IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE

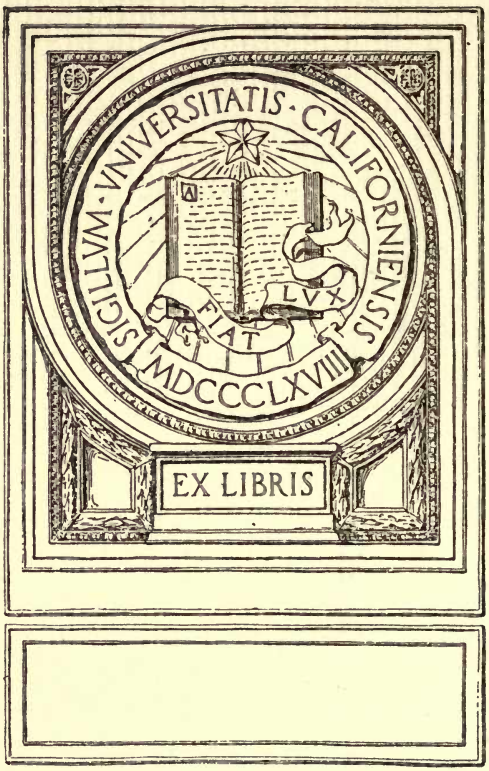
PREPARED UNDER THE DIRECTION OF THE MINERAL RESOURCES COMMITTEE OF THE IMPERIAL INSTITUTE, WITH THE ASSISTANCE OF THE SCIENTIFIC AND TECHNICAL STAFF

TIN ORES

BY G. M. DAVIES, M.Sc. (LOND.), F.G.S.
Scientific and Technical Department, Imperial Institute

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1919

Price 3s. 6d. net


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
LVX
FIAT
MDCCCLXVIII
EX LIBRIS

IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE

IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE

PREPARED UNDER THE DIRECTION OF THE MINERAL RESOURCES COMMITTEE OF THE IMPERIAL INSTITUTE, WITH THE ASSISTANCE OF THE SCIENTIFIC AND TECHNICAL STAFF

TIN ORES

BY G. M. DAVIES, M.Sc. (LOND.), F.G.S.
Scientific and Technical Department, Imperial Institute

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1919

IMPERIAL INSTITUTE

Director: Professor WYNDHAM DUNSTAN, C.M.G., LL.D., F.R.S.

Scientific and Technical Research Department and Technical Information Bureau

Superintendents: T. A. HENRY, D.Sc. (Lond.), F.C.S.; H. BROWN; E. GOULDING, D.Sc. (Lond.), F.I.C.

Assistant Superintendents: T. CROOK, A.R.C.Sc., F.G.S.; R. G. PELLY, F.I.C.

Principal Assistant: S. J. JOHNSTONE, B.Sc. (Lond.), A.I.C.

Public Exhibition Galleries.—Colonial and Indian Collections

Senior Technical Superintendent: S. E. CHANDLER, D.Sc. (Lond.), A.R.C.Sc., F.L.S.

Other Members of the Scientific and Technical Staff of the Institute

A. E. ANDREWS, F.C.S.
Miss H. BENNETT, B.Sc. (Lond.).
L. L. BLACKNELL.
G. S. BOULGER, F.L.S. F.G.S.
F. BOULTON.
G. T. BRAY, A.I.C.
W. S. DAVEY.
G. M. DAVIES, M.Sc. (Lond.), F.G.S.
F. L. ELLIOTT.
A. T. FAIRCLOTH.
F. FERRABOSCHI, M.A. (Cantab.), A.I.C., F.C.S.
J. R. FURLONG, Ph.D. (Würzburg), A.I.C.
Miss R. C. GROVES, M.Sc. A.I.C.
A. B. JACKSON, A.L.S.
H. J. JEFFERY, A.R.C.Sc., F.L.S.
A. S. JUDGE, late I.C.S.
B. E. LONG, B.A. (Cantab.).
A. D. LUMB, A.R.S.M., F.G.S.
T. MCLACHLAN, A.I.C.
F. MAJOR, B.Sc. (Lond.).
G. L. MATTHEWS, B.Sc. (Lond.), A.I.C.
E. C. MOORE.
Miss A. C. S. PALMER.
O. D. ROBERTS, F.I.C.
S. J. ROGERS, B.Sc. (Lond.), A.I.C.
F. W. ROLFE.
W. G. RUMBOLD.
H. SPOONER.
J. D. F. WEST, A.I.C.
B. W. WHITFEILD.
W. O. R. WYNN, A.I.C.

IMPERIAL INSTITUTE

Advisory Committee on Mineral Resources, 1919

The Right Hon. the VISCOUNT HARCOURT, D.C.L. (*Chairman*).

*Admiral Sir EDMOND SLADE, K.C.V.O., K.C.I.E. (nominated by the Admiralty), *Vice-Chairman.*

EDMUND DAVIS, Esq.

*Professor WYNDHAM DUNSTAN, C.M.G., LL.D., F.R.S., Director of the Imperial Institute.

W. J. GLENNY, Esq., Department of Overseas Trade (nominated by the Board of Trade).

*Professor J. W. GREGORY, F.R.S., Professor of Geology in the University of Glasgow, formerly Director of the Geological Survey of Victoria, Australia.

Sir ROBERT HADFIELD, Bart., lately President of the Iron and Steel Institute.

*Dr. F. H. HATCH, Consulting Mining Engineer, formerly President of the Institution of Mining and Metallurgy.

Major VAUGHAN MORGAN, Intelligence Department, War Office (nominated by the War Office).

W. W. MOYERS, Esq., Messrs. H. A. Watson & Co.

Dr. T. A. HENRY, *Secretary.*

Major A. D. LUMB, M.C. (*Acting Secretary*).

* *Members of the Editorial Sub-Committee.*

PREFACE

THE Mineral Resources Committee of the Imperial Institute has arranged to issue this series of monographs on Mineral Resources in amplification and extension of those which have appeared in the *Bulletin of the Imperial Institute* during the past fifteen years.

The monographs are prepared either by members of the Scientific and Technical Staff of the Imperial Institute, or by external contributors, to whom have been available the statistics and other special information relating to mineral resources collected and arranged at the Imperial Institute.

The object of these monographs is to give a general account of the occurrences and commercial utilisation of the more important minerals, particularly in the British Empire. No attempt has been made to give details of mining or metallurgical processes.

HARCOURT,
Chairman Mineral Resources Committee.

July 1919.

CONTENTS

CHAPTER I

CHAPTER II

SOURCES OF SUPPLY OF TIN ORES

CHAPTER III

PAGE

SOURCES OF SUPPLY OF TIN ORES

(continued)

TIN ORES

CHAPTER I

TIN ORES: THEIR OCCURRENCE, CHARACTERS, AND USES

THE British Empire is well supplied with workable deposits of tin ore, the total British output being between 50 and 60 per cent. of the world's supply. In early times and up to the eighteenth century Cornwall furnished the greater part of the world's output. About 1870 the rich alluvial deposits of the Malay Peninsula began to be worked on a large scale, followed in 1872 by the Australian deposits. The tin-mining areas of South Africa and Nigeria are of more recent development. India, too, produces a small amount. The chief foreign sources are Bolivia, the Dutch East Indies, Siam and China.

The chief centres of the smelting and refining of tin are in the Straits Settlements and the United Kingdom. Other important centres are those of the Dutch Indies, Germany, China and Australia. Before the war, smelting was carried on in Germany, but the industry has practically ceased there, and another result of the war is the establishment of a tin-smelting industry in the United States.

The greatest consumer of tin is the United States, which buys 40 per cent. or more of the world's output. This large consumption is to be attributed partly to the use of tin-plate cans in the preserved food, oil, and other industries, but still more to the employment of various tin-bearing alloys. Other consumers, taken in the order of their importance in pre-war days, are the United Kingdom, Germany, France, Australia, Austria-Hungary, Russia, Italy and Belgium.

The war had at first less effect on the supply of tin than on that of many other metals. The world's output had risen from about 95,000 tons in 1901 to a maximum of 134,000

tons in 1913. The loss of the German, Austrian and Belgian markets in 1914, together with diminished industrial requirements in other countries, led to a general reduction in output, whilst the increasing cost of production and difficulties of transport increased this downward tendency. The production in 1916 was about 122,000 tons, which is still greater than in any year prior to 1912. The large demands in America for tin in 1916 and the following years could with difficulty be met, and consequently the price rose to an unprecedented figure. In July 1914 the average price of tin in London was £142 10*s.* 4*d.* per ton; in the same month of each of the four following years it was £167 5*s.* 10*d.*, £168 9*s.* 6*d.*, £242 6*s.* 6*d.*, and £359 17*s.* 9*d.* respectively.

The Ores of Tin

Cassiterite or *tinstone* is practically the only important ore of tin. It consists of tin oxide (SnO_2), with a theoretical metallic content of 78·6 per cent. Oxides of iron and tantalum are sometimes present in small amounts. The mineral has usually a deep brown to black colour, but it is sometimes red (*ruby tin*), yellow (*rosin tin*), and may even be colourless. It has an adamantine lustre, due to its very high refractive index (the mean value being 2·045). Its hardness is 6 or 7, and its specific gravity usually between 6·8 and 7·1. It crystallises in the tetragonal system, with prismatic habit and pyramidal terminations, and is often twinned. The varieties known as *sparable tin* and *needle tin* are characterised by an acute ditetragonal pyramid. A compact variety composed of radiating fibres, with concentric structure, is known as *wood tin*, and *toad's-eye tin* shows a similar structure on a smaller scale. *Stream tin* is water-worn cassiterite. It is found in alluvial deposits, while *float tin* occurs in the soil formed by the disintegration of stanniferous rocks. "Black tin" is a term frequently applied to concentrated tin ore.

Cassiterite occurs in lodes that are connected with granite intrusions, or more rarely the volcanic equivalents of granite. The lodes traverse both the granite and the surrounding rocks, and mark a late phase in the consolidation of the intrusion, when emanations of fluorine and boron altered the granite into greisen and formed minerals such as tourmaline, fluorite, topaz, lithia-mica, axinite and apatite, as well as quartz. A common associate of cassiterite is wolframite, together with the secondary minerals scheelite and stolzite.

Copper sulphides, arsenopyrite, pyrite, and ores of bismuth, uranium and iron, are also found in cassiterite lodes. The variety wood-tin, which only occurs in the upper part of tin lodes and in gravel deposits, is probably an alteration product of stannite. Cassiterite itself is a very stable mineral and survives indefinitely in detrital deposits.

Stannite is a sulphide of tin, copper and iron, containing 22 to 27 per cent. of tin, and frequently contains zinc. It is tetragonal but usually occurs massive, and is opaque, with a metallic lustre, and grey, black or bronze colour. It has a hardness of 4 and a specific gravity of 4·3 to 4·5. It occurs in veins associated with cassiterite, as in Cornwall, New South Wales and Tasmania, and is sometimes worked for both tin and copper.

Native tin is reported to occur as irregular rounded grains in some of the river gravels of New South Wales and elsewhere, but it is of no commercial importance.

The remaining stanniferous minerals are of scientific interest only. They include the sulphides canfieldite, cylindrite, franckeite, teallite and plumbostannite, the borates nordenskiöldite, hulsite and paigeite, and the silicate stokesite.

Statistics of Production of Tin Ore

Reliable figures for the production of tin ore in the countries of the world are not easily obtainable. In some cases there are no official returns, in other cases these are several years in arrear. Again, some of the returns are in terms of tin ore, without the percentage of tin being stated, and in others only exports are given. Table 1 gives the most trustworthy figures indicating the amount of tin in the ores raised; these figures have been obtained or calculated from official or other returns available. (See also Diagram 1, p. 5.) The same applies to other similar tables throughout the Monograph.

Valuation of Tin Ore

Most of the Cornish ore is sold at the ticketings held fortnightly at Redruth. The smelters bid for the parcels of ore offered by the mines, having previously sampled and assayed the ore. The samples are taken from the wet ore, containing from 6 to 12 per cent. of moisture, and no allowance is made for variation in water content between sampling and delivery. In addition to an arbitrary deduction to cover the weight of the sacks in which the ore is delivered, the smelters are allowed

Table I

World's Output of Tin Ore (Tin Content)

In tons (2,240 lb.)

	1912.	1913.	1914.	1915.	1916.	1917.
British Empire :						
United Kingdom	5,254	5,288	5,056	4,968	4,697	3,936
Australia . .	7,194	8,072	5,460	5,489	5,450	—
India . .	323	302	287	430	439	607
Federated Malay States . .	48,421	50,126	49,042	46,766	43,870	39,833
Unfederated Malay States .	1,227	1,240	1,595	3,041	3,340	3,063
Nigeria . .	2,020	3,732	4,300	4,837	5,755	5,820
Union of South Africa . .	1,745	2,251	2,024	2,057	1,928	1,574
Swaziland . .	270	344	347	409	321	358
Straits Settlem'ts	8	10	6	40	21	7
Foreign Countries :						
Austria-Hungary	24	—	—	—	—	—
Bolivia . .	22,657	26,326	21,996	21,444	20,720	26,813
China . .	8,644	8,255	7,097	7,880	7,503	11,618
Dutch East Indies	19,912	20,500	17,973	19,523	19,548	—
Indo-China .	98	456	64	—	—	—
Italy . .	52	—	—	—	—	—
Japan . .	195	—	—	—	—	—
Portugal . .	100	—	—	—	—	—
Siam . .	6,587	6,748	6,591	8,999	8,765	9,154
Spain . .	130	—	—	—	—	—
United States .	79	64	93	91	125	135

to deduct 3 lb. for every hundredweight, so that 2,300 lb. must be delivered for every ton. The amount of tin contained in the ore is calculated from the dry assay of the sample, a returning charge of $1\frac{1}{4}$ per 20 ($6\frac{1}{4}$ per cent.) is deducted, and the amount (in hundredweights) is multiplied by the tin standard, the product, or price payable by the smelter, being reckoned to the nearest half-crown. The unnecessary complications of this antiquated system of trading are obvious.

One of the Australian smelters before the war made a smelting charge of £3 per ton, with a deduction of 2 per cent. from the assay to cover loss in smelting. A larger deduction was made if the concentrate contained less than 70 per cent. tin. The smelting charges in the Straits Settlements were also about £2 10*s.* to £3 per ton of ore, the assay values being reduced by varying amounts according to the grade of the ore.

In the case of Nigerian concentrates the returning charge varies with the price of tin, and usually increases by 5*s.* per

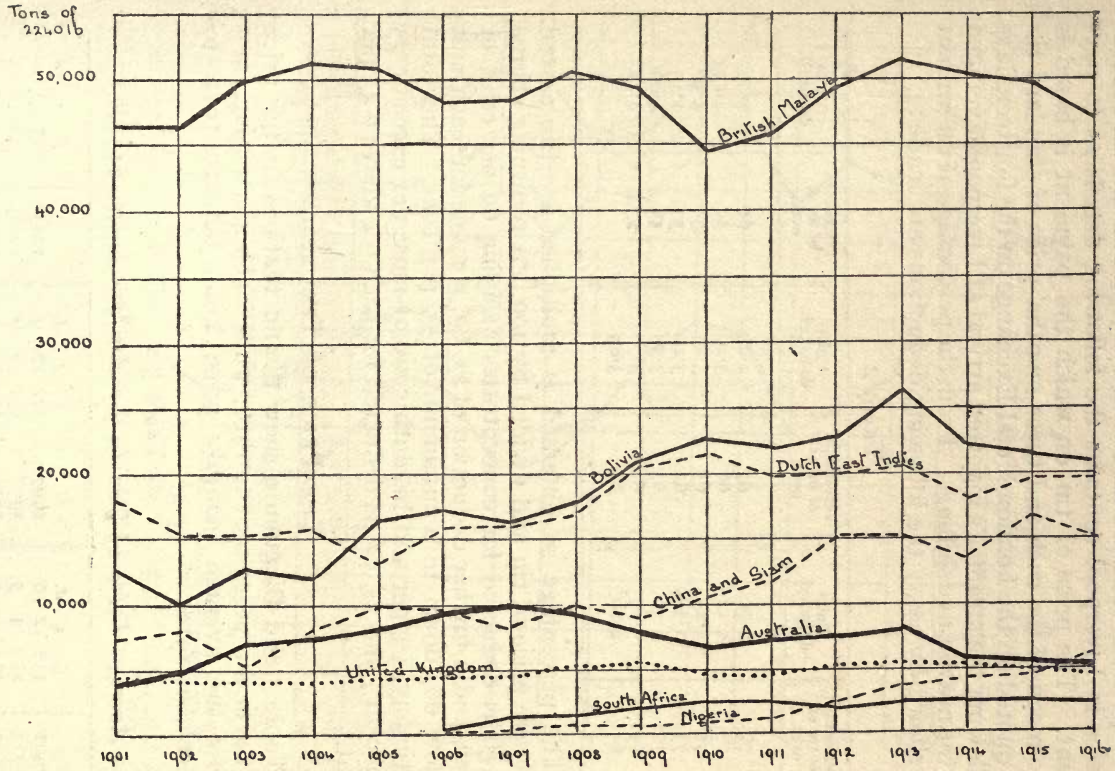


DIAGRAM I.—OUTPUT OF TIN ORE BY COUNTRIES, 1901–1916, EXPRESSED IN TERMS OF METALLIC TIN

ton for each unit below 70 per cent. down to 65 per cent., and decreases by 2*s.* 6*d.* per ton for each unit above 70 per cent.

A specimen contract for the delivery of Bolivian tin concentrates in Liverpool contains the following details as to payment. The price of tin on which the payment is based is the mean of the cash and three months' price of standard tin as quoted on the London Metal Exchange on the fourteen days following the steamer's reported arrival at Liverpool, averaged to the nearest five shillings. From the percentage of tin content as shown by assay the following deductions are made :

Table 2

Percentage of tin or over.	Units deducted.	Percentage of tin or over.	Units deducted.	Percentage of tin or over.	Units deducted.
74	2·00	67	2·95	60	4·00
73	2·125	66	3·10	59	4·15
72	2·25	65	3·25	58	4·30
71	2·375	64	3·40	57	4·45
70	2·50	63	3·55	56	4·60
69	2·65	62	3·70	55	4·75
68	2·80	61	3·85		

The percentage so obtained is multiplied by the agreed average price of tin and divided by 100. A returning charge of £6 is deducted for concentrates assaying 60 per cent. or over, and a further deduction of 2*s.* 6*d.* is made for each unit below 60, down to a minimum of 55 per cent. The total antimony, copper and bismuth content must not exceed 0·75 per cent., and 2*s.* 6*d.* is deducted for each 0·1 above 0·25 per cent.

The Price of Tin

Table 3 and Diagram 2 show the fluctuations in the price of tin in the years 1901 to 1918, while Table 4 and Diagram 3 show the average monthly price from January 1912 to December 1918.

Table 3

Average Price of Tin in London per ton (2,240 *lb.*)

	£	s.	d.		£	s.	d.		£	s.	d.
1901	118	12	8	1907	172	12	9	1913	201	14	0
1902	120	14	5	1908	132	2	6	1914	151	2	9
1903	127	6	5	1909	134	15	6	1915	164	4	0
1904	126	14	8	1910	155	6	2	1916	182	3	5
1905	143	1	8	1911	192	6	2	1917	237	13	3
1906	180	12	11	1912	209	8	5	1918	329	11	2

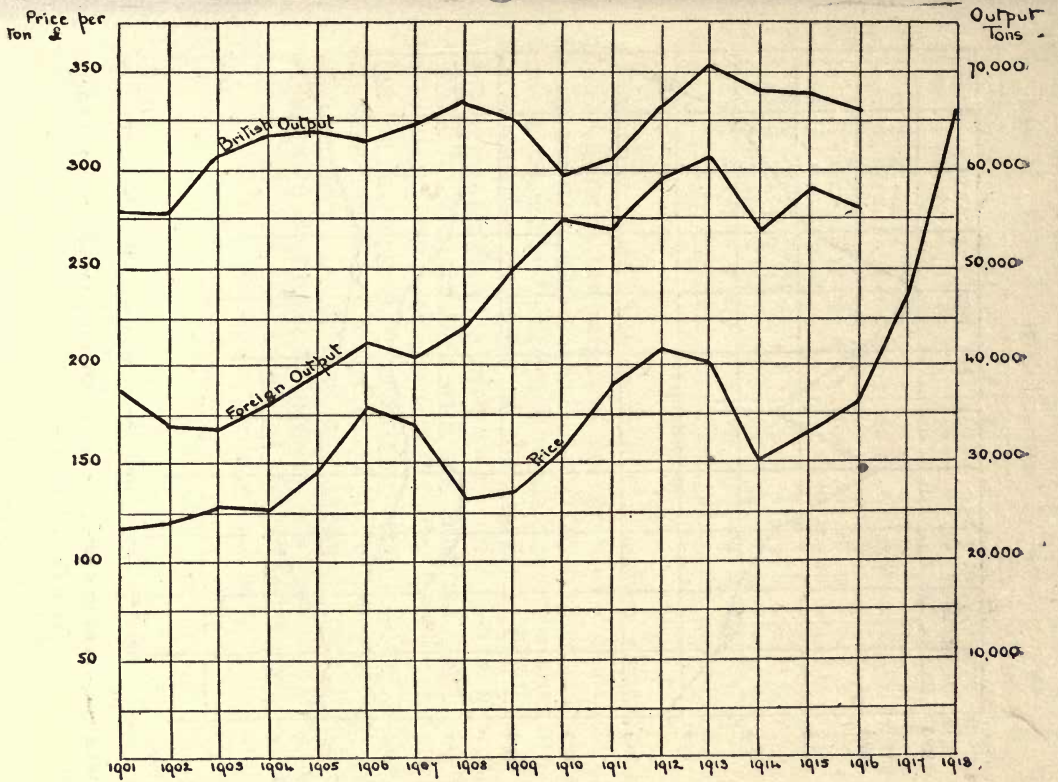


DIAGRAM 2.—BRITISH AND FOREIGN OUTPUT OF TIN ORE, 1901–1916, EXPRESSED AS TIN, AND AVERAGE PRICE OF THE METAL IN LONDON, 1901–1918.

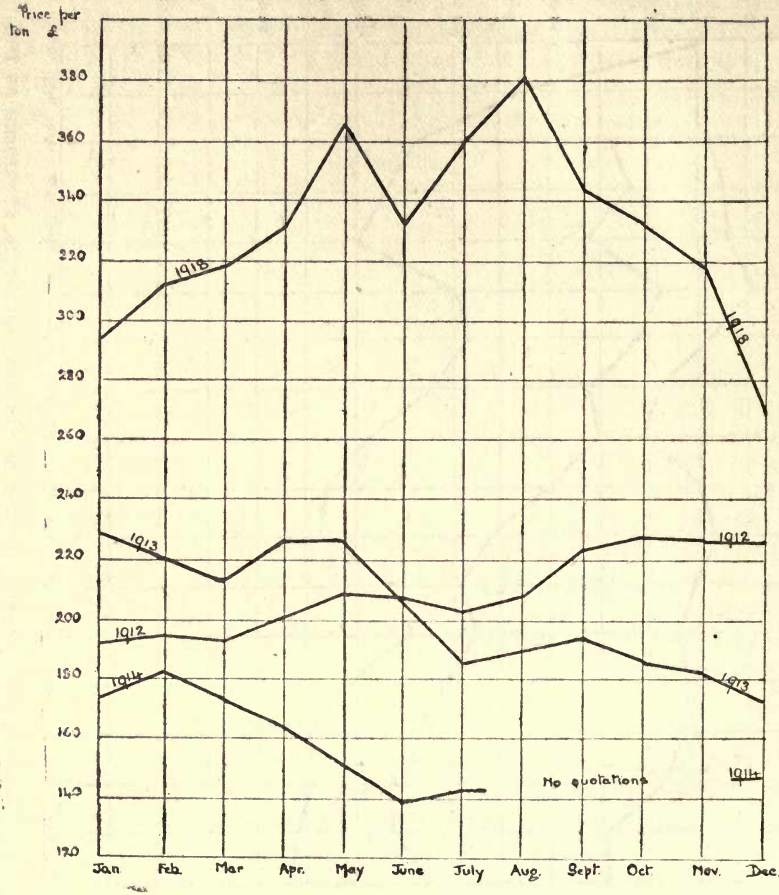


DIAGRAM 3.—AVERAGE PRICE OF TIN IN LONDON, JANUARY TO DECEMBER 1912, 1913, 1914, 1918.

Table 4

Average Price of Tin in London per ton (2,240 lb.)

	1912.			1913.			1914.			1915.			1916.			1917.			1918.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Jan..	191	14	0	228	5	0	172	0	11	156	14	6	175	16	4	186	6	4	293	6	2
Feb..	195	4	10	220	6	3	181	12	0	156	14	6	181	3	4	198	19	3	311	12	3
Mar.	192	15	0	213	11	10	174	0	1	180	10	10	193	13	11	207	10	8	318	15	0
April	200	8	3	224	14	2	164	3	7	166	10	0	199	10	0	220	3	10	329	18	1
May.	209	6	1	224	14	3	150	19	3	162	18	6	196	11	9	245	2	10	364	7	8
June	205	18	9	204	9	1	138	16	2	167	17	3	179	11	3	242	7	7	331	10	0
July.	202	8	3	183	16	11	142	10	4	167	5	10	168	9	6	242	6	6	359	17	9
Aug.	208	3	0	188	19	0		*		151	12	10	169	19	9	243	18	8	380	16	8
Sept.	223	19	6	193	7	7		*		152	18	4	171	8	4	243	19	5	343	19	0
Oct.	228	9	1	185	0	3		*		151	16	2	179	8	2	247	9	4	335	10	0
Nov.	227	16	10	181	0	0		*		167	18	5	186	19	8	275	2	10	317	7	7
Dec..	226	17	8	171	18	11	147	4	4	167	3	10	183	9	1	298	10	3	267	14	3

* No quotations.

Diagram 2, in which the price of tin has been plotted on the same diagram as the output of dressed tin ore in British and foreign countries, shows the close interdependence which exists between supply and price, and which cannot be disguised by the speculative character of the market. The output is given in greater detail in Diagram 1. In 1905–6 an increasing demand for tin, together with a diminished output in the Malay States and Banka, caused the price to rise; this stimulated the development of low-grade deposits in Australia and elsewhere, and caused an increased production, which by 1908 had overtaken the demand and brought down the price. Consumption continued to increase, however, and from 1908 to 1912 the price rose in spite of the increasing supplies from Bolivia, Banka and China. In 1913 and 1914 this increased production caused the price to fall, and the first fifteen months of the war saw a small demand, low price, and diminishing output. In 1916 and the following years, however, the American consumption grew to unprecedented proportions; the expense and difficulty of mining and shipping the ore under war conditions caused a further decline in production; and consequently prices rose to hitherto unknown figures.

High prices, as compared with those of 1914, are likely to rule for some time. To the large demands caused by industrial expansion in Allied countries after the war will be added those of Germany and Austria; and only gradually will it be possible to obtain the capital and machinery necessary for a large

increase in production. Until the supply more nearly equals the demand, high prices must prevail, and this will stimulate the exploitation of low-grade deposits which in 1914 would have been unremunerative.

The Properties of Tin

Tin has a silvery-white colour and a brilliant lustre. It has a crystalline structure, as may be seen when the surface has been slightly attacked by an acid (*moiré métallique*). To this crystalline structure may be attributed the low tensile strength of the metal, as well as the characteristic "cry" and the elevation of temperature produced by bending a bar of tin.

The atomic weight of tin is 118·7 and its specific gravity is 7·29 when cast. In commercial tin the latter often rises to 7·5, since the impurities commonly present have a higher specific gravity than tin. Tin melts at 232° C. and boils at about 2,100° C., but is volatile at lower temperatures. Its specific heat is 0·056. It has a conductivity of 14·5 for heat and of 11·3 for electricity, that of silver being taken as 100 in each case. It is very malleable and ductile, especially at 100° C., and can easily be rolled or beaten into foil. At a temperature of about 200° C., however, pure tin is so brittle that it is readily shattered by a blow from a hammer. At low temperatures, and especially about − 40° C., tin tends to pass into an allotropic modification known as grey tin. This change is sometimes referred to as "tin pest," the tin being covered with small pustules of grey tin, which is an incoherent powder and has a lower density than the common white tin.

