Fathi Habashi

My Trips to Brazil

2015

My Trips to Brazil

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.

Published by:

Métallurgie Extractive Québec
800 Alain, #504, Québec City, Québec, Canada G1X 4E7
Tel.: (418) 651-5774. E-mail: Fathi.Habashi@arul.ulaval.ca
http://pages.infinit.net/habashi
http://works.bepress.com/fathi_habashi/

Distributed by:

Laval University Bookstore Zone
Pavillon Maurice-Pollack, Cité Universitaire, Québec City, Canada G1V 0B4
Tel.: (418) 656-2600, Fax: (418) 656-2665
E-mail: conseiller@zone.ul.ca

Dépôt légal 2015

- Bibliothèque nationale du Québec, Montréal
- National Library of Canada, Ottawa

ISBN 978-2-922686-27-2

Fathi Habashi, *My Trips to Brazil.*

Page set up in Québec City by **Jean-François Morin**.

Printed in Québec City by **Les Copies de la Capitale, Inc.**

Métallurgie Extractive Québec is a non-profit publisher registered in Québec City #2240676462 devoted to diffusion of extractive metallurgy literature.

To Nadia,
Hani, and Hatem
with love

Other Books by the Author

Published by Métallurgie Extractive Québec, Québec City and distributed by Laval University Bookstore except otherwise stated.

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.

F. Habashi (editor), *Handbook of Extractive Metallurgy*, 4 volumes, 2 500 pages, WILEY–VCH, Weinheim, Germany, Also: John Wiley, 605 Third Avenue, New York, NY 10158-0012.

F. Habashi (editor), *Alloys. Preparation, Properties, Applications*, 312 pages, WILEY–VCH, Weinheim, Germany (out of print). Now available from Métallurgie Extractive Québec.

F. Habashi, *Metallurgical Chemistry*, American Chemical Society, Washington, DC, Manual (279 pages), Audio Course (MP3 CD, 5 hours playing time). Now available from Métallurgie Extractive Québec.

F. Habashi, *Metals from Ores. An Introduction to Extractive Metallurgy*, 2003, 475 pages.

F. Habashi, *Pollution Problems in the Mineral and Metallurgical Industries*, 1996. 150 pages.

F. Habashi, *Textbook of Hydrometallurgy*, 2nd edition, 1999, 750 pages.

F. Habashi, *Textbook of Pyrometallurgy*, 2002, 600 pages.

F. Habashi, *Kinetics of Metallurgical Processes*, 1999, 376 pages.

F. Habashi (editor), *Progress in Extractive Metallurgy*, Vol. 1, Gordon & Breach 1973, 239 pages (out of print). Now available from Métallurgie Extractive Québec.

F. Habashi, *Chalcopyrite. Its Chemistry and Metallurgy*. McGraw-Hill International Book Company 1978, 177, pages (out of print). Now available from Métallurgie Extractive Québec.

F. Habashi, I. N. Beloglazov, and A. A. Galnbek (editors), *International Symposium. Problems of Complex Ores Utilization*, Mineral Processing & Extractive Metallurgy. Special Issue, Gordon & Breach 1995, 280 pages (out of print). Now available from Métallurgie Extractive Québec.

F. Habashi, *Aluminum. History & Metallurgy*, 2008, 160 pages.

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

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

F. Habashi, *Gold: History, Metallurgy, Culture*, 2009, 277 pages.

F. Habashi, *Researches on Asbestos*, 2011, 115 pages.

F. Habashi, *Mineral Processing for Nano-Scientists*, 2011, 170 pages.

F. Habashi, *Extractive Metallurgy of Copper*, 2012, 412 pages.

F. Habashi, *Pyrite. History, Chemistry, and Metallurgy*, 2012, 115 pages.

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

F. Habashi, *De Re Metallica. A Metallurgist on the Move*, 7 volumes, 2015, 5523 pages.

Historical

F. Habashi (editor), *Gellert's Metallurgic Chymistry*, 1998, 500 pages.

F. Habashi, D. Hendricker, C. Gignac, *Mining and Metallurgy on Postage Stamps*, 1999, 335 pages.

F. Habashi, *Extractive Metallurgy Today. Progress and Problems*, 2000, 325 pages.

F. Habashi, *From Alchemy to Atomic Bombs*, 2002, 350 pages.

F. Habashi, *Schools of Mines. The Beginnings of Mining and Metallurgical Education*, 2003, 604 pages.

F. Habashi, *Ida Noddack (1896–1978). Personal Recollections on the Occasion of 80th Anniversary of the Discovery of Rhenium*, 2005, 164 pages.

F. Habashi, *Readings in Historical Metallurgy*, Volume 1: Changing Technology in Extractive Metallurgy, 2006, 800 pages.

F. Habashi, *Postage Stamps: Metallurgy, Art, History*, 2008, 125 pages.

F. Habashi, *The Copts of Egypt*, 2006, 92 pages.

F. Habashi, *Chemistry and Metallurgy in the Great Empires*, 2009, 272 pages.

F. Habashi, *Science, Technology, and Society*, 2009, 316 pages.

F. Habashi, *Aqua Science Through the Ages. An Illustrated History of Water*, 2010, 166 pages.

F. Habashi, *Mining and Civilization. An Illustrated History*, 2010, 510 pages.

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
Fathi.Habashi@arul.ulaval.ca

Table of Contents

Chapter 1

Introduction

Figure 1.1: Flag of Brazil.

Brazil is a major mineral and metal producer, has magnificent fauna and flora, and superb architecture. In 1693, gold was discovered in Ouro Preto and Brazil produced about half of the world's gold. In 1726, diamond was discovered in the region of Tijuco in the Province of Minas Gerais, 150 km east of Belo Horizonte. The country became independent of Portugal in 1822 as the Brazilian Empire. Today, Brazil is the largest producer of niobium, and produces a large number of other metals. The Mineral Research Centre in Rio de Janeiro is the country's main Government establishment for mineral research. The country has been a republic since 1889 and its capital has moved from Rio de Janeiro to Brasília in 1960.

The first contact with Brazilian scientists was established in 1978 when a delegation from the Fundação de Tecnologia Industrial in Lorena, State of São Paulo, visited Laval University as a result of seeing a paper published in the *Bulletin of Canadian Institute of Mining and Metallurgy* in 1976 by the writer on the preparation of technical niobium oxide from pyrochlore concentrate by chlorination. The delegation headed by Dr. Daltro Gracia Pinatti, Prof. of Physics at the University of Campinas and Director of the Refractory Materials Institute in Lorena, was on a tour of USA and Canada to get acquainted with research activities in the field of niobium metallurgy. The interest in niobium stems from the fact that Brazil has the largest and richest deposit in the world of niobium ore in form of pyrochlore; Quebec ranks second.

Figure 1.2: Map of Brazil.

Other members of the delegation were Rosa Ana Conti (wife of Dr. Pinatti) and Lino Rodrigues de Freitas of the Fundação, and Mr. Claude Meunier of Servinter Limited in Rio de Janeiro and Mr. Jean Roquet, Vice President of Sidam Incorporation in Montreal. I made use of the exchange program Canada–Brazil sponsored by the Canadian Natural Science & Engineering Research Council and the Brazilian counterpart to return this visit in 1982.

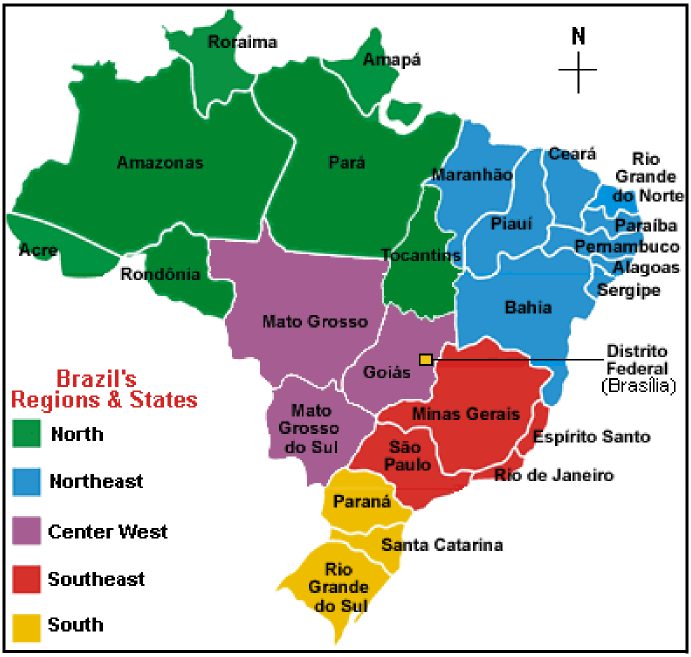


Figure 1.3: States of Brazil.

Figure 1.4: Brazilian delegation visiting the Laval University. Right to left: Prof. Daltro Garcia Pinatti, Rosa Ana Conti, Lino Rodrigues, and Robert Drouin [Vice Dean], standing F. Habashi.

Chapter 2

Historical Background

In 1500, the Portuguese explorer Pedro Álvares Cabral (Figure 2.1) discovered what became known as Brazil. The first Portuguese settlement was established in 1531 on the São Paulo coastline at São Vicente. Unlike their neighbours on the Pacific coast, the American Indians in this region did not know metals; they were still in the Stone Age.

In 1549, the seat of the colonial governor was established in Bahia (now Salvador). During the union of Spain and Portugal (1580–1640), Brazil came under Spanish domination and was invaded by powers hostile to Spain, e.g., the Dutch who founded a colony in Pernambuco and the French in Rio de Janeiro. But these colonies were ousted few years later. An independence movement from Portugal known as the Tirandentes was crushed by the colonial power in 1789.

African slaves were introduced in the colony from early times for the sugar cane and tobacco plantations in the north of the country. Iron production from local ores started in 1591 in the São Paulo region. Gold, diamonds, and other precious stones were discovered later in the province of Minas Gerais, and the colony became an important source of income for Portugal. As a result, the capital city was moved to Rio de Janeiro in 1763 to facilitate shipping the wealth to Portugal[1].

[1] The capital of Brazil was transferred from Bahia to Ouro Preto, then to Rio de Janeiro, and finally in 1969 to Brasília.

Table 2.1: Summary of trips to Brazil.

	Trip	Purpose	Visits
1	December 4, 1982–January 6, 1983	Bilateral Exchange Program Canada–Brazil: Niobium project. Host: Prof. Daltro Garcia Pinatti. Participation in First Meeting of the Southern Hemisphere on Mineral Technology	Rio de Janeiro Lorena São Paulo Araxá Caraíba Salvador Camaçari Poços de Calda Iguaçu
2	June 20–July 21, 1992	Extractive Metallurgy Course at Escola de Química in collaboration with CETEM, Rio de Janeiro. Hosts: Prof. Mari Concession and Dr. Roberto Villas-Bôas	Rio de Janeiro São Paulo Belo Horizonte Ouro Preto Juiz do Fora
3	March 8–17, 1996	Celebrating CNPq 45th Anniversary, Rio de Janeiro. Hosts: Dr. Roberto Villas-Bôas	Rio de Janeiro Petrópolis
4	April 12–May 1, 1997	Conference on Rare Earths. CETEM invitation, Rio de Janeiro. Host: Dr. Francisco Lapido-Loureir Visit to asbestos mine	Rio de Janeiro Uberaba Catalão Minaçu Brasília
5	August 22–September 1, 1998	Águas de São Pedro Conference, ABM invitation. Host: Prof. Arthur Chaves Pinto	São Paulo Águas de São Pedro Ipiranga Iguaçu Itaipu
6	December 2–9, 2000	CETEM lectures, Rio de Janeiro. Host: Dr. Juliano Barbosa	Rio de Janeiro Belo Horizonte Sabará
7	October 11–22, 2011	Plenary speaker at the XXIV National Meeting of Treatment of Minerals and Extractive Metallurgy. Host: Prof. Luiz Rogerio Pinho de Andrade Lima Visit to ilmenite processing plant	Salvador, Bahia

Figure 2.1: The Portuguese explorer Admiral Pedro Álvares Cabral (1460–1526?), proclaiming Brazil to the Portuguese Empire.

Science and Technology

The Portuguese Empire came into existence as a result of developing a new type of ships by Prince Henrique known as the caravel, that was capable of sailing in stormy seas at high speeds. Prince Henry founded a naval arsenal, an observatory, and the first school for the study of geography and navigation in Europe. He created better charts, improved ship-board instruments as the compass, the astrolabe, and the quadrant. He also compiled more detailed astronomical tables. His purpose was to extend Portuguese trade and spread Christianity. The trade of spices from the East was most profitable. The rulers of the Empire favoured importing everything that could not be found in the country and were not concerned with developing a local industry and in this way they ignored science and technology.

During the reign of Queen Maria I (1777–1816) (Figure 2.2) in Portugal and under the influence of her British allies and Army Chief William Carr (Viscount Beresford), the creation of industry in Brazil, based on local raw materials, was prohibited in 1785 so that Portugal and England could sell their manufactured products there. This naturally hampered the development of the metallurgical and chemical industries. However, in 1790, as a result of the development in the mining industry, the Portuguese government sent three graduates from the University of Coimbra to visit the main mining centres in Germany, France, Bohemia, and Hungary for a period of ten years. On their return, they were immediately appointed in the administration of the Empire.

Figure 2.2: Queen Maria I (1777–1816).

Figure 2.3: Brazilian mineralogist José Bonifácio de Andrada e Silva (1763–1838), the first metallurgy professor in Portugal.

One of these scholars was the Brazilian mineralogist José Bonifácio de Andrada e Silva (1763–1838) (Figures 2.3–2.4), who was appointed in 1800 as the first professor of metallurgy at the University of Coimbra. There he described two new minerals, which he called petalite and spodumene. It was from these minerals that the Swedish chemist Johan Arfwedson discovered lithium in 1818. After returning to Brazil in 1819 he was appointed Minister of State. Among his important publications is *Mémoire sur les diamants du Brésil*. The mineral andradite (Figure 2.5), which is common garnet ($3CaO \cdot Fe_2O_3 \cdot 3SiO_2$), is named in his honour.

Figure 2.4: Brazilian mineralogist José Bonifácio de Andrada e Silva (1763–1838), the first metallurgy professor in Portugal.

Figure 2.5: Andradite is a species of the garnet group.

The lack of qualified personnel in the growing iron industry was deeply felt. In 1803, German technicians were hired to examine the newly discovered coal mines in Brazil. Wilhelm Ludwig von Eschwege (1777–1855) (Figure 2.6), was born in Eschwege, Germany, studied engineering, then moved to Portugal where at the young age of 25 was appointed Director of Mines in Lisbon. He moved with the royal family to Brazil when Napoleon invaded Portugal. He became a high official in the Royal Corps of Engineers and was appointed director of the Royal Mineralogical Council. He was sent to Minas Gerais in 1811 and settled in Ouro Preto where he made extensive mineralogical surveys. In 1812, he produced the first Brazilian pig iron. He returned to Germany in 1821 and published in 1833 his Brazilian experience in two volumes under the title *Pluto Brazilienis*, i.e., the Brazilian Richness. These volumes prepared the ground for establishing a School of Mines in 1876 in Ouro Preto.

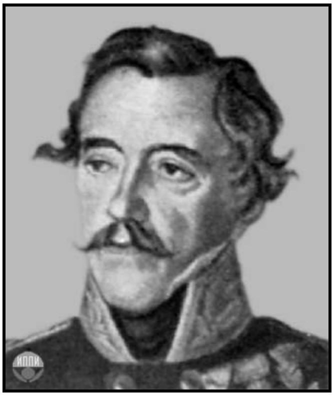


Figure 2.6: Wilhelm Ludwig von Eschwege (1777–1855).

