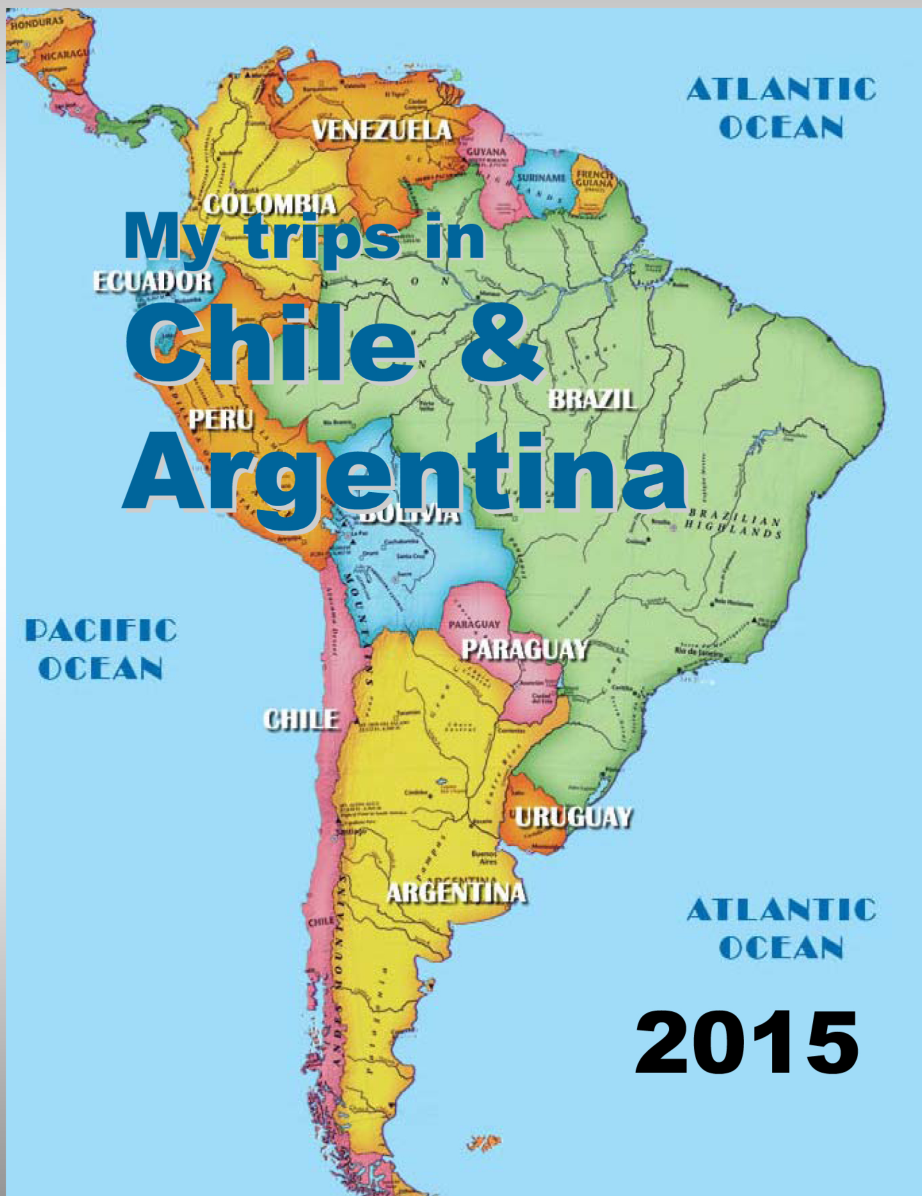
Fathi Habashi

My trips in Chile & Argentina



2015

My Trips in Chile and Argentina

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, *Researches on Rare Earths. History and Technology*, 2008, 125 pages.

F. Habashi, *Researches on Copper: History, Metallurgy*, 2009, 400 pages.

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F. Habashi, *Pressure Hydrometallurgy*, 2014, 242 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.

Fathi Habashi
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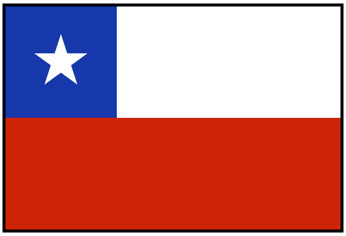
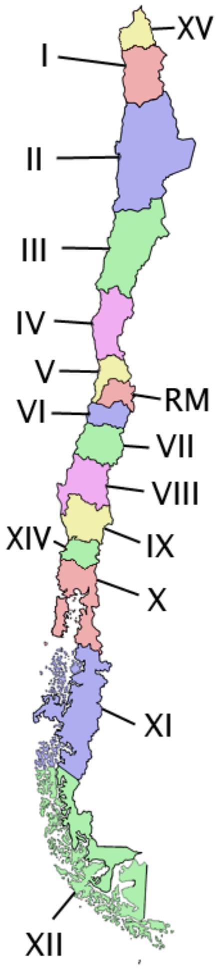


Figure 1.1: Flag of Chile.

Figure 1.2: Chile is divided into 15 regions, each is headed by an Intendant.

Table 1.1: Regions and their capitals.

Region	Name	Capital
XV	Arica and Parinacota	Arica
I	Tarapacá	Iquique
II	Antofagasta	Antofagasta
III	Atacama	Copiapó
IV	Coquimbo	La Serena
V	Valparaíso	Valparaíso
RM	Santiago Metropolitan	Santiago
VI	O'Higgins	Rancagua
VII	Maule	Talca
VIII	Biobío	Concepción
IX	Araucanía	Temuco
XIV	Los Ríos	Valdivia
X	Los Lagos	Puerto Montt
XI	Aisén	Coihaique
XII	Magallanes and Antártica Chilena	Punta Arenas



Historical Background

The colonial period (1545–1810)

In 1536, Diego de Almagro (1475–1538) (Figure 1.3), accompanied by 500 Spanish and 1 500 native men, came from Peru down to Chile searching for gold similar to that discovered by the Incas. They crossed the Copiapó Valley and, instead, found copper minerals in the Chuquicamata area. De Almagro returned to Peru but, due to a conflict with Pizzaro, he was executed. Pedro de Valdivia (ca.1500–1553) (Figures 1.4–1.5) led an expedition in 1540 with 150 people and in 1541 founded the city of Santiago where gold was found nearby.

Gold mining was the only mining activity in Chile during the first decade of the conquest, mainly, in areas near what is now Viña del Mar, Imperial (presently Carahue), Valdivia, Angol, Tucapel, Villarrica, and Osorno. In 1544, the city of Serena was founded and gold was discovered nearby, as well as in Ponzuelos, Illapel, and Choapa. Native slaves mined the gold. Gold production was two tons/year between 1545 and 1560. By the end of the sixteenth century, Chile had a Spanish population of only 3 600 while the natives amounted to about 600 000; half of them lived in southern Chile, resisting the Spanish occupation. As a result, they replaced mining activities with raising animals for export to Peru.

Figure 1.3: Diego de Almagro (1475–1538), conquerer of Chile.

Figure 1.4: Pedro de Valdivia (ca. 1500–1553), founder of Santiago.

At the beginning of the 18th century, Spanish reforms allowed an increase in the trade of raw materials between Spain and its colonies. Once again, mining became the main activity. The gold ores were milled using a *maray*, a traditional Chilean mill used by the natives before the Spanish expedition. It consisted of two stones, one fixed at the base, and the other handled manually (Figure 1.6). In 1730s, this equipment was replaced by *trapiches* in which the milling action was caused by an animal (Figure 1.7). At the end of the eighteenth century, there were 130 *trapiches* in operation in Chile producing approximately three tonnes of gold per year. Gold production began with alluvial gold which could be recovered easily by washing. A small amount was in the form of quartz veins, which were crushed and beneficiated, then treated by gravitational concentration or amalgamation. In 1743, the Royal Mint was founded in Santiago (Figure 1.8).

Figure 1.5: Founding of Santiago.

An annual silver production of seven tonnes was obtained from nine amalgamation plants. The amount of mercury consumed was two to three times the amount of silver recovered. Copper was still recovered in small clay furnaces, which were filled with oxidized ore and charcoal. At the end of the eighteenth century, there were 61 mines operating with this system in Copiapó, Huasco, Coquimbo, and Rancagua that produced 1 500 tonnes/year. In 1787, mining laws of New Spain were applied in Chile, thus allowing for the founding of the Royal Administration of Mining which included the Miners' Union. In 1778, it financed the construction of a gunpowder plant and a mining bank in Santiago.

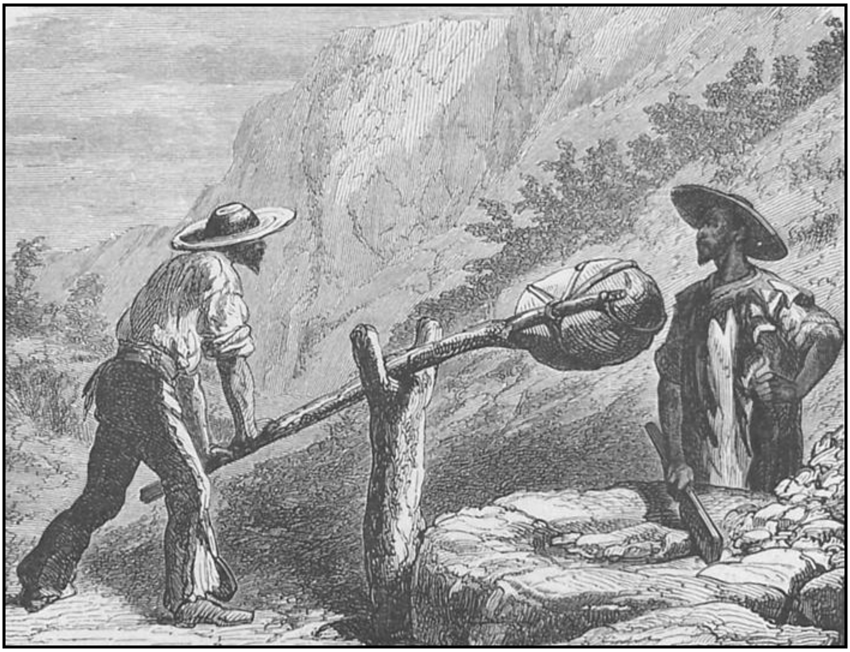


Figure 1.6: Crushing of ore during colonial period using a *maray*.

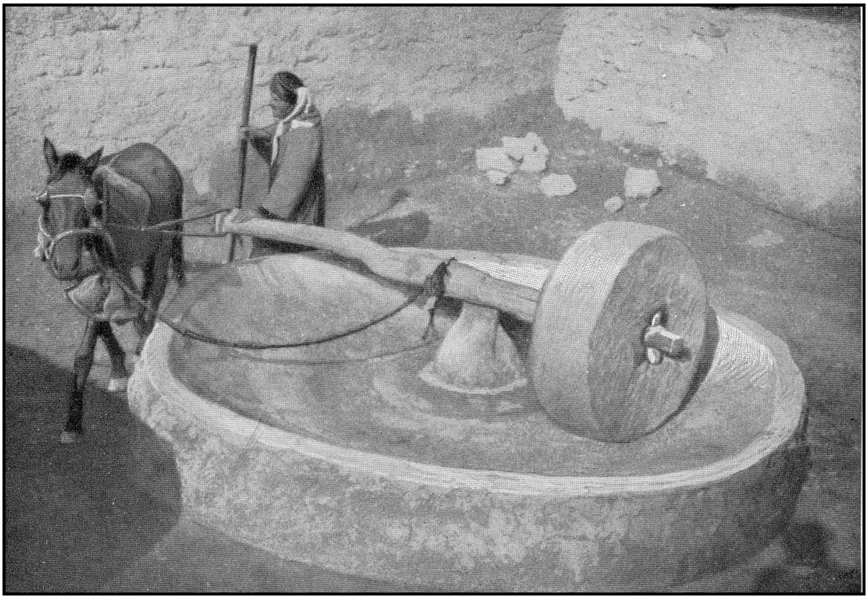


Figure 1.7: An animal-operated *trapiche* in Chile.

Figure 1.8: Casa de la Moneda in Santiago established in 1743 — Presidential Palace and Mint.

The governor of Chile, Ambrosio O'Higgins (1716–1801), solicited the help of foreign experts. Thus, between 1789 to 1795, an expedition headed by Alejandro de Malespina of Spain arrived in Chile. Thaddaeus Haenke (1761–1817) (Figure 1.9), a German scientist accompanying the expedition, visited the central and southern zones of Chile and wrote *Descripción del Reyno de Chile*, a report on geology and on the life of miners. In 1794, Jorge Passler, a German mineralogist, arrived and established a chemical laboratory and taught at the Royal Academy of San Luis in Santiago. The Academy was founded on September 6, 1797, by Chilean lawyer Manuel de Salas y Corbalán (1754–1841) (Figure 1.10) to teach grammar, drawing, and arts; arithmetic, geometry, chemistry, and mineralogy were added a few years later. In 1813, the academy merged with the newly-founded National Institute in Santiago.

Figure 1.9: Thaddaeus Haenke (1761–1817) wrote *Descripción del Reyno de Chile.*

Figure 1.10: Manuel de Salas y Corbalán (1754–1841), founder of the Academy.

Independence

Chilean independence was gained in 1818 under José de San Martín (1778–1850) (Figure 1.11) and Bernardo O'Higgins (1778–1842) (Figure 1.12).

Figure 1.11: José de San Martín (1778–1850).

Figure 1.12: Bernardo O'Higgins (1778–1842).

War of the Pacific

In 1879 there started a conflict between Chile and the alliance of Bolivia and Peru regarding taxation of the companies exploiting the caliche deposits in the Atacama Desert. This resulted in what became known as the War of the Pacific which lasted until 1884. The conclusion of the conflict ultimately led to the Chilean acquisition of the Peruvian territories of Department of Tarapacá and Province of Arica, as well as the Bolivian Department of Litoral (Figure 1.13).

Chile's Natural Wealth

The natural wealth of Chile is mainly from her porphyry copper deposits and its by-products molybdenum, rhenium, gold, and silver as well as from nitrate deposits containing iodine and lithium solutions in the Atacama Desert. After independence foreign investors were invited to re-open closed mines and to explore for the mineral wealth. In 1875, at the request of the Chilean government, a French engineer prepared a geological and mineralogical map of the Chilean territory. In 1883, the National Society of Mining was founded to bring together Chilean mining producers. The Government created in 1927 the Caja de Crédito Minero to endorse the construction of ore treatment plants and to buy and sell minerals to the miners. The Caja de Fomento Carbonero and the Superintendencia del Salitre y Yodo were created in 1928, and Corporación de Fomento de la Producción in 1939. In 1953, the Ministry of Mines was founded. Gradually coal mines were opened and iron and steel production started.

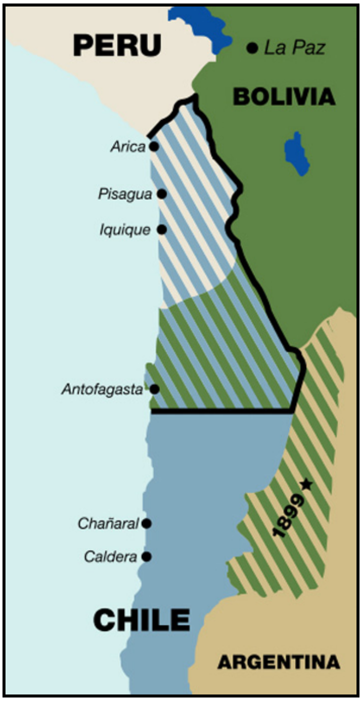


Figure 1.13: Map showing the areas acquired by Chile from Peru and Bolivia after the War of the Pacific.

The First Metallurgists in Chile

Carlos Santiago Lambert (1793–1876) was born in Strasbourg in an Alsatian family (Figure 1.14). He studied mining and metallurgy at the School of Mines in Paris. After working in a number of mines in France he was sent to Chile in 1824 as manager of the Compañía Minera Sudamericana in La Serena — a British company interested in the Chilean copper. During this period, only copper oxide ores were smelted to produce metallic copper. In 1831, Lambert decided to apply the Welsh process used in Swansea to sulfide ores from a mine near Coquimbo. In 1841, the process was used in other smelters. Sulfuric acid was produced from the smelter gases. Charcoal, and later coal, imported from England were used in this furnace. He installed the first copper and brass rolling mills in La Serena to supply the national demand, principally shipbuilding for the Chilean Marine. It was Lambert who recommended hiring Ignacio Domeyko.