The best brands of commercial tin are remarkably pure, often containing less than 0·1 per cent. of other metals. Class A tin, which contains not less than 99·75 per cent. of tin, is taken as the standard with regard to price; Class B metal, with from 99·0 to 99·75 per cent. tin, is priced at £7 per ton lower. The former is used in tin-plate manufacture, where impurities give a duller and poorer coating, but Class B tin serves for the making of alloys.

The impurities usually present are copper, iron, lead, antimony, bismuth, tungsten, sulphur, arsenic and stannic oxide. These impurities tend to make the tin harder and less malleable, and also impair the brilliancy of its lustre. Table 5 gives the analyses of several commercial brands of tin, according to the London Metal Exchange.

Table 5

Analyses of Commercial Brands of Tin

	Tin.	Anti-mony.	Arsenic.	Lead.	Bis-muth.	Copper.	Iron.	Silver.	Sulphur.
Banka . .	99·950	0·007	nil	trace	nil	0·018	0·045	nil	trace
Billiton . .	99·960	0·006	nil	nil	nil	0·023	nil	nil	nil
Penang . .	99·939	trace	0·003	trace	nil	0·016	0·028	nil	0·004
Singapore. .	99·870	0·008	0·045	0·034	0·003	0·052	0·003	0·006	0·005
Mt. Bischoff .	99·795	0·015	0 063	0·037	0·005	0·035	0·042	trace	0·008
Pyrmont . .	99·938	0·017	0·019	trace	nil	0·022	trace	nil	0·004
Irvine Bank .	99·580	0·062	0·034	0·221	0·025	0·126	0·002	0·018	0·004
Williams, Harvey & Co., No. 1	99·860	0·015	0·040	0·004	0·005	0·047	0·003	nil	0·006
Do., No. 2 .	99·560	0·166	0·037	0·162	0·007	0·050	0·005	trace	0·013
Do., No. 2*a* .	99·350	0·245	0·065	0 223	0·015	0·042	0·016	trace	0·013
Do., No. 3 .	99·200	0·300	0·037	0·396	0·007	0·100	0·013	0·014	0·006
Do., No. 4 .	99·941	0·011	0·022	trace	0·001	0·020	trace	trace	0·005
Penpoll, No. 1 .	99·720	0·118	0·054	0·041	0·007	0·052	0·004	0·009	0·007
Do., No. 2 .	98·710	0·569	0·042	0·546	0·055	0·103	0·007	0·015	0·004
Do., No. 3 .	99·300	0·325	0·056	0·212	0·050	0·088	0·002	0·021	0·009
Redruth * .	99·160	0·176	0·053	0·177	0·017	0·445	0·014	0·006	0·008
Th. Goldschmidt, No. 1 .	99·860	0·004	nil	0·102	nil	0·043	trace	nil	trace
Do., No. 2 .	99·460	0·015	nil	0·425	nil	0·069	trace	nil	trace
Do., No. 3 .	99·150	0·122	0·046	0·143	0·112	0·352	0·007	0·006	trace
Chinese, No. 1 .	99·343	0·031	0·040	0·434	0·007	0·052	0·010	trace	0·011
Wing Hong & Co., No. 2 .	98·662	0·039	0·035	1·035	0·012	0·134	0·014	trace	0·011
Do., No. 3 .	95·280	0·381	0·050	3·995	0·020	0·106	0·026	0·018	0·008

* Cobalt, 0·012 per cent.

Uses of Tin

Tin is rarely used alone, except in pipes for distilleries and in the form of tin-foil for wrapping purposes.

The most important use to which it is put is in the manufacture of tin-plate. The industry is centred chiefly in South Wales and the United States, and consists in applying a film of tin to the surface of thin sheets of mild steel. The sheets thus protected are made into " tins " or cans for the transport of preserved food, oil, and other commodities, or into cooking utensils, etc. The metal used for rolling into sheets was formerly charcoal iron, but very mild steel is now employed. The bars of steel are heated to redness, rolled, and folded in two. The rolling and doubling over are repeated until sheets of the required thickness are obtained, which are then cut to size and separated. The rough " black plates " thus produced are covered with a black scale of oxide, which is

removed by pickling them in warm dilute sulphuric or hydrochloric acid and then rubbing them with sand and water. They are then annealed, cold rolled, re-annealed, and again pickled, rubbed with sand, and swilled with water. While still wet they are passed through the tinning machine. This usually has two compartments, but the division does not reach to the bottom. The molten tin in the lower part is covered by a flux of zinc chloride in the first compartment and by melted grease in the second. The plates pass through the flux and down through the tin, emerging through the grease. They then pass through rolls which remove superfluous tin and give a smooth and bright surface.

Table 6

Pewter, Soft Solders, and Fusible Metals

	Tin.	Lead.	Bismuth.	Cadmium.	Melting Point.
Pewter, English . .	80	20	—	—	—
,, French . .	82	18	—	—	—
Solder, for electric fittings	94·5	5·5	—	—	—
,, tinsmith's . .	66·7	33·3	—	—	171° C.
,, ,, . .	60	40	—	—	168°
,, plumber's . .	50	50	—	—	188°
,, ,, . .	33·3	66·7	—	—	227°
,, bismuth . .	40	40	20	—	143·5°
,, ,, . .	40	20	40	—	113·3°
,, Bureau of Standards	10	80	—	10	183°
Fusible metal, Rose's .	25	25	50	—	93°
,, ,, Wood's .	13	27	50	10	65° to 71°

Tin alloys readily with most metals. The alloys serve a variety of purposes, and account for the greater part of the world's tin consumption. In tin-plate a true alloy is formed at the junction of the tin and iron, and the same may be said in the case of copper vessels coated with tin. An alloy of lead and tin, containing 15 to 25 per cent. of tin, is used for coating iron sheets, which are then known as terne plates and used as a substitute for galvanised iron for roofing, oil-tanks, etc. Small amounts of tin are often added to the spelter used in galvanising iron, to improve the appearance. Pewter and solder are other familiar examples of tin-lead alloys. The lead in pewter used for drinking vessels, dishes, etc., must not exceed 20 per cent., or there will be a risk of lead poisoning. A little copper is sometimes added to increase the hardness

of pewter, but the colour is adversely affected by it. Tin-lead alloys are also used for organ-pipes. Solders vary widely in composition, according to the use for which they are intended. The melting point falls with increase of tin until the eutectic proportion is reached with 63 per cent. of tin. By the addition of bismuth still lower melting points are obtained, and the alloy passes into the so-called fusible metals.

The use of tin for hardening copper has been known from ancient times. About 5 per cent. tin is added to copper for coinage purposes, while ancient bronzes contain from 8 to 15 per cent. Gun metal contains 8 to 10 per cent. of tin, and has great strength and toughness. In bell metal the percentage varies from 16 to 25. Speculum metal for reflectors contains about 33 per cent. of tin and 67 per cent. of copper, though other alloys are now frequently used for the purpose. Gun metal, formerly used for casting cannon, is now employed in various parts of machines, such as gearings, slide-valves, bearings, etc. For these purposes phosphorus is advantageously added to act as a deoxidiser, and in excess to increase the hardness and resistance to wear. Such alloys are known as phosphor-bronze.

Table 7

Bronze, Gun Metal, etc.

	Tin.	Copper.	Zinc.	Lead.	Phosphorus.
British bronze coinage .	4	95	1	—	—
Gun metal . . .	9	91	—	—	—
Bell metal . . .	25	75	—	—	—
Speculum metal . .	33	67	—	—	—
Phosphor-bronze . .	10	89	—	—	1
Bronze bearing metal .	8	77	—	15	—

Alloys of tin with antimony and one or more other metals are of great industrial importance. The white antifriction metals vary in composition according to the weight and speed of the load they are intended to bear. Britannia and similar silvery-white metals consist mainly of tin, while in type metal lead preponderates and tin is often omitted in the softer and cheaper qualities. Tin amalgam was formerly much used for making mirrors.

Table 8

Bearing Metal, Britannia Metal, and Type Metal

	Tin.	Antimony.	Copper.	Lead.	Bismuth.
Bearing metal, Babbitt's .	90	7	3	—	—
,, ,, for locomotives	82	14	4	—	—
,, ,, soft . .	11·5	13·5	3	72	—
Britannia metal for spinning	94	5	1	—	—
,, ,, ,, rolling .	90	7	3	—	—
,, ,, ,, casting .	84	10	4	—	2
Queen's metal . . .	75	8·5	—	8·5	8
Type metal . . .	10	18	2	70	—
,, ,, ...	7·5	14·5	—	78	—

Tin compounds are extensively used in the dyeing, calico-printing, and silk industries. The stannous salts have great reducing properties and are used as resists and discharges in printing. Stannic chloride, cotton spirits, or tin spirits (names given to a variety of solutions of tin) is largely used as a mordant for cotton and linen, as is also sodium stannate (preparing salts). For wool, stannous chloride (tin crystals) is usually employed. The weighting of silk also consumes large quantities of stannic chloride. Many other compounds, such as stannous nitrate, sulphocyanide, acetate, oxalate, citrate and tartrate, are also used as mordants in dyeing. The " pink salt " formerly employed by dyers consists of stannic chloride and ammonium chloride.

In ceramic industries stannic oxide is extensively used to form an opaque white in enamels, glazes and glassware. A blood-red glaze is produced by compounds of tin and chromium, while purple of Cassius is a compound of tin and gold.

Stannic sulphide is employed as a gilding material under the name of mosaic gold. Various pink, lilac, blue and green pigments contain tin, but they are of comparatively little importance.

A mixture of tin and lead oxides forms the putty powder used in polishing glass, stone and metal. Under the name of tin ash it is used also in the pottery industry.

The relative quantities of tin used in the United States for the different purposes enumerated above is shown in Table 9. The figures relate to a war year, 1917, and in other countries different proportions are probably allocated to the various industries. Chemicals (oxide, chloride, etc.) only account for 1,718 tons.

Table 9

Consumption of Tin in the United States in 1917 (*tons*)

Tin and terne plate	27,600	Collapsible tubes	2,100
Solder	17,000	White metal.	1,764
Babbitt and other bearing metals	10,800	Miscellaneous	8,193
Brass and bronze	4,800		
Foil	4,000		
		TOTAL	76,257 tons

The recent scarcity of tin has led to investigations being made, especially in America, into the possibility of reducing the tin contents of various alloys in order to make the limited supply of the metal go farther. In the case of tin-plate, it was shown some years ago that while the lustre and resistance to rusting increase somewhat with increasing weights of coating, the utility of the tin-plate for packing most classes of food is practically the same for plate carrying from 1 to 3 lb. of tin per base box (112 sheets, 14 by 20 in.). Bronze bearing metal containing 65 per cent. copper, 30 lead, and 5 tin has been used with success, and in this alloy 2 or even 3 per cent. antimony may for some purposes be substituted for tin. Babbitt metals with only 5 per cent. tin, or even no tin at all, have been tested by the Bureau of Standards as well as aluminium and other bronzes. The Bureau recommends a solder containing 80 per cent. lead, 10 tin, and 10 cadmium.

SECONDARY TIN

The recovery of tin from clean scraps of tin-plate and from alloys and compounds containing tin yields considerable amounts of tin and tin compounds in this country and the United States. Only in Germany, however, has extensive use been made of old tin cans and other such refuse, but an attempt is now being made to utilise in this country the old tins that were formerly either wasted or sent to Germany as ships' ballast. In some cases the scrap is merely placed on grids and heated, when the molten tin falls to the bottom. The Bergse process employs stannic chloride as a solvent, which dissolves the tin and forms stannous chloride. This solution is electrolysed in a separate vat, when metallic tin is deposited and stannic chloride regenerated. In an electro-chemical process the tin-plate cuttings form the anode and a 10 per cent. solution of caustic soda is used as the electrolyte. Sodium

stannate forms and is decomposed into tin and sodium hydrate. The chlorine process appears to be the most generally used. Its success depends on the fact that chlorine does not attack iron at low temperatures and under dry conditions. The dry tin scrap, free from organic matter, is treated with chlorine under considerable pressure in closed containers, stannic chloride being formed, which is largely used in the silk dyeing industry. Another apparently successful process consists in boiling tin scrap for some hours in a solution containing excess of free alkali and saltpetre, or some other oxidising agent. Crystals of sodium stannate are formed and are separated from the mother liquor, which is remade to its former strength and used again. Tin oxide is precipitated from an aqueous solution of the sodium stannate by adding sodium bicarbonate.

CHAPTER II

SOURCES OF SUPPLY OF TIN ORES

(*a*) BRITISH EMPIRE

EUROPE

UNITED KINGDOM.—The United Kingdom has an average output of some 8,000 tons of tin ore per annum, containing about 5,000 tons of tin. The production is confined to Cornwall and Devon, and Table 10 shows the annual output for the last eight years.

Table 10

Output of Tin Ore in the United Kingdom

In tons (2,240 lb.)

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Cornwall .	7,483	7,665·4	8,064·4	8,257·05	7,986·6	8,042·3	7,793·95	6,543·55
Devon .	89·45	80·65	101·7	97·85	98·65	102·25	98·2	32·2
Total .	7,572·45	7,746·05	8,166·1	8,354·9	8,085·25	8,144·55	7,892·15	6,575·75
Tin content of the ore .	4,797·3	4,872·45	5,254	5,288·3	5,056·25	4,967·85	4,697·15	3,936·45
Value of the ore . £	655,871	837,957	1,012,290	960,134	661,865	668,609	712,142	784,493

How small a proportion the domestic output bears to the total tin industry of the country will be seen by comparing Table 10 with Table 11, which gives the imports and exports in the same years.

Table 11

Imports and Exports

In tons (2,240 lb.)

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Imports of tin ore . .	26,072	28,837	28,652	34,592	32,398	44,748	33,912	41,208
Imports of tin	46,285	45,906	43,157	45,682	40,961	38,896	33,646	27,143
Exports of tin	43,916	45,589	44,706	41,749	44,242	37,531	35,516	37,389

The tin ore imported is chiefly of Bolivian origin, and is shipped to this country from ports in Chile and Peru. The total imports from South American States rose from 22,542 tons in 1914 to 35,767 tons in 1915, when the Bolivian ore which formerly went to Germany was diverted to this country. In 1916 the amount had fallen approximately to normal at 24,587 tons, the excess ore being taken up by smelters in the United States and South America. Nigeria sends the whole of its output of tin ore to be smelted in this country, but the South African ore which formerly came here now goes almost entirely to the Straits Settlements. This change, though obviously accelerated by war conditions, had begun before the war, and its effects will doubtless continue in time of peace.

The greater part of the tin imported into the United Kingdom is smelted in the Straits Settlements. Australia, Hong Kong and the Dutch East Indies are the next largest contributors. The imports from the last-named country show an increase in 1915 and 1916, due to much of the tin that was formerly sent to Holland and Germany coming to this country.

Tables 12 and 13 give details of the imports of tin ore and tin in recent years.

The exports of tin ore and tin from the United Kingdom are shown in Tables 14 to 16. Small amounts of ore were re-exported, principally to Germany. In the five years preceding the war the United States took between 28,000 and 33,000 tons of tin annually, or about 70 per cent. of our exports. In 1915 the exports to the States fell to 17,616 tons, in 1916 they were 21,672 tons, and in 1917, 18,792 tons. This fall is largely due to high freights, much foreign and colonial tin that was formerly brought to this country for trans-shipment being now sent direct to its final destination.

The tin-plate exports also show a great decrease in quantity, though not in value, during the war years, having fallen from 494,497 tons in 1913 to 177,383 tons in 1917. The United States was formerly a large customer, but now that her own tin-plate output has increased to over a million tons a year she has begun to send it to this country, besides supplying much of the needs of Canada, South America, Japan, India, and other countries.

Cornwall, with the western part of Devon, was for centuries the most important tin-mining region in the world. The industry dates back to pre-historic times. In the sixteenth century the output of tin was about 700 tons a year, which

Table 12

Imports of Tin Ore into the United Kingdom

In tons (2,240 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Australia	16	14	79	607	219	244	112	34
Nigeria	685	1,378	2,378	3,880	6,453	5,849	7,430	8,756
South Africa	3,339	3,407	826	880	903	1,456	54	54
Straits Settlements and Dependencies	10	6	67	91	25	23	16	25
Other British Possessions	13	7	86	278	148	196	388	21
Total from British Possessions	4,063	4,812	3,436	5,736	7,748	7,768	8,000	8,890
Germany	325	779	1,803	1,084	501	—	—	—
Netherlands	108	105	309	95	30	—	—	9
Belgium	23	54	76	145	59	—	—	—
France	822	852	819	1,183	518	153	221	78
Portugal	15	31	66	194	351	456	496	554
Spain	165	154	388	667	339	348	252	49
United States	72	228	240	195	67	15	75	2
Bolivia and other South American States	19,982	21,439	21,085	24,802	22,542	35,767	24,587	31,319
Other Foreign Countries	497	383	430	491	243	241	281	307
Total from Foreign Countries	22,009	24,025	25,216	28,856	24,650	36,980	25,912	32,318
Total . . . Tons	26,072	28,837	28,652	34,592	32,398	44,748	33,912	41,208
Value . . . £	1,820,782	2,306,234	2,400,886	3,308,933	2,981,473	3,777,711	3,159,622	4,710,934

Table 13

Imports of Tin into the United Kingdom

In tons (2,240 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Australia	3,872	3,571	3,244	2,251	1,463	2,312	2,607	323
India	51	—	—	130	—	50	6	1
Hong Kong	405	1,127	1,530	907	939	1,799	1,076	853
Straits Settlements and Dependencies	40,604	39,691	36,069	40,090	37,783	30,200	25,642	25,571
Other British Possessions	59	—	1	5	1	15	10	—
Total from British Possessions	44,991	44,389	40,844	43,383	40,186	34,376	29,341	26,748
Germany	42	139	223	367	51	—	—	—
Netherlands	73	184	53	209	21	—	—	—
France	20	61	31	27	57	—	—	—
Dutch East Indies	4	135	1,244	1,141	324	3,781	4,266	277
China	5	150	228	30	90	194	—	—
United States	201	440	—	200	—	10	8	—
Bolivia	943	396	511	306	154	470	—	116
Other Foreign Countries	6	12	23	19	78	65	31	2
Total from Foreign Countries	1,294	1,517	2,313	2,299	775	4,520	4,305	395
Total . . . Tons	46,285	45,906	43,157	45,682	40,961	38,896	33,646	27,143
Value . . . £	7,159,782	8,739,469	8,970,144	9,252,004	6,359,145	6,304,546	6,149,490	6,198,243

Table 14

Exports of Tin Ore (Foreign and Colonial) from the United Kingdom

In tons (2,240 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Straits Settlements	69	—	—	—	—	214	813	—
Other British Possessions		—	—	—	—	—	11	—
Total to British Possessions	69	—	—	—	—	214	824	—
Germany	2,499	3,616	2,278	2,498	2,483	—	—	—
Belgium	141	98	376	431	343	—	—	—
France	—	65	421	298	19	2	—	—
Austria-Hungary	—	239	316	326	10	—	—	—
Other Foreign Countries	—	33	7	12	46	—	—	—
Total to Foreign Countries	2,640	4,051	3,398	3,565	2,901	2	—	—
Total . . . Tons	2,709	4,051	3,398	3,565	2,901	216	824	—
Value . . . £	182,422	314,437	336,679	314,476	216,742	15,966	74,300	23

Table 15

Exports of British [1] *Tin from the United Kingdom*

In tons (2,240 lb.)

Canada	887	1,062	952	847	712	927	950	1,136
Egypt [2]	—	—	—	—	—	221	214	283
India	158	157	220	327	112	214	69	29
South Africa	111	117	214	173	212	228	337	187
Other British Possessions	142	129	116	109	166	74	84	77
Total to British Possessions	1,298	1,465	1,502	1,456	1,202	1,664	1,654	1,712

[1] Under this heading is included tin which had been imported from abroad, but which was refined at the smelting works in England and was accordingly declared by the exporters as British tin.

[2] Included in Foreign Countries prior to 1915.

Table 15 (continued).

Exports of British Tin from the United Kingdom

In tons (2,240 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Russia	1,105	1,086	1,247	1,415	2,234	1,635	1,767	4,743
Sweden	568	614	650	672	1,337	1,880	819	153
Norway	104	108	110	100	205	765	167	34
Denmark	83	79	78	98	161	227	258	175
Germany	292	216	150	70	61	—	—	—
Netherlands	206	100	120	66	179	187	1	1
Belgium	61	41	282	75	136	—	—	—
France	1,590	1,306	916	774	1,454	888	3,976	2,585
Portugal	491	442	446	473	379	535	453	420
Spain	482	471	482	484	440	595	628	538
Italy	176	109	35	36	367	541	324	287
Bulgaria	60	98	51	95	74	6	—	—
Turkey	288	248	165	264	280	64[1]	3[1]	25[1]
Egypt[2]	176	132	106	155	116	—	—	—
United States	4,182	3,965	4,558	4,082	4,006	3,713	6,633	6,903
Chile	56	54	53	86	65	82	49	25
Brazil	245	171	236	251	94	180	245	146
Argentine Republic	521	456	452	454	264	742	655	1,305
Other Foreign Countries	393	403	339	407	345	463	390	213
Total to Foreign Countries	11,079	10,099	10,476	10,057	12,197	12,503	16,368	17,553
Total . . . Tons	12,377	11,564	11,978	11,513	13,399	14,167	18,022	19,265
Value . . . £	1,866,065	2,174,783	2,503,053	2,433,065	2,061,024	2,318,750	3,254,124	4,224,504

[1] Exported to ports or places in territory formerly Turkish but now occupied by other Powers, *e.g.* Crete, Dedeagatch, Salonika, etc.

[2] Including Anglo-Egyptian Sudan prior to 1914.

Table 16

Exports of Tin (Foreign and Colonial) from the United Kingdom

In tons (2,240 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Canada	12	30	8	10	5	155	523	469
Other British Possessions	3	—	20	122	33	27	7	6
Total to British Possessions	15	30	28	132	38	182	530	475
Russia	444	303	561	338	631	2,698	20	178
Sweden	3	7	5	6	59	1,574	126	10
Norway	—	—	2	—	—	422	11	11
Germany	787	956	1,262	1,351	1,985	—	—	—
Netherlands	1,679	3,189	3,022	3,039	2,075	1,628	—	—
France	40	102	244	62	715	271	508	2,377
Spain	105	127	64	8	180	397	297	445
Italy	220	3	46	5	730	1,777	213	1,307
United States	28,035	29,096	27,224	25,065	24,197	13,903	15,039	11,889
Other Foreign Countries	211	212	270	230	233	512	750	1,432
Total to Foreign Countries	31,524	33,995	32,700	30,104	30,805	23,182	16,964	17,649
Total . . . Tons	31,539	34,025	32,728	30,236	30,843	23,364	17,494	18,124
Value . . . £	4,877,271	6,429,545	6,753,547	6,147,191	4,756,912	3,932,385	3,236,798	4,005,874

increased to 2,000 or 3,000 tons in the eighteenth century. Between 1860 and 1890 it reached nearly 10,000 tons a year, but receded to about 4,000 tons in 1899. As recently as 1870 Cornwall produced 50 per cent. or more of the world's output, whereas it now produces only about 4 per cent. The total amount of tin which has been produced from Cornish ore is estimated at about 1,500,000 to 2,000,000 tons, a figure only exceeded by one other region. The Malay Peninsula, including Banka and Billiton, produced about 2,300,000 tons of tin down to 1916, Australia and Bolivia each about 300,000 tons, whilst the lodes of Saxony and Bohemia, which are now practically exhausted, have yielded little more than 100,000 tons.

The tin and copper deposits of Cornwall and Devon are connected with five large masses of granite, and some smaller ones, which are intrusive in sedimentary rocks and associated igneous rocks known as "greenstones." The sediments are for the most part slaty in character and are called "killas." In age they are partly Ordovician (or older), partly Devonian and Carboniferous, while the granite intrusions are either late Carboniferous or Permian.

Closely connected with the granite intrusions are numerous "elvans," or dykes of quartz-porphyry, while the last phase of igneous activity was marked by the emanation of metalliferous vapours and solutions through fissures which traversed the granite and overlying killas. This gave rise to the tin-copper lodes, with their dominant east-north-east strike. The lead-silver lodes which traverse the killas in a north and south direction appear to be of later date.

The lodes and elvans are for the most part crowded together at one side of the granite intrusion, near its margin or in the surrounding metamorphic aureole. This appears to be due to excessive disturbance of the sedimentary rocks on one side of the intrusive mass. To the same cause may be attributed differences in the structure of the lodes. In the principal centres they consist of wide zones of fissured rocks, with frequent breccias and crushed material; while the outlying lodes consist of clean cracks or joints of remarkable straightness.

The chief ores found in the lodes are cassiterite, with some stannite; chalcopyrite, bornite, and chalcocite; wolframite and scheelite. Less important are galena, tetrahedrite, silver ores, zinc-blende, bismuthinite, molybdenite, cobalt and nickel ores, pitchblende (uraninite), manganese and iron ores.

Professor Cronshaw, who has made a detailed examination of a number of lodes at various depths, contributes the following

note, embodying his conclusions on the time-order of deposition of the lode contents :—

"The mineral contents show a definite arrangement within the lode fissures, and, moreover, display well-defined mutual relationships. This definite arrangement is the outcome of a definite order of intrusion, which, for the Camborne district—and it very probably admits of wider application—has been found to be as follows :—

I. Large grained and considerably brecciated quartz.

II. Small grained quartz, cassiterite, tourmaline, and chlorite.

III. (*a*) Brown, finely crystallised tourmaline and chlorite, or 'brown peach,' with minute grains of cassiterite and a certain amount of arsenopyrite.

(*b*) 'Blue peach,' with cassiterite, and some arsenopyrite.

IV. (*a*) Fluorspar, and to a less extent, secondary quartz veins containing a little copper pyrites and occasional re-crystallised cassiterite.

(*b*) Calcite veins.

(*c*) Veins of hæmatite, iron pyrites, quartz, etc.

(*d*) Veins of galena, zinc-blende, quartz and copper pyrites.

The bulk of the cassiterite made its appearance at stage III (*a*).

"The several stages were separated by intervals, towards the end of which movements re-opened the lodes, preparatory to an infiltration and deposition of additional material. The amounts of the various mineral associations deposited in the lodes at each stage differ in every case, as also the extent to which fissuring took place during each interval. Thus some lodes are characterised by the predominance of certain minerals, or associations of minerals, and likewise a certain amount of variation in character of mineral constituents takes place from point to point within one and the same lode. The commonly observed preference of copper ores for the upper parts of the lodes is probably due to the fact that the latest movements which were connected with the mineralising operations would be more likely to affect those portions of the lodes which lay within the killas than the portions situated

in the more resistant masses of granite, and the ores of copper, which were amongst the latest to arrive, would find in this zone the open spaces required for their deposition.

"The later cross-courses intersect and fault the tin-copper lodes so that their directions of strike are roughly at right-angles to one another. The cross-courses do not contain tin, but in some cases they have yielded ores of lead, zinc and silver.

"*Camborne and Land's End Areas.*—Geographically considered the lodes of south-west Cornwall show certain peculiarities in their distribution. In the Land's End area they are gathered into isolated groups, either within the granite or immediately outside its margin; in the Camborne and Redruth districts they are packed into the narrow belt of metamorphosed shales lying along the flanks of the Carn Brea and Carn Marth granite intrusions, whilst the intervening country, occupied by a broad tract of killas, is characterised by a more general distribution. These features, when considered in conjunction with the geological structure of the region, lead to the important observation that the more important ore-bodies are generally situated at or near the junctions between granite and killas. The apparently anomalous cases of lodes occurring within tracts of killas and granite still conform to the general rule, for, in the former case, the killas is underlain at no great depth by granite, and, in the latter case, lodes situated within the outcrop of granite no doubt represent the roots of eroded, and formerly more extensive, bodies. That the fissuring was far from being general is shown by the absence of valuable ore-deposits from the lower half of the Land's End mass, as also from the metamorphosed margin above Penzance, and the zone of alteration surrounding the large granite boss of Carnmenellis.

"Another factor which seems to have an important influence upon the distribution of the ores is the angle at which the surface of the granite slopes beneath the killas. Where this is high the zone of metamorphism is narrow, and the mineral deposits are sparingly developed; on the other hand, the richest and largest deposits have generally been found where the slope is gentle.

