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PATTERN OF INTERNATIONAL TRADE IN CHROMITE AND FERROCHROMIUM

AN HISTORICAL PERSPECTIVE

by

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It has long been my feeling that the lessons of economics that reside in economic history are important and that history provides an interesting and even fascinating window on economic knowledge.

John Kenneth Galbraith

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ABSTRACT

Pattern of international trade in chromite and ferrochromium -

an historical perspective

Edward N. Eadie

Chromite is the ore of chromium consumed in a wide range of applications in the metallurgical, chemical, and refractory industries, while ferrochromium is a chromium-iron alloy produced from chromite and used in the manufacture of stainless steel as well as other chromium bearing steels and alloys. Chromium is one of the most strategic materials in the world.

Annual world chromite production has shown tremendous growth since 1892, and most chromium consuming countries have not generally been chromite producers so that international trade in chromite and ferrochromium has been of vital importance, particularly to the United States as the world's largest consumer. Detailed statistics on world chromite production, exports and imports, and on world ferrochromium exports and imports by country are presented in systematic form in terms of both tonnage and percentage on an annual basis over a long period to 1980. In addition, statistics showing trade ties between countries are tabulated for specific periods.

The main features of the production and international trade patterns are described in conjunction with a consideration of the great many factors that have exerted an influence in determining the pattern of international trade world-wide in chromite and ferrochromium over its history. In the case of trade aggregates these factors include, among others, new ore discoveries, types of ore, technological developments, transportation availability, price competitiveness, economic activity levels, the effects of war, United Nations economic sanctions, and strategic

stockpiling, while in the case of trade ties the factors appear to be metallurgical characteristics, geographical proximity, political relationships, international ownership links, established buyer-seller ties, and differential tariffs. The many different factors involved at various times in the global evolution of the pattern of international trade aggregates for chromite and ferrochromium make it most appropriate to use a descriptive analysis in which the most significant factors in operation at any time are considered in their relevant historical and geographical context. This is done on a decade by decade basis that corresponds to the tabulated data, and enables the more important countries during each period to be highlighted. Further, trade ties during specific periods are examined using a model suitable for analysing transaction flows, and anomalies generated by the model are useful in explaining the spectrum of trade ties observed.

DECLARATION

This thesis contains no material accepted for the award of any other degree or diploma in any university and, to the best of my knowledge and belief, contains no material previously published or written by another person, except when due reference is made in the thesis. Consent is given for the thesis to be made available for photocopying and loan.

E.N. Eadie

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Chapter 1

INTRODUCTION

The aims of this study are:-

(a) to tabulate information on the pattern of international trade in chromite and ferrochromium in a systematic form for the whole world during a period of more than fifty years prior to and including 1980.

(b) to describe the main features of the international trade pattern, and outline the various factors that have had an influence in determining the pattern of international trade in chromite and ferrochromium.

Chromite is the ore of chromium, and comprises largely the oxides of chromium, iron, aluminium, and magnesium in varying proportions. It is a strategic mineral of chromium used in a wide range of applications in the metallurgical, chemical, and refractory industries. Ferrochromium is an alloy of chromium and iron produced from chromite, and is used in the production of stainless steel as well as in various alloys containing chromium. There is no known substitute for chromium in the production of stainless steel.

TECHNICAL ASPECTS OF CHROMIUM

Technical information on various aspects of the chromite and ferrochromium industries at and prior to 1980 is contained in a number of publications of the U.S. Bureau of Mines including Morning (1977(a)), Morning, Matthews, and Peterson (1980), and Peterson (1982), and the following discussion on technical aspects of chromium is based to a considerable extent on material in these sources. Other sources are referred to as appropriate.

Chromium is one of the most versatile and strategic elements in the industrial world. It is used in iron, steel, and non-ferrous alloys to improve various physical properties, particularly resistance to corrosion and oxidation. Two of the more important applications of chromium are in the production of stainless steel, and in the plating of metals. Other important applications are its use in various alloy steels, nickel-chromium heating elements, pigments, leather processing, catalysts, and refractories.

History

The element chromium was first identified in 1797 by the French chemist Louis Vauguelin, who discovered that the lead content of the mineral crocoite (composition $PbCrO_4$, and itself first described in the literature in 1766 as red lead) was combined with an oxide of an unknown metal. Vauguelin named this new element chromium based on the Greek word "chroma" meaning colour because of the brilliant reds, yellows, and greens of its compounds.

Although chromium occurs in a number of different minerals, the only source of chromium used commercially is the mineral chromite. During the period 1797 to 1827, chromite from the Ural Mountains of Russia was the main source of world supply. The discovery of chromite within North America in Maryland in 1827, and subsequently in Pennsylvania and Virginia, resulted in the United States becoming the major source of supply of chromite for a limited world demand. Then, large chromite deposits in Turkey were developed in 1860 to supply the world market. Since the latter part of last century, chromite has been produced in a number of countries around the world, and the world distribution of chromite production during the period from 1892 to 1980 is shown in Tables 1-20. During that time the annual world chromite production has increased by a factor of 443 from 22,000 tonnes in 1892 to 9,749,000 tonnes in 1980.

Until the early part of this century, chromite was used mainly in the manufacture of chemicals. Then, it became widely used in the manufacture of metallurgical and refractory products, primarily stainless steels and basic refractory bricks. The accidental discovery of stainless steel by Harry Brearley of Sheffield in 1913 is described by Alexander and Street (1972). Brearley was experimenting with alloy steels for use in gun barrels, and threw aside a number of samples regarded as unsuitable. Among these was one containing about 14% chromium. Some months later Brearley noticed that most of the steels had rusted, but that the one containing chromium was still bright. This discovery resulted in the development of a range of corrosion resistant stainless steels containing varying percentages of chromium.

Composition of chromite

The mineral chromite, which is black or brownish-black in colour, consists of the oxides of chromium, iron, aluminium, and magnesium in varying percentages. Historically, chromite was classified into three general grades related to end use, and these were designated metallurgical, chemical, and refractory. However, technological advances during recent decades have made possible a considerable interchangeability among the various grades, and this is particularly so in the case of the "chemical grade", which can be used in all three industries. More definitively, chromite can be classified into high-chromium chromite (metallurgical grade) containing a minimum of 46% chromic oxide (Cr_2O_3) and having a chromium-to-iron (Cr:Fe) ratio of greater than 2:1; high-iron chromite (chemical grade) containing 40 to 46% Cr_2O_3 and having a chromium-to-iron ratio of 1.5:1 to 2:1; and high-aluminium chromite (refractory grade) containing more than 20% aluminium oxide (Al_2O_3) and more than 60% Al_2O_3 plus Cr_2O_3.

Composition of ferrochromium

Chromium metal is produced only in limited quantities. For most metallurgical applications, chromium is used as additives in the form of alloys of chromium and iron that possibly contain also carbon and/or silicon. These chromium alloys are produced from chromite, and vary in composition. They are classified broadly as low-carbon ferrochromium, high-carbon ferrochromium, and ferrochromium-silicon. An alloy known as charge chromium is essentially a high-carbon ferrochromium with a higher silicon content. The composition of various commercial grades of chromium alloy are tabulated by Morning, Matthews, and Peterson (1980). In low-carbon ferrochromium the chromium (Cr) content varies from 60-75%, the carbon (C) content from 0.01 to

0.75%, and the silicon (Si) content from 1 to 8%; in high-carbon ferrochromium the Cr content varies from 52 to 72%, the C content from 4.0 to 9.5%, and the Si content from 3 to 14%; and in ferrochromium-silicon the Cr content varies from 34 to 42%, the C content from 0.05 to 0.06%, and the Si content from 38 to 45%.

Geology

An introduction to the geology of chromite deposits is given in general texts on economic geology such as Bateman (1950), which describes briefly chromite deposits in a number of countries, and Park and MacDiarmid (1964), which discusses in more detail chromite deposits in the Moa District of Cuba. Chromite deposits occur as either stratiform or podiform bodies in certain types of ultrabasic rocks composed primarily of olivine and pyroxene minerals, or rocks derived from them.

Stratiform chromite deposits occur as layers of uniform composition in igneous intrusions. In size they range up to a metre or so in thickness and extend over wide areas. The larger deposits contain many millions of tonnes of chromite. Deposits of the stratiform type are present in the Bushveld Igneous Complex in the Transvaal of South Africa, the Great Dyke in Zimbabwe, and the Stillwater Complex in Montana in the United States. More than 99% of the world's known resources of chromite are in stratiform deposits.

Further information on the geological characteristics of stratiform chromite deposits is given by Jackson (1964), and the geology of the chromite deposits in specific regions is described in various sources such as Cousins and Feringa (1964) and Cameron (1964) that deal with deposits in the Western and Eastern Belts respectively of the Bushveld Complex in South Africa, and Worst (1964) that covers deposits in the Great Dyke in Zimbabwe.

In contrast to stratiform deposits, podiform type deposits of probable magmatic origin are of irregular form that varies from tabular to lenticular to circular. Podiform deposits range in size from a few kilograms to several million tonnes, and most production is from deposits containing more than 100,000 tonnes. Typical podiform deposits occur in the Ural Mountains of the Soviet Union, in the Philippines, and on the west coast of the United States. Most podiform deposits are of the high-chromium type, and they are the only source of high-aluminium chromite. With the exception of the Great Dyke region of Zimbabwe, virtually all the world's production of high-chromium chromite is from podiform type deposits in contrast to the high-iron stratiform type deposits as in the Bushveld Complex of South Africa.

A discussion of the geological features of podiform chromite deposits is given by Thayer (1964), and the geology of chromite deposits in particular regions is discussed in papers such as Stoll (1958) and Bryner (1969) that describe deposits in the Philippines.

Exploration

Chromite deposits are most commonly discovered by means of geological prospecting and exploration followed by drilling, although geophysical and geochemical methods can be of assistance in the exploration for chromite. An OECD seminar on modern scientific methods of chromite prospecting was held in Athens, Greece, during April 1963, and the published proceedings of this seminar contains a number of useful papers on geological, geophysical, and geochemical exploration for chromite (Woodtli, 1964). Exploration is carried out in regions containing ultrabasic rocks as these provide a potential host rock for chromite deposits. Geological mapping, as well as airborne magnetic geophysical surveys (Boyd, 1970) and heavy mineral geochemical surveys (Boyle, 1969), can be used to locate areas of ultrabasic rocks. More detailed exploration involving geological mapping and prospecting is done within the area of ultrabasics in order to locate the presence of chromite. Geophysical methods are of particular use in the exploration for chromite deposits that are not exposed at the surface, and in this connection both the gravity and magnetic methods have had some success in chromite exploration. The application of the magnetic method in chromite exploration in Cuba is described by Hammer, Nettleton, and Hastings (1945) and by Davis, Jackson, and Richter (1957), and the use of the gravity and magnetic methods together in the exploration for chromite in areas of rugged topography in eastern Turkey is described by Yüngül (1956). Geological, geophysical, and geochemical methods are useful in locating the presence of chromite deposits, then detailed drilling is usually done to establish their extent, tonnage, and grade.

Mining

As in the case of most other minerals, the mining of chromite is done by both opencut and underground methods, and the size, shape, depth, and regularity of the deposit to be mined determines the method or methods used. Most podiform deposits are mined by opencut methods, while stratiform deposits such as those in South Africa and Zimbabwe are mined by underground methods. In Zimbabwe alluvial deposits of chromite that has been concentrated by nature in valleys are also mined. The variety of chromite mining operations in Zimbabwe is described by Hodges (1964). The world's largest podiform deposits located in the Soviet Union are mined by opencut methods, although more recently an underground mine was developed to produce about two million tonnes of chromite ore annually. Chromite mining techniques vary widely from the use of modern mechanised equipment at large mines in more developed countries to hand methods used at small mines in some developing countries.

Processing

Chromite is generally cleaned by hand sorting, washing and screening, or by gravity concentration. Also, chromite concentrates are prepared from fines or size-reduced lower grade ore using concentrating equipment such as jigs, tables, and spirals that operate on gravity separation, or using magnetic separators. In recent years there has been a considerable increase in the extent of beneficiation of run-of-mine ore by means of grinding followed by gravity and magnetic separation methods in order to upgrade the Cr_2O_3 content to 40% or more.

In the metallurgical industry, chromite is converted to chromium alloys by pyrometallurgical techniques in which chromite ore, fluxes, and reducing agents are smelted in a three-phase electric furnace. Various types of ferrochromium are produced by altering charge mixes and process variables.

For the chemical industry chromite is treated by a hydrometallurgical process that involves roasting ground chromite mixed with soda ash and lime followed by leaching with a weak liquor or water. After neutralisation with sulphuric acid that converts chromate to dichromate, the pregnant solution is filtered to remove alumina hydrate. The filtrate is again treated with sulphuric acid and concentrated by evaporation after which sodium sulphate is removed as a byproduct. The final purified sodium dichromate solution is marketed directly, or as crystals following crystallisation, for use in the chemical industry.

Chromite for the refractory industry can be purchased to size specifications. Alternatively, chromite is size-reduced in conventional crushing equipment, and the crushed product screened into various particle ranges. Then, a mixture of specific quantities of variously sized particles together with the mineral magnesite are charged to a blend mix prior to pressing into refractory bricks made to specification requirements.

Uses

The use of chromium in the metallurgical industry is to enhance in materials containing it such properties as hardness, creep, and impact strength, as well as their resistance to corrosion, oxidation, heat, wear, and galling. In most metallurgical applications, chromium is provided in the form of ferrochromium. This is produced from chromite, and has been described earlier.

The major metallurgical use of chromium is in stainless steel, which is available in a variety of compositions and structures that possess a wide range of mechanical properties as well as excellent resistance to corrosion and oxidation. These qualities make stainless steels highly versatile and of application in a wide variety of consumer products.

The initial discovery of stainless steel with about 14% chromium, as described earlier, led to the development of stainless steels as typified by present-day cutlery. It was subsequently found that steel containing up to about 20% chromium and 10% nickel had even greater corrosion and heat resistance, and such stainless steels have many uses in kitchen utensils, the chemical industry, and in surgery. Alloys with even higher chromium and nickel contents were found to be of use in furnace parts, the equipment of chemical plants, and in components for pumps. According to Alexander and Street (1972), the stainless steels were increasing in usage at a greater rate than any other ferrous alloys, and since 1945 the growth had been greater than 10% per annum. More recent applications of stainless steels containing chromium and nickel are described in articles contained in various issues of Nickel Topics published by The International Nickel Company, Inc.

Apart from stainless steel, chromium is used as a constituent in a variety of alloy steels, cast irons, and non-ferrous alloys. Its function in these products is to enhance their mechanical properties, or to impart special properties such as resistance to heat, electricity, or abrasion.

There are several low and medium alloy steels containing up to 12% chromium, together with other elements such as molybdenum and vanadium, that can be used continuously at temperatures in the range 500°C to 700°C for components in thermal power stations and steam turbines as described by Alexander and Street (1972). Chromium is used also in the manufacture of nickel-chromium alloy resistance-wires for electric heating elements as in electric fires and electric furnaces. The highest grades of such resistance wires contain 80% nickel and 20% chromium while lower grades are made with 10-20% iron.

The use and composition of other alloys containing chromium is described in various articles in Nickel Topics. In one such article (Hack, 1982) reference is made to a super alloy containing chromium and nickel, as well as a small percentage of yttrium oxide, that has properties superior to other alloys in respect to dimensional stability, thermal fatigue, and strength. Such properties have resulted in the adoption of this super alloy as a vane material in General Electric's advanced F404 engine for the F18 fighter aircraft in service with the U.S. Navy. The same super alloy has been found to be highly resistant to corrosion in hostile environments as encountered in gas cooled nuclear reactors.

In the chemical industry sodium dichromate is the primary base material for the manufacture of chromium chemicals. The largest use of chromium in the chemical industry is in chromium pigments, and sodium dichromate is used to manufacture chrome green, chrome oxide green, chrome yellow, molybdenum orange, and zinc chromate pigments. These chromium pigments are used in paints, inks, and roofing granules. Another use of chromium chemicals is in chromium plating familiar in automobile trim, appliances, and other consumer goods. In this application chromium in fact merely provides a thin bright hard coating over a layer of nickel as described by Alexander and Street (1972). Other uses taking advantage of special properties of chromium chemicals are in leather tanning, metal treatment (as corrosion inhibitor), drilling muds, textile dyes, catalysts, and wood treatment.

The refractory industry uses chromium in the form of chromite, and primarily to make refractory bricks to line metallurgical furnaces. The major application of chromite refractories is in iron and steel processing, non-ferrous alloy refining, glass making, and cement processing. In foundries, chromite sand is used as a moulding material in the production of ferrous castings.

In the United States during 1980 a total of 878,000 tonnes of chromite was consumed (Peterson, 1981). Of this the metallurgical industry used 59%, the chemical industry 25%, and the refractory industry 16%. The metallurgical industry consumed 520,000 tonnes of chromite to produce 217,000 tonnes of chromium ferroalloys and metal. During 1980 a total of 385,000 tonnes of chromium ferroalloys and metal was consumed in the United States, and stainless steel production accounted for 70% of this consumption.

INTERNATIONAL TRADE IN MINERAL PRODUCTS

Economic theories of international trade are discussed by Corden (1965), and applied economic issues of international trade are examined in texts such as Snape (1973) and Cameron (1972). Questions of economic policy in connection with the export of mineral products are considered by Cameron with reference to iron ore development in Australia, and he specifically discusses policy issues in relation to the level of product pricing, the selling of an exhausting resource, the basis of taxation, the establishment of a domestic processing industry, and the question of foreign capital investment.

The pattern of international trade in metal raw materials is considered in a general article by Ridge (1955) in which he gives thirteen rules governing trade in metal raw materials. Ridge recognises that the rules are generalisations to which there are exceptions, and that the rules should be considered together in examining any specific situation. The rules stated by Ridge are:

1. Concentration is carried out for all low grade ores, non-ferrous and ferrous, in the country in which they originate.
2. Mining companies of large size and of domestic ownership will carry processing through more stages at home than will companies of small size or of foreign ownership.
3. The stage of processing of any metal raw material entering world trade will tend to be the more advanced, the greater the tax penalties assessed against concentrates and partly processed materials leaving the country of origin.
4. The smaller the quantity of material to be eliminated from concentrates in the smelting process, the more likely such concentrates are to be sent abroad for smelting and refining.
5. The greater the flexibility and simplicity of a smelting process, the more likely it is to be important in a mining country producing the raw material concerned.

6. The more unstable the political situation in a given mining country, the less processed will be the mineral raw materials shipped from it.

7. The greater the modern processing capacity for a given metal raw material outside the countries that mine it, the more likely the material is to be smelted abroad.

8. The newer a mining industry is in a given country, the less likely it is that metal raw materials will be smelted there.

9. An export-import relationship, once formed, is more profitable to continue than to break off unless the economic or political changes are drastic.

10. The earlier and more rapid the industrialisation of any country the more complete the processing of metallic raw materials within its own borders.

11. The older and more advanced the industrial civilisation of a particular country, the greater will be its dependence on mineral imports, a dependence that increases the more rapidly the less well endowed the nation in question was in the beginning of its industrialisation .

12. The later a nation began to develop its industrial plant, the larger will be the number of countries from which it imports and the smaller the amount it will obtain from each.

13. In such a lately industrialised country the more intensive will have to be its development of its own resources, though these well may be economically less satisfactory than deposits of the same metals in other countries.

A series of short articles on world trade in specific minerals and metals accompany the general article by Ridge (1955) in which the above rules are discussed, and one of these articles (Ridge and Moriwaki, 1955) deals with world trade in chromite during 1952. In this article, Ridge and Moriwaki observe that the significant chromite producers with the exception of the Soviet Union are not major steel producers; that there is a direct relationship between steel production and chromite imports as in chromite-poor countries such as Germany and Belgium-

Luxembourg; that some countries such as Norway and Canada import chromite and export ferrochromium; that the United States imports chromite from more than twelve countries although greater than 85% of its 1952 imports came from four countries (The Philippines, Turkey, South Africa, and Zimbabwe); that the United Kingdom depended largely on chromite imports from African members of the Commonwealth (Zimbabwe and South Africa); that chromite (like manganese and iron ore) is attracted to nations rich in solid-fuel; and that the dependence of the United States on foreign suppliers for about 99% of its chromite is a serious problem that would be insurmountable in time of emergency.

The results of an important study on factors influencing the pattern of international trade in mineral products between pairs of exporting and importing countries are described by Tilton (1966(a) & 1966(b)), who examined trade ties between countries for a number of ores and concentrates and of refined metals during the period 1960-62. The study by Tilton covered aluminium, manganese, copper, lead, zinc, and tin, but did not include chromium. It was concerned primarily with trade ties between countries during the specific period examined, and not with the total level of exports and imports of individual countries or changes in these over time.

In examining trade ties between countries, Tilton used a linear programming transportation model, a single-equation multivariate regression analysis, and a general descriptive investigation. The study indicated that the choice of trading partners is strongly influenced by non-price factors, and particularly by international ownership ties, political blocs, governmental regulation and participation in trade, metallurgical characteristics, and established buyer-seller ties. These factors were as important, or even more important in some cases, than transportation costs or conditions of supply and demand in determining trade ties. Many of the observations and conclusions made by Tilton in relation to trade ties are based on his descriptive analysis, although each of the methods used by Tilton pointed to the conclusion that non-price factors had a strong influence in determining trading partners.

The conclusion of Tilton in relation to the importance of non-price factors has significant repercussions for international trade theory in that the classical, Heckscher-Ohlin, and location theories ignore non-price factors, and as a result cannot adequately explain trade patterns. These theories imply that trade ties are flexible, and respond rapidly to small changes in the conditions of supply and demand or transportation costs. In reality, non-price factors produce an appreciable degree of stability in trade patterns.

However, trade ties do change at times, and Tilton gives the development of manganese deposits in Brazil, the construction of a tin smelter in Nigeria, and the acquisition of British aluminium fabricators by American companies as examples of developments that resulted in significant changes in trade patterns. Tilton concludes that trade ties are not normally disrupted in response to minor price changes, but that a significant change in trading partners usually requires the intervention of a new and powerful stimulus such as war, the opening of new deposits, the construction of a new smelter or refinery, or government barter transactions. It seems also that such stimuli must exceed a minimum threshold to overcome the stabilising effect of non-price factors, and that when this occurs there is an appreciable alteration in trade patterns.

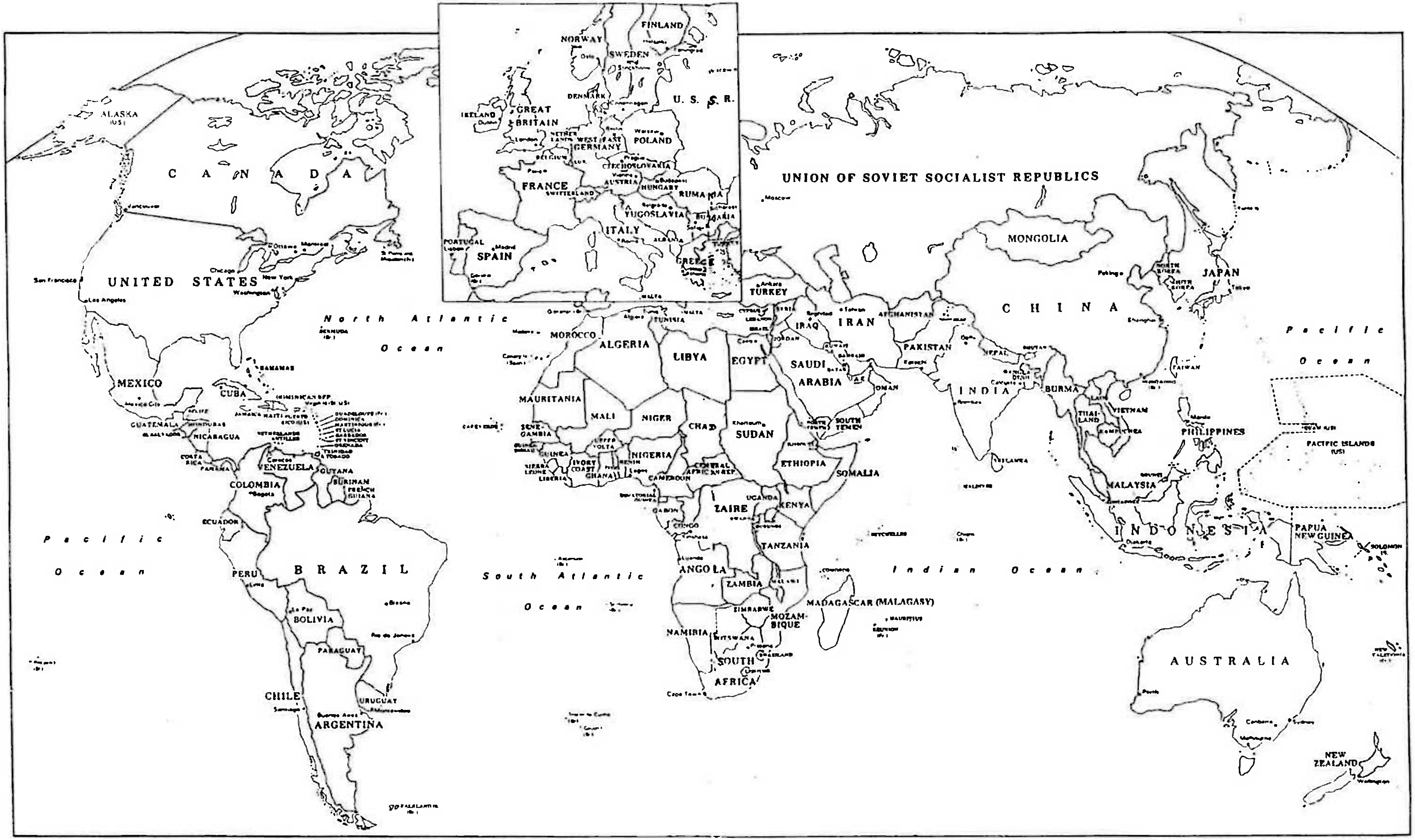
PRESENTATION OF TABULATED DATA

Tabulated data in systematic form is presented for chromite production in Tables 1-20, chromite exports in Tables 21-72, chromite imports in Tables 73-120, ferrochromium exports in Tables 121-150, and ferrochromium imports in Tables 151-184.

In the tables the name of each country as at 1980 is used throughout even though in some cases a country was known by another name at some earlier time for which tabulated data is shown. For instance, in the case of Southern Rhodesia, which became Rhodesia, then briefly Zimbabwe-Rhodesia, and finally Zimbabwe, the name Zimbabwe is used in the tables for all periods of time. The geographical location of each country is illustrated in Map 1.

Map 1

MAP OF WORLD SHOWING COUNTRIES AT 1980 (AFTER NATKIEL, 1982)



The tables showing world chromite production (Tables 1-20), world chromite exports (Tables 21-36), world chromite imports (Tables 73-86), world ferrochromium exports (Tables 121-132), and world ferrochromium imports (Tables 151-162) by country and by year for both tonnage and percentage of world total extend in each case over a period of more than fifty years, and the tables comprising a particular time series are designed in each case to cover single and successive decades. The countries included in each table are listed in decreasing order of magnitude of the parameter being tabulated for the first year of the decade covered by the table. By presenting the tabulated data in this way, a study of the tables in any individual time series readily shows the more important countries during a particular period as well as any changes in their relative position. The presentation also shows clearly the emergence of any new countries of significance. The tables are designed as "talking tables" in the sense that they largely speak for themselves rather than merely provide data for reference purposes.

In the tables showing chromite exports by country of destination (Tables 37-50 and 53-70), chromite imports by country of origin (Tables 87-94 and 97-118), ferrochromium exports by country of destination (Tables 133-148), and ferrochromium imports by country of origin (Tables 163-182) for selected countries and specific periods in terms of both tonnage and percentage of total, the countries of destination and origin are listed in each table in decreasing order of magnitude of the parameter being tabulated for the first year of the period covered by the table. Also, the selected countries included in each particular series of tables are arranged in decreasing order of their importance in terms of tonnage as exporting or importing countries during the period covered. Thus, a systematic ordering of countries is adopted both within individual tables and among the tables comprising a particular series.

Matrix tables are also given for chromite exports of selected countries by country of origin and destination (Tables 51 & 52 and 71 & 72), chromite imports of selected countries by country of destination and origin (Tables 95 & 96 and 119 &

120), ferrochromium exports of selected countries by country of origin and destination (Tables 149 & 150), and ferrochromium imports of selected countries by country of destination and origin (Tables 183 & 184). These tables show actual and null exports and imports in terms of both tonnage and percentage averaged over specific three year periods. The definition of null exports or null imports is given as appropriate in each table, and the null tonnages or percentages are shown in each case in brackets beneath the corresponding actual tonnages or percentages. This enables a convenient comparison between the actual and null figures in any particular case. The use of a three year average reduces the effect of certain fluctuations that occur from year to year in trade figures as discussed below. In the matrix tables the countries of both origin and destination are listed in each case in decreasing order of magnitude of their average total exports and average total imports for the period covered in the table. This provides consistency in the form of presentation of the tabulated data shown in these tables.

The preparation of tabulated data on production, exports, and imports of chromite and ferrochromium has involved reference to a wide range of sources dating over a long period of time. In these sources "tonnages" of chromite and ferrochromium are given variously in long tons, short tons, and metric tons (tonnes). A long ton contains 2,240 lbs., a short ton 2,000 lbs., and a metric ton 2,204.6 lbs. For consistency, and in order to provide a proper basis for comparison between countries and over time, all tonnages in the thesis, including in the tabulated data, are given as tonnes, which are metric tons comprising 1,000 kilograms. In converting from long tons and short tons to tonnes, standard conversion factors of 1.0160 and 0.9072 have been used respectively.

For every table in the thesis showing tonnages of chromite or ferrochromium, there is a corresponding table showing percentages. This is because it is important to examine not only the absolute tonnage of production, exports, and imports of particular countries and variations in these over time, but also the proportions of total production, exports, and imports attributable to these countries as well as changes in the proportions over time. Each time series giving tonnages is followed by a similar time series giving percentages, and each matrix table showing tonnages is followed by one giving percentages.

In the tables showing world chromite production, exports, and imports by country, tonnages have been rounded to the nearest thousand tonnes and are shown in the tables as thousands of tonnes, and in tables showing chromite exports for selected countries by country of destination and chromite imports for selected countries by country of origin, tonnages have been rounded to the nearest hundred tonnes and are shown in the tables as thousands of tonnes to one decimal place. Tonnages of world ferrochromium exports and imports by country, and of ferrochromium exports and imports for selected countries by country of destination and origin, have been rounded to the nearest hundred tonnes, and are shown in the tables as thousands of tonnes to one decimal place. Similarly, all actual and null tonnages in the matrix tables have been rounded to the nearest hundred tonnes, and are shown in the tables as thousands of tonnes to one decimal place. All calculated percentages in the time series have been rounded to the nearest whole percent, and are shown as such in the tables. In the matrix tables percentages are shown to one decimal place. The conversion and rounding of statistics as well as the ordering of countries, has resulted in consistency in the presentation of tabulated data, and enables convenient comparisons to be made both within and among tables.

In some cases where the component tonnages comprising a total and the total tonnage of the components are known, and both the components and the total are converted and/or rounded, there is a slight discrepancy between the total of the converted and/or rounded components and the converted and/or rounded total as a result of the conversion and/or rounding. However, in no case are these variations of any significance in examining the pattern of international trade. Similarly, as a result of rounding, in some cases the total of component percentages differs slightly from

100%, although by definition the total as a percentage of the total is 100%. Again, such variations are not of any importance in the study of trade patterns.

The exports and imports of particular countries are recorded at the time of export and the time of import. As a result of the transit time in shipment from one country to another, a discrepancy can result between the recorded exports and the recorded imports during a particular year for individual trading partners or for the world as a whole. This is accentuated by the fact that shipments of chromite, and to a lesser extent ferrochromium, are made in bulk quantities for convenience and in order to take advantage of lower freight rates applicable to such shipments, and possibly to justify the chartering of a vessel for a particular shipment. However, over a period of years, there will be a tendency for export and import figures to equalise, and this is evident in the tabulated data.

The effect of individual shipments can also result in variations from year to year in the recorded exports or imports of a particular country to or from another country, or in its recorded total exports or imports. However, there will be a tendency for these variations to be averaged out over a period of years. In the matrix tables annual figures are averaged for a three year period, whereas in the case of trade aggregates for the more important exporting and importing countries the effect of individual shipments is relatively less significant.

The more important features of the tabulated data for chromite production, exports and imports, and for ferrochromium exports and imports, are described in Chapters 2-11, and the numerous factors that have influenced the pattern of international trade in chromite and ferrochromium are discussed in their relevant historical and geographical context.

The location of world chromite production is fundamental to the pattern of international trade, and the importance of international trade in chromite and ferrochromium is accentuated by the fact that the consumption of chromium has taken place to a very large extent in countries that were not chromite producers. Moreover, there has been tremendous growth in the level of chromite production since 1892 as illustrated by the graph in Figure 1 that shows total world chromite production on an annual basis for the period 1892-1980.

DETERMINANTS OF INTERNATIONAL TRADE PATTERN

The pattern of world chromite production, exports, and imports and of world ferrochromium exports and imports is presented in Tables 1-184, and Chapters 2-11 that follow are concerned with a study of the diversity of factors that have exerted an influence in determining the pattern of international trade in chromite and ferrochromium involving many countries around the world during the period from 1892 to 1980.

In examining various factors that have contributed to shaping the pattern of international trade in chromite and ferrochromium, consideration is given first in Chapters 2-10 to factors relating to the variation with time in the tonnage and percentage of total exports and total imports of chromite and ferrochromium by individual countries as well as of the total level of exports and imports in these commodities for the whole world. Later, in Chapter 11 consideration is given to factors that have had an influence in determining trade ties between individual countries during specific periods.

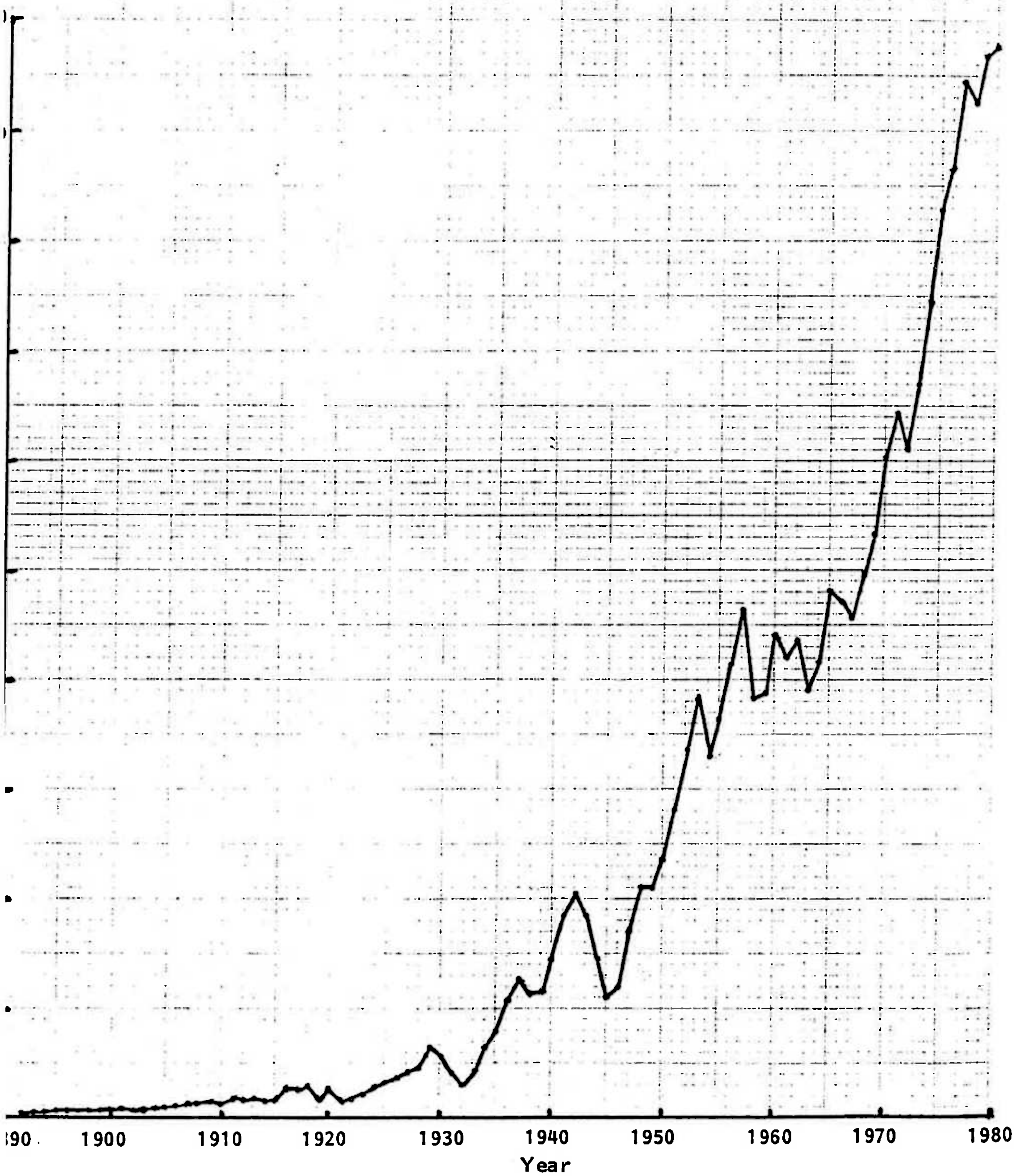
The history of the chromium industry reveals that a wide variety of factors have operated at various times to determine the aggregate level of exports and imports of chromite and ferrochromium by individual countries as well as for the world as a whole. The present study covers international trade in chromite and ferrochromium for the entire world over a long period of time, and in the circumstances a descriptive analysis is used in an attempt to outline the great many factors that have had an influence in determining the pattern of total exports and total imports by major countries and for the world as a whole during the period covered. In order to facilitate convenient reference to the pattern of international trade in chromite and ferrochromium shown in the tables, discussion of the factors influencing the

Figure 1

ANNUAL WORLD CHROMITE PRODUCTION

1892-1980

Millions of tonnes



Source: Based on data given in Tables 1-10.

volume and share of international trade by individual countries is given on a decade by decade basis. Such an approach also enables the discussion to concentrate on the more important exporting and importing countries during a particular decade, and allows the more significant factors operating during that period to be highlighted. However, countries are not considered in isolation. The countries covered during each decade account for a large proportion of international trade during the decade, although the countries discussed as well as their ranking vary from decade to decade in response to the many diverse and dynamic factors examined. The pattern of international trade observed during each decade is the product of interaction between the various factors operating during that period.

In the subsequent examination of factors that have influenced trade ties between countries, the destination of exports and the origin of imports of a number of countries are considered for selected three year periods during both the 1930's and 1970's in the case of chromite and for a three year period during the 1970's in the case of ferrochromium. For the periods 1935-1937 and 1972-1974 the average annual actual exports and imports for pairs of countries are compared with average annual null exports and imports for the same pairs of countries. Such a comparison involves the use of a "null model" as proposed by Savage and Deutsch (1960) and referred to by Tilton (1966(a), p30 &1966(b), p443). The model is used as suggested by Savage and Deutsch to identify anomalies (both positive and negative) between actual and null levels of trade for individual pairs of countries. A descriptive analysis is then used in an attempt to explain these observed anomalies.

PRE - 1892

During the period prior to 1860 the Soviet Union and the United States were the main suppliers of chromite to the world market as outlined earlier in the chapter. However, in 1848 a chromite deposit was discovered by Professor J. Lawrence Smith in Turkey at Bursa, located ninety two kilometres south of Istanbul (then Constantinople). This deposit was developed, and by the 1890's had become the most important chromite deposit in the world. It was notable for its great extent, ease of mining, high grade averaging 52% to 57% Cr_2O_3, and freedom from silica (Rothwell, 1895). In addition, large deposits of chromite were discovered in 1877 near Izmir (then Smyrna) in Turkey. The ore in these deposits was soft and granular, easily mined, close to a shipping port, contained from 55% to 58% Cr_2O_3, and was low in silica. These circumstances combined to bring Turkish chromite ores prominently into the world market, and to result in the development of Turkish deposits on a large scale (Rothwell, 1896). In 1892 Turkish chromite production was estimated at 14,000 tonnes, and represented an estimated 64% of world chromite production during that year (Tables 1 and 11).

Chapter 2

TRADE AGGREGATES 1892-1899

The discussion of trade aggregates for the period 1892-1899 is based on information contained in contemporary accounts of the world chromium industry published annually in The Mineral Industry for the years 1892-1899. During that period The Mineral Industry was edited by Richard P. Rothwell, Editor of the Engineering and Mining Journal, and was published in association with that Journal.

The major sources of supply of chromite during the period 1892-1899 were mines situated in Turkey, Soviet Union, and New Caledonia, while demand during that period was from the chemical, metallurgical, and refractory industries located mainly in Europe and North America, particularly in the Soviet Union, Germany, United Kingdom, and the United States. Although supply and demand at any given time operate simultaneously, it is convenient for the purpose of discussion to consider first the question of supply then to examine demand during the same period.

Detailed statistics on international trade in chromite and ferrochromium during the period 1892-1899 are not available. However, the importance of international trade in chromite during this period, as well as some appreciation of the various factors that have contributed in determining its pattern, will be evident from the following discussion that deals first with the geographical distribution of chromite production then with that of chromite consumption.

CHROMITE PRODUCTION AND EXPORTS

During the period 1892-1899 the main chromite producing countries in the world were Turkey, Soviet Union, and New Caledonia, while smaller quantities of chromite were mined also during the period in Australia, Canada, Greece, and the United States as illustrated in Tables 1 and 11. These tables show the variation from year to year in the tonnage and percentage of world chromite production by country during the period.

Turkey

The emergence of Turkey as an important chromite producing country during the period prior to 1892 has been described already. Subsequently, Turkish chromite production rose from an estimated 14,000 tonnes in 1892 to 20,000 tonnes in 1894 then remained at around that level during the years 1894-1896 after which it declined to 5,000 tonnes in 1899 (Table 1). During the period 1892-1899 the share of world chromite production contributed by Turkey tended to decline from an estimated 64% of world production in 1892 to 10% of world production in 1899 (Table 11).

During the period 1892-1899 chromite mining in Turkey was virtually a monopoly controlled by the English firm of Paterson & Co based in Izmir. The main Turkish production during the period came from mines located in the vicinity of Bursa and Izmir, and these ores were the most favoured in the world by consumers in the chemical industry for the manufacture of potassium dichromate and sodium dichromate. In addition, Turkish chromite production during the period came from mines in Macedonia, which then comprised part of western Turkey. The competitiveness of Turkish ores in the world market resulted from their high quality in terms of grade, softness, and freedom from impurities, and was assisted by low mining costs, which were accentuated by cheap wage rates. However, competition from New Caledonian ores resulted in a reduction of around 18% in the price delivered in England of Turkish chromite ore containing 50% Cr_2O_3 as recorded by Rothwell (1900).

Despite the preference by consumers for Turkish chromite ore, several factors appear to have operated to reduce the relative importance of Turkish chromite in the world market. These included the availability of good quality New Caledonian chromite as discussed below, reduction in the supply of Turkish ores due to exhaustion of deposits, particularly in respect of higher grade ores (Rothwell, 1894 &1898), and increasing difficulties experienced by the Turkish mining industry through the action of corrupt officials (Rothwell, 1900).

New Caledonia

Chromite ore was first mined in New Caledonia in 1875. The most important deposits were those of Mont d'Or, N'Go River, and Canoe Bay. These deposits were located near the sea and were connected to the port of shipment by a short railway (Rothwell, 1894). Chromite production by New Caledonia increased substantially from 1895 as shown in Table 1, and averaged 12,000 tonnes a year during the period 1895-1899. During that period New Caledonian chromite production amounted to 24% of world production, and exports of chromite by New Caledonia were stated by Rothwell (1899) as forming a large and increasing item in the mineral production of that island.

The New Caledonian chromite deposits occurred near the surface, and included an upper layer of "alluvial" ore, which was in reality weathered ore containing small grains of chromite in decomposed serpentine. Solid chromite ore or "rock" ore occurred beneath the "alluvial" layer. The "alluvial" ore was preferred by consumers because the contained chromite could be separated from the gangue more readily than in the solid ore. The "alluvial" ore was washed in sluices to produce chromite concentrate containing up to 52% Cr_2O_3 (Rothwell, 1899). In 1899 chromite exports by New Caledonia amounted to 11,300 tonnes.

Soviet Union

The greater part of the world's supply of chromite ore came from the Soviet Union (then Russia) and Turkey. Chromite production by the Soviet Union and Turkey in 1895 amounted in each case 21,000 tonnes (Table 1), and these countries were each responsible for 34% of world production in that year (Table 11). However, both the tonnage of chromite production by the Soviet Union and its share of world production fluctuated during the period 1892-1899 as observed in Tables 1 and 11. The chromite deposits of the Soviet Union were located in the Ural Mountains and in the Caucasus, and generally were of high grade ranging from 53% to 55% Cr_2O_3 (Rothwell, 1896). Prior to the discovery and development of chromite deposits in the

United States and Turkey, the Soviet Union commanded the world chromite market as described in Chapter 1.

In contrast to Turkish and New Caledonian chromite, which was produced exclusively for the export market, Soviet Union chromite during the period was used both for export and for domestic consumption. As stated by Rothwell (1894) the manufacture of bichromates using chromite ore from the Urals had recently been established in the Soviet Union at works near Elabougi on the river Kama. The works consumed about 2,000 tonnes of chromite annually, and since their establishment the import of chromium compounds into the Soviet Union ceased. Also, the Moscow Chrome Works in the Soviet Union was one of the chief consumers in Europe of chromite ore in the chemical industry (Rothwell 1896), and chromite from the Urals, which previously had been exported, was consumed domestically using a new process in the production of potassium dichromate (Rothwell, 1897).

Australia

Some chromite production was recorded by Australia during the years 1894-1899 (Table 1), and its production during the period reached a maximum of 10% of world production during 1899 (Table 11). The principal supply of chromite came from mines in the Gundagai region of New South Wales. The ore was usually purchased in Sydney by shipowners or charterers, who shipped the ore as dead weight to wool cargoes for sale in the London market (Rothwell, 1895). No ore containing less than 50% Cr_2O_3 was bought. Parcels graded as high as 57% Cr_2O_3, but averaged 52% to 53% Cr_2O_3. It was reported (Rothwell, 1898) that chromite mining in New South Wales during the period 1893-1897 acquired considerable importance, and this is reflected in the production tonnages given in Table 1.

Greece

In Greece chromite was mined at Volos in Thesally (Rothwell, 1894), and during the period 1892-1899 the level of chromite production was relatively small and variable (Table 1).

Canada

During the years 1894-1899 relatively small and variable tonnages of chromite were produced by Canada as shown in Table 1. Chromite production by Canada took place in Quebec as described by Penhale (1896 &1897) and by Obalski (1898), and in Newfoundland (now part of Canada) as described in Rothwell (1898). In both Quebec and Newfoundland the production came from newly discovered chromite deposits, and development of these deposits resulted in chromite exports by Canada.

Chromite ore was discovered accidentally at Black Lake near Coleraine in the Province of Quebec in the autumn of 1893 by a boy picking berries, but its value was not appreciated until the spring of 1894 when a sample of the ore was seen by Mathew Penhale. Field examination revealed an outcrop of considerable extent, and assays of samples showed that the ore contained from 50% to 55% Cr_2O_3. The announcement of the discovery generated considerable excitement, and several other outcrops were located by prospectors. By 1895 chromite mining was taking place at several locations in the Black Lake district.

Shipments of chromite ore from the Black Lake district increased from around 1,000 tonnes in 1894 to 3,000 tonnes in 1895 (Rothwell, 1896). A large proportion of these shipments comprised high-grade ore, which went mainly to Philadelphia, Pittsburg, and Baltimore in the United States, while a small tonnage of low-grade ore was sent to the United Kingdom. Significant shipments of chromite from Black Lake were made also in subsequent years, and went mainly to Pittsburg and Philadelphia (Rothwell, 1897 & 1899).

In Newfoundland extensive outcrops of what was thought to be iron ore were known to occur near Bluff Head in the Port au Port Bay area on the west coast of Newfoundland as early as 1893, but it was not until the summer of 1894 that the ore was recognised as chromite following analysis by J. Obalski. Preliminary field investigations were made in 1895, and detailed exploration of the deposits began in

1896. These revealed large deposits of chromite ore, although their immediate exploitation was limited by lack of adequate road and shipping facilities. The provision of these facilities was planned for 1897 (Rothwell, 1897), and it was expected that dressed ore would be marketed following the completion of dressing works.

During 1896 a cargo of about 150 tonnes of sorted chromite ore from Newfoundland was shipped to Philadelphia for sampling and analysis, and this revealed that the ore contained around 50% Cr_2O_3 (Rothwell, 1898). The ore was then sent to Pittsburgh, and used in the manufacture of chrome brick for basic lining of furnaces. However, there were no shipments of chromite from Newfoundland during 1897 even though the mines were in operation, and a considerable quantity of chromite was carted to the shore where around 2,000 tonnes of ore was stockpiled. The reason no shipments of chromite were made from Newfoundland in 1897 was that the Halifax Chrome Co, which controlled the chromite deposits, had undertaken to provide shipping facilities, but was prevented from doing so by the officers of French and British cruisers visiting the area on the ground that the erection of structures on the west coast of Newfoundland was forbidden by the Treaty of Utrecht (Rothwell, 1898). This provides an early example of a case where the export of chromite was effectively prevented by political action. However, in 1898 about 700 tonnes of dressed chromite ore of Bluff Head origin and averaging 55% Cr_2O_3 was exported from Newfoundland as recorded in Rothwell (1899).

United States

Prior to 1878 large quantities of chromite were mined in the United States in Maryland and Pennsylvania. However, during the period from 1879 to 1899 almost the entire domestic production of chromite in the United States came from California where chromite was first discovered in 1869. During the period 1892-1899 annual chromite production by the United States reached a maximum of 3,000 tonnes in 1894, but amounted to less than 500 tonnes during each of the years 1897-1899 as shown in Table 1.

In 1892 California was the only commercial source of United States chromite (Rothwell, 1893), and the only mine being systematically exploited at that time was the Pick and Shovel located near San Luis Obispo. Otherwise, chromite was quarried by farmers on an irregular basis and sold to dealers in small lots. Much of the known Californian chromite ore assayed less than 47.5% Cr_2O_3 and was not commercially viable at that time, while richer deposits were located in areas where the cost of transport to market was prohibitive. It was recorded by Rothwell (1893) that no ore containing less than 50% Cr_2O_3 could be shipped from San Francisco, even at ballast rates, around Cape Horn to the eastern United States in competition with Turkish ores from the Mediterranean.

Chromite production by the United States during the period 1892-1899 was insufficient to meet domestic requirements, which were met to a large extent by imports. The main supply of United States chromite imports during the period came from Turkey, although larger quantities of chromite were imported during the latter part of the period from Canada and New Caledonia (Rothwell, 1899). During 1892 United States chromite imports amounted to 5,000 tonnes compared with domestic production of 2,000 tonnes and in 1895 also imports were 5,000 tonnes compared with production of 2,000 tonnes, whereas in 1898 imports were 17,000 tonnes compared with production of only 100 tonnes as observed in Rothwell (1897 &1900). For many years prior to 1897 United States chromite production had been confined to California, but in 1897 production from California amounted to only 50 tonnes then in 1898 ceased completely, while production in the Pennsylvania-Maryland region resumed on a small scale in 1897 (Rothwell, 1899).

An existing duty of 15% on imported chromite ore was to be abolished by the Wilson tariff bill pending before Congress so that chromite ore would then be admitted free of duty into the United States (Rothwell, 1894). Abolition of the duty would make imported chromite ore even more competitive in the United States market. In a decision of the United States Circuit Court of Appeals in the case of United States v

Dana & Co it was held (Rothwell, 1900) that ferrochromium should bear a tariff of $4 per ton as for ferromanganese whereas the government had contended that a larger 20% ad valorem duty should have been paid. However, the existence of a duty on ferrochromium while chromite was admitted free of duty would have tended to favour the import into the United States of chromite rather than ferrochromium.

CHROMITE CONSUMPTION AND IMPORTS

During the period 1892-1899 chromite consumption took place mainly in the United States and Europe, and except for domestic production in the United States and Soviet Union as discussed above the supply of chromite for consumption was dependent on imports from producing countries such as Turkey and New Caledonia.

The chief use of chromite (Rothwell, 1893) was in the manufacture of potassium dichromate, which was used extensively in calico printing and also formed the basis for many pigments such as chrome yellow, chrome orange, and chrome green. In addition, considerable quantities of potassium dichromate were used in the construction of some forms of electric battery. Further, the use of sodium dichromate had been introduced extensively during the previous five years. A relatively small proportion of the total chromite supply was consumed in the production of ferrochromium for use in making chrome steel, which in contrast with common steel had great hardness, and was valuable in the manufacture of such products as cutting-tools, stamp-shoes and dies, and safes. However, even though by far the greatest quantity of chromite was consumed in the chemical industry, its metallurgical use in the manufacture of ferrochromium was growing in importance (Rothwell, 1894). At that time only high grade chromite could be used economically in the chemical industry, whereas ore of lower grade sufficed for use in the metallurgical and refractory industries.

It was reported in Rothwell (1897) that the use of chromite as a refractory for furnace lining was growing rapidly, and that the mineral was being employed with very satisfactory results both in reverberatory copper-smelting furnaces and in open-hearth steel furnaces. The consumption of chromite in open-hearth basic furnaces in the United States at that time amounted to around 2,000 tonnes a year. In Rothwell (1900) reference was made to a large demand for chromite in the manufacture of iron and steel alloys, and to its use in both the United States and Germany for the manufacture of armour plate, which was stated by the United States Navy Department to contain 1.3% chromium.

United States

It is seen from statistics given by Rothwell (1897 & 1900) that annual chromite consumption by the United States rose from around 7,000 tonnes in 1892 and 1895 to 17,000 tonnes in 1898. As described previously a large proportion of United States chromite supply came from imports, and by 1898 the United States relied almost entirely on imported chromite. The chief supplier of United States chromite imports during the period was Turkey, although increasing quantities were imported from New Caledonia and Canada (Rothwell, 1899).

In the United States the main centres of chromite consumption by the chemical industry were Baltimore and Philadelphia, while consumption by the metallurgical industry was centred at Brooklyn, and consumption by the refractory industry was located at Pittsburgh (Rothwell, 1896 &1897). Each of these centres of consumption was situated in the Northeastern United States.

Europe

The chief consumers of chromite in Europe were located in the Soviet Union, Germany, and the United Kingdom (Rothwell, 1896). In addition, France and Norway were consumers of chromite during the period 1892-1899. With the exception of the Soviet Union, these countries were not chromite producers and consequently depended on imported chromite.

FERROCHROMIUM

The level of ferrochromium production during the period 1892-1899 is not known. However, during that period chromite consumption in the metallurgical industry was much less than in the chemical industry. During 1892-1899 the tonnage of ferrochromium entering international trade was probably relatively small, although in Rothwell (1900) reference was made to exports from France to Germany and the United Kingdom of ferrochromium manufactured at Boucau in south-western France. In 1898 ferrochromium exports by France to Germany amounted to 400-500 tonnes while those to England amounted to only 40-50 tonnes. These exports were made at a time Krupp in Germany was reported to be involved in the manufacture of armour plate containing chromium.

Chapter 3

TRADE AGGREGATES 1900-1909

Detailed statistics on international trade in chromite and ferrochromium are not available for the period 1900-1909, and the following discussion of international trade in these commodities during that period is based on information contained in contemporary reports on the chromium industry. The importance of international trade during the period is revealed, and factors that operated in the determination of its pattern are outlined. The discussion examines first the geographical distribution of chromite production then considers the geographical location of chromite consumption. Finally, some discussion is given on the position of ferrochromium during the period.

CHROMITE PRODUCTION AND EXPORTS

During the period 1900-1909 the largest producer of chromite in the world was New Caledonia, while large chromite production was recorded also by the Soviet Union. In addition, significant quantities of chromite were produced during the period by Turkey, Greece, and Canada, while India emerged as a chromite producer in 1903 and Zimbabwe became a chromite producer in 1906 after which its production rose rapidly. Australian chromite production declined then ceased during the decade, and United States production was small throughout the period. The distribution of world chromite production during 1900-1909 is shown in detail in terms of tonnage and percentage in Tables 2 and 12. The tonnage of world chromite production reached its highest level for the decade in 1909 when world production amounted to 133,000 tonnes.

New Caledonia

The emergence of New Caledonia as an important chromite producer after 1895 has been discussed in the previous chapter. During the period 1900-1909 chromite production by New Caledonia averaged 32,000 tonnes a year, and its production amounted to 36% of world production during the decade. New Caledonian chromite production reached its highest level of 57,000 tonnes in 1906 (Table 2), and during that year its production represented 56% of world production (Table 12).

During the period to 1900 the principal chromite deposits mined in New Caledonia were located in serpentine in the mountains at the southern end of the island (Rothwell and Struthers, 1901). The chromite in these deposits occurred in "lenses" of large size. The Lucky Hit and Pensee deposits each yielded around 14,000 tonnes of chromite, while production from the Josephine and Alice Louise deposits, which were still being worked, amounted to around 18,000 tonnes and 10,000 tonnes respectively. The deposits included a capping of "alluvial" ore described earlier, and the layer of "alluvial" ore at times exceeded nine metres in thickness. This ore was easily concentrated by sluicing after which the enriched ore was dried and bagged for shipment. Even though the "alluvial" ore contained less chromite than the "rock" ore, it was of greater value as it occurred nearer the surface, was easily mined, did not require crushing, and could be easily concentrated by washing to produce a good quality product containing not less than 50% Cr_2O_3. In contrast, the "rock" ore had to be beneficiated by hand dressing prior to marketing.

During the years immediately prior to 1902 the great bulk of New Caledonian chromite ore came from mines at Baige N'go in the southern part of the island. However, it was reported by Struthers and Fisher (1903) that some mines in the area were closed in 1902 due to poorness of the ore, while production in the remaining mines had been considerably reduced. In consequence, chromite production by New Caledonia dropped from 17,000 tonnes in 1901 to 10,000 tonnes in 1902. However, chromite mining had recently commenced in the Gomen district on the north west coast of New Caledonia, and the prospects there appeared promising. Further, it was reported in Struthers and Fisher (1903) that two French mine owning companies had combined to form Societe le Chrome, a company with substantial capital. The company planned to develop three mines located in the Mt. Tiebaghi, Plum, and

South Bay regions. The deposit at Mt. Tiebaghi was leased to a British company, which had contracted to mine a minimum of 10,000 tonnes of ore and to pay a royalty based on the tonnage mined. A large quantity of ore had been mined already in the Plum region, which included the Lucky Hit, and developments were expected to result in a large output in the future. At South Bay the ore was particularly rich, and it was proposed to build a railway from the deposit to a favourable port. The planned developments augered well for the future of chromite mining in New Caledonia.

In 1903 chromite production in New Caledonia increased to 21,000 tonnes compared with 10,000 tonnes in 1902 (Table 2), and New Caledonian chromite was increasing in importance in world markets in which it was replacing Turkish chromite (Newland, 1904). Several large shipments were made to the United States during 1903 at favourable freight rates, and only high grade ore containing 50-56% Cr_2O_3 was exported. As well as being very rich in Cr_2O_3 the ore had an unusually low silica content, and it was regarded as very desirable for the manufacture of both chromium chemicals and ferrochromium. In 1904 New Caledonian chromite production rose sharply to 42,000 tonnes (Table 2), and there was apprehension that competition from New Caledonia might seriously affect the chromite industry in other countries. According to Judd (1905) increased chromite exports from New Caledonia in 1904 had resulted in a decline of around $5 per tonne (about 20%) in the price delivered in New York of ore containing 50% Cr_2O_3. During 1904 New Caledonian chromite exports amounted to 42,000 tonnes, and of these 17,000 tonnes were shipped directly to the United States. The rapid increase in exports by New Caledonia was made possible by the great richness of the ore and extensiveness of the orebodies, and by the low freight rates at which shipments could be made.

By 1904 the principal factor in the New Caledonian chromite industry was Societe le Chrome formed in 1902 as a combination of producing interests. Mining was most active at Tiebaghi, where the ore was especially rich and required no mechanical concentration. As stated by Judd (1905) the ore was shipped in large lots averaging 56% Cr_2O_3. In addition, the company was enlarging mining operations at Plum.

Chromite production by New Caledonia increased to 51,000 tonnes in 1905 (Table 2), and its output in that year amounted to 52% of world production (Table 12). The export of New Caledonian chromite was assisted by low freight rates from Noumea to New York as the ore was carried as ballast, and during 1905 there was a further fall in the price of chromite (Judd, 1906). In 1906 New Caledonian chromite production increased further to 57,000 tonnes (Table 2) and amounted to 56% of world production in that year (Table 12), and there was a slight improvement in the price of chromite. By 1906 the Tiebaghi mine, located in the north of the island, had become the largest and richest chromite mine in the world. The production rate of the mine was 4,000-5,000 tonnes of ore a month (equivalent to 48,000-60,000 tonnes a year), and the ore produced contained up to 57% Cr_2O_3 (Ingalls, 1907). In addition, chromite production took place at the Lucky Hit located twenty kilometres south of Noumea. The chromite was mined from a vein up to fifteen metres thick by means of an underground operation capable of producing 12,000 tonnes of ore a year. The ore from the mine contained 30-40% Cr_2O_3, and was enriched at a special works. However, no chromite mining had been carried out by 1906 in the South Bay region located in the south of the island, although a railway was being constructed to enable later development. The mining developments by Societe le Chrome during the period from 1902 to 1906 resulted in New Caledonia becoming by far the largest chromite producing country in the world.

The workings of the Tiebaghi mine were located on the top of Mt. Tiebaghi, about 550 metres above sea level. The ore was brought down by overhead cables to a tramway, which extended for eight kilometres. Punts were then used to take the ore a further six kilometres to ships in the harbour. When no ships were being loaded, the chromite was stored on an island close to the anchorage, and a reserve of around 15,000 tonnes of ore was always on hand (Ingalls, 1907).

During 1907 the Tiebaghi and Lucky Hit mines continued to be the principal sources of chromite production in New Caledonia. However, the Tiebaghi mine became inactive during the year pending alterations in the mode of transport (Yale, 1908), and this accounted for the drop in chromite production by New Caledonia from 57,000 tonnes in 1906 to 25,000 tonnes in 1907 (Table 2). In 1908 chromite production by New Caledonia rose again to 47,000 tonnes.

Chromite exports by New Caledonia in 1908 amounted to 46,000 tonnes, but fell to 32,000 tonnes in 1909 (Horton, 1910). During 1909 the price of chromite reached a very low level, and was quoted at $5-35 per tonne for 50% Cr_2O_3 in bulk at the mines and $8-35 per tonne in sacks f.o.b. Noumea. During 1909 the entire chromite production by New Caledonia came from the Tiebaghi mine, and in view of large stocks on hand its output was reduced to 3,000 tonnes per month. At the end of 1909 chromite stocks in New Caledonia were around 21,000 tonnes.

Soviet Union

During the period 1900-1909 the Soviet Union was the second largest chromite producer in the world with an average annual chromite production of 21,000 tonnes. However, it appears that chromite production by the Soviet Union during the period was used entirely for domestic consumption. According to Horton (1910) the principal chromite mines in the Soviet Union were located in the Urals, where there were about fifty mines. The market for ore was at Ekaterinburg.

Turkey

During the period 1900-1909 the level of Turkish chromite production varied considerably as indicated in Table 2. However, it should be mentioned that no official production statistics were published by the Turkish government, and reliable statistics were difficult to obtain due to the fact that smuggling was constantly carried on to avoid export duty while on many occasions chromite ore was probably shipped as iron ore (Rothwell and Struthers, 1901).

The principal chromite deposits in Turkey were located near Bursa, Izmir, and

Salonica. The largest chromite producer was the Daghardi mine situated in the Bursa region. It had an annual output of 12,000-15,000 tonnes of ore containing 51-55% Cr_2O_3 as described in Struthers and Fisher (1903). About two-thirds of the output of the Daghardi mine was exported to the United Kingdom, while the balance was sent in roughly equal proportions to the United States and Germany.

The Turkish government imposed a royalty of 20% on the value of chromite produced, and also a duty of 1% on the value of chromite exported (Struthers and Fisher, 1903). These taxes did not depend on profitability, and had the effect of reducing the competitiveness of Turkish chromite.

Competition from New Caledonia and adverse internal conditions had brought about a crisis in the Turkish chromite industry (Ingalls, 1907), and these factors greatly diminished its importance in the world market. Chromite exports by Turkey dropped from around 40,000 tonnes in 1901 to only a few thousand tonnes a year by 1906. The transportation of chromite from New Caledonia to the United Kingdom and United States was comparatively inexpensive as the chromite was shipped largely as ballast, and this made it difficult for Turkey to compete with the delivered prices at which this ore could be sold. The difficulty was accentuated by the high cost of internal transport in Turkey due to poor roads, and by burdensome Turkish taxes that were levied not only on the value of chromite as mined, but on its value after high haulage costs had been added to the cost of production.

The price of chromite dropped so much that many Turkish mines, especially those far from railways, could no longer be worked profitably (Ingalls, 1909). It was recorded that the Daghardi mine, previously the largest chromite mine in Turkey, had ceased operations. Also, the firm of Paterson & Co, which had been a major force in the production and export of Turkish chromite, had returned all its mines to the Turkish government as the annual tax on the ownership of the mines could not be justified by their profitability. In Horton (1910) reference was made to a decrease in both the production and export of chromite by Turkey due to a decline in price of the ore.

Greece

During the period 1900-1909 Greek chromite production averaged 9,000 tonnes a year and comprised 10% of world production during that period. The level of production varied somewhat from year to year (Table 2), and its share of world production tended to decline from the peak of 28% reached in 1902 (Table 12).

According to Struthers (1902) chromite production in Greece came from the Bourdaly mines in Thesally. The ore in the deposit contained 32.3% Cr_2O_3, and most of the production from the mines was exported to Austria for use in the manufacture of ferrochromium. However, some Greek chromite was exported also to the United States. A large proportion of the chromite mined in Greece came from the one deposit in Thesally (Higgins, 1908).

Canada

Chromite production by Canada during the period 1900-1909 averaged 5,000 tonnes a year, and production was greatest during the years 1904-1908 (Table 2) when it averaged 7,000 tonnes a year.

During the period 1900-1909 Canadian chromite production came from mines in the Black Lake district of the Province of Quebec, and there was no chromite production in Newfoundland. The mining and milling of chromite in the Black Lake district is described by Strangways (1908). It was found that a significant improvement in the grade of Black Lake chromite concentrates could be achieved by combining the gravity and magnetic methods of concentration (Struthers and Fisher, 1903). The leading chromite producer in the district was the Black Lake Chrome and Asbestos Company, and it was reported (Newland, 1904) that the company erected a new concentrator in 1903 and was preparing to increase its output. Subsequently, there was an increase in Canadian chromite production as seen in Table 2. According to Judd (1905) the Black Lake Chrome and Asbestos Company produced a first-grade chromite concentrate ranging around 52% Cr_2O_3 and containing not more than 3% silica, while second-grade concentrate carried 45% Cr_2O_3 and was used in the manufacture of ferrochromium. It was reported by Ingalls (1907) that the high grade concentrate running 50-54% Cr_2O_3 was coming into direct competition with high grade ore from New Caledonia, and that the Black Lake Chrome and Asbestos Company had become an important factor in the chromite trade of North America. The chief market for Canadian chromite in 1908 was the United States (Horton, 1910).

India

During the years 1904-1909 Indian chromite production averaged 7,000 tonnes a year, and reached its highest level for the period in 1907 when production amounted to 19,000 tonnes.

Chromite deposits in the Peshin and Zhob districts of Baluchistan were investigated in 1903 by the Indian Geological Survey (Newland, 1904). During the investigation an orebody 122 metres long and 1.5 metres wide containing 54% Cr_2O_3 was found near Khanogia in the Peshin district. According to Judd (1905) chromite deposits in the Peshin and Zhob districts were opened up for export, and chromite production during the first half of 1904 amounted to almost 2,000 tonnes.

During 1904-1906 (Table 2) Indian chromite production averaged 4,000 tonnes a year and came from the State of Baluchistan, but in 1907 11,000 tonnes of chromite was mined in the State of Mysore, where there had been no production previously, and this largely explained the rise in Indian chromite production to 19,000 tonnes in 1907 (Table 2). However, most of the chromite produced in Mysore was not sold, and in view of this Indian chromite production in 1908 dropped to 5,000 tonnes as explained by Horton (1910). Presumably chromite production by India during 1908 came largely from Baluchistan. However, Indian chromite production rose from 5,000 tonnes in 1908 to 9,000 tonnes in 1909 (Table 2), and according to Fay (1911) this increase in production was from Mysore.

Zimbabwe

Chromite production by Zimbabwe rose from 3,000 tonnes in 1906 to 37,000 tonnes in 1909 (Table 2), and during 1909 its production amounted to 28% of world production (Table 12).

It was reported (Ingalls, 1907) that chromite ore was produced from large deposits in the neighbourhood of Selukwe in central Zimbabwe, and that it was shipped to the United Kingdom and the continent of Europe via Beira in Mozambique. Reference was made by Yale (1908) to the increasing importance of chromite from Selukwe. A sample of chromite ore from Selukwe sent to the Imperial Institute in London was reported to contain 46.4% Cr_2O_3, 13.2% Al_2O_3, 18.7% FeO, and 4.6% SiO_2. The growth in chromite production by Zimbabwe during the years 1906-1909 is shown in Table 2, and shipments of chromite ore from Beira in 1909 amounted to around 23,000 tonnes (Horton, 1910). The ore was mined at Selukwe and sent by rail to Beira for shipment. The greater part of the ore shipped in 1909 was sent to the United States, but some went to France, Netherlands, Belgium, Italy, and the United Kingdom.