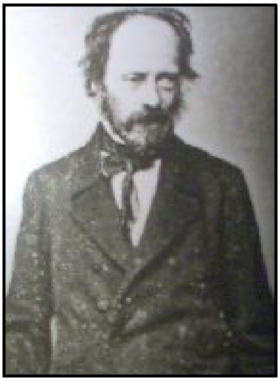


Figure 1.14: Carlos Santiago Lambert (1793–1876).

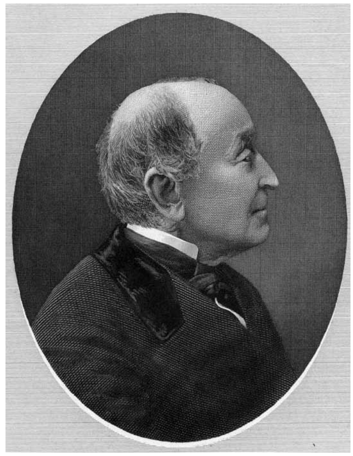


Figure 1.15: Ignacio Domeyko (1802–1889).

Ignacio Domeyko (1802–1889) (Figure 1.15) was born in Niedźwiadka, Poland. In 1817, he attended the University of Vilna to study mathematics and physical sciences. In 1832, he left Poland because it was occupied by the Russians and went to Paris to attend the School of Mines. In 1837, he obtained a degree in mining engineering, then went to Chile to teach chemistry and mineralogy at the College of Coquimbo. During the summer of 1839, wrote a report on the geology of Chile to help promote mining in the country. Based on his report, the University of Chile was founded in 1842. In 1844, he published a book on mineral analysis and in 1845 another on the mineralogy in Chile, entitled Elementos de Mineralogía, which was the first book on the subject published in the country. In 1847, he was appointed professor of mineralogy and natural sciences at the University of Chile. In 1867 he was named rector of the University of Chile, a position he held until his retirement in 1882.

It is interesting that another Pole, Joseph Obalski (1852–1915), was the son of a Polish refugee in France who left Poland after the uprising of 1831 and married a French woman. He studied at the Polish School in Paris then emigrated to Quebec in 1881 and founded the provincial Bureau of Mines. Similarly, Edward Jan Habich (1835–1909) left Poland after the 1863 uprising to work in Paris then he emigrated to Peru to work in the Peruvian Government. When in 1875 the School of Mines was created, Habich participated in the organization of the new school and, in May 1876, was named director of the School of Civil Construction and Mining.

José Tomás Urmeneta (1808–1878) (Figure 1.16) was born in Santiago. In 1852, he discovered a rich copper deposit near Ovalle. In 1858, he installed smelters in Guayacán and in Tongoy which produced bars of 97% Cu and ingots of 99.5% Cu. In 1925, the smelters closed due to financial problems and were bought by the Compañía Minera del Pacífico, who reopened it in 1929. However, the same problem persisted forcing its closure in 1934.

Figure 1.16: José Tomás Urmeneta (1808–1878).

Figure 1.17: William Braden (1871–1942).

William Braden (1871–1942) (Figure 1.17) was born in Indianapolis, Indiana, USA. He graduated from the Massachusetts Institute of Technology. Between 1893 and 1898, he worked in a number of smelters across the United States, Canada, and South America. He was commissioned in1904 by American Smelting and Refining to go to Chile to purchase the El Teniente deposit. He founded the Braden Copper Company, becoming its general manager until 1912.

Modern Chile

When Salvador Allende (1908–1973) (Figure 1.18) came to power in 1970, the population was divided nearly 50/50 between socialism and capitalism. Allende was killed in the presidential palace after the building had been attacked by army troops and planes. Thousands were killed, disappeared or were tortured under General Augusto Pinochet's (1915–2006) (Figure 1.19) rule, which lasted until 1990.

Figure 1.18: Salvador Allende (1908–1973).

Figure 1.19: Augusto Pinochet (1915–2006).

TRIPS TO CHILE

Table 1.2: Summary of trips to Chile.

	Date	Purpose of visit & places visited	Host
1	December 9–17, 1992	[1] Department of Chemical & Metallurgical Engineering, Catholic University in Antofagasta [2] Help organize the National Metallurgy Conference known as CONAMET to be held in 1994 [3] Ruins of Silver Refinery, Antofagasta [4] Escondida process [5] Empresa Minera de Mantos Blancos [6] Compañía Minera Carolina de Michilla	Dr. Raúl Ibarra
2	July 31–August 21, 1993	[1] Lecture tour [2] Chuquicamata [3] Archaeological Museum at San Pedro de Atacama [4]Salar de Atacama [5] University of Atacama at Copiapó [6] Nitrate recovery plant at María Elena [7] Department of Metallurgy, University of Santiago [8] Research Centre for Mining & Metallurgy (CIMM) in Santiago [9] El Teniente [10] Technical University Federico Santa María in Valparaíso	Dr. Raúl Ibarra Dr. Germán Cáceres

	Date	Purpose of visit & places visited	Host
3	August 2–17, 1994	[1] Viña del Mar [2] Plenary lecture at Congreso Nacional de Metalurgia [3] Universidad Técnica Federico Santa Maria in Valparaíso [4] Research Group on Prehispanic Metallurgy at the Universidad de Trapacá in Arica [5] Chuquicamata [6] Sociedad Chilena de Litio, Antofagasta [7] Sociedad Química María Elena in Antofagasta	Dr. Jorge Pontt Dr. Rougette Araneda
4	August 8–26, 2001	[1] Easter Island [2] University Arturo Prat in Iquique [3] Lecture at Chilean Mining Society, Santiago [4] Seminar at University of Concepción [5] Seminar at University of La Serena	Ing. Armando Valenzuela Prof. Mario Sánchez
5	April 7–21, 2005	[1] Short course on leaching of copper minerals at the University of Atacama [2] Copper industry in Copiapó	Prof. Germán Cáceres
6	November 22–28, 2005	Keynote Address at HydroCopper 2005, Santiago	Dr. Jesús Casas
7	May 9–17, 2009	[1] Short course on hydrometallurgy at HydroCopper 2009, Antofagasta [2] Keynote lecture at HydroCopper 2009	Dr. Jesús Casas
8	August 18–24, 2013	[1] Short course on pollution at the Catholic University of Valparaíso in Viña del Mar [2] Copper Metallurgy Update	Prof. Amelia Dondero, Chemical Engineering Department

SANTIAGO

Santiago (Figure 1.20) is the capital and largest city of Chile, founded in 1541 by the Conquistadores Pedro de Valdivia along the Mapocho River. Of the 20 million Chileans about 40% live in the Greater Santiago area.

University of Santiago

The first university in Chile, Santo Tomás de Aquino, was founded in 1622. In 1738, its name changed to Real Universidad de San Felipe, in honour of King Philip V of Spain. After independence it was replaced in 1842 by the Universidad de Chile which was formally opened on 17 September 1843 (Figures 1.21–1.23).

Figure 1.20: View of Santiago.

Figure 1.21: University of Chile at Santiago.

CIMM

Centro de Investigación Minera y Metalúrgica in Santiago was founded in 1970 and housed in a modern building located in a pleasant environment (Figure 1.24). Director Dr. Ricardo Badilla [1993].

Figure 1.22: University of Chile at Santiago. From left to right: Gerardo Fuentes, Roughette Araneda (Guide), Augusto Millán [Photo by Nadia Habashi, 1993].

Figure 1.23: With faculty members Mining Department, University of Chile, Santiago. Standing from left: Armando Valenzuela, Fathi Habashi. Jesús M. Casas de Prada, Luis Cifuentes, April 2005.

Figure 1.24: Centro de Investigación Minera y Metalúrgica in Santiago.

Museo Nacional de Historia Natural

There was a display on the history of copper and its importance in society at the Museo Nacional de Historia Natural (Figure 1.25). Two illustrated books on this topic were available (Figures 1.26–1.27).

Figure 1.25: Museo Nacional de Historia Natural.

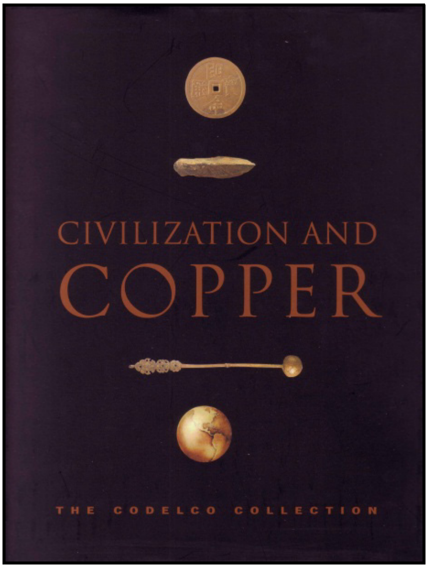


Figure 1.26: *Civilization and Copper*, The Codelco Collection, 2001.

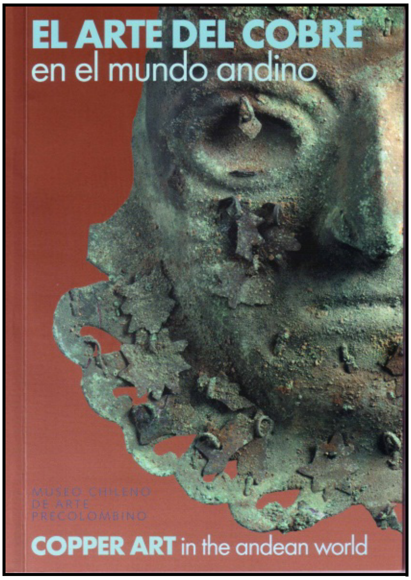


Figure 1.27: *Copper Art in the Andean World.*

Chilean Mining Society

A presentation entitled "Milestones in the History of Metallurgy" was given at the Society of Geography and History in Santiago organized by the Chilean Mining Society and sponsored by Acorga (Figure 1.28). It was translated by Armando Valenzuela into Spanish, "Hitos en la Historia de la Metalurgia," and published in *Minerales* [Santiago] **56** (240), 13–17 (2001).

Comisión Chilena del Cobre

Chilean Copper Commission known as Cochilco safeguards government interests in Codelco and Enami by auditing, assessing, and reviewing their operations and investment decisions. Cochilco also advises the Ministries of Mines and Finance on related budget development and review. A seminar was held with the staff discussing recent advances in copper metallurgy organized by Armando Valenzuela, a former graduate of Laval University (Figure 1.31).

Figure 1.28: Meeting with members of the Chilean Mining Society in Santiago [Photo by Nadia Habashi, 2001].

Figure 1.29: Cochelco, April 2005 [Photo by Armando Valenzuela].

Figure 1.30: Meeting at Cochelco, April 2005.

Figure 1.31: With Armando Valenzuela at Cochelco, April 2005.

Figure 1.32: At Cochelco, April 2005.

O'HIGGINS REGION

El Teniente

The El Teniente and La Fortuna mines, located near Rancagua (Figure 1.33), were worked since Colonial time. In 1903, William Braden purchased the deposit and founded the Braden Copper Company, together with E. W. Nash and Barton Sewell, president and vice-president of the American Smelting & Refining Co., respectively. In 1904, construction began on a 250 ton/day concentrator in Sewell. The ore having 3.34% Cu was concentrated to a product having 20% Cu at a copper recovery of 45% to 55% using gravity methods. The tailings ranged between 0.8% and 1.5% Cu. In 1907, the smelter began operation with six roasters and two shaft furnaces producing a matte having 50% Cu. A second smelter, which had two shaft furnaces, agglomeration furnaces, and a Peirce-Smith converter, was built in 1909 to replace the first because it was damaged by a fire.

Labour conflicts and other difficulties in 1909 led Braden to mortgage the company to the Guggenheim Exploration Company, which took financial control. Braden continued on as general manager until 1912. In 1915, the Guggenheim brothers sold the Braden Copper Company to the Kennecott Corporation.

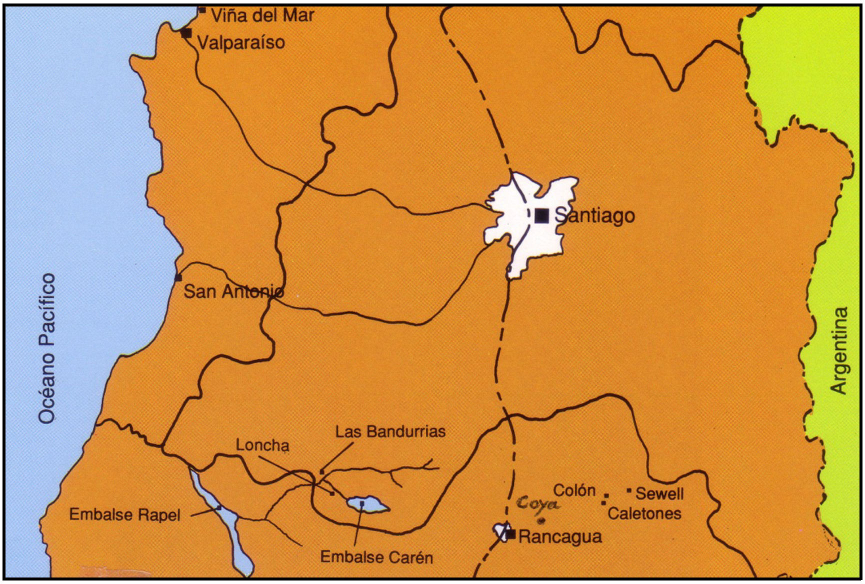


Figure 1.33: Location map of Santiago and its environment: Valparaíso, Viña del Mar to the northwest and the mining district El Teniente [Sewell, Colón, Catelones, and Coya] to the south.

In 1911, the company processed 49 650 tons of ore having 2.97% Cu producing about 6 000 tons of blister copper. In 1912, the flotation process was introduced. The processing capacity was increased to about two million tons of ore in 1918. Wedge furnaces to roast the concentrate were installed in 1915. The SO_2 produced was used to make about 30 tons/day sulfuric acid, which was sold in the local market. By 1919, the shaft furnaces could smelt about 500 tons/day and two new Peirce-Smith converters with a capacity of 40 tons each were installed. Copper production ranged between 40 to 50 tons/day. In 1922, a third smelter was built in Caletones (7.5 km east of Sewell) to replace the one in Sewell. The new smelter had three agglomeration plants, a shaft furnace, two Peirce-Smith converters, and two casting machines. In 1958, the Caletones smelter began to treat metallurgical gases to produce sulfuric acid.

In 1967, copper production increased from 180 000 to 280 000 tons/year. In 1985, a solvent extraction and electrowinning plant began producing copper cathodes from the acid mine waters from the mine. In 1992, a semi-autogenous grinding (SAG) plant began its operation. Today, El Teniente is the largest underground copper mine in the world producing about 340 000 tons/year Cu (Figures 1.34–1.35).

The most significant improvement has been the El Teniente technology, which consists of two furnaces, the Teniente converter for smelting and converting dry copper concentrate, and the slag cleaning furnace to recover copper contained in the produced slag. The first prototype for the Teniente converter furnace was tested in 1977. Today, there are seven furnaces operating in Chile, and others in Zambia, Peru, and Mexico.

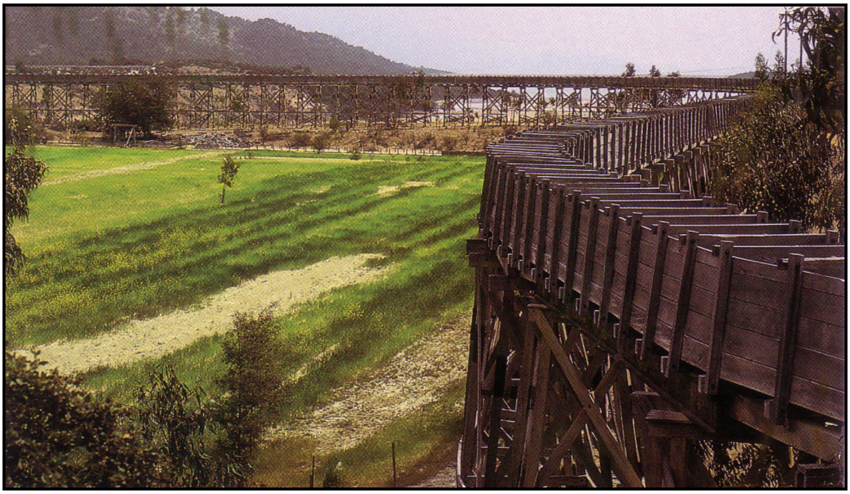


Figure 1.34: Transportation of tailings at El Teniente.