"In many cases the passing of a lode from killas into granite has effected an important change in the value and

nature of its contents. It has long been observed that, generally speaking, the lodes in the granite are richest in tin, those in killas most productive of copper, whilst in those at or near the junction of the two rocks, both tin and copper are found. Many lodes of the latter type furnish good instances of the variation in the proportions of tin to copper with change of depth ; and as a general rule it is found that in the upper parts of such lodes copper ores are dominant, whilst in depth and within the granite they give place to rich deposits of tin.

"The general distribution of the individual lodes is more conveniently considered when they are grouped into zones. This is rendered possible by the fact that, as a rule, they occur in groups of more or less closely packed and parallel individuals, which branch, intersect, and display a generally complicated structure and arrangement. It is along these lode-zones that the principal mines are arranged. The country rock between these zones has suffered only a relatively small amount of mineralisation. The individual members display many irregularities. In strike they are roughly parallel to one another, averaging about E. 30° N., and their general dip is high and towards the north. They intersect one another, branch and unite, die out or 'make' in the directions of dip and strike, and send out subsidiary offshoots. They vary in width from point to point, and in the amount and direction of their inclination. Again they 'mineralise' portions of the surrounding country rock by sending out fine offshoots."

In the west of Cornwall are the two mining centres of St. Just and St. Ives, both at the northern margin of the Land's End granite mass. In the St. Just district many of the mines are situated on the cliffs, and follow the ore for long distances beneath the sea. Much of the ore is confined to narrow fissures and, at the junction of these, nearly horizontal sheets or "floors" of tin ore often occur. The principal mines of this district are the Levant and Botallack mines. Of the St. Ives mines, St. Ives Consols is the most interesting, by reason of its irregular pipe-like deposits of tin ore known as "carbonas." The great carbona appears to have been formed at the junction of veins with a cross-course ; it had an average height of 24 feet and width of 12 feet, though in places its dimensions were much greater ; and it consisted of tourmaline, cassiterite, chlorite, fluorite, chalcopyrite and pyrite.

In the Camborne and Redruth district the primary zoning of the ores is well shown, many of the lodes being rich in copper ore while in the killas, on entering the granite the copper gives place to tin. Thus at Dolcoath, the richest as well as the deepest mine in Cornwall, copper ore prevailed to a depth of about 1,000 feet, below which tin ore was found.

Most of the lodes connected with the St. Austell granite are in the metamorphic aureole on the south side of the intrusion. In the granite they are clean cracks or joints, filled with quartz, cassiterite and wolframite, while in the killas they often contain much brecciated country rock, or consist of numerous small parallel cracks, sometimes with intersecting cracks constituting stockworks. At Park of Mines a peculiar structure occurs, most of the tin ore being in opened planes of parting in the killas through which the veins cut.

The Bodmin Moor granite intrusion has metalliferous lodes near its south-eastern margin, but they have yielded more copper than tin.

The lodes of Devonshire are chiefly in the neighbourhood of Tavistock, on the west side of the Dartmoor granite, and Ashburton on the east side of that intrusion. Most of them are in the killas, and copper ores are more abundant than tin ores.

The relative importance as sources of tin of these five great granite intrusions is shown by the following table, giving the approximate percentage of the total annual output produced by each intrusion and its surrounding rocks in recent years:—

	Per cent of total output.
Land's End granite	12
Camborne granite	85
St. Austell granite	1
Bodmin Moor granite	1
Dartmoor granite	1

The working of alluvial deposits, or "tin streaming," is an older industry than lode mining, and most of the deposits have been worked over and over again till practically exhausted. The St. Austell district is particularly famous for its tin-bearing alluvial deposits. At the old Happy Union Streamwork at Pentewan the tin ore was confined to 3 to 10 feet of gravel resting on bedrock beneath some 50 feet of barren sand and silt, and about 50 feet below sea-level. In the high-level

alluvial flats or "moors," such as Goss Moor and Red Moor, which have been worked successfully in the last few years, the tin-gravel rests on solid rock and varies from a few inches up to 30 feet. It is covered by layers of peat, gravel, sand and clay to a thickness of 20 feet. The richest ground occurs in erosion channels and hollows in the solid rock, and has sometimes yielded several per cent. of black tin. All the tin-gravels appear to be the results of the natural concentration of the heavier material brought down during a period of exceptional erosion when the land stood at a higher level than now. The output of black tin from these alluvial deposits in 1914 was 91 tons, chiefly from the "moors" in the St. Austell district.

There are also similar works which treat the refuse sand and mud discharged from tin-dressing floors into streams and rivers. Several such works are situated on the Red River, which runs from the Camborne mines into St. Ives Bay. In spite of their activity much tin ore has reached the sea, where it has been concentrated by wave action on the foreshore of the bay. The output of black tin from these sources in 1917 was 954 tons, but its average tin content was only 32·7 per cent. against 65·6 per cent. in the case of ordinary ores.

Old mine dumps contain material that was formerly thrown aside, but which may become worth treating through an increase in the price of tin or improved methods of treatment. This source yielded 350 tons of black tin in 1917.

Outside Cornwall and Devonshire there are no tin deposits of economic importance in the British Isles. Stream tin occurs, however, together with magnetite, wolframite and gold, in some of the valley gravels of County Wicklow. There is also a peculiar occurrence at Carn Chuinneag, Ross-shire, of cassiterite associated with streaks of magnetite in foliated granite-gneiss.

Asia

Ceylon.—Cassiterite has been found in gem gravels from the Balangoda area examined at the Imperial Institute, and some of the concentrates from river sands also contain small amounts of the mineral. No deposits of economic importance have yet been discovered.

Hong Kong.—In the Kowloon territory there are tin-bearing alluvial deposits, and steps were being taken before the war to

work them. The source of the tin is probably connected with the granite, which has hitherto provided almost the sole mining industry of the Colony.

Hong Kong has a considerable industry in refining the crude tin produced in Yunnan and other parts of China. There are five refineries, and the imports of unrefined tin from Yunnan amounted to 6,153 tons in 1913 and 6,741 tons in 1914.

INDIA.—The tin ore production of India is still small, though its value has increased from £9,645 in 1909 to £94,495 in 1917. South Burma was till recently the chief source, but the Southern Shan States have produced increasing amounts of ore since 1912. The output in recent years is as follows :—

Table 17

Output of Tin and Ore in India

In tons (2,240 lb.)

	1912.	1913.	1914.	1915.	1916.	1917.
Burma :						
Mergui, metal .	137·8	116·8	98·15	127·675	112·86	140·895
,, ore .	113·05	85·85	93·05	88·113	94·85	88·05
Tavoy, metal .	62·9	65·7	—	0·03	—	—
,, ore . .	1·5	1·05	38·35	12·65	82·2	88·1
Southern Shan States, ore .	60·1*	83·75*	138·35*	330·695*	243·1	404·4
Thaton, ore .	—	—	—	—	45	83·85
Amherst, ore .	—	—	—	—	0·5	1·65
Bihar and Orissa :						
Hazaribagh, metal	—	—	0·05	0·035	—	—
Total, metal .	200·7	182·5	98·2	127·74	112·86	140·895
,, ore .	174·65	170·65	269·75	431·458	465·65	666·05
Total value £	50,944	46,384	38,203	54,980	59,104	94,495

* Mixed cassiterite-wolframite concentrates.

The ore is obtained chiefly from stream deposits. Some of it is smelted locally in small native furnaces, and the rest is exported in the form of 70 per cent. concentrates, mainly to the Straits Settlements. Table 18 shows the destination of the tin ore exported, and Table 19 the source of the imported tin. The consumption of foreign tin in India amounts to about 1,700 tons in normal years, and tin-plate is imported to the extent of 40,000 to 50,000 tons a year.

Table 18

Exports of Tin Ore from British India in the years ending 31st March, 1911–1917

In tons (2,240 lb.)

Countries to which consigned.	1910–11.	1911–12.	1912–13.	1913–14.	1914–15.	1915–16.	1916–17.
United Kingdom.	19	9	35	38	28	9	12
Straits Settlements . .	101	109	178	167	86	78	202
Other countries .	—	16	1	5	1	—	—
Total . Tons	120	134	214	210	115	87	214
Value . £	10,269	13,198	20,927	24,373	12,934	8,815	23,448

Table 19

Imports of Unwrought Tin into British India in the years ending 31st March, 1911–1917

In cwt. (112 lb.)

Countries from which consigned.	1910–11.	1911–12.	1912–13.	1913–14.	1914–15.	1915–16.	1916–17.
United Kingdom	2,868	3,526	4,800	4,155	4,426	2,522	1,422
Straits Settlem'ts	33,212	30,363	26,645	37,104	33,082	25,158	25,501
Other British Possessions . .	95	103	48	57	167*	376*	733*
Foreign countries	180	2,329	43	90	202	305	309
Total . cwt.	36,355	36,321	31,536	41,406	37,877	28,361	27,965
Value . £	295,455	349,291	335,733	423,282	314,607	243,521	259,003

* Chiefly Federated Malay States.

The tin deposits of Burma form a link between the great tin fields of the Malay Peninsula to the south and those of Yunnan in China to the north. As in Malaya, the greater part of the ore is won from alluvial deposits, though the working of lodes has also begun. In most cases work is carried on only on a small scale and by native methods; and the output might be greatly increased by the extended use of modern machinery.

In the extreme south of Burma, the tin-mining areas of the Mergui district have been examined by Mr. J. J. A. Page, of the Geological Survey of India. Granite ranges, trending north and south, are flanked by hills formed of unfossiliferous

schists, slates, sandstones and quartzites. These sedimentary rocks constitute the Mergui series, but their age is unknown. The granite is in part gneissoid, and there is also a younger granite which is intrusive in the gneissic granite and the sedimentary rocks. Dykes of quartz-porphyry also penetrate the granites and sedimentaries. Decomposition products and recent alluvial deposits, together with a thick growth of jungle, conceal the rocks over large areas and add to the difficulties of exploratory work.

Cassiterite is widely distributed throughout the district, and is invariably found near the granite hills. It occurs in pegmatites, rich in tourmaline and muscovite, locally known as *kra*, and in veins and massive segregations of quartz. The disintegration of these rocks produces the hill-side talus accumulations and stream deposits which are usually worked by the Chinese and Siamese tin-miners. Among the tin-mining areas on the mainland may be mentioned Maliwun, Karanthuri, Yaungwa, Bôkpyin, Yengan, Manoron, Mergui, Thabalik and the Great Tenasserim valley. In the Mergui Archipelago cassiterite has been worked in the gravels of King's Island, and also occurs in Kissering and Davies Islands.

Farther north, tin ore is obtained in small amounts in the Tavoy district; but it is overshadowed by the important wolfram mining industry of that district, which in 1917 yielded 3,697 tons of ore. The granite and sedimentary rocks of the Mergui series are here traversed by pegmatite and quartz veins, which contain cassiterite and wolframite in varying proportions. Cassiterite is relatively more abundant in the lodes which traverse the granite, and these are frequently bordered by tin- and tungsten-bearing greisens. The granite itself is stanniferous in places. From these sources are derived the float and alluvial deposits which yield the bulk of the ore won. The Amherst district, north of Tavoy, produced a small amount of tin ore in 1916.

The Thaton district of Lower Burma also began producing in 1916. The tin-bearing alluvium is said to be rich and extensive, and a considerable output is anticipated.

The Bawlake State, Karenni, Southern Shan States, began with an output of 60 tons of ore in 1912. In 1917 it had increased to 404 tons, and the district is now the chief producer of tin ore in India.

In the Hazaribagh district of Chota Nagpur, Bengal, tin has been found from time to time in river sands by the native iron-smelters. There are two known occurrences of the ore

in situ, at Nurunga and Chappatand, and the ore occurs in a cassiterite-granulite which sometimes contains as much as 30 to 50 per cent. of tinstone. This rock has been opened up to a small extent at Nurunga, where it forms a thin band in a mass of microcline-granulite.

Isolated crystals of cassiterite have been found associated with gadolinite in pegmatite in the Palanpur State, and the mineral is known to occur in several other localities.

FEDERATED MALAY STATES.—The Federated Malay States are the largest producers of tin ore in the world. Moreover, owing to the great preponderance of alluvial over lode ore, the resulting metal is of exceptionally good quality, and consequently "Straits tin" commands high prices. Most of the ore is exported to the Straits Settlements for smelting, though some is smelted locally, principally in Perak and Selangor. The amount smelted before export is shown in the following table, which gives the exports from the four Federated States expressed as metallic tin :—

Table 20

Tin in Ore and Metal Exported from the Federated Malay States

In tons (2,240 lb.)

	1912.	1913.	1914.	1915.	1916.	1917.
Negri Sembilan.	1,731	1,884	1,697	1,244	907	734
Pahang . .	3,082	3,433	3,685	3,808	3,480	3,496
Perak . .	28,407	29,403	28,557	27,776	27,242	24,643
Selangor . .	15,201	15,406	15,103	13,938	12,241	10,960
Total .	48,421	50,126	49,042	46,766	43,870	39,833
Exported—						
as block tin .	10,404	5,089	3,642	4,369	4,777	5,415
as tin in ore .	38,017	45,037	45,400	42,397	39,093	34,418
Total value £	9,803,694	9,782,598	7,087,448	7,176,054	7,526,566	8,480,610

These export figures do not give a true idea of the relative production of tin in the four States, owing to a certain amount of inter-State trade in the ore. Thus a considerable proportion of the ore raised in Negri Sembilan is included in the exports from Selangor. Allowing for such inter-State trade, the estimated production of tin for each State in 1917 is as follows :—

Table 21

	Tons (2,240 lb.)
Negri Sembilan	1,038
Pahang	3,691
Perak	24,678
Selangor	10,426
Total	39,833

The decrease in the exports, which has become more pronounced in each year since 1913, may be in part accounted for by the war. Another and more permanent reason is that a large number of Chinese coolies have left the tin mines to take up work on the rubber estates, whilst others have migrated to Kedah and Siam. It is probable too that the area of rich tin-bearing ground suitable for Chinese methods of working is becoming reduced; and the capital necessary for modern hydraulic operations has, like the labour, been diverted to rubber plantations.

A brief account of the geology and general mining conditions of the Malay Peninsula will be given, before dealing with the four States separately. The Main Range, which forms the principal watershed of the Peninsula, consists of granite apparently of Mesozoic age. On the west side of the Main Range offshoots of the granite form hills in Province Wellesley and Penang, in the Dindings, to the east of the Larut district, and in the Kledang Range in Perak. The oldest sedimentary rock above the granite is a crystalline limestone; then follow in upward succession clays, shales, quartzites and conglomerates of Gondwana (Permo-Carboniferous) age, and finally recent alluvium. All these rocks contain tinstone, either detrital or deposited in them by pneumatolytic action at the time of the granite intrusion. An interesting series of stanniferous clays and boulder clays is believed by Mr. J. B. Scrivenor, the Government Geologist, to be a glacial deposit of Gondwana age, and to contain detrital tinstone. This theory requires an earlier pneumatolytic phase than that connected with the Mesozoic granite. Many miners and others prefer the old view that the clays and boulder clays (the Gopeng Beds of Scrivenor) are really recent alluvial deposits or alteration products.

In Pahang, the eastern foothills of the Main Range are formed of quartzites, conglomerates and shales. Further to the east lies the Benom Range, which is composed of horn-

blende granite, and still further east is a broad belt of the Gondwana rocks, together with rocks of volcanic origin.

The powerful action of the ground-water, under tropical conditions, reduces hard rocks to a soft condition for a considerable depth below the surface. In this way what were once quartzites, phyllites or granites may now be easily cut by hand, or washed away by a monitor ; and their ore content, which might otherwise have been unobtainable except at prohibitive cost, can be won at comparatively little expense. Consequently alluvial methods of working are widely employed on deposits other than alluvium. Lode mining in hard rocks furnishes only a small, though increasing, proportion of the ore won.

Associated with detrital tin ore in the crude concentrates there are other heavy minerals, including ilmenite, magnetite, wolframite, zircon, rutile, garnet, tourmaline, topaz, corundum, monazite, xenotime, andalusite, tremolite, hæmatite, limonite, pyrite, arsenopyrite, chalybite, anatase, brookite, scheelite, galena, native copper, columbite, and strüverite. The heavy minerals left after the removal of the cassiterite constitute what is known as *amang*. Several samples of amangs, and of minerals isolated from them, have been examined at the Imperial Institute (see *Bull. Imp. Inst.*, 1906, **4**, 301 ; 1908, **6**, 155 ; 1911, **9**, 354 ; and 1913, **11**, 243).

Chinese miners were the pioneers of the Malay tin industry, and about 75 per cent. of the ore still comes from mines owned and managed by Chinese. Their methods vary according to circumstances. In the granite they burrow beneath the masses of residual boulders in the valleys for the pay-dirt (*karang*) which lies below. Patches of hill-side drift are hoed into a ground-sluice or *lampan*. On larger properties the deposit is worked opencast (*lumbong*), and the *karang* is carried in baskets to the sluice boxes. Mining by shaft and galleries is sometimes adopted. In many cases, after the Chinese have thus picked out the eyes, the deposit may still be profitably worked by hydraulic means. Gravel-pump dredges have proved as successful here as in Australia, particularly in the western States, which are more developed and better provided with roads than is Pahang.

The ore smelted locally is treated in small Chinese furnaces, about 4 feet high and 2 feet in diameter. They are built of clay and held together by iron bands, while a piston worked by hand in a hollow tree-trunk supplies the blast. Wood and charcoal are used, but no flux.

Tin mining is somewhat heavily taxed by means of an export duty on tin and tin ore. The duty is on a sliding scale, and varies with the price of tin. With tin at £150 a ton it works out at about 13 per cent. of the value of the tin content, which was taken to be 70 per cent. of the weight of the ore until 1917, when the percentage was raised to 72 for purposes of assessment. A rebate is allowed in the case of ore from lodes which require blasting or crushing. An additional and prohibitive duty of $30 per pikul (£58 16s. per ton) is charged on any ore exported without a guarantee that it will be smelted in the Straits Settlements, the United Kingdom, or Australia. The tin duty is an important source of revenue to the Government, and amounted to £1,265,847 in the record year 1912.

Negri Sembilan.—In Jelebu three lodes are worked at Titi. Hydraulic methods were employed till recently, when difficulties in regard to the disposal of tailings led to their temporary abandonment. In this mine, as in many others in Negri Sembilan, a mixed cassiterite and wolframite concentrate is obtained, and the minerals are separated electro-magnetically. In 1914 the mine yielded 494 tons of tin ore and 95 tons of wolfram ore. The Triang and the Kenaboi rivers also yield tin ore.

In the neighbourhood of Seremban decomposed pegmatites with stanniferous quartz veinlets are worked by hydraulic methods. Kuala Pilah, Pantai, Rasa, Chukong, Gebok and Lukut may also be mentioned.

Pahang.—The country to the east of the Main Range is not so rich in tin ore as that to the west. There are, however, alluvial workings near the western boundary of Pahang (Bentong, Tras, Machi), and also in the east, in the Blat (Belat) valley in the Kuantan district. Lode mining is carried on near the headwaters of the Kuantan river.

The Machi tin field lies to the south of Bentong. The deposit is alluvial, and generally not more than 12 feet thick. The cassiterite is angular and varies so much in grain that a large proportion is lost by the crude Chinese method of dressing it. Small lodes exist in the locality. One of these was found to contain quartz, yellow garnet, cassiterite, zinc-blende, arsenopyrite, and pyroxene.

The alluvial flats at Bentong have been worked for tin, but at present the work is confined to the higher valleys of the Main Range, on the boundary of Pahang and Selangor. In these localities the cost of transport is a very serious matter, all supplies and ore having to be carried by coolies for long

distances over rough jungle paths. The workings are in shallow alluvium and decomposed granite. In the Chinchong valley boulders of a rock composed of quartz, topaz and cassiterite have been found and traced to the parent rock. In the Ulu of the Kenong angular cassiterite of varying grain-size is won, and near Bukit Fraser stanniferous granite and pegmatite occur. On Gunong Gapis, above Tras, a soft granitic rock is sluiced for cassiterite. A small lode on the Gau stream, traversing Gondwana beds, contains cassiterite associated with pyrite, chalcopyrite, bornite, arsenopyrite, zinc-blende, chalybite, calcite, quartz and garnet. The Liang and Triang valleys also contain stanniferous alluvium.

There are also alluvial workings on the Blat river, a tributary of the Kuantan.

The lodes on the Sungei Lembing, another tributary of the Kuantan, run east and west, and are from 2 to 10 feet wide. The country rock is an altered sediment overlying granite, and the geological conditions resemble those of Cornwall. The lodes carry workable amounts of copper as well as tin, especially in their upper portions.

Perak.—The Kinta district is the most important tin-mining region in the Malay Peninsula. Crystalline limestone underlies the wide valley through which the Kinta river flows. It is covered in part by clays and boulder-clays (Gopeng Beds) of supposed Gondwana age. The other Gondwana rocks are mostly shales and quartzites. Fault-blocks of the limestone form precipitous hills rising above these younger beds. The valley is flanked by the granite of the Main Range on the east, and by that of the Kledang Range on the west. The intrusion of this granite, which is evidently younger than the Gondwana rocks, was accompanied by pneumatolitic action and the formation of tin-bearing veins. But the boulder-clays contain detrital cassiterite which cannot, if they are Gondwana beds, be derived from the Mesozoic granites of the Main and Kledang ranges, but must be attributed to some earlier stanniferous intrusion. Boulders of tourmaline-corundum rock occur in these beds. The recent deposits include sand with seams of lignite, and stanniferous alluvium and cave deposits. Even the soil is stanniferous.

The principal mining areas in the Kinta District are as follows, beginning in the south-east, proceeding northward along the east side of the valley, and returning southward along the west side :—

Kampar.—In this district clays overlying limestone are

worked in the low-lying country, while shallow alluvial deposits on the granite slopes of Bujang Malaka have also yielded ore. In the Ulu of the Petai a pipe containing felspar, tourmaline, cassiterite and metallic sulphides was found in a tourmaline-felspar country rock. The pipe was at first only slightly inclined to the horizontal, and measured about 8 feet by 13 feet. The ore is said to have yielded 5 per cent. black tin, and about 1,000 pikuls (60 tons) were won from it. The apparent absence of quartz and the freshness of the felspar are peculiar features of this occurrence.

Malim Nawar.—Here sandy soil resting on limestone is washed for cassiterite. It appears to be the coarser residue of Gondwana clays.

Sungei Siput.—This village is situated on the Depang river south of the limestone mass of Gunong Tempurong. In Jehosaphat's (Jesophat's) Valley an old fault-fissure has been filled with detrital quartz, tourmaline, iron ores, topaz and cassiterite, and subsequently cemented with iron-stained calcite to form a rich " vein " about 4 feet wide. A large cave in the neighbourhood is also known to contain detrital tin ore.

Gopeng.—This area includes the Gopeng, New Gopeng, Ulu Gopeng, Kinta Tin, Tekka, and Sungei Raia mines. On many of these properties hydraulic operations are conducted on a large scale, the monitors removing clays and boulder-clays, phyllites, quartzites and granite.

Pulai.—Most of the tin ore of this field has been obtained from clays and boulder-clays, though it also occurs in the granite and in caves in the limestone.

Ulu Piah.—This mine is situated near Ampang on a patch of the clay beds faulted down between the granite and the limestone.

Tambun.—In both the Tambun and New Tambun mines the clays, which are practically free from boulders, are dug by hand and puddled to separate the tin ore.

Tanjong Rambutan.—Here, not far from the northern boundary of the Kinta district, there are two mines—the Rambutan and the Kinta Association. In the latter the clays are remarkable for the number of large quartz boulders they contain.

Menglembu.—On the west side of the Kinta valley, near Menglembu village, a number of ore-bodies have been found in the granite of the Kledang Range. Some of these are ordinary veins, while others may be described as pipes. To the former class belongs the lode on Bukit Kambing, which trends N.E. and S.W., and has a hade of 32°. The width of

the portion worked was 4 feet, and the average yield of ore 6 per cent. Work was abandoned when the yield fell to about 2 per cent. black tin. Several other lodes are known ; they have a similar strike to the Bukit Kambing lode, and like it are associated with fairly fresh felspar and much tourmaline. Fluorspar is sometimes present.

The pipe-like occurrence is seen in the workings of the Menglembu Lode Syndicate. Here the granite is strongly jointed and contains in places numerous minute veins of cassiterite set close together. Their general direction is 20° E. of N., cutting the joints at an angle of about 45°. The veinlets together compose ore-bodies which, though very irregular, average about 60 feet by 20 feet in horizontal dimensions, while one of them has been followed down for 500 feet.

Penkalan.—Three large excavations are worked to the north of Lahat. They are all in the Gondwana clays. In No. 2 a fault with a throw of about 20 feet has been exposed in the limestone floor, while in No. 3 small bodies of ore occur in the limestone itself, and the remains of others on its irregular surface.

Lahat.—In this great open-cast mine, stiff blue clays of Gondwana age overlie stanniferous granite which rises to the west, and are themselves covered by beds of sand and clay with seams of lignite. These recent deposits are a more important source of tin ore than the Gondwana clays themselves.

Rotan Dahan.—Here angular tin ore is distributed throughout a series of clays, 140 feet thick in places.

Redhills and Pusing Lama.—Both these mines are in red clays and boulder-clays with abundant boulders of tourmaline-corundum rock, and in both tin-bearing veins have been found in addition to detrital tin ore.

Pusing Bharu.—Here also the tourmaline-corundum rock is abundant in the boulder-clays. These are covered by stanniferous sandy beds and lignite. The limestone floor, by solution, gives rise to well-marked " cups," which are lined with Gondwana boulder-clays and filled with sand and lignite.

Siputeh.—Here the " cups " are even better developed, and caused great trouble when the mine was first opened. The rare occurrence of a tourmaline vein in limestone has been noticed here.

Tronoh.—A large open-cast mine was formerly worked by a system of shafts and galleries in the so-called " Tronoh deep-lead." This is really a huge trough or elongated cup in the limestone, filled with Gondwana clays below and sands and

lignite above. The western boundary is a reversed fault which brings down Gondwana quartzites and shales.

Tanjong Toh Allang.—The country here consists of quartzites, shales and tourmaline schists. The most prosperous mines are in the vicinity of kaolinised granite intrusions.

Tin Ore in Limestone.—The deposits of non-detrital cassiterite in limestone may conveniently be described together. They occur in the form of veins and pipes, the latter being as a rule the more valuable. Veins have been found at Siak, near Siputeh ; at Ayer Dangsang, near Lahat, where a pipe opened out into a vein in depth ; and at Penkalan No. 3 mine, where several small stringers have been noted. A larger ore-body at this locality contained calcite, cassiterite, chalcopyrite, bornite, pyrite, arsenopyrite, tremolite, green fluorite and a little quartz. None of these veins have proved worth following up, but in two cases they gave rise to rich patches of ore owing to the solution of the limestone.

Pipes have been found at Lahat, Ayer Dangsang, Menglembu, and Changkat Pari. They are roughly elliptical in section and, in the last three localities, are composed of numerous small veins. The gangue is mainly calcite, though quartz occurs also, and the cassiterite is associated with pyrite, arsenopyrite, chalcopyrite, bornite and antimonite. Fluorite and tremolite are common, but tourmaline is rare. The Lahat pipe had a similar origin, but the calcite had been dissolved and the sulphides oxidised by descending waters.

The Larut district, to the north-west of the Kinta district, is another important tin area. The country round Taiping is an alluvial flat, rich in cassiterite, bounded on the east by the granite hills of the Taiping range, and on the west by the quartzite Semanggol Range. Lode mining has been carried on at Selama and Blanda Mabok, the lode at the latter place yielding also argentiferous galena and gold.

In the Intan field, Upper Perak, a lode on Gunong Paku is being mined.

At Bruseh, in the south of Perak, a stockwork of tin-bearing veins in schist is worked between the Pinang and Durian rivers. The veins, the average thickness of which is about 1 inch, are numerous, and generally rich in tourmaline. A little wolframite is found. The decomposed schist is worked by monitors, aided by explosives, the average yield being about ½ kati per cubic yard (1 kati = 1·3 lb.).

Selangor.—Near Tanjong Malim, in the north of Selangor, there are numerous veins of quartz containing coarse cassiterite

traversing soft sandstone and shale. Kalumpang and the Selangor river produce considerable amounts of ore.

Farther south, at Serendah, decomposed granite was recently worked by monitors on the site of old *lampans*, but is now worked on tribute. The granite is traversed by veins of quartz and of greisen, both carrying cassiterite.