Australia

Chromite production by Australia during both 1900 and 1901 amounted to 3,000 tonnes and in 1903 to 2, 000 tonnes whereas during other years of the decade it did not exceed 500 tonnes (Table 2). Most of the production came from the Gundagai district of New South Wales. Two factors appear to have contributed to the decrease in Australian chromite production from the level of 5,000 tonnes reached in 1899. First, smaller deposits in the district became exhausted (Struthers, 1902), and secondly there was a decline in the average grade of ore to 46% Cr_2O_3 whereas ore containing 50% Cr_2O_3 was the lowest grade that could be marketed for export (Judd, 1905).

United States

During the period 1900-1909 United States chromite production was small (Table 2). Production during the period came from California, and was used as a refractory for lining furnaces at copper smelters in that state (Yale, 1908). Even though United States chromite deposits were known in California and North Carolina, they were remote from the manufacturing centres in the Northeastern United States where large quantities of chromite were consumed, and ore from these deposits was unable to compete with low cost high grade foreign ores that entered the United States free of duty (Judd, 1905).

CHROMITE CONSUMPTION AND IMPORTS

During the period 1900-1909 chromite consumption was located mainly in the United States and Europe, and except for domestic production in the Soviet Union and a small quantity of production in the United States the supply of chromite for consumption came from imports obtained from producing countries such as New Caledonia and Turkey .

Chromite consumption during the period 1900-1909 took place in the chemical, refractory, and metallurgical industries. According to Judd (1906) chromite was consumed in the making of chromium salts for use in the dyeing and tanning industries, the manufacture of chromite brick for refractory purposes, and the production of ferrochromium for use in making special steels.

In connection with the metallurgical application of chromite, reference was made in Rothwell and Struthers (1901) to the use of ferrochromium in the production of Krupp armour plate for protective purposes in naval vessels. However, apart from armour plate and armour-piercing projectiles, ferrochromium was used in the manufacture of other products including tool steel, magnet steel, bridge steel, rails, wire, cutlery, safes, axles, springs, stamp-mill shoes, and ore-crusher jaws. Regarding the refractory use of chromite, there was an increase in demand for chromite as a lining for furnaces as the life of such linings was several times greater than that of any other known refractory (Struthers, 1902). In this application both brick and lump chromite were employed. However, despite the rapidly growing importance of chromite consumption in the manufacture of ferrochromium and chromite refractories, the chief consumer of chromite continued to be the chemical industry in which chromite was used for the manufacture of chromium salts (Judd, 1906).

United States

During the period 1900-1909 annual chromite consumption by the United States was closely related to annual chromite imports as shown by statistics published in Fay (1911). However, both consumption and imports of chromite showed substantial fluctuation during the decade. Chromite consumption by the United States rose irregularly from 18,000 tonnes in 1900 to a peak for the decade of 56,000 tonnes in 1905 and amounted to 41,000 tonnes in 1909, while chromite imports by the United States during each of these years were around the same level as consumption.

The Mutual Chemical Company of America had plants at Baltimore and Boston and was the chief consumer of chromite for the manufacture of chemicals, while the Harbison-Walker Refractories Company of Pittsburg was the principal manufacturer of chromite bricks, and the Chrome Steel Works of Chrome, New Jersey, was the leading producer of ferrochromium based alloys (Horton, 1910). Each of these consumers was located in the Northeastern United States.

Except for small quantities of chromite produced and consumed in California, the entire chromite consumption by the United States during the period 1900-1909 was supplied by imports. These were obtained from a number of countries including New Caledonia, Turkey, Greece, Canada, India, and Zimbabwe.

Europe

Although detailed statistics are not available on chromite consumption or imports by individual countries in Europe during the period 1900-1909, it appears that the Soviet Union, Germany, and the United Kingdom were the main chromite consuming countries, although other countries including France, Norway, and Austria were also consumers. In the Soviet Union chromite consumption was satisfied by domestic production. However, other chromite consuming countries in Europe were not producers of chromite, and in consequence had to depend on imported chromite from countries such as New Caledonia, Turkey, and Zimbabwe.

FERROCHROMIUM

There is not a great deal of information available on the production of or international trade in ferrochromium during the period 1900-1909. However, during this period the consumption of chromite in the metallurgical industry was less than in the chemical industry, and it is likely that international trade in ferrochromium was relatively insignificant compared with that in chromite. During 1900-1909 ferrochromium production took place in a number of countries including the United States, Canada, France, and Austria.

According to Rothwell and Struthers (1901) three firms were involved in the manufacture of ferrochromium in North America in 1900. The Willson Aluminium Company with works at Halcomb Rock in Virginia and at Kanawha Falls in West Virginia, and the Alloy Smelting Company at Niagara Falls in New York were located in the United States, while a third firm was situated at Hamilton, Ontario in Canada. The ferrochromium was produced by reduction in electric arc furnaces using chromite ore imported from Turkey, and contained an average 71.2% Cr, 5.7% C, and 0.5% Si. Ferrochromium consumption by the United States in 1900 was estimated at around 2,000 tonnes, and this was probably supplied mainly from plants located in the United States.

In 1903 the main consumer of ferrochromium in the United States, the Chrome Steel Works, shifted its operations from Brooklyn in New York to Chrome in New Jersey, where new plant had been installed (Newland, 1904). The new works were equipped for the manufacture of chromium steel plates, angles, and bars for which it had an annual production capacity of around 60,000 tonnes of steel.

It was reported in Judd (1905) that the Willson Aluminium Company with plants at Kanawha Falls and Holcomb Rock was the only producer of ferrochromium in the United States, and that the company had doubled its output to produce 2,500 tonnes of ferrochromium in 1904. However, much of this production was exported to Sheffield in England for use in the manufacture of projectiles for which demand had increased as a result of the Eastern War.

In 1905 ferrochromium production by the Willson Aluminium Company decreased to around 2,000 tonnes due to the temporary stagnation of United States warship building pending a decision of the Congressional naval construction committee regarding the design of two new battleships recently authorised, and during the latter part of 1905 consumption of ferrochromium for making armour plate ceased entirely (Judd, 1906). In view of the reduced demand for ferrochromium in the United States, almost the entire output of the Willson Aluminium Company was exported to Sheffield in England and to Japan.

Chapter 4

TRADE AGGREGATES 1910-1919

In order to examine the significance of international trade in chromite during the period 1910-1919 and to appreciate the factors that have operated in determining its pattern, the geographical distribution of chromite production and chromite exports is studied first and then consideration is given to the geographical location of chromite consumption and imports. Finally, the position of ferrochromium during the period is discussed.

CHROMITE PRODUCTION AND EXPORTS

The location of world chromite production by country during the period 1910-1919 is shown in terms of tonnage and percentage in Tables 3 and 13. Zimbabwe and New Caledonia were by far the largest chromite producing countries in the world during 1910-1919, and accounted for 30% and 29% respectively of world chromite production during the decade. Other chromite producing countries during the period included the United States, India, Canada, Turkey, Greece, Soviet Union, Japan, Brazil, and Cuba as seen in Table 3. In the case of the United States, India, and Canada there was a dramatic increase in chromite production during the years 1916-1918 corresponding to the latter part of World War I, while Brazil and Cuba emerged as chromite producers towards the end of the decade. Total world chromite production reached a record level of 288,000 tonnes in 1918 then dropped to 142,000 tonnes in 1919.

The distribution of world chromite exports by country of origin during the period 1913-1919 is shown in terms of tonnage and percentage in Tables 21 and 29. It is seen that New Caledonia and Zimbabwe were by far the largest chromite exporting countries in the world during the period 1913-1919, and these countries were responsible for 38% and 35% respectively of world chromite exports during that period. Total world chromite exports rose to a record level of 196,000 tonnes in 1916 then fell to 87,000 tonnes in 1919 (Table 21).

The two largest chromite producing countries in the world during 1910-1919, namely Zimbabwe and New Caledonia, were also the two largest chromite exporting countries, while other chromite producing and exporting countries during the decade included India, Canada, and Greece. In contrast, the United States and Soviet Union were chromite producers, but not chromite exporters during the period.

Zimbabwe

The emergence of Zimbabwe as a chromite producer in 1906, and the rapid rise in its production to 37,000 tonnes in 1909 when its production was exceeded only by that of New Caledonia has been described in the previous chapter. During the period 1910-1919 annual chromite production by Zimbabwe averaged 54,000 tonnes a year compared with an average of 51,000 tonnes a year by New Caledonia, and these two countries together accounted for almost 60% of world chromite production during the decade.

In Of (1912) it was reported that Chrome Company Ltd with a capital of £190,000 had recently been formed. This company had a contract to acquire the chromite output of the Tiebaghi mine in New Caledonia, and also had made arrangements with Rhodesia Chrome Mines Ltd in Zimbabwe to market its output. Thus, the two most important chromite producers in the world were linked by a common marketing organisation.

Chromite production by Zimbabwe increased from 40,000 tonnes in 1910 to a peak for the decade of 81,000 tonnes in 1916 then fell to 32,000 tonnes in 1918 and 1919 (Table 3). In 1916 chromite production by Zimbabwe amounted to 30% of world production (Table 13), and this was the same as the percentage contribution of Zimbabwe to world chromite production during the decade 1910-1919.

By early in the decade the Selukwe deposits had developed into an important source of chromite, and production was rising rapidly (Of, 1912). The deposits comprised a huge segregated mass of chromite associated with serpentine, and the ore was reported to contain 46.3% Cr_2O_3. The ore was easily quarried and the deposits were situated in close proximity to the railway. Production costs were low and the supply of ore was exceedingly large. The deposits at Selukwe were worked by Rhodesia Chrome Mines Limited, which was an English controlled company, and the ore was sent by rail from Selukwe in the Matabeleland region of Zimbabwe to Beira in Mozambique, a distance of 900 kilometres.

According to Roush (1915) more than 130 lenses of chromite had been mapped on the surface at Selukwe, and these ranged in length from around 45 metres to 140 metres. Ten of the lenses were at the chromite mines, partly merging into each other, and were easily mined by ordinary quarrying methods.

Chromite production by Zimbabwe rose to a record level of 81,000 tonnes in 1916 (Table 3) in response to increased demand for exports associated with the war, but dropped to 32,000 tonnes in 1918. Much of the decrease in production during 1918 was attributed by Dolbear (1919) to the lack of ships for carrying exports. During the period from 1907 to 1919 the chromite deposits at Selukwe had yielded more than 600,000 tonnes of ore, and it was stated (Dolbear, 1920) that large quantities of ore remained in reserve.

The discovery of a chromite deposit in the Umvukwes Range of Zimbabwe was recorded by Dolbear (1919). The deposit was reported to be larger than any other previously developed in any country, and it was stated that a survey had proved the existence of 2,000,000 tonnes of ore averaging 53% Cr_2O_3. The deposit was located about 50 kilometres from the railway, and it was suggested that if a branch line were constructed to meet the main railway line at Banket Junction then the cost of ore delivered at Beira would be low.

However, by the end of 1919 the Umvukwes Range deposit had not been developed because of its distance from the railway and the inability of the owners to secure contracts for the output (Dolbear, 1920). The inability to secure contracts was probably hindered by the depressed world market for chromite in the immediate postwar period when the demand for military purposes dropped suddenly and accumulated stocks were on hand as described by Rumbold (1921).

Chromite exports by Zimbabwe during the period 1913-1919 averaged 49,000 tonnes a year, and the variation from year to year during that period was as shown in Table 21. Exports reached their highest level of 79,000 tonnes in 1916 then dropped to 19,000 tonnes in 1919, and that there was a general similarity between the pattern of exports and the pattern of production even though the level of exports was significantly below that of production during 1917 and 1919.

During the period 1913-1919 by far the largest quantity of chromite exported by Zimbabwe went to the United States, although a large quantity of exports went also to the United Kingdom as shown by Rumbold (1921). Zimbabwean chromite exports to the United States rose from 23,000 tonnes in 1914 to 60,000 tonnes in 1916 then fell to 8,000 tonnes in 1918 and remained low in 1919. The rise in exports resulted from strong demand for chromite for military purposes, while the decline after 1916 reflected the reduced availability of shipping during the latter part of the war and the subsequent drop in demand for chromite following the cessation of hostilities. Chromite exports by Zimbabwe to the United Kingdom rose from 2,000 tonnes in 1914 to 26,000 tonnes in 1918 then dropped to 5, 000 tonnes in 1919. The rise in exports to the United Kingdom was in response to war time demand, and it appears that exports to the United Kingdom were not affected by shipping restrictions during the latter part of the war.

Other countries to which Zimbabwe exported chromite during the period 1913-1919 included France, Norway, and Germany as recorded by Rumbold (1921). Chromite exports by Zimbabwe to France amounted to 13,000 tonnes in 1913, but dropped to an average of 5,000 tonnes a year during the period 1914-1916 then ceased in 1917, while exports to Norway reached their highest level of 7,000 tonnes in 1915, and exports to Germany dropped from 8,000 tonnes in 1913 to 4,000 tonnes in 1914 then ceased. As Zimbabwe was a British possession it is not surprising that no chromite exports by Zimbabwe to Germany were made after the outbreak of war between the United Kingdom and Germany in 1914.

The pattern of total chromite exports by Zimbabwe during the period 1913-1919 as shown in Table 21 was determined to a large extent by the factors operating on exports by Zimbabwe to the United States and the United Kingdom during that period.

New Caledonia

During the period 1910-1919 chromite production by New Caledonia averaged 51,000 tonnes a year, which was only slightly lower than that of Zimbabwe. New Caledonian chromite production during the period reached its highest levels of 83,000 tonnes and 74,000 tonnes in 1911 and 1916 (Table 3), and during those years its production amounted to 52% and 28% respectively of world chromite production (Table 13). In 1919 chromite production by New Caledonia dropped to 24,000 tonnes, and its production in that year was 17% of world production.

According to Fay (1911) the principal chromite mines in New Caledonia were the Tiebaghi and the Lucky Hit. The Tiebaghi mine had a production capacity of 4,000-5,000 tonnes of ore a month and yielded high grade ore containing 55-57% Cr_2O_3, while the Lucky Hit mine was capable of producing a low grade ore that contained 30-40% Cr_2O_3 and required concentration. However, under an agreement with the owners of the Tiebaghi mine, the Lucky Hit mine was closed throughout the period 1910-1919 (Dolbear, 1922), and a large proportion of the chromite production by New Caledonia during the decade 1910-1919 came from the Tiebaghi mine. In addition, about 60,000 tonnes of chromite having a grade of 53% Cr_2O_3 was extracted from the Vereingetorix mine situated on the east coast at Unia, about 100 kilometres from Noumea. This mine was opened in 1913, but became exhausted in 1919 (Dolbear, 1922).

From 1911 the Tiebaghi mine was held by Societe la Tiebaghi, an organisation registered in Paris, and the chromite ore from the Tiebaghi mine was acquired under contract by Chrome Company Ltd, a company based in London (Rumbold, 1921). The Chrome Company also had arrangements to market the chromite output of Rhodesia Chrome Mines Ltd from Selukwe in Zimbabwe (Of, 1912). The chromite mining operations at Tiebaghi and Selukwe were the largest in the world, and the output of these mines represented a large proportion of world chromite production.

According to Of (1913) and MaGuire (1914) the price of New Caledonian chromite had been raised gradually by the Chrome Company Ltd, which controlled sales of chromite in both New Caledonia and Zimbabwe. This is in contrast to the position during the period 1900-1910 when the average f.o.b. price of New Caledonian chromite gradually halved as a result of competition between New Caledonia and Turkey and later between New Caledonia and Zimbabwe. It is interesting to observe that total chromite production by New Caledonia during the decade 1910-1919 was approximately equal to that of total production by Zimbabwe.

During the period 1913-1919 chromite exports by New Caledonia averaged 53,000 tonnes a year, and varied from year to year as shown in Table 21. New Caledonian exports reached their highest level of 75,000 tonnes in 1916 then fell to 26,000 tonnes in 1918, and in so doing exhibited behaviour similar to that of exports by Zimbabwe. Statistics given by Rumbold (1921) for the period 1910-1917 show that by far the largest quantity of chromite exports by New Caledonia during that period were made to the United States, although large quantities of exports went also to the Netherlands, United Kingdom, and France.

United States

Chromite production by the United States rose from less than 500 tonnes a year during the years 1910-1913 to 3,000 tonnes in 1915 then jumped dramatically to 48,000 tonnes in 1916 and 44,000 tonnes in 1917 after which it increased further to a record of 84,000 tonnes in 1918 then collapsed to 5,000 tonnes in 1919 (Table 3). The United States was not a chromite exporter, and in fact imported large quantities of chromite throughout the decade 1910-1919 as discussed subsequently under consumption and imports.

During the years 1910-1914 the small tonnage of chromite produced in the United States was mined in California. However, in view of the long railway haul across the United States it was not possible for Californian chromite to compete in the Atlantic states with cheaply delivered foreign ore entering duty free into the United States as indicated in Roush (1915).

In view of the European war the United States was experiencing difficulty during 1915 in securing chromite from New Caledonia, and United States consumers were obliged to look to California as a source of supply (Dolbear, 1916). All the larger consumers became represented in California, and offers to purchase chromite resulted in the opening up of many new deposits as well as the development of some of the old ones. In 1915 chromite production in California amounted to 3,000 tonnes, which was more than six times annual chromite production by the United States during the years 1910-1913 (Table 3).

During 1916 chromite production by the United States amounted to 48,000 tonnes (Table 3), which was by far the largest chromite production ever recorded in the United States, and more than twelve times that of the previous year. A large proportion of this production came from California, although Oregon became a chromite producer in 1916 and shipped 3,000 tonnes of ore (Dolbear, 1917).

Most of the deposits mined in California were small and yielded less than 100 tonnes of ore, although production from a few deposits was in excess of 1,000 tonnes. New discoveries were being made constantly, and the demand for chromite at high prices stimulated prospecting in every field where ore was likely to occur. Further, the increased price of ore made it possible to work deposits that previously were too remote from rail transportation to justify operation (Dolbear, 1917). The price of chromite was based on ore containing 40% Cr_2O_3 and not more than 8% SiO_2. A premium was paid for each 1% Cr_2O_3 in excess of 40%, and a penalty was exacted for ore containing less than 40% Cr_2O_3 or more than 8% SiO_2. During the pre-war period chromite prices were usually based on ore containing 50% Cr_2O_3.

Embargoes had been placed on exports of chromite by some of the principal producing countries, and it was feared that supply of chromite to the United States would be cut off. However, after the producers received a guarantee that ore would not be re-shipped to enemy belligerents, chromite imports into the United States greatly increased, particularly from Zimbabwe, New Caledonia, and Canada. Chromite imports by the United States during 1916 amounted to 116,000 tonnes compared with imports of 78,000 tonnes in 1915 (Dolbear, 1917). During 1916 both chromite production and chromite imports by the United States were at record levels in response to war-time demand.

According to Dolbear (1918) the domestic chromite situation in the United States during 1917 was marked by the increased production and importance of the Oregon mines, the construction of concentrating plants on the Pacific Coast, the advent of Alaska as a chromite producer, and the unprecedentedly high chromite prices that prevailed. The importance of increasing chromite production by the United States during the war was accentuated not only by the demand for its use in essential war industries, but also by the need to release for other purposes ships engaged in transporting ore from New Caledonia and other countries. Chromite production by the United States during 1917 amounted to 44,000 tonnes, which was slightly lower than production during 1916, whereas chromite imports during 1917 amounted to 73,000 tonnes, which was substantially below the level of imports in 1916.

During 1917 the Brown Mine in California, operated by the California Chrome Company, closed down due to the exhaustion of ore reserves. This deposit yielded around 15,000 tonnes of chromite ore, and was the largest deposit worked on the Pacific Coast. It contrasted with the large number of small deposits in California from which chromite was mined during the war period. However, production from the Brown Mine was only about one sixth that from the Wood Mine in Pennsylvania, which yielded around 95,000 tonnes of chromite during the period prior to 1850 when Maryland and Pennsylvania were the main suppliers of chromite to the world market as described by Dolbear (1918) and Rumbold (1921).

During the first eight months of 1918 the chromite industry of the United States was characterised by intense production and strong demand. Early in 1918 the War Industries Board faced a shortage of chromite, and the Shipping Board announced it could no longer supply ships for importations (Dolbear, 1919). These circumstances made the development of domestic sources of chromite mandatory, and in April 1918 a complete embargo against the importation of chromite by water was announced.

Chromite production by the United States during 1918 amounted to 84,000 tonnes (Table 3), and represented 29% of total world production (Table 13). During 1918 the United States was the largest chromite producing country in the world, and its production was the largest ever recorded. The main supply of United States chromite continued to come from mines in California, which were responsible for 57,000 tonnes of chromite during 1918, while mines in Oregon contributed 23,000 tonnes (Dolbear, 1919). The remaining 4,000 tonnes of chromite produced by the United States during 1918 came from Maryland, North Carolina, Pennsylvania, Washington, Wyoming, and Alaska. The average price of United States chromite during 1918 was higher than in any previous year.

Following the prohibition of chromite imports into the United States by water announced in April 1918, a semi-official basic price of $1-25 per percentage unit for chromite ore containing 38% Cr_2O_3 was fixed at the instance of the War Industries and Shipping Boards (Dolbear, 1919). This price was announced on the Pacific Coast by the California Chrome Company, which was a subsidiary of the Electro-Metallurgical Company of Niagara Falls. The latter company was one of the largest consumers of chromite in the United States and a manufacturer of ferrochromium. While announcing the new chromite price during the latter part of April, California

Chrome also stated that the increased price would remain constant during 1918 and that contracts could be entered into for ore produced during the rest of the year. However, on 31st July the company undertook a policy of retrenchment and within sixty days had withdrawn from the market. This action resulted from the unexpected quantity of chromite imports into the United States, which by one pretext or another escaped the embargo. During 1918 chromite imports by the United States amounted to 102,000 tonnes of which 81,000 tonnes were brought in by water (Dolbear, 1919). The remaining imports were produced in Canada and imported by rail.

The policy of the United States government in relation to chromite was applied also to other "war minerals", and resulted in the introduction and passage of a Mineral Control Bill. This was not made law until 5th October, 1918, and did not become operative (Dolbear, 1919). The Mineral Control Bill anticipated the maintenance of a market for domestic chromite production for two years after the declaration of peace, and in many cases preparations had been made for this by the erection of concentrating plants, the construction of expensive roads, and other developments of which the cost could not be recovered in a shorter period. However, the domestic chromite market in the United States collapsed during 1918 as a result of large imports and failure to make the Mineral Control Bill operative. Then, at the end of the war, the demand for both domestic and imported chromite dropped, and the effect of this decrease in demand was accentuated by the availability of accumulated stocks. These circumstances resulted in a decrease in the price of chromite and reduction in the level of production.

At the end of 1918 unsold stocks of chromite in the hands of miners in the United States as advised to the U.S. Geological Survey were reported in Dolbear (1919) as amounting to 42,000 tonnes. In addition, large stocks of chromite were held by consumers at the end of 1918 (Dolbear, 1921), and one firm alone had stocks of more than 50,000 tonnes of chromite at its plant in December 1918.

During 1919 chromite production by the United States dropped dramatically to 5,000 tonnes compared with the record level of 84,000 tonnes reached in 1918 (Table 3), and its production in 1919 amounted to only 4% of world production compared with 29% of world production in 1918 (Table 13). The huge decrease in chromite production by the United States during 1919 resulted from the cancellation of import embargoes, the cessation of war demand, and the resumption of production and trade around the world on a competitive basis (Dolbear, 1920). Chromite imports into the United States during 1919 were 62,000 tonnes compared with imports of 102,000 tonnes in 1918, and imports were at their lowest level since 1913. However, chromite imports by the United States in 1919 were large compared with domestic chromite production, and the United States resumed its former position as a chromite producer of relatively small importance.

India

Chromite production by India declined from 9,000 tonnes in 1909 to 2,000 tonnes in 1910 then remained at a low level during the years 1910-1915 as seen in Tables 2 and 3. During 1910 no chromite was produced in Mysore, and the entire production of 2,000 tonnes came from Baluchistan (Of, 1912). It was reported that the low price c.i.f. London for chromite exports did not permit any substantial profit. However, during 1913 and 1914 chromite exports by India amounted to 5,000 tonnes and 4,000 tonnes respectively (Table 21), and these exports were made under improved market conditions for chromite.

Indian chromite production increased sharply from 3,000 tonnes in 1915 to 20,000 tonnes in 1916 then continued to rise to a record of 59,000 tonnes in 1918 after which it decreased to 37,000 tonnes in 1919 (Table 3). During the years 1916-1919 Indian chromite production averaged 36,000 tonnes a year. There was a substantial increase in the level of chromite production in both Baluchistan and Mysore during the years 1916-1918 (Rumbold, 1921). However, the quality of the chromite from Baluchistan was superior to that from Mysore, which had a high iron content (Roush, 1923). Chromite exports by India also increased significantly during the years 1916-1919 (Table 21), and during that period averaged 18,000 tonnes a year. Indian chromite production and exports each reached their highest level for the decade in 1918 when they amounted to 59,000 tonnes and 41,000 tonnes respectively (Tables 3 and 21).

The chromite deposit near Khanogia in Baluchistan, the discovery of which was referred to in the previous chapter, contained 54% Cr_2O_3 and was connected by a good road to the railway at Khani, a distance of about 27 kilometres as described by Rumbold (1921). In 1914 the Baluchistan Chrome Co Ltd, which was registered in England, acquired chromite leases in the Hindubagh district of Baluchistan. A railway was constructed from Hindubagh to Khani, and chromite shipments from these leases commenced in 1917 (Rumbold, 1921).

The increased production and exports of chromite by India during the years 1916-1918 were assisted by the strong demand and high prices for chromite prevailing during the war. Statistics on the origin of chromite imports into the United States during the years 1915-1919 recorded by Dolbear (1920) indicate that there were no chromite exports by India to the United States during that period, and it is likely that chromite exports by India went to the United Kingdom and other countries in Europe.

During the period 1916-1919 chromite production by India was significantly greater than chromite exports, and this difference is probably explained to some extent at least by demand for chromite from the large domestic leather tanning industry, which used chromium salts manufactured from chromite as referred to in Roush (1923).

Canada

During the years 1910-1914 annual chromite production by Canada did not exceed 500 tonnes. However, Canadian chromite production then rose continuously and rapidly from less than 500 tonnes in 1914 to 33,000 tonnes in 1917 after which it declined to 9,000 tonnes in 1919 (Table 3). In 1917 chromite production by Canada amounted to 14% of world production (Table 13).

In Canada chromite occurred in the neighbourhood of Black Lake, Coleraine, and Thetford in the Eastern Townships of the Province of Quebec. Several mines and mills had been operated in the district, and over the years had produced a considerable quantity of both lump ore and concentrates. However, competition from New Caledonia and Zimbabwe proved too strong, and in 1910 Canadian chromite mines ceased operations (Roush, 1915).

The revival of chromite mining in Canada in 1915 was in consequence of circumstances prevailing during the war when there was a shortage of shipping and an increased demand for chromite, which resulted in a substantial increase in chromite prices. This stimulated chromite prospecting and mine development in Canada as indicated by Rumbold (1921), and led to the large increase in Canadian chromite production during the years 1915-1918 as shown in Table 3.

A large quantity of Canadian chromite production was exported to the United States, and chromite exports by Canada showed a marked increase during the years 1916-1918 (Table 21). The proximity of the Quebec chromite deposits to the eastern markets of the United States was an advantage, and in fact they were more favourably situated than the domestic chromite deposits in California and Oregon. Chromite exports by Canada to the United States were made by rail, which was an added advantage during a period of shipping stringency. Canadian chromite exports to the United States comprised mainly crude ore containing 30-40% Cr_2O_3, but included also concentrates containing around 50% Cr_2O_3 as indicated by Dolbear (1920) and Rumbold (1921). The grade of chromite ore exported by Canada was low, and under normal circumstances such ore would not have been marketable.

The demand for chromite as well as its price dropped substantially following the cessation of hostilities, and in 1919 Canadian chromite production and exports were significantly below the record levels reached in 1917. By 1921 only one chromite mine was in operation in Canada (Roush, 1923), and in 1922 Canadian chromite production and exports amounted to only 1,000 tonnes (Tables 3 and 22).

CHROMITE CONSUMPTION AND IMPORTS

During the period 1910-1919 world chromite consumption as previously took place mainly in the United States and Europe. Except for domestic chromite production in the Soviet Union and large chromite production in the United States during the years 1916-1918, the supply of chromite in the main consuming countries was derived from imports obtained from chromite producing countries, particularly Zimbabwe, New Caledonia, India, and Canada.

Chromite continued to be consumed in the chemical, refractory, and metallurgical industries. According to MaGuire (1914) chromite was used in the manufacture of chromium compounds for use in the production of pigments, dyes, mordants, and tannages; for lining furnaces where corrosive action was very great; and in the manufacture of ferrochromium, which was employed for making special steels containing chromium, either alone or in combination with nickel, manganese, or tungsten.

Detailed information on the relative importance of the chemical, refractory, and metallurgical industries as consumers of chromite during the period 1910-1919 is not available. However, it was recorded in Of (1913) that in the United States imported chromite ore, which supplied almost the entire consumption at that time, was used chiefly in the manufacture of chemicals; that domestic ore was used mainly for furnace linings for which demand was small because of their long life; and that no ferrochromium was made in the United States on a commercial scale.

The situation changed during the war when demand for ferrochromium for use in the manufacture of high-grade steels and other products containing chromium increased sharply, and ferrochromium production took place in the United States (Dolbear, 1918). Automobile manufacturers and munitions makers were reported to be the largest users of alloy and other high-grade steel. According to Dolbear (1919) one of the largest consumers of chromite in the United States was the Electro-

Metallurgical Co of Niagara Falls, and this company was a ferrochromium manufacturer. It is interesting to observe (Roush, 1923) that chromite consumption in the United States during 1922 was divided in the ratio of 40% for ferrochromium, 35% for refractories, and 25% for chemicals, which is very different to the situation described earlier as existing during the pre-war period.

The uses of chromite in the metallurgical, refractory, and chemical industries were described in detail by Rumbold (1921), and these were essentially similar in type to many of its uses in more recent times as discussed in Chapter 1. These included the metallurgical use of chromite in the production of a range of chromium steels and chromium alloys. Even though stainless steel was not discovered until 1913 as described in Chapter 1, it was reported by Rumbold (1921) to be employed in a variety of applications including cutlery, exhaust valves for aeroplane engines, turbine blades, acid pumps, evaporating pans, and steam traps.

United States

Chromite imports by the United States rose from 39,000 tonnes in 1910 and 38,000 tonnes in 1911 to a peak for the decade of 116,000 tonnes in 1916 then decreased to 62,000 tonnes in 1919. United States chromite imports during the period 1914-1918 averaged 89,000 tonnes a year compared with an average of 46,000 tonnes a year during the period 1910-1913. During the years 1910-1915 and in 1919 a very large proportion of United States chromite supply was derived from imports, and even during the years 1916-1918 when production of chromite by the United States increased tremendously chromite imports were greater than domestic production. This was despite a shortage of shipping during the years 1916-1918, and a supposed prohibition against chromite imports by water after April 1918. However, these factors contributed to the fact that chromite imports by the United States reached their highest level for the decade in 1916 whereas chromite production by the United States was at its greatest in 1918. Nevertheless, United States chromite imports in 1918 amounted to 102,000 tonnes, and were greater than the record domestic chromite production of 84,000 tonnes.

During the period 1910-1919 the United States was the largest chromite importing country in the world, and accounted for more than half of world chromite imports during the decade. A large proportion of United States chromite imports during the period came from Zimbabwe, New Caledonia, and Canada as discussed earlier.

Europe

Even though detailed information on world chromite consumption and imports is not available for the period 1910-1919, it appears that chromite consumption outside the United States took place mainly in western Europe. Statistics given by Rumbold (1921) on the destination of chromite exports by Zimbabwe, New Caledonia, and India, which accounted for a large proportion of world chromite exports during the decade, indicated that chromite exports other than those to the United States went to countries in western Europe including the United Kingdom, France, Norway, Germany, and Italy. These countries were not chromite producers and their supply of chromite depended on imports.

FERROCHROMIUM

Detailed information is not available on international trade in ferrochromium during the period 1910-1919. However, it appears that world ferrochromium production during the period was located in Europe and North America, and that relatively little trade in ferrochromium took place between these continents. The extent and details of international trade within Europe is not known.

According to Of (1913) the price of ferrochromium was regulated by an international ferrochromium syndicate that embraced all the important European producers. American ferrochromium producers were not included in the syndicate as their small production was absorbed domestically, and imports of ferrochromium into the United States were subject to a tariff of 25%. However, despite the tariff, ferrochromium imports by the United States in 1912 amounted to around 440 tonnes and much of these imports came from France.

During the war there was increased demand for ferrochromium, and in both the United States and the United Kingdom its consumption was subject to government instructions (Dolbear, 1918). In the United States the main consumers of special steels and other products made using ferrochromium were automobile manufacturers and munitions makers, and the War Industries Board instructed ferrochromium producers that their output was to be devoted to government purposes. The ferrochromium manufacturer Electro-Metallurgical Co of Niagara Falls was one of the largest consumers of chromite in the United States (Dolbear, 1919) so it is clear that domestic production of ferrochromium in the United States increased greatly during the war.

It is not known whether any ferrochromium was imported into the United States during the war. However, in 1919 ferrochromium imports by the United States amounted to 421 tonnes as recorded in Johnston (1926), and these were around the same level as imports in 1912. During both 1912 and 1919 ferrochromium imports by the United States were small compared with chromite imports, which amounted to 55,000 tonnes and 62,000 tonnes respectively in those years as seen in Of (1913) and Dolbear (1920).

Chapter 5

TRADE AGGREGATES 1920-1929

An examination of the geographical distribution of world chromite production, exports, and imports during the period 1920-1929 shows that a large proportion of world chromite production took place in Zimbabwe, New Caledonia, and India, and that these countries exported almost their entire production. Further, a large proportion of world chromite imports during 1920-1929 were made by the United States, Germany, and the United Kingdom, and these countries were not chromite producers of any consequence. In addition, a number of other countries were involved on a smaller scale in the export and import of chromite during the period. These observations indicate the tremendous importance of international trade in the chromium industry during the decade.

CHROMITE PRODUCTION AND EXPORTS

The geographical distribution of world chromite production during the period 1920-1929 is given in terms of tonnage and percentage in Tables 4 and 14. Zimbabwe was by far the largest chromite producing country in the world during 1920-1929, and its level of production showed a dramatic increase as the decade progressed as seen in Table 4. Both New Caledonia and India were large chromite producers throughout the decade, while significant chromite production was recorded also by Greece and Turkey. During the second half of the decade substantial quantities of chromite were produced by Cuba, Soviet Union, South Africa, and Yugoslavia (Table 4). Total world chromite production averaged 318,000 tonnes a year during the decade 1920-1929, and rose continuously from 136,000 tonnes in 1922 to a record of 635,000 tonnes in 1929. During the decade Zimbabwe, New Caledonia, and India together accounted for almost 70% of total world chromite production.

The distribution of world chromite exports by country of origin during the period 1920-1929 is shown in terms of tonnage and percentage in Tables 22 and 30. Zimbabwe, New Caledonia, and India were the largest chromite exporting countries in the world during 1920-1929, and these three countries together were responsible for a large proportion of world chromite exports during the decade. Chromite exports by Zimbabwe increased tremendously during the decade to reach a record of 255,000 tonnes in 1929 (Table 22), and during each of the years 1922-1929 Zimbabwe accounted for more than 50% of world chromite exports (Table 30). Other chromite exporting countries during the decade included Greece, Yugoslavia, and South Africa (Table 22).

Zimbabwe

At the beginning of the decade 1920-1929 the operating chromite mines in Zimbabwe were located mainly in the Selukwe district (Dolbear, 1921). The chief chromite producers at Selukwe were Rhodesia Chrome Mines Ltd and the Rhodesia Metals Syndicate Ltd. These were associated ventures, and their mines were serviced by railway facilities.

During 1920 chromite exports by Zimbabwe amounted to 75,000 tonnes (Table 22) compared with chromite production of 55,000 tonnes (Table 4). According to Dolbear (1922) much of the ore exported during 1920 was mined during the war, but not shipped at that time due to a lack of shipping bottoms, and this explained the excess of exports over production. Chromite exports by Zimbabwe to the United States during 1920 were 40,000 tonnes and comprised 53% of total chromite exports by Zimbabwe in that year.

Zimbabwe was the largest chromite producing country in the world during each of the years 1921-1929, and during this period its production expanded tremendously from 46,000 tonnes in 1921 to 266,000 tonnes in 1929 (Table 4). By June 1921 the price of chromite had fallen so greatly and demand for chromite was so low that production from the Selukwe mines ceased (Roush, 1923), and this accounted for the drop in production and exports by Zimbabwe during 1921 (Tables 4 and 22). However, in May 1922 production was resumed when demand for chromite increased again following the exhaustion of stocks accumulated during the boom period associated with the war.

The Selukwe chromite deposits were enormous and the facilities for cheap working were excellent (Roush, 1923). The two associated companies operating in the Selukwe district, namely Rhodesia Chrome Mines Ltd and Rhodesia Metals Syndicate Ltd held claims in other parts of Zimbabwe also, and their deposits were of such variety that they were in a position to supply almost any grade of chromite ore, both hard and fines, of a character suitable for any of the uses to which chromite was put. However, most of the chromite produced by Zimbabwe continued to come from the Selukwe district (Johnston, 1925).

Large chromite deposits had been discovered in the Umvukwes Range as described previously, and these occurred within the Great Dyke of Zimbabwe. As reported by Johnston (1925) there was agitation by the Rhodesian Base Metals Co, which held the Umvukwes Range deposits, for the construction of a branch line from the Lomagundi railway to service the deposits. Without such a railway the development of the Umvukwes Range deposits was impeded due to the high cost of haulage of ore by wagon to the existing railway. However, the company was unable to guarantee a sufficient tonnage of traffic to convince the government to construct a branch line to the deposits.

According to a personal communication dated February 1925 from H.B. Maufe, Director of the Geological Survey of Rhodesia, quoted by Johnston (1926) production of chromite from the Great Dyke had hitherto consisted of ore derived from outcrop workings to a depth of around four metres situated within twenty four kilometres of the railway. The supply of ore obtainable under such conditions was limited, and the prevailing rate of production could not be maintained for long. Under the existing conditions of price and operating costs, it was not profitable to mine potentially large supplies of ore available at a greater distance from the railway or obtainable by underground mining methods.

During 1924 chromite production by Zimbabwe rose sharply to 157,000 tonnes (Table 4) and represented 55% of world chromite production (Table 14). The rise in production was associated with increased demand for chromite. However, in 1925 chromite production by Zimbabwe dropped to 123,000 tonnes, and this decrease in output was due (Johnston, 1920) to an extraordinarily wet season in the early months of the year that resulted in wash-outs along the Beira railway and prevented the transport of ore. In 1926 chromite production by Zimbabwe increased again to reach 164,000 tonnes, and Zimbabwe continued to be the dominant chromite producing country in the world (Table 4).

From 1924 intense prospecting activity for chromite took place in Zimbabwe (Johnston, 1926 & 1927), and this resulted in increased chromite output by Zimbabwe. During 1925 a record of 64,000 claims were pegged, and interests associated with the Vanadium Corporation of America acquired an option to purchase 5,000 claims in the Banket-Darwendale area of the Lomagundi railway north of Harare. As recorded by Charles River Associates Inc (1970) Union Carbide and Vanadium Corporation (which later became part of the Foote Mineral Group) acquired their chromite mining rights in Zimbabwe in the 1920's, and in consequence became integrated ferrochromium producers. This established chromium industry links between Zimbabwe and the United States.

The chromite deposits of Zimbabwe were of two types as described in Johnston (1929). First, those as in the Selukwe district of Matabeleland, which occurred as irregular though often lens-shaped bodies in talc schists and serpentine. The ore in these deposits contained 45-50% Cr_2O_3, and was utilized in the production of ferrochromium for steel making. Deposits of this type also occurred in Mashonaland. Secondly, those as in the Umvukwes Range, which occurred as regular seams 10 cm to 25 cm wide in the basic and ultrabasic rocks of the Great Dyke. The ore in these deposits contained in excess of 50% Cr_2O_3, and was utilized in the chemical industry. These two types of chromite deposits are designated "podiform" and "stratiform" (Chapter 1).

The Great Dyke of Zimbabwe was found to extend over a length of 530 kilometres and to have a width of around 6.5 kilometres (Johnston, 1927). Chromite seams did not occur over the whole length of the dyke, but only in certain sections of it. However, actual outcrop workings proved that an individual seam of chromite could have a length of 10 kilometres in outcrop, and prospecting suggested it might extend for 32 kilometres. It was clear the Great Dyke contained an enormous tonnage of high-grade chromite. According to Johnston (1928) the principal factor operating to limit the production of chromite from the Great Dyke was the cost of haulage to the railhead, and as stated in Johnston (1929) there was much controversy over the proposed Umvukwes railway. The chromite producers wanted a railway, but were not prepared to give the guarantees required by the government because they distrusted the permanence of the market conditions then prevailing.

The economic considerations affecting the value of the chromite deposits of the Great Dyke were considered by F.E. Keep in a report of the Geological Survey of Southern Rhodesia dated December 1928 and quoted in Johnston (1929). According to Keep, the question of the economic value of the chromite deposits of the Umvukwes Range was bound up with two things, namely markets and transport. If the chromite market were able to absorb a large tonnage of ore in addition to that already produced elsewhere, the only requisite for the establishment of a large mining industry in the Umvukwes area was the provision of cheap transport. The economic depth to which mining could be carried out depended largely on the distance between the mine and the nearest loading station on the railway, and a decrease in road transport costs to the railhead could result in a huge tonnage of previously unexploitable chromite becoming of economic value.

It was reported (Johnston, 1930) that the Zimbabwe government was to build a railway to the chromite deposits on the Great Dyke. The decision was made in mid-

1929 at a time there was a danger of better quality chromite ore from Zimbabwe being displaced by lower grade ore from South Africa simply because of the lack of transport facilities. It appeared that South African ore containing less than 45% Cr_2O_3 could be railed from Steelpoort and Boshoek to the port of Lourenco Marques much more cheaply than Zimbabwean ore could be railed to Beira, and in addition to railway freight Zimbabwean ore from the Great Dyke had to bear enormous charges for wagon transport to the railhead. Even though the level of chromite production by South Africa at the time was not great, there was a possibility of it increasing considerably. As stated in Johnston (1931) the Umvukwes railway was completed in 1930. The railway was constructed to serve the western side of the Umvukwes Range, and crossed and recrossed the chromite reefs along its whole length. It was expected the decrease in cost of transportation would result in a large tonnage of hitherto useless chromite becoming economically valuable.

During 1929 chromite production in Zimbabwe reached a record level of 266,000 tonnes, which amounted to almost five times its chromite production in 1920 (Table 4), while chromite exports by Zimbabwe in 1929 were 255,000 tonnes (Table 22) and represented 58% of world chromite exports (Table 30). The larger part of chromite production by Zimbabwe during 1929 came from the Selukwe district (Johnston, 1930), and Zimbabwe continued to produce far more chromite than any other country in the world (Tables 4 and 14). The importance of the Selukwe district in world chromite production resulted from the availability of enormous reserves of good grade chromite that could be mined at low cost and transported using established railway facilities.

<u>New Caledonia</u>

During 1920 New Caledonia was the largest chromite producing country in the world with an output of 92,000 tonnes (Table 4), and its production accounted for 39% of world production (Table 14). However, chromite production by New Caledonia dropped to 11,000 tonnes in 1922 and amounted to 8% of world production in that year. Even though New Caledonian chromite production increased to 57,000 tonnes in 1928 and 53,000 tonnes in 1929 (Table 4), its chromite production during the years 1922-1929 ranged between 8% and 12% of world production and in 1929 amounted to only 8% of world production as in 1922 (Table 14). During 1920 New Caledonian chromite production was 92,000 tonnes compared with Zimbabwean production of 55,000 tonnes, whereas in 1929 chromite production by New Caledonia was 53,000 tonnes compared with production by Zimbabwe of 266,000 tonnes. In 1929 chromite production by New Caledonia amounted to only one fifth that of Zimbabwe.

The largest chromite producer in New Caledonia was the Tiebaghi mine located at Paagoumene on the northwest coast, and prior to 1921 total chromite production from the Tiebaghi mine amounted to about 725,000 tonnes (Dolbear, 1922). During 1920 New Caledonian chromite exports were 92,000 tonnes (Table 22), and of these 59,000 tonnes came from the Tiebaghi mine (Johnston, 1931). The United States was the major recipient of New Caledonian chromite exports in 1920, and accounted for 87,000 tonnes out of total exports of 92,000 tonnes as reported in Dolbear (1922). It was also reported that the Lucky Hit mine at Plum and the Anna Madeleine mine at Carenage had been reopened. These two mines were closed for fifteen years under an agreement with the owners of the Tiebaghi mine.

According to Roush (1923) the Tiebaghi mine was unable to provide its usual large supply of chromite while considerable non-productive development was carried out in consequence of the way the mine had been worked in the past, and this would have contributed to the low chromite production of 11,000 tonnes by New Caledonia in 1922 (Table 4). However, it was reported by Roush (1924) that chromite exports by New Caledonia to the United States in 1923 were around 13,000 tonnes, which were almost the same as in 1922. This represented a large decrease compared with exports to the United States in 1920 amounting to 87,000 tonnes, and it appeared (Roush, 1924) that the steel companies were no longer willing to pay the price set for New Caledonian chromite, but were buying cheaper ore from Zimbabwe. It was recorded also by Roush (1924) that New Caledonian chromite exported to the United States was being used principally for making chemicals, and that the cost of putting this ore on the United States market was high. Subsequently, it was reported by Johnston (1926) that chromite was no longer being exported by New Caledonia to the United States due to the economic advantage of Zimbabwe. During 1924 and 1925 there was a gradual change in the type of chromite used by the chemical industry in the manufacture of bichromate, and demand shifted from New Caledonian chromite ore to the high-grade soft ore from Zimbabwe. Thus, within five years the major market for New Caledonian chromite was lost as a result of competition from Zimbabwe, although the loss was mitigated to some extent by increased exports to Europe.

However, during 1925 a large United States consumer of chemical grade chromite acquired a new mine in New Caledonia, built a loading pier, and in 1926 started shipping ore (Johnston, 1927). In consequence of this acquisition United States chromite imports from New Caledonia increased from 2,000 tonnes in 1925 to 11,000 tonnes in 1926, while total chromite exports by New Caledonia rose from 18,000 tonnes in 1925 to 24,000 tonnes in 1926 (Table 22).

Chromite exports by New Caledonia continued to increase and rose to 59,000 tonnes in 1929. During the years 1927-1929 the greater part of its exports went to Europe, although United States chromite imports from New Caledonia increased from 14,000 tonnes in 1928 to 24,000 tonnes in 1929 (Johnston, 1930).

It was reported by Johnston (1929) that in 1928 a new export tax was imposed on New Caledonian chromite. The basic rate was 10% ad valorem at the port of exportation, but was reduced to 9%, 8%, 7%, 6%, and 5% if total exports for the preceding year exceeded 24,000 tonnes, 28,000 tonnes, 32,000 tonnes, 36,000 tonnes, and 40,000 tonnes respectively. As total chromite exports by New Caledonia in 1927 were in excess of 40,000 tonnes, the 1928 export tax was at the rate of 5%. It seems surprising such an export tax was levied at a time New Caledonian chromite was being subjected to severe competition by Zimbabwe, particularly as the tax in effect added to the cost of New Caledonian exports and was not dependent on profitability. However, the competitive disadvantage imposed by the tax was reduced to some extent by its regressiveness, which in a back-handed way acted as an incentive to increased production.

During 1928 there were a number of chromite producers in New Caledonia as listed in Johnston (1929). Of these the largest producers were Societe la Tiebaghi, which operated the Tiebaghi mine at Paagoumene, and Societe Chimique du Chrome, which operated the Fantouche and Alpha mines also located at Paagoumene. Mining at the Tiebaghi property had passed the open-cut stage, and the use of underground mining methods required to obtain ore at greater depth increased mining costs. According to Johnston (1931) chromite exports by Societe la Tiebaghi and Societe Chimique du Chrome during 1929 amounted to 27,000 tonnes and 20,000 tonnes respectively, and these two producers together accounted for chromite exports in 1929 of 47,000 tonnes compared with total chromite exports by New Caledonia of 59,000 tonnes (Table 22). During 1929 chromite exports by New Caledonia amounted to 13% of world chromite exports compared with 58% of world exports provided by Zimbabwe (Table 30).

India

During the period 1920-1929 chromite production by India varied between 23,000 tonnes as in 1922 and 58,000 tonnes as in 1927 (Table 4), and accounted for 13% of world chromite production during the decade. A large proportion of the chromite produced by India was exported, although some chromite was consumed domestically by the tanning industry in which chromium chemicals were used to inhibit the absorption of moisture by leather.

It was reported by Roush (1923) that in consequence of railway construction in 1917 the chromite deposits in Baluchistan were yielding a large output. Much of the Baluchistan ore contained 50-53% Cr_2O_3 and was low in silica. According to Roush

(1924) almost the entire chromite production by India in 1922 came from Baluchistan. However, during 1923 there was greatly increased chromite production in Mysore, and chromite from that field was exported to the United States for use as a refractory. Although chromite from both Baluchistan and Mysore was exported to the United States, there was a decrease during 1924 in United States chromite imports from Baluchistan (Johnston, 1925) due to the diversion of ore from that field to European markets for use in the chemical industry.

The chromite mines in Baluchistan were controlled by a syndicate of British capitalists (Johnston, 1926), and during 1925 chromite exports from Baluchistan amounted to 29,000 tonnes, all of which went to countries in Europe including the United Kingdom and Sweden. Subsequently, it was reported (Johnston, 1928) that the Baluchistan chromite deposits were nearing depletion. However, chromite production by India increased from 34,000 tonnes in 1926 to 58,000 tonnes in 1927 (Table 4), and this large rise in production resulted from increased mining activity in Mysore (Johnston, 1929). During 1928 and 1929 there was a rise in chromite exports by India to the United States, probably in consequence of the increased production in Mysore, and in 1929 exports to the United States amounted to 21,000 tonnes (Johnston, 1930).

During the decade variable quantities of chromite were produced by India in both Baluchistan and Mysore, and Indian chromite exports went to both Europe and the United States. However, the relative importance of India as a chromite exporting country tended to decline as the decade progressed, and its share of world exports decreased from a peak of 35% in 1922 to 7% in 1929 (Table 30).

Greece

Chromite production by Greece during the period 1920-1929 averaged 15,000 tonnes a year and represented 5% of world production during the decade. Greek chromite production reached its highest level of 24,000 tonnes in 1929 (Table 4), and comprised 4% of world production in that year (Table 14). In 1929 chromite exports by Greece amounted to 20,000 tonnes and represented 5% of world exports (Tables 22 and 30).

According to Johnston (1929) Greek chromite production came principally from Thessaly and the Khalkidike peninsula. The ore contained between 38% and 40% Cr_2O_3, and was used mainly for refractories. Most of the chromite mined in Greece was exported to the United States (Johnston, 1925), and the chromite mines were operated by United States interests (Johnston, 1926).

Yugoslavia

Chromite production by Yugoslavia rose from less than 500 tonnes in 1924 to 43,000 tonnes in 1929 (Table 4), and in 1929 Yugoslavian chromite production amounted to 7% of world production (Table 14). In 1929 chromite exports by Yugoslavia reached 21,000 tonnes and comprised 5% of world exports (Tables 22 and 30).

This shows as stated by Roush (1932) that Yugoslavia had developed into an important chromite producing country within a few years. In 1930 seven chromite mines were in operation in Yugoslavia, although Alatini Mines Ltd located near Skoplye was responsible for about 70% of total output.

South Africa

Chromite production by South Africa increased from 5,000 tonnes in 1924 to 64,000 tonnes in 1929 (Table 4), and in 1929 South Africa accounted for 10% of world chromite production (Table 14). In 1929 chromite exports by South Africa amounted to 45,000 tonnes and represented 10% of world exports (Tables 22 and 30).

In Roush (1924) reference was made to the occurrence of chromite in both the Rustenburg and Lydenburg districts of the Transvaal in South Africa. It was reported that the Rustenburg district was well known for its chromite ores, which occurred very close to the surface, but were some distance from the railway lines. The question of transport over primitive roads, especially in the rainy season, was a problem. At that time very little work had been done on the chromite properties. However, it was reported that a small development syndicate was opening up a promising lode about 32 kilometres from Rustenburg. Analysis of samples from the area showed the deposit contained up to 45% Cr_2O_3, and indicated the potential for a profitable mining venture at prevailing chromite prices. The lode covered a very large area, and other parts of the Rustenburg district were reported to be awaiting development. It was also recorded (Roush, 1924) that in the Lydenburg district three separate chromite deposits were known to exist. One outcrop showed four distinct layers of chromite with a combined thickness of 1.1 metres, and was located on a farm over which a new railway extension from Lydenburg was to pass so the question of transport would present no difficulties.

South African chromite production rose from 5,000 tonnes in 1924 to 32,000 tonnes in 1928 (Table 4). According to Johnston (1929) the grade of chromite in the South African deposits was slightly lower than that of chromite in the Zimbabwean deposits, but because of the greater width of orebodies, shorter rail haul to the port of export, and better shipping facilities enjoyed by the Transvaal ore it was possible to market chromite from South Africa at a lower price per percentage unit than chromite from Zimbabwe, and as reserves of Transvaal ore appeared to be large there was much interest in future market developments. It was reported that Transvaal producers were making every effort to supplant Zimbabwean chromite in the European and United States markets, and that they were conducting a well planned educational campaign to that end. It seemed likely that a combine would emerge from the prevailing competition whereby chromite production would be controlled and the market apportioned between the African producers.

In Johnston (1930) it was stated that the price of Transvaal chromite c.i.f. European and American ports in March 1929 was 1s 6d per unit of Cr_2O_3 compared with 2s per unit for chromite from Zimbabwe. However, it was usual for higher grade ore to command a better price. The future of Transvaal chromite depended on the ability of consumers to use the ore of lower unit price without modification to plant or method and without significant increase in processing costs. In fact, the chemical and physical properties of Transvaal chromite permitted the attainment of such a result. Trial shipments of Transvaal chromite to numerous German consumers proved that Transvaal ore required no appreciable alterations in method, and that the overall cost of using it was lower than the corresponding cost of consuming Zimbabwean ore. In consequence, these users by early 1929 had entered into contracts to purchase considerable tonnages of Transvaal ore for their future requirements. It was reported also that several large United States consumers were approaching the point they could with confidence make similar provisions for the future.

According to an article by H. Schneiderhöhn published during March 1930 in Metallwirtschaft and quoted in Johnston (1931), the Bushveld chromites in the Transvaal of South Africa had been known for a good many years, but their exploitation had taken place only since 1924. By 1930 mining was in progress in two districts, namely in the Lydenburg district in the eastern part of the Bushveld and in the Rustenburg district in the western part of Bushveld. Most of the chromite bands stretched over a length of hundreds of metres or even for kilometres without interruption, although faulting was not infrequent and could result in considerable displacement of the chromite zones. The thickness of the chromite bands varied from a few centimetres to over four metres, and usually there were two or more chromite horizons.

It was recorded also that exploration of the chromite zones in different localities of the Bushveld had been carried out, and that since 1924 there had been regular exploitation of the chromite with a steadily increasing annual production. The grade of the chromite ore ranged from 40% to 46% Cr_2O_3, and had an average content of 43% Cr_2O_3 and 28.5% Fe_2O_3. The chromite was mined by both open cut and underground methods. The ore was exported via the port of Lourenco Marques in Mozambique. Transport of the chromite to the nearest railway station was rather expensive, and an early extension of railway communication to the chromite mines was proposed. Total ore reserves were reported to be very great, and were estimated to comprise hundreds of millions of tonnes.

During 1929 chromite production by South Africa rose to 64,000 tonnes compared with 32,000 tonnes in 1928, and its production was exceeded only by that of Zimbabwe (Table 4). The huge ore reserves and competitive position of Transvaal chromite contained in the Bushveld Complex indicated that South Africa would continue to develop as a major supplier to the world market.

Soviet Union

Chromite production by the Soviet Union during the years 1920-1923 amounted to only 2,000 tonnes a year or less, but then showed a substantial increase during the years 1924-1929 and reached a record for the decade of 53,000 tonnes in 1929 (Table 4). Some chromite was exported by the Soviet Union during the years 1927-1929, and exports reached their highest level of 5,000 tonnes in 1929 (Table 22). However, during 1929 chromite exports amounted to only 9% of chromite production by the Soviet Union, and represented only 1% of total world exports.

According to Roush (1932) extensive deposits of chromite occurred in the Soviet Union in the Urals, North Caucasus, Transcaucasia, and Siberia. However, only the Ural deposits were being exploited, and these only to a limited extent. The largest of the Ural deposits were the Saranov in the Perm district with estimated reserves of around 700,000 tonnes of chromite containing 35%-42% Cr_2O_3 and the Gologorsk with reserves of around 250,000 tonnes of chromite containing 33%-50% Cr_2O_3. It was reported (Johnston, 1930) that there were very large reserves of chromite with a low Cr_2O_3 content in the Ural Mountains, but mining of these would be profitable only with the construction of numerous ore concentrating plants.

During the period following the war and revolution chromite production by the Soviet Union almost ceased as reflected in the low production figures for the years 1920-1923 (Table 4). However, chromite production began to increase again in 1924 when production amounted to 12,000 tonnes, and by 1929 production had risen to a record level of 53,000 tonnes . As observed in Roush (1932) the difference between production and exports indicated a possible domestic consumption of nearly 50,000 tonnes a year in the reviving steel, chemical, and refractory industries of the Soviet Union, which was the only industrial country of any importance in the world that had its own supply of chromite.

During 1927 the Soviet Union exported chromite for the first time in many years, and chromite exports by the Soviet Union increased from 2,000 tonnes in 1927 to 5,000 tonnes in 1929 (Table 22). Most of the exports comprised high-grade chromite containing 48% Cr_2O_3, although an experimental shipment of chromite containing 45% Cr_2O_3 was sent to the United States (Johnston, 1930). During the years 1927-1929 chromite exports by the Soviet Union comprised only 10% of its total production.

Cuba

Chromite production by Cuba increased from less than 500 tonnes in 1922 to 54,000 tonnes in 1929 as shown in Table 4. A large proportion of Cuban chromite production during the decade came from mines operated by the Bethlehem Steel Co in the Province of Camaguey, and was exported to the United States (Johnston, 1926 & 1930).

CHROMITE CONSUMPTION AND IMPORTS

During the period 1920-1929 chromite consumption continued to take place mostly in the United States and Europe. The United States accounted for considerably more than half of total world chromite consumption during the decade, while in Europe chromite consumption was located mainly in the United Kingdom, Germany, Soviet Union, Sweden, and Norway. Other than in the Soviet Union no significant quantities of chromite were produced during the decade in any of the main chromite consuming countries, and these relied almost entirely for their supply of chromite on imports from producing countries, particularly Zimbabwe, New Caledonia, India, Greece, Yugoslavia, South Africa, and Cuba.

The pattern of world chromite imports by country of destination during the period 1920-1929 is shown in terms of tonnage and percentage in Tables 73 and 80. The United States was by far the largest chromite importing country in the world during each year of the period, and accounted for 75% of total world chromite imports during the decade. Other important chromite importing countries during 1920-1929 were Germany, United Kingdom, Sweden, and Norway, and these were responsible for 9%, 8%, 4%, and 2% respectively of world chromite imports during the period. The level of total world chromite imports dropped from 182,000 tonnes in 1920 to 99,000 tonnes in 1921 then rose during the decade to a record of 439,000 tonnes in 1929 as seen in Table 73.

United States

Chromite imports by the United States jumped from 62,000 tonnes in 1919 to 153,000 tonnes in 1920, but dropped to 83,000 tonnes in 1921. Subsequently, United States chromite imports increased from 83,000 tonnes in 1921 to a record of 323,000 tonnes in 1929 (Table 73).

During the period 1920-1929 chromite production by the United States was insignificant compared with chromite imports as seen from a comparison of annual production and annual imports for the decade given in Tables 4 and 73. These statistics reveal that chromite imports by the United States during 1920-1929 averaged 172,000 tonnes a year whereas chromite production by the United States during the same period averaged less than 1,000 tonnes a year.

A study of United States chromite deposits was made during 1923 by Albert Burch and E.F. Burchard acting as a sub-committee of the Committee on Foreign and Domestic Mining Policy of the Mining and Metallurgical Society of America, and an extract from their report is contained in Roush (1924). It was concluded that the United States had ore reserves in explored territory amounting to about twelve years normal supply, and that very likely the reserves would in time be materially increased as a result of further exploration. The question then arose as to why the United States was importing chromite from foreign countries instead of using domestic resources, and it was concluded that the answer depended on grade and price. Consumers were unanimous that the chromite ores of Zimbabwe and New Caledonia were much better than most of the United States ores, and as long as most chromite consumption in the United States took place within a few hundred miles of the Atlantic seaboard it would not be possible for ore from Alaska and the mountains of the western United States to compete in price with ore imported from abroad.

The summary by Julius Klein, Director of the United States Bureau of Foreign and Domestic Commerce, of a bulletin by H.M. Hoar dated August 1924 on "World Trade in Chromite" was published in Johnston (1925). It was stated that the United States was the world's largest consumer of chromite because of being the leading country in the manufacture of ferrochromium and chromium chemicals, and consequently unrestricted trade in chromite was of prime importance to the United States steel and leather industries, which were the two principal consumers. The summary referred to the remarkable decrease in United States chromite production following the removal of import difficulties consequent to the war, and attributed the decrease in domestic production to high labour costs, the widely scattered location of deposits, remoteness from markets with resultant high transport costs, and variations in the grade of ore. These factors rendered domestic mining unprofitable as the domestic product could not compete with imported chromite, and consequently the United States depended on foreign sources of supply.

The policy conclusions in relation to chromite contained in a report dated 1925 on "International Control of Minerals" prepared by committees of the Mining and Metallurgical Society of America and the American Institute of Mining and Metallurgical Engineers were recorded in Johnston (1926). It was concluded that international mineral movements were a necessary consequence of their geographical distribution, and that this was especially applicable to chromite because it was not produced to any great extent in the countries where consumption was largest. It was further concluded that international movement of certain minerals could not be stopped by enactment, and that in the case of chromite it would require a very high tariff indeed to prevent importations into the United States because of the better grade of chromite produced abroad. This was stated to be illustrated by the fact that even the wartime restrictions on shipping did not wholly stop the importation of higher-grade foreign chromite which consumers demanded.

United States chromite imports rose from 62,000 tonnes in 1919 to 153,000 tonnes in 1920 then fell to 83,000 tonnes in 1921. According to Dolbear (1921) the increase in imports from 1919 to 1920 does not accurately reflect the increase in consumption during those two years because consumers held large stocks at the beginning of 1919, and these were largely drawn upon during the year. Further, it was recorded in Dolbear (1922) that a large part of the imports during 1920 were believed to have been placed in stock to take advantage of the low prices prevailing. The average price of ore during 1920 was around $13 per tonne compared with a price of around $37 per tonne in 1918. However, chromite prices fell further and in 1921 averaged around $8 per tonne, which was lower than the average price of around $9 per tonne in 1913 prior to the war.

According to Johnston (1931) chromite consumption by the United States rose from around 80,000 tonnes in 1921 to around 300,000 tonnes in 1929, and this increase in consumption is reflected in the rise in chromite imports by the United States from 83,000 tonnes in 1921 to 323,000 tonnes in 1929 shown in Table 73. During the period 1921-1929 chromite prices remained approximately constant at around $8-$9 per tonne, and it is significant that the world supply of chromite during the period was such that the rapid increase in demand for consumption was satisfied at constant price.

During 1922 chromite consumption in the United States was apportioned in the ratio of 40% for ferrochromium production, 35% for refractories, and 25% for chemicals (Roush, 1923). Although the relative quantities of chromite consumed by the metallurgical, refractory, and chemical industries is not known for other years of the decade, it appears there was increased consumption of chromite by each of these industries as the decade progressed. Chromite imports by the United States increased sharply from 220,000 tonnes in 1928 to 323,000 tonnes in 1929 (Table 73), and this large increase in imports reflected (Johnston, 1930) the growing importance of chromium alloy steels, refractories, chromium chemicals, and chromium plating.

Reference was made by Roush (1923) to the growing importance of chromium steels, and particularly of the high-chromium stainless steels that contained 13-15% Cr, while in Johnston (1925) it was stated that the greater part of chromite imported into the United States finds its way into stainless steel and iron, chromium-nickel steel, and an increasing number of other alloys. A comprehensive tabulation of the commercial classification of chromium alloys prepared by C.E. MacQuigg is included in Johnston (1927) on page 108. This shows the principal properties and some typical applications of chromium alloys containing various percentages of chromium. According to Roush (1932) it was the chromium alloy developments, particularly of the stainless steels and irons, that were responsible for the rapid increase in the world's chromite output during the previous few years.

Regarding the use of chromite as a refractory it was recorded in Johnston (1925) that substitution of magnesite brick by chromite brick had resulted from the tariff on magnesite, but the success of chromite indicated it could compete with duty-free magnesite. No duty was imposed on chromite entering the United States. It was stated (Johnston, 1927) that the use of chromite refractories for open-hearth furnaces had become more general, and that no longer was the use of chromite refractories attributable solely to the tariff on magnesite because the neutral character and higher melting point of the chromium product had been important factors in securing its utilisation. The continued popularity of chromite refractories was reported by Johnston (1930).

Considerable quantities of chromite were consumed in the manufacture of chromium chemicals including the bichromates of sodium and potassium, which were used in the tanning and other industries (Johnston, 1926). Further, during 1926 chromium plating was firmly established on a manufacturing basis, and one of the General Motors automobiles made its appearance with a chromium-plated radiator. However, while chromium plating was highly important as a technical development, it did not require large tonnages of chromium (Roush, 1932).

Europe

The main chromite importing countries in Europe during the period 1920-1929 were Germany and the United Kingdom, although Sweden and Norway also imported significant quantities of chromite as shown in Table 73. However, chromite imports by these countries were much less than chromite imports by the United States.

Chromite imports by the United Kingdom recorded their highest level for the decade in 1929 when imports were 28,000 tonnes, while chromite imports by Germany, Sweden, and Norway reached their highest levels for the decade in 1928 when imports were 47,000 tonnes, 28,000 tonnes, and 13,000 tonnes respectively (Table 73). By comparison United States chromite imports in 1929 recorded a record for the decade of 323,000 tonnes.

It is evident from the discussion by Rumbold (1921) on the distribution of world chromite resources that the United Kingdom, Germany, Sweden, and Norway did not possess any known chromite deposits of economic consequence, and this is supported by the absence of any significant chromite production by these countries during the period 1920-1929 as seen in Table 4. Consequently, these countries relied on imports for their supply of chromite.

During 1920-1929 the United Kingdom and Germany contained the great industrial centres of western Europe, and this accounted for the demand for chromite by these countries. In the case of Sweden and Norway demand for chromite came from the ferrochromium industry, which was located in these countries as a result of the availability of low-cost hydroelectric power as indicated by Charles River Associates Inc (1970). The Soviet Union was also an important consumer of chromite during the second half of the decade as discussed earlier, but its demand for chromite was satisfied by domestic production.

FERROCHROMIUM

During the period 1920-1929 world ferrochromium production was located in North America and Europe, and the United States was the largest producer and consumer of ferrochromium in the world (Johnston, 1925). Although detailed information on international trade in ferrochromium during the decade is not known, it appears that not much trade in ferrochromium took place between the continents of North America and Europe.

New tariff rates on ferrochromium imported into the United States came into effect in September 1922 (Roush, 1923). The duty on ferrochromium containing 3% carbon or more was set at 3½ cents per pound based on chromium content while the duty on ferrochromium containing less than 3% carbon was 30% ad valorem. By contrast, there was no duty on chromite entering the United States. In the case of ferrochromium containing 3% or more carbon and 67% Cr the duty of 3½ cents per pound amounted to around $52 per tonne of ferrochromium, while in the case of ferrochromium containing less than 3% carbon the price and consequently the ad valorem duty increased as the carbon content decreased. Although it is not known to what extent the duty on ferrochromium reduced imports, it is known that the level of ferrochromium imports by the United States during the decade was relatively small.

Statistics on ferrochromium imports by the United States during the period 1920-1929 recorded in Roush (1924) and Johnston (1930) show that the volume of imports was greatest in 1920 when it amounted to 1,779 tonnes at an average price of $241 per tonne, and indicate that a large proportion of the imports during the decade comprised ferrochromium containing less than 3% carbon. United States ferrochromium imports during 1920-1929 averaged 774 tonnes a year, which were small compared with chromite imports by the United States during the decade averaging 172,000 tonnes a year.

Chapter 6

TRADE AGGREGATES 1930-1939

A large proportion of world chromite production during 1930-1939 took place in Zimbabwe, Turkey, Soviet Union, and South Africa, while New Caledonia, Yugoslavia, Cuba, India, Greece, and the Philippines were also important chromite producers during the decade. Each of these countries were also chromite exporting countries, although the Soviet Union exported only a relatively small proportion of its production and ceased to be a chromite exporter after 1935 while the Philippines did not emerge as a chromite producing and exporting country until 1935. The United States was by far the largest chromite importing country in the world during 1930-1939, although Germany, Sweden, United Kingdom, France, and Norway were also large importers of chromite during the decade. In the case of ferrochromium the largest exporting countries during 1930-1939 were Sweden and Norway while the largest importing country during the decade was the United Kingdom.

CHROMITE PRODUCTION AND EXPORTS

The distribution of world chromite production by country during the period 1930-1939 is shown in terms of tonnage and percentage in Tables 5 and 15. Among the features of the pattern of world chromite production during 1930-1939 was the rise in level of production during the decade by the Soviet Union, Turkey, and South Africa compared with a fluctuating level of production by Zimbabwe. In the case of New Caledonia, Yugoslavia, Cuba, India, and Greece a lower total chromite production for the decade was recorded and in general the level of chromite production by these countries was less variable, while after 1935 the Philippines developed rapidly into an important chromite producing country. Total world chromite production fell from 635,000 tonnes in 1929 to 299,000 tonnes in 1932 then rose to a record of 1,280,000 tonnes in 1937 after which it decreased slightly during 1938 and 1939 as seen in Tables 4 and 5.

