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

SILVER ORES

BY H. B. CRONSHAW, B.A., Ph.D., A.R.S.M.
LATELY PROFESSOR OF GEOLOGY, UNIVERSITY COLLEGE, GALWAY

WITH TWO DIAGRAMS AND A MAP

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1921

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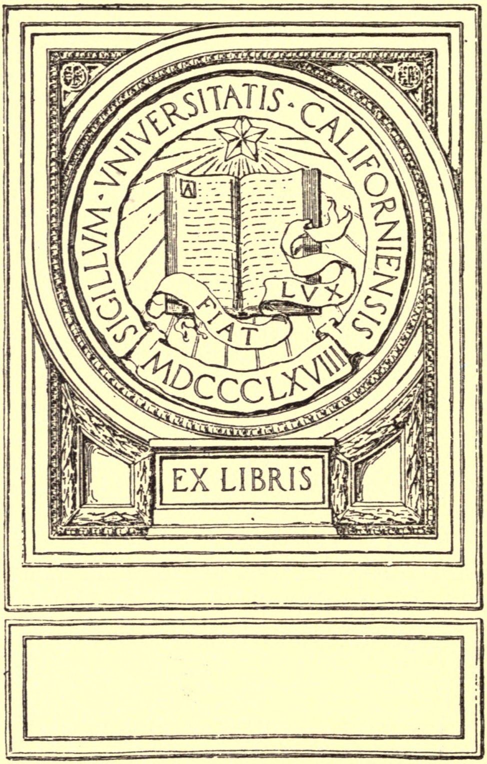
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MINERAL SECTION

The Imperial Institute is a centre for the exhibition and investigation of minerals with a view to their commercial development and for the supply of information respecting the sources, composition and value of minerals of all kinds.

The Imperial Institute is provided with Research Laboratories for the investigation, analysis and assay of minerals, and undertakes reports on the composition and value of minerals for the information of Governments and producing companies and firms, in communication with the principal users in the United Kingdom and elsewhere in the Empire.

Important minerals from within the Empire are exhibited in the respective Courts of the Public Exhibition Galleries, and also in the Mineral Reference Collections of the Institute.

A special staff is engaged in the collection, critical revision and arrangement of all important information respecting supplies of minerals, especially within the Empire, new methods of usage and other commercial developments.

Articles on these and related subjects are periodically published in the *Bulletin of the Imperial Institute*, and monographs on special subjects are separately published under the direction of the Committee on Mineral Resources.

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PREFACE

The Mineral Resources Committee of the Imperial Institute has arranged for the issue of 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 statistical 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 utilization 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.

IMPERIAL INSTITUTE,
LONDON, S.W.7.
July 1920.

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SOURCES OF SUPPLY OF SILVER ORES

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SILVER ORES

CHAPTER I

SILVER ORES: THEIR OCCURRENCE, CHARACTER AND USES

IN 1918 the British Empire produced 35,189,000 fine oz. of silver, which was nearly one-fifth of the world's supply. Of this amount, Canada supplied as much as 21,383,979 oz., or about 60% of the total British production, and 11% of the world's production

The great silver-producing country of Mexico for a long time headed the world's production, but, owing to political disturbances, the output began to fall in 1911, although not to any great extent until after 1913. By 1915 the production had fallen to less than 23,000,000 oz., or about 3,700,000 oz. below the output of Canada for that year. By 1917, however, the conditions in the country had improved and the production rose to 42,020,547 oz., and in 1918 it amounted to as much as 62,517,000 oz. [1].

In 1919 and 1920 Mexico became the world's chief producer with 75,000,000 and 63,750,000 oz. (estimated) respectively.

The United States headed the list as a silver producer in 1906, and from 1914 to 1918. In 1916 her production amounted to 43% of that of the world.

The British Empire held the third place from 1905 to 1913 inclusive, and also in 1917 and 1918, and the second place from 1914 to 1916 inclusive.

Canada is practically the only country of the British Empire where silver ores proper are mined, but a very large proportion of the silver of that country is obtained as a by-product from ores of lead, zinc, etc.

The world's annual production of silver from 1909 to 1913, or for the five years preceding the Great War, averaged about 223,000,000 oz., but from 1914 to 1919 inclusive the average was only 180,000,000 oz., a drop of about 19% as compared with previous years. For two years the shortage was not felt, owing to large stocks held, and to the comparatively small demand for silver for coinage and other purposes; but in 1916 the demand had increased and the stocks had become more or less depleted, so that the price began to rise in that year. It continued to rise until it reached as much as 7*s.* 6*d.* per oz. in February 1920, thus exceeding by 2*s.* per oz. the intrinsic value of the silver in the coinage of this country.

The recent unprecedented rise in silver was chiefly due to the demand for the white metal in the Far East, first from India, and latterly from China. The Indian demand was supplied first from Shanghai stocks, and at a later date from United States supplies. The export trade from China has increased considerably since 1918, and to meet the balance in favour of China, large shipments of silver have been made from the United States.

In March 1920 silver began to decline in price, and by December 1920 it was quoted at about 42 pence per oz., or less than half the price reached the previous February.[1] The fall in price was stated to be largely due to the cessation of bullion purchase by the British Government on India account, to the unfavourable balance of trade against India from July to December 1920, to the unfavourable monsoon or lack of rain during the summer and autumn of that year, and to the substitution of paper money for the silver rupee.

World's Production of Silver

The total world's production of silver from the discovery of America up to the year 1919 is estimated roundly to have been about 12,600,000,000 oz.

The following table gives the annual productions for various years since 1860:

[1] The price per oz. on July 28, 1921, was 39 pence.

Year.	Fine Oz.	Year.	Fine Oz.
1860 . . .	29,095,428	1910 . . .	221,715,673
1865 . . .	35,401,972	1911 . . .	226,192,923
1870 . . .	43,051,583	1912 . . .	224,310,654
1875 . . .	62,261,719	1913 . . .	224,835,067
1880 . . .	74,795,273	1914 . . .	170,907,286
1885 . . .	91,609,959	1915 . . .	168,113,947
1890 . . .	126,095,062	1916 . . .	174,348,885
1895 . . .	167,500,960	1917 . . .	180,910,305
1900 . . .	173,591,364	1918 . . .	196,936,598
1905 . . .	172,317,688	1919 . . .	187,336,000 (*e*)

(*e*) Estimated.

[1] [2]

Variations in Average Annual Production of Silver

In the following table the average annual production for periods of ten years (excepting 1911 to 1916), ranging from 1801 to 1916, are given:

Period of Time.	Average Annual Production. Million Oz.	Period of Time.	Average Annual Production. Million Oz.
1801 to 1810 . .	29	1871 to 1880 . .	71
1821 to 1830 . .	15	1881 to 1890 . .	100
1831 to 1840 . .	19	1891 to 1900 . .	162
1841 to 1850 . .	25	1901 to 1910 . .	182
1851 to 1860 . .	29	1911 to 1913 . .	225
1861 to 1870 . .	39	1914 to 1916 . .	165

The Ratio of the Weight of Silver produced as compared with that of Gold

Period of Time.	Ratio.	Period of Time.	Ratio.
1801 to 1810 . . .	50·9	1861 to 1870 . . .	6·4
1811 to 1820 . . .	46·0	1871 to 1880 . . .	12·7
1821 to 1830 . . .	32·6	1881 to 1890 . . .	19·8
1831 to 1840 . . .	29·2	1891 to 1900 . . .	15·9
1841 to 1850 . . .	14·0	1901 to 1910 . . .	10·0
1851 to 1860 . . .	4·5	1911 to 1919 . . .	9·2

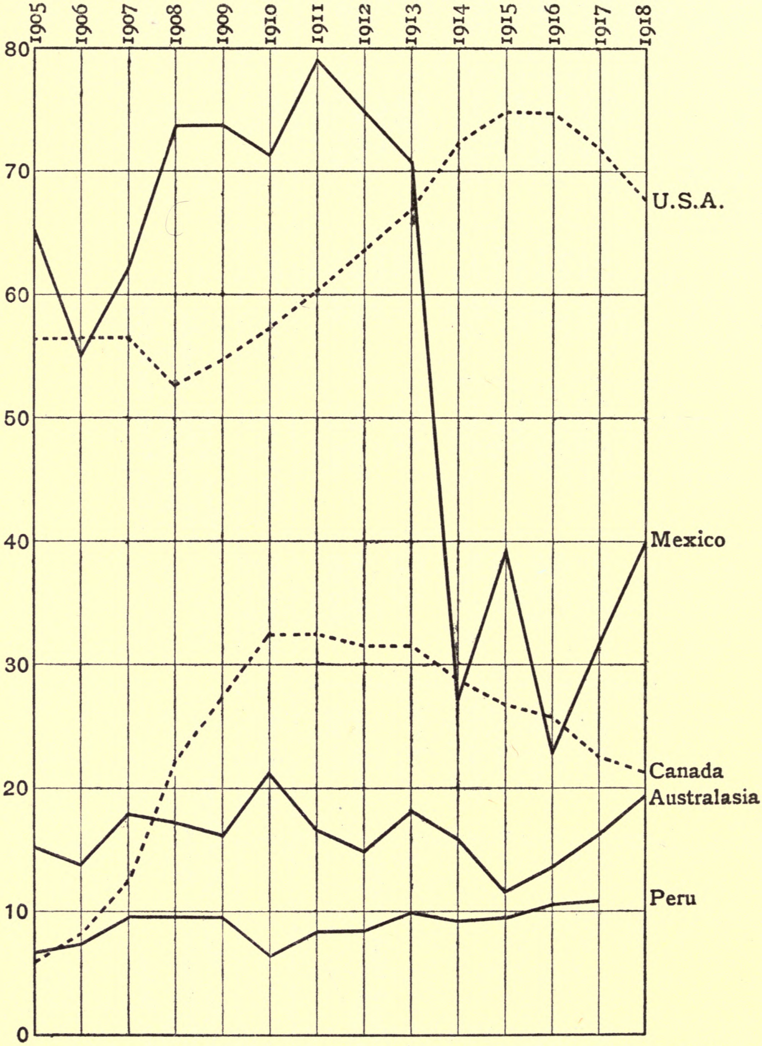
The low ratio reached during the period 1851–1860 coincided with the discoveries of gold in California and Australia, which added to the gold production, without a corresponding increase in silver [3].

World's Silver Production, 1913–1918, *in Fine Ounces* (*a*)

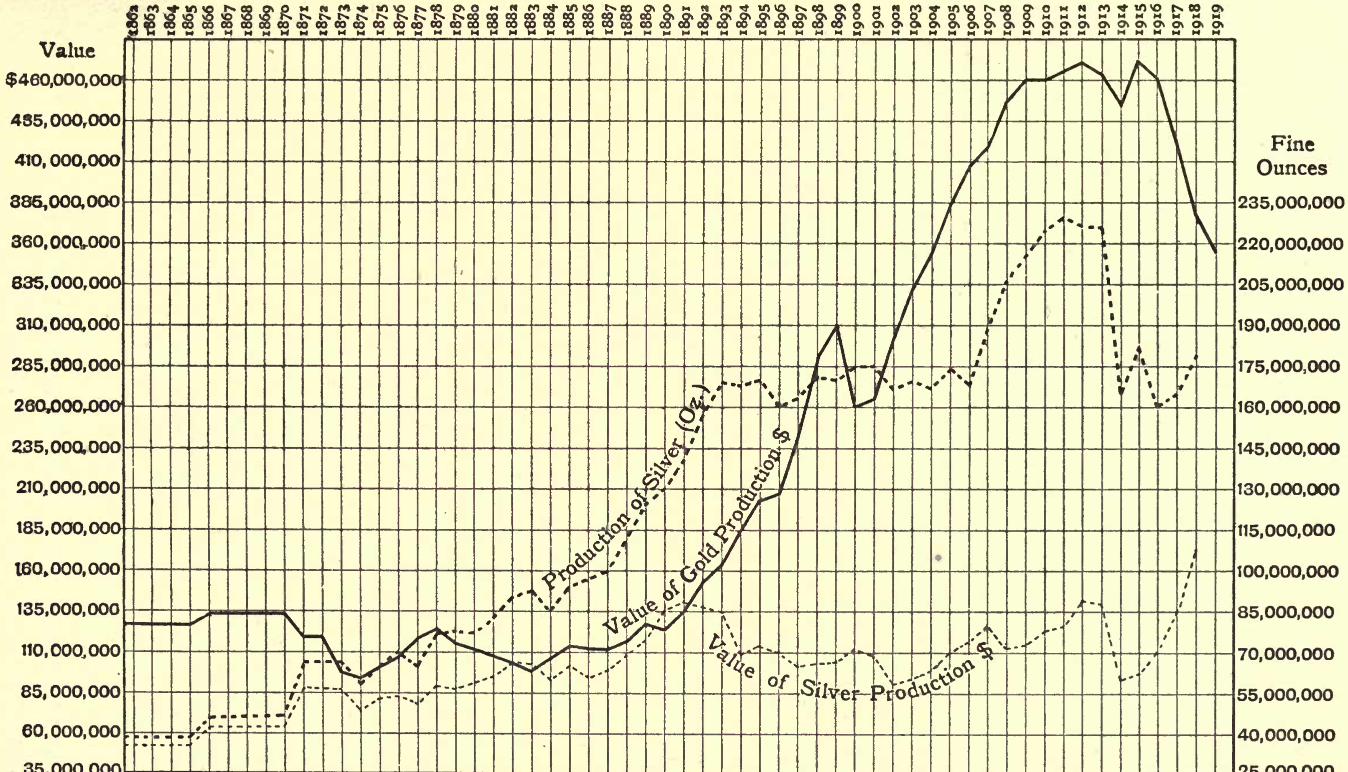
—	1913.	1914.	1915.	1916.	1917.	1918.
North America:						
United States	66,801,500	72,455,100	74,961,075	74,414,800	71,740,400	67,810,100
Canada [7]	31,845,803	28,449,821	26,625,960	25,459,741	22,221,274	21,383,979
Mexico	70,703,828	26,062,869	22,900,557	29,776,114	42,020,547	62,517,000
Central American States	2,135,641	2,754,868	2,920,496	2,602,500	2,369,500	2,900,000
South America:						
Bolivia and Chile	3,932,594	789,685	3,870,065	4,402,100	4,151,600	4,335,000
Argentina	35,271	—	—	21,300	29,000	25,000
Brazil	28,364	76,685	21,523	22,000	25,000	25,000
Colombia	587,683	351,271	351,271	309,400	325,000	325,000
Ecuador	22,642	16,726	24,655	30,000	45,000	40,000
Peru	9,971,067	9,214,190	9,419,950	10,787,000	10,864,400	9,781,733
Guiana and Uruguay	51,111	—	—	8,500	8,000	8,000
Venezuela	—	—	—	—	3,300	3,000
Europe:						
Austria-Hungary	2,104,107	1,572,746	1,772,699	1,500,000	1,500,000	1,750,000
Germany	4,984,677	—	—	—	—	—
France	520,766	—	—	—	—	—
Great Britain [1]	138,046	146,444	96,448	86,485	75,472	79,645
Greece	803,750	591,464	591,464	350,000	350,000	350,000
Italy	423,888	510,365	493,856	486,500	486,500	500,000
Norway	247,988	440,917	413,867	439,100	294,900	270,200
Spain and Portugal	4,437,637	4,434,417	4,567,454	4,517,800	2,850,000	3,100,000
Russia	—	—	638,403	550,000	500,000	400,000
Serbia	28,758	12,014	—	10,000	20,000	20,000
Sweden	58,969	33,511	24,230	37,900	35,000	31,500
Turkey	1,509,133	1,509,133	1,509,133	500,000	400,000	400,000
Australia [2]	16,081,877	14,295,944	7,940,957	8,864,860	9,401,187	9,820,231
New Zealand [3]	975,616	599,162	957,541	900,000 (*e*)	787,152	879,383