Kuala Lumpur is the centre of the most important mining district in Selangor. At Salak South a pegmatite rich in tin is worked. The Sungei Besi occurrence, like that at Tronoh, consists of unusually rich deposits occupying a great cavity at the junction of limestone and granitic rocks. Rawang, Kepong, Setapak, Ampang and Serdang are producing localities in this district.

UNFEDERATED MALAY STATES.—The Unfederated Malay States under British protection possess tin deposits, though apparently to a less extent than the Federated States. The relative smallness of their output, however, is due in part to the primitive, small-scale operations of the Malay and Chinese miners. European methods are adopted in only a few instances, and difficulties of transport further limit the development of many of the deposits. The export of tin ore in recent years is given below :—

Table 22

Exports of Tin Ore from the Unfederated Malay States

In tons (2,240 lb.)

—	1912.	1913.	1914.	1915.	1916.	1917.
Johore. . .	308	461	844	2,842	3,408	3,272
Kedah. . .	835	865	860	868	679	476
Kelantan . .	19	7	9	6	—	—
Perlis . . .	188	108	187	230	209	196
Trengganu . .	403	331	379	398	475	431
Total . .	1,753	1,772	2,279	4,344	4,771	4,375

Johore.—Up to 1914 Kota Tinggi produced most of the ore in this State, smaller amounts coming from Muar and Batu Pahat. In 1915, however, a new tin field on the east coast was opened, and produced 2,015 tons of ore, against 827 tons from Kota Tinggi. The new field appears to extend from the

Jemaluang, near Mersing, to the Sedili, and the quality of the ore is equal to that from the Kota Tinggi field.

Kedah.—There are four mining districts in Kedah, viz. Kuala Muda, Kulim, Krian and Kubang Pasu. The greater part of the tin exported from Kuala Muda district is won in alluvial workings near the town of Semiling, on the Merbok river, at the foot of the southern slope of Kedah Peak. A rich deposit of mixed tin and tungsten ore has been discovered recently near the village of Changloon in Sungei Sintok.

Kelantan.—Tin ore has been worked on a small scale at Bukit Yong, Pulau Chondong and on the Nenggiri, but, as the British Adviser says in his Administration Report for 1914, "serious mining has at present no existence in Kelantan." Good tin deposits have been reported from time to time in Ulu Kelantan and elsewhere, and transport difficulties are partly responsible for the lack of development.

Perlis.—In the State of Perlis, which lies to the north of Kedah, cassiterite is won from caves and underground streams in the limestone hills on the Setul border. Some of these underground workings extend for a distance of four or five miles.

In many cases work can only be carried on during dry seasons, or after pumping. The tin-bearing deposits in the caverns are not extensive; prospecting is difficult, cost of transport is very high, and large-scale operations are extremely risky, though the Chinese miner with a small capital will often do well. In one instance a gravel pump and steam plant were installed to work an underground stream, with quite inadequate results. The cassiterite is usually very fine-grained, and the cave deposits are in some cases cemented by oxide of iron, necessitating crushing. Some danger to the paddy fields in time of flood has been anticipated from the tailings, where these accumulate in large quantities.

Trengganu.—In Kemaman, in the south of Trengganu, lode mining is carried on at Bundi and Sungei Ayam. The bulk of the ore produced comes from these mines, both of which are under European management.

The Bundi deposit consists of soft clayey and sandy material, with masses of quartz, sulphides and iron oxides, between walls of hard granite. The length is 1,575 feet and the greatest breadth 120 feet, and the bottom has been reached only at Glen Reef, the most northerly working. The cassiterite occurs in the soft clay and in the ironstone, in the form of slender, pale yellow needles, sometimes forming spongy masses.

The Sungei Ayam lode is from 2 to 3 feet wide. It is very flat, and is mined by a succession of shallow stope-drives.

Sungei Sendok, Sungei Paka, and Sungei Kajang also produce some tin. On the Dungan river wolframite and a little cassiterite are won. At Bukit Tawang, at the head of the Trengganu river, an attempt at hydraulic mining proved unsuccessful.

STRAITS SETTLEMENTS.—The Straits Settlements are small in area and only Malacca produces any tin ore. But they possess the largest tin-smelting and refining industry in the world, which is divided between Singapore and Penang. The states of the Malay Peninsula are naturally the source of the greater part of the ore smelted, but Siam, the Dutch Indies, Australia, South Africa, Burma, and even Alaska send tin ore to the Straits for smelting. A certain amount of crude tin is also received and refined.

The magnitude of the industry is indicated in the following tables. Table 23 shows the source of the tin ore and metallic

Table 23

Imports of Tin Ore and Tin to the Straits Settlements in 1914

In tons (2,240 lb.)

Countries from which Imported.		Quantity.		Value.
		To Singapore.	To Penang.	
Malay Peninsula :				£
Johore	ore	720	—	72,760
Kedah	,,	—	819	76,161
Kelantan	,,	21	—	2,029
Trengganu	,,	379	—	39,867
Negri Sembilan	,,	1,482	1,049	262,818
,, ,,	tin	1	—	192
Pahang	ore	2,920	—	349,925
,,	tin	294	—	43,798
Perak	ore	14,716	21,087	3,859,836
,,	tin	72	1,790	277,695
Selangor	ore	12,223	8,152	2,122,722
,,	tin	1,510	1,156	403,137
India (Burma)	ore	—	113	11,470
Hong Kong	,,	2	—	168
,,	tin	2	—	252
Australia	ore	2,574	107	302,225
South Africa	,,	2,700	—	296,742
Dutch East Indies	,,	4,214	—	465,763
Siam	,,	518	7,324	801,009
,,	tin	202	356	75,993
United States	ore	26	—	3,150
Total	ore	42,495	38,651	8,666,645
,,	tin	2,081	3,302	801,067

Table 24

Imports of Tin Ore into the Straits Settlements

(Pikuls of 133⅓ lb.)

Countries from which Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Federated Malay States	778,360	767,969	860,155	1,033,360	1,035,369	987,433	882,036	756,601
Unfederated Malay States	28,107	26,052	35,089	27,218	32,610	82,641	95,528	78,874
Australia	42,091	48,039	51,810	61,813	45,032	35,311	34,867	20,393
India	1,019	1,685	2,659	2,483	1,892	1,393	2,307	5,051
South Africa	—	3,777	29,210	44,048	45,357	36,206	44,338	53,805
Other British Possessions	—	170	200	206	29	3,650	16,650	1,337
Total from British Possessions.	849,577	847,692	979,123	1,169,128	1,160,289	1,146,634	1,075,726	916,061
Dutch East Indies	73,904	54,650	65,325	54,982	70,789	108,806	113,918	132,725
Siam	62,372	75,826	114,165	135,390	131,744	174,486	194,909	190,966
United States	—	—	—	1,110	436	3,305	1,106	825
Other Foreign Countries	1,380	197	—	—	—	—	—	2
Total from Foreign Countries	137,656	130,673	179,490	191,482	202,969	286,597	309,933	324,518
Total . . . pikuls	987,233	978,365	1,158,613	1,360,610	1,363,258	1,433,231	1,385,659	1,240,579
,, . . *tons*	58,764	58,236	68,965	80,989	81,146	85,311	82,480	73,844
Value . . . £	6,023,977	7,522,054	9,836,326	11,330,506	8,666,645	9,169,349	9,522,339	10,483,574

Table 25

Imports of Tin into the Straits Settlements

(Pikuls of 133⅓ lb.)

Countries from which Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Federated Malay States . .	165,233	168,091	180,312	100,437	81,038	82,999	91,563	99,102
Unfederated Malay States . .	—	28	102	—	—	—	163	—
Hong Kong	70	4,682	—	—	27	170	24	406
Other British Possessions . .	46	24	—	1	—	—	9	—
Total from British Possessions.	165,349	172,825	180,414	100,438	81,065	83,169	91,759	99,508
Dutch East Indies . . .	1,005	—	25	95	—	26,504	37	—
Siam	32,200	33,207	20,686	15,013	9,374	11,681	8,668	7,687
Other Foreign Countries . .	—	20	9	10	—	—	—	—
Total from Foreign Countries .	33,205	33,227	20,720	15,118	9,374	38,185	8,705	7,687
Total . . . pikuls	198,554	206,052	201,134	115,556	90,439	121,354	100,464	107,195
,, . . . *tons*	11,819	12,265	11,972	6,878	5,383	7,223	5,980	6,380
Value . . . £	1,750,766	2,258,854	2,392,050	1,335,883	801,067	1,063,453	992,875	1,330,943

Table 26

Exports of Tin from the Straits Settlements

(Pikuls of 133⅓ lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
United Kingdom	586,498	559,627	563,280	591,625	596,476	381,760	421,232	449,481
India	30,036	24,804	23,313	30,494	27,583	22,793	23,257	22,967
Ceylon	498	643	1,192	491	815	964	813	1,195
Hong Kong	1,173	2,733	1,883	5,650	2,756	1,005	9,096	4,208
Canada	320	1,396	4,049	4,292	1,262	2,185	673	1,515
Australia	4,624	—	—	—	420	—	—	67
Other British Possessions	166	175	139	335	114	306	361	1,978
Total to British Possessions	623,315	589,378	593,856	632,887	629,426	409,013	455,432	481,411
Austria-Hungary	17,066	19,511	25,897	25,817	15,725	—	—	—
Belgium	—	—	—	168	6,306	—	—	—
France	53,883	46,924	60,911	81,326	66,849	78,911	71,361	100,470
Germany	1,681	2,859	6,894	10,762	21,398	—	—	—
Italy	23,211	17,746	22,241	25,016	26,530	32,561	34,667	38,094
Netherlands	12,529	15,723	—	—	421	—	—	—
Russia	4,386	4,549	5,444	8,390	3,005	69,678	28,774	18,188
Spain	253	—	252	76	168	3,026	5,769	5,969
China	2,873	2,982	1,517	2,961	1,565	2,170	268	875
Japan	7,934	11,155	10,746	13,227	13,495	15,944	20,577	28,216
Dutch East Indies	2,197	1,466	1,264	990	252	621	90	—
Siam	98	189	227	724	1,890	1,074	1,610	1,112
United States	214,426	256,547	305,168	297,955	325,079	542,404	472,076	392,327
Other Foreign Countries	550	665	406	4,308*	605	239	5,257	9,052
Total to Foreign Countries	341,087	380,316	440,967	471,720	483,288	746,628	640,449	594,303
Total . . . pikuls	964,402	969,694	1,034,823	1,104,607	1,112,714	1,155,641	1,095,881	1,075,714
,, . . . *tons*	57,405	57,720	61,597	65,750	66,233	68,788	65,231	64,031
Value . . . £	8,797,247	10,737,717	12,499,025	13,171,563	9,983,606	10,686,813	11,392,201	13,745,750

* Including 3,614 pikuls to Denmark.

tin received at Singapore and Penang in a typical year, 1914, while Tables 24 and 25 show the imports from 1910 to 1917 in a more generalised form. The increase in the imports from the Dutch East Indies in 1915 was due to the war and the Allied blockade of Germany. Table 26 gives the distribution of Straits tin in the same years, and shows one effect of war conditions in the increase in shipments direct to the United States, Russia, and other countries, instead of via England. The increased export to Germany in the early part of 1914 is noteworthy.

MALACCA.—The tin ore exported from Malacca in the years 1912–1917 amounted to 11, 15, 9, 57, 30 and 10 long tons respectively.

On the coast of Malacca, for some distance south of Kuala Linggi, the sand and mud below high-tide mark have been washed for tin. The source of the mineral is a schist with numerous quartz veinlets carrying cassiterite. The schist overlies granite, and forms the shore for some distance. This schist has been mined, but most of the tin produced in Malacca has come from the beach deposits, where the material has been disintegrated and concentrated by the waves.

At Chin-Chin some tinstone has been obtained from the soil, but ferruginous cement interferes with hydraulic operations.

AFRICA

GOLD COAST.—Stream tin has been found in small patches of gravel in the Winnebah district. Tinstone also occurs on the surface and in pegmatite-greisen dykes in the Mankofa depression and on Mount Mankwadi, in the same district.

NIGERIA.—Before the coming of Europeans, tin was produced in Bauchi by the natives, who washed the river gravels in calabashes and obtained coarse black tin with 60 to 65 per cent. of the metal. The smelting was a family secret. Small blast furnaces, 3 feet 6 inches in diameter, were used, with charcoal fuel and a blast supplied by primitive bellows of sheepskin. The metal was cast in the form of thin rods about $\frac{1}{8}$ inch in diameter and 12 inches long; it contained about 99·4 per cent. tin. There is little doubt that the metallic tin found in the gravels was smelted by the natives.

On the subjugation of the hostile Emir of Bauchi in 1902, the alluvial deposits of the Delimi river at Naraguta became known, and were worked first by the Niger Company. Between 1904 and 1909 the work of the Mineral Survey of Northern Nigeria, in conjunction with the Imperial Institute,

showed the presence of cassiterite in the stream gravels of many localities, but it was not till 1909 and 1910 that a number of companies were formed for the purpose of winning tin in Nigeria. The former inaccessibility of the field has been removed by the construction of a railway between Naraguta and Zaria, where it connects with the Baro-Kano line. An extension to Jos and Bukuru was opened in 1914.

Table 27 shows the output and exports of ore and tin from Nigeria. Practically the whole amount was sent to the United Kingdom, as is shown in Table 28.

Table 27

Output and Exports from Nigeria

In tons (2,240 lb.)

Year.	Output.	Exports.		
	Ore.	Ore.	Metal.	Value (£).
1904 . . .	1½	—	—	—
1905 . . .	½	—	—	—
1906 . . .	11	—	—	—
1907 . . .	175	21	133	25,265
1908 . . .	514	519	17	80,799
1909 . . .	253	269	39	42,141
1910 . . .	774	692	31	77,310
1911 . . .	1,470	1,530	—	181,759
1912 . . .	2,886	2,803	—	336,330
1913 . . .	5,331	4,194	2	568,428
1914 . . .	6,143	6,175	—	706,988
1915 . . .	6,910	6,535	—	723,480
1916 . . .	8,222	7,054	—	859,603
1917 . . .	8,314	9,966	—	1,485,887
Total . .	41,005	39,758	222	5,087,990

Table 28

Exports of Tin Ore and Tin from Nigeria, 1910–1917

In tons (2,240 lb.)

Countries to which Exported.		1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
United Kingdom,	ore	689·11	1,529·35	2,802·64	4,193·72	6,175	6,535	7,054	9,966
„ „	tin	30·72	—	—	2·17	—	—	—	—
Germany .	ore	2·89	0·25	0·36	0·04	—	—	—	—
„ .	tin	0·05	—	—	—	—	—	—	—
Total . .	ore	692	1,529·60	2,803·00	4,193·76	6,175	6,535	7,054	9,966
„ . .	tin	30·77	—	—	2·17	—	—	—	—
Value . .	£	77,310	181,759	336,330	568,428	706,988	723,480	859,603	1,485,887

The chief source of the tin is the river gravels and alluvial flats in the neighbourhood of Naraguta, Ngell, Bukuru, Forum, Ropp, etc., on the Bauchi plateau. The plateau has an elevation of three or four thousand feet, and the climate is consequently much healthier than in most parts of West Africa. Here in the ancient crystalline rocks is an extensive intrusion of soda granite, with pegmatite dykes and veins of quartz and tourmaline, and from these sources the stream tin was derived. Near Ngell the granite contains cassiterite associated with pyrite, chalcopyrite, tetrahedrite, zinc-blende, galena and sometimes wolframite. The concentrates from the alluvial deposits often contain much ilmenite, as well as zircon, garnet and monazite. Rolled fragments of topaz are also common.

In the upper portions of the streams the patches of tin-bearing gravel held up by bars of hard rock are usually so small that they are left to native tributers to work. The middle courses have more extensive areas yielding tinstone beneath 10 to 30 feet or more of barren overburden, and here hydraulic methods are profitably employed. The tin usually occurs close to the bedrock, but there are sometimes two or more tin-bearing layers. The overburden is often baked hard in the dry season, and black powder has been used in places to break it up. In the lower sections of the valleys the deposits near the present streams frequently yield little or no tin, and systematic prospecting by bore-holes is required to determine the position of the old stream channel with its tin-bearing gravel, which may lie beneath a cover 100 feet deep or more. The work of lifting the overburden and tin-gravel in these thick deposits will prove very costly if coal or crude oil is used to operate the gravel pumps, and it has recently been proposed to utilise the water-power of the Kwall Falls, where the Ngell River drops 800 feet over the edge of the plateau.

In addition to this central and highly important field of the Bauchi plateau, tinstone occurs in many other parts of the Northern Provinces, as in the Ningi and Burra hills in Bauchi, in the neighbourhood of Gadama and Fagam on the borders of Bauchi and Kano, around Jemaa, Amari, Gantam and Aribi in the north of Nassarawa, on the Vere hills in Yola and the Shebshi hills in southern Muri, and near Eri in eastern Ilorin, where it occurs in pegmatites carrying quartz and muscovite but no tourmaline.

In the Southern Provinces, the work of the Mineral Survey of Southern Nigeria showed the presence of cassiterite in the sands of many streams. The most notable occurrences observed

are those near Akwa-Ibami, in the Uwet district, where the proportion of cassiterite in the stream beds was found to be from 2 to 5·2 lb. per ton, with an average of 3 lb. per ton. There was a small output of 35 tons of tin ore in the Calabar Province in 1916.

NYASALAND.—A few of the concentrates from river sands examined at the Imperial Institute in connection with the Mineral Survey of Nyasaland were found to contain small amounts of cassiterite, but no deposits of economic importance are known in the Protectorate.

RHODESIA.—Promising deposits of tinstone occur in the Enterprise district, east of Salisbury, and farther south in the Ndanga district, 30 or 40 miles east of Victoria. In both localities the ore occurs in pegmatite dykes, which are more or less greisenised and traverse ancient schistose rocks in the neighbourhood of granite. Lithia-mica, lepidolite, is abundant in the tin-bearing dykes, and, with its striking purple colour, forms a useful indicator. The cassiterite is patchy in its distribution ; it is dull black in colour and, in the Victoria field, shows unusual crystalline forms. West of Umtali, alluvial tin is reported in the Odzi Reserve and along the Tsungwesi River, and the lithia greisens of the former locality yield tin, tungsten and tantalum minerals. In the Hartley district near the Umniati River, cassiterite occurs with copper ore in chlorite schist, and tin-bearing pegmatite dykes are known in the Mazoe and Shamva districts. No tin-bearing alluvial deposits have been discovered, though there are considerable amounts of shed tin in the vicinity of the dykes. Some development work has been done on the more promising lodes in these districts since the first discovery of tinstone in 1908, and 9 short tons of ore was exported in 1915, while the Secretary for Mines reports an output of 3·63 short tons of tin from the Victoria district in 1916. The high working costs are a serious obstacle to the successful extraction of tin ore in Rhodesia.

UNION OF SOUTH AFRICA (for South-West Africa see p. 92). —The chief tin-mining districts in South Africa are the Waterberg area, in the western Transvaal, and Swaziland (p. 55). The Cape Province also produces a little tin, the total output from 1906 to the end of 1917 being valued at £49,817, against a value of £3,229, 753 for the Transvaal.

There was until recently no tin-smelting industry in South Africa, and the ore, which was formerly exported to England, was later sent almost entirely to the Straits Settlements. In 1917, however, smelting began at Zaaiplaats, and these works

Table 29

Output of Tin Ore in the Union of South Africa

In short tons (2,000 lb.)

	1912.	1913.	1914.	1915.	1916.	1917.
Cape Province .	—	71½	43	39½	29	38
Transvaal . .	2,932	3,600½	3,386	3,401½	3,235	2,640
Total . tons	2,932	3,672	3,429	3,441	3,264	2,678
Value . £	367,699	436,550	311,391	331,420	339,571	346,016

are expected to supply the whole of the South African demand for tin. The output in 1917 was at the rate of about 250 tons per annum, most of which was used in the manufacture of white bearing metal for the railways. Delagoa Bay and Durban are the chief shipping ports for the ore, and Table 30 shows its destination.

Table 30

Exports of Tin Ore from the Union of South Africa

In short tons (2,000 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
United Kingdom	2,408	4,899	814	1,019	1,335	1,265	56	30
Straits Settlements . .	—	12	1,104	1,760	2,820	2,520	2,501	2,660
Other countries	—	8	5	—	23	50	—	—
Total . tons	2,408	4,919	1,923	2,779	4,178	3,835	2,557	2,690
Value . £	175,994	244,691	246,329	381,042	457,925	385,901	238,890	282,743

Table 31

Imports of Tin into the Union of South Africa

In short cwt. (100 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
United Kingdom .	1,314	1,232	1,331	1,262	1,391	1,377	1,889	2,705
Other countries .	1	2	14	9	—	20	—	312
Total . cwt.	1,315	1,234	1,345	1,271	1,391	1,397	1,889	3,017
Value . £	8,344	9,224	12,988	12,797	10,294	11,179	16,771	35,074

South African imports of tin are given in Table 31. The country's requirements are small, and have hitherto been supplied almost entirely by the United Kingdom. Imports of tin plate fell from 4,458 tons in 1915 to 2½ tons in 1917, and the imports of tin manufactures vary in value between £30,000 and £50,000 a year.

CAPE PROVINCE.—Cassiterite occurs in several localities in the neighbourhood of Cape Town. The most important appears to be at Annex Langverwacht, near Kuils River. Here it occurs disseminated through a granite, and also in veins of quartz and greisen near the junction of the granite with the Malmesbury slates. Wolframite and tourmaline are associated with the cassiterite, and considerable deposits of tin-bearing gravel have been formed by the disintegration of the rocks. The tin ore produced in 1916 was all obtained from these gravels, while a certain amount of development work has been done on the tin-bearing lodes in the neighbourhood. Stanniferous quartz veins also occur at Vredehoek, at the north-west end of the Tygersberg, and in other places.

NATAL.—In the Umfuli tin field, situated about eight miles east of Melmoth in the Entonjaneni district of Zululand, a plateau of Waterberg sandstone has been cut through by the Umfuli river and its tributary, the Ntunja. A small area of hornblende-schists of the Swaziland System has thus been exposed. The schists are permeated by numerous veins of pegmatite and aplite, and cassiterite occurs in the pegmatites in association with mica, garnet, tourmaline, quartz and felspar. The cassiterite is sporadic in its distribution, and samples of the pegmatite assayed from a trace to 0·316 per cent. of metallic tin. Prospecting in this district has so far met with disappointing results.

TRANSVAAL.—The Waterberg tin fields in north-western Transvaal include the Potgietersrust tin field (Zaaiplaats, Roodepoort, Groenfontein, Solomon's Temple, etc.), the Nylstroom tin field (Doornhoek, Kromkloof, Welgevonden), the Warmbaths tin field (Zwartkloof, Elandsfontein, Witfontein, etc.), and the Rooiberg tin field. All these localities lie on the eastern and southern margins of a geological basin, the central portion of which is composed of sandstones and conglomerates of Upper Waterberg age, constituting the Waterberg plateau. Below the escarpment of these beds is a belt of Lower Waterberg felsites with interbedded shales (and quartzites in the Rooiberg), overlying the Red Granite and the Norite of the Bushveld Plutonic Complex. Beyond the out-

crop of these lie the Older Granite and the quartzites and dolomites of the Transvaal System. These older rocks, however, are unconnected with the source of the tinstone, and the same may be said of the Karroo beds which overstep all these formations in the south-eastern part of the district. The Red Granite and the Lower Waterberg rocks are the important tin-bearing formations. In the Red Granite the cassiterite deposits occur (*a*) in the form of roughly cylindrical pipes; (*b*) associated with irregular bodies of altered granite; (*c*) as irregular disseminations in slightly altered granite; (*d*) as impregnations along well-defined lines of fissure; (*e*) associated with pegmatite and quartz veins. In the felsites, shales and quartzites of the Lower Waterberg the deposits are found (*a*) in lodes and more or less definite lines of fissure, small veins, and leaders, and (*b*) as irregular patches and pockets, often connected with fissures or determined by planes of stratification. Ancient workings, smelting places and ingots show that tin was extracted in this district at some unknown period in the past.

The most important deposits in the Potgietersrust tin field are situated on the farms Zaaiplaats, Roodepoort, Groenfontein and Solomon's Temple. They are distributed along a well-defined zone in the Red Granite, which strikes in a north-west and south-east direction and continues into Groenvlei and Appingadam in one direction and Welgevonden, Welgelegen, and Grootrivier in the other. This zone comes immediately below a coarse pegmatite. The usual type of deposit in this field is that of cassiterite-bearing pipes, roughly circular in section, descending at varying angles into the granite in a general north-westerly direction. They vary from a few inches to 20 feet in diameter. They are very erratic in direction and variable in composition, and in some cases have been followed through 3,000 feet of ramifications. They usually occur in groups, and neighbouring pipes may unite either at depth or near the surface. The pipes sometimes show an outer zone of tourmaline-quartz rock, which is usually not more than a few inches thick. The main mass of the pipe varies from slightly altered granite to an apparently homogeneous greenish material, which sometimes becomes extremely hard through secondary silicification. In the smaller pipes the cassiterite is fairly uniformly distributed, but in the larger ones it is generally more concentrated towards the periphery, and especially the lower portion, while in the central part it is less abundant or even absent. Cavities or vughs occur in

some of the pipes; they are lined with quartz crystals and contain also fluorite, galena, zinc-blende, arsenopyrite and chalcopyrite. In addition to the pipes, several other types of ore body are found, some of which show a flat and more or less lenticular form. In one case there are several sheets of tin-bearing granite separated by barren rock. Fissure veins and irregular masses of altered tin-bearing granite also occur.

The Nylstroom tin field is situated on the farms Doornhoek, Kromkloof, and Welgevonden, some sixteen miles north-east of Nylstroom. The principal deposits are associated with the felsites and shales of the Lower Waterberg. The main lode at Doornhoek cuts the bedding-planes of the shales obliquely; it averages 18 inches in width, and is largely made up of brecciated and highly altered fragments of the country rock, with quartz, tourmaline, cassiterite and fluorite. A second lode follows one of the coarser beds in the shales, which also is much altered and brecciated. In the immediate neighbourhood of these lodes the shales sometimes show minute veins of cassiterite. A short distance below the base of the shales the underlying felsites carry cassiterite, associated with quartz and hæmatite, in small pockets from ½ inch to 1½ inches in diameter, while other pockets contain tourmaline with quartz and sericitic matter.

The Warmbaths tin field extends from Zwartkloof through Droogekloof, Elandsfontein and Newbury to Witfontein and thence northward to Rhenosterpoort, forming a narrow belt which follows the junction of the felsites and the Red Granite. Cassiterite occurs in both types of rock, and also in detrital deposits. At Zwartkloof the ore bodies are somewhat irregular and ill-defined; they occur in the granite and are frequently associated with masses and veins of very coarse pegmatite and quartz. Alluvial and eluvial deposits occur on this farm. On Elandsfontein No. 1,782, there are two main sets of fissures in the granite, and the ore bodies associated with them vary in width from a few inches to 2 or 3 feet. Fissure lodes also occur in the lower part of the felsites. On Witfontein No. 371 the alluvial deposits have proved more important than the occurrences in the granite and felsite. All three types of deposit occur also on Elandsfontein No. 2,149, and small quantities of tin have been won from the granite on Rhenosterpoort.

The Rooiberg tin field lies about 40 miles west of Warmbaths. The cassiterite deposits, with the exception of one occurrence in the Red Granite, are all found in the Rooiberg

quartzites, which, with the associated shales, are overlain with apparent conformity by the Lower Waterberg felsites, while both types of rock are intruded by the Red Granite. The workings are principally on the farms Olievenbosch, Hartebeestfontein, Weynek, Quaggafontein and Leeuwpoort, and many of them are on the site of ancient workings. The lodes in the quartzites coincide with two main sets of fissures, and there are also irregular pockets in the country rock rich in tourmaline and cassiterite. Other minerals frequently present are quartz, carbonates of iron and lime, felspar, fluorite, hæmatite, pyrite, chalcopyrite and bornite. Superficial deposits of limonitic breccia, known as "ou-klip," are occasionally rich in tin. On Quaggafontein, cassiterite occurs in the upper portion of the Red Granite.

Forty miles north-east of Pretoria, cassiterite occurs in the Red Granite on the farms of Enkeldorn, Vlaklaagte and Roodepoortje.

On the Olifants River, tin ore is won at Mutue Fides and Stavoren. A considerable amount of scheelite is present in the Stavoren ore, and difficulty has been experienced in disposing of the tin-tungsten concentrate, since scheelite cannot be separated magnetically, as can wolframite. The Swaziland tin deposits cross the border into the Eastern Transvaal, but are not at present worked there.