The distribution of world chromite exports by country of origin during the period 1930-1939 is given in terms of tonnage and percentage in Tables 23 and 31. Except for the Soviet Union, which exported a smaller proportion of its chromite production than other countries and discontinued chromite exports after 1935, there was a general similarity between the pattern of world chromite exports and that of world chromite production. Zimbabwe, Turkey, and South Africa were the largest chromite exporting countries during 1930-1939, and together accounted for 60% of world chromite exports during the decade. Other large chromite exporting countries during the period included New Caledonia, Cuba, India, Greece, and Yugoslavia, while the Philippines had become a major chromite exporter by 1939 as seen in Table 23.

Zimbabwe

During 1930-1939 Zimbabwe was the largest chromite producing and exporting country in the world with average annual chromite production and exports of 130,000 tonnes and 125,000 tonnes respectively. However, during the decade the level of chromite production and exports by Zimbabwe showed large fluctuation (Tables 5 and 23).

Chromite production by Zimbabwe fell from 266,000 tonnes in 1929 to 16,000 tonnes in 1932 (Tables 4 and 5), while chromite exports by Zimbabwe dropped from 255,000 tonnes in 1929 to 35,000 tonnes in 1932 and 32,000 tonnes in 1933 (Tables 22 and 23). The dramatic decline in the level of chromite production and exports by Zimbabwe during the years 1929-1932 resulted from reduced demand for chromite associated with the Great Depression.

Chromite production by Zimbabwe in 1932 amounted to only 6% of its level in 1929, and Zimbabwe was more seriously affected by the depression than most other important chromite producing countries (Roush, 1933). In 1929 Zimbabwe accounted for 42% of world chromite production whereas in 1932 Zimbabwe was responsible for only 5% of world chromite production (Tables 14 and 15). According to Smith (1933) it appeared Zimbabwean chromite was unable to compete successfully during the depression in the world market under the lower scale of prices prevailing, and it was reported that producers in 1932 were seeking a reduction in railway freight rates from mine to seaport in order that their chromite might compete more effectively in the world market. The decrease in chromite exports by Zimbabwe during 1929-1932 was attributed largely to decreased exports to the United States and United Kingdom, which dropped in total from 234,000 tonnes in 1929 to around 20,000 tonnes in 1932. In Ridgway (1934) it was indicated that competition to Zimbabwean chromite exports during 1932 and 1933 came particularly from Turkey and the Soviet Union, while in Ridgway (1935) it was stated that Zimbabwean chromite was of good quality with grade in excess of 48% Cr_2O_3, but that costs to seaboard were rather high due to the long rail haul to the coast.

Following the depression chromite production and exports by Zimbabwe showed a marked recovery with chromite production rising from 16,000 tonnes in 1932 to 276,000 tonnes in 1937, and chromite exports increasing from 32,000 tonnes in 1933 to 259,000 tonnes in 1937 (Tables 5 and 23). In 1937 both chromite production and chromite exports by Zimbabwe exceeded the record levels of 266,000 tonnes and 255,000 tonnes respectively reached in 1929, and Zimbabwe was again the largest chromite producing and exporting country in the world. However, in 1937 Zimbabwean chromite production and exports amounted to only 22% and 26% respectively of world chromite production and exports (Tables 15 and 31) compared with 42% and 58% respectively of world chromite production and exports in 1929 (Tables 14 and 30). Thus, although by 1937 chromite production and exports by Zimbabwe had recovered to their 1929 levels, the share of world chromite production and exports contributed by Zimbabwe in 1937 was only about half that in 1929. The reduced relative importance of Zimbabwe as a chromite producing and exporting country resulted from increased chromite production and exports by other countries including Turkey and South Africa.

During 1937 a large proportion of chromite exports by Zimbabwe went to the United States, and chromite imports by the United States from Zimbabwe in that year amounted to 210,000 tonnes (Table 87). According to Brazeau (1938) the bulk of Zimbabwean chromite imported by the United States was of high grade metallurgical quality, and the Selukwe chromite mines were reported to be working at full capacity. Further, the Zimbabwean government had assisted other producers to commence operations, and considerable interest was aroused towards the examination and exploitation of new properties previously considered too far from rail heads to be competitive.

However, during 1938 and 1939 chromite production by Zimbabwe dropped sharply from 276,000 tonnes in 1937 to 139,000 tonnes in 1939 (Table 5), while chromite exports by Zimbabwe decreased dramatically from 259,000 tonnes in 1937 to 108,000 tonnes in 1939 (Table 23). In 1939 chromite exports by Zimbabwe amounted to only 13% of world exports compared with 26% of world exports in 1937 (Table 31).

The decrease in chromite exports by Zimbabwe during 1938 and 1939 was reported in Brazeau (1940) to be due largely to a fall in demand for Zimbabwean ores in the United States, which was the world's chief market for chromite. United States chromite imports from Zimbabwe decreased from 210,000 tonnes in 1937 to 49,500 tonnes in 1939 (Table 87), and the share of United States chromite imports derived from Zimbabwe dropped from 37% in 1937 to 15% in 1939 (Table 88).

During 1938 there was a severe business recession in the United States (Brazeau, 1939), and total chromite imports by the United States dropped from 563,000 tonnes in 1937 to 358,000 tonnes in 1938 and 323,000 tonnes in 1939 (Table 74). Further, as recorded in Brazeau (1940), increased demand for lower grade chromite ore at cheaper prices from Cuba and the Philippines for refractory use, as well as tougher competition from South Africa and Turkey in chemical and metallurgical ore, contributed to the reduction in chromite output by Zimbabwe.

Chromite production by Zimbabwe continued to come from both the Selukwe district and the Great Dyke (Brazeau, 1941). The chromite deposits in the Selukwe district were among the largest in the world, and provided the bulk of Zimbabwean chromite production. The other important source of chromite production by Zimbabwe was the Great Dyke, and the greater part of production from this came from the vicinity of Harare (then Salisbury). Most of the chromite produced by Zimbabwe was high grade and suitable for metallurgical, chemical, or refractory use. The main difficulty was the long expensive single track rail haul from the chromite mines to the port of Beira in Mozambique.

Turkey

During the period 1930-1939 chromite production and chromite exports by Turkey each averaged 122,000 tonnes a year. However, the level of both chromite production and chromite exports by Turkey showed a substantial rise during the decade. Turkish chromite production rose continuously from 25,000 tonnes in 1931 to 214,000 tonnes in 1938 (Table 5), while chromite exports increased from 25,000 tonnes in 1931 to 208,000 tonnes in 1938 (Table 23). During 1930 and 1931 Turkey contributed only 5% and 6% respectively of world chromite production whereas during the years 1932-1939 its share of world chromite production ranged between 15% and 19% of world production (Table 15), while the share of world chromite exports provided by Turkey rose from 7% in 1930 to 32% in 1933 then ranged between 20% and 30% of world exports during the years 1934-1939 (Table 31). During each of the years 1932-1935 and 1938-1939 Turkey was the largest chromite exporting country in the world, while during 1936 and 1937 its exports were exceeded only by those of Zimbabwe.

It was reported (Roush, 1934 & Ridgway, 1934) that in order to encourage chromite production the Turkish government in 1932 effectively reduced the existing tax of 10% on chromite exports. The reduction took the form of a tax rebate on a sliding scale related to the level of production. Based on 1931 production figures, a reduction of 50% in output would retain the 10% tax rate, but a drop in output of only 25% would reduce the tax rate to 7.5% while maintenance in the level of output would reduce the tax to 5%. An increase in output of 25% reduced the tax to 2.5%, while an increase of 50% cut the tax to 1%. The introduction of the export tax rebate provided an incentive to increase chromite production and exports, and tended to make Turkish chromite more competitive in the world market. Turkish chromite production increased from 25,000 tonnes in 1931 to 150,000 tonnes in 1935, and according to Roush (1936) the Turkish chromite industry had been fostered by the tax rebate.

From the beginning of 1936 a new system of tax rebates was introduced (Roush, 1936). The rebate to each producer was related to the increase in output over the 1932 level. An increase of 150% entitled the producer to a full tax rebate while there was a decreasing scale of rates down to a rebate of 37.5% for an increase in output of 75%. The increase in Turkish chromite output from 1932 to 1935 was such that the export tax in 1936 would have fallen only on a few small producers. However, it was stated by Ridgway (1940) that the system of tax rebates appeared to have been cancelled in 1937.

Prior to 1937 most Turkish chromite production came from the Marmaris-Fethiye, Eskisehir, and Dagardi districts in the western part of the country (Ridgway, 1940), and the chief chromite producers were Societe Miniere de Fethiye and Turk Maden Sirketi (Brazeau, 1938). Of these the Fethiye company supplied the bulk of Turkish chromite production. However, in 1937 the newly discovered Guleman deposits located in the Elazig district of eastern Anatolia came into production (Brazeau, 1938), and by 1939 these deposits had become the largest source of Turkish chromite (Brazeau, 1940). The Guleman mines were operated under the control of Etibank, which was owned by the Turkish government. During the period 1937-1939 the Guleman deposits were an important factor in the expansion and maintenance of Turkish chromite production and exports, which reached record levels of 214,000 tonnes and 208,000 tonnes respectively in 1938 (Tables 5 and 23).

According to Ridgway (1940) the Elazig district was rapidly becoming one of the most important chromite mining centres in the world. Chromite from the Guleman deposits within this district was mined by opencut methods. Ore from the various workings was assembled at the head of an aerial tramway, which connected with the Ergani-Diyarbekir Railway at Erganimaden situated about 32 kilometres away. From Erganimaden the chromite was moved by rail to the port of Mersin, a distance of 630 kilometres, and at Mersin the ore was transferred by lighter to steamers for export. The ore was lumpy and of good metallurgical grade. Typical analyses showed the Guleman ore contained around 50-52% Cr_2O_3 and had a chromium-iron ratio in excess of 3:1. Such chromite ore was among the best in the world for the production of ferrochromium.

South Africa

Chromite production by South Africa averaged 92,000 tonnes a year during the period 1930-1939, but varied between a low of 14,000 tonnes in 1930 and a high of 177,000 tonnes in 1938 (Table 5). During 1938 South Africa contributed 16% of world chromite production compared with 2% of world production in 1930 (Table 15).

South African chromite production and exports were adversely affected by the Great Depression. Chromite production by South Africa dropped from 64,000 tonnes in 1929 to an average of 19,000 tonnes a year during 1930-1932, while chromite exports fell from 45,000 tonnes in 1929 to an average of 22,000 tonnes a year during 1930-1932. However, by 1934 both production and exports of chromite by South Africa had recovered to around their pre-depression levels (Tables 5 and 23).

A controlling interest in Chrome Corporation of South Africa Ltd, a major South African chromite producer, had been purchased in 1932 by African Chrome Mines Ltd (Roush, 1932 & Smith, 1933). This British company was known as the Chrome Trust, and was reported to control a large proportion of the world's chromite output with mining interests in Zimbabwe, New Caledonia, and India as well as in

South Africa.

Following the depression chromite production by South Africa rose from 19,000 tonnes in 1932 to a record of 176,000 tonnes in 1936 (Table 5), while chromite exports by South Africa increased from 21,000 tonnes in 1932 to a record of 169,000 tonnes in 1937 (Table 23). The share of world chromite production provided by South Africa rose from 6% in 1932 to 16% in 1936 (Table 15), while the share of world exports contributed by South Africa increased from 10% in 1932 to 17% in 1937 (Table 31). During the rest of the decade the level and share of South African chromite production and exports continued at a high level, and in 1939 South Africa accounted for 21% of world chromite exports (Table 31).

Chromite production in South Africa took place in the Rustenburg and Lydenburg districts of the Transvaal (Ridgway, 1936), and South African chromite mining was virtually controlled by two producers, namely the African Mining & Trust Company Ltd and the Chrome Corporation Ltd. The African Mining & Trust Company Ltd was the largest producer and operated in both the Lydenburg and Rustenburg districts from which it supplied several grades of chromite including both friable ore and hard lumpy ore, while the Chrome Corporation Ltd operated in the Lydenburg district and supplied both friable ore and hard lumpy ore. The grade of ore produced by these companies varied between 49.6% Cr_2O_3 and 44.5% Cr_2O_3 (Ridgway, 1936).

The South African chromite deposits were located in the basic rocks of the Bushveld Complex, and comprised an eastern belt in the vicinity of Lydenburg and a western belt near Rustenburg. According to Ridgway (1938) the chromite deposits of the Bushveld Complex were extensive, and contained estimated total reserves of around two hundred million tonnes of which at least forty million tonnes were potentially exploitable under the economic conditions then prevailing.

Transvaal chromite ores were not suitable for metallurgical purposes due to their high iron content, but the friable ore was very satisfactory for chemicals and the lump ore was used as a refractory (Brazeau, 1938). The chief use for Transvaal chromite ore was in the chemical industry (Brazeau, 1939). However, during 1938 Transvaal 48% Cr_2O_3 run of mine and washed ores were being used in the metallurgical industry in Germany by blending with high grade low-iron Turkish ore, and some South African chromite was also exported to Canada for metallurgical use.

It was reported by Brazeau (1940) that in recent years Germany had a commercial agreement under which she took large amounts of Transvaal chromite ore. However, with the outbreak of war on 3rd September, 1939, the German market was immediately cut off. Despite this, chromite exports by South Africa to Germany during the first eight months of 1939 amounted to 48,800 tonnes comprising 29% of its exports in that year as seen in Tables 39 and 40. According to Ridgway (1936) the trade agreement with Germany was made in 1935 and facilitated payment in blocked reichmarks, which permitted increased chromite exports by South Africa to Germany.

During the decade measures adopted by the South African government played some part in the development of the chromite industry. It was reported in Roush (1936) that the government was paying chromite producers a subsidy of 7% of the value of ore at the port of shipment, although this was reduced to 5% on 1st August, 1935, and further similar reductions were to be made on the same date in 1936 and 1937. The existence of this subsidy assisted the South African chromite industry during its period of expansion.

The chief factor contributing to the cost of South African chromite was the distance from the mines to seaboard (Brazeau, 1938). The port of export of most Transvaal ore was Lourenco Marques, which was about 571 kilometres from Steelpoort in the eastern belt and 784 kilometres from Tussenin in the western belt. In order to assist the chromite industry the South African government in 1937 reduced rail freight rates from Steelpoort to Lourenco Marques by 28% and from Tussenin to Lourenco Marques by 22%, and according to Ridgway (1939) these reductions in rail freight rates to the port of export aided the competitive position of South African chromite. A large proportion of chromite exported by South Africa went to the United

States and Germany, which were the two largest chromite importing countries in the world during the decade (Table 74).

Soviet Union

Although the Soviet Union was one of the largest chromite producing countries in the world during the period 1930-1939 (Table 5), it exported only a relatively small proportion of its production and ceased to be a chromite exporting country after 1935 as seen by a comparison between production and exports (Tables 5 and 23). Chromite exports by the Soviet Union reached their maximum level for the decade of 41,000 tonnes in 1933 (Table 23), and in that year represented 14% of world chromite exports (Table 31).

In Roush (1934) it is stated that chromite reserves in the Urals region of the Soviet Union were estimated at six million tonnes, but as reported by Ridgway (1935) the chromite deposits of the Ural Mountains contained only about 40% Cr_2O_3 whereas only high grade chromite ores were exported by the Soviet Union. The bulk of chromite production by the Soviet Union came from the Urals (Ridgway, 1935), and it was suggested that if world demand for lower grade ores were increased chromite exports by the Soviet Union would rise. According to Ridgway (1935) deposits of higher grade chromite ore were unfavourably situated with regard to transport, and in Ridgway (1936) it was stated that the region around Khalilovo in Bashkir had become the leading source of higher grade chromite in the Soviet Union. Khalilovo was located about 900 kilometres from the Black Sea port of Novorossisk, which was the principal port of export of Soviet chromite.

It was observed in Roush (1932) that the difference between chromite production and exports by the Soviet Union indicated a domestic consumption of around 50,000 tonnes a year in the reviving post-revolution steel, chemical, and refractories industries, and in Ridgway (1936) it was stated that chromite exports by the Soviet Union had declined due to increased domestic demand. As recorded in Table 23 chromite exports by the Soviet Union fell from their peak of 41,000 tonnes in

1933 to 11,000 tonnes in 1935 then ceased completely. In contrast, chromite production by the Soviet Union rose from 62,000 tonnes in 1932 to 217,000 tonnes in 1936 as seen in Table 5, and with the absence of exports indicated that domestic consumption by 1936 had increased to around 200,000 tonnes a year.

Philippines

Prior to 1935 the Philippines was not a chromite producing country. However, during the latter half of the decade its chromite production and exports rose rapidly from 1,000 tonnes in 1935 to 127,000 tonnes in 1939 (Tables 5 and 23), and in 1939 the Philippines accounted for 15% of world chromite exports (Table 31).

In Roush (1934) reference was made to the discovery of a chromite deposit on the island of Luzon in the Philippines, and in Roush (1936) it was reported that two chromite deposits in the Philippines were being developed and operated by Benguet Consolidated Mining Co under contract from Consolidated Mines Inc and the Florannie Mining Co respectively that owned the deposits. The deposits were located at Masinloc on the west coast of Luzon and at Florannie in southern Luzon. The Masinloc deposit was reported to be much larger, but of lower grade than that at Florannie. As recorded in Brazeau (1938) chromite ore from the Masinloc property averaged about 34% Cr_2O_3 and was being exported largely to the United States for use as a refractory, while ore produced from the Florannie deposit contained at least 48% Cr_2O_3 and was being sent to the United States for ferrochromium production. In Brazeau (1939) it was reported that the Florannie deposit had been practically exhausted, while in Brazeau (1940) it was stated that the Masinloc deposit contained about ten million tonnes of low grade refractory ore.

The discovery of chromite at Florannie and Masinloc aroused considerable interest in the Philippines as a potential source of chromite, and by 1939 several chromite deposits had been discovered and brought into production (Brazeau, 1940). Chromite exports by the Philippines in 1939 amounted to 127,000 tonnes, and were exceeded only by those of Turkey and South Africa (Table 23). The Philippines exported both refractory and metallurgical grade chromite, and exports went largely to the United States. In addition, about 13,000 tonnes of chromite produced by The Philippinas Mining Corporation, a Japanese controlled company, were exported to Japan in 1939 (Brazeau, 1940). The chromite reserves of the Philippines were chiefly of low grade, but the ore was very satisfactory for refractory purposes. In this regard it was recorded by Brazeau (1939) that low grade chromite ore from the Philippines was competing favourably with Cuban chromite in the refractory industry.

The prognosis for Philippine chromite was given in the concluding paragraph of an article published in 1939 by Dean Frasche and quoted in Ridgway (1940). According to Frasche there were in the Philippines large areas of widely scattered chrome-bearing ultrabasic rocks, which were principally confined to two belts along the eastern and western borders of the islands. He stated that the known commercially important deposits had been discovered in the more easily accessible areas within these belts, but only an insignificant part of the chrome-bearing areas had been systematically prospected. Because of poor transportation facilities and lack of development work, little information was available concerning many localities in which chromite ore was known to exist. He concluded that with the remaining large areas yet to be explored and the known existence of undeveloped chromite deposits, it was not unreasonable to assume that the Philippine Islands would become more important as a source of chromite in the future.

CHROMITE CONSUMPTION AND IMPORTS

During the period 1930-1939 a large proportion of world chromite consumption continued to take place in the United States and Europe. The United States remained the largest chromite consuming country in the world, while in Europe chromite consumption was located mainly in Germany, United Kingdom, Sweden, Norway, and France. In addition, the Soviet Union was an important chromite consuming country during the decade as discussed above. With the exception of the Soviet Union no significant quantities of chromite were produced in the main consuming countries, and these depended for their supply of chromite on imports from producing countries of which the most important were Zimbabwe, Turkey, and South Africa. In addition, substantial chromite imports were derived from New Caledonia, Yugoslavia, Cuba, India, Greece, and the Philippines.

World chromite imports by country of destination during the period 1930-1939 are given in terms of tonnage and percentage in Tables 74 and 81. Throughout the decade the United States maintained its position as the largest chromite importing country in the world, and during the decade the United States was responsible for 54% of total world chromite imports. Other substantial chromite importing countries during the decade were Germany, which accounted for 19% of world chromite imports, Sweden 8%, United Kingdom 6%, France 6%, and Norway 5%. During the decade total world imports of chromite dropped from 434,000 tonnes in 1930 to 191,000 tonnes in 1932 then rose continuously to 900,000 tonnes in 1937 after which they declined to 720,000 tonnes in 1939 as observed in Table 74.

United States

Chromite imports by the United States fell from a record of 336,000 tonnes in 1930 to 91,000 tonnes in 1932 after which they recovered to 329,000 tonnes in 1936 then reached a new record of 563,000 tonnes in 1937 from which they declined to 323,000 tonnes in 1939 (Table 74). A study of annual chromite production and chromite imports by the United States during the decade (Tables 5 and 74) shows that domestic chromite production in the United States was insignificant compared with chromite imports. During the decade United States chromite imports averaged 274,000 tonnes a year whereas chromite production averaged only 1,000 tonnes a year.

The inability of United States chromite to compete with imported chromite has been discussed previously, and it was recorded by Johnston (1931) that United States chromite ore could not be profitably marketed except in times of national emergency. In support of this contention it is interesting to observe that during 1937 when chromite imports by the United States reached a record level of 563,000 tonnes chromite production by the United States amounted to only 2,000 tonnes. During 1937 imported chromite prices showed a marked increase due in part to increased demand, but to a larger degree because of rises in ocean freight rates (Brazeau, 1938), yet chromite production by the United States in 1937 remained small compared with chromite imports.

The dramatic decline in United States chromite imports from 336,000 tonnes in 1930 to 91,000 tonnes in 1932 was a consequence of the Great Depression. The rise in chromite imports by the United States prior to 1930 arose largely from the extensive development of new alloys of chromium, particularly the stainless steels and irons (Roush, 1933). Then, during the Great Depression the demand for steel decreased and the demand for chromite dropped with it. Further, the decline in the steel industry affected both the metallurgical and refractory uses of chromite. Even though the production of stainless steels remained remarkably high compared with the low output of all steel during 1931 and 1932 (Roush, 1933), the demand for chromite suffered seriously during the depression as reflected by the sharp decline in imports.

During the years 1933-1936 chromite imports by the United States recovered from the low of 91,000 tonnes in 1932 to 329,000 tonnes in 1936 (Table 74). According to Roush (1934) much of the increased demand for chromite during 1933 as reflected in increased imports was attributable to recovery in steel production, and particularly to the increasing use of low-chromium automotive steel and high-chromium stainless steels. By 1936 continued recovery in the demand for chromite had restored United States chromite imports to their pre-depression level.

In 1937 chromite imports by the United States continued to increase, and in fact showed a sharp rise from 329,000 tonnes in 1936 to 563,000 tonnes in 1937. The rise in chromite imports during 1937 was attributed by Brazeau (1938) to various factors including increased consumption, inflationary government tendencies, strikes and labour disputes, and a threatened shortage of supplies accentuated by war scares in Europe and the Orient. The influence of these factors produced a movement by buyers to cover well ahead at advancing prices, and a large proportion of 1937 chromite imports by the United States went into stocks. Most major buyers purchased chromite in excess of their needs, and at the beginning of 1938 had on hand sufficient stocks to last for a year or longer. This situation resulted partly from their desire to avoid a threatened shortage of supplies, and partly from a sudden and severe business recession that commenced in August. At the end of 1937 chromite stocks in the United States probably exceeded 350,000 tonnes (Brazeau, 1938).

In consequence of the severe business recession in the United States during 1938 steel production declined almost 50% (Brazeau, 1939), and this affected the demand for chromite as about 85-90% of all chromite consumption in the United States was in the steel industry, where it was used either metallurgically or as a refractory. However, chromite imports by the United States during 1938 declined only 36% from the record level reached in 1937 (Table 74) so that at the end of 1938 chromite stocks in the United States were even larger than their high level at the end of 1937. As indicated in Brazeau (1939) chromite prices declined progressively during 1938 as a result of reduced demand coupled with a decrease in ocean freight rates.

The depressed economic conditions prevailing in the United States during 1938 continued during the first half of 1939 (Ridgway, 1940). However, during the latter half of 1939 there was an abrupt rise in domestic steel production, and by November the level of production reached 93% of capacity. Chromite imports into the United States during the second half of 1939 were more than double those during the first half of the year, and would have been greater were it not for inhibiting factors that included a scarcity of ship bottoms as well as high ocean freight and war risk insurance rates. In addition, with the outbreak of war in Europe in September 1939, international trade in chromite during the last quarter of 1939 was adversely affected by the application of various forms of export licences, embargoes, and taxation by producing countries.

Chromite imports by the United States during 1939 amounted to 323,000 tonnes (Table 74), and despite the economic recovery during 1939 were lower than chromite imports of 358,000 tonnes made during 1938. However, large stocks of chromite were on hand in the United States at the end of 1938 as a result of the excess of imports over consumption during 1937 and 1938.

The estimated distribution by industry of chromite consumption in the United States (Brazeau, 1939) was metallurgical 50%, refractory 40%, and chemical 10%, and the chief sources (Brazeau, 1940) of metallurgical grade chromite imported into the United States during 1939 were Zimbabwe, Turkey, and New Caledonia, while refractory grade chromite was imported from the Philippines, Cuba, and Greece, and chemical grade chromite from South Africa. The main ports of entry of chromite into the United States were Philadelphia, Baltimore, and New York.

According to Brazeau (1940) stainless and heat-resisting steels containing varying percentages of chromium continued to increase in usage and importance, and during the period from 1929 to 1939 United States production of stainless steel ingots and castings increased from around 49,000 tonnes in 1929 to a record of 161,500 tonnes in 1939. The automotive industry was the largest consumer of chromium steels, and there was a growing tendency to use stainless steel in aviation construction. This increased demand for chromium steels resulted in increased demand for chromite both metallurgically and as a refractory.

Europe

The largest chromite importing country in Europe during the decade 1930-1939 was Germany, while other important chromite importing countries during the period were the United Kingdom, Sweden, Norway, and France as seen in Table 74. However, chromite imports by each of these countries during each year of the decade were much lower than chromite imports by the United States.

The extent to which European chromite imports were affected by the Great Depression is indicated by decreases in the level of chromite imports by the main importing countries during the years between 1929 and 1933 (Tables 73 and 74). It appears that chromite imports by each of these countries suffered at some stage during the depression years in consequence of reduced demand. According to Roush (1934) much of the recovery in demand for chromite during 1933 as reflected in increased imports was attributed to the recovery in steel production, and particularly to the increasing use of low-chromium automotive steels and high-chromium stainless steels. Regarding the latter steels, naval construction was reported to be responsible for an increasing demand for uses where their resistance to corrosion was promoting the replacement of ordinary steel.

During the period 1933-1937 there was continued growth in the level of chromite imports by European countries (Table 74), and as recorded in Brazeau (1938) there were widening uses for stainless steel and iron as well as increased activity generally in the steel and chemical industries that enhanced the consumption of chromite. Further, chromite as a "war mineral" was affected by tension in Europe and the Orient, and in consequence a scramble for chromite developed among consuming nations wishing to have supplies on hand in the event of hostilities. According to Brazeau (1938) much of the European buying of chromite was activated by rearmament programmes, and as stated in Brazeau (1939) European buying of chromite in 1938 was sustained much better than that by the United States, where a severe business recession was in progress. During the years 1933-1939 there was a particularly strong growth in the demand for chromite by Germany, and German chromite imports rose from 48,000 tonnes in 1933 to 193,000 tonnes in 1939 (Table 74). In 1939 Germany accounted for 27% of world chromite imports (Table 81), and its chromite imports were far greater than those of any other European country.

Prior to the second world war the ferroalloy industries in general, and the ferrochromium industry in particular, were dependent on cheap sources of electric power (Charles River Associates Inc, 1970). In consequence, ferrochromium productive capacity was located largely in areas of the world endowed with low-cost hydro-electric power, and the availability of such power accounted for ferrochromium production by Norway, Sweden, and France just as low-cost hydro-electricity was the locational factor determining ferrochromium production in the Niagara Falls and Tennessee Valley regions of the United States. In Germany the development of the ferroalloy industry was based on the availability of low-cost thermal power derived from coal. The location of ferrochromium production in these countries was an important factor in determining their demand for imported chromite, and this was particularly so as no significant quantities of chromite were mined in these ferrochromium producing countries.

FERROCHROMIUM

The distribution of world ferrochromium exports by country during the period 1930-1939 is shown in terms of tonnage and percentage in Tables 121 and 127, while the destination of world ferrochromium imports by country during 1930-1939 is given by tonnage and percentage in Tables 151 and 157. It is seen that international trade in ferrochromium during the 1930's was confined almost exclusively to countries in Europe.

The largest ferrochromium exporting countries in the world during 1930-1939 were Sweden and Norway (Table 121). These two countries had average annual ferrochromium exports of 9,900 tonnes and 9,800 tonnes respectively during that period, and together accounted for 86% of total world ferrochromium exports. During the decade Sweden and Norway were importers of chromite and exporters of ferrochromium (Tables 74 and 121), and the production of ferrochromium in these countries was facilitated by the availability of cheap hydro-electric power as discussed earlier.

The largest ferrochromium importing country in the world during the 1930's was the United Kingdom, and ferrochromium imports by the United Kingdom reached 18,400 tonnes in 1937 (Table 151). The United Kingdom was also a major chromite importing country during the decade (Table 74), and the imports of both chromite and ferrochromium by the United Kingdom were made for consumption by domestic industry. During the years 1930-1935 the Soviet Union was a significant ferrochromium importing country (Table 151), and in 1933 ferrochromium imports by the Soviet Union reached 9,600 tonnes. However, after 1935 the Soviet Union ceased to be a ferrochromium importing country. It was reported in Roush (1934) that an electric furnace plant for the production of ferrochromium was being constructed at Cheliabinsk in the Soviet Union and that the annual capacity of the plant would be around 10,000 tonnes of alloy, while in Roush (1937) it was assumed that the entire output of chromite by the Soviet Union was being absorbed by the domestic steel industry. These observations are consistent with the fact that after 1935 both chromite exports and ferrochromium imports by the Soviet Union ceased as shown in Tables 23 and 151.

Although the United States was the largest consumer of ferrochromium in the world during the 1930's its supply of ferrochromium was derived from domestic production manufactured using imported chromite. During the 1930's chromite imports by the United States averaged 270,000 tonnes a year whereas ferrochromium imports by the United States averaged only 200 tonnes a year as seen from imports given in Tables 74 and 151. Virtually all chromite consumed in the United States was supplied from imports, and about 50% of chromite consumption was used directly in the metallurgical industry (Ridgway, 1938). In the United States chromite was imported free of duty whereas ferrochromium imports were subject to a reasonably high tariff that provided incentive to import chromite rather than ferrochromium .

Ferrochromium imports by the United States during the 1930's were small (Table 151), and a large proportion of these imports comprised low carbon ferrochromium containing less than 3%C (Brazeau, 1940). The duty on imports of low carbon ferrochromium into the United States was set at 30% ad valorem by the Smoot-Hawley Tariff Act 1930 (Charles River Associates Inc, 1970). By virtue of a trade agreement with Sweden based on the principle of unconditional most-favoured-nation treatment the duty on ferrochromium imports into the United States was reduced in 1935 (Ridgway, 1936). The duty on ferrochromium containing less than 3% carbon was lowered from 30% to 25% ad valorem, while the duty on ferrochromium containing 3% or more carbon was reduced from 2½ cents to 1¼ cents per pound of contained chromium. Despite these reductions in tariff the level of ferrochromium imports into the United States remained low as seen in Table 151.

Chapter 7

TRADE AGGREGATES 1940-1949

During the period 1940-1949 a large proportion of world chromite production came from Zimbabwe, South Africa, Soviet Union, Turkey, Cuba, and the Philippines, and each of these six countries were major chromite exporting countries during the decade. Significant quantities of chromite were produced also during 1940-1949 in New Caledonia, Yugoslavia, India, and Japan, while the United States became an important chromite producer during the second world war. Throughout the period 1940-1949 the United States was the dominant chromite importing country in the world, although substantial chromite imports were made also during the decade by the United Kingdom, Canada, Germany, Norway, Sweden, France, and Japan. During the period 1940-1949 Norway and Canada were the largest ferrochromium exporting countries, while the United Kingdom was by far the largest ferrochromium importing country during the decade.

CHROMITE PRODUCTION AND EXPORTS

The pattern of world chromite production by country for the period 1940-1949 is given in terms of tonnage and percentage in Tables 6 and 16. During the decade total world chromite production increased from 1,458,000 tonnes in 1940 to a record of 2,030,000 tonnes in 1942 then declined to 1,100,000 tonnes in 1945 after which it rose to a new high of 2,100,000 tonnes in 1948 and 1949 (Table 6).

The origin of world chromite exports by country during the period 1940-1949 is shown in terms of tonnage and percentage in Tables 24 and 32. Total world chromite exports rose from 1,021,000 tonnes in 1940 to 1,138,000 tonnes in 1942 then declined to 825,000 tonnes in 1946 after which they climbed rapidly to a record of 1,697,000 tonnes in 1948 then decreased to 1,425,000 tonnes in 1949 (Table 24). During the decade the six largest chromite exporting countries namely, Zimbabwe, South Africa, Cuba, Turkey, Soviet Union, and the Philippines together accounted for

89% of total world exports, while two other countries, New Caledonia and India, were responsible for a further 8% of total exports.

Zimbabwe

During 1940-1949 chromite production by Zimbabwe rose from 248,000 tonnes in 1940 to a record of 348,000 tonnes in 1943 then declined to 151,000 tonnes in 1946 after which it increased again to 244,000 tonnes in 1949 (Table 6). Even though chromite production by Zimbabwe in 1949 was only slightly lower than that in 1940, the share of world chromite production contributed by Zimbabwe dropped from 17% in 1940 to 12% in 1949 (Table 16). The pattern of chromite exports by Zimbabwe during 1940-1949 exhibited a general similarity to that of production (Table 24), and during the decade chromite exports by Zimbabwe averaged 243,000 tonnes a year compared with an average chromite production of 245,000 tonnes a year.

The chief chromite producers in Zimbabwe were Rhodesia Chrome Mines Ltd and African Chrome Mines Ltd, both subsidiaries of the Bechuanaland Exploration Co Ltd, and these producers with operations in the Selukwe district controlled most of the chromite output of Zimbabwe (Brazeau, 1941). Next in importance as producer, although relatively small in tonnage of output, was an association of five leading independent producers known as Chrome Producers (Rhodesia) Ltd, and its output was reported to be around 1,000-2,000 tonnes of chromite a month.

The main chromite deposits in Zimbabwe were located in the Railway Block leases of Rhodesia Chrome Mines Ltd in the Selukwe district (Brazeau, 1941). The chromite mines in these leases were among the largest in the world, and it was from them that the bulk of Zimbabwean chromite production was obtained. The chromite orebodies were up to 18m thick and 137m long, and the ore mined from them was hard and lumpy with a grade ranging from 40-52% Cr_2O_3. Most of the ore was suitable for ferrochromium manufacture. The other important source of Zimbabwean chromite was the Great Dyke from which excellent ore of grade 48-52% Cr_2O_3 was produced. Although the Great Dyke extended over a distance of about 480 kilometres, the greater part of chromite production from it came from the Harare area. According to Ridgway and Melcher (1941) Chrome Producers (Rhodesia) Ltd comprising five leading independent producers obtained its supply of chromite from seams in the Great Dyke, and its output of chromite was reported to be of metallurgical grade. However, chromite production from the Great Dyke was small compared with that from the Selukwe district, which accounted for a chromite production of around 300,000 tonnes a year. As stated in Brazeau (1941) most Zimbabwean chromite ore was of high grade and suitable for metallurgical, chemical, or refractory use.

During the years 1940-1942 chromite exports by Zimbabwe were significantly greater than those of any other country as seen in Tables 24 and 32, and in 1942 they reached a record level of 348,000 tonnes and comprised 31% of total world chromite exports. Even though chromite exports by Zimbabwe declined during the years 1943-1945 they were in excess of 200,000 tonnes in each of these years and comprised more than 20% of total world exports (Tables 24 and 32). During 1943-1945 chromite exports by Zimbabwe were exceeded only by those of Cuba. A large proportion of the chromite exports of Zimbabwe during the period 1940-1945 went to the United States (Jenckes, 1948), and during the second world war Zimbabwe supplied almost half of the metallurgical grade chromite requirements of the United States (Melcher, 1949). In addition, substantial chromite exports by Zimbabwe were made to the United Kingdom during the period 1940-1945. Thus, Zimbabwe was a most important source of chromite during the war.

Reference was made in Jenckes (1948) to the unsatisfactory condition in 1946 of the railway linking the chromite mines of Zimbabwe to the port of Beira in Mozambique, and in Melcher (1949) it was reported that in August 1947 around 500,000 tonnes of chromite ore was stored at the railway awaiting transportation to Beira. Zimbabwe continued to be an important supplier of chromite to the United States, particularly of metallurgical chromite and high-grade refractory ore, but greater realisation of the potential demand by the United States, the largest chromite consuming country in the world, for Zimbabwean chromite was inhibited by transportation difficulties from mine to port (Melcher, 1949). Further, according to Parks (1950) inadequate rail facilities to the port of Beira were the main factor preventing an increase in chromite exports by Zimbabwe to an estimated capacity of around 800,000 tonnes a year. In 1949 chromite exports by Zimbabwe amounted to 206,000 tonnes (Table 24) and comprised 14% of world exports (Table 32). Thus, actual chromite exports by Zimbabwe in 1949 were far below the potential level suggested by Parks.

South Africa

Chromite production by South Africa during 1940-1949 varied between a low of 89,000 tonnes in 1944 and a record high of 413,000 tonnes in 1948 (Table 6) and averaged 240,000 tonnes a year during the decade, while chromite exports by South Africa ranged between a low of 51,000 tonnes in 1944 and a record high of 309,000 tonnes in 1949 (Table 24) and averaged 206,000 tonnes a year during the decade. In 1949 chromite exports by South Africa were exceeded only by those of Turkey (Table 24), and in 1949 South Africa accounted for 22% of world chromite exports (Table 32).

As stated in Brazeau (1941) South Africa had enormous known deposits of chromite. Most of the ore was reported to be of a friable nature, and was especially suitable for chemical use as its friability resulted in relatively low crushing costs and a low silica content reduced the cost of conversion into bichromates. The average run of mine ore ranged in grade from 43-48% Cr_2O_3. In addition, smaller quantities of hard lumpy chromite ore were produced when available, and this type of ore was subject to heavy demand. According to Ridgway (1940) demand for South African chromite in recent years had resulted in the opening of new deposits, particularly in the Rustenburg district, which contained large and easily mineable occurrences. Most of the chromite ore produced was friable, but mining developments also revealed limited quantities of higher-grade hard lumpy ore. It was recorded (Brazeau, 1941 & Ridgway and Melcher, 1941) that the African Mining & Trust Co Ltd was producing a high grade chromite concentrate containing up to 54% Cr_2O_3 and averaging 50-53% Cr_2O_3, and that during the latter part of 1940 the monthly production of concentrate had increased from around 5,000 to 10,000 tonnes a month.

Chromite exports by South Africa dropped from 169,000 tonnes in 1939 to 106,000 tonnes in 1940 (Tables 23 and 24), and this fall in exports resulted primarily from the fact that all chromite exports by South Africa to Germany were cut off because of the war (Brazeau, 1941). During the years prior to the war Germany imported substantial quantities of chromite from South Africa, and during the first eight months of 1939 such imports amounted to 48,800 tonnes (Table 39). In 1940 virtually all the chromite exported by South Africa went to the United States and the United Kingdom (Brazeau, 1941).

During 1941 and 1942 chromite exports by South Africa increased sharply to reach 270,000 tonnes in 1942 when they amounted to 24% of total world exports (Tables 24 and 32). According to Roush (1942) the United Kingdom concentrated her demands for chromite on Zimbabwe, so that South African chromite was exclusively available for shipment to the United States. It was reported by Ridgway and Melcher (1941) that on the recommendation of the United States Advisory Commission to the Council of National Defence, the Metals Reserve Company (established under the Strategic Materials Act 1939) contracted late in 1940 to purchase 100,000 tonnes of chemical grade chromite from South Africa for inclusion in the emergency stockpile, but shipment to the United States was delayed by a shortage of bottoms. However, during 1941 and 1942 South Africa was a major supplier of chromite to the United States.

In 1943 and 1944 chromite exports by South Africa fell sharply from their high level of 270,000 tonnes reached in 1942, and it is likely that a difficult shipping situation from South African ports referred to by Jenckes and Wildensteiner (1946) was a factor contributing to this decrease in exports. The drop in South African chromite exports during 1943 and 1944 led to a fall in chromite production by South Africa in 1944 and 1945(Tables 24 and 6).

Chromite exports by South Africa recovered rapidly from a low of 51,000 tonnes in 1944 to a record of 304,000 tonnes in 1947 then remained around that level with exports of 292,000 tonnes and 309,000 tonnes in 1948 and 1949 (Table 24). In 1947 South Africa was the second largest supplier (after the Soviet Union) of chromite to the United States, and provided the bulk of chemical grade chromite imported by the United States as well as smaller quantities and shares of both metallurgical and refractory grade chromite as recorded in Melcher (1949). United States imports of chemical grade chromite from South Africa in 1947 amounted to 128,000 tonnes and represented 83% of total United States imports of chemical grade chromite in that year.

During the years 1947-1949 chromite exports by South Africa were at higher levels than ever achieved previously, and the chemical grade chromite produced by South Africa was the most favoured of any in the world. According to Parks (1950) the chromite reserves of South Africa including all grades were estimated at around two hundred million tonnes to a depth of 150 metres, and it was reported by Ridgway (1951) that the railway inadequacies formerly restricting the transport of chromite from South African fields had been largely eliminated by 1949. These factors augured well for the future of South Africa as a supplier of chromite to the world market, and particularly as a source of chemical grade chromite.

<u>Cuba</u>

During 1940-1949 chromite production by Cuba rose from 52,000 tonnes in 1940 to a peak of 354,000 tonnes in 1943 then fell to 97,000 tonnes in 1949 (Table 6), while chromite exports by Cuba increased from 54,000 tonnes in 1940 to a peak of 321,000 tonnes in 1944 then decreased to 73,000 tonnes in 1949 (Table 24). Average annual chromite exports by Cuba during the decade were 176,000 tonnes compared with an average annual chromite production of 177,000 tonnes. During the years 1943-1945 Cuba was the largest chromite exporting country in the world, and during 1944 its record exports of 321,000 tonnes represented 34% of total world exports in that year (Tables 24 and 32).

Cuba had chromite reserves of more than two million tonnes of low grade ore that contained about 30-35% Cr_2O_3 and was suitable only for use as a refractory (Brazeau, 1941). The two main producers of Cuban chromite were large American owned companies, and the entire chromite output of the island was exported to the United States. In 1940 the Cuban deposits were the only known substantial source of chromite in or close to the United States, and in consequence were of strategic significance in time of war.

By 1937 chromite exports by Cuba had risen to 97,000 tonnes (Table 23), but after 1937 Cuban chromite exports were adversely affected by competition from the Philippines, which provided excellent refractory grade chromite as well as some metallurgical and chemical quality ore (Brazeau, 1941). However, in response to war time demand from the United States, coupled with the loss of the Philippines to Japan late in 1941, chromite exports by Cuba rose from 54,000 tonnes in 1940 to 321,000 tonnes in 1944 (Table 24), and by 1943 Cuba had become the largest chromite exporting country in the world.

The Cuban chromite deposits comprised irregular masses of variable size that occurred in serpentinized peridotite belts extending along most of the northern coast, although mining had been confined to the eastern half of the island (Betz, 1943(b)). Total chromite production by Cuba prior to 1942 amounted to around 800,000 tonnes of which about 85% comprised refractory ore and the remainder metallurgical ore. The chief sources of Cuban chromite were located in the Camaguey and Oriente Provinces. Refractory chromite ore from the Camaguey district contained 30-32% Cr_2O_3, while metallurgical ore from the Mayari district in eastern Oriente Province graded 55-58% Cr_2O_3.

It was reported (Betz, 1943(a)) that mining of chromite deposits in the Moa district of Oriente Province commenced in 1941. These deposits contained refractory grade chromite averaging about 33% Cr_2O_3, and by 1947 production from the deposits exceeded 500,000 tonnes (Park and MacDiarmid, 1964). During 1942 the United States Geological Survey expanded its exploration activity in Cuba, particularly in Oriente Province, in an attempt to increase Cuban chromite reserves (Betz, 1943(b)).

In 1943 chromite production by Cuba reached a record of 354,000 tonnes (Table 6), and its level of production was then around seven times that in 1940. However, production of refractory grade chromite by Cuba tapered off during the last quarter of 1943 as contracts expired (Nighman and Kenely, 1945). New contracts for 1944 were reported to involve smaller quantities of chromite than those in 1943. Although many small chromite mines had been worked out, Cuban ore reserves were still at a high level, and the lower demand for chromite resulted in a reduced level of prospecting and development. During 1944 chromite production by Cuba dropped sharply to 192,000 tonnes (Table 6). However, stocks available for shipment were large, and in 1944 chromite exports by Cuba reached their record level of 321,000 tonnes (Table 24). As recorded in Jenckes and Wildensteiner (1946) 94% of Cuban chromite exports in 1944 were of refractory grade while the other 6% of exports were of metallurgical grade. In 1945 United States Government purchases of Cuban chromite ceased (Jenckes and Wildensteiner, 1947).

By 1949 chromite production by Cuba had fallen to 97,000 tonnes (Table 6) while chromite exports by Cuba had dropped to 73,000 tonnes (Table 24). In 1949 chromite exports by Cuba amounted to only 5% of total world exports compared with 34% of world exports in 1944 (Table 32). Among the factors contributing to the reduction in production and exports of chromite by Cuba were increased production costs of Cuban refractory ore and greater competition from the Philippines (Ridgway, 1951). The rise of Cuba to become the largest chromite exporting country in the world during the years 1943-1945 was the product of war, and by 1949 both the tonnage and share of Cuban chromite exports had reverted to around their 1940 levels (Tables 24 and 32).

Turkey

Chromite production by Turkey showed relatively little variation during the years 1940-1945 when it ranged between 145,000 tonnes as in 1942 and 197,000 tonnes as in 1943 (Table 6). However, in 1946 Turkish chromite production dropped to a low for the decade of 103,000 tonnes then rose rapidly to a record of 452,000 tonnes in 1949 when Turkey became the largest chromite producing country in the world and accounted for 22% of world chromite production (Tables 6 and 16). During the years 1940-1945 chromite exports by Turkey varied between a high of 182,000 tonnes in 1940 and a low of 63,000 tonnes in 1945 (Table 24). Then, during the years 1946-1949 Turkish chromite exports exhibited a pattern generally similar to that of production by falling to a low for the decade of 36,000 tonnes in 1946 after which they rose steeply to a record of 353,000 tonnes in 1949 when Turkey was the largest chromite exporting country in the world, a position it occupied during much of the 1930's, and provided 25% of total world exports in 1949 (Tables 24 and 32). During 1940-1949 chromite exports by Turkey averaged 165,000 tonnes a year, and its exports were the fourth largest in the world during the decade.

Prior to the war Germany was the principal purchaser of Turkish chromite, but late in 1939 Turkey ceased exporting to Germany (Betz, 1943(a)). Following the outbreak of war chromite shipments by Turkey were made to the United States, United Kingdom, and France, and during 1940 increased chromite exports by Turkey to the United States partly offset the loss of exports to Germany (Roush, 1942). However, during 1941 chromite exports by Turkey to the United States declined, and the decline was probably related to shipping difficulties. During 1940 and 1941 total chromite exports by Turkey were lower than in the years 1937-1939 when Turkish exports reached record levels (Tables 23 and 24).

Turkey was one of the most important sources of metallurgical grade chromite in the world (Brazeau, 1941), and during the war Turkish chromite was the subject of much rivalry between the United Kingdom and France on the one hand and Germany on the other as described by Brazeau (1941), Roush (1942), Betz (1943(a) & 1943(b)), & Nighman and Kenely (1945). The United Kingdom had access to chromite supplies in empire countries, particularly in Africa, but it was most anxious to prevent supplies of Turkish chromite reaching Germany, while Germany desperately needed Turkish chromite imports to maintain her war effort. At the outbreak of war the United Kingdom and France contracted to purchase the entire chromite output of Turkey to 8th January, 1943 ($^{11}/_{15}$ to the United Kingdom and $^{4}/_{15}$ to France), and when France fell her share was taken over by the United Kingdom. The agreement was maintained despite efforts to the contrary by German trade negotiators. First, Germany tried to bring sufficient pressure on Turkey to force a break in the contract with Britain and France, and achieve delivery of part of Turkish chromite output to Germany. When this failed a claim was made by Germany on the French share under the contract on the grounds that France was no longer at war with Germany, but this too failed. Then, Germany tried to claim delivery of around 7,000 tonnes of chromite that had been contracted to Italy in exchange for sulphur prior to the making of the British-French agreement, and this also was denied. These attempts by Germany to obtain Turkish chromite provided good evidence that Germany badly needed chromite. In contrast, the United Kingdom had ample empire supplies of chromite that were more accessible than Turkish ore under the war conditions prevailing, and in consequence released the Turkish shipments to the United States (Roush, 1942).

According to Betz (1943(b)) Germany entered into an agreement with Turkey in October 1941 covering the supply of Turkish chromite to Germany after the expiration of the Anglo-Turkish agreement on 8th January, 1943. It was reported that Turkey would supply Germany with up to 90,000 tonnes of chromite a year during

1943 and 1944 in exchange for war materials. The future and extent of chromite deliveries by Turkey to Germany was to depend on the successful initial delivery of war materials valued at eighteen million Turkish pounds by Germany to Turkey in exchange for 45,000 tonnes of Turkish chromite during the period 15th January to 31st March, 1943. Considerable scepticism was expressed in Betz (1943(b)) as to Germany's ability to deliver goods acceptable to Turkey, and in Roush (1942) it was recorded that the goods demanded by Turkey in exchange for chromite comprised mostly armaments of which Germany would have little to spare under the war conditions prevailing, particularly to a country that had managed to straddle the fence in the conflict and might eventually drop on the wrong side. In the event some Turkish chromite was exported to Germany in 1943 and early 1944. According to estimates given in Nighman and Kenely (1945) Turkish chromite exports to Germany in 1943 amounted to 47,000 tonnes, while a further 15,000 tonnes of Turkish chromite went to Germany during the first two months of 1944. However, all chromite exports by Turkey to Germany under the agreement (known as the Claudius agreement) were halted after February 1944. The decision by Turkey early in 1944 to cease chromite exports to Germany was regarded in June 1944 by Nighman and Kenely (1945) to be an important feature of the international situation, and one that might prove to be an important factor in the war as the sources of supply of chromite remaining available to Germany were not considered adequate to maintain its great demand.

In 1940 the Turkish government made a grant of one million Turkish pounds (about US $670,000) to Etibank to assist in the sale and export of Turkish chromite (Brazeau, 1941). Etibank was able to use the funds to advance loans to producers in amounts up to 80% of the value of ore based on a price of twenty Turkish pounds per tonne for chromite stored at shipment ports, and it was hoped the programme would aid the production and export of Turkish chromite. According to Betz (1943(b)) chromite mining areas in western Turkey during 1942 were being exploited more fully again after a period of years during which the chromite deposits in eastern Turkey were the main producers, and the grant by the government to Etibank probably contributed to the resurgence of these mines. However, as reported in Jenckes and Wildensteiner (1946) the Guleman group of mines in eastern Turkey remained in 1944 the largest and most important source of high grade metallurgical lump chromite ore, and these continued to provide a substantial though relatively smaller proportion of the total chromite production and exports of Turkey. The indicated reserves in 1944 of metallurgical chromite ore in the Guleman group of mines were stated (Jenckes and Wildensteiner, 1946) to be 500,000 tonnes, and it was recorded there were indications of a further 1,000,000 tonnes of ore possibly occurring to the east and north of the Guleman group.

British and American government purchases of Turkish chromite ceased at the end of 1944 (Jenckes and Wildensteiner, 1947), and this would have been a factor contributing to the low level of Turkish chromite exports in 1945 and 1946 (Table 24). However, chromite exports by Turkey recovered sharply from 36,000 tonnes in 1946 to 184,000 tonnes in 1947, and according to Melcher (1949) the major recipients of Turkish chromite exports in 1947 were the United States, Sweden, France, and Norway.

Chromite production and exports by Turkey continued to increase dramatically during 1948 and 1949 and in 1949 reached record levels of 452,000 tonnes and 353,000 tonnes respectively (Tables 6 and 24). In 1948 chromite exports by Turkey to the United States, by far the largest chromite importing country in the world, showed an increase of 368% compared with 1947 exports as deduced from export statistics given in Melcher and Forbes (1953), and these exports comprised largely metallurgical grade chromite (Parks, 1950). During 1948 United States imports of metallurgical grade chromite from Turkey were exceeded only by those from the Soviet Union. In 1949 chromite exports by Turkey to the United States increased further, and during 1949 Turkey was by far the largest supplier of metallurgical grade chromite to the United States as seen in Ridgway (1951). Chromite imports by the

United States from the Soviet Union, most of which were of metallurgical grade, dropped sharply in 1949 as the result of a virtual embargo on shipments from the Soviet Union, and this resulted in Turkey becoming the dominant supplier of metallurgical grade chromite to the United States. As stated in Melcher and Forbes (1953) chromite produced by government owned Etibank from mines in the Guleman area contained 52% Cr_2O_3. Chromite production from the Guleman mines was amongst the highest grade in the world, and in 1950 these mines were a major source of Turkish metallurgical chromite exports.

Soviet Union

During the 1940's the Soviet Union was an important chromite producing country (Table 6), and chromite exports by the Soviet Union increased during the decade from a low of 17,000 tonnes in 1941 to a record of 364,000 tonnes in 1948 after which exports dropped sharply to 104,000 tonnes in 1949 (Table 24). Domestic chromite consumption by the Soviet Union during the 1940's was probably around 200,000-250,000 tonnes a year, while chromite exports by the Soviet Union during 1940-1949 averaged 127,000 tonnes a year. According to Charles River Associates Inc (1970) large scale production of chromite by the Soviet Union after 1936 was directly associated with the discovery of chromite deposits in western Kazakhstan.

Even though the Soviet Union was one of the leading producers of chromite in the world, much of the chromite production was consumed domestically so that chromite exports were relatively small. At that time the Soviet Union was the only important chromite consuming nation in the world that had any appreciable domestic chromite production (Roush, 1942).

During the years 1936-1939 there had been no chromite exports by the Soviet Union (Table 23). However, following the signing of a trade agreement and treaty of alliance between the Soviet Union and Germany in 1939 chromite exports were made by the Soviet Union to Germany during the early 1940's (Roush, 1942), and in 1940 chromite exports by the Soviet Union amounted to 40,000 tonnes (Table

24). Subsequently, the supply of chromite by the Soviet Union to Germany ceased when Germany broke her agreements and started the Russian campaign in 1941. Chromite exports were then made by the Soviet Union to the United States, and in 1942 the United States imported 27,000 tonnes of chromite averaging 52% Cr_2O_3 from the Soviet Union (Betz, 1943(b)). Chromite exports by the Soviet Union rose from 17,000 tonnes in 1941 to 102,000 tonnes in 1944 (Table 24), and exports of chromite by the Soviet Union to the United States during the first half of 1944 were running at the rate of around 100,000 tonnes a year (Jenckes and Wildensteiner, 1946).

Chromite production by the Soviet Union was located in the Ural Mountains, and as indicated in Jenckes and Wildensteiner (1947) the Urals contained among the foremost chromite deposits in the world. Further, the Ural Mountains were not only rich in chromite, but also in iron, manganese, copper, nickel, and other minerals (Jenckes and Wildensteiner, 1946). Following the conquest by Germany of the Ukraine, Krivoi Rog, and Donetz Basin, the heavy metallurgical centre at Nizhne Tagil in the Urals become the chief arsenal and workshop of the Red Army, and its contribution to the war effort was probably an important factor in the ultimate military success of the Soviet Union.

According to Jenckes and Wildensteiner (1947) intense and systematic geological examinations initiated by the central government had resulted by 1945 in large mineral resource developments in the Soviet Union, and almost certainly the chromite mining industry was a beneficiary of these developments. During 1946-1948 chromite production and exports by the Soviet Union increased dramatically with production rising from around 300,000 tonnes in 1946 to 600,000 tonnes in 1948 while exports climbed from 101,000 tonnes in 1946 to 364,000 tonnes in 1948 (Tables 6 and 24). The Soviet Union was the largest chromite producing country in the world during the years 1946-1948, and accounted for more than a quarter of total world chromite production during these years (Tables 6 and 16). In 1948 the Soviet Union became the largest chromite exporting country in the world, and was responsible for 21% of total world exports (Tables 24 and 32). During 1948 the Soviet Union was by far the largest supplier of chromite to the United States, which was the dominant chromite importing and consuming country in the world, and a large proportion of the exports by the Soviet Union to the United States comprised metallurgical grade chromite (Parks, 1950).

In 1949 chromite exports by the Soviet Union dropped sharply from 364,000 tonnes in 1948 to 104,000 tonnes in 1949 (Table 24), and the share of world chromite exports contributed by the Soviet Union fell from 21% in 1948 to 7% in 1949 (Table 32). The dramatic decrease in both the tonnage and share of chromite exports by the Soviet Union in 1949 resulted from a virtual embargo on shipments as described by Ridgway (1951). Most of the chromite exports during 1949 were made early in the year, and the action to reduce exports was taken without official notice from the Soviet government, but merely as an announcement by shippers, who indicated that only token shipments of chromite would be made in the future.

Philippines

Chromite exports by the Philippines rose rapidly from 1,000 tonnes in 1935 to 127,000 tonnes in 1939 as shown in Table 23 and discussed previously. In 1940 Philippine chromite exports increased further to reach 194,000 tonnes (Table 24) then dropped to much lower levels during the years 1941-1945 when exports averaged only 28,000 tonnes a year. After 1946 chromite exports by the Philippines recovered rapidly to reach record levels of 242,000 tonnes and 235,000 tonnes in 1948 and 1949 (Table 24). In 1949 the Philippines contributed 16% of world chromite exports compared with 19% of world exports in 1940 (Table 32).

Although the Philippines did not become a chromite producing and exporting country until 1935, its chromite production and exports grew dramatically to reach 201,000 tonnes and 194,000 tonnes respectively in 1940, and in that year its production and exports were exceeded only by those of Zimbabwe as observed in

Tables 6 and 24. During 1940 80% of Philippine chromite exports went to the United States while 17% of exports went to Japan as calculated from statistics given in Brazeau (1941).

During 1940 the chromite production of the Philippines came mainly from four mines as described in Ridgway and Melcher (1941). The largest chromite deposit in the Philippines was that of Consolidated Mines operated by Benguet Consolidated Mining Co at Masinloc in Zambales Province. This deposit known as the Masinloc deposit contained estimated reserves of around ten million tonnes of chromite averaging about 34% Cr_2O_3. Chromite production from the Masinloc mine was used principally as a refractory, and in 1940 production from the mine amounted to 79,000 tonnes. The second largest chromite producer in the Philippines during 1940 was the Acoje Mining Co that produced 68,000 tonnes of chromite from its mine at Santa Cruz in Zambales Province. The Acoje deposit had estimated reserves of around 150,000 tonnes of chromite containing 48-51% Cr_2O_3. The Zambales Mining Co managed by Union Management Co also mined chromite at Santa Cruz in Zambales, and in 1940 recorded a production of 15,000 tonnes of chromite. The chromite reserves of this company were reported to be around 100,000 tonnes averaging 49% Cr_2O_3. In addition, the Filipinas Mining Corporation produced 18,000 tonnes of high-grade chromite in 1940. It is seen that the Philippines was a major producer of both refractory and metallurgical grade chromite in 1940, although the known chromite reserves of the Philippines comprised mostly refractory grade ore contained in the Masinloc deposit.

Late in 1941 the Philippines fell to the Japanese onslaught (Roush, 1942). However, during the early stages of the Japanese invasion of the Philippines American engineers carried out as much sabotage as possible by burning oil and supplies as well as caving and flooding mines (Jenckes and Wildensteiner, 1947). During their occupation of the Philippines the Japanese exploited what mines they could, and according to Jenckes and Wildensteiner (1946) the Japanese mined high-grade chromite from the Acoje and Filipinas Mines, but did nothing at the Masinloc mine. Chromite production and exports by the Philippines during the Japanese occupation from late 1941 to early 1945 were at a relatively low level, and did not recover until after 1946 (Table 6 and 24). During the occupation years 1942-1944 Japanese imports of chromite from the Philippines averaged 29,000 tonnes a year.

In 1947 chromite exports by the Philippines recovered to around their 1940 level with exports of 192,000 tonnes in 1947 compared with exports of 194,000 tonnes in 1940 (Table 24). However, refractory grade chromite represented a much greater proportion of Philippine chromite exports in 1947 than in 1940, and as reported in Melcher (1949) most of the chromite production of the Philippines in 1947 came from the Masinloc deposit, which contained refractory ore of excellent quality as stated by Jenckes and Wildensteiner (1946). During 1947 a very large proportion of the chromite exports of the Philippines went to the United States, and in that year the Philippines replaced Cuba as the largest source of United States refractory grade chromite (Melcher, 1949). As discussed earlier Cuba became the major supplier of refractory grade chromite to the United States during the war when chromite from the Philippines was not available.

Chromite exports by the Philippines rose to a record of 242,000 tonnes in 1948 and remained around that level in 1949 (Table 24). However, during 1948 and 1949 the percentage contribution of Philippine chromite exports to world chromite exports remained around 15% as in 1947 (Table 32). Chromite exports by the Philippines in 1948 and 1949 went mainly to the United States, and the Philippines continued to be the largest supplier of refractory grade chromite to the United States (Ridgway, 1951). In 1948 almost 90% of United States chromite imports from the Philippines comprised refractory grade chromite compared with 9% metallurgical grade and 1% chemical grade whereas in 1949 68% of chromite imports from the Philippines were refractory grade compared with 24% metallurgical grade and 8% chemical grade.

It was reported by Parks (1950) that in June 1948 the Acoje Mining Co resumed production of metallurgical grade chromite from its mine at Santa Cruz, and this would have resulted in an increase in exports of metallurgical chromite. However, by mid-1948 no rehabilitation work following the Japanese occupation had been done at the chromite mines of either Zambales Chromite Mining Co or the Filipinas Mining Co so the full potential of the Philippines as a producer of metallurgical grade chromite was not being realised.

According to Ridgway (1951) chromite production in the Philippines was adversely affected late in 1949 by lack of demand from the United States, and operations at the Masinloc mine stopped in December. The reduced demand was reflected in lower imports of refractory grade chromite by the United States from the Philippines, which amounted to 167,000 tonnes in 1949 compared with 191,000 tonnes in 1948. However, imports by the United States from the Philippines of both metallurgical and chemical grade chromite were higher in 1949 than in 1948, although the level of imports of these grades from the Philippines was much lower than that for refractory grade chromite.

During 1949 the Philippines exported a total of 235,000 tonnes of chromite (Table 24), and in that year its exports were exceeded only by those of Turkey and South Africa. These latter two countries were the largest exporters of metallurgical and chemical grade chromite respectively in the world in 1949, while the Philippines was the largest exporter in the world of refractory grade chromite.

New Caledonia

During 1940-1949 chromite production by New Caledonia averaged 57,000 tonnes a year, which was the same as the average annual production for the decade 1930-1939. In 1949 New Caledonian chromite production reached 89,000 tonnes, which was the highest level since 1920 when production amounted to 92,000 tonnes as seen in Tables 4-6. However, in 1949 chromite production by New Caledonia amounted to only 4% of world production compared with 39% of world production in

1920 as observed in Tables 14 and 16.

The largest chromite producer in New Caledonia continued to be the Tiebaghi mine of Societe Anonyme la Tiebaghi at Paagoumene, which yielded a rich ore averaging about 55% Cr_2O_3 (Brazeau, 1941). The ore from the Tiebaghi mine was shipped as mined and had a low silica content. The next largest chromite producer in New Caledonia was the Fantoche mine of Societe Chimique du Chrome located on the flank of the Tiebaghi Dome near Nehoue. The higher grade ore from this mine contained about 53% Cr_2O_3, while the lower grade ore was washed to produce a concentrate containing 45-47% Cr_2O_3. In addition, there were several smaller producers of chromite in New Caledonia. Chromite from New Caledonia was generally of high quality with a Cr_2O_3 content exceeding 50% and a Cr:Fe ratio of 3:1 or more so the ore was suitable for metallurgical as well as chemical use. During 1940 chromite production by New Caledonia was 56,000 tonnes (Table 6), and of this production 26,000 tonnes came from the Tiebaghi mine, 12,000 tonnes from the Fantoche mine, and 4,000 tonnes from the Chagrin mine at Koumac (Roush, 1942). Thus, three mines accounted for 75% of New Caledonian chromite production in 1940.

During 1940-1949 chromite exports by New Caledonia averaged 64,000 tonnes a year, and reached record levels of 102,000 tonnes and 103,000 tonnes in 1941 and 1949 when New Caledonian chromite exports accounted for 9% and 7% respectively of world exports (Tables 24 and 32). The highest level of chromite exports previously achieved by New Caledonia was 92,000 tonnes in 1920 (Tables 22-24), and in that year New Caledonia was responsible for 43% of world exports (Table 30).

A large proportion of the chromite exported by New Caledonia went to the United States as indicated in Brazeau (1941) and Betz (1943(a)). Early in 1941 the export of chromite by New Caledonia to Japan was prohibited by the Free French Government of New Caledonia, although in practice only relatively small tonnages of

New Caledonian chromite were being exported to Japan prior to that time. In 1949 the United States imported 64,000 tonnes of chromite from New Caledonia of which 85% was metallurgical grade and 15% was refractory grade (Ridgway, 1951).

During the 1940's average annual chromite exports by New Caledonia were 64,000 tonnes compared with an average of 47,000 tonnes a year during the 1930's and an average of 38,000 tonnes a year during the 1920's. However, the share of world chromite exports contributed by New Caledonia during the 1940's amounted to only 6% compared with 9% in the 1930's and 16% in the 1920's. Thus, although the level of chromite exports by New Caledonia showed an increase during these three decades, its relative importance as a chromite exporting country diminished. This decline in relative importance of New Caledonia as a supplier of chromite to the world market resulted from the rapid growth of chromite production and exports by other countries including Zimbabwe, Turkey, and the Soviet Union, which were also exporters of metallurgical grade chromite. In addition, South Africa and the Philippines developed during the period into major producers and exporters of chemical and refractory grade chromite respectively.

India

Chromite production by India during 1940-1949 averaged 39,000 tonnes a year compared with an average of 38,000 tonnes a year during 1930-1939 and an average of 41,000 tonnes a year during 1920-1929. Thus, the general level of chromite production by India showed remarkable stability over this period even though the tonnage of production varied somewhat from year to year as seen in Tables 4-6. However, during the 1940's India contributed only 2% of world chromite production compared with 5% during the 1930's and 13% during the 1920's. During 1940-1949 chromite production by India was at its highest level for the decade in 1940 when production amounted to 56,000 tonnes (Table 6), and in that year India accounted for 4% of world production (Table 16). As recorded in Ridgway (1940) and Betz (1943(a)) Indian chromite production continued to come mainly from Baluchistan and Mysore.

Chromite exports by India during the decade 1940-1949 reached their highest level of 57,000 tonnes in 1942 (Table 24), and in that year represented 5% of world chromite exports (Table 32). During 1940-1949 Indian chromite exports averaged 29,000 tonnes a year compared with an average of 30,000 tonnes a year during 1930-1939 and an average of 38,000 tonnes a year during 1920-1929. However, during the 1940's India contributed only 3% of world chromite exports compared with 6% of world exports during the 1930's and 17% of world exports during the 1920's. Even though India continued to export significant quantities of chromite, its relative importance as a chromite exporting country declined as in the case of New Caledonia as a result of the expansion and development of chromite production and exports by other countries.

United States

Chromite production by the United States rose from 3,000 tonnes in 1940 to a record of 145,000 tonnes in 1943 then fell to 4,000 tonnes in 1946 (Table 6). In 1943 the United States accounted for 8% of world chromite production compared with less than 0.5% of world production in 1940 and 1946 (Table 16).

Under Section 7 of the Strategic Materials Act 1939, the United States Geological Survey and the United States Bureau of Mines were empowered to search for and appraise mineral deposits containing metals designated as strategic by the Secretaries of War, Navy, and the Interior upon advice of the Army and Navy Munitions Board (Ridgway, 1940). In order to finance the investigations the Act authorised an expenditure of $500,000 a year, including $350,000 a year by the Bureau of Mines and $150,000 a year by the Geological Survey, for each of the fiscal years ending 30th June 1940, 1941, 1942, and 1943. The objectives of the Act were to be achieved by close co-operation between geologists of the Survey and engineers of the Bureau. The Geological Survey was responsible for basic exploration such as geological mapping and geological surveys, while the Bureau of Mines sought to determine the extent and quality of ore, the most suitable method of mining and beneficiating it, and the cost at which it might be produced. Chromium was one of the metals designated as strategic, and exploration projects for chromite were initiated in Montana, Wyoming, Oregon, and California.

During 1940 the demand for chromium in the United States increased substantially as a consequence of the war, and chromium was regarded as one of the most strategic minerals essential for national defence as reported in Brazeau (1941). Concurrently with the increased demand for chromite, there was an increasing scarcity of available shipping space with attendant freight rate increases as well as higher marine and war risk insurance rates. These factors resulted in a steady rise during 1940 in the price of imported chromite delivered at United States Atlantic ports, particularly due to increased transportation costs. However, during 1940 domestic chromite production in the United States amounted to only 3,000 tonnes compared with chromite imports of 668,000 tonnes as seen in Table 6 and 75.