Asia :						
India (British) [4]	125,209	236,446	285,387	760,374	1,581,838	1,971,783
China	—	—	18,230	30,000	63,900	70,000
Chosen (Korea)	15,048	16,864	21,897	25,000	26,500	26,000
Dutch E. Indies	465,980	400,000	400,000	400,000	400,000	400,000
Indo-China	—	1,767	1,056	1,000	1,000	1,000
Formosa	51,763	51,080	47,653	47,700	39,600	26,900
Japan	4,649,910	4,836,228	5,120,293	5,805,700	7,111,700	6,600,400
Africa :						
Belgian Congo	1,454	4,770	4,770	11,000	10,300	10,500
Egypt	—	1,223	1,657	1,200	900	800
French East Africa & Madagascar .	—	—	—	20,000	20,000	20,000
Southern Rhodesia [5]	142,390	150,794	185,223	200,676	211,989	175,722
S. Africa [6]	952,597	890,782	966,177	968,935	938,146	877,522
Port. E. Africa	—	—	—	1,200	1,200	1,200
	224,835,067	170,907,286	168,113,947	174,348,885	180,910,305	196,936,598

[1] Mines and Quarries—Home Office Reports.
[2] Mines Repts. of the different States.
[3] Mines Statement.
[4] Rec. Geol. Surv. India.
[5] Mines Repts.
[6] Mines Repts.
[7] Mineral Prod. Canada.
(*e*) Estimated.
(*a*) U.S. Geol. Surv. 1918.



PRODUCTION OF CHIEF SILVER-PRODUCING COUNTRIES, 1905–1918.
(Millions of Fine Ounces.)



Curves showing Gold and Silver produced in the World, 1862–1919 [2]

Values of Silver

The ratio of the value of silver to that of gold has varied very much from time to time, as will be seen in the table below. Thus in ancient Arabia and Germany the value of silver appeared to have been higher than that of gold. David Barbour [4] remarks that:

"In the Middle Ages the monetary standard of England was silver, and it was not until the reign of Edward III that a successful attempt was made to put gold coins into circulation, but from that time both gold and silver coins continued to circulate in England, the ratio of exchange between them being declared from time to time by Royal authority. The legal standard of the country continued to be silver, but coins of both metals were in circulation, and were frequently debased and the ratio of exchange altered."

In the seventeenth century both metals were of equal value in Japan.

The variations in ratio between the values of gold and silver in Europe are given in the following table:

Ratio of Value of Gold to that of Silver in Europe at Different Periods [3]

Period.	Place.	Ratio.	Period.	Place.	Ratio.
A.D.			A.D.		
1250–1300 .	Florence	10·9	1725 . .	Hamburg	15·1
1300–1350 .	,,	11·6	1750 . .	,,	14·6
1350–1400 .	,,	10·8	1775 . .	,,	14·7
1400–1450 .	,,	10·4	1800 . .	,,	15·7
1450–1500 .	,,	10·4	1825 . .	,,	15·7
1500–1550 .	Netherlands	10·6	1850 . .	London	15·7
1550–1600 .	,,	11·3	1875 . .	,,	16·6
1600–1650 .	,,	12·6	1900 . .	,,	33·3
1650–1700 .	,,	14·2	1910 . .	,,	38·0
			1911 . .	,,	38·0
			1912 . .	,,	33·3

Thus in 1250, 10·9 oz. of silver were exchangeable for 1 oz. of gold; but in 1911, 38 oz. were required.

Total Sterling Values of Gold and Silver and Ratio of Values respectively [3]

Period.	Total Sterling Values of		Ratios of Total Sterling Values.	
	Gold.	Silver.	Gold.	Silver.
	£	£		
1493–1660	173,000,000	514,000,000	1 :	3
1661–1850	480,000,000	952,000,000	1 :	2
1851–1900	1,400,000,000	750,000,000	1 :	½
1901–1911	867,000,000	226,000,000	1 :	¼

World Productions and Values of Silver from 1493 *to* 1911 [3]

Period.	Number of Years.	Millions of Oz.	Value in Millions Sterling.
			£
1493–1660	168	1,490	514
1661–1850	190	3,320	952
1851–1900	50	4,010	750
1901–1911	11	2,062	226

Annual Variations in Value of Silver

In New York, quotations for silver are given in cents per ounce Troy, 999 fine, but in London they are in pence per ounce Troy, of standard silver, 925 fine. The following table gives the average yearly prices of bar silver in London from 1860 to 1920:

Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.
1860	61·69	1870	60·56	1880	52·25	1890	47·69	1900	28·25	1910	24·67
1861	60·81	1871	60·50	1881	51·69	1891	45·06	1901	27·19	1911	24·59
1862	61·44	1872	60·31	1882	51·62	1892	39·81	1902	24·09	1912	28·84
1863	61·37	1873	59·25	1883	50·56	1893	35·62	1903	24·75	1913	27·57
1864	61·37	1874	58·31	1884	50·62	1894	28·94	1904	26·40	1914	25·31
1865	61·06	1875	56·87	1885	48·62	1895	29·87	1905	27·84	1915	23·67
1866	61·12	1876	52·75	1886	45·37	1896	30·75	1906	30·87	1916	31·31
1867	60·56	1877	54·81	1887	44·62	1897	27·56	1907	30·19	1917	40·85
1868	60·50	1878	52·56	1888	42·87	1898	26·44	1908	24·40	1918	47·52
1869	60·44	1879	51·25	1889	42·69	1899	27·44	1909	23·71	1919	57·06
										1920	61·56

The Properties of Silver

Pure silver is white in colour and is capable of taking a brilliant polish [5]. In the form of a very fine powder it possesses a grey colour. It is more malleable and ductile than any other metal except gold, and may be hammered into exceedingly thin leaves. The tenacity of silver wire of 1 sq. mm. in sectional area is equivalent to 17·27 tons per square inch at 0° C. By hammering or rolling it becomes hardened, but its softness is restored by annealing at about 200° C. It is the most perfect conductor of heat and electricity known, and this conductivity is increased by annealing. The specific gravity of cast silver is 10·50, whilst that of molten silver is slightly lower and that of precipitated silver slightly higher. Cast ingots of the metal are difficult to prepare free from minute cavities. Silver crystallizes in the cubic system, but crystals rarely occur in nature. Melting takes place at about 1,000° C. and volatilization commences at about 1,080° C. In the molten state the metal is capable of absorbing oxygen from the air to the extent of 22 times its own volume. On cooling, this oxygen is violently ejected.

Silver does not oxidize in either dry or moist air at ordinary temperatures, and only very slightly when the temperature is raised. It is easily dissolved by nitric acid, and by hot and concentrated sulphuric acid. Hydrochloric acid attacks the metal only slightly. It is blackened by sulphuretted hydrogen, and readily unites with chlorine.

The Uses of Silver

Silver is mainly used in the form of its alloys with copper for conversion into coin, plate and jewellery. Pure silver is too soft for the production of durable coins, ornaments, and vessels of various descriptions, but this defect may be remedied by alloying it with a little copper. The proportion of silver present in 1,000 parts of alloy in the case of silver articles is indicated by their fineness. In Great Britain all silver coins are made of standard silver, the fineness of which, by legal definition, is 925, but a toleration of 4 units of pure silver in 1,000 of alloy is allowed, i.e. a specimen passes so long as its fineness lies between 925 and 921.[1] In Germany and in the United States all silver coins, and in France and Austria the major silver coins, are of fineness 900, with a toleration of 3 units. The minor coins of Austria are of fineness 375 to 520; in France all silver coins under 1 franc contain 835 of silver, 93 of copper, and 72 of zinc in 1,000 parts. The fineness prescribed by law or custom for silver articles is 950 in Great Britain; 800 ($\pm$ 5) in France, 750 in North Germany, 812·5 in South Germany, and 820 in Austria. Any silver-copper alloy which contains less than 750 per 1,000 of silver tarnishes very perceptibly in air [6].

Silver bullion is bought by the Mint and manufactured into coin, which is kept in stock and issued as required. One ounce of standard silver, which contains 925 parts of silver and 75 parts of copper per 1,000 of alloy, is converted into silver coin equivalent in value to 5*s.* 6*d.*, whatever may be the market price of silver bullion. The difference between the nominal value of silver and bronze coin and its intrinsic value is retained by the State to cover the expenses of manufacture and as a source of profit. The worn gold and silver coin which is withdrawn from circulation by the Bank of England and some other banks is received by the Mint at its nominal value for re-coinage. It is stated that the average deficiency in weight of worn silver coin received at the Mint is 8 to 10% and the mean age somewhat less than 50 years [7].

Of all the alloys of silver the silver-copper alloys are by far the most important. The addition of small amounts of copper to silver lowers its melting-point, prevents it from effervescing on solidification, enables sound castings to be made, and makes it harder, without sensibly impairing its malleability or altering its colour. Silver also alloys with lead, bismuth, mercury, gold, zinc, and other metals.

Electro-plating is carried out in cyanide baths containing about 3 oz. of potassium cyanide and 1 oz. of silver per gallon of water.

Oxidized silver is ordinary silver-copper alloy which has been coated with a thin film of silver sulphide by immersing

[1] The silver circulation of the United Kingdom is £60,000,000. Coins of a fineness of 500 and of the value of £5,000,000 were put into circulation in December 1920.

in a solution of sodium sulphide. *Silvering* calls for the use of thin sheets of silver or of certain compounds of silver.

Amongst the many other uses which have been found for silver and its compounds may be mentioned the employment of colloidal silver in medicine, and that of silver oxide for imparting a yellow colour to glass. Silver nitrate in a fused condition constitutes the *lunar caustic* of pharmacy: furthermore, it is used as a marking-ink, as a constituent of certain hair dyes, and is largely employed in photography and medicine.

The Silver-bearing Ores

Following the precedent set by the United States Geological Survey in its Annual Reports of the Mineral Resources of that country, silver-bearing ores may be grouped under the following heads:

1. *Dry or Siliceous Ores,* comprising gold and silver ores proper, associated with very small amounts of copper, lead and zinc.
2. *Argentiferous Copper Ores,* with over 2½% copper.
3. *Argentiferous Lead Ores,* with over 4½% lead.
4. *Argentiferous Zinc Ores,* with over 25% zinc.
5. *Mixed Ores,* comprising mixtures of types 1 to 4.

It is clear, therefore, that any account of the occurrence, distribution, and metallurgical treatment of these ores which carry silver must necessarily extend over a very wide field. Most ores of lead contain silver, and the metal is frequently present in ores of zinc and copper, as well as occasionally in ores of iron, nickel, cobalt and bismuth.

Silver Ores Proper

The following table gives the more important silver minerals together with their chemical composition:

Native silver	Ag
Argentite	Ag_2S
Cerargyrite (Horn silver)	$AgCl$
Proustite (Light-red silver ore)	$3Ag_2S.As_2S_3$
Pyrargyrite (Dark-red silver ore)	$3Ag_2S.Sb_2S_3$
Stephanite (Brittle silver ore)	$5Ag_2S.Sb_2S_3$
Polybasite	$9(Ag,Cu)_2S.Sb_2S_3$
Tetrahedrite (Fahlore)	$3(Cu,Ag)_2S.Sb_2S_3$

In addition to the above, the following are of less frequent occurrence: Stromeyerite $(Cu,Ag_2)S$; Pearceite, $9(Ag,Cu)_2S, As_2S_3$; Freieslebenite, $5(Pb,Ag_2)S.2Sb_2S_3$; Embolite, $Ag(Cl,Br)$; Iodyrite, AgI; and the gold and silver tellurides, Hessite, Ag_2Te; Petzite, $Au_2Te.3Ag_2Te$; Sylvanite, $(Au,Ag)_2Te_4$; and Krennerite, $(Au,Ag)_2Te_4$.

Native Silver.—Metallic silver occurs as lumps, as plate or foil, and in strings and wiry coils. Its hardness varies from 2½ to 3, and thus, in this respect, it falls between gold and copper. Density, 10·1 to 11; that of pure silver being 10·5. Fresh surfaces are white in colour, but tarnish to a red, brown, or blackish colour. Lustre, metallic; fracture, hackly. Fusibility, 2 (Von Kobell's scale). The native metal contains traces of copper, arsenic, antimony and iron. It is soluble in nitric acid, and gives a precipitate with hydrochloric acid.

Native silver often occurs in isomorphous admixture with gold, copper, and mercury, and also with antimony (*Dyscrasite*).

Argentite.—Sulphide of silver: Ag_2S (silver 87%). Crystallizes in cubes, octahedra, and rhombic dodecahedra, but also occurs massive. Colour and streak, a dull black or lead grey. Lustre, metallic. Opaque. Cubic cleavage imperfect. Fracture, conchoidal. Sectile. Hardness, 2 to 2½. Density, 7 to 7·4. Fusibility, 1·5. Yields a globule of silver on charcoal.

Stephanite, or brittle silver ore. A sulphide of silver and antimony, or sulphantimonite of silver; $5Ag_2S.Sb_2S_3$ (silver, 68·36). It occurs massive, or crystallized in thick six-sided tablets, or in short prisms of the orthorhombic system. Colour, iron-black. Lustre, metallic. Hardness, 2 to 2½. Density, 6·2 to 6·3. Cleavage, brachypinacoidal. Fracture, uneven to semi-conchoidal. Brittle. Before the reducing flame of the blowpipe on charcoal it yields a metallic button.

Pyrargyrite, or dark ruby silver ore. A sulphantimonite of silver; $3Ag_2S.Sb_2S_3$ (silver 59·97, antimony 22·21, sulphur 17·82%). Habit, short columnar with rhombohedral and scalenohedral termination. Often twinned. Also occurs massive. Cleavage, rhombohedral. Fracture, conchoidal to uneven. Brittle. Hardness, 2 to 3. Density, 5·77 to

5·86. Lustre, metallic-adamantine. Translucent in thin splinters. Colour in reflected light, black to grey-black; in transmitted light, deep conchoidal red. Streak, red. Fusibility, 1 (Von Kobell). Before the blowpipe gives off dense antimonial fumes; yields a globule of silver when fused with sodium carbonate on charcoal.

