OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

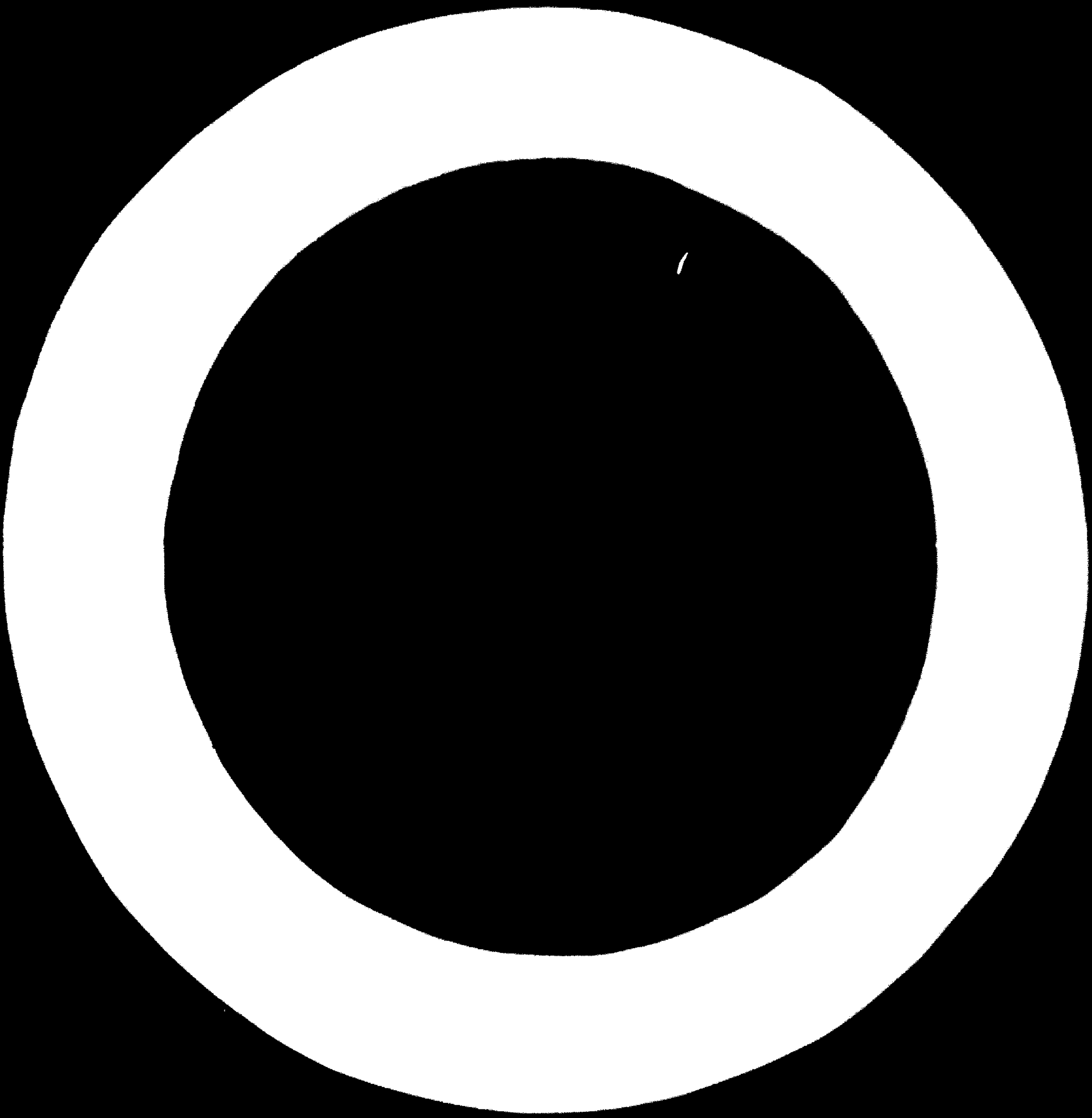
Please contact publications@unido.org for further information concerning UNIDO publications.

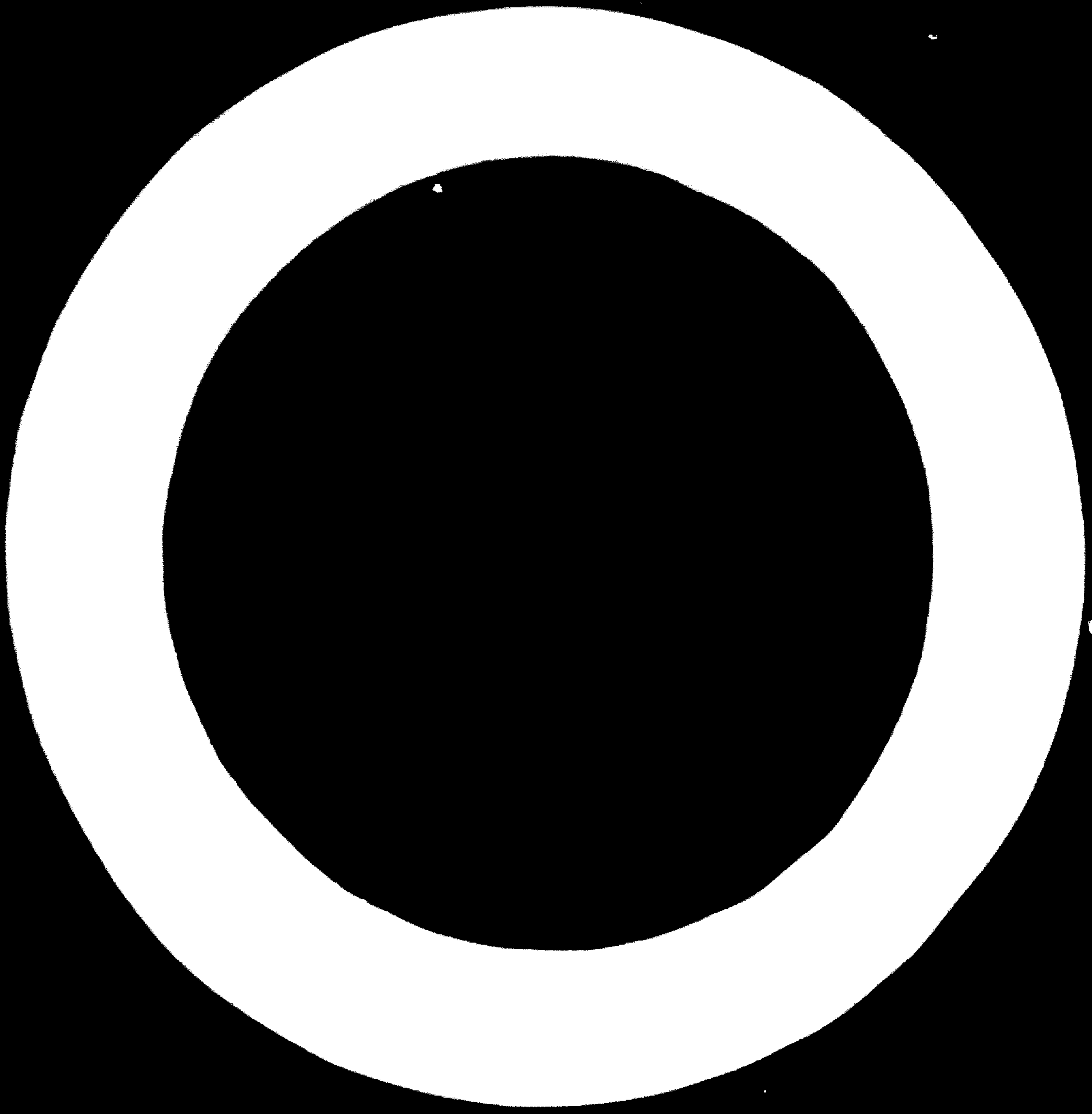
For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

non-ferrous metals in under-developed countries

UNITED NATIONS





non-ferrous metals in under-developed countries

UNITED NATIONS

Department of Economic and Social Affairs
New York, 1956

E/2798
ST/ECA/36

October 1955

UNITED NATIONS PUBLICATION

Sales No.: 1955. II.B. 3

Price: $US 1.50; 10/6 stg.; Sw. fr. 6.50
(or equivalent in other currencies)

FOREWORD

There has always been awareness in the United Nations of the close connexion between the process of economic development and the efficient use of natural resources. As early as October 1946, in resolution 1 (III), the Economic and Social Council expressed interest in "promoting the fullest and most effective utilization of natural resources . . .", and in the following year adopted resolution 26 (IV) calling for a study of "the most appropriate forms of international action for facilitating the better utilization of world resources of manpower, materials, labour and capital in order to promote higher standards of living throughout the world, more particularly in undeveloped and under-developed areas . . .".

In the summer of 1949 the United Nations sponsored a Scientific Conference on the Conservation and Utilization of Resources, the proceedings of which were subsequently published in eight volumes, the second of which dealt specifically with mineral resources.[1] The Secretary-General of the United Nations reported to the Council on the accomplishments of the conference in March 1951, and the discussion that followed led to the adoption by the Council of resolution 345 (XII), calling upon the Secretary-General "to initiate a programme designed to promote the systematic survey and inventory of non-agricultural natural resources . . .".

The first subject selected for study under this resolution was iron ore, on which a preliminary report had already been issued.[2] A committee of experts was convened in June 1953, and their report, entitled *Survey of World Iron Ore Resources: Occurrence, Appraisal and Use*,[3] was presented to the Council in April 1955.

The study of natural resources is also being pursued by the regional economic commissions. In October 1952 a group of experts on iron and steel met in Bogotá under the auspices of the Economic Commission for Latin America. The findings of this group were published, together with contributions of the secretariat of the Commission, in a report entitled *A Study of the Iron and Steel Industry in Latin America*.[4] In April 1953, a regional conference on mineral resources was held in Tokyo under the auspices of the Economic Commission for Asia and the Far East; its results were published in *Development of Mineral Resources in the Far East*.[5] Early in 1954 the Economic Commission for Europe completed an investigation of *Competition between Steel and Aluminium*.[6]

In the meantime the Bureau of Economic Affairs was engaged on a study of non-ferrous metals from the point of view of their importance in international trade as well as in various metallurgical industries. The present report is the outcome of that study. It does not deal with technical problems connected with geology, metallurgy or engineering, or with the measurement of reserves or the standardization of terminology. Rather, the report offers a general analysis of the economic aspects of the non-ferrous metals industry, with a view to providing a background against which the technical aspects may be seen in clearer perspective. It reviews the position of the major non-ferrous metals in trade and industry from the standpoint of the under-developed countries in which a sizable proportion of the world's ore resources are found. Consequently, much of the report is concerned with the manner in which the mining and smelting of the ore—as distinct from the export or local fabrication of the metal—may stimulate other economic activities.

---

[1] United Nations publication, sales number: 1950.II.B.3.

[2] *World Iron Ore Resources and their Utilization* (sales number: 1950.II.D.3).

[3] Sales number: 1954.II.D.5.

[4] Sales number: 1954.II.G.3.

[5] Sales number: 1953.II.F.5.

[6] E/ECE/184.

EXPLANATORY NOTE

The following symbols have been used in the tables throughout the report:

Three dots (. . .) indicate that data are not available or are not reported

A dash (—) indicates that the amount is nil or negligible

A blank in a table indicates that the item is not applicable

A minus sign (—) indicates a deficit or decrease

A full stop (.) is used to indicate decimals

A comma (,) is used to distinguish thousands and millions

A slash (/) indicates a crop year or fiscal year, e.g., 1953/54

Use of a hyphen (-) between dates representing years, e.g., 1950-54, normally signifies an annual average for the calendar years involved, including the beginning and end years. "To" between the years indicates the full period, e.g., 1950 to 1954 means 1950 to 1954, inclusive.

References to "tons" indicate metric tons, and to "dollars", United States dollars, unless otherwise specified.

The term "billion" signifies a thousand million.

Details and percentages in tables do not necessarily add to totals, because of rounding.

TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. PATTERNS OF CONSUMPTION, PRODUCTION AND TRADE	6
Nature of the non-ferrous metals The major non-ferrous metals — The additive metals	6
Consumption Market demand — Substitution and technological change — Fluctuations in consumption — Scrap and secondary metal	8
Production Fluctuations in output and price — Regional distribution	25
The pattern of international trade	34
3. INTERNATIONAL CONTROL SCHEMES	38
Aluminium	38
Copper	39
Lead	44
Tin	47
Zinc	50
4. MINING, SMELTING AND REFINING IN UNDER-DEVELOPED COUNTRIES	55
Exploration and survey	55
Mining	58
Smelting and refining: some general problems The nature of the metal and of the ore deposit — The criterion of cost — Technical problems — Fuel and power — Influence of international relationships — Fiscal influences	59
Smelting, refining and fabricating facilities Aluminium — Copper — Lead — Tin — Zinc	69
5. DEVELOPMENTAL EFFECTS OF THE NON-FERROUS METAL MINING AND SMELTING INDUSTRY	93
Some technical and economic effects of fluctuations in mineral output and price	93
Wage payments and employment	99
Purchases and investment Transport — Power and other ancillary investments — Stores	103
Tax contribution	107
Profits and their use	112
Some institutional considerations affecting the development of mineral economies International non-ferrous metal systems — Mining banks — Other financial and commercial institutions — Government responsibility for a wasting asset	117
INDEX	125

List of tables

Page

1. Consumption of certain non-ferrous metals and ores, by regions, selected years 7
2. Major uses of non-ferrous metals in the United States, 1950 8
3. Indices of consumption of major non-ferrous metals in western Europe and the United States, 1935-38 and 1948 to 1954 19
4. Primary non-ferrous metal consumption, 1950 (actual) and 1975 (projected) 22
5. Proportion of total output of non-ferrous ores and metals contributed by the three largest producers, 1937, 1950 and 1953 28
6. Non-ferrous metal output in industrial and under-developed areas, 1937, 1950 and 1953 29
7. Percentage of world supply of non-ferrous ores and metals coming from the United States, 1937, 1950 and 1953 31
8. Imports of non-ferrous ores and metals into selected countries, 1937-38, 1947-48 and 1952-53 36
9. Copper production, 1919 to 1923 40
10. Copper production, 1927 to 1931 42
11. Copper production, 1935 to 1938 43
12. Indices of lead production and prices, 1907 to 1916 45
13. Lead production, 1926 to 1934 46
14. Tin ore production and average prices, 1928 to 1942 48
15. Zinc smelter capacity and production, 1932 52
16. Indices of zinc production, 1928 to 1936 53
17. Exports of non-ferrous ores and metals by certain countries, 1938, 1948 and 1953 56
18. Exports and imports of certain additive metals by under-developed countries, 1948-51, and International Materials Conference allocations, 1952 60
19. Prices of certain non-ferrous ores and metals, mid-1954 62
20. United States import duties on non-ferrous metals in various stages of fabrication, January 1951 68
21. Ore and metal production of aluminium, copper, lead, tin and zinc in under-developed regions, 1948-53 69
22. Consumption of primary aluminium, copper, lead, tin and zinc in under-developed countries, 1948-53 71
23. Bauxite and primary aluminium production and smelter capacity in under-developed countries, 1938, 1948-53 and 1954 72
24. Copper ore and metal production, and smelter and refinery capacity, in under-developed countries, 1938, 1948-53 and 1954 76
25. Mine, smelter and refinery production of copper, by region, 1949-51 79
26. Chile: Copper mineral and metal exports and export unit values, 1949 to 1953 80
27. Lead ore and metal production and smelter capacity in under-developed countries, 1938, 1948-53 and 1954 82
28. Tin ore and metal production and smelter capacity in under-developed countries, 1938, 1948-53 and 1954 86
29. Tin plate production and apparent consumption, by region, 1937-39 and 1951-53 88
30. Zinc ore and metal production and smelter capacity in under-developed countries, 1938, 1948-53 and 1954 90
31. Fluctuations in proceeds derived from the export of certain non-ferrous ores and metals, 1928 to 1950 94

Page

32. Average fluctuations in volume, price and proceeds of exports of certain non-ferrous ores and metals from selected under-developed countries, 1928-50 96
33. Value of mineral output and wage bill of all mines in Northern and Southern Rhodesia, 1949 to 1954 99
34. Balance of trade and direct investment income of certain under-developed mineral economies, 1948 to 1954 114

List of charts

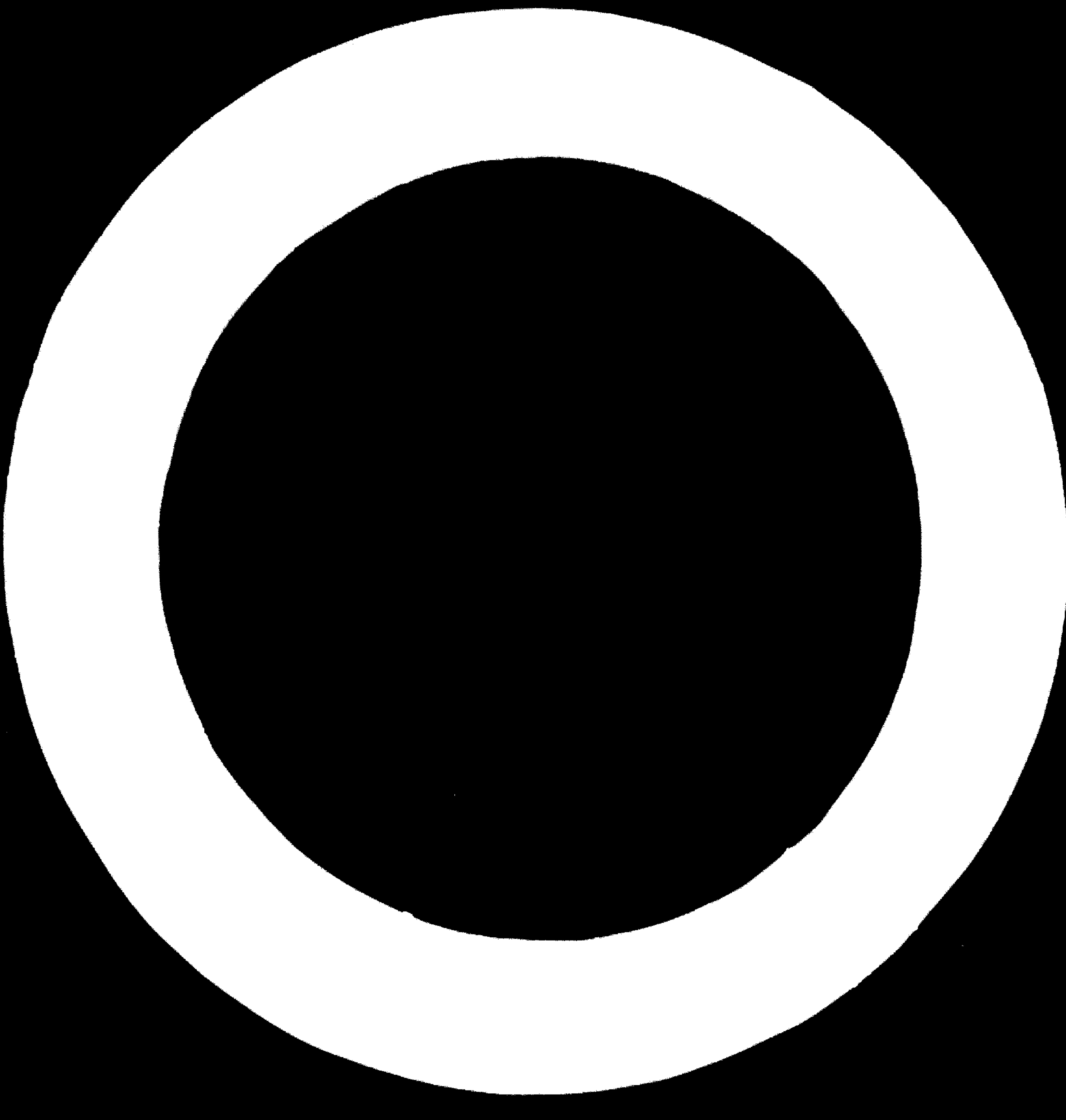
1. Price relationships among major non-ferrous metals, 1902 to 1954 12
2. Apparent consumption of copper in selected countries, 1925 to 1938 and 1946 to 1954 15
3. Apparent consumption of tin in selected countries, 1927 to 1954 16
4. Apparent consumption of lead in selected countries, 1925 to 1938 and 1946 to 1954 16
5. Apparent consumption of zinc in selected countries, 1925 to 1938 and 1946 to 1954 17
6. Apparent consumption of aluminium in selected countries, 1925 to 1954 18
7. Indices of apparent consumption of major non-ferrous metals, United States, 1908 to 1950 20
8. Indices of apparent consumption of the additive metals, United States, 1908 to 1950 21
9. Indices of world production, price and value of major non-ferrous metals, 1910 to 1954 27
10. Tin prices, 1949 to 1955 50

List of maps

(Maps will be found at end of chapter 4, following page 92.)

NON-FERROUS METAL MINES AND SMELTERS

Africa and Mediterranean Area
South America
Central America and Caribbean Area
South-East Asia
Asia



Chapter 1

INTRODUCTION

The nature, extent and rate of economic development in any country are greatly influenced by the quantity and quality of its natural resources. Among these resources, minerals occupy an important position; they provide not only metals and fuels but also essential raw materials for the building, chemical and engineering industries and therefore occupy a strategic position in the physical process of development. Among minerals, in turn, the ores of the non-ferrous metals play a significant part in the economies of many of the less developed countries. Some of these countries are major sources of one or more of the non-ferrous ores and to an increasing extent, as smelting and refining facilities are established, of the associated primary metals.

Most of these non-ferrous metals fulfil their principal function as raw materials for factories making durable goods, largely for the use of producers rather than consumers. Hence the main markets for non-ferrous metals lie in industrial countries; domestic use within less developed countries depends on the progress of local manufacturing. Industrialization and the extension and diversification of the domestic use of the mineral output are thus interrelated, and to a certain extent mutually dependent, processes.

Quite apart from the nature and use of the products, however, the actual process of exploiting a country's mineral resources has certain developmental effects on the economy as a whole, and these constitute the principal theme of the present study. They are examined in the light of a number of conditions which determine what might be called the "development potential" of the non-ferrous minerals industry. Among these conditions, the most significant are the nature and location of the mineral and the method of mining; the stage to which processing is carried within the producing country; the extent to which the industry yields raw materials that can be used in local production; the extent to which it provides a field of employment and training for local labour which might otherwise be unemployed or less productively engaged; the extent to which it brings into being ancillary facilities, such as transport and power, which are capable of serving sectors and purposes other than mining: the extent to which it creates an internal market for various types of goods and services and thus promotes diversification in the economy; the extent to which it yields a saleable export product (or the replacement of a previous import) and hence a source of foreign exchange available for financing other imports; the extent to which it provides funds for private investment; and, not least, the extent to which it contributes to public revenue, directly or indirectly, furnishing the government with funds for the financing of its development programmes. The effect of these conditions depends on the relative importance of the non-ferrous minerals industry in the economy and hence on the nature and degree of economic development the country has already attained and in the final analysis on the availability of other resources, material, financial and human.

Although circumstances and problems differ considerably from one under-developed country to another,[1] maximization of the developmental effects of the mineral industry invariably requires that it be treated as an integral part of the economy in which it operates, in terms both of the factors of production it utilizes and of the physical and financial products it yields. Hence, a mineral producing country—especially if it is under-developed—has to aim in the first instance at the most economical distribution of resources between mining and the other sectors of the economy. For this purpose, the profitability of a given mine or the gross earnings of foreign exchange from mineral exports, though important considerations, are not the only criteria or necessarily the most pertinent ones. In the mining sector itself, moreover, the most economical allocation of resources employed to operate the mines and the most productive use of output are both necessary if the mineral industry is

---

[1] For the purposes of this study it is not necessary to have a rigid definition of an "under-developed" economy. The developmental effects of the non-ferrous mineral industry are logically independent of the existing degree of development of the resource country, even though they are obviously likely to have much greater relative significance in a simple export economy than they are in an industrially advanced economy. The countries in which the industry is considered in this study are mainly the so-called "mineral economies" in which a high proportion of export earnings or national product, or both, is derived directly from the exploitation of non-ferrous ore resources.

Where, for some statistical purpose, under-developed countries are treated as a single category, they are in general a residual group, the countries remaining after abstraction from the world total of northern America, western Europe, Japan and Australasia, where manufacturing contributes more than one-fourth of the net national income or occupies more then one-fourth of the employed population. Although certain of the western European countries (Greece and Portugal, for example) do not conform to this definition, they are included for statistical convenience as part of the industrial area of western Europe. Unless specifically mentioned, Bulgaria, mainland China, Czechoslovakia, eastern Germany, Hungary, Poland, Romania and the Union of Soviet Socialist Republics have in general been omitted from this division because of the absence of recent statistics.

to exert its greatest developmental effect in the interest of the economy as a whole.

Furthermore, for the greatest long-run benefits, the rate of exploitation of a mineral resource should be co-ordinated with the country's general economic development. Over-rapid exploitation which involves "skimming the cream" of a mineral deposit may be as inimical to steady progress as sterilizing that deposit in line with an ill-conceived "conservation" policy.

Organization of the industry

It should be pointed out at this stage that in most under-developed countries the mineral industry comprises a small number of comparatively large units and a much larger number of small units. The latter often consist of marginal mines, which in several of the less developed countries have recently been the particular concern of the government—in Chile and Bolivia, for example, where they have been assisted by special credit facilities and by the establishment of central plants for the smelting of their ore output. In a few cases—Indonesia and Bolivia, for example—mining and subsequent processing and distribution of the products are carried out by the government, through special agencies established for the purpose.

Most of the small mines are domestically owned; many of the larger mining companies, however, are organized and controlled from industrial countries. This fact reflects both the historical growth of the mining industry and the trade flow of the raw material. Most of the companies with interests in more than one country originally operated mines in Europe or the United States and many of them still do, thus having direct access to the forms of capital and "know-how" that are necessary for exploiting mineral resources elsewhere.

Mineral exploration is usually a costly process requiring technical knowledge and skill of a specialized nature, which are generally very scarce, especially outside the economically advanced countries. Developing a mine, moreover, often involves considerable risk, arising from both physical uncertainties and price fluctuations and tending to make adequate capital and well-established market outlets and connexions necessary conditions for success. Furthermore, a new mine may take a long time to become productive. For these and other reasons, it may often prove mutually beneficial, and in some cases more appropriate, to have exploration and mining development financed by capital from the industrial countries rather than from the limited funds that may be available in the resource country and for which, at least in the early stages of economic growth, there are likely to be many more urgent and less risky uses.

In physical terms, the usual purpose of mining operations that result from such exploration and development is to supply minerals for sale on world markets. In some instances, however, a mine opened up in an under-developed country may be designed to supply part or all of the raw material intake of a particular refinery in one of the industrial countries. In this way, a number of fairly well-defined relationships can be traced between specific mines and specific refineries and, in some cases, specific fabricating plants too. Relationships of this nature often govern the flow of mine output, and though they tend to impart an element of rigidity to mining policy, have the advantage of facilitating distribution of the ore or crude metal.

Developmental effects

The conditions listed above as the principal determinants of the developmental effects of the mining industry may be classified into two broad groups: (1) the direct and the indirect physical outgrowths of the mine itself; (2) the results of the various monetary flows generated by the industry.

Among the indirect physical effects of a mine are the various facilities—roads, railways, water supply and so on—which usually have to be constructed in order to provide access to the site and make it habitable, and facilitate the handling of incoming mining stores and outgoing ore. The direct physical effect of the mine arises through the domestic use of its output. In the first place, the various non-ferrous ores constitute the raw materials for the corresponding smelting and refining industry. Although a good deal of the crude mineral still enters into international trade, there has been a considerable increase in the amount of preliminary processing carried out in the under-developed resource countries: about one-eighth of the world's metallic zinc supply (outside China and the Union of Soviet Socialist Republics), one-fourth of the lead supply and almost one-half of the tin and copper supply now come from under-developed countries. In a number of instances, by-products of the mining or smelting processes have, in their turn, provided the raw materials for other industries. Thus, the flue dust from Mexican zinc smelters yields cadmium, used for plating, while the sulphide ores from which copper is obtained have provided the raw material for sulphuric acid production in Chile and the Belgian Congo and more recently in Northern Rhodesia.

Subsequent use of the metal takes the industrialization process a stage further. Several of the non-ferrous metals are important raw materials in the chemical, insecticide, and paint and pigment industries. Others, notably zinc, tin, chromium, nickel and cadmium, are important in the electroplating industry. The major use of the additive metals is in the steel industry, for the production of special alloys. Most of the metals, either singly or in combination, are widely used in what has become known as the fabricating industry. Up to the present, however, very little of the non-ferrous metal output of under-developed countries has been absorbed by their domestic processing industries; nor have any of their non-ferrous metal fabricating activities expanded to major proportions. It is evident that the principal direct developmental effects of the mineral industry, as reflected in the growth of associated metallurgical, chemical and fabricating industries, lie largely in the future, to be realized as the industrialization of the less developed countries proceeds and the local demand for manufactured metal products becomes large enough to sustain producers of economic size.

In the meantime, given the existing pattern of demand for ores and metals, the main developmental effects in these countries lie less in the mineral output as such (the bulk of it being exported) than in the use that is made of mining revenue and in a number of considerations that are incidental to the actual process of mining. The significance of this conclusion is enhanced by the wasting character of any mineral reserve, which in the nature of things faces eventual depletion. In most under-developed countries the objective of utilizing non-renewable mineral resources as productively as possible necessarily involves the government, upon which rests the primary responsibility for ensuring that capital facilities are created that will ultimately be capable of replacing some of the economic functions served by the mine.

The monetary flows

Mining revenue accrues partly in domestic currency and partly (in most cases, very largely) in foreign currency. These foreign currency earnings may be used for importing mining stores, for paying the wages and salaries of foreign employees, for maintaining offices and reserve funds abroad, for repaying foreign debts, for investment in new, imported capital equipment and for the payment of interest to debenture holders or of dividends to shareholders, or they may be sold on the foreign exchange market or surrendered to the government at a prescribed rate of exchange to become available for the financing of general imports. The conversion of its foreign exchange provides the mining company with local currency for meeting local expenses—for wages and salaries, stores and services, various forms of taxation (including royalties) and dividends to local shareholders (including, in a number of instances, the government). The actual distribution of mine revenue among these various recipients depends partly on the output of the mineral and the price it realizes, partly on decisions made by the mining companies themselves, and partly on the policy pursued by the government in respect to such matters as exchange control and taxation.

Although precise measurement of the resultant monetary flows is rarely possible, in general it can be stated that in recent years there has been a tendency, especially in those countries which have experienced balance of payments difficulties, for governments to claim a larger share of the revenue created by mining than formerly and also to exercise a greater influence upon both the proportion allowed for payments in foreign currencies and the conditions and timing of such payments.

The developmental effects of the flow of mine revenue into the public purse depend upon its magnitude and the use the government makes of it and also—more significant in the present context—upon the way in which it is collected. Normal government expenditure may serve important developmental needs, especially in an under-developed country in which good administration and the provision of education and health services are often important means of raising productivity. But in some cases revenue from mine taxation has been devoted wholly or in part to definite investment programmes, on the explicit grounds that it represented the depletion of a natural asset. As far as method of collection is concerned, while it is impossible to measure with any precision the influence of a given tax upon the development potential of the mining industry, a number of the taxes commonly levied in under-developed countries have a fairly determinate effect. A royalty payable on the volume of ore removed, for example, is likely to discourage the extraction of low-grade ore; an export tax on concentrates seems calculated to encourage domestic smelting; an obligation placed on a mining company to hand over from its export proceeds the foreign currency equivalent of its local costs at an unfavourable exchange rate is likely to bring about a reduction in its local expenditure; a tax on mining income which allows a rapid writing down of capital expenditure tends to encourage new investment. In general, the most common tax is one on profit. This has the advantage of offering the least deterrent to private investment, especially if the rate declines with a decline in the ratio of profit to metal recovery. On the other hand, a tax on profits has the disadvantage, from the point of view of the government and its development plans, of being subject to the greatest fluctuations.

Fluctuations in profit reflect fluctuations in demand and output in the face of relatively inflexible costs. As the bulk of the non-ferrous metal output is consumed in the production of durable (capital and consumer) goods, the demand for these metals tends to be a function of the demand for durable goods, and in the past this has been markedly unstable. In general, changes in the output of metal have tended to follow changes in demand, but as mine output is not very flexible, changes in the level of production have often been too late to prevent major fluctuations in price. Fluctuations in output and price have consequently tended to reinforce each other on a number of occasions—notably in the period 1920 to 1922 after the First World War, in the years 1930 to 1932 during the depression, for shorter periods in 1938, 1946, 1949, and from 1950 to 1952 after the outbreak of hostilities in Korea—thus increasing the amplitude of the fluctuations in the receipts of under-developed countries from mineral exports.

Fluctuations in the demand for the product have also been reflected in fluctuations in mining employment and in wage payments, which have from time to time seriously detracted from the development potential of the mines. The use of migrant labour in some areas may have helped to reduce the burden of localized unemployment, but only at the expense of forgoing the advantages of developing a trained force of local labour. For, in general, the higher the proportion of local labour employed in mining, the wider is the development effect likely to be, especially if the workers acquire new skills in the course of service. And the more backward the country the greater are likely to be the economic, social and psychological effects flowing from the introduction of so complex an organization as a modern large-scale mine. Many of the most skilled positions, particularly in the early stages of a mine's operations, are necessarily filled by personnel from abroad, trained in some cases on other properties of a parent company. Though some of these workers are likely to be transients, those who settle in the country add to its resources of skill, and possibly of capital, too.

When a foreign company is involved, the problem of financing the purchase of equipment for use in the mine—most of which usually has to be imported—is met by the direct investment of foreign capital. For a locally owned mine, purchase of equipment means use of scarce foreign exchange resources. Hence there is a certain pressure to substitute labour for capital in mining processes, at least in the early stages, and in the normal course of events relative factor prices would tend to favour this, especially in areas with a high level of rural under-employment. Nevertheless, technical considerations are the main determinant of the particular labour-capital relationship necessary for the most economical exploitation of a given mineral deposit. Thus, the small deposits of tungsten ore (wolfram and scheelite) that are found in Peru or the small alluvial concentrations of tin ore (cassiterite) in Nigeria require far more labour per unit of capital than do the massive deposits of copper ore in Chile, bauxite in Jamaica, manganese ore in India, or chromite in Southern Rhodesia.

Up to a point, the higher the wage level in mine employment, the more favourable the effect on local standards of living. The limit is set by the fact that, in the long run, the development potential of a mine depends upon the extent to which all the valuable ore is extracted from the deposit; and if higher wages involve higher working costs, they tend to raise the pay limit and hence reduce the incentive for removing the ore that is less accessible or of poorer grade. In low-cost mines, however, an increase in the wage bill is unlikely to affect mining policy very greatly; its result is more likely to be a corresponding decline in profits, reflected in turn in lower government revenue from this source and smaller dividend payments to shareholders.

The proportion that the wage bill bears to total working costs varies considerably with the nature of the ore deposit, the technique of extraction and local wage levels. In Northern Rhodesia, for example, wages have absorbed between one-fourth and one-third of the revenues derived from mining in recent years. Where the degree of mechanization is greater, wage costs are likely to be relatively less, especially in the case of deposits which can be worked by open cut methods. In the case of some smaller and deeper mines, however, wages are usually a major item of cost.

Not all remuneration is in the form of cash wages; many mines provide free or low-rent housing for their employees and some issue food rations or operate low-cost shops for the convenience of workers—a necessary amenity on many of the more isolated properties. Another noticeable feature in recent years, whether resulting from government regulation (based, perhaps, on international conventions) or from enlightened employers' decisions, has been the extension of social services of various kinds for the benefit of workers in the mining industry.

The bulk of the cash wage payments made by the mine to its labour force flow on to the local market in due course in the form of a demand for consumer goods. The mine, too, may exercise a significant local demand for stores and services required in the course of normal operations. In a number of countries with non-ferrous ore resources this demand has proved a considerable stimulus to economic diversification and to the strengthening of existing economic activities.

Among the requirements of the mine there may be several which entail substantial investment in ancillary facilities. Given the fixed location of the mineral deposit, transport is likely to be one of these; and given the high level of mechanization of many modern mining processes, power is likely to be another, while reticulated water and its associated engineering works are likely to have high priority in most cases. The mine, its surface works and employees' housing will usually create a substantial demand for building materials, while the availability of transport, power and water may well prompt the establishment of other local industries.

Although local factories and farms have the advantage which flows from their proximity to the market, in the early stages of development this market is often too small to sustain economic production, and new industries may have difficulty in establishing themselves in the face of competition from producers in more advanced countries. In many countries imports of mining equipment are admitted duty-free, but in a number of cases the demand for stores and produce made or grown locally has been promoted by imposing protective customs duties. As such duties tend to raise the local price of imported goods, their use as an instrument of development is limited by the desirability of holding down working costs in the interests of competitive mining. This principle is in turn limited by two considerations: (1) the possibility that the domestic industry may in due course, with experience and expansion, produce goods at less than the cost of the imported equivalent and (2) the fact that the process of internal industrialization tends to expand the domestic market for the non-ferrous metals themselves, thereby reducing both their dependence on export markets and imports of fabricated metal products.

After the payment of wages, the purchase of working stores and services and the meeting of tax and debt obligations, what is left of mining revenue—net profit, the fourth of the monetary flows now being considered—is available for distribution as dividends to the owners of the company or for retention within the company for subsequent investment.

As indicated above, many of these companies are owned by parent concerns or by individual shareholders in industrial countries. In so far as this makes available knowledge, skill and capital and, in many cases, a market for the product also, it is of considerable advantage to the under-developed country, which usually lacks all these things. Indeed, in the absence of enterprise from outside and a supply of the necessary complementary factors of production, some of the non-ferrous ore resources in under-developed areas might never have been exploited at all.

Nevertheless, dependence on foreign companies also involves certain disadvantages, first in respect to balance of payments matters and second in respect to the wider problem of development and resource utilization. Thus, in the first place, when all or most of the company equity is held abroad, the fact that dividend payments are related to widely fluctuating profits, and not necessarily to the resource country's general foreign trade position, may occasionally lead to remittances which do not synchronize with the flow of foreign exchange resources and which are high enough to create or aggravate a balance of payments problem. In the second place, although the rate and method of exploitation of the ore may be influenced by lease arrangements over the mineral property (incorporating the fixing of minimal rates of expenditure or extraction, for example), and by fiscal policy and various other government measures, in the final analysis it is the mining company actually carrying out operations that must determine the course of production in the light of market conditions. In the case of international companies, the criterion of success may be the profitability not of a single mine but of a much larger unit in which a refinery and several feeder mines may be involved. Under such circumstances there is a latent possibility of divergence between the company's mining and dividend policy and the government's development policy.

Not all the company's profit is necessarily distributed; indeed, a portion of it is customarily retained in the form of a capital fund. Some of this may be used for direct reinvestment, to prove and develop new reserves of ore, for example, or to discover new mineral deposits. In this way, the expansion of many mines has been largely self-financed, and working life and capacity to earn foreign exchange periodically extended. Although there has been a general tendency for mining companies to reinvest in their own concerns, or in a related mineral field, undistributed profits have also been used to finance other types of enterprise, particularly industries producing specific mining stores or utilizing mineral by-products, thus contributing towards diversification of the economy.

Summary

The main lines of reasoning in this report may be set out in brief. In the first place, it has to be recognized that under-developed countries are important and in some instances major sources of the world's supply of many non-ferrous minerals. Domestic use of these materials, however, though increasing rapidly in a number of these countries as the process of industrialization gets under way, absorbs, with few exceptions, only a small fraction of the total output. Industrialization and the increasing use of minerals are processes which interact, the one accelerating the other: the expansion of manufacturing results in a greater consumption of minerals, while a larger internal market for minerals depends upon the extension of secondary industry. Any programme for integrated economic development, therefore, entails among other things the encouragement of greater domestic use of mineral resources.

Even with a rapid rate of industrialization, however, few under-developed mineral producing countries are likely to consume more than a small proportion of their output of non-ferrous metals in the foreseeable future. This means that in most cases the greater part of the output will continue to be exported. Accordingly, it is evident that, in many of these countries, the direct physical effect of the minerals industry will continue to be less important than the benefits derived from its role as an earner of foreign exchange; consequently, the development potential of any non-ferrous metals industry will continue to lie principally in its capacity to earn foreign exchange.

The more foreign exchange proceeds are used to import capital goods or essential consumption goods rather than non-essentials, the greater is the long-run benefit for the resource country likely to be. Hence, due account being taken of the mining companies' legitimate interests and the need of under-developed countries for capital and technical knowledge, the more the mines contribute to government revenue rather than pay out as dividends, the more they invest in the resource country—whether in their own enterprise or in other local enterprises—rather than distribute profits abroad, the more they employ local labour rather than transient immigrant labour, the more they purchase domestic rather than imported stores, the greater, in general, are the benefits likely to be for the economic development of the country.

The government of the resource country has an important part to play in this process. First, it has the direct task of making the best use of the tax receipts derived from the mining industry. Given a well conceived policy of economic development, these receipts can provide an important means for carrying it out. And, second, it has the more general task of implementing its development policy by formulating and administering laws—dealing, among other things, with taxation, labour matters, customs tariff, currency and exchange problems and with the operation of foreign companies—designed to ensure the most effective exploitation of the country's mineral resources.

To sum up, therefore, in the circumstances which prevail in most of the under-developed countries, the process of maximizing the development potential of the non-ferrous metals industry to the mutual benefit of both the resource country and the mining company is essentially a problem of making as fruitful as possible the various income flows generated by sale of the output, chiefly in external markets, while at the same time ensuring not only that the ore bodies are worked with the greatest efficiency, but also that the most effective use is made of those products and by-products of the mining process which are consumed internally.

Chapter 2

PATTERNS OF CONSUMPTION, PRODUCTION AND TRADE

NATURE OF THE NON-FERROUS METALS

The metals dealt with in this study comprise those members of the non-ferrous group whose production or consumption plays an important part in the economy of one or more of the under-developed countries. They fall into two principal categories: (1) those that are used alone or in combination with other non-ferrous metals in ways in which their individual properties yield some well-defined advantage and (2) those that are used mainly for alloying with iron (in the production of special steels).

The major non-ferrous metals

In the first category are five metals: copper, which apart from being ductile and malleable is an extremely good conductor of heat and electricity; lead, which is highly acid-resistant and heavy but easily worked, especially when alloyed with antimony; zinc, which is also workable, especially when alloyed with copper (as a brass) and, like cadmium, a protection against normal atmospheric conditions; tin, which is stable and easily fusible, especially when alloyed with lead (as a solder) or with copper (as a bronze); and aluminium, the newest member of the group to be used on a large scale, remarkable for its lightness and high conductivity.

Unlike the additive metals that form the second category, these major non-ferrous metals are not directly dependent on steel technology, even though the principal use of zinc and tin is for plating iron and steel sheet. As in the case of the additive metals, however, their chief market lies in the durable goods industries. The principal use of copper is in electrical equipment, that of lead in storage batteries (mainly for motor vehicles), that of aluminium in those items of transport and machinery in which lightness is an asset; also, all three metals play an important part in building and construction.

Apart from the five major metals there are several minor ones. As indicated above, cadmium, like zinc and tin, is predominantly a plating metal, and is therefore closely associated with those iron and steel goods which require protection against atmospheric corrosion. Most antimony is used in conjunction with lead, and in much the same way beryllium is used for strengthening copper. Magnesium and titanium are light metals whose use is increasing rapidly; the former, because of relatively low tensile strength, is used chiefly for alloying with aluminium, while the latter though much stronger has had its use restricted by its relatively high price. As none of these metals plays an important part in any of the less developed economies, their principal significance in the present study lies in the extent to which they complement or compete with the five major metals.

Consumption[1] of these major non-ferrous metals is confined very largely to the industrial countries, though it is not concentrated to quite the same extent as is use of the alloy metals. In post-war years about one-half of world consumption of copper, zinc, lead and tin (not including that of the Union of Soviet Socialist Republics and mainland China) has been accounted for by the United States and more than 90 per cent by northern America, western Europe and Japan, while almost all the aluminium has been consumed in these industrial areas (table 1). In general, in spite of a slight increase during the past three decades in the proportion of total non-ferrous metal supply used in Africa, Asia and Latin America, the overwhelming bulk continues to be consumed in the factories of northern America and western Europe.

The additive metals

In the second category are the metals used chiefly for alloying with iron and steel. For certain of these metals, such as columbium and vanadium, for example, the sole use in current technology is to impart to steel qualities of hardness and durability and, in the case of columbium, stability at high temperatures. Molybdenum also finds by far its most important use in giving to steel properties that are valuable in the making of tools. Manganese has a more general role in ferrometallurgy: ever since 1856, when it was first employed in the smelting of Bessemer steel, it has been widely used as an oxygen and sulphur removing reagent, while more recently it has also been used in the production of special tough steels. Tungsten has much the same function as molybdenum as a steel hardener, but it is also used for its electrical properties, especially as a durable incandescent material which has almost completely replaced carbon in the filament of lamps. Although chromium and nickel also owe their importance largely to the fact that they impart certain qualities to steel, both hardness and the ability to resist corrosion, they are in addition widely used as

[1] In the present context, the process of "consumption" is the use of the material in a succeeding stage of production. Thus ore is "consumed" in the process of smelting or refining, and the metal is "consumed" in the process of fabrication.

Table 1. Consumption[a] of Certain Non-Ferrous Metals and Ores, by Regions, Selected Years

(Thousands of metric tons)

Metal and year	*United States and Canada*		*Australia, New Zealand, Japan*		*Europe*[b]		*Africa*		*Asia*[c]		*Latin America*		*Total, countries listed*
	Amount	*Per cent of total*	*Amount*	*Per cent of total*	*Amount*	*Per cent of total*	*Amount*	*Per cent of total*	*Amount*	*Per cent of total*	*Amount*	*Per cent of total*	
Aluminium:													
1948	680	62	12	1	375	34	1	—	7	1	18	2	1,093
1949	630	60	22	2	368	35	1	—	6	1	14	1	1,041
1950	874	66	25	2	383	29	2	—	9	1	21	2	1,314
1951	963	62	43	3	523	33	2	—	11	1	22	1	1,564
1952	1,055	61	41	2	588	34	2	—	8	1	25	2	1,719
1953	1,479	71	48	2	529	25	3	—	8	1	20	1	2,086
Copper:													
1948	1,201	56	85	4	785	37	15	1	25	1	38	2	2,149
1949	905	48	65	3	816	43	17	1	29	2	55	3	1,887
1950	1,235	54	82	4	885	38	18	1	32	1	52	2	2,304
1951	1,311	52	128	5	918	37	23	1	35	1	86	3	2,501
1952	1,388	53	128	5	941	36	25	1	32	1	63	2	2,607
1953	1,308	55	111	5	895	37	12	1	23	1	47	2	2,396
Lead:													
1948	730	55	59	4	457	35	5	—	17	1	53	4	1,321
1949	572	47	65	5	500	41	9	1	11	1	57	5	1,213
1950	853	54	74	5	562	35	9	1	19	1	73	5	1,589
1951	665	45	93	6	620	42	15	1	12	1	73	5	1,477
1952	758	54	53	4	510	37	15	1	8	1	50	4	1,394
1953	764	50	74	5	614	40	15	1	10	1	45	3	1,522
Tin:													
1948	65	50	6	5	47	36	2	2	7	5	4	3	130
1949	52	46	6	5	43	38	2	2	8	7	3	3	114
1950	77	51	7	5	53	35	3	2	7	5	4	3	151
1951	63	46	7	5	54	40	3	2	6	4	3	2	136
1952	50	40	7	6	57	46	3	2	4	3	4	3	125
1953	59	47	7	6	48	38	2	2	5	4	4	3	125
Zinc:													
1948	784	52	84	6	580	38	13	1	34	2	21	1	1,518
1949	683	47	93	6	617	42	12	1	34	2	25	2	1,464
1950	927	52	99	6	661	37	15	1	30	2	34	2	1,766
1951	903	50	112	6	711	39	15	1	33	2	43	2	1,817
1952	820	49	119	7	663	40	13	1	30	2	33	2	1,678
1953	933	52	146	8	649	36	14	1	26	1	31	2	1,798
Chromite:													
1950	1,290	75	43	2	360	20	25	1	12	1	3	—	1,733
Manganese:[d]													
1950	1,983	56	212	6	1,234	35	44	1	63	2	23	1	3,558
Molybdenum:[e]													
1948	11,553	80	85	1	2,910	20	20	—	...	...	2	—	14,570
1949	9,768	72	215	2	3,516	26	88	1	...	...	1	—	13,588
1950	12,043	73	268	2	4,273	26	26	—	25	—	10	—	16,645
1952[f]	16,842	77	235	1	4,718	22	23	—	14	—	25	—	21,858
Tungsten:[e]													
1948	4,386	35	465	4	7,682	61	—	—	50	—	3	—	12,586
1949	2,456	25	306	3	6,846	71	12	—	60	1	1	—	9,681
1950	3,331	28	410[g]	3	8,056	68	16	—	79	1	8	—	11,900
1952[f]	9,005	51	461	3	7,984	45	67	—	23	—	22	—	17,580

Source: International Materials Conference, *Report on Operations*, for 1951-1952 and for 1952-1953 (Washington, D.C.); International Tin Study Group, *Statistical Yearbook, 1954* (The Hague, 1955); President's Materials Policy Commission, *Resources for Freedom*, volume II (Washington, D.C., 1952); American Bureau of Metal Statistics, *Yearbook, 1954* (New York, 1955); Metallgesellschaft Aktiengesellschaft, *Metal Statistics*, 1938, 1946-1953 (Frankfort on Main, 1954).

[a] Actual consumption in most cases for copper, zinc, lead, molybdenum, tin and tungsten; apparent consumption (production plus imports minus exports) in the case of aluminium, manganese and chromite. Consumption of primary metal in most cases, but secondary metal is included for some countries.

[b] Austria, Belgium, Denmark, Finland, France, western Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and Yugoslavia.

[c] India, Indonesia, Israel, southern Korea, Pakistan, Philippines, Taiwan and Turkey.

[d] Only ore with a metal content of 30 per cent or more.

[e] Metric tons of metal content of ore and primary products.

[f] Allocations recommended by the International Materials Conference.

[g] Estimated on the basis of average 1948, 1949 and 1952 consumption; the total for 1950 includes this estimate.

plating metals. Cobalt, like columbium, is especially valuable in rendering steel capable of resisting high temperatures; it also improves the magnetic qualities of iron and is therefore very useful in the electronics industry for the production of permanent magnets.

One of the important consequences of this pattern of use is the fact that the demand for the ferroalloys is channelled chiefly through those few countries whose steel industries are sufficiently developed to produce the special grades in question. In 1950, for example, six of the leading steel producers—the United States, the United Kingdom, western Germany, France, Sweden and Japan—accounted for 89 per cent of world tungsten consumption (excluding that of the Soviet Union, eastern Europe and mainland China) while the United States alone consumed more than half of the manganese, cobalt and chromium supplies, and more than two-thirds of the molybdenum, columbium and nickel supplies.

CONSUMPTION

Market demand

Since the greater part of the output of the major non-ferrous metals goes into durable goods, the demand for these metals is largely a function of the activities of the industries producing such goods, in particular the electrical industry, the transport industry (especially the automobile and aircraft sections) and the building industry. Furthermore, since a large proportion of these goods is used in the process of investment, the demand for the non-ferrous metals tends to vary with the rate of new investment.

Demand for the additive (ferroalloy) metals is derived in the main directly from the demand for special types of steel. Thus these metals are also closely linked to the various durable goods industries, and, in particular, as in the case of the major non-ferrous metals, to the industries which produce capital goods. Moreover, as noted above, their market is concentrated very largely in a small number of steel producing countries.

The importance of this dependence of the demand for non-ferrous metals upon the investment goods industries lies in the fact that these industries have tended to be among the least stable in the advanced economies. Investment has tended to fluctuate far more violently than total consumption, falling to very low levels in times of depression and rising in times of boom to a much greater extent than total production, thus introducing a high degree of instability into the market for non-ferrous metals.

The principal exceptions to this generalization arise from the use of non-ferrous metals in consumer goods—particularly tin in tin plate, the demand for which is largely dependent upon activity in the food canning industry, and aluminium (and to a smaller extent copper and other metals) in the production of utensils, the demand for which also tends to vary with consumer tastes and purchasing power. Automobiles draw on most of the metals: copper for radiators, lead for batteries, zinc for die cast components, chromium for plating and several of the additive metals for special steels. Consumer appliances, such as vacuum cleaners and washing machines, radio and television sets, and other electrical and electronic apparatus, absorb a significant amount of copper, aluminium and other non-ferrous metals, particularly in the United States (table 2). In terms of world consumption this type of use—in consumer durables—may well tend to increase more rapidly than use of such metals in

Table 2. Major Uses of Non-Ferrous Metals in the United States,* 1950
(Percentage of total consumption of each metal)

Metal	*Major use*		*Subsidiary uses* I		*Subsidiary uses* II	
Aluminium	Transport and machinery	33	Consumer durables	24	Building and construction	21
Antimony	Batteries	68	Bearing and type metals	12	Chemicals, paints and enamels	
Beryllium	Copper alloys	90				
Cadmium	Electroplating	65	Bearing metal and solders		Pigments and chemicals	
Copper	Electrical equipment	37	Transport	14	Building	12
Lead	Batteries	34	Cables	11	Construction	11
Tin	Tin plate	54	Solder and other alloys	37		
Zinc	Galvanizing	33	Die casting	20	Pigments and salts	18
Chromium	Stainless steel	50	Refractories	35	Chemicals and electroplating	
Cobalt	High temperature-resisting steel	42	Non-ferrous alloys	33	Chemicals	25
Columbium	Durable, high temperature steel	99				
Manganese	Steel flux and toughening alloy	80	Dry cells		Chemicals	
Molybdenum	Hard tool steel	90	Chemicals		Ceramics	
Nickel	Corrosion-resisting steel	43	Non-ferrous alloys	34	Electroplating	
Tungsten	Tough tool steel	63	Electric filament, electrodes		Carbides	
Vanadium	Hard steel	99	Chemicals		Dyestuffs	

Source: President's Materials Policy Commission, *Resources for Freedom*, volume II.

* The percentages give approximately the proportion of the total quantity of each metal used for the stated purpose in the United States in 1950. This distribution of consumption should be regarded as indicative rather than definitive; for all metals, the "newer" industrial metals in particular, use is subject to continuous and sometimes rapid change, for technological, price and other reasons. Though differing in a number of details—such as a greater use of lead in building and construction—the pattern of non-ferrous metal use is much the same as this in western Europe.

the production of capital goods. In the past, however, the demand for consumer durables and the demand for capital goods have tended to move together, reinforcing each other and thus increasing the amplitude of the fluctuations in the demand for non-ferrous metals.

Over and above these ordinary civilian uses of non-ferrous metals, there is the demand generated by armament production and war. At one stage, for example, nickel was used almost exclusively for the production of special steels for military use, and the high manganese steels are still used very extensively in armaments. Lead is the traditional material from which bullets are made, but several other non-ferrous metals are major components of the more modern, complex military equipment. As a result, war or threat of war is likely to cause a considerable increase in total demand and a marked distortion in the pattern of consumption. Though in some cases such changes have had permanent effects on technique and demand, they have usually been sudden, large and comparatively short-lived, thus adding significantly to the general instability of the non-ferrous metals market.

Great as the fluctuations have been in the physical quantity of the non-ferrous metals consumed, they tell only part of the story. Suppliers are concerned as much with the price of the metal as with the volume sold, and in general these two variables have tended to move in the same direction. Other things remaining the same, elasticity of supply being fairly low, a decline in demand results in a more than proportionate decline in price, and a rise in demand results in a more than proportionate rise in price; hence, fluctuations in receipts from mineral sales have in general been much greater than fluctuations in either consumption or price. This is obviously of special importance to those under-developed countries in which the export of minerals provides a significant proportion of aggregate foreign exchange earnings.

From the short-term point of view of the metal producer, the use to which his product is put—dissipative or conservative, for stockpiling or for making up into consumer goods or capital goods or armaments—is not of immediate significance; the actual sale of the metal is his prime concern. From the point of view of future demand, however, the destination of current sales is obviously important. For example, when the metal is used in ways in which it is conserved, some proportion of it is likely to return to the market in due course as scrap. Stocks, which are accumulated at various stages in the flow of material from the mine to the ultimate consumer, and in the aggregate account for a considerable volume of metal, tend to exercise an even more direct influence on the market.

Except in the case of some of the "newer" industrial metals whose supply is still somewhat uncertain, the secular growth of commercial stocks has been slower than that of consumption, and, in general, there appears to have been a relative decline in the volume of metal in the hands of merchants and manufacturers. Nevertheless, the demand for metal for stock has usually tended to exert a destabilizing influence on the market, often expanding shortly after manufacturing production begins to increase and prices to harden, and contracting shortly after manufacturing production begins to decline and prices to ease, thus reinforcing the effects of cyclical fluctuations in factory demand for the metals and user demand for their products.

In this respect, stocks held inside the industrial mechanism are quite different from stocks accumulated by producers of the metals for the purpose of stabilizing the market. The latter are designed to be run down when market demand exceeds current rates of mine output and to be added to when demand falls below mine output. An example of this type of stock is the buffer pool operated by the tin industry in the nineteen thirties, an arrangement which is described briefly in chapter 3 of the present study.

Another type of inventory accumulation is the so-called "strategic stockpile". The building up of such stockpiles augmented German and Japanese purchases on world markets in the second half of the nineteen thirties and has played an important part in inflating total demand for all the non-ferrous metals in the post-war period. Although the intention with regard to contemporary stockpiles has been to accumulate them without disrupting the ordinary market, security criteria are always likely to prevail over considerations of stability, and the desire to attain specified objectives within a relatively short period has frequently made stockpile purchases a significant addition to normal demand. The increase in United States stockpiling during the period following the outbreak of hostilities in Korea, for example, undoubtedly contributed to the rapid upsurge of mineral and other raw material prices in the second half of 1950. Since then, however, the halting of stockpile buying and the release of supplies (of copper, for example) have helped on several occasions to ease temporary stringency, while an acceleration of the rate of stockpiling (of lead and zinc, for example) has been used to offset declines in ordinary commercial demand.

The long-run effects of government stockpiles may be very small, perhaps no more than the permanent withdrawal of specific quantities of the materials from the market, although some non-ferrous metal producers appear to feel that the mere existence of a supply which may ultimately be placed on the market in competition with new production is a deterrent to further mining investment. Such a deterrent would be magnified if the security considerations which have caused the building up of national stockpiles also induced private dealers and fabricators to carry more than normal stocks, similarly susceptible of reduction without regard to the effects on primary producers.

As indicated above, the levels of consumption of the various non-ferrous metals, whether in their pure form or in the form of alloys made up of combinations of the metals—brasses, bronzes, solders and bearing metals which consist of copper, zinc, tin, lead, antimony and beryllium in prescribed proportions—are mutually influenced by the demand for machinery, vehicles, buildings, armaments and durable goods in general. Changes in the demand for durable goods, in other words, are thus reflected in corresponding changes in the demand for the whole range of non-ferrous metals; there is a tendency, at least in the short run, for rates of consumption—technological innovations apart—to move together. This is reinforced to a certain extent by the fact that in many uses one metal can be substituted for another. As the possibility of substitution has an important bearing on future demand for the various metals it is discussed in the next section.

Substitution and technological change

The demand for the various non-ferrous metals is influenced not only by their common dependence upon the demand for durable goods but also by the fact that essential properties are not invariably associated uniquely with any one metal but in a number of cases are shared by several. In consequence of this, there is a considerable amount of substitution between the metals, some of no more than transitory significance, reflecting temporary changes in price relationships or availability, some of it of more permanent significance, reflecting long-run changes in demand or technology. These changes in technology may be the fruit of scientific progress as such, but to a certain extent they may themselves be induced by changes in relative prices or scarcities, which guide and stimulate research into particular problems of substitution or utilization. The increased use of aluminium in recent years, for example, reflects not only expansion in the demand for products in which the metal has special advantages but also advances in the techniques of working this metal which have permitted its use in place of other materials, and both of these developments have been encouraged by more favourable price ratios, in relation to copper, magnesium and steel in particular.

As illustrations of temporary changes may be cited many of the substitutions brought about by the relative scarcities manifested during the war and the recent rearmament phase. Molybdenum and vanadium tended to replace tungsten as a hardening agent for steel when supplies of tungsten proved insufficient, Chinese output having ceased to flow to European and American markets. Chromium was used to supplement nickel, supplies of which were not capable of an increase sufficiently rapid to serve the suddenly enlarged demand for high-temperature steels. Titanium was used to supplement antimony for pigment purposes before the decline in Chinese supplies of the latter was offset by increases elsewhere. When cadmium-based pigments were in short supply, owing to the inadequacy of refining capacity, there was a tendency to replace them by zinc-based pigments, and at the same time, zinc plating came to be regarded as a reasonable substitute for the cadmium plating generally used for protection of small or intricately shaped objects.

Strain on the copper supply was eased somewhat by the substitution of aluminium, production of which was capable of more rapid increase. In this case, the short-term expedient operated in the same direction as the long-term trend, for aluminium—not more than a laboratory curiosity at the beginning of the electrical era—has rapidly been replacing copper and lead, as well as steel and timber, in many traditional uses of these materials.[2] Its ability to resist corrosion and to conduct electricity is of the same order as that of copper, while its lightness gives it a great advantage over most metals. By 1952, in the United States over 2 million miles of ACSR cable (aluminium conductor, steel reinforced) had been laid for high-voltage, long-distance distribution of electric current—a field at one time served exclusively by copper. Lighter electric wires are also being made increasingly from aluminium, and since the war there has been a considerable expansion in the use of aluminium for sheathing electric cables—a function that was performed by lead until the end of the nineteen thirties, when substitution began on an experimental scale in Germany. In building and construction, the field in which the post-war increase in the use of the metal has been most rapid, aluminium has been replacing not only copper and brass but also several other conventional materials; it is now being used for roofing and siding, conduits and ducts, door and window frames and many items of interior hardware. It has also replaced lead and tin as a foil material and is a serious competitor in the field of paints and pigments.

Lead is giving way not only to aluminium but also to copper, especially in its traditional field of plumbing. In cable making, lead is being gradually replaced not only by aluminium but by plastic materials such as polyethylene. For making pigments, lead, like antimony, is being displaced by the plentiful and less toxic compounds of titanium. Metallic titanium in the meanwhile bids fair to repeat the aluminium story. Since its first production on a commercial scale in the early post-war years, there have been indications that this metal is becoming a serious competitor in those fields in which high tensile strength (equal to that of steel), light weight (two-thirds that of steel) and high resistance to temperature and corrosion are important. When, through improved technology, its price is lowered, its machinability improved and its alloying propensities better explored, it is expected to replace some of the stainless steels, copper-based and nickel-based alloys and aluminium now being used under conditions of high temperature or exposure to corrosion.

Some of the competitive advantages enjoyed by aluminium are likely to be duplicated by magnesium, an even lighter metal (one-fourth the density of steel) which can be derived from a plentiful raw material, sea-water, by the application of 9 to 10 kilowatt-hours of electricity per pound of metal—power consumption of much the

[2] An interesting reversal of the historical trend was the emergency use of plywood and fibre for the construction of certain types of light aircraft during the war. This is another illustration of the competitive relationship between materials. Much more detailed treatment of one aspect of this general phenomenon is provided in a recent report of the United Nations Economic Commission for Europe, *Competition between Steel and Aluminium* (E/ECE/184).

same order as that required for the refining of aluminium. Zinc has already been replaced to a considerable extent by aluminium in the field of die-casting, and it is probable that both metals will be replaced to an increasing extent by magnesium, not only in this field but also for dry cells and engraving plates. As unclad magnesium tends to corrode easily under stress or in contact with iron, copper, aluminium or sea air,[3] its current use for structural purposes is largely limited to low stress parts such as flooring, although thicker cross-section shapes are now coming on to the market, and considerable research is being undertaken into production of alloys with zirconium and cerium, as well as commoner metals.

The metal silicon comes from a raw material even more plentiful than the materials from which aluminium and magnesium come. It is lighter than aluminium, has a melting point only just below that of iron and is highly resistant to corrosion. In 1955, its price, at between 18 and 19 cents per pound (97 per cent Si), compared favourably with those of the other non-ferrous metals. Since in its pure state it is extremely brittle, the principal commercial uses for which it is currently employed are in the production of ferrosilicon and in the coating (against oxidation and corrosion) of steel and molybdenum, though synthetic organic compounds of silicon are finding an increasing number of uses because of their special property of remaining stable over a considerable range of temperature.

The four metals silicon, aluminium, magnesium and titanium are by far the most abundant in the earth's crust,[4] but up to the present only aluminium has entered into general industrial use. This is largely a reflection of the state of technology. Advances in recovery techniques, in particular, have been responsible for a steady decline in the cost of aluminium over the past 60 years, gradually improving its competitive position in relation to other non-ferrous metals. The same process appears to be under way in the case of titanium while magnesium and 97 per cent silicon have been within the customary non-ferrous price range for some time. As the price of the pure metal reaches competitive levels, so research into the technology of utilization, alone or in alloy form, tends to be stimulated, rapidly widening the field of employment and encouraging in its turn further advances in the technique of recovery.

In general, changes in use follow in the wake of technological advances. It is only recently, for example, that it has become commercially practicable to press the metal casing of ordnance shells out of sheet steel or that aluminium could be used for the caps of electric lamps, both changes tending to displace the brass customarily used.

In those fields in which technological developments have made the various non-ferrous metals mutually competitive, relative prices tend to become a major determinant of use. One of the reasons for the displacement of lead in recent years, for example, has been the loss of part of the price advantage it previously enjoyed: during the first two decades of the present century the price of lead, on an average, was about one-third that of copper; during the nineteen thirties it was about one-half; and in the post-war period, 1946 to 1951, about two-thirds (chart 1). Similarly, the use of aluminium has been stimulated by a rapid relative decline in its price: in 1932 its average price was more than four times that of copper; during the second half of the nineteen thirties it averaged only about twice as much; during the war it declined to little more than one-fourth above the copper price, while in the period from 1947 to 1951 it was not much more than three-fourths of it.

There is thus a very close and mutually determining relationship between technological progress, demand and price. In the short run, technology—in mining and refining no less than in alloying and fabricating—probably exerts a dominant influence on substitution between metals. In the long run, however, even though the demand for non-ferrous metals as a whole is fairly inelastic, the fact that substitution of one metal for another is technically possible tends to throw the emphasis on relative price as a determinant of demand for a particular metal.

In the present context, one significant aspect of developments such as these lies in the fact that they are likely to take place in the industrial countries, especially in the United States, which possesses substantial resources of the ores of all four of the "new" metals. Whether or not a relative increase in the use of these "new" metals will react unfavourably on the non-ferrous metals industry in under-developed areas depends upon the future course of demand and the extent to which they are alloyed with metals produced in those areas. Certainly no great international trade can be expected in the raw materials for magnesium and silicon production, which are so generally available. Also, improvements in aluminium technology which made it economic to use low-grade clays as a source of the metal would doubtless tend to reduce the trade in bauxite, though they would not necessarily eliminate the advantage in the production of aluminium enjoyed by those countries that possess extensive high-grade bauxite deposits. Until techniques for working with low-grade ores are evolved, international trade in ilmenite and rutile, the high-grade ores of titanium, will undoubtedly increase. However, the United States, which

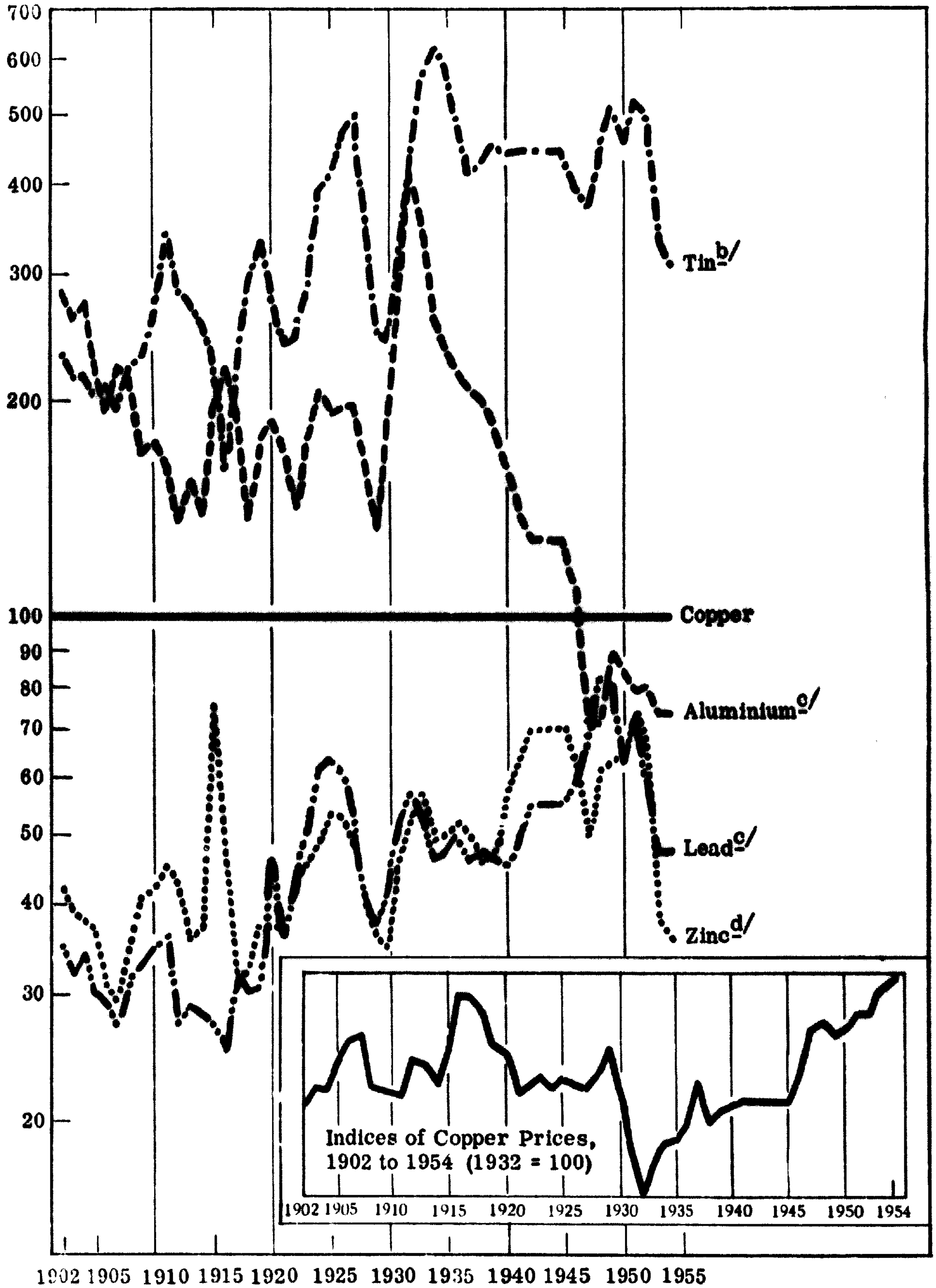
---

[3] Magnesium's reaction with sea-water, however, is opening up an increasing use of the metal as "galvanic anodes" for protecting the steel of ships' hulls, for example, against electrolytic corrosion.

[4] According to calculations made by F. W. Clarke of the United States Geological Survey, tin and molybdenum are the rarest of the common non-ferrous metals, each accounting for only 0.001 per cent of the earth's crust. If tin (or molybdenum) is taken as unity, the relative abundance (though not necessarily the availability) of the other non-ferrous metals is indicated in the following list: cobalt (10), lead (20), columbium and tantalum (30), zinc (40), tungsten (50), copper (100), vanadium (170), nickel (200), chromium (370), manganese (1,000), titanium (6,300), magnesium (20,900), aluminium (81,300) and silicon (277,200). In assessing the significance of these figures it must be borne in mind that the composition of the most accessible parts of the earth's crust is not necessarily the same, and that in the foreseeable future it is only mineral deposits of relatively high metallic content which are likely to be economically workable, and these are comparatively rare.

Chart 1. Price Relationships among Major Non-Ferrous Metals, 1902 to 1954

(Average annual price of copper[a] = 100)



Source: American Bureau of Metal Statistics, *Yearbook, 1954.*

[a] Electrolytic, New York.

[b] 1902 to 1919: standard, New York; 1920 to 1954: Straits, New York.

[c] New York.

[d] St. Louis

is well endowed at least with the former, might import relatively less than it currently obtains from Australia, Canada and India.

Other substitutions are practised besides those which involve two non-ferrous metals. One such substitution has been made possible by recent developments in the field of powder metallurgy that are beginning to open up techniques by which substantial savings of primary metal can be made through use of iron powder in place of more costly non-ferrous metals as well as through reduction of the inevitable waste which accompanies the processes of casting, cutting, milling and machining parts made of the non-ferrous metals themselves. In the production of heat-resistant materials, whose use is rapidly increasing, powder metallurgy offers the further advantage of facilitating the incorporation into the alloy of borides, carbides and silicides.

In a similar way, technical advances in the production of plastic materials have already given them certain advantages over non-ferrous metals, and this trend may well continue. The manufacture of plastics from reproducible sources of cellulose at costs which compare favourably with the cost of smelting metals from exhaustible reserves of ore would place the industrial countries, with their well developed chemical industries, at an advantage over many of the less developed countries which are now important producers of non-ferrous metals. In the long run, however, a number of the latter, by virtue of their tropical location, might become significant suppliers of the basic materials required by the plastics industry. Up to the present, however, those synthetic products which, as mouldings or laminated sheets, have competed most successfully with metals, have been the phenolics and the polyester and polystyrene resins, which are derived from a mineral, coal (tar) or petroleum, base. The plastics industry is a comparatively new one: commercial use began only after the First World War, and widespread use for industrial and household purposes is a recent development. United States production amounted to a mere 3,000 tons in 1922, but by 1950 it had exceeded the million-ton mark, and much of the output was used for purposes previously served by metals. Beyond noting the competitive relationship between certain of the non-ferrous metals and certain of the plastic materials, no attempt will be made to predict the extent to which plastics may displace metals in the future.

Even less predictable is the effect of techniques that replace the direct use of materials by various forms of energy. Cutting by means of an oxy-acetylene flame is a well-established procedure, but drilling and carrying out other operations by means of electrical discharge or ultra-sonic energy are techniques whose potentialities are at present virtually unexplored. In general, it would appear that the spread of these devices is likely to increase the demand for electricity and hence for the metals associated with its generation, distribution and conversion to usable forms, while at the same time reducing the demand for special tool steels and the ferroalloys that go into them.

Technological developments of the type discussed in this section are generally the result of periods of very active demand, during which in the face of metal scarcities (and high prices) more or less systematic attempts are made, especially in the principal consuming countries, to increase available supplies or to economize in use, or both. The first purpose is achieved by improvements in the methods of discovery (of unexposed deposits, for example) and of recovery (from low concentrations, for example, whether of low-grade ore or of scrap or secondary sources). The second purpose is achieved by methods which either use less of the given metal for performing a given function (as in the case of electrolytic tinplating[5] or the development of more durable, more efficient or lighter machinery) or substitute a more abundant or cheaper material for that which is scarce or costly.

Fluctuations in consumption

Although the first half of the twentieth century saw a considerable expansion in the rate of consumption of all non-ferrous metals, it also saw an appreciable decline in the ratio of the volume of non-ferrous metals consumption to the gross value of industrial production. Part of this decline was due to a shift in the relative importance of industries away from the large users of non-ferrous metals, part reflects the tendency for heavy metals to be replaced by lighter ones, but most of it probably has resulted from technical advances which brought about economies within the metal-using industries, and from the increase in the amount of processing undergone by each ton of metal because of the growing elaboration of the final product.

