IMPERIAL MINERAL RESOURCES BUREAU.

THE MINERAL INDUSTRY OF THE BRITISH EMPIRE

AND

FOREIGN COUNTRIES.

WAR PERIOD.

TUNGSTEN.

(1913-1919.)

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PREFACE.

The following digest of statistical and technical information relative to the production, consumption and value of Tungsten ores will form a part of the Volume or Volumes on the Mineral Resources of the British Empire and Foreign Countries constituting the Annual Mineral Conspectus of the Bureau.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included in respect of each year. Resort will also be had to graphical representation of statistics of production, consumption, costs and prices.

The weights are expressed in long tons, that is to say, the British statute ton of 2,240 lb., and values in pounds, shillings and pence at par rates of exchange.

The Governors are indebted to Dr. Coggin Brown for his valuable assistance in the preparation of this document.

R. A. S. REDMAYNE,

Chairman of the Governors.

2, Queen Anne's Gate Buildings,
London, S.W.1.

June, 1921.

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CONTENTS.

GENERAL.

The ore minerals of tungsten are wolframite and hübnerite (tungstates of iron and manganese), and scheelite (calcium tungstate). Of these wolframite (often called wolfram) is the most important. The proportions of iron and manganese in wolframite are variable, but iron predominates. The variety consisting of almost pure iron tungstate is known as ferberite, and is important as an ore mineral in Colorado, U.S.A. The difference between hübnerite and wolframite is that in the former manganese predominates over iron, and some specimens of hübnerite consist of almost pure manganese tungstate.

Wolframite is usually black, having a specific gravity about 7·5 and a hardness of about 5½. Hübnerite is reddish-brown. It has about the same hardness as wolframite, but a somewhat lower specific gravity (about 7·2). When pure, wolframite and hübnerite contain about 76 per cent. of tungstic oxide. Wolfram concentrates are sold on the basis of 65 per cent. tungstic oxide in the British Empire, and 60 per cent. tungstic oxide in the United States.

Scheelite is a white or yellowish mineral containing about 80 per cent. of tungstic oxide when pure. Its hardness is about 4½ and its specific gravity about 6.

Tungsten ores occur in veins associated with granites, and in the metamorphic rocks (slates, etc.) into which the granites intrude. They are found abundantly as loose surface deposits in most localities where these rocks have been disintegrated by weathering. Three kinds of occurrence have been distinguished : (1) loose surface deposits from which the mineral may be easily obtained by the application of hydraulic methods; (2) partly disintegrated veins near the surface, from which the mineral can be fairly easily mined; (3) deeper veins from which the mineral, often in association with cassiterite (tinstone), can only be obtained by the more systematic and expensive operations of underground mining, milling and concentration.

A large amount of concentrates have in the past been obtained in Burma from loose surface deposits, but vein-mining was begun before the war. The discovery of extensive surface deposits in China led to the production of tungsten ore in that country on a large scale during the later period of the war. Such deposits have a limited life, however, and sooner or later the more expensive methods of systematic mining have to be adopted to obtain supplies.

Pure tungsten is used in making filaments for incandescent electric lamps, contact points, voltage regulators, targets in X-ray tubes, and for electrodes in wireless and other thermionic valves and in the recently-introduced tungsten enclosed arc lamp.

It is obtained by reduction of the oxide with hydrogen. The total amount used for these purposes is very small.

The chief use of tungsten is in the manufacture of tool steels, especially those varieties known as "high-speed" steels. Tungsten steel is also used for making permanent magnets and the valves of internal combustion engines.

The essential difference between high-speed tool steel and ordinary carbon cutting-steel is that the former is able to withstand very much higher temperatures when cutting, *i.e.*, it can make deep cuts at high speeds. If the temperature of friction due to cutting reaches about 500° F., ordinary carbon steel tools begin to lose their hardness, and, as a consequence, the life of the tool on any high-speed cutting work is a very short one. With high-speed tools, the temperature may rise to, say, 1,150° F., or even higher, without the tool losing its cutting power, and such tools can consequently cut metals at speeds greatly exceeding anything obtainable with tools of ordinary carbon steel. This is especially important when it is essential that large quantities of metal should be removed in order to secure a rapid output. The execution of the shell program during the late war was possible only by the use of high-speed steel, and had this steel not been available, the output with the same amount of labour would have been halved.

The outstanding advantage is that, under favourable conditions, two or three times as much metal can be removed by high-speed tungsten steels as by simple carbon steels.

Tungsten steels containing suitable admixtures of other metals, such as chromium and vanadium, are not only exceedingly hard, but also maintain their strength and hardness at high temperatures. In a general way, it may be said that the chromium in these steels provides the hardness, while tungsten produces the self-hardening properties by raising the temperature at which tempering begins.

A finished high-speed steel, as employed for making the first-grade high-speed tools, contains from 10 to 20 per cent. of tungsten. Its qualities may be impaired or even destroyed by quite small quantities of certain other elements, such as tin, arsenic, or copper, or by excessive amounts of sulphur and phosphorus, or even manganese. This necessitates a corresponding degree of purity in the tungsten, the percentage of which is so high in the finished steel. The necessity for preparing the ores used in the metallurgy of tungsten as pure as possible need not be emphasized, as the cost of making pure tungsten from impure mineral is excessive.

High-speed steel is made either in crucible furnaces or in the electric furnace. In the former practice the correct percentages of iron and alloys are melted together, considerable skill and experience being necessary both in this operation and in the forging and rolling operations on the finished ingot. In electric furnace practice the process may consist of melting pure materials of the best quality, and thus using the furnace as a crucible, or, alternatively, melting ordinary materials and refining before adding the alloys.

Tungsten may be added to steel either in the form of metallic powder ("tungsten powder") or as an alloy with iron. Before the war, attempts were made to establish the manufacture of tungsten in England, but competition with the powerful German makers was found to be practically impossible, and steel-makers generally obtained their supplies from Germany, at an annual cost of about £300,000. In August, 1914, there was only a few months' stock of metallic tungsten in the United Kingdom, at the normal rate of consumption. Arrangements for the manufacture of tungsten were promptly made between the Government and an existing Committee of high-speed steel makers, and by July, 1915, the High Speed Steel Alloys Co., Ltd., commenced delivery. About the same time a number of other firms also embarked on the manufacture of the metal and of the alloy ferro-tungsten. By the end of 1915 four firms in England were producing metallic tungsten, two factories were making ferro-tungsten by heating pure wolfram and carbon in the electric furnace, and three factories were manufacturing the same alloy by an alumino-thermic process. These continued their operations during the war.

In the manufacture of tungsten powder for steel-making, the finely-ground pure ore is mixed with soda ash and heated in special furnaces to a bright red heat. The product is drawn out in a molten state, allowed to cool, and crushed. It is then boiled with water to dissolve the soluble tungstate of soda, while the oxides of iron, manganese, lime, etc., are insoluble and are separated by filtration. The sodium tungstate is next treated with hydrochloric acid, when insoluble tungstic acid is precipitated. This is filtered from the solution, dried and reduced to metal with carbon in graphite crucibles. The powder so produced contains about 98·5 per cent. of metallic tungsten.

Ferro-tungsten and other ferro-alloys are manufactured to a very considerable extent by the "thermit" process, in which reduction is effected by igniting a mixture of the powdered mineral and aluminium powder. In the case of ferro-tungsten, a proportion of scheelite is mixed with the wolfram to give a higher percentage of tungsten in the alloy, and to facilitate slagging.

Ferro-tungsten is also made by the reduction of wolfram or of scheelite, preferably a mixture of the two, by means of carbon in the electric furnace. The ores used must be practically free from sulphur and phosphorus. The alloy produced requires refining, which is carried out in an arc furnace, by melting under a slag of ferric oxide, lime and fluorspar. The ferric oxide eliminates carbon and silicon, the latter combining with the lime to form silicate of lime. The fluorspar is added as a flux.