Proustite, or light ruby silver ore. A sulpharsenide of silver: $3Ag_2S.As_2S_3$ (silver 65·4, arsenic 15·17, sulphur 19·43%). Habit, similar to that of pyrargyrite. Also massive. Cleavage, rhombohedral. Fracture, conchoidal to uneven. Brittle. Hardness, 2. Density, 5·55 to 5·64. Lustre, adamantine. Transparent to translucent. In reflected light, black or grey-black; in transmitted light, almost scarlet-red. Streak, red. Fusibility, 1 (Von Kobell). Heated on charcoal before the blowpipe gives off arsenical fumes (smelling of garlic); yields a globule of silver with sodium carbonate.

Polybasite.—A sulphantimonite of silver and copper; $9(Ag,Cu)_2S.Sb_2S_3$ (silver 62 to 75%, and copper 0 to 10%). Habit, thin six-sided tablets; also in scaly aggregates. Lustre, metallic. Colour, iron-black; in thin fragments by transmitted light, cherry-red. Cleavage, basal and perfect. Fracture, uneven. Hardness, 2 to 3. Density, 6 to 6·2. Fusibility, 1 (Von Kobell). Before the blowpipe gives off antimonial fumes; with sodium carbonate on charcoal yields a globule of cupriferous silver.

Cerargyrite, chlorargyrite or horn silver. Chloride of silver: $AgCl$ (silver 75·3%). Habit, cubic, also massive and in scales and plates. Colour, whitish-grey. Lustre, resinous to adamantine. Translucent. Malleable. Sectile. Hardness, 1 to 2. Density, 5·58 to 5·6. Fusibility, 1, yielding a globule of silver on charcoal.

Hessite (Ag_2Te).—A telluride of silver. An analysis quoted by Simpson [8/p. 90], gave 61·0% silver, 38·2% tellurium, and 8% gold. Occurs in small irregular-shaped masses. Colour, lead-grey, sometimes with dark grey tarnish, but usually with bright metallic lustre. It is soft (H,2½), sectile, tough and possesses an uneven fracture. In the closed tube it fuses readily and gives a white fusible sublimate of telluric oxide.

(*Petzite* $Au_2Te.3Ag_2Te$).—A telluride of gold and silver. An analysis quoted by Simpson [8/p. 91] gave 41·8% silver, 33% tellurium and 25% gold. As found at Kalgoorlie, this mineral is black in colour, with a bright metallic lustre, which tarnishes somewhat readily on exposure to the air. It is brittle and shows no trace of cleavage.

Sylvanite $(Au,Ag)_2Te_4$.—A telluride of gold and silver. An analysis of Higgins gave 36·95% gold, 8·30% silver, and 54·50% tellurium. Colour, silver-white. Possesses a perfect vertical cleavage and on heating fuses quietly. Monoclinic.

Krennerite $(Au,Ag)_2Te_4$.—A telluride of gold and silver. Very similar in appearance to sylvanite, but possesses a basal cleavage and belongs to the orthorhombic system. Moreover, on heating it decrepitates violently.

Kalgoorlite and Coolgardite.—These are undoubtedly to be regarded as mixtures of various tellurides and not as distinct species as was supposed by Pittman and Carnot.

"Broadly speaking, about two-thirds of the world's silver in 1912 was obtained from base metal ores, and one-third from precious metal ores. Further, only one-fifth, or 20%, was obtained from mines worked exclusively for silver, while four-fifths, or 80%, was derived as a by-product from mines which were worked primarily for one or more of the metals, gold, copper, lead and zinc, and which would not have been in operation if their silver had been the sole metal output" [9/p. 185].

When oxide of manganese is largely present in silver-bearing ores, it makes them rebellious and difficult or even impossible to treat economically. In numerous silver mines in the Western States, Mexico and South America, considerable bodies of rebellious manganese silver ores have been left unmined pending the solution of the so-called "manganese-silver problem" [9/p. 184].

Ores of this type are being investigated in Colorado under the direction of the U.S. Bureau of Mines, and the result is awaited with interest.

ARGENTIFEROUS BASE-METAL ORES

It is a remarkable fact, as demonstrated by mining experience, that the five metals, silver, gold, copper, lead and zinc, are closely related as regards both the genesis and geological occurrence of their ores. A single deposit may contain the ores of two or more of the metals in such intimate association that they are necessarily mined together, and generally, as in the cases of copper and silver, lead and silver, and gold and silver, retain this association even when reduced to a metallic condition, and are not separated until the later stages of metallurgical treatment have been reached. Indeed, it may be said that it is most unusual to find the ores of any one of these metals absolutely free from its customary associates. Silver ores proper yield only a fraction of the world's output of the metal, the bulk being obtained from what are primarily to be classed as lead or copper ores. Under modern metallurgical treatment the precious metal may be economically extracted from ores which are really mined for the production of lead or copper. The silver in these cases constitutes a by-product—thus the native copper of Michigan, said to contain at the most 1 part of silver per 1,000 parts of copper, yielded 509,467 oz. of silver in the year 1918 as a result of electrolytically refining 56,127,000 lb. of copper. At Butte, Montana, the copper lodes contain on an average 1 part of silver per 400 parts of copper, and this silver is profitably extracted [10/p. 163]. It is stated that there are few deposits in which the ratio of copper to silver is more than 5,000 : 1.

Similar remarks may be applied to the intimate and very frequent association of silver and lead. It is seldom that a deposit of lead occurs in which the ratio of silver to lead is less than 1 : 10,000. In most deposits the ratio is 1 : 5,000, but often the amount of silver is much higher [10/p. 164].

Silver also frequently occurs in deposits which are mined for their gold contents or for both gold and silver. Thus, in the Kongsberg district the proportion of silver to gold is given as 10,000 : 1; at Freiberg, from 5,000 to 10,000 : 1;

at Schemnitz and Nagybánya, from 150 : 1 to 1 : 1 ; at the Comstock, 24 : 1 ; and at Cripple Creek, 1 : 10 [10/p. 165].

The Metallurgical Treatment of Silver-bearing Ores

Smelting.—Silver alloys readily with gold, lead, copper and a few other metals. Lead and silver obtained in smelting argentiferous lead and other ores are separated in a cupellation furnace. When the base-bullion is not sufficiently rich in silver, the lead is first desilverized by either Pattinson's or Parkes' process—in the former by a series of fractional crystallizations, based on the fact that crystals poor in silver separate out from a mother liquor much richer in silver, until the latter contains about 2% of silver. The greater portion of copper, nickel or cobalt separates as scum. Parkes' process depends on the greater affinity of silver for zinc than for lead. Zinc is melted with argentiferous lead, and the scum, containing a mixture of alloys of lead, zinc and silver, is skimmed off, argentiferous lead remaining behind.

Silver is separated from coarse copper by an electric metallurgical process. Cupriferous and pyritic ores are first roasted and then reduced to matte (a complex-artificial sulphide) from which blister copper is obtained. Oxidized ores may be reduced directly to nearly pure copper. Calcined ores are made to yield a matte, which is calcined and then fused, producing blister copper, or the molten matte is treated in converters. In pyritic smelting copper matte is produced by smelting raw pyritic ores in shaft furnaces.

Blister copper, reduced from matte, is cast into anodes and subjected to electrolytic refining. The electrolyte used is a solution of copper sulphate in dilute sulphuric acid. The gold and silver collects at the bottom of the tank as a thin mud, which is screened, dried and cupelled ; or it is digested with dilute sulphuric acid.

Amalgamation.—This may be divided into three classes : (1) Direct amalgamation with mercury alone (for ores containing free silver) ; (2) Amalgamation with mercury and certain reagents without roasting. (It includes the Washoe process, viz. the combination and the Boss processes) ; (3) Amalgamation with mercury and reagents preceded by a chloridizing roasting. (It includes the Baird, Reese-River, and the Franck-Tina processes.)

Lixiviation.—The cyanide process has largely replaced the old Ziervogel, Augustin, Patera, Kiss and Russell leaching processes, as well as the still older patio-amalgamation process.

The ore is crushed fine with cyanide solution (by stamps, often followed by tube-mills). The pulp is concentrated on Wilfley or other tables to remove such substances as tetrahedrite, galena and blende (which are smelted), and is then separated into sand and slime. The sand is returned to the tube-mills or is subjected to a lengthy treatment with cyanide in specially-constructed vats. The slime is often treated in a series of tall cylindrical steel vats (Pachuca tanks), with cyanide solution, the pulp being agitated by compressed air. The overflow passes from one tank to another until nearly the whole of the silver is dissolved. The metallic silver is precipitated from the clear solution either by zinc-dust or zinc-shavings. The precipitate is screened to get rid of any coarse undissolved zinc, and the screened product, partly dried, is smelted, with the production of silver bullion.

CHAPTER II

SOURCES OF SUPPLY OF SILVER ORES

(*a*) BRITISH EMPIRE

EUROPE

United Kingdom

The amounts of silver obtained in recent years from ores mined in the United Kingdom are as follow :

	Oz.		Oz.
1914	146,444	1917	75,472
1915	96,448	1918	79,645
1916	86,485	1919	68,414

No silver ore has been mined in the United Kingdom since 1907. During 1919 there was a recovery of 134 oz. from copper ores and 68,280 oz. from lead ores, making a total of 68,414 oz. [11].

Silver mines were worked in Britain before the invasion of the Romans. Among the Cornish mines which produced silver may be mentioned East Huel Rose lead mine (yield from 1852 to 1861 was 260,721 oz.), and West Chiverton (yield from 1866 to 1870 was 653,780 oz.). From 1852 to 1881 (30 years) Devonshire produced 31,180 tons of lead and 1,046,085 oz. of silver, but the output diminished rapidly from 1862, and in 1881 had become practically nil. The chief producers were the Tamar silver-lead mine (yield from 1851 to 1863 was 332,204 oz.), and the Frank Mills lead mine (yield from 1857 to 1880 was 247,151 oz.).

In 1894 the yield of silver from the North of England, Wales (including Anglesey), the Isle of Man and Scotland amounted to about 260,000 oz. Yorkshire and Derbyshire are not included in the above, as the ores from both are very poor in silver.

Among the ores of the Parys Mountain, Anglesey, *bluestone* is of special interest as it contains 6 oz. 15 dwt. of silver per ton, and appears to be an intimate mixture of galena, blende and chalcopyrite. An ore of similar composition, known as *kilmacooite*, occurs at Avoca, Ireland, and also contains from 6 to 8 oz. of silver per ton [12].

ASIA

INDIA

Although India is the largest consumer of silver in the world, no true silver ores are worked in the country, the metal being obtained as a by-product in the extraction of lead at Bawdwin, and of gold at Anantapur.

The values and productions of silver from 1909 to 1919 are given as follow [13]:

—	£	Oz.	—	£	Oz.
1909 . .	2,996	27,500	1915 . .	31,150	285,387
1910 . .	4,968	49,680	1916 . .	88,687	760,374
1911 . .	11,575	103,850	1917 . .	237,216	1,581,838
1912 . .	11,829	93,476	1918 . .	295,696	1,971,783
1913 . .	15,338	125,209	1919 . .	487,246	2,165,607
1914 . .	26,896	236,446			

The first production of silver in India is recorded for the year 1909. From 1909 to 1914 the entire output given in the table above came from the Bawdwin mines. In 1919, out of 2,165,607 oz., 753 oz. came from Anantapur and 2,164,854 oz. from Bawdwin, the former producing since 1915.

The net annual average import of silver for the period 1908–13 amounted to over 62,000,000 oz., valued at over £7,000,000, so that the amount internally produced, viz. about 104,700 oz., was quite insignificant as compared with the requirements, but recent production has shown a considerable increase.

The course of the silver trade of India for three fiscal years ending March 31 is as follows:

	1916–1917.	1917–1918.	1918–1919.
	Oz.	Oz.	Oz.
Net imports, private . . .	7,436,616	9,409,903	4,558,726
Net exports, private . . .	19,383,376	7,029,136	1,232,515
Net imports, Government . .	109,522,499	79,404,555	237,189,078
Net exports, Government . .	5,381,933	7,253,824	3,486,672

During the period May, 1918 to July, 1919, large amounts of silver were imported on Government account from the United States under the Pittman Act. In the year 1918–19 the imports were 122% of the world's production as against a former annual average of 26% [14].

The silver-lead mines of Bawdwin are situated in Tawngpeng, one of the lesser Northern Shan States of Burma. Particulars of these mines are given in the Imperial Institute *Monograph on Zinc Ores* (pp. 33–4).

AFRICA

Rhodesia

No silver minerals are known to occur in Rhodesia, but a considerable amount of the metal has been produced by the gold mines as a by-product. The three principal mines, Falcon, Shamva, and Rezende, in 1919 produced 65,491, 24,632 and 22,952 oz. silver respectively.

Electrum (gold-silver alloy) is present in a pyritic lode at the Hanover mine, Filabusi. It occurs in thin scales associated with pyrite, pyrrhotite, blende, galena, quartz and gold, sometimes being present in the quartz and sometimes in the pyrite.

In the Umtali district a number of gold mines work ores largely or entirely consisting of sulphides. Silver is usually present in galena and blende, and is partly recovered. The Rezende mine, which recovers practically all its silver from the argentiferous galena, is the most important in the district. The Cairn Dhu mine formerly worked a richly argentiferous and auriferous arsenopyrite lode, and recovered, a few years ago, only 30% of its silver. Samples of arsenopyrite from the Bessie Reef are said to have assayed as much as 50 oz. of silver to the ton, and at the Clutha mine galena is stated to contain up to 400 oz. per ton. It is, moreover, stated that on the Chefamiti claims, Lomagundi, a lead-copper ore carries both silver and gold in appreciable quantities. The copper matte of the Edmundian mine (obtained from chalcopyrite) carries a few ounces of silver and 3½ dwt. of gold per ton.

During 1920, the silver production in Southern Rhodesia amounted to 158,982 oz., valued at £58,178, and the total production to the end of 1920 was 2,970,827 oz., valued at £390,828 [15].

Transvaal

Silver is said to have been formerly mined to some extent at the Albert silver mine in the extreme northern part of the Pretoria-Middelburg area, and at the Transvaal silver mine, where it is associated with copper and lead ores, in the southern portion.

Silver-lead ores occur in the lodes south of the Pretoria road, about 5 miles west of Balmoral [16].

Nigeria

According to A. D. Lumb, silver-lead ore is known to occur in many small irregular deposits in the eastern part of Nigeria, from the Afikfo district northwards into the Muri province. The silver content varies from traces up to 125 oz. per ton. Owing to the pockety and irregular nature of the deposits their value is doubtful. At Orofu in the Muri province the natives mine lead ore on a small scale, but do not attempt to extract the silver content, which, however, is present in small amount.

South-West Africa [17/p. 86]

At the Tsumeb mine, Grootfontein district, is a complex ore deposit consisting of two large, steeply-dipping lenses, in grey Otavi dolomite. The ore of the main bodies, as mined in depth, is a massive coarsely-crystalline aggregate, composed of argentiferous galena, chalcocite, and other minerals. The ore as exported contains 7·7 oz. silver per ton. Wagner reports [17/p. 109] that a number of veins carrying argentiferous galena were discovered in 1912 at Aiais, situated a few miles east of the Fish River, in the extreme western portion of the Warmbad district. The country rock is granite, which is intersected by numerous basic dykes, and the veins appear to be developed along certain of these dykes. A good deal of exploratory work was done on these deposits during 1912 and 1913 by the South African Territories, Ltd., but as yet it has not been definitely established whether the veins are payable or not.