Technical developments which result either in economies or, conversely, in new metal uses exert a long-term influence on the pattern of consumption. Substitutions between metals, on the other hand, tend to increase the short-term elasticity of demand, making for year-to-year fluctuations in the pattern of consumption. Superimposed upon these tendencies has been the cyclical pattern of economic activity which has characterized private enterprise economies, affecting most markedly the level of new investment and the production of capital goods and hence the demand for metals. Also, the pattern of metal consumption during the past 50 years has been strongly influenced by war or threat of war.

The consumption of all non-ferrous metals reached unprecedentedly high levels during the First World War, only to fall to corresponding depths in 1921. The irregular upward movement which followed reached its peak—well above war-time levels—in the boom year of 1929, but in the great depression of 1931 to 1933 consumption dropped to levels comparable with those of the first decade of the century: in 1932, world consump-

[5] Progressive improvement in the process of tinplating has reduced the weight of tin required to plate a basic box (of 112 sheets 20 inches by 14 inches) from about 14 pounds 200 years ago, and nine pounds 100 years ago, to two and one half pounds in 1900, one pound in 1938 and not much more than one quarter of a pound with the latest electrolytic method.

tion of the major non-ferrous metals was little more than half the high figure of three years earlier. The rise which followed was brought to a halt by an inventory recession originating in the United States in 1938, the 1937 peak having barely reached the 1929 level of consumption. European rearmament supervened, however, and consumption of all base metals soared to new heights during the Second World War. World consumption of copper, tin and zinc, for example, reached levels more than one-third higher than the previous peaks of 1929 and 1937.

The immediate post-war decline, which carried world consumption of some of the major non-ferrous metals (lead, tin and zinc, for example) well below 1938 levels, was moderated first by demand generated by reconstruction programmes and by the demand pent-up during the period of war-time scarcity, and then by the stockpiling of essential materials (including most of the non-ferrous metals) by various governments. This, however, was not sufficient to restore world consumption of lead, tin or zinc to peak pre-war rates or to prevent a slight decline in over-all metal consumption in 1949 when the backlog of demand for durable goods in the United States had been more or less exhausted and commercial inventories were tending to accumulate.

Production of durables began rising again in 1950, with total base metal consumption beginning to show the effects of the recovery of economic activity in western Germany and Japan; but a much greater influence on the demand for non-ferrous metals was exerted by the outbreak of hostilities in Korea and the launching, later in the year, of various national rearmament programmes. In the United States, now absorbing about one-half of the world's new supplies (excluding those of the Soviet Union and mainland China) of most of the non-ferrous metals, a major feature of the programme was the planned increase in both stockpile targets and productive capacity. This entailed a substantial increase in the immediate demand for most of the metals, not only for armaments and new facilities but also for filling industrial "pipelines" in preparation for greater rates of production, as well as to meet hoarding and speculative requirements arising from the threat of shortage. The result was a considerable strain on available supplies and a notable rise in prices of most metals. During 1951 various means were employed to control prices, to allocate existing supplies on both national and international levels and to encourage an increase in the output of strategic materials, non-ferrous metals among them. By the end of the year, prices had receded from their earlier peaks, and supplies of most of the metals were somewhat more plentiful, even though several of them were still subject to rationing in many countries. Controls on consumption were progressively relaxed during 1952, very few being operative at the end of the year, by which time prices of the metals except aluminium, copper, molybdenum and nickel had declined markedly from 1951 peaks. With these exceptions, all the non-ferrous metals remained in fairly easy supply throughout 1953 and 1954 as investments made in 1950 and 1951 began to yield additional supplies. During 1954, moreover, United States demand slackened markedly, and on several occasions the strategic stockpile was used to take surpluses (of lead and zinc, for example) off the market.

As a result of these broad movements of demand there were periods of several years in succession, especially during the early nineteen twenties and the early nineteen thirties, when, despite the low prices which prevailed, the mines were capable of supplying far more than was being consumed, and the problem was seen as one of restricting production. To meet the situation various producer groups, national and international, were formed, to divide the market and set annual production quotas, and in general, to attempt to maintain prices.[6] At other times, especially during the wars but also during the 1929 boom and the 1950 rearmament phase, current output was inadequate, and the problem became one of restraining demand and creating governmental machinery for rationing available supplies among competing users. For producers, the situation thus fluctuated between large output at a relatively high price and small output at a much lower price, a variation with very awkward consequences for those under-developed countries which depended to any great extent for their foreign exchange earnings upon the export of non-ferrous metals.

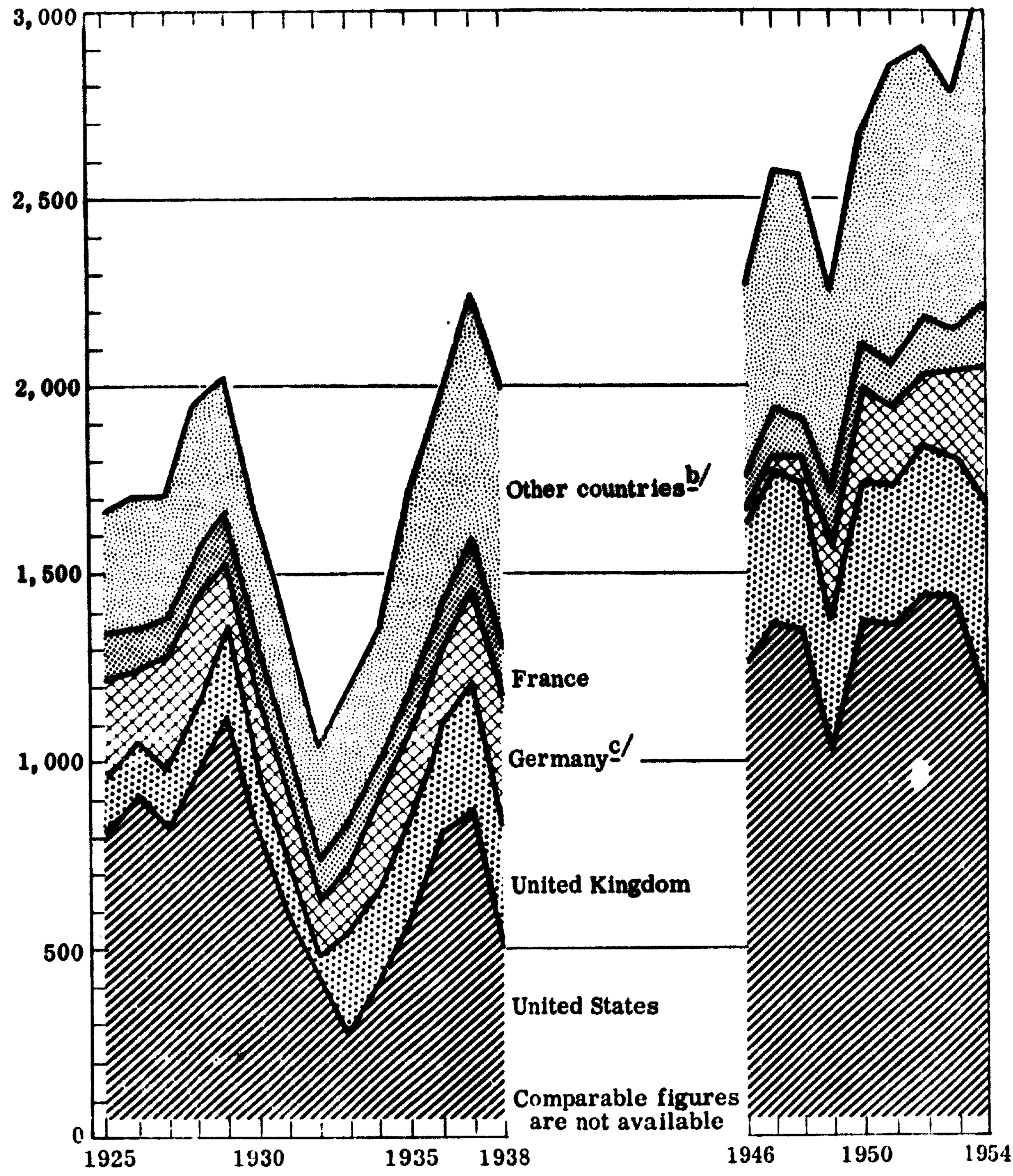
Within this general framework, consumption trends have differed appreciably from one non-ferrous metal to another (charts 2 to 6). On the one hand, the use of certain metals has shown a marked tendency to increase, aluminium among the major metals, cobalt and molybdenum among the alloy metals being the most notable examples, with copper and, to a smaller degree, zinc also showing a distinct upward trend if successive peaks—1912, 1918, 1929, 1937, 1943 and 1954—are considered. On the other hand, the consumption of tin and lead among the major metals and manganese among the additive metals has shown much less disposition to increase. Both lead and tin consumption rose steadily to the First World War peak, and then more rapidly from a post-war low to the 1929 peak; in the case of tin, this level was not regained in subsequent years, while in the case of lead the 1929 level was exceeded by 2 per cent in 1937 and by about 7 per cent in 1954.

Among the industrial countries the five chief consumers —United States, United Kingdom, western Germany, France and Japan—account for more than two-thirds of the total current consumption (outside the Soviet Union) of each of the non-ferrous metals. In the United States, the particularly rapid growth of consumption reflects the great expansion of metal-using industries in the first half of the twentieth century. Despite precipitate declines in the years 1921 and 1932, and appreciable declines in 1914 and 1938, the secular trend in consumption has been decidedly upwards for each of the metals at present under review, the rise being most marked in the case of aluminium (and bauxite), among the major metals, and chromium, cobalt and molybdenum among the additive

[6] The activities of some of these groups are discussed in chapter 3 of the present study.

Chart 2. Apparent Consumption[a] of Copper in Selected Countries, 1925 to 1938 and 1946 to 1954

(Thousands of short tons)



Source: United States National Security Resources Board, *Materials Survey: Copper, 1952* (Washington, D.C., September 1952); American Bureau of Metal Statistics, *Yearbook, 1954.*

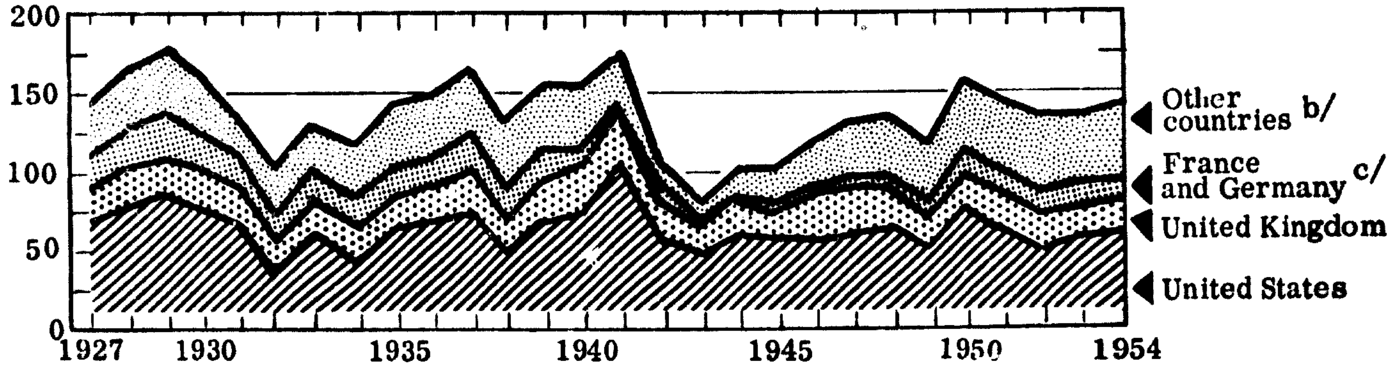
[a] Equivalent to production plus imports minus exports, allowing for changes in commercial stocks where possible; government strategic stockpiles are excluded.

[b] Excluding the Union of Soviet Socialist Republics.

[c] Beginning 1946: including a sizable proportion from scrap. 1946 to 1948: based on production in the United Kingdom and the United States zones; beginning 1949: Federal Republic.

Chart 3. Apparent Consumption[a] of Tin in Selected Countries, 1927 to 1954

(Thousands of long tons)



Source: United States National Security Resources Board, *Materials Survey: Tin* (Washington, D.C., June 1953); American Bureau of Metal Statistics, *Yearbook, 1954*; International Tin Study Group, *Statistical Bulletin* (The Hague, June 1955).

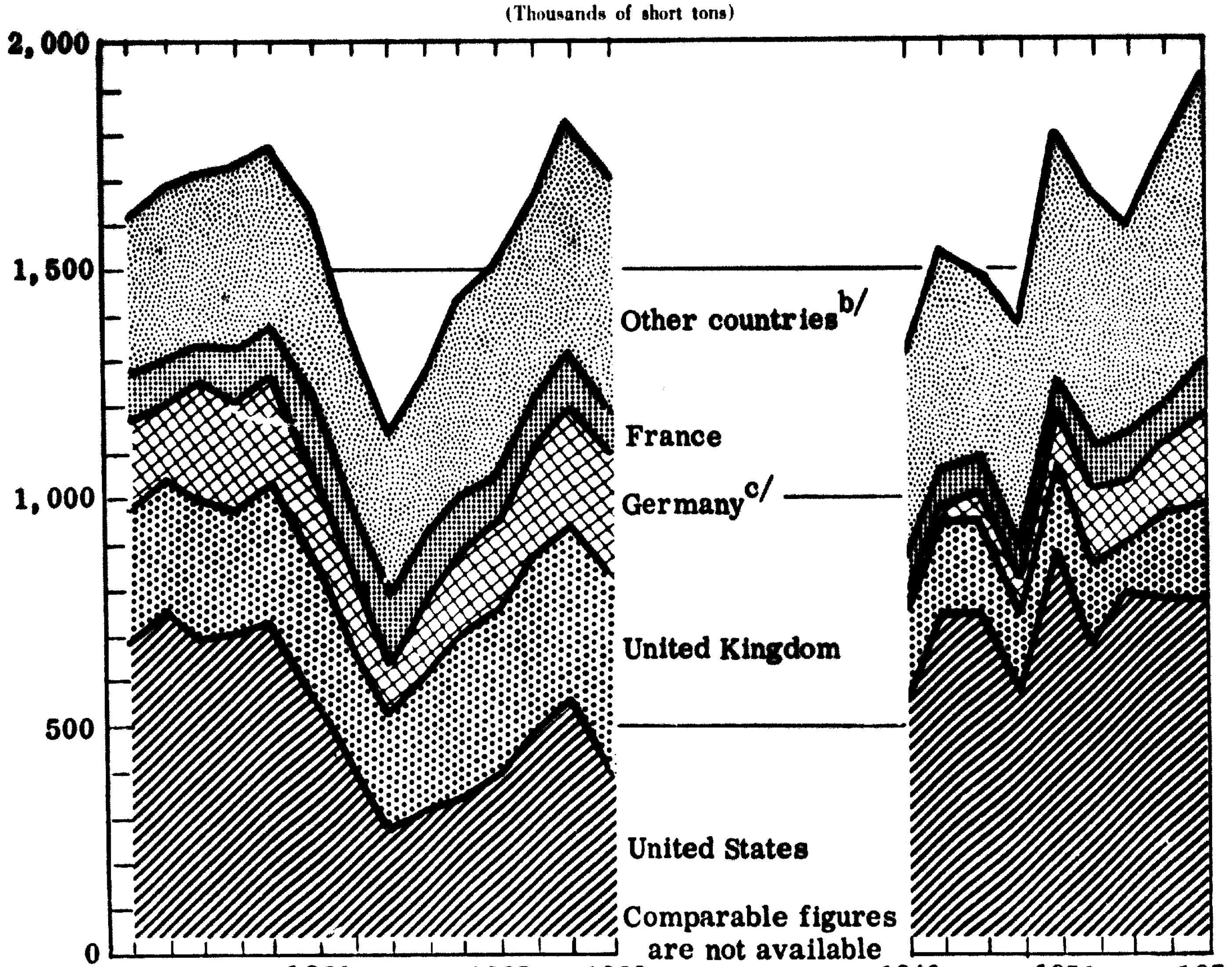
[a] See footnote *a*, chart 2.

[b] Excluding the Union of Soviet Socialist Republics.

[c] 1927 to 1935: including Austria.

Chart 4. Apparent Consumption[a] of Lead in Selected Countries, 1925 to 1938 and 1946 to 1954

(Thousands of short tons)



Source: United States National Security Resources Board, *Materials Survey: Lead, 1950* (Washington, D.C., May 1951); American Bureau of Metal Statistics, *Yearbook, 1954*.

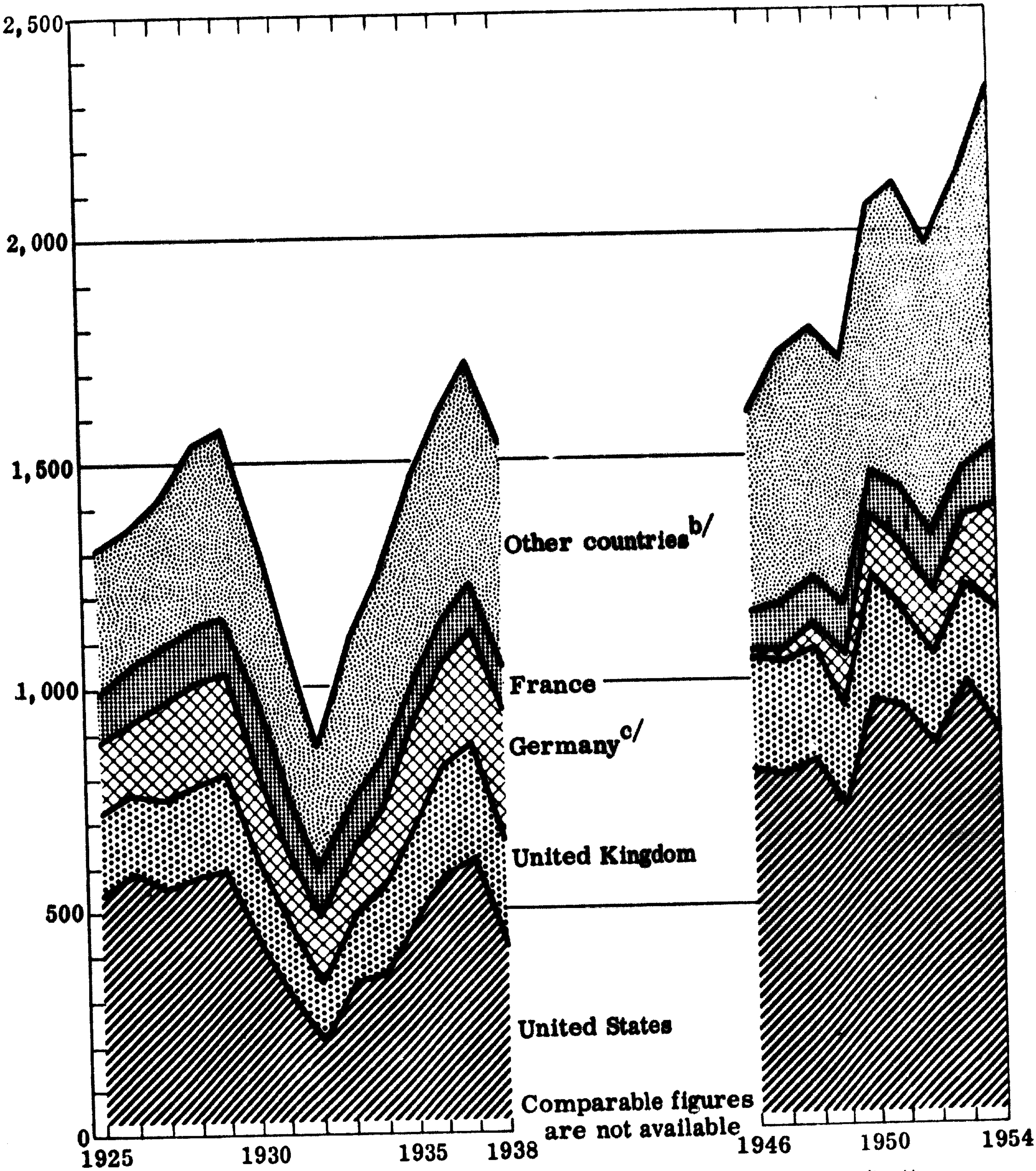
[a] See footnote *a*, chart 2.

[b] Excluding the Union of Soviet Socialist Republics.

[c] 1946 to 1947: based on production in United Kingdom zone; beginning 1949: production in Federal Republic, plus imports minus exports.

Chart 5. Apparent Consumption of Zinc[a] in Selected Countries, 1925 to 1938 and 1946 to 1954

(Thousands of short tons)



Source: United States National Security Resources Board, *Materials Survey: Zinc* (Washington, D. C., March 1951); American Bureau of Metal Statistics, *Yearbook, 1954.*

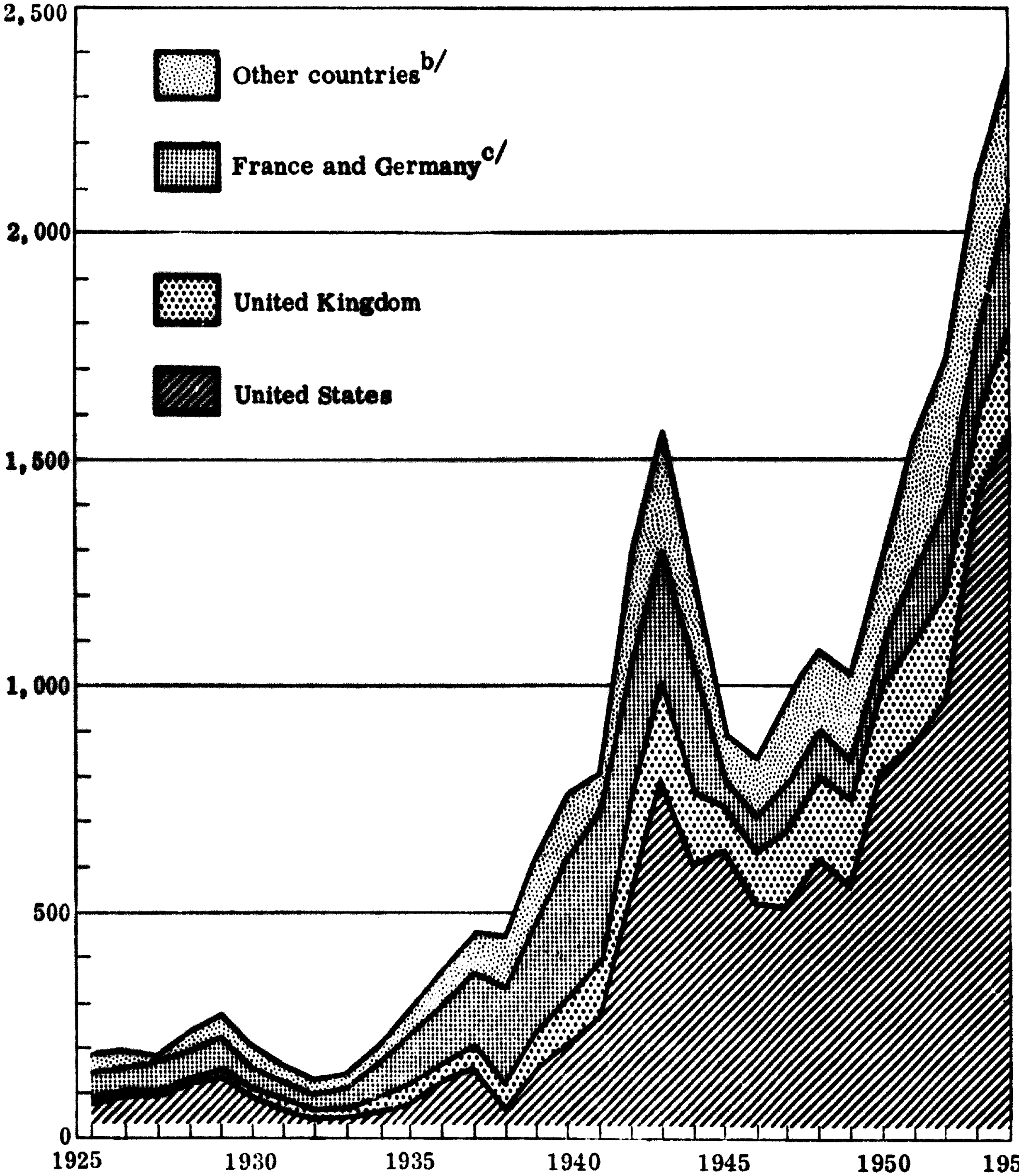
[a] Primary spelter and slab; for definition of "apparent consumption" see footnote *a*, chart 2.

[b] Excluding the Union of Soviet Socialist Republics.

[c] 1946 to 1947: based on production in the United Kingdom and United States zones, including some secondary zinc; 1948: production plus imports, estimated at 5,500 tons; beginning 1949: Federal Republic, production plus imports minus exports.

Chart 6. Apparent Consumption[a] of Aluminium in Selected Countries, 1925 to 1954

(Thousands of metric tons)



Source: American Bureau of Metal Statistics, *Yearbook, 1954* (New York, 1955); Metallgesellschaft Aktiengesellschaft, *Statistische Zusammenstellungen* for 1925 to 1933 and *Metal Statistics*, for 1928 to 1937 and 1938 to 1952.

[a] See footnote *a*, chart 2.

[b] Excluding the Union of Soviet Socialist Republics.

[c] 1938 to 1944: including Austria.

metals (see charts 7 and 8). The effect of the depression of the early nineteen thirties was more than offset by the impetus given to consumption by the Second World War. As a result, the United States emerged by far the largest consumer; average annual consumption (in terms of the combined tonnage of the major metals) in the five years immediately after the war was about double the average of the five years preceding the war, the greatest increases having taken place in aluminium and copper consumption.

In the United Kingdom, post-war consumption, except in the case of lead, was well up to pre-war level, accounting for between a sixth and a fourth of the world supplies of the major metals and a rather higher proportion of most of the minor metals. French post-war consumption, again with the exception of lead, has also been well up to pre-war rates, accounting for 4 to 7 per cent of the world total. Before the war, Germany consumed between a twelfth and a sixth of most of the non-ferrous metal supplies—rather less in the case of tin, rather more in the case of aluminium. From very low rates in the immediate post-war years, consumption both in western Germany and in Japan rose rapidly after 1948, but—except in the case of aluminium—it had not regained pre-war levels by 1954. Among other significant consumers which have maintained or increased their pre-war rates of consumption, at least in absolute terms, are Italy, Belgium and Sweden, while Canada, apart from being a producer of many of the non-ferrous metals, has increased in both absolute and relative importance as a user. In western Europe as a whole, as in the United States, it is the consumption of aluminium that has shown the greatest increase in the post-war period (table 3). By 1950, for example, aluminium consumption in the former was running at double the pre-war rate, while, at least until 1951, consumption of lead, nickel and tin was appreciably less than before the war.

The complex of economic and technical forces which determine the demand for a particular metal at any moment of time is far too involved to justify any forecast of future demand in a study of this nature. This would be true even for a single country for which accurate and comprehensive statistics were available; for world demand predictions could hardly be more than guesses.

The demand for tin, for example, which would appear from recent trends to be unlikely to expand greatly, might increase considerably as a result of experiments now being conducted at the Tin Research Institute on the use of metal in new bearing alloys, in new tableware alloys, in organic compounds as plastic stabilizers and biocides and for other metallurgical and chemical purposes. At the other end of the scale, the demand for aluminium, which has been rising rapidly in recent years, might be seriously threatened if some of the difficulties in the re-

Table 3. Indices of Consumption of Major Non-Ferrous Metals in Western Europe[a] and the United States, 1935-38 and 1948 to 1954

(1935-38=100)

Metal	Average 1935-38 consumption (thousands of metric tons)	Indices						
		1948	1949	1950	1951	1952	1953	1954
Aluminium:								
Western Europe	190	198	191	212	273	293	266	305[b]
United States	113	550	510	721	784	856	1,243	1,370
Copper:								
Western Europe	827	97	95	109	113	116	100	130[b]
United States	633	192	148	197	196	207	207	173
Lead:								
Western Europe	752	60	59	68	78	62	75	117
United States	416	163	126	193	148	171	171	170
Nickel:								
Western Europe	39	71	73	85	96	96	105	111[b]
United States	34	277	201	291	254	299	311	279
Tin:								
Western Europe	56	81	73	89	89	97	82	92
United States	63	95	75	113	91	72	80	87
Zinc:								
Western Europe	654	84	88	106	104	91	100	125
United States	472	157	137	186	179	164	189	168

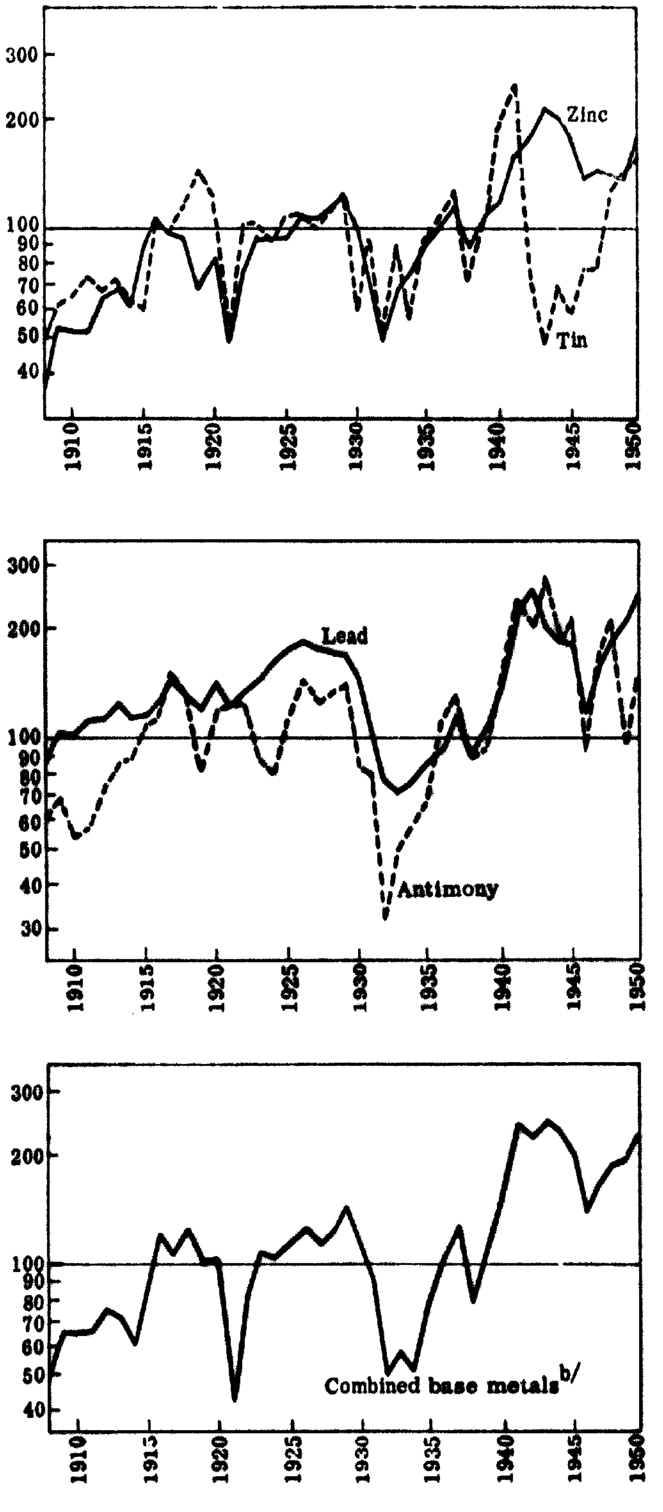
Source: Organisation for European Economic Co-operation, *The Non-Ferrous Metal Industry in Europe* (Paris, 1954), page 57; International Tin Study Group, *Statistical Yearbook, 1954*; American Bureau of Metal Statistics, *Yearbook*; United States Bureau of Mines, *Materials Survey: Nickel* (Washington, D. C., 1952).

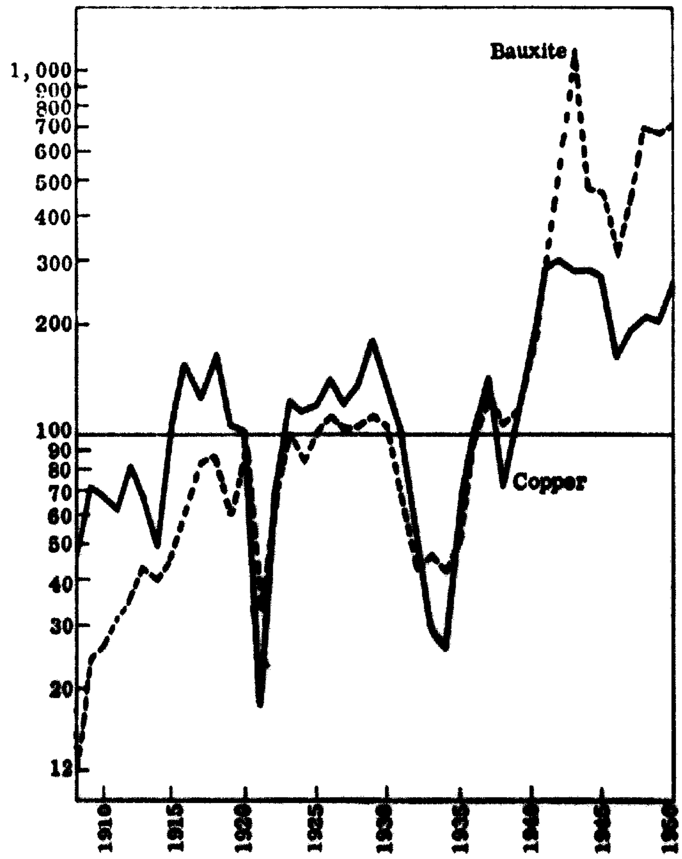
[a] Based on apparent consumption of the primary metal (production plus imports less exports) in Austria, Belgium, Denmark, France, western Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland, Trieste, Turkey and United Kingdom.

[b] Based on consumption during the first half of the year; consumption in the second half appears to have been at an appreciably higher level.

Chart 7. Indices of Apparent Consumption[a] of Major Non-Ferrous Metals, United States, 1908 to 1950

(1935-39 = 100)





Source: President's Materials Policy Commission, ***Resources for Freedom***, volume II: "The Outlook for Key Commodities".

[a] Contained metal in primary production, plus imports minus exports, at constant dollars and 1935-39 average unit values.

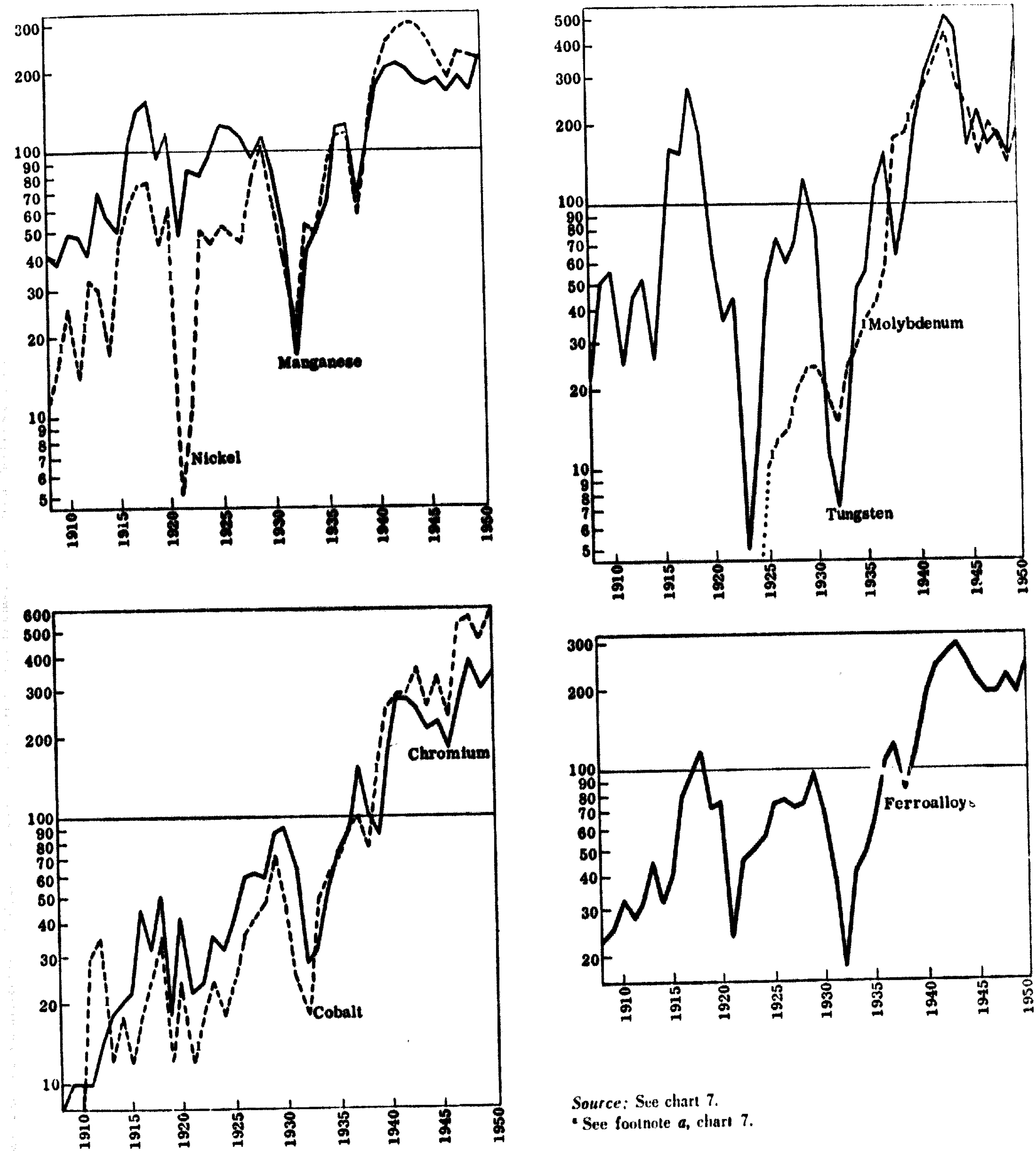
[b] Antimony, bauxite, cadmium, copper, lead, magnesium, mercury, tin, titanium and zinc.

fining and use of titanium were soon resolved. Over the past two decades, the demand for lead has shown little tendency to grow, but an extension of atomic energy to industrial use might change the prospects. If attempts to conserve and re-use manganese in steel smelters were finally successful, the demand for newly mined manganese, which on the whole has not expanded greatly since the First World War, would probably show a marked decline.

Even the immediate and direct effects of technical developments of this nature are difficult to foresee with any degree of precision. Indirect effects of technical changes and the effects of changes in price relationships, whether due to changes in the pattern of use of one of the non-

Chart 8. Indices of Apparent Consumption[a] of the Additive Metals, United States, 1908 to 1950

(1935-39 = 100)



Source: See chart 7.
[a] See footnote *a*, chart 7.

ferrous metals or to changes in the source or method of production of that metal or substitutes for it, are much more difficult to predict. Indeed, the only basis on which even short-term prediction can be undertaken involves the assumption that these things will not change during the period under examination. The only justification for such an assumption, apart from statistical expediency, lies in the fact that there is always a certain inertia in the industrial system, a resistance to change born partly of psychological factors and partly of the difficulties of adapting established production processes to the use of new materials or new combinations of materials, which

Table 4. Primary Non-Ferrous Metal Consumption, 1950 (Actual) and 1975 (Projected)

(Thousands of short tons of primary metal except as indicated)

Metal	Actual 1950 consumption			Projected 1975 consumption			Percentage increase			Average annual increase			
	United States	Other countries[a]	World[a]	United States	Other countries[a]	World[a]	United States	Other countries[a]	World[a]	Percentage[b]	Tonnage[c]	Value[d] (millions of dollars) Total	Value[d] (millions of dollars) Amount accruing to under-developed countries[e]
Tin	80	81	161	94	122	216	18	50	34	1.18	2,260	4.15	3.41
Copper	1,255	1,343	2,598	1,800	2,050	3,850	43	54	48	1.58	50,000	29.70	13.41
Zinc	1,081	1,061	2,142	1,500	1,700	3,200	39	61	50	1.64	42,250	9.04	1.05
Manganese ore[f]	1,800	1,400	3,200	2,700	2,300	5,000	50	65	56	1.80	72,000	2.53	2.36
Lead	784	844	1,628	1,200	1,500	2,700	53	78	66	2.05	42,000	11.84	4.03
Antimony	16	25	41	28	50	78	81	100	93	2.67	1,500	0.83[g]	0.72[g]
Nickel	100	32	132	200	64	264	100	100	100	2.81	5,275	6.34	0.71
Chromite	965	596	1,561	1,930	1,215	3,145	100	100	100	2.81	57,400	1.87[h]	1.81[h]
Tungsten ore	3	11	14	8	28	35	150	150	150	3.73	840	2.63[i]	1.29[i]
Molybdenum ore	13	5	18	35	14	49	170	170	170	4.05	1,220	2.56[j]	0.20[j]
Aluminium	920	465	1,385	3,600	2,400	6,000	291	415	333	6.04	184,500	80.22	3.19
Cobalt ore	5	3	8	20	13	33	340	340	340	6.11	1,020	2.65[k]	2.12[k]

Source: President's Materials Policy Commission, ***Resources for Freedom***, volume II: "The Outlook for Key Commodities".

[a] Excluding mainland China and the Soviet Union.

[b] Assuming constant proportionate increases.

[c] Short tons; assuming equal absolute annual increases.

[d] Based on equal absolute annual increases and average 1954 prices in the United Kingdom or the United States.

[e] Based on the proportion of total output of metal and ore originating in the under-developed countries in 1953, as set out in table 6 on page 29.

[f] Measured as 48 per cent ore.

[g] Valued as 99.6 per cent regulus.

[h] Valued as 48 per cent metallurgical grade ore.

[i] Valued as 65 per cent WO_3.

[j] Valued as 85 per cent MoS_2.

[k] Based on Canadian ore prices.

tends to slow down the rate at which new technical and economic developments are incorporated into industry.

In the light of this principle, it may be of interest to note the estimate of future non-ferrous metal requirements made in the United States by the President's Materials Policy Commission in 1951. This estimate was based on an extrapolation of past consumption trends, modified by a series of assumptions concerning some of the influences affecting demand, the most important of which were a doubling of the United States gross national product between 1950 and 1975, a rather smaller increase in western Europe and a much larger increase in the other industrial countries, avoidance of a major war during this period, continuance, with little change, of the 1950 price relationships, and absence of any considerable unforeseen technological innovations. On this basis estimates were made of probable consumption of copper, lead, tin and zinc in 1975. In relation to 1950 levels of primary metal consumption, the greatest increases were predicted for the countries at present under-developed—ranging from 126 per cent for tin to 228 per cent for zinc—and, among the industrial countries, for Japan—from 67 per cent for tin to 143 per cent for lead—and Australia and New Zealand—from 76 per cent for zinc to 163 per cent for tin. The smallest relative increases were predicted for the most highly industrialized countries, the United Kingdom—from 18 per cent for tin to 40 per cent for lead—and the United States—from 18 per cent for tin to 53 per cent for lead.

It was estimated that consumption of primary tin and copper in the under-developed areas would more than double within the 25 years, and consumption of primary lead and zinc more than treble. Despite this expansion, however, the proportion of the world total which Latin America, Africa and Asia (outside of Japan and mainland China) consume is unlikely to exceed one-sixth in the case of tin, one-eighth in the case of lead and one-tenth in the case of copper and zinc. The United States seems likely to continue to consume between 40 and 50 per cent of world primary non-ferrous metal output, western Europe and the United Kingdom between 30 and 40 per cent, and Australia, Canada, Japan and New Zealand a combined proportion of between 7 and 10 per cent.

Even substantial increases in the amounts of the additive metals used in under-developed countries are unlikely to affect the general pattern of consumption. As indicated above, these metals are all associated primarily with the production of special steels and are therefore likely to continue to be used very largely in the more highly industrialized countries. Even in the case of manganese, which is in rather more general use in steel making, the distribution of iron and steel capacity is such that, even with foreseeable expansion of facilities in the less developed countries, the bulk of manganese supplies will continue to be consumed in the present industrial countries.

On the whole, the consumption of ferroalloys, though subject to similar and perhaps even more marked cyclical fluctuations, has risen more rapidly than that of the major non-ferrous metals. Projecting 1900-50 trends into the decade 1970 to 1979, the Materials Policy Commission suggested a probable expansion in consumption of the major metals, ranging from one-third of the 1950 level in the case of tin, and one-half (for copper and zinc) to two-thirds in the case of lead (table 1). On the same assumptions, the use of the additive metals might be expected to increase much more: from a doubling of nickel and chromium consumption to a 340 per cent expansion of cobalt consumption. The two exceptions to these trends are manganese and aluminium. Consumption of the former would seem unlikely to expand by much more than one-half (the same order of increase as that predicted for finished steel and the major non-ferrous metals) while consumption of aluminium might be expected to increase in almost the same degree as cobalt: a threefold expansion in the United States and a fourfold expansion elsewhere.

Translated into physical terms, these postulated increases in consumption would entail an arithmetic average annual expansion of 185,000 tons of aluminium and 1,000 tons of cobalt (or a geometric rate of growth of about 6 per cent per annum) at the one end of the scale, and 50,000 tons of copper and 2,300 tons of tin (1.2 per cent per annum) at the other. In monetary terms the main increases would be in the major non-ferrous metals, particularly aluminium, and, to a much smaller degree, copper, zinc and lead. The under-developed countries as a group would gain most from the expansion in copper production, though the increases in lead, cobalt and chromite output would also add substantial sums to their foreign exchange earnings. Though they would gain only a small proportion of the increased value of metallic aluminium and nickel production, some under-developed countries would benefit from the expanded demand for the ores of these metals.

Scrap and secondary metal

So far the discussion has been in terms of "new" or "primary" consumption, that is, consumption of freshly mined ore and metal smelted therefrom. Consumption of the metal, as pointed out above, entails its transformation into usable articles, either alone or in combination with other materials. In the main, these articles fall into the category of durable goods, although a proportion of the output of most of the non-ferrous metals passes into chemical compounds that are expendable or into forms of armaments from which they are not recoverable. In the fabrication of the metals a small fraction of the input emerges from the factory not as finished articles but as trimmings, filings, spoilage and other waste metal which after suitable treatment can normally be used again. Similarly, when durable goods cease to fulfil their various functions satisfactorily, they are discarded and a certain proportion of the constituent material finds its way back into the production circuit for re-use. That portion of the factory waste and the discarded articles which is capable of fairly direct re-use by non-ferrous metal fabricators is customarily termed "scrap". Scrap usually consists more or less of pure metal—copper from an electric generator, for example—or of a more or less determinate alloy—brass from household hardware, for example. Other scrapped material may contain valuable non-ferrous metals in a combined form which, though not usable directly by fabricators, is capable of yielding the pure metal again if smelted or refined. This is customarily called "secondary" material and along with scrap adds in varying degree to the supply of metal from the treatment of newly mined ore.

The available volume of secondary and scrap material is a function of the nature of the original use: the more metal going into forms which are expendable or inevitably dispersed in their use (lead in gasoline, zinc in pigments, copper in pesticides, for example), the lower is the recoverable proportion likely to be. It is also a function of the relative price of the metal: the higher the scrap price in relation to other prices, the more intensive and extensive is scrap collection likely to become. It is also a function of the effective life of the durable goods, which in turn depends among other things on their quality and rate of obsolescence, the rate of technical advance, the level of economic activity and price expectations. The average period between the production and scrapping of automobiles in the United States, for example, has undergone a fairly steady secular decline and by 1950 was estimated at about ten years, while that of storage batteries had fallen to about three years.

The organization of the scrap market varies from one metal to another and from one country to another. Where a high proportion of metal goods output is exported, as in the United Kingdom, scrap collection from domestic consumers yields relatively less than in countries with higher internal consumption. The volume of factory-produced scrap depends in part upon the organization of the metal-using industries: in general the larger the firm and the closer the degree of integration between its various divisions, the higher is likely to be the proportion of scrap collected and re-used. Consumer collection is almost invariably the most costly to organize: it requires transport facilities over a wider area and much more sorting of the product. And, as war-time experience has shown, a general awareness of the value of scrap on the part of the metal users is necessary for collection to be successful, even in highly industrialized countries. The less developed the country, the smaller is the volume of available scrap likely to be, though the proportion actually collected for re-use may well be higher than in richer countries where waste is greater, at least among consumers, and where the factors of production are generally more profitably occupied.

In general, comparatively little of the ferroalloy supply comes from secondary sources, partly because many special steels contain only small percentages of the additive metal, partly because their refining is often a costly process, partly because they are often used in capital goods with a long life expectancy. In the case of the major non-ferrous metals, on the other hand, a large, and on the whole increasing, volume of scrap is recovered and used. In the United States in 1950, for example, the proportion of old scrap ranged from about 6 per cent of total consumption (of domestic slab and zinc) to almost 60 per cent (of antimony). The rapid increase in aluminium production has tended to hold down the relative importance of secondary sources, though in 1953 the proportion of scrap to total supplies was about 40 per cent in the United Kingdom and the United States, while in Europe war-generated scrap accounted for a considerable proportion of consumption in the early post-war years. As late as 1949, western Germany's production of aluminium comprised 31,000 short tons from ore and 57,000 short tons from scrap.

About 6 per cent of United States slab zinc consumption was derived from remelted scrap in 1950, while most zinc-based chemicals and a good deal of zinc alloy were derived from secondary sources of the metal. In 1953 about one-fourth of total supply came from scrap. In the United Kingdom the over-all proportion of secondary to total consumption of zinc has been of the order of 30 per cent in post-war years; in Norway it was 11 per cent in 1953. Between 30 and 40 per cent of United States tin consumption in the post-war period has been for plate and very little of this is recovered; much more of the tin used in babbitt and bronzes, however, and to a smaller extent in solders, too, is reclaimed, and in 1950 it was estimated that almost one-fourth of total consumption came from scrap and secondary material. The proportion of secondary copper used in that year was somewhat higher, though not quite so great as that recorded in the United Kingdom—36 per cent of gross consumption.

This was also the order of magnitude of secondary lead consumption in the United States, where storage batteries—yielding a quick return of scrap—constitute by far the largest single use. In the United Kingdom, where cable covering and sheet and pipe for buildings have remained more important uses, the proportion of secondary lead consumed has been somewhat lower. It has been estimated that between a half and two-thirds of the lead used in industrial communities now goes into non-dissipative uses and therefore stands a good chance of being recovered for ultimate reprocessing. In the United States the consumption of secondary lead has actually exceeded that of primary metal since 1946. In Denmark in 1953 no less than 80 per cent of total lead supply was derived from scrap. Antimony, which goes into batteries and type metal to an even greater relative degree than lead, also returns to the fabricator very rapidly by way of scrap: in the United States over half of gross consumption is from scrap, while in the United Kingdom the proportion is about one-third.

Theoretically, the amount of scrap available during any given period is a function of the total existing volume of goods incorporating the metal in question, the rate of obsolescence of such goods, the ratio of dissipative to non-dissipative consumption of the metal and the technique of collection.

Under normal circumstances, the total volume of made-up metal increases fairly steadily, though the rate of increase may tend to diminish. The distribution of consumption between dissipative and non-dissipative uses depends partly upon the demand for the two categories of products and partly upon technological developments which govern the way in which the metal is likely to be used, neither determinant being readily predictable. The rate of obsolescence of metal goods depends partly upon the intensity with which they are used and partly upon the course of technical progress and the rate at which new products supersede the old; on the whole this has tended to increase. The technique of collection depends partly on the geographical dispersal of the product and partly upon the organization of the institutions through which the scrap is recovered; on the whole, the collecting process has tended to become more effective. In general, these considerations being taken into account, it is probable that the absolute amount of scrap returned to the production process ordinarily tends to increase fairly steadily. However, whether its relative contribution to gross consumption in any one year increases or decreases depends, among other things, on the rate at which the production and consumption of primary metal have been expanding. Thus, the secular increase in the proportion of copper scrap used in the United States was brought to at least a temporary halt in the nineteen thirties by the expansion in total copper consumption. In 1910, only 8 per cent of the country's copper supply came from reclaimed metal; in 1920 the proportion was 17 per cent; in 1925, 20 per cent; in 1930, no less than 36 per cent. The subsequent rapid rise in primary production, however, reduced the relative importance of scrap. In general, the lower the ratio of the current rate of production (and consumption) to the rate which obtained during the preceding period—in which the durables in current use were being manufactured—the higher is the relative proportion of scrap likely to be.

It is not unlikely, therefore, that the annual volume of available scrap of most of the major non-ferrous metals will tend to increase at a more rapid rate than total demand, especially in the case of those metals, such as aluminium, new production of which has been expanding considerably in recent years. This being so, the required rate of increase in primary production is likely to be less than that of demand. Indeed, if demand failed to increase, but settled down at a stable level above that required to offset depreciation, the gradual buildup of stocks of metal products in use would ultimately result in a situation in which the annual demand for the metal might in theory be entirely satisfied by the supply of scrap. Such a stationary state is far from being realized in respect of any of the non-ferrous metals; nevertheless, the importance of scrap and secondary metal in the consumption pattern of the industrial countries is now great enough to have a significant effect upon price and upon the demand for the primary metal, and hence upon the fortune of those under-developed countries in which mineral exports make a significant contribution to the national income.

PRODUCTION

Fluctuations in output and price

The mining and smelting of non-ferrous metals have been characterized by variations in total and regional output that in general have followed fluctuations in demand fairly closely, though usually with a time lag reflecting the fact that, for both economic and technical reasons, ore and metal production is ordinarily not susceptible of very rapid expansion or contraction. Broadly speaking, non-ferrous ore and metal output has reached high levels during periods of marked activity in the industrial countries, during wars and during the boom phase of the trade cycle, only to fall off correspondingly in the wake of declining demand. Thus, non-ferrous production peaks were recorded during the First World War, in 1929, in 1937, during the Second World War and again during the period of rearmament from 1950 to 1952. From those peaks, production of most of the metals declined markedly as industrial activity slackened. Between 1917 and 1921, for example, world tin and lead output dropped by more than one-fourth, and copper and zinc output by about one-half. Between 1929 and 1932, output of lead dropped by more than one-third and that of copper, zinc and tin by 50 per cent, while production of some of the alloy metals—tungsten, nickel and manganese, in particular—dropped even more sharply.

After 1932 (1933 in the case of tin) there was a general and fairly rapid rise in production. For several metals—manganese, copper, chromium, nickel, tin and antimony, in particular—a peak output was recorded in 1937, production in 1938 being marked by a slight decline, and in a few cases—antimony, molybdenum and manganese, for example—the decline continued into 1939 as well. In the following year, the upward trend was resumed, and record outputs were delivered during the war. The war-time peak was followed by another rapid decline, low points being recorded in 1945 (in lead, bauxite, chromium and tin production) or 1946 (in molybdenum, copper, tungsten, zinc, nickel and antimony production). Since then, there has been another upswing; only in the case of manganese and zinc, however, had this carried production above the war-time peak by 1950, though by 1954 both war-time and pre-war peaks had been equalled or exceeded in all metals except tin, antimony, tungsten and vanadium.

Notwithstanding these fluctuations, the general trend of production over the past 70 years has been decidedly upwards. At the outbreak of the First World War, lead production, which at about 1.25 million metric tons was highest among the major non-ferrous metals, was three times its 1880 level; tin production had experienced a similar increase, while zinc production was four times, and copper production five times, the 1880 level. In 1895 aluminium output had exceeded 1,000 tons for the first time; in 1913 it was 70,000 tons. The expansion in output of the ferroalloy metals was of the same order: for example, the output of nickel, the oldest of these metals in terms of industrial use, increased from under 1,000 tons before 1887 to 35,000 tons in 1913.

Comparing the boom year of 1929 with the peak year of the First World War, nickel production was one-fourth higher, copper production was up by one-third, tin, lead and zinc production by one-half, while the output of aluminium had doubled. Between the 1929 and 1937 peaks there was a further increase, though in most cases of a much smaller magnitude: tin and zinc production was up by about one-tenth, copper production by almost one-fourth, aluminium production by more than three-fourths, nickel output had doubled, and only lead production was lower (by about 8 per cent). Between 1937 and the peak year of the Second World War, the increase in output was generally larger: even lead production was higher though it still had not reached the level registered at the end of the nineteen twenties.

The post-war decline, though sharp, was only temporary, and even the lowest output of the post-war years 1946 to 1953 was equal to the peak level of the nineteen thirties in the case of bauxite, molybdenum, chromium and nickel, and to the high average levels of 1929-31 and 1934-37 in the case of manganese, copper, zinc and antimony. The three metals whose 1946 output was lowest in relation to pre-war figures were lead, tin and tungsten. Production of the first two of these had been affected by some of the technical considerations mentioned in the previous section: economy of use, and substitution. Tin production, moreover, was reduced by the war-time destruction and neglect of facilities in south-eastern Asia. In the case of tungsten the main reason for the poor showing in the early post-war years was the slow recovery of production in China, whose pre-war output had amounted to almost one-half of the world total.

This brief review of production has been made in physical terms. The main interest in an under-developed economy, however, lies less in the volume of mineral output than in its value and, as pointed out in chapter 5, less in the metal itself than in the foreign exchange earned by exporting it. In consequence of this, the price of the metal or ore is as important as its quantity, and its significance to the exporting country depends on the relationship between that price and the prices of the goods purchased with the proceeds.

In general, the price variations that have characterized the international metal markets, like the variations in output, reflect the course of economic activity (and of the resultant demand for the metals) in industrial countries. Most average annual metal prices were very high in 1906-07, 1916-17, 1929 and 1937, reaching very low levels in the intermediate periods 1903-04, 1909-11, 1919-21 and 1931-32, when the demand for capital goods fell to not much more than replacement levels. There was a recession in metal prices in 1938 but an increase in armaments requirements the following year prevented any major decline.

During the war, first price control, accompanied in many instances by purchase contracts, and later, the complete control of metal distribution, exercised partly through shipping allocation, held the prices of most metals well below the levels they would doubtless have attained on a free market under conditions of so active a demand. The relinquishment of controls after the war permitted a general price readjustment, and there were substantial increases in most metal prices in 1946, stimulated by reconstruction demands but cushioned to a certain extent by the availability of substantial supplies of scrap.

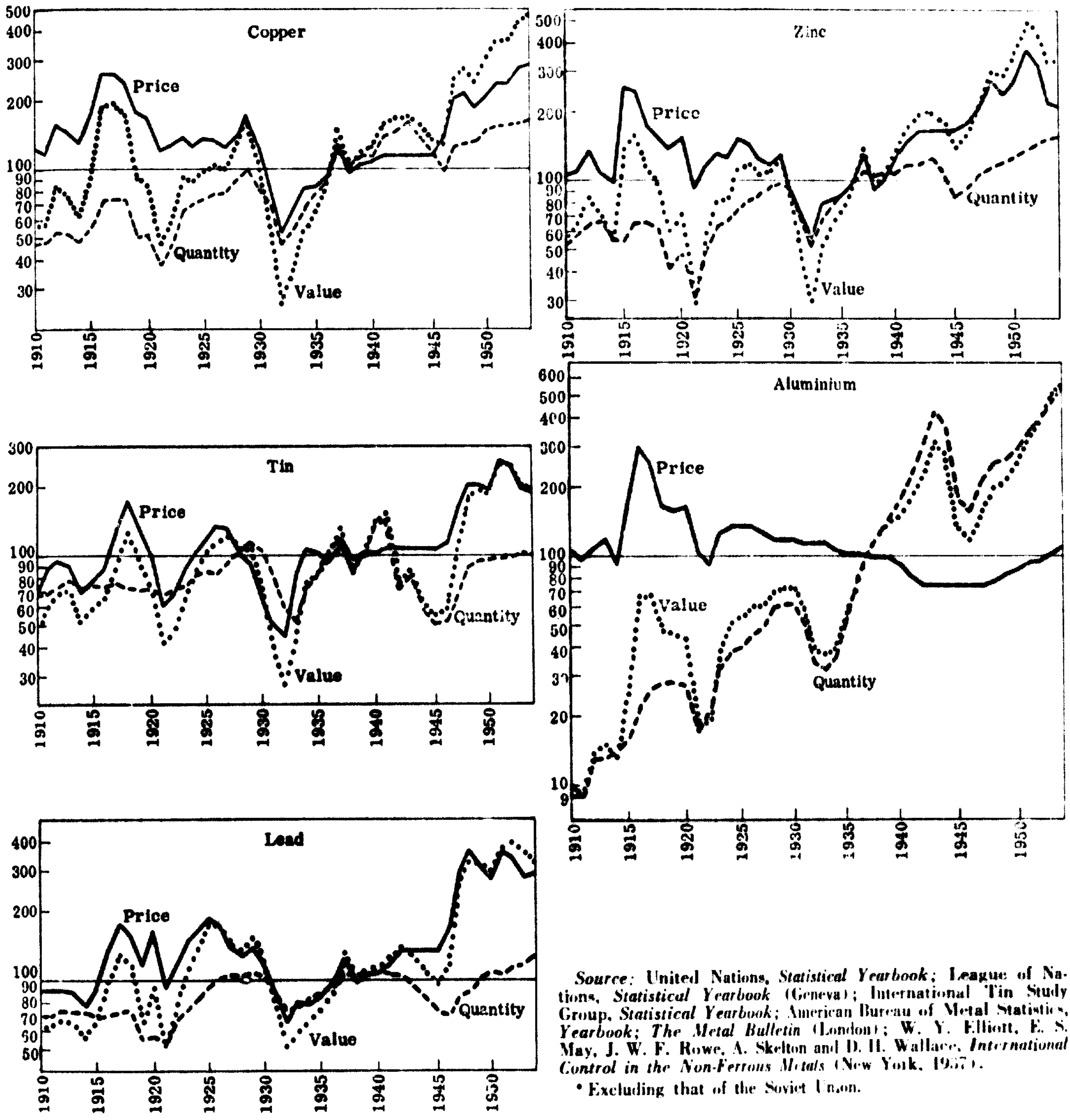
Metal prices eased slightly in 1949, in consequence of a decline in United States demand, but the outbreak of hostilities in Korea and subsequent rearmament programmes changed the problem to one of scarcity in 1950, and throughout 1951 most of the non-ferrous metals were under control—either of price or of use (or of both) — in most countries. The International Materials Conference (IMC), set up to study and make recommendations concerning the distribution of a number of particularly scarce materials, worked out allocation plans for copper, zinc, nickel, tungsten and molybdenum, and kept under review the production and consumption of lead, chromium and manganese. By the end of 1952, most non-ferrous metal prices had dropped appreciably from the high figures which had obtained during the second half of 1950 and the first half of 1951. Only copper, nickel and molybdenum remained under IMC allocation, the prices of these metals and of aluminium remaining very firm. Since then, investments made during the period of shortage have increased production and refining capacity. For many metals the supply position has therefore eased further with a consequent decline in prices, particularly of tin, lead, zinc, tungsten and antimony. The IMC ceased to operate in 1953, and in a number of cases the problem has again become one of raising consumption as an alternative to curbing production.

This brief synopsis of half a century's price movements illustrates the relationship between consumption, price and production: in general, times of active demand and high prices have preceded times of high production, while a decline in demand and then in price has usually been followed by a decline in production (chart 9). During the inter-war period these reductions in output were sometimes the result—at least in the case of the major non-ferrous metals—of organized efforts to prevent further deterioration of the market during and after a period of economic depression. In other cases, a decline in prices squeezed out marginal producers and stopped the working of marginal bodies of ore; conversely, a rise in prices tempted them back.

In so far as foreign exchange earnings are concerned, the tendency for price and production to move in the same direction results in a fluctuation in realized value substantially greater than that recorded for production alone. Thus the drop from the peak of the First World War to the lowest point of post-war depression ranged from 11 per cent (tin) to 49 per cent (copper) in terms of world output but from 57 per cent (tin) to 76 per cent (copper) and 82 per cent (zinc) in terms of realized value. Similarly, the drop from boom levels of

Chart 9. Indices of World Production,[a] Price and Value of Major Non-Ferrous Metals, 1910 to 1954

(Average 1935-39 = 100)



Source: United Nations, *Statistical Yearbook*; League of Nations, *Statistical Yearbook* (Geneva); International Tin Study Group, *Statistical Yearbook*; American Bureau of Metal Statistics, *Yearbook*; *The Metal Bulletin* (London); W. Y. Elliott, E. S. May, J. W. F. Rowe, A. Skelton and D. H. Wallace, *International Control in the Non-Ferrous Metals* (New York, 1937).

[a] Excluding that of the Soviet Union.

1929 to depression levels of 1932 ranged from 32 per cent (lead) to 48 per cent (tin) in respect of output but from 68 per cent (lead) to 85 per cent (copper) in respect of value. Furthermore, a given fluctuation in world production implies a greater relative fluctuation in the output of at least some of the contributing countries. In addition, since in general imports tend to be marginal, trade tends to fluctuate more than production, accentuating the instability of the foreign exchange earnings that an exporting country derives from its non-ferrous metal industry.

Although a decline in demand and consequent drop in price initiate forces which tend to curb production, the actual operation of these forces varies from one metal to another, from one producer to another and from one time to another. Where a large proportion of total output is under the effective control of a single organization (as tin was during part of the inter-war period) or a few large concerns (as some of the other major non-ferrous metals have tended to be) central or joint decisions may be made regarding production policy. Output quotas may be allocated to specific mines, reflecting a proportionate cut from some predetermined level of production, or perhaps a decision may be made to sacrifice high-cost producers temporarily.

The incidence of a tariff imposed in any important consuming country may also vary in its effects on exporting countries. During the great depression, for example, the high duties imposed by the United States to protect domestic mines bore heavily on Latin American suppliers, while the imperial preferences granted on the United Kingdom market discriminated in favour of Commonwealth suppliers. More recently, soft currency sources have had a more favourable market in most European countries than hard currency sources have had; this is one of the reasons for the rapid expansion of copper mining in Northern Rhodesia and for the offer by the United Kingdom Government of support for an aluminium industry in the Gold Coast. For similar reasons, special efforts have been made (by France and the United Kingdom in particular) to bring war-damaged mines back into production and to develop new mineral output so as to increase hard currency earnings—in the case of tin, cobalt and manganese, for example—or reduce the need for hard currency imports—in the case of copper and zinc, for example.

Because the effects of an over-all decline in output may be very unequal, certain countries, by reason of the place their mines occupy in the international organization or of the particular market they serve or of some other distinguishing consideration, may suffer a more than proportional cutback. Even if the less developed mineral-producing countries suffer no more than a uniform percentage reduction, however, any decline in output and revenue is likely to represent a more serious loss in relation to the gross national product than it would in a more diversified economy or in an economy in which the production cutback resulted only in a loss of turnover to a few firms rather than the loss of foreign exchange to the country as a whole.

To sum up, although the secular trend in non-ferrous metal production has clearly been upward, this fact has been overshadowed by the cyclical and year-to-year fluctuations which have characterized the demand for the metals and hence their price and output. Moreover, the fact that variations in production have tended to parallel variations in price has resulted in fluctuations in value of output appreciably greater than those in physical quantity.[7] In addition, two further facts must be recorded: (1) because of the marginal position of imports and the destabilizing influence of inventories, actual metal sales tend to fluctuate more than production; and (2) the output in individual producing countries tends to fluctuate more than that of the aggregate for the world as a whole. As a result the problem of instability is of crucial concern to those under-developed countries in which non-ferrous metal production makes a major con-

[7] Cf. United Nations, *Instability in Export Markets of Under-Developed Countries* (sales number: 1952.II.A.1).

Table 5. Proportion of Total Output[a] of Non-Ferrous Ores and Metals Contributed by the Three Largest Producers, 1937, 1950 and 1953

Ore or metal	*Percentage of total output produced by three largest producers*			*Three largest producers, and percentage contribution to total output, 1953*
	1937	*1950*	*1953*	
Zinc ore	55	58	44	United States, 20; Canada, 14; Australia, 10
Lead ore	54	57	46	United States, 18; Australia, 16; Mexico, 13
Tungsten ore	58	60	50	Southern Korea, 20; United States, 20; Portugal, 11
Lead metal	55	66	51	United States, 26; Mexico, 13; Australia, 13
Zinc metal	62	55	54	United States, 36; Canada, 10; Belgium, 9
Antimony ore	64	62	58	Bolivia, 26; Mexico, 19; Union of South Africa, 12
Bauxite	48	67	58	Surinam, 26; British Guiana, 18; United States, 13
Manganese ore	74	71	58	India; 32; Gold Coast, 14; Union of South Africa, 12
Copper ore	65	65	64	United States, 34; Chile, 15; Northern Rhodesia, 15
Copper metal	64	64	67	United States, 39; Northern Rhodesia, 15; Chile, 14
Chromite	63	72	70	Turkey, 32; Union of South Africa, 23; Philippines, 15
Tin concentrates	72	75	74	Malaya, 33; Bolivia, 21; Indonesia, 20
Tin metal	80	76	74	Malaya, 36; United States, 22; United Kingdom, 17
Aluminium	68	82	80	United States, 52; Canada, 23; France, 5
Cobalt ore and alloy	83	87	82	Belgian Congo, 69; Canada, 7; Northern Rhodesia, 6
Nickel ore	98	99	96	Canada, 75; New Caledonia, 14; Cuba, 7
Molybdenum ore	97	98	99	United States, 91; Chile, 5; Yugoslavia, 3

Sources: United Nations, *Statistical Yearbook*; United States Bureau of Mines, *Minerals Yearbook*.

[a] World production, excluding that of mainland China, eastern Europe and the Soviet Union, measured as metal content; including a certain amount of secondary metal in some cases.

tribution to the national income and the available flow of foreign exchange.

Regional distribution

In spite of the fact that mining activity is very widespread, with many countries making appreciable contributions to the supply of at least one of the non-ferrous metals, the bulk of the output of individual metals is derived from comparatively few sources. In 1953, for example, the three principal producers accounted for proportions of world supply (excluding that of mainland China and the Soviet Union) ranging from 44 per cent in the case of zinc ore and 46 per cent in the case of lead ore to 96 per cent for nickel and 99 per cent for molybdenum (table 5). On the whole, this concentration of production was somewhat greater in the early post-war years than that which had obtained before the war, though by 1953 it had declined below the 1937 level in most cases, the chief exceptions being chromite, 70 per cent of which was produced in the three main producing areas compared with 63 per cent in 1937, bauxite (58 per cent compared with 48 per cent) and aluminium (80 per cent compared with 68 per cent).

Although more than 30 of the less developed countries produce one or more of the major non-ferrous metals in significant commercial amounts, the greater part of their contribution comes from comparatively few sources. In the case of tin ore, for example, in 1953 Bolivia, Indonesia and Malaya produced about 74 per cent of the world total (not including output in mainland China and the Soviet Union); together with the Belgian Congo, Nigeria and Thailand, they produced 93 per cent, while 16 other producers among the under-developed countries contributed a further 5 per cent. In the case of copper ore, the Belgian Congo, Chile and Northern Rhodesia produced about 39 per cent of the world total in 1953; together with Mexico, Peru and Yugoslavia they produced 44 per cent, while 11 other under-developed countries contributed a further 7 per cent. Mexico alone supplied about one-third of the total output of lead and zinc coming from under-developed countries (13 per cent and 9 per cent, respectively, of the world total in 1953).

In general, the immediate effect of the Second World War was to decrease the relative importance of the less developed countries as a source of non-ferrous metals. The main exceptions to this generalization were zinc ore, lead ore and bauxite, for which the relative contribution of Latin America and Africa increased appreciably (from a combined proportion of 13 per cent of the total in 1937 to 23 per cent in 1950 in the case of zinc ore, from 21 per cent to 31 per cent for lead ore, and from 25 per cent to 55 per cent for bauxite).

In the case of zinc ore, the proportion produced in under-developed countries in 1950, though higher than immediately before the war, was still well below the level reached during the depression of 1931 to 1933. In the case of lead ore, on the other hand, post-war proportions from the less developed countries were about the same as those of the early nineteen thirties. This is also true of tin ores and concentrates which, as indicated above, come almost exclusively from under-developed countries. The contribution of under-developed countries to the world's copper supply showed a considerable expansion when the Northern Rhodesian mines began producing in

Table 6. Non-Ferrous Metal Output in Industrial and Under-Developed Areas, 1937, 1950 and 1953

Ore or metal	*Percentage of total output[a] from*					
	Industrial countries[b]			*Under-developed countries or regions[c]*		
	1937	*1950*	*1953*	*1937*	*1950*	*1953*
Bauxite	55	34	30	45	66	70
Aluminium	100	100	99	—	—	1
Antimony ore	15	13	14	85	87	86
Copper ore	50	51	49	50	49	51
Copper metal	59	59	57	41	41	43
Lead ore	68	63	59	32	37	41
Lead metal	78	74	73	22	26	27
Tin concentrates	3	4	4	97	96	96
Tin metal	37	57	62	63	43	38
Zinc ore	77	71	69	23	29	31
Zinc metal	96	94	94	4	6	6
Chromite	5	1	3	95	99	97
Cobalt ore and alloy	9	10	20	91	90	80
Manganese ore	4	9	7	96	91	93
Molybdenum ore	92	92	92	8	8	8
Nickel ore	93	94	76	7	6	24
Tungsten ore	33	63	51	67	37	49

Source: United Nations, *Statistical Yearbook.*

[a] Excluding mainland China, Czechoslovakia, eastern Germany (in 1950 and 1953), Hungary, Poland and the Soviet Union.

[b] Australia, Canada, Japan New Zealand United States and western European countries.

[c] Africa, Asia (excluding Japan and mainland China), Latin America, Finland and Yugoslavia.

the early nineteen thirties: post-war proportions have been close to the levels established then. Since 1950, the proportion of the total output of non-ferrous metals originating in under-developed countries has tended to increase (table 6). The principal exceptions are tin metal—38 per cent of which came from under-developed countries in 1953 compared with 43 per cent in 1950 and 63 per cent in 1937—and cobalt ore and alloy, the Canadian production of which has risen appreciably since 1950.

Within the group of industrial countries the war brought a general decline in the contribution of western Europe and a corresponding increase in that of Canada and the United States. Part of the decline in western European production was made good during the early post-war years, but in 1950 the relative contribution from this region was still markedly below pre-war figures except in the cases of copper metal and antimony ores, western European production of which, however, was hardly of significant proportions. Western European production of tungsten was of much greater importance after the war, but this was only because of the absence from the world market of supplies from mainland China, which was the largest single pre-war source of this metal.

The Asian contribution to total supplies of non-ferrous metals was much smaller after the war than it had been before, even if mainland China is not included; nor in most cases had Asia recovered its relative pre-war position by 1950. The only metals for which Asian output was relatively as great in 1950 as it had been in 1937 were zinc (largely from Japan), aluminium (India and Japan), bauxite (increases in Indonesia, and to a much smaller extent India, having offset a decline in Malaya), antimony, production of which, if the large pre-war Chinese contribution is excluded, actually showed a slight relative increase (from Thailand and Turkey)[8] and chromite (the relative production of which—from Turkey and to a small extent from the Philippines and New Caledonia[9]—was also somewhat greater). Cassiterite was the only non-ferrous ore of which the Asian share was preponderant: in terms of the tin content of concentrates, Asia contributed 72 per cent of the world total in 1937, 63 per cent in 1950, and 60 per cent in 1953; in terms of refined metal, 58 per cent, 11 per cent and 35 per cent, respectively. Even without the Chinese share, Asia produced 51 per cent of the world's tungsten supply in 1937; with little or nothing coming from Burma, Indochina or Malaya immediately after the war, however, the Asian contribution was down to 17 per cent of the total in 1950, though with the expansion of production in southern Korea it had recovered to 28 per cent in 1953. On the other hand, largely as a result of the expansion of Turkish production, Asia contributed 30 per cent of the world's chromite output in 1950 and 50 per cent in 1953.