Brazilwood

With the discovery of Brazil, a new market for the so-called "brazilwood" came into existence — a bright red wood of genus Caesalpinia that became popular for cabinet work but also for the extraction of a red dye. The logs were rasped to a coarse powder, moistened with water and allowed to ferment for weeks. The water extract gave bright red colour with fabrics mordanted with aluminum or tin salts. The colouring principle of brazilwood was isolated by the French chemist Michel Eugène Chevreul (1786–1889), who called it brazilin.

Sugar cane

Between 1532 and the 1700s, sugar cane and tobacco plantation were introduced in the north of Brazil by Christianized Jews from southern Portugal, utilizing slaves from Portuguese African colonies (Figure 2.7). The country became the largest sugar producer in the world but the industry soon declined because of lack of innovation, and competition with more efficient plantations in Jamaica, and other Caribbean islands.

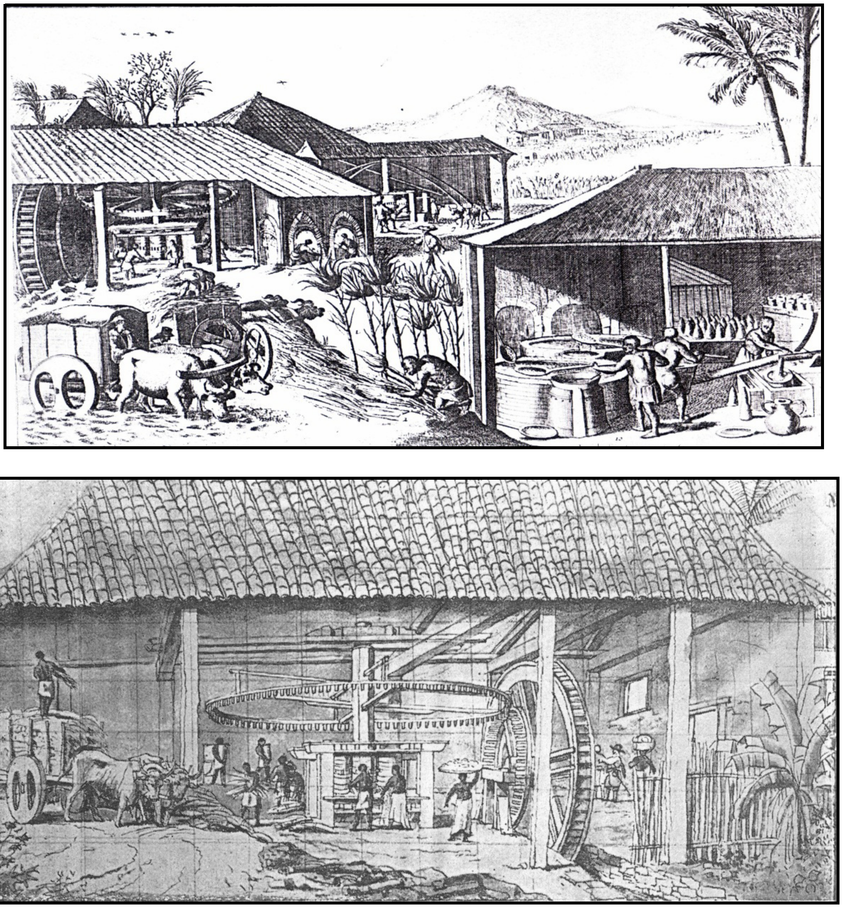


Figure 2.7: - Two views of a sugar mill in Brazil in the 17th century.

Gold

In 1693, gold was discovered in Ouro Preto. Brazil produced about half of the world's gold. Figure 2.8 shows a painting depicting gold recovery from this region. The first mint in Brazil was installed in Bahia in 1695. Production of gold, however, declined due to exhaustion of the mines in the 1780s.

Figure 2.8: A painting depicting gold extraction in Brazil.

Diamond

In 1726, diamond was discovered in Brazil in the region of Tijuco in the Province of Minas Gerais, 150 km east of Belo Horizonte. The town became known in 1838 as Diamantina. The miners there, known as garimpeiros, were panning for gold and quite often came across brilliant heavy pebbles that remained at the bottom of their pans. These were identified as diamond by the Catholic priest of the region who first saw such pebbles when he was in India. The news had sensational impact in Lisbon. The royal family received congratulations from the Pope and the European monarchs and thanksgiving parades were organized.

In 1729, an order by the governor of the province was issued prohibiting panning for gold. Since then Brazil became the third country producing diamond. All this wealth accumulated in the hands of Emperor João V, while the slaves and the natives suffered. Figure 2.9 shows African slaves exploiting the diamond deposit under the supervision of a foreman.

Coffee

In the late 19th century, coffee started to replace sugar as the country's main export crop Figure 2.10. The coffee trade caused Brazil to thrive economically, attracting many European immigrants — particularly from Italy and Germany. This influx of labour also allowed the country to develop an industrial economy and expand away from the coast.

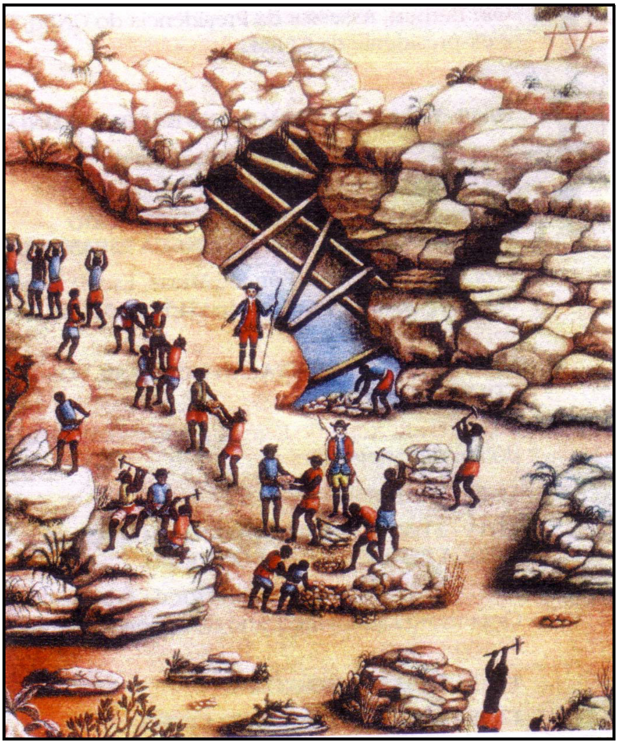


Figure 2.9: African slaves exploiting a diamond deposit.

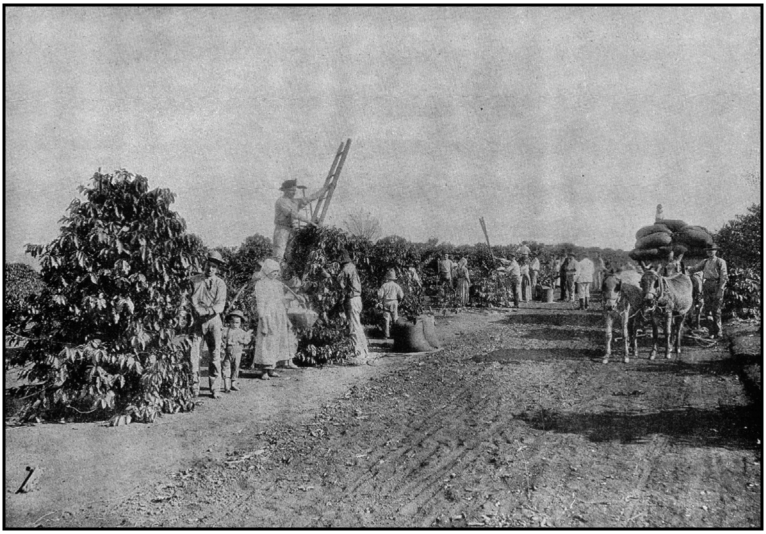


Figure 2.10: Coffee plantation in Brazil.

Figure 2.11: Brazilian coffee.

Transfer of the Seat of Portuguese Empire

In 1808, the Portuguese royal family, who was driven out of Portugal by Napoleon, made Rio de Janeiro capital of the Portuguese Empire. This imposed the creation of several institutions, including educational and scientific ones, for example, the Royal Military Academy (founded in 1810). After the downfall of Napoleon, King João VI returned to Portugal in 1821, leaving his son Pedro as regent of Brazil. Quarrels with the Portuguese Government led Pedro I to proclaim Brazil's independence in 1822. After much trouble at home, he was forced to abdicate in 1831 in favour of his infant son Pedro II (1825–1891) and returned to Portugal. Pedro II was crowned emperor in 1841 (Figure 2.12).

Figure 2.12: The Brazilian emperor Pedro II.

The reign of Pedro II was relatively peaceful and marked by prosperity but he was deposed a year later after slavery was abolished in 1888 under pressure from powerful land owners who lost heavily due to the abolition of slavery. Brazil was then proclaimed a republic in 1889 by General Deodoro da Fonseca (1827–1892), who became the country's first de facto president through military ascension. This period, known as the "Old Republic," ended in 1930 with a military coup that placed Getúlio Vargas, a civilian, in the presidency. In 1964–1984, the military took over for fear of communism. Pedro II died in Paris two years later.

Chapter 3

The Amazon

The Amazon (Figures 3.1–3.2) is the largest river in the world by volume. In most of its length, the river flows through tropical rainforest, where there are few roads and even fewer cities. The region is inhabited by many primitive tribes. Some members of these tribes can be seen on local flights.

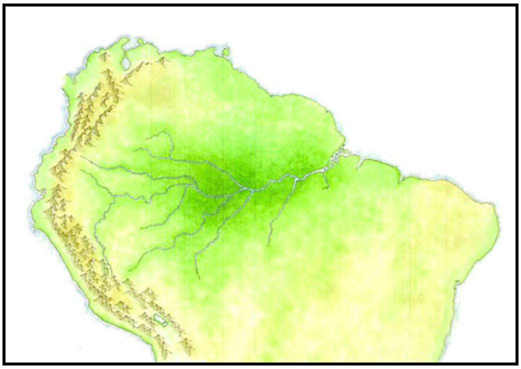


Figure 3.1: The Amazon.

Figure 3.2: The Amazon.

RUBBER

Rubber became known to Europeans during the voyages of Columbus to the New World. In 1876, H. A. Wickham, an Englishman, succeeded in obtaining from the Amazon region seeds of rubber trees and secretly transferred them to England, where they were planted in the royal gardens at Kew. Some of the seedling which spouted was sent to Ceylon and Singapore. In 1881, seeds from these were distributed to Java, the Malay States, and India. Thus, began the rubber industry in the East. The rubber trade was in the hands of British and Dutch businessmen. In 1903 the United States Rubber Company made a start in the Far East. Research in the chemistry of colloids thrived during this period because the juice collected was a colloidal suspension.

The manufacture of water-proof raincoats, carriage and bicycle tires, and other rubber articles was a thriving little business. All rubber came from the Amazon region, where it was gathered by natives from wild trees. Until 1910, the world's supply of rubber came chiefly from the jungles bordering Manaus, the capital city of the Amazon Region which became a prosperous city.

Figure 3.3: Rubber trees in Amazon.

In a day, the native worker taps and collects the juice from seventy to one hundred trees. He has then to coagulate the milk of rubber tree immediately after collection to prevent the juice from spoiling. This was done by evaporating the water from the juice by heating. Each tapping, at the rate of two drops per second, yields one fluid ounce of latex per tree, and this contains one third of an ounce of dry rubber. This represents an annual production of about three pounds of rubber for each tree. An acre will yield about one pound per day. Considering the quantity of rubber required for an average automobile tire, it requires the output of two full grown trees for a whole year to supply the rubber for one tire. It takes about seven years for a rubber tree to begin to produce, and does not come into full production until ten years.

In 1909, Fritz Hofmann at Bayer Company in Elberfeld in Germany produced successfully the first synthetic rubber. The rubber industry had become a basic industry. The petroleum, automobile and rubber industries became intimately related. When synthetic rubber became well established, the rubber industry in Brazil declined.

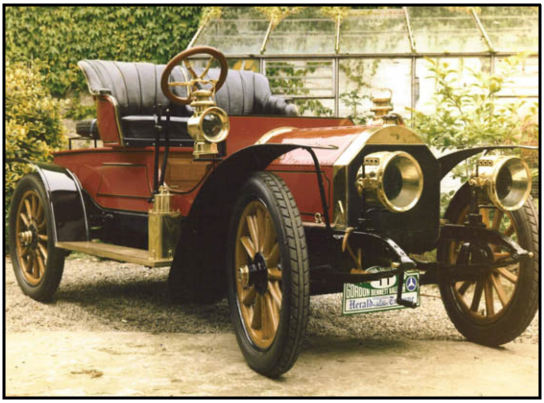


Figure 3.4: Rubber and the beginning of the automobile industry.

FLORA AND FAUNA

The region is home to ~2.5 million insect species, tens of thousands of plants, and some 2 000 birds and mammals (Figures 3.5–3.8).

Figure 3.5: Tucan.

Figure 3.6: Macaws.

MERCURY

Gold mining in the Amazon basin caused the release of toxic metal. Thousands of garimpeiros, primitive gold miners, remove ore by washing a rock face with a high-pressure stream of water. The ore is crushed, and the gold is collected by amalgamation. The amalgam is filtered manually and then retorted to release the mercury from the gold. The mercury vapour that results is distilled and reused, although a small fraction remains bound to the gold, to be released by the gold dealers during processing (Figure 3.9).

Figure 3.7: Macaws.

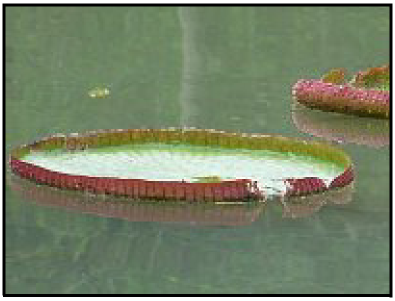


Figure 3.8: Victoria Regis water plant, 20–40 cm diameter.

Figure 3.9: Garimpeiros recovering gold by primitive amalgamation methods.

Chapter 4

Rio de Janeiro

Rio de Janeiro (Figures 4.1–4.4) was the capital of Brazil for almost two centuries — from 1763 to 1822 while it was a Portuguese colony and from 1822 to 1960 as an independent nation. It was the *de facto* capital of the Portuguese Empire from 1808 to 1821. Rio is famous of its rock known as Corcovado, meaning hunchback in Portuguese, the huge statue of Christ the Redeemer (Figure 4.5), Copacabana beaches, the annual February Carnival, and its gigantic trees (Figures 4.6–4.10).

Figure 4.1: Map of Rio de Janeiro.

Figure 4.2: View of Rio de Janeiro.

Figure 4.3: Rio de Janeiro at night.

Figure 4.4: A visit to Christ Monument, 2000.

Figure 4.5: Monument of Christ looking at the city Rio de Janeiro.

Figure 4.6: A park in Rio with impressive trees.

Figure 4.7: Ipanema Beach, Rio de Janeiro.

Figure 4.8: Typical swimming suits on the beach.

Figure 4.9: Carnival of Rio.