Other applications of tungsten include its use for special cobalt-chromium alloys, as an alloy in dental surgical instruments and in gramophone needles. Its use as a catalyser has been suggested for the production of ammonia from atmospheric nitrogen and hydrogen, and for other synthetical operations. The sodium salts are used to saturate materials with the effect that if they catch fire they smoulder and do not blaze. Sodium tungstate and tungstic acid are also used as "resists" in certain dyeing operations.

WORLD'S PRODUCTION.

In 1910 the world's production of tungsten concentrates was about 6,000 tons, averaging 60 per cent. tungstic oxide (WO_3). The principal producing countries were the United States, Portugal, and Queensland, smaller quantities being obtained from Argentina, Bolivia, and New South Wales. By 1911, wolfram mining was thoroughly established in Tavoy, and an output of over 1,200 tons in that year made Burma the leading producer, a position maintained until 1916, when the United States and Bolivia took the lead. Other producing countries included Japan, China, Siam, the Malay States and Billiton (Dutch East Indies), the Northern Territory of Australia, Tasmania, New Zealand and Peru, while Germany, Austria, and other European countries contributed small quantities.

Although no large supplies of ore were available either in Germany or any of her possessions, she has been credited with the control of two-thirds of the world's production, *i.e.*, nearly 6,000 tons of 60 per cent. concentrates in 1913. In 1915 all the British Imperial supplies were secured for the Home Government at the fixed price of 55*s*. per unit of tungstic oxide (WO_3). This price was raised in 1917 to 60s. per unit. (The minimum and maximum prices for the years 1897 to 1914 were 9*s*. and 51*s*. respectively.) In Burma, as a result of the co-operation of the Government with the mining industry, the output increased from 1,688 tons in 1913 to 4,480 tons in 1917, and from the beginning of 1914 to the end of 1918 no less than 17,636 tons, having a total value of £2,322,000, were exported.

The United States output, under the stimulus of an uncontrolled price, which reached a maximum of $93 per unit, or six times the price offered in the British Empire, rose in 1917 to 5,486 tons of 60 per cent. concentrates, and there was a corresponding increase in all other producing countries, the world's production rising from about 8,000 tons in 1914 to 12,000 in 1915, 23,000 in 1916, 28,000 in 1917, and 35,000 in 1918. In 1917, China, which had hitherto been an insignificant producer, sent 1,300 tons into the market, and in 1918 the output rose to 9,000 tons, or more than the whole world's production for any one year before 1915.

The Dominions Royal Commission reported in 1917 that the output of tungsten ore in the British Empire was probably equal to the demand.

World's Production of Tungsten Ores.§

(In long tons of concentrates.)

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	182	205	331	394	241	302	166
Southern Rhodesia	4	—	—	3	11	33	18
Union of South Africa	—	—	3	8	8	17	4
Canada	—	—	—	—	—	12	—
India (including Burma)	1,688	2,326	2,645	3,693	4,542	4,431	3,576
Malaya:							
Federated Malay States (exports)	207	261	292	515	761	356	435
Unfederated Malay States	136	168	169	297	322	1,177	706
Australia:							
Wolfram and Scheelite	636	529	755	970	1,115	1,304	766**
Bismuth ore and Wolfram	182	193	247	137	131	114	140
New Zealand ...	210	222	216	258	199	143	123
Austria	51	56	14	135*	135*	135*	
France	120	120	100	125	200	165	170*
Germany*	285	90	135	310	180	180	
Portugal (exports)	1,332	910	873	1,102	1,586	1,160*	758
Spain	231	430	503	448	537	4,482	332
Mexico	—	—	—	12	185	147	22
United States ...	1,372	884	2,082	5,288	5,486	4,525	295*
Argentina (exports)	527	402	178	786	989	563	
Bolivia (exports) ...	278	272	780	2,987	3,827	3,363	1,963
Peru	285	193	369	515	399	239	
China*	—	20	35	110	1,340	9,375	
French Indo-China:							
Tungsten and Tin Ore	194	305	416	425	511	590	
Japan and Korea...	243	192	367	779	1,042	596‡	
Siam*	300	30	425	520	590		
Dutch East Indies	30	30	30	50	50	700	

* Estimated.
** Excluding Northern Territory.
‡ Japan only.

United Kingdom.†

Cornwall produces nearly all the tungsten ores obtained in Great Britain, although a few tons are produced annually in Devonshire and Cumberland. Wolfram is the commonest mineral. Scheelite, which is obtained mainly from Cumberland, constitutes only three per cent. of the total yearly output.

In Cornwall, wolfram is restricted in its occurrence to four well-defined districts and a few minor localities. The most important

§ Small amounts were also produced in Italy, Norway, Sweden, Brazil and Chile.

† Mines and Quarries: General Report with Statistics, Part III, by the Chief Inspector of Mines (Annual).

of these is in West Cornwall, between Scorrier and Camborne, especially the parish of Illogan, where the chief active mines, East Pool, South Crofty and Tincroft, are situated. The second is in the heart of St. Austell granite area. The third extends from Kit Hill to Gunnislake. The fourth embraces the north-eastern parts of Bodmin Moor. In these districts, wolfram generally accompanies cassiterite, but it also occurs alone, embedded in quartz and felspar. In some lodes it is associated with mispickel, chalcopyrite, quartz and fluorite. At Bodmin Moor it is also an habitual constituent of pegmatite veins.

In Cumberland the rocks in which the tungsten ores occur are, in descending order, gabbro, mica-schist and greisen,* veined with white quartz. Some of the veins carry pockets and occasionally thin streaks of wolfram and scheelite with various other minerals, such as galena, bismuth, molybdenite, tourmaline and pyrite. The veins are said to become narrower and less valuable when they pass upwards from the mica-schist into the gabbro.

Tungsten ore is generally a by-product in tin-mining operations in Cornwall and Devonshire.

Production of Tungsten Ores in the United Kingdom.

Year.	Quantity (long tons).	Value (£).
1913	182	17,483 (a)
1914	205	19,722
1915	331	41,996
1916	394	49,699
1917	241	39,742
1918	302 (b)	49,215
1919	166	19,255

(a) Value of 180 tons only.
(b) Includes 2 tons of scheelite concentrates containing 1 ton of metallic tin.

United Kingdom Imports and Exports.†

Year.	Tungsten Concentrates (long tons).		Ferro-tungsten (long tons).		Tungsten Powder (long tons).	
	Imports.	Exports.	Imports.	Exports.	Imports.	Exports.
1916 ...	7,115	628	15	345	65	18
1917 ...	8,081	1,015	28	131	29	—
1918 ...	9,086	1,044	—	45	1	—

* Greisen is an altered granite, consisting of a mixture of quartz and mica, usually with some topaz; cassiterite, fluorspar, tourmaline and other minerals are sometimes present.

† Figures supplied by the Ministry of Munitions through J. F. Ronca, of the Board of Trade.

Rhodesia.*

Both wolfram and scheelite are widely distributed throughout Rhodesia, and occur in some quantity at several localities. The former mineral has been worked at Essexvale more or less continuously since 1905, and has also been found in the Sabi valley, while scheelite was first worked in 1906, near Gatooma, where it occurs in a quartz reef in gneissose granite. The Essexvale mineral is said to be the manganiferous variety (hübnerite), and to be free from impurities.

According to A. E. V. Zealley,† the Essexvale tungsten ore deposits include sixteen distinct " reefs," eleven of which have had a little work done on them from time to time. They consist of greisen, composed chiefly of mica, fluorite, topaz, and secondary felspar. The " reefs " have long strike extensions up to a distance of one mile, and average three feet in width. The country rock is a coarse-textured and massive variety of hornblende-granite. A stockwork deposit of " streaks and seams of aplite containing gashes of quartz " scattered sporadically throughout a mass of hornblende-granite is also described, in which the aplite has been greisenized to varying degrees, with the production of wolfram and other minerals. Wolfram and scheelite are also won from the detrital ground or " rubble " in the vicinity of the outcrops, which are worked by hand or by means of rotary washers.