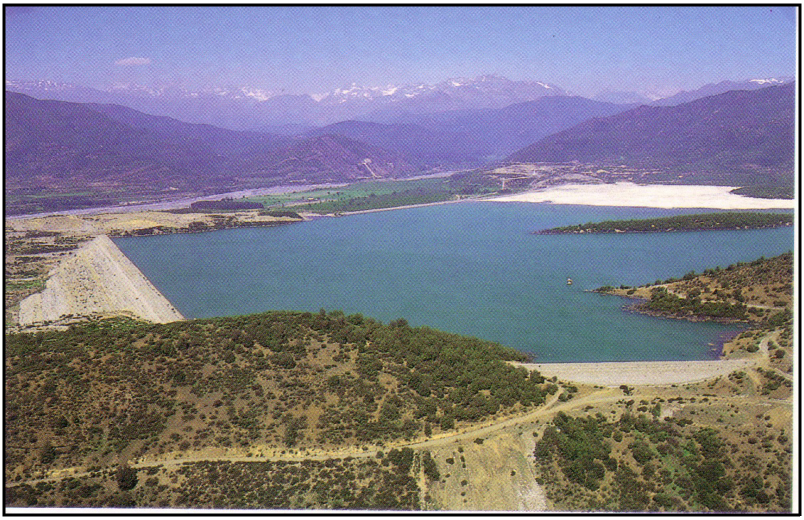


Figure 1.35: One of many tailings ponds at El Teniente.

Sewell

Sewell, the largest underground mine in the world at 2 000 m above sea level (Figures 1.36–1.37).

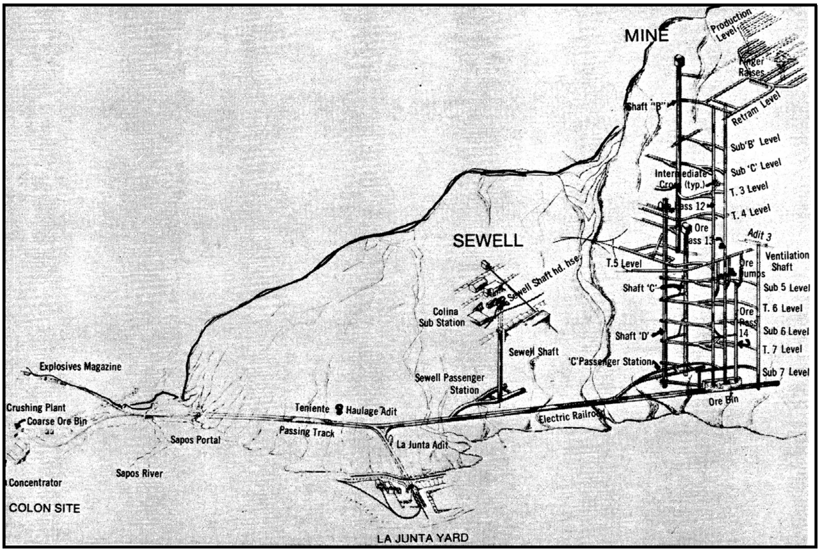


Figure 1.36: Sewell, the largest underground mine in the world.

Colón

Copper concentration plant at Colón (Figure 1.38).

Río Blanco

The Río Blanco deposit, located 80 km northeast of Santiago, was discovered in 1850, however, climate conditions and its remote location (3 700 m above sea level) made its exploitation expensive. In 1955, the Cerro Corporation, an American company, decided to exploit the deposit. Eleven years later, a joint venture was formed by the Chilean government and Cerro Corporation, which operated the mine until 1971; a concentrator was then built underground. Today, the Andina Division of Codelco-Chile exploits the mine and the open pit mine which produces about 218 000 tons of Cu.

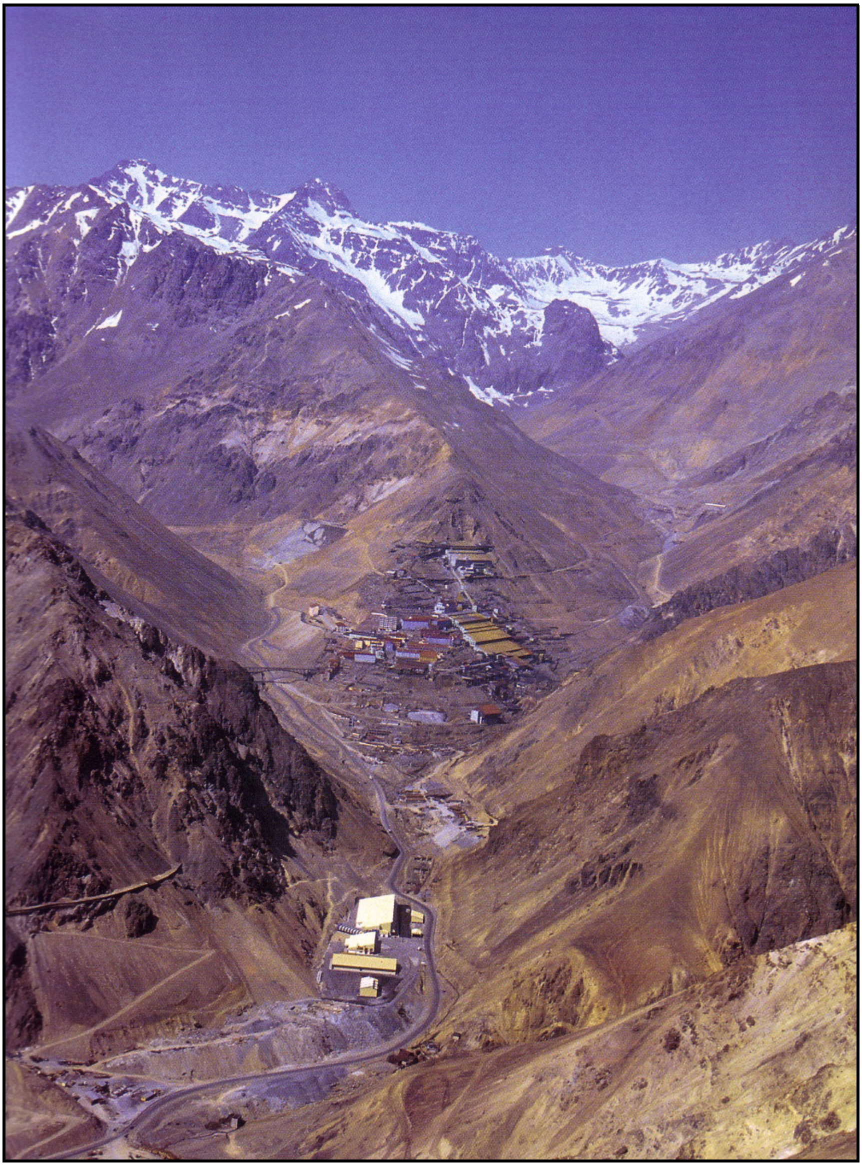


Figure 1.37: Sewell at 2000 m above sea level is the world's largest underground mine.

Figure 1.38: Concentration plant at Colón.

Figure 1.39: Valparaíso harbour, 1993.

Valparaíso Region

Valparaíso (Figure 1.39) is one of the country's most important seaports and where the National Congress of Chile and Technical University Federico Santa María are located. The naval officer Arturo Prat (1848–1879) the hero of the Pacific War spent most of his short life in Valparaíso where a monument for him stands (Figure 1.40). Prat died at the Naval Battle of Iquique at the age of 31.

Figure 1.40: Monument to Arturo Prat (1848–1879) in Valparaíso, hero of the Pacific War.

Technical University Federico Santa María

Federico Santa María Carrera (1845–1925) (Figure 1.41) was born in Valparaíso in one of the most influential Chilean families of the 19th century. He made a huge fortune in the sugar markets of Paris, in which he arrived when he was very young. His importance in the sugar market was considerable: he became a major power in the French economy. During World War I he closed down all his businesses, declaring that he did not want to profit from war. He also supported the French Army, donating clothes and weapons for an entire regiment. Because he had no descendants, he gave his entire fortune to his hometown Valparaíso for the founding of a technical and engineering school. The result of his legacy was the Federico Santa María Technical University founded in 1926. In 1960 the Graduate School was created. In 1963 the university became the first higher-education institution in Latin America to confer a doctorate (Figures 1.42–1.44).

Figure 1.41: Federico Santa María Carrera (1845–1925).

Figure 1.42: Technical University Federico Santa María.

Figure 1.43: Professor David Fuller [third from left], Washington Alyaga and staff at Technical University Federico Santa María in Valparaíso, 1993.

Figure 1.44: Professor David Fuller and staff at Technical University Federico Santa María in Valparaíso Jorge Pontt at the extreme right [Photo by Nadia Habashi, 1994].

Viña del Mar

Viña del Mar (Figures 1.45–1.54) is next door to Valparaíso and is a beautiful town on the Pacific Ocean. It is an hour and half drive from Santiago Airport. The road from airport to Viña del Mar is full of the Aromas trees, also called Maidenhair tree, in full bloom (Figure 1.55). There is also the house of Nobel Prize winner Pablo Neruda (1904–1973) (Figures 1.56–1.59). Neruda was the pen name and later legal name of the Chilean poet, diplomat, and politician Neftalí Ricardo Reyes Basoalto. He chose his pen name after Czech poet Jan Neruda. In 1971, Neruda won the Nobel Prize for Literature.

Figure 1.45: Location of Santiago, Valparaíso, and Viña del Mar.

Figure 1.46: Surroundings of Viña del Mar. Copper smelter is at Ventana.

Figure 1.47: Viña del Mar.

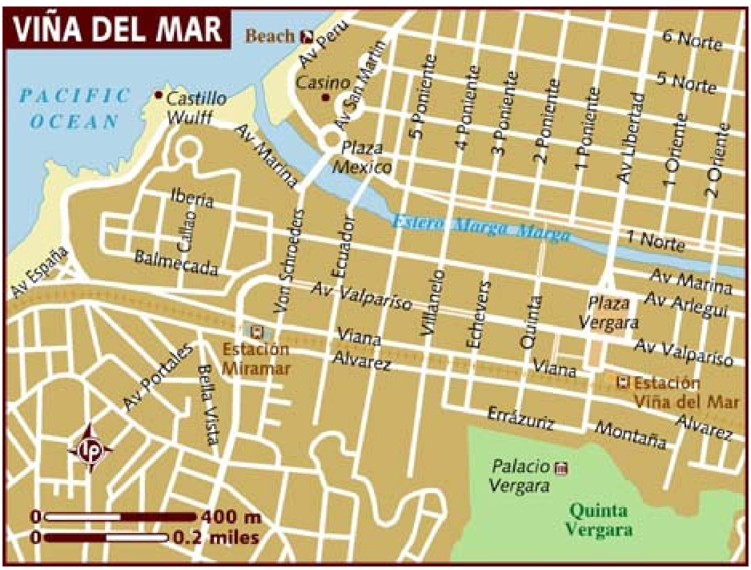


Figure 1.48: Map of Viña del Mar showing the Marga Marga River and the Casino.

Figure 1.49: Horacio Aros and Amelia Dondero standing, August 2013.

Figure 1.50: Viewing Viña del Mar from the top of the mountains.

Figure 1.51: Valparaíso and postcard. The post office workers were on strike. Photo by Nadia Habashi, August 2013.

Figure 1.52: Viña del Mar surroundings.

Figure 1.53: Viña del Mar surroundings.

Figure 1.54: Viña del Mar surroundings with guide Richard.

Figure 1.55: The Aromas trees.

Figure 1.56: Visiting the house of Pablo Neruda in Viña del Mar, now a Museum, August 2013.

Figure 1.57: Pablo Neruda (1904–1973).

Figure 1.58: The strange house of Pablo Neruda in Viña del Mar, now a Museum.

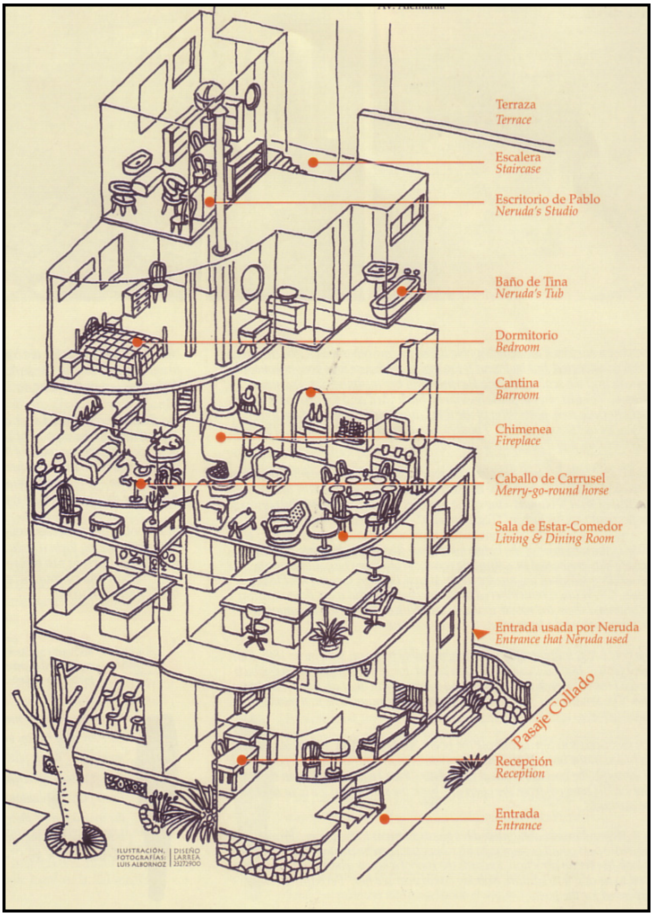


Figure 1.59: The strange house of Pablo Neruda in Viña del Mar, now a Museum.

Pontifical Catholic University of Valparaíso

The Pontifical Catholic University of Valparaíso (Figure 1.60) was founded in 1928 and the School of Chemical Engineering was founded at the same time. The School of Chemical Engineering now includes the Department of Mining and the Department of Extractive Metallurgy in addition to the Department of Chemical Engineering. The University has a student body of 14 000 and is active in international cooperation. In the past year it had 900 students exchanged world wide. Hosts: Horacio Aros Meneses, Director, School of Chemical Engineering, and Amelia Dondero Professor of Extractive Metallurgy (Figure 1.61).

Figure 1.60: Pontifical Catholic University of Valparaíso. Photo by Nadia Habashi August 2013.

Figure 1.61: Rectorate of Pontifical Catholic University of Valparaíso, August 2013.

Figure 1.62: Marcos Avilez in the middle, Amelia Dondero on the left and Horacio Aros on the right. Photo by Nadia Habashi, August 2013.

A meeting was held with Marcos Avilez (Figure 1.62), Director, International relations, to explore the possibility of exchange of students with Laval University.

Conference of Extractive Metallurgy

Students of the Department of Extractive Metallurgy at the Pontifical Catholic University of Valparaíso in Chile have organized the third conference in August 21–23, 2013 (Figure 1.63). I gave a short course entitled, "Pollution Problems in the Mineral and Metallurgical Industry" preceding the conference (Figures 1.64). Students from all over Chile came to Hotel O'Higgins (Figure 1.65–1.69) in Viña del Mar to attend the event. The conference was well attended and well organized. It is an annual event conducted by the students. A conference report appeared in *Nueva Minería y Energía* (Figures 1.70–1.71).

Figure 1.63: Flyer for the conference.

Figure 1.64: Flyer announcing the short course.

Figure 1.65: Opening of the conference.

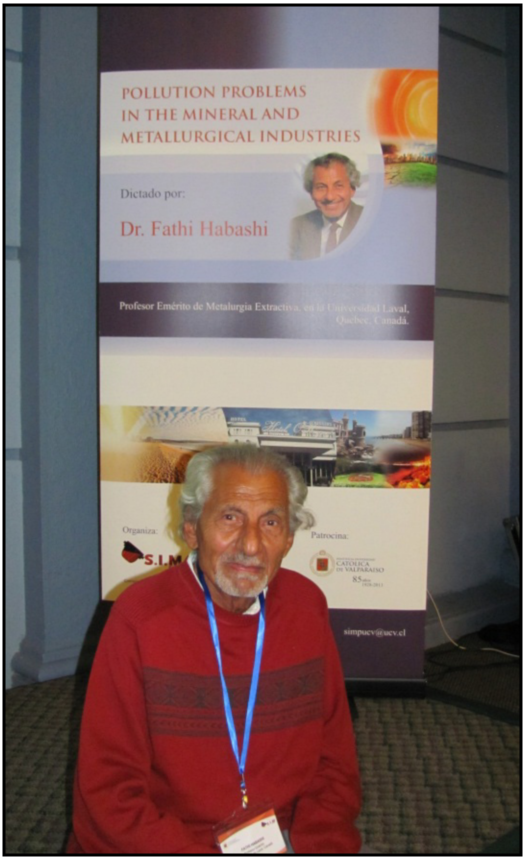


Figure 1.66: The conference.