Argentiferous galena has also been found near Blydeverwacht, in the south-east corner of the Warmbad district, and an important occurrence of this mineral was opened up some years ago in the vicinity of Swartmodder in the Maltahöhe district.

NORTH AMERICA

Canada

Amongst the silver-producing countries of the world, Canada occupies at present the third place in respect to output.

The following table gives the annual productions of silver for various years from 1887 to 1920 [18] :

Year.	Oz.	Value, Dols.	Year.	Oz.	Value, Dols.
1887 .	355,083	347,271	1914 .	28,449,821	15,593,630
1892 .	310,651	272,130	1915 .	26,625,960	13,228,842
1897 .	5,558,456	3,323,395	1916 .	25,459,741	16,717,121
1902 .	4,291,317	2,238,351	1917 .	22,221,274	18,091,895
1907 .	12,779,799	8,348,659	1918 .	21,383,979	20,693,704
1912 .	31,955,560	19,440,165	1919 .	16,020,657	17,820,474
1913 .	31,845,803	19,040,924	1920 [1] .	12,793,541	—

[1] Estimated.

From 1887 to 1893 the production ranged in value between $300,000 and $400,000 and was derived chiefly from Ontario and Quebec. The next three years saw a rapid increase in output, due to the development of the silver-lead deposits of British Columbia, and in 1896 a production of over $2,000,000 is recorded. From that year until 1905 the production varied between $2,000,000 and $3,500,000, rising rapidly during the next six years to $17,580,455 in 1910, as a result of the discovery of the rich ores of the Cobalt district. Since then there has been a gradual falling off in quantity.

The following table gives the production of silver by provinces from 1909 to 1919:

Production of Silver by Provinces, 1909–1919 [18]

Year.	Ontario.	Quebec.	British Columbia.	Yukon Territory.	Manitoba.
	Oz.	Oz.	Oz.	Oz.	Oz.
1909	24,822,099	13,233	2,649,141	45,000	—
1910	30,366,366	7,593	2,407,887	87,148	—
1911	30,540,754	18,435	1,887,147	112,708	—
1912	20,214,025	9,465	2,651,002	81,068	—
1913	28,411,261	34,573	3,312,343	87,626	—
1914	25,139,214	57,737	3,159,897	92,973	—
1915	22,748,609	63,450	3,565,852	248,049	—
1916	21,608,158	98,610	3,392,872	360,101	—
1917	19,301,835	136,194	2,655,994	119,605	7,201
1918	17,198,737	178,675	3,921,336	71,915	13,316
1919	12,117,878	140,926	3,713,537	27,556	20,760

The percentages of the total productions for each province from 1914 to 1919 were as follow:

—	1914.	1915.	1916.	1917.	1918.	1919.
Ontario	88·4	85·4	84·9	86·7	80·4	75·7
British Columbia	11·1	13·4	13·3	11·9	18·3	23·1
Yukon	0·3	0·9	1·4	0·4	} 1·3	2·2
Quebec	0·2	0·3	0·4	1·0		
Manitoba	—	—	—	—		

Exports.—The table opposite gives the recent yearly exports of silver (metallic, contained in ore, concentrate, etc.) in ounces:

British Columbia

The total amount of silver produced in British Columbia during the year 1919 was 3,403,199 oz., a decrease in amount, as compared with the previous year, of 94,973 oz.

Exports of Silver from Canada

In Ounces

Destination.	1913.	1914.	1915.	1916.	1917.	1918	1919.	1920.
To:								
United Kingdom . .	17,926,748	24,260,358	16,533,652	16,323,672	15,357,764	10,848,840	10,243,363	3,358,171
India . . .	—	—	—	—	170,800	441,942	—	—
Hongkong . . .	795,234	1,786,230	384,774	941,933	378,225	689,245	121,918	536,812
Total, British countries .	18,721,982	26,046,588	16,918,426	17,265,605	15,906,789	11,980,027	10,365,281	3,894,983
China . . .	835,780	269,701	100 890	725,131	155,090	1,409,149	1,569,202	3,559,422
France . . .	—	2,043	—	—	2,322	—	—	98
Germany . . .	105,670	710,499	229,261	—	—	—	—	—
United States . .	15,600,586	9,729,445	8,106,728	9,803,830	7,780,060	8,571,651	7,824,995	4,925,139
Total, foreign countries .	16,542,036	10,711,688	8,436,879	10,528,961	7,937,472	9,980,800	9,394,197	8,484,659
Grand total. . oz.	35,264,018	36,758,276	25,355,305	27,794,566	23,844,261	21,960,827	19,759,478	12,379,642
,, dollars	20,202,559	20,971,538	13,516,390	14,298,351	15,870,803	18,428,571	19,519,642	14,255,601

[NOTE: The fiscal years end on March 31.]

[19]

In 1919 the Slocan district, including the Ainsworth, Slocan, and Slocan City mining divisions, produced about 50% of the total provincial output of silver, and the Fort Steele mining division about 6%, all from argentiferous galena. The remainder was chiefly derived from the smelting of copper ores carrying silver. In all, about 75% of the total provincial output of silver comes from the treatment of silver-lead-zinc ores, and the balance mainly from the smelting of gold-copper ores carrying silver.

The table opposite shows the production of silver in the various districts and mining divisions for the years 1913 to 1919.

The following table shows the percentage of silver production from the different mining divisions for the years 1916 to 1919 [21]:

—	1916.	1917.	1918.	1919.
Slocan and Slocan City M. D.	44·83	52·8	53·48	45·73
Skeena M. D.	7·77	11·7	11·95	27·06
Boundary-Yale district	8·65	7·8	6·53	6·54
Ainsworth M. D.	9·73	7·7	6·54	4·92
Fort Steele M. D.	15·43	6·1	7·48	6·04
Coast district	3·52	3·8	3·33	3·08
Omineca M. D.	3·41	2·8	2·42	2·13
Windermere-Golden M. D.	—	2·7	2·63	2·02
Trail Creek M. D.	4·00	1·6	1·35	0·82
Nelson M. D.	0·99	1·6	3·91	1·32
All others	1·67[1]	1·4	0·38	0·36

From the above it is seen that the Slocan mining division has by far the greatest output. The largest producers in the Slocan in 1919 were the Surprise, the Bosun, the Queen Bess, and the Standard. The total number of mines shipping from this district was approximately forty.

A map, on a scale of 50 miles to 1 inch, showing the distribution of the various mining divisions in British Columbia, is published by the Provincial Department of Mines.

Drysdale [22] publishes a preliminary table of classification of British Columbian ore-shoots. From this it would appear that by far the greater number of such deposits were formed

[1] This includes Trout Lake-Revelstoke 0·68, and others 0·99.

Productions of Silver in Different Parts of British Columbia

—	1913.	1914.	1915.	1916.	1917.	1918.	1919.
	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.
Cariboo :							
Omineca M. D.	46,298	135,265	79,155	112,635	82,311	84,125	72,573
Cassiar :							
Atlin	—	—	—	3,054	—	1,115	—
Skeena M. D.	4,714	131,509	175,179	256,802	343,805	416,616	920,413
Kootenay East :							
Fort Steele M. D.	362,311	492,080	481,258	509,693	180,168	261,497	205,500
Windermere-Golden M. D.	4,756	—	1,188	29,178	79,685	91,784	68,634
Kootenay West :							
Ainsworth M. D.	477,015	329,586	289,565	321,202	224,461	228,699	167,453
Slocan and Slocan City M. D.	1,841,226	1,775,975	1,812,550	1,480,571	1,547,576	1,873,236	1,556,714
Nelson M. D.	129,011	150,268	9,405	32,547	46,229	136,738	44,280
Trail Creek M. D.	109,585	136,185	159,584	132,080	47,112	47,203	27,788
Revelstoke, Trout Lake and Lardeau	23,397	11,295	16,740	22,419	37,733	11,761	2,994
Yale :							
Boundary district	394,048	347,981	273,795	280,578	220,213	227,113	222,680
Similkameen, Nicola and Vernon Divns.	335	15	347	830	3,470	131	6,823
Yale, Ashcroft and Kamloops	126	57	1,702	4,215	3,525	1,317	2,096
Lillooet and Clinton Divisions	295	390	5	—	276	412	365
Coast and other districts	102,739	91,574	66,033	116,119	112,652	116,425	104,806
Total	3,465,856	3,602,180	3,366,506	3,301,923	2,929,216	3,498,172	3,403,119

M. D. = Mining Division.

during the late Jurassic times, closely following the enormous intrusions of granites and diorites. A few, however, date from Tertiary times.

The mineralized areas in the Kootenay region have probably received more attention from the student of ore-deposits than most other similar areas within the Dominion. Drysdale has shown that it is possible to divide up the Kootenay into definite metallographic belts, each characterized by the predominance of a particular metal. Of these the best known are the gold, silver-lead-zinc, and copper belts respectively, and they may be traced more or less continuously from the southern to the northern boundaries of the Kootenay district. Furthermore, it happens that the trend and areal extent of the different mineralized belts correspond with definite rock formations. In the case of silver-bearing deposits the following relationships have been established [23/p. 62]:

Metallographic Belt.	Main type of Deposit.	Rock Terrain and Formation.
Silver-lead-zinc.	Fissure veins.	Post-Cambrian terrain (Slocan, Niskonlith and Pend-d'Oreille series).
	Replacement (blanket) veins.	Pre-Cambrian terrains (Purcell and Ainsworth series).

Within the belts, the ore-deposits themselves are confined to certain ore-zones, which, with the possible exception of replacement deposits, strike either in an easterly or a north-westerly direction. The position of these fissure-zones has been chiefly determined by the intrusion and solidification of granite or dioritic rocks, whilst the filling of the fissures with ore and gangue is to be regarded as the final phase of some process of magmatic differentiation, which had yielded these previously-intruded igneous rocks. This will explain how it is that the deeply-eroded portions of batholiths, and the rock-formations, remote from granitic or dioritic intrusives, are seldom productive.

Slocan Mining Division.—The principal ores of this division are complex silver-lead-zinc ores, the mining area being situated between New Denver and Silverton on Slocan Lake and Kaslo on Kootenay Lake.

The tonnages of high-grade ore and concentrate from the principal shippers of the division in 1918 were as follow: Standard Silvertons, 34,727; Bosun, Sandon, 27,764; Van Roi, Silvertons, 25,278; Hewitt, Silverton, 19,399; Surprise, Sandon, 13,998; Rambler-Cariboo, Rambler, 7,138; Queen Bess, Sandon, 5,314; Galena Farm, Silverton, 5,250; No. 1, Sandon, 1,724. The remaining twenty mines produced 1,515 tons, making a grand total of 142,107 tons shipped.

The Standard mine, which for many years has been the leading shipper of the Slocan, has been closed down, but further development work is being done, so that it may become a large producer again in the near future [18].

Both fissure veins and replacement veins are represented in the district, the latter occurring in the metamorphosed limestone. In contrast with the fissure veins, the replacement veins carry low amounts of silver and lead, and high amounts of zinc. The main vein-fissures generally correspond in strike and dip with the master-joints. Considerable faulting and fracturing along certain axes of folding have taken place so as to result in a systematic disposition. All transitions exist from true fissure veins, with well-defined walls, to fissure zones made up of a series of interrupted torsional or crevasse-like fissures, in line or in echelon. The fissure veins and zones may pass into stock-works or a series of connected veins between the hanging and foot-wall fissures [23/p. 56].

An excellent geological map of the Slocan mining area is included in the Summary Report of the Geological Survey of Canada for 1916 [23/p. 61]. Upon it are marked the positions of the mines and the strike and dip of the lodes.

The district is occupied by sharply-folded metamorphosed sedimentary rocks, known as the Slocan series, irregularly penetrated by the Nelson granodiorite which is exposed at the surface in large and small areas. The Slocan series is furthermore traversed by numerous offshoots of granite porphyry from the Nelson batholith. The eastern part of the area is bounded by outcrops of the "Kaslo Volcanics" and the "Shuswap Series."

The various rock-groups and their stratigraphical relationships are given as follow :

Age.	Rock-groups.	Rock-characters.	Relations to the Ore-deposits.
Jurassic and post-Jurassic.	*Granite porphyry dykes.*	Tongues from the Nelson batholith.	Genetically connected with ore zones.
	Nelson granodiorite.	Batholith, cupola stocks and tongues.	Country rock to many silver-lead veins, particularly where associated with lamprophyre dykes.
Ordovician to Carboniferous.	*Slocan series.*	Argillite, slate, phyllite, quartzite, carbonaceous limestone, chert and andalusite schist.	Main country rock to silver-lead zinc deposits.
	Kaslo Volcanics.	Sheared and smashed hornblende and augite porphyrites, tuff breccia, serpentine, talcose schist, diorite and gabbro with interbeds of dolomite, quartzite and crushed conglomerate.	Country rock to gold-quartz and antimony deposits.
Pre-Cambrian.	*Shuswap series.*	Quartz biotite and muscovite schists, quartzite, paragneiss and marble. Extensively injected by granitic material.	

Most of the metalliferous veins are contained within those areas occupied by the Slocan series, which constitutes the roof-rocks of the Nelson batholith and hence, as in most other cases in the Kootenays, stands in intimate relationship to the igneous intrusion.

Slocan City Mining Division.—This division is situated on the south of, and adjacent to, the Slocan mining division. Very little in the way of development was done on the claims in 1919, but all such work has given very encouraging results [18].

Skeena Mining Division.—This is the largest, and as yet the most important division in the North-Western district, principally due to the operations at Anyox of the Granby Consolidated Mining, Smelting and Power Company, which have had a far-reaching effect on the development of mining in the coastal region. The smelting works at Anyox were built primarily to treat the copper ores of the Hidden Creek mines, but also with a view to handling other Granby and custom ores, silver being recovered as a by-product. In 1919 the tonnage treated was 647,466 tons: this yielded 4,864 oz. gold, 348,408 oz. silver, and 19,544,588 lb. copper.

The Skeena mining division extends for a distance of about 400 miles from Millbank Sound on the south, to the headwaters of the Nass River on the north. It is penetrated by numerous long, narrow inlets and is traversed from Prince Rupert to Terrace by the Grand Trunk Pacific Railway. Considering the undeveloped nature of the region, transportation facilities are unusually good.