Production of Tungsten Concentrates in Southern Rhodesia.‡

Year.	Wolframite.		Scheelite.		Total.	
	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).
1913 ...	—	—	—	—	4	427
1914 ...	—	—	—	—	—	—
1915 ...	—	—	—	—	—	—
1916 ...	3	466	—	—	3	466
1917 ...	11	2,070	—	—	11	2,070
1918 ...	10	1,708	23	3,699	33	5,407
1919 ...	—	—	—	—	18	5,103

Union of South Africa.§

Tungsten mining in South Africa is of little significance, " tungsten ore " figuring in the Customs returns for the first

* Annual Reports of the Secretary for Mines, Southern Rhodesia. Annual Reports of the Rhodesian Chamber of Mines.

† Rhodesian Geological Survey : Short Report No. 1, 1917.

‡ Practically all the ore produced was exported to the United Kingdom.

§ Annual Reports of the Government Mining Engineer of the Union of South Africa.

time in 1916. It is probable, however, that some of the tin concentrates exported in earlier years contained either wolfram or scheelite. Up to the present time these ores have not been mined for themselves, but have been obtained incidentally in association with cassiterite.

A considerable quantity of wolfram is reported to occur with cassiterite in the quartz reefs and granite at Kuils River in the Cape Province. In the Good Hope Mine, the amount of wolfram in the concentrates is reported to be sometimes nearly equal to that of cassiterite.

Scheelite occurs at many places, notably in the Stavoren tin mines, where some of the lodes are fairly rich; also near Leydsdorp, in the Transvaal, where the source of the mineral has not yet been traced, and near Stanger, in Natal.*

Production of Tungsten Concentrates in the Union of South Africa.

Year.	Quantity (long tons).	Value (£).
1915	3	—
1916	8	874
1917	8	1,551
1918	17	3,647
1919	4	699

Canada.†

The most productive sources of tungsten minerals in Canada have been Burnt Hill Brook in New Brunswick and the Moose River district in Nova Scotia. Early in 1918, 10 tons of wolfram concentrates were shipped from the former locality to New York out of a total production of 12 tons. The Moose River Mines produced 14 tons of scheelite in 1912. Other deposits occur in British Columbia and the Yukon. All the known occurrences were described in Dr. T. L. Walker's "Report on the Tungsten Ores in Canada" published by the Mines Branch of the Department of Mines, Ottawa, Canada, in 1909.

According to the First Report of the work of the Munitions Resources Commission of Canada, published in Ottawa, 1918, the demand for tungsten ores will probably continue, but Canadian tungsten mines worked for tungsten alone appear to be rare, and the supply depends on the price offered. The mining of tungsten ores from known localities in Canada was considered to offer little encouragement at a price of 55*s*. per unit.

* "The Base Metal Resources of the Union of South Africa," Wm. Versfeld. Dept. of Mines and Industries, 1919, pp. 93–94.

† Annual Reports on the Mineral Production of Canada.

India, including Burma.*

Ores of tungsten occur in the Singhbhum division of Bihar and Orissa; in the Nagpur district of the Central Provinces; in the Marwar State of Rajputana; and in Burma. In the first locality the production has been insignificant. The Nagpur occurrence was merely a prospect, and is now worked out; while the third occurrence is small, and mining operations are hindered by lack of water. Wolfram deposits have been found over a stretch of more than 700 miles in Burma, from the Kyaukse district in the north through the Yamethin district, the Southern Shan States and Karenni, to the Thaton, Amherst, Tavoy and Mergui districts in the south. These deposits are always closely associated with the intrusive granite which forms the core of the northern extension of the Indo-Malayan mountain system in Burma and continues far to the south, through Lower Siam and the Malay States, to the islands of Banca and Billiton in the Dutch East Indies.

The earliest reference to Burmese wolfram occurs in a work written about 1845, but the mineral was forgotten and was not re-discovered until 1909, when the work of the Geological Survey of India brought it to light again. Mining commenced in 1910. At that time the world's production was about 6,000 tons of concentrates (60 per cent. tungstic oxide), and the chief producing countries were the United States, Portugal and Queensland, smaller amounts being obtained in Argentina, Bolivia and New South Wales. By 1911 wolfram mining was thoroughly established in Tavoy, and an output of 1,300 tons from this province made Burma the leading tungsten-producing country of the world, a position maintained easily till 1916, when the boom and consequent high uncontrolled prices in North and South America caused the production of both the United States and Bolivia to exceed that of Burma. In 1914, out of a world's production of some 8,000 tons, Burma produced about 2,300 tons.

The demand for wolfram after the outbreak of the war was naturally felt very strongly in Tavoy, and every effort was made by the Government and by mining firms to meet the situation. A special staff of administrative and technical officers was stationed on the field, a comprehensive road-construction program was initiated to improve transport, labourers from China, the Federated Malay States and India were imported in large numbers, and free advice was given by the State to mine-owners. Previous to the war, mining had been carried on generally in a primitive manner, but during the war period great improvements were effected. Deep-level exploration with the aid of machine drills is now common, concentrating mills have been erected, and full use has been made of the water-power

* Records of the Geological Survey of India. Annual Statements of the Seaborne Trade of British India.

resources of the country in exploiting surface deposits by modern hydraulic methods.

Wolfram and cassiterite occur as segregation deposits in the granite; they occur also in pegmatites, quartz veins and greisens. Both pegmatites and quartz veins traverse the granite and the overlying schists, etc., of the Mergui series, in an ancient formation the exact age of which is not known. The associated minerals are mica and sulphides of iron, copper, lead, zinc and bismuth. The three latter metals are rare. Fluorite is widely distributed in small amounts, and tourmaline is absent as a vein mineral, although it is found in both the Amherst and Mergui districts to the north and south.

The opinion has been expressed that the easily won deposits are becoming exhausted. This may be true to a certain extent with regard to some of the older mines, but the extraordinary number of wolfram-bearing veins, the vast extent of the mineralized area in Burma—a great deal of which has still to be explored—and the comparative cheapness with which its surface deposits can be treated, make it difficult to believe that the province will not be able to maintain its position when the demand for tungsten ores becomes active again.

Production of Wolfram Concentrates in India.

	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Burma:							
Mergui	205	194	232	340	368	377	194
Tavoy	1,399	1,977	2,033	3,034	3,698	3,636	2,889
Southern Shan States	84	138	331	185	307	287	398
Thaton... ...	—	17	49	92	107	92	48
India:							
Marwar ...	—	—	—	33	42	37	45·5
Singhbhum ...	—	—	—	8	20	2	1·5
Nagpur ...	—	—	—	1	—	—	—
Total ...	1,688	2,326	2,645	3,693	4,542	4,431	3,576
Value (£) ...	127,762	178,543	296,772	497,397	623,074	726,304	521,194*

* Excluding the value of 45 tons produced in Marwar.

In 1918, out of India's total of 4,431 tons of concentrates, the Tavoy district of Burma alone produced 3,636 tons. These concentrates, though classified as tungsten concentrates, contain a certain quantity of tin ore, but, in the absence of the necessary data, it is impossible to account for that mineral separately. It has been computed that the average composition of this material was 54·3 per cent. tungstic oxide, and 18·8 per cent. stannic oxide.

It would be unsafe, however, to deduce a similar composition for other years. The tin content of the exported concentrates shown in the following table is lower, and the tungsten content higher, as some of the production is magnetically separated before shipment.

Exports of Wolfram Concentrates from India.

*(Domestic Produce).**

Fiscal years ending March 31.