Figure 1.67: Locating Quebec and Viña del Mar on the map.

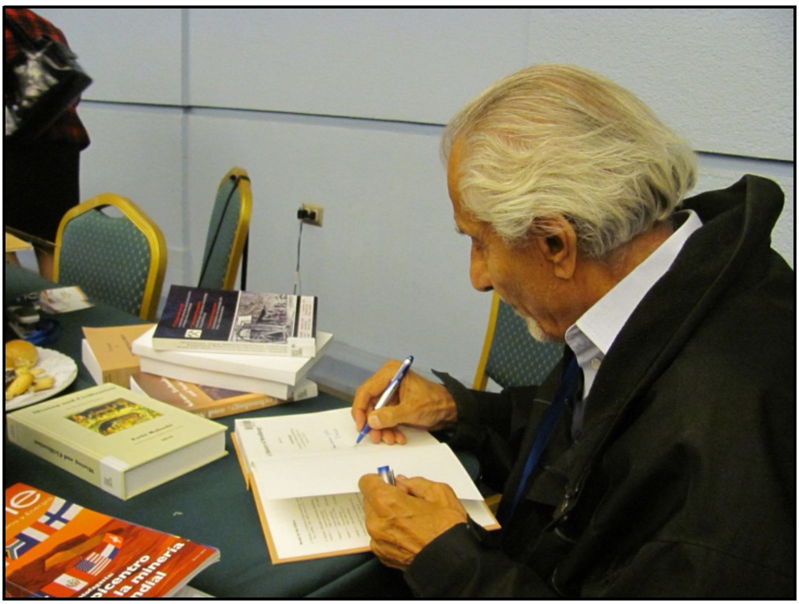


Figure 1.68: Signing of books.

Figure 1.69: Hotel O'Higgins. Photo by Nadia Habashi, 2013.

Coquimbo Region

La Serena is the capital of Coquimbo Region. It has a School of Mines (Figure 1.72) and is the home of Nobel prize winner Gabriela Mistral (Figure 1.73).

La Serena School of Mines

The School of Mines in La Serena was founded in 1887. Manuel Buenaventura Osorio (1833–1907), who was a pupil of Ignacio Domeyko's first class at the College of Coquimbo, was appointed director. In 1952, the school was incorporated in the newly founded State Technical University. In 1981, it became the Faculty of Engineering of the University of La Serena that offered programs in mining, mechanical, food, and civil engineering.

Entre el 21 y 23 de agosto:

Destacado investigador será conferencista central de encuentro de metalurgia

Fathi Habashi, autor indispensable en la docencia, participará activamente del III Seminario de Estudiantes de Metalurgia (SIM), que organizan los alumnos de la PUCV.

Eric Rivera
Desde Valparaíso

Por tercer año consecutivo los alumnos de Ingeniería Civil Química de la Pontificia Universidad Católica de Valparaíso (PUCV) realizarán el Seminario de Estudiantes de Metalurgia Extractiva, SIM, encuentro en el que participarán alumnos de todas las universidades del país que cursan la especialidad.

Programado para el 21, 22 y 23 de agosto en el Hotel O´Higgins de Viña del

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Figure 1.70: Nueva Mineria y Energia, page 98 (2013).

minería

Mar, el encuentro contará con la participación del destacado metalurgista Fathi Habashi, profesor emérito de la Universidad Laval de Quebec y autor de textos usados en docencia metalúrgica.

El investigador canadiense dictará el curso "Problemas de polución en industrias metalúrgicas y mineras" el miércoles 21, previo al seminario, que se inicia formalmente ese mismo día por la tarde. En el curso, Habashi entregará una visión global sobre la polución, tratando sobre procesos metalúrgicos, separación de polvos, tratamiento de sulfuros, y procesos de la industria del fierro, acero, aluminio y minerales radioactivos, entre otros.

Posteriormente, como conferencista central del SIM, Fathi Habashi ofrecerá una charla sobre el futuro de la metalurgia del cobre.

El investigador es un reconocido especialista en piro e hidrometalurgia, que abrió fronteras a dichas tecnologías. "Invitamos al Dr. Habashi porque esta tercera versión del SIM estará enfocado a la innovación, tanto en aspectos del tratamiento mismo como en la disponibilidad de la energía y agua y el tema de los residuos. Él ha estado en Chile dando conferencias y asesorando a empresas, y es un orgullo tenerlo esta vez con los estudiantes de metalurgia de nuestro país", destaca Amelia Dondero, académica de la PUCV que preside el SIM.

También fue invitado al encuentro el reconocido metalurgista chileno Esteban Domic, quien marcó un hito al desarrollar a escala industrial la lixiviación en pilas de sulfuros de baja ley, con su proceso TL (Thin Layer) por la formación de pilas en "capas delgadas".

Fathi Habashi, destacado metalurgista canadiense, será el principal expositor del SIM.

Otros temas

El programa del SIM abarca otros temas como la minería no cuprífera, con charlas de empresas que explotan estos recursos. Asimismo, destacan temas como el cluster minero, el recurso hídrico, el litio y la minería del oro. Todo esto se complementará con conferencias de los ministerios de Minería, Medio Ambiente y Energía, que patrocinan el encuentro.

"Queremos que los estudiantes se informen sobre las otras minerías y de los subproductos, que son otras alternativas para su desarrollo", comenta Javier Segura, de la comisión organizadora del SIM que también integran Cristián Araya y Andrés Valencia.

En total, este Tercer Seminario de Estudiantes de Ingeniería Metalúrgica tendrá una veintena de conferencias de unos 45 minutos, pues se mantiene el criterio de ofrecer más tiempo a los conferencistas para una mejor exposición. Ya se han comprometido delegaciones de 9 universidades que imparten la carrera de ingeniería civil y de ejecución metalúrgica en el país, incluyendo esta vez la Universidad Arturo Prat de Iquique y la Católica del Norte de Antofagasta.

Los organizadores destacaron que estas jornadas han creado vínculos entre los estudiantes de metalurgia de distintas zonas del país ya que pueden intercambiar experiencias valiosas y establecer redes útiles para su futuro trabajo profesional.

Las expectativas para la próxima edición del SIM (www.simpucv.com) son altas, sobre todo tras conocer los satisfactorios resultados de una encuesta realizada a los asistentes de la versión anterior, quienes coincidieron en destacar el alto nivel de los expositores. Asimismo, las empresas participantes resaltaron la organización del encuentro, la que compararon con los mejores congresos profesionales que se realizan en el ámbito minero.

Iniciativa estudiantil

El Seminario de Estudiantes de Metalurgia Extractiva, SIM, se realizó por primera vez el año 2011 por iniciativa del Centro de Estudiantes de la Carrera de Ingeniería Civil Metalurgia Extractiva de la PUCV, con la idea de generar una instancia de encuentro entre los estudiantes de la especialidad y la industria minera.

El éxito de la primera versión impulsó a los organizadores a repetir la experiencia el año siguiente, con el lema "Minería sustentable: desafíos y oportunidades". El encuentro de agosto será la tercera edición de este seminario que contó desde su nacimiento con el apoyo de Revista Nueva Minería y Energía, medio oficial del evento.

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Figure 1.71: Nueva Mineria y Energia, page 99 (2013).

Figure 1.72: University La Serena. From left to right: Rector, Claudio de Bon Canus, Fathi Habashi, Federico Brunner [Photo by Nadia Habashi, 2001].

Gabriela Mistral

Figure 1.73: Museum of Nobel literature prize Gabriela Mistral in La Serena. [Photo by Nadia Habashi, 2001].

Chile has two Nobel prize winners for literature: Gabriela Mistral (1889–1957) in 1945 (Figure 1.74) and Pablo Neruda (1904–1973) in 1971. Mistral was the pseudonym of Lucila de María del Perpetuo Socorro Godoy Alcayaga, a poet, educator, and diplomat who was the first Latin American to win the Nobel prize. She was of Basque and Amerindian descent. Her father was a school teacher who abandoned the family before she was three years old. By age fifteen, she was supporting herself and her mother by working as a teacher's aide in the seaside town of Compañía Baja, near La Serena. About 1906 she met a railway worker who killed himself in 1909. The profound effects of death were already in the poet's work. In 1914 she won a prize for her work *The Sonnets of Death*. She worked in Mexico and USA and toured Europe before returning to Chile in 1925. She served as a consul in different countries from 1932 until her death.

Figure 1.74: Gabriela Mistral (1889–1957).

ATACAMA REGION

Copiapó is the capital of the Atacama Region (Figure 1.75). It was founded in 1744 by the governor José Antonio Manso de Velasco along the Copiapó River, which is now dried up due to mining activities. The University of Atacama is located there. The first railroad in Chile was constructed in1851 from Copiapó to Caldera on the ocean coast. This first locomotive is on display at the University of Atacama (Figure 1.76).

Figure 1.75: A view of Copiapó.

Figure 1.76: The first railroad in Chile was constructed in1851 from Copiapó to Caldera on the ocean side. This first locomotive is on display at the University of Atacama.

University of Atacama

The discovery of silver deposits in the Atacama region in 1832 resulted in the creation on April 11, 1857 of the Copiapó School of Mines in Copiapó the capital of the Atacama region. In 1864, the "Engineers of Mines" program was created, and the students took their exams at the University of Chile in Santiago. As of 1875, a mining engineering degree could be obtained directly from Copiapó. In 1885, the school adopted the name Practical School of Mining. Casimiro Domeyko, son of Ignacio Domeyko, a mining engineer, was its director. In 1952, with the creation of the State Technical University, the two schools merged. In 1957, the extractive metallurgy department was created leading to a degree in metallurgy as an industrial technician. From 1969 to 1983, the degree was entitled practical engineer in extractive metallurgy, and since 1983, civil engineer in metallurgy. Since 1981, it is the Faculty of Engineering at the University of Atacama that offers programs in mining and metallurgical engineering, as well as technology in geology and metallurgical plants (Figures 1.77–1.78).

Congreso Internacional de Ingeniería de Minas

The International Congress of Mining Engineers was held in August 1993 in Copiapó and was organized by the faculty members of the University of Atacama. It followed immediately another local conference III Jornadas de Metalurgia del Norte Grande held few days earlier in Antofagasta (Figures 1.79–1.80).

Figure 1.77: University of Atacama, Copiapó.

Figure 1.78: Rector José Palacios [Photo by Fathi Habashi, April 2005].

Figure 1.79: With students at the University of Atacama, 1993. From right to left: Armando Valenzuela, Mauricio.

Figure 1.80: From right to left: Jean Frenay from University of Liège, Germán Cáceres from University of Atacama, ??, Mario Sánchez from University of Concepción, ?? [Photo by Nadia Habashi, 1993].

Paipote

Construction of the Paipote smelter, located 9 km south of Copiapó, began in 1949 using a reverberatory furnace and two Peirce-Smith converters. Production of sulfuric acid started in 1969, which was used in the oxide processing plants.

Punta del Cobre

Sociedad Punta del Cobre is engaged in the exploration, mining, and exploitation of copper in the Atacama region. The Company recovers copper from the Punta del Cobre mine. Its facilities also include the San José plant, which produces copper concentrates, and the Biocobre plant, where the production of copper cathodes is performed (Figures 1.81–1.84).

Figure 1.81: Entrance to the chalcopyrite mine Punta del Cobre, April 2005.

Figure 1.82: Heap leaching operation at Punta del Cobre, April 2005.

Figure 1.83: Chalcopyrite concentrator at Punta del Cobre, April 2005.

Figure 1.84: A copper plaque souvenir from Punta del Cobre, April 2005.

ANTOFAGASTA REGION

The city Antofagasta is the capital of Antofagasta Region and is a port city about 1 130 km north of Santiago located in the Atacama Desert on the Tropic of Capricorn (Figures 1.85–1.87). It is the seat of the Universidad Católica del Norte and is characterized by Portada de Antofagasta (Figure 1.88).

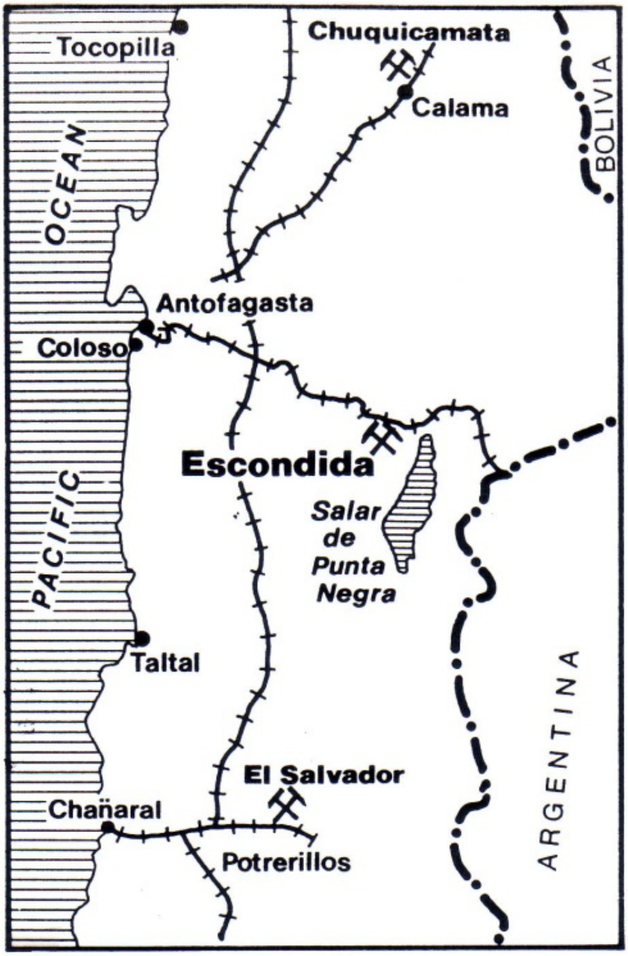

Figure 1.85: Location map of Antofagasta and its environment.

Universidad Católica del Norte

The Universidad Católica del Norte (Catholic University of the North) is a Catholic and pluralistic university founded in 1956 in the city of Antofagasta (Figures 1.89–1.93).

Figure 1.86: Plaque at Antofagasta marking the Tropic of Capricorn [Photo by Raúl Ibarra, 2009].

Figure 1.87: Monument at Antofagasta marking the Tropic of Capricorn [Photo by Raúl Ibarra, 2009].

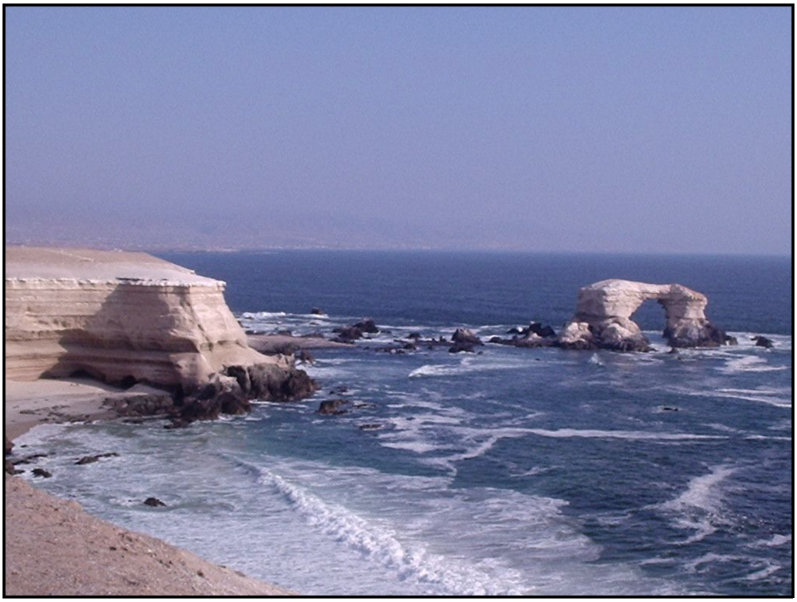

Figure 1.88: Portada de Antofagasta.

Figure 1.89: Universidad Católica del Norte.

Figure 1.90: With Raúl Ibarra at Universidad Católica del Norte in 1992.

Figure 1.91: Right: Teodoro Politis Jaramis, Dean of Engineering Faculty, left: Hugo Carcamo, Chairman Metallurgy Department, Universidad Católica del Norte [Photo by Nadia Habashi, 1993].