[8] Turkey is included with the Asian countries, since non ferrous metal output in the Middle East is too small to warrant separate discussion in the present analysis

[9] Since for purposes of this study Australasia has not been regarded as an under-developed region, New Caledonia has been grouped with the under-developed countries of Asia.

Since Africa escaped most of the physically destructive effects of the war, experiencing instead the stimulus of active war-time and post-war demand for many non-ferrous metals, there was a general increase in the proportion of the world supply contributed by African producers. Between 1937 and 1953 their share of total production rose as follows: for bauxite, from zero to 4 per cent of the total; tungsten ore, from 3 to 5 per cent; zinc ore, from 2 to 10 per cent; lead ore, from 3 to 11 per cent; tin concentrates, from 11 to 15 per cent; copper ore, from 19 to 26 per cent; antimony ore, from 5 to 23 per cent. In the case of chromite the African share of production rose from 43 per cent in 1937 to 52 per cent in 1950, but, largely as a result of transport difficulties which retarded exports, decreased to 38 per cent in 1953, while the regional contribution of cobalt ore and alloy ranged between 85 per cent in 1937 and 87 per cent in 1950.

Latin America was in an even more favourable position for increasing its relative share of world non-ferrous metal production. With the exception of copper ore, copper metal and antimony ore, the region's relative share of which declined between 1937 and 1953 from 23 to 20 per cent, from 21 to 16 per cent and from 72 to 51 per cent of the respective world totals, there was a general expansion in the regional proportions. Between 1937 and 1950 production of molybdenum ore rose from 5 to 7 per cent of the total, zinc ore from 11 to 18 per cent, tin concentrates from 14 to 20 per cent, lead ore from 18 to 24 per cent, tungsten ore from 13 to 21 per cent, bauxite from 21 to 53 per cent. Except in the case of molybdenum and tungsten ores, output of which declined slightly, in relative terms, between 1950 and 1953, the Latin American contribution to the world non-ferrous metal supply has been maintained or further expanded.

Notwithstanding the expansion of production in Africa and Latin America, the United States contribution in respect of most of the metals was greater after the war than it had been immediately before. The major increases (table 7) were in the following: tin metal, of which the United States produced 19 per cent in 1950 compared with none at all before the war; bauxite, United States production of which increased from 12 per cent of the total in 1937 to 18 per cent in 1950; aluminium (from 30 to 50 per cent); zinc (from 33 to 41 per cent). There was a sizable increase, both absolute and relative, in tungsten ore output, and, on a much smaller scale, in the output of antimony, manganese and cobalt ores, in which the United States remains notably deficient. Even in the case of copper, in which the United States share in world production had been steadily declining between 1916 and 1931, the rise which began under tariff protection in 1935 continued during the war and in the early post-war years. In 1950 the United States produced about 37 per cent of the world's mined copper, compared with 35 per cent in 1937 and less than 20 per cent in 1931 (and about 60 per cent during the First World War). More recent changes, however, have, on the whole, been downward: only in the case of chromite and tin and aluminium metals did the United States produce relatively more in 1953 than in 1950. In the case of the ores of antimony, copper, lead and zinc the United States share of world output was lower in 1953 than in 1937.

Table 7. Percentage of World[a] Supply of Non-Ferrous Ores and Metals coming from the United States, 1937, 1950 and 1953

Ore or metal	*1937*	*1950*	*1953*
Nickel ore	—	1	—
Tin ore	—	—	—
Antimony ore	3	6	2
Chromite	—	—	2
Manganese ore[b]	2	5	3
Cobalt ore and alloy	—	5	5
Bauxite	12	18	13
Lead ore	26	26	18
Tungsten ore	16	23	20
Zinc ore	32	31	20
Tin metal	—	19	22
Lead metal	26	29	26
Copper ore	35	37	34
Zinc metal	33	41	36
Copper metal	38	40	39
Aluminium	30	50	52
Molybdenum ore	90	91	91

Source: United Nations, *Statistical Yearbook;* United States Bureau of Mines, *Minerals Yearbook.*

[a] Excluding mainland China and the Soviet Union.

[b] Containing more than 35 per cent manganese.

Among the major producers of non-ferrous metals (apart from the Union of Soviet Socialist Republics) the United States is the only important consumer. Of the other industrial countries which are listed in table 5 as major producers, Canada, in respect of zinc, cobalt, aluminium and nickel, and Australia, in respect of lead and zinc, export much more than they use, while Belgium, in respect of zinc, and the United Kingdom in respect of tin, rely almost entirely on imported ores for the production of the refined metal. Though Portugal ranks third in production of tungsten ore, it actually produces little and practically all of it is exported. Though Mexico and the Union of South Africa have attained a certain measure of industrialization, their output of zinc and lead in the first case and of the ores of antimony, manganese and chromium in the second, are used domestically only to a very small extent. French production of aluminium is the only instance of a major producer, outside the United States, where the local output of ore (bauxite, in this case) provides a metal mainly for domestic consumption. For the rest, the major producers of non-ferrous metals are all under-developed countries, in which these metals have had comparatively little influence, at least as raw materials, on the level of industrialization so far attained.

It is worth noting that, of the 12 ores specified in table 5, the United States was the leading producer of no less than four, second producer of a fifth and third producer of another. Of the five refined metals listed in the table, the United States was the leading producer of four and second producer of the fifth. This indicates both the rich mineral endowment and the advanced metallurgical industry which put the United States in a strong competitive position in relation to other producers. It also indicates the degree to which its domestic resources have already been explored and exploited, a fact which may give other producers, whose resources are less accurately known and less intensively worked, a competitive advantage at some time in the future, when the United States has to depend to a greater extent on deposits that are less accessible or of lower grade, and hence on a higher proportion of imports. This tendency has, indeed, already become manifest, for in recent years United States consumption has outrun domestic production of several of the non-ferrous metals, and as indicated in a later section the United States is now an important market for foreign suppliers.

Another major producer and consumer is the Soviet Union, which, because of lack of comparable data, has not been included in this discussion. It has been estimated[10] that the primary output of major non-ferrous metals in the Soviet Union in 1950 was of the order of 265,000 tons of copper, 155,000 tons of lead, 165,000 tons of zinc, 175,000 tons of aluminium, 40,000 tons of nickel and 13,000 tons of tin, supplemented in each case by imports and by a certain amount of secondary material. In that year production of this order would have placed the Soviet Union fourth among copper producers (after the United States, Chile and Northern Rhodesia), fourth among lead producers (after the United States, Mexico and Australia), fifth among zinc producers (after the United States, Canada, Mexico and Australia), third among aluminium producers (after the United States and Canada), second among nickel producers (after Canada), and fifth among tin ore producers (after Malaya, Indonesia, Bolivia and the Belgian Congo).

It is probable that industrial expansion in the Soviet Union during the post-war period has also tended to run ahead of its domestic non-ferrous metal supply, increasing its dependence, at least temporarily, upon imports—lead and zinc from Poland, tin and tungsten from south China and other Far Eastern sources, bauxite from Hungary, copper from Finland, aluminium from Hungary and eastern Germany and several metals from Manchuria. Known reserves of many of the non-ferrous metals are probably insufficient to sustain recent rates of industrial development for many years, but since in terms of prospecting and mining much of the country is still in a pioneer stage, it is to be expected that larger reserves will be located and developed in due course.[11]

In general, the effect of the Second World War was to reduce the relative contributions to total non-ferrous metal supplies coming from Europe and Asia, and in-

[10] *The Metal Bulletin*, July 1952.

[11] *Vide* P. B. Shimkin, *Minerals: A Key to Soviet Power* (Cambridge, Mass., 1952).

crease correspondingly those coming from North America, South America and Africa. By 1950, Europe had recovered much of the lost ground, and as a result of enlarged capacity in Canada and the United States, the industrial countries as a whole were greater contributors to world supplies than they had been before the war. Furthermore, one of the results of the rearmament drive initiated in the second half of 1950 was to expand facilities to a greater extent in the United States than elsewhere. This reflects not only the part played by the United States in the rearmament programme, but also its general concern about raw material supplies, as evidenced by the advance in 1950 of both the rate and the objectives of stockpiling.[12]

However, the United States effort to expand the raw material base on which its industrial structure rests was not confined to domestic resources. The Economic Cooperation Administration (ECA) and its successors, the Mutual Security Administration (MSA) and the Foreign Operations Administration (FOA), made loans and grants and authorized the use of certain "counterpart funds"—local currency equivalents of earlier economic aid—to expand facilities in several western European countries and their dependencies. Thus, production of bauxite was assisted in Greece and Jamaica, and of aluminium in Norway and western Germany, manganese ore in Greece, cobalt in Northern Rhodesia, chromite in Turkey and New Caledonia, lead and zinc ore in French Morocco and French Equatorial Africa, copper in Northern Rhodesia and French Equatorial Africa, tin in the Belgian Congo, and zinc and cadmium in Italy. Where the loan under ECA, MSA or FOA auspices was partly or wholly repayable in metal, the loan agreement embodied in effect a purchase contract. Separate purchase contracts, as well as Export-Import Bank loans, were also used to encourage greater production in other countries: tungsten ore in Bolivia and southern Korea, nickel ore in Cuba, lead ore in Guatemala and tin metal or concentrates in Bolivia, Indonesia and Malaya, for example.

The high prices which characterized the first phase of the rearmament period also served to stimulate production and, to a certain extent, new investment in the mining industry in various parts of the world. The Burma Corporation came to an arrangement with the Government of Burma for the reopening of its lead and zinc mines; copper and lead mines were opened up in Tanganyika and Uganda; the Anaconda Copper Company made preparations for large-scale exploitation of the sulphide ores of the Chuquicamata mine in Chile; arrangements were made by four United States concerns to begin working the Toquepela copper ores in southern Peru; two new mines and several new exploration companies began operating in Northern Rhodesia. While many of these expansion schemes have thus been in under-developed countries, there has also been a good deal of investment in the non-ferrous metal industry in more industrialized countries. Apart from the expansion of aluminium facilities in western Germany, Norway and other European countries, in Australia there have been notable developments in scheelite (tungsten) and rutile (titanium) mining as well as in the older lead and zinc mines, and some of the largest investments of recent years have been made in Canada—in nickel, cobalt, copper, lead, zinc and tungsten mining and in aluminium refining. Taken in conjunction with substantial United States investment in new capacity, this is likely to enable the industrial countries, particularly those of North America, to maintain their leading positions as suppliers of the major non-ferrous metals (except perhaps tin) in the immediate future.

The effects that consumption changes of the order of magnitude postulated in the preceding section are likely to have upon the distribution of output are not easy to forecast, depending as they do not only upon the development of techniques of prospecting, mining and beneficiation but also upon the evolution of economic policy with regard to production and trade in non-ferrous metals. In general, however, the under-developed countries would seem likely to remain the principal sources of the ores of several of the non-ferrous metals, among them antimony, aluminium, chromium, cobalt, manganese and tin. Although aluminium and manganese ores are present in large quantities in several industrial countries—the United States, in particular[13]—the metal content is very low, and it would require a considerable advance in technology to render their beneficiation economically attractive. Antimony ore is produced on a small scale in the United States and to an even smaller extent in western Europe—in Austria and Italy—but the sources are either scattered deposits of stibnite, a few of which can be worked at ordinary prices, or by-products of lead or silver mines. The only economically significant deposits of chromite in Europe are found in Yugoslavia, while those in the United States are of very low grade, that in Montana being the only one worth mining under present conditions. Prospects for cobalt production in the United States seem somewhat brighter,

[12] The United States stimulated domestic expansion by means of various incentives, the most important of which were the granting of tax relief (through rapid amortization of authorized capital expenditure), the negotiation of "commitment-to-purchase" contracts (which guaranteed the market for specified products during specified periods or for specified quantities) and the offer of loans to finance expansion of capacity. In an effort to accelerate the rate at which new domestic resources were opened up, the Government also offered to meet a proportion of the costs incurred in exploration and survey ranging from 50 per cent of the total in the case of copper, lead and zinc, chromium, molybdenum, cadmium and bauxite to 90 per cent in the case of tin, cobalt, nickel, columbium and tantalum. By the end of 1951, some 1,430 applications had been made for exploration aid. Of these, 53 per cent had been denied or withdrawn and 22 per cent accepted; the remainder were still under consideration. Of the 315 explorations sponsored, 8 were for antimony, 4 for cobalt, 1 for columbium and tantalum, 28 for copper, 85 for lead, 7 for manganese, 1 for nickel, 2 for tin, 40 for tungsten and 33 for zinc. By the end of 1951, 51 of these explorations had been completed (or terminated in some other way) and, of these, twelve had resulted in discoveries warranting development, among them two tungsten deposits, two manganese deposits and one lead and zinc deposit.

[13] During the first half of the nineteen thirties the United States ranked second (next to France) as a producer of bauxite. In the period 1930 to 1934, United States production totalled about 54 million tons, compared with 10 million tons in the period 1940 to 1944, when aluminium output was at a much higher level.

especially if the new chemical technique of extraction is perfected, although not more than a small fraction of normal requirements is likely to be met from domestic resources. Tin deposits are almost unknown in North America, and relatively little is likely to be obtained from residual ores in Europe.

Even in respect to the ores of some of the major metals, such as copper and lead, of which the United States has long been the leading producer, richer deposits are known to exist in several under-developed countries. In the case of copper, for example, the United States is already mining low-grade ores whose competitive position would probably deteriorate rapidly if the ratio of cost to price were to rise or the throughput of ore to fall. In the case of zinc and lead, the decline in price from about 19 cents per pound to about 13 cents in the second half of 1952 brought about the closing of many marginal mines in the United States and caused the industry to appeal for tariff protection against lower cost imports, a large proportion of which come from under-developed countries—Bolivia, Mexico, Peru and South West Africa, for example. Furthermore, some of the metals which are just beginning to play an important part in industrial processes are derived mainly from under-developed countries: beryllium comes largely from Brazil and South West Africa, colombite from Nigeria, germanium from the Belgian Congo, indium from Peru and tantalite from Brazil and the Belgian Congo.

The competitive position of mines in under-developed countries depends largely on the extent to which they are affected by local cost-determining conditions. Among the more lasting advantages sometimes found in under-developed countries are favourable location of deposits—in relation to surface, potential power supply, ports and so on—high grade and tractability of ore, and geological conditions which permit the use of simple mining techniques. Among common temporary advantages are lower wage rates and the strength that mining companies—often large by local standards—tend to have in buying goods and services and in negotiating with governments. Apart from the possible handicap of bad climate and geographical isolation, most of the disadvantages arise from the unsuitability or immaturity of the economic environment: these are likely to be overcome only slowly as the process of development continues and ancillary industries and services are established.

Advances in technique, whether in locating new ore bodies or extracting, beneficiating or smelting the metal, though they may be evolved in the industrial countries first, tend in due course to be applied in under-developed countries.[14] In the meantime, indirect technical advantages—better transport facilities, more adequate power resources and hence a higher degree of mechanization in mining processes and, not least, an improvement in labour skills—which have in many cases enabled low-grade mines in industrial countries to compete successfully with potentially richer mines in less developed parts of the world, also tend to spread. While it is true that a good deal of mining in under-developed countries is carried on in a very primitive manner, especially in areas where labour is relatively cheap and capital costly and difficult to obtain, it is also true that many of the larger mines are technically as efficient as their counterparts in industrial countries. The difficulties of these larger mines as agents of development in the under-developed country are associated less with the actual process of mining than with the more general inadequacy of the economic environment in which they operate. In this respect, the building of smelting facilities, which has been proceeding steadily, if slowly, in most of the under-developed mineral economies, also contributes towards the equalization of advantages. However, markets are still overwhelmingly in industrial countries, and this is undoubtedly a handicap to some of the mines and refineries in under-developed countries. Local consumption of non-ferrous metals has increased very slowly, although in those countries in which steel is now produced a metallurgical industry is in the making.

In general, therefore, although mineral producers in under-developed areas are not unfavourably placed for competition with producers in industrial countries, they could be adversely affected if for any reason significant sectors of the major industrial markets were closed to them. In view of the paucity of non-ferrous mineral resources in most of the European countries, it is mainly in the United States that such policies as a high tariff, subsidization of high-cost local mining or restrictions on use, if maintained for any length of time, would seriously reduce the demand upon which production in under-developed countries so greatly depends. Selective subsidies were employed in the United States during the war, through the premium price plan, and were again resorted to from 1950 to 1953 to expand facilities and increase stockpiles. However, there has been no official suggestion of turning this into a long-term policy designed, in the interest of security, for example, to exploit the large-scale, but low-grade, resources of manganese ore, chromite, bauxite and other non-ferrous ores which the United States possesses. Although local mining interests, especially lead and zinc producers, are traditionally in favour of protection,[15] government policy has tended to move in the other direction, at least during the period of active demand for most of the base metals, regarding domestic resources more in the light of a strategic reserve to be developed but not to be exploited intensively when alternative sources of supply are open.

Non-ferrous ore and metal production in the under-developed areas as a whole is thus likely to be threatened less by the inadequacy or inferiority of resources than by changes in demand resulting from trade barriers or from technological advances which permit new economies in metal use or new forms of substitution of mate-

[14] The fact that technical progress is continuous, however, may tend to maintain the gap between the advanced countries and the less developed ones.

[15] One recent proposal for a "sliding scale stabilization tax" envisaged a "parity price" and the imposition of a duty of one cent per pound on imported metal for every cent the market price fell below this parity level.

rials. Their relative resource position, indeed, is more likely to improve than to deteriorate, for so far as currently exploitable reserves[16] are concerned, the industrial countries have a significant proportion of the world total only in the case of lead and zinc, and are notably deficient in the case of such metals as tin, manganese, chromium and cobalt. Moreover, the state of knowledge concerning unexploited resources is far more rudimentary, and the chances of future discoveries far greater, in under-developed than in industrial countries.

In general, therefore, the principal consuming countries as a group at present account for a smaller proportion of probable ore reserves than of current output. The principal exception to this generalization is the United States, which is both the largest producer of durable goods—and hence the largest consumer of metals—and a major producer of many of the metals, possessing important ore reserves. The Soviet Union, also a leading metal producer as well as a large consumer, has substantial reserves of most of the ores. Canada consumes significant quantities of several of the non-ferrous metals and is also an important producer, with major reserves of copper, nickel, lead and zinc. Australia, whose degree of industrialization results in a relatively high per capita level of metal consumption, is a major producer and exporter of lead and zinc, of which it has large reserves. Zinc is also produced in excess of domestic needs by two of the industrial countries of Europe, Italy and Sweden, while two of the continent's less developed countries, Portugal and Spain, produce sizable surpluses of several of the non-ferrous ores, as does Yugoslavia. None of the western European countries, however, has significant reserves in comparison with those of Canada or the United States or the less developed mineral economies of Africa and Latin America.

The pattern of international trade

From the preceding sections it is evident that the geographic distribution of non-ferrous metal consumption is quite different from that of production. The preponderant part of output is consumed in the industrial countries, few of which are significant producers. If, instead of past and current production, ore reserves and potential future metal production are taken as criteria, the difference is even more marked. While a few of the industrial countries are important producers of certain non-ferrous metals, all the under-developed countries which produce such metals are *ipso facto* surplus countries and exporters. Some of the principal industrial countries produce little or nothing in the way of non-ferrous metals, and all of them have deficits in respect of most of these metals. Even the United States, despite its large base metal output, has moved into the category of deficit countries, while the four main consumers of western Europe—the United Kingdom, western Germany, France and Belgium—rely almost entirely on external sources for their primary supplies of most of the non-ferrous metals.

This division of countries into surplus or deficit categories sets the basic pattern of international trade in non-ferrous metals: in general it is a flow from the less developed to the more developed countries. Within this basic pattern, the actual flow is governed by a number of technical, economic and historical considerations.

Historically, the export of mining capital and skill by an industrial country has usually been followed by the importation of a large proportion of the ore resulting from the investment, thus establishing a fairly well defined trade nexus, which, in many instances, has been made more rigid by the location and ownership of smelters and refineries for the treatment of the ore in question. More recently, the movement of non-ferrous metals, as of other raw materials, has been influenced by changes in the ability of various industrial countries to pay in specific currencies. In several instances this has served to reinforce the tendency for trade flows to conform to earlier investment flows: Belgium draws much of its own non-ferrous metal supply from the Congo, for example, and the United Kingdom has tended to rely to an increasing extent on sterling sources such as Australia and the African colonies, at the expense of Canada and Latin America. Thus, the great increase in United States demand on the international market has been accompanied in the post-war period by a tendency for European demand to concentrate on soft currency sources of supply.

One of the results of war-time control was the closing of the London market and other metal markets and the replacement of a large volume of private trading by government purchasing and distribution. This arrangement, which post-war balance of payments difficulties and consequent currency control made it necessary to continue, served to narrow the market considerably; most British transactions were negotiated directly between the producer and the Ministry of Supply, and the entire output of many mines—those of the Northern Rhodesian Copper Belt for example—flowed directly or by way of a German or American refinery into official stocks in the United Kingdom. The market for tin, a predominantly sterling commodity, was reopened in 1949, but the effect of this was offset to a certain extent when United States buying was centralized in the Reconstruction Finance Corporation (RFC) early in 1951. RFC control was relaxed early in 1952, and the London market was reopened for lead, another largely sterling commodity, later in the year, for zinc at the beginning of 1953 and for copper towards the end of that year. Although the quantities of metal, especially copper, flowing to the exchange were at first somewhat meagre, and certain restrictions were placed on transactions in order to prevent too great a leakage of dollars, one of

[16] Reserves which are economically workable at current costs and prices and with existing techniques of mining and refining. They may be "measured" or "proved" or just "indicated" in the course of mining operations. In many an under-developed country the bulk of its estimated resources is merely "inferred" from what is known of the geological structure of the area being mined, or else is only "potential" ore.

the effects of the reopening of a free market was a general reduction in the rigidity of the pattern of trade that had been established during the war.

In general, the flexibility of the trade pattern tends to vary with the degree of processing to which the mineral has been subjected before export: ore and concentrates which have undergone little beneficiation have a much more restricted market than have refined metals. Hence, the less developed the country producing the ore, the greater is its dependence on external smelting and refining facilities likely to be. Such facilities may be operated independently in one of the industrial countries or may be part of one of the non-ferrous metal systems, with central refinery and tributary mines, operated by the large international companies. By and large, the movement of most of the alloy metals is more restricted than that of the ordinary non-ferrous metals, for as indicated in an earlier section of this chapter, the main consumers are the technically advanced units of the steel industry.

Despite a number of monopolistic elements, some arising from the geographic concentration of the ore and some from the size and organization of the large companies, there are strong competitive forces at work in the non-ferrous metals industry. The producer in an under-developed country has to compete not only with producers of the same metal both in other under-developed countries and in some of the industrial countries which constitute his market, but also with the producers of potential substitutes, not least the other non-ferrous metals. However important it is for the under-developed mineral economy to maximize its foreign exchange earnings from non-ferrous metal exports, it usually has little or no control over the market for its products. Nor does its financial status permit it to carry large unsold stocks or to extend lengthy credits to purchasers. Concentration of the demand, moreover, tends to increase the dependence of such an economy on particular markets, magnifying the risk of changes and fluctuations which it cannot influence.

In the light of this, the expansion of United States demand takes on a special significance. The United States emerged from the Second World War by far the largest single market, even for some of the metals of which it had previously been a net exporter. The consequence was a considerable shift in the pattern of trade, increasing very greatly both the relative and the absolute flow of metals to the United States.

In 1937 the United States had a copper surplus (refined supply from domestic mines and secondary sources minus domestic consumption of refined metal) of about 191,000 short tons. In 1950 not only was the whole domestic output consumed by industry, which had expanded, but to meet a deficit on internal requirements of about 242,000 short tons large quantities of copper had to be imported. Over the same interval, the zinc deficit increased from about 41,000 short tons to more than 112,000, while a small lead surplus of 61,000 short tons was converted into a much larger deficit of 221,000. Over the whole range of non-ferrous metals, requirements tended to increase much more rapidly than domestic production, consumption becoming more and more dependent upon imports, either of ores and concentrates or of primary metal. In the case of aluminium, the United States has become both the largest producer and the largest importer.

Among the major non-ferrous metals, the difference between post-war (1947-50) and pre-war (1936-38) imports into the United States ranged from an increase of about 60 per cent in the case of tin and 120 per cent in the case of copper to a sixfold increase in the case of bauxite and aluminium, an eightfold increase in the case of lead and almost a fourteenfold increase in the case of zinc. The expansion of imports of ores of the minor metals, though considerable, was somewhat less: it ranged from an eighth in the case of antimony and cadmium and three-fourths in the case of manganese to a doubling in the case of nickel, a threefold increase in the case of chromium, a fourfold increase in the case of tungsten and a sixfold increase in the case of cobalt.

In western Europe the war resulted in changes of the opposite nature. In several countries—particularly western Germany and Italy—there was a marked decrease in consumption and in most countries at least a temporary increase in the use of scrap and secondary supplies available for the most part internally. The general effect was a significantly lower level of imports during the early post-war years. With economic recovery, especially in western Germany, and the exhaustion of some of the war-accumulated stocks of scrap material, the volume of non-ferrous metal trade tended to rise, but it had not regained the pre-war level by 1950. The only exception to this generalization among the major non-ferrous metals is aluminium, consumption of which has increased universally, and imports of which into western Europe in 1949 and 1950 were at four or five times the 1937 rate.

The extent to which exports from the less developed countries have been diverted from western Europe to the United States is brought out by a comparison of imports in 1937-38 and 1952-53 (see table 8). In contrast to the marked increase in imports of all the major metals and their ores or concentrates into the United States, average annual imports into the principal European consuming countries were generally lower in 1952-53 than in the pre-war years 1937-38, and in some cases lower than in the earlier post-war years 1947-48. Apart from aluminium, imports of which were higher in most countries, the only exceptions to the decline were copper and lead imports into France, imports of tin concentrates into Belgium, and zinc imports into Italy, Sweden and the United Kingdom. There was no noticeable tendency to turn from imports of ore or concentrates to imports of primary metal: imports of copper ore and concentrates were appreciably lower in Belgium and Italy but appreciably higher in western Germany and Sweden, imports of lead ore and concentrates were lower in western Germany and Italy but higher in France, imports of tin ore and concentrates were lower in western Germany and the United Kingdom but higher

Table 8. Imports[a] of Non-Ferrous Ores and Metals into Selected Countries, 1937-38, 1947-48, and 1952-53

(Thousands of metric tons, metal content, except as indicated)

Country and years (average)	Aluminium	Copper: Ore and concentrates[b]	Copper: Metal	Lead: Ore and concentrates[b]	Lead: Metal	Tin: Ore and concentrates	Tin: Metal	Zinc: Ore and concentrates[b]	Zinc: Metal
United States:									
1937–38	7.9[c, d]	62.5	174.7	36.1	16.8[d]	0.1	70.3	12.5	20.3
1947–48	44.8	79.6[e]	331.5[e]	52.0	188.4	34.0	37.7	255.0	75.1
1952–53	194.7[e]	100.9[e]	481.5	120.9	404.1	31.8	78.8	436.4	156.2
United Kingdom:[e]									
1937–38	23.5[d]	—	378.7	0.2	396.3	34.3	8.0	56.4[d]	173.8
1947–48	119.4	—	365.0	0.2	182.0	26.3	0.2	71.7	160.8
1952–53	213.3	—	367.7	—	166.0	28.3	2.0	90.5	183.3
Belgium and Luxembourg:									
1937–38	3.8[d, f]	39.1	227.4	119.6	28.1[f]	6.9	3.7	578.1	19.0
1947–48	5.3	13.6[g]	190.7	80.8	23.6	11.2	2.2	329.1	5.5[h]
1952–53	12.8	0.9	162.8	116.6	21.3	10.0	1.4	429.1	1.3
France:									
1937–38	—	0.1	114.0	47.8	60.5	0.1	9.8	174.6	34.4
1947–48	24.8	0.5	146.6[c]	62.0	49.3	0.1	9.5	75.7	49.9
1952–53	2.7	—	128.1[e]	64.2	46.8	—	7.0	176.9	26.6
Germany:									
1937–38[i]	14.5[d]	568.2	195.1[e, j]	134.1	78.4	2.1	10.3[c, k]	108.7	76.3[c]
1947–48[l]	10.3	600.0[g]	17.5[c]	—	0.7	—	0.5[c]	—	5.5[c]
1952–53[m]	9.8	1,106.6	126.9[c]	56.9	13.3	0.3	6.2	64.9	20.4[c]
Italy:									
1937–38	0.3[d, f]	3.0	76.9[f]	13.7	9.8	—	4.1	0.1	0.2
1947–48	7.4[f]	—	59.3[f]	—	9.1	—	2.0[f]	0.1	2.2
1952–53	6.0[g]	1.1	71.0	0.1	9.1	—	2.7	1.9	4.5
Sweden:									
1937–38	4.7[d]	0.8	49.8	—	22.9	—	2.4	—	18.8
1947–48	11.7	—	44.6	—	15.8	—	1.5	—	19.7
1952–53	14.9	39.3	45.2	—	12.6	—	0.7	—	24.2
Japan:									
1937–38	27.0[d]	...	74.0[n]	—	82.0	...	7.6	0.2[o]	37.8[p]
1947–48	—	...	—	0.3	2.5[g]	—	1.5[q]	1.5	...
1952–53	0.6	30.6	1.1	1.0	1.8	—	3.5	0.2	4.9

Source: Metallgesellschaft Aktiengesellschaft, *Metal Statistics:* International Tin Study Group, *Statistical Yearbook;* American Bureau of Metal Statistics, *Yearbook;* British Bureau of Nonferrous Metal Statistics, *Bulletin* (London); and national trade statistics.

[a] Imports for consumption plus withdrawals from bond.

[b] Gross weight except in the case of the United Kingdom and the United States, whose imports are measured as metal content.

[c] Including scrap.

[d] 1938 only.

[e] Total current imports, metal content.

[f] Including alloys.

[g] 1948 only.

[h] Including zinc dust.

[i] Including the Saar.

[j] 1936.

[k] 1937 only.

[l] British and United States zones.

[m] Federal Republic.

[n] Estimated on the basis of 1936 imports and reported shipments to Japan in 1938.

[o] Estimated on the basis of the difference between mine and smelter production.

[p] Estimated on the basis of the difference between primary consumption and smelter production.

[q] 1947 only.

in Belgium, and imports of zinc ore and concentrates were lower in Belgium and western Germany but higher in France, Italy and the United Kingdom.

In Japan, the demand for non-ferrous metals in the post-war period 1946 to 1950 was far below pre-war and, in the case of most of the metals, domestic output was sufficient to sustain the current level of manufacturing production. Importing much less than in the years immediately preceding the war, Japan has thus exercised comparatively little influence on post-war markets.

Increases in demand in some of the less developed countries, Argentina, Brazil, India and the Union of South Africa in particular, though large in relation to pre-war levels, remain small in relation to the requirements of the industrial countries. This is also true, though to a lesser extent, of the demand in those high-income countries, such as Australia and Canada, which have been developing rapidly and are now significant consumers of non-ferrous metals. In these countries, greater internal requirements for several of the metals have been met from domestic resources, by increased production or by withdrawal of supplies which would otherwise have been available for export.

Despite these changes in market forces which have accompanied the disproportionate rise in United States demand on the world market and, to a somewhat smaller extent, the increased African and Latin American supply, many of the earlier patterns of commodity movement have tended to persist.

Thus, the United States continues to draw the bulk of its non-ferrous metal imports from the Western Hemisphere: more than 90 per cent of its aluminium, zinc and cadmium imports, more than 80 per cent of its copper and bauxite imports, more than 70 per cent of its lead and antimony imports, and more than 20 per cent of its tin imports. The natural attraction of the large neighbouring market is reinforced by the financial ties arising from the investment of United States capital in the mining enterprises of the region, particularly in Bolivia, Canada, Chile and Mexico, and to a smaller extent in Cuba and Peru. Many of these mines remain dependent for smelting and refining facilities on establishments within the United States, technical considerations thus tending to reinforce the economic influences which determine the flow of trade. In 1952, the proportion of United States imports of the major non-ferrous metals coming from "direct investment companies" (that is, from mines and smelters controlled by United States investors) was 25 per cent in the case of zinc, 55 per cent in the case of lead, 85 per cent in the case of copper and 90 per cent in the case of bauxite and aluminium.[17]

Among the alloy metals, by contrast, only nickel comes predominantly from the Western Hemisphere; Africa is the principal source of the ores of cobalt, manganese and chromium, and Asia the principal source of tungsten ore. This distribution of sources obtained before the war as well as after, with the one exception that the Soviet Union was then the main supplier of manganese ore. In 1952, 40 per cent of the chromite and 90 per cent of the nickel imported into the United States originated in direct investment sources.[17]

Although most of the major non-ferrous metals continue to come predominantly from the Western Hemisphere, the expansion in total United States requirements does nevertheless seem to have brought about a slight tendency for the proportion of imports from these sources to decline. The proportion of cadmium, cobalt and copper imports coming from Canada, for example, was somewhat less in 1947-50 than it was in 1936-38, while the proportion of antimony, lead, zinc, chromite and manganese imports coming from Latin America had also declined slightly. The proportion of United States imports coming from outside the Western Hemisphere has in this way tended to increase for all the non-ferrous metals except aluminium, tin, zinc, cadmium and tungsten.

To a certain extent the movement of ores and concentrates to the United Kingdom is governed in much the same way as United States trade by historical, financial and technical considerations arising from investment in mines overseas and internal investment in refining. Domestic refining capacity, however, is small in comparison with that of the United States and in relation to internal metal consumption; hence a much higher proportion of United Kingdom imports is in the form of primary metal. Whether of ore or of metal, British imports originate to a large extent from within the Commonwealth: more than four-fifths of lead and aluminium imports, about two-thirds of copper and zinc imports and between a third and a half of tin imports. Canada is an important source of all metals except tin; Australia supplies most of the lead and zinc, Northern Rhodesia about half the copper and Nigeria about a third of the tin. Outside the Commonwealth, the principal source of tin is Bolivia, where British capital developed several of the mines, while both Belgium and the United States provide substantial quantities of copper and zinc.

Belgium, which has a large metallurgical industry and is an important source of copper and zinc and, more recently, of tin has no domestic ore production. It receives all its tin concentrates, three-fourths of its copper and one-fourth of its zinc from the Belgian Congo, where it has large mining investments. For the rest, it relies on European sources such as Italy and Sweden, as well as on the major exporters, Canada and Australia.

France produces all its own bauxite and since 1950 has resumed its status as a net exporter of aluminium. More than three-fourths of its lead imports and a significant proportion of its imports of zinc ore come from within the French Union, chiefly from North Africa. New Caledonia provides most of French imports of nickel and chrome ores. In recent years Belgium and Norway have been among the principal sources of zinc metal, while French imports of copper have come mainly from the Belgian Congo, Belgium, Chile and the United States. Malaya and the Netherlands have supplied most of the tin.

---

[17] United States Department of Commerce, *Survey of Current Business* (Washington, D. C., December 1953), page 14.

Chapter 3

INTERNATIONAL CONTROL SCHEMES

A serious economic problem facing the non-ferrous metals industry—and hence the under-developed mineral economies—has been the wide fluctuation in demand and price which, as pointed out in the preceding chapter, has characterized the market for durable goods and their constituent metals. To a certain extent, integration of various sections of the industry within large international companies, by linking mine to smelter, smelter to refinery and refinery to fabricator, has probably tended to reduce the instability of demand and supply for some of the components of the system. The general instability of the market has remained, however, and in the case of most non-ferrous metals, further protection has from time to time been sought by agreements and combinations among the integrated systems and independent producers. By and large these agreements have been designed to maintain price by concerted adjustments of output in response to fluctuations of demand.

On the whole it must be concluded that this type of agreement has not been particularly successful. This would appear to be partly because of the inherent difficulty of making such concerted adjustments rapidly, partly because there have always been producers who were not party to the agreement and whose output has on occasion been large enough to nullify the efforts at production control, and partly because the members of the organization have themselves been essentially competitors whose cost conditions were not necessarily identical and whose assessments of the advantages flowing from the agreement consequently tended to vary considerably. Low-cost producers, for example, have usually been the first to break away from cartels, having greater confidence than other members in their own ability to cope with free market conditions. Smelters and refineries with a high proportion of work accepted from independent mines on a custom or toll basis, whose revenue depends upon throughput rather than upon the market price of the metal, as well as those with high capital charges, whose unit costs rise rapidly if output declines, have also been among the members offering the greatest resistance to restriction.

In this respect, at least, the distinction is *not* between producers in advanced countries and those in less developed countries: both groups stand to gain by market stability and higher prices. Restrictive schemes, however, obviously have a potentially more serious effect upon the non-ferrous metals industry in under-developed countries, since they influence not only the output of ore and metal and the revenue accruing to the mining company from its sale, but also the foreign exchange earnings of the country, the revenue accruing to the government, the amount of employment and new investment in mining, the rate of opening up new ore resources and, in general, the whole development potential of the industry. The problem thus lies in the borderland between two topics in which the United Nations has a special interest: on the one hand is the field of restrictive business practices; on the other is the broad question of the stability of commodity trade. The present study is concerned with neither of these subjects, but with the implications for the industry's development potential of the attempts that have been made to maintain the level and stability of non-ferrous metal prices. It is in order to throw a little more light upon this aspect of the problem that the present chapter describes some of the international schemes under which the marketing and production of the major non-ferrous metals have from time to time been regulated.[1]

ALUMINIUM

International regulation of aluminium production was facilitated in the early stages of commercial production of the metal both by the existence of patents which limited the right to use the Heroult-Hall technique of reduction and by the relatively high capital cost and electricity requirements of the process. By the end of the nineteenth century there were four companies operating in Europe—in France, Germany, Switzerland and the United Kingdom—and one in the United States—the Pittsburgh Re-

[1] Restrictive practices aspects of the problem have been discussed in *International Cartels* (League of Nations publication: 1927. II. 16); *International Cartels* (United Nations publication, sales number 1948.II.D.2) and, at greater length, in Supplements 11, 11A and 11B to the *Official Records of the Economic and Social Council, Sixteenth Session*, documents E/2379 and addenda 1 and 2, and E/2380. Information contained in the present chapter has been derived largely from the following sources: the series of *Materials Surveys* compiled for the United States National Security Resources Board by the Bureau of Mines (1950 to 1953); W. Y. Elliot, E. S. May, J. W. F. Rowe, A. Skelton and D. H. Wallace, *International Control of Non-Ferrous Metals* (New York, 1937); United States Federal Trade Commission, *The Copper Industry* (Washington, D. C., 1947); United States House of Representatives, Hearings before the Subcommittee on Study of Monopoly Power, Serial No. 1, Part 1, *Aluminum* (Washington, D. C., January and February 1951); K. E. Knorr, *Tin Under Control* (Stanford, 1945); C. K. Leith, J. W. Furness and C. Lewis, *World Minerals and World Peace* (Washington, D. C., 1943); J. B. de Mille, *Strategic Minerals* (New York, 1947); United States Tariff Commission, War Changes in Industry Series, Report No. 14, *Aluminum* (Washington, D. C., 1946).

duction Company, later (1917) organized into the Aluminum Company of America (ALCOA).

The first aluminium cartel was organized by the four European companies in 1901 in anticipation of the lapsing of the original patents. The Northern Aluminium Company of Canada—formed by the Pittsburgh Reduction Company to exploit the rights it had acquired on the Shawinigan Falls—also acceded to the cartel agreement, which was designed to protect the domestic markets of members, allocate quotas in neutral markets, particularly Germany, and prescribe minimum prices.

During the rapid expansion of demand between 1901 and 1907 seven new companies came into existence in Europe. The original four, however, absorbed the three largest of these within a few years (and two others after the First World War). Nevertheless, in 1908, it was strain within the cartel rather than competition from without that caused its dissolution; there was disagreement over price policy, in particular, the Swiss and Canadian producers favouring higher prices than the French and British. A few months later the Aluminium Company of Canada (ALCAN, successor of the Northern Aluminium Company, the Canadian subsidiary of ALCOA) entered into an agreement with the principal European producer—Aluminium Industrie Aktien Gesellschaft (AIAG)—regarding their export sales, reserving the United States market to ALCOA (except for whatever exports from France and the United Kingdom could surmount the customs tariff). This lasted until 1911, but in the following year the European cartel was re-formed with Canadian participation, plants in Italy and Norway (the latter owned by the British Aluminium Company) being added to the total capacity under control.

War brought the second cartel to an end in 1914 and gave a considerable stimulus to production, especially in Canada and the United States. In 1926, alarmed by the growth of North American capacity, European aluminium producers, who had been associated in a price maintenance agreement since 1923, re-formed the old cartel, organizing an Aluminium Association with headquarters in Switzerland and fixing sales quotas in markets outside North America for what amounted to rather less than half of world production. At the same time, the French and Swiss companies reorganized their capital, distributing voting stock in a way intended to protect them against being bought up piecemeal. Before the full force of the depression of 1930 to 1933 had increased the degree of competition within the industry, however, Aluminium Limited (ALTED)—a company formed in 1922 to take charge of the international interests of ALCOA and ALCAN—had joined the European group in the Alliance Aluminium Company which, controlling about 60 per cent of the world's production and practically the whole of the aluminium entering international trade, undertook to fix quarterly production quotas and dispose of the surplus stock that had accumulated. In the initial distribution of quotas, Canada was given 28 per cent of the total, France 21 per cent, Germany 20 per cent and Switzerland and the United Kingdom 15 per cent each. ALCOA, not being an exporter, was left in possession of the United States market, while the Union of Soviet Socialist Republics, which had started producing in 1931, agreed not to dump aluminium abroad.

In 1933 the output of members of the Alliance Aluminium Company amounted to about 67,000 metric tons —18,000 in Germany, 16,000 in Canada, 11,000 in France, 11,000 in the United Kingdom and 7,000 in Switzerland. United States production at that time totalled about 39,000 metric tons. The only other producing countries had close links with the cartel: Norway (15,000 metric tons) where ALTED, the British Aluminium Company and the Compagnie de produits chimiques et électrométallurgiques Alais, Froges et Camargue (CAFAC—the French concern) owned subsidiaries; Italy (12,000 metric tons) where AIAG, the Vereinigte Aluminium-Werke and ALTED participated in the control of three plants; Austria (2,100 metric tons) where the Swiss company operated; and Spain (1,200 metric tons) where a small plant controlled by CAFAC and AIAG operated behind a high tariff. Before the outbreak of the Second World War brought activities of the Alliance Aluminium Company to a temporary halt, aluminium production had commenced in Sweden (by an affiliate of the British Aluminium Company), Japan (where ALTED had built a plant in 1934), Hungary (in 1938), Yugoslavia and Taiwan (in 1938) and Manchuria (where a Japanese plant had come into operation in 1939).

In 1934, Germany withdrew from the Alliance Aluminium Company, but, though refusing to limit production, agreed to restrict exports in conformity with cartel quotas. In 1936, in order to enforce these quotas, the cartel introduced a system of fines for excess production, but demand for aluminium was rising and when, shortly afterwards, rearmament programmes got under way the need for restriction disappeared.

In the post-war period more emphasis seems to have been placed on expanding markets than on curtailing production; with new uses for the metal and new methods of working with it, and the consequent increase in both military and civilian demand, the period has been one of expanding capacity. Compared with the 1939 output of about 630,000 metric tons (excluding that of the USSR) world primary aluminium capacity at the end of 1954 was more than 2.5 million metric tons. Of this, however, not much more than 111,000 tons was outside of North America and Europe, and under 30,000 tons was in the under-developed countries of Africa, Asia (excluding mainland China) and Latin America. Throughout the period under review the predominance of a few large concerns has tended to facilitate international control over production and price policies, whether on a formal or an informal basis.

Copper

In the period between 1878, when the incandescent lamp was invented (and total copper output was of the order of 150,000 metric tons a year), and the beginning of the First World War (when output had increased to a million tons a year), the chief international aspect of the organization of the industry concerned relations between the markets of Europe and the rapidly expanding production of the United States, dominated increasingly by a few large mining groups. It was not until United States companies began exploiting Chilean copper ore resources, during the war, that an under-developed country became involved in the international copper market as an important producer.

A price decline which had commenced in 1913 was cut short by the war and the consequent upsurge of demand, which stimulated an increase in production to the record level of 1.5 million metric tons in 1917. This was made possible by the rapid expansion of copper mining in the Western Hemisphere, where capacity increased by about two-thirds during the period of the war. It was at this time that the flotation process of concentrating ore—evolved, incidentally, in the relatively under-developed country of Australia in 1910—was being introduced into the United States to the very great advantage of non-ferrous metal production in general and copper production in particular.

In Chile, investment by two large United States groups, the Kennecott Copper Corporation (Guggenheim) and the Anaconda Copper Mining Company, resulted in the development of three major mining concerns—the Braden Copper Company, the Chile Exploration Company and the Andes Copper Mining Company. This not only made Chile the world's second largest producer, but also increased considerably the relative importance of United States concerns in the world copper market. By the end of the war European production had fallen far behind, in Africa output was on a very small scale, Asian production was confined largely to Japan, and Canadian production was lower than that of either Mexico or Peru, where United States concerns had also been busy. In the United States, which accounted for almost two-thirds of world output, three-fourths of the production came from 16 mines and almost two-thirds was under the control of six financial groups. The process of consolidation had been greatly assisted by virtually unlimited demand and high war-time prices which, while keeping a number of high-cost marginal mines in operation, had enabled low-cost producers, especially the porphyry mines in the United States and the new Chilean mines, to earn large profits and accumulate substantial reserves.

By 1918, however, high war-time production had also resulted in the accumulation of large stocks in the hands of producers and governments, and for the first time supplies of scrap became a significant threat to new production. Ostensibly to help in the liquidation of these stocks, the Copper Export Association was formed by major producers in the United States at the end of 1918, under the Webb-Pomerene Act. Production by members of the association was immediately restricted and later, in 1921/22, almost all member mines were closed for eight months. The consequent decline in production, together with occasional strikes during the post-war period of wage adjustment and the gradual recovery of domestic demand as the price of copper fell, served to clear surplus stocks from the association's pool.

Exports had played little or no part in the stock reduction; the principal markets in Europe had their own surplus problem and were more seriously affected by scrap accumulation than the United States. Indeed, during the first two years of the association's existence, when it controlled about two-thirds of world copper output, its attempt to maintain a high price, set early in 1919 at 23 cents per pound, but actually averaging about 19 cents during 1919 and 1920, resulted in the accumulation of no less than 191,000 short tons of copper—almost as much as the 200,000 short tons placed in the export pool early in 1921. It is not clear at what price the pool stocks were actually sold, but since the London price dropped to an average equivalent to about 12 cents and the New York price to an average of about 13 cents during 1921 and 1922, the liquidation involved a considerable sacrifice in price as well as a decline of about 400,000 tons in 1921 production.

Table 9. Copper Production,[a] 1919 to 1923

Item and year	*Members, Copper Export Association*		*Non-members*		*World total[b]*
	United States	*Other countries*	*United States*	*Other countries[b]*	
Amount (thousands of short tons):					
1919	538	162	67	303	1,071
1920	552	182	84	265	1,083
1921	162	65	77	298	602
1922	416	148	96	337	996
1923	641	232	113	426	1,412
Per cent of total:					
1919	50.3	15.1	6.3	28.3	100
1920	51.0	16.8	7.8	24.4	100
1921	26.9	10.8	12.8	49.5	100
1922	41.8	11.8	9.6	33.8	100
1923	45.4	16.4	8.0	30.2	100

Source: United States Federal Trade Commission, *The Copper Industry.*

[a] Metal content of ore.
[b] Excluding the Union of Soviet Socialist Republics.

Apart from the United States concerns which were members of the association, several United States companies operating in other countries were also involved because their output was sold through members: two Canadian concerns, Granby Consolidated Copper Company and Howe Sound Copper Company; two Peruvian companies, Backus and Johnston, and Cerro de Pasco Copper Corporation; as well as the Boleo Mining Company of Mexico and the Braden Copper Company of Chile. In general, however, production in these mines though following the same trend as United States domestic production, was not restricted to quite the same extent. Mines outside the United States not under the control of the Copper Export Association showed a decrease in production in 1920 but a rising trend thereafter; in 1921 they provided almost half of the world's reduced copper supply (see table 9). Though their relative importance declined, in absolute terms their output showed a substantial increase in 1922 and 1923. In relation to 1919 output, however, the largest gain was registered by independent mines in the United States. Compared with 1919 output, indeed, which for the association's United States members already represented a one-third cut from 1918 levels, production in 1923 showed that United States members had lost ground both to mines in other countries and to independent domestic mines. Moreover, the members' share of United States exports actually fell—from 63 per cent of the total in 1921 to 54 per cent in 1923. In 1924, when some of the larger interests, including the American Smelting and Refining Company and the Kennecott Copper Corporation, withdrew, the association ceased to function.

Perhaps most disturbing to established producers was the fact that development in the Katanga fields of the Belgian Congo, stimulated by the high prices resulting first from the war and then from the policies of the Copper Export Association, was beginning to yield large tonnages of high-grade ore. Output, which had amounted to barely 6,000 short tons of copper in 1913, reached a war-time peak of 30,000 tons in 1917 and in the post-war period rose from 21,000 short tons in 1920 to 99,000 tons in 1925, making the Belgian Congo the third largest producer.

It was the threat of new production of this nature which led United States concerns in 1926, in their second effort to strengthen their position and stabilize prices at a high level, to include a larger number of mines and smelters operating outside the United States. Technically, the relative strength of United States producers was greater on this occasion than it had been immediately after the First World War. In 1923 an important advance had been made in the flotation process for separating ore from gangue: by means of certain chemicals—sodium xanthate and sodium cyanide, in particular—a method of selective separation had been evolved, so that after the requisite degree of milling it became possible to separate not only the main ore but also subsidiary ores. Material which previously had been penalized by smelters and refiners by reason of its contamination with secondary ores now acquired an added value in by-products. The new beneficiation technique was soon applied throughout the non-ferrous metals field, and since it was of particular advantage in the treatment of ores resulting from non-selective mining, the copper industry benefited considerably, especially in the western areas of the United States.

In addition to the dominant United States groups, the organization established in 1926—Copper Exporters, Inc.—included representatives from Canada (American Metal Company of Canada, Limited), Mexico (Greene Cananea Copper Company), Chile (Andes Copper Mining Company and Chile Exploration Company), the United Kingdom (Henry Gardner and Company, Limited and the British Metal Corporation, Limited), Spain (Rio Tinto Company, Limited), Germany (four large smelters), Belgium (Société générale métallurgique de Hoboken) and the Belgian Congo (Union minière du Haut Katanga). These so-called "foreign associates" were not full voting members of the cartel but became members of its Brussels committee and supported its objects by negotiating contracts with it.

At the height of its influence in 1928, Copper Exporters, Inc., controlled almost 86 per cent of the world copper output, considerably more than its predecessor.[2] This control continued during the boom year 1929, but with the collapse of demand in 1930 and the decline in the average price, from about 18 cents a pound in 1929 to about 6 cents in 1932, the authority of the cartel began to evaporate, and it became difficult to enforce curtailment of output on producers outside the United States. Although, in November 1930, Union minière du Haut Katanga was persuaded to agree bilaterally, first with the Compagnie française des mines de Bor of Yugoslavia and then with the Chilean mines of Anaconda Copper Mining Company and Kennecott Copper Corporation, on a mutually satisfactory degree of restriction, the reduction was proportionately less than the relative importance of these mines in current output, and it was United States producer members who bore the brunt of the cut-back in production; between 1928 and 1931 their share of world output declined from 47 to 32 per cent while the share of "foreign associates" of the cartel rose from 18 to 21 per cent and that of independent producers from 15 per cent to 22 per cent (see table 10).

The cartel managed to hold the price at about 18 cents per pound until well into 1930. At this figure demand was substantially below the current level of output, and by the end of the year stocks had risen to very high levels.[3] Over and above the tendency for producers outside of the United States to maintain their output at approximately 1927-28 levels, the price maintenance efforts of the cartel encouraged considerable expansion

[2] United States Federal Trade Commission, *The Copper Industry*, page 214.

[3] Normal stocks were considered to be about two months' supply. Stocks at the end of 1930 represented supplies for about eight months at 1930 rates of consumption, 12 months at 1931 rates and almost 22 months at the 1932 rate of consumption.

Table 10. Copper Production,[a] 1927 to 1931

Item and year	Members, Copper Exporters, Inc.			Non-members		
	United States companies		Other companies			
	Operating at home	Operating abroad		United States	Other countries[b]	World total[b]
Amount (thousands of short tons):						
1927	795	334	299	53	203	1,683
1928	884	403	338	52	217	1,894
1929	968	441	395	58	256	2,118
1930	647	319	413	64	292	1,735
1931	479	322	354	45	287	1,488
Per cent of total:						
1927	47.2	19.8	17.8	3.1	12.1	100
1928	46.6	21.3	17.9	2.7	11.5	100
1929	45.7	20.8	18.7	2.7	12.1	100
1930	37.3	18.4	23.8	3.7	16.8	100
1931	32.2	21.7	23.8	3.0	19.3	100

Source: United States Federal Trade Commission, *The Copper Industry.*

[a] Metal content of ore.
[b] Excluding the Union of Soviet Socialist Republics.

of Canadian production, which had just begun to benefit from the introduction of the differential flotation process that made possible the economic exploitation of copper-nickel and copper-zinc ores. The first electrolytic refinery in Canada was built at Copper Cliff in 1930 (with a capacity of 168,000 tons a year) and a second refinery was opened at Montreal East in 1931 (capacity, 112,000 tons a year), the former by the International Nickel Company of Canada, Limited, and the latter by Noranda Mines, Limited.

More intensive exploration of the Northern Rhodesian copper fields was also encouraged by the policy of high price and restricted output that the cartel seemed to European consumers to be pursuing. Active development commenced in 1929 and production began to reach significant proportions in 1932. Negotiations between the Rhodesian producers and the cartel had been proceeding for some time, but the latter would not agree to the mines' request for a quota based on potential rather than actual production. With their development programme well under way, the Rhodesian mines refused to submit to the proposed restriction of output and this deadlock marked the end of the effective authority of Copper Exporters, Inc. When the cartel price finally broke, it rapidly followed the free market price downward; the restrictive contracts, which in March 1932 had fixed quotas at 20 per cent of 1929 capacity, ceased to be operative and, following the imposition in May 1932 of a duty of 4 cents per pound on imports into the United States, most of the "foreign associates" withdrew. This brought the cartel to a virtual end though it was not formally disbanded until early in 1933 when the United States members resigned. By this time Canada and Northern Rhodesia ranked third and fourth as copper producers, not very far behind Chile and well above the Belgian Congo.

The years 1934 and 1935 were marked by slowly rising prices and increasing production from all five major sources. In the United States the copper industry was liquidating excess stocks and, behind the prohibitive 1932 tariff, working out a code of operation under the National Industrial Recovery Act. This was the background against which another attempt was made to organize an international cartel, this time primarily among new producers. The mines involved were all in underdeveloped countries: three Rhodesian companies (Rhokana Corporation, Limited, Mufulira Copper Mines, Limited, and Roan Antelope Copper Mines, Limited); the Union minière du Haut Katanga in the Belgian Congo; the Braden Copper Company, Chile Exploration Company and Andes Copper Mining Company in Chile; and the Greene Cananea Copper Company in Mexico. Associated with this group were the Compagnie française des mines de Bor in Yugoslavia and the British-owned Rio Tinto Company, Limited, in Spain. Canadian producers co-operated but did not formally participate. No United States domestic mines were directly involved but, besides the participation of the Anaconda Copper Mining Company and Kennecott Copper Corporation through their Chilean interests, the American Metal Company, Limited, was also concerned by reason of its holdings in the Rhodesian Selection Trust and in the International Nickel Company, the largest Canadian producer. In the opinion of some analysts it is not unlikely that the cartel was assured that there would be no great increase in United States exports.[4] In these circumstances the cartel exercised direct control over about one-half of the production of copper outside the United States and the Union of Soviet Socialist Republics.

[4] In fact neither the Kennecott Copper Corporation nor the Anaconda Copper Mining Company exported any duty-free copper between mid-1935 and mid-1938, and United States exports were maintained at a fairly low level by the Phelps Dodge Corporation, the American Smelting and Refining Company and the American Metal Company, Limited: 126,000 short tons in 1934, 91,000 in 1935, 51,000 in 1936, 63,000 in 1937 and 126,000 tons in 1938 (United States Federal Trade Commission, *The Copper Industry*, page 239).

Table 11. Copper Production, 1935 to 1938

Item and year	Controlled by international copper cartel						Independent producers		World's total
	Belgian Congo[a]	Chile[b]	Mexico[c]	Northern Rhodesia[d]	Yugoslavia[e]	Total[f]	United States	Other countries[g]	
Amount (thousands of short tons):									
1935	119	273	21	164	43	620	381	617	1,618
1936	105	255	16	155	43	575	615	659	1,849
1937	166	419	22	234	43	886	842	783	2,511
1938	137	376	16	237	46	792	557	839	2,188
Per cent of total:									
1935	7.4	16.9	1.3	10.1	2.7	38.3	23.5	38.2	100
1936	5.7	13.8	0.9	8.4	2.3	31.1	33.3	35.6	100
1937	6.6	16.7	0.9	9.3	1.7	35.3	33.5	31.2	100
1938	6.3	17.2	0.7	10.8	2.1	36.2	25.5	38.3	100

Source: United States Federal Trade Commission, *The Copper Industry*, page 241.
[a] Union minière du Haut Katanga.
[b] Braden Copper Company, Andes Copper Mining Company and Chile Exploration Company.
[c] Greene Cananea Copper Company.
[d] Rhokana Corporation, Mufulira Copper Mines, Limited, and Roan Antelope Copper Mines, Limited.
[e] Compagnie française des mines de Bor.
[f] Excluding the small output of the Rio Tinto Company, Limited.
[g] Excluding the Union of Soviet Socialist Republics.

Immediately after its formation in 1935 the cartel cut its members' production quotas by 20 per cent. A further cut of 15 per cent reduced the share of cartel members in world output from 38 per cent in 1935 to 31 per cent in 1936 (table 11), United States production showing a marked increase. Increasing consumption during 1936 was met largely from inventories, which by the end of the year had been drawn down to extremely low levels. In the face of these market conditions, quota restrictions were relaxed in October 1936, and again in November, and were removed completely in January 1937, but not soon enough to prevent panic buying from driving the copper price up to 17 cents per pound, after a steady increase from the low level of 7 cents which had obtained when the cartel was inaugurated. However, the expansion of production which followed the withdrawal of restrictions brought the London price down to the equivalent of 9 cents per pound and, after being held at 13 cents for several months, the New York price also fell. Falling demand and renewed stock accumulation led the cartel to reimpose restrictions in December 1937. These were tightened in July 1938, relaxed during the last quarter of the year and reintroduced in January 1939. They remained in force until the outbreak of war, when the London market was suspended, the distribution of copper in the United Kingdom taken over by the Government and the cartel dissolved.

In some respects war-time controls were far more rigid than those devised by the cartels which the industry itself had previously organized. Governments (especially those of the United Kingdom and the United States) were in a monopsonistic position; they distributed all copper supplies, fixing prices more or less in accordance with costs which, by reason of wage and price controls, were themselves largely predetermined. The bulk of the copper output was bought at a fixed price based on designated pre-war standards, while marginal supplies were encouraged from higher-cost producers at premium prices negotiated mine by mine.

Although controls were relaxed in the United States late in 1946 and in various western European markets during the years that followed, the United Kingdom Ministry of Supply continued to act as single buyer and importer of copper, regulating both price and distribution within the United Kingdom. Following the outbreak of hostilities in Korea in 1950, moreover, there was a general reimposition of the type of controls employed during the Second World War, both price and use being regulated in most of the important consuming countries. Although international controls were not reintroduced along the lines of the war-time Combined Raw Materials Board, in mid-1951 the International Materials Conference began making recommendations concerning the equitable distribution of various scarce materials, copper among them, and from the fourth quarter of 1951 to the first quarter of 1953, international trade in copper followed the lines laid down in the recommended allocations. This continuation of control, added to the fact that the demand for copper remained very active, tended to distinguish the market in the first post-war decade from that of any earlier period of comparable duration. Even after the reopening of the free market in London in mid-1953, the price of copper, though dropping temporarily by about 12 per cent, remained firm at a comparatively high level.[5] Reconstruction and development programmes, with their emphasis on increased electrification, have been the main influences behind the sustained demand for copper; in 1951 world consumption was 23 per cent above the 1948 level and 57 per cent above the 1938 level.

During the first 75 years of the electrical era the evolution of the international copper market was marked by a sequence of events, the essential economic features of which were repeated from time to time on a widening scale: the achievement of control over production by a

[5] The index of the price of electrolytic copper on the London market in recent years (1950 = 100) has moved as follows: 1951, 123; 1952, 116; 1953, 118; 1954, 139; and 1955, first half, 151.

dominant company or group of companies, an attempt at price maintenance, usually checked by the opening of new sources of supply, followed by a reorganization of producers for another effort to control the market. Thus, within the United States, the consolidation of the important Michigan mines under the Calumet and Hecla Mining Company in the eighteen seventies was followed by the opening up of the Montana deposits. By the eighteen nineties Montana had become the leading world producer, but the consolidation of the Montana mines early in the present century under the company later to be known as the Anaconda Copper Mining Company led directly to the exploitation of the porphyry ores of Utah and Arizona and the emergence of the organization that in 1917 became the Phelps Dodge Corporation. High prices during the First World War encouraged the exploitation of Chilean ores, bringing into the picture the Guggenheim Exploration Company working through the Kennecott Copper Corporation, which had been organized in 1915 to operate rich but shallow mines in Alaska. Early post-war attempts by the three principal copper mining concerns—Anaconda, Kennecott and Phelps Dodge—to regulate the export market served to stimulate the development of the Katanga deposits in the Belgian Congo.

The next attempt to control the international market, organized in the second half of the nineteen twenties, included Katanga and other interests outside the United States, as well as the Latin American affiliates of the "Big Three", but the price policy of this group helped to turn Canada into a major producer and to bring about the exploration and opening up of the Northern Rhodesian Copper Belt. With the collapse of the cartel, copper prices fell to their lowest recorded figures.

The third attempt at international control, in which the "Big Three" were rather more passive, was cut short by the Second World War, but in the four or five years of the cartel's operation it was not very successful in eliminating or reducing price fluctuations by planning levels of production. Significant in the present context is the fact that this organization was based largely on African and Chilean mines—a recognition of the degree to which these new producers in less developed countries had become integrated into the international industry.

The desire for price stability remains strong. In the United States in the post-war period, the high degree of economic integration which characterizes the copper industry has facilitated the maintenance of lower and steadier prices than those determined on the freer markets of Europe. In relation to the war-time parity of 1911 to 1915, the average 1951 price was 250 per cent higher in the United States and 400 per cent higher in the United Kingdom. Since 1950 the United States price has risen by successive 3-cent increases, from 21 cents to 36 cents a pound; on the London Metal Exchange, since its reopening in mid-1953, prices have experienced violent short-term fluctuations but in general have been appreciably higher than in New York. It is significant that in May 1955 two of the principal sellers on the London market—the Northern Rhodesian companies, Roan Antelope Copper Mines, Limited, and Mufulira Copper Mines, Limited—offered to provide copper to fabricators in the United Kingdom at a price not only fixed for a longer period, initially one month at a time, but also markedly lower than the current quotations on the London Metal Exchange. The fact that several large manufacturers entered into contracts on the basis of this offer indicates that consumers may also be prepared to forgo the benefits of a free market in order to obtain a more stable price. In the background lies the fact that the copper industry has to meet the competition of the aluminium industry which, by virtue of its even higher degree of integration, has always been able to maintain a greater measure of price stability and in recent years has in addition offered a greater relative price advantage.

Lead

From the point of view of international organization, the lead industry is much less closely integrated than either the aluminium industry or the copper industry. This is not only because of the wider dispersion of lead mines—and smelters—but also because of the greater relative importance of scrap, whose origin is much more diverse. Furthermore, fabricating as such is much less important since, as indicated in the preceding chapter, a large proportion of lead passes straight from the refinery to chemical, automobile, petroleum and other consuming industries, without intermediate rolling, extruding or other forms of processing. There is consequently much less opportunity for vertical integration within the industry.

Both the wide dispersion of primary lead production and the widespread and increasing availability of secondary lead have tended to reduce the chances of successful international control. As a mineral usually produced jointly with zinc or silver, moreover, the supply of lead has been very responsive to changes in the demand for these other metals and hence not easily controllable by itself. With rapid price fluctuations presenting a constant challenge, however, difficulties in the way of international regulation have not prevented attempts at such regulation.

One of the earliest was organized in 1909 by Spanish, Belgian and German producers in co-operation with United States and Australian suppliers of the European market. This International Sales Association for lead attempted to prevent competition by dividing up the market, but its power was limited by the large number of independent sources of supply. After a good deal of instability in 1907 and a marked decline in 1908, prices on the New York exchange remained fairly steady during the period 1909 to 1913 though the United States market was not directly affected by the cartel. In contrast, as indicated in table 12, there was a substantial rise on the London exchange, where European market conditions were reflected. This was chiefly the result of increasing demand, however, for lead production was not curtailed; indeed, during the life of the International Sales Association (that is, until the outbreak of the First World War) total output tended to rise.

Table 12. Indices of Lead Production and Prices, 1907 to 1916
(1907 = 100)

Year	*World production*[a]	*Average price*		*Fluctuations in New York prices*		
		New York	*London*	*Average as per cent of low price*	*High as per cent of average price*	*Index of ratio of high to low price*
1907	100	100	100	116	112	100
1908	104	79	71	111	109	76
1909	107	80	68	107	107	69
1910	111	84	68	103	106	66
1911	111	83	73	104	102	61
1912	117	84	94	111	113	77
1913	116	82	98	108	107	71
1914	114	72	100	109	106	71
1915	109	88	120	125	127	97
1916	112	129	165	116	111	79

Source: American Bureau of Metal Statistics, *Yearbook, 1954* (New York, 1955).

[a] Excluding that of the Soviet Union.

During the war a certain degree of control was exercised by the Allied Governments but prices rose considerably. Total production remained fairly steady, a decline in Spanish and Mexican output being offset by an expansion of lead mining in the United States. Refining facilities in Belgium and Germany not being available to the Allies, the largest Australian producers —Broken Hill South, Limited, and North Broken Hill, Limited—developed a major smelter and refinery at Port Pirie. The post-war market was saved from a major price recession, such as might have resulted from the arrival on the market of accumulated supplies of lead scrap, by an expansion of civilian demand—occasioned to a great extent by the increased output of motorcars—and by a decline in the mine production of lead between 1919 and 1923 to rates below any prevailing during the previous decade.

Wider adoption of the technique of selective flotation began increasing lead resources during the nineteen-twenties, and output expanded steadily after 1922. Demand remained active; the average annual price recorded in 1925 was the highest attained to that time—not subsequently surpassed until 1947. By 1928, however, the average price had declined 30 per cent below the 1925 level, and a second and more comprehensive organization was created to attempt to control the market on an international basis. Members of the International Association of Lead Producers, formed by producers in the principal western European countries (Belgium, France, Germany, Italy, Spain and the United Kingdom), in association with newer producers in Australia, Burma, Canada and Mexico, were responsible altogether for just over one-half of world production.

The association at first confined itself to statistical matters but in 1929, when lead production reached a record level that was not exceeded until 1952, Mexican and United Kingdom interests entered into a marketing agreement. Output was reduced, though not to the extent necessary to prevent a further decline in price, and in April 1931, the association imposed a 15 per cent cut on the basis of members' average 1930 production. The cut was increased to 20 per cent in July, but demand was declining even more rapidly and prices continued to fall. In 1932, output was about 31 per cent below the 1929 peak, but the average price had declined by more than 53 per cent. An increase in economic nationalism, manifested in autarkic policies in some of the European countries, and a 10 per cent duty imposed on foreign lead by the United Kingdom, combined with the disruption of normal marketing by currency devaluation to bring about the dissolution of the association in 1932. Interchange of statistics was continued until 1934, and a certain degree of "derived" control was exercised over the lead industry by virtue of its association with the zinc industry, which remained under a cartel.

It is impossible to separate the effects of cartel action from all other influences affecting the lead industry during this period. In general the decline in production between 1929 and 1933 was markedly less among members of the association than among non-members. This was due largely to the collapse of United States output (table 13). Within the cartel, Australian production actually increased with the opening up of the Mount Isa mine, while only Mexico and Spain suffered serious decreases in output. In both these cases the lead industry was largely in foreign hands; Spain's customers in western Europe reduced their imports considerably, while Mexican exports to the United States practically ceased in 1933, production dropping to less than half the average 1927-30 rate.

In Mexico there was no government support for the industry such as there was in a number of other producing countries and it is possible that the American Metal Company, Limited, and the American Smelting and Refining Company, the two principal concerns in the mining and the smelting of lead, were prepared to let Mexican output fall as a means of assisting their other lead properties,[6] among which was the expanding

[6] This was the opinion of A. Skelton, in *International Control in the Non-Ferrous Metals*, page 632.

23.7.74

2 OF 3

DO 3841

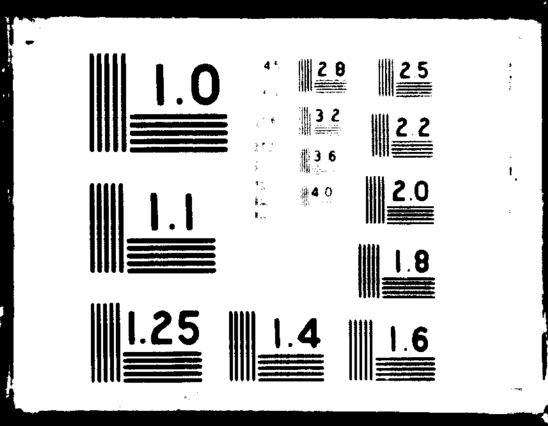


Table 13. Lead Production, 1926 to 1934

Item and year	Members, International Association of Lead Producers											Non-members		World[a] total
	Belgium	France	Germany	Italy	Spain	United Kingdom	Australia	Canada	Burma and India	Mexico	Total member producers	United States	Other countries[a]	
MINE PRODUCTION														
Amount (thousands of short tons, metal content):														
1926	—	5	51	32	150	17	204	142	85	232	918	684	162	1,765
1927	—	7	55	33	134	18	224	156	114	268	1,009	665	175	1,849
1928	—	10	63	35	137	17	201	169	114	259	1,005	627	177	1,809
1929	—	12	67	34	140	21	217	175	114	273	1,053	648	189	1,890
1930	—	12	76	33	126	23	221	186	128	257	1,062	558	199	1,819
1931	—	8	60	27	117	26	169	162	100	250	919	404	138	1,461
1932	—	4	56	24	107	37	236	168	88	151	871	293	151	1,315
1933	—	1	59	20	88	45	249	172	108	131	873	273	159	1,305
1934	—	1	65	21	74	60	257	215	99	183	975	287	184	1,446
Per cent of total:														
1926	—	—	3	2	8	1	12	8	5	13	52	39	9	100
1927	—	—	3	2	7	1	12	8	6	14	55	36	9	100
1928	—	1	3	2	8	1	11	9	6	14	55	35	10	100
1929	—	1	4	2	7	1	11	9	6	14	56	34	10	100
1930	—	1	4	2	7	1	12	10	7	14	58	31	11	100
1931	—	1	4	2	8	2	12	11	7	17	63	28	9	100
1932	—	—	4	2	8	3	18	13	7	11	66	22	11	100
1933	—	—	5	2	7	3	19	13	8	10	67	21	12	100
1934	—	—	5	1	5	4	18	15	7	13	67	20	13	100
SMELTER PRODUCTION														
Amount (thousands of short tons, metal content):														
1926	97	21	84	26	165	5	171	136	61	202	972	729	104	1,805
1927	101	35	93	26	159	7	185	148	74	254	1,082	700	116	1,898
1928	95	25	96	23	144	10	174	150	88	251	1,056	653	149	1,858
1929	91	22	108	25	157	12	199	152	90	264	1,100	702	166	1,968
1930	94	22	122	27	136	11	189	152	89	267	1,109	608	152	1,869
1931	78	21	112	27	121	12	168	139	84	232	994	412	124	1,530
1932	71	22	105	35	116	8	209	127	80	146	919	271	89	1,279
1933	76	23	128	27	97	6	230	127	79	131	924	257	92	1,273
1934	82	34	132	52	80	10	219	157	79	182	1,025	310	129	1,464
Per cent of total:														
1926	5	1	5	1	9	—	9	8	3	11	54	40	6	100
1927	5	2	5	1	8	—	10	8	4	13	57	37	6	100
1928	5	1	5	1	8	1	9	8	5	13	57	35	8	100
1929	5	1	5	1	8	1	10	8	5	13	56	36	8	100
1930	5	1	7	1	7	1	10	8	5	14	59	33	8	100
1931	5	1	7	2	8	1	11	9	5	15	65	27	8	100
1932	6	2	8	3	9	1	16	10	6	11	72	21	7	100
1933	6	2	10	2	8	—	18	10	6	10	73	20	7	100
1934	6	2	9	4	5	1	15	11	5	12	70	21	9	100

Source: United States Bureau of Mines, *Materials Survey: Lead* (Washington, D. C., 1951).

[a] Excluding the Union of Soviet Socialist Republics.

Mount Isa mine in Australia. In any case, the decline in the price of silver during this period—from an average of over 58 cents an ounce in 1928 to an average of less than 28 cents in 1932—reduced very substantially the profitability of many Mexican mines, and with United States demand at a very low ebb and an empire preference scheme operating on the United Kingdom market, Mexican lead producers were not in a strong position to compete for markets.

In 1935 some of the major United States producers, including the American Smelting and Refining Company, entered into an informal agreement with British interests in Australia, Canada and the United Kingdom not to increase lead production without prior mutual consultation. However, this did not prevent a fairly steady expansion of output between 1933 and 1940, partly under the influence of an increase in the demand for silver. Prices also began rising again, climbing steadily until 1937, when a sudden spurt raised the average to almost double that of 1932.

A marked setback in 1938, however, led to the formation of another international cartel—the Lead Producers' Association—representing about two-thirds of world production outside the Union of Soviet Socialist Republics and the United States. Members included the major producers of Australia and Canada as well as the less developed countries, Argentina, Burma, Mexico, Peru and Yugoslavia, the United States being involved only indirectly through the foreign subsidiaries of such concerns as the American Smelting and Refining Company. The declared object of the new association was to increase prices by restricting production. The initial cutback was one of 10 per cent, and members agreed to keep supplies off the market if the price fell below £15 a ton. There was in fact some recovery in 1939 but rearmament demands rather than cartel policy were probably responsible, and the outbreak of war brought the association to an abrupt end.

The Second World War saw the reimposing of government control and, as in the case of copper, price freezing and large-scale government purchasing. The United States entered into agreements with producers in Bolivia, Mexico and Peru, confining lead sales to the Western Hemisphere and the British Commonwealth and guaranteeing a fixed price. The United Kingdom Ministry of Supply negotiated long-term contracts with major Commonwealth suppliers. World production, however, declined steadily between 1940 and 1946, increasing again only with the rehabilitation of European and North African mines and the withdrawal of price controls in the United States. The outbreak of hostilities in Korea brought a renewal of government control, but lead supplies remained such that the International Materials Conference considered it unnecessary to make recommendations concerning their allocation. By October 1952, supplies from other than dollar sources were deemed to be sufficient to allow the reopening of the London Metal Exchange, for the first time since 1939. During the first post-war decade the highest average price was registered in 1948 on the New York market and in 1951 on the London market. In the face of rising world production, prices weakened significantly after 1951. Marginal producers again began seeking protection. In 1954, when world production was about 77 per cent above the 1946 level, the United States strategic stockpile was used to absorb an additional fraction of domestic output and thus prevent further pressure on the market price. In Europe, more active demand restored lead prices to the 1950 level during the year and continued firmness in the first half of 1955 removed, at least for the time being, any need that producers might have felt to reorganize formal international control.