To	Quantity (long tons).			
	1916.	1917.	1918.	1919.
United Kingdom	2,617	4,490	4,782	4,870
Straits Settlements, including Labuan	66	133	—	—
Federated Malay States ...	64	—	—	—
Total to British Possessions	2,747	4,623	4,782	4,870
France	40	—	—	—
TOTAL	2,787	4,623	4,782	4,870
	Value (£).			
United Kingdom	338,050	678,948	724,409	751,349
Straits Settlements, including Labuan	8,678	21,366	—	—
Federated Malay States ...	6,444	—	—	—
Total to British Possessions	353,172	700,314	724,409	751,349
France	4,267	—	—	—
TOTAL	357,439	700,314	724,409	751,349

* Not given separately prior to 1916.

Federated Malay States.†

In the Federated Malay States, a large proportion of the tungsten ore occurs with cassiterite in detrital deposits. In Perak, wolfram is known to occur in Larut, in the Kuala Kangsar district, in Kinta and in Batang Padang. The best known locality is Bukit Rumpian, south of Tapah, where small quartz

† J. B. Scrivenor: Tungsten Ores: a Paper read before the Federated Malay States Chamber of Mines at Ipoh, March, 1916. Annual Reports on the Administration of the Mines Department and on the Mining Industries of the Federated Malay States.

veins carrying tin ore and wolfram traverse a tourmaline-granite. In Selangor, wolfram is obtained from Ulu Klang, Ulu Langat, and Ulu Kanching; from some tributaries of the Serendah River, and from the hills behind Ampang. Scheelite is found at Kanching, and near the Batu Caves. In Negri Sembilan and Pahang, the Titi Tin Mines are the largest producers of mixed ore. Wolfram has also been found at several places along the Bentong-Kuala Pilah road.

Practically all the mixed wolfram-cassiterite ores come from places where there is a contact of granite and schist. The quartz veins when traversing schist contain fairly pure wolfram; on the contact of granite and schist the same veins carry mixed ore, and where they continue into granite they are said to become richer in tin and poorer in wolfram.

Exports of Tungsten Concentrates from the Federated Malay States.

State.	Quantity (long tons).																				
	1913.			1914.			1915.			1916.			1917.			1918.			1919.		
	Wolfram.	Scheelite.	Total.	Wolfram.	Scheelite.	Total.	Wolfram.	Scheelite.	Total.	Wolfram.	Scheelite.	Total.	Wolfram.	Scheelite.	Total.	Wolfram.	Scheelite.	Total.	Wolfram.	Scheelite.	Total.
Perak	53	—	53	36	6	42	49	4	53	76	6	82	69	4	73	20	—	20	6	—	6
Selangor	114	—	114	193	22	215	182	53	235	234	198	432	348	336	684	220	112	332	200	228	428
Negri Sembilan ...	35	—	35	3	1	4	4	—	4	—	—	—	3	—	3	4	—	4	1	—	1
Pahang	5	—	5	—	—	—	—	—	—	1	—	1	1	—	1	—	—	—	—	—	—
TOTAL ...	207	—	207	232	29	261	235	57	292	311	204	515	421	340	761	244	112	356	207	228	435

Unfederated Malay States.*

According to the Reports of the British Agents and Advisors to the Governments, wolfram is mined in the Feudatory States of Trengganu and Kedah, and in the Independent State of Johore.

In Trengganu, a wolfram deposit was opened up at Chanderong, on the Kemaman river, during 1917.

The most important wolfram localities in Kedah are Sungei Sintok and Kubang Pasu.

Production of Tungsten Concentrates in the Unfederated Malay States and the Independent State of Johore.

State.	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Trengganu... ...	108	(a) 143	156	257	196	656	495
Kedah	28	25	13	17	124	520	211
Johore (a)... ...	—	—	—	23	2	1	—
TOTAL... ...	136	168	169	297	322	1,177	706

(a) Exports.

Australia.†

New South Wales.—The principal deposits of wolfram in New South Wales are situated in the Torrington division, the ore being mined also in the Frogmore, Burrowa, Tenterfield and Deepwater divisions.

Hillgrove is the only district in which scheelite is known to exist in commercial quantities. At this locality the deposits occur as thin veins and small lenses, the ore being of good quality and carrying a high percentage of tungstic acid.

In 1912, the Department of Mines published a Bulletin (No. 15) on "The Tungsten Mining Industry in New South Wales," by J. E. Carne, Government Geologist. This deals comprehensively with all aspects of the industry, and contains analyses of typical samples, together with a full record of all known tungsten-ore occurrences in the State.

Queensland.—Tungsten ores are found in several districts in Queensland. The principal mines are at Wolfram Camp, Bamford, Coolgarra, Koorboora, Mt. Carbine, Fossilbrook and

* Annual Reports of the Administrators of the Unfederated Malay States.

† Annual Reports of the Department of Mines, New South Wales. Annual Reports of the Under Secretary for Mines, Queensland. Annual Reports of the Secretary for Mines, Victoria. Annual Reports of the Department of Mines, Western Australia. Annual Reports of the Secretary for Mines, Tasmania. Trade and Customs and Excise Revenue of the Commonwealth of Australia (Annual).

Tate River, all in the Herberton and Chillagoe Gold and Mineral Fields of Northern Queensland. In this State wolfram, molybdenite and bismuth minerals occur in close association, whereas in New South Wales the principal tin, wolfram and molybdenite-bismuth deposits occur in localities and under conditions quite distinct from each other.

At Wolfram Camp and Mount Carbine, groups of mines have been acquired by the Thermo-Electric Ore Reduction Corporation. The occurrences at the former locality are all of a similar nature, and consist of fissures and pipes in granite and greisen with a gangue of white, translucent quartz. At Mount Carbine wolfram is found in pegmatite veins.

The ore-bodies of the Bamford district fill irregular and deformed pipes in altered granite. These pipes frequently branch and give off short spurs. They are subject to tapering, and are also liable to abrupt termination.

Scheelite is found in various localities associated with mispickel, monazite and wolfram, and with bismuth, copper, gold and tin ores. The deposits of Garada, on the Chillagoe railway line, have yielded most of the scheelite produced in Queensland, the mineral occurring there as small veins in association with copper ores.

Crushing and concentrating plants for the treatment of the wolfram-bismuth and molybdenite ores are situated at Wolfram, Mount Carbine, Bamford and Khartoum.

Victoria.—Wolfram occurs in quartz veins in granodiorite at Marysville and Britannia Creek, Warburton; in quartz veins in granitic rocks at Mount Murphy and Bendoc, East Gippsland; and in quartz veins in metamorphic rocks at Wedderburn. It occurs also in the surface deposits of some of the gullies and creeks adjacent to the lode zones. The total output from the State up to 1917 amounted to 100 tons. Scheelite occurs in a quartz lode at Chiltern, and in lodes in the granitic rocks at Mount Murphy and Corryong.

The Mount Murphy Company at Benambra is the largest producer of wolfram ore in Victoria, although deposits of the mineral are also being worked at Wedderburn and in the Tallangatta Valley.

Occurrences of scheelite have been opened over a considerable area in the locality of Koltong, and a State battery for the treatment of cassiterite, scheelite and other ores has been erected there. According to the Annual Report of the Secretary for Mines for 1916, the lodes appear to be numerous, small and patchy, but, with the high market values then ruling for scheelite, it was considered that profitable results should be obtained by small co-operative parties of miners.

Western Australia.—Wolfram has been mined near Cue in the Murchison goldfield, and at Mount Singleton in the Yalgoo goldfield. It has also been found at Grass Valley near Northam, and near King's Sound in the Kimberley division. It occurs usually in association with cassiterite.

Scheelite is widely distributed and is known to occur in quantities likely to be of industrial importance in the Pilbara, Yalgoo, Yilgarn, Broad Arrow, Coolgardie, Dundas and Phillips River goldfields. It is often associated with gold.

Tungsten ores have never been mined on a large scale in Western Australia, and the small quantities exported represent hand-picked lump material from surface deposits.