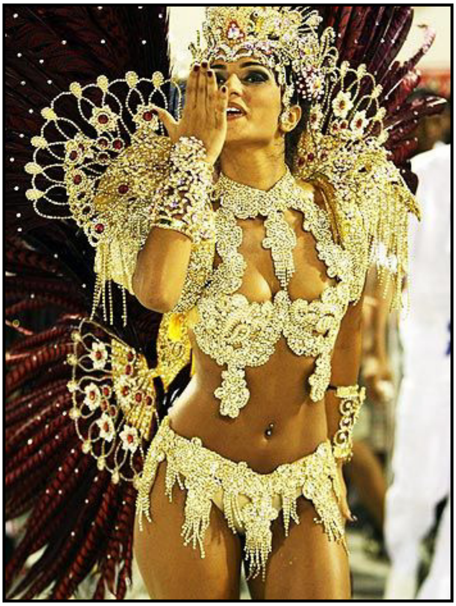
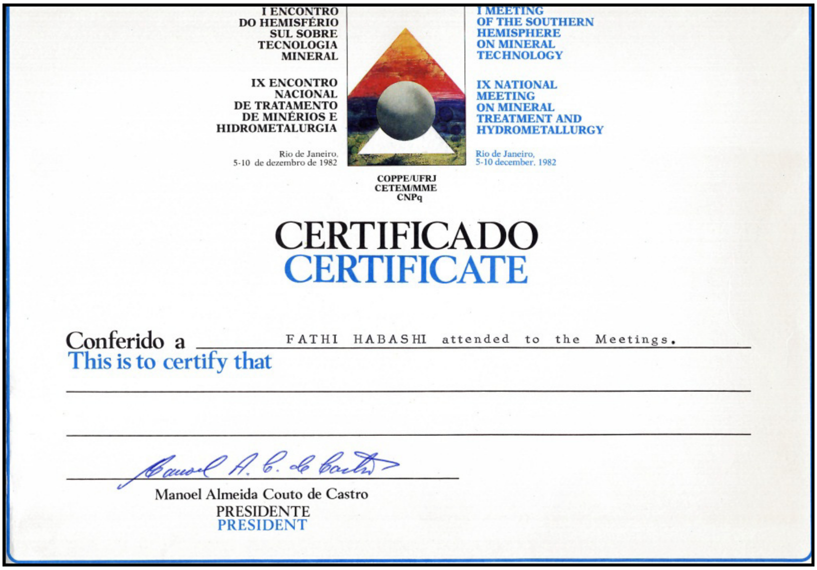


Figure 4.10: Carnival of Rio.

SOUTHERN HEMISPHERE ON MINERAL TECHNOLOGY

The First Meeting of the Southern Hemisphere on Mineral Technology that was held simultaneously with the Ninth Brazilian Meeting on Mineral Treatment and Hydrometallurgy took place in Rio de Janeiro in December 1983.



I ENCONTRO DO HEMISFÉRIO SUL SOBRE TECNOLOGIA MINERAL

IX ENCONTRO NACIONAL DE TRATAMENTO DE MINÉRIOS E HIDROMETALURGIA

Rio de Janeiro, 5-10 de dezembro de 1982

I MEETING OF THE SOUTHERN HEMISPHERE ON MINERAL TECHNOLOGY

IX NATIONAL MEETING ON MINERAL TREATMENT AND HYDROMETALLURGY

Rio de Janeiro, 5-10 december, 1982

COPPE/UFRJ
CETEM/MME
CNPq

CERTIFICADO
CERTIFICATE

Conferido a FATHI HABASHI attended to the Meetings.
This is to certify that

Manoel Almeida Couto de Castro
PRESIDENTE
PRESIDENT

Figure 4.11: A tradition in Latin American countries is to give certificates to delegates at conferences.

NATIONAL MUSEUM

The National Museum (Figure 4.12) was established by the King of Portugal Dom João VI (1769–1826) in 1818 with the name of Royal Museum, in an initiative to stimulate scientific research in Brazil. Initially the Museum sheltered botanical and animal specimens, especially birds. With the marriage of D. João VI's son and Brazil's first Emperor, Dom Pedro I (1798–1834) with Princess Leopoldina of Austria, the Museum started to attract the greatest European naturalists of the 19th century who explored the country and contributed for the collections of the Royal Museum.

By the end the 19th century the National Museum started to invest in the areas of the anthropology, palaeontology and archaeology. In this way, the National Museum was modernized and became the most important museum of Natural History and Human Sciences of South America. When the Emperor was deposed in 1889, the official residence of the emperors became vacant; and in 1892, the National Museum, was transferred to this palace, where it stays until today. In 1946, the Museum's management was passed to the University of Brazil, currently the Federal University of Rio de Janeiro.

Figure 4.12: The Museu Nacional at its first location on Campo de Sant'Anna, today's Praça da República, at the centre of Rio, ca. 1870.

Federal University of Rio de Janeiro

The Federal University of Rio de Janeiro was founded in 1920 as the University of Brazil. When Rio was no longer the capital of Brazil, the University took the present name Universidade Federal de Rio de Janeiro. The Faculty of Technology of Technology is composed of two schools:

School of Chemistry. This was one of the first schools composing the University and the first school in Brazil where chemistry was taught. At present it is composed of 4 departments: Inorganic Processes, Organic Processes, Biochemical Engineering, Chemical Engineering. It corresponds to a European Faculty of Chemical Technology. I was guest at the Inorganic Processes Department. Chair person Prof. Maria da Conceição Finamore Carlos de Oliveira.

School of Engineering. This is includes Civil, Electrical, Mechanical, Metallurgical, and Naval Engineering. It corresponds approximately to a Faculty of Science and Engineering in North American terminology.

The first graduates from the Federal University went abroad to obtain higher degrees and when they returned they founded a Graduate School for research which became known by COPPE, the acronym for Coordenação de Programas de Post-Graduação em Engenharia. It is a unique establishment in Brazil since it has its own administration, laboratories, and equipment.

Polo de Xistoquímica

This is a research centre for shale chemistry belonging to the Institute of Chemistry. Research is devoted to valorization of slags, fly ash, red mud, catalysts wastes from petroleum industry, etc. The centre produced what became known as "glass ceramics." While glass is an amorphous material, glass ceramic is a crystalline glass matrix embedded with ceramics, melting point 1200 °C, hard, highly abrasive-resistant, can be sawed and is used as material of construction for rocket shields.

Electrobras Research Centre

Known as CEPEL, the acronym of Centro de Pesquisas de Energia Elétrica, located at the University Campus. It belongs to the Ministry of Energy. Department visited: Materials. Areas of research: corrosion, degradation, metallurgy, vibration, dielectrics, glass, ceramics, heat transfer, etc.

PETRÓLEO BRASILEIRO SA

Better known as Petrobras — the Brazilian Government petroleum organization, founded in 1935. The research centre is located on the University Campus and known by the acronym CENPES which stands for Centro de Pesquisas de Petroleiras [founded in 1963]. Around 1 600 people working at this place, devoted to research on drilling, exploitation, processes for petrochemicals and refining. The centre is developing expertise for welding under water at high hydrostatic pressure, e.g., repairing leaking pipelines, anodic protection on ocean platforms, etc.

PONTIFICAL UNIVERSIDADE CATÓLICA

Pontifical Catholic University of Rio de Janeiro, known as PUC, was founded in 1940. Department of Material Science included Fathi Aref Darwish and Taymour Dorry AlKasabgy, both from Egypt.

CETEM

The Centre of Mineral Technology — CETEM — is a national research institute located on the campus of the Federal University of Rio de Janeiro and linked to the Ministry of Science and Technology (Figure 4.13). Since its creation, in 1978, it has been involved with technological development in mineral technology and in the dissemination of knowledge. CETEM is funded by CNPq, which is the Portuguese acronym that stands for the National Council of Scientific and Technological Development. CETEM includes 24 laboratories, 3 pilot plants, and a specialized library. It organizes conferences, short courses and seminars. In 1992 a course on *Extractive Met-*

allurgy was organized in collaboration with the Federal University of Rio de Janeiro (Figures 4.14–4.19).

Figure 4.13: First visit CETEM, 1983.

Figure 4.14: The lecturer with participants at the short course *Extractive Metallurgy*, 1992.

CURSO SOBRE

METALURGIA EXTRATIVA

Prof. Dr. FATHI HABASHI

29/06/92 a 03/07/92

RIO DE JANEIRO

APOIO: CNPq/CETEM; DPI-EQ/UFRJ

* ESTE EVENTO SERÁ REALIZADO SOB OS AUSPÍCIOS DO CONVÊNIO ENTRE A UNIVERSIDADE FEDERAL DO RIO DE JANEIRO E A UNIVERSIDADE LAVAL - CANADÁ.

HORÁRIO: DE 9:00 ÀS 12:00 h E DE 14:00 ÀS 17:00 h.

LOCAL : AUDITÓRIO DO CETEM - RUA 4 - QUADRA D - CIDADE UNIVERSITÁRIA

MAIORES INFORMAÇÕES: DPI-EQ/UFRJ - 270-2287 e FAX (021) 590-4991
CETEM - 260-2222 R. 201 e FAX (021) 290-9196

Figure 4.15: Flyer for the course, 1992.

Figure 4.16: A plaque of thanks from Dr. Ricardo de Andrade Medronho, Director of the School of Chemistry, Federal University of Rio de Janeiro. Photo by Nadia Habashi, 1992.

Figure 4.17: With Dr. Roberto Villas Bôas [third from right] Director of CETEM and senior staff after the closing ceremony of the Short Course. Photo by Nadia Habashi, 1992.

Figure 4.18: CETEM medal given to the writer.

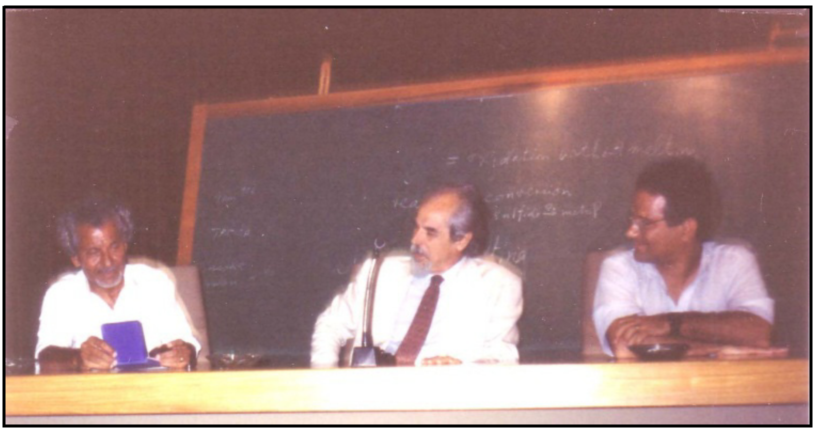


Figure 4.19: Receiving CETEM medal from Dr. Villas Bôas [centre]. Right: Dr. Ricardo de Andrade Medronho, Director of the School of Chemistry, Federal University of Rio de Janeiro. Photo by Nadia Habashi, 1992.

CNPq 45th Anniversary

On the occasion of 45 years of foundation of the National Council for Scientific Research known by the Portuguese acronym CNPq, a symposium was organized at CETEM on March 11–15, 1996 to which some speakers were invited (Figure 4.20). The paper presented at the Symposium and entitled “The Future of Extractive Metallurgy” was published by CETEM (Figure 4.21).

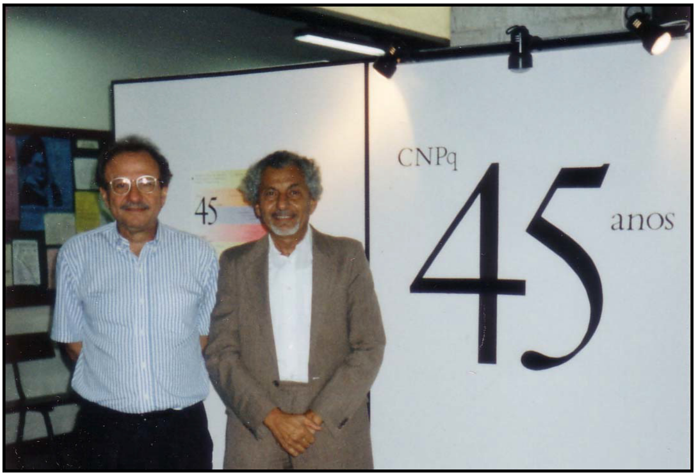


Figure 4.20: Celebrating 45th Anniversary of CNPq CETEM in 1996 with Prof. Jacob Palis, President of the Symposium.

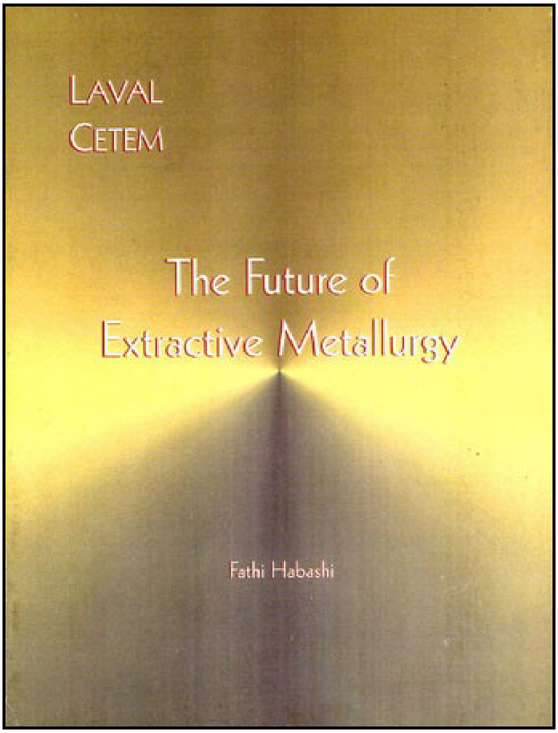


Figure 4.21: A publication of the paper presented at the Symposium [1996].

SYMPOSIUM ON RARE EARTHS

A symposium on Rare Earths was also organized by CETEM in 1997 (Figure 4.22).

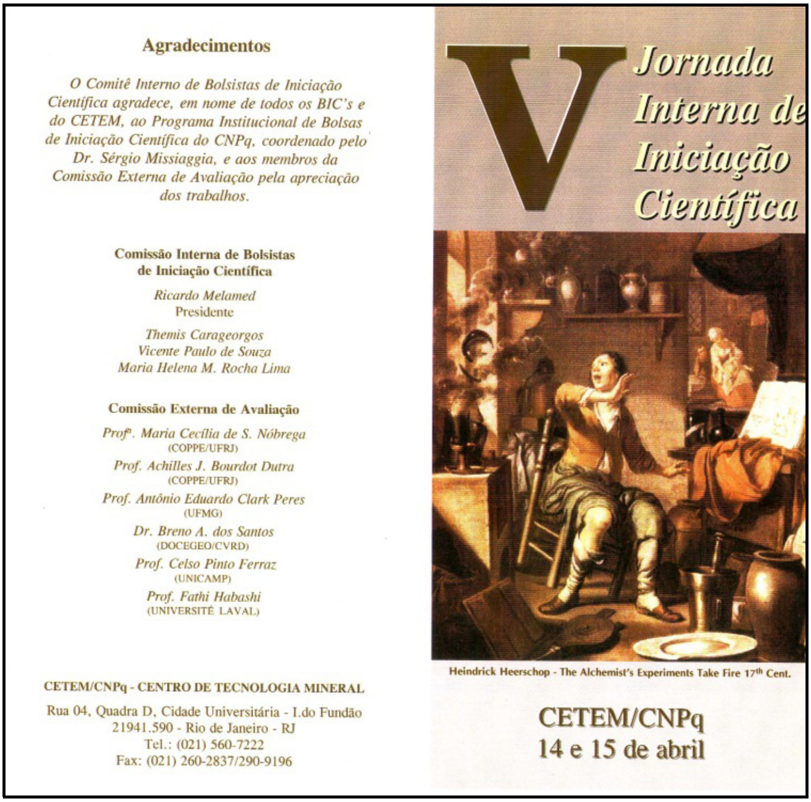


Figure 4.22: Rare Earths Symposium organized in April 1997 at CETEM in Rio de Janeiro.