SWAZILAND

Table 32

Output of Tin Ore in Swaziland in the Years ending March 31, 1911–17

—	1910–11.	1911–12.	1912–13.	1913–14.	1914–15.	1915–16.	1916–17.
Quantity .. tons *	476	313	385	492	496	584	459
Value .. £	42,250	32,397	37,946	51,220	43,256	56,067	46,732

* Kind not stated.

There are two tin-bearing districts in North-Western Swaziland, viz. the alluvial deposits of Mbabane (Embabaan) and the surrounding country, and the lodes round Forbes Reef.

The detrital deposits occur as "flats" along the course of the Mbabane and other rivers, and to a less extent on the hill slopes. At King's Flat, to take a typical example, there is a soft overburden of about 12 feet of dark soil, which carries

little tin. Below this lies 2½ feet of coarse tin-bearing gravel, composed largely of fragments of quartz up to 3 inches across, which rests on the granite floor of the valley. The cassiterite occurs in the gravel as loose crystals, but occasionally in boulders of pegmatitic rock; it is associated with other accessory minerals of the granite, including ilmenite, monazite, euxenite, æschynite, corundum and tourmaline. The cassiterite is evidently derived from the pegmatite dykes and quartz veinlets in the granite, which belongs to the Older Granite and not the Red Granite of the Waterberg tin fields. The mineral has been seen in many of these pegmatites, and at Sanders Creek a dyke of decomposed pegmatite yielded considerable amounts when worked by hydraulic methods. Since 1912, hydraulic operations have proved most successful. A race 14 miles long brings water from the Umbelusi River, which, together with local supplies, is used three times over in monitors to break ground at different levels, and also generates power for elevating the material it has already broken.

Forbes Reef is situated some 14 miles north of Mbabane on the east side of the Ingwenya Range. This range is formed of quartzites and schists of the Swaziland System, in which are intrusions of the same granite as at Mbabane. In one case the tin occurs in a dyke in the schist, 2 to 3 feet wide, composed almost entirely of white felspar with patches of chlorite and cassiterite. More usually the veins follow fissures parallel to the strike of the schists. Along these fissures the schist is tin-bearing over a width of about 3 inches.

America

Canada.—At New Ross, Lunenburg County, Nova Scotia, a quartz vein in granite carries a streak of rich ore from 3 to 5 inches wide. This contains cassiterite and chalcopyrite, with tungsten and zinc minerals, and assays from 10 to 30 per cent. tin and 8 per cent. copper. Pegmatitic zones in the granite also contain cassiterite.

Tin and tungsten ores occur on the south-west branch of the Miramichi River, New Brunswick, and cassiterite has also been recorded from several localities in British Columbia and from the Yukon district. A sample of black sand from sluice boxes in the Atlin district of British Columbia is said to have assayed 6·71 per cent. of tin.

There is, however, no production of tin ore in Canada.

The imports of the metal are shown in Table 33. Some 50,000 tons of tinned plate are imported annually, mostly from the United States.

Table 33

Imports of Tin into Canada in the Years ending March 31, 1912–17

(Short cwt. of 100 lb.)

Countries whence Imported.	1911–12.	1912–13.	1913–14.	1914–15.	1915–16.	1916–17.
United Kingdom . .	22,855	21,135	17,524	12,173	24,653	30,759
Straits Settlements .	5,939	7,073	7,619	1,876	121	112
Hong Kong . . .	—	—	405	892	346	—
Total from British Possessions . . .	28,794	28,208	25,548	14,941	25,120	30,871
United States . .	12,710	22,778	20,237	14,349	7,636	4,855
Other foreign countries .	236	333	291	112	—	—
Total from Foreign Countries . .	12,946	23,111	20,528	14,461	7,636	4,855
Total . short cwt.	41,740	51,319	46,076	29,402	32,756	35,726
Value . . £	355,558	476,280	408,321	209,125	243,250	303,079

AUSTRALASIA

Table 34

Output of Tin Ore and Tin in the Commonwealth of Australia

In tons (2,240 lb.)

—	1912.	1913.	1914.	1915.	1916.	1917.
New South Wales { metal	900	903	650	857	909	1,109
New South Wales { ore	1,175	2,118	1,667	1,331	1,220	963
Northern Territory ,,	271	258	160	140	—	—
Queensland . . ,,	3,230	3,197	2,085	2,125	1,707	1,177
Tasmania . . ,,	3,714	4,010	2,573	2,599	2,855	2,637
Victoria . . ,,	48	57	53	96	122	139
Western Australia ,,	554	601	332	326	435	—
Total, ore and metal	9,892	11,144	7,520	7,474	—	—
Value . . £	1,343,573	1,397,167	752,095	798,941	—	—

AUSTRALIA.—Since 1872, when tin mining began in New South Wales, Queensland and Tasmania, Australia has pro-

Table 35

Exports of Tin Ore and Concentrates from the Commonwealth of Australia

In cwt. (112 lb.)

Countries to which Exported.	1910.*	1911.*	1912.*	1913.*	1914–15.†	1915–16.†	1916–17.†
United Kingdom	203	2,300	511	10,596	3,590	4,536	1,579
Straits Settlements	47,964	53,207	63,680	77,584	39,255	43,540	38,352
Other countries	42	214	513	1,204	—	40	—
Total . . . . . cwt.	48,209	55,721	64,704	89,384	42,845	48,116	39,931
Tin content . . . . . ,,	33,787	37,718	44,518	57,810	29,310	32,813	27,356
Value . . . . . £	229,204	310,535	410,809	521,473	198,079	258,468	231,588

* Years ending December 31st, 1910–13.

† Years ending June 30th, 1915–17.

Table 36

Exports of Tin from the Commonwealth of Australia

In cwt. (112 lb.)

Countries to which Exported.	1910.*	1911.*	1912.*	1913.*	1914–15.†	1915–16.†	1916–17.†
United Kingdom	67,433	66,951	63,038	45,108	23,650	58,966	24,922
New Zealand	2,713	3,690	3,183	3,085	3,025	3,234	2,639
Other British Possessions	17	962	27	11	205	12	8
Total to British Possessions	70,163	71,603	66,248	48,204	26,880	62,212	27,569
Belgium	6,398	2,656	1,492	5,506	—	—	—
Germany	1,757	3,253	5,160	11,198	1,071	—	—
Italy	—	1,300	1,256	1,000	—	—	200
United States	9,200	4,090	3,300	2,400	1,929	4,200	31,278
Other Foreign Countries	11	33	45	84	11	2,278	2,038 ‡
Total to Foreign Countries	17,366	11,332	11,253	20,188	3,011	6,478	33,516
Total cwt.	87,529	82,935	77,501	68,392	29,891	68,690	61,085
Value £	675,836	765,179	790,588	690,211	226,180	576,983	571,353

* Years ending December 31st, 1910–13.
† Years ending June 30th, 1915–17.
‡ Including 1,900 cwt. to France.

duced considerable quantities of tin ore. In 1907 the output was about 14,000 tons of ore, and the Commonwealth ranked fourth among the world's producers, but since that date the output has diminished. All the States contribute, with the exception of South Australia, and Table 34 shows their shares in the annual output.

The total value of the Commonwealth output up to 1916 amounted to about £35,000,000, of which Tasmania contributed £13,000,000, New South Wales £10,500,000, Queensland £9,000,000, Western Australia £1,200,000, Victoria £800,000, and the Northern Territory £400,000.

There are tin-smelting works at Launceston in Tasmania; Woolwich, near Sydney, New South Wales; and Irvinebank, near Herberton, Queensland. The metallic tin is exported to the United Kingdom, New Zealand and other countries. An increasing proportion of the ore produced is, however, sent to the Straits Settlements for smelting. Tables 35 and 36 give details of the ore and tin exported. The reduction of the exports by over 50 per cent. in the year 1914–15, as compared with 1913, was due partly to the war, partly to the effect of the dry season which interfered with dredging operations; and a considerable recovery is shown in the figures for 1915–16.

The imports of tin into Australia, as shown in Table 37, are very small, but there is a large amount of tinned plate imported, chiefly from the United Kingdom. The total imports of tinned plates and sheets into the Commonwealth in the year ending June 30, 1917, amounted to 823,349 cwt., valued at £1,330,636.

Table 37

Imports of Tin into the Commonwealth of Australia

In cwt. (112 lb.)

Countries of Origin.	1910.*	1911.*	1912.*	1913.*	1914–15.†	1915–16.†	1916–17.†
United Kingdom .	239	100	125	2	294	10	62
Other Countries .	1	2	—	—	—	—	—
Total . cwt.	240	102	125	2	294	10	62
Value . £	1,858	972	1,401	26	2,238	101	594

* Years ending December 31st.
† Years ending June 30th.

NEW SOUTH WALES.—The total production of New South Wales, from the beginning of the industry in 1872 up to and including 1917, is 82,904 tons of tin and 33,967 tons of tin ore, of a total value of £10,963,004. The output of ore in recent years from the principal fields is given below.

Table 38

Output of Tin and Tin Ore in New South Wales

—	1912.	1913	1914.	1915.	1916.	1917.
Ardlethan Div., ore and concentrates valued at £	7,741	42,536	25,332	53,771	29,593	62,069
Bendemeer Div. ore, tons	21	52	27	*	*	*
Deepwater Div. ,, ,,	19	46	30	22	30	22
Emmaville Div. ,, ,,	1,118	1,085	991	1,045	1,088·5	936
Glen Innes Div. ,, ,,	67	128	101	103	170	138
Inverell Div. ,, ,,	14	10	*	*	31	200
Tingha Div. ,, ,,	1,006	1,169	795	662	700	600
Torrington Div. ,, ,,	76	116	*	59	61·5	103
Wilson's Downfall Div. . . ,, ,,	167	158	125	139	137·5	128
Total output, metallic tin . . tons	900	903	650	857	909	1,109
,, output, tin ore ,,	1,175	2,118	1,667	1,331	1,220	963
,, value of tin and ore. . £	338,074	421,292	267,130	266,780	306,497	373,696

* Not stated.

The metallic tin produced in New South Wales is smelted at Woolwich, near Sydney, and the ore exported goes mainly to the Straits Settlements.

Tin deposits are widely distributed over the State, but the most important are situated in the north-eastern part, with Emmaville and Tingha as the chief centres. All the localities mentioned in the above table are in this quarter, with the exception of Ardlethan.

Tin-mining began at Elsmore, near Inverell, in 1872. Here the cassiterite occurs as crystals disseminated through granite and greisen, and, on the decomposition of the rock, has become concentrated in surface deposits. It is associated in these deposits with some wolframite, and also with carbonate of bismuth. The wolframite is derived from lodes which cut the granite, but do not appear to be stanniferous.

In the surrounding district shallow alluvial deposits were soon discovered, and for the most part worked out, as at Newstead, Stannifer, Tingha and Stanborough.

Cassiterite was found abundantly in the bed of Cope's Creek, and also in the alluvial flats bordering it. At Tingha, on this stream, dredging for tin was commenced in 1900 for the first time in New South Wales. In 1912 two-thirds of the total output of the State was furnished by dredging plants, of which there were thirty-five of the suction-pump type, and only four bucket-dredges. To the end of 1917 the dredges produced 18,854 tons of concentrates, valued at £2,078,778.

In addition to recent and Pleistocene superficial deposits, there are in the Tingha-Inverell district Eocene alluvial deposits of similar origin and containing cassiterite derived from the same granitic rocks. These old valley deposits, known as "deep leads," were buried beneath sheets of basaltic lava, the outpouring of which was accompanied by eruptions of volcanic ash now altered to bauxite. The Elsmore Valley Lead is an example; there are three beds of wash-dirt, 10½ feet, 1½ feet and 1 foot thick, worked by a mine 225 feet deep. The Newstead Lead was worked from its outcrop, and found to deepen gradually northward to a depth of 130 feet or more.

Near the junction of Cope's Creek with the Gwydir River there are several hills of basalt overlying a Tertiary stream-deposit. This is worked for diamonds, which are small but numerous, and are accompanied by topaz, sapphire, zircon, tourmaline, ilmenite, magnetite, spinel, cassiterite, etc. Although not in sufficient quantity to pay the whole cost of extraction, the tinstone forms a valuable by-product of the diamond-washing.

The Emmaville or Vegetable Creek district is some 40 miles to the north-east of Inverell and Tingha, with similar geological conditions. The oldest sedimentary rocks at Emmaville are bluish-grey claystones of Carboniferous age, which have been intruded by tin-bearing granite and by quartz-felsites and diorites. There are Tertiary alluvial deposits covered by sheets of lava and volcanic ash, and also post-Tertiary stream-deposits.

Of the last type, the most productive was that of Vegetable Creek. The upper 5 miles of this stream are stated to have yielded 15,000 tons of cassiterite between 1872 and 1884, the area worked being about 150 acres, and the average depth of gravel washed about 2 feet 6 inches. Catarrh Creek also contained important shallow alluvial deposits, and there are numerous smaller occurrences in the district.

Of the Tertiary alluvial deposits some are still capped by lava, and in others the lava has been removed by denudation.

The most important deposit of the latter class is at the Y Water-holes. It has an area of 1,100 acres, and its average depth is about 20 feet. The deposit consists of current-bedded clay and sand, the richest ore occurring in the lower part and the next richest at the top, where the tin from denuded material has been concentrated. Scrubby Gully, Surface Hill and Ruby Hill are other examples of bare Tertiary deposits.

Of the basalt-covered Tertiary leads in the Emmaville district, by far the most important is the Vegetable Creek Lead. In portions of its course there are two distinct flows of lava, each overlying a bed of stanniferous wash-dirt. The old stream had two main tributaries, giving rise to the Rose Valley Lead and Fox's Deep Lead. The latter, at its junction with the Vegetable Creek Lead, was struck at 247½ feet from the surface, and is the deepest lead worked in the Emmaville district. At Bailey's Mine, Rose Valley, a stanniferous alluvial deposit is overlain by a felspar-porphyry, the only known instance in Australia of a deep lead beneath an acid lava.

To the south of Vegetable Creek Lead is the Graveyard Lead, and the two leads probably unite about 6 miles west of Emmaville. From this point a strip of basalt-covered country runs northward to Kangaroo Flat and Avoca, where stanniferous drift has been worked, and it is probable that the lead will be found rich enough to be worked in intermediate localities.

Farther west are the Spring Lead, Rocky Creek Lead and Ruby Hill Lead, and to the east is the Wellington Vale Lead, near Deepwater.

Lode-mining for tin has been carried on in the Tingha and Emmaville districts. The lodes include fissure-veins, joint-veins, pipe-veins and stockworks, and occur chiefly in granite. The associated minerals are quartz, felspar, chlorite, mica, arsenopyrite, pyrite, fluorite, tourmaline, wolframite, galena, chalcopyrite, bismuth, molybdenite, vesuvianite, stilbite, hæmatite, pyrrhotite, manganese, scheelite and beryl. In most of the veins the ore shows a tendency to run in shoots inclined to the plane of the lode. The largest veins are the Ottery, Dutchman, Butler's and Curnow's veins, all of which are from 3 to 4 feet wide. Pipe veins are a peculiar feature of both the Tingha and Emmaville districts. They usually occur at the intersection of joints in granite, and are circular or oval in section, and up to 4 or 5 feet in diameter. They consist of quartz, felspar and chlorite, with disseminated

cassiterite, molybdenite, wolframite, etc., and pass gradually into unaltered country-rock.

Still farther to the north-east is the Wilson's Downfall district, which may be regarded as an eastward extension of the Stanthorpe tin field of Queensland. Shallow alluvial deposits have been worked in the Ruby, Maryland, Herding Yard, Cemetery, Wilson's Downfall, Wylie, Two-Mile and Bookookoorara Creeks.

In the Lachlan mining district, in the southern part of the State, is the important tin field of Ardlethan, about 40 miles west of Temora. It was discovered in 1912. Here the lodes traverse granite and schist, and usually consist of greisen or quartz-tourmaline rock. Topaz is sometimes abundant, and the cassiterite is associated with bismuthinite, molybden te, wolframite, chalcopyrite, arsenopyrite, cerussite, pyromorphite, and zinc-blende. A hydrous arsenate of copper and iron is often present.

Among other localities in the central and southern parts of New South Wales may be mentioned Mount Tallabong, the Lachlan Valley, Burra Burra, Mandanah, Albury, Jingellic, Germanton, Tumbarumba, Wagga Wagga, Bungonia and Jindabyne.

In the Barrier district, in the extreme west of New South Wales, tin ore occurs at Euriowie and Poolamacca. At Euriowie cassiterite is found in coarsely crystalline dykes of granite and greisen traversing gneiss and mica-schist. The dykes are usually from 1 to 20 feet thick and terminate abruptly with rounded ends. Work in this field has been greatly hampered by scarcity of water and distance from any railway.

Small quantities of finely divided cassiterite, associated with zircon, garnet, ilmenite, monazite, gold and platinum, occur in some of the shore-sands, notably between Byron Bay and Clarence Head, and in lesser quantities between Port Macquarie and Cape Hawke, near Seal Rocks, and at Shellharbour, Termeil, etc.

Native tin has been recorded in washings from the Aberfoil and Sam rivers, near Oban, in grains from 0·1 to 1 mm. in diameter. More interesting economically are the considerable quantities of stannite at Howell (Bora Creek), near Inverell. This mineral also occurs at Tolwong, near Bungonia. At Howell it is associated with galena, zinc-blende and arsenopyrite, and at Tolwong chiefly with arsenopyrite and some chalcopyrite, galena and zinc-blende. Ore from the Conrad Mines at Howell was found to contain about 9 per cent. of

tin, 3 per cent. of which was present as a residue unattacked by all reagents and fluxes with the exception of potassium cyanide. To this residue, which is said to have the appearance of fine garnets and a composition expressed by the formula $7SnO_2 \cdot Fe_2O_3$, the name *conradite* has been given.

NORTHERN TERRITORY.—The production of tin ore in the Northern Territory is small in comparison with other Australian States, averaging about 200 tons a year, but this is partly due to the undeveloped state of the country. The concentrates are sent to Singapore for smelting. The output in recent years has been as follows :—

Table 39

Value of Tin Ore produced in the Northern Territory

In £

1910.	1911.	1912.	1913.	1914.	1915 (1st half-year).
31,113	22,900	27,001	25,526	15,200	5,545

Table 40

Output of Tin Ore in the Northern Territory

In tons (2,240 lb.)

	1911.	1912.		1911.	1912.
Horseshoe Creek and Mount Todd	40	40	Daly River	1	3
Emerald Hill	4	9	The Nellie	—	3½
Wolfram Camp	20	14	Hidden Valley	3¾	4
Fergusson	2	3	Umbrawarra	45	30
Burrundie	79½	100½	Mary River	7¾	12
Snadden's Creek	13	5¾	Stray Creek	—	5
Mount Shoobridge	3	8¾	Pine Creek	½	—
The Finnis and Mt. Tolmer	½	2½	Miscellaneous	1	—
The Cullen	—	9			
West Arm and Bynoe Harbour	18	21	Total tons	239	270¾
			Value. £	22,900	27,001

At Mount Wells, Burrundie, lode-mining is carried on, and fifty Chinese miners were employed in the early part of 1914. The mine has been producing since 1886. The lodes consist of quartz or pegmatite dykes intrusive in a shear-zone in chlorite schist, and may expand when followed into the granite.

Systematic development has, however, been neglected, and the mine is worked by Chinese tributers.

At Horseshoe Creek the lodes also cut chlorite schists. Here, as in other parts of the Territory, the Chinese miners have followed lodes down to the water level and then abandoned them, or picked out rich pockets without attempting to trace them to further deposits.

What appears to be an important tin field has recently been developed at Maranboy, at the heads of Beswick and Providence Creeks, in latitude 14° 28′ South, longitude 132° 49′ East. It is about 35 miles east of Katherine, a station on the Overland Telegraph Line. The lodes occur in pre-Cambrian tuffs overlying granite, and consist of replacements of the tuffs, in which cassiterite is associated with tourmaline or with quartz and chlorite. On the neighbouring King River cassiterite occurs in a quartz-tourmaline vein in tuff.

Hayes Creek and Rum Jungle are other localities in which tin ore has recently been found.

QUEENSLAND.—Tin mining in Queensland began in 1872 with an output of 1,407 long tons of ore, followed by 8,938 long tons in 1873. The latter figure has never been exceeded, and the total output to the end of 1917 is 141,725 long tons of ore valued at £9,156,043. The following table shows the output of the different fields :—

Table 41

Output of Tin Ore in Queensland

In tons (2,240 lb.)

—	1912.	1913.	1914.	1915.	1916.	1917.
Batavia River .	—	—	0·5	0·08	0·15	—
Charters Towers .	75·25	33·75	58·75	—	1	15·5
Chillagoe . .	504	497	228	320	186	104
Coen and Rocky .	—	—	—	—	2	2·75
Cooktown . .	272	293	223	296·75	234·5	218
Croydon . .	15	6·5	32	—	—	—
Etheridge . .	57	9·75	7	—	1	0·75
Herberton . .	1,927	1,861	1,141	1,164	821	541
Kangaroo Hills .	163	206·5	163	129	130·5	70·5
Nanango . .	0·15	2·1	—	—	—	—
Palmer . .	37·25	31·75	18	29·25	17	10
Port Douglas .	—	5·5	0·4	—	—	—
Ravenswood .	13·25	3·75	2·75	4·75	4·5	—
Stanthorpe . .	166·25	246·75	211	181	309	214·5
Total . tons	3,230·15	3,197·35	2,085·40	2,124·83	1,706·65	1,177·00
Value . . £	364,503	343,669	176,197	183,472	181,401	160,600

All the tin fields are in the northern part of Queensland with the exception of Stanthorpe and Nanango, which are near the southern border.

The Herberton and Chillagoe tin fields are situated to the south-west of the port of Cairns, with which they are connected by railway. The Herberton field is traversed by the main dividing range of Queensland, while the Herberton Range on the eastern border prevents easy access to the coast. The rocks are slates, schists and quartzites with intrusions of biotite or hornblende granite, granite-porphyry and quartz felsite. Elvan dykes penetrate both the plutonic rocks and the altered sediments. The tin lodes occur in an irregular manner. The lode material as a rule merges gradually into barren country rock, and varies from unaltered granite or quartzite to greisen and chloritic or kaolinic material. The cassiterite is often accompanied by topaz, fluorite, tourmaline, wolframite, bismuthinite, antimonite, galena, chalcopyrite and magnetite. Alluvial tin was first worked in this district in 1880, and the discovery of lodes near Herberton and Watsonville soon followed. Irvinebank, Koorboora, Stannary Hills, Sunnymount, and Newellton are other important lode-mining centres in these fields.

Farther north, in the Annan River tin field, south of Cooktown, the output is almost entirely stream tin, although lodes have been worked to some extent in a greisenised granite near its contact with slate. The district is one of rugged mountains, but the streams draining westward into the Annan River are held up by bars of harder rock, giving rise to an alternation of cascades and quiet reaches in which extensive alluvial deposits occur. Cassiterite is also found in alluvial terraces above the present stream levels, and in superficial deposits on the hillsides below the granite-slate contact. Some of the deposits have been worked continuously for tin since the opening of the field in 1885. To bring water to the higher terraces, races had to be constructed, often several miles in length ; water supply is a most important factor in many of the Queensland fields, and a dry season leads to a diminished output of tin.

At Lode Hill, on the Bloomfield River, Cooktown district, the greisenised granite has been decomposed to a considerable depth. It is removed by hydraulic means, and is stated to yield on an average 1¼ lb. of tinstone per cubic yard.

In the Stannhills tin field, near Croydon, cassiterite occurs in veins in granitic rocks, and is associated with chlorite,

quartz, pyrite, galena, zinc-blende and chalcopyrite. The Desert Sandstone, which overlies the granite and forms isolated flat-topped hills, is stanniferous in places. Alluvial deposits have been worked, but these are not extensive and are of less importance than the lodes.

The Kangaroo Hills tin field, about 100 miles south of Herberton, produces lode and alluvial tin. Lodes have recently been discovered at Watercress.

Still farther south, in the Charters Towers district, a certain amount of lode-mining for tin is carried on, but the industry is quite overshadowed by the gold production of the district.

In the Stanthorpe district, near the New South Wales border, the first discovery of tin ore in Queensland was made in 1872. The alluvial deposits are still yielding good returns to hydraulic methods of extraction, and there is a little lode-mining, especially in the Ballandean portion of the district.

Cassiterite occurs, associated with gold, platinum and monazite, in the shore sands near Currumbin Creek, in the south-east of Queensland. Similar deposits are found on the coast of New South Wales.

SOUTH AUSTRALIA.—Cassiterite has been found in the bed of a lake near Earea Dam, about 30 miles south-east of Tarcoola. It occurs in decomposed granite dykes and quartz veins, and in the superficial deposits. There has been no production of tin ore.

TASMANIA.—The ore is smelted in reverberatory furnaces at Launceston. These furnaces yield metal assaying 90 to 95 per cent. tin, which is subsequently refined to an average purity of 99·89 per cent.

The principal mine in the Northern and Southern Division is the Shepherd and Murphy, near Middlesex, otherwise known as the Bismuth Mine. The lodes appear to be connected with a Devonian granite intrusion, and traverse (1) sandstone or quartzite, (2) lime-silicate rock resembling the Swedish "skarn" (see also p. 84), which consists of garnet, pyroxene and magnetite. These rocks are covered by Tertiary basalts. The lodes contain quartz, fluorite, topaz, beryl, a greenish hydrated mica and monazite, together with cassiterite, wolframite, bismuthinite, native bismuth, molybdenite, chalcopyrite, pyrite, arsenopyrite, and rarely galena. Scheelite, bismutite, calcite and stilbite also occur. The tin, tungsten and bismuth minerals are of economic importance, and occur in the mill concentrates in approximately the following percentages: cassiterite, 53; wolframite, 30; bismuthinite, 7;

Table 42

Output of Tin Ore in Tasmania

In tons (2,240 lb.)

	1912.	1913.	1914.	1915.	1916.*	1917.
Northern and Southern Division	49·28	57·96	40·978	72·75		72·43
North-Eastern Division:						
Pioneer and Gladstone Districts	901·35	859·20	628·18	726·51		631·22
Ringarooma District	32·60	24·55	15·20	25·10		
Derby District	592·35	574·85	243·10	314·39		570·61
Branxholm District	154·20	122·05	136·09	144·92		
Moorina District	64·00	69·20	43·15	37·65		42·4
Straits Islands	2·15	5·75	1·24	4·934		6·2
Eastern Division:						
Weldborough, Lottah and Blue Tier Mines	245·10	234·40	159·00	129·85		80·975
St. Helens Mines	42·50	73·55	42·65	108·855		90·33
Avoca Mines	47·25	172·05	109·50	168·30		201·55
Schoutens	0·25	—	—	—		—
North-Western Division	1,357·26	1,461·74	889·05	673·66		691·282
Western Division	225·535	355·11	264·575	202·315		250·34
Total . . . . . tons	3,713·825	4,010·41	2,572·713	2,599·234	2,854·636	2,637·337
Value . . . . . £	543,103	531,983	259,300	292,306	350,852	427,917

* Details not available, copies of the Report intended for England having been lost at sea.

the remainder being pyrite, magnetite, quartz and fluorite. The concentrates are treated at Launceston by Wetherill magnetic separators. These give a wolfram concentrate containing 70 per cent. tungstic acid and 0·7 per cent. tin, and a non-magnetic product containing 56·3 per cent. tin, 8 per cent. bismuth, and 0·7 per cent. tungstic acid. This product is shipped to England, where the bismuth is extracted and the residue smelted as a tin ore. The Wetherill separations of mill concentrates from the deeper, unoxidised ores are carefully roasted and again passed through the separator to eliminate the pyrite and other minerals which are sometimes intimately mixed with the valuable ores.

The chief output of tin ore comes from the North-Eastern and North-Western Divisions. In the former are the Pioneer Mine, which produced 468 tons of ore in 1912, and the Briseis (Derby District) with 538 tons in the same year. Both these mines are on the Ringarooma River and work deep leads. At the Pioneer the overburden is 40 feet thick in places, and consists of cemented material which has to be blasted. The Briseis was discovered in 1872. Here the cassiterite occurs in a coarse quartz sand overlain by a sheet of olivine-basalt which is generally so decomposed as to be removable by hydraulic methods. Water has been brought from a distance of over 30 miles, and recently the river and main road have been diverted in order to follow the lead across the old river channel.

