintendent.

Skelleftehamn

At Boliden's Rönnskär Works (Figures 4.47–4.48) copper and lead concentrates from Boliden's mines and external mines are smelted and refined. It is a world-leader in the recycling of copper and precious metals from electronic scrap. There is a liquid SO_2 plant recovered by sorption–desorption in cold water from the Gulf of Bothnia. Arsenic products are also produced from the gas scrubbing system.

Figure 4.47: Boliden Rönnskär Works at Skelleftehamn.

Figure 4.48: With engineers at Rönnskär Works [photo by Prof. Mamoun Mohammed, 1990].

Luleå

Luleå is still further to the north of Skelleftehamn (Figure 4.49). A seminar was held at Luleå University of Technology (Figure 4.50).

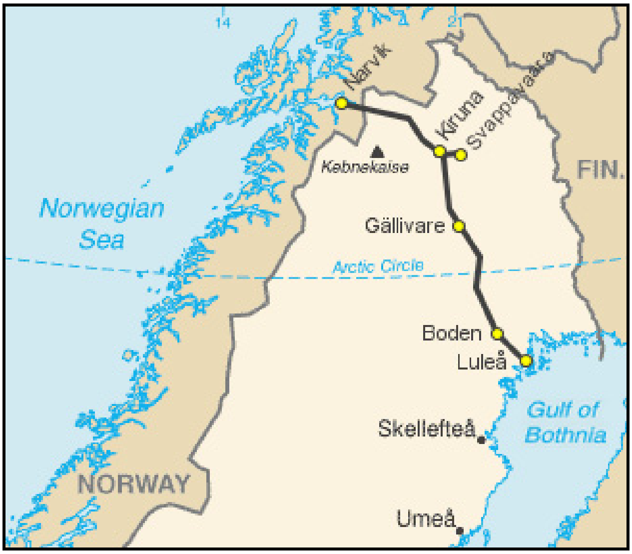

Figure 4.49: Location of Luleå.

Figure 4.50: With students and faculty members at Luleå University of Technology. Sitting on the right is Prof. Bo Björkman, next to him is Dr. Hamid Reza Manouchehri from Iran, standing in the middle with dark blue shirt is Noureddin Menad from Algeria and to his right is Prof. Åke Sandröm [Photo by Nadia Habashi, 2003].

Chapter 5

Finland

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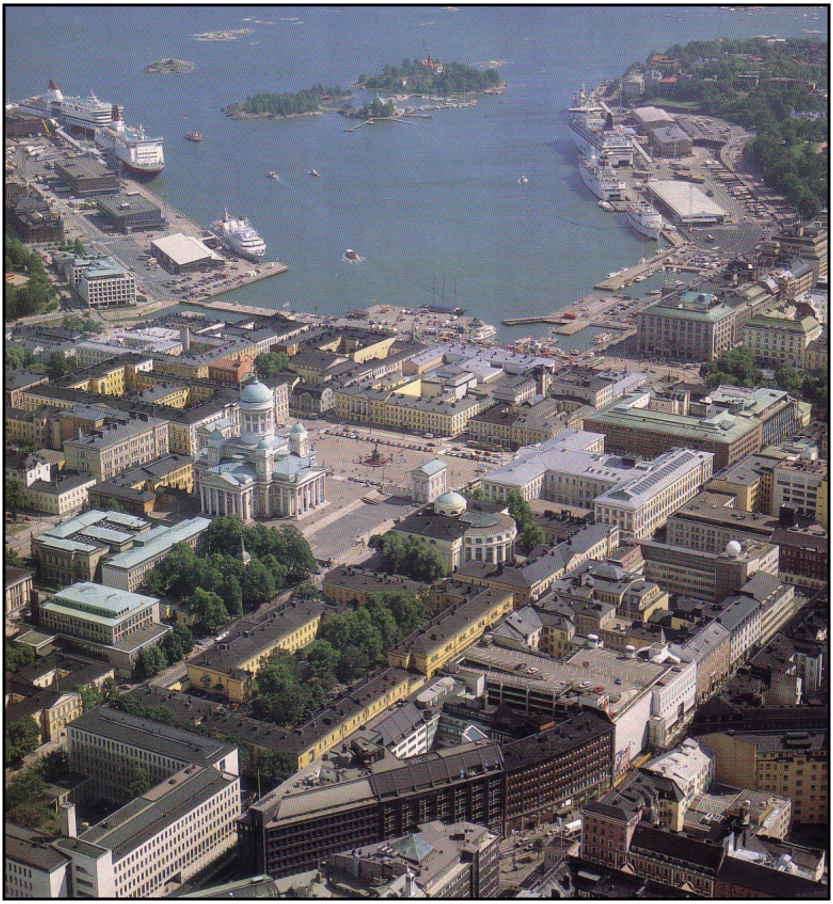