OSWALDO CRUZ INSTITUTE

A land mark of Rio de Janeiro is the Oswaldo Cruz Institute (Figure 4.23) created by the Brazilian physician Oswald Cruz (1872–1917) (Figures 4.24–4.25). Oswaldo Cruz went to Paris in 1896 to specialize in bacteriology at the Pasteur Institute. In 1900, he was appointed Director General of Public Health. He started a quick sanitation campaigns to save the country from epidemics that ravaged at the sea port of Santos.

Figure 4.23: Oswaldo Cruz Institute in Rio de Janeiro.

Figure 4.24: Brazilian paper money honouring Oswaldo Cruz.

Figure 4.25: Brazilian stamp honouring Oswaldo Cruz.

Petrópolis

Petrópolis, also known as the Imperial City of Brazil, is a town in the state of Rio de Janeiro, about 65 km from Rio. Its main attraction is the former Summer Palace of the second Brazilian Emperor, which is now a museum (Figure 4.26).

Figure 4.26: Imperial Palace in Petrópolis, now a museum.

Figure 4.27: Alberto Santos Dumont honoured on a postage stamp.

Alberto Santos Dumont

Petrópolis is the home of Alberto Santos Dumont Museum. Dumont (1873–1932) was a pioneer aviation engineer (Figure 4.27). He belonged to a wealthy family of coffee producers and dedicated himself to science studies in Paris where he spent most of his adult life. He designed, built and flew one of the first practical dirigibles. On October 19, 1901 on a flight that rounded the Eiffel Tower, made him one of the most famous people in the world during the early 20th century. The airport of São Paulo is named after him.

SOCIAL PROBLEMS

Like any other large city, homeless can be seen in Rio (Figure 4.28).

Figure 4.28: Homeless in Rio de Janeiro.

Chapter 5

Minas Gerais

The State of Minas Gerais [pronounced Minas Jra-yes and means General Mines] (Figure 5.1) is the richest province in Brazil in mineral resources.

BELO HORIZONTE

Meaning Beautiful Horizon (Figure 5.2), the third largest city of Brazil after São Paulo and Rio de Janeiro, was founded in 1893. Population 3 million [1992], became in 1896 capital of the State of Minas Gerais. It is a modern city with two airports and a large University. Prof. Virginia Ciminelli is teaching extractive metallurgy at the University.

COMPANHIA VALE DE RIO DOCE

Known by the acronym CVRD, the name can be translated as the Sweet River Valley Company, created in 1942, 51% Government and 49% private sector. She is the largest exporter of iron ore in the world. In addition she is involved with the production, beneficiation and marketing of bauxite, ores of manganese, gold, copper, silver and active in forest resource. The company transports 30 million tons of products on her own fleet of 26 large carriers. Research Director Paulo Roberto Noreiga, guide: Dr. Lino Rodrigues de Freitas [graduate of École Polytechnique in Montreal].

SABARÁ

The history of gold in the region is well documented at the Gold Museum in Sabará (Figure 5.3–5.4), a suburb of Belo Horizonte. The building was the residence of the Governor at that time.

Figure 5.1: State of Minas Gerais: Capital City *Belo Horizonte*, to its immediate right is *Sabará* and to the far left is *Araxá* and *Uberaba*. Near the border with the State of Rio de Janeiro is *Juiz do Fora*. *Ouro Preto* is to the south east of Belo Horizonte. *Poços de Caldas* is to the west near the border with the State of São Paulo. *Brasília* the Federal capital is to the far northwest. *Catalão* is three hours drive from Uberaba, half way to Brasília.

Figure 5.2: Belo Horizonte, capital city of the State of Minas Gerais.

Figure 5.3: Gold Museum.

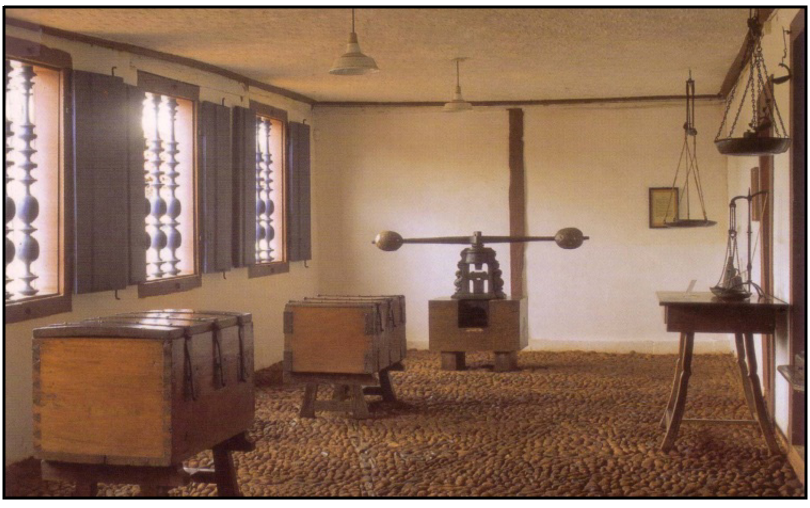


Figure 5.4: Inside the Gold Museum.

ARAXÁ

The largest niobium deposits in the world occur in Araxá about 450 km west of Belo Horizonte and Uberaba (Figure 5.5), both in the State of Minas Gerais. The deposits are exploited by two companies: *Companhia Brasileira* *de Metalurgia e Mineração* founded in 1954 and *Anglo American Brasil Mineração Catalão*. The primary mineral from which niobium is obtained is pyrochlore [$Nb_2O_5 \cdot (Ca, Ba)O \cdot NaF$]. The mining of weathered ore, running between 1 and 3% Nb_2O_5, is conducted by simple open pit mining without the need for drilling and explosives. In these facilities, the pyrochlore mineral is processed by primarily physical processing technology to give a concentrate ranging from 55 to about 60% niobium oxide. The major product is ferro-niobium with 60% niobium oxide content, for making high-strength, low-alloy steel. The company was visited in 1983.

Figure 5.5: Uberaba, State of Minas Gerais.

Poços de Caldas

Poços de Caldas, literally meaning "Springs of Juices," is a resort area in the State of Minas Gerais famous of its radioactive water springs (Figure 5.6). Recently a large uranium deposit was discovered in the neighbourhood (Figure 5.7). A plant was built for uranium recovery in 1982.

Figure 5.6: Poços de Caldas.

JUIZ DO FORA

Juiz do Fora, pronounced like French "Juge" and means "The judge from far away," is a prosperous modern city, centre for textiles, glass, and paper manufacture, southeast of the State of Minas Gerais, close to the state border with Rio de Janeiro (Figure 5.8). The massive presence of immigrants — especially from Italy, Germany, Syria, and Lebanon — throughout its history has given the city a cosmopolitan spirit and diverse cuisine. The origins of Juiz de Fora trace back to the beginnings of the 18th century, when a road called "Caminho Novo" (New Way) was opened, linking Rio de Janeiro to the gold rush area of Minas Gerais.

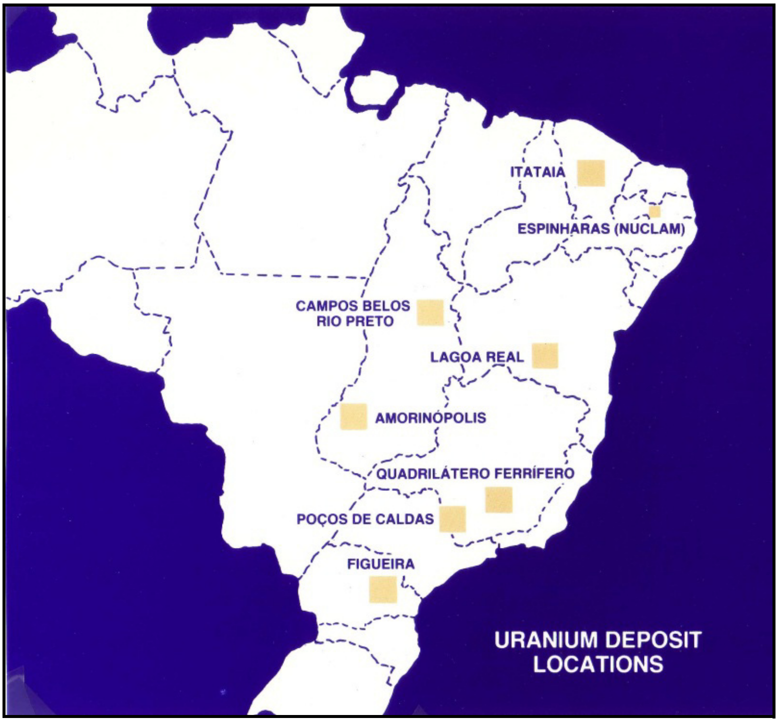


Figure 5.7: Map showing the location of uranium deposits in Brazil. Poços de Caldas in the south.

Figure 5.8: Juiz do Fora panoramic view.

Companhia Paraibuna de Metais

On the outskirts of Juiz do Fora is a zinc plant (roasting, leaching, electrowinning) belonging to Companhia Paraibuna de Metais. Production 60 000 tons/year. Started operation 1980; it imports concentrates from Peru. Some of the SO_2 (6 000 tons/month) produced is liquefied because the roasting is conducted with 2% oxygen-enrichment air. Most of the acid is shipped to the zinc silicate leaching plant belonging to the company. Iron is precipitated by the jarosite process. Beside zinc and zinc–magnesium–aluminum alloys, there are two plants to produce zinc dust: one by atomization of liquid zinc and the other by quenching of zinc vapour. Plant director [1992]: Nelson Novaes de Almeida. Director of research: António Luiz de Almeida. Consultant: Hugo Radino (guide).

Figure 5.9: Location map of Ouro Preto.

Ouro Preto

Ouro Preto in Portuguese means black gold; it was near there that gold was first discovered in 1691 in black iron oxide hence the name. Ouro Preto (Figures 5.9–5.10) was founded in 1698 as a mining settlement and within a decade it became the centre of the greatest gold and silver rush in the Americas. It was given city status in 1711 with the name Vila Rica, i.e., Rich Village. It was made capital of the newly created Minas Gerais Captaincy in

1720. After Brazil's independence from Portugal, it was named capital of Minas Gerais Province. In 1897, however, the capital was transferred to Belo Horizonte (founded in 1877) 65 km to the north.

Figure 5.10: A view of Ouro Preto.

Considered a Cultural and Historical Patrimony of Mankind by UNESCO, Ouro Preto preserves one of the finest eighteenth century baroque art collections in the world. From 1730 to 1760, gold production reached its peak in Ouro Preto and almost two tons of gold were sent to Portugal each year. It was producing half the world's gold. It became the capital of the Portuguese colony and Rio de Janeiro flourished into a major port to serve the capital.

In 1875, the Brazilian Geological Survey was founded and a year later, the emperor, Pedro II, realized the importance of mineral wealth in his country. The idea of creating a School of Mines in Brazil was proposed in

1800 by Manuel Ferreira da Câmara de Bittencourt e Sá (1762–1835) after his return from a study tour in Freiberg and other European countries. The idea that the new School would be similar to the Freiberg Mining Academy was accepted in 1803. But it was not until 1876 that Pedro II inaugurated the first School of Mines in Brazil presently it occupies the old Governor's palace (Figure 5.11). The School was founded by a French geologist Claude-Henri Gorceix (1842–1919) (Figure 5.12) who was recommended to the emperor by Gabriel-Auguste Daubrée (1814–1896), director of the School of Mines in Paris. Gorceix took the job at the age of 31, he married a Brazilian girl and made Brazil his home. He died in Ouro Preto at the age of 77. The School was visited in 1992 (Figure 5.13).

Figure 5.11: School of Mines.

Figure 5.12: Claude Henri Gorceix (1842–1919), the first director of the Ouro Preto School of Mines.

Figure 5.13: Visiting Ouro Preto School of Mines. Photo by Nadia Habashi, 1992.

Chapter 6

São Paulo

São Paulo city (Figure 6.1) is the largest city in Brazil [about 15 million], the capital of the state of São Paulo, and first in South America by population. It has a large Japanese community. It falls exactly on the Tropic of Capricorn. It was founded in 1554 by the Jesuits. Today it is the economic and industrial centre of Brazil. The Paulistas were the first to demand independence from Portugal (the so-called "Tirandentes," crushed in 1792) and earlier were responsible for expeditions into the interior of Brazil (Portuguese Eldorado) that led to the discovery of gold in Minas Gerais (the so-called "Bandeirantes"). With more than 32 millions inhabitants, the State of São Paulo concentrates ¼ of Brazil's population. It is responsible for more than 50% of the industrial production of Brazil and about 35% of total exports.

LORENA

Lorena (Figure 6.2) is a small town half way between Brazil's two largest cities, Rio de Janeiro and São Paulo, and about 250 km from Campinas — an important university city. The Refractory Materials Institute was founded in 1976 by the Fundação de Tecnologia Industrial which belongs to the Ministry of Trade and Commerce, with mandate to build pilot plants for treating ores of the refractory metals.

Under the leadership of Dr. Daltro Garcia Pinatti, the Institute has processed many tons of raw materials, produced many tons of pure niobium and tantalum, developed exact analytical techniques for analysing trace impurities (particularly gases) in such metals, and has established excellent relations with scientists in Max Planck Institute for Metal Research in Stuttgart and Japanese cryogenic engineers. The first pilot plant built was for the production of technical Nb_2O_5 from pyrochlore concentrates as proposed by F. Habashi and I. Malinsky ["Technical Niobium Oxide from Pyrochlore Concentrate," *Bulletin of Canadian Institute of Mining & Metallurgy* **68**, 85–90

(1975), **69**, 112 (1976)] and improved by Pinatti and coworkers. About 40 tons were treated in the pilot plant (Figure 6.3).

Figure 6.1: São Paulo.

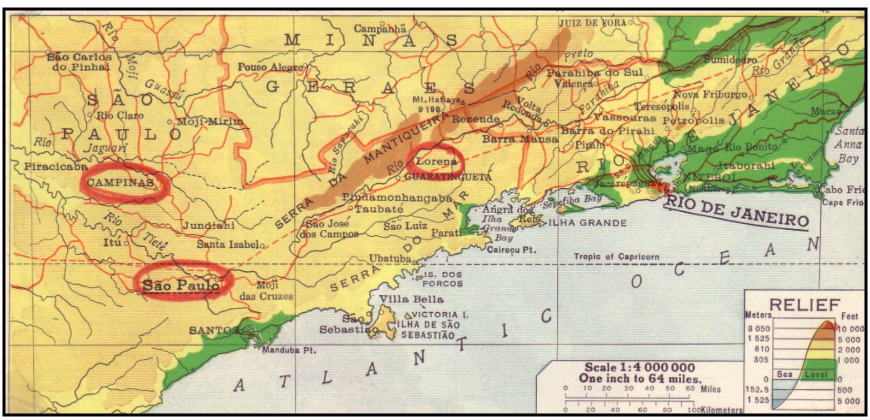


Figure 6.2: Location map of Lorena and Campinas.

Figure 6.3: Pilot plant for the chlorination of pyrochlore at Lorena.

The technical oxide prepared by this method was reduced by aluminum to produce impure niobium metal which was then refined in electron beam melting to get pure niobium ingots. Important development was done to the electron beam technology, that this Institute may be considered the best in the Western world in electron beam furnace research. Aluminothermic reduction of large batches of Ta_2O_5 is conducted daily to produce 2–3 kg metallic tantalum.