A report on the Alice Arm district by J. M. Turnbull [21, 1916] indicates that in all probability this district will, in the future, rank as an important silver-producing area. Three types of deposits containing silver are distinguishable, viz. (*a*) quartz veins of comparatively large size carrying chiefly silver. The ore is essentially a milling-ore. These veins are associated with, and occur in, a rock which is chiefly andesite, possibly diabase[1] in part. The district contains the partly developed mines, Dolly Varden and Wolf, and a number of promising prospects of a similar type. (*b*) Copper ores, with more or less gold and silver. The characteristic mineralization is pyrite, disseminated and accompanied by a certain amount of chalcopyrite. These deposits are less developed and less known or understood. (*c*) Small quartz veins of the fissure type, sometimes containing high silver contents in small erratic shoots. The ore consists of pyrite, blende, galena, chalcocite, and ruby-silver, in a quartz gangue. The country rock is the "argillite or slate formation." Little development work has been done on any of these veins.[2]

The Alice Arm mineralized area lies wholly on the eastern

[1] Dolerite is synonymous with diabase and is now more generally used.

[2] A sample of shipping-grade ore taken from the dump of the La Rose group gave 244 oz. silver, 18% lead and 12 4% zinc to the ton.

side of the great Coast Range granodiorite batholith, and is underlaid by a series of various types of metamorphosed sedimentary and pyroclastic rocks, into which have been intruded various kinds of igneous rocks. The geology of the district has not yet been systematically worked out.

The Boundary-Yale District.—The Boundary-Yale district includes the following mining divisions: Greenwood, Grand Forks, Osoyoos, Similkameen, Nicola, Vernon, Kamloops, Ashcroft and Yale. In 1919, the total output of the district was 282,131 tons, which contained—silver, 231,599 oz.; gold, 33,526 oz.; copper, 3,835,516 lb.; lead, 77,259 lb. The ores largely consist of low-grade gold-copper-silver ores. Two extensive copper-smelting plants were in operation for treatment of these ores; one, at Grand Forks, owned by the Granby Consolidated Mining and Smelting Company of Canada, Ltd., and the other, at Greenwood, owned by the Canada Copper Corporation, Ltd. The Granby smelter dealt with ores from the Granby mines at Phœnix, whilst the smelter at Greenwood dealt with ores which came chiefly from the Mother Lode mine in the Greenwood mining district, but also to some extent from other sources.

In 1916, the Granby smelter treated 1,097,299 dry tons of ore, derived from the Phœnix mines, and the following amounts of metals were obtained:—Copper, 15,992,476 lb.; silver, 204,779 oz. fine; gold, 36,801 oz. fine. The value in silver and gold per ton is given as $0·779, and the amount of copper recovered per ton of ore was 14·6 lb.

In 1917, the smelter operated by the Canada Copper Corporation, Ltd., at Greenwood, treated 196,856 tons of ore, obtaining 4,247,316 lb. of blister-copper, 9,582 oz. of gold, and 46,355 oz. of silver. Of the total amount of ore, 176,392 tons were obtained from the Mother Lode mine, 2,155 tons from the Sunset mine, 243 tons from the Oro Denoro mine, and 675 tons from the B.C. mine. The remainder, 17,391 tons, was derived from various outside sources.

Both smelters are now closed, and mining at Phœnix has ceased in consequence.

Ainsworth Mining Division.—The Ainsworth mining division lies on the east side of the Trout Lake and Slocan mining divisions, and includes Duncan Lake and the northern portions of Kootenay Lake.

The ores mined are largely of the silver-lead type, consisting chiefly of galena with some blende and occasionally a little pyrite and chalcopyrite.

Fort Steele Mining Division.—The Fort Steele mining division occupies the extreme south-eastern corner of British Columbia ; its silver production is obtained from argentiferous galena.

The Sullivan mine has produced by far the largest tonnage in the Kootenays, and is being operated by the Consolidated Mining and Smelting Company. The smelter receipts for the year 1919 show 14,890 tons of silver-lead ore treated, which yielded 126,446 oz. silver.

During the same year shipments of argentiferous lead ore amounting to approximately 776 tons were made from the St. Eugene property, the yield being 13,383 oz. silver.

Coast District.—The Coast district includes the mining divisions of Victoria, Alberni, Clayaquot and Quatsino, which are situated on Vancouver Island ; New Westminster and Vancouver, on the adjacent mainland ; and Nanaimo, which covers a large area on the mainland, and the north-east coastal belt of Vancouver Island.

The ores of the Coast district are of the copper-silver-gold type and essentially of a low-grade character. Usually they consist of magnetite, pyrrhotite, chalcopyrite and pyrite. Two principal types of ore-deposits are distinguishable, viz. the contact-metamorphic type, and the composite lode type. The first of these is represented by ore-bodies which occur in zones at or near the contact between metamorphosed limestone and igneous rocks. These ore-bodies have irregular lens-shaped outlines and are scattered. In composition they are characterized by the presence of magnetite, pyrrhotite, chalcopyrite and pyrite in a gangue of garnet, epidote and calcite, with varying amounts of tremolite and hornblende. Those deposits which are situated at the contact contain a higher percentage of magnetite and pyrrhotite, whilst those which occur within the zone of metamorphism, but at some distance from the actual contact, contain a higher percentage of pyrite and chalcopyrite.

The second type is represented by mineralized shear-zones in igneous rocks. Along these lines of disturbance, the secondary production of hornblende appears to be common. The ores consist of sulphides of iron and copper, together with magnetite, which varies in amount and may be absent, in a siliceous gangue consisting of comminuted country rock.

Victoria Mining Division.—Three distinct types of ore-deposits are represented in the division—the composite lode type, occurring in shear-zones in the Sooke gabbro, on Sooke peninsula; the Tyee type, occurring on Mount Sicker; and the contact type, occurring on Mount Gordon and the Koksilah River. Brewer describes several properties which have not, as yet, been adequately developed [21/1916, p. 309].

Alberni Mining Division.—Although there are many places at which mineralization occurs within the Alberni mining division, only a small amount of development work has so far been carried out, principally due to the low-grade nature of the ore, which contains small amounts of copper, gold and silver.

Clayoquot Mining Division.—Only one group of mines, the Indian Chief group, is reported as having shipped ore in 1919. The mineral localities within this division were examined by Brewer in 1916 [21/1916, p. 327]. In manner of occurrence and composition, the ore-bodies resemble those in the Alberni mining division. They are essentially low-grade copper-silver-gold ores consisting of chalcopyrite, pyrrhotite, pyrite and magnetite. The deposits belong to the replacement type and are found within crystalline limestone and along shear zones in igneous rocks. The gangue usually consists of garnet, epidote and calcite. The division is well supplied with safe harbours and good wharf sites.

Quatsino Mining Division.—No shipments of silver-bearing ore were recorded for the year 1919. Up to the present time lode-mining operations are confined to the neighbourhood of the south-east arm of Quatsino Sound [21/1916, p. 337].

Nanaimo Mining Division.—Metalliferous mining in the Nanaimo mining division at the present time is chiefly confined to the northern portion of Texada Island. During 1919 shipments of copper-silver-gold ores were made from several mines. At the Marble Bay mine, native silver was especially abundant in some of the lower levels far below the zone of surface enrichment. It produced regularly during 1919.

At the Loyal mine the ore-body consists of irregular areas of limestone, and occasionally, dyke rock, replaced by secondary minerals, largely garnet and epidote, with some copper sulphides, galena, pyrite and magnetite. The silver content is high, reaching 20 oz. to the ton. This is probably due to the presence of galena, a mineral not found in the principal producing mines [27].

Vancouver Mining Division.—There are several localities at which very low-grade copper-silver-gold ores occur in composite lodes within highly disturbed schists and igneous rocks.

Omineca Mining Division.—The Omineca mining division comprises an extensive territory, something like 58,000 square miles, in the north-western portion of British Columbia. It includes the headwaters of the Skeena, Fraser and Peace rivers, Lakes Tacla, Stuart, Babine and Francois, and the towns of Hazelton, Aldermere, Fort St. James, and Fort Fraser.

The only portion which has so far produced silver-bearing ores is the Hazelton-Telkwa section. These ores include both lead-silver and the copper-silver-gold types.

As a rule the ore-bodies in the Hazelton-Telkwa district may be considered as small bodies of medium to high-grade ore, as distinguished from the large low-grade ore-bodies found in other parts of the province. For this reason this section should prove attractive to small mining syndicates and individual operators.

In the Hazelton-Telkwa district the important rock-groups are the great series of pyroclastic, extrusive and sedimentary rocks known as the Hazelton formation; the intrusive granitoid rocks known as the Bulkley eruptives, and the sedimentary, coal-bearing Skeena formation.

The rocks of the Hazelton formation consist of quartzites, argillites and schists, as well as partly altered volcanics, and a third class of pyroclastic rocks. Mineralization has taken place in the Hazelton formation or in the Bulkley eruptives at points not far removed from the contact. Shearing and fissuring of the country rock accompanied the intrusion and cooling of the eruptives. Mineralization represents the last phase of the granitoid intrusives. The dykes associated with the plutonics are probably either contemporaneous or but slightly antecedent to the mineralizing phase.

The Bulkley eruptives are usually granodiorite, but true diorite and quartz-diorite are often seen. Wide variations in composition and texture are found in different places, but at all points the rocks are easily identified. Attendant dykes of felsite, granite porphyry, etc., are common.

Throughout the district many different types of ore-bodies are to be found. The principal types of wide distribution are: (*a*) composite lodes accompanied by replacement, in shear-zones; (*b*) simple lodes, or the "true fissure vein type," and (*c*) metasomatic deposits.

From the point of view of mineral contents the ore-deposits of the Hazelton-Telkwa district may be broadly divided into two groups, which, however, grade into one another. One is the copper-silver-gold group, and the other the lead-zinc-silver group. The predominating minerals in the first group are chalcopyrite, pyrite, arsenopyrite, pyrrhotite, and bornite, and in the second, galena, blende, tetrahedrite, stibnite, and very subordinate amounts of chalcopyrite, pyrite, arsenopyrite and native silver. As a rule the silver content is at least 1 oz. to the unit of lead, but higher and lower ratios than this are common. Usually the blende does not carry much silver. Tetrahedrite, on the other hand, is nearly always high in silver. Stibnite, found principally in the claims of Nine-mile Mountain, stands in much the same relation to silver content as does galena.

The mineral properties of the district were examined by Galloway in 1916 [21/1916, p. 92].

Windermere and Golden Mining Divisions.—A small amount of silver is obtained from silver-lead ores occurring in the Windermere-Golden division. At the Paradise mine, in the Windermere mining division, the ore probably replaces limestone in a sheared zone between limestone and quartzite.

From a shipment in 1919 some 2,000 tons of ore from an average of about 25% lead and 25 oz. silver per ton were obtained. At the Lead Queen the country rock is quartzite, and the ore, which is galena, is stated to contain 30 to 40 oz. per ton in silver, and from 65% lead. These examples are fairly typical of other ore-bodies, which are at various points within this region. Some of these are described in the annual reports on the Mineral Production of Canada [18].

Trail Creek Mining Division.—The silver production of this division is confined to the Rossland mining camp, which is described by Drysdale [28] and by Bruce [21/1916, p. 214]. The following three groups shipped gold-silver-copper ores during 1916 to 1918:

—	1916.	1917.	1918.
	Tons.	Tons.	Tons.
Le Roi group	130,000	49,827	54,900
Centre Star	163,000	36,890	49,298
Gosie group	15,800	11,803	—

From 1894 to 1914 the total production in silver of the Le Roi group amounted to 1,148,362 oz.

From 1894 to 1914 the total production in silver of the Centre Star-War Eagle group was 1,082,499 oz. The ore from the Centre Star claim itself would perhaps average 0·6% copper, 0·3 oz. silver and $7 to $10 in gold per ton.

At the town of Trail are situated the extensive smelting and refining plants of the Consolidated Mining and Smelting Co., of Canada, which produce the following refined metals: gold, silver, copper, zinc, lead, as well as copper sulphate, sulphuric acid and compounds of arsenic and antimony. Since the company took over the plant in 1894, over 5,000,000 tons of ore had been treated up to 1917, with a gross yield of 27,500,350 oz. of silver. In addition to the ores from Rossland, a large tonnage of custom ore is treated.

The Rossland area is occupied by a complex of igneous rocks of Carboniferous age, designated the "Mount Roberts Formation." The igneous rocks include augite-porphyrite, of Carboniferous age, monzonite, Nelson granodiorite, and pulaskite, along with minor intrusions of porphyry and lamprophyre.

The Rossland ore consists mainly of pyrrhotite and chalcopyrite, associated with a gangue of altered country rock, containing some quartz, and locally a little calcite. The ore-deposits of the producing belt at least are replacement lodes, along fissures and shear-zones. In the South Belt and within the augite-porphyry are lodes of pyrite and marcasite, with arsenopyrite. Silver may be the most important metal in such lodes.

The Nelson Mining Division.—The three principal mining areas within this division are the Ymir, Sheep Creek and Nelson camps. The most important properties are described in the Annual Reports on the Mineral Production of Canada [18], whilst Drysdale deals with the Ymir Camp in considerable detail [22].

The ores are of various types and include those of gold-silver, lead-silver, and gold-silver-copper.

In the Ymir area the lodes occur in the granitic rocks of the Nelson batholith, in small intrusions of monzonite, and within the metamorphic rocks of the Pend d'Oreille and Rossland groups. The ores containing silver essentially consist of galena, pyrite and blende. Some of these ores contain gold. At present very little mining is done in the Ymir area. Without doubt many undiscovered veins are still hidden under the thick cover of wash and drift in certain promising belts. It is recommended [22/p. 62] that veins parallel to those of the main producers of the past should be sought after and many of the abandoned barren veins should be tested further for the occurrence of ore-shoots at geologically favourable localities.

South-Eastern Cassiar.—An account [24/p.70] is given by C. Camsell of the results of a geological reconnaissance, carried out in 1915 in the little-known region, lying north of the Grand Trunk Pacific Railway, and between 124° and 126° long. and 54° and 56° lat. This region includes the basins of Stuart, Trembleur, and Takla lakes of the Fraser River drainage system, and the headwaters of the Omineca, Manson and Nation rivers of the Peace River system.

Parts of the area investigated showed evidence of important mineralization and are worthy of more serious attention. Although fairly high-grade gold- and silver-bearing quartz veins are known to occur, no lode mining has yet been attempted owing to the high cost of transportation. Camsell considers that portion occupied by the slates, schists and associated rocks of the Omineca district as presenting the most favourable conditions for the occurrence of ore deposits. These rocks are penetrated by igneous intrusive rocks and are traversed by mineralized veins of quartz.

Ontario

The silver produced in Ontario is obtained from silver-cobalt-nickel ores occurring in narrow, but rich veins, closely associated with sills of quartz-diabase which are intruded into a complex of rocks of pre-Cambrian age. Most of the silver comes from the immediate neighbourhood of the town of Cobalt, but small amounts are also produced at Gowganda in South Lorrain. The following are the productions of silver from the four mining districts of Ontario, and from by-products in 1919 :

	Fine Oz.
Cobalt	10,315,889
Casey Township	171,278
Gowganda	722,564
South Lorrain	4,586
Recovered from gold ores	92,675
" " nickel-copper refining	56,260
Total	11,363,252

[29]

From 1866 to 1903 considerable quantities of silver were obtained from the district about Port Arthur, Lake Superior, and particularly from the Silver Islet mine situated on a small island ¾ mile from the western shore of Lake Superior, and near Port Arthur. When the mine was abandoned in 1884, work had been carried to a depth of 1,160 feet, and it is estimated that $3,250,000 of silver had been extracted [30].