Figure 5.1: General view of Helsinki.

HELSINKI

Helsinki was established as a trading town by King Gustav I of Sweden in 1550 as the town of Helsingfors. When Russia defeated Sweden in the War of 1808–1809 Finland was annexed to Russia as an autonomous Grand Duchy. In 1812 Russian Czar Alexander I then moved the Finnish capital from Turku to Helsingfors, which became known as Helsinki to reduce Swedish influence in Finland and to bring the capital closer to Saint Petersburg.

Profiting from a visit to Leningrad in October 1977, I made a stop in Helsinki to visit the Institute of Technology in Otaniemi and Outokumpu Company.

Figure 5.2: The Cathedral and the Statue of Russian Czar Alexander I (1777–1825) during whose reign Finland was annexed to Russia.

Figure 5.3: With Professor Lauri Holappa and Mrs. Hollapa. Photo by Nadia Habashi, 1993.

Figure 5.4: Monument to Jean Sibelius (1865–1957) in Sibelius Park.

Figure 5.5: Details in the monument to Sibelius.

Figure 5.6: Helsinki Railway Station.

Figure 5.7: Details from the facade of the Railway Station.

Figure 5.8: Parliament building.

Figure 5.9: Monument to metal workers in Helsinki.

National Museum

The National Museum of Finland (Figure 5.10) presents Finnish history from the Stone Age to the present day.

Helsinki University of Technology

First contact with Finnish scientists was established at the First International Conference on Hydrometallurgy held in Dallas, Texas in January 1963. Through Professor Franz Pawlek from Berlin I was introduced to Professor M. H. Tikkanen from the Helsinki Institute of Technology. I then received copies of doctorate theses conducted under his supervision. Two of these were of particular interest to me: Lauri Holappa's work on the sulfation of cobalt oxide and the other by Juho Makkinen on the reduction of copper sulfide by hydrogen in presence of lime. As a result contact was established with these young engineers. When Prof. Tikkanen retired he was succeeded by Prof. Kaj Lilius

The Helsinki University of Technology is situated at Otaniemi, a suburb of Helsinki on the Gulf of Finland (Figures 5.11–5.15). It is characterised by its modern architecture.

Figure 5.10: National Museum of Finland.

Figure 5.11: Helsinki University of Technology at Otaniemi.

Figure 5.12: A metallic ornament at the Institute of Technology.