Alcohol Research Institute

There are about 500 plants in Brazil producing alcohol for use as a fuel from biomass (total annual production 5×10^9 L alcohol), and a central research institute in Lorena belonging to the Fundação de Tecnologia Industrial (Ministry of Trade and Commerce). Tour Guide: José António Bentine, a graduate of the Chemical Engineering School operated by the Foundation and located next to the Alcohol Research Institute. This school graduates about 120 chemical engineers annually.

Sugar cane is cut and squeezed in special presses. The solution fermented to alcohol and the baggasse compressed into solid cylindrical rods about 5 cm diameter and 30 cm long to be used either as a fuel or as a feed material for acid hydrolysis unit to produce sugar. One hectare yields 50 t sugar cane from which are obtained 3 500 L alcohol (Figure 6.4).

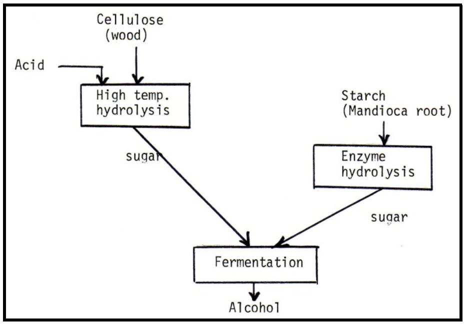


Figure 6.4: Alcohol from biomass.

Enzyme hydrolysis of starch

Mandioca root (botanical name *cassava*) is a root with dark brown skin and white in the inside, about 5 cm diam. × 25 cm long. Analysis 67% H_2O, 30% starch, balance mineral salts, proteins, and cellulosic fibres. The clean root is wet crushed to form a paste, heated to 90 °C in agitated stainless steel tanks together with certain enzymes, e.g., Nova's Termamill (Swedish), or Pfeitzer's alpha-amylase for ½ hr, cooled to 60 °C then second enzyme added, e.g., Nova's San or Pfeitzers amyloglucosidase. Process repeated until the starch and amylopectin is transformed completely to dextrin then dextrose, and the amylose to maltose. The slurry is then cooled to 30 °C and fermented in tanks with circulating pumps using *sucaromesis serevise* bacteria which are cultured in place. When the desired alcohol content is reached the material is distilled to recover the alcohol. There are three pilot plants in operation: two batch (2 000 and 5 000 L/day, and one continuous 2 000 L/day alcohol. One ton mandioca yields 180–200 L alcohol, one hectare yields 15 t mandioca.

Acid hydrolysis of wood

Wood undergoes hydrolysis at high temperature and pressure to yield a solution containing pentoses and furfural and a solid brown residue composed mainly of lignin. The solution containing the sugar is fermented to yield alcohol, while the lignin is pelletized and carbonized in a special furnace to yield a high-grade coke (99.8% fixed carbon and sulfur-free). Either H_2SO_4 or HCl are used in the hydrolytic reaction. Hydrolysis by sulfuric acid is conducted at 180 °C and 12 atm in a pressure reactor with false bottom where the acid continuously percolates by HCl is faster, and the product of hydrolysis yields more alcohol but the reactor must be constructed of special acid resisting alloy. Legnin is used in Brazil to replace bentonite as a binder in the pelletization of iron ores (Figure 6.5). This is an excellent substitute since in this way SiO_2 content of the pellets is not increased.

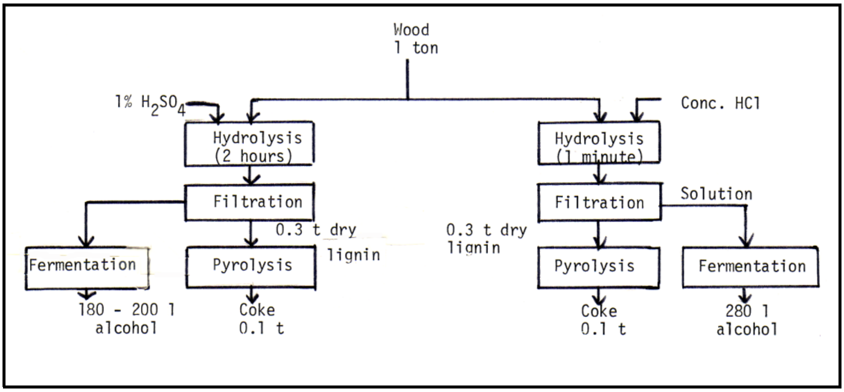


Figure 6.5: Acid hydrolysis of wood.

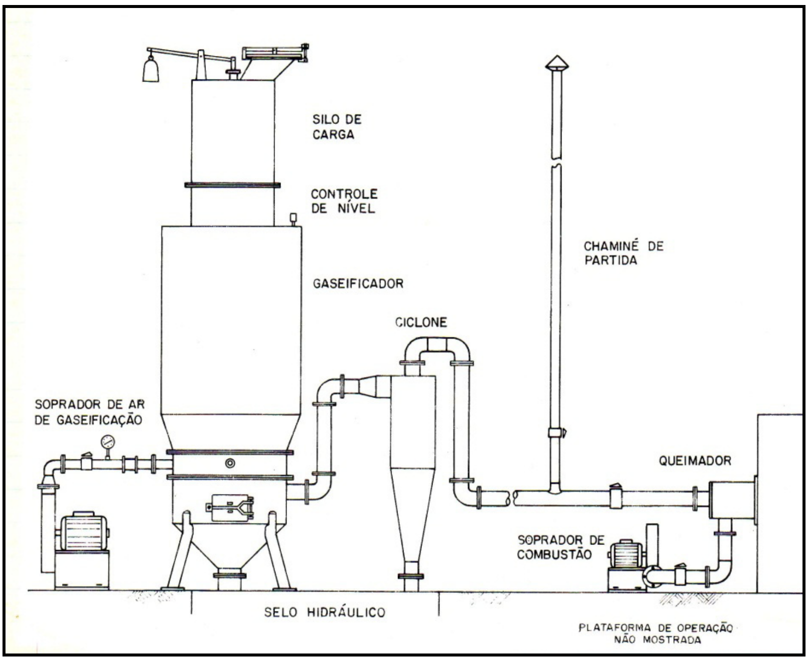


Figure 6.6: Wood gasification unit.

Wood gasification

Wood gasification (Figures 6.6 and 6.7) is a reality in Brazil. Industry burning fuel oil will no longer be doing so by law starting 1983. They will be obliged to use the wood gasification units that are now available in units of variable sizes (100 000 to 50 000 000 kcal/hr). In these units, pieces of wood are gasified by burning in a limited supply of air. Reaction in the bed is started by an electric coil transformer. Gas composition depends on the humidity of wood. To produce 1 million kcal, 325 kg of wood (10% humidity) are needed as compared to 102 kg fuel oil. An advantage of using the wood system however is the absence of SO_2 in the combustion gas as compared to when burning fuel.

Figure 6.7: Wood gasification unit.

Brazil and the Rare Earths

The industrialization of the rare earths started in Austria in 1885 by Carl Auer von Welsbach (1858–1929) and this was possible only because of the discovery of large economic deposits of monazite sand near Santos, Province of São Paulo in Brazil in the same year. The first industrial application of the rare earths was the gas mantle for lighting purposes. In 1887 Carl Auer opened a factory at Atzgersdorf, a suburb of Vienna, to prepare the rare earths salts necessary for preparing the soaking solution and to sell it to customers in Germany, England, and the United States. To secure supplies of raw material for his factory he went to Sweden and Norway to buy eight tons of cerite, a relatively rare and expensive mineral. He also got one ton of monazite, which was produced in North Carolina in USA as a waste product of a gold operation, to be used as an experimental source for rare earths. However, after two years of success, sales declined because the light of the gas lamps was too greenish, the life of the lamps was too short, the raw material was rare and too expensive, and there was competition with the new electric light. He, therefore, had to shut down the factory in 1889.

The mineral dealer in New York who sold Auer a ton of monazite had a brother who was a coffee dealer in Santos. He sent Carl Auer a sample of the heavy yellow sand from the coast of Brazil. This sand contained monazite that soon became the raw material for the growing gas mantle industry. Its inexpensive availability was an important factor in the survival of the industry in spite of competition from the electric lamp. It was shipped to Austria as a ballast in ships. When the Brazilian government, however, realized the importance of this sand, export was prohibited.

NUCLEMON

A plant in the city of São Paulo was constructed in 1949 by Nuclemon Minero Química, a state-owned company, to treat the sand for the recovery of its various fractions (zircon, magnetite, rutile, etc.) as well as the production of the individual rare earths oxides by ion exchange. The monazite concentrate was attacked by NaOH because Brazil imports most of its sulfur requirement to make H_2SO_4. The rare earths, thorium, and uranium collected in the residue is then dissolved in HCl for further separation (Figures 6.8–6.9). The plant, however, was shut down in the late 1990s because environmental problems, being located in the centre of an inhabited area and emitting radioactive gases during processing.

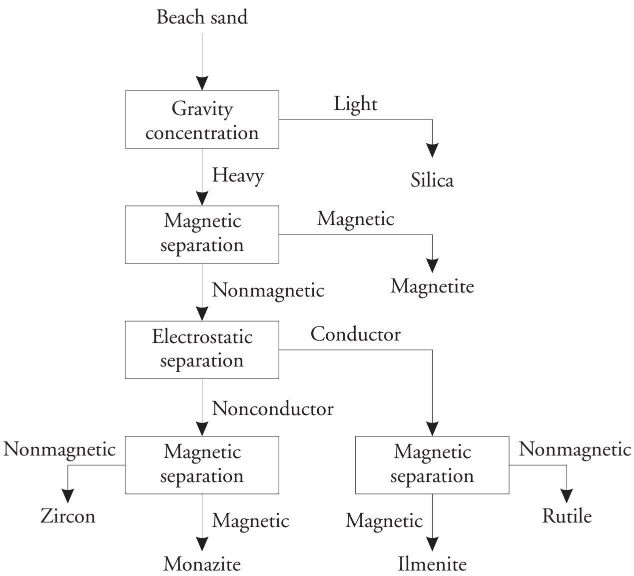


Figure 6.8: Recovery of monazite and other minerals from the monazite sand.

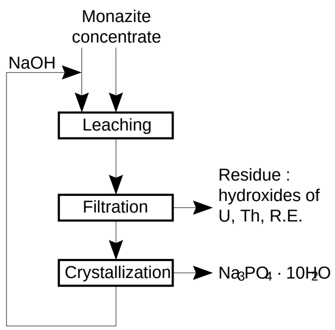


Figure 6.9: Chemical processing of monazite sand.

LITHIUM

Nucleon also recovered lithium from amblygonite — a complex hydrated lithium mineral containing fluorine, phosphate, and aluminum, $(Li, Na)_2(F, OH)_2 \cdot Al_2O_3 \cdot P_2O_5 \cdot {}^1/_2H_2O$ (Figure 6.10).

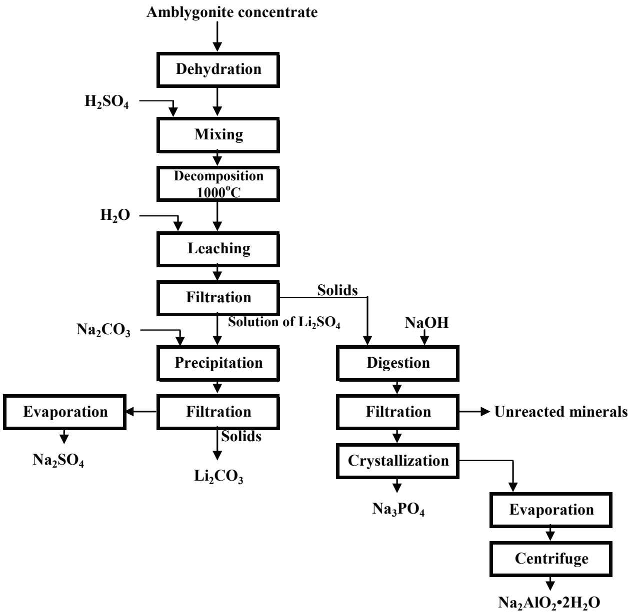


Figure 6.10: Flowsheet for lithium production.

INSTITUTO BUTANTAN

Snake Research Institute in Butantan is a Brazilian biomedical research centre affiliated to the São Paulo State Secretary of Health. It is located near the campus of the University of São Paulo, in the city of the same name. The Institute was founded by the Brazilian physician and biomedical scientist Vital Brazil (1865–1950) (Figures 6.11–6.13) in 1901. It is internationally renowned for its research on venomous animals. It maintains one of largest collections of serpents in the world, comprising ca. 54 000 specimens, and it is also a state-supported producer of vaccines against many infectious diseases, such as rabies, hepatitis, tetanus, diphtheria, tuberculosis, as well as polyvalent and monovalent antivenoms against the bites of snakes, lizards, bees, scorpions and spiders. A museum telling the story of the Institute is included.

Figure 6.11: Vital Brazil on paper money.

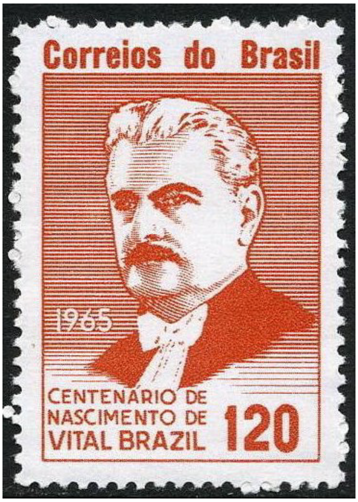


Figure 6.12: Vital Brazil postage stamp.

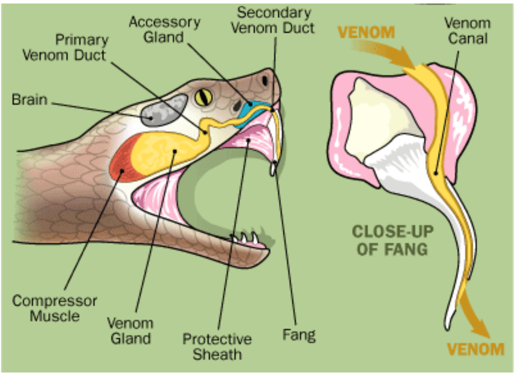


Figure 6.13: Ejection of venom from a snake.

POLYTECHNIC SCHOOL

This is the first polytechnic school in Brazil, founded in 1894 and one of the largest. In 1934 the University of São Paulo was created and the Polytechnic became part of it (Figure 6.15). The University of São Paulo is presently the largest university in Brazil with enrolment over 55 000, 6 000 faculty members, and 18 000 employees [1992]. The Department of Metallurgical and Materials Engineering was founded in 1939 with the help of Prof. Robert Mehl and Prof. Prof. Arthur Philips from USA.

Figure 6.14: With faculty members of Polytechnic [Photo by Nadia Habashi, 1992].

NUCLEAR ENERGY RESEARCH INSTITUTE

Located on the University Campus and known by the acronym IPN which stands for Instituto de Pesquisas de Energia Nuclear. The Institute has 1 460 employees, The Metals Research Department is concerned with the production of zirconium and hafnium (Figure 6.16).

Figure 6.15: Entrance to the University of São Paulo. Photo by Fathi Habashi, 1992.