Tin

The first scheme for controlled marketing of tin was organized by the Government of the Netherlands East Indies, in co-operation with Malayan producers. This was immediately after the First World War when, under stress of excess stocks accumulated during the war, the Bandung pool was formed to withhold new tin from the market so that prices might be maintained as stocks were liquidated. The pool successfully achieved its limited objective, but a decline in demand in 1921 and 1922 brought prices down from the high levels maintained in 1919 and 1920. Between 1922 and 1926, however, prices again rose steadily, reaching peace-time records under the influence of rumours of impending shortage and a very active demand. During this period there was considerable new investment, especially in the form of dredge installation, particularly in Malaya, where the newly formed Anglo-Oriental Mining Corporation opened up a number of areas, raising the capacity of the industry to more than 220,000 tons a year. There was also a large amount of speculation in the shares of tin mining companies, and this was the period of some of the major company amalgamations.

The new capacity was never fully utilized, however, for demand began to recede in 1928 and prices started moving downward. In 1929 the principal companies operating in Burma, Malaya, Nigeria and Thailand met in London and founded the Tin Producers' Association. Netherlands East Indies and Bolivian producers joined the association in the following year when the price had dropped to less than half that of 1926-27. Almost three-fourths of world tin capacity was represented in the association, but a decision to limit production, at first to 80 per cent of the 1929 level and then by a complete two months' shutdown, did not halt the decline in price. Some of the companies which had increased their capital during the nineteen twenties doubtless preferred to maintain or even increase output so long as variable costs were being covered: in order to strengthen control therefore, the original organization was put on an inter-governmental basis in 1931, the United Kingdom Government taking the initiative.

The first four members of the new International Tin Committee—Bolivia, Malaya, the Netherlands East Indies and Nigeria accounted for over 90 per cent of the world output at that time, and with the accession of Thailand later in 1931 and the Belgian Congo, Indochina, Portugal and the United Kingdom in 1934, all the major producers had joined the scheme. The average quota was reduced successively from 78 per cent of 1929 production in March 1931, to 65 per cent in June 1931, 56 per cent in January 1932, 44 per cent in June 1932 and, after a two months' suspension of exports, to 40 per cent in September 1932. With prices rising slowly in 1933 and 1934, the quota was increased from the 40 per cent at which it had been held for almost 18 months.[7] During this period excess stocks of 21,000 long tons which had been accumulated by British and Netherlands companies in 1931 were successfully liquidated.

In 1934 a formal "buffer pool" of 8,282 long tons of tin metal was organized by the Governments of Bolivia, Malaya, the Netherlands East Indies and Nigeria, in order to supplement quota adjustments as a stabilizing force in the face of fluctuating demand. With the withdrawal of Bolivia in 1935, the pool was liquidated but, following a sharp break in prices, it was reconstituted, at a 10,000 to 15,000-ton level, in 1938. By this time the committee had been reorganized to include consumer representation. Until the outbreak of war, operation of the buffer pool helped to keep tin prices between the upper and lower limits (£230 to £200 per long ton) set by the committee, but the fact that the pool's resources never represented much more than one month's consumption at contemporary rates limited its usefulness. With the overrunning of the Asian producers by Japanese troops in 1942, cartel agreements fell away. In some respects the functions of the pool were handed over to the United States under agreements with the Reconstruction Finance Corporation (and later the Metals Reserve Company) which undertook to purchase whatever tin its members were able to produce. The pool was dispersed, but the committee itself was not wound up until 1946, when its statistical and research functions were taken over by the International Tin Study Group, which convened for the first time in Brussels in April 1947.

The tin control scheme was not conspicuously successful in avoiding instability in prices during the nineteen thirties: neither the market operations of the managers of the buffer stock nor the changes that were made in production quotas seem to have been prompt enough

[7] The average quota was 45 per cent of the 1929 level of production in 1934, 59 per cent in 1935, 93 per cent in 1936 and 108 per cent in 1937.

Table 14. Tin Ore Production and Average Prices, 1928 to 1942

Item and year	*Output*									*Average price, London (Pounds sterling per long ton)*
	Belgian Congo	*Bolivia*	*Malaya*	*Netherlands East Indies*	*Nigeria*	*Thailand*	*World total*[a]	*Bolivia, Indonesia, Malaya and Nigeria*	*Rest of world*[a]	
***Amount** (thousands of metric tons, metal content):*										
1928	0.8	41.4	64.6	35.7	9.1	7.6	178.3	150.8	27.5	227.1
1929	1.0	46.3	69.4	35.2	10.7	10.5	192.6	161.6	31.0	203.9
1930	0.9	38.2	64.0	34.6	8.6	11.5	175.1	145.4	29.7	141.9
1931	0.2	31.1	52.6	27.4	7.1	12.5	147.0	118.2	28.8	118.4
1932	0.7	20.6	28.4	16.8	4.3	9.3	99.6	70.1	29.5	135.8
1933	2.0	15.1	25.3	13.0	3.7	10.3	89.4	57.1	[illegible]	194.5
1934	4.4	21.0	38.2	20.0	5.1	10.8	122.4	84.3	38.1	230.3
1935	6.2	27.6	43.0	20.5	6.7	10.0	140.7	97.8	42.9	225.5
1936	7.4	24.5	67.8	31.2	9.9	12.9	183.4	133.4	50.0	204.4
1937	9.2	25.5	78.5	38.2	11.0	16.2	209.8	153.2	56.6	242.1
1938	9.8	25.9	44.1	30.2	9.1	15.1	167.6	109.3	58.3	189.5
1939	8.3	27.9	48.2	27.2	9.6	15.9	170.2	112.9	57.3	226.2
1940	12.5	38.5	84.3	42.0	12.2	17.4	239.0	177.0	62.0	256.4
1941	16.0	42.7	80.7	54.2	12.3	16.1	250.0	189.9	60.1	261.1
1942	16.1	38.9	16.0	10.1	12.6	8.0	123.0	77.6	45.4	275.0
***Index** (1929 = 100):*										
1928	80	89	93	101	85	72	93	93	89	111
1929	100	100	100	100	100	100	100	100	100	100
1930	90	83	92	98	80	110	91	90	96	70
1931	20	67	76	78	66	119	76	73	93	58
1932	70	45	41	48	40	89	52	43	95	67
1933	200	33	36	37	35	98	46	35	104	95
1934	440	45	55	57	48	103	64	52	123	113
1935	620	60	62	58	63	95	73	60	138	110
1936	740	53	98	89	93	123	95	83	161	100
1937	920	55	113	109	103	154	109	95	183	119
1938	980	56	64	86	85	144	87	68	188	93
1939	830	60	69	77	90	151	88	70	185	111
1940	1,250	83	122	119	114	166	124	110	200	126
1941	1,600	92	116	154	115	153	130	117	194	128
1942	1,610	84	23	29	118	76	64	48	146	135

Source: International Tin Study Group, *Yearbook* (The Hague).

[a] Excluding the Union of Soviet Socialist Republics.

to prevent variations in demand from causing wide fluctuations in price. It did, however, spread the burden of excess capacity over the bulk of the industry when otherwise it would have fallen most severely upon the high-cost producers in the Belgian Congo, Bolivia and Nigeria and the least efficient of the Asian mines. As it was, the cutback was borne in the main by the three leading producers—Bolivia, Malaya and the Netherlands East Indies—and by Nigeria. In 1933 the output of these four areas was little more than one-third that of 1929 (table 14). Thereafter production in Malaya, the Netherlands East Indies and Nigeria increased steadily, exceeding the 1929 rate in 1937; in Bolivia, however, quotas were not fully met (owing in part to disruption caused by the Chaco War) and it was not until 1940 that output exceeded two-thirds of the 1929 level. In the Belgian Congo, production continued to expand; in 1937 it was more than twice, and in 1941 nearly four times, the rate registered at the time the country acceded to the cartel. In Thailand, production reached a peak in 1931 but under cartel control it was held to about 80 per cent of this rate during the four succeeding years. Production of non-members, benefiting from the effect upon prices of restriction in output, increased from about 10 per cent of the world total at the beginning of the nineteen thirties to about 15 per cent at the end of that decade.

The high concentration of ownership and control simplified cartel organization, and the comparatively low price elasticity of demand favoured restrictive policies. On the other hand, tin shows a high income elasticity of demand and, in general, a low elasticity of supply, accentuated since the nineteen twenties by the relative decline of the more flexible small-scale units, making price stability very difficult to attain. In the opinion of some observers, bold use of a large buffer stock might have helped to stabilize the price but, tin being a relatively costly base metal (during the nineteen thirties its price varied between three and six times the price of copper), there was a tendency to keep stocks down to a minimum. This tendency persists, and even smelters try to avoid market fluctuations by linking the purchase of ore from the mines with the simultaneous sale of an equivalent volume of tin metal.

During the post-war period of tin scarcity, the Combined Tin Committee, an extension of the Combined Raw Materials Board which functioned between 1942 and 1945, recommended allocations of exportable supplies. A Tin Conference convened by the United Nations in October 1950, at the request of the International Tin Study Group, recognized the desirability of a new stabilization scheme but was unable to agree upon its form and operations. In the meantime, tin dealings on the London Metal Exchange which had been suspended in 1939 at the outbreak of war were resumed in November 1949, the Ministry of Supply relinquishing its control over purchases in the United Kingdom. The rapid rise in price which followed the beginning of the conflict in Korea led the United States to centralize its tin buying in the Reconstruction Finance Corporation early in 1951. This probably contributed to the subsequent reduction in price, from an average of about 172 cents per pound in January to a more stable level of 103 cents in August. A rise to 121.5 cents per pound early in 1952 was followed in August by the restoration of private trading. This was the prelude to a substantial decline in price, and in August 1953 the low level of 78.5 cents per pound was reached.

These price fluctuations, together with substantial reduction in United States stockpile buying and the consequent seemingly chronic surplus, again raised the question of a stabilization scheme. In March 1953, the International Tin Study Group set up a working party, on the basis of whose report the United Nations Tin Conference was reconvened in November. The outcome was a new International Tin Agreement which will come into operation upon the accession of the requisite minimum number of members.

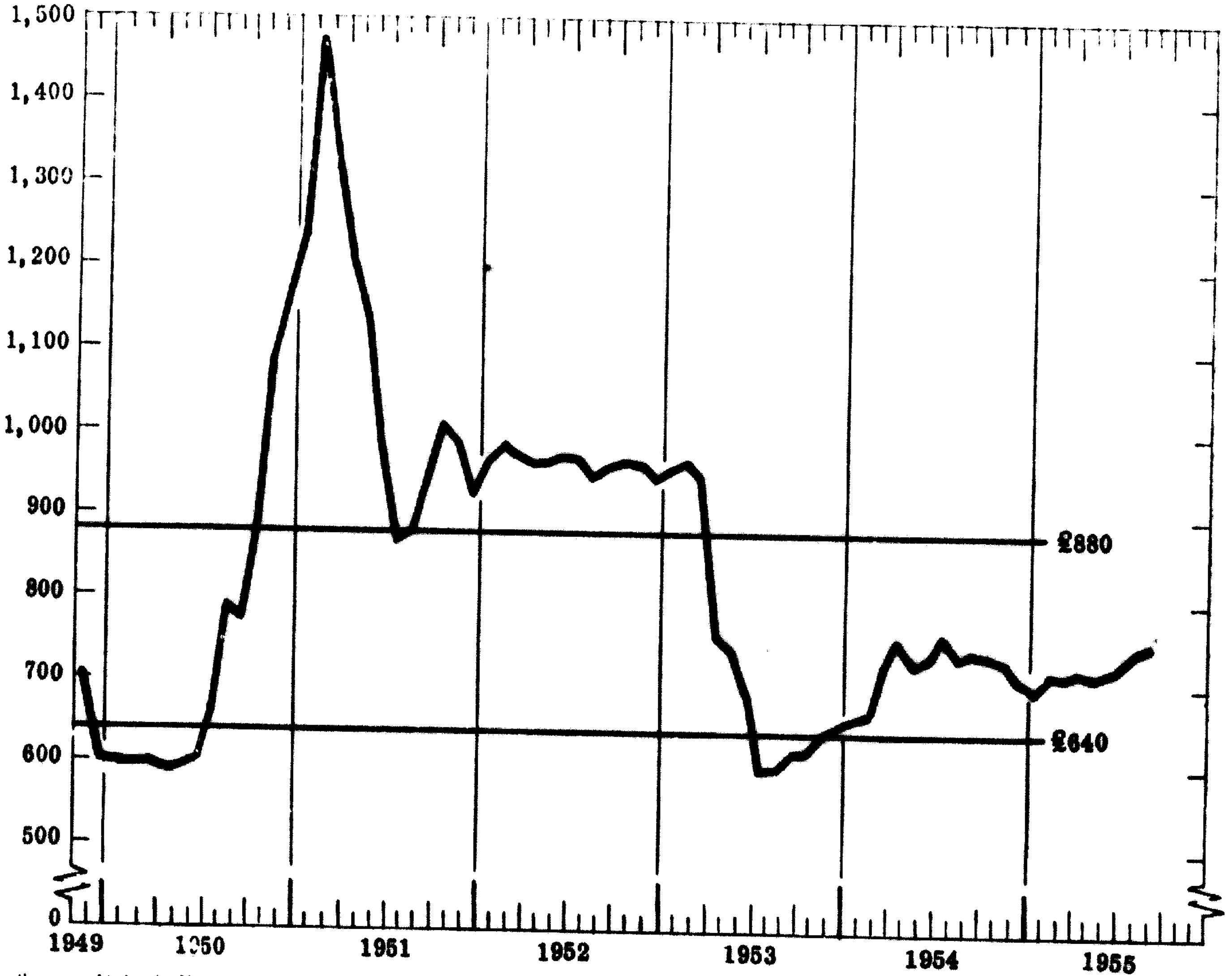
The agreement is an inter-governmental instrument to be administered by the International Tin Council, among whose functions are the fixing of floor and ceiling prices and the allocation of export quotas. The latter become operative only after 10,000 long tons of tin have been accumulated in a buffer stock which is to be built up in the first instance by members' contributions. These are to amount in the aggregate to 25,000 tons of tin or the equivalent in cash (computed at the established floor price) contributed by producer members as follows: 36.61 per cent by Malaya, 21.50 per cent each by Bolivia and Indonesia, 8.72 per cent by the Belgian Congo (and Ruanda Urundi), 6.29 per cent by Thailand and 5.38 per cent by Nigeria. This buffer stock is the scheme's principal stabilizing instrument. When the price is at or above the established ceiling the manager of the stock is required to enter the market as a seller, either by offering tin on the London Metal Exchange or by accepting bids at the ceiling price. Conversely, when the price is below the floor, the manager is required to enter the market as a buyer. When prices are within the critical range the manager's function is also prescribed: in the upper third he may sell at his discretion and in the lower third he may buy at his discretion, while in the middle third he is required to stay out of the market unless the International Tin Council directs otherwise.

In the event of a persistent surplus which carries the buffer stock above 10,000 tons, the International Tin Council is authorized to fix a total export quota for each three-month period and this is to be divided among the producing countries in the same proportion as their contributions to the buffer. Arrangements are made for quota adjustments and for the absorption of under-utilized quotas, as well as for penalties for over-export, the first of which is to be the payment into the buffer stock of an amount of tin (or its equivalent in cash) equal to the excess.

In view of the penalty provision, it is premature to pass judgment on the size of the buffer stock. It should be noted, however, that 25,000 tons represents rather less than two months' production at the average rate that obtained in the first seven post-war years, 1946 to

Chart 10. Tin Prices, 1949 to 1955

(Pounds sterling per long ton)



Source: United Nations, *Monthly Bulletin of Statistics*, July 1955, page 133; American Bureau of Metal Statistics, *Yearbook, 1953* (New York, 1954), page 113. Figures represent monthly average daily cash prices for standard tin, London.

1952. On the other hand, even this low figure involves an outlay, at July 1954 prices, of more than £19 million—a sizable sum for six under-developed countries.[8] It should also be noted that the United States, which accounts for well over half of world tin consumption (excluding that of mainland China, eastern Europe and the USSR) has not acceded to the scheme, though a consumer voting quota is reserved for it.

Between November 1949, when the London Metal Exchange was reopened for tin dealings, and August 1955, the monthly average price was within the established range of £640 to £880 per long ton less than one-half of the time, though it remained between £640 and £760 during 22 months beginning from December 1953 (chart 10). Unless the trend in consumption turns upward, success in keeping price fluctuations within the prescribed limits is likely to depend very largely upon the willingness of low-cost producers to curtail their output sufficiently for the maintenance of a price which allows for at least a minimal rate of return on the investment of high-cost producers.

[8] In the case of Malaya, the largest contributor, the transaction will presumably be financed by means of a loan from the United Kingdom.

Zinc

Production of zinc, like that of lead, is widely dispersed. In 1949, for example, United States output came from no fewer than 765 different producers, many of whom were chiefly concerned with mining copper or lead ores. Moreover though a large part of the zinc output is used in the iron and steel industry, where it fulfils what is quantitatively its most important function in the process of galvanizing, much of it is not used in metallic form but passes directly into the chemical and paint industries. These circumstances militate against integration and control, but offsetting them is the fact that a high proportion of mine output (about three-fourths in recent years) is derived from Europe and North America, where the great bulk of consumption takes place, and the fact that smelting is much more concentrated, most of the output coming from a comparatively small number of firms. In the face of these conflicting influences, control within the industry has never operated on a global basis, and European schemes, even when enlarged to incorporate Australia, Canada, Mexico and Northern Rhodesia, have not been conspicuously successful in stabilizing production or maintaining prices.

The first of these schemes came into being in 1879 when the three largest German firms, Aaron Hirsch und Sohn, Beer Sondheimer and Company and the Metallgesellschaft Aktiengesellschaft, agreed to curtail output in order to maintain prices; in 1882 this arrangement was extended to Belgium (second only to Germany in world production), where the zinc industry was largely in the hands of the Société anonyme de la Vieille Montagne. The resultant International Zinc Syndicate established production quotas in 1885 and continued more or less in control of the European zinc industry until the outbreak of the First World War, the United Kingdom having joined Belgium and Germany in a zinc convention in 1909. In contrast to this restrictive policy in Europe was the expansion that took place elsewhere; especially in Australia where the mining of zinc ores had commenced in 1868, in the United States where output overtook that of Belgium in 1901 and that of Germany in 1909, and in Canada where zinc production became increasingly important after 1908.

The war accelerated this development. Between 1914 and 1916 United States smelter capacity was doubled, and the technique of electrolytic refining perfected, to the great advantage of areas with low-cost power. The introduction of the flotation process of ore separation, followed some years later (1925) by the process of selective flotation, made possible the economic exploitation of a number of ore bodies that had previously been unworkable, again with particular benefit to the newer producers in Australia, Canada and the United States. Australian production was also stimulated by a favourable long-term contract concluded between the United Kingdom Government and the Zinc Producers' Associated Proprietary, Limited, a group comprising the principal Burmese mine as well as the mines at Broken Hill and Mount Lyell. Shipping difficulties in the last year of the war resulted in the accumulation of large stocks of concentrates (estimated at 750,000 tons in 1921) in Australia, disposal of which added considerably to the uncertainty of the post-war period. In 1919, and again in 1921, there was a drastic decline in mine output in all producing countries.

World zinc production rose from the low level of under half a million tons in 1921 to almost a million and a half in 1929. Although consumption and price were fairly well maintained during this period, ore stocks began accumulating rapidly at European smelters in 1925, 1926 and 1927, and by 1928, in the face of a substantial growth of electrolytic capacity in Canada and other non-European countries, there was sufficient uncertainty about the future to cause the leading producers to seek protection in a joint organization called the European Zinc Cartel.

The output reductions agreed upon at an early meeting of the cartel ranged from 5 to 10 per cent during the first half of 1929 but, though Belgian, French, Polish and Spanish smelter output declined slightly, world production continued to expand and, in the face of internal friction and a temporary rally in zinc prices, the cartel was dissolved at the end of the year. It was revived in 1931, however, in the middle of the depression, and an attempt was made to extend its coverage. Canadian, Mexican and Rhodesian producers were included along with those of Europe and Australia in the new International Zinc Cartel, which is estimated to have embraced about 94 per cent of the smelter capacity outside the United States (table 15). Output restrictions were immediately imposed; quotas starting at 45 per cent of average output from 1927 to 1930 were gradually raised to 60 per cent in 1933, when a system of bonuses for under-production and penalties for over-production was introduced. There was some recovery in price as well as output in 1933 and 1934, but the cartel did not survive the combined effects of the conflicts of interest that arose within it and the widespread increase in nationalism in the countries in which its members operated. Illustrative of the latter were the offer by the German Government of a premium for domestic zinc production and by the imposition by the United Kingdom of a 10 per cent duty on zinc from other than "empire" sources.

In the year after the dissolution of the cartel, a private agreement to restrict exports was entered into between the New Jersey Zinc Company, which had recently developed a new vertical retorting furnace permitting continuous distillation, and its licensees in Belgium, Canada, Germany and the United Kingdom. In 1936 there was a restrictive pact among Czech, German and Polish producers with regard to supplies to be offered on the European market. Shortly afterwards, the Imperial Smelting Corporation, Limited, a subsidiary of the Consolidated Zinc Corporation, Limited, which controlled the Broken Hill mines in Australia, agreed to limit its annual output to 60,000 tons in return for a subvention payable by "empire" producers on the zinc tonnage sold in the United Kingdom. In 1938, in the face of reduced consumption and a marked drop in price, European producers, in another attempt to regulate competition, organized an international zinc sheet cartel, but war brought this to an end in the following year.

Perhaps more important for the under-developed countries was the fact that in 1937 the United States became a net importer of zinc. In a trade agreement with Canada in 1939, United States import duties were cut by 20 per cent; in 1943 an agreement with Mexico increased this cut to 50 per cent, bringing the rates to three-quarters of a cent per pound on zinc in ore and seven-eighths of a cent per pound on zinc metal; in 1947 these rates

Table 15. Zinc Smelter Capacity and Production, 1932

(Thousands of short tons)

Group and country	Nominal capacity	Production: Amount	Production: Per cent of capacity
European cartel members:			
Belgium	307.8	106.2	35
Poland	252.5	93.6	37
France	155.4	50.4	32
Germany	155.4	46.3	30
United Kingdom	83.7	30.1	36
Norway	52.0	43.4	83
Italy	34.1	25.7	75
Netherlands	30.0	17.2	57
Spain	30.0	10.5	35
Czechoslovakia	22.0	6.6	30
Sweden	7.7	—	—
Total	1,130.6	430.0	38
Non-European cartel members:			
Canada	170.0	86.1	51
Australia	79.0	59.6	75
Mexico	54.5	34.4	63
Northern Rhodesia	26.7	—	—
Total	330.2	180.1	55
Non-members:			
United States	931.0	207.1	22
Union of Soviet Socialist Republics	45.0	15.6	35
Japan	27.2	29.8	100
Yugoslavia	10.0	2.4	24
Indochina	5.5	2.5	45
Total	1,018.7	257.4	25
World total	2,479.5	867.5	35

Source: American Bureau of Metal Statistics, *Yearbook, 1932* (New York, 1933).

were made generally applicable under the General Agreement on Tariffs and Trade.

During the war, zinc supplies among the Allies were controlled by the Combined Raw Materials Board. The London Metal Exchange, which was closed in 1939, was not reopened until January 1953. During this period, and especially after 1946 when war-time controls were withdrawn, the world price tended to follow that on the East St. Louis and New York markets, reflecting the fact that the United States accounted for about one-half of world zinc consumption outside the Soviet Union and, after 1937, for a rapidly increasing proportion of imports. Zinc was among the metals reviewed by the International Materials Conference; the first allocation was recommended for the fourth quarter of 1951 but, with the easing of the market, recommendations were not made after May 1952. Production continued to rise, and with slackening demand, the average United States price in 1953 was a third lower than that of 1952. The lowest post-war price level was reached early in 1954. Nevertheless, there was no curtailment of world production even though United States output declined in 1954. The mild price recovery which began in March 1954 and was still continuing in mid-1955 was the result of very active demand in Europe, supplemented in the United States, first, by the use of the strategic stockpile to take part of the newly mined supply off the market, and then by a fairly rapid recovery of industrial consumption.

It is difficult to assess the effect of cartel arrangements upon production in the less developed countries. So far as smelter production was concerned, depression and cartel restrictions during the period 1930 to 1934 did not reduce output below 1929 levels in Australia, Canada[9] and Mexico, though the output of European members dropped to half that level in 1932, Northern Rhodesia actually ceased producing for 18 months during 1931 and 1932 and Swedish smelting operations were closed down in 1931 (see table 16). In contrast to what happened when the copper cartel was functioning, the output of non-members declined appreciably more than that of members, but, as in the case of lead, this was due largely to the collapse of demand in the United States, where the market was isolated by a high tariff wall. Output in Japan and the Union of Soviet Socialist

[9] The new Hudson Bay plant in Canada was given special quota allowances under the first cartel agreement.

Table 16. Indices of Zinc Production, 1928 to 1936

Group and country	Index (1929 = 100) 1928	1930	1931	1932	1933	1934	1935	1936	Actual production, 1929 (thousands of short tons, metal content)
MINE PRODUCTION									
European cartel members:									
Germany	101	97	74	53	73	93	99	110	157.0
Poland	95	95	57	26	40	47	44[a]	46[a]	115.7
Italy	96	92	54	37	33	53	72	78	95.9
Spain	88	113	75	63	63	56	56	69	88.2
Sweden	48	100	98	82	83	97	116	115	33.0
France	94	82	44	12	—	—	—	—	10.9
Norway	—	364	529	636	721	521	479	550	1.5
United Kingdom	78	78	22	—	—	56	133	478	1.0
Total	93	106	78	63	73	87	90	96	503.2
Non-European cartel members:									
Mexico	93	71	69	33	51	72	78	86	191.7
Australia	96	77	48	75	80	89	96	112	173.1
Canada	94	136	120	87	101	151	162	169	98.6
Burma	116	110	82	73	100	99	105	111	62.0
Newfoundland	—	131	194	289	326	384	314	280	25.4[a]
Northern Rhodesia	60	88	31	—	83	88[b]	121	118	24.9
Total	91	86	68	57	73	91	99	108	575.7
Non-members:									
United States	96	82	57	39	53	61	72	80	724.3
Indochina	114	85	43	27	27	27	27	28	20.7
French North Africa[c]	106	56	20	10	5	13	12	29	20.6
Japan	92	110	119	119	145	152	167	214	19.5
Peru	44	91	—	2	2	45	38	90	13.7
Turkey	51	84	13	29	61	125	128	181	7.6
Greece	76	63	97	117	210	100	17	78	6.5
Yugoslavia	102	160	330	492	606	664	660	649	5.2
Austria	80	90	18	40	53	65	65	80	4.4
USSR	73[d]	143[d]	300	457	553	903	1,523[a]	2,200[a]	3.3[d]
Bolivia[e]	164	429	1,050	929	957	686	593	971	1.5
Korea	100	75	—	—	63	50	38	100	0.9
Finland	175	125	...	350	375	425	400	350	0.4
Total	95	84	60	46	61	70	81	95	828.6
WORLD TOTAL	93	90	67	54	68	81	90	99	1,907.5
SMELTER PRODUCTION									
European cartel members:									
Belgium	104	89	68	49	69	88	92	102	218.1
Poland	96	103	77	50	49	55	50	55	186.3
Germany	96	96	44	41	50	70	122	131	112.4
France	106	100	65	52	60	54	54	59	96.2
United Kingdom	95	83	36	46	70	88	104	104	65.3
Netherlands	105	90	75	61	72	77	53	60	28.3
Italy	67	122	107	147	147	157	175	171	17.4
Spain	115	87	85	81	72	69	65	66	13.0
Czechoslovakia	75	125	75	56	62	71	91	72	11.8
Norway	...	624	713	712	811	812	813	813	6.1
Sweden	108	87	—	—	—	—	—	—	5.2
Total	98	100	70	51	68	79	87	93	760.1
Non-European cartel members:									
Canada	95	141	138	100	107	157	174	176	86.0
Australia	97	106	104	103	104	105	130	136	58.1
Mexico	75	195	237	201	178	193	214	212	16.6
Northern Rhodesia	79	148	57	—	153	161	171	171	13.6
Total	92	135	130	103	116	143	163	165	174.3
Non-members:									
United States	96	80	47	33	49	58	67	74	625.3
Japan	90	116	120	127	144	151	161	184	23.4
Yugoslavia	78	88	72	35	55	64	54	58	6.9
Indochina	76	102	76	60	76	112	100	107	4.2
USSR	66[d]	134[d]	332	411	482	784	1,389	1,884	3.8[d]
Total	96	82	51	39	55	66	78	93	663.6
WORLD TOTAL	97	96	69	54	68	80	92	101	1,599.0

Source: United States Bureau of Mines, *Materials Survey: Zinc* (Washington, D. C., 1951); League of Nations, *Statistical Yearbook, 1937/38* (Geneva); United Nations, *Statistical Yearbook, 1948.*

[a] Estimated.
[b] Smelter production.
[c] Including Algeria, French Morocco and Tunisia.
[d] Production in 12 months ending 30 September of year stated.
[e] Exports.

Republics increased, as it did in two member countries, Norway[10] and, in respect of smelter production, Italy. The drop in mine production was greater among non-members than among members, expansion in Bolivia, Finland, Japan, the Soviet Union and Yugoslavia being more than offset by the drop in United States output. The decline in mine output in Mexico and Northern Rhodesia, two under-developed members of the cartel, was relatively greater than that of non-members as a whole, though in Burma it was appreciably less. Mexico, like Peru, suffered chiefly from the decline in United States demand. Thus, though the cartel was dominated by the major European producers there is little evidence that under-developed member countries were penalized.

On the other hand, the cartel appears to have achieved very little in the way of stabilizing the market. The London price, which averaged £36.6 per long ton in 1925, declined steadily, to £24.8 in 1929, and then fell precipitantly to £16.5 in 1930 and £12.2 in 1931, averaging more than £16 in only one year before the war. On the United States market the margin between the year's highest and lowest quotations rose from 14 per cent in 1928 to about 30 per cent in 1930, 1931 and 1932, increasing to 84 per cent with the first upturn of prices in 1933.

Cartel organization brought out not only rivalry among companies and countries, but also a serious conflict of interest between elements within the industry. Thus, custom smelters, which earn their revenue by performing a service, ordinarily protecting themselves against price fluctuations by selling metal at the same time as they buy ore, tended to oppose reductions in throughput, whereas integrated firms resorted more readily to curtailment of production in the hope of maintaining prices and gross revenue. Similarly, electrolytic refineries, with their relatively heavy burden of overhead capital charges, tended to oppose restrictions much more strenuously than furnace refineries, whose cost structure is generally more flexible.

[10] The new plant of the Compagnie royale asturienne des mines in Norway was also given special quota allowances under the first cartel agreement.

Chapter 4

MINING, SMELTING AND REFINING IN UNDER-DEVELOPED COUNTRIES

This chapter and the following one discuss domestic problems of mining and metallurgical development. For this reason, they are chiefly concerned with the mineral economies, that is, countries in which non-ferrous metal mining and associated metallurgical operations provide a significant part of national product or foreign exchange earnings. Among these countries are Northern Rhodesia, Bolivia and Surinam, in which exports of non-ferrous metals play an overwhelming part in foreign trade and in the local exchange sector; Chile, the Belgian Congo and Cyprus, in which mining, though less important, is none the less a major determinant of production and incomes; and Peru, Mexico, Yugoslavia and Malaya, in which mining exerts a considerable influence on the general level of activity (see table 17).

The present chapter examines the extent to which the mineral economies have been able to maximize the value of their non-ferrous metal exports by domestic processing — beneficiation, smelting and refining — and the degree to which the product has been used in domestic manufacturing. As a preliminary both to this discussion and to the analysis of the development potential of the non-ferrous metal industry contained in the next chapter, some consideration is given to aspects of locating and mining deposits of ore which have particular relevance to the problems facing under-developed countries in the exploitation and utilization of their non-ferrous resources.

Exploration and survey

The process of discovery of ore bodies usually entails two steps: general geological exploration and survey, and then more intensive geophysical examination of mineralized districts; the first, to determine and map the geological structure of the area as a whole and the second, to measure the extent and grade of the ore bodies located in the course of the initial survey. Most of the mineral discoveries of the past, however, especially in under-developed areas, have resulted from prospecting, which tends to combine the two phases just distinguished. In the absence of any detailed knowledge of regional geology, the success of prospecting has depended on the presence of readily detectable surface signs and, in most cases in the past, on the actual location of an outcrop of the ore.

The general state of geological knowledge is still far from satisfactory; many of the less developed countries have only a rudimentary knowledge of their geological structures and even in the United States not much more than a fourth of the land surface has been topographically mapped on an adequate scale and less than an eighth geologically mapped in any detail. New techniques, especially those based on aerial, geochemical and geophysical methods, have recently speeded up the course of geological survey, but though some of the new devices have tended to shorten and cheapen the process it is still a very costly undertaking. Furthermore, even when survey costs can be met, the problem of personnel remains; in many cases the main consideration holding up exploration in recent years has been the shortage of suitably trained and skilled staff.

Although more adequate geological knowledge would undoubtedly be of great value to under-developed countries, the prompt initiation of complete geological or mineralogical surveys is not necessarily the wisest course. Such a survey has many of the attributes of a long-term investment and when judged by the criterion of early economic benefits may well command only a low priority in any development programme. The balance of advantages is more likely to lie with comparatively small-scale surveys conducted in accessible areas in which either some geological or mineralogical knowledge already exists or the surface signs indicate the possible presence of ore deposits that would yield a fairly readily marketable product. It is only in the case of countries which have attained a fair degree of economic development but are still short of raw materials that more thorough surveys are likely to prove both feasible and worthwhile.

In western Europe and the United States the chances of locating new non-ferrous ore bodies by means of surface exposure are very much smaller than they are in less developed countries, except perhaps in the case of relatively "new" metals, such as columbium, tungsten and molybdenum, which have been prospected for only during recent years.[1] In under-developed areas, where many parts still await surface exploration, new discoveries of most of the non-ferrous ores are not unlikely, especially in countries with relatively low population densities.

However, techniques are being devised for locating and exploiting ore bodies that may exist at considerable depth underground. As a result, the domestic resources of industrial countries may eventually be appreciably augmented, though presumably the cost of mining the metal will be substantially higher than in the case of more accessible deposits. In the meantime the conclusion expressed tentatively in chapter 2 would appear to hold: with the exploitation not only of deposits presently known but also of

[1] It is worth noting that a newly discovered tungsten deposit in Idaho became the main domestic source of the metal for the United States during the Second World War.

Table 17. Exports of Non-Ferrous Ores and Metals by Certain Countries, 1938, 1948 and 1953

(Value in millions of indicated currency)

Country and unit	1938 All exports	1938 Non-ferrous ores and metals: Value	1938 Non-ferrous ores and metals: Per cent of all exports	1948 All exports	1948 Non-ferrous ores and metals: Value	1948 Non-ferrous ores and metals: Per cent of all exports	1953 All exports	1953 Non-ferrous ores and metals: Value	1953 Non-ferrous ores and metals: Per cent of all exports
Northern Rhodesia (United States dollar)	49.0	46.0	94	113.4	108.4	95	262.5	253.8	97
Bolivia (United States dollar)	34.8	29.1	84	112.7	105.4	94	111.7[b]	103.1[b]	92
Surinam (florin)	5.8	3.8	66	26.3	21.9	83	45.8	36.1	79
Chile (peso)	675.0	329.0	49	1,596.0	953.0	60	1,995.9	1,711.3	86
Belgian Congo and Ruanda-Urundi (Belgian franc)	1,537.0	687.0	45	10,251.0	4,594.0	45	19,772.0	11,021.0	56
Cyprus (pound sterling)	...	...	...	...	...	...	11.4	3.4	30
Peru (United States dollar)	77.5	18.8	24	162.4	34.2	21	252.5[b]	61.8	24
Mexico (United States dollar)	195.9	71.1	36	467.7	128.8	28	538.7	125.1	23
Yugoslavia (dinar)	5,017.0	478.0	9	7,930.0[c]	1,285.0[c]	16	55,791.0	10,538.0	19
Malaya (Malayan dollar)	587.0	96.0	16	1,764.0	214.0	12	3,917.0[a]	716.0[a]	18
Morocco, French (United States dollar)	43.6	2.1	5	166.2	8.2	5	273.5[a]	34.7[a]	13
Turkey (Turkish lira)	145.0	6.0	4	551.0	28.0	5	1,100.0	131.0	12
Gold Coast (United States dollar)	30.4	4.4	8	197.4	10.9	6	219.6	21.1	11
Indonesia (rupiah)	657.8	33.4	5	1,040.4	147.8	14	9,343.8	921.0	10
Tunisia (French franc)	1,353.1	64.3	5	12,690.2	1,913.4	15	40,059.9[a]	3,918.3[a]	10
Nigeria (United States dollar)	45.3	7.0	15	246.5	18.7	8	341.6	30.2	9
Thailand (baht)	197.0	31.0	16	2,079.0	52.0	3	5,853.0	351.0	6
Burma (rupee or kyat)	478.0	57.0	12	744.0	22.0	3	1,177.0	54.0	5
Angola (escudo)	338.5	...	...	1,488.6	0.4	—	2,751.8	66.7	2
Sierra Leone (pound sterling)	2.1	...	...	4.2	—	1	9.9	0.3	3
Philippines (United States dollar)	115.1	1.9	2	297.3	4.1	1	100.6	7.8	8

Source: United Nations, *Yearbook of International Trade Statistics*, 1950, 1951 and 1953; United States Department of Commerce, *Foreign Commerce Yearbook, 1949* (Washington, D.C.)

Major mineral exports of these countries were as follows:

Northern Rhodesia: Blister and electrolytic copper; lead pigs, ingots and bars; zinc ingots; cobalt and alloy.

Bolivia: Copper ore and sulphide; lead ore and slag; tin concentrates, ore, slag and bars; zinc ore; antimony ore; wolfram concentrates and ore.

Surinam: Bauxite.

Chile: Electrolytic copper, in bars or plates; standard or blister copper (with gold and silver) in bars.

Belgian Congo and Ruanda-Urundi: Granulated cobalt and white alloys; copper; tin ore and ingots; zinc ore, crude and grilled concentrates (latter excluded in 1938).

Cyprus: Copper ore and concentrates; chromium ore and concentrates.

Peru: Ores and concentrates of antimony, copper, lead, tungsten, vanadium and zinc; refined bismuth bars; copper bars, containing gold and silver; refined lead bars.

Mexico: Antimony ore and concentrates; copper ore, concentrates and bars; lead ore, concentrates and bars; antimonial lead bars; zinc ore, concentrates and refined zinc; metallic mercury; manganese ore.

Yugoslavia: Chrome ore and concentrates (concentrates excluded in 1938); zinc concentrates; blister and electrolytic copper; refined lead; raw, and refined and powder zinc (refined and powder zinc excluded in 1938); antimony regulus (excluded in 1938); mercury (excluded in 1938).

Malaya: Tin blocks, ingots, bars and slabs.

Morocco, French: Lead, cobalt, manganese and zinc ores.

Turkey: Copper ingots; chrome ore.

Gold Coast: Manganese ore.

Indonesia: Tin ore and slag.

Tunisia: Zinc ore; copper and copper alloys (excluded in 1938); lead and alloys.

Nigeria: Tin ore; columbite.

Thailand: Tin metal, ore and concentrates.

Burma: Antimony ore; copper ore and matte; lead ore, concentrates and alloys; manganese ore; nickel ore and alloys; tin ore, concentrates, blocks, ingots and slabs; tungsten ore and concentrates; zinc concentrates.

Angola: Manganese ore; copper ore (excluded in 1938).

Sierra Leone: Chrome ore.

Philippines: Chromite; copper ore and concentrates; manganese ore.

[a] 1952.

[b] 1951.

[c] 1950.

others (with surface outcrops) still to be discovered, the proportion of the world non-ferrous ore supply to come from less developed countries is likely to increase.

As suggested above, the lack of knowledge concerning resources, characteristic of under-developed countries, obviously hinders their development, especially if the cost of acquiring a sufficient body of knowledge to justify exploitation is considered prohibitive by would-be investors. It may be noted that the American Smelting and Refining Company had spent nearly $2 million investigating the lead-zinc ore deposits of northern Nigeria before the option on the property was abandoned in 1953 because of underground flooding which could not be overcome with the inadequate power facilities available to the area. Many of the non-ferrous ore bodies now being exploited in under-developed areas were discovered not as a result of systematic survey but rather from the fortuitous unearthing of outcrops, in some cases by ancient civilizations and in other cases by nineteenth and twentieth century prospectors searching for precious metals.

The function of the prospector is well recognized in most countries. In the United States and parts of Canada, the law gives to the discoverer of a mineral deposit title to a tract of about 20 acres.[2] In United Kingdom dependent territories, and in a number of other countries, prospectors are licensed for operation within prescribed districts and any ore body thus discovered may subsequently be exploited under a mining lease negotiated with the government,[3] or in a few cases (the Belgian Congo and Northern Rhodesia among them) with the concessionary holder of the land or mineral rights in the area in question. In some cases the prospector himself may stay on the site to mine the deposit, as in the case of many of the small tin mines in Bolivia, the small copper mines in Chile and more recently the small lead-copper mines in French Morocco. In other cases, the prospector may dispose of his rights to a concern better equipped to exploit the deposit, as happened with the copper-lead mine opened at Mpanda in Tanganyika in the post-war period. Where one of the conditions of a lease is the carrying out within a certain period of a specified minimum development — as in the case of tin leases in Nigeria, for example — prospectors may be obliged to call upon holders of greater capital resources for the exploitation of a mineral discovery.

In some areas the private prospector still plays an important role, though his inadequate training and resources may increase his dependence upon government-operated or company-owned laboratories and field facilities. In Brazil, for example, it is thought that the work of the "garimpeiro"— who in many instances may be no more than a spare time operator, perhaps a farmer whose agricultural activities have been interrupted by drought — could frequently be made more productive if it were promptly followed up by more thorough exploration and assaying by the appropriate department of the Government or by qualified and well-equipped mining companies.

On the whole, better organized and more highly capitalized companies are in a position to make a more accurate geological assessment of an area than a number of separate prospectors or small miners, and when the mineralized region appears to be large there is strong pressure towards the emergence of large concerns whose policies are susceptible of co-ordination or even consolidation under a single direction. In recent years, many of the prospectors have in fact been field geologists employed by established mining companies to explore regions which are thought to hold promise of mineralization. This happened in Northern Rhodesia where, after the First World War, the proximity of the Katanga ore fields of the Belgian Congo was regarded by important mining interests as *prima facie* evidence that copper might be found beneath parts of the forest land of the north-west. The Katanga deposits, whose outcrops consisted of easily smelted oxides, were worked by the early inhabitants of the region. Their general location was discovered in the nineteenth century by European travellers, both from the concentration of copper ornaments in the neighbourhood and from information gleaned from the indigenous inhabitants much further afield. Even with the backing of large companies, however, it took about eight years for the main conformation of the Northern Rhodesian copper belt to be plotted. The area was first scanned by parties consisting of prospector, recorder-assistant and indigenous helpers; from 1923 on, two groups worked steadily on what was more properly a geological survey. The accuracy of the survey and the speed with which mining subsequently became productive are attributed to the tabular nature of the deposits and the consistency of grade over considerable distances of strike and dip. These are rare conditions, and comparable success in discovering and opening up other base metal fields is much less likely.

In general, the importance of field geologists employed by mining companies seems to have increased considerably in the twentieth century. This is partly a result of the increase in the importance of company organization itself, especially in its international ramifications, but it also reflects the lag in government survey work[4] — relative to the great expansion in the use of non-ferrous metals — as

---

[2] Plus certain extra-lateral rights which extend the claim sideways to the limits of the lode or vein picked up on the original site. It was a dispute over these extra-lateral rights, on the copper ores being worked at Butte, Montana, by the Anaconda Copper Mining Company in 1898, that gave rise to what is thought to have been the first systematic geological survey conducted by an operating mining concern.

[3] To judge by recent complaints in Malaya, the prospector is not automatically granted a mining lease, as appears to have been the case in pre-war years.

[4] Since the war, however, there has been an extension of government activity in this field. In the British and French dependent territories, for example, geological survey staffs have expanded greatly. Expert staff in the British geological services overseas numbered 186 in 1952, compared with 58 in 1947, while in the 1948 plan for the development of French oversea territories (excluding North Africa) provision was made for an expert staff of 155, compared with 25 in 1947, and for the establishment of a Bureau minier de la France d'Outre-mer — a public corporation with a capital of 700 million francs — to promote prospecting and the development of mines. Under the ten-year plan of the Belgian Congo, 25 million francs was set aside for investment in the geological service, while recurrent annual expenditure was to be stepped up from 11 million francs in 1948 to nearly 27 million francs in 1952. Government mining departments exist in most of the countries possessing mineral wealth; geological survey sections in many of them — Bolivia, Chile and the Union of South Africa, for example — and the amount of exploratory work has increased markedly in recent years.

well as the complications and capital costs of the new scientific techniques of geological investigations, which tend to handicap the private prospector whose reliance is necessarily placed on simple instruments and keen powers of observation.

Since much official geological survey work is necessarily associated with such civil engineering problems as road building, irrigation and water table levels, it is doubtful whether government surveys can completely replace the work of the private geologist in the search for non-ferrous ore deposits. For present purposes, the most useful function of a government geological office is probably the provision of fundamental data of a general nature against which the economic exploitability of particular ore bodies can be better assessed. Certainly the under-developed countries would benefit greatly from a more accurate and comprehensive knowledge of their own mineral resources and of the underlying geological structure.

Mining companies with trained staff and well-equipped geological and mineralogical departments are in many cases more favourably placed to build up knowledge and experience in specialized fields, thus facilitating the commercial exploitation of specific ore deposits. Geological data of a more general nature gained from company operations, both in prospecting and in mining, might well be made available to the public through appropriate government agencies. In recent years some important mining concerns — International Nickel Company of Canada, Limited, Cerro de Pasco Corporation, Rhokana Corporation and Anaconda Copper Mining Company, for example — have established geological research laboratories, which should facilitate their activities in the field of exploration in a period when new resources will probably have to be opened up to meet the world's increasing requirements of non-ferrous metals. Nevertheless, the bulk of the intensive geological investigation presently being carried out is connected with deposits already being worked, one of the geologist's main commercial functions being to help ensure not only that new development of reserves in the mine will keep pace with the rate of extraction, but also that over the life of the mine the maximum proportion of workable ore will in fact be extracted.

Mining

In view of the fact that the development potential of a mine — the principal subject of the next chapter — is greatly influenced by the methods used in its operation, it seems advisable at this point to examine very briefly certain aspects of some of the techniques generally used in mining non-ferrous ores.

In physical terms, the principal technical objective in any mine is to extract from a given deposit the maximum amount of ore with the minimum amount of waste material. In economic terms, however, the critical relationship is not between ore and waste rock but between the value of the ultimate metallic product and the cost of the resources which have to be expended in winning it from the earth. The dual objective becomes the maximization of the metal output and the minimization of the factor input. The technical means by which this can be achieved depend primarily upon the physical nature of the deposit. Where the ore exists in the form of more or less widely scattered pockets, for example, operations are necessarily organized on a small scale and, conversely, the larger the ore body the more elaborate are likely to be the methods of extraction.

Much of the tungsten and antimony that is mined in under-developed countries comes from dispersed ore pockets which are worked by individual miners or small companies. Much of the tin ore, cassiterite, is also found in quantities that are too small to justify large capital expenditure. In contrast with this type of resource are the massive deposits of manganese ore in Brazil, India and the Union of South Africa, of chromite in Southern Rhodesia and Turkey, of bauxite in the Gold Coast, Jamaica and Surinam, and of copper oxides and sulphides in the Belgian Congo, Chile, and Northern Rhodesia, to mention but a few, in which the volume of ore is such that a long-term investment in mechanical handling facilities is warranted, at least on technical grounds.

Apart from differences in the size of the deposit, there may be important differences in its position in relation to the surface. A small body of ore is of little commercial value unless it lies fairly near the surface and is capable of being extracted by means of the type of equipment likely to be at the disposal of individual miners. A massive ore body, on the other hand, may be workable even though it extends for considerable depth.

A massive deposit with a sufficiently large surface or near-surface outcrop may be exploited by the open-pit or opencast method. This involves the use of mechanical shovels and a system of transport — conveyor belt, rail or truck — designed to remove the material as fast as it is excavated. When the metallic ore is disseminated in rock, as in the Chuquicamata copper deposit in Chile, a considerable amount of blasting is necessary for the quarrying; in softer deposits, such as the Caribbean bauxite, more digging implements and less explosives are used. An example of this technique is employed in Malaya, and to a smaller extent in some of the other tin-producing areas, where the digging, transporting and sorting are all accomplished with a single piece of equipment, a large dredge which lifts the alluvial tin ore from the river mud in which it has been accumulating.

The bulk removal of ore, along with the matrix of earth and rock in which it lies, is commonly referred to as mass mining. It is practised most frequently in the case of massive ore deposits with a large surface outcrop or a light overburden of waste material. The more homogeneous the product the more suitable for mass mining, and the higher the proportion of metal present the more economical the result. High-grade manganese (such as is found in the Gold Coast), bauxite (as in Surinam) and chromite (as in Southern Rhodesia), in which between one-third and two-thirds of the material is metal, are commonly handled in this way. A high metal content is not essential, however; some of the most successful examples of mass mining have involved low-grade porphyry ores with a copper content of less than one per cent. Where the metal is disseminated sparsely but uniformly through a section of the earth's crust, indeed, mass mining offers the only method of extracting it; the economic success of the process depends upon the effectiveness of the subsequent handling of the large tonnages of material that flow from the mine through crusher, mill and flotation plant.

Where the ore takes the form of a lode or vein, or a series of such lodes or veins (as in the zinc and lead ore deposits in Northern Rhodesia) mass mining is seldom appropriate. In these cases, the ore veins usually have to be followed in the ground and as much as possible of the ore removed with as little as possible of the unwanted material around it. This usually involves sinking a shaft (or perhaps several shafts) and tunnelling in such a way as to facilitate the extraction of the ore and the ventilation of the area of work; in other words, mining in its traditional sense. Many of the medium-sized zinc and lead mines of Mexico, the copper mines of Northern Rhodesia and the larger tin mines of Bolivia are based on underground operations of this nature.

In this type of mine, the width of the lode is unlikely to remain uniform over its whole length, nor is the concentration of metallic ore likely to be constant. It is thus possible in most such mines deliberately to vary, within certain limits, the average grade of ore actually extracted; by mining the wide lodes or the concentrated ore, the grade may be raised and, conversely, by mining the narrow lodes or the more dispersed ore, the grade may be lowered. It is this degree of control over the composition of the ore being fed to the crushers that has given the name "selective mining" to this system of ore extraction.

Changes in the grade of ore are not the only ones that may be encountered in the course of working a given deposit. The very nature of the ore may change as mining proceeds; metallic oxides at the surface may give way to sulphides at depth, for example, as has happened in the case of certain of the Chilean copper deposits, necessitating a complete change in the methods of milling, separating and smelting, with the corollary of additional large-scale capital expenditure on new processing works. The continuity of the ore body may be broken by faults or, to a lesser degree, by dikes or intrusions which at best may merely change the grade of the ore but may require the relocation of the lode, the sinking of new shafts and a considerable amount of new development before productive extraction can be resumed. The temperature gradient may be much steeper than originally seemed likely, thus upsetting the arrangements for ventilation and raising the costs of deeper mining. Underground water may complicate the process of mining considerably, necessitating expansion of the pumping system and perhaps the extension of cementation to parts of the mine where simple timbering had been planned. The unexpected appearance of underground gases may require a revision of lighting, blasting and other mining practices. Changes in the geological formation may necessitate changes in the technique of ore extraction as well as of tunnelling and stoping.

Physical irregularities such as these will inevitably continue to characterize underground ore bodies. Not all of them are necessarily unfavourable and in the original financial computations made by a mining company, before the decision to begin exploitation is taken, due allowance is presumably made to cover all probable risks of ore variability as well as all probable mining hazards. In the present context it is the fact of variation rather than the direction that is significant, though unexpected deterioration in the ore body or in mining conditions is likely to be more seriously disruptive of mining plans. Advances in geological techniques, however, may succeed in providing information about such variations far enough ahead to allow mining methods to be adapted without undue interruption in the flow of ore, though not necessarily without considerable additional expenditure.

Smelting and refining: some general problems

For an under-developed country, the refining of a locally mined non-ferrous ore represents a major industry. It is a means of diversifying employment, and forms a training ground for new skills; it expands the market for domestic produce — certain items of refinery equipment and stores and the requirements of personnel — in much the same way as the process of mining itself stimulates local demand; and it adds considerably to the value of the ore, thus increasing the industry's capacity for earning foreign exchange. The refined product may also be used within the country itself, forming the basis of a fabricating industry.

Despite the tendency for import duties to rise with the degree of processing, the refined metal is usually more readily saleable than the ore. A switch from ore to metal exports, however, may involve a switch in markets, and with the world divided into currency blocs as it has been in recent years, an under-developed country may have preferred to sell concentrates for dollars rather than refined metal for some soft currency. Given the great refining capacity in the United States, an advance in the degree of processing in an under-developed country may tend, at least at first, to diminish the chances of sale on the dollar market. This, in turn, may tend in the short run to retard development of refining in countries which depend on the United States market for their foreign exchange from the sale of raw materials. In the long run, however, the advantages of a domestic metallurgical industry are likely to outweigh those flowing from particular market attachments. Moreover, the reopening of the London Metal Exchange and the progress made by major European currencies towards convertibility have considerably weakened this argument against further domestic processing. In any case, the rapid expansion of its metal consuming industries in recent years has turned the United States, like other major industrial countries, into an importer not only of the ores of almost all the non-ferrous metals but also of the metals themselves. In general, therefore, it is in the interest of under-developed mineral economies to process, at least to some degree, the ores they produce, and in the light of this conclusion, the present section reviews very briefly some of the considerations which influence the establishment and expansion of smelting and refining facilities in the neighbourhood of the mine.

That such facilities are already fairly widespread — at least in respect of the major non-ferrous metals — is brought out by the maps presented in this chapter. Though these maps do not show the distribution of known resources, they give the location of most of the important mines and smelters operating in under-developed countries.

The nature of the metal and of the ore deposit

The first of these considerations is the nature of the mineral product. The under-developed country with mineral resources would have much less to gain from the preparation of metallic manganese or chromium or molybdenum or even tungsten than from the production of copper or lead or even aluminium; the reduction of the ores of the former group involves complicated processes, and only a comparatively small proportion is used in pure metallic form. In the case of these and other additive metals, domestic utilization of the ores in the country where they originate depends on the correlative growth of a steel industry sufficiently advanced to produce other than straight carbon steels. The steel industries of Brazil, Chile, India, Mexico and the Union of South Africa all make use of domestic manganese resources and produce small quantities of some of the special steels. In the Union of South Africa in 1951/52 for example, the largest producing company actually exported some 4,000 tons of ferroalloys, from an output of about 21,000 tons. In 1952/53, the corresponding figures had increased to 7,000 and 35,000 tons. Southern Rhodesia, with a steel output of only 40,000 to 50,000 tons a year, but large reserves of iron ore and metallurgical chromite, has begun to produce ferrochrome; with the support of a British steel firm a company was established for this purpose in Gwelo in 1952. By 1954, its annual output was of the order of 5,000 to 7,000 tons though capacity was capable of considerable expansion.[5] Of the tungsten producers, however, only the larger of the under-developed countries — Argentina, Brazil and the Union of South Africa, for example — consume even small quantities of the metal, either as such or as ferrotungsten (see table 18).

At present, the under-developed countries as a whole account for less than one per cent of world consumption of any of the additive metals. Their output of the various ferroalloys will doubtless increase as iron and steel production increases, and as industrial progress expands both the demand for the metals and the supply of power for the electric furnaces which their production requires, but by and large the under-developed countries which produce the minor non-ferrous metals will continue for a long time to export the bulk of their output as ore or concen-

[5] The company began exporting on an experimental scale in 1953. It has been estimated that if Southern Rhodesian exports of chromite were converted into ferrochrome before being shipped, volume would be halved and value increased tenfold.

Table 18. Exports and Imports of Certain Additive Metals by Under-Developed Countries, 1948-51, and International Materials Conference Allocations, 1952

(Metric tons, metal content)

Country	Tungsten[a]			Molybdenum[a]			Nickel[b]	Cobalt[c]
	Exports 1948-51	Imports 1948-51	Allocation 1952	Exports 1948-51	Imports 1948-51	Allocation 1952	Allocation 1952	Allocation 1952
Argentina	34	3	8	—	—	0.5	44.5	9.0
Belgian Congo	122	—	—	—	—	—	—	—
Bolivia	1,214	—	—	—	—	—	0.8	0.4
Brazil	390	4	12	—	3	20.5	87.6	19.1
Burma	688	—	—	—	—	—	—	—
Chile	—	1	2	1,287	2	4.1	45.0	0.3
India	—	48	23	—	12[d]	4.3	385.1	10.5
Korea, southern	621	—	—	4	—	—	—	—
Mexico	76	—	—	—	—	—	16.0	3.5
Peru	183	—	—	—	—	—	—	—
Southern Rhodesia	44	—	—	—	—	—	2.4	0.8
Thailand	424	—	—	—	—	—	—	—
Turkey	—	—	—	—	1	9.6	16.8	3.4
Union of South Africa[e]	99	9[f]	67	—	37[f]	23.3	81.4	20.0
Rest of Africa[g]	75	—	—	—	—	—	3.8	0.4
Rest of Asia[h]	40	—	—	—	—	—	10.5	0.2
Rest of Latin America	—	—	—	—	—	—	15.2	1.9
TOTAL	4,010	65	112	1,291	55	62.3	799.1	69.5
WORLD TOTAL[i]	8,443	10,948	17,580	4,042	3,647	21,858	142,398	9,765

Source: International Materials Conference, *Report on Operations, 1952–53* (Washington, D. C., 1953).

[a] Ores, concentrates and primary products, including ferroalloys.

[b] Metal and oxides, ferronickel and certain other alloys.

[c] Metal, oxides and salts.

[d] Average for 1950–51.

[e] Including South West Africa.

[f] Average for 1948–50.

[g] Excluding French North Africa.

[h] Excluding the mainland of China.

[i] Excluding mainland China, eastern Europe and the Union of Soviet Socialist Republics. Before 1949 a sizable proportion of Chinese exports of tungsten customarily entered bonded warehouses. As this material passed through customs only later upon withdrawal, it is statistically possible for total imports for consumption to have exceeded total exports, during the period 1948 to 1951.

trates to more industrialized consumers. In the case of these metals, therefore, the industry in the under-developed country will continue to consist largely of the extraction of the ore, its beneficiation to a technically satisfactory metal content and the conveyance of the bulk of the output to a port for shipment. If these operations are performed as efficiently as possible, account being taken of the frequent advances in beneficiation techniques, then the development potential of the industry will depend on such considerations as the progress of domestic steel manufacture, the price realized for the ore on oversea markets and the manner in which the resultant funds are employed within the economy. These lie outside the industry itself and are discussed in the next chapter.

Apart from the ferroalloy ores, non-ferrous minerals are all marketable as metals; indeed as suggested above, they are generally more readily marketable as metal than as ore. Moreover, there is a considerable pecuniary advantage in processing the ore as far as the country's economic and technical resources allow, since beneficiation adds substantially to the value of the ore, while smelted and refined metal is worth very much more than it was when still contained in its ore (see table 19).

Whether in any particular case the mining industry can economically be extended to include smelting and refining depends in the first place upon the size of the ore body. Investment in smelting and refining plant is commercially justified only if there is a supply of ore sufficient to feed the plant at optimum rate at least until the original investment has been amortized. Such ore need not be of domestic origin, but though a country with advanced power facilities may be able to build up a metallurgical industry on the basis of imported ores, it is to domestic ore resources that an under-developed country must first look before a decision is made regarding the erection of a smelter.

Evidence of this fact is found in the concern manifested by some of the larger non-ferrous metal groups to control ore resources that are sufficiently productive to supply indefinitely the bulk of the required intake of their own smelters and refineries. Many of the mineral deposits in less developed areas are fully capable of sustaining technically independent smelting and refining facilities; such are to be found in the copper ore deposits of the Belgian Congo, Chile and Northern Rhodesia. There are many places, on the other hand, where small pockets of ore justify mining but not the erection of elaborate surface works, and in these cases there may be no alternative to treating the ore in the manner suggested for the ferroalloy ores above: extraction, beneficiation and shipment. If, however, there are many of these pockets which could be mined over an extended period, the erection of a central smelter might be warranted. This has been done in Chile, where in 1951 a government-sponsored smelter was built at Paipote to serve a number of small independent mines which had previously exported their product in the form of concentrates. In much the same way, the Mining Bank of Bolivia has constructed a smelter to handle the concentrates of small tin mines. A similar central smelter might add to the development potential of small lead mines in French Morocco, which at present have to export their output as concentrates to be refined in France. Nigeria, too, might benefit from a central refinery to handle tin ore now gathered from a large number of small placer deposits, although in this case technical evaluations indicate that at this stage the country's tin resources are too slender, and the expected life of the mines too short, to warrant investment in a local refinery.

The criterion of cost

Another determinant of the location of metallurgical works is the cost of their establishment and operation, and in this an under-developed country may often be at a disadvantage in comparison with some of the more industrially advanced countries. In the first place, most of the requisite equipment is manufactured almost exclusively in highly industrialized countries, and its acquisition, transportation and installation involve costs which tend to increase with the remoteness and lack of facilities of the area in which they are to be used. Maintenance of plant and replacement of equipment likewise present special problems in under-developed regions. Technological progress in the industry, moreover, has usually tended to favour the industrial countries, emphasizing mechanization and the use of power and reducing the relative employment of labour, to the disadvantage of areas in which capital tends to be a much scarcer factor than labour.

In the copper industry, for example, growth in the size of the smelter, as well as in the capital cost of installation, is illustrated by the fact that, whereas the reverberatory furnace used towards the close of the nineteenth century was about 25 feet long by 16 feet in diameter and could handle a charge of 15 to 20 tons a day, furnaces built just before the Second World War were about 180 feet long by 22 feet in diameter and capable of handling a daily 1,000-ton charge, with no increase in the amount of supervisory labour. With the relative increase in the volume of fine (milled) ore which has followed the growing use of flotation separation, the reverberatory furnace has tended to replace the blast type. Similar development has taken place in the design of converters: from the first model which carried a 4-ton load of matte, and the early twentieth century models which handled 15 to 20 tons, to those in current use, which take up to 100 tons of matte and are capable of producing up to 3,000 tons of blister copper each month.

By and large, the higher the metal content, the greater the value of each ton of ore, and the higher the value of the ore, the greater are the distances over which it may be economically shipped. Other things being equal, therefore, the lower the grade of ore the stronger the forces making for treatment at the mine. Transport costs, however, are only one element in the total cost of producing and marketing the metal. Moreover, as indicated later in this chapter, within an integrated system the problem of smelter and refinery location is one of minimizing cost, not necessarily for any individual mine or smelter component, but for the system as a whole.

In general, the greater the degree of beneficiation achievable at the mine, the less is the disadvantage of exporting concentrates instead of metal. Thus tin ore,

Table 19. Prices of Certain Non-Ferrous Ores and Metals, Mid-1954

Item, market and unit	*Price per unit*		*Description*	
	Ore	*Metal*	*Ore*	*Metal*
Aluminium:				
France (thousands of francs per metric ton)	6.1	180	72 per cent aluminium, 3 per cent iron, f.o.r.	99 per cent, f.o.r.
United Kingdom (pounds sterling per long ton)	7.5	156	Bauxite ex British Guiana, c.i.f.	Ingots, 99 to 99.5 per cent, delivered
United States (dollars per long ton)	18.5	497	Abrasive quality, 82 to 84 per cent, f.o.r.	Ingots, 99 per cent, f.o.r.
Copper:				
Mexico (United States cents per pound, metal content)	8	30	Unit value, f.o.b., ores and concentrates exported in 1954	Unit value, f.o.b., blister and electrolytic copper exported in 1954
United States (cents per pound, metal content)	20.2	30.6	Unit value, f.o.b., imports of Canadian ores and concentrates, average 1953	Unit value, f.o.b., imports from Canada, average 1953
Lead:				
United States (dollars per long ton)	198	330	Galena, 80 per cent, f.o.r. Joplin	Common grade, f.o.b. New York
Tin:				
Australia (Australian pounds per long ton, metal content)	800	968	Concentrates, 70 per cent, delivered Sydney	Delivered Sydney
United Kingdom (pounds sterling per long ton, metal content)	301	739	Unit value, f.o.b., ores and concentrates imported in 1954	Ingots, 99.75 to 99.9 per cent, London
United States (cents per pound, metal content)	75	92	Unit value, f.o.b., concentrates exported from Indonesia	Straits tin, New York
Zinc:				
United Kingdom (pounds sterling per long ton)	17	74	Sulphide, 52 to 55 per cent recoverable content, c.i.f.	Refined, delivered
United States (dollars per short ton)	64	230	Concentrates, 60 per cent f.o.r. Joplin	Prime western, f.o.b. East St. Louis
Antimony:				
United Kingdom (pounds sterling per long ton)	117	210	Sulphide, 60 per cent, delivered	Regulus, 99 per cent, delivered
United States (dollars per short ton, metal content)	470	570	60 to 65 per cent, c.i.f.	99.5 per cent, bulk, f.o.b. Laredo
Chromite:				
United Kingdom (pounds sterling per long ton)		84		Ferrochrome, lumpy: 60 per cent chromium, 4 to 6 per cent carbon, delivered, 6 to 10 ton lots.
	14	742	Lumpy, metallurgical, ex Southern Rhodesia, c.i.f.	98 to 99 per cent, delivered
United States (dollars per long ton)	44.5	2,755	48 per cent, chromium-iron ratio, 3:1, dry, f.o.b. Atlantic Coast	97 per cent, 1 per cent iron, ton lots
Cobalt:				
Northern Rhodesia (shillings per pound)	8	21	Alloy, average unit value, f.o.r., Nkana	Average unit value, f.o.r. Nkana
United Kingdom (shillings per pound)	13	21	Black oxide, delivered	Delivered
United States (dollars per pound, metal content)	1.3	2.6	F.o.b. Ontario	Rondelles or granules, 97 to 99 per cent, 500 to 600 pound lots, f.o.b. Niagara Falls
Manganese:				
United Kingdom (pounds sterling per long ton)	29	54	48 per cent, c.i.f.; price of metal content	78 per cent ferromanganese, delivered
		244		96 to 98 per cent refined metal, delivered
United States (dollars per long ton, metal content)	88	672	48 per cent, c.i.f.	Electrolytic, 99.9 per cent, f.o.b. Knoxville, Tennessee

Table 19. Prices of Certain Non-Ferrous Ores and Metals, Mid-1954 (*continued*)

Item, market and unit	*Price per unit*		*Description*	
	Ore	*Metal*	*Ore*	*Metal*
Molybdenite:				
United Kingdom (shillings per pound, metal content)	8	11	85 per cent MoS_2 c.i.f.	Ferromolybdenum, carbon-free, 65 to 75 per cent, delivered
		40		Powder
United States (dollars per pound, metal content)	1	3	F.o.b. Climax, Colorado	99 per cent, New York
Nickel:				
United States (cents per pound, metal content)	28	60	Unit value of imports, f.o.b.	Electrolytic, New York
Tungsten:				
United Kingdom (shillings per pound)	11	17	Wolfram, 65 per cent, c.i.f.	Ferrotungsten, 80 to 85 per cent; price of metal content, delivered
		20		Powder, 98 to 99 per cent; price of metal content, delivered
United States (dollars per pound)	3	4	Domestic scheelite, 65 per cent; price of WO_3 content	98.8 per cent; in 1,000 pound lots, New York

Source: *Metal Bulletin* (London); *American Metal Market* (New York); *Engineering and Mining Journal* (New York); and national trade statistics.

which can be concentrated up to 70 per cent or more of metal content, is shipped great distances: from Indonesia to the Netherlands and the United States, from Nigeria to the United Kingdom, from the Belgian Congo to Belgium. Even lower grade and more recalcitrant ores from Bolivia are shipped to the United Kingdom and the United States. Similarly, zinc and lead concentrates move from Australia to the United Kingdom and the United States, from the Belgian Congo to Belgium, from Peru and South West Africa to the United States. Copper concentrates, which usually have a much lower metal content, tend to travel very much less, though even in this case the smaller producers, Bolivia, Cuba, Cyprus and Newfoundland, export their whole output in the form of ore or concentrates.

An important consideration influencing the relative movement of ore and metal is the existence of a differential in the actual cost of transport. Where the freight rate per unit weight is lower for the ore than for the metal it constitutes a force militating against the establishment of a local smelter or refinery. The freight rate on tin from Indonesia, for example, appears to be based on metal content, so that no additional costs are incurred when concentrates are shipped instead of refined tin. When the destruction of the Bangka refinery during the Second World War opened the question of where the Indonesian concentrates were to be shipped, it was found that rates could be obtained which made the journey to the Arnhem smelter in the Netherlands no costlier than the very much shorter journey to the Straits Trading Company's smelter in Singapore. Similarly, an export duty levied on metal content — as in the case of tin in Bolivia, for example — tends to discourage both beneficiating and smelting at the mine.

When there is no freight discrimination between metal and ore, there is an obvious advantage in shipping the former. Where the distance is great, indeed, especially in the case of rail journeys, it may be economically impossible to ship anything but the pure metal. This was one of the reasons for the establishment of the first lead smelter at Broken Hill in Northern Rhodesia, in spite of economic and technical difficulties arising from the remoteness of the ore deposit.

There is also an advantage in reducing the amount of moving and handling of ore by rapid and direct transfer from mine to metallurgical works. Furthermore, the physical shortening of the flow of materials tends to reduce the size of the inventories which must be held at each stage of the beneficiation and smelting process, and this in turn makes for the more productive use of capital.

Where there is an incipient domestic demand, moreover, there is an additional advantage in having the metal produced at the mine, for, other things being equal, its cost to local industries using metals is likely to be lower than the cost of imports from foreign refineries. Where the demand is small, however, as it is likely to be in most under-developed countries, it may be difficult to provide the metal in the various forms in which it is required by local industries. The Union of South Africa, for example, in spite of metallic copper exports of almost 32,000 tons per annum in recent years, has had to import copper to the extent of about 15,000 tons a year largely because neither the Okiep blister nor the Messina fire-refined product is suitable for local producers of electrical equipment.[6]

Technical problems

Implicit in the preceding section is the fact that the economic criterion of cost does not operate in a vacuum; it has to be applied within a given technological framework. The location of the metallurgical plant depends

[6] In this instance local copper fails to meet the standards laid down by the International Electrotechnical Commission in 1925 which have been adopted by fabricators.

partly on the nature of the smelting problem, and this varies from one metal to another and even from one ore body to another. In general, lead is more easily refined than the other non-ferrous metals; tin, copper, zinc and aluminium, in that order, tend to present increasingly difficult tasks. The less tractable the ore the more likely is its shipment (in concentrate form) to an industrial country possessing metallurgical facilities capable of handling it. This is not to say that technical problems are necessarily insoluble with the technological resources at the disposal of an undeveloped economy; much depends on the extent to which technicians are available for research and experiment at the mine, though in some cases the close organization of some sections of the non-ferrous metals industry may tend to prevent the exporting country from taking an independent line.

Where the ores are of a fairly standard nature, there may be no new metallurgical problems to solve; the question is then largely one of engineering and involves the adaptation of known techniques to the particular circumstances of a given mine and its available facilities of water, fuel, power and labour. With some ores, however, standard metallurgical techniques and straightforward smelting methods may not be good enough. Economic success may depend on maximum recovery of the metal, as it does, for example, in the case of the tin ores of Bolivia which, unless "sweetened" by admixture with more tractable ores, are subject to excessive losses when treated in the normal way.

Quite apart from the technical difficulty that may arise in treating the recalcitrant ores of a single metal, the presence of subsidiary metals in an ore, if these are of sufficient value, may militate against treatment at the source, by making it economically preferable to export the ore to a plant where all the by-products can be fully recovered. The presence of zinc or silver in lead ores (as in many Mexican and Peruvian deposits), of nickel in copper ores (in certain Canadian deposits), of gold in copper ores (in a number of Yugoslav deposits), of copper in lead ores (in the Mpanda deposit in Tanganyika and the Tsumeb deposit in South West Africa), of vanadium in zinc ores (in Northern Rhodesia), of cadmium in zinc ores (in numerous Mexican deposits), of tungsten in tin ores (in Bolivia, Malaya, and Thailand), of copper in tungsten ores (in Bolivia and Portugal), of molybdenum in copper ores (in the porphyry deposits of Mexico), have all tended at various times and in various ways to complicate the problem of recovery. The evolution of the technique of differential flotation in the nineteen twenties was a major step forward in the handling of complex ores, facilitating their beneficiation not only in Australia, Canada and the United States, where it was first used, but also in Mexico, Peru, Northern Rhodesia and other under-developed countries. Nevertheless, there are still many deposits of recalcitrant ore which require more than the metallurgical skills commonly available in an under-developed country for successful smelting and refining.

Some of these problems may be illustrated by the development of the Broken Hill mine in Northern Rhodesia where lead-zinc ores were discovered in 1903. Although the railway line reached the site in 1906, it was not until 1915 that the first metal was produced. This was lead, produced under lease by the Rhodesian Lead and Zinc Syndicate from the rich oxidized ore which formed the most accessible of the Broken Hill deposits. The ore was smelted directly, without preliminary treatment, in a small (4-foot diameter) blast furnace which yielded fairly high-grade pig-lead. A large water-jacketed furnace was erected in 1917, and when the mining company took over the metallurgical works in 1919, two furnaces were operating with a capacity of 1,200 tons of pig-lead per month. Two more furnaces were erected in 1920 and 1921, but the supply of high-grade oxidized ore was inadequate, and after 1923 production tailed off, the original deposit being mined out by 1929. In the meantime experiments had been conducted on the oxidized zinc ores derived from another part of the property, and a pilot plant had shown the feasibility of electrolytic reduction of these silica-rich ores from an acid solution. In 1923 work was begun on a hydroelectric station about 35 miles from the mine, and in 1928 a new electrolytic zinc plant came into operation. Except for an 18-month shut-down during the depression, zinc production continued at about 20,000 tons per annum until 1936, when exhaustion of the oxidized deposits caused a gradual decline in output. A diamond drilling programme launched in 1936, however, revealed considerable ore reserves below the 225-foot level which was then the limit of mining. As these new ores were largely mixed lead and zinc sulphides, their treatment involved new metallurgical processes: a system of differential flotation for the separation of the ores, a flash roaster unit for calcining the zinc sulphide prior to leaching, and new kettles in the lead smelter for the production of refined metal. During the war a second hydroelectric station was built, as well as a 4,500-kilowatt stand-by thermal station, and two new and deeper shafts were sunk, one for pumping and the other for ore delivery. By 1946, the plant was capable of producing 14,000 tons of refined lead and 22,000 tons of electrolytic zinc each year. Separation of vanadic ore has been undertaken intermittently ever since the commencement of zinc refining, but the technical problems have not yet been solved, and production has sunk to a low level in post-war years.[7]

The Rhodesia Broken Hill Development Company, Limited, had a strong economic incentive to solve its major metallurgical problems, for, given the metal prices prevailing during the period between the wars, it probably would not have been able to cover the high cost of exporting zinc or lead ores or concentrates from so remote a mine. On the other hand, the oxide ores that were first mined were rich enough — 14 per cent lead and 27 per cent zinc, comparable to the best deposits in Australia — and sufficiently tractable to bear the high cost of erecting and operating local processing facilities. Moreover, the company also had certain advantages from its connexions with a large mining group — the Anglo American Corporation — and in having on its staff technicians who had had experience with the lead-zinc mines of Australia.