At Gladstone, lower down the Ringarooma River, alluvial and lode workings yield tinstone, often associated with gold and wolfram. The lodes occur near the junction of the Mount Cameron granite with Palæozoic slates; and the alluvial deposits have been in part re-distributed by marine action during a comparatively recent depression of the country beneath the sea.

In the Eastern Division the Anchor is the chief mine in the Blue Tier district. The rock worked is a tin-bearing granite averaging ½ per cent. cassiterite. The biotite of the ordinary Blue Tier granite is altered to muscovite and talc, much of the felspar is kaolinised, and cassiterite, wolframite, scheelite, fluorite, pyrite, molybdenite, galena and chalcopyrite occur. Farther south, in the Ben Lomond and Avoca districts, tin lodes occur in granite. The overlying grits and conglomerates of Permo-Carboniferous age contain water-worn fragments of the granite and of quartz and cassiterite, and form one of the most ancient deposits of detrital tin hitherto

recorded. In the Scamander district cassiterite and wolframite occur in lodes.

The North-Western Division contains the most important tin mine in Tasmania, the Mount Bischoff, which produced 1,110 tons of ore in 1912. The mine was discovered in 1871 and the output to the end of 1914 was 72,500 tons of ore. It is situated 45 miles from the north coast at Emu Bay. Mount Bischoff consists of contorted slaty rocks traversed by dykes of quartz-porphyry, while the surrounding plains are largely formed of sheets of basalt. The porphyry dykes carry topaz and cassiterite, and there are fissure veins containing cassiterite, pyrite, arsenopyrite, fluorite, wolframite, tourmaline and siderite. Disintegration of the slaty rocks has given rise to extensive residual deposits in which the cassiterite is concentrated, known as the Brown Face, White Face, etc., and small alluvial deposits also occur.

In the Western Division is the North Dundas tin field, including the Renison Bell, Dreadnought-Boulder and Montana mines. Here the Dundas Slates were cut, probably in Devonian times, by dykes of quartz-porphyry and basic igneous rocks, and by various types of veins. In some of the veins cassiterite is associated with quartz and tourmaline, or with quartz alone, in others with sulphides. Of these pyrrhotite is the most abundant, though pyrite is often present in large amount, and arsenopyrite, chalcopyrite, galena and zinc-blende are usually seen. Quartz and dolomite are the chief gangue minerals, with smaller amounts of tourmaline, chlorite, epidote and fluorite. The alluvial deposits contain cassiterite and chromite, with traces of gold and osmiridium.

Immediately to the east of the North Dundas field, in the X River district, the same types of lodes occur.

In the Zeehan field, nearer the west coast, a variety of veins are found, some of which carry tin. Both cassiterite and stannite are often present, associated with pyrite, chalcopyrite, bismuthinite, tetrahedrite, wolframite, galena, quartz, tourmaline, siderite and fluorite.

In the Heemskirk district the primary tin deposits are veins in granite and the overlying slates and sandstones. Quartz and tourmaline are the usual vein minerals. An interesting occurrence is an irregular pipe-like body at the Federation Mine. This was followed for a distance of 115 feet, and its cross section diminished from 25 by 15 feet near the surface to 5 by 1 feet at the deepest point exposed. The pipe consisted of soft greenish-grey material resembling pinite, with

abundant cassiterite and pyrite, and these minerals, together with quartz and tourmaline, occurred also in the surrounding zone of altered granite.

The tin lodes of the Stanley River and Mount Balfour districts are similar to those of the Heemskirk and North Dundas tin fields.

VICTORIA.—Victoria has a low output of tin ore as compared with most of the other States in the Commonwealth. The localities producing ore in recent years are given below :—

Table 43

Output of Tin Ore in Victoria

In tons (2,240 lb.)

—	1912.	1913.	1914.	1915.	1916.	1917.
Beechworth	19	8·9	2·7	14·25	24	11
Chiltern	5·25	—	—	—	—	4·5
Diggers Creek	—	—	—	—	0·1	—
Eldorado	—	3·5	4	75·0	85	105·5
Eskdale	0·5	0·05	0·25	—	—	—
Glen Wills	—	—	6	—	—	—
Koetong	—	4·2	1·6	—	—	3·2
Lightning Creek	0·3	—	—	—	—	—
Mitta Mitta	—	—	—	—	—	1·5
Myrtleford	3·8	7·25	5·2	—	—	—
Rutherglen	1·95	—	—	—	—	3·75
Sunnyside	—	1·05	—	—	—	—
Surveyor's Creek	—	4·45	2·85	—	—	—
Tallandoon	4	1·8	0·75	—	—	—
Toora	4·35	17·5	29·25	6·25	11	9·5
Walwa	8·75	8·75	—	—	—	—
Total . tons	47·9	57·45	52·6	95·5	122	138·95
Value . £	5,733	6,980	4,955	9,447	12,955	19,709

Most of the Victorian tin ore is from alluvial deposits, many of which yield both cassiterite and gold. Stream tin occurs at Glen Wills, Beechworth, Eldorado, Chiltern, Stanley, Rutherglen, Koetong, and Cudgewa, in the North-Eastern District ; at Toora, Tin Creek and Agnes River in Southern Gippsland ; near Bruthen in Eastern Gippsland ; at Gembrook, Neerim, Darnum, the Bunyip and Tarago Rivers in Western Gippsland ; Upper Yarra, and other districts. Tin-bearing lodes, some of which have been worked, are known at Mount Cudgewa, Mount Wills, Pilot Range, Mitta Mitta, Eskdale and Tallandoon in the North-Eastern District, and Mount Singapore on Wilson's Promontory, in Southern Gippsland.

WESTERN AUSTRALIA.—The most important tin fields of Western Australia are those of Greenbushes and Pilbara, which have produced about 9,700 and 5,300 tons of ore respectively to the end of 1916. In 1913 a small production was reported at Murchison and Coolgardie, and other occurrences are known in the Kimberley district and on the Thomas River in the Gascoyne valley. The output of black tin reported to the Mines Department during the years 1912 to 1916 is given below.

Table 44

Output of Tin Ore in Western Australia

In tons (2,240 lb.)

	1912.	1913.	1914.	1915.	1916.	1917.
Greenbushes Mineral Field .	430·45	458·48	244·54	247·33	281·74	
Pilbara Gold Field (Marble Bar District)	123·38	139·10	87·40	78·65	153·17	
Murchison Gold Field (Cue District)	—	3·20	—	—	—	
Coolgardie Gold Field (Coolgardie District) . .	—	0·15	—	—	—	
Total . . tons	553·83	600·93	331·94	325·98	434·91	
Value . . £	65,159	67,717	29,313	29,064	43,258	

The Greenbushes district is in the south-west of the State. Cassiterite occurs in pegmatite and quartz-tourmaline veins and impregnations in granite. This is covered by lateritic alteration products, which in places contain concentrated residual tin ore. This material usually requires crushing. More important sources of tin are the alluvial deposits in the stream valleys. The richest of these is in Spring Gully, where an upper layer of sand, known as " free dirt," rests on stiff white " clayey dirt." The former is particularly rich in tinstone. Tantalite and stibio-tantalite occur with the cassiterite in some of these deposits.

About twelve miles south of Greenbushes, tin ore has been obtained at Nannup or Smithfield.

In the Pilbara district, in the north-west division, tin ore is produced at Moolyella, Cooglegong, Old Shaw (Eley's Well), Green's Well, Wodgina, Stannum, and Mill's Find. At all these localities the original source of the cassiterite is the pegmatite veins which traverse granite and metamorphic rocks. At Wodgina, where, unlike most other tin fields in the State, the output of lode tin has exceeded that of stream tin, the

lodes vary from mere threads to masses over 500 feet in width and carry tourmaline and tantalite. At Moolyella the pegmatite veins consist largely of albite. From these sources are derived the shallow alluvial and residual deposits which, in most localities, have yielded the greater part of the tin produced. Tantalite, monazite, gadolinite and euxenite are occasionally found with the cassiterite in these deposits.

At the King's Sound Tin Mine, West Kimberley, narrow veins of quartz in a slaty rock contain scorodite (hydrous arsenate of iron), with cassiterite and wolframite in varying but usually small amounts.

NEW ZEALAND.—There is no production of tin ore in New Zealand. Table 45 shows the imports of tin, which is mainly of Australian origin. The importation of tinned plate has practically doubled between 1910 and 1916, reaching 6,584 tons in the latter year; the plate is mainly English, though increasing quantities have come from the United States in recent years.

Table 45

Imports of Tin into New Zealand

In cwt. (112 lb.)

Countries whence Imported.*	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
United Kingdom .	1,011	1,149	953	1,256	2,045	981	504	250
Australia . .	2,630	2,770	3,214	2,529	2,975	2,267	2,512	2,702
Other countries .	—	—	5	2	5	5	—	—
Total . cwt.	3,641	3,919	4,172	3,787	5,025	3,253	3,016	2,952
Value . £	28,876	36,470	44,500	41,570	40,450	26,365	29,922	36,970

* Countries whence imported in 1910–13, countries of origin in 1914–17.

Stream tin has been reported from various localities near the west coast of the South Island, as at the foot of Mount William Range, at Karamea, Mokihinui, Canoe Creek and Clarke River. It has been found in the sluice-box concentrates from auriferous gravels at Waimangaroa and the Blackball district. One sample from the latter locality was found to contain 33·3 per cent. of metallic tin. "Tin crystals" (probably cassiterite) are recorded at Slaty Creek and in the vicinity of Lake Brunner, and "tin" is said to occur in the Thames subdivision, Hauraki, Auckland. Stream tin and lodes also occur near Port Pegasus in Stewart Island. No deposits of economic value appear to be known.

CHAPTER III

SOURCES OF SUPPLY OF TIN ORES (*continued*)

(*b*) FOREIGN COUNTRIES

EUROPE

AUSTRIA-HUNGARY.—The tin-bearing lodes of Bohemia will be dealt with under Germany (p. 78), as they are closely connected with those on the Saxon side of the Erzgebirge. Though once important, their output in recent years has been insignificant, as Table 46 shows :—

Table 46

Output of Tin Ore and Tin in Austria-Hungary

In metric tons (2,204 lb.)

	1910.	1911.	1912.	1913.
Output of tin ore . .	37	943	605	939
,, ,, tin . . .	40	15	13	11
Value of the ore . £	90	3,289	4,592	—

The above figures represent low-grade ore, not concentrates, the value being under £8 per ton.

Tables 47 and 48 give the imports and exports of tin for Austria-Hungary. The trade was chiefly with Germany, but the imports from the Straits were nearly as large as the German imports in 1913.

Table 47

Imports of Tin into Austria-Hungary

In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.
United Kingdom	288	227	178	116
British Indies	1,706	1,750	1,831	1,908
Germany	2,321	2,461	2,553	2,000
Holland	163	180	110	77
Dutch East Indies	70	160	60	69
Other countries	126	17	74	44
Total, metric tons	4,674	4,795	4,806	4,214
Value £	734,160	930,971	1,001,250	842,820

Table 48

Exports of Tin from Austria-Hungary

In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.
Germany	400	553	608	827
Other countries	109	206	430	234
Total, metric tons	509	759	1,038	1,061
Value £	73,665	134,776	199,007	194,590

FRANCE.—The production of tin ore in France has been small and erratic, the last output, apparently, being 22 tons from Montebras in 1909. There is, however, a small tin-smelting industry. The imports and exports of ore and metal are shown in the following tables:—

Table 49

Imports of Tin Ore into France

In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
United Kingdom	*	74	540	374	103		
Chile	1,280	1,814	1,136	1,932	1,983		
Peru	274	771	82	32	125		
Indo-China	372	211	171	128	123		
Other countries	78	113	128	338	211		
Total, metric tons	2,004	2,983	2,057	2,804	2,545	205	445
Value £	72,144	119,320	89,694	121,128	86,537		

* Not stated.

Table 50
Imports of Tin into France
In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
United Kingdom	2,334	1,852	1,577	1,560	(1,962)†		
British Indies	5,055	4,961	5,029	5,014	(2,665)		
Germany	1,083	1,231	769	835	(565)		
Holland	425	396	419	446	(685)		
Dutch Indies	1,236	1,718	1,515	1,359	(702)		
China	*	*	537	941	(115)		
Other countries	670	509	668	230	(208)		
Total, metric tons	10,803	10,667	10,514	10,385	{ (6,902) 8,779 }	10,290	12,068
Value £	1,685,268	2,005,490	2,144,815	2,097,730	1,404,704		

* Not stated.
† The figures in brackets represent "commerce spécial," *i.e.*, imports for consumption.

Table 51
Exports of Tin Ore from France
In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.
United Kingdom	599	847	911	1,147	393
Belgium	167	242	180	101	193
Germany	368	355	222	151	309
Other countries	29	111	68	35	—
Total, metric tons	1,163	1,555	1,381	1,434	895
Value £	41,854	62,200	60,229	61,940	30,427

Table 52
Exports of Tin from France
In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.
United Kingdom	1,815	1,765	822	921	819
Belgium	38	65	52	31	53
Germany	63	172	65	*	42
Holland	226	96	46	151	46
Italy	347	172	524	382	413
Russia	327	409	432	506	486
Spain	147	160	268	224	221
Switzerland	338	151	134	203	212
United States	*	467	851	570	77
French Colonies	257	131	143	166	121
Other countries	91	190	92	131	69
Total, metric tons	3,649	3,778	3,429	3,285	2,559
Value £	569,182	710,245	699,496	663,469	409,504

* Not stated.

In Brittany lodes occur in granite and slate, as in Cornwall. The chief minerals present are quartz, cassiterite, apatite, fluorite, molybdenite, arsenopyrite, pyrite, zinc-blende, chalcopyrite, and galena. Topaz and tourmaline are of rare occurrence, and wolframite is absent. At La Villeder, south-west of Ploermel, in Morbihan, mining was carried on from 1856 to 1863 and again from 1880 to 1886. Lodes also occur at Piriac, in Loire-Inférieure, and at Montebras, Vaulry, Cieux and other localities on the Central Plateau. At Montebras the lodes have been worked at various times; they occur in a fine-grained granite, and many of them are rich in phosphates such as apatite, wavellite, and amblygonite.

GERMANY.—Tin-mining in the Erzgebirge was an important industry in mediæval times. Now, however, the lodes on both the Saxon and Bohemian sides of the range are practically exhausted. Table 46 (p. 75) shows the Austrian output in 1910–1913, and for Germany the output was 125 metric tons of ore in 1910 and 116 in 1911, valued at £2,800 and £5,850 respectively. In 1912 the output of tin ore was included with that of cobalt, nickel and bismuth ores.

Before the war Germany had a considerable tin-smelting industry based chiefly on Bolivian ore. Tin was imported from the Dutch Indies, the Straits Settlements, Australia, the United Kingdom, and elsewhere, and the imports of tin-plate from the United Kingdom amounted to 48,061 metric tons in 1912.

The exports of tin, as shown in Table 55, were mainly to the United States and the countries bordering on Germany.

Table 53

Imports of Tin Ore into Germany

In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.
United Kingdom . .	34	320	102	82
Australia . . .	7	4	480	1,015
Bolivia	15,925	15,227	13,296	15,831
Chile	914	1,874	914	868
Other countries . . .	463	536	1,765	940
Total, metric tons .	17,343	17,961	16,557	18,736
Value . . . £	1,335,450	1,796,050	2,069,650	2,342,050

Table 54

Imports of Tin into Germany

In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.
United Kingdom	1,303	1,524	1,644	1,697
British Indies, etc.	1,105	1,266	1,387	942
British Malaya, etc.	471	249	494	941
Hong Kong	10	5	21	*
Australia	1,129	1,114	1,519	1,661
Austria-Hungary	630	422	340	393
Belgium	229	87	272	297
France	86	210	164	71
Holland	607	787	1,033	569
Switzerland	59	143	180	92
China	364	148	353	142
Dutch East Indies	8,135	8,210	7,254	6,384
United States	82	148	684	929
Other countries	87	187	205	143
Total, metric tons	14,297	14,500	15,550	14,261
Value £	2,188,650	2,764,100	3,242,700	2,973,350

* Not stated.

Table 55

Exports of Tin from Germany

In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.
United Kingdom	189	256	510	521
Belgium	658	732	335	565
France	1,174	1,257	711	929
Italy	522	616	334	338
Holland	390	449	387	227
Austria-Hungary	945	494	437	647
Russia	442	427	691	771
Switzerland	341	405	554	470
Spain	94	155	195	129
Turkey	84	213	207	198
Argentina	106	179	73	59
United States	2,159	1,777	1,304	1,041
Other countries	417	646	630	542
Total, metric tons	7,521	7,606	6,368	6,437
Value £	1,169,550	1,239,350	1,054,100	1,166,800

The principal tin deposits of Germany and Austria are those on both sides of the Erzgebirge, where tin-mining commenced

in the twelfth century. The lodes are connected with two granite intrusions which cross the range from Saxony into Bohemia, and they occur chiefly in the upper part of the granite and in the overlying phyllite, gneiss and porphyry, the deeper and more central portions of the granite being barren. Thus at Altenberg the ore was followed to a depth of 760 feet, below which it was no longer worth working. The ore here is in the form of a stockwork, with innumerable small veins or *Zwitter* bands. Farther south, at Zinnwald, flat lodes (*Flöze*) and greisen yield tin, wolframite and lepidolite, the last named having been worked as a source of lithia. At Graupen, on the Bohemian side of the range, orthoclase and fluorspar are abundant in the vein material, with topaz in the adjacent rock. Farther west are the lodes of Geyer and Ehrenfriedersdorf.

At Berggiesshübel, near the eastern end of the Erzgebirge, thin veins of orthoclase, quartz, fluorspar and cassiterite occur in altered limestone bands near a granite intrusion.

Tin lodes were formerly worked in the granite of the Fichtelgebirge, at Weissenstadt and elsewhere.

HOLLAND.—Holland is important, not as a producer or large smelter of tin ore, but as the distributing centre of the greater part of the tin produced in the Dutch East Indies. Tables 56 to 59 show the imports and exports of tin and ore. Small amounts of ore, mostly Bolivian, were imported in the years preceding the war, but this is insignificant in comparison with the metallic tin. Practically the whole output of tin in Banka was sold in Holland, and there were also imports from the

Table 56

Imports of Tin Ore into Holland

In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.
United Kingdom . .	62	—	4	2	—
Australia	—	21	—	—	—
France	29	110	7	21	—
Germany	—	3	1	603	1
Chile	244	45	300	60	389
Dutch East Indies . .	—	—	20	5	20
Other countries . . .	—	—	—	5	—
Total, metric tons .	335	179	332	696	410
Value . . £	4,468	2,388	4,439	9,279	5,467

Table 57

Imports of Tin into Holland

In metric tons (2,204 lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.
United Kingdom .	2,718	4,024	4,376	3,926	2,969
Straits Settlements .	707	774	1,557	505	511
Germany . . .	2,606	3,010	1,322	1,309	867
Dutch East Indies .	14,713	15,974	15,808	15,641	12,232
China . . .	138	180	3,083	61	220
Other countries . .	794	513	1,497	682	110
Total, metric tons	21,676	24,475	27,643	22,124	16,909
Value . £	1,806,337	2,039,614	2,303,611	1,843,656	1,409,069

Table 58

Exports of Tin Ore from Holland

In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.
United Kingdom .	25	—	140	—	5
Germany . . .	256	142	49	21	—
Other countries . .	2	—	—	—	—
Total, metric tons	283	142	189	21	5
Value . £	3,767	1,887	2,520	284	72

Table 59

Exports of Tin from Holland

In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.
United Kingdom .	160	509	1,697	1,373	478
Belgium . . .	1,389	1,276	1,639	1,369	762
France . . .	329	305	270	249	255
Germany . . .	13,463	13,080	13,754	12,048	10,128
Russia . . .	1,875	2,025	2,319	2,605	1,614
United States . .	2,073	3,032	3,640	476	409
Other countries . .	596	779	780	667	809
Total, metric tons	19,885	21,006	24,099	18,787	14,455
Value . £	1,657,092	1,451,731	2,008,230	1,565,620	1,204,607

United Kingdom and other countries. The greater part of the tin was re-exported, two-thirds going into Germany, and it was therefore necessary at an early stage in the war to limit the imports of tin into Holland to an amount sufficient for domestic consumption. According to the monthly statistics of the New York Metal Exchange, the tin deliveries in Holland in the years 1913–17 were 15,522, 12,025, 4,734, 943, and 962 tons respectively.

ITALY.—The production of tin ore in Italy is small, and was estimated at 20 tons in 1911 and 350 tons in 1912, all from one mine. The imports of tin are normally between 2,500 and 3,000 tons; in 1915 they rose to 4,245 metric tons, but became normal again in 1916. Some 30,000 tons of tin-plate is produced yearly.

At Campiglia Marittima, in Tuscany, iron and tin were mined in early times, and the deposits were re-discovered in 1871. Masses of cassiterite occur in veins of limonite, probably derived from pyrite, which traverse limestones and shales of the Lower Lias. The occurrence is of interest as forming almost the only example in Europe of tin deposits of Tertiary age, to which the great Bolivian deposits belong. In the neighbouring island of Elba specimens of cassiterite have been found in granites of Tertiary age.

PORTUGAL.—The Portuguese tin deposits will be described with those of Spain (p. 84), with which they are closely connected. The output in recent years is given below.

Table 60

Output of Tin Ore in Portugal

In metric tons (2,204 lb.)

1910.	1911.	1912.	1913.	1914.
9	85	196	254	370

RUSSIA.—Russia produces little tin, and her imports in normal years are between 5,000 and 6,000 tons. Table 61 shows the effect of the war on the imports. In 1915 the total was 42 per cent. greater than in the previous year, and nearly nine-tenths came from the United Kingdom; imports from Continental Europe practically ceased, and the only other imports of any significance were from Japan and the United States.

Table 61

Imports of Tin into Russia

In pouds (36 lb.)

Countries whence Imported.		1912.	1913.	1914.	1915.
United Kingdom		97,272	106,818	148,705	434,239
Austria-Hungary		9,159	8,366	8,147	—
Belgium		4,596	5,927	2,825	—
France		10,789	11,278	10,496	—
Germany		120,347	112,204	76,802	4,380
Holland		84,892	83,774	81,331	3,617
Spain		4,109	19,703	7,595	—
East Indies		8,199	10,369	4,783	—
Japan		—	—	170	34,686
United States		2,514	—	498	11,078
Other countries		3,824	9,999	7,457	6,613
Total	pouds	345,701	368,438	348,809	494,613
,,	*tons*	5,556	5,921	5,606	7,949
Value	£	1,204,904	1,276,464	899,147	1,699,996

An extensive tin-plate industry formerly existed at Odessa, using black plate imported from Wales. Since 1903, however, this trade has decreased, owing to the discovery of suitable iron ore for black plate in the Urals near Perm. Modern works, copying those in Wales, were erected, and these Ural works now command the Russian market. There is still, however, a small tin-plate industry at Odessa. The tin-plate imported before the war was mainly from Germany.

In the Russian Empire tin deposits are known in the Trans-Baikal province, in the Urals, and in Finland. The Trans-Baikal deposits consist of lodes and placers near the villages Olovianoy Roudnik and Nizhni-Sharanai on the Onon River, and in the valleys of the Malaya Koulinda and Ingoda, tributaries of the Onon. At Olovianoy, about 150 miles south-west of Nerchinsk, the lodes contain quartz and cassiterite, together with beryl, fluorite and lepidolite. They have been known since 1811, and were worked on a small scale between 1812 and 1835. In more recent years a German company was formed to exploit them.

The occurrence at Pitkaranta, north of Lake Ladoga in Finland, was worked from 1814 to 1904, during which period it is said to have yielded some 250,000 tons of iron ore, 6,617 tons of copper, 489 tons of tin, and 11·2 tons of silver. The ores consist of magnetite with some cassiterite and chalcopyrite

and a little scheelite; they occur in altered limestones and schists, and particularly in a rock known as "skarn," which is made up of salite and garnet.

Tin deposits have also been reported in the Sossnowics and Dombroff basins in Poland.

SPAIN.—The tin-bearing gravels of the Iberian peninsula were worked by the Phœnicians and Romans, but at the present time neither the gravels nor the veins yield any large amount. The output given in Table 62 represents very low-grade material, the total value in 1912 being only £3,506, which is equivalent to about 14s. per ton. In normal years Spain imports about 1,400 tons of tin, chiefly from the United Kingdom and Germany.

Table 62

Output of Tin Ore in Spain

In metric tons (2,204 lb.)

1910.	1911.	1912.	1913.	1914.	1915.	1916.
35	34	5,079	6,626	—	102	86

The most extensive series of occurrences in the Peninsula are the lodes in a belt stretching north-westward from Zamora, across the north-eastern part of Portugal, into the province of Orense in Galicia. In this belt are the lodes of Penuta, Romilo, Verin, Monterey, Almaraz, Lumbrales, Viana del Bollo and Pontevedra in Spain, and those of Mirandella, Montesinhos, Parada, Coelhoso, Marao Angueria and Valle Seixo in the Province of Traz os Montes in Portugal. Other occurrences are those of Terrubias and Santo Tomé de Rozadas near Salamanca, San Isodoro and Marinera near Cartagena, near Almeria on the south coast of Spain, and near Ramalhoso, Vizeu, and Belmonte in Portugal. In 1914 a bucket dredge was erected in the Gaia valley near Belmonte (Beira Alta). The lodes occur in granite and schist. Wolframite is often abundant, either in association with cassiterite or in separate lodes.

ASIA

CHINA.—China exports some 8,000 tons of crude tin yearly, nearly all of which is sent to Hong Kong (Table 63). The industry is entirely in the hands of the Chinese, who smelt the

Table 63

Exports of Tin from China

In piculs (133⅓ lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Hong Kong	107,613	99,793	144,664	136,195	117,787	131,990	125,237	195,025
French Indo-China	17	334	261	72	152	108	98	515
Japan	—	—	186	1	62	73	48	288
France	6	2	—	2,161	1,190	—	—	—
United States	—	—	116	84	—	168	504	411
Other countries	—	—	—	175	34	40	157	88
Total . . . piculs	107,636	100,129	145,227	138,688	119,225	132,379	126,044	196,327
,, . . . *tons*	6,407	5,960	8,644	8,255	7,097	7,880	7,503	11,686
Value . . . £	840,923	864,775	1,787,211	1,648,908	1,088,741	1,199,196	1,431,618	2,634,855

Table 64

Imports of Tin into China

In piculs (133⅓ lb.)

Countries whence Imported.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
United Kingdom	45	83	23	432	95	123	184	14
Hong Kong	40,418	29,402	38,479	49,814	62,602	39,807	48,388	41,401
Straits Settlements, etc.	3,686	3,140	1,360	2,147	2,368	1,330	2,051	961
Japan	70	222	209	205	167	156	411	571
Other countries	201	153	99	189	85	314	279	522
Total . . . piculs	44,420	33,000	40,170	52,787	65,317	41,730	51,313	43,469
,, . . . *tons*	2,644	1,964	2,391	3,142	3,888	2,484	3,054	2,587
Value . . . £	228,123	165,428	239,638	351,023	390,113	266,599	434,575	561,478

ore in small furnaces and obtain a product containing about 90 or 92 per cent. of tin, part of which is sent to Hong Kong to be refined. In 1913 refining works of German design were completed near the Kochiu mines, but have not proved very successful.

The exports to Hong Kong do not represent the total output of tin in China, nor yet the quantity of Chinese tin which reaches the European and American markets. About one-third is returned to China in a refined state, as shown in Table 64. The imports of tin-plate into China are from 20,000 to 25,000 tons in normal years. Most of this was of British origin until recently; but in 1917 the United States supplied 68 per cent. of the total.

Some 90 per cent. of the tin exported is produced in the Mengtze district of Yunnan. Here are situated the Kochiu mines, 20 miles from Mengtze, which are worked by native methods and employ 30,000 men. The production of tin at these mines in the years 1912 to 1916 is said to have been 8,234, 7,636, 6,681, 7,405, and 6,862 tons respectively. In eastern Kwangsi are the Ho Yuan mines at Hohsien and the Fuchuan mines; in Hunan the mines of An Yuan, Lenshee and Shanwha-ling; and in Hainan the Niutsongling mines near Nodoa. The Kowloon extension, Hong Kong, also contains tin ore.