Below is given a list of the mines or companies which, in 1919, produced more than a quarter of a million ounces of silver with their individual contributions. Unless otherwise indicated, these mines fall within the Cobalt district proper.

	Oz.		Oz.
Nipissing	3,731,892	Miller Lake O'Brien (Gowganda)	108,872
Mining Corporation	1,088,064	O'Brien	648,501
Coniagas	918,063	Buffalo	577,811
Kerr Lake	802,243	La Rose	290,227
McKinley-Darragh-Savage	760,787	Crown Reserve	265,853
		Beaver Consolidated	263,388

Other producing silver mines in 1919 were: Adanac, Chambers-Ferland, Keeley, Temiskaming, Provincial, Silver Queen, Crews-McFarlan (Gowganda), Tretheway, Green Meehan, Foster, Hargrave, Hudson Bay, Copper Cliff, Penn-Canadian, Peterson Lake, Currie, Right-of-Way and Waldman.

Table I (p. 41) gives the shipments of ore, concentrate and silver bullion from the Cobalt silver mines from 1909 to 1919. The figures take no account of inter-camp movements, but include all shipments to outside points, whether in Ontario or the United States. The diminution in raw ores sent out, and the increase of concentrate and bullion will be noted.

Table II (p. 42) shows the quantity and value of all the constituents recoverable and recovered, in the ores of the Cobalt camp since 1909.

At the beginning of the silver-mining industry, in 1904, the entire output was sent to smelters in the United States. Afterwards concentration methods were introduced, which were followed by the establishment of refineries within the province. At a number of the mines themselves, smelting and cyanidation processes were introduced for the production of merchantable bars, and custom concentration and reduction plants were erected. As at the Nipissing mine, special methods of ore treatment were devised, and the introduction of the flotation process enabled large quantities of low-grade material to be concentrated. Out of the total quantity of silver contained in the product of the cobalt mines in 1917, namely 19,401,893 oz., 14,504,681 oz. were refined at the mines in Cobalt or in Ontario works, being about 75% of the whole. The silver-cobalt refineries in operation during 1919 in Ontario were: The

Table I

Silver Production, Cobalt Mines, 1909 *to* 1919 [29]

Shipments and Silver Contents

Year.	Number of Producing Mines.	Ore.			Concentrate.			Bullion.	Total.	
		Tons.	Oz.	Average per Ton.	Tons.	Oz.	Average per Ton.	Oz.	Oz.	Value.
				Oz.			Oz.			$
1909 . .	31	27,729	22,436,355	809	2,948	3,461,470	1,174	—	25,897,825	12,461,576
1910 . .	41	27,437	22,581,714	821	6,845	7,082,834	1,030	980,633	30,645,181	15,478,047
1911 . .	34	17,278	20,318,626	1,176	9,375	8,056,189	858	3,132,976	31,507,791	15,953,847
1912 . .	30	10,719	15,395,504	1,436	11,214	9,768,228	871	5,080,127	30,243,859	17,408,935
1913 . .	35	9,861	13,668,079	1,386	11,016	8,489,321	770	7,524,575	29,681,975	16,553,981
1914 . .	32	4,302	6,504,753	1,511	12,152	8,915,958	733	9,742,130	25,162,841	12,765,461
1915 . .	24	2,865	6,758,286	2,359	11,196	10,001,548	834	7,986,700	24,746,534	12,135,816
1916 . .	28	2,177	4,672,500	2,146	8,561	7,598,011	887	7,644,579	19,915,090	12,643,175
1917 . .	28	2,288	3,271,353	1,429	13,720	6,445,243	469	8,053,318	19,401,893	16,121,013
1918 . .	38	1,456	1,401,050	962	17,958	5,793,756	323	10,466,888	17,661,694	17,341,790
1919 . .	33	850	806,341	949	15,208	4,024,212	265	6,383,764	11,214,317	12,738,994

Table II

Total Production, Cobalt Silver Mines, 1909 *to* 1919 [29]

Year.	Nickel.		Cobalt.		Arsenic.		Silver.		Total Value.
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Oz.	Value.	
		$		$		$		$	$
1909	766	—	1,533	94,965	4,294	61,039	25,897,825	12,461,576	12,617,580
1910	504	—	1,098	54,699	4,897	70,709	30,645,181	15,478,047	15,603,455
1911	392	—	852	170,890	3,806	74,609	31,507,791	15,953,847	16,199,346
1912	429	14,220	934	314,381	4,166	80,546	30,243,859	17,408,935	17,818,082
1913	377	13,326	821	420,386	3,663	64,146	29,681,975	16,553,981	17,051,839
1914	(2) 90	28,978	(2) 351	590,406	2,030	116,624	25,162,841	12,765,461	13,501,469
1915	(3) 35	28,353	(3) 206	383,261	2,490	148,379	24,746,534	12,135,816	12,695,809
1916	(3) 79	59,380	(3) 400	805,014	2,160	200,103	19,915,090	12,643,175	13,707,672
1917	(3) 155	125,071	(3) 337	1,136,190	2,592	608,483	19,401,893	16,121,013	(1) 18,028,597
1918	(3) 186	156,893	(3) 380	1,640,310	2,545	556,332	17,661,694	17,341,790	(1) 19,741,490
1919	(3) 276	188,418	(3) 298	1,019,479	2,834	485,360	11,214,317	12,738,994	(1) 14,474,523

(1) Including small amounts of copper and lead recovered from certain silver ores and concentrates shipped to United States refineries.
(2) Metallic contents of nickel and cobalt oxides respectively.
(3) Metals and metallic contents of all nickel and cobalt compounds.

Deloro Smelting and Refining Co., Ltd., at Deloro; the Coniagas Reduction Co., Ltd., at Thorold; the Metals Chemical, Ltd., at Welland, and the Standard Smelting and Refining Co., Ltd., at Chippawa.

Results of Operations of Ontario Silver-Cobalt Refineries, 1919

Product.		Quantity.	Value.
			$
Ore treated	tons	881	—
Concentrate treated	,,	2,999	—
Residue treated	,,	4,380	—
Silver recovered and marketed	fine oz.	4,390,539	5,070,102
Arsenic, white, shipments ,, crude, shipments	lb.	5,274,884	483,604
Cobalt oxide, shipments	,,	426,573	634,553
,, hydroxide, sulphate, etc., shipments	,,	66,193	46,615
,, metallic, shipments	,,	121,926	243,554
Nickel oxide, shipments	,,	11,817	3,762
,, sulphate and carbonate, shipments	,,	353,267	46,711
,, metallic, shipments	,,	399,584	137,945
Total		—	6,666,846

[29]

In Cobalt camp itself, the Nipissing, O'Brien and Buffalo mines produce bullion from their own ores, and the first-named also from purchased ores. There are two plants which concentrate ores purchased for the purpose, or act as custom concentrators. These are the Dominion Reduction Co., and the Northern Customs Concentrators, Ltd. The former produces bullion, the latter concentrate only. In 1919, the various reduction works at Cobalt produced 1,666,135 oz. silver.

The silver deposits at Cobalt, Gowganda, Shiningtree Lake and at other points, are associated with sills of quartz-diabase. The veins on Florence Lake, which carry no silver and only traces of cobalt, but a considerable amount of chalcopyrite and quartz rather than calcite, are associated with a sill which is partly a quartz-norite. The veins occurring in North Williams, Dufferin, and Browning townships, containing a little smaltite, cobalt bloom, stibnite, galena, etc., and little or no silver, are also associated with a sill intermediate between a quartz-diabase and a quartz-norite. As far, then, as present experience in northern Ontario goes, typical silver cobalt veins are to be expected in association with sills of quartz-diabase and not with sills of quartz-norite. The distribution of these two rock-types is, accordingly, a matter of economic importance [31/p. 121].

Cobalt District.—The Cobalt district lies about 330 miles due north of Toronto, and midway between Lake Ontario and Hudson Bay. According to the geological maps published by the Department of Mines of Ontario, the district is occupied by those subdivisions of the pre-Cambrian designated the Keewatin and Lower Middle Huronian formations, which consist of conglomerates, quartzites and various members of a metamorphic complex. These rocks are cut by intrusions of diabase, and in places are overlaid by Niagara limestones.

The more common minerals of the remarkably rich veins mined in the Cobalt district are the arsenides of cobalt and nickel, *smaltite* with some *chloanthite*, *cobaltite* and *niccolite*, associated with native silver. Less frequent are *native bismuth*, *pyrargyrite*, *proustite*, *dyscrasite*, *argentite*, *millerite*, with occasional *arsenopyrite* and *tetrahedrite*. Pyrite, galena and blende are sometimes found in the wall rocks. The gangue minerals are calcite with a little quartz, but both are subordinate constituents in the rich parts of the veins. Calcite veins often serve as leaders which are followed in searching for the valuable ore. The cobalt-bearing veins are indicated at the surface by the pale reddish-blue colour of "cobalt bloom."

The great majority of the veins are very narrow cracks, each a fraction of an inch in width, filled with calcite. They are generally vertical, but seem to be rather irregular in strike, and pass without interruption from the Huronian into the underlying Keewatin. Also they traverse the intrusions of diabase. For considerable distances they may be quite barren of metallic minerals, and may pass into a series of parallel fractures, one of which will carry ore. Portions rich in ores may be from 4 to 8 inches in width, and, in exceptional cases, more than a foot for short distances, carrying a solid mass of cobalt and nickel arsenides, more or less impregnated with native silver, and with a rather subordinate amount of gangue, mostly calcite with sometimes a little quartz. The linear extent of the pay portions of the veins is not great and does not generally exceed a few hundred feet. The very rich ore, which carries 2,000 to 6,000 oz. per ton, does not extend, as a rule, more than 200 feet in depth.

It seems probable that the veins at Cobalt, as they exist at the present day, represent merely the roots of what was formerly a much more extensive system. Denudation has apparently removed the upper portions. The genesis of the minerals is evidently bound up in an intimate fashion with the intrusion of the post-Huronian diabase eruption. It is interesting to note the similarity of these deposits with those of Kongsberg in Norway [32].

Gowganda.—The first-discovered silver-bearing vein in the Gowganda district was found east of Gowganda Lake in 1908. The production during 1919 from the district amounted to 722,564 oz., of which the Miller Lake O'Brien mine produced 708,872 oz. The discovery of high-grade silver ore on the O'Brien property at Miller Lake was made in 1916, and during 1917 the Gowganda district received considerable attention from mining companies in search of new properties, no doubt as a result of this discovery. In the same year a small production was recorded from the Reeve-Dobie mine.

The Gowganda mining division forms a part of the great pre-Cambrian peneplain of northern Canada and is occupied by a complex of gneisses, schists and igneous rocks, whose stratigraphic relations are given as follow [33]:

Pleistocene			Unconsolidated glacial till, stratified clay and sand.
Pre-Cambrian	Post-Huronian intrusions		Olivine diabase, quartz diabase and aplite.
	Huronian	Lorrain series (Upper or Middle)	Quartzite, arkose and quartz conglomerate.
		Cobalt series (Middle or Lower)	Conglomerate, greywacke, slate and arkose.
			Rhyolite and rhyolite tuff.
			Great unconformity.

Pre-Cambrian (*continued*) . .	Laurentian batholithic intrusions . . .	Hornblende and biotite granites, granodiorite and syenite and their gneissic equivalents.
	Keewatin . . .	Basic and acid volcanic and intrusive rocks, and various schists.

The crystalline basement and mantle of Huronian sediments are penetrated by dykes and sills of quartz-diabase and quartz-norite. As a rule the dykes do not exceed 100 feet in width; the sills attain thicknesses up to 500 feet or more and are many square miles in horizontal extent. The dykes are vertical, and more numerous in the crystalline basement than in the Huronian formation. The sills, on the contrary, are found only within the Huronian. Between quartz-diabase and quartz-norite all intermediate gradations are to be observed. An exhaustive study of the various modifications included under the head of quartz-diabase has led Collins [31/p. 97] to the conclusion that a quartz-diabase magma gave rise to the following differentiation products:

(1) A diabase series.

(2) An aplite series.

(3) Calcite.

(4) Quartz-calcite veins carrying silver, cobalt and other ores, that occur along with the diabase sills.

Practically all the veins at Gowganda occur within the quartz-diabase sills. They are sharply-defined fissures rarely 2 feet wide and usually less than one foot. The dip is vertical or nearly so. Generally speaking, there does not appear to be any common trend to the veins in any one area or in the region as a whole.

The veins contain native silver, smaltite, niccolite, and chalcopyrite in a gangue of calcite and quartz. Native bismuth, pyrite, specular hæmatite, stibnite and galena are less constant constituents. The carmine stain of cobalt bloom is one of the most conspicuous signs whereby the veins may be recognized. The mineral constituents of the veins are believed to represent a late differentiation product from the quartz-diabase magma.

South Lorrain.—The production of silver for the year 1919 in South Lorrain amounted to 4,586 oz., the chief operating company being the Pittsburg-Lorrain Syndicate, working on the Currie mine. The Keeley mine, formerly one of the chief producers, has been reopened and an 80-ton mill is being constructed.

The manner of occurrence of the ore deposits within the South Lorrain area is similar to that at Cobalt. The veins occur chiefly in the diabase and in the Keewatin near the contact with the diabase.

Quebec

The small quantity of silver recorded as produced in Quebec is obtained from the pyritic ores mined at Eustis and Weedon, in the Eastern Townships, and the lead-zinc ores of Notre-Dame des Anges, Portneuf County. The productions for the years 1915–1920 were respectively: 78,809; 58,054; 96,620; 142,829; 127,223; and 57,514 fine oz.

Yukon

The annual productions of silver from Yukon for the years 1909 to 1919 are given below:

—	Oz.	Value.	—	Oz.	Value.
		$			$
1909	45,000	23,176	1915	248,049	132,241
1910	87,418	46,756	1916	360,101	236,466
1911	112,708	60,078	1917	119,605	97,379
1912	81,068	49,318	1918	71,915	69,594
1913	87,626	52,392	1919	27,556	30,621
1914	92,973	50,959			

[18]

The greater part of the total output is derived from alluvial workings, the rest being recovered from the gold and copper ores of Whitehorse and the silver-lead ores shipped from Mayo. In the former case the silver occurs alloyed with the placer gold. On an average, about one ounce of silver is contained in each 5 oz. of crude bullion from the alluvial workings. In 1916 about 13% of the total output was contributed by lode mining. In 1909 the whole of the silver was derived from placer deposits, the first output from lodes being in the following year.

Mayo Area (*Duncan Mining Division*).—This area includes the town of Mayo on Stewart River, and lies within the western portion of Duncan Creek mining district. Cairnes examined and reported on the area in 1915 [24/p. 10]. So far, prospectors have been mainly occupied with placer deposits, with the result that very inadequate attention has been given to the occurrence of lodes. In addition, there is a heavy mantle of superficial deposits, which obscures the underlying bedrock in most places. This bedrock mostly consists of mica-schists and quartzites, with crystalline limestones, and is believed to be of pre-Cambrian age. At certain points intrusions by granite, rhyolite, and greenstone have taken place.