In view of the limited stocks of chromite on hand in the United States, increasing consumption demand, and a threat to imports arising from a shortage of shipping, the uses of chromium were placed under priority control by the Office of Production Management in July 1941, and this was supplemented subsequently by orders restricting certain uses of chromium, while finally a complete system of allocation was implemented early in 1942 as stated in Roush (1942) and Betz (1943(a)). Chromite production in the United States increased from 3,000 tonnes in 1940 to 13, 000 tonnes in 1941 (Table 6), and in 1941 the level of chromite production was higher than that for any year since 1918 (Tables 3-6). However, domestic production remained small compared with imports. Most of the chromite production in the United States in 1941 came from California, although some production came also from Oregon (Betz, 1943(a)). The largest individual source of chromite was the Pilliken mine in Eldorado County, California from which a concentrate averaging 43% Cr_2O_3 was produced. In November 1941 an expansion of the United States government programme for the purchase of domestic chromite was announced by the

Metals Reserve Co (Betz, 1943(a)). Specifications regarding the minimum quantity and minimum grade of chromite purchased by the Metals Reserve Co were gradually reduced (Roush, 1942), and during 1942 purchase depots were established in California and Oregon where miners could sell truck load lots of chromite, while the minimum chromite content for low grade ore was reduced from 40% to 35% Cr_2O_3.

During 1942 chromite production by the United States increased sharply from 13,000 tonnes in 1941 to a record of 102,000 tonnes in 1942 (Table 6). Previously, the highest chromite production achieved by the United States was 84,000 tonnes in 1918 as observed in Tables 1-6. The dramatic increase in United States chromite production during 1942 was made possible by the opening of chromite deposits in Montana from which no commercial production had been obtained previously (Betz, 1943(b)), and the large domestic output was the fruition of efforts by government agencies to free the United States from almost complete dependence on foreign sources for its chromite supply. In 1942 chromite imports by the United States amounted to 890,000 tonnes compared with domestic production of 102,000 tonnes as seen in Tables 75 and 6.

More than 50% of United States chromite production in 1942 came from Montana while 40% came from California and the balance was from deposits in Oregon, Idaho, and Washington (Betz, 1943(b)). During 1942 there were 150 producers of chromite in the United States of which almost three-quarters operated in California. However, two producers in Montana and eleven in California accounted for 90% of total chromite production. The two largest sources of domestic chromite in 1942 were the Stillwater and Red Lodge deposits in Montana, while the next largest producers were the Grey Eagle and Pilliken deposits in California (Betz, 1943(b)). The average grade of chromite (ore and concentrates) shipped by producers in the United States during 1942 was 39% Cr_2O_3. Chromite from California had the highest average grade of 44% Cr_2O_3 while chromite from Montana had the lowest average grade of 36% Cr_2O_3.

Among the exploration projects for chromium undertaken by the Geological Survey and Bureau of Mines was the investigation of chromite deposits located in the Stillwater Complex of Montana (Ridgway, 1940). During 1939 detailed geological mapping of the chromite zone in the Stillwater Complex east of the Stillwater River was completed by the Geological Survey (Ridgway, 1940). Also, during 1939 surface exploration involving trenching and large-scale sampling of chromite deposits in the Stillwater Complex was carried out by the Bureau of Mines, and this exploration showed the deposits to be extensive (Ridgway and Melcher, 1941). The surface sampling was followed by diamond drilling in 1940, and this indicated in excess of one million tonnes of chromite ore at workable widths down to a depth of around 90 metres in one group of claims. However, the drilling campaign had to be stopped before completion because of weather conditions. During 1941 extensive diamond drilling of the Stillwater chromite deposits was continued by the Bureau (Betz, 1943(a)), and in 1941 the equipment of a mine and construction of a mill was begun in order to facilitate exploitation of the deposits (Betz, 1943(b)). The Anaconda Copper Mining Co was designated to operate the Stillwater chromite deposits on behalf of the government, and the first concentrates were produced in the Benbow mill in March 1942. During the 10 months of operation in 1942 chromite production from the Benbow mill was greater than the annual production ever recorded from any domestic chromite property in the United States. The Stillwater Complex comprises a stratiform body of ultrabasic rocks about fifty kilometres long and two to eight kilometres wide. The chromite deposits within the Stillwater Complex occur as lenses and discontinuous layers that form horizons parallel to the layering of the Complex. All the chromite in the deposits was found to contain less than 40% Cr_2O_3.

Following the announcement of its buying programme in November 1941 the Metals Reserve Co became the largest purchaser of domestic chromite in the United States (Betz, 1943(b)). Originally, this government agency offered to contract for lots of 5,000 to 10,000 long tons of ore produced in the United States, but in December

1941 the minimum contract was lowered to 1,000 tons. The buying programme was extended in March 1942 to include the purchase at designated depots of truck load lots of chromite produced in Oregon and northern California with the aim of encouraging production from small deposits in the region and providing an easily accessible market. The minimum grade originally specified for the purchase of low grade chromite was 40% Cr_2O_3, but in May 1942 the minimum grade was lowered to 35% Cr_2O_3. The Metals Reserve Co published a schedule of prices covering various grades of chromite, and this could be adjusted to stimulate domestic production.

During 1943 chromite production by the United States increased further to reach a new record of 145,000 tonnes (Table 6). Although the quality of chromite produced was below the standards normally set by industrial consumers, the output from domestic mines served an important role in guarding against possible disaster in connection with foreign sources of supply (Nighman and Kenely, 1945). Chromite imports by the United States in 1943 amounted to 833,000 tonnes, and were at a lower level than imports during 1941 and 1942 (Table 75). However, imports of chromite in 1943 were sufficiently high to provide a safe margin under the revised stockpile programme requiring only six months stocks within the country. Further, the almost complete defeat of enemy attacks on shipping lanes made a return of the critical supply conditions of 1941 and 1942 unlikely.

The record chromite production of 145,000 tonnes achieved by the United States in 1943 was partly the result of increased prices offered to producers by the Metals Reserve Co, but was mainly the consequence of the completion of several large projects that had been in the development stage for the greater part of 1942 as described in Nighman and Kenely (1945). In fact, production from three government operations became so large that work on each was stopped before the end of 1943. The projects were originally planned and developed during the period of emergency in 1941 and 1942, but their large output was too low in quality to be any longer required as imports of chromite from foreign sources were maintained at adequate levels despite war time transportation difficulties.

During 1943 47% of United States chromite production came from Montana, 39% from California, 10% from Oregon, and 3% from Alaska as derived from statistics given in Nighman and Kenely (1945). The number of individual producers reached a record of 175 of which 148 were in California, 21 in Oregon, 4 in Montana, 1 in Alaska, and 1 in Texas. The average grade of chromite (ore and concentrates) shipped from mines in the United States during 1943 was 41% Cr_2O_3 compared with 39% Cr_2O_3 in 1942. The production of chromite from Montana during 1943 amounted to 69,000 tonnes, which was the largest production recorded from a single state since California supplied 64,000 tonnes of chromite in 1918, and the record production achieved by Montana in 1943 would have been even greater were it not for the cancellation of operations at the Stillwater Complex by the Metals Reserve Co in September. This was especially so as a new 1000-ton mill commenced operations in May 1943 to treat chromite ore from the Mouat-Sampson properties within the Stillwater Complex, and supplemented the output of the 400-ton Benbow mill that began treating ore from the Stillwater Complex in March 1942. According to Nighman and Kenely (1945) the Geological Survey estimated that around twenty million tonnes of low grade chromite were available in the Stillwater Complex. In California the Grey Eagle property continued to be the largest chromite producer as in 1942, while in Oregon a large chromite production came from beach sands along the Pacific Coast of the Coos and Curry Counties. The increase in prices and revision of quality standards by the Metals Reserve Co resulted in a chromite production of around 37,000 tonnes by small operators during 1943, and this group was responsible for virtually all the metallurgical grade lump ore produced in the United States. During 1943 production by small operators included 8,000 tonnes of lump ore averaging 49% Cr_2O_3.

In 1944 chromite production by the United States dropped sharply from 145,000 tonnes in 1943 to 41,000 tonnes in 1944 (Table 6), and during 1944 76% of domestic production came from California while 17% came from Oregon and the remainder from Alaska and Montana (Jenckes and Wildensteiner, 1946). The Metals Reserve Co continued to be the major purchaser of domestic chromite as it had been since November 1941.

Chromite production by the United States fell further in 1945 to reach 13,000 tonnes, which was the same as domestic production in 1941 (Table 6). During 1945 only California and Oregon shipped chromite as in 1941, and in 1945 69% of production was derived from California while 31% came from Oregon (Jenckes and Wildensteiner, 1947). The average Cr_2O_3 content of chromite shipped in 1945 was 46% compared with an average of 44% in 1944, and the increase in average Cr_2O_3 content followed action by the Office of Metals Reserve (formerly the Metals Reserve Co) in raising the minimum acceptable Cr_2O_3 content of chromite purchased from 35% to 42% on 1st January, 1945. Subsequently, the purchasing programme by the Office of Metals Reserve for domestic chromite, both contract and small lot purchases, was terminated on 31st December, 1945, and in fact the only depot for small lot purchases that remained in operation after 1st July, 1945, was that at Grants Pass, Oregon.

In 1946 chromite production by the United States dropped to 4,000 tonnes, which was around the same level as that in 1940 (Table 6). California and Oregon were again the only states that shipped chromite, and in 1946 the average Cr_2O_3 content of chromite shipped was 46% compared with 44% in 1945 (Jenckes, 1948). Chromite production by the United States remained at a low level during the years 1947-1949, and in 1949 decreased to less than 500 tonnes (Table 6). Domestic chromite production in 1949 was the lowest since 1936, and came only from California (Ridgway, 1951).

In 1947 chromite was free from United States government control for the first time in seven years (Melcher, 1949). However, under the authority of the Stockpiling Act 1946 the United States government was a potential buyer during 1947 of both domestic and foreign chromite, but only at prices directly competitive with those paid by industry. Any acquisitions of strategic materials purchased by the government under the Act were for the strategic stockpile, and both metallurgical and refractory grade chromite were classified by the Munitions Board as materials of a strategic and critical nature for which stockpiling was deemed the only satisfactory means of insuring an adequate supply for a future emergency.

According to Jenckes and Wildensteiner (1947) chromite production by the United States from 1880 to 1945 totalled 558,000 tonnes of which 180,000 tonnes (32%) was mined during World War I, 321,000 tonnes (58%) was mined during World War II, and 57,000 tonnes (10%) was mined in peace time. During World War II United States chromite production reached a peak of 145,000 tonnes in 1943 compared with a peak during World War I of 84,000 tonnes in 1918 as observed in Tables 6 and 3. However, domestic chromite production as a percentage of production plus imports was only 15% in 1943 compared with 45% in 1918. In peace time domestic production amounted to a negligible proportion of the total chromite supply of the United States as indicated by Nighman and Kenely (1945).

During a period of thirty years domestic chromite production by the United States twice rose to unprecedented heights in time of war then decreased rapidly when hostilities ceased, and there appeared no reason to expect an increase in the consumption of low grade domestic chromite unless and until a commercially feasible method of treatment is found as observed in Jenckes and Wildensteiner (1946). It was further observed by Jenckes and Wildensteiner (1947) that, judged by wartime production alone, domestic chromite produced in the United States takes on an apparent importance entirely out of proportion to its true position in industry. This assertion is supported by the fact that of 308,000 tonnes of domestic chromite produced during the war and purchased by the Metals Reserve Co or by the Office of Metals Reserve in the years 1941-1945, only 59,000 tonnes (19% of the total) was absorbed by industry, even under the pressure of wartime shortages, because of its low quality. According to Nighman and Kenely (1945) chromite produced in the

United States was classified as chemical grade, although consumption reports from chemical producers reveal that the industry uses chromite with an averaged Cr_2O_3 content of 45-50%. Only a small proportion of United States chromite production was of metallurgical grade, and there was no domestic production of refractory grade chromite. Thus, the major part of chromite production in the United States did not satisfy the normal specifications of any consumer group. In order to compete with imported chromite under normal circumstances the United States would need to produce a product of acceptable quality at economically viable cost, and it appears from the evidence that it was unable to do so.

CHROMITE CONSUMPTION AND IMPORTS

Most of world chromite consumption during the period 1940-1949 took place in North America, Europe, and Japan. The United States continued to be by far the largest chromite consuming country in the world, and in North America a significant quantity of chromite was consumed also in Canada. During 1940-1949 the Soviet Union was a major consumer of chromite as described above, while other important chromite consuming countries in Europe were the United Kingdom, Germany, Norway, Sweden, and France. In addition, a significant quantity of chromite was consumed by Japan during the decade. Except for the Soviet Union, United States, and Japan the main chromite consuming countries during 1940-1949 depended almost entirely for their supply of chromite on imports from producing countries, particularly Zimbabwe, South Africa, Cuba, Turkey, Soviet Union, and the Philippines, and in fact the Soviet Union was the only important chromite consuming country that did not import chromite.

The destination by country of world chromite imports during the period 1940-1949 is shown in terms of tonnage and percentage in Tables 75 and 82. The United States was the dominant chromite importing country in the world during each year of the period, and accounted for 76% of total world chromite imports during the decade. Other countries that imported significant quantities of chromite during 1940-1949 were the United Kingdom, which was responsible for 7% of world chromite imports during the decade, Canada 5%, Germany 4%, Norway 2%, Sweden 2%, France 2%, and Japan 1%. Total world chromite imports reached a record of 936,000 tonnes in 1940 then rose further to 1,318,000 tonnes in 1942 after which they declined to 881,000 tonnes in 1946 then climbed to a new record of 1,706,000 tonnes in 1948 from which they decreased to 1,450,000 tonnes in 1949 (Table 75). During the 1940's world chromite imports during each year of the decade except 1946 were higher than total world imports during any year of any previous decade.

North America

During 1940-1949 both the United States and Canada were chromite importing countries. However, chromite imports by the United States during the decade were more than fifteen times those of Canada, and averaged 920,000 tonnes a year compared with chromite imports by Canada averaging 60,000 tonnes a year.

Chromite imports by the United States during 1940-1949 varied between a low of 668,000 tonnes in 1940 and a high of 1,399,000 tonnes in 1948 (Table 75). Previously, the highest chromite imports recorded by the United States were 563,000 tonnes in 1937. Thus, although United States chromite imports in 1940 were at their lowest level for the decade, they were the largest ever recorded to that time.

United States chromite imports rose sharply from 323,000 tonnes in 1939 to 1,011,000 tonnes in 1941 (Tables 74 and 75). During the latter half of 1939 the United States economy recovered from a severe business recession as discussed previously, and during 1940 the demand for chromium in the United States increased substantially with the continuation of war as recorded by Brazeau (1941). The automotive industry as well as the food handling and processing industries were major consumers of chromium steels, while chromium steels were used also in the rearmament programme, particularly in the manufacture of armour plate and rifles, and a considerable quantity of chromium steel went into the production of destroyers, submarines, and battleships.

In addition to the enlarged domestic demand for chromite associated with the manufacture of products for national defence, the consumption of chromite in the United States increased as a result of the demand for chromium alloys and chemicals in the export trade arising from the need to supply Britain with ferroalloys, particularly after the fall of Norway, and exports to supply chromium chemicals to countries in Latin America and the British Empire that before the war obtained supplies from continental Europe, particularly Germany as reported in Ridgway and Melcher (1941). Another factor contributing to the large increase in chromite imports by the United States during 1940, which were more than double those in 1939, was the programme initiated by the Government and industry to increase stocks of chromite as an insurance against a more stringent shipping situation, and at the end of 1940 all chromite offered on the market was being moved as rapidly as the availability of ships would allow.

During 1940 chromite imports by the United States amounted to 668,000 tonnes compared with chromite consumption of 511,000 tonnes as given in Betz (1943(b)) so that imports were significantly greater than consumption. Under the Strategic Materials Act 1939 purchases of chromite of all grades were made for inclusion in the emergency stockpile, although during 1940 imports arising from these purchases comprised only 58,000 tonnes of metallurgical grade chromite of which roughly equal quantities came from Zimbabwe and Turkey (Ridgway and Melcher, 1941). A large proportion of the chromite purchased during 1940 for the emergency stockpile remained to be delivered at the end of the year.

Chromite imports by the United States continued to rise steeply during 1941, and increased from 668, 000 tonnes in 1940 to 1,011,000 tonnes in 1941 (Table 75). As reported in Roush (1942) the consumption of chromium alloy steels in munitions work continued to expand, and this resulted in increased demand for chromite. During 1941 chromite consumption by the United States amounted to 726,000 tonnes compared with chromite consumption in 1940 of 511,000 tonnes as shown in Betz

(1943(b)). However, it is seen that chromite imports by the United States in 1941 were substantially higher than chromite consumption so that chromite stocks held by the United States showed a healthy increase during 1941. United States chromite imports in 1941 were far higher than ever previously recorded, and despite war conditions that hampered shipping throughout the world most of the principal foreign sources of supply continued to export large quantities of chromite to the United States (Betz, 1943(a)).

United States chromite imports were at lower levels during the years 1942-1946, and decreased from 1,011,000 tonnes in 1941 to 691,000 tonnes in 1946 as observed in Table 75. Although chromite imports by the United States decreased after 1941, chromite consumption by the United States rose from 726,000 tonnes in 1941 to a record of 875,000 tonnes in 1943 then fell to 667,000 tonnes in 1946 as recorded in Jenckes and Wildensteiner (1946) and Jenckes (1948). In 1943 chromite consumption by the United States was slightly greater than chromite imports and in 1944 chromite consumption and imports were almost equal whereas in 1942, 1945, and 1946 chromite imports exceeded chromite consumption as in 1940 and 1941. During the years 1942-1944 significant quantities of chromite were produced in the United States as shown in Table 6, and in 1943 domestic chromite production by the United States reached a record level of 145,000 tonnes as described previously.

During 1942 the United States government continued the development of its stockpiling programme designed to procure adequate supplies of foreign chromite to fulfil wartime requirements, and concurrently continued to stimulate domestic production (Betz, 1943(b)). In addition, chromium was placed under a system of complete allocation in 1942. By the end of 1942 total stocks of chromite in the United States owned by both industry and the government amounted to around 1,250,000 tonnes, and during the years 1940-1942 industry stocks declined progressively while government stocks increased greatly with the result that in 1942 government stocks exceeded those under private control.

The major development with regard to chromite in the United States during 1943 was a transition in the supply situation from one of anxiety to that of a comfortable working margin as described in Nighman and Kenely (1945). This was achieved despite record consumption by a combination of maintaining a high level of imports, reaching a peak domestic production, and the successful fruition of control measures taken by government war agencies. Further, the almost complete defeat of enemy attacks on shipping lanes made the supply situation more secure.

During 1944 both chromite imports and chromite consumption were lower than in 1943, and each amounted to 770,000 tonnes. In accordance with the Surplus Property Act 1944 the Army and Navy Munitions Board submitted a report to Congress recommending the transfer of surplus government owned chromite of all grades to a national stockpile as well as the further acquisition of both metallurgical and refractory grade chromite, but not of chemical grade chromite (Jenckes and Wildensteiner, 1946). However, for security reasons no quantitative recommendations were included in the report. Subsequently, chemical grade chromite was added to the stockpiling list in 1949 so the list was then complete with regard to the various grades of chromite (Ridgway, 1951). During 1945 United States chromite imports increased while chromite consumption decreased further as seen in Jenckes and Wildensteiner (1947). However, consumption remained at a relatively high level, and this was due in part to the fact that large tonnages of stainless steel were needed to satisfy a deferred civilian demand.

In 1946 chromite imports by the United States dropped to 691,000 tonnes and were at their lowest level since 1940 as seen in Table 75, while chromite consumption by the United States fell to 667,000 tonnes and was also at its lowest level since 1940 as observed from statistics given in Jenckes and Wildensteiner (1946) and Jenckes (1948). Even though chromite imports exceeded chromite consumption during 1946 and resulted in a slight increase in total chromite stocks held by the United States, there was a deficiency during 1946 in the supply of metallurgical grade chromite of which consumption was 25% greater than imports (Jenckes, 1948). In contrast, imports of chemical and refractory grade chromite by the United States during 1946 exceeded consumption. The deficiency in imports of metallurgical grade chromite in 1946 was made up partly by sales of metallurgical ore by the Office of Metals Reserve and partly by the substitution of high-grade chemical chromite ore for metallurgical ore. During 1946 the consumption of metallurgical grade chromite by the United States dropped 12% compared with 1945 and the consumption of refractory grade chromite fell 10% while the consumption of chemical grade chromite increased 2½%. The fact that 1946 was the first full postwar year and corresponded to a period of transition from conditions of war to those of peace probably accounted for the reduced chromite consumption by the United States, particularly as the immediate demand for products of war no longer existed.

Chromite imports by the United States rose sharply from 691,000 tonnes in 1946 to a record of 1,399,000 tonnes in 1948 then decreased to 1,092,000 tonnes in 1949 as shown in Table 75. However, during each of the years 1947-1949 United States chromite imports were much greater than chromite consumption as seen in Ridgway (1951) so that in each of these years a large tonnage of chromite went into stocks including both the national stockpile and consumer stocks. During 1947-1949 chromite imports by the United States averaged 1,165,000 tonnes a year compared with an average chromite consumption of 720,000 tonnes, and in 1948 when chromite imports by the United States reached a record of 1,399,000 tonnes chromite consumption amounted to only 794,000 tonnes, which did not greatly exceed chromite consumption in 1946. At the end of 1949 consumer stocks amounted to 687,000 tonnes of which 296,000 tonnes were metallurgical grade, 275,000 tonnes were refractory grade, and 116,000 tonnes were chemical grade. In addition, a large quantity of chromite was held in the national stockpile.

During 1949 the percentages of metallurgical, refractory, and chemical grade chromite consumed in the United States were 43%, 40%, and 17% as stated in

Ridgway (1951) compared with percentages of 46%, 33%, and 21% in 1940 and 58%, 29%, and 13% in 1943 as derived from statistics given in Parks (1950). According to Nighman and Kenely (1945) the consumption of metallurgical grade chromite in the United States increased 114% during the period 1940-1943 in consequence of the war programme, and this increase is reflected also in the increased percentage of metallurgical grade chromite consumed in 1943 compared with 1940 and 1949. During 1940-1943 the consumption of refractory grade chromite increased 45% while the consumption of chemical grade chromite remained relatively stable even though its share of total consumption declined from 21% to 13% during that period.

The principal metallurgical use of chromite continued to be the production of ferrochromium, which in turn was used in the manufacture of chromium alloy steels of which stainless steel with its corrosion resistance was the most important (Parks, 1950). As a refractory chromite bricks and patching cement were used to line and repair furnaces for both ferrous and nonferrous metals, and the neutral character of chromite made it resistant to different types of slag. The main chemical use of chromite continued to be the manufacture of sodium bichromate, which was the primary chromium chemical from which other compounds were made. The largest consumption of chromium chemicals was in pigments, while tanning and electroplating were responsible also for substantial consumption of chromium chemicals.

In 1949 United States chromite imports amounted to 1,092,000 tonnes and accounted for 75% of world chromite imports (Tables 75 and 82). The largest supplier of metallurgical grade chromite imported by the United States during 1949 was Turkey, although substantial quantities of metallurgical grade chromite were derived also from the Soviet Union, Zimbabwe, Philippines, South Africa, and New Caledonia (Ridgway, 1951). In 1949 the major suppliers of refractory grade chromite to the United States were the Philippines and Cuba, while most of the chemical grade chromite imported by the United States came from South Africa.

During 1940-1949 Canada was also an importer of chromite (Table 75), although its imports amounted to only 5% of world imports during the decade compared with 76% of world imports by the United States. Canadian chromite imports during the 1940's varied between 94,000 tonnes as in 1943 and 14,000 tonnes as in 1946.

Although chromite production by Canada showed an increase during the years 1942-1944, Canadian chromite production was generally small compared with chromite imports (Tables 6 and 75). In Canada ferrochromium was produced at Welland, Ontario, by Electrometallurgical Co, and Chrom-X was made at Sault Ste Marie, Ontario, by Chromium Mining & Smelting Corporation Ltd using imported chromite ores as described by Ridgway (1940) and Brazeau (1941). Chrom-X was a recently discovered and patented product similar to ferrochromium. In addition, Canada produced almost its entire requirements of chromite refractory brick, and this was manufactured chiefly from imported chromite (Brazeau, 1941).

Europe

During the decade 1940-1949 the largest chromite importing countries in Europe were the United Kingdom and Germany, while substantial quantities of chromite were imported also during the period by Norway, Sweden, and France as seen in Table 75. However, throughout the decade chromite imports by each of these countries were very much less than chromite imports by the United States.

United Kingdom chromite imports averaged 83,000 tonnes a year during 1940-1949, and represented 7% of world chromite imports during the decade. Imports of chromite by the United Kingdom fluctuated during the period 1940-1945 when they averaged 71,000 tonnes a year then rose continuously from 44,000 tonnes in 1945 to 134,000 tonnes in 1949 (Table 75). As reported in Brazeau (1941) United Kingdom chromite imports were consumed in the refractory and chemical industries, whereas her metallurgical requirements were satisfied by importing ferrochromium. During the war the United Kingdom had access to adequate resources of chromite in her empire through either political or commercial control, and a large proportion of world chromite production was owned by British nationals. However, following the outbreak of war the United Kingdom in association with France contracted to purchase the entire output of Turkish chromite until early 1943 as described in Roush (1942). This was done not so much out of need for supplies, but rather to keep Turkish chromite from German hands. Prior to the war Turkey had been a major supplier of chromite to Germany as discussed previously.

Chromite imports by Germany dropped from 193,000 tonnes in 1939 to 37,000 tonnes in 1940 and 25,000 tonnes in 1941 (Tables 74 and 75), and only during 1942 and 1943 did German chromite imports approach their 1939 level. Subsequently, chromite imports by Germany decreased again, and did not show signs of recovery until 1949. The difficulties experienced by Germany in obtaining adequate supplies of chromite during the war have been referred to previously. Early in the war imports of chromite were made by Germany from the Soviet Union, but these imports ceased when Germany started the Russian campaign in 1941. Germany gained control of chromite deposits in Greece and Yugoslavia following their occupation, although there was uncertainty regarding the condition of the mines in these countries at the time they were seized (Roush, 1942). During 1943 and early 1944 some chromite was exported by Turkey to Germany under the Claudius agreement, but these exports were halted after February 1944 (Nighman and Kenely, 1945). Chromite shipments to Germany from all other foreign sources were subsequently cut off during 1944 in consequence of the disruption to all rail traffic from the Balkans, and with the absence of chromite deposits in Germany the loss of foreign sources of supply was a staggering blow to German industry (Jenckes and Wilderwsteiner, 1946).

The serious shortage of chromium experienced by Germany as well as its implications for the war effort were clearly expressed in a memorandum from Albert Speer to Hitler dated 11th November, 1943, in which he tabulated the level of domestic stocks, consumption rate, and duration of reserves for each of the alloy metals, and drew the following conclusion quoted in his memoirs (Speer, 1970):

> Hence, the element in shortest supply is chromium. This is especially grave since chromium is indispensable to a highly developed armaments industry. Should supplies from Turkey be cut off, the stockpile of chromium is sufficient only for 5.6 months. The manufacture of planes, tanks, motor vehicles, tank shells, U-boats, and almost the entire gamut of artillery would have to cease from one to three months after this deadline, since by then the reserves in the distribution channels would be used up.

In his analysis Speer assumed that chromite imports from Turkey and the Balkans would be lost, which in fact subsequently happened.

During 1940-1949 chromite imports by Norway and Sweden averaged 21,000 tonnes and 20,000 tonnes a year respectively, and each accounted for 2% of world chromite imports during the decade. These countries imported chromite in order to produce ferrochromium using cheap hydro-electric power. During the war chromite imports by Norway and Sweden were adversely affected by the British blockade that followed the occupation of Norway by Germany in 1940 (Brazeau, 1941), but after the war chromite imports by these countries were restored to around their former levels (Tables 74 and 75).

Although chromite imports by France averaged 21,000 tonnes a year during 1940-1949, French chromite imports were very low or non-existent during the years 1941-1944 when France was occupied by Germany (Table 75). Most of the chromite imports by France during the decade were made in 1940 and during the years 1946-1949. When France fell to Germany in 1940 French stocks of chromite as well as supplies of ferrochromium of which France was a manufacturer were confiscated by Germany as recorded by Brazeau (1941).

<u>Japan</u>

During 1940-1949 Japan was a substantial consumer of chromite of which supplies were derived from both domestic production and imports as shown in Tables

6 and 75. Japanese chromite production during 1940-1949 averaged 38,000 tonnes a year, while Japanese chromite imports during 1940-1945 averaged 30,000 tonnes a year. However, chromite production by Japan during the years 1946-1948 averaged only 6,000 tonnes a year, and chromite imports by Japan in 1945 dropped to 4,000 tonnes. The principal location of Japanese chromite production was on Hokkaido Island (Brazeau, 1941), while Japanese chromite imports during the period 1940-1945 came mostly from the Philippines (Jenckes, 1948).

FERROCHROMIUM

The pattern of world ferrochromium exports by country of origin for the years 1940-1949 is shown in terms of tonnage and percentage in Tables 122 and 128, and the pattern of world ferrochromium imports by country of destination for the years 1940-1949 is given in terms of tonnage and percentage in Tables 152 and 158. It is observed that international trade in ferrochromium during the 1940's was confined almost entirely to countries in Europe and North America.

The largest ferrochromium exporting countries in the world during 1940-1949 were Norway and Canada, which were not chromite producers of any significance, but took advantage of the availability of relatively inexpensive hydro-electric power to manufacture ferrochromium for export using imported chromite. By far the largest ferrochromium importing country in the world during 1940-1949 was the United Kingdom, which relied on imported ferrochromium for its metallurgical requirements. Ferrochromium imports by the United States continued to be small compared with chromite imports even though the United States was by far the largest consumer of ferrochromium in the world, and the maintenance of this situation involving the production of ferrochromium in the United States using imported chromite was assisted by a tariff on ferrochromium imports whereas chromite entered the United States free of duty.

During the 1940's chromite producing countries continued to be exporters of chromite rather than ferrochromium, while ferrochromium exports continued to come mainly from countries that imported chromite for the manufacture of ferrochromium using cheap hydro-electric power. Further, the tonnage of chromite entering international trade during the 1940's was more than fifty times that of ferrochromium.

Chapter 8

TRADE AGGREGATES 1950-1959

During the period 1950-1959 Turkey, Soviet Union, South Africa, Philippines, and Zimbabwe were by far the largest chromite producing countries in the world, and these five countries accounted for a large proportion of world chromite production during the decade. In addition, substantial quantities of chromite were produced during 1950-1959 by Albania, Yugoslavia, United States, New Caledonia, Cuba, India, Greece, and Japan. By far the largest chromite exporting countries in the world during 1950-1959 were South Africa, Turkey, Philippines, and Zimbabwe, which were responsible for a large proportion of world chromite exports during the decade, while substantial quantities of chromite were exported also during the period by the Soviet Union, New Caledonia, Cuba, Yugoslavia, India, Greece, and Albania.

The United States continued to be the dominant chromite importing country in the world during 1950-1959, although West Germany, United Kingdom, France, Japan, Canada, Sweden, Norway, and Austria also imported substantial quantities of chromite during the decade.

The largest ferrochromium exporting countries during 1950-1959 were Norway, Canada, France, and Sweden, while by far the largest ferrochromium importing countries during the period were the United States and United Kingdom.

CHROMITE PRODUCTION AND EXPORTS

The distribution of world chromite production by country during the period 1950-1959 is shown in terms of tonnage and percentage in Tables 7 and 17. It is seen that throughout 1950-1959 world chromite production was consistently dominated by five countries, namely Turkey, Soviet Union, South Africa, Philippines, and Zimbabwe, and that in general the share of world production contributed by each of these countries remained remarkably uniform during the decade. The five countries were individually responsible for 19%, 18%, 17%, 15%, and 12%

respectively of world chromite production during 1950-1959, and together accounted for more than 80% of world chromite production during the decade. The balance of world chromite production during 1950-1959 came from a number of other countries of which the largest producers were Albania, Yugoslavia, and the United States, and these three countries each provided 3% of world chromite production during the decade. The level of Yugoslavian chromite production did not vary greatly during 1950-1959, whereas chromite production by Albania expanded during the decade and United States chromite production rose to a peak in 1956 then declined. Total world chromite production rose steeply from 2,347,000 tonnes in 1950, which was the highest level ever recorded at that time, to reach a new record of 4,629,000 tonnes in 1957, which was double that in 1950, and amounted to 3,891,000 tonnes in 1959 as shown in Table 7.

The distribution of world chromite exports by country of origin during the period 1950-1959 is given in terms of tonnage and percentage in Tables 25 and 33. It is observed that four countries, namely South Africa, Turkey, Philippines, and Zimbabwe, dominated world chromite exports throughout 1950-1959. These four countries individually contributed 22%, 21%, 21%, and 17% respectively of world chromite exports during 1950-1959, and together were responsible for more than 80% of world chromite exports during the decade. The remaining chromite exports during 1950-1959 came from a number of countries of which the Soviet Union was the largest chromite exporter and accounted for 5% of world chromite exports during the decade. Among the five countries that dominated world chromite production during 1950-1959 South Africa, Turkey, Philippines, and Zimbabwe each exported a large proportion of their chromite production, whereas the Soviet Union exported a relatively small although significant proportion of its chromite production. During 1950-1959 world chromite exports increased from a record of 1,711,000 tonnes in 1950 to a new record of 3,123,000 tonnes in 1957 and amounted to 2,920,000 tonnes in 1959 as seen in Table 25.

<u>South Africa</u>

During 1950-1959 chromite exports by South Africa averaged 521,000 tonnes a year compared with an average of 206,000 tonnes a year during the previous decade. The revival of the United States economy that began early in 1950 and the outbreak of war in Korea in June 1950 gave a tremendous boost to raw material consumption, and resulted in 1950 in the largest annual chromite consumption ever recorded at that time (Melcher and Forbes, 1953). In 1950 South Africa was the largest supplier of chromite to the United States, which was the dominant chromite importing country in the world, and was the only source of United States chemical grade chromite. During the latter part of 1950 South African chromite exports were hampered by a lack of rail cars as well as a shortage of shipping bottoms (Melcher and Forbes, 1953), but despite this chromite exports by South Africa in 1950 amounted to 492,000 tonnes and were far greater than ever previously recorded. In 1950 South Africa was the largest chromite exporting country in the world as shown in Table 25.

South Africa and Zimbabwe possessed the largest known chromite reserves in the world (Melcher and Hozik, 1954). In the case of South Africa most of the chromite reserves were of chemical grade, although they included also some metallurgical and refractory grade ore, while in contrast Zimbabwean chromite ore was principally of metallurgical grade. The quantity of chromite available for export from both South Africa and Zimbabwe depended on the volume of ore transported to stockpiles at the Mozambique ports of Lourenco Marques and Beira respectively, and in the case of both South Africa and Zimbabwe the railing of chromite from mine to port was subject to curtailment during certain seasons of the year in favour of coal, tobacco, and other agricultural products.

The Bushveld Complex in the Transvaal of South Africa contained chromite reserves estimated at hundreds of millions of tonnes (Katlin and Heidrich, 1955), and South Africa was at that time the only producer of chemical grade chromite in the world. The dominance of South Africa as supplier of chemical grade chromite to the world market depended on the composition, reserves, uniformity, and price of its chromite ores (Katlin and Heidrich, 1956). The Transvaal chemical grade chromite ores (such as Grade B Friable) contained 43-45% Cr_2O_3 and had a silica content of around 2.5-3.5%, which made them technically suitable for use in the chemical industry, while their price was the lowest of any chromite ore available and this determined their selection in preference to other ores. Further, the huge ore reserves in the South African chromite deposits enabled a continuing supply of relatively uniform raw material. The high iron content of most South African ores made them unsuitable for standard metallurgical use, but did not detract from their consumption in the chemical industry to which South Africa was virtually the sole supplier of chromite. In the chemical industry finely ground chromite was roasted with soda ash in the production of sodium bichromate from which all other chromium chemicals were derived. For this purpose a high iron content in the chromite ore was not detrimental, but a low silica content not exceeding 5% was desirable to minimise soda ash loss.

Although metallurgical grade chromite, which generally comprised hard lump ore having a Cr_2O_3 content of at least 48% and a Cr:Fe ratio of 3:1 or higher, was traditionally used in the manufacture of ferrochromium, the practice had developed by 1953 of blending chromite of all types for use in the production of ferrochromium (Katlin and Heidrich, 1956). However, the major portion of chromite used in making ferrochromium conformed to the traditional metallurgical standard (Katlin and Heidrich, 1958). Although the percentage of chemical grade chromite used for metallurgical purposes increased considerably during 1954, it still amounted to only 8% of the total. According to Katlin and Heidrich (1958) the chromite consumed by the metallurgical industry in the United States in 1954 comprised 84% metallurgical grade, 8% chemical grade, and 8% refractory grade. By 1958 the percentage of chemical grade chromite used in the metallurgical industry had risen to 14% (McInnis and Heidrich, 1959). It was stated by the Commonwealth Economic Committee (1962) that the market for

South African chemical grade chromite had been broadened in recent years by technological changes in steel making processes that made possible the metallurgical use of lower grade chromite ore than previously, and enabled the use of chromite ore with a Cr:Fe ratio of less than 3:1. In the case of South African chemical grade chromite ore the Cr:Fe ratio was about 1.6:1.0, and such ore could be blended with other ores as described above.

During 1956 transportation difficulties continued to plague South African chromite producers, who were reported to have large stocks of chromite ready for shipment to port (McInnis and Heidrich, 1958(b)). However, according to Charles River Associates Inc (1970) the shortage of railway equipment (and rail cars in particular) that constrained the output of South African chromite in the early postwar period by creating bottlenecks was overcome between 1956 and 1958. Improved transport facilities were probably a contributing factor in enabling South Africa to achieve record chromite exports of 642,000 tonnes in 1957, and maintain its share of world exports as observed in Tables 25 and 33. During 1957 both South African chromite exports and world chromite exports reached record levels as well as their highest levels for the decade (Table 25).

Turkey

Chromite exports by Turkey averaged 502,000 tonnes a year during 1950-1959 compared with an average of 165,000 tonnes a year during the previous decade. During 1950-1959 Turkish chromite exports reached their highest levels in 1952 and 1956 when exports amounted to 626,000 tonnes and 641,000 tonnes respectively (Table 25). Turkey was the largest chromite exporting country in the world during the years 1951-1956 except during 1954 when its exports were exceeded by those of South Africa and the Philippines. However, in 1959 Turkish chromite exports fell to 306,000 tonnes, and were at their lowest level for the decade.

During the years 1950-1952 Turkish chromite exports rose sharply from 354,000 tonnes in 1950 to 626,000 tonnes in 1952 (Table 25), and its share of world chromite exports increased from 21% in 1950 to 29% in 1952 (Table 33). In 1952 chromite exports by Turkey were significantly larger than ever recorded by any country in any previous year. It was reported by Melcher and Forbes (1953) that in 1950 Economic Co-operation Administration (ECA) funds were being made available by the United States to Turkey to assist in the expansion of its chromite mining industry, and according to Melcher and Hozik (1954) the determination of the United States to develop alternative sources of metallurgical grade chromite to offset the 1950 embargo by the Soviet Union on shipments of chromite to the United States resulted in considerable interest in and expansion of the chromite mining industry in Turkey. Further, the Korean war and efforts by the United States to fulfil minimum National Stockpile objectives created a brisk market in all grades of chromite during 1951. The ECA funds made available by the United States were used to stimulate the Turkish chromite industry, and a large part of the resulting increased output was reported (Melcher and Hozik, 1954) to have gone into the National Stockpile. During the years 1950-1952 chromite exports by Turkey to the United States increased sharply as did total chromite exports by Turkey (Table 25), and in each of these years 68-70% of Turkish chromite exports went to the United States as deduced from statistics given in Katlin and Heidrich (1955).

In Turkey chromite mining was undertaken by both private and government organisations, and according to Melcher and Hozik (1954) independent mining operations accounted for 73% of total chromite output by Turkey in 1951 while the government owned Etibank was responsible for 27% of total output. Etibank controlled the chromite mines in the Guleman area of eastern Turkey, and from this area some of the highest grade chromite in the world was produced (Melcher and Forbes, 1953). Chromite mined in the Guleman area was of metallurgical grade and had a Cr_2O_3 content of 52%. According to McInnis and Heidrich (1958(c)) there were many privately operated chromite mines in Turkey in 1957, and the majority of these were small. Chromite production took place in several provinces, and private mines accounted for about two-thirds of Turkish chromite production in that year. Chromite reserves in Turkey were then estimated at 3-4 million tonnes.

Turkish chromite exports dropped from 626,000 tonnes in 1952 to 356,000 tonnes in 1954 (Table 25), and the decline in chromite exports by Turkey during this period was accentuated by reduced demand for high priced chromite ores. Turkey's share of world chromite exports fell from 29% in 1952 to 20% in 1954 (Table 33). It was reported in Katlin and Heidrich (1956) that by the end of 1953 some mines were ceasing operations because of slackened demand for the high priced Turkish chromites. During 1954 there was a general decline in chromite prices, but the price of Turkish chromite showed the greatest fall because of dwindling demand for high priced ores (Katlin and Heidrich, 1958).

During the latter half of 1954 the flagging Turkish chromite mining industry was bolstered by the rejuvenation of an old contract for 100,000 tonnes of chromite for the United States National Strategic Stockpile, and the signing of a contract for the barter of Turkish chromite in exchange for 100,000 tonnes of United States wheat (Katlin and Heidrich, 1958). Further, the duty on Turkish chromite exports was reduced from 5% to 1% in November 1954 with the aim of assisting chromite miners to lower their prices to a competitive level on the world market. Turkish chromite exports rose from 356,000 tonnes in 1954 to a record of 641,000 tonnes in 1956, and Turkey's contribution to world chromite exports increased from 20% in 1954 to 23% in 1956 (Tables 25 and 33). According to McInnis and Heidrich (1958(b)) the supply of high grade Turkish chromite ore during 1956 was largely sold in advance of production, and this resulted in higher prices for the small quantities available on the open market.

Above half the chromite acquired by the United States for the National Stockpile during the years 1951-1956 was of metallurgical grade, and the country most directly affected by these purchases of metallurgical ore was Turkey (Charles River Associates Inc, 1970). Although data is not available on acquisitions by country of origin it is probable that Turkey supplied most of the 1,200,000 tonnes of foreign metallurgical chromite added to the National Stockpile during 1951-1956. The Soviet Union was not an exporter of chromite to the United States during that period, and stockpile purchases from Zimbabwe were relatively small.

Turkish chromite exports declined from the record of 641,000 tonnes in 1956 to 516,000 tonnes in 1958 then dropped dramatically to 306,000 tonnes in 1959 (Table 25). During 1959 Turkey's share of world chromite exports fell sharply to 10% compared with 22% in 1958, and was much lower than during any other year of the decade (Table 33). The decrease in tonnage and share of Turkey's chromite exports during the latter part of the decade took place despite efforts by the government to assist the expansion of chromite production and exports. These included the introduction in 1958 of a foreign exchange premium applied to chromite exports (McInnis and Heidrich, 1959)), and increase in May 1959 in the size of the export premium in an attempt to improve the competitive position of its chromite producers (McInnis and Heidrich, 1960).

According to a review of the Commonwealth Economic Committee (1962) the weakened position of Turkish chromite producers since 1957 was partly the result of technological changes in the United States steel industry. Prior to that time Turkish chromite ore because of its superior quality including a consistently high Cr:Fe ratio had commanded a substantially higher price in the United States market than Zimbabwean chromite ore of similar grade. However, in consequence of improved smelting techniques, the quality differential of Turkish chromite became less important to United States consumers, and their usage of Zimbabwean and South African chromite ores increased relatively to that of Turkish ore. In view of their high costs of production many Turkish chromite producers were unable to reduce prices to a competitive level, even with the help of export premiums, and this resulted in lower Turkish chromite production and exports. The decline in Turkey's share of world chromite exports was due to high production costs coupled with increased competition from metallurgical grade chromite produced in Zimbabwe and the Soviet Union, particularly in the United States market. During the years 1950-1952 almost 70% of Turkish chromite exports went to the United States as described earlier whereas during 1959 only 36% of Turkish chromite exports were sent to the United States (McInnis and Heidrich, 1960). However, increased industrial activity in West Germany and France during the 1950's provided markets for Turkish chromite, and compensated to some extent for reduced exports by Turkey to the United States as indicated by the Commonwealth Economic Committee (1962).

During 1957-1959 chromite prices declined from the peak reached early in 1957 as observed in Charles River Associates Inc (1970), and by 1959 many small Turkish chromite mines had closed as indicated in McInnis and Heidrich (1960). In 1959 chromite production by Turkey fell to its lowest level since 1948 (Tables 6 and 7) while Turkish chromite exports were lower than in any year since 1947 (Tables 24 and 25).

Philippines

During 1950-1959 chromite exports by the Philippines averaged 495,000 tonnes a year, which were almost five times average exports of 100,000 tonnes a year during the previous decade. Chromite exports by the Philippines showed a rising trend during the period 1950-1959, and increased from 250,000 tonnes in 1950 to a record of 747,000 tonnes in 1959 when the Philippines was the largest chromite exporting country in the world as seen in Table 25.

Both refractory and metallurgical grade chromite continued to be produced and exported by the Philippines during the 1950's, and refractory grade chromite generally comprised more than 80% of total production although the relative proportions of refractory and metallurgical grade chromite produced varied somewhat from year to year. For instance, in 1956 82% of the chromite produced in the Philippines was refractory grade compared with 18% metallurgical grade (McInnis and Heidrich, 1958(b)) while in 1958 93% of the chromite production of the Philippines was refractory grade compared with 7% metallurgical grade (McInnis and Heidrich, 1959).

The only source of refractory grade chromite in the Philippines continued to be the Masinloc deposit located in the Zambales Mountains of western Luzon, and operated by Benguet Consolidated Mining Co on behalf of Consolidated Mines Inc as described in Katlin and Heidrich (1956). The Masinloc deposit comprised a massive body of chromite averaging 32% Cr_2O_3 located near the surface of a hill about 150m high and 300m wide at the base. As stated in Katlin and Heidrich (1958) Masinloc was the largest known deposit of refractory grade chromite in the world. During the decade exploration was carried out to establish additional chromite ore reserves at Masinloc, and at the beginning of 1959 total ore reserves were estimated at 5,836,000 tonnes (McInnis and Heidrich, 1960). In 1959 78% of the refractory grade chromite exports of the Philippines were sent to the United States while 12% went to the United Kingdom and 6% to Japan, and in that year the Philippines supplied 77% of the refractory grade chromite imports of the United States, which was by far the largest chromite importing country in the world. During the 1950's the price of Philippine refractory grade chromite showed a steady rise with two small peaks in 1953 and 1957 corresponding to expansionary periods in the United States economy as observed in Charles River Associates Inc (1970).

A large proportion of the metallurgical grade chromite produced in the Philippines continued to come from the Acoje deposits, which were also located in the Zambales Mountains of western Luzon and contained the largest known reserves of metallurgical grade chromite in the Philippines with ore reserves in 1953 estimated at well in excess of a million tonnes as described in Katlin and Heidrich (1956). During 1956 18% of the chromite production of the Philippines was metallurgical grade, and of this more than three quarters came from the Acoje mine (McInnis and Heidrich, 1958(b)). Total chromite production by the Philippines in 1956 was 709,000 tonnes as shown in Table 7, so that chromite production from the Acoje mine probably amounted to around 100,000 tonnes. According to McInnis and Heidrich (1960) metallurgical grade chromite exported by the Philippines in 1959 went to Japan, United States, and Italy of which Japan was the major recipient. In 1959 the Philippines supplied only 4% of United States metallurgical grade chromite imports compared with 77% of its refractory grade chromite imports.

Among developments that assisted expansion of chromite production by the Philippines during the 1950's were the construction of a 1,000 ton a day concentrating mill completed in 1952 at the Acoje mine as reported in Melcher and Hozik (1954), and the expansion in 1955 of the heavy-medium separation plant at the Masinloc mine that doubled capacity of the plant from 75 tons an hour to 150 tons an hour as recorded in McInnis and Heidrich (1958(a)). Further, the construction of a railway to replace high cost truck haulage of Masinloc chromite from mine to port and enable increased production was completed in 1955 as described in Katlin and Heidrich (1955) and McInnis and Heidrich (1958(a)). However, a factor inhibiting future expansion of chromite production from the Masinloc mine was the execution in July 1956 of a new agreement (resulting from litigation) between Consolidated Mines Inc and Benguet Consolidated Inc (formerly Benguet Consolidated Mining Co) under which the operating company's share of profits was reduced from 50% to 25% and chromite sales from Masinloc were limited to a maximum of 544,000 tonnes a year as reported in McInnis and Heidrich (1958(b)).

Zimbabwe

Chromite exports by Zimbabwe averaged 390,000 tonnes a year during the period 1950-1959 compared with an average of 243,000 tonnes a year during 1940-1949. During 1950-1959 Zimbabwean chromite exports varied between 242,000 tonnes in 1950 and a record of 636,000 tonnes in 1957 (Table 25). In 1957 Zimbabwe accounted for 20% of world chromite exports (Table 33) compared with 17% of total world exports for the decade, and in 1957 its chromite exports were only slightly below those of South Africa and the Philippines (Table 25), which were the largest exporters in the world of chemical and refractory grade chromite respectively.

During the 1950's Zimbabwe produced and exported all three grades of chromite of which metallurgical grade chromite production was the largest. In 1957 Zimbabwean chromite production was stated by the government to comprise approximately 80% metallurgical grade ore averaging 48% Cr_2O_3, 17% chemical grade ore averaging 45-48% Cr_2O_3, and 3% refractory grade ore averaging 42-46% Cr_2O_3 (Commonwealth Economic Committee, 1962).

According to Katlin and Heidrich (1955) three companies accounted for 95% of the chromite production of Zimbabwe in 1952. These were Rhodesia Chrome Mines Ltd at Selukwe, which was the largest producer in the country, African Chrome Mines Ltd at Banket, and Vanadium Corporation of Rhodesia. The level of chromite production by Zimbabwe was reported to be limited by the availability of transportation to port, which was never adequate, although it was hoped the delivery of six diesel locomotives to Rhodesia Railways late in 1952 would help alleviate chronic rail shortages. In any event both chromite production and chromite exports by Zimbabwe increased sharply during 1953, and reached record levels of 420,000 tonnes and 430,000 tonnes respectively as observed in Tables 7 and 25.

An important factor in facilitating the expansion of chromite production and exports by Zimbabwe was the completion in May 1955 of the railway from Zimbabwe to the port of Lourenco Marques in Mozambique (McInnis and Heidrich, 1958(a)). Previously, Zimbabwean chromite was exported through the port of Beira in Mozambique, and the new railway provided relief from the dependence of chromite producers on the Salisbury-Beira railway line. According to Charles River Associates Inc (1970) Zimbabwean chromite producers accumulated stocks of ore at mine site in anticipation of the end of the transportation bottleneck, and release of these stocks contributed to the expansion of Zimbabwean chromite exports after 1955. As reported in McInnis and Heidrich (1958(c)) the large stockpile of ore at the mines was eliminated by the end of 1957, and the vast improvement in rail haulage in Zimbabwe following the completion of the Lourenco Marques railway in 1955 enabled both production and exports of chromite by Zimbabwe to reach record levels in 1957. Chromite production by Zimbabwe increased from 401,000 tonnes in 1954 to 593,000 tonnes in 1957 as shown in Table 7, while chromite exports by Zimbabwe rose from 289,000 tonnes in 1954 to 636,000 tonnes in 1957 as seen in Table 25.

During 1958 chromite exports by Zimbabwe were adversely affected by recession in the United States steel industry, which greatly reduced the demand for imports of metallurgical grade chromite from Zimbabwe (McInnis and Heidrich, 1959). However, Zimbabwean chromite exports recovered significantly during 1959 when they amounted to 500,000 tonnes compared with 373,000 tonnes in 1958, and were higher than in any other year of the decade except 1957 (Table 25). In 1959 Zimbabwe accounted for 17% of world chromite exports as during each of the years 1953-1956 (Table 33). Thus, Zimbabwe maintained its share of world chromite exports despite renewed competition from metallurgical grade chromite exports by the Soviet Union, and technological changes in the United States steel industry resulting from an improvement in smelting technique that enabled the use of lower grade chromite in the metallurgical industry as discussed by the Commonwealth Economic Committee (1962). The effect of this technological development was to weaken the demand for Zimbabwean chromite relative to much cheaper lower grade South African chromite, but to improve its competitive position in relation to more expensive Turkish chromite.

The two largest chromite producers in Zimbabwe, namely Rhodesia Chrome Mines Ltd and African Chrome Mines Ltd, were subsidiaries of Union Carbide, and a large proportion of their chromite production was channelled through Union Carbide's ferrochromium plants in the United States (Charles River Associates Inc, 1970). At the end of the 1950's these companies were expanding their chromite output, while many small chromite mining companies in Zimbabwe were ceasing production or being forced to stockpile ore due to lack of markets (Commonwealth Economic

Committee, 1962).

In Zimbabwe chromite occurred in podiform, stratiform, and eluvial deposits. These comprised large lenticular bodies in the Selukwe, Belingwe, Mashaba, and Kwanda areas, parallel seams in the Great Dyke, and eluvial concentrations in flat poorly drained soils in some areas of the Great Dyke as described in McInnis and Heidrich (1960). Total chromite ore reserves in Zimbabwe were estimated in 1959 at more than 450 million tonnes, which indicated the potential for long term chromite production by Zimbabwe.

Soviet Union

Chromite production by the Soviet Union during 1950-1959 averaged around 650,000 tonnes a year, and its level of production during the decade was exceeded only by that of Turkey. During the years 1950-1954 chromite production by the Soviet Union remained relatively stable, and was estimated to average 526,000 tonnes a year. However, during the period 1954-1959 Soviet Union chromite production rose from an estimated 544,000 tonnes in 1954 to 853,000 tonnes in 1959 (Table 7), and in 1959 the Soviet Union was the largest chromite producing country in the world.

Although total chromite exports by the Soviet Union during the years 1950-1954 are not known, chromite imports by the United States, United Kingdom, West Germany, Sweden, and Norway from the Soviet Union during the period 1950-1953 together averaged only 36,000 tonnes a year, and these five countries accounted for a large proportion of total world chromite imports during that period as observed in Table 83. However, during the years 1955-1959 total chromite exports by the Soviet Union are known, and increased significantly from 158,000 tonnes in 1955 to 272,000 tonnes in 1959 as shown in Table 25. Chromite exports by the Soviet Union during 1955-1959 averaged 225,000 tonnes a year compared with average chromite production during the same period of 768,000 tonnes a year so that 29% of Soviet Union chromite production during 1955-1959 was exported. This indicates that a large proportion of the chromite production of the Soviet Union continued to be consumed domestically, and the Soviet Union remained the only major chromite consuming country in the world that did not depend on imports for its supply of chromite. It appears from the production and export statistics given in Tables 7 and 25 that chromite consumption by the Soviet Union at the end of the 1950's was around 580,000 tonnes a year.

During 1954 the Soviet Union became active in the western world chromite market, and trade agreements were signed for the export of Soviet chromite to both Europe and Japan (Katlin and Heidrich, 1958). Chromite exports by the Soviet Union in 1958 amounted to 215,000 tonnes (Table 25), and according to McInnis and Heidrich (1960) 59% of these exports went to western countries. In 1959 chromite exports by the Soviet Union increased to 272,000 tonnes, and the United States, West Germany, Sweden, France, and Japan provided substantial western markets for Soviet chromite as indicated by the Commonwealth Economic Committee (1962).

During 1949 chromite imports by the United States from the Soviet Union dropped sharply from 357,000 tonnes in 1948 to 97,000 tonnes in 1949 following a virtual embargo on exports by the Soviet Union as described in Ridgway (1951), and in 1950 United States chromite imports from the Soviet Union dropped further to 65,000 tonnes, which were 82% lower than imports from the Soviet Union during 1948 (Melcher and Forbes, 1953), while in 1951 there were no chromite imports by the United States from the Soviet Union (Melcher and Hozik, 1954). In 1954 the United States was approached regarding the barter of American butter and edible oils for Soviet chromite, but no agreement resulted as reported in Katlin and Heidrich (1958). In fact, chromite imports by the United States from the Soviet Union did not resume until 1959 when chromite imports amounted to 57,000 tonnes of metallurgical grade chromite (McInnis and Heidrich, 1960).

United States

Chromite production by the United States rose from less than 500 tonnes in 1950 to a record of 188,000 tonnes in 1956 then declined to 95,000 tonnes in 1959

(Table 7), while its share of world chromite production increased from less than 0.5% in 1950 to 5% in 1956 then decreased to 2% in 1959 (Table 17).

In 1950 chromite production by the United States amounted to only 367 tonnes comprising metallurgical grade chromite from the Lambert mine in California (Melcher and Forbes, 1953). Only during periods of national emergency had much consideration been given to domestic chromite deposits, and at other times during the present century chromite consumers in the United States relied on less expensive, more plentiful, and higher quality imported chromite as observed by Melcher and Hozik (1954) and discussed by the author in previous chapters. However, during 1951 chromite consumption by the United States rose 24% while chromite imports increased by only 10%, and this resulted in National Stockpile requirements not being satisfied.

In order to increase chromite supply the United States government introduced a Chrome Purchase Programme in August 1951 that involved the establishment of a depot at Grants Pass, Oregon, as during World War II for the purchase of up to 203,000 tonnes (200,000 long tons) of metallurgical grade domestic chromite ore or concentrates at incentive prices, and this provided a real encouragement for the production of chromite in Oregon and northern California (Melcher and Hozik, 1954). By the end of 1951 there were thirty four chromite mining operations in the United States compared with one in 1950, and chromite production by the United States increased from less than 500 tonnes in 1950 to 6,000 tonnes in 1951 (Table 7).

As stated in Katlin and Heidrich (1958) the purchase programme provided for the acquisition of either a maximum total of 203,000 tonnes of metallurgical grade chromite or any smaller total quantity of chromite delivered at Grants Pass, Oregon, by 30th June, 1957, whichever occurred first. Originally, the termination date for the purchase programme was 30th June, 1955, but this was extended for two years in 1953 (Katlin and Heidrich, 1956). Then, in August 1956 the closing date for the purchase programme was extended again to 30th June, 1959, and chromite could be delivered also at locations other than Grants Pass (McInnis and Heidrich, 1958(b)). In the event the purchase programme was terminated in May 1958 when General Services Administration (GSA) announced that the 203,000 tonne limit had been reached (McInnis and Heidrich, 1959), and termination of the programme resulted in the closure of all chromite mines and mills in the United States except for the American Chrome Company's operation at Nye, Montana, from which virtually the entire output of chromite was delivered under contract to the United States government stockpile as discussed below.

It was reported (Melcher and Hozik, 1954) that at the end of 1951 the United States government was negotiating with a private company to reopen the Mouat chromite mine in Montana that had been operated during World War II, and it was stated (Katlin and Heidrich, 1955) that in April 1952 a contract was signed between the Defence Materials Procurement Agency as signatory for the Government and the American Chrome Company as operator to equip and develop the Mouat chromite mine located within the Stillwater Complex in Stillwater County, Montana. Production was expected to commence in 1953, and the company agreed to supply the government with 816,000 tonnes (900,000 short tons) of chromite concentrate over an 8-year period.

Operations at the Mouat mine began in August 1953, and by the end of that year chromite production from the Mouat mine was 80% as much as total chromite production for the year from the other 145 producing mines in the United States of which 96 were located in California and 49 in Oregon (Katlin and Heidrich, 1956). During 1953 the quantity of chromite purchased by the Government at the Grants Pass depot in Oregon increased 46% as more mines were brought into production, and in 1953 total chromite production by the United States rose to 53,000 tonnes (Table 7).

In 1954 chromite production by the United States jumped to 148,000 tonnes, which was slightly higher than the previous record of 145,000 tonnes recorded in

1943 (Tables 6 and 7), and in 1954 the United States accounted for 4% of world chromite production compared with 8% of world production in 1943 (Tables 16 and 17). Chromite imports by the United States in 1954 were 1,334,000 tonnes compared with chromite imports of 833,000 tonnes in 1943 (Tables 75 and 76) so that United States chromite production as a percentage of production plus imports amounted to 10% in 1954 compared with 15% in 1943. Thus, even though chromite production by the United States was at record level in 1954, it remained a relatively small proportion of total chromite supply. During 1954 the Mouat chromite mine operated by American Chrome Company was in full production, and accounted for about three quarters of total chromite production by the United States in that year (Katlin and Heidrich, 1958).

United States chromite production rose to a new record of 188,000 tonnes in 1956 (Table 7). However, this production figure included 41,000 tonnes of chromite concentrate recovered by Pacific Northwest Alloys Inc during 1955 and 1956 from low-grade chromite ore and concentrate owned by the Government and stockpiled near Coquille in Oregon during World War II (McInnis and Heidrich, 1958(b)). Exclusion of this recovered chromite from the 1956 production figure gives a balance of new chromite production for 1956 of 147,000 tonnes, which is around the same level as United States chromite production in 1954 and 1955 (Table 7).

Virtually all the 147,000 tonnes of new chromite produced in 1956 was purchased by the Government under the individual contract with American Chrome Company for output from the Mouat mine or at incentive prices under the Purchase Programme for Domestic Ores and Concentrates as reported in McInnis and Heidrich (1958(b)). During 1956 about three quarters of new chromite production in the United States was derived from the Mouat mine in Montana, and comprised a submetallurgical grade concentrate averaging 38.5% Cr_2O_3 and having a Cr:Fe ratio of 1.7:1.0. The remaining quarter of new chromite production during 1956 came from 136 other mines and mills in the United States including 97 in California and 37 in Oregon as well as one in Alaska and one in Washington, and virtually all the chromite ore and concentrates produced in these states satisfied the minimum government specifications for the metallurgical grade chromite purchase programme (McInnis and Heidrich, 1958(b)). The minimum specifications under the GSA price schedule for domestic chromite were 42% Cr_2O_3 and a Cr:Fe ratio of 2.0:1.0.

In the case of lump chromite ore containing 48% Cr_2O_3 and having a Cr:Fe ratio of 3:1 the GSA price under the schedule for domestic chromite purchases was $113 per tonne whereas the quoted price of imported chromite of similar grade and specification from Turkey varied from around $52 per tonne f.o.b. cars U.S. east coast ports at the beginning of 1956 to $59 per tonne at the end of 1956 and the quoted price of similar grade and specification chromite from Zimbabwe varied from around $45 per tonne at the beginning of 1956 to $56 per tonne at the end of 1956 based on chromite prices recorded in McInnis and Heidrich (1958(b)). This shows that the incentive price paid by the United States government in 1956 for domestic chromite delivered in Oregon in the western United States was about twice the price of essentially similar imported chromite from Turkey and Zimbabwe delivered at US Atlantic ports close to the areas of chromite consumption. A significant factor in the price increase of imported chromite during 1956 was the rise in ocean freight rates resulting from a shipping shortage following the closure of the Suez Canal as indicated by Charles River Associates Inc (1970).

In 1957 chromite production by the United States amounting to 151,000 tonnes (Table 7) was all from newly mined ore, and was the largest production of new chromite ever achieved in the United States. Subsequently, chromite production by the United States decreased to 140 000 tonnes in 1958 then dropped to 95,000 tonnes in 1959 (Table 7). As reported by McInnis and Heidrich (1959) all chromite mines in the United States except the Mouat mine in Montana ceased production during the first half of 1958 because the government purchase programme for domestic chromite at incentive prices was terminated in May when the 203,000 tonne limit was reached after a period of almost seven years. During 1959 virtually all the chromite production of the United States came from the Mouat mine from which 95,000 tonnes of chromite concentrate averaging 38.5% Cr_2O_3 was shipped by the American Chrome Company to the United States government stockpile under a long term contract due to expire in 1961 (McInnis and Heidrich, 1960). In addition, the American Chrome Company consumed a small quantity of chromite concentrate in the manufacture of charge ferrochromium in its own pilot plant, and this was the only domestic chromite used in the production of chromium ferroalloys.

During the 1950's chromite production by the United States was relatively small compared with chromite imports, and even though United States chromite production reached record levels during the decade the production took place under contract to the government or for sale to the government at incentive prices for stockpiling purposes. It is unlikely that under normal circumstances chromite produced in the United States would be competitive with chromite imported from other producing countries such as Zimbabwe and Turkey.

CHROMITE CONSUMPTION AND IMPORTS

During the period 1950-1959 most of the world's chromite consumption continued to be located in North America, Europe, and Japan. In North America both the United States and Canada were chromite consumers, and the United States remained by far the largest chromite consuming nation in the world. During 1950-1959 the Soviet Union was a major consumer of chromite as discussed above, while in western Europe the largest chromite consumers were West Germany and the United Kingdom and significant quantities of chromite were consumed also by France, Sweden, Norway, and Austria. In addition, Japan was a significant chromite consumer during the decade. With the exception of the Soviet Union whose demand for chromite was satisfied from domestic production, the main chromite consuming countries during 1950-1959 relied largely or entirely for their chromite supply on imports from producing countries of which the largest exporters of chromite were South Africa, Turkey, Philippines, Zimbabwe, and the Soviet Union.

The pattern of world chromite imports by country of destination during the period 1950-1959 is shown in terms of tonnage and percentage in Tables 76 and 83. The United States continued to be the dominant chromite importing country in the world during each year of the decade, and was responsible for 65% of total world chromite imports during that period. Other significant chromite importing countries during 1950-1959 were West Germany, which accounted for 7% of world chromite imports during the decade, United Kingdom 6%, France 4%, Japan 4%, Canada 3%, Sweden 3%, Norway 2%, and Austria 2%. Together with the United States these countries were responsible for 96% of world chromite imports during 1950-1959. The level of total world chromite imports showed a rising trend during 1950-1959, and reached peaks of 2,660,000 tonnes in 1953 and 3,239,000 tonnes in 1957 as seen in Table 76. During 1950-1959 total world chromite imports averaged 2,401,000 tonnes a year, which was almost double average world chromite imports of 1,211,000 tonnes a year during the previous decade.

North America

Both the United States and Canada were chromite importing countries during 1950-1959 (Table 76). However, chromite imports by the United States during the decade averaged 1,564,000 tonnes a year compared with average chromite imports by Canada of 80,000 tonnes a year so that United States chromite imports were almost twenty times those of Canada.

During the period 1950-1959 chromite imports by the United States reached their highest levels in 1953 and 1957 when imports amounted to 2,020,000 tonnes and 2,071,000 tonnes respectively, while United States chromite imports were at their lowest levels for the decade in 1950 and 1958 when imports amounted to 1,180,000 tonnes and 1,146,000 tonnes respectively (Table 76). However, in 1953 76% of total world chromite imports were made by the United States compared with 64% in 1957, and in 1950 73% of world chromite imports went to the United States compared with 56% in 1958 (Table 83). During the period 1950-1959 the share of world chromite imports going to the United States showed a decline, and this was attributable largely to a rapid growth in chromite imports by West Germany, France, and Japan during the decade as seen in Tables 76 and 83.

In 1950 United States chromite imports amounted to 1,180,000 tonnes, and were higher than in any previous year except 1948 when chromite imports reached a record level of 1,399,000 tonnes. During 1950-1953 chromite imports by the United States rose each year from 1,092,000 tonnes in 1949 to a new record of 2,020,000 tonnes in 1953 (Tables 75 and 76). Early in 1950 the United States economy began to recover from the depressed conditions experienced in 1949, and in June 1950 hostilities broke out in Korea (Melcher and Forbes, 1953). The rearmament programme gathered momentum, and economic recovery continued to increase throughout 1950. Raw material consumption was given a tremendous boost, and in 1950 the United States recorded record chromite consumption of 889,000 tonnes, which was 46% higher than in 1949.

Except for a slight decline in 1952 chromite consumption by the United States continued to increase, and reached a new record of 1,212,000 tonnes in 1953 as shown in Katlin and Heidrich (1956). As chromite consumption increased chromite consumers enlarged their level of stocks, and these rose from 550,000 tonnes at the end of 1950 to a record of 922, 000 tonnes at the end of 1953 when they represented about nine months supply of chromite at the 1953 consumption rate. Both the rise in chromite consumption and the increase in consumer stocks of chromite contributed to the growth in chromite imports during the years 1950-1953. In 1953 United States consumption, stocks, and imports of chromite all reached record levels.

However, during the latter part of 1953 the chromite market in the United States became generally sluggish (Katlin and Heidrich, 1956), and during most of 1954 the general trend throughout the chromium industry was downward (Katlin and Heidrich, 1958). Chromite consumption by the United States dropped sharply from the record of 1,212,000 tonnes in 1953 to 829,000 tonnes in 1954 and was at its lowest level since 1949. In consequence of the reduced demand for chromite for consumption as well as lower demand for government stockpiling chromite imports by the United States fell sharply during 1954 as reported in Katlin and Heidrich (1956) and shown in Table 76. However, the decrease in commercial chromite imports during 1954 failed to keep pace with the drop in chromite consumption so that chromite stocks in the hands of United States consumers actually built up during 1954, and were at a record level of 1,150,000 tonnes at the end of the year.

During 1955-1957 chromite imports by the United States again rose each year from the low of 1,334,000 tonnes in 1954 to a new record of 2,071,000 tonnes in 1957 (Table 76). In 1955 there was a high level of industrial activity in the United States, and chromite consumption recovered rapidly from its slump in 1954 to achieve a new record of 1,437,000 tonnes in 1955 (McInnis and Heidrich, 1958(a)). Chromite imports by the United States also increased significantly during 1955 in response to the improved economic conditions while consumer stocks declined from the high level reached in 1954.

During 1956 there was a further significant increase in both chromite consumption and chromite imports by the United States while the level of consumer stocks also increased during the year as seen in McInnis and Heidrich (1958(b)). Chromite consumption reached a new record of 1,675,000 tonnes in 1956, and consumer stocks at the end of 1956 represented eight months supply of chromite at the 1956 consumption level. Chromite imports by the United States in 1956 amounted to 1,973,000 tonnes, and were only slightly below record imports of 2,020,000 tonnes recorded in 1953 as shown in Table 76. During 1957 United States chromite imports continued to increase, and reached a record level of 2,071,000 tonnes. However, the rise in chromite imports in 1957 was less than that during each of the two previous years (Table 76). In 1957 chromite consumption by the United States decreased compared with that in 1956 as a result of lower industrial activity, and consumer stocks rose to a record level as recorded in McInnis and Heidrich (1958(c)).