South Australia.—The insignificant quantities of wolfram hitherto produced in South Australia are believed to have been obtained from pegmatite veins at Callawonga Creek.

Northern Territory.—The chief tungsten-producing localities of the Northern Territory are the districts of Pine Creek and Hatches Creek. The Burns wolfram mine, 40 miles east of Pine Creek, is by far the largest producer, although other concerns are active at Yenberrie in the same region. Here wolfram and molybdenite occur in quartz veins traversing pre-Cambrian rocks invaded by granite. At Hatches Creek wolfram is obtained from quartz veins traversing diorite.

Tasmania.—There are at present two centres of wolfram mining in Tasmania, *viz.*, Story's Creek, Ben Lomond, and Moina. The country rocks are sediments invaded by granite and the ores are found in veins, greisens, and pegmatites. At Story's Creek there is a magnetic separation plant for the treatment of tin-wolfram ore, the wolfram concentrates of which average 73 per cent. of tungstic oxide. The ores and concentrates from the tin-wolfram-bismuth mines at Moina are treated at Launceston, a clean wolfram product being obtained which averages 69 or 70 per cent. tungstic oxide.

In 1917, a new wolfram property was taken up near Mt. Pelion, in a somewhat inaccessible part of the island; the lode is being prospected, and it is hoped that it may prove payable.

The production of scheelite appeared in the mining statistics of the State for the first time in 1917, the ore being worked by the King Island Scheelite Company, which during that year treated 4,937 tons of ore, obtaining 69 tons of concentrates, averaging 70 per cent. tungstic oxide. The mineral is said to be disseminated through a metamorphosed rock consisting chiefly of garnet.

Australia.

Production of Tungsten Ores in Australia.

Year.	New South Wales.				Victoria.		Queensland.						Tasmania.				Northern Territory.
	Wolfram.		Scheelite.		Wolfram content of ore.		Wolfram.		Scheelite.		Bismuth and Wolfram.		Wolfram.		Scheelite.		Tungsten Ore.
	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).*	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).
1913	126	13,037	44	4,457	1	60	359	35,359	·1	8	182	17,867	68	7,040	—	—	37
1914	139	14,438	57	5,852	—	—	241	21,764	—	—	193	15,319	47	4,327	—	—	45
1915	50	5,031	33	4,004	5	712	416	54,300	2	117	247	26,003	95	11 115	—	—	154
1916	183	31,163	81	13,719	1	100	370	57,813	—	—	137	19,069	106	16,910	—	—	229
1917	118	21,682	127	23,419	23	3,600	353	58,367	9	1,523	131	21,172	172	28,714	69	12,130	244
1918	136	24,552	117	21,078	4	828	249	43,041	17	3,495	114	18,041	155	27,239	216	39,252	410
1919	135	22,818	80	15,193	2	400	229				140		121	26,613	199	43,181	

NOTE.—One ton of scheelite-wolfram was produced in Queensland in each of the years 1917 and 1918. During the period 1913 to 1918, inclusive, 25 tons of wolfram ore was produced in Western Australia, having a metal content of 1·5 tons; in 1919, 319 tons of scheelite, valued at £930, was produced.

Exports of Tungsten Concentrates from Australia.

(Domestic Produce).

To	Quantity (long tons).						
	Calendar year 1913.	Jan.-June 1914.	Fiscal years ending June 30.				
			1915.	1916.	1917.	1918.	1919.
United Kingdom ...	123	98	253	965	1,068	1,164	919
Straits Settlements	—	26	—	—	—	—	—
Total to British Possessions	123	124	253	965	1,068	1,164	919
Belgium	11	10	—	—	—	—	—
France	107	55	193	21	—	—	—
Germany	559	243	70	—	—	—	—
Total to Foreign countries	677	308	263	21	—	—	—
TOTAL ...	800	432	516	986	1,068	1,164	919

New Zealand.*

Scheelite occurs in many of the quartz veins of the Otago gold-field, especially near Glenorchy, Paradise, Macrae's, Mount Highlay, Stoneburn, and Barewood, Otago; also at Wakamarina Valley, Marlborough; and milling and concentrating plants have been installed for the treatment of the ore. The principal localities are near Glenorchy, where irregular quartz veins and lenses carry both scheelite and gold. The following table shows the quantity of quartz crushed, and scheelite concentrates obtained (minimum of 70 per cent. of tungstic oxide) :—

Year.	Quartz crushed (long tons).	Scheelite concentrates obtained (long tons).	Value (£).
1913	17,529	210	20,756
1914	21,745	222	21,825
1915	20,421	216	29,989
1916	19,360	258	47,374
1917	19,655	199	37,863
1918	15,098	143	31,279
1919	8,890	123	21,771

* Mines Statements of New Zealand (Annual).

Prior to the war, the greater part of the output of scheelite in New Zealand was exported to Germany, but in September, 1915, all supplies were requisitioned by the Imperial Government. The stimulus thus given to the industry will be seen from the fact that, while at the time of the inauguration of the scheme only five recognized companies were in operation, at the end of 1916 supplies were furnished by no fewer than forty companies, syndicates and private individuals.

The quantity and value of scheelite exported during the period under review are as follows :—

Year.	Scheelite concentrates exported (long tons).	Value (£).
1913	221	22,933
1914	204	21,498
1915	194	27,784
1916	266	49,070
1917	161	28,972
1918	170	37,922
1919	131	29,489

FOREIGN COUNTRIES.

The foreign countries that have been chiefly concerned in the production of tungsten ore in recent years are China, Japan, the United States, Bolivia, Peru, Argentina, Spain and Portugal. The quantities produced in France, Germany and other countries have been comparatively small.

France.

Wolfram occurs with cassiterite and other minerals in quartz veins at various localities in Brittany, notably at Montbelleux, in the department of Ille-et-Vilaine. Various other occurrences are known in different parts of France, but they are of little or no importance. The total production of France is small, as shown by the following table :—

Production of Tungsten Ore in France.

Year.	Ore (long tons).	Metal Content (long tons).
1914	12,514	68
1915	5,965	59
1916	7,172	76
1917	8,411	122
1918	7,295	99

Germany and Bohemia.

Wolfram occurs with cassiterite in the Erzgebirge region on the borders of Saxony and Bohemia. The most important producing districts are Zinnwald in the former and Graupen in the latter province. The production of tungsten ores in Germany during pre-war years was insignificant as compared with the large imports. It has been stated that slightly increased quantities were obtained during the war by working over the old mine dumps of the Erzgebirge region.

Production figures are given on page 9. The following table shows the sources of the German supplies of tungsten ore during 1912, which was a typical pre-war year :—

Imports of Tungsten Ore into Germany during 1912.

	Quantity (long tons).
United Kingdom	1,039
India	459
Malaya	194
Australasia	1,090
France	110
Portugal	314
Argentina	500
Bolivia	391
Other Countries	364
Total from British Empire ...	2,782
Total from Foreign Countries ...	1,679
TOTAL	4,461

Portugal.*

Wolfram is found in the Central and Northern provinces of Minho, Douro, Tras-os-Montes, Beira Alta, and Beira Baixa. It occurs usually in small quartz veins, but is also found in surface deposits. Before the war, the cost of production was approximately 300 to 450 escudos (£62 to £94) per ton. Increased demand, higher wages, taxes and transport charges resulted in an immediate advance in cost to 800 and 1,500 escudos per ton. The selling price was established by the Government during the war on the following basis :—

Mineral with 60 per cent. WO_3, 100 francs at the export station.

,,	over 60	,, ,,	3 francs more per unit up to 65 per cent.
,,	,, 65	,, ,,	2 francs more per unit up to 70 per cent.
,,	,, 70	,, ,,	3 francs more per unit.

* Boletim de Minas (Annual). Boletim Comercial e Maritimo (Monthly).