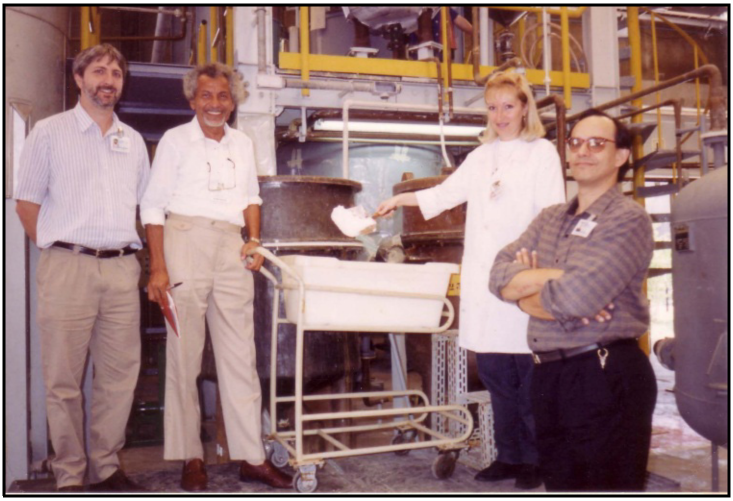


Figure 6.16: Visiting the zirconium production pilot plant, 1992 [Photo by Nadia Habashi].

AQUATEC RESEARCH CENTRE

This is a large modern chemical and microbiological research centre on the outskirts of São Paulo, founded in 1947 (Figure 6.17). Headquarters of the Company is in São Paulo. The Company has also branches in USA, Germany, Egypt, and other places. The Company produces and trades with the raw materials for biocides (e.g., carbamates and glucoaldehydes), for cosmetics (shampoos, tooth paste, chemicals, etc.), surface active agents, detergents, EDTA chemicals, etc. Therefore, there is active research on chemicals for boiler water, for cooling water in power plants (biocides to kill moss, algae, etc.), anti-corrosion chemicals (sulfate-reducing bacteria). The Company is expanding in the mineral industry field, e.g., the possible use of surface active agents to increase rate of leaching of gold in dumps.

Figure 6.17: Aquatec [Photo by Nadia Habashi, 1992].

There is an active corrosion test laboratory for serving industries that uses Aquatec's chemicals as well as a sophisticated water analysis laboratory. Guides: José Carlos de Souza Botto (chemist), Cecilia Yolande G. Camales (microbiologist from Chile) and Villiam Latorre (microbiologist from the Head Office).

VILLARES STEEL COMPANY

Companhia de Aços Villares (Figure 6.18) is located on the outskirts of São Paulo, one of four plants belonging to the Villares family. The São Paulo plant was founded in 1953, but the Company started as a manufacturer of elevators. The company produces about 1 million tons of special steels, tool steels, high speed steels, rolling mills and stainless steels — all from scrap using electric furnaces. The Company, however, is equipped with all modern technology: vacuum induction melting furnaces, electric slag remelting, ladle vacuum treatment, vacuum degassing, argon for cooling and mixing, CaSi powder addition inside the molten metal through a refractory pipe. The plant is remarkably clean. A standing problem, however, is the disposal of electric furnace dust. The Company has great similarity to Atlas Steel in Quebec. It has also excellent steel testing facilities. Guide: José Roberto Bolota.

Figure 6.18: Engineers at Villares Steel Company [Photo by Nadia Habashi, 1992].

The visit was in company of Prof. Marcello Mourao and Dr. Jorge Terrório from the Polytechnic School of São Paulo and Prof. Maria da Conceição Filamore from Rio de Janeiro.

Paulista Museum

The Paulista Museum (Figure 6.19) is located in Ipiranga neighbourhood south of São Paulo near where Emperor D. Pedro I proclaimed the Brazilian independence on the banks of Ipiranga River in the city of São Paulo. It contains a huge collection of furniture, documents and historically relevant artwork, especially relating to the Brazilian Empire era.

Águas de São Pedro

Águas de São Pedro is a resort town famous for its mineral water, about 190 km north west of São Paulo (Figure 6.20). The XVII National Meeting for Mineral Processing and Extractive Metallurgy, organized by the Associação Brasileira de Metalurgia e Materiais, known by the abbreviation ABM, in August 1998 (Figures 6.21–6.22).

Figure 6.19: Paulista Museum, São Paulo.

Figure 6.20: Grande Hotel, Águas de São Pedro.

Figure 6.21: Conference organizers at Águas de São Pedro: Prof. Arthur Pinto Chaves [second from left] and Prof. Roberto Villas Bôas [seond from right]. Photo by Nadia Habashi, 1998.

Figure 6.22: Conference participants at Águas de São Pedro. Left: Luiz António from Fosferti. Photo by Nadia Habashi, 1998.

Chapter 7

Bahia

The State of Bahia is located in the northeastern part of the country on the Atlantic coast. It is also one of the most important states in Brazil's history and culture. The capital is Salvador, a well-protected port (Figure 7.1).

Figure 7.1: The well protected port of Salvador.

Salvador

Salvador (Figures 7.2–7.4) was for a long time also known as Bahia or as Salvador da Bahia. It was the first colonial capital of Brazil, founded in 1549 by Portuguese settlers. It is noted for its large Carnival celebrations, which include a strong Afro-Brazilian musical and spirituals. The historic square in the heart of the old city has colourful colonial buildings and cobble stoned streets was declared a World Heritage Site by UNESCO. It is now home to groups who reclaim their African heritage through music, dance, drums and art. Salvador is the third most populous Brazilian city, after São Paulo and Rio de Janeiro. Over 80% of the population of metropolitan region of Salvador has some Black African ancestry. No wonder the food there is different from Rio or São Paulo (Figure 7.5). A copper smelter located in Camaçari on the outskirts of the city is owned by Caraiba Metais.

Figure 7.2: Map of Brazil showing Salvador.

Figure 7.3: Salvador.

Figure 7.4: Salvador.

Figure 7.5: Bahia food.

Caraiba

A copper mine in Caraiba, in the State of Bahia, was discovered in 1874. It was not until 1969 that a Brazilian private firm took control of the mine. However, due to financing difficulties, the Federal Government assumed control in 1974 [Caraiba Metais]. In 1978 surface mining began, in 1980 the concentrator went into operation, and in October 1982 the smelter, located in Camaçari not far from Salvador, went into operation.

The mine in Caraiba is about 500 km northwest of Salvador. The reserve is estimated at 1.2 million tons of copper in a bornite ore containing on the average 1% Cu. Exploitation is conducted by open pit and underground mining. Daily production in the open pit at present is 13 500 tons of ore and 55 500 tons of waste. Underground mining is not yet in operation [1983]. The ore body is less than 1 km deep, and the decision was made to use these two methods of mining instead of open pit alone as one would expect.

The concentrator, located next to the mine, treats about 800 t/hr of ore and has the capacity to produce 55 000 t/year of copper contained in the concentrate at 90% recovery and a concentrate analysing 40–46% Cu. Tailings analyse 0.1–0.3% Cu. Water for the plant is obtained from the San Francisco River, 85 km away.

A hydrometallurgical pilot plant is operated in collaboration with the Centre for Mineral Technology (CETEM) in Rio de Janeiro. In this plant, the overburden, mainly malachite containing 0.7% Cu with iron and magnesium silicate gangue minerals, is leached in dumps, and the solution extracted by organic solvents in 2 stages mixer settlers, organic aqueous ratio 1:1, 15% LIX 64 N in kerosene, less loading capacity but easy to strip, fast phase separation 15% Acorga P5100 in kerosene, high loading capacity at lower pH but difficult to strip.

Copper recovery is only 50% because the pieces leached are rather large (20–30 cm diam). The leach solution obtained contains 5 g/L Cu, 4 g/L Fe and pH 0.8–2. The strip solution 50 g/L Cu, 120–150 g/L H_2SO_4, 1 g/L Fe is electrolysed to recover metallic copper. Guides: José Volnei Fagundes Prudente (Mining Engineer from the University of Salvador), Luis Daniel Moreira, Claudimiro Concalves Lima, and Sergio Augusto Guimarães.

Camaçari

The company's smelter is in Camaçari (a petrochemical complex), 53 km from Salvador and 30 km from the Port of Aratu. The plant was designed to produce 150 000 t/year refined copper; it is one of the most modern copper smelters combining all desirable features to abate pollution. Total cost US $750 million (including H_3PO_4 plant). Guide: Dr. Luiz Carlos Barreto Martins (Graduate of Carnegie-Mellon University, Pittsburgh). Director: Luis Guidi Olavarria.

The concentrate is first dried in a stainless steel rotary kiln co-current with air (to prevent ignition), then melted in a flash smelting furnace at a rate of 1 632 t/day concentrate, producing a 60% Cu matte at the rate of 32 t/hr. Air for smelting is enriched to 40% oxygen (oxygen plant on site produces 97% pure O_2) and preheated to 200 °C in a heat exchanger using steam as a heating fluid (generated in a waste heat boiler situated at the hot gas exit). The furnace is water-cooled from the outside.

The matte is purified and converted to copper in oxygen enriched (30% O_2) Hoboken converters; capacity 303 t/day blister of 98% Cu. The slag flows directly to a Søderberg electric furnace to recover its copper values. The hot exit gases from the flash furnace first pass in a waste heat boiler to recover its heat as superheated steam (250 °C). Dust deposition on the boiler tubes are eliminated by blowing air through small nozzles. The cooled, dust-free gases contain 10–15% SO_2 are directed to a H_2SO_4 plant. Acid produced is pumped in a 3-km pipeline to a phosphate rock treatment plant to produce 165 000 t/year H_3PO_4. If the acid plant shuts down, the smelter will shut down.

Slag and matte tapping channels are covered and the crucibles receiving these molten materials are enclosed in large chambers that are connected to suction lines so that no SO_2 is emitted in the working space. Slag from Hoboken converter is also treated in the electric furnace. The purified slag leaving the electric furnace is dumped in water for granulation and rejection.

Figure 7.6: Salvador 2011.

The blister copper is fire-refined in two rotating anode furnace using butane gas to get a product 99.2% Cu which is cast in form of anodes at the rate of 70 t/hr. Electrolytic refining produces copper 99.98% purity. A pressure leaching process is under development by CEPED in Salvador to treat the anodic slimes for precious metals recovery. Cathode copper is melted in ASARCO furnace. The furnace is heated by combustible gas generated from a wood gasifier (Brazilian invention). Molten copper is continuously cast. Guide: Leonardo Henrique de Souza.

As part of the XXIV National Conference on Mineral Processing and Extractive Metallurgy held in Salvador in October 2011, I gave a 2-day short course on pyrometallurgy. About 40 participants took part (Figure 7.7–7.9). The course was simultaneously translated into Portuguese. The conference was chaired by Professor Luiz Rogerio Pinho de Andrade Lima, a Laval University graduate (Figure 7.10).

Figure 7.7: Participants in a 2-day course on pyrometallurgy.

Figure 7.8: From left: interpreter, Fathi Habashi, two participants, Prof. Luiz de Lima, conference chairman.

Figure 7.9: In front of the hotel.

Figure 7.10: From right: Prof. Vladimiros Papangelakis [University of Toronto], Prof. Luiz Lima [Conference Chairman]. Mrs. Lima, Prof. Virginia Ciminelli [Universidade Federal de Minas Gerais].

Naturally, Salvador in 2011 was completely different when I visited in 1982. Now it is a large city of 1.8 million inhabitants and many high rise modern buildings (Figure 7.12–7.14).

Figure 7.11: The Old City.

Figure 7.12: A view of Salvador.

Figure 7.13: In front of a painting depicting the city.

Figure 7.14: The flag of Brazil.

Titanium Pigment plant

Ilmenite plant of Crystal Global, Millennium Inorganic Chemicals do Brasil, is the world's second-largest producer of titanium dioxide and a leading producer of titanium chemicals. It was formed when the National Titanium Dioxide Company Ltd. combined with Millennium Chemicals and is located in Camaçari. The headquarters are in Jeddah, Saudi Arabia. Sulfuric acid is used to leach ilmenite and ferrous sulfate and the dilute acid are thrown in the ocean. Leaching is conducted in heated pugmills. Guides: Fabio Augusto de Assis Andrade and Andre Luiz Batista Cabral.

Chapter 8

Goiás

Goiás is located in the centre of Brazil. It occupies a large plateau, between 750 and 900 m above sea level and forms the divide between three of Brazil's largest river systems: the Goiás, the São Francisco, and the Araguaia River and the Tocantins River and their tributaries.

Figure 8.1: Asbestos mine at Minaçu, State of Goiás.

MINAÇU

Brazil is among the major producers of asbestos. It is extracted by SAMA Saint-Gobain Company in France at Minaçu, a small city and municipality in the north of the State of Goiás near the capital city Brasília where one of the world's largest chrysotile asbestos mines is located (Figure 8.1). It is interesting to note that the tailings are stockpiled under a thick layer of soil on top of which plantation was introduced. (Figure 8.2). I visited the plant in April 1997 and it was shut down in 1999 (Figures 8.3–8.4).

Figure 8.2: Asbestos tailings at Minaçu covered with soil and vegetation.

Figure 8.3: Discussing the colouring of asbestos to render it non-toxic with engineers of the asbestos company in Minaçu.

CATALÃO

Catalão is located half way between Uberaba in the State of Minas Gerais and Brasília (Figure 8.5). Famous of its phosphate exploited by FOSFERTIL and pyrochlore deposits used to produce ferroniobium (Figure 8.6).

Figure 8.4: Asbestos production plant at Minaçu.

Figure 8.5: Location map of Catalão.

Figure 8.6: Meeting with engineers of Fosfertil. From left to right: Luiz António Fonseca, Neder Cagliati, Carlos Cordeiro, Francisco Lapido (CETEM). Photo by Fathi Habashi, 1997.

Chapter 9

Brasília

The city of Brasília arose from a 1956 government plan to transform the centre of Brazil from vast wilderness to a new capital city. Workers, materials and food were flown in to build it. Brasília's futuristic buildings and wide roads were completed four years later (Figures 9.1–9.13).

Figure 9.1: Brasília, general view.

Figure 9.2: Brasília, general view.

Figure 9.3: Congress.

Figure 9.4: Blue Cathedral.

Figure 9.5: Blue Cathedral.

Figure 9.6: Blue Cathedral.

Figure 9.7: Blue Cathedral.

Figure 9.8: Brasilia 1997, with Dr. Fracisco Lapido, geologist from CETEM.

Juscelino Kubitschek de Oliveira (1902 –1976), a medical doctor of Czech descent, was born in Diamantina, Minas Gerais, became prominent Brazilian politician and was President of Brazil from 1956 to 1961. His term was marked by relative economic prosperity and political stability, being most known by the construction of a new capital, Brasília where an excellent museum dedicated to him known as Memorial JK, which was opened in 1981. The country went into debt trying to pay for various ambitious projects. The tremendous rise of the external debt was made by the military during their dictatorship, which started in 1964 with a coup d'État and lasted for 21 years. When the military took power, Kubitschek's political rights were suspended for 10 years. He went into self-imposed exile and stayed in numerous US and European cities, returned to Brazil in 1967 but was killed in a car crash.

Figure 9.9: Brasília.

Figure 9.10: Church.

Figure 9.11: Model of large quartz crystals in Brasília — Brazil's speciality, made of concrete (Photo by Fathi Habashi, 1997).

Figure 9.12: Kubitschek Bridge.

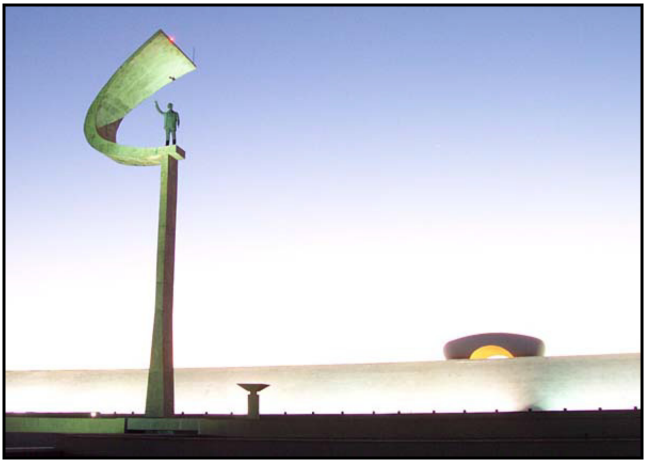


Figure 9.13: Kubitschek memorial.