[7] See P. J. Gleeson, "The Story of the Broken Hill Mine in Northern Rhodesia," *Optima*, volume 2, No. 3, September 1952 (Johannesburg), page 5.

Fuel and power

The brief description of the conversion of ore to metal at the Broken Hill mine in Northern Rhodesia indicates the importance of adequate power, not only in the treatment of complex ores but also in smelting and refining processes in general. The electrolytic refining of copper requires as much as 2,500 kilowatt-hours of electricity per ton of metal, the refining of zinc 3,000 kilowatt-hours and the conversion of alumina into aluminium no less than 20,000 kilowatt-hours per ton.

Lack of fuel — coal is generally the most convenient, though fuel oil and natural gas are being increasingly used — makes even simple smelting with current techniques both difficult and costly in many areas, and places such countries as Cuba and Cyprus, and to a certain extent Bolivia, in the position of either importing large quantities of coal or exporting their mineral output in the form of ores and concentrates. Chile, on the other hand, has the fuel and power resources required for the development of a metallurgical industry. In Mexico the established mineral areas have the necessary power capacity, but the newer areas, which are likely to become increasingly important with the exhaustion of older mines, still lack adequate facilities.

In Peru, one of the first investments of the Cerro de Pasco mine in the early years of the present century was in a colliery. In Nigeria, the seasonal closing of the tin mining industry is largely a result of the inadequacy of electric power during the dry period of the year, and shortage of power was probably one of the reasons why no local smelter was ever established. In Southern Rhodesia, the new ferrochrome industry has been severely handicapped by power shortage due largely to difficulties in improving the mining and transporting of coal from the Wankie colliery. In all countries economic reduction of alumina depends largely on the availability of cheap power; the establishment of refineries in the Gold Coast and Peru, for example, is at present contingent on the completion of hydroelectric projects — on the Volta River and the Cañón del Pato, respectively.

The Belgian Congo, though affected by occasional droughts which have from time to time reduced some of the river flows, is well placed in respect of hydroelectric potential, and at present the mining industry is both the largest producer and the largest consumer of power. The Union minière, the largest of the Belgian Congo mining groups, now operates four hydroelectric stations with a normal output of some 2.5 billion kilowatt-hours a year—sufficient to supply not only its own mines and refineries but also the public utility requirements of Katanga and leave a margin for export. Northern Rhodesia, however, has had its copper production curtailed throughout the post-war period by coal shortages which are (in mid-1955) in the process of being remedied by the mechanization of the Wankie colliery in Southern Rhodesia and the improvement of the railway service which carries coal to the Rhodesian Copper Belt. Within the next decade energy supplies are likely to be increased considerably by hydroelectric projects — at present in the planning stage — in the Kariba gorge and on the Kafue River. In the meantime, the four producing mines have established an interconnected grid which reduces the need for stand-by equipment and provides for a relatively convenient link with the Katanga electricity network across the border in the Belgian Congo, from which it is intended to buy energy, at least until the domestic plants start generating.

In Malaya, electric power development has been stimulated by tin mining ever since the early years of this century, but neither of the large smelters (at Penang and Singapore) seems to have been handicapped by fuel or power shortages. When the Bangka smelter in the Netherlands East Indies was operating before the war, however, it relied on imported fuel. In New Caledonia, the construction of hydroelectric facilities for the chromite mines also provided the nickel mines with power, permitting a higher degree of beneficiation of ore and reducing their dependence upon imported high-cost coal.

The availability of low-cost power is one of the main reasons for the prominence of Canada in the aluminium industry. In much the same way, the hydroelectric potential of Norway has made that country more important in the metallurgical field than its ore resources or its status as a consumer would have justified; it has a large output of aluminium, operates a sizable nickel refinery and is a major producer of several ferroalloys. Power facilities also helped Switzerland become an early and significant producer of aluminium and Sweden one of the principal exporters of ferrotungsten and ferromolybdenum. The pattern of non-ferrous smelting and refining activities may thus be greatly influenced by the availability of power and in this respect the development of nuclear energy may permit a considerable expansion of the metallurgical industry in some of the less developed countries in which conventional sources are scarce.

Influence of international relationships

Proximity to an industrialized country sometimes tends to retard the growth of metallurgical activities in a less developed one; the disparity in facilities when combined with relatively low transport costs may make it profitable to move ore (or concentrates) to a foreign smelter rather than smelt it at the mine and later move the refined metal to the markets of an industrial country. Thus metallurgical development in Mexico would probably have been more rapid had not efficient smelting and refining plants existed across the United States border in Arizona and Texas. In 1948, no less than 80 per cent of the Mexican zinc output of 200,000 tons was exported as concentrates to the American Smelting and Refining Company (ASARCO) smelter at Amarillo, Texas, and its associated refinery at Corpus Christi; while the whole output of the Moctezuma Copper Company of Mexico was exported for processing in the Phelps Dodge Corporation smelter in Douglas, Arizona, and the Phelps Dodge Corporation refinery in El Paso, Texas.

In the same way, the copper ore output of the Granby Consolidated Mining, Smelting and Power Company, Limited, and the Britannia Mining and Smelting Company, Limited, in western Canada crosses the border to be smelted and refined at the ASARCO plant in Tacoma, Washington. The rapid development of the metallurgical industry in Canada in recent years has not significantly reduced the proportion of non-ferrous metal exports in the form of ore. In 1938, about one-fifth of the Canadian mine output was exported as ore, matte or concentrates; in the period 1952 to 1954 the proportion exported in this form was about one-fourth in the case of copper, almost one-third in the case of lead and about one-half in the case of zinc, while a good deal of the nickel output is still exported as matte or speiss for refining to the United States.[8]

Before the war, both Spanish and Yugoslav metallurgical development was probably handicapped by the nearness of the more advanced industries of France, Germany and the United Kingdom. It is probable that the existence of adequate smelting and refining facilities for tin in Malaya has similarly militated against the establishment of plants in Burma, Indochina and Thailand, where the output of concentrates is very much smaller.

Easy physical access to established facilities, however, is not of itself sufficient to prevent the construction of a processing plant at the mine in a less developed country. Much depends on the organization of the industry. It is as well to recall at this stage that the modern non-ferrous metals industry grew up in the principal industrial countries in response to new demands for metal arising from the advance of machine technology in general and, in the last quarter of the nineteenth century, of the electrical engineering industry in particular. In the first instance, the industry was organized almost entirely on the basis of domestic ore resources. Thus, most of the smelters and refineries of Europe and the United States were located initially so as to provide economical transportation of fuel and ore supplies that were for the most part of domestic origin. Many of the early smelters were independent enterprises treating ores or concentrates from small mines on a custom or toll basis.

As in the case of other industries, however, there were strong forces, both technical and economic, making for vertical and horizontal integration. The merging of mines under single ownership or control often resulted in more effective exploitation of a given ore body. Technical advances in methods of smelting and refining, generally accompanied by greater mechanization, tended to increase the economic size and throughput of metallurgical works. This in turn stimulated the search for new sources of ore to feed into the new or expanded works and, as a corollary, a tendency to tighten the bonds between the smelter and the mines which supplied it with ore. Prompting these organizational developments was a rapidly expanding demand for most of the base metals. This was the background for the birth and growth of the large multiple-unit concerns which have since come to predominate in several branches of the industry, exercising a major influence on the subsequent location of processing facilities.

A mine acquired or developed specifically as a tributary to an existing smelter is more likely to ship its output as ore or concentrates than to build up its own processing facilities. A tributary to an existing refinery, however, may set up its own smelter, shipping crude metal rather than ore or concentrates on the one hand or refined metal on the other. The cost criterion may no longer be considered appropriate to the mine as a separate economic unit but, as indicated above, may be applied to the system as a whole.

The effect of organizational affiliation is illustrated by the contrast between the Moctezuma Copper Company in Mexico, which became a tributary to the well-established system of the Phelps Dodge Corporation in Arizona and Texas and remained an exporter of ore, and the Cananea Consolidated Copper Company, S.A., not far away, which was not incorporated into the small Arizona system of the Anaconda Copper Mining Company of which it is a subsidiary but rather into the much larger system based on the more distant Raritan Copper Works in New Jersey, and became an exporter of blister copper from the smelter constructed at the mine. Similarly, before the war, the copper mine of the Cerro de Pasco Corporation in Peru was associated with the American Metal Company system based on a 200,000-ton refinery in Carteret, New Jersey, exporting blister copper from its own smelter in La Oroya, Peru. The enlargement of the system by the accession of new mines supplying Carteret — the Okiep Copper Mining Company, Limited, and the Tsumeb Corporation, Limited, in southern Africa and a portion of the Northern Rhodesian blister output from the Mufulira Copper Mines Limited, and the Roan Antelope Copper Mines, Limited — was accompanied by the construction of a refinery at La Oroya which turned the Cerro de Pasco Corporation into a small self-contained system, with the American Metal Company responsible for selling the output of refined copper — about 28,000 short tons in 1954. Thus, the internal organization of the large non-ferrous metals groups may tend to inhibit the metallurgical progress of a mining area at one stage and encourage it at another.

Not subject to economic calculation in the same way as most of the preceding influences on location is the question of the security of the investment and the reliability of the flow of materials. If the mine, smelter or refinery is located outside the country in which the parent concern is domiciled, the flow of the product may be more easily cut off in the event of war, for example, while political shifts may lead to fundamental changes in the status of the enterprise. In any event a foreign branch is usually more difficult to control,

[8] At Huntington, West Virginia, in particular, where the International Nickel Company of Canada, Limited (INCO), operates a refinery. INCO also exports crude nickel sulphide and oxide to a refinery it operates at Clydach in Wales, and the Falconbridge Nickel Mines, Limited, sends nickel matte from its smelter at Sudbury, Ontario, to a 20,000-ton capacity refinery at Kristiansand in Norway.

and its profits may not always be freely transferable.[9] Some weight is necessarily given to these additional risks in the assessment of costs by a potential investor, such as a non-ferrous metal group deciding on the location of a new refinery, especially when, by such investment, the foreign ore-to-metal system is made more or less self-sufficient and its dependence on the organization as a whole reduced.

Where the risks are considered high and the future particularly uncertain, it is unlikely that a sound long-term mining policy will be pursued, whether the mine is autonomous or linked to an international group. There may be a tendency to exploit known ore resources with undue haste, inadequate development of reserves and little investment in surface facilities.[10]

Fiscal influences

The influence of the government of an under-developed country with non-ferrous ore resources upon the location of processing facilities is exercised primarily through its fiscal policies, which are likely to have a significant effect upon the magnitude and direction of the investment of mining concerns. By such measures as remission of duty on imported metallurgical plant and equipment, tax incentives which encourage the reinvestment of mining profits, and differential levies favouring the export of refined metals as against their ores or concentrates, a country with mineral resources can make it more attractive for the industry to undertake domestic processing than to limit itself to the simple mining and export of ore. While it is true that in the case of international groups such incentives may be offset, wholly or in part, by fiscal measures enacted in the industrial country in which the parent concern is domiciled, in general they have played a significant part in influencing the structure of the non-ferrous metals industry in under-developed areas.

In 1901, for example, Malaya, which was then producing more than half of the world's tin supply, imposed a very high export duty on tin concentrates in an effort to deter other countries from entering the smelting field. This duty probably contributed to the maintenance of Malayan leadership in the industry in Asia, though by 1948, when the duty on concentrates was reduced to the level of the duty on tin metal, large smelters had been established in the Netherlands East Indies as well as the Belgian Congo, the Netherlands and the United States.

Contemporary policy in Malaya is not designed to encourage the processing of domestic ores — on the contrary, the tax tends to be higher on the metal than on the ore, at least when the price is high;[11] it is aimed rather at attracting imported ores for local processing, since tin smelted from these ores may be exported without duty. So far as discouraging the establishment of smelters in neighbouring tin producing countries is concerned, this policy probably serves the purpose more effectively than a high duty on exports of domestic ore.

In contrast to the early Malayan export tax, the one levied in Bolivia was based on metal content, designed to raise revenue rather than encourage local smelting. In Chile the early taxes on copper were *ad valorem*, but towards the end of the nineteenth century they were transformed into specific duties levied on each ton of concentrates. This provided some incentive for attempts to reduce their effect by increasing the value added through domestic processing. In the event, however, the change had very little influence on the copper industry since declining world prices magnified the burden of the fixed tax and contributed to the diversion of capital to the nitrate industry.

In general, import and export tariff policies are two-edged weapons; their usefulness from the point of view of the under-developed country can be greatly impaired or even nullified by corresponding devices in the industrial countries which provide much of the mining capital and most of the equipment, and purchase most of the resultant mineral output. It is not uncommon for the customs tariff in industrial countries to vary directly with the degree of processing undergone by imports, unworked raw materials enjoying the lowest rate of duty.

In the United Kingdom, for example, most non-ferrous ores and concentrates are admitted duty-free. Tin and copper metal are also free of duty, though a specific duty (not exceeding 10 per cent *ad valorem*) is levied on lead and zinc. In the case of articles wholly or partly manufactured from any of the non-ferrous metals, however, the general rate of duty is 20 per cent *ad valorem*.[12]

A similar gradation of tariff obtains in the customs union of Belgium, the Netherlands and Luxembourg (BENELUX): all raw (unmanufactured) non-ferrous metals are admitted free of duty, 2 per cent *ad valorem* is charged on copper bars, 4 per cent on other copper semi-manufactures and on bars, wire, slabs and sheets of lead, tin and zinc, 6 per cent on tubes and pipes and similar semi-manufactures of non-ferrous metal, 8 per cent on tanks and cables and other more processed articles, and 15 per cent on padlocks and fittings and other fully manufactured non-ferrous metal goods.

[9] A reasonable assurance of the ability to transfer profits is more likely in the case of mining investment than manufacturing investment. As most of the ore or metal is likely to be sold on foreign markets, the mining enterprise usually earns the foreign exchange out of which its profits are to be transferred. In some cases, inter-company transactions may be effected at nominal prices which allow most of the profit to accrue to the unit—refinery or fabricating plant—in the industrial country in which the group is domiciled.

[10] Some of these points are examined in greater detail in the following chapter, where the developmental potential of the non-ferrous metals industry is discussed.

[11] The present export duty on tin in Malaya, intended to be primarily a revenue-raising tax (and an anti-inflation device) reverses the principle on which the early duty was based. The duty on ore is the same as that on metal — 2.40 Malayan dollars per picul — so long as the market price of tin does not exceed Mal $44 per picul. As the price rises the duty rises by 12 cents on every Malayan dollar; in the case of ore, however, there is an additional levy of 80 cents per picul, whereas in the case of metal smelted from local ore there is a surcharge of one-third.

[12] These *ad valorem* duties are subject to imperial preference.

In some countries, duties may be refunded upon the re-export of the goods on which they were originally levied. Refunds of this nature have their counterpart in the practice of permitting imports "in bond", under which the non-ferrous metal refining industry in the United States built up a large export business between 1910 and 1930. During this period, United States exports of refined and fabricated metals consisted not only of domestic production surplus to internal needs but also of the products of metallurgical plants working on imported ores, concentrates and crude metal. United States refinery capacity was thus enlarged well beyond the output of domestic mines. Before the Second World War this refinery capacity was also in excess of domestic requirements of refined metal, but in the late nineteen-thirties an increasing proportion of refinery output was retained for domestic consumption, while in the post-war period, as indicated in chapter 2 above, the country emerged as a net importer of most of the base metals.

The United States tariff has traditionally protected domestic mines as well as domestic manufacturers. Lead imports were dutiable as early as 1790; a copper duty was in force during the period 1883 to 1894 and was reimposed (at a prohibitive level) in 1932; zinc and tungsten duties were first imposed in 1909 and manganese duties in 1922. The country's recent conversion from a net exporter to a net importer, however, has reduced the advantages of such protection and, under the 1950 tariff schedule, imports of many ores and concentrates were admitted duty free, though lead and zinc ores remained subject to a specific duty of 0.75 cent and 0.6 cent, respectively, per pound of metal content (see table 20). While their ores are admitted free, antimony and chromium metal are both dutiable. Duties on aluminium metal and manganese alloys are appreciably higher than those on the ores. Semi-manufactures of copper are subject to a duty rising from 1.25 cents per pound of metal content in the case of the simplest articles (rolls, rods and sheets) and 3.5 cents in the case of seamless tubes and unground plates, to 5.5 cents in the case of brazed tubes and ground plates and 30 per cent *ad valorem* in the case of fully manufactured household ware.[13] For

[13] During the period of relative scarcity, most of the duties on copper and its manufactures have remained suspended, as has also an inland revenue tax of 2 cents a pound of copper content, which may be imposed if the monthly average price of copper falls below 24 cents a pound.

Table 20. United States Import Duties on Non-Ferrous Metals in Various Stages of Fabrication,[a] January 1954

(Cents per pound ad valorem; per cent of total value)

Commodity	*Rate*
Antimony:	
Ore	Free
Regulus or metal	2.0 cents
Manufactures	20 per cent
Aluminium:	
Bauxite	50 cents per ton
Ingots	1.5 cents
Plates, sheets, bars	3.0 cents
Household utensils	4.25 cents + 20 per cent
Copper:[b]	
Ore	Free
Unrefined; pigs, bars	Free
Refined; ingots, plates, bars	Free
Wire, cable	17.5 per cent
Lead:[c]	
Ore	0.75 cent
Bullion, base bullion	1.06 cents
Pigs, bars	1.06 cents
Pipe, sheets, wire	1.31 cents
Tin:[c]	
Ore	Free
Bars, blocks, pigs	Free
Powder, flitters, metallics	12.0 cents
Manufactures	12 per cent
Zinc:[c]	
Ore	0.6 cent
Blocks, pigs, slabs	0.7 cent
Zinc[c] *(continued)*:	
Sheets	1.0 cent
Manufactures	22.5 per cent
Chromite:	
Ore	Free
Ferrochrome, nickel chrome, vanadium chrome, silicon chrome	12.5 per cent
Cobalt:	
Ore	Free
Metal	Free
Manganese:[c]	
Ore (over 10 but under 35 per cent manganese)	0.25 cent
Ferromanganese (30 per cent or more manganese)	0.94 cent + 7.5 per cent
Molybdenum:[c]	
Ore	35.0 cents
Ferromolybdenum	25.0 cents + 7.5 per cent
Nickel:	
Ore	Free
Pigs, ingots	1.25 cents
Bars, rods, plates, sheets	12.5 per cent
Manufactures	22.5 per cent
Tungsten:[c]	
Ore	50.0 cents
Ferrotungsten	42.0 cents + 12.5 per cent
Metal and carbide	42.0 cents + 25 per cent

Source: United States Bureau of the Census, *Statistical Classification of Commodities*, Schedule A (Washington, D. C., January 1954), pages 615-624; Metal Information Bureau, Limited, *Quin's Metal Handbook, 1951* (London), page 393.

[a] Chiefly the effective rates under the General Agreement on Tariffs and Trade (GATT).

[b] Plus an internal revenue tax of 2 cents per pound suspended to 30 June 1956, with provision for reimposition if monthly average price of copper falls below 24 cents per pound, delivered Connecticut Valley.

[c] Metal content.

the other metals, duty rates also rise with the degree of processing: 0.7 cent per pound of metal content for zinc blocks, one cent for tin plate, 1.125 cents for zinc-plated sheets, 2 cents for lead rivets, washers, nuts and screws (subject to *ad valorem* limits of 15 and 30 per cent), 22.5 per cent *ad valorem* for tin household ware and 35 per cent for tin foil. Imports of tin ores and blocks are duty-free until domestic cassiterite production reaches 1,500 tons a year, when rates of 4 and 6 cents, respectively (per pound of metal content) become applicable. In 1950, the *ad valorem* equivalent of the specific duty on molybdenum sheet was about 40 per cent, on magnesium metal 66 per cent, and on ferrotungsten about 68 per cent.

SMELTING, REFINING AND FABRICATING FACILITIES

Although almost two-thirds of the world's bauxite supply (outside mainland China, eastern Europe and the Soviet Union) comes from under-developed countries, their aluminium capacity is less than one per cent of the total. Expansion under way in some under-developed countries and new facilities planned for others, though impressive in relation to past figures, may not be sufficient to counterbalance the foreseeable increase in Canadian and United States capacity, so that whatever the long-term result of the opening up of new sources of water-power or of the application of new forms of nuclear power, in the immediate future the share of under-developed countries in world production is more likely to decline than to increase.

Rather more than half the output of copper ore in under-developed countries is refined at the place of origin. Most of the ore is locally smelted, however, the contribution of Latin America, Africa and Asia in the period 1948 to 1953 being almost half of the world ore supply (outside that of the Soviet Union) and about 42 per cent of the world blister copper supply (see table 21). Facilities for smelting or refining are lacking in Bolivia, Cuba, Cyprus and the Philippines; existing plants are capable of considerable expansion in Mexico and the Union of South Africa and are being, or are likely to be, expanded in Northern Rhodesia, Peru, Turkey and Yugoslavia.

Though non-ferrous metal refining in the under-developed countries is furthest advanced in the case of lead, a large amount is still exported in the form of concentrates, about two-thirds of mine output having been smelted at the source in recent years. In the period 1948 to 1953 producers in Latin America, Africa and Asia accounted for about one-third of world ore output and rather more than one-fifth of world metal output (excluding the Soviet Union in both cases). Further increases in their relative shares of lead metal output depend largely on the establishment of smelting and refining facilities in such countries as Bolivia and South West Africa and the expansion of facilities in such areas as French North Africa and Peru.

While almost all tin ore originates in the under-developed areas, only about 42 per cent was smelted in those areas in the period 1948 to 1953 — chiefly in

Table 21. Ore and Metal Production of Aluminium, Copper, Lead, Tin and Zinc in Under-Developed Regions, 1948-53

(Thousands of metric tons, metal content)

Item	World[a] total	Africa		Asia		Latin America		Middle East		Total specified under-developed regions	
		Amount	Per cent of total	Amount	Per cent of total	Amount	Per cent of total	Amount	Per cent of total	Amount	Per cent of total
Aluminium:											
Ore[b]	9,617	202	2	548	6	4,906	51	—	...	5,656	59
Metal	1,530	—	—	7	—	1	...	—	...	8	1
Per cent smelted[c]	*95*	—		*8*		—				*1*	
Copper:											
Ore	2,278	520	23	19	1	502	22	33	1	1,074	47
Metal	2,292	507	22	6	—	439	19	16	1	968	42
Per cent smelted	*101*	*98*		*32*		*87*		*49*		*90*	
Lead:											
Ore	1,540	139	9	6	—	361	23	11	1	517	33
Metal	1,510	52	3	6	—	282	19	—		340	22
Per cent smelted	*98*	*37*		*100*		*78*		...		*66*	
Tin:											
Ore	168	24	14	103	61	35	21	—	...	162	96
Metal	172	4	2	68	40	1	—	...	...	73	42
Per cent smelted	*102*	*17*		*66*		*3*				*45*	
Zinc:											
Ore	2,177	150	7	3	—	345	16	1	...	509	23
Metal	1,888	25	1	—	—	63	3	...		88	4
Per cent smelted	*87*	*17*		—		*18*		...		*17*	

Source: United Nations, *Statistical Yearbook, 1954*; International Tin Study Group, *Statistical Yearbook, 1954*; American Bureau of Metal Statistics, *Yearbook, 1954* (New York).

[a] Excluding the Union of Soviet Socialist Republics.

[b] Gross weight.

[c] Assuming that one-sixth of the gross weight of bauxite represents recoverable aluminium.

the Belgian Congo and Malaya. Facilities are lacking in Bolivia, Burma, Nigeria and Thailand, but are being expanded in the Belgian Congo and may again be brought into operation in Indonesia.

About a fourth of world zinc ore production (outside the Soviet Union) originated in under-developed countries in the period 1948 to 1953, but only a sixth of this output was refined at the source. Indeed, Northern Rhodesia was the only producer among the under-developed countries in which the entire mine output was refined locally. Capacity has since been created in the Belgian Congo and expanded in Argentina and Peru, but two-thirds of the Mexican output and three-fourths that of Yugoslavia are still exported as concentrates, and there are no refinery facilities for zinc in Bolivia, French North Africa and South West Africa.

So far as fabricating is concerned, the bulk of newly refined aluminium is rolled into plates, sheets or strips, but increasing proportions are being turned into structural shapes, rods, bars and wire, and extruded shapes and tubing. As indicated in chapter 2, the main use for these semi-manufactures is in the field of transportation and construction, but a substantial part of total output is used in the production of cooking utensils and household appliances, while a growing amount is absorbed by the electrical and the machinery industries.

Most metallic copper is turned first into wire, or into various shapes of rods, bars and sections, or into strip, sheet and plate, or into tubes. In these primary forms the copper may be unalloyed, of ordinary purity or of extra high purity for high conductivity purposes, or alloyed with other metals, especially with zinc to form brass. A small proportion may be used directly for making castings or for the production of a chemical product, such as copper sulphate, which in turn may have a direct use, as a pesticide, for example, or may serve as a raw material for another industry.

Lead is used rather more widely in the chemical and paint industries in the form of oxides, carbonate and sulphate, and as tetraethyl for lowering the rate of petrol combustion. As a metal it is made into foil and collapsible tubes, into alloys with tin and antimony for use as bearings, solder and printers' type, into castings for engineering use, and into pipe and sheet for building purposes. It is used directly in the manufacture of ammunition and — quantitatively much more important — for storage batteries and as an extrusion for covering electric cables.

Tin finds important uses when alloyed with lead or copper as solder, babbit, bronze and pewter, chiefly for the purpose of bearing, casting and type metal. To a certain extent it is made into sheet and foil, pipes and tubes, but by far the largest use is for plating iron and steel sheets and other shapes.

Apart from its use with copper to form brass, zinc is made into rolled sheets, or used, generally in alloy form, for die castings in the engineering industry, or for galvanizing various iron and steel products, or for conversion into zinc oxide for use in the chemical and pharmaceutical industries.

Merely to list the principal uses of the major non-ferrous metals in the industrial countries is to indicate that their effective market in less developed countries is likely to be very circumscribed. In the period 1948 to 1953, the proportion of world consumption (excluding that of the Soviet Union) in under-developed countries ranged from about 2 per cent in the case of primary aluminium to about 10 per cent in the case of primary tin (see table 22). Demand for many of the intermediate industrial products in which these metals play a special part is necessarily limited in countries with only rudimentary secondary industries; in most of the under-developed mining economies this limitation of demand would tend to rule out mass production for many of the semi-finished items a metal fabricator would ordinarily produce. As pointed out earlier, therefore, expansion of internal demand in such countries depends very largely on the rate of industrialization, and in so far as the actual process of industrial investment involves a good deal of specialized equipment and materials, it is likely to be served more satisfactorily by established non-ferrous metal plants in industrial countries than by small-scale domestic plants. In other words, there would seem to be little point in granting a particularly high priority to fabricating plants for non-ferrous metals in the industrial development plans of less developed countries or in holding back other forms of investment until the country is capable of satisfying its own requirements for this particular type of capital equipment.

Fabricating is likely to be at the least relative disadvantage in under-developed countries in the simpler and more standardized shapes and the more widely consumed articles produced from them. In this category fall wire and cable, and other electrical conductors made from copper; storage batteries, solder and building and printing metals made from lead and antimony; locks, faucets, and other building and furniture hardware made from brass, and utensils and the commoner structural shapes made from aluminium. Technically, any of the simpler forms of pressing, stamping, extruding, casting and forging are feasible, though whether production is economic would depend upon whether the demand is large enough to ensure more or less continuous operation of even a relatively small plant. Where there is an iron and steel industry, tin and zinc find an important use in plating, while many of the non-ferrous metal salts may be used as raw materials in local paint and chemical industries.

The limitation on simple fabrication and other uses of non-ferrous metals does not lie usually or mainly in technological difficulties or even, in most countries, in theoretically attainable unit costs, but results rather from the lack of effective internal demand which, by curtailing the rate of production, tends to inflate actual unit costs. Nevertheless, though demand for non-ferrous metals may be inadequate within a single country whose level of industrialization and standard of living are relatively low, over a wider region it might be sufficient to justify the establishment of a central plant, particularly for the production of items which serve common development or consumption needs. This is the case with certain copper and aluminium products which are used not as materials or components for other manufacturing industries but directly in construction or electrification projects.

Domestic markets for many of the manufactured products of non-ferrous metals are often shielded by protective tariffs, but if production in an under-developed country is based on a wider international market, competition with established metal working concerns is unavoidable. Moreover, the export of fabricated products, even of so-called semi-manufactures such as tubes and sheets and wire, presents an under-developed country with a number of difficulties arising from the fact that in this specialized trade it is of considerable advantage to be in close contact with consumers. As the principal consumers of most non-ferrous metal products are the durable and capital goods industries, fabricators in industrial countries are usually in a better position to produce material conforming to precise specifications set by users with whom they are likely to be in close touch, and with whom, in the case of the major non-ferrous metal systems, they may be financially and organizationally allied. Furthermore, it is generally more costly, in terms of both freight rates and packing, to transport finished products than unmanufactured metal, and this tends to favour the marketing of the latter. In this way, advantages for non-ferrous fabrication that a mining country might have in respect of accessibility and price of raw metal are likely to be offset by handicaps in respect of the scale of production and the process of marketing abroad. Hence, the metal fabricating industry in most under-developed countries is likely to remain dependent to a very large extent upon internal demand.

Table 22. Consumption[a] of Primary Aluminium, Copper, Lead, Tin and Zinc in Under-Developed Countries, 1948-53

(Thousands of metric tons)

Region and country	*Aluminium*	*Copper*	*Lead*	*Tin*	*Zinc*
Africa[b]	2	27	14	1.9	14
Algeria	...	7	3	0.1	0.7
Morocco, French	...			0.2	
Southern Rhodesia	...	...	...	0.1	...
Union of South Africa	...	18	10	1.4	13
Asia[b]	9	37	18	6.1	32
China mainland	2	...	4	1.0	3
India	6	28	9	4.0	26
Indonesia	...	...	...	0.3	...
Malaya	...	...	...	0.1	...
Pakistan	...	7[e]	3[e]	0.2	...
Philippines	...	...	0.3	0.1	0.2
Thailand	...	...	...	0.2	...
Europe: Yugoslavia	...	18	8	0.3	9
Latin America[b]	20	73	63	3.9	40
Argentina	...	14	30	1.4	15
Brazil	...	21	18	1.5	10
Chile	...	27	2	0.3	3
Mexico	...	9	9	0.4	9
Peru	...	0.2[d]	2[d]	—	1[d]
Middle East[b]	...	12	2	0.9	1
Egypt	...	5[e]	...	...	...
Turkey	...	6[d]	1[d]	0.7	0.2[e]
TOTAL, UNDER-DEVELOPED COUNTRIES[b]	32	167	105	13.1	96
WORLD TOTAL[f]	1,693	2,401	1,442	136.1	1,674
PER CENT IN UNDER-DEVELOPED COUNTRIES	2	7	7	10	6

Source: United Nations, *Statistical Yearbook, 1954;* Minerais et Métaux S.A., *Statistiques, 1935/1938—1946 à 1953* (Paris), July, 1954; American Bureau of Metal Statistics, *Yearbook, 1954;* International Tin Study Group, *Statistical Yearbook, 1954;* Metallgesellschaft Aktiengesellschaft, *Metal Statistics, 1938, 1946-1953* (Frankfort on Main); International Materials Conference, *Report on Operations* for 1951/52 and for 1952/53.

[a] Apparent consumption (production plus imports minus exports) where actual figures are not available.

[b] Including estimates for some countries.

[c] 1948-50.

[d] 1948-51.

[e] 1949-51.

[f] Excluding the Union of Soviet Socialist Republics.

Table 23. Bauxite and Primary Aluminium Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954

(Thousands of metric tons)

Region, country and period	Production: Mine	Production: Smelter	Per cent smelted[a]	Smelter capacity
Africa:				
French West Africa:				
1938	—	—	—	—
1948-53	95[b]	—	—	—
1954	435			—
Gold Coast:				
1938	—	—	—	—
1948-53	120	—	—	—
1954	163[c]	—	—	—
Asia:				
India:				
1938	15	—	—	—
1948-53	54	3.7	41	
1954	80	4.9	37	7.5[d]
Indonesia:				
1938	245	—	—	—
1948-53	464	—	—	—
1954	163	—	—	—
Malaya:				
1938	56	—	—	—
1948-53	89[e]	—	—	—
1954	166	—	—	—
Taiwan:				
1938	—	4.6[f]		
1948-53	6[g]	2.9[f]	289	...
1954	6	7.0[f]	700	8.0[h]
Europe:				
Yugoslavia:				
1938	405	1.3	2	
1948-53	368	2.4	4	...
1954	670	3.4	3	18.0[i]

Although effective internal demand is probably the main consideration in the establishment of industries working on non-ferrous metals, other economic influences cannot be dismissed as unimportant. Competent management and a good sales organization and, on the production side, adequate power and efficient labour are all prerequisites of success, especially in the case of an independent concern which may have to compete with the products of integrated non-ferrous metal groups, whether on the domestic market or abroad.

In view of the importance of the products of the non-ferrous metal fabricating industry in the manufacture of capital goods, the efficiency of its operation, once such an industry has been established, is of considerable significance to the process of development. A high-cost industry, sustained by heavy protection and showing no signs of increasing efficiency, may actually constitute a drain on national resources, retarding the very growth of the home market on which the normal economic development of local non-ferrous fabricating so largely depends. This means that unless there are some special reasons expanding local demand or ensuring a high degree of efficiency, the expansion of the fabricating industry cannot proceed much faster than the development of the domestic economy in general and the industrial metal-using sector in particular. At the same time, it is also true that the growth of a fabricating industry is itself an important part of that very process of development and diversification on which it depends for a market.

Aluminium

As already indicated, very little aluminium is as yet produced in under-developed countries (table 23).[14] At post-war levels of price, almost two-thirds of the finished cost of aluminium metal is incurred in the final stage — the process of reducing alumina — and more than one-third of the cost of this reduction is in the provision of electric power. Hence, technologically, the key to eco-

[14] Aluminium is obtained from bauxite, its hydrous oxide, in two stages: the chemical preparation of alumina (Al_2O_3) and the electrolytic reduction of this oxide to metal. The first process involves the digestion of finely ground bauxite in a hot concentrated caustic soda solution, precipitation from the resultant sodium aluminate solution of aluminium hydroxide and filtering, drying and calcining the latter to produce pure alumina. The alumina is then dissolved in molten cryolite (a sodium-aluminium fluoride) at about 950°C; the solution is electrolyzed, and metallic aluminium is formed at the cathode. This process is carried out in rows of steel refractory-lined cells, called a "pot-line", connected in series to an adequate source of direct current.

Table 23. Bauxite and Primary Aluminium Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954 (*continued*)

(Thousands of metric tons)

Region, country and period	Production: Mine	Production: Smelter	Per cent smelted[a]	Smelter capacity
Latin America:				
Brazil:				
1938	13	—	—	—
1948-53	17	1.0[e]	35	
1954	22	1.4	38	12.4[j]
British Guiana:				
1938	455	—	—	—
1948-53	2,059	—	—	
1954	2,125[c]	—	—	—
Jamaica:				
1938	—	—	—	—
1948-53	830[e]	—	—	
1954	2,065[k]	—	—	—
Surinam:				
1938	377	—	—	—
1948-53	2,555	—	—	
1954	3,361	—	—	—
TOTAL, UNDER-DEVELOPED COUNTRIES:				
1938	1,566	5.9	2	6.0[l]
1948-53	6,701	10.0	1	
1954	9,256	16.7	1	45.9
WORLD TOTAL[m]				
1938	3,700	540	87	700.0[l]
1948-53	9,617	1,530	95	
1954	14,450	2,420	101	2,687.1

Source: United Nations, *Statistical Yearbook, 1953;* American Bureau of Metal Statistics, *Yearbook, 1954;* Metallgesellschaft Aktiengesellschaft, *Metal Statistics, 1938-1953.*

[a] Assuming that one-sixth of the gross weight of bauxite represents recoverable aluminium.
[b] 1949-53; production began in 1949.
[c] Exports.
[d] Two refineries—at Alupuram (5,000 tons) and Jaykaynagar (2,500 tons).
[e] 1952-53; production began or resumed in 1952.
[f] Based wholly or in part on imported bauxite.
[g] 1951-53; production resumed in 1951.
[h] A refinery at Takao.
[i] A small plant at Sibenik (3,000 tons) and a larger one at Strniace (15,000 tons), to be expanded to 30,000 tons by 1958.
[j] A small plant at Saramenha (2,400 tons) and a larger one (10,000 tons) at Sorocaba, producing for the first time in 1955, to be expanded to 50,000-ton capacity.
[k] Estimated dry weight.
[l] Estimated on the basis of production.
[m] Excluding the Union of Soviet Socialist Republics.

nomic aluminium production lies in the availability of a large amount of low-cost electric power and in this respect the under-developed countries have generally been at a disadvantage.

At the beginning of the nineteen thirties aluminium production was confined to western Europe and Canada and the United States, but during the decade reduction plants were established in a number of other countries, often with technical assistance and financial support from older companies. Production commenced in the Union of Soviet Socialist Republics in 1932, in Japan in 1933, in Hungary in 1934, in Yugoslavia and India in 1937, in Poland in 1938 and in Greece in 1939. At that stage, however, it was only in the Soviet Union and Japan among these new producers that output had become a significant proportion of the world total; of an aggregate production of nearly 600,000 metric tons, the remaining plants contributed less than one-half of one per cent.

During the war, not only was there an increase in capacity in Hungary, India and Yugoslavia, but new facilities were established in Brazil and Taiwan. Yet with the expansion in Canada, the Soviet Union, and the United States, which brought world capacity up to an estimated 2.3 million metric tons of primary aluminium, the proportionate output in less developed countries was little more than before the war.

Production fell far below capacity in the early post-war years and it was not until the outbreak of hostilities in Korea that any major new investment was made in aluminium reduction plants. Outside the Soviet Union this was concentrated overwhelmingly in Canada and the United States, based largely on bauxite supplies from the Caribbean area, and reducing to almost negligible proportions the relative capacity in under-developed countries. Of a world total of 3 million metric tons at the end of 1954, the latter amounted to about 32,000 metric tons, distributed as follows: two plants in Taiwan each with a capacity of about 1,000 tons, one plant in India with a capacity of about 2,500 tons and one of 5,000 tons, two plants in Yugoslavia of 3,000 tons and 15,000 tons, and another in Brazil of 2,100 tons. In addition, a number of reduction plants were under construction in under-developed areas at this time: a 13,200-ton plant in Tasmania, a 10,000-ton plant in Brazil and extensions to Indian and Yugoslav capacity of 10,000 tons and 15,000 tons, respectively.[15]

In most instances, the aluminium smelter is backed by a local alumina plant. Brazil, for example, operates an alumina plant of 12,000-ton capacity and has another, of double that size, under construction; each of the Indian smelters has its own domestic facilities for producing alumina. On Taiwan, alumina capacity is of the order of 32,000 tons per annum; the Strnisce smelter in Yugoslavia draws on a local 50,000-ton alumina plant. In Jamaica, alumina production has been organized as an export industry within the North American systems of Aluminium, Limited, Kaiser Aluminum and Chemical Corporation and Reynolds Metals Company.

Apart from the expansion of smelter capacity that is at present under way in India and Yugoslavia, a projected addition to the Companhia Brasileira de Aluminico would raise Brazilian capacity to 50,000 tons, and there are plans for creating new primary facilities in several under-developed countries. Argentina has a 10,000-ton reduction works in its current five-year plan. Even before the war, the Nederlands Indonesische Aluminium Industrie had plans for a 10,000-ton smelter in Sumatra, using power from the Asahan River. More recently, a joint research organization, Société africaine de recherches et d'études pour l'aluminium was set up by Pechiney, Compagnie de produits chimiques et électrometallurgiques and the Société d'électrochimie, d'électrometallurgie et des aciéries électriques d'Ugines, the two leading French companies, to investigate the possibilities of constructing a plant with a capacity of 100,000 tons per annum in French Guinea, using local bauxite and power generated on the Kouron River. A second French smelter—a 40,000-ton plant in the Cameroons which would use alumina imported from France—has reached the planning stage. The Reynolds Metals Company is reported to have plans for aluminium production in Peru, subject to obtaining cheap power from the Chimhote hydroelectric plant at present being constructed by the Government on the Cañón del Pato; and in Brazil, subject to the development of the hydroelectric potential of the Paulo Afonso falls on the São Francisco River. Aluminium, Limited, which during the Second World War obtained concessions over bauxite deposits on the boundary between Venezuela and British Guiana, has plans for a 60,000-ton Venezuelan smelter using power generated on the Caroni River. A 10,000-ton smelter has been recommended for Surinam, utilizing local bauxite and power derived from the Suriname River at Brokopondo, and though local bauxite is generally of relatively low grade, it has been suggested that Mexico might set up a reduction plant at the President Alemán dam on the Papaloapan River. Considerable research has been conducted in Nyasaland and Sarawak in respect of both bauxite resources and hydroelectric potential. Though in both territories aluminium production seems technically feasible, it would appear that the harnessing of the Volta River in the Gold Coast and the erection of a smelter to reduce alumina prepared from local bauxite is likely to be realized sooner. To bring the latter project to its ultimate target of 210,000 tons of aluminium a year would require an outlay, at 1952 prices, of about £144 million — a figure which indicates the financial implications of this type of investment in an under-developed country.

High capital costs, combined with high energy requirements and the importance of cheap and adequate means of transportation between bauxite deposits and smelter on the one hand, and smelter and fabricating plants, on the other, explain why, even more than in the case of other non-ferrous metals, aluminium refining capacity is much more readily expanded in industrial countries. Moreover, the importance of the leading companies — Aluminum Company of America (ALCOA), Kaiser Aluminum and Chemical Corporation and Reynolds Metals Company in the United States, Aluminium Company of Canada, Limited (ALCAN) in Canada and Aluminium, Limited (ALTED) in the international field — is even greater than that of the major copper, lead or zinc groups: it is probable that only the prospect of very decided advantages for the system as a whole would encourage any of these concerns to make a significant investment in an under-developed area outside of the North American and Caribbean region.

Despite its high capital cost, the Gold Coast project does offer certain advantages, not least of which in the eyes of British consumers is the fact that it provides a technically suitable site for production outside of the hard currency area. The United Kingdom's annual consumption of aluminium is more than ten times its own primary production, and there is little prospect of economic domestic expansion much above the present levels of output. The principal increase in the facilities of British aluminium concerns in the post-war period has been in Norway, where low-cost hydroelectricity is available, but the United Kingdom has remained dependent on Canadian supplies, expansion of which, both during the war and subsequently, has been financed largely by British Government loans, negotiated on the basis of contracts giving the United Kingdom an option over a certain proportion of future output. It is in the light of these circumstances that the industrial country has sup-

---

[15] The figures given for smelter and refinery capacity throughout this chapter are necessarily approximate. Capacity is a function of many variables — the physical size of the smallest component in the processing sequence, the grade of ore input, the availability of adequate power, the continuity of operations, the time devoted to plant maintenance and repairs, and so on — and there may be an appreciable difference between theoretical nominal capacity and practical working capacity computed on an annual basis, and the latter in turn may be quite different from actual usable capacity over a period of years.

ported plans for the construction of an aluminium smelter in the Gold Coast. From the point of view of the less developed country, on the other hand, instead of exporting bauxite, it would be able to export a metal, first in ingot form, later perhaps in more fabricated forms, and it would acquire not only a valuable raw material for its own industrial use but also a source of power, new communication facilities and other important assets for development.

Partly because of the ease with which aluminium ingots, plate and strip may be transported, and partly because aluminium utensils constitute an important type of consumer goods, facilities for fabricating the metal are more widely dispersed than facilities for producing it. A single concern (Aluminium, Limited) has found it feasible in recent years to set up plants not only in various parts of Canada and western Europe but also in Aden, in Australia at Sydney, in Brazil at São Paulo, in Burma at Rangoon, in China at Shanghai, in India at Bombay, Madras and Calcutta, in Mexico at Mexico City and in the Union of South Africa at Pietermaritzburg.

In India, factories using imported aluminium antedated local smelting by several years and, apart from the two integrated concerns — the Aluminium Corporation of India, Limited, and the Indian Aluminium Company, Limited — which operate rolling-mills and utensil plants, there are a number of independent establishments making foil, cable and utensils, as well as one or two aluminium foundries. Fabricating facilities in northern Korea, Manchuria and Taiwan were originally constructed by the Japanese. More recently, Pakistan has acquired a small rolling-mill, with a capacity of about 1,200 tons a year.

Fabricating capacity in Yugoslavia in 1953 was of the order of 25,000 tons a year, substantially greater than the local output of ingots, and more in line with the prospective output of the Struisce plant.

Brazil, the only other under-developed country with facilities for reducing alumina, had a rolling-mill capacity of about 15,000 tons a year in 1953. Until the new smelter is completed, the mill will depend largely on imported ingots. Fabricating plants under construction at the end of 1953 had an estimated annual capacity of 10,000 tons. In Argentina, imports of primary aluminium in recent years have averaged about 12,000 tons a year. This has been the input of local fabricating plants which had an annual capacity in 1953 of the order of 15,000 tons. In Mexico, both Aluminium, Limited, and the Reynolds Metals Company operate small manufacturing plants to which ingots and shapes are exported from Canada and the United States.

Small plants in Algeria, Israel and Kenya also depend on imported semi-finished aluminium for their raw material input. The factory of Aluminium, Limited, in the Union of South Africa, using ingots imported from the Arvida smelter in Quebec, had an output of about 1,000 tons in 1953.

In most cases these factories enjoy the duty-free import of primary aluminium — sometimes in ingot form, more frequently in semi-fabricated shapes — and are protected by customs duties against the competition of finished aluminium products such as might be exported by larger factories in Europe or North America. In general, they are saving foreign exchange to the extent of the difference between the c.i.f. cost of the metal and the cost of the manufactured article; in some cases the expansion of domestic or regional demand is gradually permitting a greater volume of production, bringing local unit costs more into line with those of the larger plants.

Copper

Whatever economic weight is given, in the cost calculations of investors, to various disadvantages attached to operating plants in foreign countries, the fact remains that the process of smelting and refining copper[16] has been extended steadily in under-developed mining regions, chiefly as a result of the activities of large international concerns (see table 21).

In Chile, where practically the whole output of copper ore from the larger mines has long been locally smelted (in 1938 only 1 per cent was exported before being smelted), the proportion locally refined increased from about one-half before the Second World War to about three-fourths in the period 1948 to 1952. In the latter period the proportion of copper refined electrolytically declined from almost one-half to not much more than one-third, the fire-refined proportion rising correspondingly. The Andes Copper Mining Company refines copper from oxide ores at the mine but ships blister copper reduced from its sulphide ores to the Raritan Copper Works in Perth Amboy, New Jersey, for refining. In 1948, work commenced on a new plant[17] to handle the Chuquicamata sulphide ore that is to be mined on an increasing scale in place of the surface oxides that are now approaching exhaustion. Since a large part of the new output is to be exported in blister form to the

[16] Copper is recovered from oxidized ores by direct smelting in blast or reverberatory furnaces. Where the ores are water soluble, however, leaching followed by precipitation on metallic iron is usually a more economical process. Recovering it from sulphide ores involves preliminary crushing and flotation, followed by roasting to reduce the sulphur content. In a blast, or more commonly a reverberatory, furnace, the ore is then reduced to a matte, usually containing 30 to 45 per cent of copper, which in most smelters is transferred directly to a converter in which it is air blown in the presence of a silica flux and thus reduced to blister copper. Since substantial heat economies are achieved by rapid movement from furnace to converter, trade in matte has declined considerably. Because the next step in the refining process entails a complicated electrochemical procedure, however, blister copper (98 per cent or more pure) is a common article of commerce. It is first fire-refined by being melted, aerated and fluxed to eliminate the remaining sulphur and it is then reduced to eliminate all traces of oxide. The resultant copper is pressed into 2 inch sheets which are then used as anodes in an electrolysis bath of copper sulphate in which the cathodes are sheets of pure copper. The passage of sufficient current through the solution causes the deposition of almost chemically pure copper on the cathode while precious metals and other impurities are precipitated.

[17] This sulphide plant consists of crushers, concentrator and smelter, an investment which had amounted to some $110 million by the end of 1952. In addition, it has involved the building of a dam on the Arroyo Salado river, the laying of 15 miles of 30-inch water pipe and the construction of about 12 miles of standard railway track and 600 houses and hotels with ancillary services for new employees. The smelting capacity available at Chuquicamata will be of the order of 250,000 tons a year.

Table 24. Copper Ore and Metal Production, and Smelter and Refinery Capacity, in Under-Developed Countries, 1938, 1948-53 and 1954

(Thousands of metric tons)

	Production			Capacity	
Region, country and period	*Ore*	*Metal*[a]	*Per cent smelted or refined*	*Smelter*	*Refinery*
Africa:					
Belgian Congo:					
1938	123.9	75.0[b]	60[b]		
1948-53	180.8	180.8	100	134	52
1954	224.0	224.0	100	134	120
Northern Rhodesia:					
1938	254.9	216.4	85		
1948-53	293.5	293.5	100	260	36
1954	398.0	352.0	88	400	176
South West Africa:					
1938	10.8	—	—		
1948-53	11.1	—	—	...	—
1954	13.1	—	—	—	—
Union of South Africa:					
1938	11.3	10.9	96		
1948-53	32.3	32.4	100	12	12
1954	39.6	39.2	99	40	20
Asia and the Far East:					
Burma:					
1938	3.5	—	—		
1948-53	0.7[c]	—	—	9	—
1954	...	—	—	—	—
India:					
1938	6.1	5.4	89		
1948-53	8.1	6.3	78	8	8
1954	7.3	7.3	100	8	8
Korea:					
1938	1.2	5.8	483		
1948-53[d]	0.3	0.2	67	15	10
1954[d]	1.5	...	...	...	10
Philippines:					
1938	4.4	—	—		
1948-53	9.7	...	...	...	—
1954	14.4	...	...	15	—
Europe:					
Yugoslavia:					
1938	45.0	42.0	93		
1948-53	38.5	34.6	90	60	12
1954	32.1	30.3	94	60	40
Latin America:					
Bolivia:[e]					
1938	2.9	—	—		
1948-53	5.1	—	—	—	—
1954	3.7	—	—	—	—
Chile:					
1938	351.5	337.5	96		
1948-53	390.6	367.0	94	250	282
1954	363.5	338.2	93	400	500
Cuba:					
1938	13.4	—	—		
1948-53	18.0	—	—	—	—
1954	15.2	—	—	—	—
Mexico:					
1938	41.9	37.1	88		
1948-53	60.7	52.3	86	60	—
1954	56.5	53.6	95	67	39
Peru:					
1938	37.5	35.7	95		
1948-53	28.9	20.2	70	45	—
1954	37.7	26.5	70	45	23

Table 24. Copper Ore and Metal Production, and Smelter and Refinery Capacity, in Under-Developed Countries, 1938, 1948-53 and 1954 *(continued)*

(Thousands of metric tons)

Region, country and period	Production: *Ore*	Production: *Metal*[a]	Production: *Per cent smelted or refined*	Capacity: *Smelter*	Capacity: *Refinery*
Middle East:					
Cyprus:					
1938	36.6[f]	—	—	—	—
1948-53	17.0	—	—		
1954	27.3	—	—	—	—
Turkey:					
1938	2.5	2.2	88	3	—
1948-53	16.4	16.4	100		
1954	25.1	25.1	100	24	11
TOTAL, UNDER-DEVELOPED COUNTRIES:					
1938	947	802	85	856	500
1948-53	1,120	1,013	90		
1954	1,259	1,096	87	1,273	1,027
WORLD TOTAL:[g]					
1938	1,880	1,910[h]	101	2,400[i]	2,950
1948-53	2,278	2,292[h]	101		
1954	2,490	2,680[h]	107	3,000[i]	3,900

Sources: American Bureau of Metal Statistics, *Yearbook*, 1939 and 1954; *Metal Bulletin World Register of Non-Ferrous Smelters and Refineries, 1942* and *World's Non-Ferrous Smelters and Refineries, 1954* (edited by H. G. Cordero, London).

[a] Blister or refined.

[b] Estimated; production of cathodes at Panda amounted to 45,000 metric tons.

[c] 1950-53; production resumed in 1950.

[d] Southern Korea only.

[e] Exports.

[f] Including the estimated copper content of iron pyrites exported, much of which may not in fact have been recovered.

[g] Excluding the Union of Soviet Socialist Republics.

[h] Including a small amount of scrap.

[i] Estimates based partly on the mine production of countries not listed in the table. Only a small part of this capacity produces metal for direct consumption; most of the smelter output is subsequently refined.

Notes on smelters and refineries in individual countries

Belgian Congo (including Ruanda-Urundi): Two smelting plants—at Lubumbashi (Elisabethville) and Panda (Jadotville); in 1938 the former consisted of eight blast and five reverberatory furnaces (capacity about 80,000 metric tons) and the latter of four reverberatory furnaces for treating poorer sulphide ores. Two refining furnaces at Panda, idle since 1932, were reactivated during the war. These facilities were supplemented by a leaching and electrolysis plant and three reverberatory furnaces at Shituru (Jadotville) and a new furnace refinery at Lubumbashi.

Northern Rhodesia: Three smelting plants—at Luanshya, Mufulira and Nkana; in 1938 the Luanshya smelter comprised two reverberatory furnaces and four converters (capacity about 85,000 metric tons), the Mufulira smelter, two reverberatory furnaces and three converters (capacity about 65,000 tons) and the Nkana smelter, three reverberatory furnaces and three converters (capacity about 110,000 tons). There was a 36,000-ton electrolytic refinery at Nkana. Facilities at Nkana have been substantially increased, partly to handle concentrates from the Nchanga mine. The Mufulira smelter was also expanded, and a new electrolytic refinery built there (capacity about 50,000 tons).

South West Africa: In 1938, two blast furnaces were in operation at Otavi.

Union of South Africa: A smelter at Messina, two reverberatory furnaces and a converter in 1938, capacity increased to about 20,000 metric tons by 1954; a furnace refinery at Messina was expanded in much the same way. A 20,000-ton smelter was built at Okiep in 1940.

Burma: Two blast furnaces in a plant at Namtu for treating copper concentrates separated from the mixed lead-zinc-copper-silver-nickel-cobalt ores taken from the Bawdwin mine.

India: One reverberatory furnace and two converters in a furnace refinery at Moubhander.

Korea: Three smelters—at Chinnamp'o, Munp'yong and Yong-amp'o—of about equal capacity; in 1938 the Chinnamp'o plant consisted of six blast furnaces and fifteen Japanese-type converting furnaces. Before the war a refinery was operated at Seoul by Chosen Seiren, K. K. The only large metallurgical works in southern Korea in 1954 was the 10,000-ton Chan-chung copper refinery.

Philippines: Before the war a small reverberatory furnace and stationary converter treated accumulated matte at irregular intervals, shipping the resultant 250-pound blister slab to Tacoma, Washington, for refining. Since 1950 the Philippine Smelting Company has operated a 15,000-ton smelter at Mambulao Bay.

Yugoslavia: A smelting plant, consisting of five reverberatory furnaces and four converters operated at Moravska Banovina by the Compagnie Française des Mines de Bor before the war and by Rudnici Bakra i Topionice in the post-war period. An electrolytic refinery began operating at Bor in mid-1938; its capacity has recently been increased.

Chile: Before the war the smelting plant consisted of three reverberatory furnaces and four converters at Potrerillos (capacity about 74,000 metric tons), two reverberatory furnaces and four converters at Caletones (145,000 tons), two reverberatory furnaces and four converters at El Monte (7,000 tons), two blast furnaces, two reverberatory furnaces and one converter at Chagres (6,000 tons), certain facilities for producing blister copper at Chuquicamata and two reverberatory furnaces and three converters in an idle plant at Gatico; while refining facilities comprised two plants for refining directly from oxide ores at Chuquicamata and Potrerillos, and a furnace refinery at Caletones. By 1954 smelting and refining capacity had been substantially enlarged: in addition to the plants at Potrerillos (capacity increased to about 120,000 tons) and Caletones (and the inactive Chagres smelter of the Compañía Minas y Fundición de M'Zaita), there were expanded facilities for smelting at Chuquicamata—an oxide plant with capacity of about 205,000 metric tons and a sulphide plant of about 71,000 tons, allowing for successive treatment of mixed ores—and a new national smelter at Paipote with a capacity of about 18,000 tons. The three refining plants—at Caletones, Chuquicamata and Potrerillos—had capacities of about 168,000 tons, 168,000 and 243,000 tons, respectively. *(Footnote continued on page 78)*

Raritan refinery in New Jersey,[18] this development may tend in the first instance to lower the proportion of electrolytic copper exported from Chile. On the other hand, the government smelter built in Atacama in 1951 should reduce if not eliminate the export of ore and concentrates from small mines.

The bulk of the Mexican copper output is exported as blister, but there is still a substantial movement of ore, concentrates and matte (within the system operated by the Phelps Dodge Corporation based on a refinery in Douglas, Arizona, and on the American Smelting and Refining Company's refinery in El Paso, Texas). Since the construction of a refinery at Atzcapotzalco in 1947, an increasing proportion of the output of primary metal has been in the form of electrolytic copper. In the period 1949 to 1951, refined copper constituted 32 per cent of primary output and 25 per cent of mine output. The refinery — Cobre de Mexico, S.A. — draws much of its blister copper from the Cananea Consolidated Copper Company, and in 1952 one-fourth of its issued stock was acquired by the Anaconda Copper Mining Company, the effective owner of the mine.

Since 1948, when a 23,000-ton refinery was built at La Oroya by the Cerro de Pasco Corporation, about three-fourths of the copper exported from Peru has been refined. Previously, exports consisted almost entirely of blister copper.

In Northern Rhodesia, smelter capacity grew with mine capacity from the early nineteen thirties, but refining capacity lagged; in 1937, only about one-sixth of mine production was electrolytically refined. With post-war expansion in mine output and refinery capacity, the refined proportion has risen significantly: to 32 per cent in 1951 and 46 per cent in 1954. At this stage the newly built refinery at Mufulira was being enlarged and another refinery was under construction at Ndola.

The Belgian Congo exported a substantial amount of copper matte before the war — about 40 per cent of its gross mine output in 1938. At that stage the remainder of its output was exported as blister, none being refined. By 1948, it was smelting its whole output and refining rather more than half of it, partly at a fire refinery at Lubumbashi and partly at a Jadotville-Shituru plant, which refines directly from the oxide ore. In 1952, 56 per cent of the copper exported from the Belgian Congo was refined.

In the Union of South Africa, there are smelters at Okiep and Messina. A fire refinery is also operated at Messina; this was built during the First World War when the increase in freight rates made it uneconomic to export matte, just as some years earlier an increase in freight rates had made it uneconomic to export concentrates and had prompted the building of a blast furnace for reducing ore to metal. In recent years about one-third of the production of the Union of South Africa has been in the form of fire-refined copper.

In Turkey, copper ores were first smelted in 1937, and since then the entire Turkish output has been in the form of blister copper. Following the completion of a plant at the Murgul mine in 1950, about 1,100 tons of fire-refined copper was produced in 1951. Exports, however, have continued to be in blister form — 23,000 metric tons in 1953.

During the nineteen thirties, almost all copper exported from Yugoslavia was in blister form. Recent expansion of the plant operated at the Bor mines, however, has made possible the further processing of a larger proportion of the domestic ore output: during the period 1949 to 1952 about one-third was refined and in 1953, almost one-half.

Smaller producers, such as Bolivia, Cuba, Cyprus, Newfoundland, the Philippines and South West Africa, continue to export ore and concentrates and, to a limited extent, copper matte. In India, where for many years the entire mine output has been refined at the source, the resultant primary copper is used by domestic industry, supplemented to an increasing extent by imports of semi-fabricated products.

In recent years mine production in under-developed regions has amounted to about one-half of the world total (excluding that of the Soviet Union). About seven-eighths of this production has been smelted at the source and about one-half refined there. In the period 1949 to

[18] This refinery — one of the largest in the world, with an annual capacity of 240,000 tons — is operated by the International Smelting and Refining Company, a completely owned subsidiary of the Anaconda Copper Mining Company.

(Footnote continued from page 77)

Mexico: Pre-war smelting facilities consisted of four blast furnaces at Matehuela (capacity 327,000 metric tons of ore and flux — about 9,000 tons of metal); two blast furnaces and two converters at San Luis Potosi (capacity 262,000 tons of ore and flux — about 7,000 tons of metal); six reverberatory furnaces and two converters at Santa Rosalia (capacity 270,000 tons of ore and flux — about 10,000 tons of metal); two reverberatory furnaces and six converters at Cananea (capacity 290,000 tons of ore and flux — about 27,000 tons of metal) and four blast furnaces at the idle plant of the Mazapil Copper Company at Concepción del Oro (capacity 250,000 tons of ore and flux — about 6,000 tons of metal). In 1954 there were three operating smelters: at San Luis Potosi (287,000 metric tons of ore and flux — about 20,000 tons of metal), Cananea (27,000 tons of metal) and Concepción del Oro (182,000 tons of ore and flux — about 13,000 tons of metal). The Santa Rosalia plant of Boleo Estudios e Inversiones Mineras, S.A. (109,000 tons of ore and flux — about 7,000 tons of metal) was idle. In addition a small electrolytic refinery was operated by Cobre de Mexico, S.A. at Atzcapotzalco.

Peru: Pre-war smelting facilities consisted of one blast furnace, two reverberatory furnaces and six converters at a plant at La Oroya (capacity about 45,000 metric tons) and one blast furnace and two converters at Shorey in a small plant operated by the Northern Peru Mining and Smelting Company between 1924 and 1932 (capacity unknown). These facilities have since been supplemented by an electrolytic refinery operated by the Cerro de Pasco Corporation at La Oroya.

Turkey: Pre-war plant comprised two small smelters at Ergani (which commenced operations in 1933) and Kuvarshan — capacity about 1,000 metric tons. The smelter at Ergani has been expanded to about 14,000 metric tons capacity and new facilities were built at Murgul during the war (capacity about 10,000 tons). There are small furnace refineries associated with the smelters at Ergani and Murgul.

Table 25. Mine, Smelter and Refinery Production of Copper, by Region, 1949-51
(Thousands of metric tons)

Region	Production		
	Mine	Smelter[a]	Refinery[a]
Australia and New Zealand	15.7	13.9	19.2
Japan	36.5	83.4	81.8
Canada and the United States	924.5	1,149.3	1,397.5
Western Europe[b]	56.5	167.1	568.9
TOTAL, ABOVE REGIONS	1,033.2	1,413.7	2,070.4
Africa	502.2	488.1	183.2
Asia[c]	17.3	6.5	6.6
Latin America	488.1	426.4	331.1
Middle East	33.4	13.0	0.8
Yugoslavia	38.9	25.3	14.2
TOTAL, UNDER-DEVELOPED REGIONS	1,079.9	959.3	535.9
WORLD TOTAL[d]	2,113.1	2,373.0	2,606.3

Source: International Materials Conference, *Report on Operations, 1952-1953* (Washington, D.C.).
[a] Including a small amount of secondary copper.
[b] Austria, Belgium, Denmark, Finland, France, western Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.
[c] Excluding mainland China and Japan.
[d] Excluding the Union of Soviet Socialist Republics and a few small producers, such as Angola, Burma, mainland China, Ecuador, Korea and Romania.

1951 the proportion of mine output smelted at the source ranged from 39 per cent in the case of the Middle East and Asia (excluding mainland China and Japan) to 87 per cent in Latin America and 97 per cent in Africa (table 25). The proportion refined was appreciably lower: less than 3 per cent in the Middle East, about 37 per cent in Africa, Asia and Yugoslavia, and 68 per cent in Latin America. The statistical corollary to this situation lies in the fact that in the industrial regions primary copper output exceeds mine output: in the period 1949 to 1951, average smelter production was 37 per cent and average refinery production 100 per cent above average mine production.

One of the deterrents to the expansion of refinery capacity in under-developed countries in the post-war period has been the relatively high price obtainable for blister copper.[19] In 1953, for example, when the price of electrolytic copper in London averaged about £263 per long ton, blister copper realized as much as £250 a ton and there have been occasions when the difference in price was only £6 a ton. Such a margin hardly seems sufficient to justify the large expenditure which the erection of an electrolytic refinery necessarily entails — £3 million for the 55,000-metric-ton plant now under construction at Ndola in Northern Rhodesia, for example.

The narrowness of the price gap between blister and electrolytic copper is probably a reflection of a general shortage of supplies. Among consumers there is a strong and growing preference for the electrolytic grade, and mines that have no refinery tend to find it expedient to have their blister output refined on toll before sale. This, influenced by an assessment of the future pattern of demand and price, rather than present profitability, would appear to lie behind the recent construction of a refinery by Mufulira Copper Mines, Limited, in Northern Rhodesia. In the financial year 1953/54 this company's costs — production, selling and administration — averaged less than £114 a long ton for copper refined at the mine and more than £125 for copper refined overseas, yielding average margins between revenue and cost of about £116.1 and £108.4, respectively. These margins on sales of electrolytic copper, however, were lower than that — £119.4 a ton — earned from sales of blister copper produced at a significantly smaller cost, averaging just over £109 a ton.[20]

As in the case of aluminium, copper fabrication, though much less dependent on supporting or ancillary industries than tin or zinc, is equally limited by market factors. This may be illustrated by developments in Chile, one of the three largest producers of refined copper. Before the war practically the whole of the copper output was exported, fabricated copper products (chiefly wire and cable) being imported to the extent of 3,000 to 4,000 metric tons a year. A law passed at the end of 1941 obliged the mining companies to reserve for domestic consumption such metallic copper as might be required by local industries. Under the stimulus of war a number of small-scale fabricating concerns were set up, and the steel industry employed some of its rolling and drawing plant to produce heavy copper plate and wire, which were then turned over to fabricators. Only a few of these concerns survived long after the end of the war; one was the government factory supplying military needs; another was the Manufactura de Cobre, S.A. (MADECO),

[19] See N. J. Maas, "Possibilities for the Establishment of an Electrolytic Copper Refinery in the Union", *South Africa Mining and Engineering Journal*, 19 September 1953 (Johannesburg), page 14.

[20] See *The Mining Journal: Annual Review, 1955* (London), page 271.

sponsored by the Chilean Development Corporation, catering chiefly for the Government's electrification programme. In 1949, annual manufacturing capacity was estimated at some 50,000 tons of sheets, bars, tubes and other shapes (about ten times the estimated domestic requirements at that stage) and 79 million metres[21] of wire, cable and other electrical conductors (about four times the estimated domestic requirements). A substantial proportion — one-third in 1947 and one-half in 1948 — of these semi-manufactures (mostly simple billets) was exported, the bulk of the remainder being absorbed by domestic electrification schemes.

Table 26. Chile: Copper Mineral and Metal Exports and Export Unit Values, 1949 to 1953

Item and unit	*1949*	*1950*	*1951*	*1952*	*1953*
Value of exports:					
Millions of gold pesos:					
Copper ores and concentrates[a]	6.6	7.7	16.7	30.1	21.1
Primary copper[b]	753.8	686.2	813.1	1,238.9	1,113.4
Fabricated copper[c]	23.5	19.7	142.9	121.7	59.2
TOTAL	783.8	713.7	972.6	1,390.7	1,193.6
Per cent of total:					
Copper ores and concentrates[a]	0.8	1.1	1.7	2.2	1.8
Primary copper[b]	96.2	96.1	83.6	89.1	93.3
Fabricated copper[c]	3.0	2.8	14.7	8.7	4.9
Volume of exports:					
Thousands of metric tons:					
Copper ores and concentrates[a]	16.1	17.3	21.6	29.3	34.5
Primary copper[b]	354.0	322.3	310.0	354.1	295.0
Fabricated copper[c]	9.1	7.1	30.5	24.8	13.5
TOTAL	379.2	346.7	362.1	408.2	343.0
Per cent of total:					
Copper ores and concentrates[a]	4.2	5.0	6.0	7.2	10.1
Primary copper[b]	93.4	93.0	85.6	86.7	86.0
Fabricated copper[c]	2.4	2.0	8.4	6.1	3.9
Export unit value (gold pesos per kilogramme):					
Copper ores and concentrates[a]	0.4	0.4	0.8	1.0	0.6
Primary copper[b]	2.1	2.1	2.6	3.5	3.8
Fabricated copper[c]	2.6	2.8	4.7	4.9	4.4

Source: Central Statistical Office, *Estadistica Chilena* (Santiago), December 1953, pages 633, 634.

[a] Including precipitates and slag.

[b] Cement, electrolytic, blister and refined copper in ingots and bars.

[c] Bars, sheets, wire, springs, tubes, pipes, and cable.

Although semi-manufactured products have not accounted for more than 15 per cent of the value of all Chilean copper exports in any post-war year and were less than 3 per cent from 1948 to 1950, the effect of local fabrication has been to reduce imports of copper manufactures from more than 3,000 tons in 1938 to less than 1,900 in 1946 and an average of about 1,200 tons between 1950 and 1953, in spite of a substantial increase in local demand. Nevertheless, Chilean expenditure on imports of copper and copper alloys, mostly in fabricated form, averaged about $1,355,000 a year during the years 1949 to 1953. The fact that manufactures, besides constituting only a small proportion of total exports, consist very largely of products representing only elementary processing (table 26) suggests that, at least in the immediate future, the Chilean fabricating industry will have to depend chiefly on the development of internal demand. The market in neighbouring countries is not very promising; with the exception of Argentina, they are all less industrialized, and of four countries to the north, Bolivia, Peru, Ecuador and Colombia, the first two are themselves established exporters of copper and may be expected, when domestic demand justifies it, to attempt to fabricate part of their own output. As a result, through most of the post-war decade Chile carried a manufacturing capacity well in excess of current needs, and in consequence prices of many of its copper products are likely to have been higher than would have been the case if these had been imported from favourable sources or if facilities had been fully utilized and optimum production attained.

In the Belgian Congo, war-time and post-war investment has also laid the foundations of a fabricating industry, but production is still on a very limited scale, dependent even more than in Chile upon the industrial development of the country. Exports of simply fabricated

[21] Including an annual capacity of 27 million metres of copper wire and 4 million metres of electrical cord from a newly completed plant at Los Corillos, Santiago.

copper began in 1950, and in the following two years just under 46 tons of drawn wire were shipped. Imports of fabricated copper and copper alloy products in 1951 were valued at about $412,000 and came mostly from Belgium. The corresponding imports in 1952 and 1953 amounted to 1,194 metric tons ($1,513,000) and 494 metric tons ($691,000), respectively. Of the two years' imports of over $2.2 million, rather more than one-half was for bars, wires, sheets and plates, somewhat under one-fourth for pipes, tubes, cables and other semi-manufactures and the remainder for more highly fabricated copper articles.

In Northern Rhodesia, as in Bolivia and Peru, the non-ferrous metals industry is still based on the export of the entire mine output. However, the Anglo American Corporation of South Africa, Limited, whose affiliated company, Rhodesian Anglo American Corporation, Limited, controls two of the four major copper mines and the lead-zinc mine, has established an important fabricating plant — African Cables, Limited, in the Union of South Africa. This plant, incorporated in 1936 and employing some 700 workers in 1951, uses Northern Rhodesian lead and copper to produce a comprehensive range of electric cables — bare, insulated and steel reinforced — from one-sixteenth of an inch to five inches in diameter. Through W. T. Henley's Telegraph Works Company, Limited — its original technical managers — it is linked to the cable makers of the United Kingdom.

In the Union of South Africa the production of electrical engineering products has increased greatly in recent years; at 1950 prices, the value of local consumption of domestic output grew from under £100,000 in 1928 to more than £7.2 million in 1950. Nevertheless, local factories still serve less than half of local demand and most of the copper they use is imported high-conductivity metal. In 1952, for example, only 6 per cent of the country's primary copper output was consumed domestically; the 2,400 tons of local copper used in local factories being supplemented by about 17,000 tons of imported copper.

In general, therefore, though there is a considerable amount of smelting and refining in under-developed mining economies, there is very little fabricating. Even in a more industrialized country such as Canada, post-war consumption of copper has amounted to only about one-third of the domestic output of raw metal, while in 1950 exports of semi-manufactures — rods, strips, sheets and tubing — were valued at about $7.5 million, out of a total of $87.5 million for all copper and copper products.

Among the under-developed copper producing countries, average annual consumption in the four years 1948 to 1951 represented less than one per cent of output in the Belgian Congo, Bolivia, Cuba, Cyprus, Northern Rhodesia, Peru and the Philippines. India, with an annual mine output of about 6,000 metric tons a year, imported refined copper to the extent of about 25,000 tons a year. During this period, other importers among the less developed countries included Argentina (about 10,000 tons a year), Brazil (24,000), Egypt (5,000), French North Africa (3,000) and Pakistan (5,000). The small domestic output of these countries was derived chiefly from remelted scrap. Imports totalling about 1,000 tons a year maintained the small repair and manufacturing establishments of Indonesia, Israel, southern Korea, Taiwan and Uruguay. Chile consumed about 5 per cent of its output. Mexican consumption amounted to about a seventh of domestic output, that of the Union of South Africa and South West Africa combined, to about a third, and that of Turkey and Yugoslavia, each to about a half.

Small quantities of refined copper are occasionally exported to other less developed countries: between 1950 and 1953, for example, Angola received about 137 tons, Honduras about 200 tons, Iran about 651 tons, New Caledonia about 15 tons and Venezuela and a few areas in Africa even smaller amounts. Part of this is used in railway and engineering maintenance workshops and part in handicraft industries. Most countries draw some extra material from scrap, but the less industrialized the region the smaller is its domestic scrap supply likely to be.

Lead

Technical difficulties and power requirements being less, lead smelting[22] is carried out to a greater extent in under-developed countries than is the smelting of other non-ferrous metals (table 27). Among the significant producers of ore, only Bolivia, Newfoundland and South West Africa lack smelting and refining facilities, exporting their entire output as concentrates to group plants; the mines in the first two are members of the American Smelting and Refining Company's system and that in the third (the Tsumeb Corporation, Limited) is controlled by a group in which the American Metal Company, Limited, and Newmont Mining Corporation hold the largest interest.

Mexico, second only to the United States as a lead ore producer, began producing refined lead in 1929 and now has refining capacity well in excess of its domestic mine output, two-thirds under the control of the American Smelting and Refining Company and the remainder owned by American Metal Company, Limited. Since the rehabilitation of the plant at Namtu, Burma has also had a smelting capacity in excess of recent rates of ore production. Northern Rhodesia and Tunisia have facilities that are capable of handling current mine output.

In Peru, smelting capacity has been increased significantly in recent years, but mine production continues to keep ahead, and the proportion of ore refined before export, though appreciably higher than before the war, is still not much above one-half of the total. In Yugoslavia, on the other hand, refinery capacity appears to

[22] Lead ore is usually roasted to remove sulphur and then reduced in a blast furnace to what is commonly known as base bullion, a good deal of which enters into international trade. Refining of the base bullion is generally done electrolytically, either in the country of origin or in its industrial customer. Zinc impurities were at one time regarded as a great handicap, and lead ores were penalized for excessive zinc, but improvements in differential flotation — enabling the two ores to be separated before smelting — and the introduction of zinc reducing and volatilizing techniques in the furnace have resulted in high zinc recovery and consequent enhancement of the value of the mixed ore.