Figure 1.92: With metallurgy faculty members at the Universidad Católica del Norte [Photo by Nadia Habashi, 1993].

Figure 1.93: With students at the Universidad Católica del Norte, 1993.

Escondida process

Minera Escondida, which means "hidden" in Spanish, is a mining company that operates two open pit copper mines in the Atacama Desert, 170 km southeast of Antofagasta. It is currently the highest producing copper mine in the world. Production in 2007 was 1.483 million tons of copper mainly as metal in concentrate but some as cathode. The concentrate is shipped at the port of Coloso. A cross section of the ore body is shown in Figure 1.94 and the concentrator is shown in Figure 1.95. The Escondida process was developed by Wilem Duyvesteyn and coworkers at the Minerals Laboratory of BHP in Sunnyvale, California in 1991 and was closed few years later. The 600 kg/day plant was constructed at Coloso near Antofagasta in Chile. The ore was mainly chalcocite, Cu_2S, and it was intended to extract only half of the copper to produce a CuS concentrate for shipment (Figure 1.96).

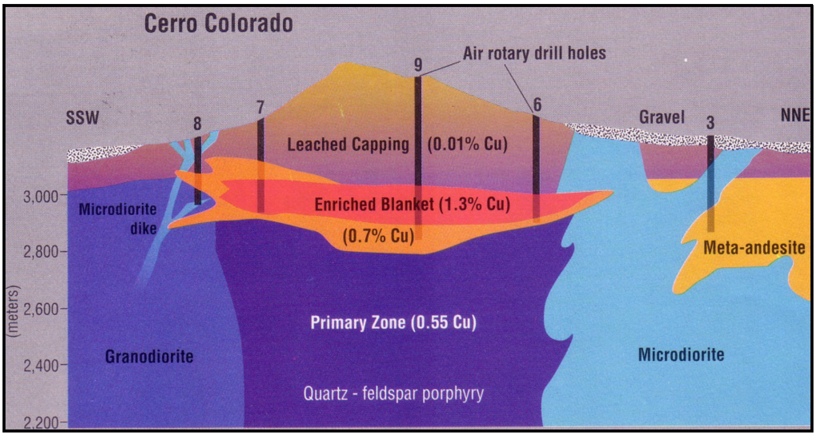

Figure 1.94: Cross section of the Escondida ore body.

An ammoniacal solution under mildly oxidizing conditions at atmospheric pressure was used to leach half of the copper in the concentrate. The mild leaching conditions also prevent the dissolution of unwanted impurities. Solution purification is carried out by solvent extraction with LIX-54 which is selective for copper ions. Stripping is conducted by sulfuric acid. Copper cathodes of high purity were produced in a conventional sulfuric acid-based electrowinning system. Ammonia was regenerated from the solutions by distillation and recycled for leaching. One scrubbing step was needed between the ammoniacal and acid circuits. The residue is a high-grade copper concentrate ready for shipment.

Figure 1.95: View of Escondida concentrator.

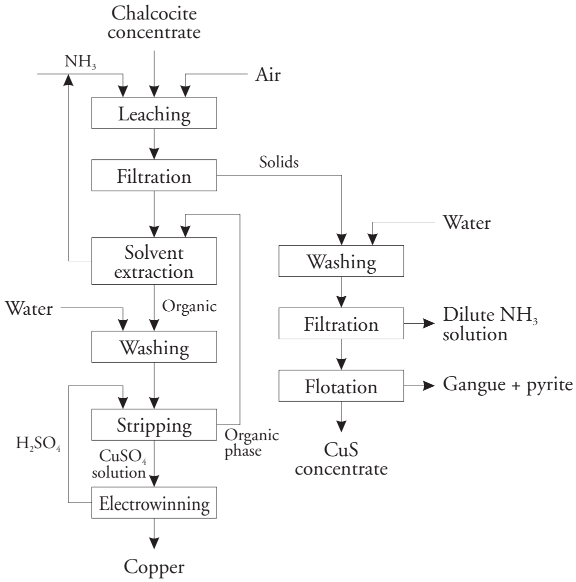

Figure 1.96: Escondida process.

Chalcocite behaves in leaching as if it were a mixture of metallic copper and cupric sulfide:

$$Cu_2S \approx Cu + CuS$$

$$Cu + 4NH_3 + {}^1/_2O_2 + H2O \rightarrow [Cu(NH_3)_4]^{2+} + 2OH^-$$

Conditions were so chosen that CuS was not attacked. The reaction is slow but accelerated when NH_4^+ ion is present. There are some problems, however, with ammonia leaching:

- Absorbing CO_2 from the atmosphere. Thus an appreciable amount of ammonium ion builds up
- Partial oxidation of NH_3 to nitrite, Cu^{2+} ion acting as catalyst:

  $$2NH_{3(aq)} + 3O_2 + 2OH^- \rightarrow 2NO_2^- + 4H_2O$$

- Transferring the extraction system from ammoniacal to acid generates a dilute ammoniacal solution which necessitates recovery
- Washing of residue also generates a similar solution

Recovery of NH_3 from such solutions requires boiling with lime to distil off NH_3 and form calcium carbonate for disposal. If some sulfides go in solution, then a corresponding amount of gypsum will also form for disposal. Recovery of ammonia from ammonium salts is not economical and losses of ammonia cannot be tolerated.

Mantos Blancos

Empresa Minera de Mantos Blancos is located 45 km northeast of Antofagasta, owned by the German magnate Mauricio Hochschild, who owns also mineral properties in Bolivia. The plant was designed by Lurgi, and is presently operated by about 1 000 workers. There is an open-pit mine since 1961 (1% Cu oxide ore) and an underground mine since 1981 (1.2% Cu sulfide ore). Guide: Jorge Arias Parra, Chief Metallurgist. Flowsheet is shown in Figure 1.97.

Sulfide Plant. After crushing and grinding, sulfides are floated to obtain a concentrate containing 45% Cu and 500 g/t Ag for shipping. The remaining oxide minerals are then treated with NaHS solution and floated to get an oxide concentrate containing 20% Cu which is leached in agitated tanks by H_2SO_4 and CCD to get a $CuSO_4$ solution and a residue still containing some sulfides which are recovered by flotation and added to the concentrate destined for shipping.

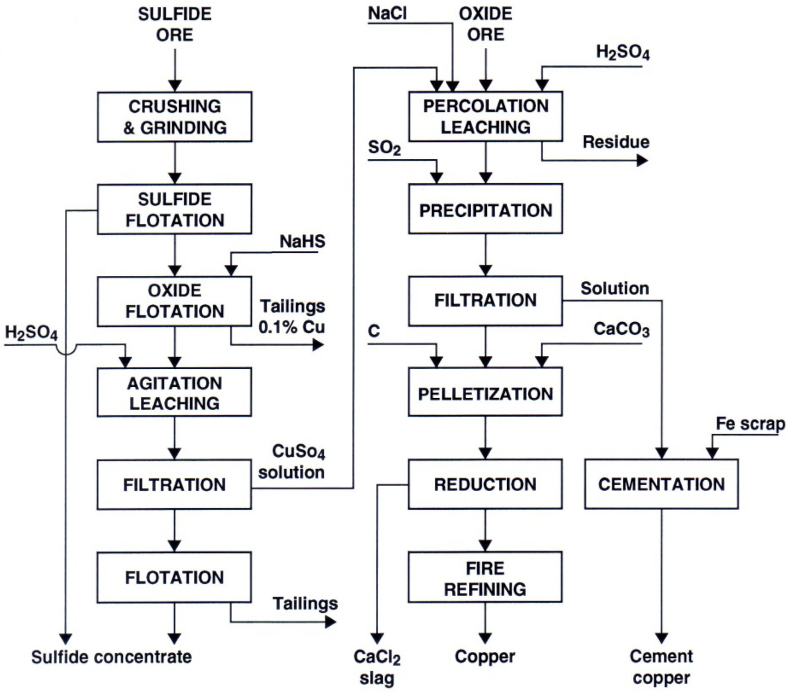

Figure 1.97: Mantos Blancos process.

Oxide Plant. The ore contains 1 % Cu mainly as atacamite (10 000 t/day), is crushed to −1/4" and leached in 10 vats, 4 000 t each, by H_2SO_4 for 100 hours. $CuSO_4$ solution from Sulfide Plant is added together with some NaCl. The solution obtained contains 30 g/L Cu at Cl/Cu ratio = 1. Copper(I) chloride is precipitated from this solution by reduction with SO_2 gas (prepared by burning imported elemental sulfur) in a series of towers (counter-current, no packing) (Figure 1.98). It is thickened, centrifuged, then pelletized with 4 % coke and 36 % limestone (pellets contain 36 % Cu), then heated in small rotary furnaces (Kurz Trommel Ofen) (Figure 1.99) to get crude copper 99.5–99.9 % and a $CaCl_2$ slag. This is then refined to ingots 99.96 % Cu (25 000 t) by blowing and poling (Figure 1.100). Solution after Cu precipitation contains Cu^+ ion in solution is treated with scrap iron in rotating drums to get cement copper (5 000 t). Figure 1.101 shows the reaction and refining plant outline.

The plant will be shut down in the next few years [1992] because it is highly polluting and inefficient. For example:

- Large amounts of $CaCl_2$ are produced; they contain 1 % Cu.

- Six small rotating reduction furnaces are highly inefficient (heat loss by radiation) and no provision for collecting the dust emitted.

New Oxide Pilot Plant. The chloride precipitation technology will be replaced by solvent extraction–electrowinning. A pilot plant is presently in operation treating 10 t/d ore, washing to remove Cl^- ion before electrowinning; SX 11 L/min, 80 kg/d cathodes [1992].

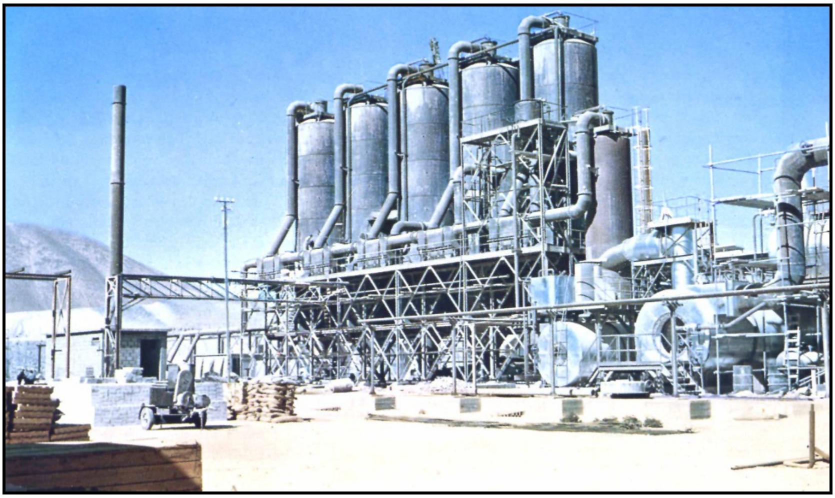

Figure 1.98: Sulfur dioxide towers for precipitating Cu_2Cl_2.

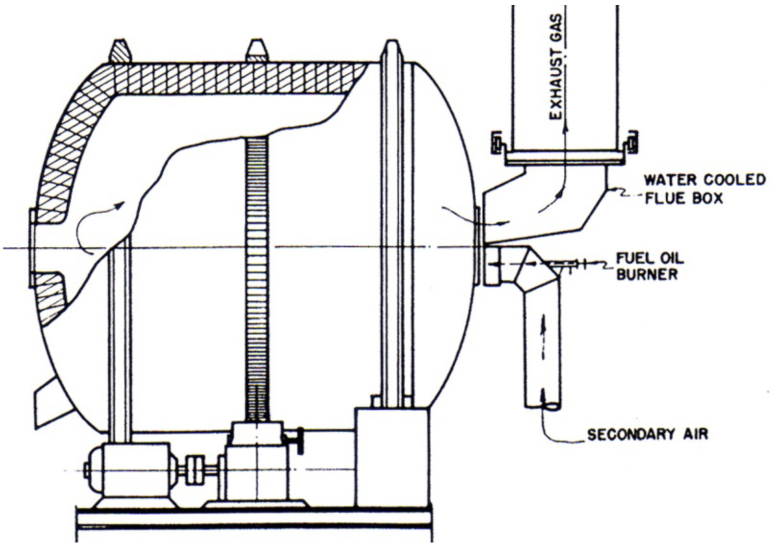

Figure 1.99: Lurgi short drum reaction furnace.

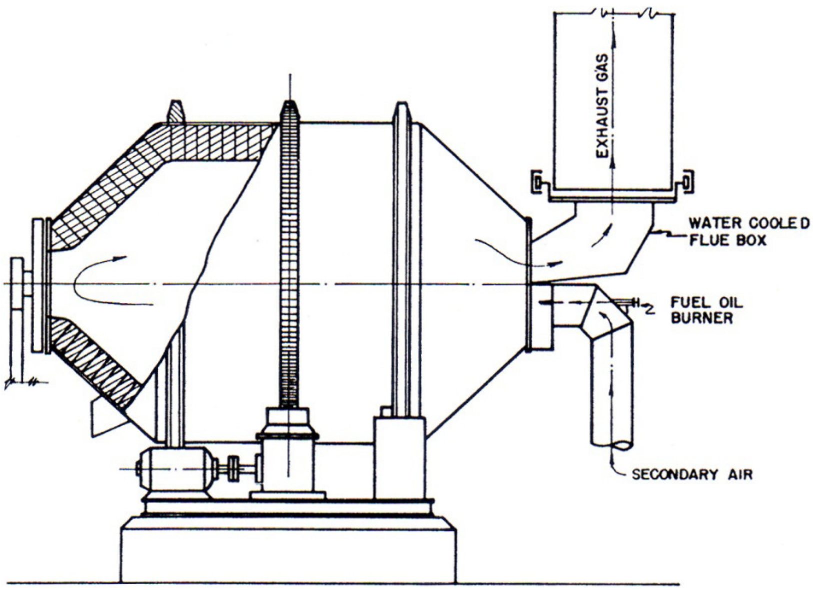

Figure 1.100: Lurgi copper refining furnace.

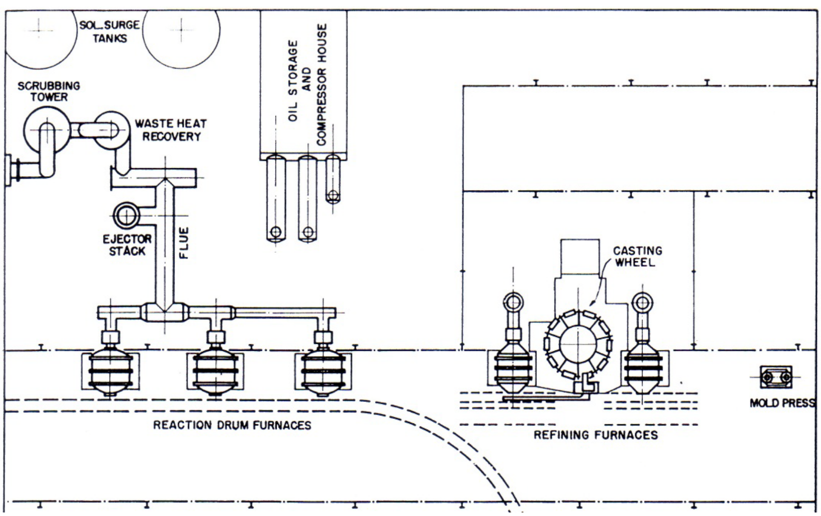

Figure 1.101: Mantos Blancos plan of reaction and refining furnaces.

Compañía Minera Carolina de Michilla

Chief metallurgist and guide: Ing. Gustavo Fuentes. The mine and plant is located 110 km north of Antofagasta. The minerals are mainly atacamite, chrysocolla, chalcocite, and bornite. Average grade 2.5% Cu oxide–sulfide. Flotation concentrate obtained 1 600 t/month at 44–54% Cu. Tailings contain 0.16% Cu is leached in agitation tanks and CCD system to throw away a residue containing 0.10% Cu. Copper recovered from solution by cementation with scrap iron in large rotating drums.

Thin layer leaching process. An oxide ore containing 2.3–2.5% Cu mainly as atacamite and chrysocolla is ground to 3/8" then sprayed with concentrated H_2SO_4, 30 kg/ton in rotating drum; the temperature rises. The material is then transported in trucks and dumped to form pads 2.6 m high. Sea water is then spayed at the top of the dump at a controlled rate, and the strong $CuSO_4$ solution 25–50 g/L is collected at the bottom. In about a week, 87% of the copper is recovered. The pad is then removed and discarded, while the solution is treated with pig iron ingots to get cement copper for sale to copper smelters. The process is therefore not a dump leaching process but rather acid curing and vat leaching (without vats).