The most important lode deposit so far discovered is a rich silver-lead vein on Galena Creek. Other veins are known carrying gold, silver, lead and zinc minerals; but in most cases they have not been developed, and very little is known concerning them.

Galena Creek.—The ore of this mine consists chiefly of galena and ruby silver, with pyrite. Samples assayed at the Government Assay Office, Whitehorse, Yukon, were found to contain:

Sample	Gold.		Silver.		Total value per ton of gold and silver.	Lead percentages.
	Oz. per ton.	Value per ton.	Oz. per ton.	Value per ton.		
		$		$	$	
1	Trace	—	306·00	153·00	153·00	2·43
2	0·16	3·20	533·44	266·72	269·92	40·90

Whitehorse Mining District.—In this district silver is recovered from gold and copper ores. The latter are chiefly associated with magnetite and generally occur as contact-metamorphic deposits in limestone at its contact with granite.

Conrad Mining Division.—The Conrad mining division lies on the northern side of the Atlin mining division of Northern British Columbia, although, geologically speaking, the two divisions are inseparable. Two subdivisions are recognized, the Wheaton area and the Windy Arm area.

Wheaton Area.—Practically the entire area is believed to be underlaid by the granite rocks of the Great Coast Range batholith, which outcrop over the greater part of the area. In addition, there are various groups of sedimentary, metamorphic and igneous rocks. The following is given as the stratigraphic relations of these rock-groups :

Era.	Formation.	Lithological character.
Kainozoic		Various volcanic rocks and minor intrusive rocks, with tuffs and breccias.
Mesozoic	Coast Range intrusive rocks.	Granitic and dioritic intrusive rocks, volcanic rocks with tuffs and breccias.
	Laberge series	Shale, sandstone, arkose, greywacke, conglomerate and breccia.
	Probably corresponds to the Kootenay	Conglomerate with sandstone, shale, and seams of coal.
Palæozoic		Limestone, pyroxenite.
Pre-Cambrian (?).	Mt. Stevens group	Various schists and gneisses.

The silver-bearing ore deposits are of three principal types, viz. :

(*a*) Gold-silver veins.
(*b*) Antimony-silver veins.
(*c*) Silver-lead veins.

Veins of the gold-silver type are widely distributed in Southern Yukon. The more important occur on Mount Anderson, Mount Stevens, Wheaton Mountain, Gold Hill, and along the south side of Watson River to the north of Hodnett Mountain. The ore-bodies are chiefly in the coast range intrusive rocks, but also in the schistose members of the Mount Stevens group. Within the granitic rocks the deposits are generally of the simple lode type ; where the country rock is made up of schists, however, the gold-silver ores have been deposited in lens-shaped masses and irregular fissures. The most important constituent is galena. Pyrite and chalcopyrite occasionally exist in small amounts. The gangue consists of quartz, with which is usually associated calcite in subordinate amounts. The most important mines so far prospected are the Buffalo Hump, the Tally-Ho and the Whirlwind, all of which lie within the big bend of Wheaton River.

The antimony-silver veins occur chiefly on the western or north-western slope of Carbon Hill facing Wheaton River. The country rock is for the most part the Coast Range granitic intrusive, but occasional veins are found in the Mesozoic andesitic rocks, which are older than the former. The mineral contents are stibnite, galena, tetrahedrite, blende, and in some cases arsenopyrite, together with quartz and smaller amounts of calcite and barytes. Some of the lodes contain important amounts of silver, but these are generally low in antimony, and those rich in antimony are as a rule low in silver. In a few places, however, both silver and antimony occur together in important amounts.

Veins of the silver-lead type are limited in their occurrence in the Wheaton district, so far as is known, to one small area situated on the east slope of Idaho Hill, facing Annie Lake. It is doubtful whether, under existing conditions, they are of any considerable economic importance.

Windy Arm Area.—The southern portion of this district, the Windy Arm area, was described by Cairnes [23/p. 34] in 1916.

Caribou, a point on the White Pass and Yukon Railway, serves as a distributing centre for the Windy Arm area. All the properties are quite readily accessible and practically all are situated at distances of from ½ to 4 miles from Windy Arm, and at elevations of from 1,200 to 3,600 feet above it. Thus aerial tramways for conveyance of ore to the water's edge for shipment or treatment have been or can be readily constructed.

The ores chiefly consist of pyrite, galena, arsenopyrite, pyrargyrite and argentite, in a gangue of quartz, and generally carry fairly high amounts of silver and gold.

Locally, the country is made up of porphyrites, andesites, basalts and tuffs, which comprise a portion of the Windy Arm-Conrad series. The ore deposits are fissure veins, which, with one exception, intersect andesitic rocks.

The exception is the Big Thing, which is about 5½ miles almost due south of Caribou. The ore occurs in a fissure vein which intersects granitic rocks of Jurassic or Cretaceous age, and is composed dominantly of quartz, pyrite and some disseminated arsenopyrite, as well as occasional particles of chalcopyrite, galena and stibnite. The vein, which is usually 2 to 8 feet in thickness, although in places it becomes as much as 12 feet thick, is chiefly of value for its gold content, but also contains some silver. The Montana mine is situated about 3 miles south of Big Thing. The ore occurs in a fissure intersecting basalts, andesites and related rock-types, thought to be of Cretaceous or Jurassic age. The M. and M. vein outcrops on the left bank of Pooly canyon near the top of the hill. The vein occurs as a fissure in andesite, and is in most places from 6 to 12 inches in thickness. The ore consists of pyrargyrite, stephanite, freibergite, tetrahedrite, and blue and green copper carbonates in a gangue of quartz. This deposit is especially rich in silver.

Venus No. 1 and Venus No. 2 are adjoining properties. A considerable amount of mining has been carried out on the latter. Some small shipments of ore were made in 1916; the ore consists mainly of galena, pyrite and some jamesonite, yukonite, chalcopyrite and chalcocite in a gangue of quartz. The gold and silver contents vary greatly. In most places the vein carries from less than one ounce to over 100 oz. of silver per ton, and from a trace to about $100 in gold. Where the ore is unaltered, it contains up to 15% lead, and from a trace to nearly 1% copper. A shipment of 300 tons of sorted ore averaged about $70 per ton. The vein occurs as a fissure traversing andesites, and the mineral contents have a banded and comb structure. To a certain extent, replacement of the wall rock has also occurred.

The Dail and Fleming group comprises a number of claims located along the west side of Windy Arm, immediately to the south of the Venus No. 2. Three principal veins have been found, known as the Venus, Humper and Red Deer, respectively.

The Venus vein is the same as the one developed on the Venus No. 2 mine. In the weathered portion, pyrite, arsenopyrite, galena, yukonite, together with realgar and orpiment are noted as occurring. The average silver content is believed to be generally under 10 oz. per ton, but varies from less than an ounce to over 100 oz. The gold content averages in value about $15 per ton, whilst that of the lead ranges from about $1 to $30 per ton.

The Humper vein is of the fissure type and traverses andesitic rocks. The thickness of the vein is from 10 to 24 inches in most places where explored, and the ore consists of argentite, pyrargyrite, stephanite, galena, pyrite and some native silver in a gangue of quartz. Parts of the vein, at least, are very rich in silver.

The Red Deer vein is also a fissure in andesitic rocks. Where exposed it is found to carry pyrite, galena and various high-grade silver minerals in a quartzitic gangue. Very little is known concerning this vein.

Nova Scotia

In Nova Scotia there are some argentiferous galena deposits near East Bay and at Musquodoboit, which have been intermittently worked.

AUSTRALASIA

New South Wales

Most of the silver extracted from ores mined in New South Wales is contained in ores of the silver-lead type, and the Broken Hill mines are by far the largest contributors. A small amount of the metal, however, was obtained from the copper ores raised by the Great Cobar mine.

Only a small fraction of these ores receive metallurgical treatment at works within the confines of the State; the major portion of ores and concentrate is either forwarded to oversea countries, or else these have their silver contents extracted in other States of the Commonwealth.

Silver is recorded as having been produced in 1919 at two smelting works in New South Wales. One of these, the Electrolytic Refining and Smelting Co., of Australia, Ltd. at Port Kembla, produced 114,081 oz. silver. The other, that of the Sulphide Corporation, Ltd., at Cockle Creek, Boolaroo, furnished 1,108,102 oz. silver [34].

The following table gives the productions of silver in New South Wales from 1910 to 1919:

Estimated Quantity and Value of the Silver yielded by the Mines of New South Wales

Year.	Produced in Australia.	Contained in Concentrate, etc., exported.	Total Production.	Total Value of Production.
	Oz. fine.	Oz. fine.	Oz. fine.	£
1910 . .	5,196,323	7,608,336	12,804,659	1,404,537
1911 . .	5,731,468	8,797,677	14,529,145	1,593,788
1912 . .	5,220,538	8,293,711	13,514,249	1,678,422
1913 . .	5,908,638	8,596,251	14,504,889	1,757,963
1914 . .	5,481,286	7,879,240	13,360,526	1,451,412
1915 . .	5,302,199	1,710,058	7,012,257	723,675
1916 . .	6,382,518	1,725,374	8,107,892	1,145,100
1917 . .	7,562,286	983,693	8,545,979	1,568,795
1918 . .	8,724,018	535,943	9,259,961	1,969,833
1919 . .	5,886,947	417,871	6,304,818	1,595,309

[34]

Broken Hill Mines.—The famous silver-lead-zinc deposits of the Broken Hill district are situated within the Albert mining district and about 15 miles from Silverton, a town lying near the western boundary of New South Wales. The first discoveries in the district, namely, of cerargyrite, were made in the year 1884, and from 1889 to 1896 the Broken Hill Proprietary, Ltd., the most important of the operators, produced over 2,000 tons of silver. By the year 1915 the total output of silver by this Company had reached approximately 177,000,000 oz. It was stated at the 39th ordinary general meeting on June 12, 1919, that the reserves of the Broken Hill Proprietary Co., Ltd., were estimated in December, 1918, at 1,095,015 tons of ore of an average assay value of 6·7 oz. silver, 12·8% lead, and 11·6% zinc. Details concerning the operations of the other companies engaged in the exploitation of the metalliferous deposits are given below. In 1918 the ore raised from the mines on the Broken Hill field amounted to 1,251,161 tons. A serious strike reduced the 1919 output to 415,400 tons.

The district consists of an ancient and highly contorted complex of gneisses, quartzite and mica-, hornblende- and garnet-schists, into which are intruded dykes of basic diorite. These rocks are covered in greater part by sedimentary deposits of recent and Pleistocene age. The ore-bodies are conformably intercalated in the metamorphic complex, and the principal deposit is in the form of a saddle. The foot-wall is generally sharply defined, but on the hanging-wall side, the ore and country rock pass insensibly into one another. The principal oxidized ores are limonite, hæmatite, psilomelane, rhodonite, cerussite, cerargyrite, native silver, together with kaolinized felspar, garnet, etc. At greater depths this association passes into sulphide ores, consisting principally of a coarse-grained mixture of galena and blende. In addition one finds quartz, garnet, felspar and rhodonite, and, more seldom, pyrite, chalcopyrite, arsenopyrite and fluorspar. The average ore contains 5 to 7 % lead, 14 to 30 % zinc, and 5 to 38 oz. of silver per ton. High-grade " dry ore," consisting of kaolin with some quartz and garnet, contains 4 to nearly 300 oz. silver per ton, whilst low-grade " dry ore " usually has 5 to 40 oz. silver per ton.

No general agreement has been reached on the subject of the genesis of these ore-deposits. There are typical contact minerals present, but these are older than the ore-deposits.

The following details of the output of the various companies engaged in the exploitation of the Broken Hill deposits have been taken from the Annual Report of the Department of Mines, New South Wales, for the years 1917 to 1919 [34]:

Name of Company.	Value of Output.		
	1917.	1918.	1919.
	£	£	£
Broken Hill Proprietary Co., Ltd.	1,696,065	1,709,294	717,179
Broken Hill Proprietary, Block 14 Co., Ltd.	32,892	71,224	114,567
British Broken Hill Proprietary Co., Ltd.	340,082	632,562	360,725
Broken Hill Proprietary Block 10 Co., Ltd.	153,767	183,627	147,835
Sulphide Corporation, Ltd.	878,926	1,042,112	334,602
Broken Hill South Silver-Mining Co.	822,251	1,189,238	346,450
North Broken Hill Co., Ltd.	569,568	604,201	236,354
Broken Hill Junction Lead-Mining Co.	57,679	70,697	40,171
Junction North Broken Hill Mine	253,203	331,891	117,014
The Zinc Corporation, Ltd.	343,883	413,989	147,851

The output of the Broken Hill Proprietary Co., Ltd., to June 2, 1915, included 176,781,329 oz. fine, of silver; 102,857 oz. gold; and 1,487,640 tons of lead.[1] The total contents of the crude ore, bullion and concentrate disposed of up to the end of 1919 by the Broken Hill Proprietary Block 14 Co., Ltd., are estimated at 13,993,907 oz. silver and 255,883 tons lead. In the case of the Broken Hill Proprietary Block 10 Co., Ltd., the crude ore and products (including tailing) disposed of were estimated to contain 38,209,213 oz. silver and 393,586 tons lead. The output of the Central mine since the commencement of operations by the Sulphide Corporation, Ltd., in 1897, to the end of the year 1919, includes 41,863,181 oz. silver. The concentrate produced by Broken Hill South Silver-Mining Co. contained 18,695,921 oz. silver. Likewise, considerable amounts of silver have been produced by the other companies not enumerated above. The output of the North Broken Hill, Ltd., for the year 1919 was 53,984 tons milled, which produced 10,890 tons of concentrate of an average assay value of silver, 27·4 oz. to the ton; lead, 63·6%; zinc, 7·5%.

Cobar Mining Field [35].—Considerable amounts of gold, silver and copper, together with small amounts of lead, have been obtained from the ore-bodies of the Cobar mining district. By far the most important mine is the Great Cobar mine, situated in the parish of Cobar, County Robinson, and 459 miles west by rail from Sydney. The country is composed of sandstones and slates probably of Silurian age. The Cobar Lode consists of large lens-shaped impregnations and replacements of the country rock. No true walls exist, as is usual with deposits of this type. The ore is largely made up of pyrrhotite, associated with which are pyrite and chalcopyrite. It is comparatively poor in silica and thus affords a cheap and efficient means of extracting the gold and silver contents of the siliceous ores obtained from the neighbouring Cobar Peak Silver mine. During 1901–2 an electrolytic plant was established at Lithgow for the separation of the gold and silver and the production of electrolytic copper.

The following table gives the quantity of silver obtained

[1] From information published at time of the disposal of the company's reduction works to the Broken Hill Associated Smelters Proprietary, Ltd.

from the Great Cobar mine, and the mines held in the same interests, during various years from 1898 to 1919. (The mine is now closed down.)