Table 27. Lead Ore and Metal Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954

(Thousands of metric tons, metal content)

Region, country and period	Production: Ore	Production: Metal	Production: Per cent smelted	Smelter or refinery capacity
Africa:				
Algeria:				
1938	5	—	—	—
1948-53	3	—	—	
1954	10	—	—	—
Belgian Congo:				
1938	5	—	—	—
1948-53	—	—	—	
1954	—	—	—	—
French Equatorial Africa:				
1938	3	—	—	—
1948-53	3	—	—	
1954	3	—	—	—
Morocco, French:				
1938	19	—	—	—
1948-53	58	19[a]	30[a]	
1954	82	29	32	35
Northern Rhodesia:				
1938	4	—	—	20
1948-53	13	13	100	
1954	15	15	100	17
South West Africa:				
1938	19	—	—	—
1948-53	43	—	—	
1954	59	—	—	—
Tunisia:				
1938	19	24	126	38
1948-53	19	23	118	
1954	27	27	100	38
Asia:				
Burma:				
1938	89	82	92	98
1948-53	4	4	101	
1954	12	12	100	67
China mainland:				
1938	...	2	...	4
1948-53	...	1	...	
1954	...	...	...	...
India:				
1938	—	—		—
1948-53	—	1		
1954	—	2		6
Korea:				
1938	3	4	133	12
1948-53	—	—		
1954	—	—	—	17
Philippines:				
1938	—	—	—	—
1948-53	1	—	—	
1954	2	—	—	—
Europe:				
Yugoslavia:				
1938	85	9	11	44
1948-53	76	60	79	
1954	84	67	80	75
Latin America:				
Argentina:				
1938	24	11	46	18
1948-53	21	19	91	
1954	26	26	100	25

Table 27. Lead Ore and Metal Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954 *(continued)*

(Thousands of metric tons, metal content)

Region, country and period	Production			Smelter or refinery capacity
	Ore	Metal	Per cent smelted	
Latin America (continued):				
Bolivia:[b]				
1938	13	—	—	—
1948-53	28	—		
1954	18	—	—	—
Brazil:				
1938	—	—	—	—
1948-53	...	3	...	
1954	...	...	...	10
Chile:				
1938	1	—	—	—
1948-53	5	—	—	
1954	3	—	—	—
Guatemala:				
1938	—	—	—	—
1948-53	3	—	—	
1954	...	...	...	...
Mexico:				
1938	282	231	82	294
1948-53	224	217	97	
1954	217	211	97	328
Peru:				
1938	58	26	45	42
1948-53	80	43	54	
1954	109	58	53	70
Middle East:				
Iran:				
1938	...	...	...	...
1948-53	10[c]	...		
1954	16	...	...	...
Turkey:				
1938	7	1	14	15
1948-53	1	—		
1954	...	...	...	6
TOTAL, UNDER-DEVELOPED COUNTRIES:				
1938	640	390	61	563[d]
1948-53	600	405	71	
1954	690	450	65	666[d]
WORLD TOTAL:[e]				
1938	1,700	1,570	93	2,945[f]
1948-53	1,540	1,510	98	
1954	1,710	1,770	103	3,070[g]

Source: United Nations, *Statistical Yearbook, 1954*; American Bureau of Metal Statistics, *Yearbook*, 1938 and 1954.

[a] Data for 1949-53; production began in 1949.

[b] Exports.

[c] Estimated annual output, 1950-53.

[d] A small proportion of this capacity relates to lead bullion which may subsequently be reprocessed in a refinery in one of the industrial countries.

[e] Excluding the Union of Soviet Socialist Republics.

[f] Nominal capacity, of which the United States accounted for 970,000 metric tons. A number of lead-silver smelting plants in Canada and the United States have been excluded. Effective capacity is estimated at 2,270,000 metric tons: 860,000 in the United States, 510,000 in the under-developed countries, and 900,000 elsewhere.

[g] Excluding some lead-silver smelting plants in Canada and the United States. In a few instances plant capacity has been estimated on the basis of pre-war figures.

Notes on smelters and refineries in individual countries

Morocco, French: Fonderies Peñarroya-Zellidja at Oued el Heimer, built in 1947 and being enlarged to 60,000 metric tons.

Northern Rhodesia: A smelter was built at Broken Hill in 1917, expanded in 1920 and left idle after 1929, when the rich oxide ores had been exhausted. A new plant, to treat sulphide ores, was brought into operation in 1946.

Tunisia: Three plants: a 25,000-ton smelter at Mégrine and two furnace refineries at Souk el Khemis (4,000 tons) and Bizerte (3,500 tons).

Burma: Smelter at Namtu, damaged during the war, reactivated in 1952.

China mainland: Before the war there were two blast furnaces at Chang-sha; subsequently a smelter was built at An-shan, Manchukuo, by Manshu Enko, K.K., a subsidiary of Nippon Kogyo Kaida; capacity not known. Ores from Ch'ang-ning are treated by the Hunan Provincial Lead Smelting Plant at Chang-sha. (Footnote continued on page 84)

be overtaking mine output: before the war large quantities of ore and concentrates were exported to western Europe; since 1946, however, more than three-fourths of ore production has been locally smelted. Argentine lead smelting capacity has also increased since the war and in recent years has been sufficient to treat almost the whole domestic ore output.

Lead smelting began in French Morocco in 1949, but as a result of the expansion of mine production, the average proportion of ore treated during the years 1949 to 1954 was somewhat less than one-third. If the trend in mine output is maintained, the doubling of plant capacity which is at present under way would still leave a substantial volume of lead to be exported in the form of concentrates.

Production of lead ore in Bolivia and South West Africa since the war has been substantially above pre-war levels. Exports from these countries, however, continue to be in the form of concentrates,[23] as they do from the much smaller producers, such as Algeria, Chile, French Equatorial Africa, Guatemala and the Philippines.

In the industrial countries as a whole, post-war lead production has utilized not much more than half of nominal capacity. This is due largely to the situation in the United States, where at the end of 1949, for example, capacity amounted to 866,000 short tons a year for primary lead (300,000 tons a year above average 1947-49 primary production) plus at least 500,000 short tons a year used mainly for refining secondary lead. One explanation for this apparent excess of capacity lies in the fact that before the war, United States imports of lead were largely in the form of ore, matte and base bullion, much of which was smelted and refined in bond and re-exported. Between 1940 and 1950, by contrast, three-fourths of all lead imports consisted of refined metal.

In 1951, about one-fifth of the world's primary lead refining capacity (outside the Soviet Union) was in under-developed countries. If Burma is omitted because its large refinery was not recommissioned until later, this capacity appears to have been utilized more fully than that in industrial countries during the post-war period — about 70 per cent on the average during the years 1946 to 1951. New primary lead facilities that have come into operation in under-developed countries since the war include refineries in Northern Rhodesia (1946), French Morocco and India (1947), Argentina and Mexico (1951) as well as small smelters in Brazil and Guatemala and an expansion in refining plants at the Cerro de Pasco mine in Peru and the Trepca mines (Rudnici i Topionice Olova i Cinka) in Yugoslavia. Most of the expansion in lead smelting and refining capacity since 1938 has thus taken place in under-developed countries, and with world capacity well above current levels of mine production, secondary supplies growing in relative importance and most of the producers in these countries refining the bulk of their own ore output, the immediate prospects of further rapid expansion are not very great, unless new uses for lead increase total demand.

In recent years, the ratio of the volume of metal consumed in under-developed areas to the volume produced there has been appreciably higher in the case of lead (about one-fifth in 1948-53) than in the case of copper (about one-eighth in 1948-53). Lead consumption in most of the larger producers among the under-developed countries, however, rarely reaches 10 per cent of mine or smelter output. Most of it is used in construction, printing and engineering repair work.

In the period 1948 to 1951, little if any lead was used in Bolivia, Northern Rhodesia and South West Africa, whose combined annual output was about 75,000 metric tons (metal content). In Northern Rhodesia the only domestic consumption has been for the production of a certain volume of antimonial lead sheet and pipe for use in the Copper Belt. In Mexico and Peru, with a combined output of 280,000 tons of lead a year, consumption amounted to no more than 4 per cent of production; in French North Africa it amounted to 6 per cent; in Yugoslavia to 8 per cent. Most of the small output of lead concentrates in Turkey and the Union of South Africa is exported; domestic consumption (about 1,000

[23] The National Lead Company, S.A., of Argentina smelts a certain amount of Bolivian lead ore at its Puerto Vilelas plant and, since 1951, in an experimental smelter at Tupiza in Bolivia where a daily output of about one ton of lead is produced from low-grade ores.

(Footnote continued from page 83)

India: One smelter at Tundoo.

Korea: Before the war a smelter was operated at Chinnamp'o; subsequently a second smelter (capacity 5,000 metric tons) was built at Yongamp'o.

Yugoslavia: Before the war there were three refineries—at Zvecan (20,000 metric tons), Mezica (15,000 metric tons) and Kraljevo (5,000 tons), as well as a blast furnace (4,000 tons) operated by Metalokemika, A.G. The refineries operating in 1954 were two nationalized plants—at Zvecan (60,000 tons) and Mezica (15,000 tons).

Argentina: Before the war facilities comprised a blast furnace and six hearths (18,000 tons) operated by the National Lead Company, S.A., at Puerto Vilelas. A second plant (capacity 7,200 metric tons) is in operation at Mercedes.

Brazil: Facilities consist of a smelter (8,000-ton capacity) at Panelas and an experimental refinery (2,000-ton capacity) at Apiai.

Guatemala: There is a small plant at Villa Linda-Huehuetenango, capacity not known.

Mexico: Facilities consist of five smelters — at Chihuahua (125,000 tons), Torreón (100,000 tons), San Luis Potosí (75,000 tons), Mazatlán (18,000 tons) and Concepción del Oro (10,000 tons)—which handle silver-lead ores prior to refining at one of the two plants at Monterrey operated by the American Smelting and Refining Company (Harris process, capacity about 216,000 tons) and the American Metal Company, Limited (Parkes process, capacity about 100,000 tons). The plant at Mazatlán, operated by the Compañía Metalúrgica Occidental, S.A., represents a post-war addition to capacity.

Peru: A smelter at La Oroya, capacity about 40,000 metric tons in 1938 and about 70,000 in 1954. Before the war there were also two small blast furnaces at Vesuvio and Pompei, with a combined capacity of just under 2,000 tons of crude lead a year.

Turkey: There are small blast furnace smelters at Balya (idle since 1930) and Vinçdebi, Anamur, the crude lead capacities of which were about 12,000 metric tons and 3,000 metric tons, respectively, in 1938, and appreciably lower in 1954.

tons a year in the former and 10,000 in the latter) depends almost entirely on imports of primary metal.

The largest user of lead in Latin America is Argentina which, during the period 1948 to 1951, consumed about 29,000 tons a year, or 50 per cent more than it produced, most of it in the form of locally made pipe, sheet, solder, anti-friction metal, type metal, battery metal and plumbing accessories. Brazilian consumption was of the order of 23,000 tons, compared with production of only 3,000 tons. Chilean consumption (mostly of imports) has averaged about 2,000 tons a year in recent years, a figure that has been exceeded since 1950 by the output of a mine operating in the southern part of the country from which small quantities of high-grade ore are sent to Argentina for smelting.

Both India and Pakistan are importers of lead; their combined consumption in the period 1948 to 1951 was of the order of 15,000 tons a year. Small quantities of lead concentrates are exported from El Salvador. Guatemala, Honduras, southern Korea and the Philippines, but these countries, together with Egypt, Indonesia, Israel and Uruguay, consumed in the aggregate no more than 4,000 tons a year in the period under review, and the bulk of this was imported as primary metal in the form of pigs or bars.

Tin

In contrast to the trend in the lead industry, recent expansion of tin smelting facilities has been greater in the industrial than in the less developed countries.[24] This is the result of the war-time installation of a large smelter in Texas and the destruction or deterioration of facilities in south-eastern Asia. Indonesian tin production, one-third of which was refined domestically before the war, has been exported almost entirely in concentrate form in the post-war years, at first to Malaya, and more recently to the Netherlands (about 60 per cent) and the United States (about 40 per cent). The dismantled smelters on Bangka Island, Pangkalpinang and Belinjoe have not yet been reinstalled and the Muntok smelter has produced very little during the post-war period.

Malaya, which is the only under-developed tin producing country with smelting capacity in excess of average mine output (table 28), draws additional concentrates from neighbouring producers, especially Burma and Thailand. A small plant was built at Yala in Thailand just before the war; it produced a certain amount of tin metal in subsequent years, but since 1947 the entire output has been exported as concentrates, chiefly to Malaya and the United States. Apart from Japan, which has a small smelter capacity (of the order of 2,000 tons a year), the only other producer of tin metal in Asia is mainland China, whose annual mine output since 1948 is estimated to have averaged between 5,000 and 6,000 long tons, all of which is locally refined.

Rather less than one-fourth of the Belgian Congo output is smelted locally at the Manono plant of the Compagnie géologique et minière des ingénieurs et industriels belges; the remainder goes chiefly to Belgium as concentrates. The entire Nigerian output is shipped to the United Kingdom in the form of concentrates. In recent years, the Union of South Africa, the only other African producer of any magnitude, has been more or less self-supporting in respect of tin: the major producer is the Zaaiplaats Tin Mining Company, Limited, which operates a small smelter and refinery built just before the war and capable of handling not only the local ore but also concentrates imported from South West Africa and Swaziland.

The high metal content of most tin concentrates (70 per cent or more) makes shipment, even over long distances, economically feasible, especially when the price is high, as it has been during much of the post-war period. Bolivia, whose ore is relatively poorer, has always exported its entire output in the form of concentrates containing 30 to 40 per cent tin. In 1951 these exports totalled more than 90,000 long tons, with aggregate fine tin content of just over 33,000 long tons, or about 37 per cent of the gross weight. The recalcitrance of the ore, high losses sustained during treatment and the need to "sweeten" the feed with higher-grade alluvial ores are among the technical difficulties standing in the way of the successful operation of a large-scale plant. An experimental smelter built at Oruro in 1947 has not yet fulfilled its main purpose of increasing tin metal exports to Argentina, where existing facilities are capable of handling only the small output — between 200 and 300 tons a year in the post-war period — of local tin mines. Argentine tin consumption in the decade 1945 to 1954 averaged about 1,300 long tons a year; the bulk of this was derived from imports, and plans to increase domestic smelting capacity to the extent necessary to secure at least that country's large requirements of tin plate, by utilizing part of the Bolivian output of concentrates at present going to the United Kingdom and the United States, have not yet materialized.[25]

A small amount of tin smelting is carried on in several other Latin American countries: in the post-war period production of primary tin has ranged up to 500 tons a year in Brazil, between 200 and 400 tons a year in Mexico and up to 60 tons a year in Peru.

Before the war, between 50 and 60 per cent of the world's tin metal output came from under-developed countries; in 1948 the proportion was less than 40 per

---

[24] Most tin is extracted in the form of oxide ores, chiefly cassiterite, which because of their high specific gravity can be separated quite easily, usually in a washing plant or gravity mill, from the gravels in which they are commonly found in concentrations of one-half to two pounds per ton. The initial smelting is also quite easy, at least for most of the alluvial ores; the concentrates are roasted to expel sulphur and arsenic and then reduced by limestone flux and powdered anthracite in a blast or reverberatory furnace, from the bottom of which fairly pure tin can be tapped. As a good deal of the tin unites with the flux, the slags have to be resmelted under more carefully controlled conditions in order to achieve an acceptable recovery. Refining involves another remelt under even more precise control, which permits only the impurities to be oxidized.

[25] In September 1952, a group of Argentine industrialists signed a contract with the Bolivian Government for the establishment of a tin smelter in Bolivia, but this was rescinded in April 1953.

Table 28. Tin Ore and Metal Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954

(Metric tons, metal content)

	Production			
Region, country and period	*Ore*	*Metal*	*Per cent smelted*	*Smelter or refinery capacity*
Africa:				
Belgian Congo:[a]				
1938	9,824	2,229	23	6,000
1948-53	14,028	3,192	23	
1954	15,323	1,975	13	10,000
Nigeria:				
1938	9,119	—	—	—
1948-53	8,703	—	—	
1954	8,054	—	—	—
Union of South Africa:				
1938	567	—	—	—
1948-53	783	759	97	
1954	1,336	750	56	1,000
Rest of Africa:[b]				
1938	1,449	—	—	—
1948-53	579	72	12	
1954	800	27	3	100
Asia:				
Burma:				
1938	5,026	305	6	...
1948-53	1,378	—	—	
1954	963[c]	—	—	—
China mainland:[c]				
1938	13,410	13,410	100	14,000
1948-53	5,017	5,016	100	
1954	7,620	7,620	100	11,000
Indochina:				
1938	1,624	2,335[d]	144[d]	4,000
1948-53	109	—	—	
1954	46	—	—	—
Indonesia:				
1938	30,200	10,256	34	20,000
1948-53	32,439	—	—	
1954	36,435	1,373	4	10,000
Malaya:				
1938[e]	44,063	64,758	147	200,000
1948-53	55,463	63,054	114	
1954	61,662	72,305	117	108,000
Thailand:				
1938	15,055	—	—	—
1948-53	8,698	—	—	
1954	9,932	—	—	—

cent, in 1952 about 43 per cent and in 1954 about 42 per cent. As world smelter capacity is in excess of post-war levels of tin consumption — even when measured on an effective or useful basis as against a theoretical or nominal basis — there would seem to be little prospect of much immediate expansion of smelting and refining in less developed areas. However, if the closing down of the Longhorn (Texas) smelter — periodically debated in the United States Congress — were accompanied by the building of new facilities in Bolivia or the reconstruction of the Indonesian plants, the pre-war balance of facilities between under-developed and industrial countries would be restored.

Almost the entire output of tin ore is produced in under-developed areas, but very little of it is used in manufacturing processes in those areas. Tin plate, for example, which accounts for between a third and a half of total tin consumption, is almost exclusively a product of the industrial countries with advanced steel industries. Although several less developed countries have started to produce tin plate in recent years, one of the effects of the Second World War was to concentrate production to a greater degree in North America; in the period 1935 to 1939 the United States produced about 56 per cent of the world output (excluding that of the Soviet Union) and Canada about one per cent, while in the period 1948 to1952, the United States share was no less than 71 per cent of the total and Canada's 4 per cent. In the latter period a further 20 per cent came from western Europe and the United Kingdom.

Table 28. Tin Ore and Metal Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954 (*continued*)

(Metric tons, metal content)

Region, country and period	Production: Ore	Production: Metal	Per cent smelted	Smelter or refinery capacity
Latin America:				
Argentina:				
1938	1,746	1,110	64	1,500
1948-53	249	242	97	
1954	168	61	36	1,500
Bolivia:[f]				
1938	25,892	—	—	—
1948-53	34,305	164	1	
1954	29,285	199	1	1,200
Brazil:				
1938	—	—	—	—
1948-53	199	140	70	
1954	193	488	267	2,000
Mexico:				
1938	253	—	—	—
1948-53	378	281	74	
1954	381[c]	244	64	...
TOTAL, UNDER-DEVELOPED COUNTRIES:				
1938	158,232	92,827	59	247,000[g]
1948-53	164,199	74,024	45	
1954	172,188	77,422	45	145,000[g]
WORLD TOTAL:				
1938	167,640	164,694	98	450,000[g]
1948-53	168,283	171,950	102	
1954	179,324	185,928	103	372,000[g]

Source: International Tin Study Group, *Statistical Bulletin*, (The Hague) August 1954; American Bureau of Metal Statistics, *Yearbook, 1939*.

[a] Including Ruanda-Urundi.

[b] Cameroons under French administration, Egypt, French West Africa, French Morocco, Mozambique, Northern Rhodesia, South West Africa, Southern Rhodesia, Swaziland, Tanganyika and Uganda.

[c] Estimated.

[d] Partial figure representing the output of the smelter in Tonkin.

[e] Production of Federated Malay States, and exports of Straits Settlement and United Malay States.

[f] Exports.

[g] Including estimates based on output for certain countries.

Notes on smelters and refineries in individual countries

Belgian Congo and Ruanda-Urundi: An electrolytic plant consisting of a reduction furnace and four refining furnaces built in 1934 at Manono. During the war, capacity was enlarged to 10,000 tons a year and a second plant (capacity 5,000 tons) was built and operated temporarily at Lubudi.

Union of South Africa: A smelting and refining plant built during the war at Potgietersrust. It treats local ores and a certain volume of concentrates from South West Africa and Swaziland.

Southern Rhodesia: A small refinery at Bulawayo (capacity about 100 metric tons a year) treats most of the local concentrates.

China mainland: Three smelters operated before the war—at Hohsien (Kwangsi) and in Ko-chiu. The Hohsien plant (4,000-ton capacity) was built by the National Resources Commission to treat ores from Hunan, Kiangsi and Kwangsi. The larger of the Ko-chiu plants (4,000-ton capacity) was built by the Yunnan Tin Corporation for treating the company's own ore and refining crude metal produced by as many as fifty small local smelters. It was to have been expanded to 20,000-ton capacity, but has probably operated well below this level in recent years. Before the war a certain amount of Chinese ore was treated in four small refineries operated in Hong Kong.

Indochina: Two smelters operated before the war—at Haiphong and Thakhek (Laos). Between 1933 and 1941 the Haiphong smelter of Rondon et Cie., originally built to treat local ore, refined crude tin imported from Yunnan; its capacity was about 3,000 tons a year.

Indonesia: Before the war the Netherlands East Indies Government operated smelters at Pangkal-balam, Muntok and Belinjoe; the first two of these (combined capacity about 20,000 metric tons) treated practically all the ore from Bangka, while the third was of outmoded design and was held largely in reserve, chiefly for treating stanniferous slags. Since the war the Muntok plant (original capacity about 10,000 tons a year) has been partly rehabilitated and is operated by the Indonesian Government concern, Banktinwinning.

Malaya: Two large refineries operated by the Eastern Smelting Company, Limited, at Penang and the Straits Trading Company, Limited, at Pulau Brani. Capacity of the former was about 100,000 tons a year before the war and about 67,500 tons in 1954; capacity of the latter, about 90,000 tons a year before the war and about 40,000 tons in 1954. A small smelter at Butterworth used as a standby immediately before the war has since been partly dismantled. Several small Chinese plants were in operation before the war; one at Kuala Lumpur reopened in 1948.

Thailand: A small plant at Yala smelting local ores during the period 1942 to 1947.

Argentina: A small plant at Buenos Aires treating concentrates from the mines at Jujuy.

Bolivia: A pilot smelter (theoretical capacity about 100 tons a month) built at Oruro in 1947.

Brazil: An electric furnace built by the Companhia Estanifera do Brasil at Volta Redonda to smelt tin concentrates from São João del Rei.

Mexico: A small amount of smelting is carried on at San Luis Potosí.

Though almost one-eighth of the world's output of tin plate is used by the canning industries of under-developed countries, only about 3 per cent is manufactured outside the main industrial areas (table 29). In the period 1937 to 1939 India produced about 54,000 long tons of tin plate a year and consumed about 63,000 tons, of which about 14 per cent was thus imported. In the period 1951 to 1953, production was a fifth higher, but consumption was up by more than a third, and over 25 per cent of domestic requirements were imported, chiefly from the United Kingdom and the United States. In Mexico, annual production almost doubled between 1948-50 and 1951-53 — from 7,400 to 14,300 long tons — but in absolute terms the level of consumption rose more, so that the deficit to be met from imports increased from 11,900 tons to 16,700 tons. The same is true of Brazil, where despite a doubling of the output of the Volta Redonda steel works — from 21,000 to 42,000 long tons — import requirements increased from 53,000 tons to nearly 76,000 tons. In Chile, however, tin plate production began at the new Corporación de Fomento steel works at Concepción in 1950, and that country was able to meet over 90 per cent of domestic requirements in the period 1951 to 1953. In the Union of South Africa, where production began in 1951, average output during 1951-53 was sufficient to satisfy only the expansion in consumption since 1948-50, and imports remained at about 42,000 long tons a year. Consumption in Argentina — 56,000 tons a year in 1948-50 and 67,000 in 1951-53 — is met entirely from imports.

Table 29. Tin Plate Production and Apparent Consumption, by Region, 1937-39 and 1951-53

Region	Production 1937-39	Production 1951-53	Consumption 1937-39	Consumption 1951-53
Amount (thousands of long tons):				
Canada and the United States	2,056	4,183	1,919	3,702
Europe and the United Kingdom[a]	1,335	1,156	1,041	1,082
Japan and Oceania	167	98	291	255
Latin America	—	70	170	283
Asia[b]	54	65	148	178
Africa	—	22	48	102
Middle East	—	—	18	31
TOTAL	3,612	5,594	3,635	5,633
Percentage of total:				
Canada and the United States	57	75	53	66
Europe and the United Kingdom[a]	37	21	29	19
Japan and Oceania	5	2	8	5
Latin America	—	1	5	5
Asia[b]	2	1	4	3
Africa	—	—	1	2
Middle East	—	—	—	1

Source: International Tin Study Group, *Statistical Yearbook*, 1949 and 1954; *Statistical Bulletin*, May 1955.

[a] Excluding Bulgaria, Czechoslovakia, Hungary, Poland, Romania and the Union of Soviet Socialist Republics; and eastern Germany in 1951-53.

[b] Excluding mainland China, Japan and the Union of Soviet Socialist Republics.

The main sources of tin ore, however — Bolivia, Indonesia, Malaya, Thailand — lack the steel industry on which tin plate manufacture is necessarily founded. Before the war, Indonesia imported 25,000 to 30,000 long tons of tin plate each year and in 1937 exported 13,500 tons of tin metal. Post-war tin exports have been much smaller, and average 1948-52 imports of tin plate were only about 6,500 long tons; there would seem to be no immediate prospects of using indigenous coal and iron ore resources for a local steel industry in which a tin plate section might be established. Imports of tin plate into Indochina amounted to 10,000 long tons in 1937 but to only 3,300 tons a year in the period 1948-52. Tin exports were also much lower, and here too there is no early prospect of a domestic steel and tin plate industry. Much the same is true of Malaya, which is both a much larger exporter of tin metal and a larger importer of tin plate for the use of its substantial food canning industry.[26] Tin plate consumption, which was about 20,000 long tons a year immediately before the war, averaged not much more than half of this (11,500 tons a year) in 1948-52, all imported. Both Indochina and Malaya mine coal and iron ore; post-war production has been much below pre-war levels, however, and it was not until 1950 that Malaya resumed its export of iron ore to Japan. Thailand's tin plate requirements are also imported; they averaged about 5,400 tons a year in the period 1948-52.

In the period 1948 to 1953, the eight major tin ore producers accounted for more than 95 per cent of world

[26] Fish, butter, coffee and vegetables are canned, but pineapples are the major item; before the war Malaya produced about one-fourth of the world's canned pineapple output.

output but less than one per cent of world consumption. In 1951, the Belgian Congo, Indonesia, Malaya, Nigeria, Spain and Thailand — all significant tin producers — spent the equivalent of almost $700,000 on imports of wrought and unwrought tin metal and tin alloys, from Belgium, the Netherlands and the United Kingdom. Most under-developed countries, including those which export significant quantities of tin concentrates, import not only tin plate but also varying amounts of other tin products — solder, bronze, anti-friction metals and tin foil, as well as metallic tin itself in different forms.

Zinc

Technical complexities and high power requirements have tended to retard the growth of zinc refining facilities in the less developed areas;[27] even Australia continues to export a large proportion — more than half during the period 1950 to 1954 — of its output in the form of concentrates. Nevertheless, as in the case of lead, the history of the zinc industry has been characterized by a relative decline in European mine output in the face of increasing production in the United States and, later, in less developed countries. This was accompanied by the gradual spread of smelting and refining facilities from the United Kingdom, where the first smelter was established in 1740, to Silesia (1798), Belgium (1807), Russia (1816), France (1855), the United States (1860), Spain (1866), the Netherlands (1893), Italy (1897), Australia (1903), Norway and Sweden (1911), Japan (1913), Czechoslovakia and Yugoslavia (1919), Mexico (1923), Indochina (1924), Northern Rhodesia (1925), Argentina (1942) and, most recently, Peru (1951) and the Belgian Congo (1953).

In 1938 the under-developed countries refined less than a sixth of their ore output and accounted for less than 4 per cent of the world's primary zinc production (excluding that of the Soviet Union). By 1954, the proportion of ore locally refined had risen to almost a fourth, and their contribution to world production amounted to 7 per cent (table 30).

In absolute terms, however, the construction of smelter capacity has hardly kept pace with the expansion of mine output. In 1925 mine production in the under-developed countries exceeded smelter production by about 164,000 metric tons; in 1953, though smelter production had risen from about 4,000 tons to about 124,000 tons, it fell short of mine production by no less than 516,000 tons. Mine output had also expanded to a greater extent than smelter output in Australia, Canada and Japan. This disparate growth was counterbalanced by changes in the United States and western Europe. In the United States, where mine production exceeded smelter production by about 125,000 tons in 1925, construction of refining facilities was such that by 1953 smelter output was about 334,000 tons greater than mine production. In western Europe, despite a substantial increase in mine output, dependence on imported concentrates was appreciably greater in 1953 than in 1925.

The only under-developed country which refines most of the zinc ore it produces is Northern Rhodesia; output from this source, however, amounts to little more than one per cent of the world total. Another small producer with a smelting capacity large enough to treat all domestic ore at recent rates of mine production is Argentina; in the period 1948 to 1954, however, metal output has not been much over half of ore output, even though part of the intake of the new refinery at Comodoro Rivadavia consists of concentrates imported from Chile.

Since the completion of its electrolytic refinery at Kolwezi in 1953, the Belgian Congo has been able to refine about a third of its ore output at recent rates. The latter have been substantially above pre-war figures and in 1954 accounted for almost 4 per cent of the world total (excluding output of the Soviet Union). Yugoslavia, a somewhat smaller producer, also refines a higher proportion of its ore output than before the war; even so, three-fourths of mine production is still exported as concentrates.

In Peru, where mine production of zinc has risen from a pre-war peak of 21,000 metric tons in 1939 to 60,000 tons in 1946 and 155,000 tons in 1954, smelting capacity has also expanded. A 2,000-ton pilot plant operated by the Cerro de Pasco Corporation during the war was replaced by a 12,000-ton refinery in 1951, and this has since been supplemented by a 23,000-ton plant. In 1954 just over 10 per cent of mine output was locally refined and capacity now exists for treating about twice that proportion at current rates of production. Four-fifths of mine output will continue to be exported in the form of concentrates. Plans for expanding Peruvian capacity by means of a 30,000-ton refinery to process concentrates of too low a grade to be commercially exported, as well as a government-sponsored plant to handle the product of some of the small mines and a certain amount of ore from Bolivia, are in abeyance until the electricity investment programme of the Corporación de Fomento del Santa has been completed.

Mexico, third among producers of zinc ore and contributor of about one-tenth of the world's supply during the past two decades, smelted its first slab zinc in 1923. In 1953 it had a refinery capacity of about 55,000 metric tons, sufficient for about one-fourth of its mine output, contributing between 2 and 3 per cent of the world's production of zinc metal.

---

[27] Most zinc ores contain a high proportion of sulphides and require initial low temperature roasting to convert them to oxides. The roast may be leached by acid solutions which are then electrolysed to form pure zinc sheets. The proportion of electrolytic zinc is tending to increase, but the bulk of the smelter output still comes from retort smelting and distillation. The raw material of the smelter is the oxide roast or a zinc fume derived from the volatilization of the zinc constituent of mixed lead-zinc ores in a specially designed lead smelting blast furnace. The oxides or fume are mixed with hard coal and distilled in small refractory tubes of clay and carborundum, banked horizontally 200 or more together in a coal or gas fired furnace or more recently, in areas with cheap power, in an electric furnace. Experiments with vertical retorts have resulted in important improvements—mechanical charging and discharging and a reduction in the amount of unwanted oxidation within the tubes—but have entailed briquetting the feed, which increases costs.

Table 30. Zinc Ore and Metal Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954

(Thousands of metric tons, metal content)

Region, country and period	Production			Smelter or refinery capacity
	Ore	Metal	Per cent smelted	
Africa:				
Belgian Congo:				
1938	5.9	—	—	—
1948-53	82.1	7.8[a]	6[a]	
1954	82.5	32.0	39	36
Algeria:				
1938	7.0	—	—	—
1948-53	9.5	—	—	
1954	27.0	—	—	—
French Equatorial Africa:				
1938	1.3	—	—	—
1948-53	0.3	—	—	
1954	—	—	—	—
Morocco, French:				
1938	2.8	—	—	—
1948-53	16.5	—	—	
1954	34.4	—	—	—
Northern Rhodesia:[a]				
1938	12.7	10.4	82	26
1948-53	23.5	23.0	98	
1954	31.6	27.0	85	27
South West Africa:				
1938	—	—	—	—
1948-53	13.6	—	—	
1954	16.3	—	—	—
Tunisia:				
1938	0.4	—	—	—
1948-53	3.2	—	—	
1954	5.2	—	—	—
Asia:				
Burma:				
1938	56.7	—	—	—
1948-53	4.1[b]	—	—	
1954	6.5[c]	—	—	—
Indochina:				
1938	5.2	4.5	87	6
1948-53	—	—	—	
1954	—	—	—	—
India:				
1938	—	—	—	—
1948-53	1.0	—	—	
1954	2.3	—	—	—
Europe:				
Yugoslavia:				
1938	44.6	4.6	10	16
1948-53	46.8	11.9	25	
1954	57.3	13.6	24	16
Latin America:				
Argentina:				
1938	15.3	—	—	—
1948-53	13.8	7.3	53	
1954	18.9	11.0	58	22
Bolivia:[c]				
1938	10.7	—	—	—
1948-53	24.8	—	—	
1954	20.4	—	—	—
Guatemala:				
1938	—	—	—	—
1948-53	5.8[d]	—	—	
1954	...	—	—	—

Table 30. Zinc Ore and Metal Production and Smelter Capacity in Under-Developed Countries, 1938, 1948-53 and 1954 (*continued*)

(Thousands of metric tons, metal content)

Region, country and period	Production			Smelter or refinery capacity
	Ore	Metal	Per cent smelted	
Mexico:				
1938	172.2	37.1	22	41
1948-53	202.5	52.9	26	
1954	224.0	55.0	25	55
Peru:				
1938	14.6	—	—	—
1948-53	96.8	3.2	3	
1954	155.0	15.4	10	35
Middle East:				
Turkey:				
1938	17.3	—	—	—
1948-53	1.3	—	—	
1954	...	—	—	—
TOTAL, UNDER-DEVELOPED COUNTRIES:				
1938	366.7	56.6	15	89
1948-53	545.6	106.1	19	
1954	681.4	154.0	23	191
WORLD TOTAL:[e]				
1938	1,829	1,490	82	2,026[f]
1948-53	2,177	1,888	87	
1954	2,300	2,200	96	3,040[g]

Source: United Nations, *Statistical Yearbook, 1954;* American Bureau of Metal Statistics, *Yearbook* for 1939 and 1954; Metallgesellschaft Aktiengesellschaft, *Metal Statistics, 1938, 1946-1953.*

[a] 1953 only, when refining began.

[b] 1952-53; production resumed in 1952.

[c] Exports.

[d] 1950-53; production began in 1950.

[e] Excluding the Union of Soviet Socialist Republics.

[f] Spelter capacity 1,322,000 metric tons (600,000 tons in the United States) and electrolytic capacity 704,000 tons (214,000 tons in the United States).

[g] Spelter capacity 2,127,000 metric tons (981,000 tons in the United States) and electrolytic capacity 1,094,000 tons (387,000 tons in the United States).

Notes on smelters and refineries in individual countries

Belgian Congo and Ruanda-Urundi: An electrolytic refinery built in 1953 at Kolwezi, operated by the Société métallurgique de Katanga.

Northern Rhodesia: An electrolytic refinery built in 1925 at Broken Hill, operated by the Rhodesia Broken Hill Development Company, Limited.

Indochina: A 1,050-retort smelter at Quang-Yen operated between 1924 and 1942 by the Compagnie minière et métallurgique de l'Indochine.

Yugoslavia: A 2,040-retort smelter built in 1919 at Celje, operated by Cinkarna d.d. until 1942, nationalized after the war.

Mexico: A 6,400-retort smelter built in 1923 (expanded to 7,200 retorts during the war) at Rosita, operated by the Mexican Zinc Company, a subsidiary of the American Smelting and Refining Company.

Argentina: Facilities consist of two electrothermic furnaces (capacity 16,000 metric tons a year) completed in 1951 at Comodoro Rivadavia, operated by the Compañía Metalúrgica Austral, S.A., a subsidiary of the St. Joseph Lead Company and an electrolytic plant of 6,000 tons capacity, built in 1942 at Zárate, operated by Meteor Establecimientos Metalúrgicos, S.A.

Peru: An electrolytic plant of 12,000-ton capacity built in 1951 and an electrothermic smelter (total capacity 23,000 tons), one unit of which came into operation in 1954 and the second in 1955; both plants are operated by the Cerro de Pasco Corporation at La Oroya.

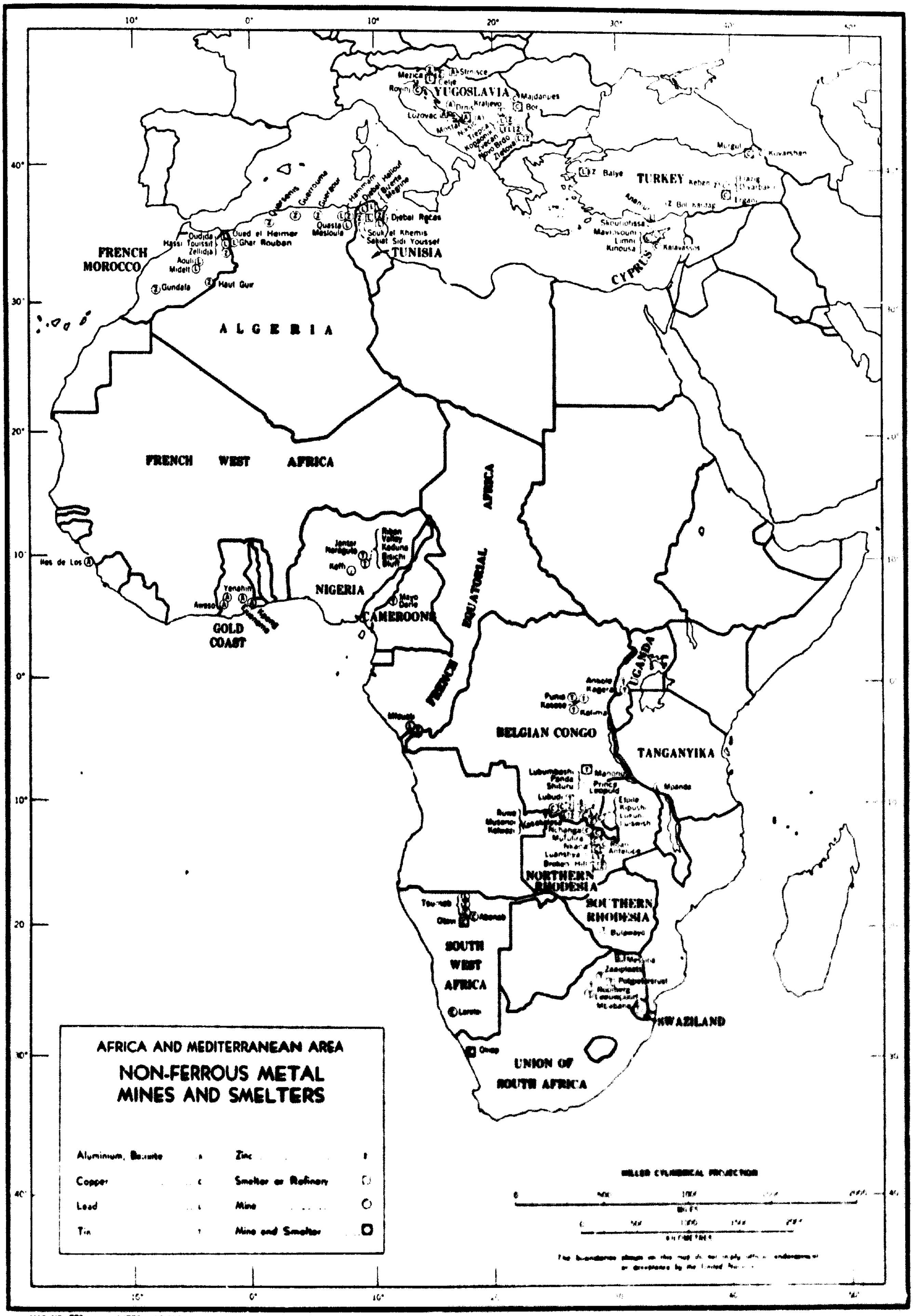
Among the under-developed countries that produce significant quantities of zinc ore, Algeria, Bolivia, Burma, French Morocco and South West Africa still lack smelting facilities. These countries accounted for just over 3 per cent of the world's mine output in the period 1948 to 1953 and 4.5 per cent in 1954. Though refining capacity in under-developed countries was more than doubled between 1938 and 1954, it accounts for little more than 6 per cent of the world total (excluding output of the Soviet Union).

So far as the proportion of output actually used in under-developed countries is concerned, zinc lies between copper and lead; for the group as a whole consumption during the period 1948 to 1951 was about 22 per cent of mine production, for the zinc producing countries of the group, about 14 per cent.

The Belgian Congo, Bolivia, Northern Rhodesia and South West Africa consumed little or none of the zinc they produced. Peru used less than 2 per cent of its domestic output and Mexico about 5 per cent. Since 1953, however, Mexican consumption has tended to increase somewhat, partly because of the completion of a sheet zinc plant which a United States company began building at Avalos in 1952. While exporting about 21,000 metric tons a year in concentrate form during the period 1948 to 1951, French North Africa imported its requirements of primary metal — less than 1,000 tons a year. On a much smaller scale, this was also the course of trade in Turkey.

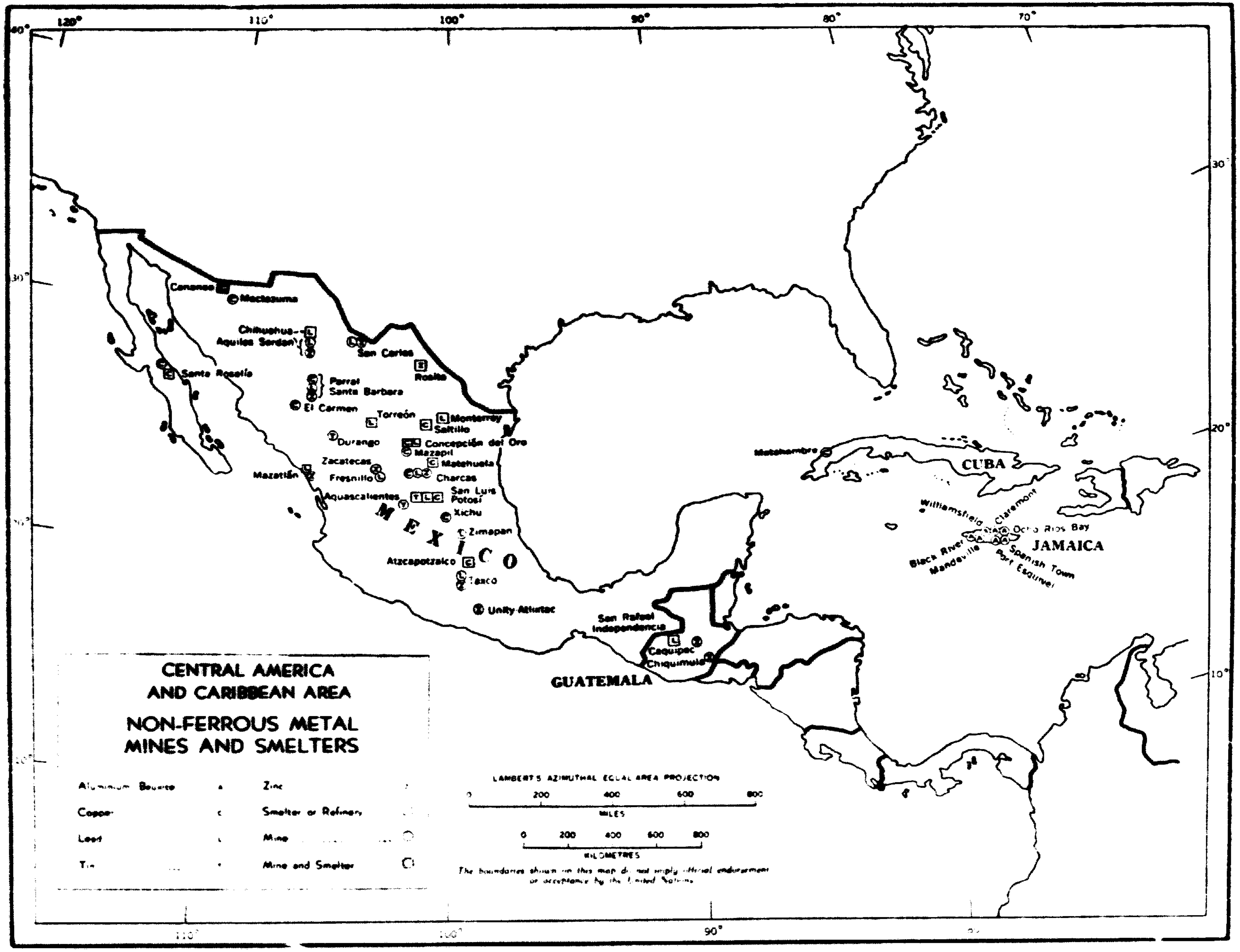
Yugoslavia's annual production during this period was of the order of 10,000 metric tons, of which about one-fifth was consumed locally. The whole of the Union of South Africa's annual consumption of about 13,000 tons was imported, as was Brazil's average consumption of about 10,000 tons. Argentina, by contrast, required only marginal imports to maintain its average consumption of almost 15,000 tons. Chilean consumption was much less (4,000 tons a year) but most of it was imported, even though small quantities of concentrates have been exported in recent years.

In these major Latin American consumers, as in the Union of South Africa, the principal user of zinc is the iron and steel industry, which employs it in the process of galvanizing. This is also true of India, which is completely dependent upon imports for its consumption — about 26,000 tons a year in the period 1948 to 1951.

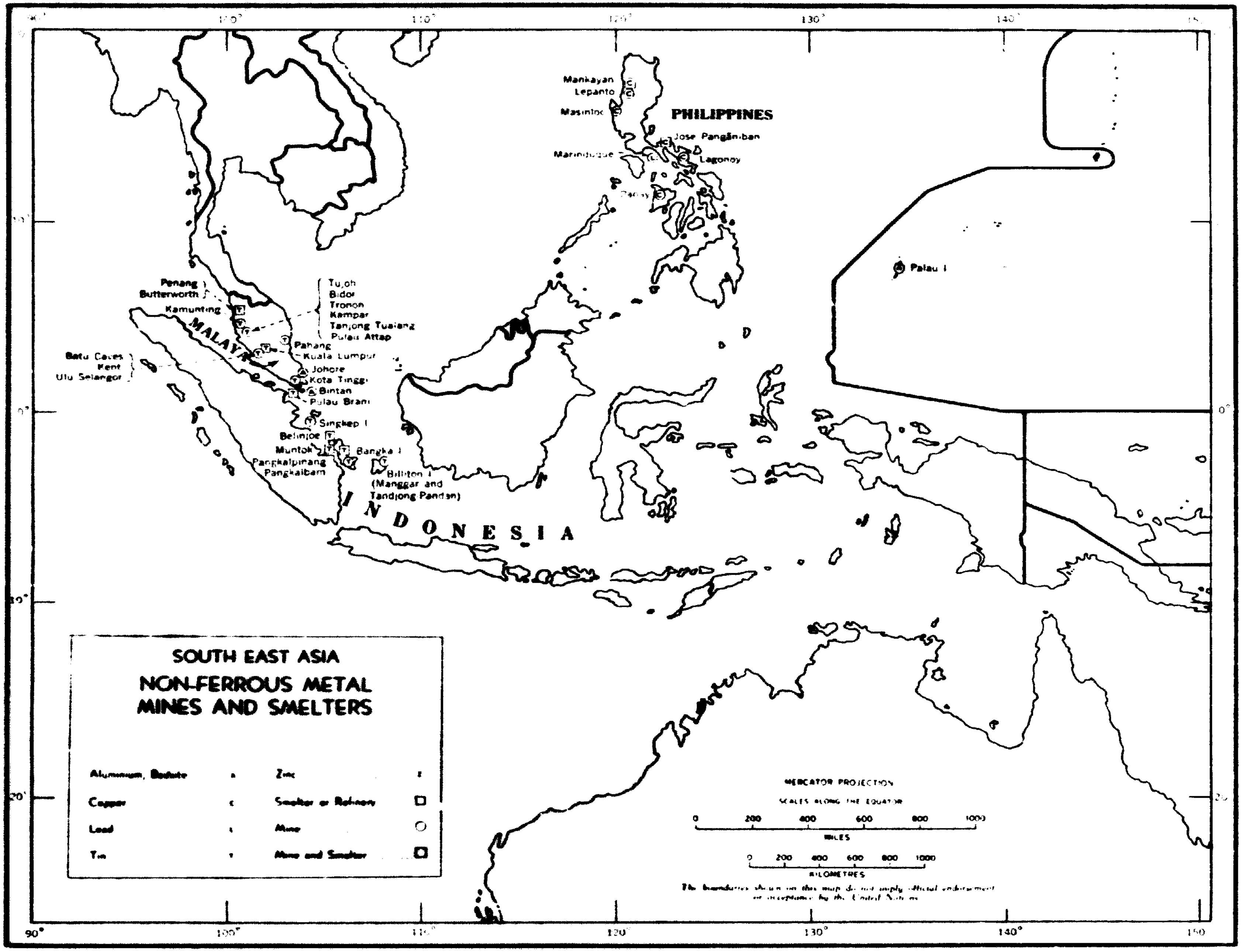


MAP NO 772 UNITED NATIONS
JANUARY 1956

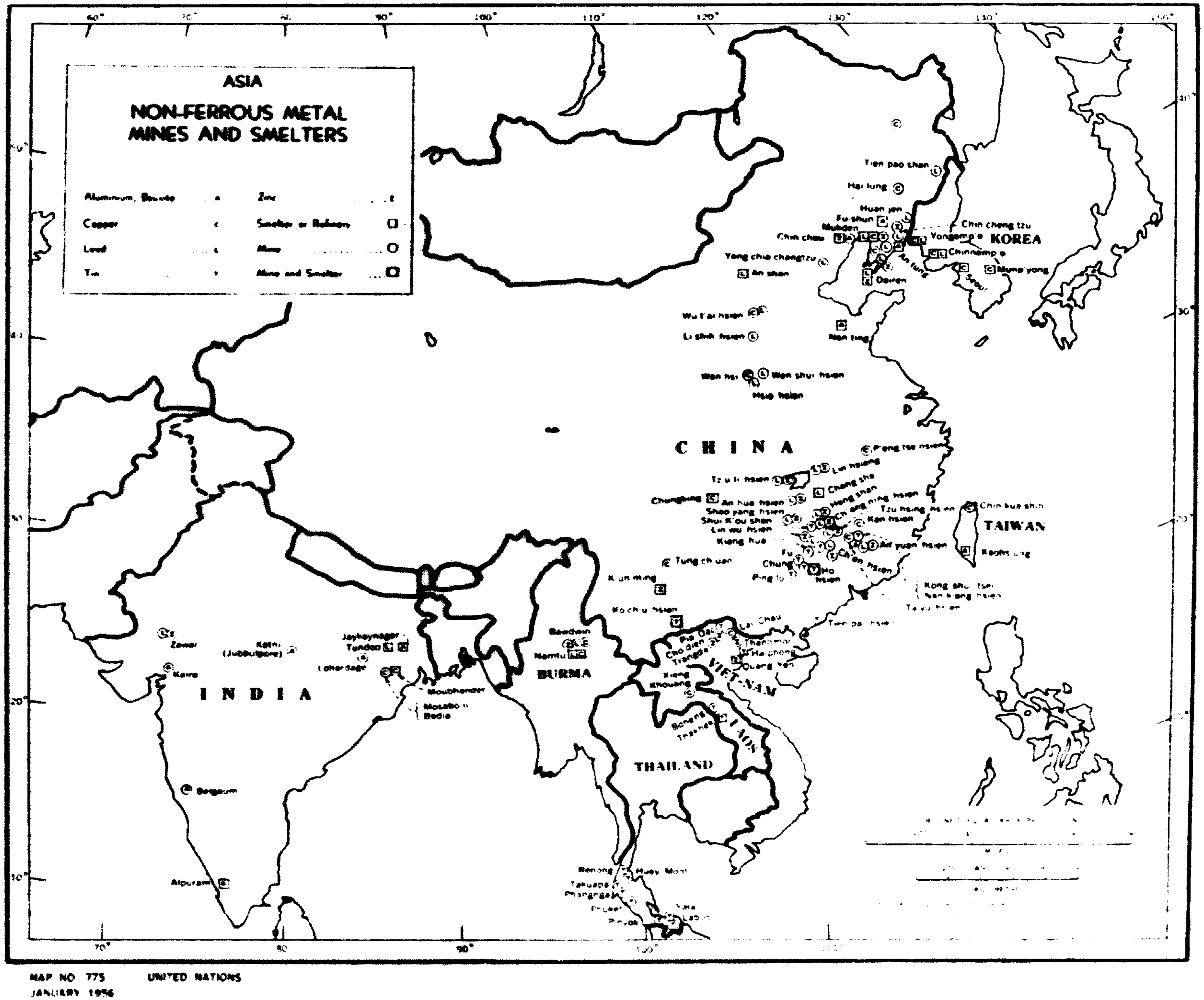
MAP NO. ... UNITED NATIONS
JANUARY 195.

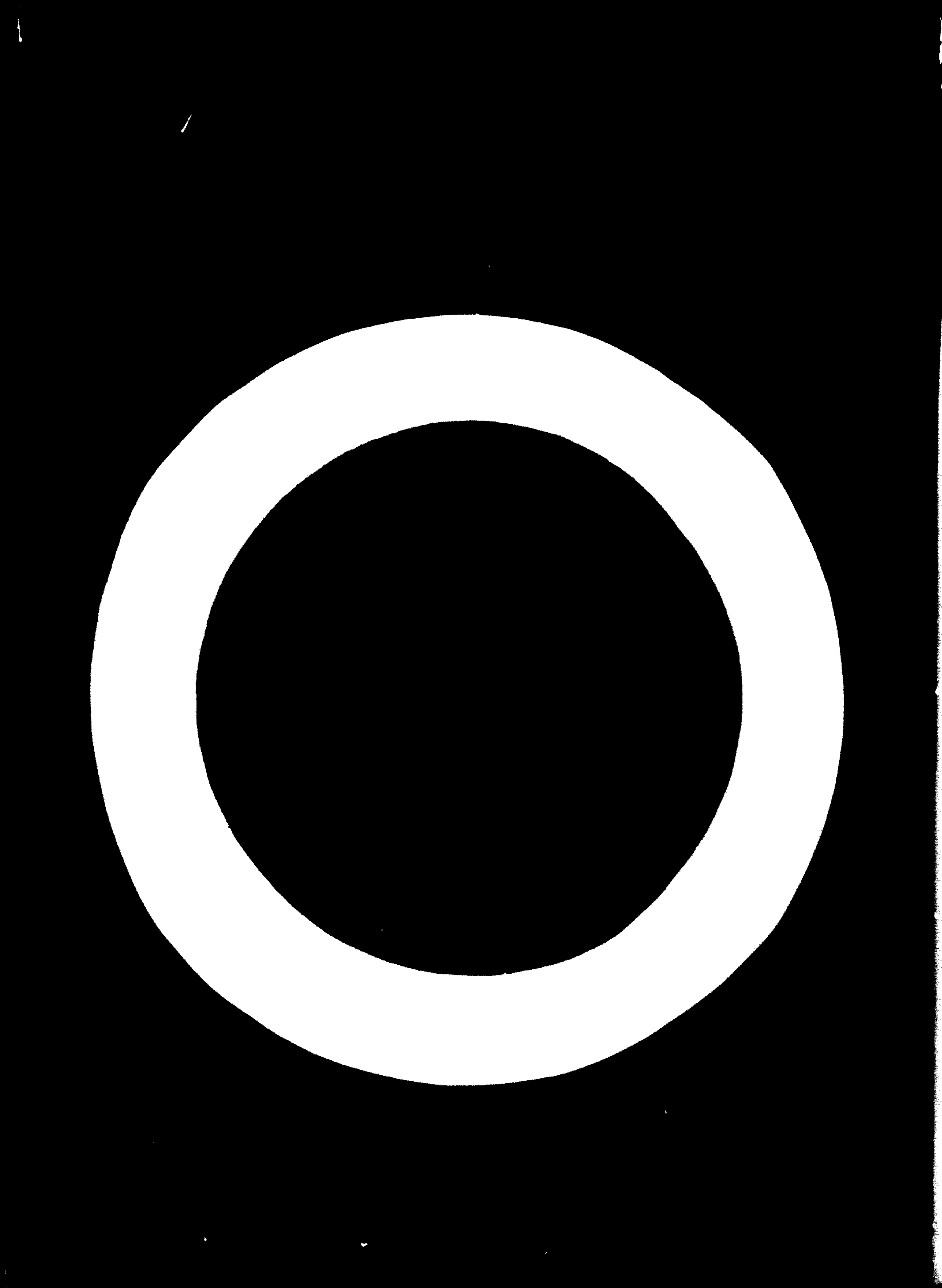


MAP NO. 774 UNITED NATIONS
JANUARY 1956



MAP NO. 776 UNITED NATIONS
JANUARY 1956


ASIA
NON-FERROUS METAL MINES AND SMELTERS
Aluminium, Bauxite
Copper
Lead
Tin
Zinc
Smelter or Refinery
Mine
Mine and Smelter
CHINA
KOREA
TAIWAN
INDIA
BURMA
THAILAND
VIET-NAM
LAOS
Tien pao shan
Hai lung
Huan jen
Fu shun
Mukden
Chin chou
Chin cheng tzu
Yongampo
Chinnampo
An tung
Dairen
Seoul
Yang chia chang tzu
An shan
Wu t'ai hsien
Li shih hsien
Nan ting
Wen hsi
Wen shui hsien
Hsia hsien
Tz'u li hsien
Lin hsiang
Chang sha
Chungking
An hua hsien
Shao yang hsien
Shui K'ou shan
Lin wu hsien
Kiang hua
Kan hsien
Tzu hsing hsien
Chin hua shih
Kao hsiung
Tung ch'uan
K'un ming
Ko chiu hsien
Bawdwin
Namtu
Lai chau
Cho dien
Trangda
Kieng Khouang
Haiphong
Quang Yen
Jaykaynagar
Tundoo
Katni
(Jubbulpore)
Zawar
Kawa
Lohardaga
Moubhander
Mosaboni
Bedia
Belgaum
Alpuram
Ronong
Huey Moat
Takuapa
Phangnga
Phuket
MAP NO 775
JANUARY 1956
UNITED NATIONS



Chapter 5

DEVELOPMENTAL EFFECTS OF THE NON-FERROUS METAL MINING AND SMELTING INDUSTRY

Apart from being a source of supply of one or more of the metals, the types of mining and smelting operations with which this study is concerned fulfil a number of other important functions. To an under-developed resource country, indeed, the fact that a mine yields a particular metal may be of comparatively little consequence, at least until the stage of economic development is reached when that metal can become the basis of specific domestic industries. In the meantime, the nature of the metal is significant chiefly as a determinant of the extent to which it is likely to be saleable overseas: for in the early stages of development, the mine serves its main function by earning foreign exchange for the resource country.

Various aspects of this development function have been mentioned in preceding chapters. It is now proposed to bring together the more significant points by examining the flow of the income which accrues to the mining company as a result of mineral sales, discussing in particular the four main categories of mining expenditure: (1) disbursements made to the labour force working at the mine; (2) payments made to agencies supplying the mine with goods and services necessary for its operation; (3) contributions made to the public purse by way of taxation; and (4) the distribution of the residual profit — to reserves, to reinvestment or to the owners of the mine's capital. For it is through this monetary flow that the mine exercises its principal developmental effects.

Mining differs from most other economic activities in under-developed countries in the extent to which the revenue it distributes is derived from abroad and hence in the degree to which it helps to widen the choice of goods over which the new purchasing power can be exercised, enabling the country to acquire commodities and equipment essential to its development but obtainable only from abroad. To this extent non-ferrous ore mining thus has much the same economic significance as any other export activity. Nevertheless, on the economic level no less than the technical one, mining activities differ from those carried out on a plantation, and the extraction of a mineral involves different problems from those associated with the cultivation of an agricultural crop. Though the flow of export income through the domestic economy exerts its developmental effects in much the same general way, therefore, mining and smelting operations possess a number of features which distinguish them from other export industries. It is the object of the present chapter to bring out these features and to discuss their relevance to the broad problem of maximizing the development potential of the non-ferrous metals industry in general, and the mining section of that industry in particular.

One of the features of mining is its peculiar reaction to fluctuations in the sale and price of its product. As these fluctuations and the resultant reaction have a profound effect upon the flow of income generated by the mine, it is advisable, before proceeding to analyse the nature and effects of the four income streams distinguished above, to discuss the problem of instability and some of its technical and economic consequences.

SOME TECHNICAL AND ECONOMIC EFFECTS OF FLUCTUATIONS IN MINERAL OUTPUT AND PRICE

One of the criteria of the development potential of any industry is its stability, and on this score the non-ferrous metals industry has a far from satisfactory record. For, apart from uncertainty as to the precise extent and nature of the ore resources themselves, the industry has been characterized by substantial short-term fluctuations in demand and price on world markets, which have resulted in corresponding variations in the money proceeds from mineral exports. Some indication of the magnitude of these variations is given by the figures in table 31. Between 1928 and 1950, the largest relative declines in non-ferrous ore and metal export proceeds were concentrated in the years 1930, 1931, 1932 and 1938 and, to a smaller extent, at the end of the war, in 1945 and 1946. During the period 1929 to 1933, indeed, there were numerous cases of large relative declines in proceeds in two or even three successive years, which in many cases reduced the foreign exchange earnings of the under-developed exporting country to very low levels.

Although it is these large and sudden reductions in export receipts which are most disruptive of orderly economic development and of the systematic utilization of available foreign exchange, resources, the general instability of export proceeds during any given period is also an important consideration and one that is perhaps more easily measurable by a single average. Among the 25 cases set out in table 31, the unweighted arithmetic mean year-to-year fluctuation in export proceeds was no less than 27 per cent (table 32). In other words, during the period from 1928 to 1950, the average annual change in the foreign exchange yield of the specified ores and metals exported by the countries in question

Table 31. Fluctuations in Proceeds[a] Derived from the Export

	Percentage decline[b] compared with											
Commodity and country	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*
Antimony ore:												
Bolivia	6	74	+	8	+	+	+	+	+	+	+	+
Mexico	12	27	+	73	+	+	+	+	+	39	2	+
Bauxite:												
Guiana, British	+	25	+	48	49	+	+	+	+	+	+	24
Surinam	+	+	35	28	15	+	1	+	+	3	+	29
Copper, concentrates and metal:												
Belgian Congo	+	6	48	70	+	+	8	+	+	40	+	+
Chile	+	44	34	69	+	+	+	+	+	30	+	+
Mexico	+	26	52	56	+	+	13	9	+	30	+	13
Peru	+	27	38	68	+	+	+	+	+	+	1	+
Lead, concentrates and metal:												
Algeria	+	30	43	+	83	71	+	+	+	33	26	+
Mexico	+	22	31	43	15	+	+	+	+	11	20	+
Morocco, French	+	6	88	+	100	+	+	+	+	16	+	+
Tunisia	+	17	27	32	+	+	+	−	+	49	−	+
Tin, concentrates and metal:												
Belgian Congo	+	54	79	+	+	+	+	+	+	18	6	+
Bolivia	+	42	40	43	+	+	+	19	+	23	+	+
Malaya	+	35	39	55	+	+	+	+	+	57	+	+
Zinc, concentrates and metal:												
Mexico	+	50	23	61	+	+	+	+	+	20	14	+
Peru	+	39	100	+	+	+	13	+	+	42	+	+
Chromite:												
Southern Rhodesia	+	24	59	83	+	+	+	+	+	30	26	+
Turkey	+	+	4	+	+	+	+	+	+	+	14	+
Manganese ore:												
Brazil	+	38	36	87	+	71	+	+	+	+	23	+
India	+	22	40	61	1	+	+	+	+	+	20	+
Nickel ore and concentrates:												
New Caledonia	+	+	10	31	2	+	5	40	+	+	+	+
Tungsten ore:												
Bolivia	+	57	60	+	61	+	+	+	+	+	+	+
Burma	+	+	12	6	+	+	+	+	+	−	+	+
China	+	36	18	69	+	+	+	+	+	69	13	9

Source: Calculated from national statistics by United Nations Bureau of Economic Affairs, Resources and Industry Branch.

[a] Computed in United States dollars at official rates of exchange.

was, on the average, from an index of 100 in any one year to an index of 73 or 137 in the next.[1] The median fluctuation was also about 27 per cent, one-half of the 25 cases studied showing average year-to-year movements greater than this.

The average annual variation of 27 per cent recorded by these non-ferrous metals was greater than that recorded by agricultural exports and other primary exports of under-developed countries during the same period.[2] Both for the non-ferrous metals and for the other primary commodities, fluctuations in proceeds were greater than either those of price or those of volume taken separately. The tendency of price and output to move in the same direction, mutually reinforcing rather than compensatory, was somewhat more marked among the metals than among the agricultural commodities, indicating that, in general, mining activity is likely to respond more rapidly to a change in the price of the product than is agricultural activity. In both groups, however, instability of output contributed more to the fluctuations in export proceeds than did instability of price, the differences being rather greater among the metals, especially among the minor metals. Only in the case of copper from Peru and tin from Bolivia was price instability greater than volume instability. Average variation in price was much the same for the major non-ferrous metals — copper, lead, tin and zinc — as for the agricultural commodities. The other metals and ores, particularly bauxite, chromite and nickel, showed much less variation in price, so that average price fluctuation

[1] See footnote *b* of table 32.

[2] United Nations, *Instability in Export Markets of Under-Developed Countries* (sales number: 1952.II.A.1).

of Certain Non-Ferrous Ores and Metals, 1928 to 1950

preceding year										Number of declines in 22 years	Average magnitude of declines (per cent)	Number of major declines[a]
1941	1942	1943	1944	1945	1946	1947	1948	1949	1950			
+	+	+	59	26	+	+	+	12	35	7	31	3
9	+	+	20	20	18	+	+	18	22	11	24	3
+	+	+	52	17	+	+	+	11	13	8	30	3
+	+	+	54	+	+	+	+	+	8	8	22	4
+	+	+	+	7	–	+	+	21	+	7	29	3
+	+	+	+	5	17	+	+	24	7	8	29	4
+	+	+	14	+	+	+	+	14	+	9	25	3
17	4	1	–	1	16	+	12	+	+	10	19	3
35	100	+	+	74	+	+	14	+	+	10	51	8
21	+	+	15	+	+	+	3	+	+	9	20	2
54	35	+	+	+	+	+	+	+	+	6	50	4
+	39	69	+	+	+	+	+	+	+	6	49	5
+	+	+	+	+	8	+	+	+	+	5	33	2
+	6	+	1	+	3	+	+	3	12	10	19	3
1	80	+	63	68	+	+	+	+	+	8	40	7
+	+	+	+	4	28	+	+	10	+	8	26	3
+	+	+	+	+	+	+	+	+	+	4	49	3
+	+	17	3	33	18	8	+	+	+	10	30	4
19	14	+	+	19	29	12	+	+	7	8	15	1
+	22	23	+	+	29	17	6	+	12	11	33	5
+	4	17	25	41	+	+	–	+	+	9	26	3
12	36	20	+	27	17	18	26	+	+	12	20	4
+	+	+	+	53	48	+	6	13	+	7	42	5
7	81	–	2	4	78	+	+	66	3	9	29	3
+	+	27	64	15	9	+	+	8	+	11	31	5

[b] A plus sign indicates an increase; a dash indicates no change.

[a] More than the arithmetic average fluctuation of 27 per cent.

was somewhat less for all ten non-ferrous metals than for the group of agricultural raw materials.

In general, sudden and frequent variations in the volume of ore produced, in the cost of producing it and in the amount of foreign currency realized when it is sold abroad all tend to retard and make more difficult and more erratic the process of economic development based on the mineral industry. Fluctuations in production, cost and revenue directly affect the volume of employment and the reliability of the four income streams which determine development potential, thus disrupting the various dependent functions. Some of the implications of this are analysed in succeeding sections of the present chapter.

Fluctuations of this nature also influence mining policy itself. The initial technical plan for exploiting a given deposit of ore is based on certain assumptions regarding the future course of the relevant economic and fiscal variables, both in the producing and in the consuming countries. Subsequent mining development takes into account the relative movements of these variables, and, for any individual mine, if not always for the larger integrated non-ferrous metal systems, the average grade of ore extracted at any particular time tends to be the one, technical factors permitting, that would maximize net profit (after tax).[3] Consequently, rapid changes in cost-price relations, whether caused by market fluctuations or by fiscal changes, are very disruptive of exploitation plans, complicating considerably the problem of making the most of a given ore body.

[3] The tendency for the integrated systems to aim at the maximization of profit for the organization as a whole rather than for any constituent mine is examined in a later section of this chapter.

23.7.74

3 OF 3

DO

3841

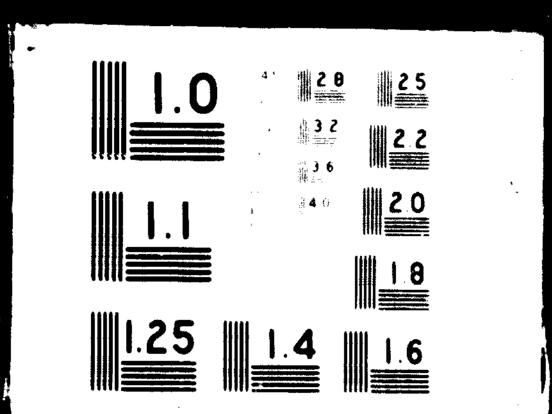


Table 32. Average Fluctuations in Volume, Price and Proceeds[a] of Exports of Certain Non-Ferrous Ores and Metals from Selected Under-Developed Countries, 1928-50

Commodity and country	Year-to-year fluctuations as per cent of higher value[b] Volume	Price	Proceeds
Antimony:			
Bolivia	21.4		27.9
Mexico	21.2		29.2
Average	21.3	13.8	28.6
Bauxite:			
Guiana, British	29.0		28.4
Surinam	22.0		23.3
Average	25.5	6.1	25.9
Copper:			
Belgian Congo	13.7		22.4
Chile	15.3		23.5
Mexico	14.3		21.9
Peru	12.7		18.5
Average	14.7	13.1	22.8
Lead:			
Algeria	44.9		50.1
Mexico	16.3		21.9
Morocco, French	37.5		42.2
Tunisia	20.6		27.0
Average	20.5	14.2	26.0
Tin:			
Belgian Congo	23.5		27.5
Bolivia	13.8		19.8
Malaya	33.7		40.6
Average	25.9	13.8	32.2
Zinc:			
Mexico	17.1		23.6
Peru	31.3		37.7
Average	19.5	12.1	26.0
Chromite:			
Southern Rhodesia	29.8		31.9
Turkey	22.9		24.4
Average	26.4	5.7	28.2
Manganese:			
Brazil	30.7		34.1
India	22.3		23.6
Average	24.4	7.5	26.2
Nickel:			
New Caledonia	23.7	2.9	23.5
Tungsten:			
Bolivia	30.9		35.2
Burma	24.1		28.0
China	27.3		30.5
Average	27.4	10.0	21.2
Simple arithmetic average of above case studies	22.9	9.9	27.1
Weighted arithmetic average of above case studies[c]	19.9	11.6	25.8
Simple arithmetic average for 18 primary commodities and 46 case studies[d]	20.4	14.1	25.1

Source: United Nations, *Instability in Export Markets of Under-Developed Countries* (sales number: 1952.II.A.1).

[a] Computed in United States dollars at official rates of exchange.

[b] Downward fluctuations have been measured in the conventional manner as percentages of the starting value, but upward fluctuations have been measured as percentages not of the lower starting value but of the higher value which followed. This gives figures somewhat lower than would be the case with conventional measurement. The reason for adopting this method of calculation is explained in *Instability in Export Markets of Under-Developed Countries*, appendix B.

[c] Metals weighted according to value of quantities consumed in the United States, 1928-50.

[d] The commodities and cases are those analysed in *Instability in Export Markets of Under-Developed Countries*, but for purposes of comparison, the average fluctuations have been computed for the period 1928 to 1950.

In the course of mining operations, at least when these are conducted on a selective basis, once a pocket of low-grade ore is by-passed as uneconomic under existing conditions, it is unlikely that technically favourable circumstances will ever recur for its later extraction. Anything which makes for the abandonment of ore in this way tends to shorten the effective life of the mine. When the Leadville mines of Colorado were closed down in 1933 because of the low price of lead, the area became inundated and ten years' work plus the expenditure of large sums of money had not succeeded in getting the mines back into production by 1951.

The course followed by an autonomous mine reacting to a decline in metal price will depend on such considerations as expectations concerning the future trend in prices, the relation between its cost schedule and the current market price of its product, the ratio of variable to fixed costs and the extent to which it is technically feasible to reduce activities without unduly prejudicing future production. A temporary recession in prices may not affect mining policy greatly, whereas, if price remains below cost for any length of time, mining policy is likely to be adjusted and every effort made to minimise losses.

In general, a high-cost mine is likely to be affected by a price decline more seriously than a low-cost mine, and if the price recession continues, adjustments of total supply tend to be made by the elimination of marginal mines (in the absence of any cartel arrangement for proportionate reduction of output). As long as variable cost is being covered, a highly capitalized mine,[4] though postponing new development, may tend to continue producing from at least some of its working faces, perhaps putting the rest on a care and maintenance basis to preserve timbering, prevent flooding and protect fixtures.

Small workings, especially surface workings, such as the tungsten mines of Argentina, Bolivia or Southern Rhodesia[5] or the antimony mines of China, might be closed down with relatively less loss to their operators than in the case of larger mines, which may be prevented by both technical and financial considerations from suddenly contracting. Where selective mining is practised by the larger mine, however, a temporary solution may be sought by raising the average grade of ore extracted, leaving untouched ore which under the new conditions of price and cost has ceased to be payable.

The effect of the 1930 to 1932 depression on the larger Bolivian tin mines, for example, was to concentrate production on the richer and more accessible lodes, probably to the detriment of long-range mining policy.[6] As flexibility of wage bill adds to the relative advantage that smaller mines with lower fixed costs tend to have in the face of a decline in metal price, this may have been one of the conditions that enabled the small Bolivian tin mines, which had lost ground between 1926 and 1929, to maintain production better than the larger mines between 1931 and 1935.

In Chile, however, the depression reduced output among the small copper mines almost as much as among the large mines.[7] Here, as in some of the other Latin American countries, small mines with their relatively higher wage bill have been favoured from time to time by currency devaluation or flexible exchange rates which have reduced their unit costs (payable to local factors of production) in relation to the foreign currency equivalent payable by the larger mines for the acquisition, maintenance, and amortization of imported capital equipment. In Malaya, on the other hand, the larger tin mines, many of which had installed costly dredging units during the nineteen twenties, endeavoured to keep down average costs and to take advantage of the new capital expenditure by maintaining a fairly high level of production during the following decade. This raised appreciably their share of total output, and the main burden of the decrease in production during the depression fell on the smaller units using gravel pumps and other hydraulic methods of mining.