Portugal is the chief tungsten-producing country in Europe. The following important mines may be mentioned: the Panasqueira at Silvares, near Covilhão in Beira Baixa (worked by an English company), where wolfram occurs with cassiterite and other minerals in quartz veins traversing ancient sedimentary rocks; the Moimenta da Beira near São João de Pesqueira; a mine at Borralha near Montalegre in Tras-os-Montes (worked by a French company), where the veins are found at the contact of granite and crystalline schists; the Montado de Adoria in the same region, where there are several large veins and a stockwork in granite.

The wolfram deposits of Portugal are reported to be generally irregular, and often have a lenticular form with a maximum width of 3 feet. The gangue is usually white or yellowish quartz with mica, the only other mineral of importance being arsenopyrite, though iron- and copper-pyrites and galena also occur. Most of the wolfram veins contain little or no tinstone, but in the north of Portugal there are some big lodes carrying both minerals in about equal proportions.

Wolfram and cassiterite are also obtained from surface deposits in some parts of Portugal by hydraulic methods.

Exports of Wolfram from Portugal.

Year.	Quantity (long tons).	Value* (£).
1913	1,332	71,392
1914	910	45,183
1915	873	75,530
1916	1,102	372,331
1917	1,586	775,535
1918		
1919	758	

* Values converted to £ sterling at the rate of 1 escudo=4*s.* 6*d.*

Spain.†

The greater part of the Spanish production of wolfram comes from Badajos. The best known occurrence is in the district of Oliva de Jerez and Zabinos, near Jerez de los Caballeros. The most important mine is La Virgen de la Gracia, where a number of lodes traverse gneiss penetrated by granite. Large surface deposits are also treated. The Tres Amigos mine is near the village of Valle de la Serrana, where the country rocks are slates and quartzites traversed by granites.

In the province of Corunna the San Finx mine, near Lousame and Cabana, was formerly operated by an English company. The

† Estadistica Minera de España (Annual).

Tyre and Sidon mine at Carbia in Pontevedra was also a large producer, and there is another large mine near the village of Silleda.

The province of Zamora produced nearly 4,000 tons of high-grade wolfram concentrates in 1918.

Wolfram has also been recorded from various places in the provinces of Cordoba and Jaen. Near the great lead-producing region of Cordoba, at the village of Conquista (Pennaroya), three wolfram lodes were opened up in 1916.

United States.*

Tungsten deposits are widely distributed in the United States, especially in the areas of quartzose, granitoid rocks that lie in and to the west of the Rocky Mountains. The most important deposits occur in Colorado, California, Nevada, South Dakota, Arizona and Alaska.

The Boulder field of Colorado is centred in Nederland, Boulder county, from which it extends about 10 miles north-east, and scattered deposits have been reported at localities for a distance of 10 or 12 miles to the south. The belt is 4 or 5 miles in width. The veins are narrow and often brecciated. They occur mostly in granite, some of them following porphyry dykes. The gangue is quartz and fine-grained silica. Kaolin is abundant. The principal mineral is the iron tungstate (ferberite) which occurs with a little pyrite. Some of the best deposits of the Boulder Field have been exhausted, and the cost of production has become much greater owing to the impoverishment of others.

The Atolia district of San Bernardino county, California, is the largest scheelite producer in the world, and, during the tungsten boom in 1915, prospecting operations were carried on very actively at this locality. During 1917 and 1918 the tendency throughout the Atolia district has been to deepen the large number of small properties which were formerly worked only superficially, and some of the mines are stated to be now well-equipped with power plants and concentrating mills.

In the Black Hills of South Dakota occurrences of tungsten ore have been known for many years, but it was not mined there in commercial quantities until 1915. The ore is wolframite associated with cassiterite and gold, and most of the output has been obtained by opening up old and abandoned gold mines. Scheelite is seldom encountered, and is found only in small grains.

Tungsten occurs in nearly every county of Arizona, the chief producers being Cochise, Mohave, Pima and Yavapai counties. In 1915, a vein of wolframite was exposed to a depth of 800 feet in the old workings of the Tip Top silver mine, the tungsten ore having been ignored when the property was worked for its

* Mineral Resources of the United States (Annual).

silver ores. This mine is the largest in Yavapai county. Hübnerite and wolframite occur in all the workings, and appear to be associated with a pegmatite.

The Fairbanks district and Seward Peninsula are the principal tungsten producers in Alaska. Tungsten minerals have been found for a long time in the sluice boxes of the placer-gold workings of the Fairbanks district, but the original vein deposits were discovered only about 1917. In the Seward Peninsula the mineral is produced principally by sluicing the residual scheelite-bearing lode material in Sophie Gulch.

In 1918, the United States imported for consumption about a third of the world's total output of tungsten ore. Adding this to the domestic output makes the consumption of the United States for that year about half of the world's production. During 1912, prices ranged from 27*s*. 1*d*. to 31*s*. 3*d*. per unit for 60 per cent. WO_3 ores. During 1913 and part of 1914 similar prices prevailed, but they began to advance towards the end of the latter year. Subsequently, larger orders were received from Europe, and there was a sudden inflation in prices until 166*s*. 8*d*. per unit was common. In 1916, after the manufacture of munitions had commenced on a great scale in the United States, the demand for tungsten ores increased enormously, with a correspondingly great advance in prices. At the beginning of the year 60 per cent. ore was sold at 275*s*. per unit, the maximum price being reached at the end of March, when the ores realized 389*s*. 7*d*. per unit at the mill. Over-production resulted, and June closed with prices around 83*s*. 4*d*. per unit. In 1917, and for part of 1918, prices ranged about 104*s*. 2*d*. per unit, but by the end of 1919 had dropped to about 29*s*. 2*d*. per unit in New York.

It has been stated officially that many of the known deposits show signs of impoverishment, and that it is likely that some which appeared to be the richest will never again produce largely. On the other hand, the newly discovered contact-metamorphic deposits of the Great Basin (California, Nevada, and north-eastern Utah), which were only partially developed, are said to promise well.

It is now proposed to put a tariff of 41*s*. 8*d*. per unit on tungsten ores, with a corresponding tariff of 4*s*. 2*d*. per pound, plus the 15 per cent. *ad valorem* duties now in force on tungsten in any form, whether metal, alloy, or salt. It is hoped by this means to raise the price, now about 29*s*. 2*d*. per unit in New York, to 70*s*. 10*d*. a unit.

United States Production, Imports, and Exports of Tungsten Ores, etc.

Year.	Production (long tons).	Imports for consumption.			Exports.*		Apparent consumption (long tons).
		Ore (long tons).	Tungsten and ferro-tungsten (long tons).	Estimated equivalent in ore carrying 60 per cent. of tungstic oxide† (long tons).	Tungsten and ferro-tungsten (long tons).	Estimated equivalent in ore carrying 60 per cent. of tungstic oxide (long tons).	
1913 ...	1,372	401	661	1,921	—	—	3,293
1914 ...	884	267	195	727	—	—	1,611
1915 ...	2,082	1,586	7	1,734	—	—	3,816
1916 ...	5,288	3,547	38	3,929	256	518	8,700
1917 ...	5,486	4,354	1	4,718	1,037	2,161	8,043
1918 ...	4,525	10,491	—	11,365	550	1,129	9,404
1919 ...	‡295	8,400	177	9,498	17	37	9,755

* No record of tungsten ore exported is available, although it is known that some has been shipped abroad.

† These items include the ore (considered as carrying 65 per cent. of tungstic oxide) and the tungsten and ferro-tungsten (considered as equivalent to 2¼ times their weight in ore carrying 60 per cent. of tungstic oxide). Chinese ore imported has been considered as containing 67½ per cent. of tungstic oxide.

‡ Estimated.