Chapter 10

Iguaçu

Iguazú National Park is one of the world's largest and most impressive waterfalls, extending over some 2 700 m plunging 82m into Iguaçu River which makes them wider than Victoria, higher than Niagara (Figures 10.1–10.4). It is home to many rare and endangered species of flora and fauna, among them the giant otter and the giant anteater. The clouds of spray produced by the waterfall are conducive to the growth of vegetation.

The name of the falls comes from the Guarani, Indian word meaning "great water." In 1986 Iguaçu Falls were declared a Natural Heritage of Mankind by Unesco.

Figure 10.1: Location map of Iguaçu.

The Itaipu Dam hydroelectric power plant is the largest development of its kind in operation in the world. Built from 1975 to 1991 by Brazil and

Paraguay on the Paraná River. It took 16 years to build this series of dams whose length totals 7 744 metres. The name "Itaipu" was taken from an island that existed near the construction site. Itaipu, from the Guarani language, means "singing stones." The main dam, as high as a 65-story building, is composed of hollow concrete segments; while the flanking wings are earth and rock fill. Itaipu generates an average of 90 million megawatt-hours per year (Figure 10.5).

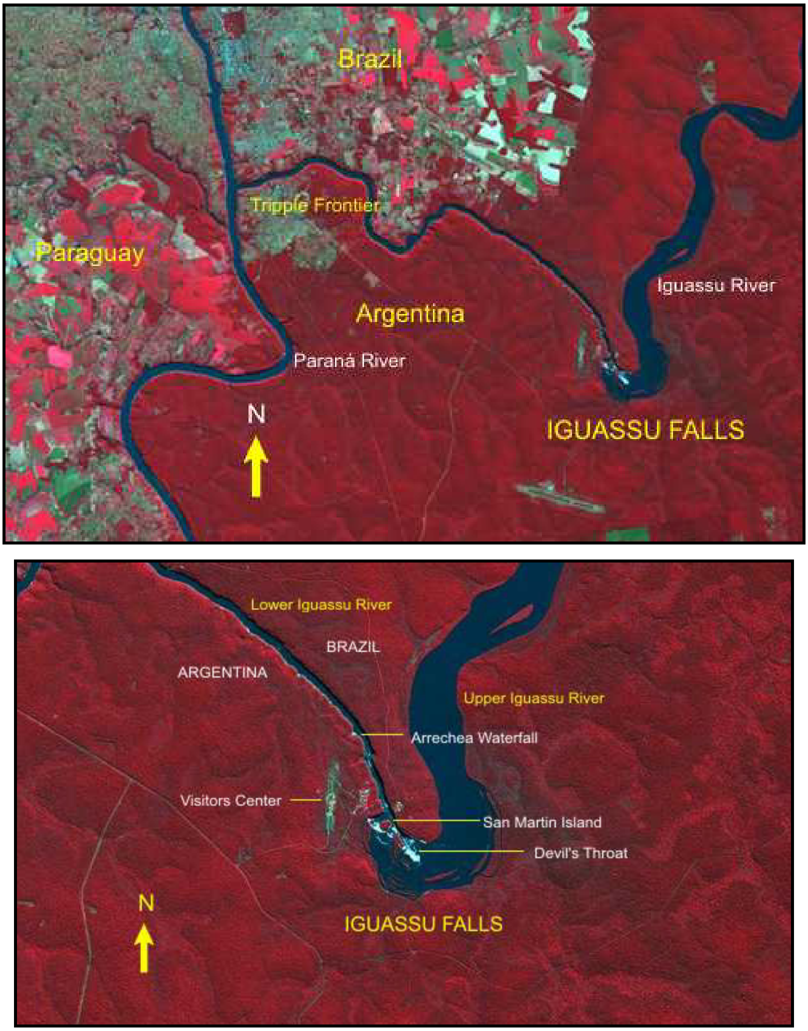


Figure 10.2: Detailed location maps of Iguaçu.

Figure 10.3: Second visit to Iguaçu with wife Nadia, 1998.

Figure 10.4: Iguaçu Falls.

Figure 10.5: Itaipu Dam.

Chapter 11

Gemstones in Brazil

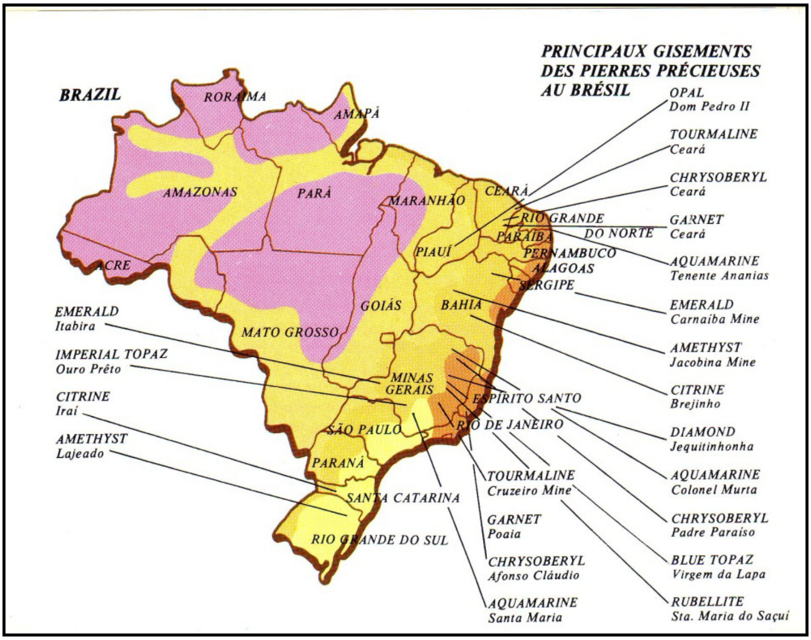


Figure 11.1: Gemstones in Brazil.

Hans Stern

In 1939, on the eve of World War II, Hans Stern, a German Jew from Essen, arrived in Brazil with his parents. Six years later, the enterprising teenager sold his accordion for $200 and used the money to start his own jewellery business in Epanema. Today, H. Stern Comercio e Indústria S.A., based in Rio de Janeiro, is Latin America's leading jewellery conglomerate, with 180 stores in luxury hotels, shopping malls, and airports from Belo Horizonte to Bogotá.

Figure 11.2: Hans Stern Gemstones Museum in Rio de Janeiro, 1983.

AMSTERDAM SAUER

Jules Roger Sauer, a French-born from Alsace–Lorraine, immigrated to Brazil, alone, in 1939, when he was 18 years old. Although he could speak four languages, Portuguese was not among those he knew. After being introduced to some precious gems, he became immediately fascinated by them and decided to establish himself in Belo Horizonte the capital of the state of Minas Gerais, which had the richest diversity of coloured stones in the world at the time.

With a minimal start-up capital, Jules founded his company in 1941. He named it Amsterdam Limited. The city of Amsterdam was the world's benchmark for excellence in the cutting and trading of diamonds. In just a few years, Amsterdam Limited became an important Brazilian gemstone trading company, involved in mining, purchasing, cutting and wholesaling fine coloured stones. The company mainly worked with aquamarines, tourmalines, imperial topazes, amethysts and citrines at the time.

Figure 11.3: Jules Sauer analyses gemstones (1945).

Jules married Zilda in 1950 and the couple decided to move to Rio de Janeiro, the capital and the financial centre of Brazil. The first retail store was inaugurated, in 1953, beside the famous Copacabana Palace Hotel. The store was initially named SAUER, later AMSTERDAM SAUER, as it is known today. The emerald was first discovered in Brazil in 1963. The story and the quest of Jules Sauer and his family can also be found in the three books written by him:

- *Brazil, Paradise of Gemstones* — 1982 (available in many languages)
- *Emeralds Around the World* — 1992 (available in many languages)
- *The Eras of the Diamond* — 2002 (available in English and Portuguese)

Stamps from Brazil devoted to precious stones are shown in Figure 11.4.

Figure 11.4: Stamps from Brazil devoted to precious stones.

Chapter 12

Debret

I was introduced to Jean-Baptiste Debret (1768–1848) (Figure 12.1) in 1992 when my wife and I stayed at Hotel Debret (Figure 12.2) in Rio de Janeiro. Many paintings of the French painter were decorating the hotel. Debret produced many valuable lithographs depicting the people of Brazil. He studied at the French Academy of Fine Arts. He stayed in Brazil from 1816 to 1831 as a member of the French Artistic Mission, which was in charge of creating in Rio de Janeiro an arts and crafts lyceum (Escola Real de Artes e Ofícios) under the auspices of King D. João VI, later upgraded to the Academia Imperial de Belas Artes (Imperial Academy of Fine Arts) under Emperor Dom Pedro I.

Figure 12.1: Jean-Baptiste Debret (1768–1848).

Figure 12.2: Hotel Debret in Rio de Janeiro.

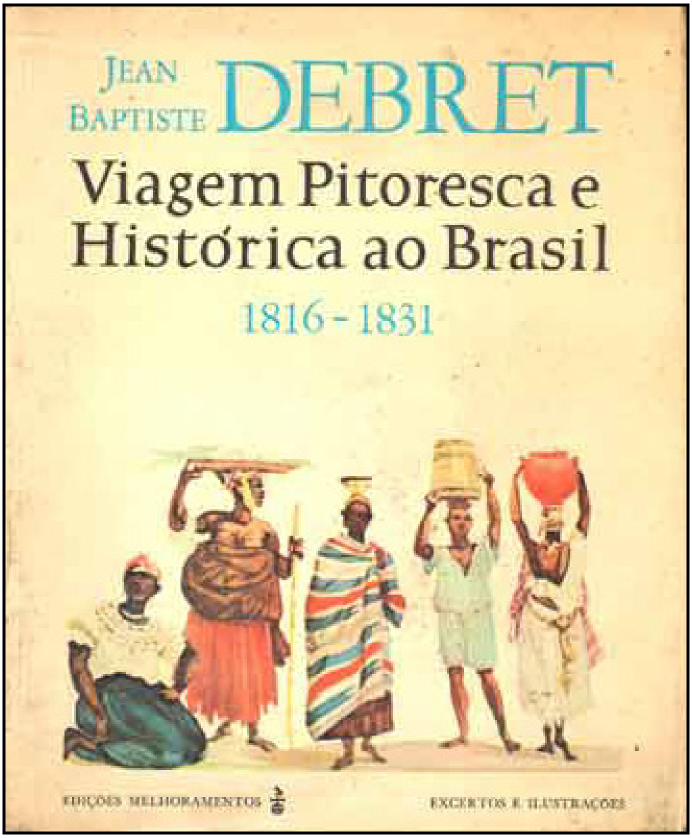


Figure 12.3: Front page of Debret's book.

Debret was frequently commissioned to paint portraits of many of its members. He organized the first arts exposition in Brazil in 1829, where he presented many of his works and of his disciples. He was also involved in the production of ornamental work for many of the public ceremonies and official festivities of the court. Soon he developed an interest in ethnography and started to paint many scenes depicting the social costumes and relations of the Brazilians in the period between 1816 and 1831. He took a particular interest in slavery of blacks and in the indigenous peoples in Brazil. When he returned to France, he published three volumes of engravings, titled *Voyage pittoresque et historique au Brésil* (Figure 12.3). A stamp was also issued by Brazil honouring him (Figure 12.4). Some of his paintings are shown in Figures 12.5–12.54.

Figure 12.4: A Brazilian stamp honouring Jean-Baptiste Debret.

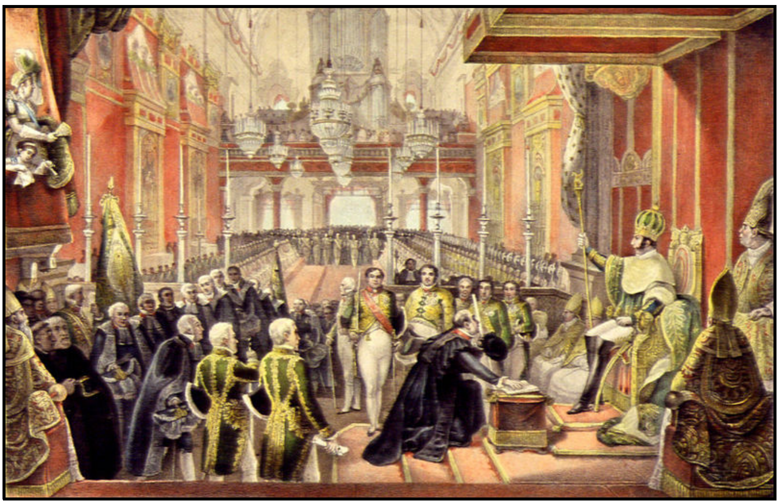


Figure 12.5: Picture of upper class.

Figure 12.6: Picture of upper class.

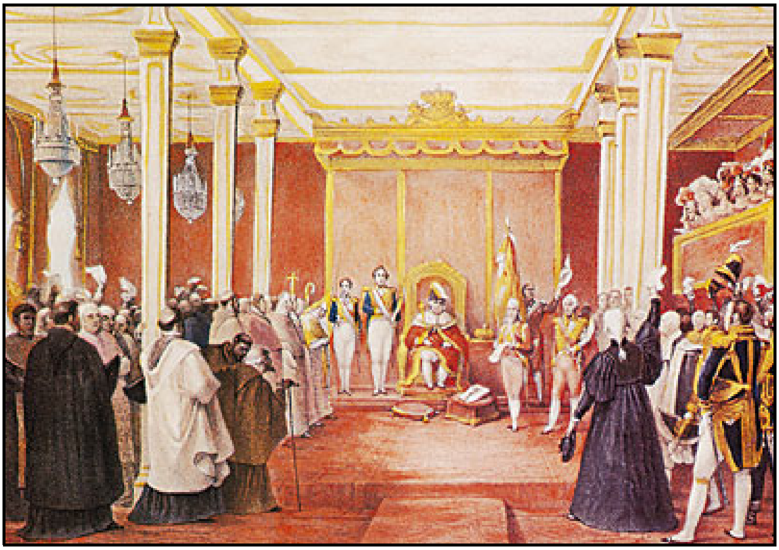


Figure 12.7: Picture of upper class.

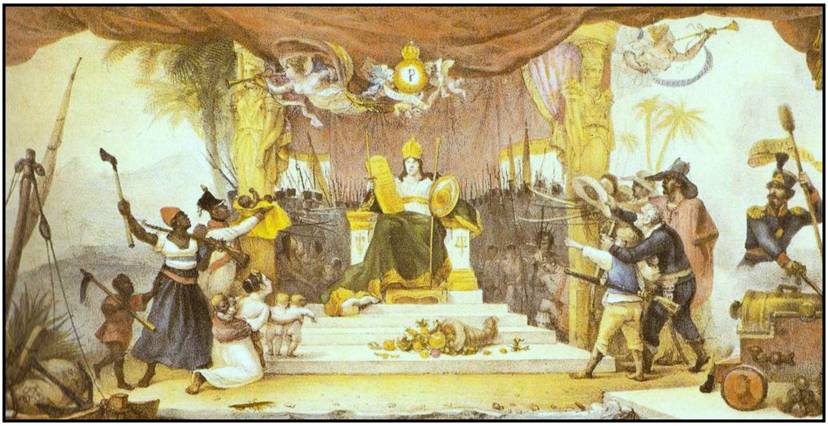


Figure 12.8: Picture of upper class.