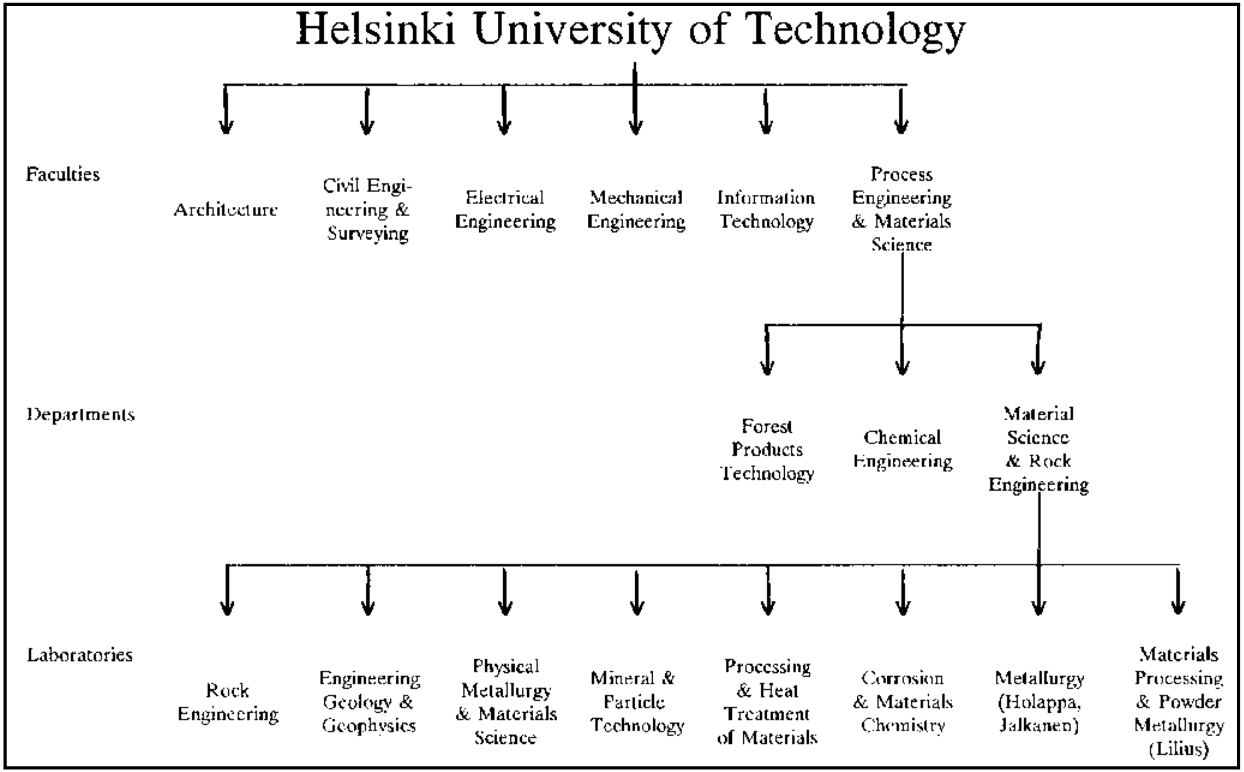

Figure 5.13: Organization of Helsinki University of Technology (1993).

Figure 5.14: With Professor Kaj Lilius, Head of Metallurgy Department. Photo by Nadia Habashi, 1993.

Figure 5.15: With students at Helsinki Institute of Technology. Extreme right is Prof. Holappa, next to my right is Prof. Olof Forsen, next with a beard is Prof. Heikki Jalkanen. Photo by Nadia Habashi, 1993.

OUTOKUMPU

In 1910, a large copper ore deposit was discovered in a place called Outokumpu in the wooded hills of Eastern Finland that formed the basis of Outokumpu company's activities for decades. In 1918, a young mining engineer, Dr. Eero Mäkinen (Figure 5.16) who had recently graduated from the Technical University of Stockholm joined the company. He was to have a tremendous impact on Outokumpu's development as its president and leader for decades. In 1924, Mäkinen advocated that the Finnish State assume ownership of Outokumpu. This took place in December of the same year.

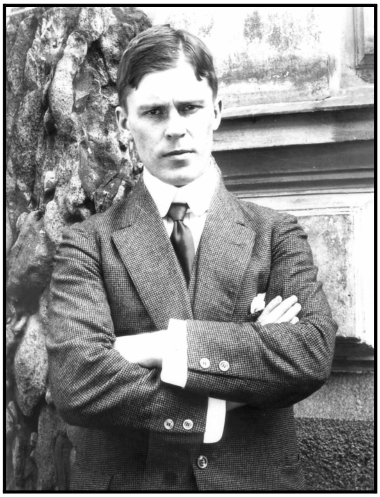

Figure 5.16: Eero Mäkinen.

Finland moved from an agrarian economy and a strong dependence on forest products to become an industrial society based on modern technology. An important driving force in this industrial expansion was the rapid development of hydroelectric power plants, first at Imatra and then on all the major rivers.

The Imatra copper smelter

In 1935, the company constructed what was then the world's largest electric copper smelter in Imatra on Finland's eastern border with Russia in Viborg Province (half way between Helsinki and Saint Petersburg). A process to recover SO_2 from the smelter gases in liquefied form for transportation in railway tank cars to pulp mills and chemical industries was constructed. The facility was the world's largest, with an annual production rate of 16 000 tons SO_2.