Argentina.§

Tungsten ores are widely distributed through the pampa ranges of the Argentine Republic, but are most abundant in the provinces of San Luis and Cordoba. The ores were first worked in the Sierra de Cordoba about 25 years ago, but the most important mine is now the Los Condores in the Sierra de San Luis. The deposits occur in regions of crystalline schists and ancient metamorphosed sediments intruded by granites and granodiorites of pre-Cambrian to post-Silurian age. The later granites are accompanied by pegmatites with which the veins are genetically associated.

The veins have been classified as follows :—

(A) Wolfram-bearing pegmatites (of no economic importance).

(B) Wolfram in veins with quartz and mica.

- (*a*) without cassiterite.
  - (i) with tourmaline.
  - (ii) without tourmaline.
- (*b*) with cassiterite.

Important localities of the wolfram-tourmaline veins are Loma Blanca and El Aguila in San Luis, and San Virgilio, Santa Barbara, Santo Tomas and La Brillante in Cordoba. The Loma

§ Estadistica Minera (Annual). The Mineral Deposits of South America, by B. L. Miller and J. T. Singewald, 1919.

Blanca veins are thin; they contain muscovite, chlorite, and large quantities of fluorite which is lacking elsewhere; on the other hand, apatite, which is abundant elsewhere, occurs but sparingly here. At San Virgilio, the veins are partly in granite, and they range from typical pegmatite varieties to hydrothermal types in which sulphides like chalcopyrite are relatively abundant. The tourmaline-wolfram veins include those of Los Condores which have been worked for about 15 years by the Hansa Sociedad de Minas. The country rock is phyllite. The principal vein has an average width of 30 to 40 inches. It has micaceous walls, and contains pyrite, chalcopyrite, and zinc-blende. Tourmaline is not abundant. The percentage of tungstic oxide is stated to be unusually high for this part of the world, ranging from 1 to 4 per cent. The only example of the occurrence of wolfram and cassiterite in the same vein is at Mazan in La Rioja. The filling consists of quartz with a border of mica. Arsenopyrite is present, but tourmaline and fluorite are rare. The ore is low-grade, and averages only 0·25 per cent. of tungstic oxide. Attempts to work the deposit have consequently failed.

Exports of Wolfram Concentrates from Argentina.

Year.	Concentrates exported (long tons).	Tungstic oxide obtainable (long tons).
1913	527	339
1914	402	258
1915	178	100
1916	786	505
1917	989	
1918	563	
1919		

During the years 1912-14 practically the whole of the exports were consigned to Germany. In 1915, with the exception of one cargo to the United Kingdom, the whole of the output went to the United States.

Bolivia.*

Tungsten ores occur in Bolivia either in subordinate amounts in the tin-bearing veins or in separate veins in the same general region in which the tin veins are found. The ores of tin, silver, bismuth and tungsten are intimately associated in Bolivia, and districts in which one or more of them occur extend almost throughout the country from Carabuco in the north to Esmoraca near the southern boundary. All the veins are probably the product of a common mineralization active throughout a well defined metallogenetic epoch which followed the intrusion of a series of acidic igneous rocks. Tin and silver ores are the most

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* Comercio Especial de Bolivia (Annual). Miller and Singewald *op. cit.*

widely distributed, tungsten ores occur less abundantly and are not so well distributed, while bismuth is still more restricted in occurrence and quantity. The tungsten veins represent a varying phase of the mineralization which produced the tin veins.

During the tungsten boom of the war period, the departments of La Paz, Cochabamba, Oruro and Potosi contributed to the output. In the department of La Paz, the producing mines were Milluni, Araca, Yaco, Ichoca, and Quimsa Cruz, the last-mentioned being the largest. Between Quimsa Cruz and Cochabamba, in the department of Cochabamba, the most important localities were Kami, Chicote, Solano and Amutara. Patino's mine at Kami became the largest tungsten producer in Bolivia. Oruro, Huanuni and San Jorge were the most active mines in the department of Oruro. In the department of Potosi, the largest output came from Sala Sala at Chorolque, other producers being Frias, Llallagua and Uncia. The commonest ore-mineral is wolframite, but scheelite is also found in the Potosi ores. The wolframite is mixed with quartz, and accompanied frequently by arsenopyrite and rarely by native bismuth. The mode of occurrence and geological features are identical with those of the tin deposits.

Most of the Bolivian tungsten deposits are of such low grade that they cannot be worked in normal times, but they are numerous enough to be susceptible to a considerably expanded output under the stimulus of high prices.

Exports of Wolfram Concentrates from Bolivia.

Year.	Quantity (long tons).
1913	278
1914	272
1915	780
1916	2,987
1917	3,827
1918	3,363
1919	1,963

The destinations of exports of Bolivian concentrates during the years 1916-1919 were as follows :—

Year.	United States (long tons).	United Kingdom (long tons).	France (long tons).
1916	2,063	872	26
1917	1,903	1,376	537
1918	2,498	545	316
1919	1,363	384	207

Peru.*

The tungsten production of Peru comes almost entirely from a district lying on both sides of the Pelegatos River, which forms part of the boundary between Pallasca province in Ancachs and Santiago de Chuco province in Libertad. The ore is hübnerite in a quartz gangue, with tetrahedrite and occasionally galena. At Huaura in Pallasca, sandstones and shales are metamorphosed by a granite intrusion along the contacts of which are two immense quartz veins. Hübnerite occurs in irregularly distributed nests near the hanging and footwalls and in crystals and crystal groups throughout the veins. Comb quartz, pyrite, tetrahedrite and galena belong to a secondary mineralization. Some apatite occurs with the earlier tungsten ore.

The quartz-pyrite-wolfram veins of Cerro Julcani, in the Angaraes province, Huancavelica, have been worked for many years on account of their gold content, but not for tungsten. The gold occurs in small specks, and the country rock is porphyrite or diorite, more or less altered and impregnated with pyrite near the veins.

Wolfram mining in Peru is carried on in a primitive manner by Indians at periods of high prices. From the table given below it will be seen that the exports for the past five years averaged about 348 tons a year. Prior to the war about 60 per cent. of the total exports of wolfram concentrates went to Germany. The concentrates as shipped contain from 58 to 60 per cent. of tungstic oxide. Transport from the mines to the railways is difficult.

Exports of Tungsten Ores from Peru.

Port of Shipment.	Quantity (long tons).	Value† (£).	Destination.	Quantity (long tons).	Value† (£).
1913.					
Chimbote ...	121	7,583	Germany ...	149	9,515
Salaverry ...	165	11,858	United States ...	116	8,479
			France	8	521
			Great Britain ...	13	926
Total ...	286	19,441	Total ...	286	19,441
1914.					
Callao ...	3	291	Germany ...	120	12,882
Chimbote ...	70	7,113	United States ...	9	972
Salaverry ...	120	12,969	France	2	177
Not specified ...	—	13	Great Britain ...	26	2,665
			Italy ...	36	3,690
Total ...	193	20,386	Total ...	193	20,386

* Miller and Singewald, *op. cit.* Tungsten situation in Peru; Chem. and Met. Eng., 1919, vol. 21, p. 739.

† Values converted to £ sterling at the rate of 1 dollar=4*s*. 2*d*.

Exports of Tungsten Ores from Peru—contd.

Port of Shipment.	Quantity (long tons).	Value* (£).	Destination.	Quantity (long tons).	Value* (£).
1915.					
Callao ...	16	2,854	United States...	284	43,720
Salaverry ...	174	27,963	France... ...	8	1,675
Chimbote ...	144	21,163	Great Britain...	42	6,585
Total ...	334	51,980	Total ...	334	51,980
1916.					
Callao ...	9	2,598	Bolivia ...	—	101
Chimbote ...	186	87,912	United States...	509	222,189
Puno ...	—	101	France... ...	6	1,227
Salaverry ...	320	132,906			
Total ...	515	223,517	Total ...	515	223,517
1917.					
Callao ...	1	241	United States...	411	101,045
Chimbote ...	150	38,009			
Salaverry ...	260	62,795			
Total ...	411	101,045	Total ...	411	101,045

* Values converted to £ sterling at the rate of 1 dollar=4*s*. 2*d*.