New pilot plant. All cementation processes will be discontinued in the next few years, to be replaced by solvent extraction–electrowinning. A pilot plant is at present in operation using LIX622N and stainless steel cathodes. Engineer: Gabriel Araya Garrido.

Huanchaca Silver Refinery ruins

In 1888, The Huanchaca Company of Bolivia established a large silver refinery at Playa Blanca in Antofagasta that became the largest in South America (Figures 1.102–1.103). It was built by the American engineer C. W. Wendt who brought all the necessary equipment from the USA. The building material for the plant was the stone which was obtained from an existing quarry to the south of the Universidad Católica del Norte in Antofagasta. Silver ore was mined from the Pulacayo Mine in Potosí which was owned by the company. It was transported 500 kilometres to Antofagasta for smelting. The plant was recognized as the most modern of its time, crushing more than 100 tons of ore daily and producing 20 tons of silver per month. The plant was characterized by its enormous pumps that raised water from the sea for cooling purposes and the huge steam engine whose flywheel was 7 metres diameter.

At the Huanchaca refinery a variety of silver-bearing sulfides were treated by amalgamation and by cupellation. A number of roasting furnaces were used prior to both operations. When the ore was refractory chloridizing roasting was used in the Stetefeldt furnace. The material charged to this furnace must have a sulfur content of about 8%. If the ore contains higher than this, then excess sulfur must be first removed in the rotary kilns. The purpose was to transform all the silver mineral to a chloride and as little as possible of the other metals, with the exception of copper, using NaCl. The chloridized residue as well as the chloridized dust collected from the escaping gases were combined and treated with mercury.

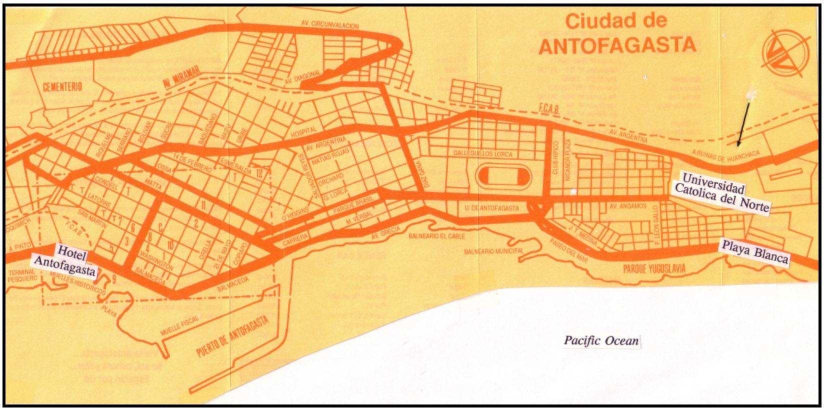

Figure 1.102: The arrow refers to the location of the silver refinery ruins in Antofagasta.

Figure 1.103: With Professor Hugo Carcamo of the Universidad Católica del Norte, Antofagasta [Photo by Nadia Habashi, 1993].

After 12 years in operation, management decided to close and sell the property because the technology used was already outdated. The cyanidation process for treating silver ores, invented in 1888, was already successful and rendered amalgamation methods uneconomical.

III Jornadas de Metalurgia del Norte Grande

The Third Conference of Metallurgy in the North was attended in 1993 (Figures 1.104–1.105).

Figure 1.104: With conference organizers [Photo by Nadia Habashi, 1993].

Figure 1.105: Souvenir from the conference.

CONAMET 94

The VIII Congreso Nacional de Metalurgia known as CONAMET was held in Antofagasta jointly with the III Congreso de la Asociación Latinoamericana de Metalurgia y Materiales in August 1994 (Figure 1.106).

Figure 1.106: CONAMET 94. From left: Alejandro Morales, Maria Cecilia, Fathi Habashi, and Alonso Arenas [Photo by Nadia Habashi, 1994].

Calama

Calama, the second-largest city in the Antofagasta Region, is 213 km northeast of the regional capital.

Chuquicamata

Various Chilean miners sporadically worked the Chuquicamata mine after the Pacific War. In 1903, there were 300 operations producing 18 000 tons of concentrate and 3 325 tons of copper. Several attempts were made in the early 1900s to develop the mine however, it was the Boston-based businessman Albert Burrage, who saw the potential in a mountain of low-grade ore. The oxide ore had about 2% Cu, which was considered barely economic at the time. He employed the newly developed Bradley process to leach the oxide ores with sulfuric acid and succeeded in persuading the Guggenheim family of New York to help finance construction. In 1912, a geological team was sent to determine the mineral reserves; these were estimated at 690 million tons having 2.58% Cu and were divided as follows:

- Oxides: 329 million tons at 1.91% Cu
- Sulfides: 210 million tons at 1.84% Cu
- Mixed: 151 million tons at 2.98% Cu

In 1913, the American company established the Chile Exploration Company and bought all the operations in the Chuquicamata district. The mine was operated using large-scale open-pit mining techniques, which were first demonstrated in 1906 by Daniel C. Jackling at Bingham Canyon in Utah as well as in Cananea, Mexico.

Oxide exploitation began in 1915 sulfuric acid vat leaching then copper electrowinning. In 1923, Anaconda Copper acquired a controlling stake in the Chile Exploration Company. In 1929, Daniel Guggenheim sold his remaining interest to Anaconda. Concentration by flotation began in 1952 together with concentrate smelting. In 1967, the Chilean government purchased 51% of the Anaconda property to form the Company of Copper Chuquicamata S.A. Currently, about 180 000 tons/day of ore having about 1% Cu are processed at Chuquicamata producing about 600 000 tons/year Cu.

Codelco is the main copper company in the world. In 2009 produced 1 700 000 tonnes. Codelco is one the largest molybdenum producer. In 2008, the production was 21 000 tons. It also produces gold (5,5 tpy), silver (130 tpy), and selenium as by-products. A recent view of Chuquicamata mine is shown in Figure 1.107. Director of Research at Chuquicamata in 1993 was Gustavo Cartagena (Figure 1.108).

Figure 1.107: Chuquicamata copper mine.

Figure 1.108: Gustavo Cartagena, Director of Research, 1993.

Alliance Copper

Bacterial leaching has been successfully applied for heap leaching of copper ores. It was extended to treat auriferous pyrite concentrates to liberate gold and render it amenable to cyanidation by a process known as BIOX. In the past few years there has been interest to apply bacterial leaching to treat chalcopyrite concentrates. For example, Engineering of BacTech Mining Corporation operated a continuous small scale bioleach pilot plant in 1998 at Mt. Lyell in Tasmania. A demonstration scale plant was constructed in 2001 by the joint technology partnership of BacTech and Mintek in conjunction with Peñoles in Monterrey in Mexico. The plant operated for a year with a capacity of 200 tpa copper cathode production using commercial equipment.

It is interesting that in 2002, Alliance Copper, which is a joint venture between BHP Billiton and Codelco built also a 20,000 tonnes/year demonstration plant 30 km from Calama for US $ 50 million. The plant is composed of six large reactors, mechanically agitated, and lined with acid-resisting brick (Figure 1.109). Since a thermophilic bacteria is used in the system it is possible to operate at a temperature of about 90 °C and this accelerates the reaction.

In spite of this enthusiasm for bioleaching technology, one cannot recommend its use for leaching chalcopyrite concentrates because it cannot be economical for the following reasons. The leaching reaction for chalcopyrite is as follows:

$$CuFeS_2 + 4O_2 \rightarrow CuSO_4 + FeSO_4$$

Figure 1.109: Alliance Copper plant near Calama.

From this it can be seen that a large amount of oxygen will be consumed, a large amount of lime will be needed to precipitate ferrous sulfate, and there will be an excessive disposal and material handling problem of ferrous hydroxide–gypsum mixture:

$$FeSO_4 + Ca(OH)_2 + 2H_2O \rightarrow Fe(OH)_2 + CaSO_4 \cdot 2H_2O$$

The reaction is slow — it is complete in 4–5 days when conducted and in addition, some bacterial nutrients such as phosphate and ammonium ions must be supplied to the reaction mixture. In the recovery step by electrolysis, acid will be generated and must be disposed of. When bioleaching technology is compared with pressure leaching, the reaction that takes place in one autoclave at 150 °C and 4 000 kPa oxygen partial pressure is as follows:

$$2CuFeS_2 + 4H^+ + {}^5/_2O_2 \rightarrow 2Cu^{2+} + Fe_2O_3 + 4S + 2H_2O$$

The advantages of this route are the following:

- The reaction is fast — complete in 20–30 minutes.
- Oxygen consumption is $1\,{}^1/_4$ moles per mole chalcopyrite as compared to 4 moles in the case of bioleaching, that is less than one third that required for bacterial leaching.
- One reactor is enough.
- Cu^{2+} is already separated from Fe^{2+} since Fe_2O_3 is precipitated during the reaction.
- All the sulfur in the concentrate can be obtained in the elemental form.

- When copper is recovered from solution by electrowinning, the acid generated at the anode is equal to that required for leaching hence no acid disposal problem.
- There is no material handling and disposal problem involving lime addition.
- Any arsenic present in the concentrate will remain in the residue as ferric arsenate.

No wonder that the plant was shut down few months after my visit in 2005.

Potrerillos and Salvador

The Potrerillos deposit, located in the Atacama region, was exploited until 1913 by the Potrerillos Mining Company, a small Chilean company. It was then purchased by William Braden and, in 1916, it was sold to Anaconda, which through its subsidiary, Andes Copper Mining, began exploitation. In 1921, the reserves reached 137 million tons having 1.5% Cu; 48 million tons were oxides and 89 million tons, sulfides. In 1924, for the first time in Chile, the block caving method was used to exploit the mine. In 1927, a 17 000-ton/day concentration plant and a smelter began operation; oxide ore was leached by sulfuric acid then copper electrowinning, recovering 86% Cu.

The concentrate obtained from the flotation process was roasted in seven roasters. Calcine was smelted in three reverberatory furnaces having a 1 200 ton/day capacity. The matte having 50% Cu was fed into converters to obtain blister copper having 99.3% Cu and 1.2 ppm Au. The off-gas allowed for the producing of sulfuric acid, which was used in the leaching process.

In 1939, the company processed about 5 million tons/year of ore having 1.45% Cu, producing 50 000 tons/year Cu. In 1959, the reserves were exhausted and the company began developing the Salvador deposit near Potrerillos (340 million tons having 1.5% Cu), where a new concentrator was built with a production capacity of 85 000 tons/year of copper concentrate. In 1960, the company built an electrolytic refinery in Potrerillos. Today, the Salvador Division produces about 70 000 tons of copper.

Caliche

Following the Pacific War, Chile took possession of the Tarapacá and Antofagasta saltpetre deposits. There were about 80 saltpetre plants that employed approximately 25 000 people. Production increased from 500 000 tons in 1884 to 1 060 000 tons in 1890, and was mainly intended for export to Europe. In addition to iodine, the deposits also produced borates, sodium chloride, and chlorates.

Production was reduced during World War I when synthetic ammonia was produced in Germany by the Haber-Bosch process, which was used to make nitric acid, and took the place of the Chilean saltpetre. In 1924, the Guggenheim family acquired the María Elena saltpetre plant in the Antofagasta region and formed the Anglo Chilean Consolidated Nitrate Corporation, developing the Guggenheim crystallization system. This method allowed for the mechanization of the operations. Nitrate crystallization from the solution was achieved by cooling and later by solar evaporation. The final product was melted and granulated for handling.

Elias Anton Cappelen Smith (1873–1949) (Figure 1.110) was born in Trondheim in Norway, son of founder and owner of the trading companies E. A. Smith AS. Smith was related to the Cappelen family originally from Cappeln in Oldenburg in Northern Germany. The family immigrated to Norway in 1653. Elias Anton Cappelen Smith received his education at the Polytechnic Institute at Trondheim. He migrated to USA in 1893 to work with the Chicago Copper Refining Company, the Anaconda Company, the Baltimore Copper Smelting & Rolling Company, the American Smelting & Refining Company, and then became one of the partners of Guggenheim Brothers in New York.

Figure 1.110: Elias Anton Cappelen Smith (1873–1949).

In 1911, Guggenheim bought Chuquicamata and developed the copper mine, under the leadership of Elias Anton Cappelen Smith. He developed the leaching process for copper extraction from the low grade ore and devised with William H. Peirce what became later known as the Pierce–Smith converter (1909).

During more than a decade, Smith was appointed first administrator of the Chacabuco Saltpetre Refinery built in 1924. He studied the technology of the saltpetre industry and designed a new method for extracting and purifying the sodium nitrate. All activities were halted in 1940 when synthetic ammonia became a substitute of natural nitrate. In 1965, the company handed the management over to Soquimich Chemical and Mining Society of Chile. The community's name was given by Elias Anton in honour of his wife Mary Helen who died at the young age of 54. Figures 1.111–1.114 show some views of the Salar.

Figure 1.111: Salar de Atacama [Photo by Nadia Habashi, 1993].

Figure 1.112: Salar de Atacama [Photo by Nadia Habashi, 1993].

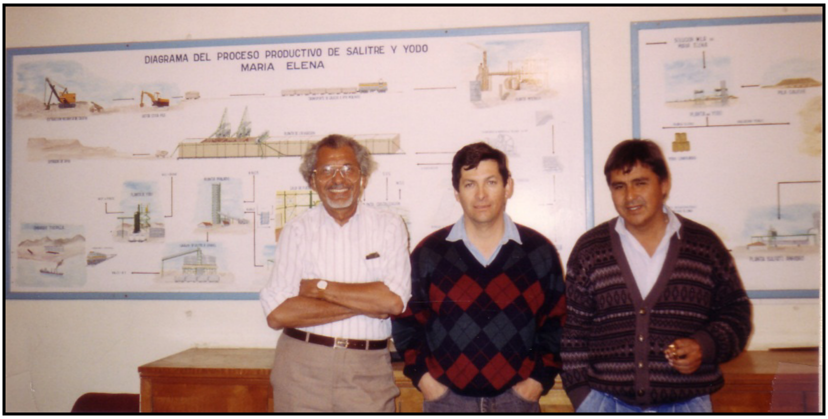

Figure 1.113: María Elena. From right: Dr. Patricio Araya, Director of Research, Ing. Bernardo Araya, Production Manager [Photo by Nadia Habashi, 1993].

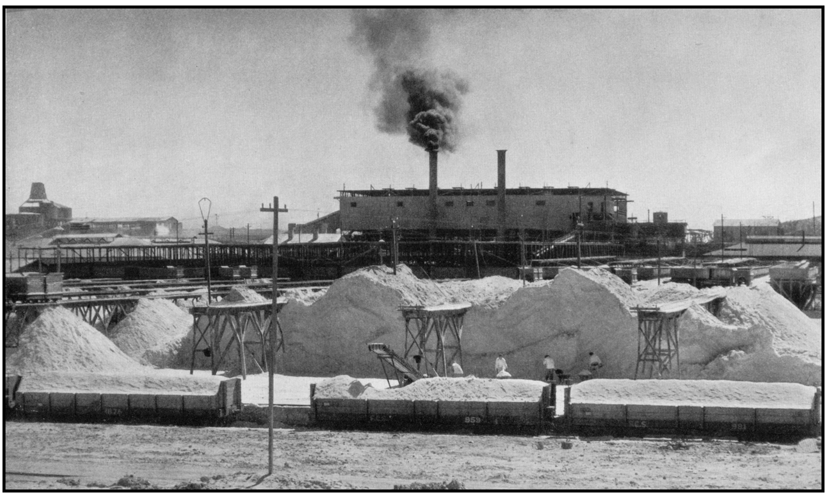

Figure 1.114: A nitrate plant in Tarapacá.

San Pedro de Atacama

San Pedro de Atacama is located east of Antofagasta, some 106 km southeast of Calama and the Chuquicamata copper mine, overlooking the Licancabur volcano. It features a significant archaeological museum, the Archaeological Museum founded by Gustavo Le Paige, with a large collection of relics and artefacts from the region related to pre-Columbian cultures. Father Gustavo Le Paige (1903–1980) was born in Tilleur near Liège in Belgium, studied Philosophy and Theology at the University of Louvain, then went to Belgium Congo as missioner from 1936 to 1952 before coming to Chile in 1953, where he was assigned to San Pedro de Atacama church. Figures 1.115–1.119 show some details of the region.