Figure 12.9: Picture of upper class.

Figure 12.10: Picture of upper class.

Figure 12.11: Picture of upper class.

Figure 12.12: Picture of upper class.

Figure 12.13: Picture of upper class.

Figure 12.14: Picture of upper class.

Figure 12.15: Picture of upper class.

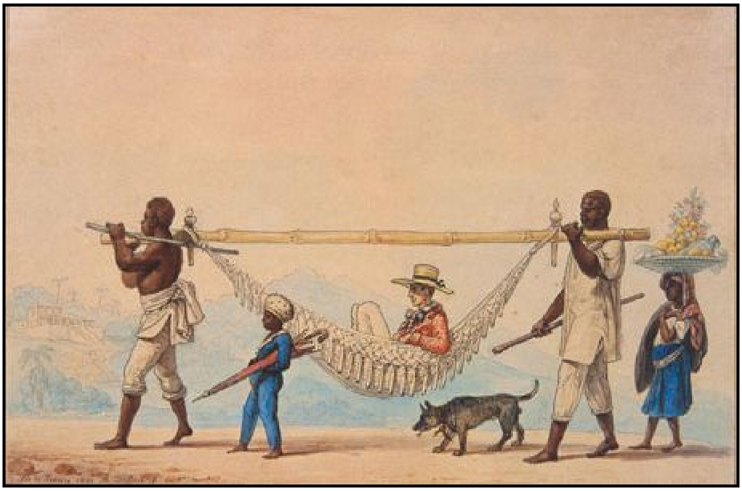


Figure 12.16: Picture of upper class.

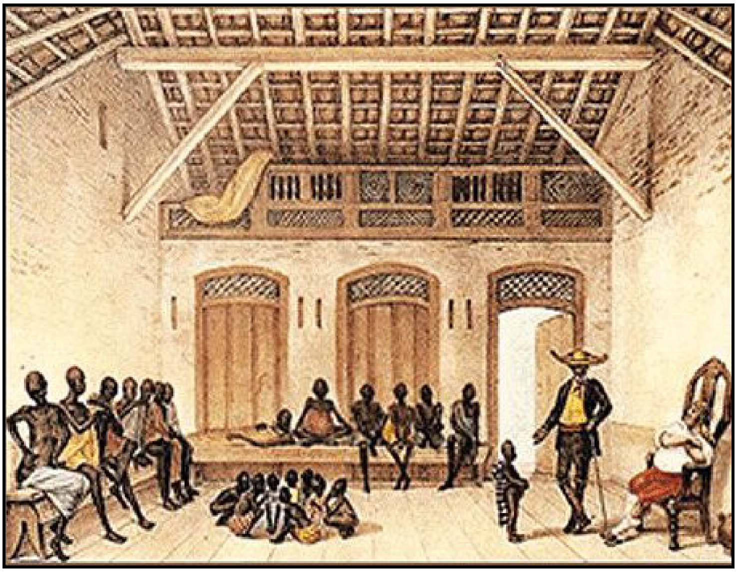


Figure 12.17: Picture of upper class.

Figure 12.18: Picture of upper class.

Figure 12.19: Picture of upper class.

Figure 12.20: Picture of natives.

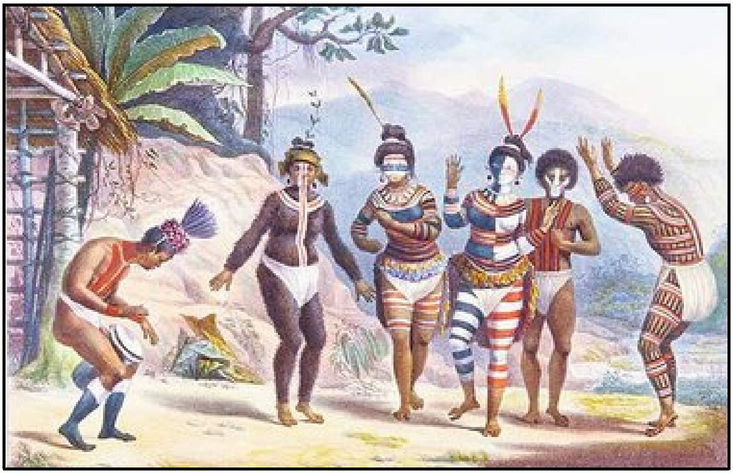


Figure 12.21: Picture of natives.

Figure 12.22: Picture of natives.

Figure 12.23: Picture of natives.

Figure 12.24: Picture of natives.

Figure 12.25: Picture of natives.

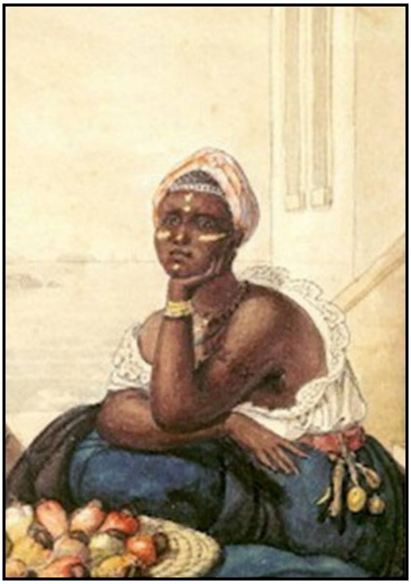


Figure 12.26: Picture of natives.

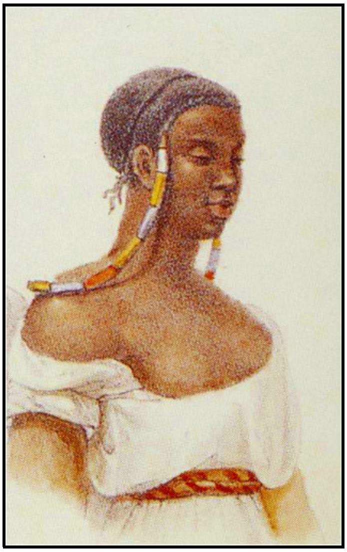


Figure 12.27: Picture of natives.

Figure 12.28: Picture of natives.

Figure 12.29: Picture of natives.

Figure 12.30: Picture of natives.

Figure 12.31: Picture of natives.

Figure 12.32: Picture of natives.

Figure 12.33: Picture of natives.

Figure 12.34: Picture of natives.

Figure 12.35: Picture of natives.

Figure 12.36: Picture of natives.

Figure 12.37: Picture of Africans.

Figure 12.38: Picture of Africans.

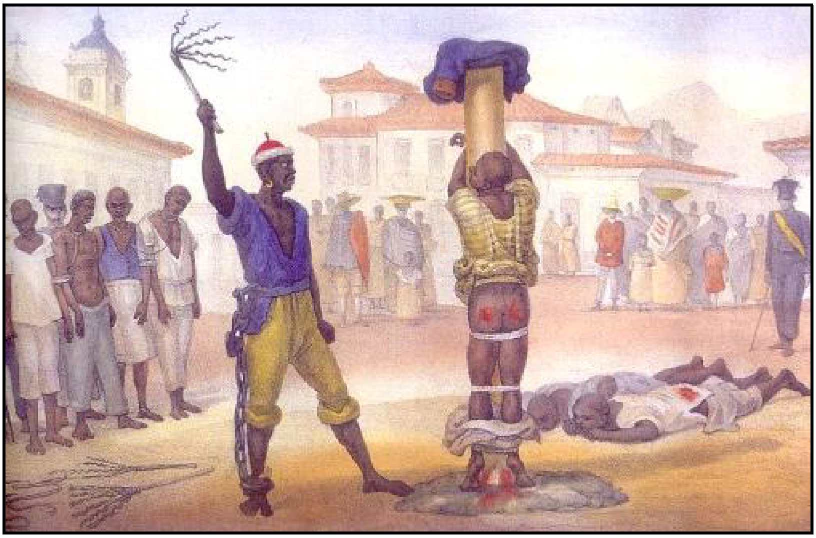


Figure 12.39: Picture of Africans.

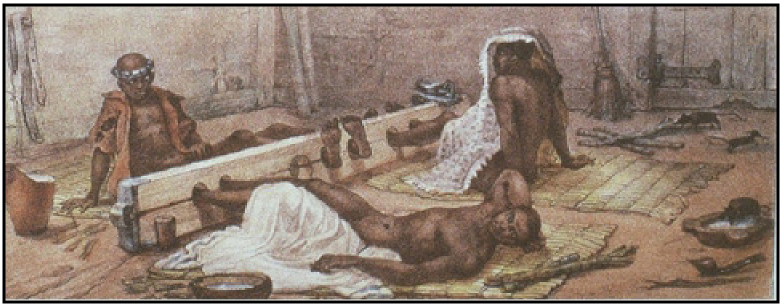


Figure 12.40: Picture of Africans.

Figure 12.41: Picture of Africans.

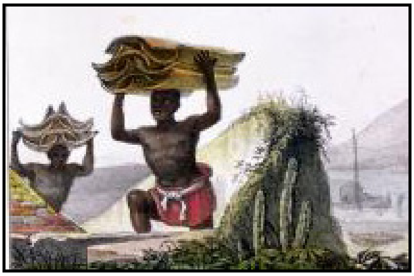


Figure 12.42: Picture of Africans.

Figure 12.43: Picture of Africans.

Figure 12.44: Picture of Africans.

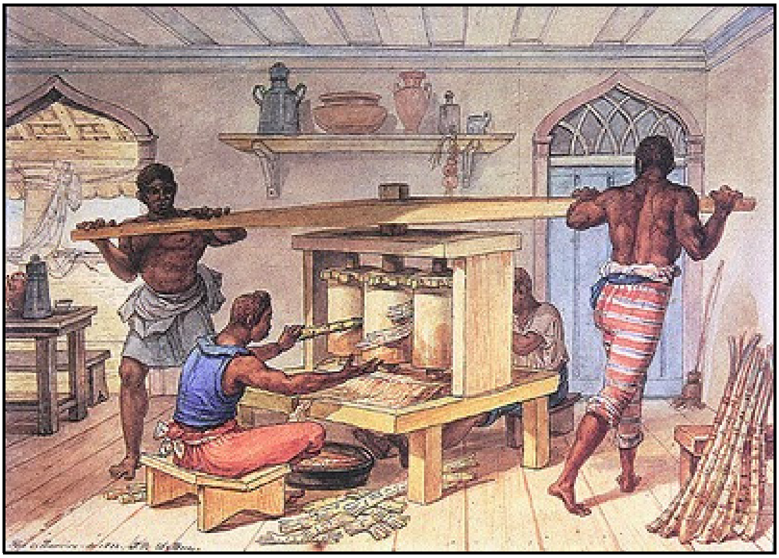


Figure 12.45: Picture of Africans.

Figure 12.46: Picture of Africans.

Figure 12.47: Picture of Africans.

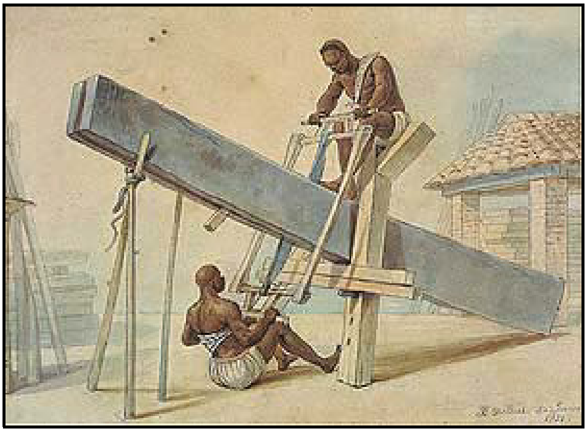


Figure 12.48: Picture of Africans.

Figure 12.49: Picture of Africans.

Figure 12.50: Picture of Africans.

Figure 12.51: Picture of Africans.

Figure 12.52: Picture of Africans.

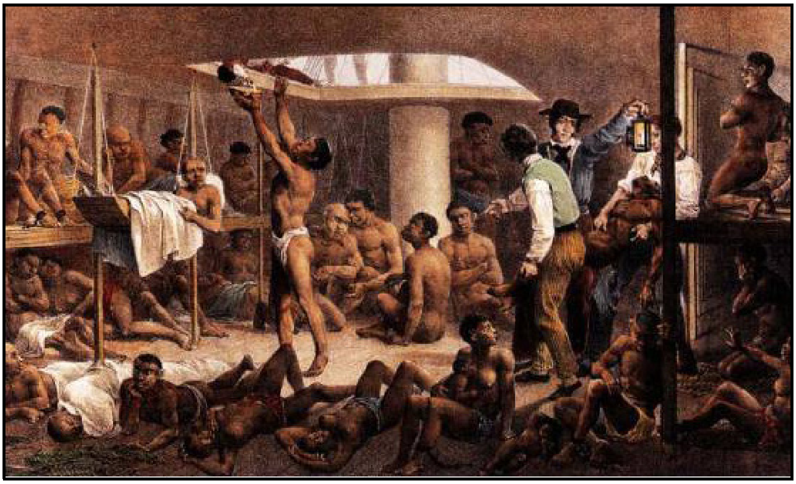


Figure 12.53: Picture of Africans.

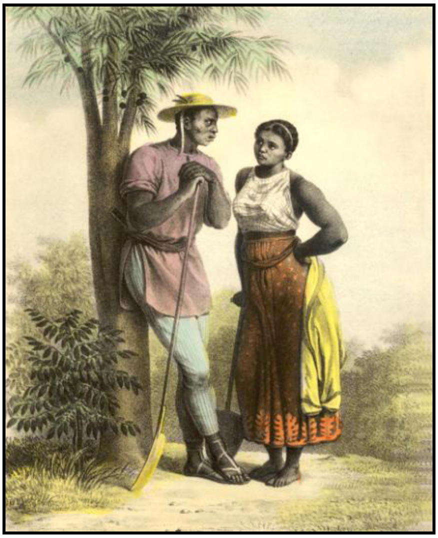


Figure 12.54: Picture of Africans.

Chapter 13

Acknowledgements and References

ACKNOWLEDGEMENTS

The author is most grateful to Dr. Roberto Villas Bôas, former Director of CETEM, and his Deputy the late Juliano Barbosa for their invitations to Brazil and for organizing the visits. Thanks also to Dr. Arthur Pinto Chaves, former Professor of Mining Engineering at the Polytechnic in São Paulo for his invitation to the XVII Conference of Mineral Dressing and Extractive Metallurgy at Águas de São Pedro and to Prof. Luiz Andrade Lima.

REFERENCES

1. F. Habashi, *Trip Reports*:
   - Brazil, December 4, 1982–January 6, 1983 [Bilateral Exchange Program Canada–Brazil: Niobium project]
   - Brazil Revisited, June 20–July 21, 1992 [Extractive Metallurgy Course at Escola de Química in collaboration with CETEM]
   - Brazil. Third Visit, March 8–17, 1996 [Celebrating CNPq 45th Anniversary]
   - Brazil. Fourth Visit, April 12–May 1, 1997 [Conference on Rare Earths. CETEM invitation.]
   - Brazil. Fifth Visit, August 22–September 1, 1998 [São Paulo Conference]
   - Brazil Sixth Visit, December 2–9, 2000 [CETEM lectures]
   - Brazil Seventh Visit, October 11–22, 2011 [Salvador National Conference]

2. F. Habashi, "Chemistry and metallurgy in the Portuguese Empire," *Bull. Can. Inst. Min. & Met.* **93** (1044), 109–113 (2000).

Name Index

Subject Index

P

Q

R

S

T

U