Exports of Tungsten from Peru to New York, 1918.

Port of Shipment.	Gross Weight (long tons).	Net Weight (long tons).	Tungsten contained (long tons).	Commercial Value* (£).	Freight Value* (£).	Net Value* (£).
Salaverry ...	176·0	173·6	108·0	50,794	4,113	46,681
Chimbote ...	54·7	54·0	32·9	15,460	855	14,605
Callao ...	10·8	10·6	7·4	3,457	189	3,268
Mollando ...	·8	·8	·5	247	9	238
Total ...	242·3	239·0	148·8	69,958	5,166	64,792

* Values converted to £ sterling at the rate of 1 dollar=4*s*. 2*d*.

China.†

The principal districts in which tungsten ores are found are in the provinces of Hunan (southern part), in Hangchow and its vicinity; Kiangsi (southern part), in the Lungnan Hsien, Tinnan, Sinfeng Hsien, Nankang Hsien, and Taiyu districts; and Kwangtung (eastern part) in the Wuwha, Hingning Hsien, Kaiyung, Heifung, Lukfung, and Wailia districts, (northern part) in the Namyung, Lokchong, Chining and Chukiang

† United States Commerce Reports, 22nd Dec. 1919. China Yearbook, 1919.

districts. These districts comprise only those in which operations are now being carried on, but there are other large areas in which wolfram deposits are found in the southern parts of the Hunan and Kiangsi provinces and in north-eastern Kwangtung.

Other localities include the "New Territory" of Hongkong and the neighbourhood of Swabue, half-way between Hongkong and Swatow.

The mineral is said to occur in small veins in granitic rocks and in stream deposits with magnetite and cassiterite. Though found in widely scattered regions, the deposits are never large in any particular area. Mining is mainly carried on by farmers in their spare time, and appliances and methods are exceedingly primitive. The farmers take their concentrates to the local market and sell at the best prices obtainable to dealers who re-sell to licensed collectors from the ports. The impure concentrates have to be re-treated before export, and to do this work a few native and foreign companies have sprung up. Mining operations ceased in February, 1919, and it is stated that they cannot be resumed unless the market price is high enough to enable operators to pay each workman 20 tael cents per day for his labour.

The following is an estimate of the cost of placing a short ton (2,000 lb.) of concentrates on the market. The figures are given in taels owing to the great fluctuations in exchange. The average rate of exchange in 1917 was 4s. $3\frac{13}{16}$d.; in 1918, 5s. $3\frac{7}{16}$d., and in 1919, 6s. 4d.

	Taels per short ton.
Cost of extraction	300
Cost of transportation	40
Customs dues, license fees, local taxes, etc. ...	100
Cost of insurance and incidental charges ...	20
Total cost	460

The above figure was arrived at by estimating the cost of labour at 20 tael cents per workman per day. Each workman can extract about $1\frac{1}{3}$ lb. of ore per day. The cost of transportation covers the cost from the mines to Shanghai or Hongkong. The export duty on every ton of ore is about 15 taels; local taxes and license fees amount to 85 taels.

The market prices after the outbreak of the war were as follows:—

War-time prices, 800 to 1,000 taels per ton.
November, 1918, to January, 1919, 500 taels per ton.
January, 1919, to August, 1919, no market in Shanghai and Hongkong, only a few transactions in Canton and Swatow at from 250 to 350 taels per ton.

It is difficult to estimate even approximately the quantities of further production for any definite length of time, as thus far no authoritative survey has been made of this field, but it is estimated that all the mines in the above-mentioned districts are capable of equalling their production during the year 1918 for more than 10 years. Future shipments abroad will be governed entirely by the demands of the American and European markets.

According to F. L. Hess, after the accumulated stocks of the world are used up, Chinese wolfram production will again proceed as it has done in the last few years. The surface deposits are not exhausted, the veins are scarcely touched, and the tungsten-bearing area is large and only partly prospected. Labour is cheap and a large future output is assured for a long time, though it may never again equal that for 1918. The same writer has expressed the opinion that Chinese wolfram could be imported into the United States, so far as ordinary charges are concerned, at something under 29/2 per unit, but that Chinese officials would not allow it to be exported unless they received dues on the basis of the earlier prices.

According to the statistical abstracts prepared by the Chinese Maritime Customs, the total exports of tungsten ore in 1918 amounted to 10,198 tons, but the production exceeded this amount, as large quantities could not be sold and were left in the mining districts.

Indo-China.*

Wolfram occurs in veins associated with cassiterite and quartz in a granitic formation on the flanks of the Pia-Ouac mountain, in the province of Cao Bang.

Production of Tungsten and Tin Ore in Indo-China.

Year.	Quantity (long tons).	Value† (£).
1913	194	
1914	305	29,780
1915	416	59,200
1916	425	71,440
1917	511(a)	111,200
1918	590	
1919		

† Values converted to £ sterling at the rate of 25 francs = £1.
(a) Exports.

* Statistiques de l'industrie minière dans les colonies françaises. Études Minéralogiques sur l'Indochine Française, by G. Dupouy, 1913.

Japan and Korea.*

Information concerning the wolfram industry of Japan is scanty. According to the Department of Agriculture and Commerce of Japan, the principal ores of tungsten found in Japan are scheelite and wolframite. These are commonly associated with cassiterite, bismuth ore or molybdenite, with the characteristic gangue-minerals which contain fluorine or boron, such as fluorite, topaz, tourmaline, apatite and axinite. The deposits occur mostly associated with granitic or liparitic rocks. There are three types of deposits: (1) veins, (2) contact-metamorphic deposits, and (3) detrital deposits. The last type is of no economic importance. The occurrences of tungsten ore are numerous, but scattered. At Nishizawa, wolframite and hübnerite occur in auriferous quartz veins intimately associated with iron pyrites. At the Kurasawa mine scheelite and ferberite occur in the pegmatite veins in granite. The occurrence at the Kanoya mine resembles that in the Kurasawa mine, except that wolframite is present instead of ferberite. At Akenobe large wolframite plates are associated with cassiterite in quartz veins. The occurrences of the metal in the mines of Naganobori and Otogafuchi are somewhat similar, but in these, copper minerals are present. Besides the above mines there are several other localities that are known to be productive in the province of Satsuma, Buzen in Kyushu, and Nagato, Suwo and Hitachi in Honshu.

Production in Japan was stimulated by the war, but a larger increase still was obtained from Korea, where new deposits were discovered and actively exploited. The principal producing mines of Japan proper are said to be the Kiwada in Yamaguchi Ken and the Takatori mine in Ibaraki Ken.

Production of Tungsten Ores in Japan and Korea.

Year.	Quantity (long tons).	Value† (£).
1913	243	23,205
1914	192	18,771
1915	367	47,795
1916	779	259,290
1917	1,042	195,621
1918	596‡	141,794
1919		

† Values converted to £ sterling at the rate of 10 yen = £1.
‡ Japan only.

Siam.

Deposits of tungsten ores, chiefly wolfram, are scattered through Siamese Malaya and Northern Siam, especially in the Nakon Sritamarat district. The high-grade ores contain from

* Annual Reports of the Department of Agriculture and Commerce. Mining in Japan, Past and Present, 1909.

60 to 72 per cent. tungstic oxide, but mixed ores containing nearly equal parts of tin and tungsten occur. In the fiscal year 1912-1913 the production of wolfram in Siam was 304 tons; in the year ending March 31st, 1917, 575 tons; and in the succeeding year about 767 tons.

The war price reached 160 taels (£12 6*s.*) per picul (133⅓ lb.). The price in 1919 was about 40 taels or less per picul. There is no consumption of tungsten in Siam, and the entire output is exported.

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