Figure 1.115: Location map of San Pedro de Atacama.

Figure 1.116: San Pedro de Atacama Museum.

Figure 1.117: Museum director of San Pedro de Atacama Museum.

Figure 1.118: San Pedro de Atacama Volcano Licancabur.

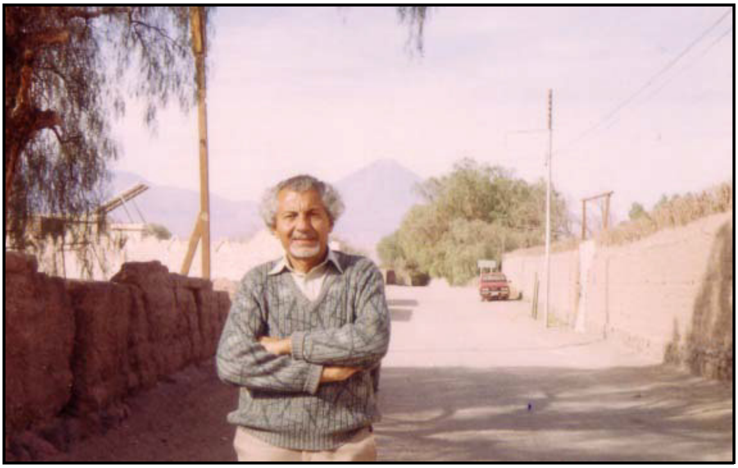

Figure 1.119: San Pedro de Atacama volcano on the background.

Lithium

In 1980 the Sociedad Chilena del Litio, a joint venture between Corporación de Fomento de la Producción de Chile known as CORFO and Foote Mineral Co., began to produce lithium carbonate from Atacama brines (Figures 1.120–1.121). The process included a solar evaporation to increase lithium concentration of the salar brine from 0.23% to 5.8%. The product was sent to a chemical plant where it was purified to eliminate the magnesium, and then treated by Na_2CO_3 to precipitate lithium carbonate.

In 1968, the Sociedad Química y Minera de Chile S.A. (SQM) was created as part of a plan to re-organize the Chilean saltpetre industry. In the beginning, the ownership of the company was shared between the government (CORFO, 37.5%) and private capital (Compañía Salitrera Anglo Lautaro S.A., 62.5%). In 1971, the company became completely state-owned. In 1983, CORFO started the privatization of the company, which was completed in 1988. In 1989, CORFO sold its share to Foote, which was controlled by Cyprus Minerals Co.

Between 1988 and 1993, the company carried out a modernization process of their production plants. Heap leaching and a fertilizer mixing plant were introduced. Potassium nitrate, iodine derivatives, and speciality blends of fertilizers were added. Between 1994 and 1998, the company developed the Salar de Atacama project where lithium carbonate, potassium chloride, potassium sulphate, and boric acid were produced.

Figure 1.120: Salar de Atacama.

Figure 1.121: Lithium plant near Antofagasta [Photo by Nadia Habashi, 1994].

Tarapacá Region

Iquique (Figures 1.122–1.123) is the capital of Tarapacá Region, a former Peruvian province that was annexed by Chile in 1883 at the close of the War of the Pacific. It is the home of Arturo Prat University. In December 1907, the city of Iquique was marred by a massacre when the Chilean Army, under the command of General Roberto Silva-Renard, opened fire on thousands of saltpetre miners, and their wives and children, who assembled inside the Santa María School. The workers had marched into town to protest their working conditions and wages. Somewhere between 500 and 2 000 people were killed.

Universidad Arturo Prat

The Arturo Prat University in Iquique, named after the Chilean Admiral who died young during the battle in the War of the Pacific (Figure 1.124), organized in August 2001 the 7th Mining Meeting of Tarapacá jointly with the 2nd Mining Meeting of South America. Chair person of the Organizing Committee was Professor Ximena Veloso.

Figure 1.122: View of Iquique in Tarapacá Region.

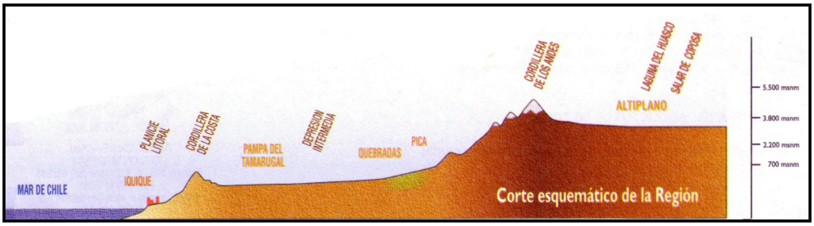

Figure 1.123: A cross section through Iquique region.

Figure 1.124: Arturo Prat (1848–1879).

A metallurgy conference was held in Iquique in 2001 (Figures 1.125–1.126).

Figure 1.125: Invited speakers at the Iquique conference 2001 with Professor Ximena Veloso, Chair person of the Organizing Committee.

Figure 1.126: With old friends. From left: José Hevia [Universidad Católica del Norte, Fathi Habashi, Guillermo Coloma [Antofagasta], Iquique 2001.

Figure 1.127: View of Arica and the Morro [the Castle] on top.

Arica Region

Arica (Figure 1.127), the capital of Arica and Parinacota Region, is the home to the University of Tarapacá. In 2007, the region was subdivided to create the Arica and Parinacota region and the present day Tarapacá Region to the south. The archaeological remains of the Inca were visited in 1994 (Figures 1.128–1.129).

Figure 1.128: Archaeological route of Inca in Arica. From left: Jaime Villanueve, Ernesto Ponce (Host), Fathi Habashi, Guillermo Focacci (Archaeologist) [Photo by Nadia Habashi, 1994].

Biobío Region

Concepción, the capital of Biobío Region, was founded by Pedro de Valdivia in 1550 north of the Bío-Bío River and is the second-largest city in the country and the seat of the University of Concepción. It was the headquarters of the military forces engaged against the Mapuche Indians.

University of Concepción

The University of Concepción was founded in 1919 and its Department of Metallurgy was established in 1961 by Alexander Sutulov (1925–1991) (Figure 1.130) who was born in the former Yugoslavia and moved to Chile in 1955. The University was visited in 1994 (Figures 1.131–1.132).

Figure 1.129: With Rector of the University of Tarapacá Luis Tapia (centre) [Photo by Nadia Habashi, 1994].

Figure 1.130: Alexander Sutulov (1925–1991).

Figure 1.131: With Faculty members at the University of Concepción. Extreme right Mario Sánchez [Photo by Nadia Habashi, April 2005].

Figure 1.132: Mural at the University of Concepción [Photo by Mario Sánchez, April 2005].

HydroCopper Conferences

HydroCopper is annual conference devoted to the hydrometallurgy of copper since 2003 organized by the Mineral Engineering Department of the University of Chile in collaboration with Gecamin Ltda. (Figures 1.133–1.134).

Figure 1.133: Receiving a certificate at the Third International Copper Hydrometallurgy Workshop known as HydroCopper 2005 that was held in Santiago November 23–25, 2005. The citation reads, "In recognition of five decades of contributions to the knowledge in science, technology, and history of extractive metallurgy."

Molybdenum and rhenium

In 1939, molybdenum concentrate was obtained as a by-product of flotation at El Teniente mine. Later, it was recovered from copper concentrates at the Chuquicamata, El Salvador, and Andina operations. In 1994, Disputada started production of molybdenum concentrate and today produces about 2 000 tons/year. In 2000, Los Pelambres mine began production and currently produces 6 933 tons/year. In 2002, Chilean molybdenum concentrate production was about 30 000 tons; 68 % was obtained from Codelco's operations.

Figure 1.134: Banquet at HydroCopper 2009. From right: Estebán Domic, [two unknown], Luis Sobral from CETEM in Rio de Janeiro, Jorge Menacho, Conference Chairman. Sitting: Mrs. Darvishi-Alamdari, graduate student from Laval University in Quebec City.

About 50% of world rhenium production comes from Chile. The largest producer of molybdenum concentrates in Chile is Corporación Nacional del Cobre (Codelco). Codelco roasts a portion of their concentrate production to make technical grade molybdenum oxide, exports a portion of their concentrate directly to various overseas customers, and sends the balance to Molibdenos y Metales (Molymet) for processing. Only the portion sent to Molymet is known to be processed for rhenium recovery. Molymet also receives concentrates from two other mines in Chile and at least one in Peru. Rhenium concentration in the South American molybdenum concentrates ranges from about 250 to 400 ppm. Rhenium production at Molymet is about 12.6 t/yr. Molymex's production of molybdenite concentrates is closely tied to production from the La Caridad Mine in Sonora, Mexico.

Molibdenos y Metales was formed in 1975 Molymet acquired Molymex in 1994 in the area of Sonora, Mexico. In 2000 Molymet Corporation was formed in Baltimore, USA: in 2001 CM Chemiemetall GMBH was bought in Bitterfeld, Germany. They acquired Sadaci in Ghent in Belgium in 2003 and at the end of 2005 they formed Molymet Services in the UK. Since January 2010 Molynor plant began operations at Mejillones, located at Chile's second region. During May this year Molymet through ChinaMoly makes a 50% Joint Venture with the company Luoyang High-Tech from China. Figure 1.135 shows a flowsheet for rhenium recovery.

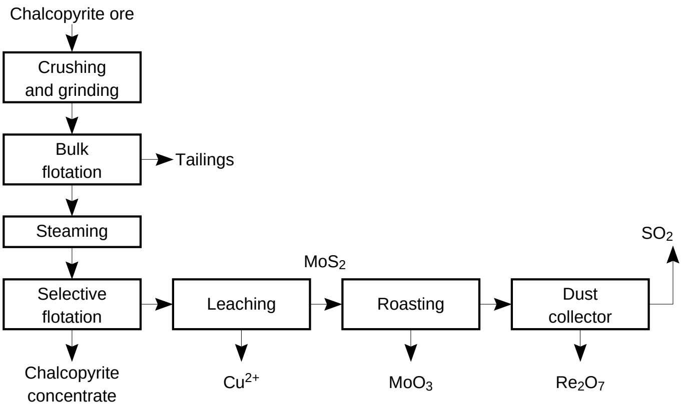

Figure 1.135: Recovery of molybdenum and rhenium.

Molymet uses molybdenum concentrate roasting to recover the by-product rhenium. It produces technical molybdenum oxide, molybdenum oxide briquettes, ferromolybdenum, high-purity molybdenum chemicals, and all the rhenium products such as ammonium perrhenate, perrhenic acid, rhenium powder, and rhenium pellet.

EASTER ISLAND

On Easter Sunday, April 5, 1722, a Dutch sea captain named Jacob Roggeveen landed his ship on an island known as Te Pito o Te Henua, meaning "The Centre of the World" (Figures 1.136–1.138). He re-named it Easter Island. Located 3 500 km off the coast of Chile, it is about 100 km in size with three extinct volcanoes. At first, Polynesian travellers from the Marquesas, or Society Islands, populated the island. As the population increased, the food chain broke, resulting in famines. Those who survived were left to the mercies of slave traders from other lands. Since the island consists of volcanic rock, the early inhabitants quarried the material into giant statues, some as tall as 5 m and weighing about 14 tonnes (Figures 1.139–1.141). The villagers used the trees to transport these giant rocks all over the island. Most of the surviving statues are lined up all along the shoreline facing out to sea. The statue cult symbolized male dominance and power throughout the societal structure of the inhabitants.

Figure 1.136: Location of Easter Island.

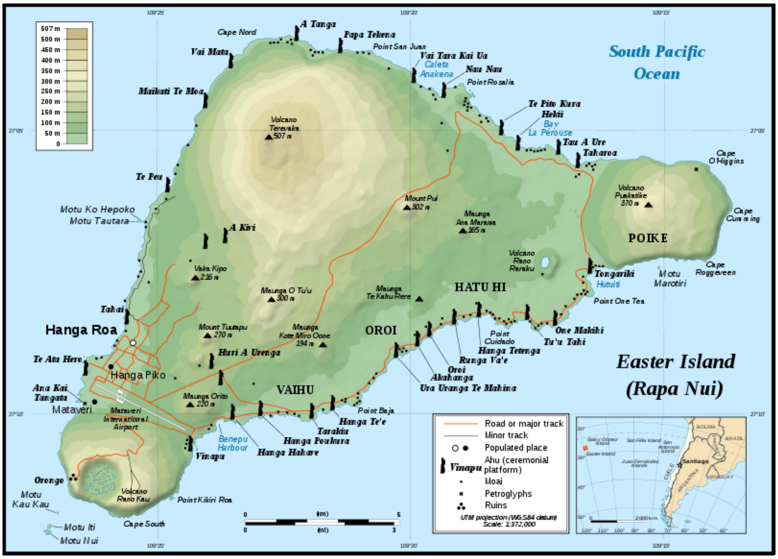

Figure 1.137: Map of Easter Island.

Figure 1.138: Easter Island [Photo by Nadia Habashi, 2001].

Figure 1.139: Statues carved by Stone Age people in Easter Island.

Figure 1.140: Easter Island [Photo by Nadia Habashi, 2001].

Figure 1.141: Easter Island monuments.

EPILOGUE

Copper and gold have been recovered by natives before the arrival of Spanish conquerors. Later, during the Colonial period (1545–1810), gold and silver were also recovered by the Spanish using mercury. Towards the end of the eighteenth century, foreign engineers from Europe began arriving to introduce new technologies. In modern times Chile became the top producer and exporter of copper and the largest producer of rhenium recovered from molybdenite. Chile is also one of the world's significant producers and exporters of industrial minerals such as potassium and sodium nitrate, iodine, lithium salts, and borate.

Chile is at present the largest copper and rhenium producer and was before World War I the largest nitrate producer. She is also an important producer of lithium carbonate and molybdenum oxide. An important event in the history of the country is the Pacific War of 1879–1883, in which she acquired the northern provinces initially belonged to Bolivia and Peru. In 1888 Chile annexed Easter Island. The Chilean mineral and cultural history is briefly reviewed together with the people who contributed to her development. The present report is the result of a number of academic and industrial visits to Chile during the period 1992 to 2009.

Suggested Readings

O. Bermudez, *Historia del Salitre*, Ediciones de la Universidad de Chile, Santiago de Chile 1963.

G. Coloma and F. Habashi, "The Silver Refinery Ruins at Antofagasta, Chile," pp. 429–441 in *Proceedings VIII Congreso Nacional de Metalurgia*, Antofagasta 1994. Reprinted in *Bull. Can. Inst. Min. & Met.* **87** (984) 93–96 (1994). Transl. in Spanish, "Las Ruinas de la Refinería de Plata en Antfagasta, Chile," *Minerales* (Santiago) **55** (236), 19–24 (2000).

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F. Habashi, Trip Reports

- Chile, December 9–17, 1992
- Chile, Lecture Tour, July 31–August 21, 1993
- Chile, Third Visit, August 2–17, 1994
- Chile, August 8–26, 2001
- Chile, April 7–21, 2005
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A. Valanzuela, "History of Mining in Chile. Part 1," *Bull. Can. Inst. Min. & Met.* **97** (1084), 65–69 (2004). Part 2 *ibid.* **98**(1085), 71–72 (2005). Part 3 *ibid.* **98**, (1086) 119–121(2005). Part 4 *ibid.* **98** (1087) 64–66 (2005).

Chapter 2

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Figure 2.1: Flag of Argentina.

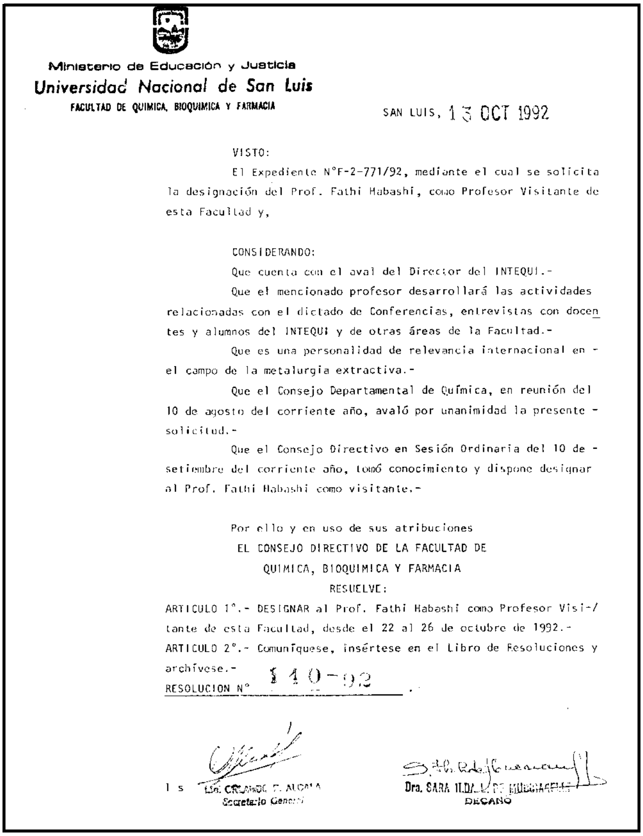
Introduction

From October 22 to 26, 1992, I accepted an invitation for the position of Visiting Professor at the University of San Luis (Figure 2.2). Following this appointment, I was invited to give a plenary lecture at the Second Argentinean Meeting of Mineral Processing held in La Plata City and to visit Mineral Processing Research Institute in Buenos Aires.