Conversely, in times of rapidly rising metal prices, it has usually been the small mines which have been first on the market with marginal increases in ore supply. The larger mine, unless it is an opencast working, is likely to need a much longer time to speed up its development programme, open up new faces and prepare for the extraction of larger tonnages. Once the necessary new investment has been made, however, the contribution to increased output coming from the larger mines is likely to be very much greater than from the small workings, even though the latter may be more numerous.

The contrast between large mines and small workings has been accentuated in recent years by the evolution of mass mining, described in the previous chapter. In the case of the major non-ferrous metals, mass mining, associated with a large and continuous flow of unselected ore, continuous flotation, beneficiation and reverberatory furnace and converter smelting, has made it profitable to work suitable bodies of ore of very low tenor, thus making it possible, for example, for ores containing less than one per cent copper to be successfully exploited in the United States in the face of competition from 3 per cent ores in Chile and Northern Rhodesia.[8] Although the suitability of a deposit for mass or non-selective mining may be extremely important in holding down

[4] In this context, capitalization is not merely a matter of the amount of capital employed; it depends also upon the capital structure, rigidity being increased by debentures and other fixed interest-bearing debt.

[5] A typical small scheelite property might operate with little more in the way of fixed capital than a "jaw breaker", a light three-stamp mill or mineral jig and a james table.

[6] See K. Knorr, *Tin under Control* (Stanford University, 1945).

[7] In Chile, perhaps the clearest demonstration of the strategic importance of flexibility in costs is furnished by the nitrate industry, in which, in the years following the devaluation of the peso in 1932, the mines using the simple Shanks process gained appreciably over those using the more highly capitalized Guggenheim process.

[8] One effect of this development has been a considerable increase in labour productivity. For example, between the end of the First World War and the beginning of the Second, the expansion of open-pit mining in the west, combined with improvements in beneficiation techniques, resulted in a doubling of the productivity of labour in United States copper mines (measured in tons of metal output per man-day).

costs, the fact remains that, even with this type of mining, the lower the grade of ore the nearer the mine is likely to be to the margin of payability, the less flexibility mining policy will have and, from the point of view of the under-developed resource country, the lower its development potential will be.

Where mass mining is practised, the fact that it tends to be much less sensitive to price changes than selective mining may be an advantage to the resource country at one time and a handicap at another. On the one hand, operations are not unduly affected by a short recession: it is only by continuous capacity or near-capacity throughput that mass mining can successfully offset the poverty of the ore with which it is commonly employed. On the other hand, flexibility of production policy is sometimes an advantage, and in this respect a raising of ore grade or a reduction of output and average cost are much more easily effected when mining is selective. Thus, among underground mines during a long period of low prices, such as in the early nineteen thirties, caving and shrinking and other techniques associated with mass mining lost considerable ground in relation to selective mining, especially in the United States. Where mass mining can be carried on by open cut methods, however, as it has been at Chuquicamata in Chile and in many of the western United States workings, temporary reduction or cessation of production is effected more easily and with smaller losses and less chance of permanent damage than in the case of underground mining, whether by mass or selective methods. In this connexion it is of interest to note that the Nchanga mine in Northern Rhodesia has recently increased the flexibility of its extraction policy by working two ore bodies simultaneously: a high-grade deposit (with an estimated reserve of 37 million tons of ore containing an average of 7 per cent copper) by traditional underground methods and a larger and lower-grade deposit by opencast methods.

While it is true that the large and highly capitalized mine as an autonomous unit is less likely than the smaller mine to change its rate of extraction in response to short-term changes in market conditions, it should also be borne in mind that the former is usually in a stronger bargaining position and hence more likely to be willing to forgo some of its independence by entering into production and price agreements with other mines. Cartel history, reviewed briefly in chapter 3, indicates that when organized adjustments to market conditions have been made it has been the larger mines whose production policy has been affected most. In the face of adverse market conditions, small independent mines have been known to maintain or even expand production under the unintended protection of some restrictive agreement which imposed the main burden of cutting back output upon the large member units. This presupposes smelting and refining by the independent mine itself or alternatively, and more frequently, the willingness of certain smelters and refineries to treat its ore on toll. The small mine can get no more than the market price for its output, but this price, however low, is presumably higher than it would have been had the larger mines not acted in concert to curtail production in the face of reduced demand.

Adjustments are more complicated in mines in which the ores yield more than one metal. At one time, for example, lead output in Mexico was influenced by the price of silver even more than it is today. Copper output from the Sudbury deposits in Canada has sometimes been a function of the price of nickel. Changes in the relationship of zinc to lead prices have brought about changes in exploitation policy at the Broken Hill mine in Northern Rhodesia, while in the United States the lead-zinc mines in recent years have sought to have a minimum combined price of lead and zinc recognized as the basis for the application of tariff or subsidy plans.

When they are neither too large nor too lengthy, production adjustments may be made by means of changes in stocks, especially in mines which yield complex ores. When the price is low a secondary ore may not be worth beneficiating and after separation from the main ore it is left to accumulate against the day when a rise in price justifies its treatment. This has happened from time to time with low-grade zinc ores mined in Peru. Similarly, at Gravelotte in the Union of South Africa what was primarily a gold mine before the Second World War became the world's largest antimony producer in the post-war period: the rise in the price of antimony in 1950/51 encouraged a considerable increase in production, but when the price declined in 1952/53 output of concentrates fell, stocks of ore were allowed to accumulate and gold again became the more important product. A similar situation arises in connexion with certain processing techniques. When a low price does not warrant complete extraction of the metal, tailings may be accumulated with a metal content high enough to justify further treatment when the price increases. The rise and fall of stocks of this nature in response to market changes tend to increase the elasticity of supply, which for most non-ferrous metals is normally rather low.

The preceding discussion indicates that both mine production and mining policy need to be kept under constant review if net returns are to be maximized in the face of physical uncertainties in respect to the ore body and economic uncertainties in respect to the market. In general, the resultant fluctuations tend to disrupt the flow of trade and income, and create or aggravate difficulties for the under-developed mineral economies. Moreover, despite the attraction of occasional speculative profit it is probable that violent fluctuations which unduly magnify the risks of long-term mining investment tend — by putting a premium on predatory techniques of mining aimed at "picking the eyes" of the deposit in question — to discourage such investment and hence to make the effective and beneficial exploitation of the country's mineral resources slower, more difficult and more costly.

Nevertheless, just as the physical uncertainties of mining may be lessened by the accumulation of more accurate and detailed geological knowledge and by improvements in the techniques of ore extraction and beneficiation, so may it not be impossible for the economic uncertainties of the minerals industry to be reduced. The major cause of fluctuations in the demand for non-ferrous metals would be removed if large variations in the rate of investment in the industrial countries were smoothed out. Where the forces which make for sudden and drastic changes in the demand for metals in the industrial countries cannot be entirely eliminated, then at least it may be feasible to reduce their disruptive effects, perhaps by the negotiation of price- and trade-stabilizing agreements between producing and consuming interests. It is of interest to note that this point of view was expressed in the report of the President's Materials Policy Commission (the Paley Commission) in the United States in 1951 which, in acknowledging the harmful effects of violent fluctuations of price and output, while deprecating both the national schemes for protecting domestic producers and the international schemes for restricting output which were so prominent during the inter-war period, concluded that greater stability should be sought through multilateral contracts or through international buffer stocks, reinforced if necessary by limited quota arrangements. Both the multilateral contract and the international buffer stock would probably have to be provided with an element of flexibility by being organized to operate within a price range to be determined from time to time by agreement between the principal producing and consuming countries. The Commission suggested that production quotas would probably not be required for metals — such as aluminium or copper — the demand for which has shown a definitely rising secular trend, but might be necessary for a metal such as tin whose future consumption trend is much less certain. As indicated in chapter 3, the International Tin Agreement that was signed in July 1954 conforms fairly closely to the pattern suggested in the Paley report, even though the United States — the largest consumer — was not a party to it.[9]

WAGE PAYMENTS AND EMPLOYMENT

In some ways the most important stream of income generated by the non-ferrous metal and ore export industry is that which passes to local labour. The proportion of the realized value of the product that accrues to the workers employed varies considerably from mine to mine, depending, in particular, upon the nature of the deposit, the techniques used in its exploitation and the prevailing wage rates. Where traditional techniques of underground mining are practised on a fairly large scale, for example, wages may absorb between one-fourth and one-third of the total revenue derived from the sale of minerals. On properties on which opencast mass mining is practised, the proportion is likely to be appreciably lower, whereas for smaller mines, where the ratio of labour to capital is much higher, wage payments are likely to account for a much greater proportion of total revenue.

The difference may be illustrated by comparing the average ratios of the wage bill to the value of mineral output in Northern Rhodesia and Southern Rhodesia (table 33). In recent years the relative importance of wage payments has been almost twice as great in Southern Rhodesia, where between 400 and 600 comparatively small mines — gold and non-metallic as well as non-ferrous — have been operating, as in Northern Rhodesia, where the industry is dominated by a small number of large non-ferrous mines.

Table 33. Value of Mineral Output and Wage Bill of all Mines in Northern and Southern Rhodesia, 1949 to 1954

(Millions of Rhodesian pounds)

Year	Value of mineral output: Northern Rhodesia	Value of mineral output: Southern Rhodesia	Total mine wage bill[a]: Northern Rhodesia	Total mine wage bill[a]: Southern Rhodesia	Ratio of wage bill to output (per cent): Northern Rhodesia	Ratio of wage bill to output (per cent): Southern Rhodesia
1949	35.6	11.3	7.6	3.6	21	32
1950	49.3	13.6	8.9	4.5	18	33
1951	72.2	15.1	12.0	5.2	17	34
1952	78.9	17.8	13.5	6.3	17	35
1953	95.0	19.5	16.6	6.4	18	33
1954[b]	97.5	18.8	19.1	6.5	20	35

Source: Federation of Rhodesia and Nyasaland, *Monthly Digest of Statistics* (Salisbury), April 1955, pages iv and xiv.

[a] Partly estimated; including payment in kind.
[b] Provisional.

In general, the higher the wage rate and the greater the total wage payment to mining employees, the more favourable is the effect on local levels of living likely to be. From the point of view of resource utilization, the limit to the amount paid to workers is set in the last analysis by the fact that every increase in the wage bill is reflected to a greater or lesser extent in higher working costs, and is therefore likely ultimately to strengthen the forces which tend to reduce the incentive for extracting the less accessible and poorer grade ores and hence to shorten the life of the mine. Although

[9] Some of the problems referred to in this paragraph are discussed in greater detail in United Nations, *Commodity Trade and Economic Development* (sales number: 1954.II.B.1).

high local wage payments may be an important economic stimulus to the area in question, it has to be borne in mind that, in the long run, the development potential of a mine depends also on the extent to which the entire ore body is effectively exploited.

Apart from the payment of wages and the direct benefits flowing from this generation and distribution of income, one of the ways in which a mine may realize part of its development potential lies in the broader effects of the employment it provides. In many underdeveloped countries, for example, the opening of a mine has been the means of introducing division of labour and the process of commercialization into areas in which economic organization had been largely of a subsistence nature. The resultant gain in productivity and production has been greatest in those countries in which rural under-employment had previously been most prevalent, and least in those places where the competitive pull of the mines has tended to disrupt an established agricultural economy through which at least internal demand had previously been satisfactorily met.

Even where the economy is organized largely on a subsistence basis and is characterized by a fairly high degree of under-employment, however, the diversion of workers to the mines at too rapid a rate or on too large a scale may have harmful social and economic effects on the country as a whole. At one stage, one of the difficulties in the Belgian Congo, for example, was the serious disequilibrium caused by the rapid development of mining and ancillary enterprise which depleted the rural population in several parts of the country and began to threaten not only the advance of agriculture but even basic food supplies. Where the mine employs migrant labour on short-term contracts other difficulties may arise: the educative effects of employment tend to be reduced and the traditional social order may be disrupted without necessarily being made more productive.

Nevertheless, the fact remains that in most of the under-developed areas, mining employment is usually more productive than most other forms of occupation, especially when metal prices are high and especially in countries in which there is a large population in the subsistence sector of the economy. In recent years, in Latin America, for example, employment in mining has accounted for less than one per cent of the total working population, although in 1950 it was responsible for about 4 per cent of the combined gross national product. Measured in these terms, productivity in mining was between two and three times as great as that in transport and public utilities, or in manufacturing and building, or in commerce and other services and about eleven times as great as the average productivity of agricultural labour.[10]

In most of the less developed countries, mine workers, as a result of their higher productivity, tend to receive higher average money wages than workers in occupations requiring comparable skill and effort. In the case of the large mines, moreover, money wages have been supplemented to an increasing degree with various types of services — medical and hospital attention, schooling, sports and recreation, and so on — which have tended to raise real levels of living even further above those of other groups of workers and have extended the educative effects of mine employment. At some mines, an increase of real income is achieved by means of the operation of stores, which make goods available to employees at prices lower than those customarily charged in the area.

On the other hand, in many instances mining is still an arduous and unpleasant occupation, while in other cases it involves attracting workers to remote, and sometimes uncongenial, districts where amenities are few and alternative employment non-existent, at least in the early years of the mine's operation. The opening up of a region that may later prove to be of crucial importance in the economic development of the country may thus entail unfavourable conditions of employment, at least in the initial phase. Such disadvantages usually have to be offset by higher cash wages. This was the case in central Africa, for example, in the early years of the Katanga and Northern Rhodesia copper mines, and to a less extent in Bolivia during the opening up of the very high and very dry tin-bearing area.

In Chile, where the early colonial copper, silver and gold mines had been manned largely by forced labour, it was the nitrate mines that, in the second half of the nineteenth century, provided the country with its first field of large-scale wage employment, thus furnishing workers who had previously been engaged in agriculture with their first training in industrial activity. Later, in the second decade of the twentieth century, the new copper mines benefited by being able to draw to a certain extent on this labour, though a nucleus of specially trained technicians and specialists had to be brought in from abroad by the responsible United States companies.

Skilled workers have also come from foreign countries to Northern Rhodesia and the Belgian Congo, where the greater number of mine labourers are from the indigenous subsistence society, not only within the territories in question but also from as far afield as Nyasaland and to a lesser extent Tanganyika and Angola. In Malaya, too, many of the foreign-owned tin mining companies have drawn the top stratum of workers from abroad, chiefly from Europe. In the past, the rest of the labour force has also been transient, consisting for the most part of immigrants from India and China, some under indenture for limited periods of service. The larger mines in Bolivia, until nationalization in 1952, were also under the technical direction of foreign specialists. The rest of Bolivian mine labour is entirely indigenous, but throughout the history of mining in that country such labour has been difficult to obtain. The silver mines used forced labour until well into the eighteenth century, while the tin mines, situated, as indicated above, in an unpleasantly high and arid part of the country, have always found it hard to attract and retain workers. The expansion during the first decade of the twentieth cen-

[10] United Nations, *Economic Survey of Latin America, 1951-52* (sales number: 1953.II.G.3), chapter 1.

tury, that brought the tin mining labour force up to about 15,000 by 1910, was achieved largely by means of a substantial increase in real wages, which contributed, incidentally, to the difficulties of the silver mines, several of which, being unable to compete successfully for workers, were forced to close.

In general, the mine that employs and trains local labour is realizing a higher development potential than one that employs foreign transients, especially when mining activity is appreciably more productive than that in which the indigenous workers had previously been engaged. As suggested above, the effect is most marked when the previous status was one of rural under-employment, as it often is in under-developed semi-subsistence economies. The gain is reflected not only in the enlarged flow of internal incomes but also in the higher capacity and skill, not least in the managerial field, acquired by the workers: the former tends to expand the domestic market for consumer goods and add to the country's potential source of savings, while the latter prepares workers for more diverse and more productive employment, thus facilitating the process of industrialization.

Development of the mining industry itself helps to extend the range of employment, as the proportion of workers employed in the process of ore extraction declines and the proportion employed in associated metallurgical operations increases. In Chile, for example, though the total number of workers in the large copper mines was the same in 1937 as in 1913 (rather more than 18,000) the proportion engaged in extraction and transport had fallen from 77 per cent to 44 per cent, while the proportion engaged in processing showed a corresponding increase.

In so far as an under-developed area is characterized by an abundance of labour in relation to available capital — and in consequence by a considerable degree of under-employment or disguised unemployment — the capacity of a mine to absorb labour is an important measure of its development potential. In this connexion it should be noted that mass mining, despite its economic advantages in the way of lower costs and lower pay limits, may, because of its higher degree of mechanization, its greater dependence on imported equipment and its relatively low labour requirements, be less effective in its development effects than smaller scale or selective mining.

In Malaya, for example, mechanization, which started with a steam engine and centrifugal pump in 1877 and increased rapidly after 1912 when the first dredge was introduced, has been the main reason for the decline in employment as well as the displacement of small miners (usually Chinese), whose contribution to gross mine output declined from more than three-fourths in 1910 to about one-third in 1950. Total employment in tin mining, which was 79,000 in 1931, had dropped to 46,000 in 1950, a decline of 42 per cent — compared with a decline in output of only 14 per cent — from almost 4 per cent to less than 2 per cent of the country's working population.

Similarly, in Chile the mechanization of mining processes brought to an end the expansion of mining employment, the peak (for all mining) of 85,000 having been attained in 1913. In the copper mines, the productivity of extraction workers has increased steadily since the inauguration of mass mining during the First World War: in the large mines it rose from not much more than 11 tons of copper per man-year in 1925 to about 33 tons in 1951.

In Northern Rhodesia, where selective underground mining is practised, employment has continued to rise since the end of the initial development phase in the mid-1930's: in 1939 it stood at 29,000 persons, in 1946, 35,000, and in 1953, 52,000. Over-all productivity, which fell appreciably during the war, has risen steadily since then, although it was not until 1952 that it exceeded the 1939 level of 7.3 tons of copper per man-year.

In Bolivia, the mechanization which accompanied the inflow of foreign capital after 1910 also tended to increase average productivity, and until 1929 the labour force increased more slowly than output. Employment in the larger mines reached a peak of nearly 61,000 in 1943, only to decline to about 39,000 in 1950. During the period 1929 to 1950 a deterioration in average ore grade — from 3.94 per cent to 2.18 per cent — tended to reduce the output of metal per unit of labour.

In Malaya, the productivity of mining labour has increased fivefold in the course of 40 years: in 1907, 230,000 workers produced 48,000 tons of tin; in 1950, 46,000 produced 55,000 tons. The principal increase occurred in the late nineteen twenties when the high price of tin induced considerable new investment: the number of operating dredges, for example, rose from 20 in 1920, to 40 in 1925 and to 105, an all-time peak, in 1929.

Though mining wages have generally been above the national average wage in most under-developed countries, both the volume of employment and the wage bill have tended to reflect the instability of the market. In most cases, however, fluctuations in employment and wages have been smaller than those in demand for the metal and in mine output.

In Chile there were substantial declines in copper mine employment after 1913, between 1918 and 1922 and again after the 1929 boom, though copper miners fared much better than the nitrate miners, who were concentrated in the northern section of the country where little alternative employment was available.

In Malaya, the practice of using immigrant labour for tin mining tended to shelter the domestic economy from some of the effects of recessions in the demand for tin, workers not needed being repatriated to India or China. During periods of increasing demand, however, competition of the rubber industry, which was a much larger employer also relying heavily on immigrant labour, usually tended to force up wages in the tin industry to a somewhat greater extent than in other fields of employment. After the price rise in 1952 miners' wages were linked to the price of tin, by means of a bonus based on a standard price equivalent to £1,078 per ton. The initial scheme was terminated in 1953, by which time the price had fallen to an average of £588 per ton, but it was replaced by arrangements for a temporary allowance also linked to the tin price. Though there was no decline in output, average receipts for tin were 24 per cent lower in 1953 than in 1952. The dredging companies maintained the bonus in 1953; nevertheless, there was a 9 per cent decline in average gross cash wages and a similar decline in the number of workers. In the smaller Chinese-owned mines basic wages of daily paid workers declined by about 11 per cent while the cash bonus declined by almost 57 per cent, the combined effect being a drop of 25 per cent in gross cash earnings. Since this was accompanied by a 25 per cent decline in employment, there would seem to be a danger that although such wage-price links may suit the workers when the metal price is high and employers when the market is slack, destabilization of wage rates — ostensibly in order to help stabilize employment — may tend to increase the instability of the wage bill and of the money flow in the mining areas.

In Northern Rhodesia, where the copper mines were still being opened up when depression hit the industry in 1930, there was a considerable reduction in wage employment at the conclusion of the construction phase in the Copper Belt: mining employment fell from 19,000 in 1930 to 8,000 in 1932 and associated building employment from 30,000 to 7,000. The fluctuation in employment and investment was in large measure merely the result of the sudden launching of a great capital venture in the middle of an almost entirely subsistence economy, although the rapid decline in the price of copper — from a maximum of 21.25 cents per pound on the New York market in 1929 to a minimum of 4.75 in 1933 — deepened the effects. During the investment boom, workers had been recruited from the local subsistence economy as well as from abroad, and when it was over a sizable proportion of them returned home without undue disruption of the societies of which they were still part. The principal decline in employment was among African workers, most of whom at that stage were still capable of being reabsorbed into the tribal subsistence society from which they had not yet been completely separated.

In the Belgian Congo the effect of the depression was rather more severe, the mines having been in operation much longer and the working population being therefore much less mobile. As it was, the two-thirds reduction that took place in the labour force of the copper mines of the Union minière du Haut Katanga between 1929 and 1931 caused a considerable amount of local hardship, if only temporarily.

The mines in Northern Rhodesia (and much more so in the Belgian Congo) have since then encouraged and catered for an increasing proportion of permanent workers: consequently, if another major recession should occur its effect would probably be much more serious. The extension of the exchange economy, especially in the Congo, is tending in any case to remove the cushion of tribal society which heretofore has served the purpose of a reserve pool in the flow of African labour in and out of wage service. Similarly, in Malaya the policy of importing labour for specific purposes and periods has been abandoned, so that in future the full impact of fluctuations in employment will have to be borne by the country itself.

Though, proportionately, fluctuations in employment have generally been less violent than those in mineral output or foreign exchange earnings,[11] they may well prove to be more intractable in the future. For not only has a body of more or less specialized mine workers been assembled in most of the mineral economies, but the trend of social legislation and trade union organization has been such that both employment and wage bill have become much less flexible than they were in the inter-war period. Sudden reductions in working force or wages are less acceptable and less likely, even though there have been attempts to tie wage rates more firmly to metal prices. The relative growth of the larger mining companies may also have contributed to an increase in the stability of employment.

In Bolivia, for example, the decline in metal exports in 1949 and 1950 was not accompanied by a decline in aggregate wage payments; on the contrary, the ratio of wage bill to metal export proceeds, which had stood at less than 13 per cent in 1940, rose from 18 per cent in 1948 to 23 per cent in 1950. In Mexico, the protective influence of the law has extended so far as to prescribe substantial bonus payments to workers who lose their employment through the closing down of a mine, irrespective of the reason, a development that appears to have discouraged exploitation of new ore deposits, especially those whose probable life is relatively short.

Apart from the fluctuations in employment and wage bill that have their genesis in the instability of the market for non-ferrous metals, there are certain variations which arise from technical causes. There is, for example, in respect of expenditure and manpower requirements, a large difference between initial development of a mine and regular mining operations after it is in production. One of the characteristics of large-scale mining is the amount of preliminary investment that it usually entails. Several years may elapse between the decision to exploit a given deposit of ore and the beginning of continuous production. During this period shafts are sunk, headgear erected and the ore lode exposed for extraction; power and water are made available; surface works are constructed for handling the ore and maintaining the plant; housing and other amenities are built for the employees; a transport network is laid out for conveying materials both within the mine property and

[11] This is partly because management, particularly at the larger mines, tends to keep together at least a basic element of the labour force even if many workers have to be transferred to jobs that are less immediately productive. There thus tends to be a decline in average labour productivity in the mines during a slump in the non-ferrous metal market, offset financially to a certain extent by a decline in average wage rates.

outside, for shipment to external markets. All this construction usually involves the employment of a much larger labour force than is subsequently required to operate the mine once it has attained the production stage. It also involves the disbursement of much greater sums of money than are subsequently required to meet the normal operating costs of the mine. Unless the supply of goods and services is in some way geared to this process, there is a danger that the high level of expenditure may set in motion inflationary forces in an under-developed country, especially if it is financed from external funds without provision for additional imports or a corresponding increase in domestic savings.[12] Similarly, the termination of the preliminary investment phase may also have a considerable, though opposite, effect upon the level of employment and income. To yield the most beneficent results, therefore, the development of a new mine should not commence with a high rate of expenditure and end abruptly; the longer it can be spread out, the greater the chance of organizing alternative investment and hence the less disruptive it is likely to prove to the economy in general.

Purchases and investment

Another stream of income generated by the mine is the one which flows to the agencies that provide the multiplicity of goods and services used in the course of actual mining and smelting operations. The demand for these things which is generated by the mine constitutes one of its principal potential development effects. It has often been the means of bringing into being facilities whose usefulness extends far beyond their immediate service to the mine. Two of these facilities — transport and power — are themselves important means of further development in fields other than mining and deserve separate discussion.

Transport

Location of an ore body determines the point of mining operations much more precisely than the site of agricultural or manufacturing activities is usually determined. To exploit the ore, the other factors of production have to move to the deposit, and after extraction the ore or metal has to be moved to market. Only if the costs involved in this multiple movement are fully covered by the price of the product is the deposit of immediate economic importance.[13] Hence, one of the main characteristics of the mining industry is its dependence upon transport.

In the 50 years preceding the First World War, this fact made the desire to exploit mineral deposits one of the principal determinants of railway location in the under-developed and developing areas, where it also stimulated investment in harbours and port facilities. Later mineral development has called for road transport as well as rail transport, but in cases where very large tonnages of relatively low value ore have been involved, railways are still indispensable. Thus, in the nineteen thirties the Copper Belt of Northern Rhodesia was opened up with the aid of an extension to a main railway line, which itself had been built in the first decade of the century to provide a coastal link for the Katanga copper mines of the Belgian Congo. The Benguela railway, linking Katanga with the west coast at Lobito Bay in Angola, was also built to provide access to the copper mines. At present, the Rhodesian railway system is being extended from Bannockburn to the east coast to provide an outlet at Lourenço Marques, the single line to Beira having proved inadequate to cope with post-war traffic, which has included large shipments of copper and chromite[14] as well as the importation of a good deal of mining equipment. Since the war, a 150-mile narrow gauge branch line has been constructed in Tanganyika to connect the copper-lead deposits at Mpanda with the main line to Dar es Salaam on the east coast. In Brazil, a 134-mile line is under construction to carry manganese ore from Amapá to a shipping point on the Amazon River. In Morocco, on the other hand, most of the additional transport facilities required for the development of lead mining in the post-war period have been provided by roads and motor vehicles.

The suitability of a given form of transport is a function of several variables. It depends partly on the distance between deposit and market, which in the first instance, in the case of most under-developed countries, means between deposit and port, and partly on the topography and the actual and potential productivity of the intervening area. It depends also on the type of mining: a long-term project, whether deep level or opencast, selective or mass mining, requires much more in the way of equipment and supplies than does the exploitation of small pockets of surface ore, and is likely to provide a larger and steadier mineral traffic over a period long enough to make the amortization of a railway investment seem feasible. It depends partly on the nature of the ore, the metal and the intermediate products: in particular, on their weight-value ratio, on the degree to which they lose weight in processing and on the extent to which the ore can in fact be beneficiated — or smelted and refined — at the mine. This last consideration in turn depends partly on the availability of fuel, which may also

---

12 Investment may be just as inflationary when internally financed if not matched by savings and would be more so if it involved diverting foreign exchange resources from the importation of consumer goods to the importation of plant and equipment for the mine. In general, a large fraction of the initial investment in opening up a mine in an under-developed country is paid out in wages and in the purchase of land and supplies from local sources, and this often entails the injection of new purchasing power into sectors previously only on the fringe of the full market economy.

13 Unless, indeed, the mine is to be organized as part of a development scheme covering several projects using common facilities and measurable — in respect of cost of development effects only as a unit.

14 Export shipments of chromite from Southern Rhodesia totalled 295,000 long tons in 1952 and 498,000 tons in 1953; this still left a backlog of some 400,000 tons in the Selukwe stockpile waiting to be moved in fulfilment of orders. Average tonnages hauled from mines to port in the period 1949-54 amounted to 317,000 long tons of chromite and 366,000 long tons of copper.

be both a function and a determinant of the transport system.

During the sudden upswing in demand in 1950/51, non-ferrous metal output was held down in many of the less developed countries — Brazil (manganese), Mexico (lead), Northern Rhodesia (copper, because of inadequate coal deliveries), Southern Rhodesia (chromite), Turkey (chromite, because of the inadequate handling facilities at the port of Iskenderun) and the Union of South Africa (chromite and manganese) among others — by the inability of the transport systems to cope with extra traffic. Just as the original exploitation of the ore often involved a large concomitant investment in transport facilities, so expansion of mining output depends on corresponding development in transport. In the Gold Coast, for example, the projected aluminium refinery at the site of the Volta reservoir is part of a scheme which includes not only a rail link with the bauxite deposits at Yenahin but also the building of a new port at Tema and its connexion by railway to the refinery and to the existing port of Accra, which is incapable of further expansion.

This serves to emphasize the fact that in many of the under-developed countries exploitation of a mineral deposit is heavily capital-intensive, especially in the initial phase, and is likely to entail not only the importation of all the mining equipment necessary for the project itself but also the construction of essential ancillary works which, since the existing facilities are usually insufficient to cope with the new activities, often entails the importation of additional capital goods. The resultant strain is not limited to the physical facilities; it falls also, and sometimes to a greater extent, upon the foreign exchange resources of the country in question or of the company which is setting out to exploit the deposit. In the initial stages of mineral development, therefore, it has been common practice to have recourse to foreign borrowing, whether directly by government or private domestic company or indirectly through the activities of a foreign concern. Where such borrowing results in a direct fixed-interest-bearing debt, its servicing will be a prior charge on the proceeds of subsequent mineral exports. Some of the implications of this are examined later in the present chapter.

As suggested above, a railway or other transport system is itself a potent instrument of development; for even if designed for the limited purpose of serving the mines, it serves the indirect purpose of extending the market economy and opening up intermediate areas. In many instances, indeed, the cost of these ancillary investments is so high that the exploitation of the ore deposit would be uneconomic if the mine alone had to bear the financial burden. Though the mine may be the prime cause prompting the building of a railway line, the investment is usually predicated upon the assumption that the existence of the line will stimulate other development and attract other traffic. In most cases such railways have in fact been financed either by government or by some independent concern, often after the mine has guaranteed a certain minimum volume of freight.

Thus, although the initial economic impetus has come from the mine, the transport system becomes a development agency in its own right. In Northern Rhodesia, for example, the so-called "railway belt" has become the area in which exchange is practised; it stands in marked contrast to the rest of the country, which is still organized very largely on a subsistence basis. In Chile, the railway line which had originally been built to serve the nitrate mines later facilitated the working of the copper deposits. Similarly, in Bolivia, railways built to facilitate the exploitation first of silver and then of tin deposits, later provided the cheap transport required for the exploitation of the much lower priced ores of zinc, lead, antimony and copper, as well as for a certain amount of non-mining development. In Australia, the transport system built to serve the lead-zinc mines at Broken Hill assisted later in the establishment of an iron and steel industry.

In the Union of South Africa, railway lines built in the last quarter of the nineteenth century to connect mines and ports did much to extend the market economy through the intervening territory, not least by bringing about the establishment of towns at successive termini during the construction period. Subsequently, the use of differential freight rates — in particular, the transportation of agricultural produce and certain other goods at substantially lower rates than those charged on mining traffic — exerted a considerable influence on the distribution of investment. It is evident that the development potential of a railway system built to aid in the opening up of an ore body depends partly upon rating policy and this may have a neutralizing or even a negative or distorting effect upon general economic development. It is possible, for example, that the Benguela railway would have been a more potent development agency in Angola had its rates been lower. From the Northern Rhodesian Copper Belt, as late as 1951, it was more costly to route certain types of traffic over this line to the west coast than over the much longer line to Beira on the east coast.

Similarly, the tariff on the line connecting the Bolivian tin mines in the Oruro district with the port of Antofagasta (part of which line was built in the eighteen eighties by the silver mining companies at Uyuni) had the effect of encouraging traffic on the return journey from port to mines. This, in conjunction with the very existence of the port and railway, and the continual arrival of ships to carry away exports of ore — offering low freight rates for incoming goods rather than travel under ballast — helped to place imports in a favourable position in relation to domestic produce and doubtless tended to help perpetuate the importation of foodstuffs and other bulk goods. Later, a railway line to the south, completed in 1925, connected the Altiplano with the Argentine transport network, thereby weakening the Pacific port monopoly of the Antofagasta Railway, but at the same time opening the country to agricultural imports from Argentina. No line has yet been built, however, to open up the eastern agricultural districts within Bolivia itself, though the recent completion of a highway from Cochabamba to Santa Cruz, started many years ago, has rendered such a line somewhat less urgent as a means of stimulating local food production.

Power and other ancillary investments

Although transport is probably the most important ancillary service in the exploitation of a mineral deposit whose location is fixed within very narrow limits, it is by no means the only such service, and the development potential of the mining industry depends partly on the extent to which other ancillary investment is in fact made.

Power is one of the commonest requirements of the industry and, as in the case of railway investment, mining demand has often provided the initial stimulus for the setting up of power facilities capable in due course of serving other markets. Investment in aluminium production in an under-developed country almost inevitably hinges on the concurrent provision of hydroelectric power. In the Gold Coast, Nyasaland, Peru, Surinam and Venezuela such projects are mutually dependent, for without substantial continuous demand such as that created by an aluminium refinery, it is doubtful whether large-scale power development would be the most economic means of meeting the relatively scattered and erratic requirements of other users of electricity in the areas in question. In Malaya, where the effective horsepower of machinery employed at the tin mines rose from 79,000 in 1924 to no less than 336,000 in 1940, it was the mechanization of the mines — especially during the nineteen twenties — that provided the immediate justification for the building by the Government of several hydroelectric stations. In general power station construction constitutes an important investment furthering the process of economic development.

The provision of water supplies, like that of electric power, is an essential part of mining operations and it also involves an investment whose function may transcend that of catering only for the mine. The recent expansion of the Chuquicamata mine in Chile, for example, involved the building of a dam on the Arroyo Salado and the laying of 45 miles of 30-inch pipeline to deliver to the mine site some 40,000 tons of water each day.

Other construction undertaken by the mining companies, whether of workshops or of employee housing, may also be of a developmental nature. Since in most under-developed areas facilities are unlikely to exist within a reasonable distance of a newly discovered ore site, a good deal of the original investment in the opening up of the mine will necessarily take the form of new buildings for workers' quarters and for servicing and processing plant.

Most mines run workshops for the assembly, maintenance and repair of materials and machinery being used on the property. In under-developed countries, such workshops tend to become more comprehensive than they would be if outside services were more readily obtainable, forming, indeed, along with the workshops attached to the transport system, the rudiments of a local mechanical and electrical engineering industry. This is the case in the Katanga region of the Belgian Congo, for example; likewise, during the war, when oversea facilities were cut off, mine workshops in several of the less developed countries were able to undertake a good deal of engineering work not connected with the mines.

In many cases, mines tend to provide goods and services for themselves which in more advanced economies would be purchased from outside producers. This is partly to assure supply and to avoid dependence on sources which are feared to be less efficient or less reliable. But, apart from the investment programme of the mine itself, the fact that both the newly opened mine and its employees constitute new markets in the economy may give rise to a certain amount of independent investment in facilities designed to serve these markets. Induced investment in manufacturing industry, indeed, is often one of the important developmental effects of the mining industry in an under-developed country. The extent of such secondary investment depends in part upon the purchasing policy pursued by the mine, and this is discussed in the following section.

Stores

Mine stores fall into three main categories: (1) capital goods and construction material; (2) expendable materials used in the course of mining; and (3) consumer goods for the labour force.

In the first group are such items as plant and machinery, winding gear, drills and compressors, power equipment and dredges, mechanical shovels and various types of transport and haulage equipment, as well as boilers and furnaces and all the specialized apparatus of smelters and refineries. A newly forming mining concern in an under-developed country usually has no alternative but to import most of whatever plant and equipment the nature of the ore body and the technical plan for its exploitation dictate. In general, this material is admitted into the country duty free or at fairly low rates. In those under-developed mineral economies in which a steel industry has been established, however — Chile, Mexico and the Union of South Africa, for example — a certain amount of structural material, such as shaft headgear and rails, as well as cement, is likely to be obtainable from domestic sources, the mines often being an important market for local industry.

Local production of this nature is usually possible on a wider scale in respect of the category of requirements labelled expendables, among which would be belts, tires and other leather and rubber goods, bolts and nuts, wire rope, chain and other iron and steel fittings, sulphuric acid, flotation reagents and other chemical products, tool handles, explosives, fuel and many other classes of goods consumed by the mine in the course of its normal operation. In this fairly specialized field of mining stores and materials, purchases from established local industries may be feasible in certain cases, while in others the mine may even take a direct part in encouraging or in actually or ·mizing the production of items in regular use. Investment in such industries may add substantially to the contribution non-ferrous mining may make to the resource country's development. The establishment of an explosives factory, as in Chile, the Union of South Africa and, more recently, the Belgian Congo, has resulted in each case in an industry whose product is widely used in the field of civil engineering. The establishment of a sulphuric acid plant based on smelter by-products, as in the Belgian Congo, Chile and Mexico, has provided a basic chemical industry serving areas far beyond the copper refinery for which it was originally intended. Beehive coke ovens installed by the Mexican lead and zinc industry for internal requirements have provided a surplus which is used in the local iron and steel industry.

The consumer goods segment of mining demand includes food and special types of clothing, bought directly by mine workers or by the management for issue to employees, and in general more easily supplied from local sources than the other categories. By and large, these goods are the products of the simpler industries with which the process of economic diversification in under-developed countries has usually begun. Here, as elsewhere in this field, the development potential of the mine is a function of the volume of new production stimulated by the mining market and not of the degree to which previous production is merely diverted to the new market. And where for any reason — cheapness, convenience, lack of appropriate organization, quality or mere custom — the mine resorts to imports for supplies of foods and other consumer goods for use by its employees, local agriculture and manufacturing are denied the stimulus of this new market.

A mining community also constitutes a market for a number of the service industries associated with urban life in an exchange economy. There is also demand for health services, often provided by the mining company itself, and for schools, usually provided by the government. The requirements of a mining community have often proved an important stimulus to diverse economic activities and, in the least developed countries, quite new ones. The precise effect exerted by such new demands on the domestic pattern of production, however, depends greatly on the purchasing policy of the mines, and the trade and fiscal policy of the government.

Mining interests, by and large, have tended to oppose both the threat of curtailment of their freedom to make purchases in the market of their choosing and official policies thought likely to cause price increases. To a certain extent the broad objective of their normal purchasing policy — to minimize operating costs — is sound, not only in terms of the financial results of the mining enterprise itself but also from the long-term point of view of the under-developed country anxious to have its mineral resources exploited as efficiently as possible. But as indicated in the final section of this chapter, the fact that these resources are limited and exhaustible makes it advisable for the country to work towards the establishment during their lifetime of alternative activities capable of sustaining employment and incomes (and if possible foreign exchange earnings) when the mine has been worked out — even if this involves policies which might tend to shorten that lifetime.

The Bolivian economy, for example, would doubtless have been stronger at the time of the 1930 to 1933 depression had a higher proportion of mining revenue been spent within the country on goods produced locally. As it was, during the first quarter of the twentieth century, the railways which carried the Bolivian ores towards their overseas markets destroyed a large part of the natural protection which the country's agriculture, in particular, had enjoyed when internal markets had been less accessible to imports. It was not until the early nineteen thirties that government policy turned to fostering domestic industry — by exchange control, customs duties and credit facilities designed to assist the importation of machinery and raw materials and discourage the importation of manufactured products. In 1950, employment in secondary industry totalled about 25,000, compared with about 45,000 in mining.[15] This progress, limited as it has been, stands in contrast to the continued backwardness of agriculture. At one stage the importation of cheaper food was favoured in order to hold down the urban cost of living, but since 1941, when the Banco Agricola was established, government policy has tended to support agriculture in the interests of a better balanced economy. This trend became especially marked after 1945, when an attempt was made by the Corporación de Fomento to stimulate rural activity by new investment in such fields as sugar, rice and cotton production, as well as in the improvement of road transport.

In Malaya, until recently, comparatively little attention seems to have been paid to the possibility of meeting more of the country's food requirements from domestic agriculture. Immigrants employed on rubber plantations or in tin mines were not allowed subsequently to settle as cultivators, and the country has continued to import large quantities of food. Post-war development plans, however, have included proposals for improving and mechanizing the cultivation of rice.

In Northern Rhodesia, the mines constitute the territory's principal market for basic foods such as maize and meat, only a small proportion of which local agriculture has so far been able to supply. The problem is complicated by poor soils, inadequate rainfall and tsetse infestation in many parts of the country, but investment in the subsistence sector of the economy — in transport facilities as well as in improved farming techniques — holds promise of increasing both productivity and the marketable supply of foodstuffs. African producers are already responsible for a sizable proportion of the maize crop sold in the exchange sector as well as the bulk of the cattle inflow to the abattoir and cold storage at Livingstone.

---

[15] United Nations, *Report of the United Nations Mission of Technical Assistance to Bolivia* (sales number: 1951.II.B.5), page 94.

The existence of a significant, concentrated domestic market must certainly be ranked as an advantage to local agriculture and manufacturing industry, and the ability to constitute such a market is part of the development potential of a non-ferrous mine. Whether the latter should be encouraged to support domestic suppliers — by a customs duty imposed on competing imported goods, for example — is a question which can be answered only case by case. Inasmuch as mining costs are raised in the process, the general effect would be on the one hand to reduce the profits and the tax contribution of the mine and raise the pay limit of the ore, thus shortening its economic life, and on the other hand to increase manufacturers' incomes (and taxes). Whatever the theoretical considerations, several of the mineral economies — Chile (in 1913), Union of South Africa (1925), Bolivia (1928), Mexico (1930) for example — have in fact attempted to advance their rate of development by means of a protective tariff, one of the indirect effects of which was to inflate mining costs, at least in the first instance. As a general rule, a mine that buys its supplies on the local market contributes more to developing the country than a mine that imports most of the goods it requires, provided the process does not raise working costs to such an extent that appreciable proportions of ore fall below the pay limit.

As with the training of local labour, however, so the organization of a local market may take some time, especially in a society accustomed in the main to a subsistence form of economy. In such a society efforts to supply a sizable demand for food from workers at the mines and in ancillary occupations might ultimately bring about a revolution in agricultural technique and organization, with an accompanying development of transport facilities and an increased division of labour. The mere existence of the mining demand, however, is not of itself decisive as a stimulant to local agriculture: as indicated above, notwithstanding the availability of potentially productive land and other agrarian resources, much of the food consumed by miners in Malaya and Bolivia is still imported, and Northern Rhodesia is still far from self-supporting. Since, in an economy that is being transformed from a subsistence to an exchange basis, agricultural investment can be neutralized by the inadequacy of transport facilities, by lack of credit or by the unsuitability of the emerging system of land tenure, the government evidently has a major part to play in the rural development of countries that are heavily dependent on non-ferrous mining.

Tax contribution

It has already been pointed out that the technical objective of mining policy is the exploitation of the ore body in such a way that with the minimum expenditure of real resources the maximum amount of metal-bearing ore will be removed. However, while it is true that, other things being equal, the higher the proportion of available ore actually extracted, the more the resource country stands to gain from its mineral deposits, the extraction process is not merely a technical exercise carried out in an economic vacuum. On the contrary, the technical problem is conditioned at every turn by the interrelationships between ore and metal prices and operating (wage and material) costs.

Nor can the time element be ignored. Even from the point of view of the autonomous mining company aiming to maximize not its development effects but its own profit, the desirability of rapid extraction and early realization of the value of the ore has to be balanced against the higher capital costs involved in larger shafts and stopes, the operation of more working faces, and the greater investment in transport and handling equipment and in surface works for crushing, floating and reducing the ore. Other things being equal, extraction policy is likely to represent a compromise between the optimum rate of daily recovery and the optimum level of total recovery, adjustments being made from time to time in accordance with changes in the knowledge of the deposit, in the cost structure and in the current and prospective price of the metal.[16]

For an individual mine at any moment of time, ore and metal prices are given — determined by market forces which in general cannot be significantly affected by the policies pursued by any one mine. Costs, on the other hand, are constantly being influenced by local policies and local actions. Among these influences government taxation is of particular importance, not least because it is an instrument by which mining policy can be guided towards the objective of maximizing the development potential of the mineral industry.

In the present context, therefore, a tax is regarded less as a means of raising public revenue than as a cost or charge whose incidence is an important determinant of mining practice. This is not to say that the contribution that the mining industry makes to the public purse is not significant. On the contrary, it is one of the principal means whereby the external earnings of the mining industry are channelled into the domestic economy, and, as indicated later in this section, government revenue in the mineral economies is derived to a large extent from tax receipts from the mining industry. The developmental effects of this income flow clearly depend upon government expenditure policy; although certain aspects of this problem are touched upon in the final section, more detailed treatment lies in the field of public finance, outside the scope of the present study. For present purposes, it is more fruitful to examine the impact of fiscal measures upon the operation of the mine.

Mines may be taxed in many different ways, and in most of the under-developed mineral economies several types of tax are employed simultaneously. There is, for example, the royalty, which in general takes the form of a charge for each ton of ore removed. The export tax is of a similar nature, being levied on the ore or metal

[16] The theoretical relationships between rate and level of extraction are discussed in some detail in Donald Carlisle, "The Economics of a Fund Resource with particular reference to Mining" in *The American Economic Review* (Menasha, Wisconsin), September 1954.

as it passes through a customs depot on the way to a foreign market. The income or profit tax is levied on the net revenue of the mining company regarded as a corporate entity; its rate may differ from that to which other — industrial or commercial — forms of company are liable, and its assessment usually involves special rules concerning the allowances for depletion of the mine and depreciation of the investment. A comparatively new form of tax is that collected in some countries through the medium of exchange control, local currency being sold to the exporting mineral industry at rates of exchange that are less favourable than the official or market rate. A much older method of taxing mines is by imposing customs or excise duties on the things they buy. There are also licence payments, concession fees, lease rentals and other such imposts on property or mineral rights.

In the ways in which these general types of tax may be imposed there are many variations. The tax on product, for example, may be levied either on quantity or on value, on the ore or on the metal content of the ore, at a flat rate or at a variable rate. The income tax may be charged at a flat rate or at a progressive rate. The exchange rate may be differentiated according to the purpose for which the local currency is required.

This range of tax types and methods of applying them makes for flexibility, and, although freedom from sudden and arbitrary variation is most desirable in mining taxes — as indeed all taxes — the peculiar nature of mining with its high physical and economic risks makes flexibility a particularly valuable attribute of any system of mining taxation.

The problem may be illustrated by the position of the Andes Copper Mining Company in Chile, which since 1926 has been exploiting a mixed deposit of oxide and sulphide ore at Potrerillos. After the removal of about 150 million tons (one per cent copper content) by the end of 1953, the exhaustion of the oxide ores left the mine with only low-grade sulphide ores to work. The best of these (0.7 per cent copper content) could be mined profitably at 1953 prices, costs and taxes, but the rest of the ore was considered submarginal. In all, this submarginal ore was estimated to contain three times as much copper as that which was economically workable and its abandonment would be a considerable loss to the Chilean economy. Under a flexible tax system, a formula might be devised which would encourage the mining company to extract the submarginal ore along with the better grade ore in such a ratio as to exhaust both grades simultaneously, thereby prolonging the life of the mine and increasing its total development potential. This is not necessarily a matter of subsidizing the mine or of allowing it to use more in the way of real resources than it recovers by way of ore and metal output. The net effect of such an adjustment of tax and mining policies might be the sacrifice of a portion of two income streams — tax and profit — in order to maintain not only their flow but also that of the two other income streams — wages and purchases — and, perhaps more important in the case of Chile, the mine's contribution to the country's foreign exchange earnings.

As far as the mining operations in general are concerned, the higher the price of the metal and the lower the working costs of the mine, the lower, other things being equal, is likely to be the grade of ore that it is economically feasible to extract and the greater the fraction of ore that is removable from the deposit. By the same token, most of the taxes which raise costs tend to raise the pay limit below which the ore is not worth working, thereby reducing the economically exploitable reserve.

Thus, a tax levied in the form of a royalty on the weight of rock crushed or on the volume of ore removed, such as was imposed in several British dependent territories before the war, tends to raise the "cut-off" grade (at which it ceases to be profitable to mine) and hence to lead to the abandonment of untouched ore, at least in those mines that are operated on a selective extraction basis. In Surinam, in addition to a rental based on the area of the mine property, a flat rate royalty (of 0.25 florin) is payable on each ton of bauxite exported, thus imposing a burden which tends to increase as the grade or the price of the ore declines. In French overseas territories, on the other hand, royalties have generally been payable in proportion to the value of the products extracted from the mines and not their physical amount: a decline in price therefore reduces the burden proportionately. This type of royalty, however, is equivalent to a turnover tax whose incidence on net revenue tends to become heavier as unit cost of production rises — as it is likely to do if the grade of ore mined declines.

In contrast to this, a royalty on metal content or a profit or income tax at rates which become proportionately less as the ore grade falls,[17] such as has been effective for many years in the case of gold mines in the Gold Coast and in the Union of South Africa, tends to lower the cut-off point and increase the payable reserves of the mine. This principle was extended to manganese and bauxite mining in the Gold Coast by the system of taxation introduced in 1952 under which export duties became payable at rates varying with the "yield ratio" (the ratio of profit to the value of output) of the mine in question, from zero when the yield ratio is under 15 per cent, to 21 per cent of export value when it is more than 80 per cent. Similarly, in Nigeria, new lead-zinc mines will be taxed chiefly by means of a duty varying with financial yield: the risk of deterring non-ferrous mining enterprise by penalizing success and efficiency has been deemed less than the risk of allowing unduly exploitive mining policies.

In Uganda, a revision of the mining law in 1949 permitted the substitution of a profit tax of 15 per cent for a production royalty of 5 per cent in the case of small mines and certain low-grade properties. In Bolivia,

[17] The general form of such a tax is represented by the formula $y = a - \frac{b}{x}$ where y is the tax rate expressed as a percentage of profit, x is the percentage ratio of profit to recovery and *a* and *b* are constants.

a similar purpose was achieved by a change in the tax formula introduced in 1919. Previously, exports of tin concentrates had borne a levy on gross weight, which increased on a sliding scale geared to the price of tin quoted on the London Metal Exchange. The new tax was levied on metal content rather than gross weight, thus making it possible to export lower grades of concentrates. This change probably stimulated the export of tin ore and concentrates, though, as indicated in the preceding chapter, it doubtless discouraged the extension of local beneficiation, the first phase of the metallurgical industry.

As noted in the previous chapter, Malaya at one time practised almost the reverse of this system; by imposing a prohibitive tax on the export of tin ore and concentrates, it sought to ensure that local ore would be smelted and refined within the country. The revenue-raising export tax was levied on tin metal. In the Belgian Congo, where export duties contribute a sizable proportion of government revenue, the rates in recent years have been *ad valorem* and on balance have tended to favour the local processing of the mineral. In 1954, for example, the rate of duty on zinc was 3 per cent on metal, 6 per cent on concentrates; on cobalt 14 per cent on granulated metal, 18 per cent on copper-cobalt alloy; on manganese 6 per cent on metal, 11 per cent on ore. In the case of tin, however, 7 per cent was levied on both concentrates and metal, while copper was exported entirely in metal form, taxable at 15 per cent of value.

The burden of a profit tax depends in the first instance upon the definition of profit, which, as indicated above, involves the concept of depletion and depreciation. Experience has shown that where the depletion allowance depends partly upon the company's estimates of the mine's reserves, there is a tendency to understate them and in some instances a failure to keep their development proceeding at the pace dictated by the rate of exploitation of known ore bodies.

In general, the higher the permissible write-off of capital expenditure each year, the more thoroughly is the ore likely to be removed. Moreover, rapid amortization tends to reduce the risks inherent in mining investment, postponing but not necessarily diminishing, government participation in the successful exploitation of an ore body. In Northern Rhodesia, where mining is not subject to any special taxes but pays ordinary company income tax computed as a proportion of net profit, a 1951 amendment to the law gives new mines the option of treating all expenditure during the first five years of development as current, and hence of writing off these early capital costs during the period in which they are incurred, instead of slowly over the life of the mine, or over a period of 20 years, as had previously been the case.

In Peru, the 1951 mining code allows, in addition to normal amortization of equipment, a deduction of up to 15 per cent of gross sales (but not exceeding 50 per cent of profits) against the ultimate exhaustion of the mine.

Another form of tax, used particularly in Latin America, is imposed by means of a system of differential exchange rates. Such a system was first applied in Bolivia and Chile in the early nineteen thirties when currency devaluation placed a fortuitous profit in the hands of the exporting mines, which until then had been required to surrender to the central bank not the whole of their foreign exchange earnings but only the equivalent of their local costs. It was considered that, with price determined on oversea markets and output quota fixed by a producer cartel, the purchase from the mines of their foreign currency savings at an exchange rate somewhat below that at which the local currency was available for other purposes would constitute an easily collectible tax unlikely to affect production. Subsequently, inflationary increases in internal prices brought about considerable depreciation in local currencies, increasing the gap between the ordinary exchange rate and the unchanged rate at which the mines were obliged to sell their currency holdings, thereby imposing a substantial tax on local production costs. In Chile, in 1951 for example, when on the free market a United States dollar would buy an average of 85 Chilean pesos, the mines were still allowed only 19.37 — the pre-war rate.

This exchange differential tax, reinforced by the tendency for local unit costs to rise more rapidly than those abroad, induced the mines to make a smaller proportion of their purchases within the country of operation. Thus, in Chile, the large copper mines have continued to import almost all their stores even though many items could have been provided by local factories, some of which have already built up a market among other domestic consumers. In Bolivia, where, as indicated in the previous section, a substantial proportion of the food consumed by miners and their families is still imported from abroad, unfavourable rates of exchange granted to the mining companies while they were still privately owned also militated against local purchases. Moreover, to the extent that smelting and refining add to the foreign currency equivalent of local costs more than would be saved by shipping the metal instead of the ore, the exchange differential tax probably tends to discourage domestic processing.

In the long run, differential exchange rates of this nature tend to isolate mining operations from the rest of the economy, militating against integrated development. Moreover, they often have a considerable effect upon unit costs, especially in the case of mines in which wages are a high proportion of total cost. In terms of United States cents, for example, Chilean costs per pound of copper, under operating conditions prevailing in 1952, would have varied from 21.6 to 9.1 as the rate of exchange for local expenditures was raised from 19.37 to 150 pesos per United States dollar.[18]

Although producers might normally tend to regard this type of discriminating taxation as a temporary element in their cost structure, and therefore not a justification for any special long-term research into methods of reducing costs at the mine, it is probable that the imposi-

[18] Cf. United Nations, *Economic Survey of Latin America, 1953* (sales number: 1954.II.G.1).

tion of unfavourable differential exchange rates has hastened the process of mechanization by which local manpower has been replaced by imported machinery. This has raised the productivity of the mines' residual labour force but has probably reduced their development potential in respect to both employment and the generation of additional demand from it. Where real wage costs are so directly affected by foreign exchange policy, all disagreements and negotiations between management and labour almost inevitably involve the government and its tax structure.

Latin American countries which have mineral resources have tended to regard a system of differential exchange rates as an easily applicable means of benefiting directly from the relatively high productivity of the export industry. As a tax, moreover, it is capable of rapid and simple adjustment to changes in the cost-price structure, and it may be graduated in order to maximize the amount of foreign exchange surrendered by each category of producer. In Chile, in pre-war years, for example, the small, higher-cost copper mines, which were required to relinquish all the foreign exchange they earned, were granted a more favourable conversion rate than the large mines, and in the post-war period their relative advantage increased. However, the construction of the new sulphide plant at Chuquicamata, referred to in the preceding chapter, was encouraged by the Government by the grant of more favourable conversion rates — 43 pesos to the United States dollar in 1949, between 50 and 60 in 1950, and 60 in 1951 — to meet the local costs of the new facilities.

In 1951, the agreement between the Chilean Government and the United States copper companies was widened, by limiting to the 1951 figure the amount of foreign exchange that had to be sold by the companies at the old rate of 19.37 pesos. Above this amount, local currency would be sold to the companies at the prevailing official rate, which at the time of the agreement was 100 pesos per dollar. In return for this concession the companies undertook to expand Chilean copper production to 500,000 tons a year. This arrangement was superseded in 1955 when the companies were given greater freedom in marketing their copper output. More reliance has been placed on a profit tax to stimulate investment and increase production: over and above a basic tax of 50 per cent of net profit a form of surtax has been imposed at a rate which diminishes from 25 per cent of net profit to zero as the output of copper increases to 600,000 tons a year.

The first profit tax (of 12 per cent) to be imposed on the Chilean copper mines dates back to 1921. In 1929, after the collapse of the nitrate industry as a source of revenue, the tax structure was overhauled, the rate of the profit tax raised, a general income tax on mining companies introduced and the system of multiple exchange rates, described above, established. In the year 1928/29, direct taxes absorbed about 7 per cent of the net value of the oversea sales of the large mines; during the post-war period 1946 to 1950 the average proportion was about 22 per cent, raised chiefly through a tax which appropriated one-half of the difference between a prescribed datum price for copper (13.5 cents per pound) and the price actually realized on the market. The general income tax, levied on the difference between the datum price and the effective unit cost, has tended to lose significance because of the steady rise in costs. But if the contribution levied through the differential exchange rate and customs duties are added the total tax burden borne by the large mines in 1948, for example, amounted to about 40 per cent of the proceeds of their oversea sales. During this period the small mines were subject only to a general income tax, but at a rate which was rising and which by 1951 had reached a level not far below that applicable to the large mines.

In Peru, where multiple exchange rates had been in effect since 1945, the first step taken when mining policy was liberalized in 1949 was an adjustment of conversion rates and the granting of more favourable rates to exporters of minerals than those obtaining for other exporters. Tax discrimination against mining — chiefly in the form of an additional 30 to 40 per cent levy on the margin between the New York price of the metal and a specified datum figure (16 cents per pound for copper, for example) — was brought to an end in 1950 when all taxes on mining, other than normal income tax (at 20 per cent of profit for most mining companies), a 12 per cent tax on dividends and a comparatively small land tax, were suspended for a period of 25 years.

The Mexican tax system has also tended to discriminate against mining in recent years, for in addition to the normal income tax and excess profit tax levied on all companies, the mines have had to pay both local and federal production taxes. Since 1921 the latter have taken the form of a price-progressive royalty on the realized value of ore extracted, amounting in 1952 to 23.5 per cent in the case of copper and zinc and 26.25 per cent in the case of lead. Over and above this there has been a general export tax of 15 per cent. In five post-war years, 1946 to 1950, taxation absorbed more than one-half of all mining profits, compared with about one-third of the profits of other industries, and in 1952 approximately 30 per cent of the gross value of mining output went into the public purse. This tax policy probably contributed to the relative decline in mining investment during the period 1949 to 1951: reinvested profit was practically the only form of capital entering the industry, and many mines closed down. More recently a modification of government policy, promulgated in 1952, has resulted in an increase in road building in mining districts, the subsidizing of certain small mines and the waiving of production taxes for five years in the case of new mines opening up in specified undeveloped parts of the country.

In general, direct taxes on income are likely to be much less of a deterrent to sound mining practice and optimum resource utilization than are indirect taxes, either on the ore or metal output of the mine or on the commodities used by the mine in the course of its operation. The tendency for royalties and export duties that are based on the volume of ore to militate against the working of low-grade deposits was pointed out above. The imposition of customs duties may tend to have a similar effect, for in so far as they raise the cost of mine stores they will tend to raise the cut-off point and thereby reduce the volume of ore that can be economically extracted. So, too, does a tax or duty on consumer goods, which tends to raise the cost of living, and hence the wages, of mine workers, unless indeed the bargaining position of the mine is strong enough to force the workers to bear the whole of the resultant cut in their real wages.

In most under-developed countries that depend greatly on mineral exports, customs duties are in fact levied on a wide range of imported goods, including many that are used by the mines and their employees. Mining equipment, however, is usually given preferential treatment, often to the extent of being admitted duty-free. In some countries — Peru, for example, under the 1951 code[19] — mining stores are also exempt from duty. Where the duty on goods used largely by the mines is designed for raising revenue, resource utilization would probably benefit if it were replaced by an equivalent tax on profits, even though such a tax might not be as simple to compute or to collect.[20] On the other hand, where the duty is intended not for revenue but for protection of a domestic industry, its soundness from the point of view of its effect not only on mineral resource utilization but also on general economic development depends, as indicated in the preceding section, on a wide range of considerations.

Quite apart from customs duties that may be payable by the mines on imported stores, government revenue in most of the under-developed mineral economies depends very greatly on the taxes levied on the mines. In one or two cases, however, that dependence has tended to decrease in recent years, as a result of a broadening of the tax base. This has been so in Chile, for example, even though the tax on the copper mines has tended to absorb an increasing proportion of their gross revenue.

In Malaya, the export duty on tin yielded 40 to 45 per cent of total government revenue during the early years of the present century. A good deal of public investment — in roads and railways for example — was financed by the tax on tin. With the growth of other sources of revenue, however, chiefly as a consequence of the expansion of the rubber industry, the importance of this tax tended to decline. It accounted for less than 20 per cent of gross revenue by the beginning of the First World War and dropped to 8 per cent in 1932. In the post-war period it rose to 13 per cent of gross revenue in 1949 but with the decline in tin prices had decreased to 8 per cent by 1953.

In Bolivia, on the other hand, mining taxation has increased in importance in relation to both value of output and public revenue. Before the First World War, mining taxes absorbed rather less than 5 per cent of the realized export value of mineral output; by 1929 the proportion had risen to 10 per cent and in 1950 it was 15 per cent. Increasing much more rapidly than other taxes, direct mining taxes yielded about 19 per cent of total government revenue in 1929 and no less than 43 per cent in 1950, most of it being collected in the form of export duties. Over and above direct taxes during this period was a system of differential exchange rates, which acted, as in the case of Chile, as a tax on the local production costs of the large mines.

In Northern Rhodesia, public revenue has been even more dependent on the proceeds of direct mining taxation. This has been levied on a non-discriminatory basis at a specified rate (37.5 per cent in recent years) on net profit, and in post-war years up to two-thirds of total government receipts has come from this source.

In the Belgian Congo, where the connexions between the Government and the mines are much closer, public revenue has benefited not only from royalties, concession fees, export duties and a tax on mine profits but also from dividends accruing from government participation in mining investment. In general, about one-half of the profit earned by the mines and distributed to shareholders has passed to the Government. In 1951, almost one-fourth of the gross value of sales made by the Union minière du Haut Katanga went into public revenue, somewhat more than half as dividends, the rest as taxation.

The Indonesian Government is also a participant in mine profits, owning as it does the whole of the important Bangka tin property and five-eighths of the shares of the Billiton Company.

The corollary to the dependence of government revenue on mining taxation is the hazard of year-to-year fluctuation. In Malaya, for example, the tin export duty, which yielded $M 18 million in 1927, yielded only $M 4 million in 1932, while between 1937 and 1938, when the average price declined by about 22 per cent, tin exports declined by 45 per cent and the yield of the export duty declined by 50 per cent. More recently, fluctuations in the receipts from export taxes have also reflected changes in the rates of tax: policy, in Malaya, as elsewhere, has been to adjust the export tax rate to changes in the market price of the metal in order, in particular, to draw off part of the high returns accruing to producers during boom conditions. The export tax on manganese shipped from India, for example, was raised to 15 per cent *ad valorem* in 1951, but abolished in 1954 when the market was depressed and many of the smaller mines were unable to sell their output. Such adjustments are usually aimed primarily at reducing potentially inflationary forces in times of high metal price, but they also tend to stabilize to a certain extent the actual receipts of the mines.

In the general course of these movements of prices and taxes, fluctuations in physical output have usually

[19] In Peru, the 4 per cent duty which is levied on mining imports is deductible from subsequent income tax liability.

[20] The difficulties of administering a profits tax are likely to be greatest where the mine is part of an integrated concern and adjustments have to be made to the prices at which inter-company transactions take place.

been greater than those in price, and fluctuations in export proceeds have almost invariably been greater than those in either price or output, while fluctuations in mining profits have been greatest of all. Fluctuations in the receipts from mining taxes are necessarily a function of the particular variable or variables to which they are by law attached. A tax on profit, which as indicated above is likely to be the soundest from the point of view of resource utilization, is thus likely at the same time to be the least reliable from the point of view of the revenue it produces.

PROFITS AND THEIR USE

From one point of view the organization of the non-ferrous metals industry reflects the fact that the under-developed mineral economy with its ore resources complements the advanced industrial economy with its supply of capital and skill and its market for metals. Since lack of capital is one of the main characteristics of under-developed countries, the funds required for exploitation of most of their major mineral deposits have been raised abroad, either by direct borrowing or through the formation of a joint-stock company or a branch or subsidiary of such a company, in which shareholders acquire an equity interest. In this way, most of the larger non-ferrous metal mining companies operating in under-developed areas have been organized in industrial countries, most of the shares continue to be held there, and in many cases effective control in all but routine matters continues to be exercised from there.

In some respects it is an important advantage for an under-developed country to be able to use foreign equity capital for the discovery and opening up of its mineral resources. The process of exploring an ore body and developing an operating mine is both costly and risky, for even when a high-grade deposit is indicated success is by no means assured; spectacular results achieved in a few instances or at certain times tend to obscure the fact that a considerable proportion of prospecting and mining investment yields little or no return. Even in the case of mines that are ultimately successful, a long period — perhaps three or four years or more — may elapse between the initial investment and the production of the first saleable ore or metal. Under these circumstances, there is much to be gained by having the original financing undertaken by risk capital from the more advanced countries, especially if it is in the hands of mining experts technically capable of exploiting in the most efficient and economic manner whatever mineral resources may be discovered.

Tending to offset the advantages attaching to the use of foreign capital for mineral exploitation is the fact that it reduces the resource country's control over the disposal of any profits the mining enterprise may earn. Before discussing some of the effects of this on the mine's development potential, it is advisable to examine the ways in which capital is raised to finance mining operations.

The initial stages of mineral exploitation, during which the concern which bears the expense has no real assets, have usually been financed by syndicates of persons with some knowledge of the area to be explored, or, to an increasing extent, by larger mining companies or groups with technical facilities as well as the cash resources for undertakings of this nature. If the report of the exploring party is sufficiently favourable — in the light of market conditions as well as technical considerations — a prospectus may be issued inviting the public in the country which has the mineral resource or, more frequently, in one of the industrial countries, to subscribe the capital of a mining company to be set up to exploit the newly located ore deposits. This sort of prospectus would normally be aimed at individuals who dispose of venture capital and who are likely to be prepared to invest in an unproved and therefore essentially speculative enterprise in the hope of a high return.

The actual mining enterprise, as distinct from an exploration company, usually requires considerably more capital. It is estimated that the development of the Bancroft mine in Northern Rhodesia, for example, will have cost £13 million to bring it into production with an output of about 43,000 long tons of copper a year by 1957 plus a further £5 million to expand capacity to 86,000 tons by 1960. The significance of this sum is indicated by comparing it with the £19 million which, during the years 1950 to 1953, was the average annual total of investment in the whole territory. Though the newly formed Southern Peru Copper Corporation will exploit the Cuajone-Quellaveco-Toquepala ore deposits by opencast methods, well over $200 million — more than twice the average annual figure for net domestic capital formation during the period 1948 to 1952 — will be required to prepare the site, construct the transport facilities, mill, power plant, smelter, workers' quarters and other works necessary for handling an estimated 30,000 tons of ore a day. In both these cases almost all the initial capital will have been raised and disbursed before the first metal is obtained, and three to five or even more years — during which the price of copper may have changed considerably — may have elapsed before any return can be made on this investment.

Once a mine is in steady operation, its sources of further capital are more extended: it may retain part of its own net earnings for reinvestment; it may appeal to the investing public again on the basis of its proved earning capacity; and once it is in possession of fixed assets and other valuable property, it may be able to borrow additional funds through debentures, mortgages, or special types of shares.[21]

[21] The process may be illustrated by the history of the Rhokana Corporation, the company which operates the Nkana mine in Northern Rhodesia. Under the name of the Rhodesia Congo Border Concessions, it was founded in 1923 as an exploration and prospecting concern with an authorized capital of £150,000. In 1930, after part of the area had been proved and the extent of the copper ore deposit estimated, actual mining operations finally started at Mindola and Nkana. The company's capital was increased to £2 million, and 676,086 shares of £1 each were issued in payment for the assets of the old copper mine at Bwana Mkubwa and the rights over the new Nchanga property, where another ore body had been located. In 1931, the company adopted its present form, issuing a further 100,000 shares of £1 each in

Mining investment being subject to a number of major risks and uncertainties, equity shareholding is generally the most appropriate method of financing. Over a long period it will probably turn out to be less of a burden than a fixed-interest debt, both directly to the company itself and indirectly to the under-developed country as a whole. In the case of a debt incurred abroad, funds for its servicing are likely to be derived largely from the export proceeds of the mineral industry which is being financed: the higher the proportion of gross revenue absorbed by prior charges or costs, the less will be the net revenue subject to income or profit tax, and also the amount potentially available for new investment. In this connexion, it is worth recording that one of the reasons for the decision not to proceed with the proposed Baluba mine in Northern Rhodesia in 1953 was the fact that the bulk of the £13 million required as capital would have been borrowed, leaving the mine with a fixed debt and service charge considered too large to be safely carried on an output of some 24,000 tons of copper a year.[22] In the case of equity financing by foreign shareholders, although the success of an enterprise may mean the payment of higher dividends abroad, this usually tends to follow the earning of greater foreign exchange income through increased exports.

Although a fixed-interest debt may mean lower relative payments during a period of high prices or production, by the same token it means relatively higher payments during a period of low demand for the metal exports. This argument is reinforced by the fact that some of the ancillary investments in the under-developed country — in public utilities, for example — the expansion of which is prompted by mineral development (though not necessarily paid for by the mines) are likely to require financing by means of fixed-term loans whose servicing will impose a prior burden on available foreign exchange resources. It should be pointed out, however, that, notwithstanding the risks involved in saddling a fluctuating income with a load of fixed costs, a long-term inflationary trend such as has been experienced in the twenty years since the great depression may have the effect of lightening very appreciably the incidence of fixed-interest obligations, unless indeed payment has to be made in gold or a foreign currency against which the currency of the resource country has depreciated.

Although most mining companies raise their initial capital through an issue of ordinary shares or common stock, fixed-interest borrowing is often resorted to for financing subsequent development. In this way a good deal of the recent expansion of non-ferrous metal mining and refining in Africa and Latin America has been financed by loans, some of which have been made repayable in actual ore or metal production. Some £5 million of the £6 million capital requirements of the new Chibuluma mine in Northern Rhodesia, for example, has been provided as a loan by the Defense Materials Procurement Agency of the United States Government, which is to be repaid in metal over a period commencing in 1956, the agency having a prior option on 10 per cent of the mine's output of cobalt. The remainder of the capital (£1 million) is in the form of an equity holding of the Mufulira Copper Mines, Limited. The programme for opening up the copper fields in southern Peru is being financed largely by means of a $120 million loan from the Export-Import Bank of Washington, the remainder of the capital — at least $95 million in new money — being provided by four large United States metal concerns, the American Smelting and Refining Company, the Cerro de Pasco Corporation, the Newmont Mining Corporation and the Phelps Dodge Corporation.

When, from the export earnings of a mining company, the three main monetary streams have flowed to meet the various local costs discussed in the preceding sections and fixed prior charges have all been met, the balance left in the hands of the company is its net profit. This is the most variable of all the elements into which the company's revenue may be divided, and indeed may sometimes be negative. Profits belong to the owners (shareholders) of the company, but their disposal is usually in the hands of a board of directors, who have the choice of distributing them among the shareholders, reinvesting them in the mine, investing them in some other economic activity or holding them in a fairly liquid form pending a decision as to their use.

The effect of the distribution of profits as dividends depends in the first instance upon the domicile of the shareholders. In so far as these shareholders reside outside the country where the mine is located, the distribution of dividends represents a "leakage" of export earnings, and its influence on the domestic economy is exerted mainly through the country's balance of payments. When metal prices are low and mining profit decreases or vanishes, little or nothing may be remitted abroad, but, conversely, in times of high metal prices and high profits the outward flow of funds from the mineral economies

---

payment for prospecting rights over a 55,000-square-mile concession. In 1932, capital was increased again by the issue of ordinary shares, while two years later, when the production of blister copper was well under way, further expansion was financed by an issue of 5½ per cent redeemable cumulative preference shares, this time at 5 per cent premium. The success of the mine is indicated by its ability to sell 57,709 ordinary shares in 1936 at no less than ten times their nominal value, thus raising its outstanding capital to nearly £4 million.

22 The danger in debenture financing of speculative ventures may be illustrated by the history of the Chile Copper Company and its subsidiary, the Chile Exploration Company, after the First World War. Interest and amortization charges were of the order of $3.3 million a year, and in 1919, when revenue dropped to the level of operating costs, this was the magnitude of the companies' joint deficit. A rise in revenue in 1920 just made it possible to meet the year's capital charges, but a more drastic fall (averaging almost 30 per cent) in the copper price in 1921 reduced revenue well below operating costs and left the enterprise, after its interest burden had been met, with a deficit of almost $5.7 million. In 1922, a considerable increase in revenue was almost offset by an increase in costs; net income was insufficient to meet interest charges and there was a further loss of about $1.4 million. It was at this stage that the majority of the company's 3,808,020 shares (par value $25 each) were acquired by the Anaconda Copper Mining Company. For this and other purposes, Anaconda in its turn issued and sold $150 million in bonds (United States Federal Trade Commission, *The Copper Industry*, Washington, D.C., 1947).