The tin lodes of Kochiu are said to be connected with pegmatite of post-Triassic age, and traverse limestones. Copper and iron sulphides, sometimes arsenical, occur at depth, but near the surface the limestone weathers to a red clay containing tinstone free from sulphides. At Fuchuan and Lenshee the ore is found in a sandy soil overlying granite near its junction with limestone. Pipes and caves in the limestone are also worked. The yearly output of the Fuchuan district is said to be about 150 tons of metal; it generally assays over 98 per cent. tin, and is used by the refiners in Hong Kong to improve the grade of the Yunnan tin. The workings at Shanwha-ling follow pipes in limestone close to a granite intrusion; pyrrhotite and pyrite are abundant, and tourmaline, fluorite, zinc-blende and galena also occur.

In the Tungchwan district, Yunnan, a lode of stannite is worked. The metal obtained on smelting is known as perhtung or white copper, and contains 42·57 per cent. of tin, 49·7 of copper, 1·3 of sulphur, and 1·8 of lead.

Dutch East Indies.—The tin-producing islands of the Dutch East Indies are Banka, close to the east coast of Sumatra, Billiton, south-east of Banka, and Singkep, a small island

north-west of Banka. Sumatra also possesses tin deposits, especially in Siak. The output of the three islands is given in the following table:—

Table 65

Output of Tin in the Dutch East Indies

In tons (2,240 lb.)

—	1910.	1911.	1912.	1913.	1914.
Banka . . .	16,374	15,180	14,833	15,457	14,226
Billiton . . .	4,469	4,081	4,382	4,540	5,111
Singkep . . .	399	855	625	661	821
Total . . .	21,242	20,116	19,840	20,658	20,158

According to *The Ironmonger Metal Market Year Book* the production in Banka was 13,229 tons in 1915–16 and 14,522 tons in 1916–17, while that of Billiton was 5,691 tons in the former year.

In Banka tin mining is carried on by the Government. The ore deposits are almost exclusively alluvial and are worked in open pits by Chinese coolies, either under contract or under direct Government supervision. The ore is smelted locally in blast furnaces, or sent to central smelters which exist in some districts. Before the war Banka tin was all sold by auction in Holland, with the exception of small amounts sold in Batavia or used for Government services. To prevent the tin reaching Germany during the war, the supplies to Holland were limited by the Allies, and much of the Banka tin came direct to England and the United States. In Billiton and Singkep private companies work the tin deposits, and a large part of the ore obtained is smelted at Singapore.

The three islands lie on the south-easterly extension of the axis of the Malay Peninsula. The primary tin deposits are in granites and ancient sediments, and consist more of impregnations than true veins. The granite enclosing them is altered to greisen containing cassiterite and topaz, while the veins contain cassiterite, pyrite, wolframite, tourmaline, magnetite and sometimes siderite.

There is some lode mining, but most of the tin ore is obtained from detrital deposits. These are of two kinds: *kulit*, or eluvial deposits on the hillsides, and *kollong*, or alluvial deposits in the valleys. The former result from the weathering of the

rocks almost *in situ*, and sometimes contain great masses of cassiterite weighing nearly a ton. In the valley deposits the tin is practically confined to a rich zone known as *kaksa*, which rests immediately on the bed-rock (*kong*) and is covered by barren sand and clay to a depth of 12 to 50 feet. The *kaksa* is commonly from 4 to 10 inches thick, though it may be as much as 3 feet. It consists chiefly of grains and blocks of quartz with some clay, and contains tourmaline, muscovite, hornblende, topaz and corundum, as well as cassiterite, wolframite, scheelite, magnetite, monazite and sometimes gold. This material, which often contains 2 to 4 per cent. of cassiterite, is washed and concentrated to a 68–73 per cent. metallic tin content, and the concentrate is often smelted on the spot. Some lode-mining is carried on in Billiton, and off the coast of Singkep stanniferous deposits are worked by dredges. In addition to tin, Billiton yields some wolfram ore and Singkep a little gold.

Tin mining in Banka began in 1718, and the island is said to have yielded some 500,000 tons of tin up to the present. The Billiton deposits were not exploited on a large scale till the middle of last century, and those of Singkep about thirty years later.

INDO-CHINA.—This French colony produces small amounts of tin ore, part of which is smelted locally and part exported to France and elsewhere. A large amount of crude tin from Yunnan also passes through the country on its way to the refineries at Hong Kong. No production figures are available, but the exports are given below.

Most of the tin ore comes from the neighbourhood of Kao-Bang, in the north of Tonkin, where it occurs with wolfram ores in eluvial and alluvial deposits. These are derived from veins of quartz with cassiterite and wolframite in granite.

Table 66.

Exports of Tin Ore (of Domestic Origin) from Indo-China

In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.
Hong Kong . .	—	6	50	33	11
France . . .	153	236	84	94	61
Belgium . . .	7	—	8	50	10
Total . .	160	242	142	177	82
Value . £	6,423	9,700	5,687	7,076	3,293

Table 67

Exports of Tin (of Domestic Origin) from Indo-China

In metric tons (2,204 lb.)

Countries to which Exported.	1910.	1911.	1912.	1913.	1914.
Hong Kong . .	17	1	—	287	—
France . . .	98	1	2	58	10
Other countries . .	—	—	3	—	—
Total . . .	115	2	5	345	10
Value . £	17,702	307	729	53,120	1,591

Table 68

Exports of Yunnan Tin in Transit to Hong Kong, etc.

In metric tons (2,204 lb.)

	1910.	1911.	1912.	1913.	1914.
Quantity . . .	5,760	6,358	8,040	6,610	4,645
Value . . £	887,074	979,150	1,238,184	1,018,004	715,352

Tin ore occurs also at Ban-ta-coua in Laos, in what appears to be an ancient alluvial deposit. Although water-worn, it is very impure; it is intimately mixed with limonite, and contains also arsenic, bismuth, molybdenum, lead and copper. The natives sink small shafts 30 feet deep or less, crush and pan the ore, and smelt it to a tin with 10 or 20 per cent. of impurities, or even to a tin-iron alloy which they use for weighting nets, etc.

JAPAN.—Japan has a small output of tin ore, but this meets only a fraction of her requirements, and about 1,200 tons of tin and 25,000 tons of tin-plate are imported in normal years. The following tables give the statistics so far as they are available :—

Table 69

Output of Tin Ore in Japan

	1910.	1911.	1912.
Quantity, metric tons (2,204 lb.) .	23	352	410
Value . . . . £	3,579	24,222	37,476

Table 70

Imports of Tin into Japan

In kin (1·3228 lb.)

Countries whence Imported.	1911.	1912.	1913.	914.*	1915.*	1916.*	1917.*
Hong Kong . .	96,932	124,753	142,749	—	—	—	—
Straits Settlements	1,557,948	1,615,813	1,384,991	—	—	—	—
China . . .	141,187	135,769	346,686	—	—	—	—
Other countries .	55,824	129,126	82,350	—	—	—	—
Total . kin	1,851,891	2,005,461	1,956,776	2,183,703	1,989,540	1,839,190	3,377,701
,, *tons*	1,094	1,185	1,156	1,290	1,175	1,086	1,995
Value . £	196,595	211,516	236,865	210,609	186,697	183,397	385,954

* Details not available.

The chief mine is that of Taniyama in the province of Satsuma. Other mines in the extreme south (Kyushu) are those of Nagao in the province of Osumi, Iwato and Mitate in Hyuga, and Kiura in Bungo, while there are productive placer deposits at Taniyama and, nearer to the centre, at Nayegi in Mino and at Sudzukoya in Hitachi.

At Taniyama the veins traverse a Tertiary tuff; they average about a yard in width, and some reach a length of one mile. They consist of quartz with cassiterite and varying amounts of galena and pyrite. These veins have been worked almost continuously since 1655.

The veins near the border of Hyuga and Bungo appear to be connected with a quartz-porphyry which cuts Palæozoic limestones and quartzites. They are composed chiefly of pyrrhotite, sometimes with arsenopyrite, chalcopyrite or zinc-blende, while cassiterite occurs in quartz veinlets.

In the alluvial deposits of Nayegi in Mino the cassiterite is found close to the granite bed-rock, and is associated with quartz, topaz, corundum, wolframite, fergusonite, etc.

SIAM.—The tin deposits of Siam form part of the great tin-bearing belt which stretches from Banka through the Malay Peninsula into Burma, and are connected with the granite of the Main Range which forms the watershed of the peninsula.

As in the Malay States, the chief production is from detrital deposits on the west side of the Main Range, in Monthon Puket, while the east-coast Monthons of Chumporn, Nakorn Sitamarat and Patani produce far smaller amounts. Tin ore also occurs in small amount in the valley of the Nam Sak river and other places in the north of Siam.

In the year 1916–17 the output of dredging operations

amounted to 32 per cent. of the total production. The following table shows the output of tin by provinces :—

Table 71

Output of Tin in Siam in the years ending March 31, 1911–1917

In piculs (133⅓ lb.)

Monthons.	1910–11.	1911–12.	1912–13.	1913–14.	1914–15.	1915–16.	1916–17.
Chumporn . .	2,782	2,911	3,092	2,558	2,327	2,250	2,278
Nakorn Sitamarat .	2,547	1,279	1,564	2,156	2,025	2,462	3,653
Patani . . .	6,207	8,083	6,067	8,351	7,989	15,469	10,689
Puket . . .	70,719	87,354	99,901	100,297	98,390	130,994	130,739
Total piculs	82,255	99,627	110,624	113,362	110,731	151,175	147,259
,, . *tons*	4,896	5,930	6,587	6,748	6,591	8,999	8,765

Table 72 shows the amounts contributed by the various Muangs in the Monthon of Puket to the total exports, treated as metallic tin.

Table 72

Exports of Tin from the Monthon of Puket in the years ending 31st March, 1911–14

In tons (2,240 lb.)

Muangs.	1910–11.	1911–12.	1912–13.	1913–14.
Puket . . .	2,480·7	3,203	3,548	3,703·7
Pangnga . .	650·5	803·4	877·1	834·2
Renong . .	402·5	509	797·9	688·2
Takuapa . .	527	505·5	511·2	538·9
Trang . . .	123	178·7	216·4	205
Setul . . .	—	—	0·6	—
Total . .	4,183·7	5,199·6	5,951·2	5,970

Africa

Belgian Congo.—To the north of the copper-bearing belt of Katanga a tin-bearing belt extends in a north-east and south-west direction for over 100 miles. Promising deposits are known at Busanga, Muika, Kiambi, Muanga and Mulongo, and development work has been done at some of these localities. The cassiterite occurs, often in large crystals, in veins of quartz

and pegmatite cutting schist and granite. The Muika mine is said to have produced 10 tons of concentrates a month at the beginning of 1914, but operations were suspended on the outbreak of war.

At the Busanga ridge, between the Lualaba and Lufupa rivers, tin-bearing quartz veins occur in schist. Disintegration of the rocks has produced a mass of loose material fairly rich in tin.

PORTUGUESE EAST AFRICA.—Some of the concentrates from stream deposits in the territory of the Companhia de Moçambique, examined at the Imperial Institute, were found to contain small amounts of cassiterite. The streams in question flow over foliated granite. A recent discovery at Chimoio is said to be important.

SOUTH-WEST AFRICA.—This former German colony produced tin ore to the value of £31,568 in 1913. The tin-bearing belt extends from Otjimboyo, on the Khan River north-east of Karabib, through the Erongo Mountains in a north-westerly direction to Uis, which is east of the Brandberg and about fourteen miles south of the Ugab River. Cassiterite was first discovered in 1910 at Ameib, south of the Erongo Range, and further discoveries soon followed at Dawib, Aubinhonis, Tsomtsaub, Neineis, Uis, Kawab, Otjumue and Kohero East. At all these localities the mineral occurs in pegmatite intrusive in the ancient rocks and genetically connected with the older granites of the Erongo area. The pegmatite is usually a coarse-grained rock composed of quartz, felspars and pale greenish-white muscovite. The accessory minerals include tourmaline, garnet, magnetite and apatite, together with beryl at Ameib, wolframite, monazite, columbite and molybdenite at Dawib, and lepidolite at Kohero East. Tourmaline and cassiterite rarely occur together in the pegmatite. The cassiterite occurs sporadically in large grains and crystalline masses, sometimes of very large size, one mass found at Dawib having weighed 500 lb.

The results obtained from the opening up of the veins have been somewhat disappointing, owing to the patchy distribution of the ore in the pegmatite and the way in which many of the veins die out at comparatively shallow depths. The Kohero East Mine, however, was successful in producing about 120 tons of concentrates, averaging over 70 per cent. of metallic tin, before the outbreak of the war. This mine was only worked to a depth of 92 feet, below which the pegmatite disappeared completely.

Alluvial deposits and "float," formed from the erosion of the stanniferous pegmatites, occur at Chatputz (north-west of Ameib), Otjimboyo, Tsomtsaub, Aubinhonis, Neineis and Kawab. In general they were found to be poor and of slight extent, and most of the good ground appears to have been worked out. Occasional nuggets of gold were obtained at Neineis, Aubinhonis and Chatputz, and at the last-mentioned locality a large storage dam, to supply water for hydraulic working, was erected in 1913, but was destroyed during the recent campaign.

America

Bolivia.—Tin mining in Bolivia only began late in the nineteenth century, but the country now ranks second among producers. The output increased steadily up to 1913, and the export of barilla (tin ore concentrate containing about 60 per cent. metallic tin) in recent years is shown in Table 73 :—

Table 73

Exports of Tin Ore (Barilla) from Bolivia

In metric tons (2,204 lb.)

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Barilla . .	38,548	37,073	38,378	44,594	37,259	36,324	35,097	45,418
Tin contents (estimated at 60 per cent.) .	23,129	22,244	23,027	26,756	22,355	21,794	21,058	27,251

According to the British Legation at La Paz (*Met. Ind.* 1918, **13**, 27) the destination of the tin ore exported is as follows :—

Table 74

Exports of Tin Ore from Bolivia

In metric tons (2,204 lb.)

Country of Destination.	1914.	1915.	1916.	1917.
United Kingdom . .	35,957	35,358	32,569	Official figures not available.
Germany . . .	1,114	28	—	—
United States . .	20	1,101	2,884	—
Other countries . .	168	5	1,090	—
Total . . .	37,259	36,492	36,543	46,000

Only a small amount of metallic tin was smelted in Bolivia in the years preceding the war, the bulk of the barilla being shipped from Antofagasta, Mollendo and other Pacific ports. Most of it was sent to the United Kingdom, but a considerable amount went to Germany. The exports to Germany, which in 1913 amounted to about 35 per cent. of the total production, ceased on the outbreak of war. A fresh market for this ore was found in the United States, which took increasing amounts of the Bolivian exports in 1915 and 1916, most of the remainder going to the United Kingdom. Smelting works for Bolivian ore were erected at Perth Amboy, New Jersey, and others at Arica in Chile and La Paz in Bolivia.

The Bolivian tin mines are situated on the Eastern Cordillera and the high plateau between the Eastern and Western Cordillera, some of them being over 17,000 feet above sea-level. Three-quarters of the production come from the department of Potosi, and the most important mining centres, from north to south, are Araca, Oruro, Machacamarca, Huanuni, Llallagua, Uncia, Potosi, Sala Sala, Chocaya and Chorolque. The Uncia and Llallagua mines together produce over 40 per cent. of the total. The tin is often associated with silver ores, especially in the southern districts, and is connected with eruptive rocks of Tertiary age. The most important gangue mineral is quartz, which is sometimes accompanied by calcite and barite, but tourmaline, fluorite, topaz, apatite and lithia-mica are either absent or rare.

In addition to cassiterite and the silver minerals tetrahedrite, pyrargyrite, proustite, etc., there occur also pyrite, arsenopyrite, pyrrhotite, chalcopyrite, stibnite, galena, zinc-blende, stannite, bournonite and bismuth minerals, as well as the rare tin-bearing minerals plumbostannite, canfieldite, cylindrite and franckeite. The element germanium is present in the last three minerals and in argyrodite. The lodes have an oxidised gossan of considerable depth, which is rich in primary cassiterite and wood-tin formed from tin sulphides, and which often contains native silver and cerargyrite together with much iron oxide.

In the time of the Spanish domination, the mines of Bolivia were worked only for gold, silver, and copper. The tin ores were rejected, and accumulated on the dumps and in old stopes, forming valuable deposits. Where the tin and silver ores are in close association, it is usual to roast the ore and leach out the silver before concentrating the cassiterite on jigs and tables. At the present day, however, the bulk of the Bolivian tin ore

comes from simple tin lodes free from silver. The barilla as shipped to England usually contains about 80 per cent. oxide of tin, 16 per cent. oxide of iron, and 4 per cent. silica, sometimes with traces up to 1 per cent. of sulphur and antimony. Some of the mines have installed electro-magnetic separators to improve the grade of the concentrates. Some stream tin is obtained, as at Potosi, Uncia and Llallagua. The gravel at Uncia is up to 90 feet in thickness and is worked by shafts, as the cassiterite is mainly at the bottom.

Other South American States.—Chile and Peru export large quantities of tin ore mined in Bolivia, but apart from the last-named state there appears to be no appreciable production in South America. Tin deposits, many of them workable, are known to occur in many parts, and transport difficulties are the chief obstacle to the development of some of these deposits. In Argentina cassiterite occurs in granulite in the provinces of Catamarca and La Rioja.

Mexico.—Cassiterite is widely distributed in Mexico, and has been worked by the natives in Durango, Jalisco, Guanajuato, San Luis Potosi, Aguas Calientes and Coahuila. As in Bolivia, the mineral occurs in volcanic rocks of Tertiary age usually in rhyolites with porphyritic quartz and felspar, in rhyolite-tuffs, or occasionally in trachyte (Durango). It is found in fissures and fault-planes in mineralised belts in these rocks, sometimes limited between well-defined walls, sometimes impregnating the altered country rock for a considerable distance. Chalcedony is the commonest of the associated minerals, and others are quartz, opal, calcite, oxides of iron and manganese, fluorite, topaz, durangite (fluo-arsenate of sodium, aluminium and iron), wolframite and bismuth ores. Nodules of crystalline cassiterite are found showing a radiating structure and weighing as much as 25 lb. Alluvial deposits also occur, as at Tepezala in Aguas Calientes.

Tin mining was carried on in the Aztec period and still continues on a small scale, the output of tin being under 50 tons a year. The ore is cobbed by hand to about $\frac{1}{4}$ inch, and washed first in a planilla (a hole in the ground with a sloping surface about 5 feet long draining to a cup-shaped hollow), and finally in a wooden batea. The dried concentrate usually contains 45 to 65 per cent. of tin. The blast furnaces are built of stone and clay, are only 2 feet 6 inches high, and have two bellows of ox-hide. The concentrate is smelted with charcoal and hard-head obtained by crushing and washing the

slag from previous operations. The metal produced contains from 90 to 96 per cent. of tin, and is sold locally.

UNITED STATES.—The United States is the largest consumer of tin in the world, taking about 40 per cent. of the world's output before the war and over 50 per cent. in 1916 and 1917. Nevertheless, its production of tin ore is insignificant, and it had till recently no tin-smelting industry, even the ore raised in the country being sent, for the most part, to the Straits Settlements for smelting. Its large requirements were met by tin imported in the metallic state, mostly from the Straits by way of England; but direct shipments from the Straits Settlements and the Dutch East Indies have increased during the war.

Table 75

Output of Tin Ore in the United States

In short tons (2,000 lb.)

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Quantity, short tons	59	66 *	107	84	104 *	102 *	232	254
Value . £	4,885	11,799	26,000	9,729	13,867	16,426	25,363	—

* Metallic equivalent.

Table 76

Imports of Tin Ore into the United States in the years ending June 30th, 1916 to 1918. Imports for previous years are not published

In tons (2,240 lb.)

Whence Imported.	1915–16.	1916–17.	1917–18.
South America	5,415	5,110	—
Central America	2	—	—
China	—	10	—
Total . . . tons	5,417	5,120	14,816
Value . . . £	571,899	584,435	2,144,013

The war rendered uncertain the supply of tin from British sources, and at the same time stopped the export of Bolivian ore to Germany. These circumstances have resulted in the

establishment of a considerable tin-smelting industry in the United States, treating Bolivian ore, the purer ores from British sources not being available for smelting outside the British Empire. Electrolytic refining of the tin is being tried. The first tin-smelting works, excluding an unfortunate attempt in the past, began operations at Perth Amboy, New Jersey, early in 1916, and is reported to have produced 3,800 tons of metal from Bolivian concentrates during that year. Other plants constructed or planned by American companies, both in the United States and in Bolivia or Peru, have an estimated capacity of some 35,000 tons of metal annually, which exceeds the present ore-output of Bolivia and also the smelting capacity of Great Britain. So great an expansion of the world's smelter capacity, accompanied as it is by diminishing ore production, must lead to keen competition for ore in the immediate future. The output of tin ore in the United States is given in Table 75, and Table 76 shows the imports of ore.

Table 77 shows the imports of tin. The figures for 1912–13 were the largest on record, but those for 1915–16 are 25 per cent. higher than these. Including tin in ore the total imports for 1917–18 are estimated at 78,100 short tons. In 1916 the production of tin-plate amounted to 1,383,200 short tons, or double the production in 1909, and 260,930 short tons of plate were exported in the fiscal year 1916–17.

Alaska is the only commercial producer of tin ore, about two-thirds of the output in 1916 coming from dredges in the York district, and the remainder from gold-tin placers in the Hot Springs district on the Lower Tanana. There is also some lode mining on the Lost River. Stream tin was first discovered in 1900 on Buhna Creek, near York, some twelve miles south-east of Cape Prince of Wales in the western part of the Seward Peninsula.

In this district the placer deposits of Buck Creek and Lost and Anikovik Rivers have been the chief producers, the last named yielding gold as well as tin ore. Lode mining has been carried on, to a small extent, at Cape Mountain and on the Lost River, and lodes are also known to exist at Ear Mountain, Buck Creek, Brooks Mountain and other localities. In the Lost River region, dykes of quartz-porphyry in limestone contain irregular seams and stringers of quartz and lithia-mica, with which are associated cassiterite and wolframite. Pyrite, arsenopyrite, galena, zinc-blende and molybdenite are sometimes present, and the chief gangue minerals are fluorite, zinnwaldite and topaz. On Brooks Mountain, at the head of

Table 77

Imports of Tin into the United States in the years ending June 30th, 1910–1917

In short tons (2,000 lb.)

Countries whence Imported.	1909–10.	1910–11.	1911–12.	1912–13.	1913–14.	1914–15.	1915–16.	1916–17.
United Kingdom	28,305	30,204	33,055	26,170	26,515	22,954	20,865	20,973
Straits Settlements	18,837	15,089	16,638	25,422	19,579	21,577	40,804	28,110
Hong Kong	542	918	954	1,563	1,135	369	2,050	2,536
Canada	32	89	94	57	36	161	44	117
Australia	160	568	235	201	146	130	168	1,493
Total from British Possessions	47,876	46,868	50,976	53,413	47,411	45,191	63,931	53,229
Austria-Hungary	—	29	56	28	—	—	—	—
Belgium	1	3	11	392	—	—	—	—
France	45	69	511	185	127	—	80	—
Germany	2,228	2,622	1,983	1,543	2,054	251	—	—
Netherlands	417	2,079	2,025	1,764	413	146	—	—
China	—	—	—	13	28	11	679	2,168
Dutch East Indies	—	—	—	—	28	1,815	7,113	12,944
Other Foreign Countries	—	50	40	20	28	18	189*	447†
Total from Foreign Countries	2,691	4,852	4,626	3,945	2,678	2,241	8,061	15,559
Total	50,567	51,720	55,602	57,358	50,089	47,432	71,992	68,788
Value £	6,431,152	7,903,329	9,627,958	11,065,124	8,213,016	6,412,004	10,599,354	11,457,520

* Including 118 tons from Japan and 68 tons from South America.

† ,, 364 ,, ,, ,, ,, 46 ,, ,, ,, ,,

the Lost River, the tin-iron borates hulsite and paigeite occur in limestone metamorphosed by a granite intrusion.

In the Yukon basin the placer deposits of Sullivan Creek, Tanana River, in the Hot Springs district, yield cassiterite and gold, and stream tin also occurs in the Circle and Ruby districts. A small amount of the Alaskan tin concentrates has been smelted at Seattle; some has been sent to Swansea; but the greater part has been shipped to Singapore for treatment.

On the borders of North and South Carolina, at Gaffney, King's Mountain and Lincolnton, small amounts of tinstone have been obtained from alluvial deposits and from pegmatite dykes which traverse decomposed gneiss. The Black Hills of South Dakota and Wyoming include two tin-bearing regions, Spearfish and Tinton in the north and Harney Peak in the south, in both of which mining operations have had disappointing results. In Texas veins and impregnations in granite have been mined on the east slope of Mount Franklin, ten miles north of El Paso. The concentrate was smelted on the spot in a small oil-fired reverberatory furnace, and the output was 3 tons of block tin in 1910 and 4 tons in 1911.

In Lander County, Nevada, mammillary cassiterite occurs with hæmatite, chalcedony, opal, tridymite and quartz in Tertiary rhyolite. Tinstone also occurs in veins in the Shenandoah valley, Virginia, in San Diego County, and at Temescal, California, and at a number of other localities.

The recovery of "secondary tin," mainly from clean tin scrap, and to a less extent from old tin cans, etc., is an important industry in the United States. In 1916 the amount thus recovered was about 24 per cent. of the tin imported into the country, the amount being 17,400 tons valued at £3,152,300. The quantity recovered as tin was 7,600 tons, and that in alloys and chemical compounds 9,800 tons. The latter consisted mainly of tin chloride, with some tin oxide, putty powder, etc., and alloys such as babbitt metal, bronze, solder, pewter and electrotype metal.

REFERENCES TO LITERATURE ON TIN

General

Beck, R.—The Nature of Ore Deposits, translated by W. H. Weed. *The Engineering and Mining Journal*, New York and London, 1905.

Beyschlag, F., J. H. L. Vogt and P. Krusch.—The Deposits of the Useful Minerals and Rocks, translated by S. J. Truscott. Macmillan & Co., London, 1914–16.

Colonial Reports. H.M. Stationery Office, London.

Davies, D. C.—A Treatise on Metalliferous Minerals and Mining. Crosby Lockwood, London, Sixth Edition, 1901.

De Launay, L.—Gîtes Minéraux et Métallifères. Ch. Béranger, Paris et Liège, 1913.

Diplomatic and Consular Reports. H.M. Stationery Office, London.

Fawns, S.—Tin Deposits of the World. *Mining Journal*, 1905.

Ferguson, H. G., and A. M. Bateman.—Geologic Features of Tin Deposits, *Econ. Geol.*, 1912, **7**, 209.

Gowland, W.—The Metallurgy of the Non-ferrous Metals. Griffin, London, Second Edition, 1918.

Grünwald, J. (translated by H. H. Hodgson).—The Raw Materials for the Enamel Industry. Griffin, London, 1914.

Home Office.—Mines and Quarries. Part IV. Colonial and Foreign Statistics. H.M. Stationery Office. Annual.

Jones, W. R.—Tin and Wolfram Ores, *Mining Magazine*, 1917, **17**, 230.

Lacroix, A.—Minéralogie de la France et de ses Colonies. Baudry et Cie., Paris, 1893–1913.

Lindgren, W.—Mineral Deposits. McGraw Hill Book Co., New York and London, 1913.

Metal Statistics. American Metal Market Co., New York. Annual.

Mineral Industry. McGraw Hill Book Co., New York and London. Annual.

Phillips, J. A., and H. Louis.—A Treatise on Ore Deposits. Macmillan & Co., Second Edition, 1896.

Ries, H.—Economic Geology. John Wiley, Fourth Edition, 1916.

Singewald, J. T., Jr.—Some Genetic Relations of Tin Deposits, *Econ. Geol.*, 1912, **7**, 263.

Steinhart, O. J.—The Sale of Tin Ores, *Min. Mag.*, 1912, **6**, 202.
Thibault, P. J.—Metallurgy of Tin. Pitman, London, 1908.
Thomas, H. H., and D. A. MacAlister.—The Geology of Ore Deposits. Arnold, London, 1909.
Turner, T.—Tin: Thorpe's Dictionary of Applied Chemistry. Longmans, London, 1913.
Symposium on the Conservation of Tin. *Chem. and Met. Eng.*, 1918, **19**, 656.