Chromite imports by the United States dropped dramatically from the record level of 2,071,000 tonnes reached in 1957 to 1,146,000 tonnes in 1958 and were lower than during any other year of the decade as seen in Table 76. The fall in chromite imports during 1958 was in response to a sharp drop in chromite consumption associated with economic recession in the United States as indicated by the Commonwealth Economic Committee (1962), and consumption fell to its lowest level since 1954 while consumer stocks of chromite also declined during 1958 as shown in McInnis and Heidrich (1959). The decrease in chromite consumption in 1958 resulted largely from decreased output of stainless steel and other alloy steels in the production of which most chromium ferroalloys were consumed, and to reduced production of ferroalloys for delivery to the United States government. In 1959 there was an increase in chromite consumption by the United States despite the steel strike, which reduced the demand for chromite by the ferroalloy and refractory industries during most of the latter half of the year (McInnis and Heidrich, 1960). During 1959 there was a significant recovery in United States chromite imports, which amounted to 1,409,000 tonnes (Table 76), while chromite stocks held by consumers also increased significantly and represented sixteen months supply of chromite at the 1959 consumption level.

During 1950-1959 chromite consumption by the United States reached peaks of 1,212,000 tonnes in 1953 and 1,675,000 tonnes in 1956, and in 1956 chromite consumption was almost double consumption of 889,000 tonnes in 1950. In 1959 chromite consumption amounted to 1,213,000 tonnes, which was around the same level as that in 1953. Except for a slump in 1954, the period 1950-1956 was one of tremendous growth in chromite consumption by the United States. During 1950-1956 increased quantities of chromite were consumed by each of the metallurgical, refractory, and chemical industries. However, the greatest growth in chromite consumption during the period took place in the metallurgical industry. In 1956 the metallurgical industry accounted for 65% of chromite consumption in the United

States compared with 26% by the refractory industry and 9% by the chemical industry as deduced from consumption levels given in McInnis and Heidrich (1958(b)) whereas in 1953 the percentage of chromite consumed by the metallurgical industry was 56% compared with 33% by the refractory industry and 11% by the chemical industry as stated in Katlin and Heidrich (1956) and in 1950 the percentage of chromite used in the metallurgical industry was 50% compared with 36% in the refractory industry and 14% in the chemical industry as reported in Melcher and Hozik (1954). Thus, the proportion of chromite consumed by the metallurgical industry rose from 50% of total consumption in 1950 to 65% in 1956.

The metallurgical, refractory, and chemical uses of chromite are described by Katlin and Heidrich (1956), Katlin and Heidrich (1958), & McInnis and Heidrich (1958(a)), while a detailed account of the chemistry and metallurgy of chromium is given by Udy (1956(a) & 1956(b)). Consumption of chromite in the United States during 1955 was confined largely to the six adjoining States of New York, Ohio, Pennsylvania, Maryland, West Virginia, and New Jersey (McInnis and Heidrich, 1958(a)). In the metallurgical industry chromite was used almost entirely to produce various chromium ferroalloys of which low carbon ferrochromium and high carbon ferrochromium were the most important, and these ferroalloys were used as chromium additives in making stainless steels, high-speed steels, high-temperature alloys, and various other special purpose alloys. During 1956 the proportional consumption of total chromium ferroalloys and metal used in the production of these products was stainless steels 63.3%, high-speed steels 0.6%, other alloy steels 30.3%, and high-temperature alloys 4.0%, while other uses accounted for 1.8%, and generally similar consumption percentages were recorded for other years of the period 1952-1956 as shown in McInnis and Heidrich (1958(b)). Stainless steels were used wherever corrosive conditions or high temperatures were encountered as in chemical manufacturing and food processing equipment, petroleum production and refining, and for architectural trim and exterior wall facings on buildings, while high-speed steels were used in metal-cutting tools and machinery (Katlin and Heidrich, 1958). High strength low alloy steels were used in the manufacture of trains, trucks, automobiles, ships, farm machinery, and in construction and mining equipment, while high-temperature alloys were used for jet engines and gas turbines.

The main use of chromite in the refractory industry was in steel mills for lining basic open-hearth and electric arc furnaces (Katlin and Heidrich, 1958). Chromite refractories were used in the hearth, sides, and roof of basic open-hearth furnaces. In furnaces having basic hearths and acid roofs chromite brick was used at the junction between the two because of its neutral character, while basic electric arc furnaces could be almost completely lined with chromite refractories. In making refractory bricks chromite could be used alone or mixed in varying proportions with magnesite. Chromite refractories were used also in furnaces for smelting nonferrous metals, in lining naval boilers, and in the ceramics and paper industries.

In the chemical industry chromite was converted into sodium bichromate from which virtually all other chromium chemicals were made. According to McInnis and Heidrich (1958(a)) about 38% of the chromium chemicals consumed in 1955 went into the manufacture of pigments for use in paints, printing inks, rubber, plastics, textiles and linoleum, while 21% of chromium chemicals were used in electroplating and other metal treatment, and 18% were absorbed in leather tanning. Other uses of chromium chemicals included the production of chromium metal by reduction from chromic oxide using the aluminothermic process.

It is seen from the foregoing discussion that the metallurgical and refractory industries together accounted for a large percentage of total chromite consumption, and that in these industries a large proportion of the chromite consumption was related to the steel industry. This involved both the direct consumption of ferrochromium in the production of stainless and other alloy steels as in the case of the metallurgical industry and the indirect consumption of chromite brick in lining steel furnaces as in the case of refractory industry, and supports the statement in Mining

Journal Annual Review (1957) that the outlook for chromite depended primarily on the volume of steel produced.

During the period 1950-1959 chromite imports by the United States reached their highest level in 1957 when imports amounted to 2,071,000 tonnes as shown in Table 76, and comprised 1,276,000 tonnes of metallurgical grade chromite, 532,000 tonnes of refractory grade chromite, and 263,000 tonnes of chemical grade chromite as recorded in McInnis and Heidrich (1958(c)). The main sources of metallurgical grade chromite imported by the United States in 1957 were Zimbabwe, which supplied 36% of the metallurgical grade imports, Turkey 29%, South Africa 17%, and the Philippines 10%. In the case of refractory grade chromite imported by the United States in 1957 the Philippines supplied 73% of the imports and Cuba 16%, while all the chemical grade chromite imported by the United States in 1957 came from South Africa.

Although a general correspondence existed between chromite grade and industry consumption, there was increasing use of both chemical and refractory grade chromite by the metallurgical industry in the production of ferrochromium as discussed previously. For instance, in 1957 84% of the chromite consumed in the metallurgical industry was metallurgical grade, 11% was chemical grade, and 5% was refractory grade (McInnis and Heidrich, 1958(c)).

During the years 1946-1958 the United States imported chromite for the National Stockpile under the Strategic and Critical Materials Stockpiling Act 1946 (PL520) as described by Charles River Associates Inc (1970). After 1950 National Stockpile acquisitions of chromite were concentrated in the years 1951 to 1956, and purchases during that period amounted to around 2,565,000 tonnes of which about half was metallurgical grade and a third refractory grade. Most of the metallurgical grade chromite acquired for the National Stockpile during 1951-1956 was imported from Turkey, while the refractory grade chromite came from the Philippines and Cuba and the chemical grade chromite from South Africa.

Chromite was also imported by the United States for a Supplemental Stockpile through the Commodity Credit Barter Program under which chromite was acquired in exchange for surplus agricultural products exported abroad (Charles River Associates Inc, 1970). Although the barter programme was initiated in 1954 almost all the acquisitions arising from it were made between 1958 and 1963. Total imports of chromite under the programme amounted to 1,122,000 tonnes of which almost 40% was chemical grade while the balance comprised almost equal quantities of metallurgical and refractory grade chromite. Chromite for the Supplemental Stockpile was obtained under barter arrangements with South Africa, Turkey, Philippines, and Cuba. In addition, about 120,000 tonnes of metallurgical grade chromite was imported during the 1950's for government stockpile under the Defence Production Act 1950. However, most of the chromite acquired under that Act for inclusion in the government stockpile comprised domestically produced chromite from the Mouat mine in Montana.

During the period 1950-1959 Canada was also a chromite importing country as seen in Table 76. However, Canadian chromite imports amounted to only 3% of world chromite imports during the decade compared with 65% of world imports by the United States. Chromite imports by Canada were at their highest levels for the decade during the years 1950-1953 when they averaged 121,000 tonnes a year compared with average imports of 53,000 tonnes a year during 1954-1959.

Prior to 1954 a large proportion of Canadian chromite imports were consumed in the production of ferrochromium for export to the United States and the United Kingdom, but loss of ferrochromium sales in these markets resulted in reduced chromite imports by Canada as indicated by the Commonwealth Economic Committee (1962), and Canadian chromite imports fell steeply from a peak of 135,000 tonnes in 1952 to 34,000 tonnes in 1954 (Table 76). During the years 1955-1957 chromite imports by Canada rose again and reached 101,000 tonnes in 1957 as a result of larger domestic production of chromite refractories and stainless steel, but in 1958 Canadian chromite imports fell sharply to 35,000 tonnes due to recession in the steel industry.

Europe

The largest chromite importing countries in Europe during the decade 1950-1959 were West Germany and the United Kingdom with average annual chromite imports of 176,000 tonnes and 155,000 tonnes respectively, while substantial quantities of chromite were imported also during the decade by France, Sweden, Norway, Austria, and Italy as observed in Table 76. However, chromite imports by each of these countries during each year of the decade were very much lower than those by the United States.

During the period 1950-1959 there was a tremendous increase in the level of chromite imports by both West Germany and France with West German chromite imports rising from 74,000 tonnes in 1950 to 268,000 tonnes in 1959 while French chromite imports rose from 22,000 tonnes in 1950 to 154,000 tonnes in 1959 (Table 76), and the growth in chromite imports by these countries during the decade resulted from an upsurge in the level of their industrial activity as indicated by the Commonwealth Economic Committee (1962). In the case of West Germany the expansion of its iron and steel industry was such that West Germany again became the second largest chromite importing country in the world after the United States during each of the years 1954-1959 except 1957 when its chromite imports were exceeded by those of the United Kingdom.

Chromite imports by the United Kingdom varied somewhat irregularly during 1950-1959 (Table 76). However, during the years 1957-1959 chromite imports by the United Kingdom were significantly greater than their average for the decade, and this was attributed by the Commonwealth Economic Committee (1962) to an increased demand by the steel industry for chromite refractory bricks at the expense of other types and this resulted in larger imports of refractory grade chromite by the United Kingdom.

During 1950-1959 Sweden and Norway each imported chromite for the production of ferrochromium using cheap hydro-electric power, and the level of their chromite imports did not vary greatly during the decade. Further, both Sweden and Norway were importers of chromite and exporters of ferrochromium as seen in Tables 76 and 123. However, even though Sweden imported slightly more chromite than Norway during the period 1950-1959, Swedish ferrochromium exports during the decade were less than half those of Norway, and this was because of the greater consumption by Sweden of domestically produced ferrochromium in the domestic production of chromium bearing steels (Ridge and Moriwaki, 1955).

Japan

During 1950-1959 Japan was both a producer and an importer of chromite as shown in Tables 7 and 76, and during this period Japanese chromite imports averaged 91,000 tonnes a year compared with an average chromite production of 41,000 tonnes a year so that chromite imports accounted for slightly more than two thirds of Japanese chromite supply during the decade. However, there was tremendous growth in the level of chromite imports by Japan during the period 1950-1959 with imports rising from 7,000 tonnes in 1950 to 261,000 tonnes in 1959 (Table 76), while Japan's share of world chromite imports rose from less than 0.5% of world chromite imports in 1950 to 10% of world imports in 1959 (Table 83), and in 1959 Japanese chromite imports were only slightly lower than those of West Germany. In contrast, the level of Japanese chromite production remained relatively stable during 1950-1959 (Table 7), so that chromite imports represented an increasing proportion of Japanese chromite supply as the decade progressed.

The spectacular increase in chromite imports by Japan during 1950-1959, and particularly during the latter half of the decade, was in response to an equivalent expansion in Japanese ferrochromium production during the period (Commonwealth Economic Committee, 1962). At the end of 1959 Japan had the capacity to produce around 103,000 tonnes of ferrochromium a year of which 63,000 tonnes was for low carbon ferrochromium and 40,000 tonnes was for high carbon ferrochromium (McInnis and Heidrich, 1960), and there were more than eight ferrochromium producing firms in the country. Most of the ferrochromium produced by Japan during the 1950's was for consumption in the domestic steel industry.

FERROCHROMIUM

The pattern of world ferrochromium exports by country of origin during the period 1950-1959 is shown in terms of tonnage and percentage in Tables 123 and 129, and the pattern of world ferrochromium imports by country of destination during 1950-1959 is presented in terms of tonnage and percentage in Tables 153 and 159.

During the decade 1950-1959 Norway and Canada were again the largest ferrochromium exporting countries in the world, while substantial quantities of ferrochromium were exported also by France and Sweden during that period. These countries were not chromite producers, but imported chromite for the manufacture of ferrochromium using low cost hydro-electric power. In the case of Canada ferrochromium exports fell sharply after 1953 as discussed previously, while ferrochromium exports by France and Sweden increased during the latter half of the decade as seen in Table 123. Significant quantities of ferrochromium were exported also during the years 1955-1959 by Zimbabwe, Yugoslavia, and Japan. During the period 1950-1959 ferrochromium imports by both the United States and the United Kingdom were very much larger than those of other countries (Table 153) and United States ferrochromium imports during the decade were in total even greater than those of the United Kingdom, whereas during 1940-1949 ferrochromium imports by the United Kingdom were far larger than those of any other country including the United States (Table 152).

Even though the United States imported more ferrochromium than any other country in the world during the period 1950-1959, the quantity of ferrochromium imported by the United States remained relatively small compared with its ferrochromium consumption. For instance, in 1955 when United States ferrochromium consumption was at a record level of 195,000 tonnes (McInnis and Heidrich, 1958(a)), ferrochromium imports by the United States amounted to 25,300 tonnes (Table 153) and represented only 13% of United States ferrochromium consumption in that year. During 1955 chromite imports by the United States totalled 1,664,000 tonnes of which 882,000 tonnes comprised metallurgical grade chromite, and the United States continued to manufacture ferrochromium domestically using imported chromite rather than import ferrochromium produced abroad. This situation was assisted by the fact that chromite entered the United States free of duty whereas ferrochromium imports were subject to tariff.

During the 1950's the import duty on low carbon ferrochromium was reduced from 12.5% ad valorem in 1951 to 10.5% in 1958, while the duty on high carbon ferrochromium remained at 0.625 cents per pound of contained chromium and that on ferrochromium-silicon remained at 12.5% ad valorem (Charles River Associates Inc, 1970). However, these lower rates of duty did not apply to ferrochromium imports from the Soviet Union and other communist countries, which continued to be subject to duties of 30% ad valorem for low carbon ferrochromium, 2.5 cents per pound for high carbon ferrochromium, and 25% ad valorem for ferrochromium-silicon as set by the Smoot-Hawley Tariff Act 1930 for ferrochromium imports from all countries. Even though the tariff levels for ferrochromium imports from western countries were much lower than those existing in 1930 and ferrochromium imports by the United States did increase during the 1940's and 1950's, ferrochromium imports continued to represent only a relatively small proportion of the total ferrochromium supply of the United States, which comprised mostly domestically produced ferrochromium. Further, at the end of the 1950's a large proportion of the ferrochromium imports of the United States were made by the Government, and its imports entered the United States duty free as indicated in McInnis and Heidrich (1960).

In October 1954 a National Stockpile Specification was established by the United States government for the purchase of low carbon ferrochromium while a revised National Stockpile Specification (superseding that issued in December 1950) was established for the purchase of high carbon ferrochromium (Katlin and Heidrich, 1958), and during each of the years 1955-1958 ferrochromium production by the United States was much greater than ferrochromium consumption as seen in Charles River Associates Inc (1970). During 1955-1958 United States ferrochromium production averaged 388,000 tonnes a year compared with average ferrochromium consumption of 237,000 tonnes a year, and ferrochromium imports by the United States during 1955-1958 averaged 30,000 tonnes a year. Both producer stocks and consumer stocks of ferrochromium (in contrast to chromite) amounted to only a small proportion of annual production and consumption, and it appeared that a substantial proportion of United States ferrochromium production during the period 1955-1958 was added to the National Stockpile.

The introduction and successful use by 1952 of low carbon ferrochromium-silicon was reported in Katlin and Heidrich (1955) to be one of the most outstanding recent developments in steelmaking. Ferrochromium-silicon was produced in an electric furnace by carbon reduction of selected chromite ores, and the alloy commonly contained 40% Cr, 40% Si, and less than 0.05% C. Ferrochromium-silicon was used by virtually all stainless steel producers to reduce melting time, lower costs, and improve product quality. The price of the alloy was reported to be substantially lower than the price of low carbon ferrochromium that it displaced because the chromium content of ferrochromium-silicon was charged for at the same rate as that in high carbon ferrochromium, which was 28% below the rate for chromium in low carbon ferrochromium of the same carbon content as ferrochromium-silicon. The extent to which ferrochromium-silicon was being used in the metallurgical industry at the end of the 1950's is seen from consumption statistics for chromium ferroalloys given in McInnis and Heidrich (1960). These show that in the United States in 1959 the consumption of low carbon ferrochromium-silicon amounted to 40,000 tonnes compared with 103,000 tonnes of low carbon ferrochromium and 82,000 tonnes of high carbon ferrochromium, and that the production of stainless steel accounted for a large proportion of the consumption of each of these alloys and particularly of those having a low carbon content. In practice, low carbon ferrochromium-silicon, low carbon ferrochromium, and high carbon ferrochromium were all used together as charge materials in the melt to produce stainless steel as described by Charles River Associates Inc (1970).

During the 1950's ferrochromium exports were made largely though not exclusively by countries that were not chromite producers, but imported chromite for the manufacture of ferrochromium using low cost power. Chromite producing countries continued to be exporters of chromite rather than ferrochromium, and the tonnage of chromite traded internationally during 1950-1959 was more than thirty times that of ferrochromium.

Since early this century Zimbabwe had been an important producer and exporter of chromite, and during the 1950's its chromite exports averaged 390,000 tonnes a year. In 1950 it was announced that a plant to produce ferrochromium would be constructed in the industrial area of Gwelo in Zimbabwe, and that chromite for use in the plant would be obtained from the Selukwe district (Melcher and Forbes, 1953). Production of ferrochromium at Gwelo commenced during 1953, and trial shipments of ferrochromium were made by Rhodesia Alloys Ltd from its pilot plant to various steel companies in the United Kingdom and the United States (Katlin and Heidrich, 1956). The ferrochromium production plant constructed at Gwelo had a rated annual capacity of around 7,000 tonnes of low carbon ferrochromium containing 70% Cr, and most of the chromite consumed in the plant was supplied by Rhodesia Chrome Mines Ltd from its new heavy-medium separation plant at Selukwe while the balance of the chromite input came from the Windsor mine at Que Que. In the manufacture of ferrochromium about two tonnes of chromite are consumed for the production of one tonne of ferrochromium. Exports of ferrochromium by Zimbabwe rose from 200 tonnes in 1953 to 9,800 tonnes in 1959 (Table 123), and in 1959 Zimbabwe accounted for 7% of world ferrochromium exports (Table 129). However, in 1959 Zimbabwean chromite exports amounted to 500,000 tonnes (Table 25), so the tonnage of chromite exported by Zimbabwe in that year was more than fifty times that of ferrochromium.

Chapter 9

TRADE AGGREGATES 1960-1969

A large proportion of world chromite production during the period 1960-1969 took place in the Soviet Union, South Africa, Philippines, Turkey, Zimbabwe, and Albania, and these six countries were by far the largest chromite producers in the world during the decade. In addition, substantial quantities of chromite were produced during 1960-1969 in Iran, India, Yugoslavia, Japan, and Greece. During 1960-1969 South Africa, Soviet Union, Philippines, Zimbabwe, Turkey, and Albania were also very much the largest chromite exporting countries in the world, and consequently these same six countries accounted for a large proportion of world chromite exports during the decade. Iran and India also exported substantial quantities of chromite during 1960-1969, while other significant chromite exporting countries during the period included Greece, Yugoslavia, Cuba, Cyprus, and New Caledonia.

During 1960-1969 the United States continued to be by far the largest chromite importing country in the world, while Japan, West Germany, France, and the United Kingdom were also major chromite importing countries. In addition, substantial quantities of chromite were imported during the decade by Sweden, Poland, Italy, Norway, Canada, Austria, East Germany, Czechoslovakia, and Yugoslavia.

The largest ferrochromium exporting countries during 1960-1969 were South Africa, Norway, Soviet Union, Sweden, and France, while the largest ferrochromium importing countries during the decade continued to be the United Kingdom and United States.

CHROMITE PRODUCTION AND EXPORTS

The pattern of world chromite production by country during the period 1960-1969 is presented in terms of tonnage and percentage in Tables 8 and 18. It is seen that world chromite production during 1960-1969 was largely dominated by six countries, namely Soviet Union, South Africa, Philippines, Turkey, Zimbabwe, and

Albania. Of these the Soviet Union and South Africa together contributed more than 50% of world chromite production during 1960-1969 while the Philippines, Turkey, Zimbabwe, and Albania provided almost 40% of world production during that period, and these six countries accounted for 90% of world production during the decade. Other chromite producing countries included Iran, India, and Yugoslavia, which were each responsible for 2% of world production during 1960-1969. Total world chromite production varied during 1960-1969 between a low of 3,914,000 tonnes in 1963 and a record high of 5,321,000 tonnes in 1969 as seen in Table 8.

The origin of world chromite exports by country during the period 1960-1969 is shown in terms of tonnage and percentage in Tables 26 and 34. During 1960-1969 more than 90% of world chromite exports were made by six countries, namely South Africa, Soviet Union, Philippines, Zimbabwe, Turkey, and Albania, and these were the same countries that dominated world chromite production. In addition, Iran and India were significant chromite exporting countries during the decade. Total world chromite exports during 1960-1969 were at their lowest level for the decade in 1963 and almost certainly were at their highest level for the decade in 1969 as in the case of world chromite production.

South Africa

During 1960-1969 chromite production by South Africa averaged 973,000 tonnes a year while chromite exports by South Africa during the decade averaged 758,000 tonnes a year. In 1960 both chromite production and chromite exports by South Africa amounting to 772,000 tonnes and 756,000 tonnes respectively were higher than ever previously recorded. Subsequently, South African chromite production rose from 772,000 tonnes in 1960 to a new record of 1,198,000 tonnes in 1969 as shown in Table 8, while chromite exports by South Africa varied during the decade between a low of 605,000 tonnes in 1963 and a new record of 920,000 tonnes in 1969 as observed in Table 26. During 1960-1969 South Africa accounted for 21% of world chromite production and 24% of world chromite exports.

Although South Africa was a producer of chemical, metallurgical, and refractory grade chromite, a large proportion of South African chromite production was of chemical grade and South Africa continued to be the dominant supplier of chemical grade chromite to the world market. During the period 1960-1969 total chromite exports by South Africa were larger than the chromite exports of both the Soviet Union and the Philippines, which were major suppliers of metallurgical and refractory grade chromite respectively to the world market during the decade.

In 1960 South Africa was the largest source of chromite imports made by the United States, which was the largest chromite importing country in the world, and accounted for 36% of its total chromite imports in that year (McInnis and Heidrich, 1961). United States chromite imports from South Africa in 1960 amounted to 453,000 tonnes of which 74% was chemical grade, 16% was metallurgical grade, and 10% was refractory grade. Except for 347 tonnes of chemical grade chromite imported from Zimbabwe in 1960, South Africa was the sole supplier of chemical grade chromite to the United States.

Most of the chromite mined in South Africa came from the Bushveld Complex in the Transvaal (Charles River Associates Inc, 1970), and South African chromite reserves in 1960 were estimated at around two thousand million tonnes of which 95% was chemical grade chromite. Transvaal chromite was generally friable, had a Cr_2O_3 content averaging 44%, and a Cr:Fe ratio of 1.6:1.0. However, by mining from various chromite seams and using concentrating plants it was possible to produce ores and concentrates having a wide range in their Cr_2O_3 content and Cr:Fe ratio (Morning, 1971).

The chromite seams worked in the Bushveld Complex had an average width of about a metre as recorded by Charles River Associates Inc (1970). Although the deposits were mined by underground techniques, large-scale low-cost operations were used and low wage rates were reported to be a factor contributing to the low mining costs. In 1960 mining costs accounted for about a quarter of the cost of South

African chromite delivered at United States Atlantic ports, while transportation costs including both inland and ocean freight amounted to around three quarters of total costs.

In view of the extensive physical and chemical refinement involved in the production of sodium dichromate from chromite ore, the chemical industry valued chromite solely in terms of its Cr_2O_3 content provided the iron oxide and silica contents were within tolerable limits as was in fact the case for all the main chromite ores on the world market (Charles River Associates Inc, 1970). During the entire postwar period, South African Transvaal chromite had been the cheapest source of Cr_2O_3, and consequently the chemical industry bought Transvaal chromite almost exclusively. For instance, in 1960 the price per percentage unit of chromium contained in South African 44% Cr_2O_3 chromite was only 56% that of a unit of chromium contained in Turkish 48% Cr_2O_3 chromite and 58% that of a unit of chromium contained in Zimbabwean 48% Cr_2O_3 chromite, and a similarly favourable price relationship continued throughout the 1960's. However, almost all the chromite ores available on the world market were potential substitutes for South African chromite in the chemical industry, and a sufficient rise in the price of South African chromite relative to that of other ores such as those from Turkey, Zimbabwe, and the Philippines would result in their use as a source of chromium by the chemical industry.

As recorded by Prokopovitsh and Heidrich (1962) refractory grade chromite from the Philippines and Cuba had been used continuously by the basic refractories industry for a period of more than thirty years. However, in 1961 E.J. Lavino and Co, a major United States refractory producer, announced a conversion in its operations to use South African Transvaal chromite instead of refractory grade chromite from the Philippines. Transvaal chromite had not been used previously for refractory purposes, and the announcement indicated an important development as observed in Thomson (1962). The conversion by E.J. Lavino and Co was made to ensure the long term supply of chromite refractories in the event of depletion of Philippine chromite reserves.

Chromite from the Philippines and Cuba satisfied the traditional chemical and physical specifications for refractory grade ore. Hardness and lumpiness were desired physical properties so that soft friable ores as mined in the Transvaal did not qualify for refractory grade material (Charles River Associates Inc, 1970). However, by 1960 researchers at E.J. Lavino had developed a commercially viable method of making basic refractories using Transvaal chromite, and there was no significant difference in the refractory properties of bricks made from South African and Philippine chromite. Transvaal chromite ore was particularly suitable for the high firing bonding technique used in the Lavino process because its low silica content was a desirable property in the technique used, and its high iron content (undesirable in finished brick) was reduced during the process. E.J. Lavino substituted Transvaal chromite for Philippine ore as its main source of refractory chromite, and acquired mining properties in South Africa to supply its chromite requirements. However, according to Charles River Associates Inc (1970), E.J. Lavino was the only refractory producer to use Transvaal rather than Philippine ore for the bulk of its chromite requirements, although some other producers used limited quantities of Transvaal ore. A possible explanation for this was that E.J. Lavino's process was proprietary, and other companies were unable to make refractory bricks more cheaply using Transvaal ore.

Another development that increased the demand for South African chemical grade chromite as a refractory was introduction of the use of chromite in foundry sand moulds for steel castings in which chromite sand was substituted for zircon, olivine, and silica sands (Charles River Associates Inc, 1970). Although the level of chromite consumption for this purpose was not known, industry sources suggested that consumption in the United States at the end of the 1960's was around 20,000 to 50,000 tonnes a year and that it was expected to increase significantly. For foundry use South African chemical grade chromite was preferred to the traditional refractory chromite ores. According to Middleton and Bownes (1968) chromite was found to be an excellent moulding medium as it offered higher resistance to metal penetration than did zircon or silica, and had a low and uniform thermal expansion so that it was very suitable for use as a mould and core material in heavy steel casting production. Chromite proved to be at least as suitable as zircon for use in steel foundries, and it was used successfully for this purpose in the United States, Europe, and South Africa. Further, the price of chromite was about two-thirds that of zircon.

In ferrochromium production substitution took place among the major metallurgical grade chromite ores produced by Turkey, Zimbabwe, and the Soviet Union. According to Charles River Associates Inc (1970) chemical grade chromite could be substituted for metallurgical grade chromite in the production of ferrochromium although traditionally this had not been done in spite of its lower price. The price of South African Transvaal chemical grade chromite was much less than that of the metallurgical grade ores. For instance, in 1968 the price of metallurgical grade chromite from Turkey and the Soviet Union delivered in the United States was around twice that of chemical grade chromite from South Africa (Morning, 1969). However, United States ferrochromium producers still found it more profitable to use Turkish or Soviet Union chromite rather than South African chromite (Charles River Associates Inc, 1970). The two principal reasons why substitution had not taken place were that Transvaal chromite ore was friable and consequently difficult to smelt in submerged arc furnaces, and probably more importantly the high iron content of Transvaal chromite resulted in ferrochromium containing less than 60% Cr whereas stainless steel producers were accustomed to using ferrochromium having a high chromium content. Although the main metallurgical grade chromite ores available on the market were virtually perfect substitutes for use in the production of ferrochromium, South African chemical grade chromite was not perfectly substitutable as an input for ferrochromium production.

However, as discussed in the previous chapter, the practice had developed of blending limited amounts of chemical and refractory grade chromite with metallurgical grade chromite in the production of ferrochromium. This facilitated an ore mix of the requisite chemical and physical properties at minimum cost (Charles River Associates Inc, 1970), and resulted in a demand for South African chemical grade chromite imports by the metallurgical industry. The consumption of chemical grade chromite by the United States metallurgical industry as a percentage of total chromite consumption by that industry increased from 14% in 1960 to 16% in 1962 then declined to 1% in 1968. In 1962 the actual consumption of chemical grade chromite by the United States metallurgical industry amounted to 84,000 tonnes (Prokopovitsh and Heidrich, 1963) whereas in 1968 the consumption of chemical grade chromite by the metallurgical industry amounted to only 9,000 tonnes (Morning, 1969). However, in 1969 the quantity of chemical grade chromite consumed by the United States metallurgical industry rose to 63,000 tonnes (Morning, 1971).

In 1962 Anglo American Corporation of South Africa Ltd and Avesta Jernverks AB of Sweden were planning a new company, Transalloys (Pty) Ltd to produce ferrochromium near Witbank in South Africa using domestic chromite (Prokopovitsh and Heidrich, 1963). The production plant was expected to use a new process patented by Avesta that would enable the use of lower grade South African Transvaal chromite ore to produce low-carbon ferrochromium having a high chromium content. According to Thomson (1962) the ferrochromium produced would be exported to Sweden and other stainless steel producing countries.

It was recorded in Holliday (1965) that two new ferrochromium plants designed to use Transvaal chemical grade chromite ore commenced production in South Africa in May 1964. One of these was that of Transalloys (Pty) Ltd, a subsidiary of Anglo American and Avesta, built at Witbank in the Transvaal with an initial annual capacity of 14,000 tonnes of low-carbon ferrochromium, 5,000 tonnes of high-carbon ferrochromium, and 1,000 tonnes of ferrochromium-silicon. The other plant was built for R.M.B. Alloys (Pty) Ltd, a subsidiary of Rand Mines, at Middleburg in the Transvaal to produce 32,000 tonnes of low-carbon ferrochromium annually. The production of ferrochromium in South Africa increased the domestic consumption of chromite ore and contributed to the increase in chromite production relative to chromite exports by South Africa during the latter half of the 1960's as observed in Tables 8 and 26.

The development of an economically viable method for producing ferrochromium from Transvaal chemical grade ore increased the potential for substitution of South African chromite by the metallurgical industry (Charles River Associates Inc, 1970). Even though United States and European ferrochromium producers had not found it profitable to adopt the process, the availability of the new method limited the extent to which metallurgical grade chromite prices could increase relative to chemical grade chromite prices. The new process was used mainly in South Africa where transportation cost differentials favoured the use of domestically produced chromite by any process in South Africa involving chromium inputs.

During the period 1960-1969 South Africa was responsible for 24% of world chromite exports, and its share of world exports did not vary greatly during the decade as observed in Table 34. Chromite exports by South Africa reached their lowest level for the decade in 1963 when they amounted to 605,000 tonnes (Table 26). However, in 1963 South Africa maintained its share of world exports with 23% of total exports (Table 34). During 1963 South African chromite production was also at a significantly reduced level of 792,000 tonnes (Table 8), although South Africa maintained its share of world chromite production at 20% of total production (Table 18). According to Holliday (1964) chromite production by most of the world's major traditional sources declined in 1963 because of the large level of chromite stocks existing from previous years as well as increased availability of chromite from the Soviet Union.

Two factors related to the stockpiling of chromite by the United States contributed to a slightly larger than average share of world chromite exports by South Africa during the earlier and later years of the 1960's as observed in Table 34. First, chromite was acquired by the United States for a Supplemental Stockpile through the Commodity Credit Corporation Barter Program under which chromite was obtained in exchange for surplus agricultural products (Charles River Associates Inc, 1970). Almost all the acquisitions under this programme were made between 1958 and 1963, and total acquisitions amounted to 1,122,000 tonnes of which 440,000 tonnes were chemical grade chromite. These barter transactions absorbed more than 10% of South African chromite production during the period, and the chromite exports associated with it contributed to an increase in South Africa's share of world chromite exports. Secondly, sales of metallurgical grade chromite were made by the United States Government from the General Services Administration (GSA) stockpile under Public Law 89-415 of May 1966 (Morning, 1971). Annual deliveries of metallurgical grade chromite arising from GSA stockpile sales increased from 27,000 tonnes in 1966 to 220,000 tonnes in 1969, and assisted in compensating for the loss of metallurgical grade chromite imports from Zimbabwe following the unilateral declaration of independence by that country in November 1965, and the subsequent implementation by the United States in January 1967 of mandatory economic sanctions against Zimbabwe in accordance with a decision of the United Nations Security Council made in December 1966. The sale and delivery of metallurgical grade chromite from the United States GSA stockpile had the indirect effect of increasing the share of world chromite exports contributed by South Africa and other countries during the latter part of the decade.

By 1965 there were twelve large or medium sized companies involved in chromite mining in the Transvaal of South Africa (Charles River Associates Inc, 1970). The six largest companies were divisions or affiliates of Union Corporation, Union Carbide, Rand Mines, Allied Chemical, Lavino, and Marble Lime and Associated Industries, and these six companies probably accounted for at least 75% of South African chromite production. The latter four companies became involved in chromite production in South Africa during the postwar period, and their entry into chromite mining was associated with vertical integration. Chromite production by these new entrants involved the development of known deposits rather than the discovery of new deposits.

Soviet Union

Throughout the period 1960-1969 the Soviet Union was the largest chromite producing country in the world, and accounted for 30% of world chromite production during the decade. In 1960 chromite production by the Soviet Union was at a record of 916,000 tonnes compared with 853,000 tonnes in 1959 (Tables 7 and 8). Subsequently, Soviet Union chromite production rose continuously from 916,000 tonnes in 1960 to a new record of 1,700,000 tonnes in 1969 (Table 8) so that the level of chromite production by the Soviet Union doubled from 1959 to 1969.

Chromite exports by the Soviet Union were also at a record level in 1960 when they amounted to 427,000 tonnes compared with 272,000 tonnes in 1959 (Tables 25 and 26). During the period 1960-1969 Soviet Union chromite exports increased continuously from 427,000 tonnes in 1960 to a new record of 1,144,000 tonnes in 1969 (Table 26), and in 1969 the level of chromite exports by the Soviet Union was more than four times that in 1959. The Soviet Union accounted for 24% of world chromite exports during the period 1960-1969 as did South Africa, and during each of the years 1964-1969 the Soviet Union was the largest chromite exporting country in the world as observed in Table 26. During the period 1960-1969 the Soviet Union exported 56% of its total chromite production while the balance of its chromite production was used for domestic consumption.

During both 1960 and 1961 chromite exports by the Soviet Union amounting to 427,000 tonnes and 438,000 tonnes respectively (Table 26) were much larger than chromite exports of 272,000 tonnes made by the Soviet Union in 1959 (Table 25). The increased level of Soviet Union chromite exports in the early 1960's was made possible by the availability on the export market of large tonnages of high grade Soviet ore (Prokopovitsh and Heidrich, 1962), and during these years chromite from the Soviet Union was offered at very competitive prices (Thomson, 1962). The proportion of world chromite exports contributed by the Soviet Union rose from 9% in

1959 to 13% and 14% respectively in 1960 and 1961 (Tables 33 and 34).

About two-thirds of the chromite exported by the Soviet Union during 1960 and 1961 went to western countries, particularly West Germany, Japan, Sweden, France, United Kingdom, and Italy that accounted for most of these exports, while the remainder of the exports went to Sino-Soviet Bloc countries, particularly Poland, Czechoslovakia, China, and East Germany (Prokopovitsh and Heidrich, 1962). In 1960 and 1961 United States chromite imports from the Soviet Union amounted to 6,000 tonnes and 18,000 tonnes respectively (Prokopovitsh and Heidrich, 1962), and represented only a small proportion of chromite exports by the Soviet Union during those years. Chromite imports by the United States from the Soviet Union resumed in 1959 after a period of eight years during which there were no such imports as discussed in the previous chapter.

During 1962 and 1963 Soviet Union chromite production and exports continued to increase while world chromite exports decreased (Tables 8 and 26). However, even though the Soviet Union increased chromite production from 921,000 tonnes in 1961 to 1,152,000 tonnes in 1962, the climate for chromite mining world-wide was not one of vigor as many producers were accumulating large stocks of unsold ore (Prokopovitsh and Heidrich, 1963). Indeed, chromite production by the Soviet Union rose 25% during 1962 whereas chromite exports by the Soviet Union increased only 8% as deduced from Tables 8 and 26. Further, chromite exports by both Zimbabwe and Turkey, the other major world producers of metallurgical grade chromite, actually decreased during 1962 (Table 26). According to Thomson (1963) Zimbabwe and Turkey were seriously affected during 1962 by exports of metallurgical grade chromite by the Soviet Union at prices lower than these western suppliers were prepared to quote. At the end of 1962 there was a reluctance among consumers to contract for future chromite production as substantial quantities of high grade chromite were available at low prices as recorded by Prokopovitsh and Heidrich (1963). This resulted in intense competition and lower prices.

By early 1963 the Soviet Union controlled about 70% of the European chromite market, and high grade metallurgical as well as refractory quality chromite from the Soviet Union was being offered in Europe at a dollar per tonne below the lowest price quotation of western producers (Thomson, 1963). This led to allegations by Zimbabwean chromite producers that the Soviet Union was dumping chromite on western markets, and they supported their argument by the fact that high freight costs had to be incurred in transporting the chromite from where it was mined to the port of export on the Black Sea, a distance of about 1,200 kilometres from western Kazakhstan and 1,600 kilometres from the Urals. During 1963 chromite imports by the United States from the Soviet Union showed a substantial increase from 34,000 tonnes in 1962 to 174,000 tonnes in 1963 (Prokopovitsh and Heidrich, 1963 & Holliday, 1964), and in 1963 chromite imports from the Soviet Union represented 14% of United States chromite imports compared with 7% in 1962. By early 1963 several United States ferrochromium producers had signed contracts for the purchase of Soviet Union chromite (Thomson, 1963), and one contract involved around 300,000 tonnes of chromite for shipment at the rate of 100,000 tonnes a year. According to Charles River Associates Inc (1970) the period from 1959-1963 was one in which Soviet Union chromite was in the process of gaining consumer acceptance in the United States.

During 1963 there was a significant increase in both chromite production and chromite exports by the Soviet Union while total world chromite production and exports decreased (Tables 8 and 26), and the proportion of world chromite production provided by the Soviet Union rose from 26% in 1962 to 31% in 1963 while the share of world chromite exports contributed by the Soviet Union increased from 16% in 1962 to 22% in 1963 (Tables 18 and 34). Zimbabwe and Turkey were the main competitors with the Soviet Union in the world market for metallurgical grade chromite, and during 1963 there was a substantial reduction in the level of chromite production and chromite exports by both Zimbabwe and Turkey (Tables 8 and 26). Among the factors contributing to this situation were the existence of large chromite inventories from previous years, and the availability of large quantities of chromite from the Soviet Union (Holliday, 1964). These circumstances resulted in a highly competitive world chromite market, and western chromite producers attributed their marketing difficulties to increased exports by the Soviet Union. However, the increase in chromite exports by the Soviet Union during 1963 was significantly less than the combined decrease in exports by Zimbabwe and Turkey as seen from Table 26 so that increased exports by the Soviet Union were not the only factor contributing to the marketing difficulties of western chromite producers, who were adversely affected by the low level of world demand for chromite in 1963 referred to by Holliday (1965). Indeed, world chromite production and exports were each at their lowest level for the decade in 1963 as observed in Tables 8 and 26.

World chromite production and exports recovered during 1964 and 1965, and in 1965 each reached record levels (Tables 8 and 26). Chromite production and exports by the Soviet Union continued to increase during 1964 and 1965 (Tables 8 and 26), while the percentages of world chromite production and exports contributed by the Soviet Union were each maintained at around their 1963 levels (Tables 18 and 34). In 1965 chromite exports by the Soviet Union amounted to 748,000 tonnes (Table 26), and were 75% higher than in 1960. The Soviet Union accounted for 21% of world chromite exports in 1965 compared with 17% by Zimbabwe and 12% by Turkey (Table 34). According to Morning (1966) high quality Soviet Union chromite set the level of world chromite prices in 1965, and these remained relatively stable during the year.

Chromite produced in the Soviet Union was used for both domestic consumption and export, and an indication of the level of domestic consumption in the Soviet Union is given by the difference between production and export tonnages shown in Tables 8 and 26. These suggest that chromite consumption by the Soviet Union during 1960-1969 averaged around 600,000 tonnes a year. On the basis of consumption statistics quoted by Charles River Associates Inc (1970) for 1965 it appears that 45% of the chromite consumed by Soviet industry in that year was used in the metallurgical industry, 32% in the refractory industry, and 23% in the chemical industry. Chromite exports by the Soviet Union consisted almost entirely of metallurgical grade ore, and were characterised by their high chromium content. Chromite imports by the United States from the Soviet Union generally had a Cr_2O_3 content of 50% or more and a Cr:Fe ratio of 3.5:1.0 or higher compared with a Cr_2O_3 content of 48% and a Cr:Fe ratio of 3.0:1.0 for typical Zimbabwean and Turkish metallurgical grade chromite ores (Charles River Associates Inc, 1970).

Chromite imports by the United States from the Soviet Union increased further during 1964 to reach 250,000 tonnes compared with 174,000 tonnes in 1963 (Holliday, 1964 & 1965), and in 1964 chromite from the Soviet Union represented 19% of United States chromite imports compared with 14% in 1963. The tonnage of United States chromite imports from the Soviet Union in 1964 was equivalent to 38% of total chromite exports by the Soviet Union in that year as given in Table 26. It was reported by Thomson (1964) that high grade metallurgical chromite from the Soviet Union was selling in the United States market at prices much lower than chromite ore from Zimbabwe, and ferrochromium manufacturers in the United States maintained they were compelled to sign contracts for Soviet Union chromite in order to meet competition from chromium ferroalloys produced in Europe using Soviet chromite purchased at very low prices. According to Charles River Associates Inc (1970) the Soviet Union priced its chromite exports below their equilibrium price during the earlier part of the 1960's in order to induce consumers to change from Zimbabwean and Turkish metallurgical ores, and they were successful in doing so. This illustrates the influence of price as a factor in determining the pattern of international trade, and shows the ease with which various metallurgical grade chromite ores can be substituted for one another. Such substitution was further demonstrated by the replacement of Zimbabwean metallurgical grade chromite by Soviet Union chromite following the imposition in 1966 of economic sanctions against Zimbabwe as discussed below. It was suggested by Thomson (1964) that in all probability improvements in the quality of Soviet Union chromite shipped during the early 1960's would not have eventuated except for the fact that good clean hard lumpy chromite ores with a high Cr:Fe ratio were readily available from Zimbabwe and Turkey, and in any event they represented an element of quality competition.

During the period 1966-1969 chromite production and exports by the Soviet Union continued to increase, and in 1969 they were each at record levels of 1,700,000 tonnes and 1,144,000 tonnes respectively (Tables 8 and 26). The Soviet Union continued to be the largest chromite producing and exporting country in the world during 1966-1969, and accounted for around one third of total world chromite production and exports during these years (Tables 18 and 34).

The expansion in chromite exports by the Soviet Union during 1966-1969 was facilitated by economic sanctions against Zimbabwe that were applied following its unilateral declaration of independence late in 1965. Voluntary sanctions against the importation of Zimbabwean chromite were imposed during 1966, and these were replaced by mandatory sanctions in 1967 (Charles River Associates Inc, 1970). The effect of the boycott against exports of chromite from Zimbabwe was to create an artificial world shortage of high grade metallurgical chromite, and increase the dependence of western chromite consuming countries on metallurgical grade ore from the Soviet Union as observed by Thomson (1969). This dependence was accentuated by the fact that Turkey and Iran, which were the other major sources of high grade hard lump metallurgical chromite, were not able to supply the shortfall created by the exclusion of Zimbabwean chromite ore from the market. Chromite exports by the Soviet Union increased from 748,000 tonnes in 1965 to 1,144,000 tonnes in 1969 (Table 26), and its share of world chromite exports rose from 21% in 1965 to 33% in 1969 (Table 34). In contrast, chromite exports by Turkey during the years 1966-1969 averaged around their 1965 level while chromite exports by Iran during 1966-1969 were significantly lower than in 1965. According to Thomson (1970) the Soviet Union took advantage of the Zimbabwean situation by increasing the price and lowering the quality of its chromite exports.

Chromite imports by the United States from the Soviet Union reached their highest level for the decade in 1968 when imports amounted to 304,000 tonnes as recorded by Morning (1971), and in 1968 the Soviet Union supplied 31% of the chromite imports of the United States compared with 7% in 1962 as described earlier. The tonnage of United States chromite imports from the Soviet Union in 1968 was more than twice that of chromite imports from Turkey, and all the chromite imported by the United States from the Soviet Union in 1968 was of high grade with a Cr_2O_3 content classified as 46% or more whereas the chromite imported from Turkey was of variable grade and only 39% of the imports had a Cr_2O_3 content of 46% or higher. Further, in 1968 the Soviet Union accounted for 67% of United States chromite imports having a Cr_2O_3 content of 46% or more while Turkey provided only 12% of United States imports of that grade. This shows the position of great importance attained by the Soviet Union as supplier of high grade metallurgical chromite to the United States by the latter part of the decade.

During the three year period 1967-1969 the quoted price per tonne f.o.b. rail cars United States Atlantic ports of Soviet Union metallurgical grade chromite containing 55% Cr_2O_3 and having a Cr:Fe ratio of 4:1 increased from around $31-25 at the beginning of 1967 to $56-30 at the end of 1969, and the price of Turkish metallurgical grade chromite containing 48% Cr_2O_3 and having a Cr:Fe ratio of 3:1 rose from around $32-50 to $47-25 during the same period (Morning, 1968 & 1971). Thus, the quoted price of metallurgical grade chromite from the Soviet Union and Turkey delivered in the eastern United States increased during the years 1967-1969 by 80% and 45% respectively. In contrast, the equivalent price delivered in the United States of South African chemical grade chromite containing 44% Cr_2O_3 remained at around $20 per tonne during 1967-1969. The sharp rise in price of metallurgical grade chromite from the Soviet Union and Turkey during 1967-1969 reflected the existence of mandatory economic sanctions against Zimbabwe that were in force during the last three years of the decade.

It is interesting to observe that early in 1967 the quoted price of Soviet Union chromite in the United States was slightly lower than that of Turkish chromite even though the Soviet Union chromite had a much higher grade and Cr:Fe ratio than the Turkish ore, whereas by the end of 1969 the price of chromite from the Soviet Union was substantially higher than that from Turkey as would be expected in view of its higher grade and ratio. Further, chromite ores from the Soviet Union did not vary greatly in quality whereas in Turkey there were many small producers as well as small scattered mines so that variation in the quality of Turkish chromite could be great (Charles River Associates Inc, 1970), and this was another reason for Soviet Union chromite being able to command a higher price than that from Turkey. The relatively low price quoted for Soviet Union chromite compared with that for Turkish chromite of lower grade and ratio at the beginning of 1967 provided evidence that chromite from the Soviet Union was being sold cheaply in order to gain markets, and according to Thomson (1968) the Soviet Union was involved in aggressive marketing of chromite during 1967.

The Soviet Union Five-Year Plan covering the period 1966-1970 envisaged an expansion of 30% in chromite production by 1970 compared with chromite production in 1965 (Thomson, 1968), and it appears from production figures given in Tables 8 and 9 that Soviet Union chromite production during the five year period increased by 23%. Even though the growth in chromite production by the Soviet Union during 1966-1970 was slightly below that proposed, the situation that developed in relation to Zimbabwe enabled Soviet chromite production during much of the period to take place in a climate of rapidly rising export prices. During 1967-1969 the Soviet Union exported 65% of its chromite production (Tables 8 and 26), and would have benefited substantially from the higher export prices it was able to charge.

The availability of large chromite reserves in the Soviet Union was an important factor in making possible the tremendous expansion in the level of its chromite production and exports during the 1960's. According to Charles River Associates Inc (1970) estimates of the tonnage of Soviet Union chromite reserves ranged from around ten million tonnes to seventy five million tonnes of which the latter was regarded as being the more realistic. In any event, the existence of large chromite reserves in the Soviet Union was evidenced by the growth in chromite production by the Soviet Union from 916,000 tonnes in 1960 to 1,700,000 tonnes in 1969 (Table 8) as well as by the reported discovery in the mid-1960's of large chromite deposits in the Soviet Union (Strishkov, 1967). Further, the expansion in chromite production envisaged in the Soviet Five-Year Plan for the period 1966-1970 was decided upon prior to the unilateral declaration of independence in Zimbabwe and the imposition of economic sanctions that arose from it, and consequently did not reflect a short term expansion in response to abnormal circumstances.

The metallurgical chromite mines of the Soviet Union were located in the Donskoye area of the Kimpersayskiy district of Kazakhstan (Charles River Associates Inc, 1970). The orebodies in the area varied in size, but included some that were exceptionally large. The Donskoye mines were operated by three open pits from which the chromite output almost trebled between 1959 and 1965, and these mines probably accounted for much of the expansion in Soviet Union chromite production that took place after 1959. The chromite deposits in Kazakhstan were the principal source of Soviet Union chromite, and consisted of more than seventy orebodies distributed in irregular clusters within a large mass of serpentinised ultrabasic rock of which the outcrop extended over an area of a thousand square kilometres. The erratic geographical distribution of the chromite deposits indicated they were of the discontinuous podiform type.

It is seen that during the 1960's there was a tremendous growth in both the tonnage and world share of chromite exports by the Soviet Union. Prior to 1967 this was achieved by aggressive marketing and intense price competition from Soviet Union chromite in both Europe and the United States, then after 1967 the demand for Soviet Union chromite increased in consequence of mandatory economic sanctions against Zimbabwe and exports during that period took place in a climate of rising prices.

Philippines

Chromite production by the Philippines decreased from 734,000 tonnes in 1960 to 531,000 tonnes in 1962 then fluctuated around the 500,000 tonne level and remained within the 400,000-600,000 tonne range during the period 1962-1969 (Table 8), while chromite exports by the Philippines fell from 796,000 tonnes in 1960 to 442,000 tonnes in 1962 then oscillated around the 500,000 tonne level and remained within the 400,000-600,000 tonne range during 1962-1969 (Table 26). During the period 1960-1969 the share of world chromite production contributed by the Philippines declined from 17% in 1960 to 9% in 1969 (Table 18), while the share of world chromite exports derived from the Philippines fell from 24% in 1960 to 15% in 1962 then fluctuated within the 15%-19% range during the years 1962-1969 (Table 34). In 1960 the Philippines was the largest chromite exporting country in the world, but during each of the years 1961-1969 its exports were exceeded by at least one other country as observed in Tables 26 and 34. During the period 1960-1969 the Philippines accounted for 17% of world chromite exports, and its total exports for the decade were exceeded only by those of South Africa and the Soviet Union.

Throughout the 1960's the Philippines continued to produce refractory and metallurgical grade chromite from the Masinloc and Acoje deposits. In 1960 refractory grade chromite comprised 82% of the total chromite production of the Philippines compared with 76% in 1969 (McInnis and Heidrich, 1961 & Morning, 1971). Total chromite production by the Philippines dropped from 734,000 tonnes in 1960 to 469,000 tonnes in 1969 (Table 8) so that refractory grade chromite production by the Philippines fell from 602,000 tonnes in 1960 to 356,000 tonnes in 1969 while metallurgical grade chromite production decreased from 132,000 tonnes in 1960 to 113,000 tonnes in 1969.

The refractory grade chromite production of the Philippines during 1960-1969 came from the Masinloc deposit as it had done since the 1930's when the deposit was discovered. According to Charles River Associates Inc (1970) the Masinloc deposit consisted of several orebodies, which were mined by open cut methods, and the deposit provided the bulk of refractory grade chromite consumed by western countries. Indeed, the Masinloc deposit remained the traditional source of refractory grade chromite imported by the United States as observed by Thomson (1969). Chromite ore from the Masinloc deposit was hard, lumpy, high in Al_2O_3, and had a Cr_2O_3 content of around 34%. These characteristics made it ideally suitable for refractory use. The deposit was owned by Consolidated Mines and operated under contract by Benguet Consolidated.

The main producer of metallurgical grade chromite in the Philippines was the Acoje Mining Company. A very large proportion of the metallurgical grade chromite production of the Philippines comprised chromite concentrate having a Cr_2O_3 content of around 50% while the balance consisted of lump ore with a Cr_2O_3 content of 53% (Prokopovitsh and Heidrich, 1962). In late 1966 Acoje Mining began using open cut operations in order to expand production (Morning, 1968), and in fact metallurgical grade chromite production by the Philippines increased from 106,000 tonnes in 1966 to 134,000 tonnes in 1967 so it was restored to its 1960 level.

Chromite exports by the Philippines amounted to 796,000 tonnes in 1960 compared with 515,000 tonnes in 1969 (Table 26). During 1960 53% of the refractory grade chromite exports of the Philippines were made to the United States while 26% went to the United Kingdom and the remaining 21% were sent to six other countries, whereas virtually all the metallurgical grade chromite exported by the Philippines went to Japan (McInnis and Heidrich, 1961). In 1969 46% of the refractory grade chromite exports of the Philippines went to the United States and 22% to the United Kingdom while the other 32% of refractory exports were made to ten other countries including Japan and Canada, and all the metallurgical grade chromite exports of the Philippines went to Japan (Morning, 1971). Thus, even though chromite exports by the Philippines were much lower in 1969 than in 1960, the United States and the United Kingdom continued to be the major recipients of refractory grade chromite exported by the Philippines and accounted for roughly a half and a quarter of such exports respectively, while Japan was virtually the sole market for metallurgical grade chromite exported by the Philippines.

In 1960 United States imports of refractory grade chromite from the Philippines totalled 341,000 tonnes and the Philippines accounted for 79% of United States refractory grade chromite imports in that year (Prokopovitsh and Heldrich, 1962), whereas in 1969 United States chromite imports from the Philippines amounted to only 174,000 tonnes, all of which had a grade classified as not exceeding 40% Cr_2O_3 and comprised refractory grade chromite, and these imports represented 70% of total United States imports of that grade classification (Morning, 1971). Thus, the Philippines continued to be the major supplier of refractory grade chromite to the United States although at a reduced level of imports. During the 1960's the price of United States imports of refractory grade chromite from the Philippines showed little variation (Charles River Associates Inc, 1970), and this was despite a decline in demand for such imports during the decade.

The iron and steel industry accounted for almost the entire consumption of chromite refractory brick, and two technological developments in the steel industry had a strong influence on the demand for chromite refractories as described by Charles River Associates Inc (1970). These were the basic brick open-hearth roof and the basic-oxygen converter. In open-hearth furnaces higher operating temperatures and improved lining lives were achieved by the replacement of silicon refractories by basic refractories. Such substitution in furnace walls began in the 1930's, but the completely basic brick roof was not introduced until 1954, and following perfection it was widely adopted after 1958. The transition to basic roofs increased the demand for chrome-magnesite bricks, although improvements in the quality of magnesite resulted in the substitution of magnesite-chrome bricks (containing more magnesite than chromite) for chrome-magnesite bricks (containing more chromite than magnesite) in steel furnaces. It was reported by McInnis and Heidrich (1961) that the number of open-hearth furnaces in the United States operating with basic roofs had increased from one in 1954 to more than two hundred at the beginning of 1960. This resulted in expanded demand for refractory grade chromite, and the increased consumption of chromite by refractory producers during 1960 was attributed (McInnis and Heidrich, 1961) mainly to the greater use of basic refractories in the roofs of open-hearth steel furnaces.

In contrast, the adoption by the steel industry of the basic-oxygen converter as an alternative to the open-hearth furnace was a major factor in reducing demand for chromite by the refractory industry during the 1960's (Charles River Associates Inc, 1970). In the basic-oxygen converter refractories were exposed to conditions much more severe than in open-hearth furnaces, and under the operating conditions encountered magnesite, dolomite, and magnesite-dolomite refractories were the most suitable to employ. Indeed, no chromite bearing refractories were used in the basic-oxygen converter. The extent to which open-hearth furnaces were being replaced by basic-oxygen converters in steel production as well as the impact of such replacement on the demand for chromite refractories is seen from statistics tabulated by Charles River Associates Inc (1970). These show that during the period 1960-1968 total steel production in the United States increased 32% while basic open-hearth steel production fell 24%, and that the consumption of refractory chromite per tonne of total steel produced decreased 40% during 1960-1968 whereas the consumption of refractory chromite per tonne of steel produced by basic open-hearth furnace remained roughly constant at around five kilograms per tonne. The greatest rise in total steel production for the period took place during 1963 and 1964 and included an increase in basic open-hearth steel production, while the main decline in basic open-hearth steel production for the period occurred during the years 1965-1968. Chromite consumption by the United States refractory industry decreased from 355,000 tonnes in 1960 to 282,000 tonnes in 1968 (McInnes and Heidrich, 1961 & Morning, 1971), which represented a drop of 21% and was roughly equivalent to the proportional fall in United States open-hearth steel production during the same period. The reduction in open-hearth steel production resulted in lower imports of refractory grade chromite by the United States from the Philippines. It is interesting to speculate that if there had been no conversion from the open-hearth to basic-oxygen processes and total steel production in the United States attained the level it did in 1968, it is likely that the consumption of chromite by the United States refractory industry in 1968 would have been around 300,000 tonnes higher than it was, and this perhaps best indicates the true impact on the potential demand for chromite refractories that arose from the introduction of the basic-oxygen converter.

According to Industrial Minerals (1972) there was a world-wide trend in steel production to replace open-hearth furnaces by basic-oxygen furnaces, which operated more quickly and enabled greater economies of scale, and it was concluded by the National Materials Advisory Board (1970) that even though the consumption of chromite refractories in other uses such as electric furnaces was growing at the end of the 1960's, such increases were not expected to compensate fully for the anticipated reduction in the consumption of refractory chromite used in open-hearth steel production in the United States. Such a trend and prognosis had particular relevance to the Philippines as the major supplier of refractory grade chromite to western countries.

Zimbabwe

During the period 1960-1965 Zimbabwe accounted for 12% of world chromite production and 14% of world chromite exports. Chromite production by Zimbabwe decreased from a record of 606,000 tonnes in 1960 to 374,000 tonnes in 1963 then recovered to 586,000 tonnes in 1965 (Table 8), while chromite exports by Zimbabwe declined from 490,000 tonnes in 1960 to 280,000 tonnes in 1963 then rose to 635,000 tonnes in 1965 (Table 26). During 1966-1969 Zimbabwean chromite production was estimated to average 345,000 tonnes a year, but chromite exports by Zimbabwe during this period are not known.

The decline in chromite production and exports by Zimbabwe during the period 1960-1963 was associated with various factors including competition from the Soviet Union, the existence of large chromite stocks, and a reduced level of world demand as referred to earlier in the chapter. Even though chromite exports by Zimbabwe in 1963 were 43% lower than in 1960, the proportion of world chromite exports contributed by Zimbabwe fell less sharply from 15% in 1960 to 11% in 1963 (Tables 26 and 34). Subsequently, Zimbabwe benefited from the recovery experienced by the world chromite market, and its chromite exports in 1965 were 127% higher than in 1963 while its proportion of world chromite exports rose to 17% in 1965. Chromite exports by Zimbabwe in 1965 amounted to 635,000 tonnes (Table 26), and were almost at their record level of 636,000 tonnes reached in 1957 following completion of the Lourenco Marques railway as discussed in the previous chapter.

Even though all grades of chromite were produced in Zimbabwe, metallurgical grade chromite comprised the greatest proportion of its production (McInnis and Heidrich, 1961). Both Union Carbide and Vanadium Corporation, which were the largest consumers of metallurgical grade chromite in the United States, had tied mines in Zimbabwe (Thomson, 1963), and in 1964 64% of the chromite exported by Zimbabwe went to the United States (Thomson, 1966). During 1964 and 1965 metallurgical chromite consumption by the United States recovered strongly as seen in Morning (1966) while world chromite consumption rose to record level in 1965 as a result of wide-spread expansion in the steel and chemical industries (Thomson, 1966), and these factors contributed to the rapid recovery in chromite exports by Zimbabwe. According to Thomson (1966) the operations of Rhodesia Chrome Mines Ltd at

Selukwe accounted for about three quarters of the chromite exports of Zimbabwe, and that company was controlled through London by the United Kingdom subsidiary of Union Carbide.

In November 1965 an illegal unilateral declaration of independence from the United Kingdom was made by the Prime Minister of Zimbabwe (then Southern Rhodesia), and this led to economic sanctions that had profound effects on the export of chromite by Zimbabwe and on the world market in metallurgical grade chromite. Soon after the declaration of independence by Zimbabwe, the British Government imposed sanctions forbidding the importation of chromite from Zimbabwe and urged other countries to apply similar sanctions (Charles River Associates Inc, 1970). However, this had only a limited effect on chromite exports by Zimbabwe during 1966 as the United Kingdom accounted for only 4% of Zimbabwean chromite exports in 1965, and many other chromite importers did not respond to the call for voluntary sanctions. Nevertheless, the voluntary sanctions did result in reduced Zimbabwean chromite exports. In January 1966 the Queen approved an Order-in-Council giving the United Kingdom Government powers to place an embargo on trade with Zimbabwe in any commodity, and following study of that Order the United States Government requested American importers to cut off shipments of chromite from Zimbabwe (Thomson, 1966). Several chromite importers including Union Carbide and Vanadium Corporation indicated their intention to comply with the request. In the event, chromite imports by the United States from Zimbabwe in 1966 were 45% lower than in 1965 as seen in Morning (1966) and Hibbard (1967). Further, it was reported in February 1966 that Rhodesia Chrome Mines Ltd and its associated company African Chrome Mines Ltd (both of which were related to Union Carbide through its U.K. subsidiary) had been obliged to cancel contracts to supply Japan and France as well as other countries with chromite from Zimbabwe (Thomson, 1966). However, during 1966 Zimbabwe continued to produce chromite, and ore from Zimbabwe was stockpiled in Mozambique as reported by Thomson (1967).

Subsequently, when no political compromise had been reached between the United Kingdom and Zimbabwe, the United Nations Security Council voted in December 1966 for mandatory economic sanctions against Zimbabwe, and these involved a ban on the importation of chromite of Zimbabwean origin (Charles River Associates Inc, 1970). With the exception of South Africa chromite importing member countries of the United Nations agreed to stand by the decision of the Security Council, and in the case of the United States, which was the largest importer of chromite from Zimbabwe, the ban on imports was implemented by Executive Order of the President in January 1967. The United States prohibition against imports applied not only to chromite, but also to chromium bearing products so that South African ferrochromium produced from Zimbabwean chromite could not be imported. However, the United States boycott did not apply to Zimbabwean chromite stockpiled at Beira and Lourenco Marques in Mozambique prior to the ban, and in 1967 the United States legally imported 133,000 tonnes of Zimbabwean chromite as shown in Morning (1968). However, there were no chromite imports by the United States from Zimbabwe during 1968 and 1969 (Morning, 1971).

The effect of economic sanctions against Zimbabwe was to create an artificial world shortage of metallurgical grade chromite, and consumers were forced to rely largely for their supply of such chromite on the Soviet Union, Turkey, and to a lesser extent Iran. Following the declaration of independence by Zimbabwe and the introduction of sanctions early in 1966, chromite exports by the Soviet Union increased substantially as observed in Table 26 and during the period 1967-1969 the price of metallurgical grade chromite from both the Soviet Union and Turkey increased sharply as described earlier in this chapter.

There was considerable speculation and rumour that the embargo on the export of chromite from Zimbabwe was not fully effective and that some illegal trading took place. According to Charles River Associates Inc (1970) there were various reports during 1967 and 1968 that the transport of chromite from Zimbabwean mining areas to Lourenco Marques in Mozambique as well as the shipment of chromite from that port continued, while it was suggested by Thomson (1968) that probably chromite from Zimbabwe had been passed off as being of South African origin. It was observed by Thomson (1969) that the Soviet Union might have been importing Zimbabwean chromite for re-export in order to maintain its high level of exports to western countries, and that Japan and China also had been mentioned as possible destinations for chromite from Zimbabwe. In the case of the United States customs officials analysed consignments of chromite to ensure they had not originated in Zimbabwe (Thomson, 1969), although it was not possible to establish the origin of the chromium in ferroalloys. However, United States imports of ferrochromium remained relatively small compared with its imports of chromite after the imposition of sanctions (Tables 77 and 154). Thus, the ban imposed by the United States against the importation of chromite from Zimbabwe seems to have been successfully maintained, while the United States continued to be the largest chromite importing country in the world (Table 77). Previously, the United States provided the largest market for chromite exported by Zimbabwe. Even though no trade statistics for Zimbabwe are available after 1965, it appears that chromite exports by Zimbabwe declined to a level substantially below that existing prior to the embargo as suggested by Charles River Associates Inc (1970). Further, the effectiveness of mandatory economic sanctions against Zimbabwe was evidenced by the sharp rise in price of metallurgical grade chromite that took place during the years 1967-1969.

Turkey

Chromite production and exports by Turkey during the period 1960-1969 averaged 445,000 tonnes and 381,000 tonnes a year respectively, and Turkey was responsible for 10% of world production and 12% of world exports during the decade. As seen in Tables 8 and 26 the annual tonnage of Turkish chromite production and exports during 1960-1969 fluctuated around their average levels, and did not show any discernible trend in contrast to the rising trend in both chromite production and exports exhibited by the Soviet Union during the same period. The proportion of world chromite production and exports contributed by Turkey during the years 1960-1969 also fluctuated around their percentages for the decade as observed in Tables 18 and 34.

During 1960-1962 chromite exports by Turkey remained relatively stable and averaged 375,000 tonnes a year, but fell sharply from 350,000 tonnes in 1962 to 213,000 tonnes in 1963 (Table 26). The decrease in Turkish chromite exports during 1963 as in the case of chromite exports from Zimbabwe was associated with a number of factors including reduced world demand and competition from the Soviet Union. However, the drop in chromite exports by Turkey in 1963 was accentuated by the cessation of barter shipments to the United States as recorded by Holliday (1964). In 1962 around 90,000 tonnes of Turkish chromite was exported to the United States in exchange for agricultural products and placed in the Supplemental Stockpile described in the previous chapter. According to Charles River Associates Inc (1970) 95% of Turkish chromite output during 1960-1963 was classified as metallurgical grade and the remaining 5% as refractory grade so that Turkey was predominantly a producer and exporter of metallurgical chromite.

After 1963 chromite exports by Turkey like those from Zimbabwe recovered as the world market for metallurgical grade chromite improved, and Turkish chromite exports rose to 424,000 tonnes in 1965 when they were double those in 1963 (Table 26). There was a strong demand for Turkish chromite at the end of 1964 (Holliday, 1965), and by early March 1965 virtually all the Turkish chromite available for delivery that year had been sold out (Morning, 1966). However, chromite exports by Turkey during the last quarter of 1965 were below the rate for the previous nine months, and at the end of 1965 stocks of chromite at Turkish ports amounted to 82,000 tonnes.

In 1966 voluntary economic sanctions were applied against chromite exports from Zimbabwe, and Turkish chromite exports rose further to reach 509,000 tonnes and were at their highest level since 1958 (Tables 25 and 26). However, during the years 1967-1969 when mandatory economic sanctions were imposed against Zimbabwean chromite exports, Turkish chromite exports were lower than in 1966 and varied from 314,000 tonnes in 1967 to 497,000 tonnes in 1969 (Table 26). According to Morning (1968) the exhaustion of accumulated stocks was a factor contributing to the lower chromite exports by Turkey in 1967 compared with 1966, although it is seen that Turkish chromite exports in 1969 were not greatly below the high level reached in 1966. Chromite production by Turkey during each of the years 1967-1969 was lower than that in both 1965 and 1966 (Table 8), and it appears that Turkey was unable to expand production to take full advantage of the opportunity provided by the artificial shortage of metallurgical chromite created by the boycott against Zimbabwe. However, even though Turkish chromite production and exports during 1967-1969 were below their 1966 levels, both the production and export of chromite by Turkey did rise over the years 1967-1969, and most of the chromite produced during that period was exported as seen from Tables 8 and 26. Further, the price of Turkish metallurgical grade chromite delivered in the United States increased 45% during the years 1967-1969 in consequence of the Zimbabwean situation as discussed earlier in this chapter.