In 1939, Russian forces invaded the Karelian District near to the new plant. When World War II erupted and the German armies moved into the Soviet Union, Finland allied itself with Germany in the hope of reclaiming its lost territories. In June 1944, the threat of Soviet invasion forced moving the smelter out of the war zone to Harjavalta on the west coast. Six months later the Russians occupied the area.

Nickel

Following the discovery and development of the copper ore body, Finnish prospectors discovered a major nickel deposit in the Petsamo region, almost on the Arctic Ocean. In 1934, the Petsamo find was leased to the International Nickel Company of Canada. At the end of 1937, it was decided to build an electric furnace plant in the immediate vicinity of the mine. The plant would be located 90 km north of the Paatsjoki hydroelectric power station project. The Winter War forced cancellation of the project when Russian troops invaded the eastern border of the country.

The German's need for nickel was urgent. An agreement between IG Farben[1] and the newly founded Finnish company Petsamo Nikkeli Oy was signed on July 23, 1940. Plans were to smelt the ore at Imatra, then complete the refining in the electrolytic plant at Pori. When war broke out anew in the summer and Finland was an ally of Germany, operations stopped in September 1944. With the collapse of Germany, Finland suffered the loss of Karelia and the cession of Petsamo to the Soviets which now became known by the Russian name Pechenga. The new nickel smelter at Kolosjoki, now partially destroyed was taken by the Russians. It was rebuilt and supplied by electricity form Murmansk.

Nickel re-entered the picture with the discovery of the nickel-bearing pyrrhotite ore deposit at Kotalahti in 1954. The company's engineers succeeded in applying the flash smelting and electrowinning method to nickel production, and construction of the Harjavalta nickel plant was completed in 1960. The ore mined at that time analysed 0.8% Ni and 0.3% Cu.

Flash smelting process

Flash smelting was developed independently by Outokumpu and INCO engineers in the 1940s. Today, most of the world's primary copper production uses this process. The concept of flash smelting was invented as a result of the need to economize energy. Imatra's all-electric smelter was dependent on cheap hydroelectric power. When the plant was moved to Harjavalta and the Russians took over the hydroelectric power station in the region, alternatives had to be found because of the lack of foreign exchange to import

[1] Full name is *Interessengemeinschaft für Farbenindustrie*; the German Chemical Monopoly.

fossil fuel. The company's metallurgists came up with an old idea that had never been tried on an industrial scale — autogenous smelting. The method would use the heat of oxidation of iron and copper sulfides to bring the concentrate up to the smelting temperature. The first facility was built in 1947 (Figure 5.17). The flash smelting of nickel concentrates started in 1960s at Harjavalta. The adoption of oxygen enrichment of the flash smelting process air in 1971.

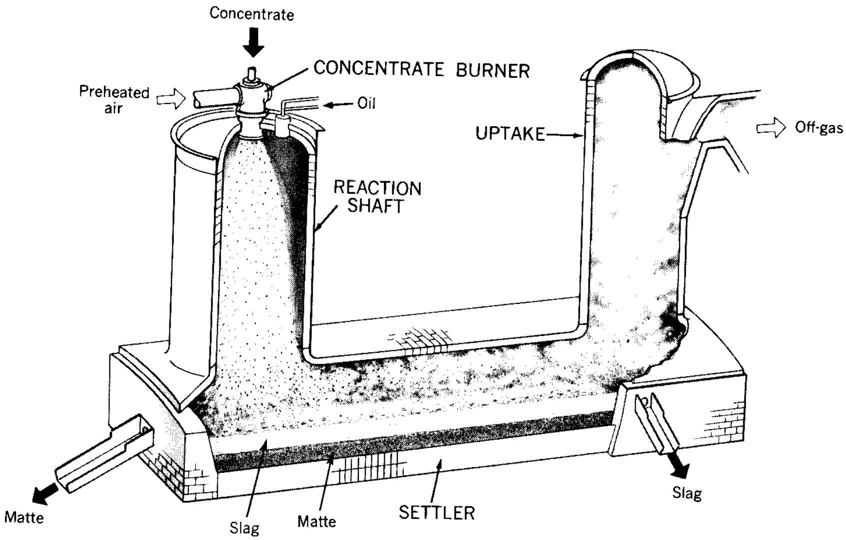

Figure 5.17: Flash smelting.