United Kingdom

Statement of the Trade of the United Kingdom with Foreign Countries and British Possessions. H.M. Stationery Office. Annual.
Home Office.—Mines and Quarries. Part III, Output. H.M. Stationery Office. Annual.
Flett, J. S., and C. T. Clough.—Magnetite with Tinstone from Rossshire, *Summ. Prog. Geol. Survey for* 1903, 1904, p. 58.
Hill, J. B., and D. A. MacAlister.—The Geology of Falmouth and Truro and of the Mining District of Camborne and Redruth. *Mem. Geol. Survey*, 1906.
MacAlister, D. A.—Geological Aspects of the Lodes of Cornwall, *Econ. Geol.*, 1908, **3**, 363.
Maclaren, M.—The Geology of the East Pool Mine, *Min. Mag.*, 1917, **16**, 245.
Reid, C., and others.—The Geology of the Land's End District. *Mem. Geol. Survey*, 1907.
—— —— The Geology of the Country around Tavistock and Launceston. *Mem. Geol. Survey*, 1911.
—— —— The Geology of Dartmoor. *Mem. Geol. Survey*, 1912.
Ussher, W. A. E., and others.—The Geology of the Country around Bodmin and St. Austell. *Mem. Geol. Survey*, 1909.

Ceylon

Imperial Institute Report on the Results of the Mineral Survey of Ceylon, 1904–5. Colonial Reports—Miscellaneous No. 37 [Cd 3190], 1906, 36, 40.
—— —— —— 1905–6. Col. Rept. Misc. No. 42 [Cd 3762], 1907, 11, 13, 14, 16, 19, 29, 30.
—— —— —— 1906–7 and 1907–8. Col. Rept. Misc. No. 74 [Cd 5390], 1910, 10.
—— —— —— Col. Rept. Misc. No. 87 [Cd 7175], 1914, 4.
Coomaraswamy, A. K.—Mineralogical Survey Report. Ceylon Administrative Report for 1904, E. 10.
—— —— —— for 1905, E. 9.

Hong Kong

Administrative Reports. Hong Kong. Annual.
Colonial Reports. Annual. H.M. Stationery Office, London.

India

Mineral Production of India. *Rec. Geol. Surv. India.* Annual.
Quinquennial Review of Mineral Production for the years 1909 to 1913. *Rec. Geol. Surv. India*, 1915, **46**.
Ball, V.—Geology of India. Part III. Economic Geology. *Geol. Surv. India*, 1881.
Bleeck, A. W. G.—Wolframite in Tavoy. *Rec. Geol. Surv. India*, 1913, **43**, 48.
Brown, J. C.—The Cassiterite Deposits of Tavoy. *Rec. Geol. Surv. India*, 1918, **49**, 23.
Hayden, H. H. (Tin at Nurunga, Hazaribagh district).—General Report for 1911. *Rec. Geol. Surv. India*, 1912, **42**, 79.
Holland, Sir T. H. (Mergui District).—General Report for 1907, 1908. *Rec. Geol. Surv. India*, 1908, **37**, 38, and 1909, **38**, 53.
Hughes, T. W. H.—Tin-mining in Mergui District. *Rec. Geol. Surv. India*, 1889, **22**, 188.

Malaya

Federated Malay States. Report on the Administration of the Mines Dept., etc. F.M.S. *Government Gazette.* Annual.
Malay States. Report on the Federated Malay States. F.M.S. *Government Gazette*; also H.M. Stationery Office. Annual.
—— —— Reports on the Unfederated Malay States under British Protection. H.M. Stationery Office. Annual.
Negri Sembilan Administration Report. F.M.S. Government Printing Office, Kuala Lumpur. Annual.
Pahang Administration Report. F.M.S. Government Printing Office, Kuala Lumpur. Annual.
Perak Administration Report. F.M.S. Government Printing Office, Kuala Lumpur. Annual.
Selangor Administration Report. F.M.S. Government Printing Office, Kuala Lumpur. Annual.
Straits Settlements. Return of Imports and Exports. Singapore. Annual.
Belfield, H. C.—Handbook of the Federated Malay States. Stanford, London, Third Edition, N.D.
Brelich, H.—Mining in Trengganu, *Min. Mag.* 1915, **13**, 263.
Collet, O. J. A.—L'Étain: Étude Minière et Politique sur les États Fédérés Malais. Falk, Brussels, N.D.
Graham, W. A.—Kelantan: a State of the Malay Peninsula. MacLehose, Glasgow, 1908.
Jones, W. R.—The Origin of the Secondary Stanniferous Deposits of the Kinta District, Perak, *Quart. Journ. Geol. Soc.*, 1917, **72**, 165.
——Mineralisation in Malaya, *Min. Mag.*, 1915, **13**, 195 and 322.

Scrivenor, J. B.—Geologist's Report of Progress, Sept. 1903—Jan. 1907. F.M.S. Government Press, Kuala Lumpur, 1907.
—— Geologist's Annual Report. F.M.S. Government Press, Kuala Lumpur.
—— The Geology and Mining Industries of Ulu Pahang. F.M.S. Government Printing Office, Kuala Lumpur, 1911.
—— The Geology and Mining Industry of the Kinta District, Perak. F.M.S. Government Printing Office, Kuala Lumpur, 1913.
—— Notes on Prospecting for Tin Ore in the Federated Malay States. F.M.S. Government Press, Kuala Lumpur, 1911.
—— The Origin of Tin Deposits. F.M.S. Government Printing Office, Kuala Lumpur, 1909.
—— The Deposits of Tin Ore in the Limestone of the Kinta Valley, Perak. Times of Malaya Press, Ipoh, 1914.
—— On an Occurrence of Native Copper with Tin Ore in the Federated Malay States, *Mineralogical Magazine*, 1908–10, **15**, 299.
—— The Lahat "Pipe," *Quart. Journ. Geol. Soc.*, 1909, **65**, 382.
—— The Tourmaline-Corundum Rocks of Kinta, *Quart. Journ. Geol. Soc.*, 1910, **66**, 435.
—— The Gopeng Beds of Kinta, *Quart. Journ. Geol. Soc.*, 1912, **68**, 140.
—— The Geological History of the Malay Peninsula, *Quart. Journ. Geol. Soc.*, 1913, **69**, 343.
—— Notes on Cassiterite in the Malay Peninsula, *Mineralogical Magazine*, 1911, **16**, 118.
—— Malayan Geology, *Mining Mag.*, 1918, **19**, 254.
Warnford-Lock.—Mining in Malaya for Gold and Tin. Crowther & Goodman, London, 1907.
Wright, A., and T. H. Reid.—The Malay Peninsula. Fisher Unwin, 1912.

Gold Coast

Kitson, A. E.—*Rep. Geol. Surv.*, 1914, p. 7.
—— *Rep. Geol. Surv.*, 1915, p. 7.

Nigeria

Blue Book: Colony and Protectorate of Nigeria. Govt. Printer, Lagos. Annual.
Colonial Reports.—Nigeria. H.M. Stationery Office, London. Annual.
—— Miscellaneous. Imperial Institute Reports on the Mineral Survey of Northern Nigeria, [Cd 2875] 1906, [Cd 3914] 1908, [Cd 3915] 1908, [Cd 4719] 1909, and [Cd 5899] 1911.
—— Imperial Institute Report on the Mineral Survey of Southern Nigeria [Cd 2876], 1906.

Calvert, A. F.—Nigeria and its Tin Fields. Stanford, London, 1912.
Canning, A. R.—The Alluvial Tin Properties belonging to the Northern Nigeria (Bauchi) Tin Mines, Ltd., *Min. Mag.*, 1918, **18**, 176.
Falconer, J. D.—The Geology and Geography of Northern Nigeria. Macmillan, London, 1911.
—— Nigerian Tin, its Occurrence and Origin, *Econ. Geol.*, 1912, **7**, 542.
Nicholls, H. E.—The Nature of Nigerian Tin Deposits, *Min. Mag.*, 1916, **14**, 321.
Thomas, W. E.—Tin Deposits in Nassarawa, Nigeria, *Min. Mag.*, 1918, **19**, 240.

Nyasaland

Colonial Reports.—Miscellaneous. Imperial Institute Reports on the Results of the Mineral Survey, [Cd 3916] 1908, [Cd 4908], 1909.

Rhodesia

Rhodesia Chamber of Mines, Bulawayo. Annual Report.
Southern Rhodesia. Report of the Secretary for Mines. Govt. Printer, Salisbury, Rhodesia. Annual.
Rhodesia Munitions and Resources Committee. Interim Report for the Period ended June 30th, 1916. Bulawayo, 1916.
Maufe, H. B.—The Geology of the Victoria Tin Field. Rep. Dir. Geol. Surv. S. Rhodesia for 1911. Argus Publishing Co., Salisbury and Bulawayo, 1912.
—— Geological Notes on the Enterprise Tinstone, *Rhodesian Mining Review*, 1911, **7**, 559.
Zealley, A. E. V.—The Mineral Resources of Rhodesia. Appendix to Ninth Ann. Rep. of the Rhodesia Museum, Bulawayo, 1910.

Union of South Africa

Report of the Government Mining Engineer. Government Printing Office, Pretoria. Annual.
Trade and Shipping of the Union of South Africa and of Southern and Northern Rhodesia. Government Printing Department, Cape Town. Annual.
Hatch, F. H.—Report on the Mines and Mineral Resources of Natal. Clay, London, 1910.
Humphrey, W. A.—On a Portion of the Bushveld bordering the Crocodile River and including the Rooiberg Tinfield. *Rep. Geol. Surv. for* 1908. Govt. Printing Office, Pretoria, 1909.
Johnson, J. P.—The Ore Deposits of South Africa. Part I. Crosby Lockwood, London, 1908.

Kynaston, H.—Geological Survey Report for 1911. Govt. Printing Office, Pretoria, 1912.
—— On a Portion of the Waterberg District West and North-west of Warmbaths. *Rep. Geol. Surv. for* 1909. Pretoria, 1910.
—— and E. T. Mellor.—The Geology of the Waterberg Tinfields. Geol. Surv. Transvaal, Mem. No. 4. Govt. Printing Office, Pretoria, 1909.
—— —— The Geology of the Country round Warmbaths and Nylstroom, including the Rooiberg Tinfields. Geol. Surv. Pretoria, 1912.
—— —— and A. L. Hall.—The Geology of the Country round Potgietersrust. Geol. Surv. S. Africa, Explanation of Sheet 7. Govt. Printing Office, Pretoria, 1911.
Mellor, E. T.—On a Portion of the Waterberg District West of Potgietersrust. *Rep. Geol. Surv. for* 1908. Govt. Printing Office, Pretoria, 1909.
—— The Geology of a Portion of the Waterberg District North of Nylstroom. *Rep. Geol. Surv. for* 1909. Pretoria, 1910.
Rogers, A. W., and A. L. Du Toit.—The Geology of Cape Colony. Longmans, London, Second Edition, 1909.
Trevor, T. G.—Article on "Tin" in the Official Year Book of the Union of South Africa. Pretoria, 1918.
Wagner, P. A.—Notes on the Tin Deposits in the Vicinity of Cape Town, *Trans. Geol. Soc. S. Africa*, 1909, **12**, 102.

Swaziland

Colonial Office Reports.—Swaziland. H.M. Stationery Office. Annual.
Garrard, J. J.—Hydraulic Tin Mining in Swaziland. *Bull. Inst. Min. and Metall.*, No. 149, 1917.
Hall, A. L.—Notes on the Tin Deposits of Embabaan and Forbes Reef in Swaziland, *Trans. Geol. Soc. S. Africa*, 1913, **16**, 142.

Canada

Report on the Mineral Production of Canada. Canada Dept. of Mines, Mines Branch. Annual.
Summary Report of the Geological Survey, Department of Mines, for 1907, 1908, 1910, 1911, and 1912.
Johnston, R. A. A.—A List of Canadian Mineral Occurrences. Canada Geol. Surv., Memoir 74. No. 61, Geological Series, 1915.

Australia

Record of Mining in the Northern Territory of South Australia. Adelaide, 1900.
Report of the Department of Mines, New South Wales. Annual.
—— —— —— —— Western Australia. Annual.

Report of the Secretary for Mines, Tasmania. Annual.
—— —— —— —— Victoria. Annual.
Report of the Under Secretary for Mines, Queensland. Annual.
Report of the Administrator, Northern Territory. Annual.
Ball, L. C.—Tin, Copper, and Silver Mining in the Stanthorpe District. Geol. Surv. Queensland, Pub. 191, 1904.
—— Gold, Platinum, Tinstone and Monazite in the Beach Sands of the South Coast. Geol. Surv. Queensland, Pub. 198, 1905.
—— The King of the Ranges Tin Mine, Watsonville. Geol. Surv. Queensland, Pub. 222, 1910.
—— The Etheridge Mineral Field (the Potentialities of the Southern Portion). Geol. Surv. Queensland, Pub. 245, 1915.
Bathurst, F. H.—Mount Bischoff, *Min. Mag.*, 1910, **3**, 195.
Blatchford, T.—Mineral Resources of the North-West Division. Investigations in 1912. Geol. Surv. W. Australia, Bull. No. 52, 1913.
—— The King's Sound Tin Mine, West Kimberley. Geol. Surv. W. Australia, Bull. No. 59, 1914, p. 232.
Brown, H. Y. L.—Record of the Mines of South Australia. Govt. Printer, Adelaide, Fourth Edition, 1908, p. 310.
Cameron, W. E.—The Kangaroo Hills Mineral Field. Geol. Surv. Queensland, Pub. 167, 1901.
—— The Herberton Tin Field. Geol. Surv. Queensland, Pub. 192, 1904.
—— The Annan River Tinfield. Geol. Surv. Queensland, Pub. 210, 1907.
—— The Tin Lodes of Sandy Creek, Charters Towers District. Geol. Surv. Queensland, Pub. 235, 1911.
Carne, J. E.—The Tin-Mining Industry and the Distribution of Tin Ores in New South Wales. N.S.W. Dept. of Mines, 1911.
Conder, H.—The Tinfields of North Dundas. Dept. of Mines, Tasmania. Geol. Surv., Bull. No. 26, 1918.
Dunn, E. J.—Tin Ore on Wilson's Promontory. Rec. Geol. Surv. Victoria, Vol. II, Part 2, 1907, p. 103.
—— Tin Ore at Glen Wills. *Ibid.* p. 104.
—— Gold and Tin Workings at Tin Creek, near Buxton. *Ibid.* p. 105.
—— Tin Ore at Koetong and Cudgewa. *Ibid.* Vol. III, Part I, 1909, p. 90.
Dunstan, B.—The Stanhills Tinfields (near Croydon). Geol. Surv Queensland, Pub. 211, 1907.
Feldtmann, F. R.—The Ore Occurrences of the Kapanga Mine, Greenbushes Tinfield. Geol. Surv. W. Australia, Bull. No. 59, 1914, p. 156.
Godfrey, J. R.—The Ardlethan Tinfield. N.S. Wales Dept. of Mines, 1915.
Gregory, J. W.—The Mount Cudgewa Tinfield. Bull. Geol. Surv. Victoria, No. 22, 1907.

Herman, H.—Economic Geology and Mineral Resources of Victoria. Bull. Geol. Surv. Victoria, No. 34, 1914. (Reprinted from *Handbook to Victoria, Brit. Assoc. for the Advancement of Science, Australian Meeting*, 1914.)

Howitt, A. M.—The Toora Tin Deposits. Rec. Geol. Surv. Victoria, Vol. III, Part I, 1909, p. 54.

Kitson, A. E.—The Economic Minerals and Rocks of Victoria. Dept. of Mines, Victoria, 1906. Reprinted from the *Victorian Year-book for* 1905.

Liversidge, A.—Minerals of New South Wales. Trübner, London, 1888.

Maclaren, J. M.—On the Stannary Hills Tin Mines, Eureka Creek, Watsonville District. Geol. Surv. Queensland, Pub. 146, 1900.

Maitland, A. G.—The Geological Features and Mineral Resources of the Pilbara Goldfield. Geol. Surv. Western Australia. Reprint of Bulls. Nos. 15, 20, and 23, 1908.

—— Geological Investigations of parts of the Gascoyne, Ashburton, and West Pilbara Goldfields. Geol. Surv. Western Australia, Bull. No. 33, 1909.

—— and A. Montgomery.—The Geology and Mineral Industry of Western Australia. Geol. Surv. W. Australia, Bull. No. 50, 1912.

Pittman, E. F.—The Mineral Resources of New South Wales. Geol. Surv. N. S. Wales, 1901.

—— and A. G. Maitland.—Mining Fields of Australia. Brit. Assoc. Handbook for Australia, Melbourne, 1914.

Saint-Smith, E. C.—Geology and Mineral Resources of the Stanthorpe, Ballandean and Wallangarra Districts. Geol. Surv. Queensland, Pub. 243, 1914.

—— Geology and Mineral Resources of the Cooktown District Tinfields. Geol. Surv. Queensland, Pub. 250, 1916.

Simpson, E. S., and C. G. Gibson.—The Distribution and Occurrence of the Baser Metals in Western Australia. Geol. Surv. W. Australia, Bull. 30, 1907.

Skertchley, S. B.—On the Deep (Tin) Lead, Herberton. Geol. Surv. Queensland, Pub. 115, 1896.

—— On the Tin Mines of Watsonville, etc. Geol. Surv. Queensland, Pub. 119, 1897.

—— On the Geology of the Country round Stanthorpe and Warwick. Geol. Surv. Queensland, Pub. 120, 1898.

Twelvetrees, W. H.—Report on Cox's Bight Tinfield, Tasmania. Geol. Surv. 1906.

—— Report on the Renison Bell Tinfield, Tasmania. Geol. Surv. 1906.

—— The Scamander Mineral District, Tasmania. Geol. Surv., Bull. No. 9, 1911.

—— The Middlesex and Mount Claude Mining Field, Tasmania. Geol. Surv., Bull. No. 14, 1913.

Twelvetrees, W. H.—The Gladstone Mineral District, Tasmania. Geol. Surv., Bull. No. 25, 1916.
—— and L. K. Ward.—Geological Examination of the Zeehan Field, Tasmania. Geol. Surv., Bull. No. 7, 1909.
—— —— The Ore-bodies of the Zeehan Field, Tasmania. Geol. Surv., Bull. No. 8, 1910.
Ward, L. K.—The Tinfield of North Dundas, Tasmania. Geol. Surv., Bull. No. 6, 1909.
—— The Mount Balfour Mining Field, Tasmania. Geol. Surv., Bull. No. 10, 1911.
—— The Cross River Tinfield, Tasmania. Geol. Surv., Bull. No. 12, 1911.
Waterhouse, L. L.—The Stanley River Tinfield, Tasmania. Geol. Surv., Bull. No. 15, 1914.
—— The South Heemskirk Tinfield, Tasmania. Geol. Surv., Bull. No. 21, 1916.
Whitelaw, O. A. L., J. P. L. Kenny and J. G. Easton.—The Mitta Mitta Tin and Gold Field. Bull. Geol. Surv. Victoria, No. 37, 1915.
—— Notes on the Geology of the Greenbushes Tinfield (with special reference to the Deep Leads). Geol. Surv. W. Australia, Bull. No. 32, 1908.
Woodward, H. P.—The Geology and Ore Deposits of the West Pilbara Goldfield. Geol. Surv. W. Australia, Bull. No. 41, 1911.

New Zealand

Mines Statement. Govt. Printer, Wellington. Annual.
New Zealand Geological Survey, various Bulletins.
Handbook of New Zealand Mines. Govt. Printer, Wellington, 1887.
Binns, G. J.—Mining in New Zealand, *Trans. Fed. Inst. Min. Eng.*, 1892.

Austria-Hungary

Statistik des Auswärtigen Handels der Österr.-Ungar. Monarchie. Vienna. Annual.

France

Le Commerce de la France. Paris, Imprimerie Nationale. Annual.

Germany

Statistik des Deutschen Reichs, Berlin. Annual.
Singewald, J. T., Jr.—The Erzgebirge Tin Deposits, *Econ Geol.*, 1910, **5**, 166 and 265.

Portugal

Down, T. A.—Tin and Tungsten in Portugal, *Min. Mag.*, 1916, **14**, 19.

Russia

The Russian Year-Book. Eyre & Spottiswoode. Annual.

Spain

Preiswerk, H.—Über einige Zinnerzlagerstätten in Spanien und Portugal, *Zeit. f. prakt. Geol.*, 1913, **21**, 74.

China

The China Year-book. Routledge. Annual.

The Maritime Customs. Statistical Series. Shanghai. Annual.

Brown, G. E.—Visiting the Hunan Tinfields, *Min. Mag.*, 1915, **13**, 141.

Collins, W. F.—Tin Production in the Province of Yunnan, China, *Trans. Inst. Min. and Met.*, 1909–10, **19**, 187.

Wheler, A. S.—Metalliferous Mines of Hunan. *Min. and Sci. Press*, 1916, **112**, 337.

Yung, M. B.—Tin and Coal Deposits of the Fu Chuan District, China, *Bull. Amer. Inst. Min. Eng.*, 1914, **93**, 2451.

Dutch East Indies

Year-book of the Netherlands East Indies. Sub-dept. of Industry and Commerce, Buitenzorg, Java.

Indo-China

Statistiques de l'Industrie Minière dans les Colonies Françaises. Paris: Bureau de Vente des Publications Coloniales Officielles.

Japan

Mining in Japan. Bureau of Mines, Japan, 1909.

Siam

Statistical Year Book. Dept. of Commerce and Statistics. Annual.

Belgian Congo

Ball, S. H., and M. K. Shaler.—Economic Geology of the Belgian Congo, *Econ. Geol.*, 1914, **9**, 640.

Farrell, J. R.—The Copper and Tin Deposits of Katanga, *Eng. and Min. Journ.*, 1908, **85**, 747.

Guillemain, C.—Zur Kentnis der Lagerstätten in der Provinz Katanga, *Zeit. f. prakt. Geol.*, 1913, **21**, 335.

Portuguese East Africa

Companhia de Moçambique.—Mineral Survey Map, Explanatory Notes and Photographs.

South-west Africa

Calvert, A. F.—The German African Empire. Werner Laurie, 1916.

Dahms, A.—Über Erzlagerstätten in sauren Eruptivgesteinen Deutsch-Südwestafrikas, *Zeit. f. Prakt. Geol.*, 1912, **20**, 240.

Wagner, P. A.—The Geology and Mineral Industry of South-West Africa. Union of South Africa Mines Dept., Geol. Surv. Mem. No. 7. Govt. Printing Office, Pretoria, 1916.

Bolivia

Bancroft, H.—The Tin Situation in Bolivia, *Bull. Amer. Inst. Min. Eng.*, 1913, **81**, 2311.

Lewis, H. A.—The Berenguela Tin District, *Min. Mag.*, 1914, **11**, 369.

Lincoln, F. C.—Milluni Tin-Mining District, Bolivia, *Min. and Sci. Press*, 1915, **110**, 470.

—— Quimsa Cruz Tin District, Bolivia. *Ibid*, 721.

—— Potosi Tin-Mining District, Bolivia. *Ibid.* 1915, **111**, 127.

—— Oruro Tin-Silver District, Bolivia. *Ibid.* 1917, **115**, 57.

Rumbold, W. R.—The Origin of the Bolivian Tin Deposits, *Econ. Geol.*, 1909, **4**, 321.

Singewald, J. T., and B. L. Miller.—The Mining Industry of Bolivia, *Eng. and Min. Journ.*, 1916, **102**, 1005.

Walle, P.—Bolivia. Unwin, London, 1914.

Wepfer, G. W.—Tin Mining in Bolivia, *Min. and Sci. Press*, 1914, **108**, 251.

Mexico

Master, G. C.—Tin Mining in Mexico, *Min. Mag.*, 1913, **9**, 199.

Wittich, E.—Zinnerze in der Sierra von Guanajuato (Mexiko), *Zeit. f. Prakt. Geol.*, 1910, **18**, 121.

United States

Mineral Resources of the United States. Part I. U.S. Geol. Surv. Annual.

Statistical Abstract of the United States. U.S. Dept. of Commerce. Annual.

Collier, A. J.—The Tin Deposits of the York Region, Alaska. U.S. Geol. Surv., Bull. No. 229, 1904.

Eakin, H. M.—Tin Mining in Alaska. Mineral Resources of Alaska: Report on Progress of Investigations in 1914. U.S. Geol. Surv., Bull. No. 622, 1915, p. 81.

Hess, F. L.—The York Tin Region. Mineral Resources of Alaska: Report on Progress of Investigations in 1905. U.S. Geol. Surv., Bull. No. 284, 1906, p. 145.

—— Tin Resources of Alaska. Mineral Resources of Alaska: Report on Progress of Investigations in 1911. U.S. Geol. Surv., Bull. No. 520, 1912, p. 89.

Knopf, A.—Geology of the Seward Peninsula Tin Deposits, Alaska. U.S. Geol. Surv., Bull. No. 358, 1908.
—— Some Features of the Alaskan Tin Deposits, *Econ. Geol.* 1909, **4**, 214.
—— Wood Tin in the Tertiary Rhyolites of Northern Nevada, *Econ. Geol.* 1916, **11**, 652.
Weed, W. H.—The El Paso Tin Deposits. U.S. Geol. Surv., Bull. No. 178, 1901.

Printed by Hazell, Watson & Viney, Ld., London and Aylesbury, England.

IPERIAL INSTITUTE SERIES OF HANDBOOKS TO THE
OMMERCIAL RESOURCES OF THE TROPICS, WITH
SPECIAL REFERENCE TO BRITISH WEST AFRICA

UED UNDER THE AUTHORITY OF THE SECRETARY OF STATE FOR
THE COLONIES

EDITED BY WYNDHAM R. DUNSTAN, C.M.G., M.A., LL.D., F.R.S.
ECTOR OF THE IMPERIAL INSTITUTE; PRESIDENT OF THE INTERNATIONAL ASSOCIATION
FOR TROPICAL AGRICULTURE

HE AGRICULTURAL AND FOREST PRO-

DUCTS OF BRITISH WEST AFRICA. By GERALD C. DUDGEON, Consulting Agriculturist, Minister of Agriculture, Egypt; lately Inspector of Agriculture for British West Africa. Pp. x + 170. With Maps and Illustrations. Demy 8vo. Price 6s. net.

OCOA: Its Cultivation and Preparation. By

W. H. JOHNSON, F.L.S., Director of Agriculture in Southern Nigeria, and formerly Director of Agriculture in the Gold Coast and in the Territories of the Mozambique Company, Portuguese East Africa. Pp. ix + 186. With Illustrations. 6s. net.

CONTENTS: Historical—Botanical—Climatic Requirements of Cocoa Trees—Soil Requirements
he Cocoa Tree—Laying out a Cocoa Plantation—Shading and Inter-crops for Cocoa—Propaga-
—Planting, Cultivating, and Pruning—Manuring—Results of Manurial Experiments in Various
intries—Diseases—Vegetable Parasites and Epiphytes—Harvesting and Transporting Cocoa
ns to Fermenting-Houses—The Science of Cocoa Fermentation—Methods of Fermentation in
gue in Various Countries—Washing and Drying Cocoa—Yields and Expenditure—Commercial
oa; its Manufacture and Uses.

UBBER. By HAROLD BROWN, Technical Super-

intendent, Scientific and Technical Department, Imperial Institute. Pp. xiii + 245. With Illustrations. 6s. net.

CONTENTS: Introduction—Rubber in British Africa—The Principal Rubber-yielding Plants—
ex—The Tapping of Rubber Plants—The Preparation of Rubber—The Chemistry of Rubber—
tistics of Consumption and Prices—The Para Rubber Tree—The Ceara Rubber Tree—The
ican Rubber Tree—The African Rubber Vines—The Central American Rubber Tree—The
am Rubber Tree and Other Species of Ficus.

OTTON AND OTHER VEGETABLE FIBRES:

Their Production and Utilisation. By ERNEST GOULDING, D.Sc., F.I.C., Scientific and Technical Department, Imperial Institute. Pp. x + 231. With Illustrations. 6s. net.

CONTENTS: Introductory—Cotton—Cotton Production in the Principal Countries and the
ef Commercial Varieties—Cotton Growing in British West Africa and Other Parts of the
tish Empire—Flax—Hemp—Sunn Hemp—Ramie—Jute and Jute Substitutes—Manila Hemp—
hana Fibre—Sisal Hemp—Mauritius Hemp—Bowstring Hemp—New Zealand Hemp—Bro
ring Fibres—Flosses—Raffia—Paper-making Materials, etc.