According to Morning (1971) the Turkish chromite industry that at one time comprised around thirty active companies producing from a hundred mines had by 1969 been reduced to three large and several small private producers together with government owned Etibank. Increasing costs, particularly of labour and transportation, had been a factor in the closure of small mines located in the interior of Turkey. Further, reserves of high grade chromite had been decreasing, and by 1969 about 50% of Turkish chromite exports were in the form of concentrate. It was recorded by Charles River Associates Inc (1970) that metallurgical grade chromite imported by the United States from Turkey during the period 1955-1960 consisted of lumpy material having an average Cr_2O_3 content of 46-47% and a Cr:Fe ratio of 3:1 whereas in the latter half of the 1960's the quality of Turkish ore appeared to have declined. In 1969 the United States imported 155,000 tonnes of chromite from Turkey, and of this 43% had a Cr_2O_3 content of 46% or more while 37% had a Cr_2O_3 content of greater than 40% but less than 46% and 19% had a Cr_2O_3 content of not more than 40% as shown in Morning (1971). In contrast, 94% of the chromite imported by the United States from the Soviet Union in 1969 had a Cr_2O_3 content of 46% or higher.

Albania.

Chromite was discovered in Albania by Italian geologists near Lake Ohrid in 1937 (Rabchevsky, 1985), and in 1939 Albanian chromite production was estimated at 3,000 tonnes (Table 5). During the 1940's chromite production by Albania was small and variable as seen in Table 6. In 1941 it rose to an estimated 20,000 tonnes, but in 1942 fell to 5,000 tonnes, and in 1948 it amounted to 17,000 tonnes. Subsequently, Albanian chromite production rose during the 1950's from 52,000 tonnes in 1950 to 248,000 tonnes in 1959 (Table 7), then during the 1960's production increased further to reach a record level of 454,000 tonnes in 1969 (Table 8). In 1969 Albania accounted for 8% of world chromite production (Table 18).

The increased importance of Albania as a chromite producer is seen from the fact that its production averaged 315,000 tonnes a year during 1960-1969 compared with an average of 119,000 tonnes a year during 1950-1959, and that Albania contributed 7% of world chromite production during 1960-1969 compared with 3% of world production during 1950-1959. A large proportion of Albanian chromite production was exported, and Albanian chromite exports during the period 1960-1969 are shown in Table 26. During 1967 Albania was responsible for 11% of world chromite exports compared with 7% of world exports in 1960 (Table 34).

The chromite deposits of Albania are located in rugged inland terrain, and the chromite occurs as podiform deposits within ultrabasic rocks that extend roughly north-south through the country (Rabchevsky, 1985). It was reported by Morning (1968) that Albanian chromite production came from two mines in the Kukes area in the north-east of the country as well as from the Belquize area where two mines at

Klose and Kuesi were brought into production during the 1960's. According to Grabfield (1974) Albanian chromite production comprised essentially a hard lumpy ore that typically contained 43% Cr_2O_3, 10% SiO_2, 8% Al_2O_3, and had a Cr:Fe ratio of 3:1. Albanian chromite ore was described by Charles River Associates Inc (1970) as being of refractory grade and traded within the Communist Bloc, and it was recorded by Morning (1968) that the major markets for Albanian chromite were China, Czechoslovakia, East Germany, Hungary, Poland, and Yugoslavia.

CHROMITE CONSUMPTION AND IMPORTS

Even though there was an increase in chromite consumption by chromite producing countries in Africa, a very large proportion of the world's chromite consumption during the period 1960-1969 continued to take place in North America, Europe, and Japan. The United States remained the largest chromite consuming country in the world during 1960-1969, while the Soviet Union, Japan, West Germany, France, and the United Kingdom were each major chromite consumers. Except for the Soviet Union, which was the largest chromite producer in the world, these chromite consuming nations relied largely or completely for their supply of chromite during 1960-1969 on imports from producing countries, particularly South Africa, Soviet Union, Philippines, Zimbabwe, Turkey, and Albania.

The destination by country of world chromite imports during the period 1960-1969 is given in terms of tonnage and percentage in Tables 77 and 84. The United States was the largest chromite importing country in the world throughout 1960-1969, and accounted for 39% of total world chromite imports during that period. Other large chromite importing countries during 1960-1969 were Japan, which was responsible for 13% of world chromite imports during the decade, West Germany 10%, France 7%, and the United Kingdom 6%. These five countries including the United States together accounted for 75% of world chromite imports during 1960-1969. In addition, Sweden was the destination for 4% of world chromite imports during 1960-1969, Poland 4%, Italy 3%, Norway 2%, Canada 2%, Austria 2%, East Germany 2%, Czechoslovakia

2%, and Yugoslavia 2% so that in all fourteen countries were responsible for around 98% of world chromite imports during the decade. Total world chromite imports declined from 3,058,000 tonnes in 1960 to 2,512,000 tonnes in 1963 then rose to 3,998,000 tonnes in 1969 as shown in Table 77. During 1960-1969 world chromite imports averaged 3,198,000 tonnes a year, which was 33% higher than the average of 2,401,000 tonnes a year for the previous decade.

North America

The United States and Canada were each chromite importing countries during 1960-1969 (Table 77). However, United States chromite imports averaged 1,251,000 tonnes a year during the decade and were eighteen times Canadian chromite imports that averaged 71,000 tonnes a year.

During 1960-1969 chromite imports by the United States varied between a high of 1,691,000 tonnes in 1966 and a low of 984,000 tonnes in 1968 (Table 77), and total United States chromite imports during 1960-1969 were 20% lower than during the previous decade. Even though the United States continued to be the largest chromite importing country in the world throughout 1960-1969, its proportion of world chromite imports varied during the decade between a high of 51% in 1962 and a low of 25% in 1969 (Table 84), and there was a continuation of the declining trend in the United States' share of world chromite imports evident during 1950-1959 (Table 83). Indeed, the United States accounted for only 39% of world chromite imports during 1960-1969 compared with 65% of world imports during the previous decade.

On 1st September, 1963, revised United States Tariff Schedules came into effect, and these replaced those established by the Tariff Act 1930, as amended (Holliday, 1964). Under the new schedules chromite was classified according to its Cr_2O_3 content rather than by metallurgical, refractory, or chemical grade. The new classification categories comprised chromite containing not more than 40% Cr_2O_3, chromite containing more than 40% but less than 46% Cr_2O_3, and chromite containing 46% or more Cr_2O_3. However, under the new schedules as previously there were no import duties on chromite ores and concentrates entering the United States.

Chromite production by the United States amounted to 97,000 tonnes in 1960 and 74,000 tonnes in 1961(Table 8), but no chromite production took place in the United States during the years 1962-1969. The entire chromite output of the United States during 1960 and 1961 comprised chromite concentrate produced from the Mouat mine located within the Stillwater Complex in Montana, and was delivered to United States government stockpile under a contract signed in 1952 as described in the previous chapter. United States chromite production ceased in 1961 following the fulfilment of this contract that involved the delivery of a total of 816,000 tonnes (900,000 short tons) of chromite concentrate containing 38.5% Cr_2O_3 to the Government (Prokopovitsh and Heidrich, 1962). During 1960 and 1961 chromite production by the United States averaged 86,000 tonnes a year (Table 8), and was small compared with chromite imports by the United States in 1960 and 1961 that averaged 1,232,000 tonnes a year (Table 77).

During the period 1958-1963 substantial chromite imports were made by the United States Government in exchange for surplus agricultural products under the Commodity Credit Barter Program for inclusion in a Supplemental Stockpile as discussed previously. This programme involved the importation of 1,122,000 tonnes of chromite comprising 440,000 tonnes of chemical grade chromite from South Africa, 338,000 tonnes of metallurgical grade chromite from Turkey, and 344,000 tonnes of refractory grade chromite of which 292,000 tonnes came from the Philippines and 52,000 tonnes from Cuba, and except for 10,000 tonnes of metallurgical grade chromite imported in 1956 all these imports were made during the years 1958-1963 (Charles River Associates Inc, 1970).

It is seen that both domestic chromite production and chromite imports were added to United States government stockpiles during the early part of the 1960's. However, in May 1966 a total of 785,000 tonnes of metallurgical grade chromite contained in the General Services Administration (GSA) stockpile was sold by the

United States Government, and this facilitated chromite deliveries to industry that rose from 27,000 tonnes in 1966 to 220,000 tonnes in 1969 (Morning, 1971). These releases of chromite from the GSA stockpile assisted in alleviating the shortage of metallurgical grade chromite arising from the economic sanctions against Zimbabwe, while at the end of 1969 a balance of 352,000 tonnes of the chromite sold remained in the stockpile for future delivery. Except for the 433,000 tonnes of metallurgical chromite released from the GSA stockpile during 1966-1969, chromite consumption in the United States during the 1960's was supplied from imports as all domestic chromite production, which took place only during 1960 and 1961, went into the Defence Production Act (DPA) government stockpile.

Chromite consumption by the United States during the decade 1960-1969 varied between a low of 1,026,000 tonnes in 1962 and a high of 1,437,000 tonnes in 1965 as seen in Holliday (1965) and Morning (1971). During the period 1960-1963 United States chromite consumption averaged 1,075,000 tonnes a year, and was lower than during the years 1964-1969 when chromite consumption averaged 1,297,000 tonnes a year. Chromite imports by the United States did not vary greatly during the years 1960-1964 when they averaged 1,266,000 tonnes a year, but rose from 1,295,000 tonnes in 1964 to 1,691,000 tonnes in 1966 after which they fell to 984,000 tonnes in 1968 and remained around that level in 1969 (Table 77). Thus, chromite consumption by the United States during 1960-1969 was at its highest level in 1965, while chromite imports by the United States reached their highest level for the decade in 1966. However, United States chromite consumption of 1,437,000 tonnes in 1965 was lower than record chromite consumption of 1,675,000 tonnes achieved in 1956, and United States chromite imports of 1,691,000 tonnes in 1966 were below record chromite imports of 2,071,000 tonnes reached in 1957 as described in the previous chapter.

During the years 1966-1969 chromite consumption by the United States did not vary greatly, and the decrease in chromite imports by the United States after 1966 was associated with a decline in consumer stocks of chromite, which fell from 1,185,000 tonnes at the end of 1966 to 612,000 tonnes at the end of 1969 (Morning, 1971). The reduction in United States chromite imports and fall in the level of consumer stocks that took place during the years 1967-1969 occurred during the application of mandatory economic sanctions against Zimbabwe. However, the decrease in consumer stocks of metallurgical grade chromite during 1967-1969 was accompanied also by lower consumer stocks of both refractory and chemical grade chromite as seen in Morning (1971). Nevertheless, at the end of 1969 consumer stocks of metallurgical grade chromite in the United States amounted to only four months supply at the 1969 consumption level compared with nine months supply for refractory grade chromite and eight months supply for chemical grade chromite, and the low level of metallurgical grade chromite stocks in the hands of consumers reflected the effect of economic sanctions against Zimbabwe.

In 1965 United States chromite consumption was at its highest level since 1957 as well as at its highest level for the decade. The metallurgical industry accounted for 57% of chromite consumption by the United States during 1965 while the refractory industry was responsible for 29% of chromite consumption and the chemical industry for 14% of chromite consumption (Morning, 1966). Around 90% of the chromite consumed by the United States metallurgical industry consisted of metallurgical grade chromite, while the balance comprised chemical and refractory grade ores that were blended with it. Virtually all the chromite consumed by the metallurgical industry went into the production of high-carbon ferrochromium, low-carbon ferrochromium and ferrochromium-silicon, and these chromium ferroalloys in turn were used largely in the manufacture of stainless steels as well as other alloy steels containing chromium. During 1965 around 70% of all chromium ferroalloys (along with a small quantity of chromium metal) consumed in the United States went into the production of stainless steels, while a further 25% was absorbed in making other steels (Morning, 1966). A large proportion of the chromite consumed by the

United States refractory industry was used for lining open-hearth steel furnaces, although these were being replaced by basic-oxygen furnaces that did not use chromite refractories (Charles River Associates Inc, 1970). The United States chemical industry consumed chromite in the production of sodium bichromate, which in turn provided the basis for other chromium chemicals for which chromium pigments, chromium plating, and leather tanning were the major applications, and in 1968 these three uses together accounted for around 70% of United States chromium chemical consumption (National Materials Advisory Board, 1970).

During the 1960's United States chromite consumption was supplied very largely by imports as discussed previously. Most of the metallurgical grade chromite imports were obtained from the Soviet Union, Turkey, and Zimbabwe (prior to economic sanctions), while refractory grade chromite imports were derived mainly from the Philippines and chemical grade chromite imports came from South Africa.

Europe

During the period 1960-1969 the largest chromite importing countries in Europe were West Germany with average annual chromite imports for the decade of 307,000 tonnes, France 220,000 tonnes, and the United Kingdom 192,000 tonnes, while other European countries that imported significant quantities of chromite during 1960-1969 were Sweden, Poland, Italy, Norway, Austria, East Germany, Czechoslovakia, and Yugoslavia (Table 77). However, chromite imports by each of these countries including West Germany remained much lower than those of the United States throughout the decade. With the exception of Yugoslavia, none of these European chromite importing countries were chromite producers during 1960-1969 (Table 8).

The tonnage of chromite imported by West Germany during the period 1960-1969 was 74% higher than during the previous decade while chromite imports by France rose 134% and those by the United Kingdom increased 24%, and this was a reflection in varying degrees of the world wide expansion in the steel and chemical industries referred to by Thomson (1966). Further, the percentage of world chromite imports made by both West Germany and France during 1960-1969 was significantly higher than during the previous decade, while the proportion of world chromite imports made by the United Kingdom was maintained at the same level. During 1960-1969 these three largest chromite importing countries in Europe together accounted for 23% of world chromite imports compared with 17% of world imports during 1950-1959. The variation from year to year in the tonnage and percentage of chromite imports for each of these countries is as shown in Tables 77 and 84.

During 1960-1969 both Sweden and Norway continued to be importers of chromite and exporters of ferrochromium (Tables 77 and 124). However, Swedish chromite imports were much higher than those of Norway whereas Swedish exports of ferrochromium were significantly lower than those of Norway, and this reflected a substantial domestic consumption of ferrochromium by Sweden as discussed in the previous chapter. France was also an exporter of ferrochromium during 1960-1969, but its ferrochromium exports were relatively small in relation to its chromite imports (Tables 77 and 124).

Japan

Japan was both a producer and importer of chromite during 1960-1969 (Tables 8 and 77). However, during 1960-1969 chromite production by Japan averaged only 46,000 tonnes a year compared with chromite imports that averaged 423,000 tonnes a year, so that domestic chromite production provided only 10% of Japanese chromite supply during the decade. Further, Japanese chromite production tended to decline during 1960-1969 whereas chromite imports by Japan rose sharply during the latter part of the decade.

Chromite imports by Japan did not vary greatly during the years 1960-1963 when they averaged 271,000 tonnes a year, but rose from a low of 227,000 tonnes in 1963 to a record of 733,000 tonnes in 1969 (Table 77). In 1960 Japanese chromite imports were exceeded by those of the United States, West Germany, and the United

Kingdom, but in 1961 Japan's chromite imports equalled those of West Germany as joint second largest chromite importer in the world, then during the years 1962-1969 Japan stood alone as the next largest chromite importing country in the world after the United States. In 1969 Japan accounted for 18% of world chromite imports compared with 9% in 1960 (Table 84), and during the period 1960-1969 Japan was responsible for 13% of world chromite imports compared with 4% of world imports during the previous decade.

According to Holliday (1964) Japan imported chromite from the Philippines, Soviet Union, South Africa, and India during 1963, and showed interest in importing chromite from Iran. Subsequently, it was reported by Thomson (1966) that Japan did import chromite from Iran in 1964. The limited domestic chromite production by Japan was used primarily in refractories (Holliday, 1965).

In 1965 approval was given by the government Fair Trade Commission for the Japanese Ferro-Alloy Producers' Association to regulate ferrochromium production in Japan (Morning, 1966). The association comprised twenty one ferroalloy producers, and these accounted for 100% of Japan's high-carbon ferrochromium production and 94% of its low-carbon ferrochromium production. Japanese ferrochromium production increased from 82,000 tonnes in 1963 to 197,000 tonnes in 1967 (Holliday, 1964 & Morning, 1968), and this 140% expansion in ferrochromium production in four years was accompanied by a 163% rise in Japanese chromite imports from 227,000 tonnes in 1963 to 596,000 tonnes in 1967 (Table 77).

The Japanese ferroalloy industry expanded to keep pace with the growing steel industry, and with this growth in the ferroalloy industry over a period of fifteen years from 1955 to 1969 many small furnaces were replaced by larger furnaces (Morning, 1971). Further, some ferroalloy producers became integrated with the steel industry, and it was reported that Showa Denko Co Ltd planned to supply molten ferrochromium to its neighbour Nisshin Steel, which was Japan's largest producer of stainless steel. The tremendous expansion that took place in the Japanese steel and ferrochromium industries resulted in a corresponding increase in chromite imports by Japan, and these rose from 58,000 tonnes in 1955 to 733,000 tonnes in 1969 as shown in Tables 76 and 77.

FERROCHROMIUM

The pattern of world ferrochromium exports by country of origin during the period 1960-1969 is shown in terms of tonnage and percentage in Tables 124 and 130, while the pattern of world ferrochromium imports by country of destination during 1960-1969 is given in terms of tonnage and percentage in Tables 154 and 160.

Throughout the period 1960-1969 Norway, Soviet Union, Sweden, and France were major exporters of ferrochromium, and during the latter part of the decade South Africa developed into the largest ferrochromium exporting country in the world (Table 124). Of these countries Norway, Sweden, and France were not chromite producers, but imported chromite and exported ferrochromium, whereas the Soviet Union and South Africa were chromite producers and ferrochromium exporters. The United Kingdom and United States were the largest ferrochromium importing countries in the world throughout the period 1960-1969 (Table 154), and these two countries together accounted for more than half the world's ferrochromium imports during the decade.

A significant development during the period 1960-1969 was the expansion in ferrochromium exports by chromite producing countries, particularly South Africa, Zimbabwe, and the Soviet Union, and this removed the dominance previously enjoyed by ferrochromium exporting countries, notably Norway, Sweden, France, and Canada, that imported chromite to produce ferrochromium for export using low-cost hydro-electric power. Indeed, by the end of the 1960's countries that produced chromite and exported ferrochromium accounted for more than half the world's ferrochromium exports, and the emergence of both Zimbabwe and South Africa as ferrochromium producing countries in Africa has been described previously.

During 1969 the total tonnage of world chromite exports was twelve times that of world ferrochromium exports compared with a ratio of twenty in 1959, and this indicated an increase in the relative importance of international trade in ferrochromium. Further, total world ferrochromium exports amounted to 288,200 tonnes in 1969, and were almost double world ferrochromium exports of 145,800 tonnes in 1959 (Tables 123 and 124).

During the period 1960-1969 ferrochromium imports by the United States averaged 45,000 tonnes a year, and were 51% higher than average annual ferrochromium imports during the previous decade. However, the tonnage of chromite imported by the United States during 1960-1969 was thirty five times that of ferrochromium, and the United States continued to import chromite for the domestic production of ferrochromium rather than import ferrochromium. During the 1960's United States ferrochromium consumption reached its highest level for the decade of 379,000 tonnes in 1966 (Hibbard, 1967), and in that year United States ferrochromium imports were also at their highest level for the decade and amounted to 88,900 tonnes (Table 154). Thus, ferrochromium imports by the United States in 1966 were equivalent to 23% of ferrochromium consumption in that year. However, for the decade as a whole ferrochromium imports supplied only 14% of United States ferrochromium consumption.

Ferrochromium imports by the United States continued to be subject to tariffs whereas chromite imports entered the United States duty free. However, the tariff on low-carbon ferrochromium was reduced from 10.5% to 8.5% ad valorem in 1963 then further reduced to 7.5% in 1968 and 6.5% in 1969, while the duty on ferrochromium-silicon was lowered from 12.5% to 10.0% ad valorem in 1963 (Charles River Associates Inc, 1970). The duty on high-carbon ferrochromium remained at 0.625 cents per pound of contained chromium throughout the decade, and ferrochromium imports of all kinds from the Soviet Union and other communist countries continued to bear much higher duties as described in the previous chapter. Even though the Soviet Union was a major ferrochromium exporting country during 1960-1969 (Table 124), imports of ferrochromium by the United States from the Soviet Union during the decade were very small and amounted to only 149 tonnes in 1967 (Morning, 1968). In 1969 South Africa was the largest source of both low-carbon ferrochromium and high-carbon ferrochromium imported by the United States as observed in Morning (1971).

Chapter 10

TRADE AGGREGATES 1970-1979 & 1980

South Africa and the Soviet Union were by far the largest chromite producing countries in the world during the period 1970-1980, while Albania, Zimbabwe, Turkey, and the Philippines were also large chromite producers, and India, Finland, Iran, Brazil, and Malagasy each produced substantial quantities of chromite during the period. South Africa and the Soviet Union were also very much the largest chromite exporting countries in the world during 1970-1980, while Albania, Philippines, and Turkey were the next largest chromite exporting countries, and India, Finland, Malagasy, and Iran were substantial exporters of chromite during the period.

The United States and Japan were by far the largest chromite importing countries in the world during 1970-1980, while West Germany, Sweden, and France were also major chromite importing countries. In addition, substantial quantities of chromite were imported during 1970-1980 by Italy, Poland, Yugoslavia, and the United Kingdom, and significant chromite imports were made by East Germany, Canada, Austria, Spain, Czechoslovakia, and Norway during the period.

South Africa was the dominant ferrochromium exporting country in the world during 1970-1980, and Zimbabwe, Sweden, Soviet Union, West Germany, Finland, Japan, Yugoslavia, Norway, and Brazil were also ferrochromium exporting countries. The United States, West Germany, and Japan were the largest ferrochromium importing countries in the world during 1970-1980 while the United Kingdom and Italy were also substantial importers of ferrochromium during the period.

CHROMITE PRODUCTION AND EXPORTS

The location of world chromite production by country during the period 1970-1979 and in 1980 is shown in terms of tonnage in Tables 9 and 10 and as a percentage of world total in Tables 19 and 20. During both 1970-1979 and 1980 world chromite production was largely dominated by South Africa and the Soviet

Union, which accounted for 28% and 26% respectively of total world production during 1970-1979 and for 35% and 25% of world production in 1980. These two countries together were responsible for 54% of world chromite production during 1970-1979 and for 60% of world production in 1980, and during each of the years 1970-1980 chromite production by each of these countries was far greater than that of any other country as seen in Tables 9 and 10. During 1970-1979 and also in 1980 Albania, Zimbabwe, Turkey, and the Philippines were each major chromite producers and together accounted for a further 29% of world chromite production during 1970-1979 and for 26% of world production in 1980, so that in all six countries provided 83% of world chromite production during 1970-1979 and 86% of world production in 1980. Other significant chromite producing countries during 1970-1979 as well as in 1980 were India, Finland, Iran, Brazil, and Malagasy. During 1970-1979 total world chromite production rose from 6,053,000 tonnes in 1970 to 9,685,000 tonnes in 1979 then increased further to a record of 9,749,000 tonnes in 1980 (Tables 9 and 10).

The pattern of world chromite exports by country of origin during the period 1970-1979 and in 1980 is shown in terms of tonnage in Tables 27 and 28 and as a percentage of world total in Tables 35 and 36. During 1970-1979 South Africa and the Soviet Union were the two largest chromite exporting countries in the world, and accounted for 26% and 22% respectively of world chromite exports during the period. However, the importance of South Africa as a chromite exporting country increased relative to that of the Soviet Union as the decade progressed, and in 1980 South African chromite exports were more than twice those of the Soviet Union. Other major chromite exporting countries during 1970-1979 were Albania, Philippines, and Turkey, and these three countries together accounted for a further 34% of world chromite exports during that period, so that in all five countries were responsible for 82% of world chromite exports during the decade. In addition, substantial chromite exports were made during 1970-1979 by India, Finland, Malagasy, and Iran. During 1970-1979 total world chromite exports were somewhat variable, but reached a record level of 5,272,000 tonnes in 1975 (Table 27).

South Africa

Chromite production by South Africa rose from 1,427,000 tonnes in 1970 to 3,297,000 tonnes in 1979 (Table 9), and averaged 2,207,000 tonnes a year during 1970-1979 compared with an average of 973,000 tonnes a year during 1960-1969. In 1980 South African chromite production was at a record level of 3,414,000 tonnes (Table 10). During 1970-1979 chromite exports by South Africa varied between a low of 879,000 tonnes in 1970 and a high of 1,482,000 tonnes in 1977 (Table 27), and averaged 1,175,000 tonnes a year during the decade compared with an average of 758,000 tonnes a year during 1960-1969. In 1980 South African chromite exports amounted to 1,237,000 tonnes (Table 28). It is seen that during the period 1970-1980 there was a sharp rise in South African chromite production relative to chromite exports. During 1970-1979 South Africa accounted for 28% of world chromite production and 26% of world chromite exports, and it was the largest chromite producing and exporting country in the world during the decade.

According to Grabfield (1974) South African chromite production was concentrated in the hands of a few large mining houses that employed modern methods of extraction and handling, and as a result of mergers and acquisitions there were two major independent chromite producers in South Africa. These were the Barlow Rand group that controlled the Winterveld, Millsell, and Henry Gould operations of the Transvaal Consolidated Land and Exploration Company Ltd, and the General Mining group that managed and marketed the chromite production of the Chrome Mines of South Africa, Marble Lime, and Montrose operations. Each of the two groups were involved in mines in both the Lydenburg (Eastern Bushvelt) and Rustenburg (Western Bushvelt) districts of the Transvaal, and together they accounted for a large proportion of South African chromite production. Other groups with substantial chromite mining interests in South Africa included International Minerals and Chemical (Lavino), Union Carbide, Amcor, and Bayer.

Barlow Rand Ltd with the combined chromite production of its three mines was the largest chromite producer in South Africa during 1972 (Morning, 1974). Its chromite output was in excess of 300,000 tonnes a year, and most of the production was exported unconverted (Morning, 1972) . However, a considerable tonnage of chromite produced by the company was utilized by Middelburg Steel and Alloy (Pty) Ltd that was formed in 1968 and acquired the entire capital of RMB Alloys (Pty) Ltd and the Southern Cross Steel Co (Pty) Ltd. In 1969 Palimet Chrome Corp (Pty) Ltd was merged into the group, so that Middelburg Steel and Alloys became a major ferrochromium producer. The largest source of chemical grade chromite in South Africa was the Zwartkop mine of Chrome Mines of South Africa Ltd in the Rustenburg district (Thomson, 1971), and chromite production of all grades from this operation amounted to around 300,000 tonnes a year. Chrome Mines of South Africa was not only a leading supplier of chemical grade chromite, but also pioneered the use of chromite sand in foundry applications (Industrial Minerals, 1972).

During the early 1970's chromite production and exports by South Africa reached record levels of 1,644,000 tonnes and 1,162,000 tonnes respectively in 1971 then decreased to 1,483,000 tonnes and 932,000 tonnes in 1972 (Tables 9 and 27). In 1971 South Africa accounted for 26% of world chromite production and 27% of world chromite exports (Tables 19 and 35), and during 1971 around 70% of South Africa 's chromite production was exported. On the basis of statistics given by Morning (1973) 63% of South African chromite production in 1971 had a grade in the range 44-48% Cr_2O_3 while 31% of chromite production had a grade of less than 44% Cr_2O_3 and 6% of chromite production had a grade higher than 48% Cr_2O_3.

The price of South African Transvaal chromite delivered US Atlantic ports was increased about 30% during 1970 in response to strong consumer demand and higher shipping charges, and this was the first substantial price rise for such chromite in some years in contrast to the relatively stable price exhibited by Transvaal chromite throughout the 1960's (Morning, 1972). This higher price level for South African chemical grade chromite was essentially maintained during 1971 and 1972 (Morning, 1974). During 1971 when chromite production and exports were at record levels, there was an economic recession accompanied by decreased consumption of chromite in the United States, Europe, and Japan (Thomson, 1972), and this was reflected in the decreased production and exports of chromite by South Africa in 1972.

The economic recession lasted until the middle of 1972 after which there was a strong upturn (Mining Annual Review, 1973), and during 1973 there was significantly increased demand for chromite of all grades associated with a high level of industrial production throughout the western world (Thomson, 1974). In response to the improved conditions South African chromite production and exports both recovered during 1973 when they amounted to 1,649,000 tonnes and 1,093,000 tonnes respectively (Tables 9 and 27).

Indeed, after 1972 South African chromite production rose dramatically from 1,483,000 tonnes in 1972 to a record of 3,414,000 tonnes in 1980 (Tables 9 and 10), while chromite exports by South Africa increased from 932,000 tonnes in 1972 to a record of 1,482,000 tonnes in 1977 then decreased to 1,237,000 tonnes in 1980 (Tables 27 and 28). It is observed that chromite production by South Africa in 1980 was higher than ever previously achieved by any country, and that chromite exports by South Africa in 1977 were greater than ever recorded by any country. However, in 1972 South African chromite exports amounted to 63% of chromite production whereas in 1977 chromite exports by South Africa were 48% of chromite production and by 1980 chromite exports had fallen to 36% of chromite production. The increase in production tonnage together with a decrease in exports as a proportion of production reflected a marked increase in domestic chromite consumption by South Africa as the decade progressed, and this was attributable largely to a rapid expansion in South African ferrochromium production and exports as discussed later in the chapter. It is seen in Tables 18 and 19 that the proportion of world chromite production contributed by South Africa rose from 24% in 1972 to 35% in 1980.

South Africa exported chromite for consumption by the chemical, metallurgical, refractory, and foundry industries (Industrial Minerals, 1975). During 1972-74 a number of countries including Japan, United States, West Germany, United Kingdom, France, Austria, and Italy imported chromite from South Africa, and of these Japan, United States, and West Germany were the largest importers of South African chromite as seen in Table 119. In the case of the United States chromite imports from South Africa in 1974 amounted to 309,000 tonnes, and South Africa was the largest source of chromite imported by the United States as observed in Morning (1976). Of the chromite imports made by the United States from South Africa in 1974 73% had a Cr_2O_3 content of more than 40% but less than 46% while 26% had a Cr_2O_3 content of 46% or more and only 1% had a Cr_2O_3 content of 40% or less, and South Africa continued to be the dominant supplier of chemical grade chromite imported by the United States.

In 1977 South African chromite exports reached a peak and record level of 1,482,000 tonnes (Table 27), and in that year South Africa contributed 30% of total world chromite exports (Table 35). However, even though South African chromite exports declined from 1977 to 1980, their share of total world exports was maintained. In 1980 chromite exports by South Africa amounted to 1,237,000 tonnes (Table 28), and South Africa continued to be by far the largest chromite exporting country in the world.

The expansion of South African chromite exports during the 1970's was assisted by use of the sophisticated mechanised loading facilities of the Matola berth at the port of Lourenco Marques in Mozambique through which South African chromite was exported (Grabfield, 1974). Although designed originally to handle iron ore and concentrates from Bomvu Ridge and Palabora, the Matola berth was made available for loading chromite and storage facilities of 1,100,000 tonnes were provided. Access to Matola with a rated loading capacity for chromite ore of 2,400 tonnes per hour enabled the use of large bulk ore carriers to transport chromite from East Africa, and this resulted in reduced transportation costs.

Throughout 1976 South African chromite exports suffered a bottle-neck at the port of Lourenco Marques (Maputo), and this resulted from a lack of maintenance and trained manpower (Morning, 1978). Ore carriers frequently encountered delays of several weeks, and this resulted in high demurrage costs as well as unpredictable delivery schedules. These problems, which followed the achievement of complete independence by Mozambique from Portugal in June 1975 (Whitaker, 1982), were probably a contributory factor in the lower chromite exports by South Africa during 1976 (Table 27).

During the 1970's there was a tremendous expansion in the production and export of ferrochromium by South Africa, and this resulted in a large rise in the demand for South African chromite for domestic consumption. In consequence, there was a substantial increase in South African chromite production relative to chromite exports as discussed earlier in the chapter. South African ferrochromium exports rose rapidly from 87,800 tonnes in 1970 to 716,200 tonnes in 1979 (Table 125), then increased further to 768,000 tonnes in 1980 (Table 126). During the years 1976-1980 South Africa accounted for about 50% of world ferrochromium exports (Tables 131 and 132).

Even though South African chromite production exceeded three million tonnes a year after 1977 and was much larger than that of any other country, chromite production by South Africa was small in relation to its huge ore reserves. According to Matthews and Morning (1980) South African chromite reserves to mineable depths in the Bushveld Complex had been recently revised to an estimated three thousand million tonnes grading in excess of 35% Cr_2O_3, so that South Africa's future as a long term supplier of chromite for both domestic consumption and export appeared secure.

As tabulated by Buchanan (1979) the largest chromite producers in South Africa continued to be Barlow Rand Ltd, which produced 1,207,000 tonnes of chromite in 1977 from its Henry Gould, Millsell, and Winterveld operations, and General Mining and Finance Corp. Ltd which produced 988,000 tonnes of chromite in 1977 from its Groothoek, Kroondal, Montrose, and Zwartkop mines. Other large South African chromite producers included International Minerals and Chemical Corp. (Lavino) with a chromite production in 1977 of 330,000 tonnes, S.A. Manganese Amcor Ltd (Samancor) 274,000 tonnes, Union Carbide Corp. 134,000 tonnes, and Bayer AG 120,000 tonnes.

The largest ferrochromium producer in South Africa was Samancor with an estimated production capacity of 280,000 tonnes of ferrochromium a year from two plants including that at Witbank operated by Ferrometals (Thomson, 1980). According to Dickson (1980) chromite output by Samancor from its Ruighoek, Mooinooi, and Grasvally mines had risen to around 500,000 tonnes a year, and Samancor became the third largest chromite producer in South Africa. Most of the chromite mined by Samancor was consumed in the production of ferrochromium at its Witbank plant, which was the largest ferrochromium smelter in South Africa with a capacity of 200,000 tonnes a year. The next largest South African ferrochromium plant was that of Tubatse Ferrochrome at Steelpoort with a capacity of 170,000 tonnes a year. This operation was jointly owned by Union Carbide and General Mining, and was officially opened in May 1977 (Morning, 1980). Another new South African ferrochromium smelter was that of Johannesburg Consolidated Investments located at Lydenburg, and designed to produce 120,000 tonnes of ferrochromium a year (Jones, 1978).

In 1980 there were six ferrochromium smelters in South Africa, and these had a combined production capacity of around 750,000 tonnes a year of high-carbon ferrochromium, 46,000 tonnes a year of low-carbon ferrochromium, and 24,500 tonnes a year of ferrochromium-silicon (Thomas and Boyle, 1984). At full capacity operation these smelters would consume around two million tonnes of chromite a year. The smelters in decreasing order of total production were located at Witbank, Tubatse (Steelpoort), Machadodorp, Middleburg, Lydenburg, and Krugersdorp, and each was involved solely or predominantly in the production of high-carbon ferrochromium although the smelters at Machadodorp and Middleburg produced also low-carbon ferrochromium and ferrochromium-silicon. Total ferrochromium production capacity of the smelters ranged from 200,000 tonnes at Witbank to 80,000 tonnes at Krugersdorp, and in 1980 South Africa accounted for around 20% of world high-carbon ferrochromium production.

The type of chromite input used by the South African ferrochromium smelters varied from plant to plant, and ranged from conventional feed consisting entirely of lumpy ore as at Machadodorp and Krugersdorp, a combination of lumpy ore and briquettes made from fines and concentrates as at Middleburg and Witbank, a combination of fines and concentrates together with run-of-mine ore as at Tubatse, and feed consisting entirely of fines and concentrates converted to partially reduced pellets for use in the Showa-Denko process as at Lydenburg (Thomas and Boyle, 1984). Each of the South African ferrochromium smelters was ideally located in relation to chromite mining operations, other raw materials (including dolomite and silica), energy sources (coal and electricity), labour supply, and transportation facilities.

The predominant proportion of South African ferrochromium production comprised high-carbon ferrochromium, and reflected the greater world demand for high-carbon ferrochromium compared with low-carbon ferrochromium (Thomas and Boyle, 1984). The invention by Union Carbide of the Argon Oxygen Decarburization (AOD) process for the production of stainless steel created a large market for high-carbon ferrochromium, and this resulted in increased demand for South African chromite. According to Stanford Research Institute (1976) use of the AOD process rapidly increased after 1967, and it was estimated that by the mid-1970's around 50% of stainless steel production in Europe and the United States and around 70-75% of the stainless steel production in Japan was based on the AOD or equivalent processes.

These stainless steel making processes favoured the use of lower cost high-carbon ferrochromium rather than the more expensive low-carbon ferrochromium and ferrochromium-silicon previously required to maintain low carbon levels (Stanford Research Institute, 1976). In the AOD and related processes more than 80% of the chromium input can be added in the form of high-carbon ferrochromium (also known as charge ferrochromium) comprising either traditional high-carbon ferrochromium containing up to 70% Cr or lower grades of high-carbon ferrochromium containing 50-55% Cr. In many instances, ferrochromium having a lower chromium content was preferred, and lower grade South African Transvaal chromite was suitable for use in the production of such ferrochromium whereas the production of higher chromium content ferrochromium generally required the use of more expensive higher grade metallurgical chromite ores from the Soviet Union, Turkey, or Zimbabwe.

It was reported by Thomson (1979) that one reason for the competitive position of South African ferrochromium on the world market was the switch by stainless steel producers to AOD furnaces that were able to use cheaper lower grade charge ferrochromium having a 50-55% Cr content. The introduction of the AOD process provided a large market for chemical grade chromite for metallurgical use as well as for high-carbon ferrochromium (charge ferrochromium) as an additive in the manufacture of stainless steel (Thomas and Boyle, 1984), and in consequence was an important factor in the expansion of South Africa's chromium industry.

During 1980 the United States imported 270,000 tonnes of ferrochromium of which 93% comprised high-carbon ferrochromium, and South Africa supplied 80% of these high-carbon ferrochromium imports as deduced from import statistics given by Peterson (1981). In contrast, United States ferrochromium imports in 1970 amounted to 37,000 tonnes of which 30% consisted of high-carbon ferrochromium, and South Africa provided 5% of these high-carbon ferrochromium imports as seen in Morning (1972). This demonstrates the increased use of high-carbon ferrochromium relative to low-carbon ferrochromium as well as the rapid rise in importance of South Africa as a supplier of high-carbon ferrochromium.

According to Thomas and Boyle (1984) South Africa could export ferrochromium to the United States more cheaply than the United States could produce ferrochromium from chromite imported from South Africa. The cost advantage of South African ferrochromium together with the close proximity of abundant raw material inputs to smelter locations, the existence of large installed smelter capacity with attendant economies of scale, the advantages of vertical integration, and a desire to achieve added value through domestic processing should ensure South Africa's future as a major ferrochromium producing country. Indeed, it was predicted by Thomas and Boyle (1984) that South African ferrochromium smelting capacity would increase while that in the United States, Europe, and Japan would decline. The limiting factor on the expansion of South African ferrochromium production and exports might be a reluctance on the part of western governments to become too reliant on South African ferrochromium, or indeed on South African chromite, in view of the strategic importance of chromium, and this factor might well impose an artificial ceiling on the export potential of South African chromite and ferrochromium as suggested by Buchanan (1979).

Soviet Union

Chromite production by the Soviet Union rose from 1,751,000 tonnes in 1970 to 2,313,000 tonnes in 1979 (Table 9), and averaged 2,022,000 tonnes a year during the decade. In 1980 Soviet Union chromite production was at a record level of 2,449,000 tonnes (Table 10). Chromite exports by the Soviet Union did not vary greatly during the years 1970-1975 when they averaged 1,158,000 tonnes a year, but were lower during the years 1976-1979 when they averaged 790,000 tonnes a year (Table 27). In 1980 Soviet Union chromite exports fell to 567,000 tonnes, and were at their lowest level since 1963 as seen in Tables 26-28. During 1970-1979 the Soviet Union accounted for 26% of world chromite production and 22% of world chromite exports, and its chromite production and exports during the decade were exceeded only by those of South Africa.

Soviet Union chromite ores were characterised by a very high Cr_2O_3 content and a high Cr:Fe ratio, and comprised lump chromite, run-of-mine ore, and fines with a typical Cr_2O_3 content in the range 53-55% Cr_2O_3 (Grabfield, 1974). The ores were relatively fine in texture and had a high magnesia-to-alumina (MgO Al_2O_3) ratio. A relatively small tonnage of true lumpy ore was available on the world market, and much of the ore exported for metallurgical use was best described as being a run-of-mine material of which more than 50% could pass through a one inch screen. In view of the high magnesia-to-alumina ratio Soviet Union chromite ores as well as briquettes made from chromite fines were blended with South African Transvaal chromite having a high alumina content in order to provide a well balanced furnace burden for metallurgical use, and in Europe chromite fines from the Soviet Union were used by chromium chemical producers. As well as the traditional high Cr_2O_3 content and high Cr:Fe ratio metallurgical chromite ores, the Soviet Union produced a high alumina refractory chromite ore from Saranovaskaya in the Urals that contained around 37% Cr_2O_3 and 16% Al_2O_3.

According to Thomson (1979) measured chromite ore reserves in the Soviet Union were estimated at twenty to twenty five million tonnes while total ore reserves were probably around one hundred million tonnes. It was reported by Morning (1977(b)) that about 94% of Soviet Union chromite reserves were located in Kazakhstan while the balance were in the Ural Mountains. Further, the Donskoye mining operation in western Kazakhstan accounted for more than 90% of the chromite output of the Soviet Union, and was the only source of high grade chromite ore produced in the Soviet Union. The chromite deposits in the Urals had a low Cr_2O_3 content as well as a low Cr:Fe ratio, and were used in the chemical and refractory industries.

At Donskoye the chromite deposits were selectively mined by open pits

(Morning, 1978). In 1976 100-ton trucks and large bulldozers were used for the first time. During 1974 the first chromite concentrator in the Soviet Union was brought into production, and in 1976 there were two concentrators in operation to convert low grade Donskoye chromite ore that was previously stockpiled from a 45% Cr_2O_3 content to a marketable product containing 54% Cr_2O_3. However, most Soviet Union chromite ores could be shipped without beneficiation other than hand picking (Thomson, 1977).

Chromite production by the Soviet Union was used for both domestic consumption and export. In 1974 the Soviet Union consumed an estimated 770,000 tonnes of chromite of which 45% was used in metal production, 32% in refractories, and 23% in chemicals and other products (Morning, 1977(b)). During 1974 chromite exports by the Soviet Union amounted to almost 60% of chromite production as seen from Tables 9 and 27. According to Industrial Minerals (1975) 75-80% of the chromite exports of the Soviet Union went to western countries, and most of the chromite imported by these countries from the Soviet Union was for metallurgical use although some chemical grade chromite was imported by Italy. During 1972-1974 the Soviet Union exported chromite to a number of countries including the United States, Sweden, West Germany, Poland, Japan, France, Italy, and East Germany (Table 71). Of these the United States was the largest market for Soviet Union chromite, and accounted for 25% of chromite exports by the Soviet Union during 1972-1974 (Table 72).

Although the tonnage of Soviet Union chromite exports did not vary greatly over the period 1970-1975 (Table 27), the price of Soviet Union chromite was subject to considerable change during these years. The price of metallurgical grade chromite had already increased sharply over the period 1967-1969 as described in the previous chapter, and during 1970 the trend of rising prices continued (Morning, 1972). This reflected the continuation of United Nations economic sanctions against Zimbabwe, a restricted chromite supply, and increased shipping costs. By the end of 1970 the price for 1971 delivery of Soviet Union metallurgical grade chromite containing 55% Cr_2O_3 and having a Cr:Fe ratio of 4:1 had risen to around $69 per tonne f.o.b. rail cars United States Atlantic port (Morning, 1972). This was more than double the price of equivalent Soviet Union chromite at the beginning of 1967.

In contrast, the price of Soviet Union chromite for 1972 delivery fell significantly as observed in Morning (1974). This corresponded to a reduced world demand for chromite imports following the economic recession that took place in the United States, Europe, and Japan during 1971 and the first half of 1972. Further, the ban by the United States on the importation of Zimbabwean chromite was formally lifted in January 1972 despite opposition from the United Nations (Thomson, 1972). However, United States imports of chromite from the Soviet Union increased 41% during 1972 whereas total United States chromite imports fell 18% as seen in Morning (1974), and these imports of chromite from the Soviet Union were assisted by the reduced chromite price.

Following recovery from the economic recession there was increased demand world-wide for chromite in 1973, and by the end of June in that year a world steel boom was underway (Morning, 1975). During March 1974 the price of Soviet Union chromite increased sharply in response to strong demand (Morning, 1976), and during 1974 United States chromite imports from the Soviet Union increased 23% although total Soviet Union chromite exports in 1974 were 9% lower than in 1973 (Table 27). In 1974 the demand for chromium in the United States was at a record level, and at the beginning of 1975 the price of Soviet Union chromite containing 48% Cr_2O_3 and having a Cr:Fe ratio of 4:1 more than doubled to around $135 per tonne f.o.b. Black Sea ports, then moved higher to reach $150 per tonne in September (Morning, 1977(b)). United States chromite imports from the Soviet Union rose 17% during 1975 to reach 317,000 tonnes while total Soviet Union chromite exports in 1975 increased only 3% to 1,171,000 tonnes (Table 27). The rise in United States chromite imports from the Soviet Union during 1975 was in line with the 14% increase in total United States chromite imports in 1975 (Morning, 1977(b)), and in 1975 84% of the chromite imports made by the United States from the Soviet Union had a Cr_2O_3 content of 46% or more while the other 16% of imports had a Cr_2O_3 content of 40% or less. However, there was a substantial reduction in chromite consumption by the United States in 1975, and in consequence there was a large increase in stocks. Subsequently, this led to a reduction in imports of metallurgical grade chromite by the United States as discussed below.

Following the relatively stable volume of total chromite exports made at variable price by the Soviet Union during the period 1970-1975, there was a reduced level of Soviet Union chromite exports during the years 1976-1979 and in 1980 as shown in Tables 27 and 28. During 1976 and 1977 the quoted price of Soviet Union chromite remained at the high level of $150 per tonne f o.b. Black Sea ports as in 1975 (Morning, 1980), then in February 1978 the price of Soviet Union chromite was suspended and continued to be unquoted at the end of 1980 (Matthews and Morning, 1980 & Peterson, 1981). Chromite exports by the Soviet Union decreased sharply from 1,171,000 tonnes in 1975 to 673,000 tonnes in 1977 after which there was some increase to 775,000 tonnes in 1979 before they fell to 567,000 tonnes in 1980 (Tables 27 and 28). In 1980 Soviet Union chromite exports amounted to only 23% of chromite production compared with 56% of chromite production in 1975 and 67% of chromite production in 1970 (Tables 9, 10, 27, and 28).

Chromite imports by the United States from the Soviet Union dropped steeply from 317,000 tonnes in 1975 to 73,000 tonnes in 1977 (Morning, 1978 & 1980), and this fall in United States chromite imports from the Soviet Union was roughly equivalent to the decrease in total Soviet Union chromite exports from 1975 to 1977. In contrast, total United States chromite imports increased slightly from 1975 to 1977, although imports by the United States of chromite containing 46% or more Cr_2O_3 decreased substantially from 535,000 tonnes in 1975 to 196,000 tonnes in 1977 and included a reduction in chromite imports from the Soviet Union of this grade from

265,000 tonnes in 1975 to 45,000 tonnes in 1977. Thus, the fall in United States imports of high grade chromite during 1975-1977 was actually greater than the reduction in its imports of such chromite from the Soviet Union, and reflected a generally decreased demand for metallurgical grade chromite imports by the United States.

Subsequently, there was a recovery in chromite imports by the United States from the Soviet Union during 1978 and 1979 (Matthews and Morning, 1980), and this was accompanied by an increase in chromite exports by the Soviet Union (Table 27). However, during 1978 and 1979 the imports of chromite by the United States from the Soviet Union comprised mainly low grade chromite having a Cr_2O_3 content of less than 40%, and indeed in 1979 no imports of chromite having a Cr_2O_3 content of 46% or more were made by the United States from the Soviet Union (Matthews and Morning, 1980).

According to Economist Intelligence Unit (1976) it was uncertain whether lower deliveries of chromite by the Soviet Union to the western market in 1976 reflected reduced chromite availability after domestic needs had been satisfied or whether the Soviet Union was holding ore from the market to defend the price, but in any event that result was achieved by the reduction in exports. In the chromite market contracts for a year's supply were usually negotiated towards the end of the previous year (Economist Intelligence Unit, 1975). At the end of 1975 there was a substantial increase in consumer stocks of metallurgical grade chromite in the United States as the result of decreased consumption and increased imports during the year (Morning, 1977(b)), and this in turn was reflected in reduced demand for future imports of metallurgical grade chromite by the United States including imports of high priced chromite from the Soviet Union. Even though metallurgical grade chromite imports by the United States decreased in 1976 and 1977, there was a further increase in consumer stocks of metallurgical grade chromite during these years as seen in Morning (1980). This was so despite a slight recovery in chromite consumption by the metallurgical industry in the United States during 1976 and 1977.

The ultimate demand for metallurgical grade chromite depended primarily on stainless steel production. However, greater demand for stainless steel has to work down through lower consumer stocks of ferrochromium by steel producers to lower producer stocks by ferrochromium manufacturers to an increase in ferrochromium production together with a reduction in consumer stocks of chromite to an increase in chromite purchases by ferrochromium smelters, so that there is a time lag between increased stainless steel production and improved demand for chromite imports as observed by Economist Intelligence Unit (1977). Further, the price of metallurgical grade chromite imports remained high during 1976 and 1977 while the price of imported ferrochromium fell (Morning, 1978 & 1980), and this contributed further to reduced demand for chromite imports by the United States from the Soviet Union. Indeed, substantial imports of ferrochromium were made by the United States during 1976 and 1977 although they were significantly lower than the record tonnage of ferrochromium imports made in 1975 (Table 155).

At the end of 1977 consumer stocks of metallurgical grade chromite in the United States remained at a high level, and indeed were significantly higher than at the end of 1975 as shown in Matthews and Morning (1980). The chromite market early in 1978 reflected the general weakness of recovery in the production of stainless steel following the world recession of 1975 when stainless steel production in the United States fell almost 50% during the year, the continuing impact of the AOD process on the demand for chromite in the manufacture of stainless steel by reducing the demand for low-carbon ferrochromium and thus high grade chromite ores, and the major expansion during 1977 in the production by South Africa of low grade friable chromite ores (Economist Intelligence Unit, 1978). In consequence, chromite prices for 1978 contracts were generally lower than in 1977, and high grade lumpy ores from the Soviet Union were among the worst to suffer. Chromite consumers were offering less than $110 per tonne c.i.f. European ports for 1978 contracts of Soviet Union chromite ores that in 1975 sold at prices of more than $150 a tonne. The Soviet Union decided to suspend shipments of high grade ore in 1978 in preference to accepting such prices, while around 35,000 tonnes of Soviet Union chromite that had been on offer in 1977 was still on the market seeking a buyer at a price more than $40 a tonne below that in 1977.

In the United States consumption of chromite by the metallurgical industry in 1978 was slightly lower than in 1977, but increased significantly in 1979 (Matthews and Morning, 1980). However, this increased consumption in 1979 was reflected in a decrease in consumer stocks rather than an increase in imports. In 1980 chromite consumption by the United States metallurgical industry again fell to slightly above its 1978 level (Peterson, 1981). It is seen that the reduction in exports of metallurgical grade chromite by the Soviet Union after 1975 corresponded to a period of reduced demand for such chromite by the United States, and during 1978 and 1979 United States chromite imports from the Soviet Union comprised mainly refractory grade chromite.

Albania

Chromite production by Albania rose from 468,000 tonnes in 1970 to an estimated 1,016,000 tonnes in 1979 and 1,080,000 tonnes in 1980 as shown in Tables 9 and 10, while chromite exports by Albania increased from 452,000 tonnes in 1970 to 800,000 tonnes in 1978 (after which they are not known) as observed in Table 27. A large proportion of Albanian chromite production was exported, and in 1977 Albanian chromite exports surpassed those of the Soviet Union so that Albania became the second largest chromite exporting country in the world after South Africa. During the period 1970-1979 Albania was responsible for 9% of world chromite production and in 1980 it accounted for 11% of world production, while during the period 1970-1978 Albania provided 13% of world chromite exports including 18% of world exports in 1978.

In Albania chromite was produced from a number of mines located within an ultrabasic belt that extends roughly north-south through the eastern half of the country adjacent to Yugoslavia and Greece (Rabchevsky, 1985). The chromite occurs in podiform deposits, and most of the ore produced was suitable for metallurgical and refractory use. Albanian chromite has an average Cr_2O_3 content of 43% and a Cr:Fe ratio of 3:1. The ore is massive, hard, and of good quality. The Bater-Martanesh area east of Tiranë in central Albania and the Tropoje-Kukes area in northern Albania were the main chromite producing districts in the country.

According to Rabchevsky (1985) Albania marketed two grades of chromite. These comprised a medium grade lumpy ore containing 42-44% Cr_2O_3 and a high grade concentrate containing 48-50% Cr_2O_3. Albanian chromite was marketed through a state owned export agency, and this guaranteed a minimum Cr_2O_3 content of 42% and a maximum SiO_2 content of 10.5% for the chromite it sold. Chromite concentrate was first exported by Albania in 1972 (Morning, 1975), and the concentration plant that was located at Belqize and then recently brought into production was built using an interest free loan from China (Thomson, 1972). Another concentration plant was situated at the large Todo Manco mine at Martanesh (Dickson, 1980). Each of these two concentrators had a capacity of 200,000 tonnes a year, and enhanced Albania's importance as a chromite exporting country.

As stated in Industrial Minerals (1972) communist bloc countries were the main customers for Albanian chromite, which was suitable for metallurgical production, while Albanian chromite was exported also to Italy (Grabfield, 1974). Exports were made through the port of Durres, which was fairly primitive. According to Dickson (1980) chromite was exported by Albania to China in return for economic and technical aid associated with its industrialisation programme that began in the mid-1950's. Albanian chromite exports to China increased from 13% of Albania's exports in 1960 to 54% of its exports in 1976 (Dickson, 1980). However, in 1978 close links between Albania and China were broken, and subsequently a larger proportion of Albanian chromite exports went to western countries. In addition, chromite exports by

Albania continued to be made to Comecon countries of which Yugoslavia became the principal market following a trade agreement signed in 1970, and most of the chromite exported by Albania to Yugoslavia was probably destined for refractories manufacture. As observed by Grabfield (1974) substantial quantities of chromite fines were exported by Albania to Yugoslavia where they were concentrated.

In 1979 more of Albania's chromite exports were being marketed in western Europe and the United States (Matthews and Morning, 1980), and indeed United States chromite imports from Albania amounted to 96,000 tonnes in 1979 compared with 23,000 tonnes in 1977 (Matthews and Morning, 1980 & Morning, 1980). Albanian chromite exports continued to increase after 1975 whereas chromite exports by the Soviet Union were at a reduced level (Table 27), and in 1978 Albania accounted for 18% of world chromite exports compared with 16% of world exports contributed by the Soviet Union (Table 35). By 1980 Albania had become a keen competitor in the international chromite market as observed in Economist Intelligence Unit (1980). Further, Albanian chromite reserves were estimated at two hundred and fifteen million tonnes so that Albania's future as a major chromite exporting country appeared secure.

Philippines

During 1970-1979 chromite production by the Philippines fluctuated between a low of 349,000 tonnes in 1972 and a high of 581,000 tonnes in 1973, then in 1980 amounted to 496,000 tonnes (Tables 9 and 10). Average annual chromite production by the Philippines during 1970-1979 was 504,000 tonnes, which was slightly less than the average annual production of 528,000 tonnes during 1960-1969. Chromite exports by the Philippines during 1970-1979 ranged between a low of 378,000 tonnes in 1976 and a high of 642,000 tonnes in 1974, and during 1980 were 484,000 tonnes (Tables 27 and 28). During 1970-1979 chromite exports by the Philippines averaged 489,000 tonnes a year, which was only slightly lower than average annual production so that virtually all the chromite produced by the Philippines during the decade was exported. The Philippines were responsible for 6% of world chromite production and 11% of world chromite exports during 1970-1979 compared with 12% of world production and 17% of world exports during 1960-1969, so that the relative importance of the Philippines as a chromite producing and exporting country was significantly diminished even though the quantity of its production and exports were not greatly reduced.

Chromite exports by the Philippines decreased from 596,000 tonnes in 1970 to 383,000 tonnes in 1972 then rose to 642,000 tonnes in 1974 after which they fell to 378,000 tonnes in 1976 before rising again to 497,000 tonnes in 1979 (Table 27). The relatively low levels of Philippine chromite exports recorded in 1972 and 1976 followed economic recessions in the United States, Europe, and Japan during 1971 and 1975 as discussed previously. Recovery from the 1975 recession was slower than that from the 1971 recession, and this was reflected in the sluggish increase in chromite exports by the Philippines after 1976 compared with the rapid rise after 1972.

The Philippines continued to produce both refractory and metallurgical grades of chromite. In 1972 80% of the chromite produced by the Philippines comprised refractory grade chromite while the remaining 20% of production consisted of metallurgical grade chromite as recorded by Morning (1973), and during the years 1970-1975 the relative quantities of refractory and metallurgical chromite produced in the Philippines fluctuated around these proportions. Refractory grade chromite continued to be produced from the Masinloc deposits of Consolidated Mines Inc, and the metallurgical grade chromite was mined as previously by Acoje Mining Co Inc. During 1971 the refractory grade chromite exported by the Philippines went mainly to the United States, which accounted for 38% of the exports, United Kingdom 24%, and Japan 12% while the balance was shipped to eleven other countries, and all the metallurgical grade chromite exported by the Philippines went to Japan (Morning, 1973).

Between 1975 and 1977 several new chromite producing companies commenced mining operations in the Philippines for both refractory and metallurgical grade chromite (Morning, 1978), and by 1977 there were six companies producing refractory grade chromite and twelve companies producing metallurgical grade chromite in the Philippines (Morning, 1980). However, in 1977 Consolidated Mines Inc accounted for 88% of the refractory grade chromite produced in the Philippines while Acoje Mining Co Inc was responsible for 63% of the metallurgical grade chromite mined, so that the two traditional producers continued to supply a large proportion of the total chromite production of the Philippines. In 1977 75% of the chromite produced in the Philippines was refractory grade and 25% was metallurgical grade (Morning, 1980). Despite the increased number of chromite producers in the Philippines during the latter half of the 1970's, total chromite production by the Philippines in 1979 amounting to 556,000 tonnes was around the same level as that in 1970 (Table 9).

In 1976 the refractory grade chromite reserves of the Philippines were estimated at 7,800,000 tonnes while the metallurgical grade chromite reserves were estimated at 4,000,000 tonnes (Thomas and Boyle, 1984). These reserves were sufficient to last for around 25 years and 40 years respectively at the production rates then prevailing.

According to Grabfield (1974) both lump ore and concentrates were produced from the Masinloc refractory grade chromite deposits in the Philippines. The lump ore containing around 32% Cr_2O_3, 29% Al_2O_3, and 0.6% CaO was used as a conditioning material by the metallurgical industry in the production of ferrochromium because of its high Al_2O_3 content that enabled a suitable Al_2O_3:MgO balance, and such material comprised around a third of total exports from the deposits. The chromite concentrates produced from Masinloc contained around 34-35% Cr_2O_3 and 28-29% Al_2O_3, and were very suitable for refractory use because of their high Al_2O_3 content. The chromite concentrates produced from the Acoje mine contained around 50%

Cr_2O_3, had a Cr:Fe ratio of 2.4:1, and were exported for consumption by the metallurgical industry. Chromite from the Masinloc mines was exported through the nearby port of Masinloc, while chromite from the Acoje mine was exported through the port of Santa Cruz.

For many years the principal use of chromite refractories was in open-hearth steel furnaces. However, since the mid-1960's these furnaces were being replaced by basic-oxygen furnaces that used refractory bricks containing magnesite or dolomite instead of chromite as discussed in the previous chapter, and this trend was continuing as indicated by Morning (1973) and Thomson (1973). Some compensation for this was provided by increased demand for chromite refractories in electric arc furnaces and glass making furnaces, and this reduced the adverse impact on the demand for refractory grade chromite resulting from conversion to basic-oxygen furnaces in steel making. During 1970-1979 the level of production of refractory grade chromite by the Philippines did not change greatly, and the Philippines continued to be a leading supplier of refractory chromite to the world market.

It was reported by Peterson (1981) that Benguet Corporation and Consolidated Mines Inc had renewed the contract due to expire at the end of 1980 under which Benguet operated the Masinloc refractory chromite mines of Consolidated Mines in Zambales Province of the Philippines. The new agreement was scheduled to run for a period of twenty five years, and would then be subject to renewal by mutual consent of both parties.

During 1979 Voest-Alpine of Austria acquired a substantial financial interest in Acoje Mining Co, which was the largest producer of metallurgical grade chromite in the Philippines (Matthews and Morning, 1980), and at the end of 1980 construction of the first ferrochromium smelting facility in the Philippines commenced (Peterson, 1981). The plant was a joint venture between Voest-Alpine of Austria and the Herdis Group of the Philippines, and had a proposed ferrochromium production capacity of 52,000 tonnes a year. The facility was located in northern Mindanao, and was expected to commence production in 1982. Chromite feed for the smelter was to be provided by the Acoje Mining Co, which was a Herdis Group affiliate and operated the Acoje metallurgical chromite mine in Zambales Province. This arrangement will undoubtedly reduce the amount of metallurgical grade chromite available for export by the Philippines to Japan, and construction of the smelter reflected the continuing trend towards ferrochromium production in chromite mining countries as observed by Thomas and Boyle (1984).

Turkey

During 1970-1979 Turkish chromite production varied between a high of 717,000 tonnes in 1975 and a low of 375,000 tonnes in 1978 (Table 9), and averaged 525,000 tonnes a year during the decade compared with an average of 445,000 tonnes a year during 1960-1969. In 1980 chromite production by Turkey amounted to 399,000 tonnes (Table 10). Chromite exports by Turkey during 1970-1979 ranged between a high of 648,000 tonnes in 1975 and a low of 285,000 tonnes in 1978 (Table 27), and averaged 481,000 tonnes a year during the decade compared with average exports of 381,000 tonnes a year during 1960-1969. In 1980 Turkey exported 335,000 tonnes of chromite (Table 28). During 1970-1979 Turkey was responsible for 7% of world chromite production and 11% of world chromite exports.

In Turkey ultrabasic rock outcrops are widespread and numerous as illustrated by Thomas and Boyle (1984), and chromite is known to occur in forty of the sixty seven provinces of Turkey as recorded in Ethem (1979) in which a huge number of chromite deposits in various regions or districts of Turkey are listed. It was reported (Ethem, 1979) that the state owned mineral research and exploration institute (MTA) put probable chromite ore reserves in Turkey at around thirty six million tonnes while total potential reserves in 1973 were estimated at around a hundred million tonnes.

The major chromite producing provinces in Turkey were Elazig that is situated in eastern Turkey and includes the Guleman district, and Eskisehir that is located in western Turkey and contains the Kavak mine (Thomas and Boyle, 1984). Chromite produced in the Guleman district was exported through the port of Iskenderun on the Mediterranean, while chromite from Eskisehir was shipped through the port of Izmit on the Sea of Marmara. In each case transportation of the chromite to port was expensive, and involved long distance rail haulage following conveyance to the railhead by aerial tramway and/or truck. In contrast, Turkish chromite mines located in the Mugla province in south western Turkey were only 40-100 kilometres from the port of Fethiye on the Mediterranean, and delivery of chromite from these mines to the port of shipment involved much lower inland transportation costs. However, these mines accounted for only a relatively small proportion of total Turkish chromite production.

By far the largest chromite producer in Turkey was state owned Etibank that had a production capacity of 260,000 tonnes of ore and concentrate a year (Dickson, 1980). The next biggest Turkish chromite producer was privately owned Turk Maadin Sirketi, which was associated with a Swedish ferrochromium manufacturer and had a production capacity of around 150,000 tonnes of chromite a year. Other substantial chromite producers in Turkey were Bilfer Maden Ltd Sirketi, Bursa Toros Chromite Company, H. Ogleman Mining Ltd, and Kiyra Chromite Ltd. In addition, Egemetal Madenclik AS played an important role in the Turkish chromite industry. Although this company was not a chromite producer, it acted as a kind of clearing house for many small chromite producers in Turkey, and handled around 150,000 tonnes of chromite a year. Egemetal was associated with Metallgesellschaft of West Germany, and that company was involved in its overseas sales of chromite. As well as being a buyer of chromite, Egemetal was able to supply mining equipment, trucks, technical expertise, and financial support to small operators that marketed their chromite through it, and this enabled considerable flexibility in the level of production. According to Ethem (1979) Turkish chromite production was derived from about thirty mining companies as well as almost twenty single man operations, and the total number of active chromite mines in Turkey varied from 150 to 200 depending on conditions prevailing in the chromite market at the time. Presumably the high chromite prices in the mid-

1970's resulted in considerably increased mining activity, and it is seen in Table 9 that Turkish chromite production reached a peak of 717, 000 tonnes in 1975.

Although there were some small surface chromite mining operations in Turkey, all the major chromite producers used underground mining methods (Thomas and Boyle, 1984), and each of the eight largest Turkish chromite mines had an accompanying beneficiation plant (Peterson, 1981). Most of the chromite produced in Turkey was destined for the metallurgical industry (Dickson, 1980). However, it was recorded in Industrial Minerals (1972) that high grade chromite reserves in Turkey were being depleted rapidly, and that about half the Turkish chromite exports were derived from associated low grade material.

According to Grabfield (1974) the famous top quality chromite produced by Etibank from the Guleman area had provided the basis for a standard against which other chromite ores consumed by the metallurgical industry were measured. It was defined as an ore that contained a minimum of 48% Cr_2O_3, had a Cr:Fe ratio of 3:1 or higher, and was of hard lumpy character. Originally, the SiO_2 content of high quality Turkish chromite ore was around 5%, but over the years this tended to increase as the Cr_2O_3 content of the ore dropped from around 53% to close to the minimum guaranteed, and this reflected the decreasing availability of higher grade ore. In fact, by 1974 the grade of lump chromite ore had fallen below the traditional standard minimum, and 46% Cr_2O_3 became to be regarded as the accepted minimum. Further, a reduction in the standard minimum to 44% Cr_2O_3 was anticipated as an ultimate future development.

Concurrently with the reduction in ore grade, there was an increase in the production of chromite concentrate in Turkey (Grabfield, 1974). Lower grade Turkish chromite ore was relatively abundant, and had a high Cr:Fe ratio close to 3:1. By washing out SiO_2 it was possible to produce a chromite concentrate containing a minimum of 48% Cr_2O_3 while maintaining the Cr:Fe ratio of the original feed. Such concentrate could be agglomerated into products such as pellets and briquettes for use by the metallurgical industry, although these were less suitable than lump ore for traditional high-carbon ferrochromium production.

During 1972-1976 Turkey exported chromite to a number of countries (Table 57) of which the United States was the largest market, while other important destinations for Turkish chromite exports included West Germany, Japan, Sweden, France, Norway, Italy, Spain, Austria, and Czechoslovakia. In the case of the United States chromite exports by Turkey during 1972-1976 averaged 124,000 tonnes a year, and reached their highest level of 169,000 tonnes in 1975. As deduced from Morning (1977(b)) 50% of the chromite imports made by the United States from Turkey in 1975 had a Cr_2O_3 content of 46% or more, while 18% of the imports had a Cr_2O_3 content of more than 40% but less than 46%, and 32% of the imports had a Cr_2O_3 content of 40% or less.

It was reported by Thomson (1972) that Japan Metals and Chemical Co had contracted to import around a million tonnes of chromite from Turkey. The ore was to be supplied by Etibank over a twelve year period commencing in 1972, and in exchange the Japanese company was to construct a new ferrochromium smelter in Turkey. Chromite exports by Turkey to Japan increased sharply from around 10,000 tonnes in 1972 to 91,000 tonnes in 1975 then decreased to 64,000 tonnes in 1976 (Table 57).

During the 1970's the price of Turkish metallurgical chromite fluctuated markedly as in the case of chromite from the Soviet Union as discussed earlier in the chapter. There was an increase in the price of Turkish chromite in 1970 for 1971 delivery, and this continued the trend of rising prices experienced during the period 1967-1969 (Morning, 1972 & 1974). However, the price of Turkish chromite for 1972 delivery fell significantly even though the published price remained the same as for 1971 delivery (Morning, 1974), and during 1973 the price of Turkish chromite decreased further (Morning, 1975). The direction of price movement was reversed again in 1974 when the price of Turkish chromite rose sharply, then at mid-year the price increased further and in September moved still higher to reach $64 per tonne f.o.b. Turkish ports for chromite containing 48% Cr_2O_3 and having a Cr:Fe ratio of 3:1 (Morning, 1976). In September 1974 the price of Turkish chromite was much higher than it was at the end of 1970. Then, early in 1975 the Turkish chromite price more than doubled and remained in the range $130-$140 per tonne f.o.b. Turkish ports for the rest of the year (Morning, 1977(b)). During 1975 the price of Turkish chromite was more than four times what it was at the beginning of 1967 (Morning, 1968). Throughout 1976 and 1977 the published price of Turkish chromite was held at the high level reached in 1975 (Morning, 1978 & 1980). However, the price quotation for Turkish chromite was lowered to $105 per tonne f.o.b. Turkish ports in June 1978 because of lack of sales, then increased slightly to $110 per tonne in 1979 and remained at that level during 1980 (Matthews and Morning, 1980 & Peterson, 1981). The variations in price of Turkish chromite essentially reflected changes in demand, although it appears the price changes were at times slow to respond to altered demand conditions.

Turkish chromite exports rose from 314,000 tonnes in 1967 to 546,000 tonnes in 1970 and remained around that level at 539,000 tonnes in 1971 (Tables 26 and 27). The increase in chromite exports by Turkey during this period corresponded to the application of mandatory economic sanctions against Zimbabwe that created an artificial world shortage of metallurgical grade chromite. During 1970 and 1971 there was a substantial increase in chromite imports by the United States from Turkey, and particularly of chromite having a Cr_2O_3 content of 46% or higher (Morning, 1972 & 1973). However, in 1972 Turkish chromite exports dropped steeply to 342,000 tonnes (Table 27), and in 1972 United States chromite imports from Turkey also fell sharply (Morning, 1974). The decrease in chromite exports by Turkey in 1972 was associated with reduced demand for chromite following economic recession in the main chromite importing countries during 1971 and the first half of 1972. Further, early in 1972 the United States removed its prohibition on the importation of chromite from Zimbabwe.