Figures 5.18–5.22 show the status of Outokumpu in 1977. Pori, Harjavalta Works started production in 1945, Kokkola and Tornio were built in the 1960s. Harjavalta Works is 20 km south of Pori, produces copper and nickel. The copper refining is done in Pori. Zinc production is in Kokkola while stainless steel is in Ternio in the north.

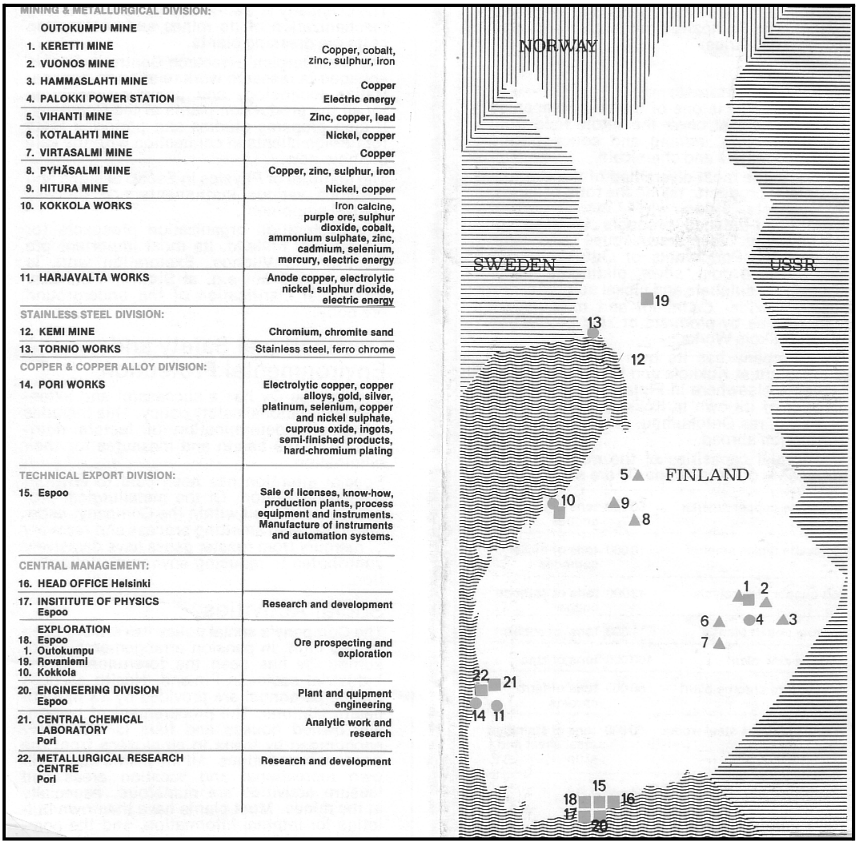

Figure 5.18: Outokumpu in 1977.

Figure 5.19: Harjavalta smelter is 20 km south of Pori, 1977.

Figure 5.20: Outokumpu's Pori Works.

Figure 5.21: Kokkola Zinc Works.

Figure 5.22: Tornio Stainless Steel Works.

Pori

Pori (Figures 5.23–5.24) is a small port town exporting timber, about 240 km from Helsinki. In 1852 it suffered a fire that destroyed the whole city that is why today it looks a modern town after it was completely rebuilt. It is the seat of Outokumpu Research Department (Figure 5.25). My first visit was in 1977 where I gave a talk entitled Recent Advances in the Extractive Metallurgy of Copper. Director of Research was Dr. Tapio Tuominen. The Department did a pioneering work on the removal of mercury from smelter gases using concentrated sulfuric acid.

Figure 5.23: A view of Pori.

Figure 5.24: A modern shopping centre in Pori.

Figure 5.25: With Dr. Juho Makkinen, Vice President and Mrs Makinnen , 1993.

Finnish sauna

As a symbol of hospitality Outokumpu invites her guests to the sauna at the end of the day. My host was Dr. Jyrki Juusela (Figure 5.26). I performed badly because I was unable to withstand the high steam temperature. However, Jyrki graciously promoted me and signed the certificate. Unfortunately, I forgot it in the changing room. Juusela became Outokumpu President few years later.

Figure 5.26: Dr. Jyrki Juusela.

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