Historical Background

The Spaniards arrived in Argentina in 1516. By the late 1700s, Buenos Aires was growing rapidly due to illegal trade financed by British interests. In 1776, Río de la Plata became a vice-royalty, with Buenos Aires as the main port and administrative centre. When in 1796, Spain joined France in its war with Britain, Britain justified its military action against Spanish colonies. After the defeat of the Franco-Spanish fleet at the Battle of Trafalgar, Spain was forced to reduce its naval communications with its American colonies. In May 1810, after the capture of King Ferdinand VII of Spain by the

French, Buenos Aires deposed the viceroy and declared independence on July 9, 1816.



Ministerio de Educación y Justicia
Universidad Nacional de San Luis
FACULTAD DE QUIMICA, BIOQUIMICA Y FARMACIA

SAN LUIS, 13 OCT 1992

VISTO:
El Expediente N°F-2-771/92, mediante el cual se solicita la designación del Prof. Fathi Habashi, como Profesor Visitante de esta Facultad y,

CONSIDERANDO:
Que cuenta con el aval del Director del INTEQUI.-
Que el mencionado profesor desarrollará las actividades relacionadas con el dictado de Conferencias, entrevistas con docentes y alumnos del INTEQUI y de otras áreas de la Facultad.-
Que es una personalidad de relevancia internacional en el campo de la metalurgia extractiva.-
Que el Consejo Departamental de Química, en reunión del 10 de agosto del corriente año, avaló por unanimidad la presente solicitud.-
Que el Consejo Directivo en Sesión Ordinaria del 10 de setiembre del corriente año, tomó conocimiento y dispone designar al Prof. Fathi Habashi como visitante.-

Por ello y en uso de sus atribuciones
EL CONSEJO DIRECTIVO DE LA FACULTAD DE
QUIMICA, BIOQUIMICA Y FARMACIA
RESUELVE:
ARTICULO 1°.- DESIGNAR al Prof. Fathi Habashi como Profesor Visitante de esta Facultad, desde el 22 al 26 de octubre de 1992.-
ARTICULO 2°.- Comuníquese, insértese en el Libro de Resoluciones y archívese.-
RESOLUCION N° 140-92

ls Lic. ORLANDO F. ALCALA
Secretario General

Dra. SARA M. DE MUBANAGEN
DECANO

Figure 2.2: Letter of appointment as Visiting Professor at the University of San Luis.

Thousands of European immigrants flocked to the country each year. Social conflicts however intensified during the late 19th century as the gap between the wealthy classes and the poor widened. The National Party, under the leadership of General Roca and supported by the military and landowners, dominated the nation. To combat this powerful coalition, a middle-class party called the Radical Civic Union was formed which took control in 1916 but little changed for the working classes. Social disorder and violence were common during this period until an economic crisis precipitated by the world depression led to a military coup in 1930.

The military–landowner alliance brought economic recovery but also political corruption. During World War II, military Nazi-sympathizers came to power in 1943. Argentina had undergone an industrial expansion accelerated by the war. This expansion led to the formation of a large workforce, under the direction of the military head of the Labour Department, Colonel Juan Domingo Perón, who became president in 1946. He made political, economic, and social changes. His wife Eva ("Evita"), a woman of modest upbringing, captivated the masses with her work on behalf of the poor. After re-election in 1951, Perón became increasingly dictatorial and erratic, especially after the death of Evita a year later. Finally, a military group took over in September 1955, Perón left to Spain, and his party declared illegal.

In June 1966, following election victories by the Peronists, the military leaders installed an anti-Peronist Onganía as President. He dissolved the legislative bodies, suspended the constitution, and imposed strict controls on all means of mass communication. Students denounced these repressive policies and violence erupted in the early months of 1969 in Córdoba and Rosario. Dissatisfaction mounted and the most serious incident was killing former President Aramburu by a Peronist group. In June 1970, high-ranking military officers removed Onganía, and began to move toward democratic reform.

Perón returned to Argentina in June 1973, won the presidency in September, cracked down on the very terrorist groups he had encouraged, but the economy sagged. When he died in July 1974, his widow succeeded to the presidency. Her administration plunged Argentina more deeply into chaos. In March 1976, she was arrested and a military junta took over.

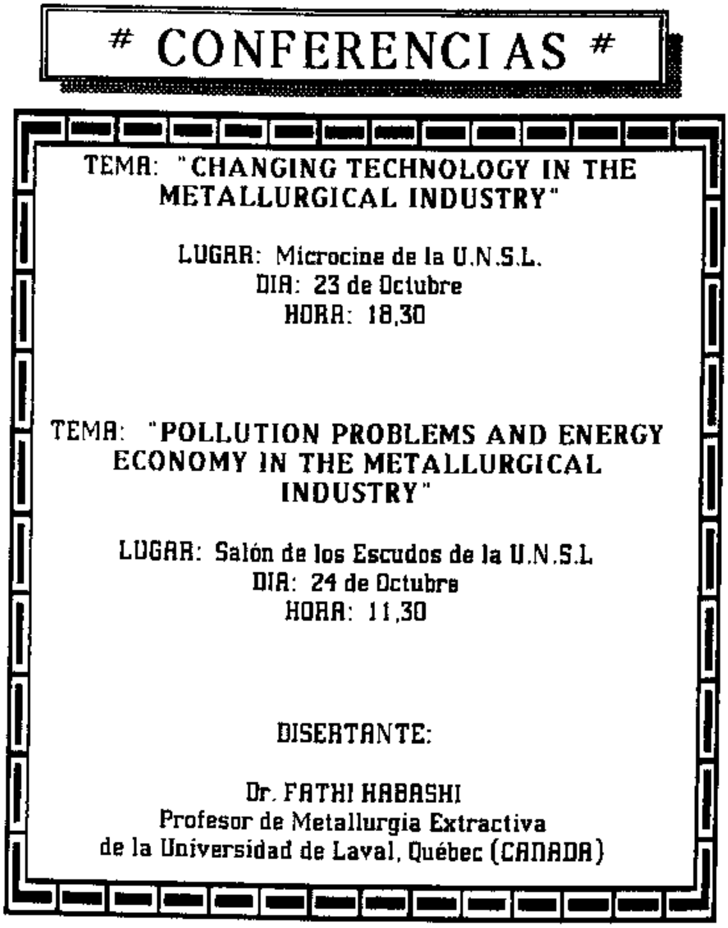
Lt. General Videla became president. He dissolved Congress, suspended political and trade union activity, and attempted to "purify" Argentina by imprisoning, torturing and executing leftists, Peronists, and trade unionists. He privatized banking and industry but was unable to solve the problem of inflation. Lacking political support from the general populace, he invaded the Falkland Islands in April 1982, claiming sovereignty over them. After his defeat he was replaced by Major General Bignone.

Liberalization measures during the remainder of 1982 led to strikes and anti-government demonstrations. In addition to demands for a return to civilian rule, Argentines demanded to know the fate of the 30 000 persons who had disappeared during 1976–1983. In December 1983, Alfonsín took office. In December 1985, five former military leaders were convicted, including Lt. Gen. Videla. This irked the military, and in April 1987, an abortive military uprising spread to a number of bases. Alfonsín retreated from his position, limiting the trials to a few superior officers. He failed to stabilize the economy or bring military leaders to justice.

In May 1989 Carlos Saúl Menem was elected. He cut government spending, liberalized the economy, pardoned and released top military leaders. In May 1995, following a first term marked by economic success and political stability, Menem was re-elected to a second four-year term.

SAN LUIS

Figure 2.3: San Luis is 800 km west of Buenos Aires and 300 km to the east of the border with Chile.



CONFERENCIAS

TEMA: "CHANGING TECHNOLOGY IN THE METALLURGICAL INDUSTRY"

LUGAR: Microcine de la U.N.S.L.
DIA: 23 de Octubre
HORA: 18,30

TEMA: "POLLUTION PROBLEMS AND ENERGY ECONOMY IN THE METALLURGICAL INDUSTRY"

LUGAR: Salón de los Escudos de la U.N.S.L
DIA: 24 de Octubre
HORA: 11,30

DISERTANTE:

Dr. FATHI HABASHI
Profesor de Metallurgia Extractiva
de la Universidad de Laval, Québec (CANADA)

Figure 2.4: Announcement for the lectures, October 1992.

Figure 2.5: Host, Dra. María del Carmen Ruiz, October 1992.

Figure 2.6: With faculty members and graduate students at the University of San Luis. Host María del Carmen Ruiz, 4th from left, October 1992.

Figure 2.7: Monument in memory of Rector of the University who disappeared during the military dictatorship, October 1992.

Figure 2.8: Researchers at Institute for Investigations in Chemical Technology. From left, sitting: Roberto Olsina, Juan Rivarola, Manuel Gómez. Standing, Antonio García, Edgardo Nolesco, María del Carmen Ruiz, Manuel Ojeda, José Marchese, and machinist. Photo by F. Habashi, October 1992

La Plata

La Plata (Figures 2.9–2.10), founded in 1882, is the capital of the Province of Buenos Aires, one hour drive from the national capital Buenos Aires. It was there that Second Argentina Mineral Processing Conference was held (Figures 2.11–2.14).

Figure 2.9: Location of La Plata, Buenos Aires, and San Luis.

Figure 2.10: Government building.

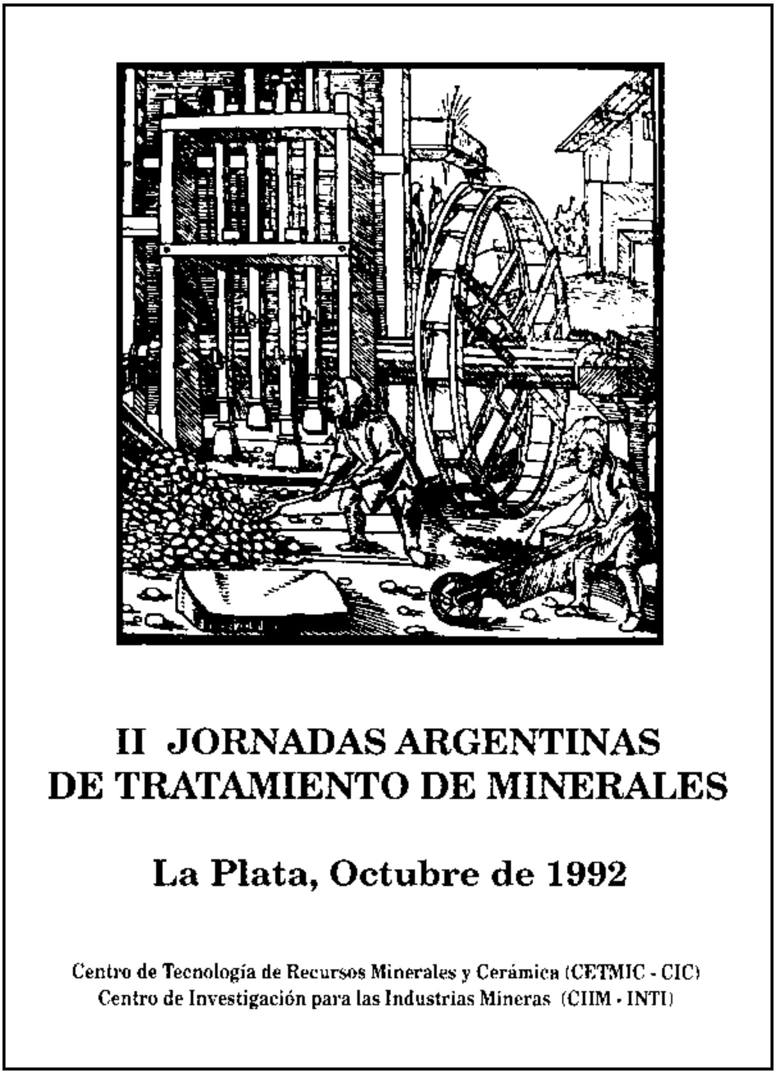
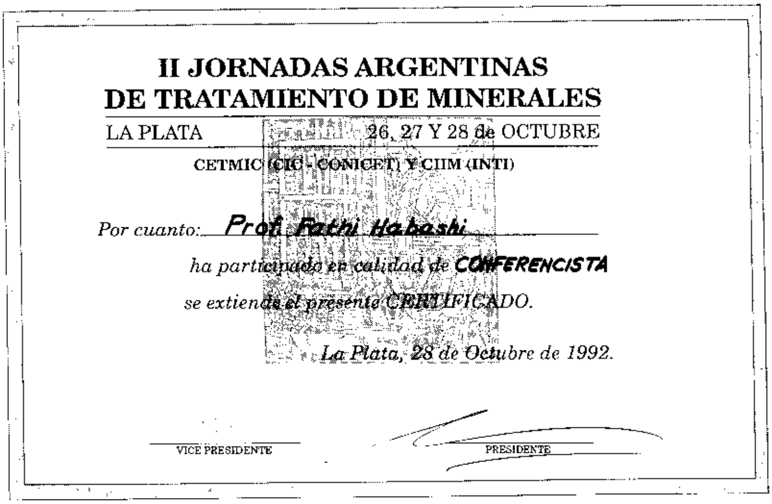


Figure 2.11: Flyer for the conference.



II JORNADAS ARGENTINAS
DE TRATAMIENTO DE MINERALES

LA PLATA 26, 27 Y 28 de OCTUBRE

CETMIC (CIC - CONICET) Y CIIM (INTI)

Por cuanto: Prof. Fathi Habashi

ha participado en calidad de CONFERENCISTA

se extiende el presente CERTIFICADO.

La Plata, 28 de Octubre de 1992.

VICE PRESIDENTE PRESIDENTE

Figure 2.12: The traditional certificate given to conference participants.

O CETEM - Centro de Tecnologia Mineral,
por ocasião do seu **Jubileu de Prata**, confere o presente

Diploma de Reconhecimento

a Fathi Habashi

pelas relevantes contribuições prestadas ao Centro
ao longo dos seus 25 anos.

Rio de Janeiro, 18 de abril de 2003.

Gildo de Araújo Sá Cavalcanti de Albuquerque
Diretor do Cetem

Figure 2.13: Letter of thanks.

Figure 2.14: Friends from Brazil: Roberto Villas Bôas and his wife on the left, and new friends from Argentina. Photo by F. Habashi, October 1992.

Mineral Resources & Ceramics

In Spanish it is *Centro de Tecnología de Recursos Minerales y Cerámica*, known by the acronym CETMIC, located in Gonnet, a suburb of La Plata.

Figure 2.15: With Dr. Enrico Periera, Director, Centre for the Technology of Mineral Resources & Ceramics [CETMIC], 1992.

Figure 2.16: Researchers at CETMIC. Photo by F. Habashi, 1992.

Buenos Aires

Pedro de Mendoza founded the Ciudad de Nuestra Señora del Buen Ayre (Our Lady of the Fair Winds) on 2 February 1536 as a Spanish settlement. The site eventually became known as Buenos Aires, one of the largest in the Americas. It is a beautiful city with elegant architecture and impressive buildings, monuments, and fountains (Figures 2.17–2.21).

Figure 2.17: The Revolution Square with the 60-m high obelisk.

Figure 2.18: Opera House.

Figure 2.19: La Casa Rosada, i.e., The Pink House is the official executive mansion of Argentina. Nevertheless, the President normally lives at the Quinta de Olivos, in Olivos, Buenos Aires Province.

Figure 2.20: National Assembly.

Figure 2.21: Monument for Independence from Spain in front of National Assembly.

Research Centre for Mineral Industry

In Spanish it is *Centro de Investigación para las Industrias Minerales*, known by the acronym CIIM, located in San Martín, a suburb of Buenos Aires.

Figure 2.22: From left: Ing. Augustín Correa, Lic. Ana María Celeda, Ing. Emilio Dublanc from Mineral Research Centre. Photo by F. Habashi, October 1992.

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