Subsequently, chromite exports by Turkey rose sharply from 342,000 tonnes in 1972 to 646,000 tonnes in 1974 then remained around that level at 648,000 tonnes in 1975 (Table 27), and this reflected a rapid recovery from the economic recession. Even though there was a further recession in 1975, chromite exports by Turkey in 1975 remained high following the strong world demand for chromite in 1974. Indeed, chromite consumption by the United States in 1974 was at record level (Morning, 1977(b)). However, in 1975 United States chromite consumption dropped to less than that in 1971. Turkish chromite exports declined from 648,000 tonnes in 1975 to 285,000 tonnes in 1978 then increased somewhat to 322,000 tonnes in 1979 and 335,000 tonnes in 1980 (Tables 27 and 28). The reduction in Turkish chromite exports after 1975 was the reflection of a number of factors including a slow recovery from the economic recession of 1975, the existence of large consumer stocks of chromite, reduced demand for metallurgical grade chromite arising from introduction of the AOD process in stainless steel production, price competition from other metallurgical chromite suppliers, increased ferrochromium exports by chromite producing countries (particularly South Africa), and expanded domestic consumption of chromite by Turkey for ferrochromium production.

Some compensation for the lower chromite exports by Turkey during 1978 and 1979 as well as in 1980 was afforded by an increase in exports of Turkish ferrochromium as observed in Tables 125 and 126. These averaged 28,500 tonnes a year during 1978-1980 compared with only 8,000 tonnes in 1977. In Turkey there were two ferrochromium smelters located at Antalya and Elazig (Thomas and Boyle, 1984). The Antalya smelter had a production capacity of 10,000 tonnes of ferrochromium a year and was built in the 1960's, while the Elazig smelter had a design capacity of 50,000 tonnes of ferrochromium a year and commenced production in 1976. Each of the smelters was owned and operated by Etibank.

Turkish metallurgical grade chromite had an average Cr_2O_3 content of 46%, and was suitable for producing ferrochromium containing at least 65% Cr (Thomas and Boyle, 1984). Further, Turkey was the main source of high grade metallurgical chromite in the world outside the Soviet Union, Albania, and Zimbabwe, and its ore reserve potential should enable it to continue supplying chromite and ferrochromium to the world market.

Zimbabwe

Mandatory economic sanctions imposed by the United Nations in December 1966 against the importation of chromite from Zimbabwe remained in force until they were lifted in December 1979 (Matthews and Morning, 1980), and in retaliation against the United Nations economic sanctions the government of Zimbabwe placed an embargo on mining news, particularly production data for which the 1965 figures were the latest published (Morning, 1973). However, estimates of chromite production by Zimbabwe during 1970-1979 were made by the United States Bureau of Mines (Table 9), and estimated chromite production by Zimbabwe during the decade averaged 574,000 tonnes a year. Even though chromite production by Zimbabwe was estimated for the 1970's, no detailed information on or estimates of chromite exports by Zimbabwe during 1970-1978 are available.

The effect of economic sanctions against Zimbabwe was to create a world shortage of metallurgical grade chromite, bring about a distortion in the pattern of international trade in such chromite, result in higher metallurgical grade chromite prices, and increase dependence of consumers on chromite imports from the Soviet Union as discussed previously. Despite these consequences, the Nixon Administration in the United States consistently affirmed that it did not intend lifting the economic sanctions while the political situation in Zimbabwe remained unchanged as reported by Thomson (1971). However, in September 1970 approval was given under the "hardship provisions" contained in the United States Executive Order governing trade with Zimbabwe for Union Carbide to import from Zimbabwe chromite that had been ordered and paid for before the sanctions came into effect, and it is seen in Morning (1973) that in 1971 the United States imported 24,000 tonnes of high grade chromite from Zimbabwe.

During the latter part of 1971 United States Public Law 92-156 (Section 503) was amended to allow the importation of strategic and critical materials from Zimbabwe, and in January 1972 the Department of Treasury published regulations removing controls on the import of these materials (Morning, 1974). The amendment became known as the Byrd Amendment, and in consequence of it the United States became the only member country of the United Nations that could legally import chromite from Zimbabwe (Grabfield, 1974). This was in spite of the United Nations resolution imposing sanctions against Zimbabwe, and lifting of the ban by the United States was opposed by the United Nations as reported by Thomson (1972). The Byrd Amendment did not specifically refer to chromite, but prohibited the President of the United States from barring the import of a strategic material (such as chromite) from a "free world" country while the United States was importing the same material from a communist nation. Naturally, the Byrd Amendment was welcomed by large chromite consumers in the United States as indicated in Industrial Minerals (1972). During the years 1972-1975 chromite imports by the United States from Zimbabwe ranged from 39,000 tonnes in 1973 to 125,000 tonnes in 1975 (Morning, 1975 & 1977(b)), then fell to 32,000 tonnes in 1976 (Morning, 1978). As stated by Byrd (1975) the principal effect of the Byrd Amendment was to permit the importation into the United States of chromite from Zimbabwe, and at any time the President could nullify the Byrd Amendment by either eliminating the importation of chromite from the Soviet Union or removing chromite from the strategic list although no such action had ever been taken.

During the period 1972-1977 there was substantial controversy in the United States regarding the Byrd Amendment as well as moves in Congress to have it repealed, and these involved consideration of the political ramifications of the amendment on the one hand and national security issues on the other (Morning, 1977(b)). For instance, in 1975 the international relations committee of the U.S.

House of Representatives voted in favour of a bill to reimpose the embargo on chromite imports from Zimbabwe whereas the armed services committee of the House voted against it as reported in Industrial Minerals (1975).

Finally, in March 1977 the United States passed Public Law 95-12 that amended the United Nations Participation Act 1945 so as to halt the importation of chromium from Zimbabwe, and in essence repealed the Byrd Amendment that allowed the importation of Zimbabwean chromite (Morning, 1980). Further, the new law prohibited the importation from any country of both ferrochromium and steel mill products containing more than 3% chromium (primarily stainless steels) if these contained Zimbabwean chromium. In an attempt to make the new law more effective, the United States entered into agreements with Japan, South Korea, the European Economic Community countries, Austria, Norway, Spain, Sweden, and Yugoslavia to ensure that their exports of steel products to the United States did not contain Zimbabwean chromite as reported in Economist Intelligence Unit (1977). However, repeal of the Byrd Amendment in March 1977 and the consequent reintroduction by the United States of the United Nations ban on imports from Zimbabwe was made at a time there was reduced demand for high grade Zimbabwean chromite resulting from introduction of the AOD process in stainless steel making. This process used charge ferrochromium made from low Cr:Fe ratio friable chromite ores from South Africa rather than high chromium content ferrochromium in the production of which Zimbabwean chromite was particularly suitable. Indeed, in 1976 the United States imported only 32,000 tonnes of chromite from Zimbabwe compared with 125,000 tonnes in 1975, and in 1976 imports of high grade chromite from Zimbabwe represented only 4% of United States chromite imports containing 46% or more Cr_2O_3 compared with 17% of such imports in 1975 as seen in Morning (1978). Further, in March 1976 the President of Mozambique declared a state of war against Zimbabwe, closed the border, seized Zimbabwean property, and declared that United Nations sanctions would be implemented fully (Morning, 1978), and these actions adversely affected the export of chromite and ferrochromium by Zimbabwe through the port of Lourenco Marques.

In December 1979 the United Nations and the United States removed economic sanctions against the import of chromite and other products from Zimbabwe following the establishment of a representative government and election of a prime minister by that country (Matthews and Morning, 1980). Further, Union Carbide resumed the management of its Zimbabwean affiliate, Union Carbide Rhomet, and planned to import ferrochromium produced by it into the United States beginning in 1980. Previously, in 1967 the Zimbabwean regime had mandated certain of the more important chromite mines in the country, namely those operated by subsidiaries of Union Carbide and Foote Mineral (formerly Vanadium Corporation) of the United States, in order to ensure their continued chromite production despite economic sanctions as recorded by Charles River Associates Inc (1970) and Grabfield (1974). In 1980 the United States imported 18,300 tonnes of ferrochromium from Zimbabwe whereas there were no imports of chromite (Peterson 1981), and this reflected the transition from chromite export to domestic ferrochromium production and export by Zimbabwe as discussed later.

During the 1970's there was continued speculation and comment regarding the question of illegal sanction breaking involving chromite and ferrochromium imports from Zimbabwe during the period of United Nations economic sanctions. As reported by Thomson (1970) it was alleged by United States ferroalloy producers that some European countries were buying chromite cheaply from Zimbabwe, and that this together with lower labour costs put them in a very favourable competitive position compared with United States ferrochromium producers that were prohibited from importing Zimbabwean chromite. Indeed, it was claimed the European ferrochromium producers were able to undersell American producers by almost 20% in the United States market. According to Thomson (1971) reports of Zimbabwean chromite reaching countries that were signatories to the United Nations economic sanctions continued to circulate and probably had some credibility, and it was believed in some quarters that China had recently imported chromite from Zimbabwe. Further, in Grabfield (1974) it was stated that Japan was alleged to have been importing large quantities of "Northern South African" chromite for some time, and that the Japanese Ministry of International Trade and Industry (MITI) had recently announced that the situation would be carefully policed to prevent any continuation of this practice.

There were suggestions the Soviet Union was importing Zimbabwean chromite for re-export to western markets, although a more likely possibility if at all was that chromite was being imported from Zimbabwe by some of the East Bloc countries in Europe so that Soviet Union chromite that would otherwise be exported to them became available instead for export to western countries (Grabfield, 1974). Besides, it would not be difficult to identify re-exported Zimbabwean chromite by its chemical composition. In 1979 there were rumours that some Zimbabwean chromite excluded from its traditional markets by the sanctions was being bought by the Soviet Union and China (Economist Intelligence Unit, 1979). It was suggested that the Soviet Union could without difficulty buy Zimbabwean chromite at distress prices for domestic consumption then use domestically produced chromite to bolster its dwindling chromite exports at higher prices, while China was in the process of reorganising its chromite supplies following the break with Albania in 1978.

According to Thomson (1980) much Zimbabwean ferrochromium had undoubtedly reached the export market despite economic sanctions, and was probably shipped through other African countries using falsified certificates of origin. Further, in contrast to chromite it was not possible to use chemical analysis to detect the origin of the chromium in ferrochromium.

In addition to the speculation and rumour regarding sanction breaking in relation to Zimbabwean chromite and ferrochromium, there were cases involving actual convictions for violation of economic sanctions. During 1974 a British company was convicted and fined by a Hull court for sanction breaking in connection with

Zimbabwean chromite (Thomson, 1975), and in 1979 arising out of a Rotterdam case the Dutch were required by law to "destroy" 6,000 tonnes of confiscated Zimbabwean ferrochromium (Economist Intelligence Unit, 1979). Although the full extent of violation of the economic sanctions against Zimbabwe is not known, it is clear that the sanctions were not totally effective. Indeed, it is probable that substantial quantities of chromite and ferrochromium were exported by Zimbabwe during the currency of the sanctions.

In 1980 chromite production by Zimbabwe amounted to 552,000 tonnes (Table 10). According to Thomas and Boyle (1984) an estimated 50% of production came from mining podiform chromite deposits in the Selukwe district, 45% was derived from working chromite seams in the Great Dyke, and 5% came from other chromite mining operations. The two main chromite mines in the Selukwe district were the Selukwe Peak and Railway Block, and both were worked from deep vertical shafts (Prendergast, 1984). The size and shape of the podiform orebodies allowed a high degree of mechanisation underground, and mining costs at Selukwe were about half those on the Great Dyke where the seams were too thin for mechanised mining. The Selukwe ore had a Cr_2O_3 content of 44-50% Cr_2O_3 and a high Cr:Fe ratio of 3.0-3.8:1.0. In addition, the ore had relatively high proportions of MgO and Al_2O_3. Except for crushing, chromite ore mined at Selukwe required no further treatment before being charged into an arc furnace to produce ferrochromium. The ore was lumpy in character, and its refractory chemical components helped to reduce the carbon level in ferrochromium produced. The properties of Selukwe chromite ore made it very suitable for producing ferrochromium having a high chromium content. Indeed, it was probably the highest quality metallurgical chromite ore in the world. The Great Dyke chromite ores comprised a Lower Group having a Cr_2O_3 content of 43-54% together with a Cr:Fe ratio of 2.6-3.5:1.0, and an Upper Group having a Cr_2O_3 content of 36-49% together with a Cr:Fe ratio of 1.9-2.5:1.0.

According to Prendergast (1984) high grade lump chromite ore reserves at

Selukwe in 1980 amounted to around three million tonnes compared with about twelve million tonnes of chromite produced from Selukwe since mining operations commenced in 1906. In contrast, the chromite potential of the Great Dyke was enormous with total chromite resources estimated at around ten thousand million tonnes of which about 90% was high grade chromite in the Lower Group seams. However, a very large proportion of the chromite contained in the Great Dyke seams was not economic under prevailing conditions as it was located well below the current mining depth or was too far from existing railheads. Nevertheless, there were sufficient Great Dyke chromite ore reserves close to established mining centres to last for many years.

The Great Dyke is a huge geological intrusion about five hundred and thirty kilometres long and up to eleven kilometres wide extending roughly north-south through the middle of Zimbabwe, and comprises a line of four elongated basic-ultrabasic layered complexes arranged end to end as described by Prendergast (1984). Within the Great Dyke all the known chromite seams occur in the Ultrabasic Sequence portion of the rock succession, while the Selukwe podiform chromite deposits are situated adjacent to the Great Dyke in the Selukwe district.

Union Carbide of the United States was the largest producer of chromite in Zimbabwe, and through its subsidiaries Rhodesia Chrome Mines Ltd and African Chrome Mines Ltd operated chromite mines at Selukwe and Mtoroshanga on the Great Dyke (Grabfield, 1974). In 1980 chromite production by Union Carbide in Zimbabwe amounted to around 350,000 tonnes, and it was reported by Peterson (1981) that chromite production from the Union Carbide mines at Selukwe and Mtoroshanga was being expanded by almost 40% to around 500,000 tonnes a year to meet increased demand for chromite from two new ferrochromium furnaces being constructed by Union Carbide Rhomet and scheduled to commence operation during 1981 and 1982. The new furnaces were designed to supplement ferrochromium production from the four existing furnaces being operated by the company in 1980.

It was the stated objective of the Zimbabwean government that all chromite mined in the country should be domestically smelted to produce ferrochromium (Thomas and Boyle, 1984), and in fact Zimbabwe became the first chromite mining country in the world to trade all its chromium output in alloy form (Prendergast, 1984). In 1980 ferrochromium exports by Zimbabwe amounted to 257,300 tonnes (Table 126) whereas chromite exports by Zimbabwe in 1980 were only 15,000 tonnes (Table 28). Even though ferrochromium exports by Zimbabwe in 1980 were only about one third those of South Africa, Zimbabwe was the second largest ferrochromium exporting country in the world in 1980 and accounted for 19% of world ferrochromium exports (Table 132).

Among the advantages of exporting ferrochromium rather than chromite were that Zimbabwe enjoyed the benefits associated with a substantial increase in the added value of its exports by the domestic processing of chromite, and the export of a lower volume of higher priced product better utilized scarce railway and port facilities. Following the independence of Mozambique from Portugal in 1975 and the subsequent disruption to rail and port facilities associated with civil war in Mozambique as well as the application by it of economic sanctions, the importance to Zimbabwe of Beira and Lourenco Marques as export ports declined and it had to rely more heavily on South African ports, particularly Durban, for the shipment of its exports (Thomas and Boyle, 1984). However, even after the lifting of economic sanctions against Zimbabwe in 1980 the shipment of chromium products through Beira and Lourenco Marques in Mozambique was restricted by a continuing limited capacity of those ports to handle cargo. Further, transportation costs from Zimbabwe to South African ports were substantially greater than those to Beira where loading capacity was limited, and this militated against the export of chromite as opposed to ferrochromium. In addition, the existence of economic sanctions coupled with "anonymity" of ferrochromium in contrast to chromite probably accelerated the development of Zimbabwe as a ferrochromium producing country.

According to Economist Intelligence Unit (1980) Zimbabwean ferrochromium was proving extremely competitive in Europe, and this was assisted by the availability of cheap hydro-electric power from Kariba on the Zambesi River as well as thermal power from domestic coal deposits. Further, during 1980 the United States imported 18,300 tonnes of ferrochromium from Zimbabwe (Peterson, 1981).

In 1980 there were two ferrochromium smelting facilities in Zimbabwe as described by Thomas and Boyle (1984) and Peterson (1981). The larger of these was situated at Que Que and operated by Union Carbide Rhomet (later Zimbabwe Mining and Smelting Co) that was a subsidiary of Union Carbide of the United States. This smelter had the capacity to produce around 170,000 tonnes of high-carbon ferrochromium a year from four furnaces. The other Zimbabwean ferrochromium smelter was located at Gwelo (about fifty kilometres south of Que Que) and operated by Rhodall Ltd (later Zimalloys), which was a subsidiary of Anglo American Corporation. The Gwelo smelter had the capacity to produce a total of around 110,000 tonnes of high-carbon ferrochromium, low-carbon ferrochromium, and ferrochromium-silicon a year from six furnaces. Each of the Zimbabwean ferrochromium smelters was situated on a main railway line, and each was in reasonably close proximity to chromite mining operations.

According to Prendergast (1984) the high-carbon ferrochromium smelter of Union Carbide at Que Que used a chromite feed comprising a blend of approximately 80% high grade lump ores from Selukwe and 20% mixed Great Dyke ores without prior agglomeration of fines, and this smelter produced ferrochromium containing 67% Cr and 6% C. The chromite feed used by the Gwelo smelter consisted entirely of various Great Dyke ores, and in the case of the high-carbon ferrochromium furnace about half the chromite input comprised briquetted friable ores and concentrates. The high-carbon ferrochromium produced at Gwelo contained 64% Cr and 8% C, while the low-carbon ferrochromium from Gwelo contained 68% Cr and 0.05% C.

The podiform chromite deposits of Zimbabwe were very cost competitive compared with other high grade chromite deposits in the world such as those in Turkey (Thomas and Boyle, 1984), and this contributed to the competitive position of Zimbabwean ferrochromium although ferrochromium made solely from Great Dyke chromite ores was also produced and exported. It is probable that overall chromite production costs in Zimbabwe will rise in the future (although possibly not for some time) due to a greater proportion of chromite production being derived from seam-type deposits in the Great Dyke as the Selukwe and other podiform deposits become depleted. Nevertheless, Zimbabwe has very large high grade chromite resources in the Great Dyke, and it is likely to remain an exporter of ferrochromium rather than chromite.

India

During 1970-1979 chromite production by India reached an estimated 500,000 tonnes in 1975 (Table 9) and averaged 334,000 tonnes a year during the decade, while chromite exports by India rose to a high of 359,000 tonnes in 1975 (Table 27) and averaged 199,000 tonnes a year for the decade. In 1975 about 72% of Indian chromite production was exported, and for the decade as a whole 60% of Indian chromite production was exported. During the period 1970-1979 India accounted for 4% of world chromite production and 4% of world chromite exports, whereas during 1960-1969 it was responsible for 2% of world chromite production and 2% of world chromite exports.

In 1975 Indian chromite reserves were estimated at seventeen million tonnes on the basis of a cutoff grade of 40% Cr_2O_3 (Thomas and Boyle, 1984). However, ore reserves were several times greater than this if the cutoff grade was reduced to 30% Cr_2O_3 as established in subsequent assessments made by the Geological Survey of India and the Minerals Exploration Corporation. A dominant proportion of Indian chromite reserves were situated in Orissa State on the east coast of India, and largely within the mining districts of Cuttack-Dhenkenal and Keonjhar. These districts were the source of most of India's chromite production during the 1970's, and Indian chromite exports from Orissa were made primarily through the port of Paradip on the Bay of Bengal.

Japan was the sole market for Indian chromite exports in the early 1970's as observed by Grabfield (1974) and Morning (1975). During 1972-1976 chromite imports by Japan from India (Table 97) averaged 257,000 tonnes a year, and India supplied 23% of Japanese chromite imports over that period. Further, India was the second largest source (after South Africa) of chromite imported by Japan as seen in Table 97.

High grade chromite produced by India in the Cuttack-Dhenkenal and Keonjhar districts of Orissa was suitable for metallurgical use, and was directly competitive with high grade chromite from the Soviet Union, Turkey, Iran, and the Philippines (Thomas and Boyle, 1984). However, Indian chromite embraced a variety of product types comprising lump ore, fines, and concentrates, and each of these was produced in a wide spectrum of grades. Chromium mining in India generally involved shallow opencut operations that were labour intensive though semi-mechanised, and such operations enabled considerable flexibility in the tonnage as well as in the type and grade of production.

According to Grabfield (1974) Indian chromite production consisted primarily of ore in the form of fines although small tonnages of lump ore were also exported. The ores were very high in both grade and Cr:Fe ratio, and an analysis quoted (Grabfield, 1974) showed a Cr_2O_3 content of 56% and a Cr:Fe ratio of 3.8:1.0, which was among the highest grade of any chromite in the world. The main chromite producers in India were Misrillal Jain (with production of around 140,000 tonnes a year), Orissa Mining (80,000 tonnes), and Tata Iron and Steel (80,000 tonnes). In 1970 almost 60% of Indian chromite exports had a grade in the range 48-56% Cr_2O_3 (Morning, 1973).

During the period 1970-1979 chromite exports by India reached their highest levels of 334,000 tonnes and 359,000 tonnes in 1974 and 1975 (Table 27), and in each of these years India accounted for 7% of world chromite exports (Table 35). Subsequently, Indian chromite exports declined to 67,000 tonnes in 1978 when they were at their lowest level for the decade, and in that year India contributed only 2% of world chromite exports. In both 1974 and 1975 there was a strong world demand for chromite imports and the price of metallurgical chromite rose sharply, whereas during the years 1976-1978 there was reduced world demand for chromite imports and in 1978 particularly there was a low demand for imports coupled with substantially reduced prices as discussed previously. It appeared that India was able to increase both its tonnage and percentage of world exports during a time of strong demand and high prices, but experienced a reduction in both its tonnage and share of exports when world demand was reduced and prices were lower.

In Dickson (1980) it was recorded that Japanese chromite imports from India had been falling. This was attributed partly to reduced demand, but also to the fact that some of the chromite tenders from India in 1977 were not competitive and Japan increased chromite imports from other sources. Subsequently, the export of Indian chromite was channelled through Minerals and Metals Trading Co, and discussions took place with a Chinese delegation regarding possible sales. It was reported by Matthews and Morning (1980) that some success had been achieved by India in developing chromite markets in China and western Europe to compensate for the loss of most of its Japanese market, and in 1979 chromite exports by India recovered substantially to 236,000 tonnes as seen in Table 27.

According to Thomas and Boyle (1984) the decrease in chromite production and exports by India after 1976 was due mostly to the imposition of controls by the Indian government on the domestic chromite industry as part of a conservation policy rather than to reduced chromite demand. These controls included banning the export of high grade lump ores containing more than 40% Cr_2O_3 and high grade fines containing more than 47% Cr_2O_3, the levy of export taxes on all other chromite products, and the imposition of export quotas for all chromite exporting companies.

Further, it was predicted that the future of Indian chromite exports would depend more on government policy towards the conservation of high grade resources, expansion of the domestic ferrochromium industry, and problems associated with transportation and infrastructure rather than with questions related to the availability of resources, technology, or production costs. It was anticipated that in the future there would be increased emphasis on the domestic consumption of chromite in the production of ferrochromium rather than on the export of chromite.

In 1980 there were two ferrochromium smelters in India, and these were located at Shreeram Bawar north of Bombay in Maharastra State and at Cuttack in Orissa State (Thomas and Boyle, 1984). Both plants were commissioned in 1969, and during the latter half of the 1970's their combined ferrochromium output amounted to around 20,000 tonnes a year. Operation of the smelters involved the consumption of domestically produced chromite, and some of the ferrochromium produced was exported. During 1977-1979 Indian ferrochromium exports ranged from 9,000 tonnes to 10,000 tonnes a year whereas prior to 1972 there were no ferrochromium exports (Table 125). In the future ferrochromium exports by India will probably rise further as new ferrochromium smelters come into operation.

Finland

Chromite deposits were discovered at Kemi in Finland during 1959 (Industrial Minerals, 1972), and chromite production by Finland commenced in 1966 as indicated in Table 8. By 1969 Finnish chromite production had risen to 72,000 tonnes compared with 6,000 tonnes in 1967.

Production of chromite by Finland increased further to 121,000 tonnes in 1970 then declined to 97,000 tonnes in 1972 after which it rose steeply and continuously to 435,000 tonnes in 1979 then decreased to 341,000 tonnes in 1980 (Tables 9 and 10), while chromite exports by Finland climbed from 4,000 tonnes in 1970 to 508,000 tonnes in 1977 then decreased to 309,000 tonnes in 1979 and 207,000 tonnes in 1980 (Tables 27 and 28). During 1970-1979 Finnish chromite production averaged 256,000 tonnes a year and chromite exports averaged 179,000 tonnes a year so that Finland exported 70% of its chromite production during the decade. Finland accounted for 3% of world chromite production and 4% of world chromite exports during the period 1970-1979 although its share of both world production and world exports rose from below to above these overall percentages as the decade progressed (Tables 19 and 35).

In Finland chromite occurs in the Kemi deposits located at Elijarvi about seven kilometres northeast of the town of Kemi situated at the north eastern head of the Gulf of Bothnia (Thomas and Boyle, 1984). The chromite deposits are associated with a basic-ultrabasic sill-like intrusion that crops out from Kemi in a northeasterly direction over a distance of fifteen kilometres, and has a maximum width of 1,500 metres. Economic chromite ore bodies within the intrusion occur only over a five kilometre length located north and northeast of the town of Elijarvi. The grade of the chromite ore is relatively low with an average Cr_2O_3 content of about 27%, which reflects the strong brecciation of the ore bodies and dilution with gangue material, and the ore has a Cr:Fe ratio of around 1.5:1.0. By the mid-1970's eight ore bodies were known to occur over the prospective five kilometre length of the intrusion.

Chromite from the Kemi deposits in Finland was rather similar in chemical properties to South African Transvaal chromite (Grabfield, 1974), and this is consistent with its Cr:Fe ratio of around 1.5:1.0. According to Dickson (1980) the Kemi chromite mine was the only major source of chemical grade ore in the western world outside South Africa. As discussed earlier in this chapter such chemical grade chromite had come into demand for the production of high-carbon ferrochromium for consumption in the manufacture of stainless steel using the AOD process.

Open pit mining of the Kemi deposits commenced in 1967 at the Elijarvi orebody (Thomas and Boyle, 1984), and continued until 1977 when the pit was closed. In 1977 a new pit known as Viaa was brought into production to mine the Viiaanranta and Viianlahti orebodies. Total chromite ore reserves in the Kemi deposits suitable for open pit mining were estimated to be in the range of 25 to 30 million tonnes, and in addition there was the longer term possibility of mining further chromite resources from the Kemi deposits by means of underground mining. The chromite deposits at Kemi were owned and operated by a government company, Otokumpu Oy, that also operated a domestic ferrochromium smelter at Tornio, located about fifty kilometres by road from the deposits.

The chromite mined at Kemi was separated into lump ore for direct shipping or into feed for on-site milling (Thomas and Boyle, 1984). The mill produced either a concentrate for consumption in the Tornio ferrochromium smelter or direct sale, or a concentrate used as raw material for further processing into chromite foundry sand. However, a large proportion of the chromite production from the Kemi deposits comprised direct shipping ore, and this is reflected in the fact that the weighted-average grade of all products derived from Kemi ore was a low 31% Cr_2O_3 compared with an average ore grade of 27% Cr_2O_3. According to Grabfield (1974) two grades of concentrate were produced, and these contained 42% Cr_2O_3 and 46% Cr_2O_3 respectively. The lower grade concentrate was converted into pellets containing 45-46% Cr_2O_3 for use as feed in the Tornio ferrochromium smelter.

The Kemi mine was one of the lowest cost major chromite producing operations in the world (Thomas and Boyle, 1984), and this was in spite of the relatively low grade of ore and adverse weather conditions. It was possible for Otokumpu Oy to mine, process, and transport chromite to the port of Ajos near Kemi for an average price f.o.b. of only US$25.00 per tonne. This was achievable because of the low stripping ratio resulting from the relatively steep dip of the ore bodies, the practice of selective mining that allowed the concentration ratio to remain relatively low, and the favourable situation of the deposits in relation to infrastructure and port facilities.

The ferrochromium smelter at Tornio was part of a state-owned integrated steel works, and had the capacity to consume around 30% of the chromite ore and concentrate produced from the Kemi deposits in the domestic manufacture of high-carbon ferrochromium, while the balance of the chromite produced from the deposits was exported. The Kemi deposits enjoyed a locational advantage in the supply of high-iron chromite and foundry sand to markets in northern Europe, particularly Sweden and West Germany (Table 63).

It was reported by Morning (1977(b)) that a five year contract had been signed in 1975 with Airco Inc of Sweden for the supply of Finnish chromite, and chromite from Kemi was to provide up to 75% of the ore required by the Vargon ferrochromium smelter in Sweden operated by Airco, and some chromite was to be shipped also to other Airco plants. Chromite exports by Finland to Sweden increased from 15,500 tonnes in 1974 to 135,700 tonnes in 1976 (Table 63).

The production and export of Finnish chromite from the Kemi deposits was assisted by the relatively low operating and transport costs as well as the suitability of high-iron chromite in the production of high-carbon ferrochromium for use in the manufacture of stainless steel. It is seen in Table 9 that Finnish chromite production reached a record of 435,000 tonnes in 1979 compared with a chromite production of 121,000 tonnes in 1970.

Chromite exports by Finland increased from 4,000 tonnes in 1970 to 508,000 tonnes in 1977 (Table 27), and during this period Finnish chromite exports increased from less than 0.5% of world exports in 1970 to 10% of world exports in 1977 (Table 35). Even though chromite exports by Finland decreased subsequently to 207,000 tonnes in 1980 (Table 28), the share of world exports contributed by Finland remained relatively high at 7% of world exports in 1980 (Table 36). In 1977 chromite exports by Finland were abnormally high in that exports significantly exceeded production in that year. However, during 1979 chromite exports by Finland amounted to 309,000 tonnes compared with chromite production of 435,000 tonnes so that chromite exports represented 71% of production, which was almost the same as the proportion of exports to production of 70% for Finland over the decade as a whole, and in 1979

Finland contributed 9% of world exports.

The state-owned integrated steel works at Tornio was operated by Otokumpu Oy, and included the ferrochromium smelter constructed in 1968 and expanded subsequently. At 1980 the smelter had a rated ferrochromium production capacity of 50,000 tonnes a year. About 30% of the chromite produced from the Kemi mines during the 1970's was consumed by the Tornio smelter in the manufacture of high-carbon ferrochromium. Some of the ferrochromium produced was used domestically by the Tornio steel works, while substantial quantities of ferrochromium averaging 32,500 tonnes a year were exported by Finland during the 1970's (Table 125). It is expected that the availability of ore reserves and relatively low costs will ensure the continued operation of the Kemi chromite deposits and Tornio ferrochromium smelter, and this should enable Finland to remain an important producer and exporter of both chromite and ferrochromium for many years.

Malagasy

Chromite production by Malagasy during 1970-1979 ranged between a low of 112,000 tonnes in 1972 and a high of 221,000 tonnes in 1976 (Table 9) and averaged 155,000 tonnes a year during the decade. In 1980 Malagasy chromite production amounted to 180,000 tonnes (Table 10). Chromite exports by Malagasy during 1970-1978 varied between a low of 98,000 tonnes in 1973 and a high of 180,000 tonnes in 1974 (Table 27) and averaged 130,000 tonnes a year over that period. Malagasy accounted for 2% of world chromite production during 1970-1979, and was responsible for 3% of world chromite exports during 1970-1978.

According to Peterson (1981) chromite was the most important mineral mined in Malagasy. Prior to 1976 chromite production in Malagasy was carried out by Campagnie Miniere d' Andriamena (Comina) that was controlled by the French Pechiney-Ugine-Kuhlmann Group. Comina was owned 80% by Pechiney-Ugine-Kuhlmann and 20% by the Malagasy government (Grabfield, 1974). In December 1975 chromite mining in Malagasy was nationalised, although under the takeover settlement the former owners were to retain one-third of future chromite output at a predetermined price and contracted to manage the mining operations. On nationalisation the assets of Comina were transferred to Kroamita Malagasy, a company 100% owned by the state (Morning, 1978 & Peterson, 1981). In Malagasy chromite was produced solely for the export market (Peterson, 1981), and the main markets for Malagasy chromite were Japan and France as indicated in Table 61.

The chromite deposits of Malagasy occur in three major districts located in the northern half of the country (Thomas and Boyle, 1984). These are the Andriamena, Ranomena, and Bafandriana districts of which the Andriamena district is by far the most important in terms of both reserves and production. The Andriamena district is situated about 180 kilometres by air north of the capital Tananarive, and about 200 kilometres by air northwest of the port of Tamatave. The district covers a rectangular area that extends about 60 kilometres north-south and 40 kilometres east-west. A large number of chromite lenses and eluvial deposits are known to occur within the district.

The first chromite deposit to be mined on a large scale in the Andriamena district was the Bemanevika orebody, which comprised relatively high grade ore that contained 42% Cr_2O_3 and had a Cr:Fe ratio of 2.6 to 3.3:1.0 (Thomas and Boyle, 1984). Production from the Bemanevika deposit began in 1964, but was shut down in 1974 when the pit face collapsed and dilution by waste rock became excessive. In 1974 the Ankazatoalana deposit located a few kilometres from the Bemanevika deposit was developed to replace output from Bemanevika. The ore from Ankazatoalana was lower in grade with a Cr_2O_3 content of 30% to 37%, but a concentrate having a Cr:Fe ratio of 2.4 to 2.7:1.0 was produced from it. In 1975 chromite mining began in the Befandriana district, located about 100 kilometres southeast of the port of Majunga, and production from this operation during the rest of the decade ranged from 40,000 to 50,000 tonnes of chromite ore a year. The Befandriana ore was high grade with a Cr_2O_3 content of 46% and a Cr:Fe ratio of

2.6:1.0. All the chromite produced by Malagasy came from surface mining operations .

At 1980 a very large proportion of the chromite ore reserves of Malagasy were located in the Andriamena district where reserves were estimated at ten million tonnes averaging 31.4% Cr_2O_3. (Thomas and Boyle, 1984). In contrast, ore reserves in the Befandriana district were estimated at only 100,000 tonnes averaging 45.0% Cr_2O_3, which seriously limited the future life of the mining operation in that district, while ore reserves in the Ranomena district, where earlier chromite production ceased in 1964, were estimated at 250,000 tonnes averaging 37.0% Cr_2O_3. This makes the chromite ore reserves of Malagasy very small compared with those of South Africa and Zimbabwe, and no substantial increase in the importance of Malagasy as a chromite exporting country was expected. By 1980 no ferrochromium smelter had ever been constructed in Malagasy, and the likelihood of such a smelter being built remained doubtful.

Iran

During 1970-1979 Iranian chromite production ranged between an estimated high of 233,000 tonnes in 1977 and a low of 136,000 tonnes in 1979 (Table 9), and in 1980 chromite production by Iran fell to an estimated 82,000 tonnes (Table 10). Chromite production by Iran averaged 177,000 tonnes a year during 1970-1979 compared with an average of 105,000 tonnes a year during 1960-1969 and an average of 27,000 tonnes a year during 1950-1959. Iranian chromite exports during 1970-1979 varied between a high of 222,000 tonnes in 1970 and a low of 5,000 tonnes in 1976 (Table 27), and averaged 108,000 tonnes a year during the decade. In 1980 chromite exports by Iran amounted to 29,000 tonnes (Table 28). During 1970-1979 Iran provided 2% of world chromite production and 2% of world chromite exports.

Chromite production in Iran came from two main sources (Industrial Minerals, 1975). These were the Froumad deposits that extend from northwest of Sabzevar to south of Meshad in the north of the country, and deposits situated further south in the

Esfandegheh area that is located 200 kilometres northeast of the port of Bandar Abbas on the Persian Gulf. These deposits were operated by the Faryab Mining Co and the Esfandegheh Mining Co respectively, and output comprised both metallurgical and refractory grade chromite. It was recorded by Morning (1978) that in 1976 proven chromite ore reserves in Iran totalled around 1.5 million tonnes containing 40-48% Cr_2O_3, while probable ore reserves amounted to more than 2.0 million tonnes.

According to Grabfield (1974) Iranian chromite production included both lump ore and concentrates that were of high grade with a Cr_2O_3 content of 48% and a Cr:Fe ratio of 3:1 or higher. A typical analysis quoted by Grabfield for Iranian chromite shows a Cr_2O_3 content of 49.0% and a Cr:Fe ratio of 3.2:1.0. However, the chromite industry in Iran was disadvantaged by poor inland transport facilities and the need to use inefficient ports from the point of view of bulk-handling. In addition, port limitations necessitated the use of smaller ships, and this tended to place Iran at a freight rate disadvantage.

Iran exported chromite to a wide range of countries during the period 1970-76 (Table 59). Japan and France were the largest customers for Iranian chromite, while the United States, China, and various other countries in both western and eastern Europe were important destinations. Chromite exports by Iran to Japan were assisted by trade agreements with Japan that had the effect of granting substantial subsidies to Iranian chromite producers (Grabfield, 1974).

During the period 1975-79 and 1980 chromite exports by Iran averaged around 45,000 tonnes a year, and were much lower than those during the period 1970-74 when exports averaged 155,000 tonnes a year (Table 27). This reduction in the level of exports by Iran was probably associated with a lower demand for metallurgical grade chromite as well as slow recovery from recession as discussed earlier in the chapter.

In January 1979 the Shar of Iran departed from the country following widespread and persistent opposition to his regime, and at the beginning of February

1979 the spiritual leader Ayatollah Khomeini returned to Iran from exile (Whitaker, 1982). Subsequent to a national referendum, Iran was declared an Islamic Republic by Ayatollah Khomeini in April 1979, and following invasion by Iraq in September 1980 war broke out between Iran and Iraq. These momentous political changes created a climate of uncertainty for the future of Iranian chromite production and exports.

Brazil

Chromite production by Brazil during 1970-1979 rose from 27,000 tonnes in 1970 to 340,000 tonnes in 1979 and in 1980 amounted to 287,000 tonnes (Tables 9 and 10), whereas chromite exports by Brazil during 1970-1979 were variable and ranged from less than 500 tonnes in 1970 and 1975 to 82,000 tonnes in 1978 (Table 27). During 1970-1979 Brazilian chromite production averaged 159,000 tonnes a year while chromite exports averaged 30,000 tonnes a year, so that Brazil exported only 19% of its chromite production during the decade. In global terms Brazil was responsible for 2% of world chromite production and 1% of world chromite exports during 1970-1979.

A large proportion of the chromite reserves of Brazil are located in the Campo Formoso District in the State of Bahia, and it is from this district that Brazilian chromite production came (Thomas and Boyle, 1984). The main producers were FERBASA and COMISA, the latter of which was a subsidiary of the Bayer group of West Germany. The chromite occurs in stratiform deposits, and was mined by open pit operations. Two chromite concentrating mills having capacities of 1,000 tonnes of ore per day and 333 tonnes of ore per day were operated by FERBASA and COMISA respectively. The grade of crude ore fed to the FERBASA mill averaged 21% Cr_2O_3. According to Grabfield (1974) the concentrate produced had a Cr_2O_3 content of around 49.4% and a Cr:Fe ratio of 1.7:1.0, and this low ratio made the concentrate rather similar to Transvaal chromite ore. The demonstrated chromite resources of the Campo Formoso District were estimated at 1980 to total around 17.0 million tonnes comprising 13.0 million tonnes averaging 21.0% Cr_2O_3 in the Pedrinhas trend and 4.0

million tonnes averaging 17.0% Cr_2O_3 in the Limoeiro trend (Thomas and Boyle, 1984).

Chromite produced by FERBASA was either exported or converted to ferrochromium in a smelter owned by FERBASA and located at Pojuca that is situated around 75 kilometres north of the port of Salvador, while around two-thirds of the chromite produced by COMISA was sold to the domestic chemical industry and the balance to FERBASA for use in the production of ferrochromium at Pojuca (Thomas and Boyle, 1984). The chromite mining operations in the Campo Formoso District were located at an average distance of around 375 kilometres northwest of the ferrochromium smelter at Pojuca and about 450 kilometres from the port of Salvador. A large proportion of the chromite produced in Brazil was consumed by the domestic ferrochromium and chemical industries, and this resulted in a relatively low level of chromite exports compared with production. By 1980 Brazil had become a significant ferrochromium exporting country, and in that year Brazilian ferrochromium exports amounted to 45,900 tonnes (Table 126).

In 1972 FERBASA entered into an agreement with a consortium of seven large Japanese corporations to form a company known as SERJANA to conduct exploration for new chromite deposits, and this new company was owned 51% by FERBASA and 49% by the Japanese consortium (Morning, 1974 & Grabfield, 1974). Substantial exploration for chromite was carried out by SERJANA east of the Limoeira fault in the Campo Formoso District from May 1972 to late in 1974, and mine development began in 1975 (Thomas and Boyle, 1984). However, the mining operation ran into grade and pit slope problems almost from the outset, and these resulted in much lower grades and higher stripping ratios than expected. In 1980 the Japanese consortium sold its interest in SERJANA to FERBASA. During the period 1975-1980 the only chromite exported by Brazil came from the Limoeira mine operated by SERJANA, and this all went to Japan. Following sale of the Japanese interest in SERJANA chromite produced from Limoeira was sent to the FERBASA smelter at Pojuca, so that all the chromite mined in Brazil was consumed domestically.

It seems likely that in future most or all of the chromite produced in Brazil will be used domestically by the metallurgical and chemical industries, and that the availability of ferrochromium for export will depend largely on the demand for ferrochromium by the domestic steel industry.

CHROMITE CONSUMPTION AND IMPORTS

During the period 1970-1980 there was increasing chromite consumption by chromite producing countries in Africa and South America, notably South Africa, Zimbabwe, and Brazil. However, a major proportion of the world's chromite production during 1970-1980 continued to be consumed in North America, Europe, and Japan. The United States, Soviet Union, Japan, and South Africa were the largest chromite consuming countries in the world during 1970-1980, while West Germany, Sweden, and France were substantial chromite consumers. With the exception of the Soviet Union and Finland that were chromite producers, chromite consumers in North America, Europe, and Japan during 1970-1980 continued to rely largely or exclusively for their supply of chromite on imports from producing countries of which South Africa, Soviet Union, Albania, Philippines, and Turkey were the major sources.

The pattern of world chromite imports by country of destination during the period 1970-1979 and in 1980 is shown in terms of tonnage in Tables 78 and 79 and as a percentage of world total in Tables 85 and 86. During 1970-1979 the United States and Japan were the two largest chromite importing countries in the world with each accounting for 23% of world chromite imports, while other major chromite importing countries during 1970-1979 were West Germany with 10% of world imports, Sweden 7%, and France 7%, and these five countries were responsible for 70% of world chromite imports during the decade. Other significant chromite importing countries during 1970-1979 were Italy, Poland, Yugoslavia, and the United Kingdom, and these accounted for a further 15% of world imports, so that nine countries provided the destination for 85% of world chromite imports. During 1970-1979 total world chromite imports varied between a low of 3,698,000 tonnes in 1972 and a record of 5,342,000 tonnes in 1975, and in 1980 total world imports amounted to 4,167,000 tonnes. World chromite imports averaged 4,635,000 tonnes a year during 1970-1979, and were 45% greater than average chromite imports of 3,198,000 tonnes a year during the previous decade.

North America

Even though both the United States and Canada were chromite importing countries during 1970-1979 and in 1980 (Tables 78 and 79), the tonnage of chromite imported by the United States during 1970-1979 was more than eleven times that by Canada with United States chromite imports averaging 1,057,000 tonnes a year compared with Canadian imports averaging 92,000 tonnes a year. In 1980 United States chromite imports were more than ten times those of Canada with imports amounting to 892,000 tonnes and 86,000 tonnes respectively.

During 1970-1979 chromite imports by the United States declined from 1,275,000 tonnes in 1970 to 845,000 tonnes in 1973 then rose to 1,173,000 tonnes in 1977 after which they fell to 919,000 tonnes in 1978 and remained around that level in 1979 (Table 78). United States chromite imports during 1970-1979 averaged 1,057,000 tonnes a year, and were 15% lower than chromite imports during the previous decade. This continued the downward trend already evident, and in 1980 chromite imports amounted to 892,000 tonnes (Table 79). During 1970-1979 total United States chromite imports were only slightly larger than those of Japan, and each of these countries was responsible for 23% of world imports (Tables 78 and 85). During the previous decade 1960-1969 the United States accounted for 39% of world chromite imports, so there was a further continuation of the declining trend in the United States' share of world chromite imports. In 1980 the United States accounted for 21% of world chromite imports (Table 86).

An important factor in the declining tonnage of chromite imported by the United States was the increasing tonnage of ferrochromium imported by that country.

During 1960-1969 average annual chromite imports by the United States were 1,251,000 tonnes compared with average annual ferrochromium imports of only 45,000 tonnes, whereas during 1970-1979 average chromite imports decreased to 1,057,000 tonnes a year while average ferrochromium imports increased to 180,900 tonnes a year, and in 1980 chromite imports amounted to only 892,000 tonnes compared with ferrochromium imports of 274,200 tonnes (Tables 77-79 and 154-156). This change in the composition of imports was made possible by a substantial increase in ferrochromium production capacity in chromite producing countries coupled with price competition between ferrochromium imports by the United States and ferrochromium produced domestically from imported chromite even though ferrochromium imports were subject to tariffs.

The average Cr_2O_3 content of chromite consumed in the United States during 1975 was 42.5% (Morning, 1977(b)), and based on the atomic weights of Cr and O, namely 52.0 and 16.0 respectively (Garside and Phillips, 1953), it is calculated that the average Cr content of the chromite consumed was 28.9%. It can be deduced from the chromium content of ferrochromium imports by the United States in 1975 given by Morning (1977(b)) that the average Cr content of the ferrochromium imported was 62.1%. This shows a Cr content of ferrochromium slightly more than twice that of chromite, and indicates that in terms of chromium content one tonne of ferrochromium is equivalent to around two tonnes of chromite. In consequence, the fall in average annual chromite imports by the United States of 194,000 tonnes during 1970-1979 compared with 1960-1969 was more than compensated for by the increase in average annual ferrochromium imports of 135,900 tonnes during 1970-1979 compared with 1960-1969.

The increase in United States' imports of ferrochromium and the associated decrease in those of chromite was an important factor also in the declining percentage of world chromite imports made by the United States. Another important factor in the declining share of world chromite imports attributable to the United States was the increased tonnage of chromite imports made by other countries, particularly Japan. The spectacular growth in Japanese chromite imports is illustrated by the rise in average annual chromite imports by Japan from 91,000 tonnes in 1950-1959 to 423,000 tonnes in 1960-1969 and 1,052,000 tonnes in 1970-1979, and this was accompanied by a decline over the same period in average annual chromite imports by the United States from 1,564,000 tonnes in 1950-1959 to 1,251,000 tonnes in 1960-1969 and 1,057,000 tonnes in 1970-1979 (Tables 76-78). The enormous rise in the level of chromite imports by Japan reflected the tremendous economic development achieved by that country during the postwar period. Japan's share of world chromite imports rose from 4% in 1950-1959 to 13% in 1960-1969 and 23% in 1970-1979, whereas the United States' share of world imports fell from 65% in 1950-1959 to 39% in 1960-1969 and 23% in 1970-1979 (Tables 83-85).

There was no chromite production in the United States during 1970-1979 or in 1980 except in 1976 when a small quantity of chromite was produced from the Butler Estates mine and mill near Coalinga in California (Morning, 1978). Most of the usable output from this operation was exported because of the high cost of transportation to domestic markets, and the United States continued to rely on chromite imports to meet its consumption needs.

During the period 1970-1977 chromite imports by the United States were supplemented considerably by deliveries of chromite from the General Services Administration (GSA) stockpile that were made in consequence of chromite sales by the United States Government. The tonnage of these deliveries varied from year to year, and comprised differing proportions of metallurgical, chemical, and refractory grade chromite. For instance, in 1973 around 51,000 tonnes of metallurgical grade chromite, 141,000 tonnes of chemical grade chromite, and 57,000 tonnes of refractory grade chromite were delivered from Government stockpiles as a result of current year and prior sales contracts, and in 1975 around 215,000 tonnes of metallurgical grade chromite, 76,000 tonnes of chemical grade chromite, and 89,000 tonnes of refractory grade chromite were delivered from Government stockpiles (Morning, 1975 & 1977 (b)). These deliveries made an important contribution to the total chromite supply and level of stocks available for consumption in the United States. However, by 1978 the inventory levels of most chromium materials in the national stockpile were close to current goals, and in 1978 and 1979 there were no sales of chromium materials from the Government stockpile nor any deliveries of chromite based on sales contracts from previous years (Matthews and Morning, 1980).

Chromite consumption by the United States during 1970-1979 declined from 1,273,000 tonnes in 1970 to 992,000 tonnes in 1971 then rose to 1,313,000 tonnes in 1974 after which it fell to 799,000 tonnes in 1975 then increased to a level of around 912,000 tonnes during the years 1976-1978 after which it increased further to 1,097,000 tonnes in 1979 (Morning, 1976 & Matthews and Morning, 1980). In 1980 chromite consumption by the United States decreased to 878,000 tonnes (Peterson, 1981). The relatively low levels of chromite consumption by the United States in 1971 and 1975 corresponded to periods of economic recession as discussed earlier in the chapter. The high level of chromite consumption reached in 1974 reflected the rapid economic recovery that followed the 1971 recession whereas the more subdued rise in consumption following the 1975 recession reflected a more sluggish recovery from that recession.

The level of chromite imports in a particular year tends to reflect conditions and expectations prevailing during the previous year towards the end of which purchases for the forthcoming year are made as described previously. The high level of chromite imports by the United States during 1971 was influenced by the high level of chromite consumption in 1970, and the sharp fall in chromite consumption experienced during 1971 was not matched by a similar drop in chromite imports (Table 78). In consequence, there was a substantial increase in consumer stocks of chromite during 1971. This was accentuated by GSA stockpile deliveries, and consumer stocks of chromite at year end rose from 665,000 tonnes in 1970 to

924,000 tonnes in 1971 (Morning, 1973). However, following the 1971 recession that lasted until mid-1972 chromite imports declined sharply from 1,178,000 tonnes in 1971 to 958,000 tonnes in 1972 and 845,000 tonnes in 1973 (Table 78).

With recovery from the economic recession chromite consumption by the United States rose from 992,000 tonnes in 1971 to 1,313,000 tonnes in 1974, while chromite imports increased from 958,000 tonnes in 1972 to 1,136,000 tonnes in 1975. During the 1975 recession chromite consumption in the United States dropped sharply to 799,000 tonnes, but as in the case of the 1971 recession chromite imports during 1975 were at a high level that reflected the increased level of consumption during 1974, and there was a build up in consumer stocks of chromite as in 1971. It is seen in Morning (1977(b)) that consumer stocks of chromite in the United States fell to 520,000 tonnes at the end of 1974, but rose to 864,000 tonnes by the end of 1975. However, chromite imports remained high following the 1975 recession, and the slow recovery from recession was accompanied by a further build up in stocks that was accentuated by GSA stockpile deliveries.

The tonnage of chromite consumed by the metallurgical industry in the United States fell from 827,000 tonnes in 1970 to 520,000 tonnes in 1980 (a fall of 37%) and the tonnage of chromite consumed by the refractory industry dropped from 252,000 tonnes in 1970 to 141,000 tonnes in 1980 (a drop of 44%), whereas the tonnage of chromite consumed by the chemical industry rose from 193,000 tonnes in 1970 to 218,000 tonnes in 1980 (a rise of 13%) as recorded by Morning (1972) and Peterson (1981). The percentage of chromite consumed by the metallurgical industry decreased from 65% in 1970 to 59% in 1980, the percentage consumed by the refractory industry dropped from 20% in 1970 to 16% in 1980, and the percentage consumed by the chemical industry jumped from 15% in 1970 to 25% in 1980.

The fall in chromite consumption by the metallurgical industry during the 1970's was the result of and compensated for by an increase in ferrochromium imports by the United States that rose from 37,500 tonnes in 1970 to 274,200 tonnes in 1980 (Tables 155 and 156), whereas the consumption of chromium by the refractory industry showed a real decline during the decade. A decrease in chromite consumption by the refractory industry early in the decade was attributable to a continuing decline in the production of steel made using open-hearth furnaces (Morning, 1973). This resulted from the replacement of open-hearth furnaces by basic-oxygen converters in steel production as discussed in the previous chapter. Towards the end of the decade there was a further decline in the consumption of chromite refractories, and this was probably associated with the adoption of water-cooled panels in the upper walls of ultra-high-powered electric arc steelmaking furnaces as well as improvements in tar-bonded magnesite and burned dolomite bricks used competitively with chromite in basic-oxygen steel making furnaces (Matthews and Morning, 1980). During the recessions of 1971 and 1975 there was a fall in chromite consumption by each of the metallurgical, refractory, and chemical industries, but the percentages of chromite consumed by these sectors remained relatively unchanged as seen from statistics given by Morning (1976) and Matthews and Morning (1980).

During 1980 the United States metallurgical industry consumed 520,000 tonnes of chromite in the production of 217,000 tonnes of chromium alloys and metal (Peterson, 1981). The latter comprised 167,000 tonnes of low-carbon and high-carbon ferrochromium as well as 49,000 tonnes of ferrochromium-silicon, chromium metal, and other chromium additives and alloys. About 38% of the chromite consumed by the metallurgical industry in the United States during 1980 had a Cr:Fe ratio of 3:1 or higher, 27% had a ratio between 2:1 and 3:1, and 35% had a ratio lower than 2:1, and this reflected the increased versatility in the type of chromite used in the production of ferrochromium. The domestically produced chromium alloys were supplemented by imports of ferrochromium that in 1980 comprised 250,000 tonnes of high-carbon ferrochromium and 20,000 tonnes of low-carbon ferrochromium (Peterson, 1981).

The principal use of chromium in the metallurgical industry was in the production of stainless steel that accounted for 70% of total chromium alloys consumed in the United States during 1980, while the production of full-alloy steels was responsible for 16% of chromium alloy consumption, superalloys 4%, high-strength low-alloy and electrical steels 3%, cast irons 2%, carbon steels 1%, tool steels 1%, and other alloys 1% as calculated from consumption statistics given by Peterson (1981). In the refractory industry chromium in the form of chromite was used primarily for manufacturing refractory bricks to line metallurgical furnaces, and in the chemical industry chromite was consumed in the manufacture of sodium and potassium bichromate that were the base materials for a wide range of chromium chemicals used in pigments, electroplating, and leather tanning.

Among the diversity of applications for chromium was the use of chrome yellow paint in the marking of highways as part of road safety, and this was expected to increase (Morning, 1974). Chrome yellow is the chemical lead chromate, and contains a nominal 16% chromium. In addition to the advantage provided by its high visibility, chrome yellow has a good resistance to degradation by light as well as to chemicals that are used to remove snow and ice. Other uses for chromium that were both new and expanding included fabricated stainless steel exhaust manifold systems for motor vehicles that replaced cast iron and reduced weight, and turbochargers for small-engined vehicles that enabled good performance without sacrificing fuel efficiency (Matthews and Morning, 1980). Another growing application for stainless steel and other corrosion resistant alloys was in power generation where they were used in the construction of large wet scrubbers in utility power plants to remove sulphur dioxide (SO_2) from coal combustion exhaust gases.

During the 1970's and in 1980 the United States imported chromite from many of the producing countries. The main suppliers of chromite containing 46% or more Cr_2O_3 were the Soviet Union, Turkey, South Africa, and Zimbabwe (exempted from United Nations economic sanctions by the Byrd Amendment that was in effect in the United States from January 1972 to March 1977), while the major supplier of chromite containing more than 40% but less than 46% Cr_2O_3 was South Africa, and the main supplier of chromite containing 40% or less Cr_2O_3 was the Philippines. The classification of chromite by its Cr_2O_3 content rather than by metallurgical, chemical, and refractory grade came into effect in September 1963 with the introduction of revised United States tariff schedules as described in the previous chapter, but there is a close correspondence between the two classification systems.

In 1980 the United States imported 177,000 tonnes of chromite containing 46% or more Cr_2O_3 of which 44% came from South Africa and 28% from the Soviet Union, 386,000 tonnes of chromite containing more than 40% but less than 46% Cr_2O_3 of which 65% was from South Africa, and 328,000 tonnes of chromite containing 40% or less Cr_2O_3 of which 38% was from the Philippines (Peterson, 1981), whereas in 1970 the United States imported 638,000 tonnes of chromite containing 46% or more Cr_2O_3 of which 58% came from the Soviet Union, 19% from Turkey, and 14% from South Africa, 355,000 tonnes of chromite with more than 40% but less than 46% Cr_2O_3 of which 79% was from South Africa, and 282,000 tonnes of chromite with 40% or less Cr_2O_3 of which 61% was from the Philippines (Morning, 1972). During 1975 when the Byrd Amendment was in effect the United States imported 535,000 tonnes of chromite in the category containing 46% or more Cr_2O_3, and of this 49% came from the Soviet Union, 17% from Zimbabwe, 15% from Turkey, and 12% from South Africa as calculated from import statistics given by Morning (1977(b)).

It is interesting to observe that in 1980 43% of total chromite imports by the United States had a Cr_2O_3 content of more than 40% but less than 46% compared with only 20% of imports having a Cr_2O_3 content of 46% or more, whereas in 1970 only 28% of chromite imports had a Cr_2O_3 content of more than 40% but less than 46% compared with 50% of imports that had a Cr_2O_3 content of 46% or more. This reflected the suitability and increased use of South African chemical grade chromite in the production of high-carbon ferrochromium that was used in the newly developed AOD and related processes for the manufacture of stainless steel as discussed earlier in the chapter.

Europe

The largest chromite importing countries in Europe during the period 1970-1979 were West Germany with average annual chromite imports for the decade of 469,000 tonnes, Sweden 344,000 tonnes, and France 323,000 tonnes, while other European countries that imported substantial quantities of chromite during 1970-1979 were Italy, Poland, Yugoslavia, and the United Kingdom (Table 78). The chromite imports by each of these countries during the 1970's were much lower than those of either the United States or Japan, which were almost equal, and even West Germany had chromite imports for the decade that were less than half those of the United States and Japan. However, chromite imports by Europe as a whole during the 1970's were slightly more than twice those of the United States and Japan, and indeed slightly greater than the chromite imports of the United States and Japan combined. None of the main chromite importing countries in Europe except Yugoslavia were chromite producers during the 1970's, and chromite production by Yugoslavia dropped to a very low level after 1973 (Table 9). In 1980 the largest chromite importing countries in Europe were Sweden and West Germany with roughly equal imports of 332,000 tonnes and 329,000 tonnes respectively, while France and Yugoslavia each had chromite imports of 279,000 tonnes (Table 79).

During 1970-1979 West Germany, Sweden, and France were not only importers of chromite, but also importers and exporters of ferrochromium (Tables 78, 125, and 155). West Germany and France were net importers of ferrochromium during 1970-1979 with average annual net imports of 87,800 tonnes and 14,100 tonnes respectively, and these ferrochromium import surpluses were available to supplement chromite imports for use in domestic consumption by the metallurgical industry. In contrast, Sweden was a net exporter of ferrochromium with average annual net exports of 27,000 tonnes. On the assumption that ferrochromium has a chromium content twice that of chromite as estimated previously, the net ferrochromium exports of Sweden were equivalent to around only 16% of its chromite imports, so there remained substantial potential for the further domestic processing of chromite and ferrochromium by Sweden as in the case of West Germany and France. Indeed, it is seen in Pariser (1984) that West Germany, France, and Sweden were the largest producers of stainless steel in western Europe during 1970-1980 with average annual productions during that period of 622,000 ingot tonnes, 520,000 ingot tonnes, and 402,000 ingot tonnes respectively, so that the three largest chromite importing countries in Europe during the 1970's were also the three largest producers of stainless steel (though not in exactly the same order). The average annual stainless steel production of West Germany, France, and Sweden combined during 1970-1980 amounted to 1,544,000 ingot tonnes, and this was slightly larger than average annual stainless steel production by the United States of 1,530,000 ingot tonnes during the same period.

The tonnage of chromite imported by West Germany during the period 1970-1979 was 52% greater than during the previous decade, while chromite imports by Sweden were 147% higher and those by France were 47% larger (Tables 77 and 78). During 1970-1979 West Germany and France each maintained their share of world chromite imports at 10% and 7% respectively as in 1960-1969, while Sweden increased its share of world chromite imports from 4% in 1960-1969 to 7% in 1970-1979 (Tables 84 and 85). These three largest chromite importing countries in Europe during the 1970's were together responsible for 24% of world chromite imports during 1970-1979, and their combined share of world chromite imports was slightly greater than that of the United States and Japan, which each accounted for 23% of world chromite imports during the decade.

Variations from year to year in the tonnage and percentage of chromite imports for each country in Europe during 1970-1979 and in 1980 can be seen in

Tables 78-79 and 85-86. According to Thomson (1972) world chromite consumption was adversely affected by the 1971 economic recession, in particular by the downturn in stainless steel production in the United States, Europe, and Japan, and it appears (Table 78) that chromite imports by most countries in Europe dropped sharply in 1972 following the 1971 recession then recovered as economic conditions improved. However, chromite imports by the main European importing countries dropped only slightly during 1976 following the economic recession of 1975. As in the case of the United States, ferrochromium produced in Europe using imported chromite was subject to competition from imported ferrochromium, particularly low priced ferrochromium from South Africa and Sweden, and this caused hardship to European ferrochromium producers (Thomson, 1979). It is seen in Table 155 that ferrochromium imports by West Germany and France increased significantly during the years 1976-1979, and this appears to have had an adverse effect on the level of chromite imports by West Germany and France during the latter part of the decade as indicated in Table 78. In contrast, chromite imports by Sweden increased during this period as did ferrochromium exports by both South Africa and Sweden (Table 125).

During 1970-1979 chromite imports by Sweden and Yugoslavia increased very substantially in terms of both tonnage and percentage as the decade progressed (Tables 78 and 85). Swedish chromite imports rose dramatically from 197,000 tonnes in 1970 to 674,000 tonnes in 1979 and their percentage of world imports increased from 4% in 1970 to 14% in 1979, while Yugoslavian chromite imports climbed from 70,000 tonnes in 1970 to 298,000 tonnes in 1979 and their share of world imports increased from 2% in 1970 to 6% in 1979. An important factor in the increased chromite imports by Sweden, particularly after 1974, was the expansion in chromite exports by Finland associated with the development of and increased production by the Kemi chromite mine, and the agreement in 1975 between Otokumpu Oy of Finland and Airco of Sweden for the supply of chromite as described earlier in the chapter. The increased chromite imports by Yugoslavia during the 1970's were accompanied by the virtual demise of chromite production by that country, although the growth in chromite imports by Yugoslavia was far more significant than the reduction in chromite production.

During 1970-1979 both Sweden and Yugoslavia imported chromite and exported ferrochromium as observed in Tables 78 and 125, and ferrochromium exports by these countries increased substantially during the decade. Indeed, Swedish ferrochromium exports rose from 27,900 tonnes in 1970 to 141,600 tonnes in 1979, and Yugoslavian ferrochromium exports increased from 10,200 tonnes in 1970 to 57,200 tonnes in 1979 (Table 125). It was reported by Thomson (1979) that South Africa and Sweden had reduced the price of ferrochromium exports to such an extent that ferrochromium prices prevailing in the EEC were below the domestic cost of production, and that the United States' International Trade Commission had ruled twice during 1978 that ferrochromium imports from South Africa, and to a lesser extent Yugoslavia, were injuring domestic ferrochromium producers. This indicated the extent to which Swedish and Yugoslavian ferrochromium exports were competitive in the world market, and such price competitiveness enabled the growth in ferrochromium exports by these countries as well as increased their demand for chromite imports.

Japan

During 1970-1979 Japan was both a producer and an importer of chromite (Tables 9 and 78). However, chromite production by Japan during 1970-1979 averaged only 22,000 tonnes a year compared with chromite imports that averaged 1,052,000 tonnes a year, and domestic chromite production accounted for only 2% of Japan's chromite supply during the decade. Further, chromite production by Japan declined from 33,000 tonnes in 1970 to 12,000 tonnes in 1979. In 1980 Japanese chromite production amounted to only 14,000 tonnes compared with chromite imports of 950,000 tonnes (Tables 10 and 79).

Japan's average annual chromite imports of 1,052,000 tonnes during 1970-

1979 were 149% higher than average annual imports of 423,000 tonnes during 1960-1969, and Japan was responsible for 23% of world chromite imports during 1970-1979 compared with 13% of world imports during 1960-1969 (Tables 77-78 and 84-85). However, the rapid growth in chromite imports by Japan during 1960-1969 when chromite imports rose 163% from 279,000 tonnes in 1960 to 733,000 tonnes in 1969, followed by a sharp jump to 1,150,000 tonnes in 1970, was not continued during 1970-1979 when the level of chromite imports remained relatively steady for much of the decade except for an isolated drop to 875,000 tonnes in 1972 and a reduction in the level of imports during the years 1977-1979 that was more than balanced by higher imports of ferrochromium as discussed subsequently.

It is interesting to observe in Pariser (1984) that there was very strong growth in stainless steel production by Japan during the 1960's and in 1970 whereas during the 1970's stainless steel production by Japan increased at a much slower rate. This reflected the relationship between chromite imports and stainless steel production in which chromium through chromite and ferrochromium is a fundamental ingredient. During the period 1970-1980 average annual stainless steel production by Japan was 1,900,000 ingot tonnes, and Japan was the largest producer of stainless steel in the world, whereas in 1960 Japanese stainless steel production was only around 240,000 ingot tonnes (Pariser, 1984).

Japanese chromite imports did not vary greatly during the years 1970-1976 when they ranged fairly narrowly between 1,150,000 tonnes and 1,269,000 tonnes except in 1972 when they fell to 875,000 tonnes (Table 78). The sharp drop in chromite imports by Japan in 1972 was similar to that experienced by the United States as well as various countries in Europe, and followed the economic recession of 1971 when chromite consumption was substantially reduced while chromite imports remained at a high level. In 1972 Japan's share of world chromite imports was largely maintained at 24%, even though the tonnage of chromite imports fell sharply, and during the years 1970-1976 the proportion of world chromite imports made by Japan ranged between 23% and 26% (Table 85).

During the years 1977-1979 the level of Japanese chromite imports was significantly lower than that during the period 1970-1976 (except in 1972) as observed in Table 78. Indeed, Japanese chromite imports averaged 844,000 tonnes a year during 1977-1979 compared with chromite imports that averaged 1,142,000 tonnes a year during 1970-1976. The significant decrease in the level of chromite imports by Japan after 1976 was accompanied by a sharp rise in ferrochromium imports by Japan during the years 1976-1979 (Table 155). It is seen in Tables 78 and 85 that during 1977-1979 there was not only a decrease in the tonnage of chromite imports by Japan, but also a fall in its share of world chromite imports that ranged between 16% and 20% in these years compared with a range of 23% to 26% during 1970-1976, and this indicated that Japan's chromite imports were particularly affected by competition from imported ferrochromium. In 1980 chromite imports by Japan amounted to 950,000 tonnes compared with ferrochromium imports of 280,400 tonnes (Tables 79 and 156), and Japan was responsible for 23% of world chromite imports and 21% of world ferrochromium imports (Tables 86 and 162). Japan was the largest importer of chromite in the world during 1980, and its ferrochromium imports in that year were exceeded only by those of West Germany.

During 1970-1979 and in 1980 Japan was both an importer and an exporter of ferrochromium as shown in Tables 155-156 and 125-126. Ferrochromium imports by Japan averaged 24,000 tonnes a year during the period 1970-1975 then rose steeply from 29,100 tonnes in 1975 to 280,400 tonnes in 1980, while ferrochromium exports by Japan rose from 2,000 tonnes in 1970 to 85,200 tonnes in 1975 then decreased to 8,900 tonnes in 1980. During the years 1970-1975 Japan oscillated between being a net importer and a net exporter of ferrochromium with overall average annual net exports of 11,400 tonnes over this period, whereas during the years 1976-1980 Japan was a net importer of ferrochromium with net imports rising continuously from 52,200 tonnes in 1976 to 271,500 tonnes in 1980 and average annual net imports of 165,700 tonnes over that period. The increase in net ferrochromium imports by Japan after 1976 more than compensated for the lower level of chromite imports by Japan during the period 1977-1980.

According to Matthews and Morning (1980) the viability of the Japanese high-carbon ferrochromium industry at the end of the 1970's was being challenged by rapidly increasing ferrochromium imports from South Africa, and it was reported by Thomson (1979) that rising ferrochromium imports by Japan were causing concern to domestic ferrochromium producers, who petitioned the Ministry of International Trade and Industry (MITI) to take action to combat the situation. It was observed by Peterson (1981) that the Japanese ferrochromium industry, like that in the United States, continued to suffer from rising energy costs, rigid pollution control requirements, and increasing competition from ferrochromium imported from South Africa that in 1980 not only supplied more than 50% of the chromite, but also around 80% of the ferrochromium imported by Japan. In order to mitigate the high cost of energy, Japanese ferrochromium producers increased their purchases of high-grade chromite that included ores containing well in excess of 50% Cr_2O_3 from the Philippines and India, and this also reduced the reliance of the Japanese ferrochromium industry on South African chromite imports. The Economist Intelligence Unit (1979) recorded that the price of domestically produced Japanese ferrochromium was being very substantially undercut by that of ferrochromium imports from South Africa, and suggested this was inevitable as Japanese power costs were influenced by the price of OPEC oil and to some extent the price of oil on the spot market whereas South African power costs reflected the availability of cheap coal. In any event South Africa was the dominant supplier of both chromite and ferrochromium imported by Japan in 1980, and in consequence the overwhelming source of Japan's chromium requirements.