Table 34. Balance of Trade and Direct Investment Income of Certain Under-Developed Mineral Economies, 1948 to 1954[a]

(Millions of indicated currency)

Country, currency and year	Exports f.o.b.	Imports c.i.f.	Balance of merchandise trade	Direct investment income[b]: Receipts	Payments: Amount	As per cent of: Exports	Trade surplus
Belgian Congo[c] (Belgian Congo francs):							
1948	13,173.0	8,427.0	4,746.0	197.0	1,216.0	9	26
1949	12,550.0	10,341.0	2,209.0	267.0	1,523.0	12	69
1950	15,776.0	9,927.0	5,849.0	253.0	1,548.0	10	27
1951	20,554.0	16,523.0	4,028.0	401.0	1,717.0	8	43
1952	22,735.0	21,560.0	1,175.0	447.0	2,225.0	10	190
1953	21,438.0	20,442.0	996.0	655.0	2,867.0	13	288
1954	23,783.0	22,129.0	1,654.0	494.0	2,954.0	12	179
Bolivia (United States dollars):							
1948	100.3	82.5	17.8	—	16.5	16	93
1949	89.8	94.1	−4.3	—	0.6	1	d
1950	77.1	65.0	12.1	—	2.2	3	18
1951	124.7	108.5	16.2	—	2.4	2	15
1952	96.0	111.2	−15.2	—	−20.0	e	e
Chile (United States dollars):							
1948	342.1	278.5	63.6	—	68.1	20	107
1949	265.2	305.9	−40.7	—	38.3	14	d
1950	296.6	255.7	40.9	—	49.9	17	122
1951	378.7	361.3	17.4	—	57.2	15	329
1952	453.3	388.9	64.4	—	53.5	12	83
1953	329.3	358.3	−29.0	—	32.5	10	d
Indonesia (rupiah):							
1948	1,045.0	1,230.0	−185.0	...	73.0[f]	7	d
1949	1,503.0	1,724.0	−221.0	...	176.0[f]	12	d
1950	3,040.0	1,684.0	1,356.0	...	390.0[f]	13	29
1951	4,795.0	3,390.0	1,405.0	12.0	575.0[f]	12	41
1952	10,288.0	11,228.0	−940.0	151.0	1,063.0[f]	10	d
Mexico (United States dollars):							
1948	461.0	608.5	−147.5	...	71.3[g]	15	d
1949	463.0	532.5	−69.4	...	47.0[g]	10	d
1950	520.9	596.6	−75.7	...	65.1[g]	12	d
1951	629.7	888.2	−258.5	...	90.7[g]	14	d
1952	655.5	829.0	−173.5	...	113.8[g]	17	d
1953	589.2	807.6	−218.4	...	82.8[g]	14	d
Northern Rhodesia (Southern Rhodesian pounds):							
1948	27.4	18.7	8.7	...	11.6	42	133
1949	33.9	24.4	9.5	...	13.7	40	144
1950	48.8	30.7	18.1	...	22.1	45	122
1951	73.5	40.3	33.2	...	29.4[h]	40	89
1952	83.3	48.5	34.8	...	35.2[h]	42	101
Peru (United States dollars):							
1948	162.5	168.5	−6.0	—	12.6	8	d
1949	156.7	168.8	−12.1	—	10.0	6	d
1950	194.1	177.5	16.6	—	8.5	4	51
1951	254.3	264.4	−10.1	—	20.1	8	d
1952	242.4	300.9	−58.5	—	19.2	8	d
1953	226.4	300.3	−73.9	—	17.8	8	d
1954	253.7	254.8	−1.1	—	19.1	8	d

Source: International Monetary Fund, *Balance of Payments Yearbook*, volumes 5 and 6 (Washington, D. C.).

[a] Or latest year for which data are available.

[b] Income, after deduction of taxes, accruing from investments located in one country but effectively controlled by residents of another country. For the definition of "control" in this context see International Monetary Fund, *Balance of Payments Yearbook*, volume 5, page 10.

[c] Including Ruanda-Urundi. The trade figures are inflated slightly by inclusion of the value added to exports by processing in Belgium. The figures for direct investment income are inflated somewhat by inclusion of other (indirect) investment income.

[d] Not calculable since the balance of merchandise trade was passive.

[e] Not calculable, since there was a passive balance of merchandise trade and a net loss by foreign-owned mining companies.

[f] Including remittances by foreign-owned oil companies. Profits, oversea expenses and capital movements connected with these oil companies involved a net outflow of 6 million rupiah in 1948, 39 million in 1949, 297 million in 1950, 406 million in 1951 and 608 million in 1952.

[g] Including reinvested earnings as follows: 1948, $14.4 million; 1949, $12.7 million; 1950, $27.0 million; 1951, $43.5 million; 1952, $48.3 million; 1953, $17.9 million.

[h] Including dividends declared by mining companies whose head offices were transferred to Northern Rhodesia in 1951: £7.9 million in 1951 and £10.0 million in 1952.

may be considerable. Although mine profits and the country's export earnings are not independent variables, the fact remains that dividends are related primarily to the profits (and hence to previous sales) of the mines in question and not necessarily to the exporting country's immediate balance of payments position. Hence it is possible for a country's import programme and its mines' dividend policy to be out of phase: when the balance of trade is passive, the distribution abroad of large profits earned in some earlier period by the mining industry may result in a rapid depletion of foreign exchange reserves and possibly in temporary balance of payments difficulties.

Something of this nature seems to have occurred in Bolivia in 1938, for example, when miscellaneous receipts on current account were insufficient to offset the combined effect of a small passive balance on merchandise trade and a large payment — amounting to 24 per cent of total export value — of profit on foreign-owned investments, chiefly tin mines. In the two following years, the balance of trade was active, though smaller than the net payment made on foreign investments in 1939 and only 20 per cent larger than the net payment in 1940.

In Chile the initial effects of the depression of 1930 to 1933 were doubtless aggravated by the fact that in 1929 net earnings of foreign companies — largely nitrate and copper mines — were almost 50 per cent greater than the balance on merchandise trade. A similar situation has emerged in more recent years. In 1948, for example, remittances by the large mining companies exceeded the surplus earned by trade (see table 34). In 1949 a considerable drop in the value of exports, combined with a rise in imports, resulted in a substantial trade deficit; however, a small deficit on other current transactions was partly offset by investments by the large mining companies in excess of the interest and profits earned in that year. Balance of trade surpluses achieved in 1950 and 1951 were again smaller than direct investment payments. In 1952, however, the trade surplus was augmented by the mining companies' investments, which exceeded by a small margin their net earnings. In 1953 there was another passive trade balance, but this was again partially offset by the excess of mining investment over remittances of profit.

In Indonesia, trade deficits in the post-war period were accompanied on several occasions by appreciable outflows of the earnings of foreign concerns, not counterbalanced to any marked extent by increases in their investments. In these movements the oil and rubber industries played a much larger part than the non-ferrous metals industry.

In Mexico, where the non-ferrous metals industry is of greater relative importance, substantial remittances of foreign company profits have continued alongside trade deficits throughout the post-war period. The proportion of such profits reinvested locally has ranged between 20 per cent in 1948 and 48 per cent in 1951.

In Peru, where merchandise trade balances have been passive in most post-war years, remittances of earnings of foreign companies have remained in the neighbourhood of 8 per cent of gross export value. Until 1950 they were not offset to any marked extent by new investment by these companies; in 1950, indeed, there was an appreciable disinvestment. In the period 1951 to 1953, however, new foreign investment substantially exceeded the income transferred to parent concerns abroad.

In Northern Rhodesia net direct investment earnings exceeded the active balance on trade account in most of the years between 1947 and 1953, despite a rapid increase in the value of exports. Except in 1949 and 1952, however, the rate of new investment by the mining companies was high enough to reduce actual transfers below the level of the trade surplus. Though the removal of the headquarters of two of the large companies from London to Kitwe in 1951 had a noticeable effect upon the territory's balance of payments, this was largely of a technical nature, involving merely the reclassification of investment income. From an economic point of view, the principal immediate result was a reduction in the companies' tax burden and a corresponding increase in profit available for distribution to shareholders, most of whom continued to be non-residents. In the long run, however, the transfer may well have a more profound effect on the distribution of mine earnings; the presence of the company directorate and headquarters staff in the country where the mines are located is likely to affect the direction and rate of local investment, while the local government may have been placed in a better position to increase its share of mine profits.

This brief review of the balance of payments of some of the principal mineral economies in recent years indicates that a current account deficit, caused or enlarged by profit transfers by foreign companies, may be counterbalanced, completely or partially, by an inflow of capital to finance new investments of these companies. Even when there is no compensatory movement of company capital, there may be adequate opportunities for other types of borrowing. If not, shortfalls on current account may be successfully met by drawing down foreign exchange reserves. Disequilibria of this nature may cause no more than a temporary strain; if they occur at the onset of a period of declining exports or deteriorating terms of trade, however, they may enhance the difficulty inevitably experienced by an under-developed mineral economy in adjusting foreign exchange expenditures to a reduced level of earnings.

Considered in isolation from both the pattern of imports and the nature of international capital movements at the time, these examples do no more than indicate one aspect of the problem facing the less developed country whose exports consist largely of minerals and metals derived from ore resources which are being developed by foreign concerns. More generally, the balance of payments of most of the under-developed mineral economies has passed through two stages analytically distinct but in practice often overlapping, because of the continuing, organic nature of the development process: (1) an investment or borrowing phase; and (2) a debtor or repayment phase. In some instances the former has been quite short, while the latter has often been protracted. The investment phase, when unfavourable trade balances are being financed by the inflow of foreign capital, is characteristic of the opening up of the country's non-ferrous mineral resources. At the end of this primary development stage, both capital inflow and merchandise imports may tend to decline temporarily as the need for additional equipment drops, while exports have usually risen rapidly as the initial investment has begun to yield ore or metal which is marketable abroad, thus creating an active balance of trade. This process may be repeated, another borrowing-repayment cycle being superimposed on the previous pattern, as a new inflow of foreign capital is invested in the development of more of the country's natural resources.

Fluctuations in export income have tended to be particularly disruptive in those economies in which the financing of diversification during at least the early stages of development was being undertaken, directly or indirectly, from the proceeds of the mineral industry, especially where this source of new investment was being supplemented to any considerable extent by foreign borrowing. A public utility which is quite capable of earning the amounts required for interest and amortization when the mineral industry is an active user of its output, for example, may become an embarrassment when the industry is buying less of its product and providing less of the foreign exchange required to service the debt. It was in this manner that Chile's fixed-interest borrowing in the nineteen twenties added appreciably to the crisis caused by the collapse of the copper and nitrate markets in 1930. Thus, in the early stages the very effort to realize part of the development potential of the mineral industry through use of some of the revenue derived from it for investment in other productive fields may, by adding disproportionately to total foreign exchange requirements, whether for capital equipment or for components or raw materials, tend to add to the risk of balance of payments difficulties in the under-developed economy inherent in fluctuations in mineral export earnings.

In a number of under-developed countries where foreign, equity-financed companies are exploiting non-ferrous mineral resources, attempts have been made from time to time to apply fiscal deterrents to check the transfer of profits and thus retain within the economy a larger share of foreign exchange earnings. In some Latin American countries such deterrents, operated as part of a system of exchange control, have often consisted of a direct limitation (absolute or in proportion to some definition of capital) on the total amount a foreign company is permitted to transmit each year as dividends to its shareholders abroad. Where the company is not required to surrender all the foreign exchange earned by the export of metals or where a mine is a unit in one of the integrated systems, dividend limitation is more difficult to administer. In the Union of South Africa one check to the transfer of profits has taken the form of a non-resident shareholder tax by means of which a proportion of the dividend outflow is channelled back to the public purse. More generally, in line with the principle that the mine that uses its profit for reinvestment within the resource country is contributing more towards development than the mine that distributes its profit to shareholders, especially when those shareholders reside outside the country, tax systems have been designed to impose a greater burden on profits that are distributed than on profits that are retained in the company, ploughed back into the mine or reinvested in some way in the resource country.[23]

For the company the problem of whether or not profits should be distributed in the form of dividends arises irrespective of the domicile of the shareholder; for the resource country, however, there is no *a priori* reason why purchasing power should not be used as productively by a resident shareholder as by the mining company, even though the shareholder may be less likely to invest or save the proceeds.

The company's main reason for withholding or reducing dividends is usually its desire to accumulate resources sufficient to finance its own expansion. It is fairly common practice, for example, for a portion of realized profit to be reinvested in the mine itself in order to develop the reserve of ore in such a way that exploitation can proceed smoothly and continuously and give maximum ore extraction in the minimum time. When one ore body approaches exhaustion, part of the reinvestment process usually consists in a search for alternative resources, if possible within the same country but if necessary elsewhere. Herein lies some of the peculiar strength of the large companies which have tended to dominate the non-ferrous metal industry: their special knowledge and skill and their international organization equip them to reinvest in the non-ferrous metal field to the greatest advantage and without special regard for national boundaries.

Whether the economic development of the resource country is advanced more by reinvestment in the mineral industry or by new investment in an unrelated activity is a question that must be decided case by case. In general, the mining company is best equipped to operate its own particular type of undertaking, even though investment in smelting and refining facilities and associated metallurgical works may take it far into the field of secondary industry. Where mining companies have invested beyond the limits of the minerals industry it has usually been in fields in which they were concerned as purchasers. As indicated earlier in this chapter, many mines in under-

[23] This poses a major problem for many under-developed countries: being dependent largely on private foreign capital (and skill) for the exploitation of their mineral resources, they are usually anxious not to cut off the future flow of funds by fiscal policies which might curb the movement of realized profit below the rate considered minimal by investors, bearing in mind the risk and slow maturation of most mining investment, or below the rate obtainable in comparable investment elsewhere. The company itself faces a similar dilemma, for apart from the fact that its principal aim is to earn profits and distribute them eventually in the form of dividends to shareholders, there is a certain psychological necessity for a successful company to maintain an adequate flow of dividends, especially if it intends to raise further capital on the market from time to time.

developed countries have financed the construction of facilities which in more advanced economies would be provided through independent investment. An outstanding example of the ramifications of a large mining company in an under-developed economy is provided by the copper industry in the Belgian Congo.

The peculiar position of Union minière du Haut Katanga as a highly capitalized and profitable concern operating in a remote, under-developed part of central Africa, with its policies influenced to a certain extent by government participation in its direction, has tended to widen its activities far beyond the limits of a simple mining company. It has gradually become, in effect, a large development corporation.[24]

A successful non-ferrous ore mine is certainly an important potential source of new capital in an under-developed economy, although exactly how this capital may be most fruitfully used is a question which lies outside the province of this study. To judge by the history of the various mineral economies, the degree to which development is likely to be furthered by the distribution of mining profit among resident shareholders is partly a function of the existing economic environment, including, in particular, the status of the local capital market. In general, the less developed the country, the more likely it is that mining company profits will be put to better use either by the company itself, through reinvestment within the mining industry or in an associated field, or by the government, through the creation of economic and social "overhead" facilities. Investment in the latter, whether by government or by a mining company, constitutes an essential part of the development process, contributing in particular to the building up of an economic environment in which smaller amounts of private capital can be more profitably employed.

Northern Rhodesia would appear to be an example of a mineral economy in that rudimentary phase when more diversified economic development, at least in the immediate future, depends largely on government investment, which in its turn depends mainly upon taxation of mining incomes. This has been true of the Belgian Congo, also, where the Government and the large mining companies have accounted for the great bulk of new investment. Less dependent on mining but equally dependent on export activities, Malaya would seem to be in much the same phase. Chile and Peru, the major producers of non-ferrous minerals in South America, appear to be at a somewhat later stage of development, in which diversifying domestic investment may also be effectively promoted by public or semi-public corporations deriving their financial resources partly from borrowing and partly from government revenue, which in turn still comes to a marked degree from mining taxation. Mexico and the Union of South Africa seem to have reached the stage when investment by government, mines and development corporation is effectively supplemented by direct investment of privately owned domestic capital. As the mineral economies become economically more mature, partly as a result of the expansion and improved organization of the local capital market, economic development is likely to be much more diverse and mining capital much less conspicuous in the flow of new investment.

In all these countries capital remains very scarce, both in relation to need and in relation to available land and labour, and the degree to which the profits of mining companies are used within the domestic economy — whether by the mines themselves, by resident shareholders or by government — is still an important determinant of the rate of economic development.

Some institutional considerations affecting the development of mineral economies

The institutional background of the under-developed mineral economies is by no means uniform; it varies with a country's historical growth, with its natural resources, with the nature and size of its population and with the way in which its ore deposits have been exploited. Nevertheless, there are a number of features common to several of the mineral economies — the operations of international non-ferrous metal companies and of certain other financial and commercial institutions, for example — and one feature that is common to all — the wasting nature of their mineral assets. These common features are discussed briefly in this final section.

International non-ferrous metal systems

It was pointed out in the previous section that many major non-ferrous ore deposits in under-developed countries are exploited by foreign companies. It is now proposed to examine some of the implications of the fact that many of these foreign companies are branches, subsidiaries or components of larger integrated international concerns.

Although the histories of these concerns differ in many details, they reveal a certain uniformity arising in part from the way in which the technical and economic nature of the flow of ore and metal tends to encourage and determine the pattern of integration. If the original company was founded on a mine, expansion took the form

[24] In 1951, the list of enterprises in which it held substantial interest included the Société générale des forces hydro-électriques du Katanga and the Société générale africaine d'électricité, generator and distributor, respectively, of power to the mines and urban areas of Katanga; the Société générale industrielle et chimique du Katanga, producer of sulphuric and hydrochloric acids, caustic soda and sodium chlorate, distilled water, hydrogenated palm oil, glycerine and, from foundry dusts, metallic cadmium; the Compagnie foncière du Katanga, a housing and construction concern; the Minoteries du Katanga, a producer of foodstuffs and feed; the Compagnie du chemin de fer du Katanga, owner of the Katanga railway network, recently amalgamated with the Leopoldville-Katanga-Dilolo system; the Compagnie maritime congolaise, another transport concern interested chiefly in river shipping; the Société africaine d'explosifs, operating factories at Kakontine and Manono; the Exploitation forestière au Kasai, a timber and saw-milling concern; the Ciments métallurgiques de Jadotville, a new producer of fire bricks and other refractory materials; and the Société d'élevage de la Luilu, a ranching company. More directly concerned with its mining activities are its interests in the Société de recherche minière du Sud-Katanga, the Syndicat pour l'étude géologique et minière de la cuvette congolaise and the Syndicat de recherches minières Bas et Moyen-Congo — three prospecting and exploration concerns through which investment can be channelled more directly into the minerals industry.

of the establishment of an associated smelter and refinery. To keep these plants running at optimum rates additional ore was often purchased from outside mines or treated on toll for small producers. In the course of time other mines were often acquired or other deposits opened up. Metal from the refinery was sold to established users, and in many cases the trade links thus formed were later strengthened by financial links and ultimately by unified control. An integrated system was thus established with a smelter or refinery at the centre, several mines feeding it with ore or concentrates and a number of fabricating or consuming plants receiving the outflow of metal. In general, the fabricating and consuming plants were situated near the market and hence usually in the manufacturing areas of industrial countries. Increasingly, however, the mines have been located in less developed countries, and to a certain extent smelting, and to a rather smaller extent refining, facilities have tended to follow them.

One of the results of the growth of these concerns and the expansion of the demand for the various non-ferrous metals was an increase in the outflow of capital from major industrial countries to mineralized areas — known or conjectured — of less developed countries. In the last decade of the nineteenth and the first decade of the twentieth century, there were substantial investments by United States non-ferrous metal companies in Canada, Bolivia, Chile, Cuba, Mexico and Peru; by British interests in Australia, Bolivia, Burma, Canada, Malaya, Nigeria and Spain and later in the Rhodesias; by German interests in Greece, South West Africa, Turkey and Yugoslavia; by French interests in Morocco, New Caledonia and Spain; by the Netherlands in the East Indies; and by Belgium, somewhat later, in the Belgian Congo. In this way, most of the larger mines in these less developed countries not only were financed by capital raised in the main industrial countries but also were managed by the leading metal companies in those countries and linked in a very close and direct way with established systems of mines, smelters and refineries.

The desire to exercise control over raw material supplies became one of the main determinants of policy of the metal companies and also a matter of increasing concern to governments conscious of the growing strategic significance of non-ferrous metals. This question of control over raw materials thus tended to emphasize the distinction between more advanced industrial countries and less developed mineral producing countries. In certain respects international non-ferrous metal organizations, arising as they have in the main from the older companies' search for new raw material supplies to replace depleted or more costly domestic sources, reflect the disparity between levels of economic development attained in different areas. Industrially advanced countries, with their large metal companies and their wider experience of the most effective techniques of geological survey, mechanized extraction and treatment of ore, have been the natural source of the capital and skill that are necessary to locate and mine any ore body which is more than a surface pocket or placer. Thus, industrially advanced countries have tended either to draw off the ore for smelting in their established metallurgical industries or to supply the capital and skill that are necessary to build and operate smelting facilities in the country when the resource is located. Industrial countries are also natural markets for the resultant metal, for it is likely to be used on only the smallest scale in the under-developed country of its origin.

Historically, therefore, the non-ferrous metal systems have spread from the industrial countries to the less developed countries. Hence, although numerous branches have been established, with smelters and refineries, in under-developed countries, in general the integrated systems are still heavily weighted by their interests in the industrial countries. This reflects both the centre of gravity of capital ownership and also the technical advantages of the industrial environment, not only from the point of view of operating a mine or a refinery, but also from the point of view of marketing the product.

Nevertheless, less developed countries have become increasingly involved and increasingly important in the various non-ferrous metal systems. In some cases this has been the result of the opening up of new deposits which, as indicated in chapter 3, followed the attempts of established producers to exercise control over the markets for a particular metal. In other cases it has been the inevitable consequence of the exhaustion of ore resources in industrial countries, several of which have become almost completely dependent on imports for their non-ferrous metal supplies. The result, at least so far as the larger non-ferrous mines are concerned, has been to make the autonomous unit the exception rather than the rule in under-developed areas: in most cases the local industry is directly or indirectly part of one of the integrated international groups of mines, smelting and refining facilities, and fabricating plants.

The level of activity of such a group tends to vary with the demand for its final products, which in turn is a function of the general level of expenditure and investment, primarily in the industrial countries. Refinery operations are governed by the metal requirements either of the group's own manufacturing plants or of more or less closely associated industrial consumers. In their turn refinery operations determine the intake of raw metal, whether from primary or secondary sources. The demand for primary metal regulates the activity of the smelters in the system and this in turn ultimately dictates the rate at which ore is mined.

Several of the non-ferrous metal systems — that of the Anaconda Copper Company, for example — are more or less self-contained, mining output being geared to smelter and refinery capacity and refinery output geared to fabricating capacity. A change in the demand for manufactured products thus affects the whole system, though each refinery-centred branch may be affected differently, depending to a large extent upon its marginal cost. In general, the branch in which the marginal cost of the refined metal is low is likely to be expanded to meet an increase in demand, the branch in which the marginal cost is high is likely to be contracted to meet a decrease in demand while, irrespective of changes in demand, forces operate within the system tending to equalize marginal costs. In these circumstances, the broad criterion of success is the degree to which the net returns of the system as a whole are maximized. There is in general much less concern about the maintenance of optimum rates of production or the attainment of optimum levels of extraction in any one unit than there would be if that unit were completely autonomous.

Because of the opportunities it gives for the sharing of technical experience, for reducing the levels of inventories held at each stage of production and for close co-ordination of activities in each constituent unit, the integrated form of organization presents a number of advantages for the efficient operation of the industry. Policies directed towards maximization of the net returns of the group as a whole, however, may lead to adjustments less favourable to particular components and more favourable to others than might have been the case if these had been autonomous units freely competing and co-operating.

There may, for example, be a tendency to concentrate output adjustments upon those mines possessing the best grade of ore, which, in general, are more flexible production instruments than the mines with lower-grade ore. In the limiting case, some of the lowest grade ores can be worked at a profit only on the basis of continuous mass extraction and treatment. The degree to which the rate of exploitation can be varied is very narrow; an increase involves the expansion of all beneficiation and processing facilities, a decrease soon raises average costs to the point where it becomes commercially preferable to close the mine altogether. Where richer ores are being mined, by contrast, average costs seldom change so quickly in response to changes in the rate of extraction; if selective mining is practised the average grade of the ore actually extracted provides another variable through which adjustments can be made. Within the group such adjustments are not necessarily influenced by the nationality or location of the component elements, except in so far as these are reflected in cost — as additions to transport charges or tax bills, for example — or in strategic considerations which might give nearby resources an advantage over those that are more distant and less secure.[25] Many of the higher-grade ore bodies, especially in the case of copper, are, however, located in less developed countries in which changes in the rate of extraction might be expected to have their greatest incidence and, because of the importance of mining in the economy, exert the greatest secondary effect.

Within a given group, in other words, the constituent elements of a mine-smelter-refinery-fabricator system tend to be regarded not as independent variables but as interdependent parts. Whether a new ore body should be exploited or an operating mine developed more or less rapidly is decided not necessarily in the light of the raw material or financial needs of the economy in which it happens to be situated, or even of the relative grade or potential profitability of the mine itself, but rather in accordance with the technical and financial requirements of the whole non-ferrous metal organization of which it is a member. The development potential of the Cananea mine in Mexico, for example, is inevitably affected by the fact that it is a tributary of the Raritan refinery in New Jersey. A change in the rate of mining at Cananea would involve not only a change in the throughput of the Cananea smelter but also new arrangements at the Raritan refinery, which would, in turn, affect to a greater or lesser extent all its various other tributaries, the Andes Copper Mining Company at Potrerillos, the Miami, Castle Dome and Inspiration mines in Arizona and the Chile Exploration Company at Chuquicamata, as well as the intake of scrap; and in the last resort the change presumably would be acceptable only if, according to the criterion of net returns, it benefited the system as a whole.

In general, therefore, the fact that a mine in an underdeveloped country forms part of an international system often based technically on facilities in an industrially advanced country and almost invariably based financially on an organization whose dominant interests are in the advanced country means that the dynamics of mining operations (and even more of smelting, refining and fabricating) are governed less by the net returns of the mine itself or of its ancillary works than by the technical requirements and financial results of the branch of the system of which it is part, or even by the profitability of the system as a whole. Thus, irrespective of its potential ore resources, a feeder mine may be developed no more at a given stage than is warranted by the capacity of the plant which it has been designed to serve with ore or concentrates. Conversely, a very close link between the intake of a particular smelter or refinery and the output of a particular mine may result in a rate of extraction which differs significantly from the optimum and may involve the ultimate sacrifice of ore reserves which might otherwise have extended the effective life of the mine.

The maintenance of an equilibrium between fabricating plants, refineries, smelters and mines which yields optimum results for the system as a whole may thus leave a particular mine in a less developed country, and perhaps its smelter, either with an unused potential capable of considerable expansion, or with reserves which might have been more effectively exploited had the rate of extraction been adjusted to allow for maximizing the total amount of ore removed. In a hypothetical case of this nature the rationale of an increase in the rate of production or of attempts to lengthen the life of the mine lies in the concomitant effects on the development process

[25] Long-run strategic considerations may cut across cost criteria. There may be a tendency to regard domestic mines, irrespective of their cost status, partly as a strategic reserve to be developed fully but exploited only when internal requirements cannot be met conveniently and cheaply from foreign sources. This was one of the suggestions of the President's Materials Policy Commission, but it is doubtful whether it has had much influence upon mining development in the United States.

in the resource country. This would require that greater importance be attached to needs and opportunities within the under-developed country and somewhat less to changes in world market conditions that affect chiefly the position and interests of the international non-ferrous group as a whole.

When market conditions call for a cutback in output, marginal supplies of ore purchased from independent mines are likely to be eliminated first. Where a system has to reduce its own mine production, however, cost criteria have to be weighed not only against technical considerations but also against the somewhat less tangible psychological forces which govern relations both with mine personnel and with the public at large. As a result, a lower-cost mine in an under-developed country might have to sustain a relatively greater reduction in output than a poorer contributary mine located in the industrial country from which the system as a whole is controlled.

In this way the participation of a local mine in an international non-ferrous metal organization may involve the loss of a certain amount of the influence the government of the under-developed country might otherwise expect to exercise in regard to decisions about production and sales, about where the ore should be processed, about reinvestment of profits and about numerous matters of mining policy and administration in which there may be a divergence between the interests of the resource country and those of the system of which the particular mine forms a part. This is likely to affect the development potential of the mine, especially if the group of which it has become a contributing part holds a dominant position in world production.

By bringing an element of the market within the organization formed by mines, smelters and refineries, on the other hand, integration has probably helped participating units to reduce some of the risks of fluctuating demand and price which have characterized the non-ferrous metals industry. The integrated system tends to have a certain economic resilience which any single mine is likely to lack. Thus it is able to plan and distribute changes in output to avoid the mutually reinforcing fluctuations in inventories which tend to occur at different points in the normal distribution system and hence can adjust its rate of activity more readily to changes in demand. In so far as assuring a more regular sales outlet and reducing inventory fluctuations tend to increase the stability of the market for the individual mineral producer-member of the system in an under-developed country, this in itself should permit sounder mining practice and more economical exploitation of the ore. Nevertheless, the group as a whole remains dependent upon outside demand for fabricated products; if this falls drastically, major adjustments within the system cannot be avoided, and in the interest of the group as a whole these might entail heavier burdens on particular components than would have been incurred had the units in question been competing independently on the open market.

Whether, over a long run, the development potential of a non-ferrous mineral resource in an under-developed country is raised or lowered by being thus integrated into a foreign-based system is a question to which no *a priori* answer can be given. Without the skill and capital made available by major metal concerns some of the ore resources of under-developed countries would probably not have been exploited at all. Moreover, a mine in an under-developed country must in any event sell all or almost all its output on an external industrial market. The less the degree of beneficiation undergone by the ore, the more confined are its marketing opportunities likely to be, since the plants equipped to process it are fewer and the relative cost of transport is higher than in the case of refined metal. In general, there is evidence of mutual concern on the part of producer and consumer of non-ferrous metals to establish a working connexion, the former to assure a steady market for his product and the latter to assure his supply of raw material. Since consumers of the major non-ferrous metals operate very largely if not entirely in industrially more advanced countries, the independent producer in an under-developed country is at a disadvantage in effecting such marketing arrangements. As a participant in one of the major metal systems, however, the producer probably strengthens his marketing position.

So far as the world market for non-ferrous metals is concerned, however, the activities of the major systems are not necessarily stabilizing in their effects. Indeed, it would appear that attempts to increase stability within these more or less self-contained systems have tended to narrow the outside market and hence indirectly induce somewhat greater fluctuations. To that extent, autonomous mines in less developed countries, being so heavily dependent upon the world market, are in a particularly vulnerable position. Because, in the last resort, both the autonomous mine and the group tributary — and for that matter, the under-developed country itself, in the utilization of its non-ferrous mineral resources — are governed by the market for the metal and its products, the desiderata of their several policies are not necessarily incompatible. Although the development policy of an under-developed country is likely to be guided in the main by internal requirements and domestic resources, while the policy of the metal system in respect of its mine and its reduction and refining facilities in that country is usually based on a completely different set of considerations — most of which have their genesis not in the resource country but in the relationships between competing and co-operating elements in the international group — reconciliation is usually possible either through appropriate fiscal arrangements or by special lease or other agreement between the mining company and the government of the country in which the resource is located.

Mining banks

One of the principal influences on the development potential of the non-ferrous metal industry is the efficiency with which ore deposits are worked. Where deposits are small and scattered, as are some of the copper ores in Chile, some of the tin ores in Bolivia and Malaya, most of the antimony ores in Mexico and most of the tungsten ores in Southern Rhodesia, mining operations are necessarily organized on a small scale. Many of these small-scale mines, however, either through lack of knowledge and skill or, more frequently, through lack of capital, are worked at a lower level of efficiency than is inherent in their nature.

If mining credit were more readily available, the efficiency of these small workings could doubtless be raised substantially, while in many cases an investment in facilities serving a number of properties would improve the rate of extraction and make possible a greater degree of local processing. High metal losses in "fines", for example, are often tolerated because of the relatively heavy capital cost of recovery plants for treating slimes. Where a single working might not have a throughput large enough to justify such a plant, it might be economically feasible to have the plant shared by a group of workings. This would probably require not only a suitable co-operative organization but also a geological knowledge of the region sufficiently detailed to enable both workings and plant to be properly located.

The capital costs of survey and plant would require outside financing, and this is one of the functions that might well be carried out by a mining bank, to the advantage of both the miners and the economy as a whole. Similar arguments might be advanced for assistance in the establishment of facilities for finer milling than can normally be carried out in small plants, at least in areas where this would make a significant difference in the average rate of extraction. To meet the needs of the small independent mine, in recent years several governments, especially in Latin America, have set up mining banks of this nature. Such banks helped to finance the central copper smelter in Chile and the pilot tin smelter in Bolivia, for example.

The Banco Minero de Bolivia, established in 1936, draws its funds from the central bank and the Government, and has been mainly concerned with marketing the output and supplying the credit needs of small mines. Before 1936, most of the small mines had sold their output of ore to an intermediary group known as *rescatadores*, who not only undertook the export of concentrates but also sold stores and materials to the mines and often assisted them with credits. The *rescatadores* actually received quota allocations during the period of tin control. After 1936 many of their functions were taken over by the Banco Minero, and in 1939 the *rescatadores* were eliminated altogether when the bank was granted exclusive rights to handle the tin output of the small mines. In 1936 it handled 2 per cent of the country's tin exports; by 1949 the proportion had increased to 16 per cent; and in 1952, when the three major companies were nationalized, the bank became the sole exporter of tin until the Corporación Minera de Bolivia was formed to take over their operation on behalf of the Government. In recent years it has initiated the exploitation of new copper and tin deposits and in 1953 it began a survey of iron and manganese resources.

In Chile, the Caja de Crédito Minero was established in 1927 and the Instituto de Fomento del Norte in 1935 — both concerned with providing credit to small miners and improving their marketing facilities. The bank was financed by government contributions and bank loans, but it was not until it gained the support of the Corporación de Fomento in 1950 that it was able to erect a sizable copper and gold smelter for the use of small-scale miners.

The mining industry of Turkey has received a certain amount of assistance from the Eti Bank, but the functions of this institution, like those of the Banco de Crédito Industrial in Argentina, are rather wider than mining finance.

Though mining banks are not designed to assist in the diversification of the local economy — except, perhaps, by helping to organize and finance the further processing of locally mined ores — they might well play a more important part in the domestic capital market by helping to mobilize local capital for the mineral industry, in addition to the part they have so far played as distributors of credit provided by governments.[26]

Other financial and commercial institutions

One force militating against the economic development and diversification of certain under-developed mineral exporting countries has been a tendency for parts of the institutional framework, particularly in the commercial and financial sectors, to become rigid and unadaptable. In one or two countries, this lack of flexibility may be ascribed to close ties that exist between the local mining industry and the large international concerns referred to earlier in this section, but it extends beyond this relationship. Local financial institutions, particularly banks, tend to specialize in transactions of the established type: financing export shipments of metal or ore and import shipments of manufactured commodities — mining stores and consumer goods. Although in general mines with foreign connexions have at least their long-term, and often their short-term, capital needs met by parent or associate companies, local financial institutions may participate in the financing of a new mining venture, but rarely do they finance activities outside the narrow fields of mining and trade in mine products and stores. This is one reason why development corporations with funds provided by the government, as in Chile or the Union of South Africa, have usually concentrated on secondary industry — a field that tends to be neglected by the less flexible financial institutions common to mineral economies during the early stages of economic development.

---

26 In several less developed mineral economies, large mining concerns have often had more credit at their disposal than the government, and in at least one case — Bolivia — the mines have occasionally become lenders to the Government, either by granting it an advance on future tax payments or by subscribing to a short-term loan pending the issue of longer-term bonds on the oversea capital market.

In some of the mineral economies, Bolivia and Northern Rhodesia, for example, the mining concerns organize and carry on most of their own import trade. This also tends to result in a certain institutional rigidity, which militates against experiment and diversification. Even when the import trade is in the hands of independent merchants, however, the degree of flexibility may not be much greater. For, in much the same way, the commercial organization built around the relatively large and concentrated market which the mines constitute in several under-developed countries also tends to acquire an inertia leading it to oppose changes in the pattern of trade in which local merchants derive the bulk of their income from acting as distributors of imported goods. Moreover, merchants with an established interest in import trade tend to oppose tariff protection under which a domestic industry selling directly to the mines might be established.

The normal tendency of mining companies to resist changes which threaten to increase their working costs also contributes to institutional rigidity. In general, so long as there is no immediate possibility that the changes will result in a rapid and sizable increase in the domestic consumption of their products, export industries — non-ferrous mines not least among them — naturally tend to be much more concerned about holding down costs in order to compete sucessfully on international markets than about developing the economy by competitive investment in other fields. The fear that such investment will occasion increased costs arises on two distinct accounts. First, there is the possibility that in order to protect local industry customs duties may be imposed and other measures enacted that would tend to raise the price of products bought by the mines. Secondly, there is the probability that the establishment of domestic industries will result in greater competition for local factors of production, particularly labour, thus raising costs.[27] Whether or not these fears are justified,[28] their existence constitutes an impediment to change and therefore to economic diversification.

In such ways the traditional institutional structure of the mineral economies sometimes tends to impede the process of economic experiment and diversification. Established institutions, unless they have been set up especially for the purpose of initiating changes, inevitably tend to follow rather than direct the process of economic development. In general, therefore, institut.. al factors in under-developed mineral economies have tended to preserve the *status quo* rather than assist in reducing the dependence of these countries on ore and metal exports by diversification of investments and production.

[27] In the Union of South Africa, the mines have tended to avoid the full effect of the higher wage rates induced by the competition of other employers, particularly in secondary industry, by increasing dependence on immigrant labour.

[28] There are many examples of local industries in developing economies which have in due course produced goods at lower prices than those quoted for imported products, and in the long run the growth of a domestic market for the output of non-ferrous metal mines depends on the multiplication of such industries.

Government responsibility for a wasting asset

Mining differs from most other forms of economic activity in that it involves the exploitation of a non-renewable resource of strictly limited if not precisely known magnitude. On the one hand, the value of an ore deposit is realized only when it is exploited but, on the other hand, as a wasting asset it ultimately becomes more and more difficult or costly to work and, in the end, after the removal of all paying portions, a residue is left which has no economic significance. The value of a deposit is relative, not absolute, and no body of ore can be defined in terms of an exploitable life of a specified number of years. The length of a mine's life obviously depends on a number of variables, among which the extent and grade of the ore body, the technique of mining, the rate of extraction, the trend of metal prices, and the cost of mining and smelting the ore are probably the most important.

Nevertheless, the life of a mine is limited in a much more definite way than the life of a factory. As a "development industry", therefore, mining must measure its success not only by the profit it earns for an owner or the wage it pays to its labour force or the contribution it makes to the public revenue, but in the main by the extent to which the purchasing power it generates while the ore is being extracted during its life is used directly or indirectly to create more lasting or renewable assets which are at least as productive of income as the mines themselves. This is not an argument for setting aside definite amounts of mine revenue for specific forms of alternative investment. What is important, however, is that, at least in a public programme of expenditure, the rate and direction of investment should be determined in full knowledge of the transience of mineral resources and the revenue being currently derived from them.

The concepts of obsolescence and replacement are applicable to natural and man-made assets alike. What distinguishes a mineral deposit from any other asset worn out or depleted in the course of its use, is the fact that the latter is always replaceable by something that is its functional equivalent and often by an asset which is actually more productive. In the case of an ore body, by contrast, the only replacement that can be effected will necessarily be of a different nature, and the exhaustion of a particular deposit may well mean the end of the country's ability to produce the metal in question.

The Cornish mines in England were once the world's leading producers not only of tin but also of tungsten. Most countries in the "old world" have worked out their major non-ferrous metal deposits and have long since become dependent — partially if not entirely — upon imports. Even in the "new world" ghost towns are not unknown memorials to vanished mineral resources.

In economic terms, the exhaustion of a mineral resource makes necessary a change in the pattern of trade; markets must be found for the products of such substitute assets as may be created during the life of the mine. Here again this creates a special problem for the under-developed country from which the output of ore or metal was all (or almost all) exported, since it is unlikely that the products of such assets as were built by the investment of revenue derived from the mine will be saleable in the same markets as the mineral. Indeed, they may not be exportable at all, in which case the country will suffer a reduction in its foreign exchange receipts — either gradual, if mine production declines slowly as it nears exhaustion, or sudden, if mine operations cease abruptly when unit costs reach an uneconomic level. In the case of some of the mineral economies the decline in export earnings might be of major dimensions.

In theory such a situation might be avoided if the mine were treated as an exhaustible development enterprise and an investment policy pursued, either through the medium of government or through the shareholders, that during the expected life of the mineral deposit created manufacturing or other undertakings yielding at least the equivalent export revenue or saving at least the equivalent import expenditure. As a matter of policy, however, it may not be desirable and in practice it may not be possible for a mining company to map out a compensatory investment policy confined to the use of funds generated by the mine, partly because, in normal circumstances, the type of investment likely to serve the desired purpose is unlikely to appeal to shareholders, especially if they are non-resident, unless, indeed, it takes the form of renewed geological exploration to discover new ore reserves permitting a continuation of mining operations and postponing the day of exhaustion.

Resident shareholders may be somewhat more willing than foreigners to pursue the required investment policy, and in some of the more advanced mineral economies, such as Chile, Mexico and the Union of South Africa, a good deal of the revenue from the mines has in fact found its way into other forms of investment which, though seldom contributing significantly to export earnings, have often achieved appreciable savings in imports. In these countries, mining has accounted for a steadily decreasing proportion of the gross national product, even though its contribution to export earnings is still predominant. In this connexion, the post-war transfer of the headquarters of a number of British non-ferrous mining companies from London to the place of operations may tend to enhance the development potential of these companies, for local investment opportunities are likely to be given more careful consideration by directors living in the under-developed country and familiar with its needs and progress than by directors operating in the country which happens to provide most of the company's capital.

In general, however, it requires government action to offset the consequences of the limited and non-renewable nature of a country's mineral resources, even though in many under-developed countries the disproportion between receipts and needs often makes it difficult for governments so to frame their general budgetary policy as to devote an appropriate share of tax revenue for purposes other than current expenditure of a non-developmental nature. The problem of budgeting — in under-developed mineral economies, as elsewhere — obviously transcends the allocation of funds derived from mining taxes but it is always likely to be influenced by the temporary nature of this source of revenue.

In point of fact, the principle of using for developmental purposes revenue derived from taxes to which the mining companies are major contributors has been recognized by a number of under-developed mineral economies. Countries such as Bolivia and Northern Rhodesia, whose public revenue comes directly or indirectly almost entirely from non-ferrous mines, have little choice in the matter of using mining taxes for administrative and other current expenditures, but even they are tending to increase the proportion of government expenditure used for investment purposes while in some of the other countries in which mining plays an important part mining taxes have from time to time been specifically allocated to special developmental purposes.

In Chile, at the turn of the last century when the nitrate industry was enjoying great prosperity, almost all government expenditure, capital as well as current, was financed by the export tax on iodine and saltpetre, supplemented by import duties. Later, in the nineteen thirties, income taxes, to which the copper mines contributed a substantial proportion, were allocated to the Caja de Amortización and the Corporación de Fomento de la Producción, to the former for servicing the external debt and to the latter for use as development capital. Subsequently, however, with the decline in the relative importance of income taxes as a source of revenue, they were absorbed in the general budget, from which a special contribution was made to the Corporación. Most of the receipts accruing from the exchange differential on copper exports were devoted to subsidizing essential imports; thus during the nineteen thirties and nineteen forties only a small fraction of the revenue from mining taxation was used directly for development purposes as against the improvement of administration, health and education and other indirect developmental purposes.

In post-war years, a sizable part of the capital expenditure under the development plans of several less developed territories — the Gold Coast and Tanganyika, for example — has been financed from current taxation. Similarly, the ten-year (1947 to 1956) programme in Northern Rhodesia is being financed, according to the 1951 revision, to the extent of some 57 per cent, or £20.5 million, from ordinary revenue, the bulk of which accrues from income taxes paid by the copper mines. In the Union of South Africa, the principle was established in the nineteen twenties of crediting a certain portion of mining taxes (from lease revenues) to a loan account which was reserved for capital purposes, such as the construction of irrigation dams, on the explicit ground that such tax revenue was derived ultimately from using up part of the nation's capital resources. And, as indicated above, a good deal of public investment in highways and railways in Malaya was financed from the tax on tin exports.

The primary responsibility for investment in activities outside of mining which will ultimately replace functions of the mine in generating and distributing income evidently rests on the government of the under-developed mineral economy. This responsibility is discharged in the first instance through its fiscal policy, not only by means of appropriate spending on capital assets which will raise the level of national income but also by appropriate methods of taxation which will induce the most thorough and efficient exploitation of the country's mineral resources on the one hand, and encourage investment in suitable replacement industries on the other. Where the financial and commercial institutions operating in the economy are oriented too narrowly around the mineral industry and its associated foreign trade, the government may also have to take the initiative in stimulating investment in activities of a compensatory nature by the creation of public and semi-public agencies through which the process of economic diversification can be accelerated.

INDEX

A

Aden, aluminium fabricating, 75

Africa
- bauxite, 29
- consumption of non-ferrous metals, 6, 7, 23
- copper, 40, 78-79, 81
- international trade in non-ferrous metals, 37
- lead, 29
- production of non-ferrous metals, 37
- tin plate, 88
- zinc, 29
- *see also* specific countries and areas

Alaska, copper production, 44

Algeria
- aluminium, 75
- lead, 84
- zinc, 91

Alliance Aluminium Company, 39

Aluminium
- consumption, 6-3, 14-20, 23, 35, 39, 70-71, 74
- international control, 38-39
- international trade, 35-37
- power and, 65, 105
- prices, 14, 26
- production, 25-26, 29-34, 64, 65, 69-70, 72-75
- scrap, 24, 25
- taxes, 68-69
- *see also* Bauxite

Aluminium ore, *see* Bauxite

Angola, 81, 103

Antimony
- consumption, 6, 10, 20, 23
- international trade, 35-37, 93-99
- mining, 58; organization, 121; price fluctuations and, 97, 98
- price, 26, 93-99
- production, 25-26, 29-34; fluctuations, 93-99
- scrap, 24
- taxes, 68-69

Argentina
- aluminium, 74, 75
- consumption of non-ferrous metals, 36, 60, 85, 88, 92
- copper, 80, 81
- international trade in non-ferrous metals, 60, 80, 81, 85, 88, 92
- lead, 47, 84, 85
- tin, 85, 88, 92
- tin plate, 88
- tungsten, 60, 97
- zinc, 70, 89-91, 92

Asia
- aluminium, 69-70
- consumption of non-ferrous metals, 6, 7, 23, 88
- copper, 40, 78-79
- international trade in non-ferrous metals, 37
- production of non-ferrous metals, 30, 31-32
- tin plate, 88
- *see also* specific countries

Australia
- aluminium, 75

Australia (*continued*)
- consumption of non-ferrous metals, 23, 31, 36-37
- copper, 40, 78-79
- international trade in non-ferrous metals, 37, 89
- lead, 31, 45-47
- railways and mining in, 104
- zinc, 31, 51-54, 89

Austria
- aluminium, 39
- antimony, 32
- zinc, 51-54

B

Balance of payments, 115-16

Banco Agrícola, Bolivia, 106

Banco de Crédito Industrial, Argentina, 121

Banco Minero de Bolivia, 121

Banks, mining, 120-21

Bauxite
- consumption, 20
- international trade, 35-37
- mining, 58, 108
- price, fluctuations, 93-99
- production, 25-26, 29-34, 72-73; fluctuations, 93-99
- taxes, 108

Belgian Congo
- copper, 29, 41, 42-43, 44, 57, 77-78, 80-81
- fuel and power resources, 65
- government mining investment, 117
- international trade, 37, 80-81, 85, 109
- local industries, 106
- mining, companies, investments of, 117; employment, 100, 102; importance, 55; railways and, 103; wages, 100; workshops, 105
- prospecting, 57
- taxes, 109, 111
- tin, 29, 31, 32, 48, 49, 67, 69-70, 85, 89-91
- zinc, 70, 89, 91

Belgium
- consumption of non-ferrous metals, 19
- copper, 41
- international trade in non-ferrous metals, 35-36, 37, 85
- lead, 45-46
- mining investments in Belgian Congo, 118
- taxes, 67
- tin, 85
- zinc, 51-54, 89

Beryllium, 6, 33

Bolivia
- balance of payments, 115
- copper, 69, 78, 81
- fuel and power, 65
- international trade in non-ferrous metals, 37, 55, 84, 85, 102
- lead, 47, 69, 81-83, 84
- mining, banks, 121; company purchases, 106, 107; employment, 100-101; exchange control and, 109; transport and, 104-105; wages, 100, 102
- prospecting, 57
- taxes, 67, 107, 108-109, 111, 123
- tin, 29, 31, 47-48, 49, 64, 69-70, 85, 88, 91, 97

Bolivia (*continued*)
- tungsten, 97
- zinc, 51-54, 70

Brazil
- aluminium, 73-75
- consumption of non-ferrous metals, 36, 60, 88, 92
- copper, 81
- international trade in non-ferrous metals, 60, 81, 85, 88, 92
- lead, 84, 85
- manganese, 60
- prospecting, 57
- tin, 85, 88, 92
- transport and mining, 103, 104

British Guiana, 73-75

Burma
- aluminium, 75
- lead, 45, 47, 81-84
- tin, 47-48, 69-70, 85
- tungsten, 30
- zinc, 51-54

C

Cadmium
- international trade, 35-37
- use, 6, 10

Caja de Amortización, Chile, 123

Caja de Crédito Minero, Chile, 121

Cameroons, aluminium smelting in, 74

Canada
- aluminium, 31, 39, 73, 75
- cobalt, ore, 30
- consumption of non-ferrous metals, 19, 23, 31, 36-37, 81, 88
- copper, 40, 41, 42, 44, 78-79, 81
- international trade in non-ferrous metals, 37
- lead, 45-47
- nickel, 31, 34
- prospecting, 57
- tin plate, 86, 88
- zinc, 31, 51-54, 89

Caribbean mining, 58

Cartels, *see* International control

Cassiterite, 58, 63, 64

Chile
- balance of payments, 115
- copper, 29, 31, 40-44, 58, 59, 61, 67, 75-78, 79-80, 81, 97, 108
- fuel and power, 65
- government borrowing, 116
- international trade in non-ferrous metals, 37, 60, 80, 84-85, 88, 92
- lead, 84-85
- manganese, 60
- mine profits, use of, 115
- mining, banks, 121; development corporations, 121; development process and, 117; employment, 100, 101; exchange control and, 109, 110; financing, 113n; importance, 55; investment policies, 123; price fluctuations and, 97, 98; railways and, 104; techniques, 58, 59; water supplies and, 105
- prospecting, 57
- taxes, 67, 107, 108, 110, 111, 123
- tin, 88, 92

China, mainland
antimony, 30, 97
tin, 31, 85-87
tungsten, 30, 31
China: Taiwan
aluminium, 39, 72-75
copper, 81
Chromite
consumption, 6-8, 23
mining, 58
price fluctuations, 93-99
production, 29-34; fluctuations, 93-99
Chromium
consumption, 6, 8, 10, 21
import of, in United States, 35-37
price, 26
production, 25-26
Cobalt
consumption, 8, 14-19, 21-23
import of, in United States, 35-37
production, 29-34
taxes, 109
Colombia, 80
Colombite, ore deposits, 33
Columbium, use, 6
Combined Raw Materials Board, 43, 49, 52
Consumption, 6-25
see also specific metals, countries or regions
Control schemes, 38-54, 117-20
Copper
consumption, 6-8, 10, 14-19, 20, 23, 35, 43, 70-71, 80-81
international control, 39-44
international trade, 35-37, 80
prices, 14, 26, 27, 40, 41-42, 43-44, 79; fluctuations, 93-99
production, 25-26, 29-34, 39-44, 61, 64, 65, 69-70, 75-81; fluctuations, 93-99
scrap, 24, 25, 40
taxes, 67-69, 108-11
transport of concentrates, 63
Copper Export Association, 40-41
Copper Exporters, Inc., 41
Corporación de Fomento, Bolivia, 106
Corporación de Fomento, Chile, 88, 121, 123
Corporación Minera de Bolivia, 121
Cuba
copper, 69, 78, 81
fuel and power, 65
international trade in non-ferrous metals, 37
nickel, 32
Cyprus
copper, 69, 78, 81
fuel and power, 65
mining, importance, 55
Czechoslovakia, zinc production, 51-54, 89

D

Defense Materials Procurement Agency (United States Government), 113
Denmark, 24
Depression, mining and, 97, 102
Development, effect of mining and smelting, 93-124

E

Economic Cooperation Administration (ECA), 32
Ecuador, 80
Egypt, 81, 85
El Salvador, 85
Employment in mining, 3-4, 99-103
Eti Bank, 121
Europe
consumption of non-ferrous metals, 6, 7, 88
output of non-ferrous metals, 31-32, 40, 88
see also specific countries
Europe, western
aluminium, 75
antimony, 30
consumption of non-ferrous metals, 19, 23
copper, 30, 78-79
ore discoveries, 55
production of non-ferrous metals, 30
tin plate, 86, 88
tungsten, 30
zinc, 89
see also specific countries
European Zinc Cartel, 51
Exchange control, mining and, 108, 109-10
Exploration, survey and, 55-58
Export Association, Copper, 40-41
Export-Import Bank, 32, 113
Exports
proceeds, 113-16; fluctuations, 93-99
taxes, 107-108, 109, 111
see also specific metal: international trade

F

Finland, 31, 51-54
Flotation, differential, 64
Foreign Operations Administration (FOA), 32
Formosa, *see* China: Taiwan
France
aluminium, 39
consumption of non-ferrous metals, 14-19, 31, 34
international trade in non-ferrous metals, 37
lead, 45-46
zinc, 51-54, 89
French Equatorial Africa, 32, 84
French Guinea, 74
French Morocco, *see* Morocco, French
French West Africa, 72-75
Fuel, *see* Power

G

General Agreement on Tariffs and Trade (GATT), 52
Geological exploration, 57-58
Germanium ore deposits, 33
Germany
aluminium, 39
copper, 41
lead, 45
stockpiling, 9
zinc, 51-54
Germany, eastern, USSR imports from, 31
Germany, western
aluminium, 32
consumption of non-ferrous metals, 14-19, 34
international trade, 35-36
scrap consumption, 24
Gold Coast
aluminium, 72-75, 105
fuel and power, 65, 105
taxes in, 108, 123
transport and mining in, 104
Greece
aluminium, 73
bauxite, 32
zinc, 51-54
Guatemala
lead, 32, 84, 85
zinc, 90

H

Honduras, 81, 85
Hungary, 31, 39, 73

I

IMC, *see* International Materials Conference
Imports
by mining companies, 121-22
see also specific metals: international trade
India
aluminium, 30, 72-75
copper, 78, 81
demand for non-ferrous metals, 36
international trade in non-ferrous metals, 60, 81, 85, 88, 92
lead, 84-85
manganese, 60
smelting and refining, 74-75, 78, 84, 90
taxes, 111
tin, 48, 88, 92
zinc, 90
Indochina
tin, 88
tungsten, 30
zinc, 51-54, 89
Indonesia
aluminium, 72-75
bauxite, 30
copper, 81
government participation in mining, 111, 115
lead, 85
taxes on mining, 111
tin, 29, 31, 32, 48, 49, 69-70, 85-87, 88, 89
Institutional considerations, metal industry and, 117
Instituto de Fomento del Norte, Chile, 121
International Association of Lead Producers, 45
International control, 38-54, 117-20
aluminium, 39
copper, 40-43, 44
lead, 44-45, 47
tin, 47-50
zinc, 45, 51-54
International Materials Conference (IMC), 26
copper, 43
lead, 47
zinc, 52
International Sales Association, for lead, 44
International Tin Agreement, 49-50, 99
International Tin Committee, 47-48
International Tin Council, 49-50
International Tin Study Group, 48-49
International trade, 34-37
see also specific metal or country
International Zinc Cartel, 51
International Zinc Syndicate, 51
Iran, 81
Israel
aluminium, 75
copper, 81
lead, 85
Italy
aluminium, 39
antimony, 32
cadmium, 32
consumption of non-ferrous metals, 19
international trade in non-ferrous metals, 35-36, 37
lead, 45-46
zinc, 32, 51-54, 89

J

Jamaica
  aluminium, 73-75
  bauxite, 32
Japan
  aluminium, 30, 39, 73
  consumption of non-ferrous metals, 6, 7, 14-19, 23, 88
  copper, 40, 78-79
  stockpiling, 9
  tin, 85, 88
  zinc, 30, 51-54, 89

K

Kenya, 75
Korea, 51-54
Korea, northern, 75
Korea, southern
  copper, 81
  lead, 85
  tungsten, 30, 32

L

Latin America
  bauxite, 29-30
  consumption of non-ferrous metals, 6, 7, 23
  copper, 78-79
  exchange control, 116
  international trade in non-ferrous metals, 37
  lead, 29
  production of non-ferrous metals, 30, 69-70
  tin, 88
  zinc, 29
  see also specific countries
Lead
  consumption, 6-8, 9, 10, 14-19, 20, 23, 35, 44, 70-71, 84-85
  international control, 44-47, 67, 68-69
  international trade, 35-37, 84
  prices, 26, 27, 43-44, 47; fluctuations, 93-99
  production, 25-26, 27, 29-34, 64, 69-70, 81-85; fluctuations, 93-99
  scrap, 24
  stockpiling, 47
  taxes on, 108, 110
  transport of concentrates, 63
Lead Producers, International Association of, 45
Lead Producers' Association, 47
London Metal Exchange, 47, 49, 50, 52, 109
Luxembourg, 35-36, 67

M

Magnesium, 6, 10-11
Malaya
  aluminium, 72-75
  bauxite, 30
  fuel and power, 65, 105
  international trade in non-ferrous metals, 37
  mining, company purchases, 106; development process and, 117; employment, 100, 101, 102; importance, 55; organization, 121; price fluctuations and, 97; techniques, 58; wages, 101-102
  tax policy, 67, 109, 111, 123-24
  tin, 29, 31, 47-48, 67, 69-70, 85-87, 88, 89, 97, 105
  tungsten, 30
Manchuria
  aluminium, 39, 75
Manganese
  consumption, 6-8, 9, 14-19, 20, 21, 23
  international trade, 35-37, 109, 111
  price, 26; fluctuations, 93-99
  production, 25-26, 29-34; fluctuations, 93-99
  taxes, 108, 109, 111
Mass mining, 58-59, 97-98, 101
Materials Conference, *see* International Materials Conference
Metals Reserve Company, 48
Mexico
  aluminium, 74, 75
  consumption of non-ferrous metals, 31
  copper, 29, 40, 41, 42, 69, 78, 78*n*, 81
  fuel and power, 65
  international trade in non-ferrous metals, 37, 60
  lead, 29, 31, 45-49, 81-83, 84
  manganese, 60
  mining, development process and, 117; importance, 55; investment policies, 123; organization, 121; price fluctuations and, 98; techniques, 59; transport and, 104; wages, 102
  taxes, 107, 110
  tin, 85, 88, 89, 91
  trade deficit, 115
  zinc, 29, 31, 51-54, 70, 89
Middle East
  copper, 78-79
  ore and metal production, 69-70
  tin plate, 88
Mine stores, 105-107
Mining, 58-59
  see also under specific metals
Mining banks, 120-21
Molybdenite, 63
Molybdenum
  consumption, 6-8, 10, 14-19, 21, 23
  prices, 14, 26
  production, 25-26, 29-34
Morocco, French
  lead, 32, 84
  prospecting, 57
  transport and mining, 103
  zinc, 32
Mutual Security Administration, 32

N

National Industrial Recovery Act (United States), 42
Netherlands
  international trade, 37, 89
  mining investments of, 118
  taxes, 67
  tin, 67, 85, 89
  zinc, 51-54, 89
Netherlands East Indies
  aluminium, 74
  fuel and power, 65
  tin, 47-48, 49, 67
New Caledonia
  chromite, 30, 32
  copper, 81
  fuel and power, 65
  international trade in non-ferrous metals, 37
Newfoundland
  copper, 78
  lead, 81
  zinc, 51-54
New Zealand
  consumption of non-ferrous metals, 23
  copper, 78-79
Nickel
  consumption, 6, 8, 9, 10, 21, 23
  international trade, 35-37
  prices, 14, 26, 63; fluctuations, 93-99
  production, 25-26, 29-34; fluctuations, 93-99
Nigeria
  fuel and power, 65
  international trade in non-ferrous metals, 37, 85
Nigeria (*continued*)
  prospecting, 57
  tin, 29, 47-48, 49, 69-70, 85-87, 89
North Africa, French
  copper, 81
  lead, 69, 84
  tin, 91-92
  zinc, 51-54, 70
Northern Rhodesia
  balance of payments, 115
  copper, 29-30, 31, 42-43, 57, 69, 78, 81, 97
  Copper Belt, 34, 44
  fuel and power, 65
  international trade in non-ferrous metals, 37, 55
  lead, 81, 84
  mine earnings, distribution, 115
  mining, development process and, 117; employment, 100, 101, 102; financing, 112, 112*n*-13*n*, 113; price fluctuations and, 98; purchases, 106; railways and, 103, 104; techniques, 59; wages, 99-100
  prospecting, 57
  tax policy, 109, 111, 123
  tin, 89, 91
  zinc, 51-54, 64, 70, 89
Norway
  aluminium, 32, 39, 74
  fuel and power, 65
  international trade in non-ferrous metals, 37
  scrap consumption, 24
  zinc, 51-54, 89
Nyasaland, 74, 105

O

Oceania, 88
Ore(s)
  prices, 61-63
  technical problems in refining, 60-61, 63-64

P

Pakistan
  aluminium, 75
  copper, 81
  lead, 85
Peru
  aluminium, 74, 105
  balance of trade, 115
  copper, 29, 40, 41, 69, 78, 78*n*, 80, 81
  flotation, differential, 64
  fuel and power, 65, 105
  international trade in non-ferrous metals, 37
  lead, 33, 47, 69, 81, 84
  mining, development process and, 117; exchange control and, 110; financing, 112; importance, 55; price fluctuations and, 98
  tax policy, 109, 110, 111
  tin, 85, 91
  zinc, 33, 51-54, 70, 89-91, 98
Philippines
  chromite, 30
  copper, 69, 78, 81
  lead, 84, 85
Poland
  aluminium, 73
  lead, 31
  zinc, 31, 51-54
Portugal
  consumption of non-ferrous metals, 31
  tin, 48
Power
  aluminium and, 72-73
  mineral exploitation and, 105
  smelting and refining and, 65
President's Materials Policy Commission (United States), 99

Price fluctuations, 93-99
  see also specific metals
Production, 25-34; fluctuations, 93-99
  see also specific metals, countries or regions
Profits, use of mining, 112-17
Prospecting, 57

R

Railways, mine transport and, 103-105
Raw Materials Board, see Combined Raw Materials Board
Reconstruction Finance Corporation (RFC), 34, 48, 49
Refining, see Smelting and refining
Rhodesia, see Northern Rhodesia; Southern Rhodesia

S

Sarawak, 74
Scrap, 23-25, 40
Selective mining, 58-59
Silesia, 89
Silicon, 11
Silver, 47
Smelting and refining
  aluminium, 72-75
  copper, 75-81
  cost, 61-63
  facilities, 69-92
  fiscal influences, 67-69
  fuel and, 65
  international relations and, 65-67
  lead, 81-85
  ore characteristics and, 60-61
  power and, 65
  problems, general, 59-69
  processes, 72n, 75n, 81n, 85n, 89n
  techniques, 63-64
  tin, 85-89
  zinc, 51, 89-92
South West Africa
  beryllium, 33
  copper, 64, 78, 81
  lead, 33, 64, 69, 81, 84
  tin, 85, 91
  zinc, 33, 70, 91
Southern Rhodesia
  fuel and power, 65
  international trade in non-ferrous metals, 60
  mining, organization, 121; wages, 99-100
  tran ort and mining, 104
  tungsten, 97
Spain
  aluminium, 39
  copper, 41, 42
  lead, 45-46
  tin, 89
  zinc, 51-54, 89
Stockpiling
  consumption and, 9, 14
  lead, in United States, 47
  tin, in United States, 49
Stores, mine, 105-107
Substitution, technological change and, 10-13
Surinam
  aluminium, 73-75, 105
  bauxite, 58
  exports of non-ferrous metals, 55
  taxes, 108
Survey, see Exploration
Swaziland, 85
Sweden
  aluminium, 39
  consumption, 19
Sweden (continued)
  fuel and power, 65
  international trade in non-ferrous metals, 35-36, 37
  zinc, 34, 51-54, 89
Switzerland, 39, 65

T

Taiwan, see China: Taiwan
Tanganyika
  copper, 32, 57, 64, 103
  financing development, 123
  lead, 32, 57, 64, 103
Tantalite ore deposits, 33
Tasmania, 74
Taxes
  contribution of metal industry, 107-112
  financing of development plans and, 123-24
  influence on metal industry, 67-69
Thailand
  antimony, 30
  tin, 29, 47-49, 69-70, 85-87, 88, 89
Tin
  buffer pool, 9, 48
  consumption, 6-8, 14-19, 20, 23, 47, 49, 50, 70-71, 85-89
  international control, 47-50
  international trade, 35-37, 85, 88-89, 111
  power and, 105
  prices, 26, 47-48, 49-50; fluctuations, 93-99
  production, 25-26, 27, 29-34, 64, 69-70, 85-89; fluctuations, 93-99
  scrap, 24
  stockpiling, 48-50
  taxes, 67-69, 109, 111
Tin Agreement, International, 49-50, 99
Tin Committee, Combined, 49
Tin Committee, International, 47-48
Tin Conference, United Nations, 49
Tin Council, International, 49-50
Tin ore, see Cassiterite
Tin Producers' Association, 47
Tin Research Institute, 19
Tin Study Group, International, 48-49
Titanium
  occurrence, 11
  use, 6, 10, 20
Transport, 4, 61-63, 103-105
  see also specific countries
Tungsten
  consumption, 6-8, 10, 21, 23, 60
  international trade, 35-37, 60
  prices, 26, 63; fluctuations, 93-99
  production, 25-26, 29-34; fluctuations, 93-99
Tunisia, 90
Turkey
  antimony, 30
  chromite, 30, 32
  copper, 69, 78, 78n, 81
  lead, 84-85
  tin, 92
  transport and mining, 104
  zinc, 51-54, 91

U

Uganda, 32, 108
Union of South Africa
  aluminium, 75
  antimony, 98
  consumption of non-ferrous metals, 31, 36, 60
  copper, 69, 78, 81
  industrial development corporation, 121
  international trade in non-ferrous metals, 60, 63
Union of South Africa (continued)
  lead, 84-85
  manganese, 60
  mining, development process and, 117; investment policies, 123; railways and, 104; wages and, 122n
  tax policy, 107, 108, 116, 123
  tin, 85-88, 92
Union of Soviet Socialist Republics
  aluminium, 31, 73
  consumption of non-ferrous metals, 31
  international trade in non-ferrous metals, 37
  production of non-ferrous metals, 31
  zinc, 51-54, 89
United Kingdom
  aluminium, 39, 74
  consumption of non-ferrous metals, 14-19, 23, 31, 34, 74, 88
  copper, 41, 43, 44
  international trade in non-ferrous metals, 37
  lead, 45-46
  mining investments abroad, 118
  prospecting, 57
  scrap consumption, 24
  tariff policy, 67
  tin, 48, 85, 88, 89
  zinc, 51-54, 89
United Kingdom Ministry of Supply, 47
United States
  aluminium, 39, 73
  antimony, 32
  bauxite, 32
  cobalt, 32
  chromite, 32
  consumption of non-ferrous metals, 6, 7, 14-19, 20-23, 31, 34
  copper, 40-44, 78-79, 97
  international trade in non-ferrous metals, 37
  lead, 44, 45-47, 84
  manganese, 32
  mass mining, 98
  mining investments abroad, 118
  ore reserves, 34, 55
  production of non-ferrous metals, 30-31, 32
  prospecting, 57
  scrap consumption, 24, 25
  stockpiling, 9, 49
  tax policy, 68-69
  tin, 48, 49, 50, 67, 85, 86, 88
  zinc, 50, 51-54, 89
Uruguay, 81, 85
USSR, see Union of Soviet Socialist Republics

V

Vanadium
  output, 25-26
  use, 6, 10
Venezuela
  aluminium, 74, 105
  copper, 81

W

Wages in mining, 4, 99-103
War
  consumption and, 9, 13-14, 35-37
  copper control, 43
  controls during, 47
  lead production and, 45
  metal markets and, 34, 35
  production of non-ferrous metals, 25, 29-32
  tin plate production and, 86
  zinc production and, 51
Webb-Pomerene Act (United States), 40
Western Europe, see Europe, western
Workshops, mining, 105
World War, First and Second, see War

Y

Yugoslavia
- aluminium, 39, 72-75
- chromite, 32
- copper, 29, 41, 42, 69, 78-79, 81
- lead, 47, 84
- tin, 89, 92
- zinc, 51-54, 70, 89

Z

Zinc
- consumption, 6-8, 10, 11, 14-19, 20, 23, 35, 50, 51, 52, 70-71, 91-92
- international control 45, 50-54
- international trade, 35-37, 89, 91-92
- power and refining, 65
- prices, 26, 51-52, 54; fluctuations, 93-99
- production, 25-26, 29-34, 64, 65, 69-70, 89-92; fluctuations, 93-99

Zinc (*continued*)
- scrap, 24
- taxes, 51-52, 67, 68-69, 108, 109, 110
- transport of concentrates, 63

Zinc Cartel, European, 51

Zinc Cartel, International, 51

Zinc Producers' Associated Proprietary, Limited, 51

Zinc Syndicate, International, 51

SALES AGENTS FOR UNITED NATIONS PUBLICATIONS

ARGENTINA
Editorial Sudamericana S.A., Alsina 500, Buenos Aires.
AUSTRALIA
H. A. Goddard, 255a George St., Sydney, and 90 Queen St., Melbourne.
Melbourne University Press, Carlton N.3, Victoria.
AUSTRIA (see below)
BELGIUM
Agence et Messageries de la Presse S.A., 14-22 rue du Persil, Bruxelles.
W. H. Smith & Son, 71-75, boulevard Adolphe-Max, Bruxelles.
BOLIVIA
Librería Selecciones, Casilla 972, La Paz.
BRAZIL
Livraria Agir, Rio de Janeiro, São Paulo and Belo Horizonte.
CANADA
Ryerson Press, 299 Queen St. West, Toronto.
Periodica, Inc., 5112 Ave. Papineau, Montreal.
CEYLON
Lake House Bookshop, The Associated Newspapers of Ceylon Ltd., P.O. Box 244, Colombo.
CHILE
Librería Ivens, Moneda 822, Santiago.
Editorial del Pacífico, Ahumada 57, Santiago.
CHINA
The World Book Co. Ltd., 99 Chung King Road, 1st Section, Taipeh, Taiwan.
The Commercial Press Ltd., 170 Liu Li Chang, Peking.
COLOMBIA
Librería América, Medellín.
Librería Nacional Ltda., Barranquilla.
Librería Buchholz Galería, Av. Jiménez de Quesada 8-40, Bogotá.
COSTA RICA
Trejos Hermanos, Apartado 1313, San José.
CUBA
La Casa Belga, O'Reilly 455, La Habana.
CZECHOSLOVAKIA
Československý Spisovatel, Národní Trida 9, Praha 1.
DENMARK
Einar Munksgaard, Ltd., Nørregade 6, København, K.
DOMINICAN REPUBLIC
Librería Dominicana, Mercedes 49, Ciudad Trujillo.
ECUADOR
Librería Científica, Guayaquil and Quito.
EGYPT
Librairie "La Renaissance d'Egypte," 9 Sh. Adly Pasha, Cairo.
EL SALVADOR
Manuel Navas y Cía., 1a. Avenida sur 37, San Salvador.
FINLAND
Akateeminen Kirjakauppa, 2 Keskuskatu, Helsinki.
FRANCE
Editions A. Pedone, 13, rue Soufflot, Paris V.
GERMANY (see below)
GREECE
"Eleftheroudakis," Place de la Constitution, Athènes.
GUATEMALA
Goubaud & Cía. Ltda., 5a. Avenida sur 28, Guatemala.
HAITI
Librairie "A la Caravelle," Boîte postale 111-B, Port-au-Prince.
HONDURAS
Librería Panamericana, Tegucigalpa.
HONG KONG
The Swindon Book Co., 25 Nathan Road, Kowloon.
ICELAND
Bokaverzlun Sigfusar Eymundssonar H. F., Austurstraeti 18, Reykjavik.
INDIA
Oxford Book & Stationery Co., Scindia House, New Delhi, and 17 Park Street, Calcutta.
P. Varadachary & Co., 8 Linghi Chetty St., Madras 1.
INDONESIA
Pembangunan, Ltd., Gunung Sahari 84, Djakarta.
IRAN
Ketab-Khaneh Danesh, 293 Saadi Avenue, Tehran.
IRAQ
Mackenzie's Bookshop, Baghdad.
ISRAEL
Blumstein's Bookstores Ltd., 35 Allenby Road, Tel-Aviv.
ITALY
Libreria Commissionaria Sansoni, Via Gino Capponi 26, Firenze.
JAPAN (see below)
LEBANON
Librairie Universelle, Beyrouth.
LIBERIA
J. Momolu Kamara, Monrovia.
Albert Gemayel, Monrovia.
LUXEMBOURG
Librairie J. Schummer, Luxembourg.
MEXICO
Editorial Hermes S.A., Ignacio Mariscal 41, México, D.F.
NETHERLANDS
N.V. Martinus Nijhoff, Lange Voorhout 9, 's-Gravenhage.
NEW ZEALAND
United Nations Association of New Zealand, C.P.O. 1011, Wellington.
NORWAY
Johan Grundt Tanum Forlag, Kr. Augustsgt. 7A, Oslo.
PAKISTAN
Thomas & Thomas, Fort Mansion, Frere Road, Karachi, 3.
Publishers United Ltd., 176 Anarkali, Lahore.
The Pakistan Cooperative Book Society, Chittagong and Dacca (East Pakistan).
PANAMA
José Menéndez, Plaza de Arango, Panamá.
PARAGUAY
Moreno Hermanos, Asunción.
PERU
Librería Internacional del Perú, S.A., Lima and Arequipa.
PHILIPPINES
Alemar's Book Store, 749 Rizal Avenue, Manila.
PORTUGAL
Livraria Rodrigues, 186 Rua Aurea, Lisboa.
SINGAPORE
The City Book Store, Ltd., Winchester House, Collyer Quay.
SPAIN (see below)
SWEDEN
C. E. Fritze's Kungl. Hovbokhandel A-B, Fredsgatan 2, Stockholm.
SWITZERLAND
Librairie Payot S.A., Lausanne, Genève.
Hans Raunhardt, Kirchgasse 17, Zurich 1.
SYRIA
Librairie Universelle, Damas.
THAILAND
Pramuan Mit Ltd., 55 Chakrawat Road, Wat Tuk, Bangkok.
TURKEY
Librairie Hachette, 469 Istiklal Caddesi, Beyoglu, Istanbul.
UNION OF SOUTH AFRICA
Van Schaik's Bookstore (Pty.), Ltd., Box 724, Pretoria.
UNITED KINGDOM
H. M. Stationery Office, P.O. Box 569, London, S.E. 1 (and at H.M.S.O. Shops).
UNITED STATES OF AMERICA
Int'l Documents Service, Columbia University Press, 2960 Broadway, New York 27, N. Y.
URUGUAY
Representación de Editoriales, Prof. H. D'Elía, Av. 18 de Julio 133, Montevideo.
VENEZUELA
Librería del Este, Edificio Galipán, Ave. F. Miranda No. 52, Caracas.
VIET-NAM
Papeterie-Librairie Nouvelle Albert Portail, Boîte postale 283, Saigon.
YUGOSLAVIA
Drzavno Preduzece, Jugoslovenska Knjiga, Terazije 27-11, Beograd.

United Nations publications can also be obtained from the following firms:
AUSTRIA
B. Wüllerstorff, Waagplatz, 4, Salzburg.
Gerold & Co., Graben 31, Wien 1.
GERMANY
Elwert & Meurer, Hauptstrasse 101, Berlin-Schöneberg.
W. E. Saarbach, Gereonstrasse 25-29, Köln (22c).
Alex. Horn, Spiegelgasse 9, Wiesbaden.
JAPAN
Maruzen Company, Ltd., 6 Tori-Nichome, Nihonbashi, Tokyo.
SPAIN
Librería Bosch, 11 Ronda Universidad, Barcelona.

Orders and inquiries from countries where sales agents have not yet been appointed may be sent to: Sales and Circulation Section, United Nations, New York, U.S.A.; or Sales Section, United Nations Office, Palais des Nations, Geneva, Switzerland.

(56B1)

Printed in U.S.A.

Price: $U.S. 1.50; 10/6 stg.; Sw. fr. 6.50
(or equivalent in other currencies)

23799—February 1956—3,150

23.7.74