FERROCHROMIUM

Many matters relating to the production, export, import, and consumption of ferrochromium have been considered already where appropriate earlier in the chapter, and the following discussion should be regarded as supplementary to those.

The pattern of world ferrochromium exports by country of origin during the period 1970-1979 and in 1980 is shown in terms of tonnage and percentage in Tables 125-126 and 131-132, while the pattern of world ferrochromium imports by country of destination during 1970-1979 and in 1980 is given in terms of tonnage and percentage in Tables 155-156 and 161-162.

The dominant ferrochromium exporting country in the world during 1970-1979 was South Africa with average annual exports of 314,600 tonnes, and South Africa accounted for 45% of world ferrochromium exports during the decade (Tables 125 and 131). In 1980 South Africa exported 768,200 tonnes of ferrochromium, and was responsible for 53% of world ferrochromium exports (Tables 126 and 132). Other countries that exported substantial quantities of ferrochromium during 1970-1979 were Sweden, Soviet Union, West Germany, Finland, Yugoslavia, Norway, and Brazil, while Zimbabwe emerged as a major ferrochromium exporter at the end of the decade (Table 125). In 1980 Zimbabwe exported 257,300 tonnes of ferrochromium, and provided 19% of world ferrochromium exports (Tables 126 and 132). Of these countries South Africa, Zimbabwe, Soviet Union, Finland, and Brazil were chromite producers and ferrochromium exporters during the 1970's, whereas Sweden, West Germany, Yugoslavia, and Norway were chromite importers and ferrochromium exporters (Tables 9, 78 and 125). Even though Yugoslavia did produce some chromite during the decade, it imported much more chromite than it produced. Sweden and West Germany were both exporters and importers of ferrochromium, and of these Sweden was a net exporter of ferrochromium while West Germany was a net importer (Tables 125 and 155). The five major chromite producing and ferrochromium exporting countries accounted for more than 60% of world ferrochromium exports during the 1970's as well as almost 80% of world ferrochromium exports in 1980, and this indicated the increasing importance of chromite producing countries as ferrochromium producers and exporters.

The largest ferrochromium importing country in the world during 1970-1979 was the United States with average annual ferrochromium imports of 180,900 tonnes, and the United States was responsible for 26% of world ferrochromium imports during the decade (Tables 155 and 161). Other substantial ferrochromium importing countries during 1970-1979 were West Germany, Japan, United Kingdom, and Italy as observed in Table 155. In 1980 West Germany, Japan, and the United States were the three major ferrochromium importing countries in the world with ferrochromium imports of 312,900 tonnes, 280,400 tonnes, and 274,200 tonnes respectively, and these countries accounted for 24%, 21%, and 21% respectively of world ferrochromium imports in that year (Tables 156 and 162). The five largest ferrochromium importing countries in the world during 1970-1979 were responsible for 72% of world ferrochromium imports during the decade, while the three major ferrochromium importing countries in 1980 accounted for 66% of world ferrochromium imports in that year. Even though the United States, West Germany, Japan, United Kingdom, and Italy were exporters as well as importers of ferrochromium during the 1970's, each of these countries was predominantly a ferrochromium importer during the decade (Tables 125 and 155). Further, each of these five countries imported chromite as well as ferrochromium during the 1970's, and except for a relatively low chromite production by Japan throughout the decade and a small output in the United States during 1976, none of the countries was a chromite producer (Tables 9 and 78). This indicated the almost complete dependence by these highly industrialised countries on imports of chromite and ferrochromium to meet their chromium requirements.

During 1970-1979 world ferrochromium exports rose 313% from 326,000 tonnes in 1970 to 1,346,600 tonnes in 1979, and averaged 692,400 tonnes a year during the decade compared with an average of 176,500 tonnes a year during 1960-1969 (Tables 124 and 125). In 1980 world ferrochromium exports amounted to

1,386,100 tonnes compared with world chromite exports of 2,973,000 tonnes whereas in 1970 world ferrochromium exports were only 326,300 tonnes compared with world chromite exports of 4,295,000 tonnes (Tables 27-28 and 125-126). This shows that the tonnage of world chromite exports in 1980 was only slightly greater than twice that of world ferrochromium exports whereas in 1970 the tonnage of world chromite exports was thirteen times that of world ferrochromium exports, and indicates (on the assumption that the chromium content of ferrochromium is around twice that of chromite) that in 1980 the quantity of chromium traded internationally as ferrochromium was about the same as that traded in the form of chromite.

A major factor in the increased importance of ferrochromium relative to chromite in international trade during the 1970's was the rapid growth in ferrochromium exports by South Africa as well as by Sweden and Yugoslavia that was made possible by the favourably competitive position of ferrochromium imports from these countries in relation to domestically produced ferrochromium made from imported chromite in the United States, Japan, and various countries in Europe as discussed previously. Another important factor was the greatly increased level of ferrochromium exports by Zimbabwe following the lifting of United Nations economic sanctions against that country, and the fact that Zimbabwe became the first country in the world to export all its chromium in the form of ferrochromium rather than chromite as described earlier.

During 1970-1979 there was an enormous growth in ferrochromium exports by South Africa that rose 716% from 87,800 tonnes in 1970 to 716,200 tonnes in 1979 then increased further to 768,200 tonnes in 1980 (Tables 125 and 126). This was made possible by advances in technology associated with the development and expanded use of the AOD and related processes in stainless steel production as discussed earlier. These processes facilitated the greatly increased use of high-carbon ferrochromium in the production of stainless steel, and such ferrochromium could be produced using South African chemical grade chromite. In consequence, South Africa was able to become a major world ferrochromium producer using abundantly available and favourably priced domestic chromite coupled with the supply of cheap power based on domestically produced coal, and such ferrochromium exported by South Africa was very competitive with ferrochromium produced domestically in consuming countries using imported chromite including that from South Africa.

In the case of the United States ferrochromium imports in 1980 amounted to 270,000 tonnes compared with only 37,000 tonnes in 1970, and in 1980 93% of the ferrochromium imports comprised high-carbon ferrochromium of which 80% came from South Africa whereas in 1970 only 30% of the imports were high-carbon ferrochromium and of these only 5% came from South Africa as calculated from statistics given by Morning (1972) and Peterson (1981). This reflected not only the increased role of high-carbon ferrochromium in stainless steel production, but also the increased importance of South Africa as a ferrochromium exporting country.

During the 1970's ferrochromium imports by the United States continued to be subject to tariffs whereas chromite imports entered free of duty. In accordance with the schedule of tariff reductions agreed under the 1967 "Kennedy round" of negotiations the tariff on low-carbon ferrochromium (containing less than 3% carbon) was gradually reduced from the 8.5% ad valorem existing in 1967 to 7.5% in 1968 and 6.5% in 1969 then 5.5% in 1970, 5.0% in 1971, and 4.0% in 1972 (Charles River Associates Inc, 1970 & Morning, 1972 and 1973) after which it remained at 4% ad valorem for the rest of the decade (Matthews and Morning, 1980), while the tariff on high-carbon ferrochromium (containing 3% or more carbon) was kept as in 1967 at 0.625 cents per pound of contained chromium throughout the period 1970-1979. It is clearly evident that the tariff on high-carbon ferrochromium will decrease as a percentage of price as the price of such ferrochromium rises. Indeed, during 1974 the quoted price for imported high-carbon ferrochromium in the form of charge chromium rose throughout the year in response to strong demand (Morning, 1976), and the imposed duty of 0.625 cents per pound of contained chromium decreased from 3.0% on a price of 21 cents per pound of chromium at the beginning of the year to 0.9% on a price of 70 cents per pound of chromium at the end of the year. By the end of 1975 the quoted price of imported charge chromium fell to around 47 cents per pound of chromium in consequence of reduced demand (Morning, 1977(b)), and the import duty at that price amounted to 1.3%. In the case of ferrochromium imports from the Soviet Union and other communist countries much higher tariffs of 30.0% ad valorem on low-carbon ferrochromium and 2.5 cents per pound of contained chromium on high-carbon ferrochromium applied.

It was reported by Morning (1980) that in January 1977 the Committee of Low-Carbon Ferrochromium Producers petitioned the International Trade Commission (ITC) for import relief under Section 201 of the Trade Act 1974, and after conducting hearings the ITC reported to the President of the United States that imports of low-carbon ferrochromium were not causing serious injury or the threat thereof to the domestic industry. However, in another trade import action, the Committee of Producers of High-Carbon Ferrochromium in July 1977 petitioned the ITC for import relief, and subsequent to hearings held in October 1977, a majority of ITC Commissioners reported to the President that high-carbon ferrochromium imports were a substantial cause of threat of serious injury to domestic producers. Nevertheless, the President determined early in 1978 that the provision of import relief was not in the national economic interests of the United States.

According to Morning (1980) domestic ferrochromium prices during 1977, despite strong though not record demand, decreased under the pressure of competition from lower-cost foreign ferrochromium, and in December 1977 the quoted price of imported charge chromium containing 50-55% chromium was 32.5 cents per pound of chromium compared with a quoted price of 40.0 cents per pound for the equivalent domestically produced product. Following a request by the United States Congress for a reinvestigation of alleged injury to the domestic ferroalloy industry resulting from imports of high-carbon ferrochromium at low prices, the ITC initiated an investigation in June 1978 and recommended that the industry be protected by quotas or additional duties (Matthews and Morning, 1980). This was achieved by Presidential Proclamation 4608 dated 15th November, 1978, authorised by the Trade Act 1974, that provided for a temporary increase in duty of 4.0 cents per pound of contained chromium on all high-carbon ferrochromium imported at an exit port price of less than 38.0 cents per pound, and the proclamation was to remain in force for up to three years to 15th November, 1981. The additional duty resulted in a total duty of 4.625 cents per pound of contained chromium on high-carbon ferrochromium imports covered by the proclamation.

The Tokyo Round of Multilateral Trade Negotiations was completed in 1979, and culminated in new tariff agreements (Peterson, 1981). However, during the initial seven year period commencing 1st January, 1980, the new tariff rates applicable to chromite and ferrochromium as published in the Tariff Schedules of the United States remained largely unchanged from those already in existence. Chromite imports from all countries continued to be free of duty, while ferrochromium imports from countries enjoying Most Favoured Nation (MFN) status were subject to a duty as previously of 4% ad valorem in the case of low-carbon ferrochromium and 0.625 cents per pound of contained chromium (together with an additional duty of 4.0 cents per pound of contained chromium where provided for under the Presidential Proclamation of 1978) in the case of high-carbon ferrochromium. Imports of ferrochromium from Non-MFN countries carried much higher duties of 30% ad valorem for low-carbon ferrochromium as previously, and a revised 25% ad valorem for high-carbon ferrochromium that replaced the previously existing duty of 2.5 cents per pound of contained chromium.

During the 1970's there was a tremendous expansion in ferrochromium imports by the United States (Table 155) with imports rising from 37,500 tonnes in 1970 to 297,100 tonnes in 1978, and this took place in spite of the existence of tariffs. In 1980 ferrochromium imports by the United States (Table 156) amounted to 274,200 tonnes, not greatly below the record imports reached in 1978, and this was subsequent to the imposition in November 1978 of an additional duty on certain high-carbon ferrochromium imports.

Chapter 11

TRADE TIES 1935-1937 AND 1972-1974

In Chapters 2-10 detailed consideration has been given in the relevant historical and geographical context to the many and diverse factors that have influenced the tonnage and percentage of chromite and ferrochromium exports and imports for individual countries as well as for the world as a whole on a year by year and decade by decade basis over a long period in their history, whereas in the present chapter an attempt is made to identify factors that appear to have exerted an influence on the tonnage and percentage of chromite and ferrochromium exports and imports traded between particular pairs of countries during specific periods. This analysis of trade ties covers chromite exports and imports during the period 1935-1937 (Tables 51-52 and 95-96), chromite exports and imports during 1972-1974 (Tables 71-72 and 119-120), and ferrochromium exports and imports during 1972-1974 (Tables 149-150 and 183-184). For each period the actual tonnage and percentage of exports or imports between various pairs of exporting and importing countries are presented in the form of matrix tables, and the actual tonnage or percentage is compared in each case with the null tonnage or percentage as defined in the table and shown in brackets beneath the corresponding actual tonnage or percentage. In each table the exports or imports are given as average annual tonnages or percentages for the three year period covered.

The pattern of null exports is a theoretical allocation of exports calculated on the assumption that the actual total exports of each exporting country are distributed among each importing country in the same proportion as that of its total imports in relation to total world imports, and similarly the pattern of null imports is a theoretical allocation of imports calculated on the assumption that the actual total imports of each importing country are derived from each exporting country in the same proportion as that of its total exports in relation to total world exports. A model that compares actual and null exports or imports was proposed by Savage and Deutsch (1960), and can be used to identify anomalies between the actual and null levels of international trade between individual pairs of countries. Such anomalies can result from the influence of non-price factors, particularly the existence of international ownership ties, political blocks, government regulation and participation in trade, metallurgical characteristics, and established buyer-seller ties, as observed by Tilton (1966 (a) & 1966 (b)) in relation to the international trade in a number of mineral commodities that did not include chromite or ferrochromium, or as a consequence of differential transportation costs between pairs of exporting and importing countries. The descriptive analysis that follows is based on a comparison between actual and null exports and imports of chromite and ferrochromium, and even though the analysis is somewhat subjective it is an attempt to indicate various factors that might have contributed to the anomalies observed.

In the discussion of trading partners Country E - Country I refers to the trade tie between Country E and Country I in which chromite or ferrochromium is exported by Country E and imported by Country I, and this applies independently of whether reference is made to data in an export table or an import table. An excess of actual exports or imports compared with null exports or imports for a particular pair of countries is described as a positive anomaly, whereas an excess of null exports or imports compared with actual exports or imports is described as a negative anomaly. Naturally, the existence of positive anomalies in the trade between some pairs of countries will be balanced by negative anomalies between others as total null exports or imports are by definition equal to total actual exports or imports for the world as a whole.

CHROMITE 1935-1937

The average annual actual and null chromite exports of selected countries by country of origin and destination for the period 1935-1937 are shown as matrices in terms of tonnage and percentage in Tables 51 and 52, and the average annual actual and null chromite imports of selected countries by country of destination and origin for the period 1935-1937 are presented as matrices in terms of tonnage and percentage in Tables 95 and 96. In view of the transportation time involved between the export and import of individual shipments there is some discrepancy between the data given in the two sets of tables covering exports and imports respectively.

For convenience of reference the countries of origin shown in the chromite export tables are arranged in descending order based on the tonnage of their total chromite exports during 1935-1937, while the countries of destination given in the chromite import tables are listed in descending order based on the tonnage of their total chromite imports during the period. Even though Zimbabwe, Cuba, and India were substantial exporters of chromite during 1935-1937, these countries are not included in the export tables (Tables 51 and 52) as detailed information on the destination of their exports is not known. However, some information on the destination of their exports is given in the import tables (Tables 95 and 96). Similarly, even though France and Norway were substantial importers of chromite during 1935-1937, these countries are not included in the import tables (Tables 95 and 96) as detailed information on the origin of their imports is not known, but some information on the origin of their imports is seen in the export tables (Tables 51 and 52). A comparison of actual and null chromite exports and imports for the various pairs of countries shown in Tables 51-52 and 95-96 for exports and imports respectively during the period 1935-1937 reveals the existence of several pronounced positive and negative anomalies in the trade ties for both exports and imports, while for other pairs of countries there is a reasonable correspondence between actual and null exports or imports.

In seeking an explanation for the anomalies observed it is not surprising that the metallurgical characteristics of chromite entering international trade appear to be an important factor in determining trade ties. It is seen in Tables 51 and 95 that there are substantial positive anomalies in chromite trade between Turkey-Sweden and

Turkey-France as well as a rough balance in chromite trade between Turkey-Norway, whereas there is a substantial negative anomaly in chromite trade between Turkey-United Kingdom and substantial positive anomalies in chromite trade between Greece-United Kingdom and South Africa-United Kingdom. Turkey was an exporter of metallurgical grade chromite of which Sweden, France, and Norway were major importers for consumption in the production of ferrochromium using cheap hydroelectric power, whereas the United Kingdom was not a producer of ferrochromium and consequently not an importer of metallurgical grade chromite. However, the United Kingdom did import chromite for use in the refractory and chemical industries, and supplies of refractory and chemical grade chromite were imported by the United Kingdom from Greece and South Africa. This strongly suggests that metallurgical characteristics were a major contributing factor in the anomalies observed.

Geographical proximity and hence lower transportation costs probably played an important part in the import of metallurgical grade chromite by Sweden, France, and Norway from Turkey rather than from Zimbabwe or New Caledonia that also produced metallurgical grade chromite, and the import of refractory grade chromite by the United Kingdom from Greece rather than from Cuba or the Philippines that were also refractory grade chromite producers. This assertion is consistent with the anomalies observed in Tables 51 and 95 for these pairs of countries. In the case of chemical grade chromite South Africa was the predominant world source.

Both Turkey and New Caledonia were producers of metallurgical grade chromite, and these countries were traditional suppliers of such chromite to Germany and the United States respectively. It is seen in Tables 51 and 95 that there are significant positive anomalies for chromite trade between Turkey-Germany and New Caledonia-United States, while there are large negative anomalies in chromite trade between Turkey-United States and New Caledonia-Germany. This indicates that established buyer-seller ties played an important role in the chromite trade between

Turkey-Germany and New Caledonia-United States. Further, the relatively closer geographical proximities of Turkey to Germany and New Caledonia to the United States probably contributed to the establishment and maintenance of the existing trade ties.

A pronounced positive anomaly is observed for the chromite trade between South Africa-Germany (Table 51). This is probably due in part to the role of Germany as a major world producer of chemicals, and its demand for chemical grade chromite of which South Africa was the dominant world supplier for use in the production of chromium chemicals. However, another important factor in the positive anomaly between South Africa-Germany would have been the trade agreement made in 1935 under which chromite exports by South Africa to Germany were to be increased and payment facilitated in blocked reichmarks. Even though South African chemical grade chromite was not generally suitable for metallurgical purposes, such chromite was used in the German metallurgical industry by blending it with high grade low-iron metallurgical chromite from Turkey.

It is seen in Table 95 that a significant positive anomaly exists in chromite trade between Zimbabwe-United States, and this is consistent with established buyer-seller ties that existed between these countries in the trade for metallurgical grade chromite. This buyer-seller relationship was in turn a reflection of international ownership ties in which Union Carbide and Vanadium Corporation of the United States were not only major domestic producers of ferrochromium in the United States, but had financial interests in tied chromite mining operations in Zimbabwe.

The United States was the dominant destination for chromite exported by the Philippines during 1935-1937, and there is a large positive anomaly for exports of chromite by the Philippines to the United States as shown in Table 51. This trade tie reflects the historical political and economic relationships that existed between the Philippines and United States as well as the geographical location of the Philippines in the Pacific region. The Philippines became a chromite exporter in 1935 following the discovery and development of chromite deposits in that country, and its exports increased rapidly between 1935 and 1937 (Table 45). The exports comprised both refractory and metallurgical grade chromite, and the importance of the Philippines as a supplier of chromite to the United States increased rapidly after 1935 (Table 87).

There is a large positive anomaly for chromite trade between Cuba-United States (Table 95) that can be attributed to international ownership ties reflected in the operation of Cuban refractory grade chromite mines by Bethlehem Steel Company of the United States as well as the close geographical proximity of Cuba to the United States.

Several different factors, particularly metallurgical characteristics, relative geographical proximity, traditional buyer-seller relationships, and international ownership ties, appear to have exerted an influence in determining trade ties between various pairs of countries, and in the case of individual pairs of countries some factors seem more important than others. The international trade pattern observed in the matrix tables is a product of the integrated effect of the diverse range of factors in operation, and this results in a spectrum of trade tie relationships that include a number of distinct positive and negative anomalies as well as rough balances between actual and null levels of trade.

CHROMITE 1972-1974

The average annual actual and null chromite exports of selected countries by country of origin and destination for the period 1972-1974 are tabulated as matrices in terms of tonnage and percentage in Tables 71 and 72, and the average annual actual and null chromite imports of selected countries by country of destination and origin for the period 1972-1974 are presented as matrices in terms of tonnage and percentage in Tables 119 and 120. Naturally, there is some discrepancy between the data given in the export and import matrices that arises from the transportation time involved in individual shipments of chromite.

The countries of origin and destination shown in the chromite export and import matrices are arranged in descending order based on the total tonnage of their chromite exports and imports respectively during the period 1972-1974. South Africa, Albania, and India are not included in the export matrices (Tables 71 and 72), even though they were substantial exporters of chromite during 1972-1974, as detailed information on the destination of their exports is not known. Nevertheless, some information on the destination of the exports by these countries is shown in the import matrices (Tables 119 and 120). Similarly, Poland, East Germany, and Spain are not included in the import matrices (Tables 119 and 120), even though they were substantial importers of chromite during the period, but some information on the origin of their imports is seen in the export matrices (Tables 71 and 72). The export and import matrix tables taken together provide a largely comprehensive picture of the trade ties involved in the international trade in chromite during the period 1972-1974, and a study of these matrix tables reveals a number of positive and negative anomalies in the trade ties between various pairs of countries.

Several major geographical changes took place in the supply of chromite to the world market during the period from 1935-1937 to 1972-1974. These included the demise of New Caledonia as an important source of metallurgical grade chromite, and the rise of the Soviet Union to become the leading world exporter of metallurgical grade chromite as seen from a comparison of Tables 51 and 71. During 1935-1937 Zimbabwe was the largest supplier of metallurgical grade chromite to the world market, whereas in 1972-1974 exports of chromite by Zimbabwe were subject to mandatory economic sanctions by the United Nations that lasted from 1966 to 1979. However, facilitated by the Byrd Amendment that was in operation from 1972 to 1977 and contrary to United Nations sanctions, the United States became the only country in the world that could legally import chromite from Zimbabwe during the period 1972-1974, and indeed chromite was imported by the United States from Zimbabwe during this period as seen in Table 99. These imports of chromite by the United States from Zimbabwe during 1972-1974 are included in the import data for "other" countries of origin shown in Tables 119 and 120.

Additional changes in the geography of chromite supply were brought about by the discovery and development of new chromite deposits after 1937 that resulted in the emergence of Albania, Iran, Malagasy, Finland, and Brazil as exporters of chromite for use in the metallurgical industry, and their contributions to world chromite trade during 1972-1974 are seen in Tables 71 and 119. Further, the Philippines rose from being a new chromite exporter in 1935-1937 to become the largest supplier of refractory grade chromite in the world during 1972-1974, whereas Cuba declined from being a significant exporter of refractory grade chromite in 1935-1937 to a position of relative unimportance as a source of chromite supply in 1972-1974. In the case of chemical grade chromite South Africa remained the dominant supplier of such chromite to the world market during 1972-1974 as it was in 1935-1937.

Another important impact on the pattern of international trade in chromite resulted from technological changes associated with the development of the AOD and related processes for the manufacture of stainless steel that enabled much greater use of South African and other chemical grade chromite by the metallurgical industry from the late 1960's. These changes involved the consumption of chemical grade chromite in the production of high-carbon ferrochromium having a lower than traditional chromium content, and this in turn was used in the AOD and other processes for the production of stainless steel. In consequence, there was greatly increased flexibility in the type of chromite that could be used by the metallurgical industry, and this resulted in new market opportunities for chromite from South Africa, Finland, and Brazil that are reflected in trade ties.

Sweden and Norway continued to import metallurgical grade chromite for the production of ferrochromium using cheap hydroelectric power, and Turkey was a traditional supplier of such chromite to these countries. It is seen in Tables 71 and 119 that there are large positive anomalies for chromite trade between Turkey-Norway and substantial positive anomalies for chromite trade between Turkey-Sweden. In addition, there are substantial positive anomalies for chromite trade between Soviet Union-Sweden and Finland-Sweden associated with the import of chromite by Sweden for use in the metallurgical industry. In contrast, the United Kingdom did not produce ferrochromium, and was not an importer of metallurgical grade chromite. This is reflected in the large negative anomalies observed in Tables 71 and 119 for chromite trade between Turkey-United Kingdom and Soviet Union-United Kingdom. However, the United Kingdom did import chromite for use in the refractory and chemical industries, and large positive anomalies occur for chromite trade between Philippines-United Kingdom and South Africa-United Kingdom as shown in Tables 71 and 119. This is consistent with the nature of United Kingdom chromite consumption, and the role of the Philippines and South Africa as suppliers of refractory and chemical grade chromite respectively. The type of anomalies observed in the circumstances described indicates clearly that the metallurgical characteristics of chromite entering international trade are a very important factor in determining trade ties between countries, and a similar conclusion was reached earlier in connection with the international trade in chromite during the period 1935-1937.

It seems reasonable that geographical proximity involving shorter distances and lower transportation costs should play a role in determining trade ties, and some examples from the export and import matrix tables indicate this is the case. Finland and South Africa were both suppliers of chemical grade chromite that was suitable under recently developed technology for use in the metallurgical industry, and such chromite was consumed for that purpose by both Sweden and Japan. It is seen in Tables 71 and 119 that there are large positive anomalies for chromite trade between Finland-Sweden and a large negative anomaly for chromite trade between South Africa-Sweden, whereas there is a large positive anomaly for chromite trade between South Africa-Japan and large negative anomalies for chromite trade between Finland-Japan. These anomalies are consistent with the close geographical location of Finland to Sweden compared with that of South Africa to Sweden, and the relatively closer geographical situation of South Africa to Japan than that of Finland to Japan. Geographical proximity was probably an important factor also in the trade tie involving metallurgical grade chromite between India-Japan for which there is a large positive anomaly (Table 119). In contrast, there are large negative anomalies for chromite trade between India-West Germany and India-Sweden as well as for chromite trade by India with other European countries, while in the case of the Soviet Union, which was also a supplier of metallurgical grade chromite, there are positive anomalies for chromite trade between Soviet Union-West Germany and Soviet Union-Sweden, and large negative anomalies for chromite trade between Soviet Union-Japan (Tables 71 and 119). Other examples that indicate the importance of geographical proximity are the trade ties involving chemical and metallurgical grade chromite that existed between Finland-West Germany and Turkey-Spain for which large positive anomalies are present as seen in Tables 71 and 119. Further, it is likely that geographical location was a factor in determining trade ties in refractory and metallurgical grade chromite between Philippines-Australia and Iran-Australia for which positive anomalies are observed in Table 119. However, even though geographical proximity through lower transportation costs and shortened delivery times seems clearly to be an important factor in determining trade ties, there are other factors influencing trade ties that operate simultaneously.

Another factor that appears to exert an influence on trade ties is the existence of former or current colonial links and political blocks. In the case of former colonial relationships examples are provided by the chromite trade ties between Malagasy-France and Cyprus-United Kingdom for which large positive anomalies are observed (Tables 71 and 119). The trade link between Malagasy and France was enhanced by an international ownership tie prevailing during 1972-1974 under which the French Pechiney-Ugine-Kuhlmann Group owned a controlling interest in Comina that operated chromite mining in Malagasy. In the case of trade within existing political blocks it is seen in Table 71 that substantial positive anomalies occur for chromite trade during 1972-1974 between Soviet Union-Poland and Soviet Union-East Germany, although geographical proximity would have been a contributing factor also in these anomalies. Most chromite trade by Albania during 1972-1974 took place with communist countries, and this accounts for the large negative anomalies observed for chromite trade between that country and the major world chromite importers including Japan, United States, and West Germany as seen in Table 119. Further, an historical political relationship existed between the Philippines and United States, and this is consistent with the positive anomalies for chromite trade between Philippines-United States shown in Tables 71 and 119.

The presence of international ownership ties such as those between Pechiney and Comina in the case of chromite trade between Malagasy and France could be expected to exert an influence on trade ties, and large positive anomalies do occur for chromite trade between Malagasy-France as described above. Another international economic relationship during 1972-1974 was that involving Turkey and Sweden under which the second largest chromite producer in Turkey was associated with a Swedish ferrochromium manufacturer, and it is seen in Tables 71 and 119 that significant positive anomalies are observed for chromite trade between Turkey-Sweden. The long standing international ownership link that existed between Zimbabwe and the United States through Union Carbide and Vanadium Corporation was removed by the compulsory disposal by those companies of their mining interests in Zimbabwe during the period of United Nations economic sanctions against that country, but by means of the Byrd Amendment the United States became the only country in the world that openly imported chromite from Zimbabwe during 1972-1974 as discussed earlier.

A number of long established trade ties persist in the chromite export and import matrix tables for 1972-1974, and these include those between South Africa-West Germany, Turkey-Sweden, South Africa-United Kingdom, and Philippines-United States (Tables 71 and 119). In each of these cases substantial positive anomalies are observed, although factors other than established buyer-seller ties such as metallurgical characteristics, geographical proximity, and political links probably contribute also where relevant to these anomalies. In addition, a trade tie involving refractory grade chromite had extended over many years between Philippines-United Kingdom, and a positive anomaly is present for chromite trade between these countries during 1972-1974. Further, trade ties involving metallurgical grade chromite had existed over a number of years between Soviet Union-United States and Soviet Union-West Germany, and positive anomalies are observed during 1972-1974 for chromite trade between these countries. Such continuing trade relationships suggest that established trade ties tend to be perpetuated.

During the period following the second world war there was a tremendous expansion in the Japanese steel and ferroalloy industries, particularly during the period 1955-1970, and this was reflected in a commensurate growth in chromite imports by Japan. Further, the development of the AOD and related processes for the manufacture of stainless steel, together with the wide adoption of these processes by Japanese stainless steel producers, had an important impact on the source countries from which Japan obtained chromite imports, particularly South Africa in consequence of the increased demand for chemical grade chromite that was suitable for producing a lower than traditional chromium content charge ferrochromium that was used in the AOD and similar processes for producing stainless steel. Indeed, by the mid-1970's about 70-75% of Japanese stainless steel production was based on the AOD or equivalent processes compared with around 50% of stainless steel production in Europe and the United States. This was probably an important factor in the large positive anomaly for chromite trade between South Africa-Japan observed in Table 119.

A similar demand for chemical grade chromite for metallurgical purposes was probably a significant factor also in the substantial positive anomalies observed during 1972-1974 for chromite trade between South Africa-United States and South Africa-

West Germany (Table 119). In addition, there was a considerable demand for chemical grade chromite by the United States and West Germany for consumption in their domestic chemical industries, and South Africa was the major world supplier of such chromite.

In the case of the United States the main supplier countries for metallurgical grade chromite during 1972-1974 were the Soviet Union, Turkey, South Africa, and Zimbabwe, while the major sources of refractory and chemical grade chromite during that period were the Philippines and South Africa respectively. It is seen in Tables 71 and 119 that positive anomalies occur for chromite trade between each of these supplier countries and the United States, except for Zimbabwe-United States as that trade tie is not specifically shown as explained earlier in the chapter, but a positive anomaly can be assumed for it also in view of the chromite trade arising from the application of the Byrd Amendment. However, the presence of an important trading relationship as in these cases does not necessarily mean that a positive anomaly will be observed, although the existence of such a relationship makes a positive anomaly highly likely.

It is clear that a number of factors resulted in changes to the pattern of international trade ties for chromite observed during 1972-1974 compared with that in 1935-1937. These included the emergence of Albania, Iran, Malagasy, Finland, and Brazil as new chromite exporting countries together with an expansion in chromite exports by other countries such as the Philippines, Soviet Union, and South Africa, the decline in chromite exports by New Caledonia and Cuba, the application of mandatory United Nations economic sanctions against Zimbabwe, technological advances involving introduction of the AOD and related processes for the manufacture of stainless steel that enabled greater consumption of chemical grade chromite for ferrochromium production, and an enormous postwar expansion in the Japanese steel and ferroalloy industries that resulted in greatly increased demand for chromite imports. Nevertheless, it appears that metallurgical characteristics, geographical proximity, political relationships, international ownership links, and established buyer-seller ties continued to play an important role as factors exerting an influence in the determination of trade ties between chromite exporting and importing countries during 1972-1974 as they did in 1935-1937.

FERROCHROMIUM 1972-1974

The average annual actual and null ferrochromium exports for selected countries by country of origin and destination for the period 1972-1974 are shown as matrices in terms of tonnage and percentage in Tables 149 and 150, and the average annual actual and null ferrochromium imports for selected countries by country of destination and origin for the period 1972-1974 are presented as matrices in terms of tonnage and percentage in Tables 183 and 184. There is some discrepancy as can be expected between the data given in the export and import matrices arising from the transportation time involved between the export and import of individual ferrochromium shipments.

The countries of origin and destination shown in the ferrochromium export and import matrix tables are arranged in descending order based on the total tonnage of their ferrochromium exports and imports respectively during the period 1972-1974. Even though South Africa, Soviet Union, and Yugoslavia were substantial ferrochromium exporters during 1972-1974, these countries are not included in the export matrices (Tables 149 and 150) as the destination of their exports is not known. However, some information on the destination of the exports by these countries is seen in the import matrices (Tables 183 and 184). Similarly, the United Kingdom is not included in the import matrices (Tables 183 and 184), even though it was a substantial importer of ferrochromium during 1972-1974, but some information on the origin of its imports is given in the export matrices (Tables 149 and 150). The export and import matrix tables considered together provide a detailed picture of the web of trade ties involved in the international ferrochromium trade during 1972-1974, and it is seen that a wide spectrum of positive and negative anomalies is observed for the trade ties between the various pairs of countries shown in the tables.

During the period 1972-1974 South Africa was the major supplier of ferrochromium to a number of ferrochromium importing countries including the United States, West Germany, and Japan as shown in Table 183. In addition, there was substantial intra-European trade in ferrochromium during 1972-1974 as observed in Tables 149 and 183, while the United States was the main market for Japanese ferrochromium exports during that period as seen in Table 149. Even though there were mandatory United Nations economic sanctions against Zimbabwe that prohibited the importation of ferrochromium from that country during 1972-1974, the United States by means of the Byrd Amendment did import ferrochromium from Zimbabwe during those years. Indeed, ferrochromium imports by the United States from Zimbabwe during 1972-1974 averaged 31.2 thousand tonnes a year as seen from Table 163, and this trade with Zimbabwe is included as the dominant component in imports by the United States from "other" countries shown in Table 183.

Several countries, particularly West Germany, Sweden, Japan, France, and Italy, were both exporters and importers of ferrochromium during the period 1972-1974. Of these, West Germany and Italy were substantial net importers of ferrochromium with average net imports of 55.3 and 37.2 thousand tonnes a year respectively during 1972-1974, while Sweden and France were smaller net importers of ferrochromium with average net imports of 10.4 and 2.7 thousand tonnes a year during that period, and Japan was a net exporter of ferrochromium with average net exports of 4.4 thousand tonnes a year during the period as seen from Tables 125, 149, 155, and 183. Further, there was a two-way trade in ferrochromium between certain pairs of countries, particularly for that involving intra-European trade between West Germany, Sweden, France, and Italy as observed in Tables 149 and 183. In this intra-European two-way trade the largest net exports were those for France to Italy and West Germany to Italy that averaged 7.0 and 4.6 thousand tonnes a year respectively during 1972-1974 (Table 149).

A study of the anomalies observed in the ferrochromium export and import matrices (Tables 149 and 183) strongly suggests that geographical proximity involving lower transportation costs and reduced transit times was an important factor in determining international trade ties in ferrochromium during 1972-1974. This is evidenced by the prevalence of large positive anomalies for ferrochromium trade between many adjacent or geographically close pairs of countries. These include the large positive anomalies that occur for intra-European ferrochromium trade between West Germany-France, West Germany-Belgium-Luxembourg, West Germany-Italy, Finland-Sweden, Sweden-United Kingdom, Norway-United Kingdom, Norway-Sweden, France- Italy, and Italy-Austria as shown in Tables 149 and 183. In contrast, there are pronounced negative anomalies for the much more distant ferrochromium trade between South Africa and most European countries including Italy, Sweden, Austria, Belgium-Luxembourg, and France as seen in Table 183. There is, however, a positive anomaly for ferrochromium trade between South Africa-West Germany, and this is probably associated with the well established trade links existing between these two countries. In addition, positive anomalies are found for ferrochromium trade between Japan-United States, whereas there are negative anomalies for ferrochromium trade between Japan and the main European importing countries including West Germany as shown in Tables 149 and 183. It is seen that the various positive and negative anomalies observed provide persuasive evidence that geographical proximity was an important factor in influencing trade ties in ferrochromium during 1972-1974.

In connection with the intra-European trade in ferrochromium it is interesting to observe that during 1972-1974 West Germany, France, Belgium, Luxembourg, and Italy were Members of the European Economic Community (EEC), while Norway and Sweden were Members and Finland an Associate Member of the European Free Trade Association (EFTA). Further, the United Kingdom was a Member of EFTA until the end of 1972 prior to becoming a Member of the EEC from the beginning of 1973.

The existence of these politico-economic blocks was probably a contributing factor also in many of the large positive anomalies such as those for West Germany-France (EEC Members) and Norway-Sweden (EFTA Members) observed for intra-European trade in ferrochromium during 1972-1974.

Even though United States tariffs on ferrochromium probably inhibited imports to some extent, the United States was the major importer of ferrochromium during 1972-1974 as seen in Table 183. However, there was a differential tariff schedule under which imports of ferrochromium by the United States from the Soviet Union had to bear a tariff of 30% ad valorem on low-carbon ferrochromium and 2.5 cents per pound of contained chromium on high-carbon ferrochromium compared with a tariff of 4% ad valorem on low-carbon ferrochromium and 0.625 cents per pound of contained chromium on high-carbon ferrochromium that generally applied. It is seen in Table 183 that a large negative anomaly is observed for ferrochromium trade between Soviet Union-United States during 1972-1974, and it is probable that the much higher tariff rates applying to ferrochromium imports by the United States from the Soviet Union were an important factor contributing to this anomaly. Indeed, there were no ferrochromium imports by the United States from the Soviet Union during 1972-1974 (Table 183), whereas a substantial quantity of chromite, which was free of duty, was imported by the United States from the Soviet Union during that period, and furthermore there is a significant positive anomaly for chromite trade between Soviet Union-United States as seen in Table 119.

The matrix tables showing international trade ties for ferrochromium during 1972-1974 reveal a wide range of positive and negative anomalies, and it is seen that a number of factors including geographical proximity, politico-economic links, and differential tariffs appear to have exerted an influence in determining the pattern of trade ties that is observed. In addition, international trade in ferrochromium during 1972-1974 was distorted by the application of United Nations economic sanctions against Zimbabwe, and the United States was the only country in the world that openly imported ferrochromium from Zimbabwe during that period.

Chapter 12

CONCLUSIONS

Many diverse factors have been important at various times in determining the prevailing pattern of international trade in chromite and ferrochromium and in exerting influence on its evolution. The observed pattern of international trade reflects the integrated effect of a range of factors that operate to determine both trade aggregates for individual exporting and importing countries as well as trade ties between countries.

TRADE AGGREGATES

The numerous factors that have affected the level and share of trade aggregates for individual countries include the geographical location of production and consumption, the discovery and development of new deposits, differences in type of ore, developments in technology, availability of transportation, the level of economic activity, price competitiveness, the effects of war, United Nations economic sanctions, strategic stockpiling, the cost of energy, and government regulation of various kinds.

Geographical location of production and consumption

During the period from 1892 to 1980 several countries including Turkey, Soviet Union, New Caledonia, Zimbabwe, and South Africa have been at various times the largest chromite producing country in the world, and other countries including the Philippines, Albania, and Finland have been important chromite producers. In contrast, chromite consumption over the period has taken place predominantly in North America, Western Europe, and Japan. Indeed, a large proportion of world chromite consumption has been located in countries other than those in which chromite was mined so that international trade in chromite has been of particular importance in the chromium industry. However, during the more recent years of the period an increased proportion of world chromite production has been consumed domestically to make ferrochromium, and this has resulted in greater international trade in ferrochromium even though international trade in chromite continued to be very substantial. Furthermore, the Soviet Union was the only country that has been a major long term producer and consumer of chromite.

Discovery and development of new deposits

The discovery and development of new chromite deposits has been of fundamental importance in the evolution of the pattern of international trade, and has made possible an enormous increase in chromite supply to satisfy a rapidly expanding demand for chromite and ferrochromium. The chromite deposits whose discovery and development have contributed substantially to the changing pattern of international trade include those at Bursa and Izmir in Turkey during the latter part of last century, the deposits at Tiebaghi in New Caledonia and Selukwe in Zimbabwe brought into production early this century, deposits within the Bushveld Complex in the Transvaal of South Africa developed since the 1920's, deposits within the Great Dyke of Zimbabwe made more accessible since the 1930's, the then newly discovered Guleman deposits in the Elazig district of eastern Turkey and the Masinloc and Acoje deposits on the island of Luzon in the Philippines that were each developed during the latter half of the 1930's, the deposits in the Donskoye area of Kazakhstan in the Soviet Union from which production expanded rapidly during the 1960's, and the Kemi deposits near the head of the Gulf of Bothnia in Finland developed since the mid-1960's. Furthermore, the existence of large known ore reserves as in the case of the chromite deposits in South Africa, Zimbabwe, and the Soviet Union has been an important factor also in contributing to the enormous expansion in chromite production by these countries.

Types of ore

Traditionally, chromite ores were classified as being of metallurgical, chemical, or refractory grade on the basis of the industry by which they were consumed, and these three types of chromite ore were characterised by their high-chromium, high-iron, and high-aluminium content. Even though there was some flexibility regarding the type of chromite consumed by each industry, and the development of a practice of blending various types of ore by the metallurgical industry, each of the three industries predominantly consumed chromite of the type that bears its name. Moreover, even though some countries produce chromite of various types, most countries became renowned for being a supplier of a particular type of ore.

The Selukwe and Great Dyke chromite deposits in Zimbabwe, the Guleman deposits in Turkey, and the Donskoye deposits in the Soviet Union contain metallurgical grade chromite, and Zimbabwe, Turkey, and the Soviet Union have been traditional suppliers of high grade chromite for the production of ferrochromium consumed by the metallurgical industry. In contrast, the chromite deposits of the Bushveld Complex in South Africa and the Masinloc deposits in the Philippines contain chemical and refractory grade chromite respectively, and South Africa and the Philippines have been regarded as major sources of supply of chromite for use by the chemical and refractory industries. In addition, the Acoje deposit in the Philippines contains metallurgical grade chromite so that the Philippines has been a supplier of both refractory and metallurgical grade chromite even though refractory grade chromite exports have been much the largest, and South Africa has been a supplier of metallurgical and refractory grade chromite even though the production of chemical grade chromite has been predominant. The nature of the consuming industry has largely determined the type of chromite demanded, and this was imported from a supply country producing that type of chromite. Consequently, this relationship has had an important bearing on the pattern of international trade in chromite. However, since the 1960's there has been increased demand for chemical grade chromite by the metallurgical industry associated with the introduction of the AOD and related processes in stainless steel production. This has created an additional demand for chemical grade chromite of which South Africa has been the dominant producer, and resulted in a substantial increase in chromite as well as ferrochromium exports by that country.

Technological developments

A number of technological developments have had substantial influence on the pattern of international trade in chromite and ferrochromium. The most important of these resulted from the accidental discovery of stainless steel by Harry Brearley of Sheffield in 1913, and the subsequent development of a range of corrosion resistant stainless steels containing differing percentages of chromium that have been used in a wide variety of applications. Indeed, in 1980 the production of stainless steel accounted for 70% of chromium alloy consumption in the United States, and both Europe and Japan also had become major producers of stainless steel. The introduction and expansion of stainless steel production has created an enormous demand for chromite by the metallurgical industry to produce ferrochromium from which stainless steel is made. Traditionally, the production of stainless steel resulted in demand for metallurgical grade chromite from counties such as Zimbabwe, Turkey, and the Soviet Union, but technological developments in stainless steel making led to the widespread adoption since the 1960's of the AOD and other processes that resulted in demand for chemical grade chromite from South Africa, Finland, and Brazil to produce ferrochromium with a lower than traditional chromium content suitable for use in the new stainless steel making processes. Furthermore, these developments have contributed to a substantial proportional shift during the more recent decades in ferrochromium production from chromite importing and ferrochromium exporting countries possessing cheap hydro-electric power such as Norway and Sweden to the domestic production and export of ferrochromium by chromite mining countries such as South Africa and Finland. The growth, scale, and method of stainless steel production has been reflected in the demand for chromite by the metallurgical industry, and these have resulted in profound effects on the pattern of international trade in both chromite and ferrochromium.

Two other technological developments involving the steel industry generally had a pronounced influence on the demand for chromite as a refractory, namely the basic brick open-hearth roof and the basic-oxygen converter. Even though chromite had been used successfully for many years in furnace walls, it was only during the latter half of the 1950's that the use of chromite refractories was widely adopted for the lining of open-hearth furnace roofs, and this increased the demand for refractory grade chromite from the Philippines and other countries. In contrast, the replacement of open-hearth furnaces by basic-oxygen converters in steel making during the latter half of the 1960's reduced the demand for refractory grade chromite as such converters did not use chromite refractories.

In connection with the chemical use of chromite, the process of chromium plating was an important technical development even though it did not require large quantities of chromium. The process was firmly established on a manufacturing basis in the mid-1920's with the production by General Motors of an automobile having a chromium-plated radiator. Another technical innovation that increased demand for chemical grade chromite was the development by E.J. Lavino around 1960 of a commercially viable process for making basic refractories from South African chromite. However, the process was proprietary, and other chromite refractory producers continued to consume more expensive refractory grade chromite from the Philippines, even though some producers used limited quantities of South African chemical grade chromite.

Transportation availability

The availability or otherwise of rail transportation facilities has been an important factor in assisting or inhibiting the development and expansion of chromite production and export from known chromite deposits. This has been particularly relevant at times to chromite production by Zimbabwe and South Africa.

Even though large high grade chromite deposits had been discovered in the Umvukwes Range within the Great Dyke of Zimbabwe prior to 1920, the absence of railway facilities in the vicinity of the deposits inhibited their development because of the high cost of haulage by wagon to the nearest railway. Indeed, mining of chromite from the Great Dyke was restricted to shallow workings within a relatively short distance from the railway. Although pressure had been placed on the government for a number of years to build a railway to service the chromite deposits of the Umvukwes Range, a decision to build such a railway was not made until mid-1929 when there was a danger of high quality chromite from Zimbabwe being displaced by lower grade chromite from South Africa merely because of the lack of transportation facilities, and the Umvukwes railway was completed in 1930 to make the deposits accessible over their entire length.

Zimbabwe was an important source of supply of high grade chromite, particularly to the United States, during the second world war with production coming from both the Selukwe and Great Dyke deposits. In 1946 the railway linking the chromite mines of Zimbabwe to the port of Beira in Mozambique was in unsatisfactory condition, and inadequacy of rail facilities from mine to port was the main factor in preventing Zimbabwe from realising its proper potential as a chromite exporting country during the early postwar years. However, in 1955 a new railway linking Zimbabwe with the port of Lourenco Marques in Mozambique was completed. This eliminated the dependence of Zimbabwean chromite producers on the Beira railway, and was an important factor in enabling an expansion in chromite production and exports by Zimbabwe. In the case of South Africa transportation difficulties associated with an insufficiency of railway equipment during the early postwar period were overcome after 1956, and this facilitated an expansion in chromite exports by South Africa.

Demand and economic activity levels

The general level of economic activity has had an important bearing on the demand for chromite, and consequently on international trade in chromite. Annual world chromite production has shown an enormous increase from 1892 to 1980, particularly during the thirty five year period from the end of the second world war to 1980. Demand for chromite by the metallurgical and refractory industries has been closely related to the iron and steel industries with large chromite consumption arising from the demand for ferrochromium in the production of stainless steel and other alloy steels containing chromium in the case of the metallurgical industry and the use of chromite in the manufacture of refractory bricks for lining metallurgical furnaces in the case of the refractory industry, while the demand for chromite by the chemical industry has been created by the production of sodium and potassium bichromate as base materials for a range of chromium chemicals used in pigments, electroplating, and leather tanning.

The growth in world chromite consumption has been adversely affected at times by a reduction in the level of economic activity. During the Great Depression of the early 1930's the demand for chromite suffered seriously in consequence of reduced consumption in both the United States and Europe, and various recessions such as those in 1971 and 1975 resulted in lower demand for chromite and a consequential reduction in the level of international trade in chromite. Frequently, the reduction in chromite imports occurred in the year following the onset of recession.

During the more recent decades there has been strong growth in chromite imports for consumption by Europe and Japan, and this reduced the relative importance of the United States that was previously the dominant chromite importing country in the world. In the case of Japan, there was a dramatic expansion in the steel and ferroalloy industries following the second world war, particularly over the period from 1955 to 1970, and this resulted in a commensurate growth in Japanese chromite imports.

Price competitiveness

The price of chromite and ferrochromium has played an important role in the evolution of the pattern of international trade. Late last century and early this century chromite exports by Turkey were subjected to strong price competition by chromite from New Caledonia whose exports were assisted by low ballast freight rates at which chromite could be shipped, and competition from New Caledonia contributed to a crisis in the Turkish chromite industry. Subsequently, New Caledonian chromite was involved in price competition with that from Zimbabwe, and this continued to put pressure on chromite prices prior to 1910. Again, during the first half of the 1920's New Caledonian chromite was replaced by that from Zimbabwe in the metallurgical and chemical industry markets of the United States as a result of price competition.

Towards the end of the 1920's chromite from the newly developed South African deposits could be marketed at a lower price per percentage unit of Cr_2O_3 than chromite from Zimbabwe, and this was accompanied by a promotional campaign and testing by chemical producers of its suitability. In consequence, there was a shift in consumption by the chemical industry from Zimbabwean to South African chromite. Subsequently, the chemical industry that values chromite solely on the basis of its Cr_2O_3 content has used South African chemical grade chromite almost exclusively because of being the cheapest source of Cr_2O_3 available on the market.

South African chemical grade chromite is not suitable for traditional ferrochromium production. However, metallurgical grade chromite ores from Turkey, Zimbabwe, and the Soviet Union used in such production are almost perfect substitutes, and in consequence are subject to price competition among one another. Indeed, during the early 1960's chromite exports by Zimbabwe and Turkey were seriously affected by the marketing of Soviet Union metallurgical grade chromite at prices below those quoted by western suppliers, and the period prior to 1967 (after which mandatory economic sanctions were implemented against Zimbabwe) was one of aggressive marketing and price competition from Soviet Union chromite in both Europe and the United States that resulted in substantial growth in the tonnage and percentage of chromite exports by the Soviet Union.

During the latter part of the 1970's domestic ferrochromium producers in Europe and the United States were seriously affected by intense price competition from imports of ferrochromium from South Africa. Indeed, ferrochromium from South Africa was reported to be selling in Europe at prices below the domestic cost of production, and the United States' International Trade Commission twice ruled during 1978 that domestic ferrochromium producers were being injured by South African ferrochromium imports. Furthermore, similar price competitiveness during the same period resulted in a growth of ferrochromium exports by Sweden and Yugoslavia as well as by South Africa.

Effects of world war

Global warfare has had important effects on the pattern of international trade in chromite by disrupting trade ties as a result of hostilities, increasing the demand for chromite in the production of war materials, and providing an impetus for domestic chromite production in the United States to ensure security of supply and alleviate pressure arising from a shortage of shipping. More restricted war such as that in Korea after June 1950 provided a boost to raw material consumption including that of chromite.

During the first world war supplies of chromite to the United States came from major producing countries, particularly Zimbabwe and New Caledonia, once guarantees were given that chromite would not be re-shipped to enemy belligerents. The United Kingdom had access to chromite from empire countries, and Germany was an ally of Turkey. Chromite production by Zimbabwe reached record level in 1916 in response to export demand created by the war, while exports of chromite by Zimbabwe to Germany had ceased following the outbreak of war in 1914. During 1916-1918 there was a dramatic increase in chromite production and exports by both India and Canada resulting from strong demand and high prices. The exports of chromite by Canada to the United States were made by rail, and this helped relieve a stringent shipping situation. Domestic chromite production by the United States was stimulated by high prices and increased tremendously during 1916-1918, but chromite imports by the United States continued to be larger than domestic production. This was despite a shipping shortage, and the attempted prohibition of chromite imports by water after 1918. Following the war chromite production by the United States in 1919 dropped dramatically.

Major changes to the pattern of international trade in chromite occurred at the end of 1939 and during the first half of the 1940's as a result of the second world war. The United States and United Kingdom continued to obtain supplies of chromite from Zimbabwe, South Africa, and India. Furthermore, the United Kingdom was successful in intense rivalry with Germany to secure Turkish chromite supplies even though subsequently limited quantities of Turkish chromite were exported to Germany in 1943 and early 1944. The United Kingdom had access to sufficient supplies of chromite from empire countries and released the secured Turkish chromite to the United States, but was anxious to ensure that Germany was deprived of much needed Turkish chromite. In contrast, Germany had been a major importer of chromite from both South Africa and Turkey prior to the war, and supplies of chromite from these countries ceased following the outbreak of hostilities in September 1939. Moreover, the supply of chromite to Germany from the Soviet Union stopped when Germany in breach of agreement commenced the Russian campaign in 1941. However, Germany obtained control of chromite deposits in Greece and Yugoslavia after their occupation, but following the loss of chromite from Turkey and the Balkans late in the war Germany was facing a critical shortage of chromite that was so necessary for the maintenance of a war effort.

In late 1941 the Philippines was occupied by Japan, and an important source of refractory grade chromite imports by the United States was cut off. However, the United States was able to obtain substantial supplies of refractory grade chromite from Cuba, and in 1943 Cuba became the largest chromite exporting country in the world. During the period 1940-1943 the consumption of metallurgical grade chromite by the United States more than doubled in response to wartime demand, and supplies of such chromite were obtained by the United States from Zimbabwe, Turkey, and the Soviet Union. In view of limited chromite stocks, increasing chromite consumption, and threat to chromite imports arising from a shipping shortage, various types of control on chromite usage were introduced in the United States during 1941 and 1942. Furthermore, a programme of domestic chromite production involving both purchase at incentive prices and production under contract was implemented by the government, and this reached a peak in 1943 although domestic chromite production in that year amounted to only 15% of supply represented by production plus imports.

United Nations economic sanctions

Mandatory economic sanctions against the importation of chromite and ferrochromium from Zimbabwe were imposed by the United Nations in December 1966 and remained in force until lifted in December 1979. The economic sanctions created an artificial world shortage of metallurgical grade chromite, forced consumers to rely largely on the Soviet Union, Turkey, and to a lesser extent Iran for their supply of such chromite, brought about a distortion in the pattern of international trade in chromite, and resulted in higher metallurgical grade chromite prices. Soviet Union chromite exports continued to expand after 1967 with increased demand arising from the economic sanctions against Zimbabwe, and the expansion took place in a climate of rising prices.

In the case of the United States the import of chromite from Zimbabwe during the period from 1972 to 1977 was facilitated by the Byrd Amendment that was contrary to United Nations sanctions, and the United States became the only country that openly imported chromite from Zimbabwe during currency of the sanctions. In 1977 when the Byrd Amendment was effectively repealed by the United States and the ban on imports from Zimbabwe reinstated, there was reduced demand for Zimbabwean metallurgical grade chromite resulting from the introduction of the AOD and other processes in stainless steel making that used ferrochromium produced from South African chemical grade chromite.

The effectiveness of economic sanctions against Zimbabwe was evidenced by the sharp rise in price of metallurgical grade chromite that followed the introduction and operation of sanctions. However, there was considerable speculation and rumour that sanctions on the import of chromite and ferrochromium from Zimbabwe were not fully effective, and some cases of actual violation were detected.

Economic sanctions were removed in December 1979 following the establishment of a representative government in Zimbabwe. The stated objective of the new government was that all chromite mined in Zimbabwe should be smelted domestically to produce ferrochromium, and Zimbabwe became the first chromite producing country to export its entire chromium output in the form of alloy.

Strategic stockpiling

Chromite stockpiling activities by the United States government during and subsequent to the second world war resulted in chromite exports by producing countries, and in consequence had an important influence on the pattern of international trade. This is exemplified by purchases in the early 1940's by the United States of metallurgical grade chromite from Zimbabwe and Turkey and chemical grade chromite from South Africa under the Strategic Materials Act 1939 for inclusion in the emergency stockpile.

During the years 1951 to 1956 there was a concentration of chromite imports made by the United States under the Strategic and Critical Materials Stockpiling Act 1946 for addition to the National Stockpile. Most of the metallurgical grade chromite comprising about half the acquisitions during that period was imported from Turkey, while refractory grade chromite imports were made from the Philippines and Cuba and chemical grade chromite from South Africa. Furthermore, chromite was imported by the United States for inclusion in a Supplemental Stockpile under the Commodity Credit Barter Program by means of which chromite was obtained in exchange for surplus agricultural products that were exported. Chromite acquisitions under this programme were made almost entirely between 1958 and 1963, and comprised chemical grade chromite from South Africa, metallurgical grade chromite from Turkey, and refractory grade chromite from the Philippines and Cuba. Some metallurgical grade chromite was imported also during the 1950's under the Defence Production

Act 1950 for inclusion in the government stockpile, although most of the chromite acquired under that Act was produced domestically from the Mouat mine in Montana.

Energy costs

The cost of energy has been an important locational factor in the production of ferrochromium. The availability of low-cost hydro-electric power provided the basis for ferrochromium manufacture by Sweden, Norway, and Canada, and these countries were importers of chromite and exporters of ferrochromium. The production of ferrochromium in the Niagara Falls and Tennessee Valey regions of the United States was also based on cheap hydro-electric power, while the development of the ferrochromium industry in Germany was made possible by the availability of low-cost thermal power generated from coal. Both the United States and Germany were importers of chromite and consumers of ferrochromium. In Zimbabwe the production of ferrochromium has been assisted by cheap hydro-electric power from Kariba on the Zambesi River as well as by thermal power made from domestic coal, while in South Africa ferrochromium production has been based on power derived from abundant domestic coal supplies, and these countries were producers of both chromite and ferrochromium.

During the 1960's and 1970's there has been a tremendous expansion in the export of ferrochromium by chromite producing countries, particularly South Africa, Zimbabwe, and the Soviet Union, and this removed the dominance held previously by chromite importing and ferrochromium exporting countries, namely Sweden, Norway, and Canada, whose ferrochromium production was based on cheap hydro-electric power. Indeed, by the end of the 1960's countries that produced both chromite and ferrochromium were responsible for more than half the world's ferrochromium exports.

Government regulation

International trade in chromite and ferrochromium has been influenced by government regulation of various types. In the case of the United States that has been the largest consumer of chromium in the world, the importation of chromite rather than ferrochromium has been assisted by the imposition of tariffs on ferrochromium imports whereas chromite has been imported free of duty. However, there has been a progressive reduction in tariffs on ferrochromium imports since the Smoot-Hawley Tariff Act 1930, although imports of ferrochromium from the Soviet Union and other communist countries remained subject to the high tariffs that applied in 1930. Concurrently, there has been an increase in the relative importance of ferrochromium imports compared with those of chromite by the United States, particularly in the most recent decades, and during the latter half of the 1970's ferrochromium producers in the United States experienced intense competition and suffered injury from imported ferrochromium such as that from South Africa and Yugoslavia. In consequence, a substantial additional duty was imposed in November 1978 on certain high-carbon ferrochromium imports.

Other cases of government action affecting international trade in chromite have included the imposition by Turkey in the early 1900's of both a production royalty and export tax on chromite that reduced competitiveness, while in the early 1930's Turkey introduced a scheme of export tax rebates as an incentive to increase production and exports. During the 1930's South Africa paid a subsidy to chromite producers to assist development of the industry, although the level of subsidy was gradually reduced during the decade, and in 1937 the government lowered rail freight rates to improve the competitive position of South African chromite. In 1949 the Soviet Union placed a virtual embargo on the export of chromite, even though chromite exports by the Soviet Union had expanded dramatically during the postwar period to reach record level in 1948. Subsequently, Soviet Union chromite exports increased again during the latter half of the 1950's. In the case of India the government as part of conservation policy imposed controls on the chromite industry in the mid-1970's that included a ban on the export of high grade chromite as well as the application of export taxes and quotas on other chromite, and these had the effect of reducing Indian chromite exports after 1976.

TRADE TIES

Trade ties between exporting and importing countries involved in the international trade of chromite and ferrochromium have been influenced by metallurgical characteristics, geographical proximity, political relationships, international ownership links, established buyer-seller ties, and differential tariffs. These conclusions are supported by an investigation of trade ties for the periods 1935-1937 and 1972-1974 based on examination of positive and negative anomalies between actual and null levels of trade generated using a model suitable for analysing transaction flows, and show that non-price factors together with transportation costs and tariff differentials play a major role in determining the pattern of trade ties.

Metallurgical characteristics

The importance of metallurgical characteristics as a factor in determining trade ties is illustrated by the trade during 1935-1937 in metallurgical grade chromite from Turkey to Sweden, France, and Norway that consumed this type of chromite in the traditional production of ferrochromium using cheap hydro-electric power, and the trade in refractory grade chromite from Greece and chemical grade chromite from South Africa to the United Kingdom that was a consumer of both these types of chromite for use in the refractory and chemical industries, but not a consumer of metallurgical grade chromite as the United Kingdom did not produce ferrochromium. Similarly, metallurgical characteristics influenced the trade in metallurgical grade chromite from Turkey to Norway and Sweden as well as that from the Soviet Union to Sweden during 1972-1974, and the trade in refractory grade chromite from the Philippines and chemical grade chromite from South Africa to the United Kingdom. Furthermore, chemical grade chromite from South Africa was imported during 1972-1974 by Japan, United States, and West Germany to produce ferrochromium utilised by the newly developed AOD and other processes in the manufacture of stainless steel, and these countries also required chemical grade chromite for use in their domestic chemical industries.

Geographical proximity

The influence of relative geographical proximity involving shorter distances and enabling lower transportation costs is seen in the importation during 1935-1937 of metallurgical grade chromite by Sweden, France, and Norway from Turkey rather than from Zimbabwe or New Caledonia that were also metallurgical grade chromite producers, and the importation of refractory grade chromite by the United Kingdom from Greece rather than from Cuba or the Philippines that also produced refractory grade chromite. Similarly, during 1972-1974 Sweden imported chemical grade chromite from Finland rather than from South Africa and Japan imported chemical grade chromite from South Africa rather than from Finland, even though both Sweden and Japan were consumers of chemical grade chromite for the production of ferrochromium used in stainless steel production following recent technological developments and both Finland and South Africa were producers of chemical grade chromite. Furthermore, the trade in metallurgical grade chromite from India to Japan rather than to countries in Europe during 1972-1974 was probably influenced strongly by geographical proximity. In the case of ferrochromium geographical proximity is likely to have been a significant factor in the prevalence of ferrochromium trade ties involving intra-European trade between many adjacent or geographically close countries during 1972-1974.

Political relationships

The trade tie between the Philippines and United States during 1935-1937 reflected the historical political and economic relationship that existed between these countries, and involved trade in both refractory and metallurgical grade chromite from newly discovered and developed deposits. During 1972-1974 trade ties between Malagasy and France and between Cyprus and the United Kingdom were influenced by former colonial links, while those between the Soviet Union and both Poland and East Germany involved trade within an existing political block. Furthermore, most Albanian chromite trade during 1972-1974 took place with communist countries.

Moreover, the presence of politico-economic blocks in western Europe during 1972-1974 were possibly a contributing factor in some of the intra-European trade ties involving ferrochromium that included trade between West Germany and France that were members of the European Economic Community and between Norway and Sweden that were members of the European Free Trade Association.

International ownership links

Chromite trade between Cuba and the United States during 1935-1937 can be attributed to an economic ownership tie and the operation of Cuban refractory grade chromite mines by the Bethlehem Steel Company of the United States. During 1972-1974 the presence of an international ownership link between Pechiney and Comina was a factor in the chromite trade between Malagasy and France, and the association of the second largest chromite producer in Turkey with a Swedish ferrochromium manufacturer contributed to chromite trade between Turkey and Sweden. Moreover, a long standing international ownership link had existed between Zimbabwe and the United States through Union Carbide and Vanadium Corporation that were major producers of ferrochromium in the United States, but this was suspended by the compulsory disposal by these companies of mining interests in Zimbabwe during United Nations economic sanctions against that country. Nevertheless, by means of the Byrd Amendment the United States imported chromite from Zimbabwe during 1972-1974, and was the only country that openly did so.

Established buyer-seller ties

Since early in the century Turkey and New Caledonia had been traditional suppliers of metallurgical grade chromite to Germany and the United States respectively, and this probably played a significant role in the chromite trade between Turkey and Germany and between New Caledonia and the United States during 1935-1937. Furthermore, there had been a traditional link in metallurgical grade chromite trade between Zimbabwe and the United States prior to 1935-1937, and this was cemented by international ownership ties involving Union Carbide and Vanadium

Corporation. Several of the chromite trade ties during 1972-1974 had persisted over a long period, and these included those between South Africa and West Germany, Turkey and Sweden, South Africa and United Kingdom, and the Philippines and United States. This suggests that long established trade ties tend to be perpetuated, although other factors also would have contributed to their maintenance.

Differential tariffs

During 1972-1974 the United States was a major importer of ferrochromium, even though tariffs on ferrochromium would have inhibited imports to some extent. However, there was a differential tariff schedule under which ferrochromium imports by the United States from the Soviet Union were subject to much higher duties than those applying to ferrochromium imports from most other countries. There were no imports of ferrochromium by the United States from the Soviet Union during 1972-1974 even though the United States was a large importer and the Soviet Union an important exporter of ferrochromium, and this demonstrates the influence of differential tariffs on trade ties in ferrochromium. Moreover, the United States was a major importer of chromite from the Soviet Union during 1972-1974, and chromite imports entered the United States free of duty.

RELATIONSHIP OF FINDINGS TO PREVIOUS RESEARCH

The findings of the present work are discussed in relation to the article by Ridge and Moriwaki (1955) on international trade in chromite during 1952, and the research by Tilton (1966(a) & 1966(b)) on trade ties between countries during the period 1960-1962 for a number of metalliferous commodities that did not include those containing chromium.

Ridge and Moriwaki, 1955

Some of the observations of Ridge and Moriwaki (1955) given in Chapter 1 regarding international trade in chromite in 1952 no longer applied to the same extent in the mid-1970's as a result of changed circumstances. There had been substantially increased production of ferrochromium in chromite mining countries by the mid-

1970's, and the relationship between steel production and chromite imports stated by Ridge and Moriwaki needs to be extended to include ferrochromium imports as well as those of chromite. Furthermore, even though some countries such as Norway and Sweden continued to import chromite and export ferrochromium, such countries were no longer the dominant type of ferrochromium producer because of the expansion in domestic ferrochromium production by chromite mining countries.

The United States continued to rely on a small number of chromite suppliers in 1975, namely the Soviet Union, South Africa, Philippines, Turkey, and Zimbabwe that accounted for 93% of United States chromite imports, and except for the Soviet Union these same countries were the main suppliers in 1952. However, in 1975 the Soviet Union was the largest source of chromite imports by the United States, whereas in 1952 chromite exports by the Soviet Union were subject to an embargo. Chromite imports by the United Kingdom in 1975 were derived mainly from South Africa and the Philippines that provided 56% and 37% of imports respectively, whereas in 1952 chromite imports came largely from Zimbabwe and South Africa, and the United Kingdom no longer depended so much on chromite imports from present or past Commonwealth countries. However, in 1975 chromite imports from Zimbabwe were subject to United Nations economic sanctions that were applied by the United Kingdom.

Since 1952 there has been an enormous increase in chromite imports by Japan that showed particularly strong growth during the period 1955-1970, even though Japan is not a country rich in solid-fuel and has had to rely heavily on imports of coal from Australia and other countries. In 1975 as in 1952 the United States depended on foreign suppliers for its chromium requirements, and there was no chromite production in the United States during 1975. However, after 1952 the United States undertook considerable strategic stockpiling so the possibility of a serious problem in time of emergency was lessened.

Tilton, 1966(a) & 1966(b)

The findings of the present research that trade ties between countries for international trade in chromite during the periods 1935-1937 and 1972-1974 and for that in ferrochromium during the period 1972-1974 were influenced by non-price factors, notably metallurgical characteristics, political relationships, international ownership links, and established buyer-seller ties, are consistent with the conclusions of Tilton (1966(a) & 1966(b)) outlined in Chapter 1 in relation to trade ties for other mineral products investigated for the period 1960-1962. Further, Tilton observed that trade ties do change at times in response to new developments and powerful stimuli, and in the case of international trade in chromite and ferrochromium it has been found in the present study that substantial changes have been brought about as a result of the discovery and development of new chromite deposits as in Zimbabwe, South Africa, Philippines, and Finland, the disruption to trade arising from hostilities during global warfare, the imposition of United Nations economic sanctions against Zimbabwe, the development and introduction of the AOD and other processes of stainless steel making that utilised ferrochromium made from chemical grade chromite, and the establishment of ferrochromium smelting facilities in chromite producing countries such as South Africa and Zimbabwe.

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APPENDICES

Appendix 1

INTERNATIONAL TRADE IN CHROMITE

An historical perspective

EDWARD N. EADIE

Eadie, Edward N. (1984) International trade in Chromite: a historical perspective.
Chromium Review, no. 2, January 1984

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

Appendix 2

INTERNATIONAL TRADE IN FERROCHROMIUM

A historical perspective

EDWARD N. EADIE

Corrections

1. First page of article (p11). The last sentence of the first paragraph under the heading World Ferrochromium Exports should read:

The distribution of exports for the various types of ferrochromium production is shown in Table 2.

2. Second page of article (p12). The heading for TABLE 2 should read:

   The distribution of exports for the various types of ferrochromium production over the years based on the averages for the decades shown. This distribution is illustrated graphically below the table.

3. Second page of article (p12). At bottom left corner of TABLE 2 "Percentage of production" should read:

   Percentage of exports.

Eadie, Edward N. (1985) International trade in Ferrochromium: a historical perspective.
Chromium Review, no. 3, March 1985

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.