	Oz.		Oz.
1898	145,665	1915	1,838[1]
1903	40,403	1916	47,819
1908	90,196	1917	45,206
1913	103,837	1918	38,009
1914	24,305	1919	8,594

[34]

The quantities of silver obtained in the Cobar mining district for the years 1911 to 1919 are represented by the following figures:

	Oz.		Oz.
1911	125,276	1916	47,968
1912	275,861	1917	55,923
1913	125,297	1918	98,203
1914	24,612	1919	18,340
1915	1,838		

[34]

Yerranderie Field.—A number of mines situated in the Yerranderie division, which lies within the confines of the Southern Mining District, raise ores of the lead-silver-gold type. The following table shows the outputs of silver of the Yerranderie field for various years from 1900 [34]:

	Oz.		Oz.
1900	58,527	1915	475,180
1905	243,403	1916	174,321
1910	783,295	1917	276,034
1913	475,866	1918	317,459
1914	520,880	1919	286,955

During the year 1919 the Colon Peaks mine raised 1,156 tons of ore containing 110,584 oz. silver, 342 tons lead, and 178 oz. gold; and the new Burragorang mine, 769 tons of ore containing 30,856 oz. silver, 62 tons lead, and 44 oz. gold; the Tonalli mine 4,466 oz.; and Dunn's mine 520 oz. of silver. Other mines producing silver are those of Silver Peak, Silver King and Yerranderie.

Other Localities.—A few years ago a considerable quantity of silver was obtained from ores raised by the old Conrad mines at Howell, in the Tingha division. In 1912 these

[1] Peak mine only.

mines yielded 395,244 oz. silver. In 1919 only 50 tons of silver-lead ore, which after treatment gave a return of 3,291 oz. of silver, were raised on a mineral lease which originally formed part of the old Conrad mines. During the same year, small amounts of ores containing silver, chiefly of the silver-lead type, were raised in the parish of Opton, Burrowa division; at Carboona, Tumbarumba division; in the Condobolin division; also in the divisions of Orange, Sunny Corner, Leadville, and Drake. During the year 1910 the silver-lead-copper deposits of the Kangiara field yielded 133,777 oz. silver, and in 1912, 93,088 oz., but in 1919 the output had fallen below 3,000 oz. silver.

In addition to the above localities, where the occurrences are essentially of the silver-lead type, there are a large number of places in New South Wales at which copper ores containing appreciable amounts of silver have been found.

Queensland

The silver produced in Queensland is obtained as a by-product in the metallurgical treatment of copper, gold, lead and arsenical ores. The bulk of the metal is derived from copper and gold ores. Thus the Herberton and Mackay fields yield copper and silver; the Cloncurry, Chillagoe, Charters Towers, and Mount Coolon fields, gold and silver; the Mount Morgan and Gladstone fields, copper, gold and silver; the Etheridge and Cania fields, lead and silver, and in the Stanthorpe field, ores of copper, lead, gold, silver and arsenic are found together.

The table on page 58 gives the production of silver in Queensland for the years 1916 to 1919:

Herberton Field.—Here the most important producer is the Empress mine, which in 1918 yielded copper and silver combined to the value of nearly £10,000. The second largest producer of copper and silver is the Rio Tinto mine, Mount Albion, where the silver content amounts to about 514 oz. per ton of copper and 90 oz. per ton of ore. The proportion of silver at the Richard's Queen mine averages 146 oz. per ton of copper.

Production of Silver in Queensland, 1916–1919 [36]

Mining Fields.	1916.	1917.	1918.	1919.
	Oz.	Oz.	Oz.	Oz.
Herberton . .	48,725	66,620	33,464	20,031
Cloncurry . . .	59,337	46,246	29,496	15,284
Mount Morgan . .	38,023	50,500	25,550	21,702
Stanthorpe . .	5,004	5,708	24,509	4,555
Etheridge . . .	21,810	15,301	16,059	4,872
Chillagoe . . .	5,508	20,232	5,953	814
Charters Towers . .	21,804	9,694	5,759	2,912
Gympie, Kilkivan, Glastonbury . .	6,801	5,442	3,090	2,639
Croydon	14,841	4,191	2,044	3,679
Burketown . . .	8,017	7,556	—	—
Other sources . . .	13,214	10,149	6,575	15,560[1]
Totals . . .	243,084	241,639	152,499	92,048

[1] Including 10,082 from Brisbane district.

Cloncurry Field.—This is by far the most important copper-producing centre in the State. Returns of the total mineral output for the field for 1918 show that 189,219 tons of copper ore were treated at the various smelters on the field, for a yield of 11,625 tons of copper, 3,851 oz. of gold, and 19,362 oz. silver. Some 8 tons 3 cwt. of silver ore, treated at the Sulphide Corporation Works, yielded 10,124 oz. silver.

Stanthorpe Field.—Practically the whole of the silver output of this field comes from the Silver Spur mine, in County Clive. In 1918 this mine produced, besides some gold and copper, 24,239 oz. silver and 21 tons lead. The lode was discovered in 1890, and during the period 1892–1913 a total of a little over 2,000,000 oz. of silver was produced. The predominant country rock is described as a fine-grained, slaty mudstone, and an intrusion of diorite occurs in the neighbourhood of the ore-deposits, which are confined to lines of crush and possess a general lenticular shape. The ore consists of chalcopyrite, blende, pyrite, galena, quartz and calcite. The amount of silver recovered averages 22 oz. per ton of ore [37].

At the Comet mine the ore consists of arsenopyrite with varied amounts of galena, chalcopyrite, wolframite and cassiterite. Two samples gave 10 oz. and 28 oz. of silver respectively. Similar associations of minerals carrying a little silver occur at the Orient and Gibbinbar mines, and in the neighbourhood of Sundown and Ballandean. Gold, silver and arsenic are associated in the Norton Arsenical Goldfield, the ore containing about 5 oz. silver per ton [38].

Etheridge Field.—In this district practically the whole of the silver is obtained from silver-lead ores. The principal producers of silver-lead ores during the year 1918, arranged in order of importance, are the Queenslander, Aspasia, Percy River Copper Co., Dry Hash, Southern Cross Extended, and Mount Jackson mines.

Chillagoe Field.—Here the only important producer of gold and silver is the Tyrconnell mine, at Kingsborough. During the year 1918 this mine yielded from 3,550 tons of ore raised, 3,725 oz. gold and 1,758 oz. silver.

Charters Towers.—The silver is obtained as a by-product from gold and other ores.

Gladstone Field.—The Mount Cannindah mine and the mines at Glassford Creek yield copper, silver and gold, whilst the Mircam mine yields copper and silver.

Mount Coolon Field.—Here small quantities of silver are associated with the gold. The principal workings are at the Native Bear mines.

Mackay Field.—A small quantity of silver was, in 1918, obtained from two copper mines, viz. Mount Flora and Pine Vale.

Cania Field.—[39] The Mount Prospect silver-lead lode is situated 4 miles by road south-east from Cania, and 116 miles by rail from the port of Rockhampton. The oxidized galena ores contain about 44% lead and 55 oz. silver per ton. The ore is principally galena and the lode occurs in granite. In 1918 work was confined to opening up the lode, but in absence of a treatment plant, only the sorted higher grade ore can be marketed. The returns for February 1919 show 171 oz. silver and one ton of lead from 5·7 tons of ore.

It is stated that ore containing silver and lead has been discovered in the parish of Jondaryan, County Aubigny, Darling Downs [40/p. 117]. Also, a silver-lead deposit is reported as having been discovered on Finney's Hill, Indooroopilly. Twelve tons of ore gave a return of 1,245 oz. silver and 8 tons of lead. In addition ½ ton of galena gave 138 oz. silver [40/p.135].

South Australia

True silver ores do not occur in South Australia, but a small annual output is recorded as a by-product from the smelting of copper and lead ores. The ores of the Wallaroo and Moonta district furnish the bulk of the production, although small quantities are also obtained from argentiferous galena. The total production of silver from 1910 to 1919 is given as 25,889 oz., valued at £3,340, and of silver-lead ore as 1,623 tons, valued at £28,800. The following table gives various outputs and values of silver and silver-lead ores from 1907 to 1919:

Production of Silver and Silver-lead Ores in South Australia

Year.	Silver.		Silver-lead Ore.	
	Quantity. Oz.	Value. £	Quantity. Tons.	Value. £
1907	5,845	780	1,000	11,000
1911	1,400	140	—	—
1915	2,462	277	59	625
1916	3,427	514	243	4,659
1917	1,825	333	622	12,018
1918	1,608	331	503	10,161
1919	561	180	—	—

[41]

The following table gives the silver production at Wallaroo and Moonta from 1909 to 1916:

	Oz. silver 0·966 Fine.		Oz. silver 0·966 Fine.
1909	4,995	1913	1,000
1910	2,011	1914	2,936
1911	1,400	1915	2,884
1912	2,045	1916	3,014

[42]

The Silver-Lead Deposits [41].—Taken individually the silver-lead mines of South Australia have in general yielded but small amounts of silver, and have shown no inclination towards continuous production. Mining operations have been carried on in a somewhat desultory fashion. This observation applies more particularly to those which have been active at various times during the past ten or twenty years. The old silver-lead mines of the Glen Osmond group, situated in the Mount Lofty Ranges, were the first mines to be worked in South Australia—Wheal Gawler, opened in 1841, is possibly the oldest mine in Australia—but little has been done on these since the early days and nothing at all during the last twenty-seven years. Mining operations are conducted on a small scale, having suffered from want of capital. Many of the deposits do not appear to have been adequately tested. Most of them occur as fissure-veins, although, at Ediacara, for example, argentiferous galena occurs disseminated through a gently-inclined bed of crystalline limestone of about 18 inches in thickness. The fissure-veins are generally narrow, but tend to occur in groups.

The silver-lead lodes are confined to the complex of Cambrian and pre-Cambrian rocks which has an extensive distribution in the southern part of the State, as will be seen in the Mines Department's geological map [43]. More particularly they show a disposition to fall within three areas, viz. (*a*) the district immediately to the south and east of Adelaide; (*b*) the country between Lakes Frome and Torrens; and (*c*) the neighbourhood of Olary. Thus the Aclare, Wheal Coglin, Commonwealth, Mount Malvern, Olivaster, Yattagolinga, Talisker mines and the Glen Osmond group would fall within the first district; the Avondale and Williams mines belong to the second district; and the Commodore, Perseverance, Uncle Tom, and Wincklen's mines are situated comparatively near Olary.

In general, it may be said that the Cambrian and pre-Cambrian rocks—which have not so far been differentiated at most points—consist of a highly disturbed series of mica-schists, quartzites, crystalline limestones and dolomites, and various types of gneisses, penetrated by a variety of igneous rocks [44] [45].

As already mentioned, the chief constituent of the silver-bearing deposits is argentiferous galena. The content in lead varies from about 10 to 70%, the average being about 45%. The amount of silver varies considerably, being from 2 to 40 oz. per ton.

Tasmania

The productions of silver-lead ores in the whole of Tasmania for recent years are as follow:

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Tons.	£		Tons.	£
1910 . .	51,227	247,576	1916 . .	11,229	153,796
1911 . .	61,501	253,361	1917 . .	9,576	152,122
1912 . .	90,124	309,098	1918 . .	7,241	127,176
1913 . .	83,289	319,997	1919 . .	525,343 [1]	125,564
1914 . .	11,565	96,225	1920 . .	623,359 [1]	166,767
1915 . .	10,383	91,689			

[1] Oz. silver.

[46]

North Pieman, Huskisson and Sterling Valley District [47].—This district forms a portion of the west coast mining region and occupies the south-eastern corner of Russell County. The ore deposits can be classified as:—(*a*) silver-lead veins; (*b*) pyrite and galena replacement bodies; (*c*) galena-blende-chalcopyrite deposits, and (*d*) chalcopyrite veins. Silver, in varying amounts, is associated with galena and chalcopyrite.

The silver-lead veins consist of galena, blende, pyrite, with a little arsenopyrite and chalcopyrite. The gangue is quartz. The veins are of the tabular-fissure type and occur in sheared graphitic slate, near its junction with the porphyry intrusions. The average width of the lodes is about 4 feet.

The district is occupied by the West Coast conglomerate, the Read-Rosebery schists, the Farrell slates and the Dundas slates and breccias, all of pre-Silurian age, in addition to pre-Silurian felsites, keratophyre and porphyries. Within the igneous rocks the lodes carry chiefly chalcopyrite, whilst in the sedimentary rocks near the contact, blende, galena and pyrite predominate.

Rosebery District [48].—In the Rosebery district the silver of the zinc-lead sulphide ore-bodies amounts to about 10 oz. per ton of ore, and is associated with galena and tetrahedrite.

Scamander Mineral District [49].—This district lies on the east coast of Tasmania and on the north side of St. Mary's railway station. It is occupied by Ordovician slates and sandstones intruded during Devonian times by granite and granite porphyry. The silver-bearing ores consist of pyrite, arsenopyrite, galena, blende, chalcopyrite and gold in varied amounts, and occur in lodes which occupy the coastal zone, chiefly in granite porphyry. To the west of this zone is another characterized by lodes of chalcopyrite and pyrite carrying smaller amounts of silver. The Scamander silver-mines in 1911 were reported as having been abandoned.

Zeehan Field [50].—This area is occupied by Palæozoic sediments, with spilites, tuffs, gabbro-amphibolite, and the granite massif of Mount Heemskirk which has played an important part in the genesis of the lodes. The ores, which consist of argentiferous galena and pyrite with various amounts of blende, chalcopyrite, tetrahedrite, siderite and stannite, occupy simple fractures and crush-zones in the Silurian rocks. The first discovery of mineral wealth was made in 1882, but serious operations were not begun until 1890. During the next few years mining was very active, the most prominent mines being Zeehan-Montana, Zeehan-Western and Oonah. At 300 to 400 feet, however, the lodes began to be unremunerative, causing most operations to be suspended. In 1898 the works of the Tasmanian Smelting Company were erected on the Zeehan-Strahan Railway, two miles from Zeehan.

Gladstone Mineral District [51].—The township of Gladstone lies on the north-eastern corner of the island. The gold of the Royal Tasmanian field at Gladstone, as is usual in Tasmania when in close proximity to the granite, is accompanied by a considerable proportion of silver. Assays show an irregular proportion of gold to silver. Samples from Fleming's Reef in the new shaft have given as much as 4 oz. silver to 10 oz. gold, and as little as 1 oz. silver to 8 oz. gold per ton.

In the Portland district and in the Portland gold mine, four miles north-east of Gladstone, the silver exceeded the gold content two or threefold. This mine is now abandoned.

In the slate country north-east of Gladstone and west of the Great Mussel Roe a group of gold-quartz reefs occur which carry small quantities of gold and silver with arsenopyrite, galena and blende. No work had been done in depth.

Mount Lyell [35].—The pyritic copper deposits at Mount Lyell, operated by the Mount Lyell Mining and Railway Co., Ltd., on the west coast of Tasmania, are richer in silver and gold than is usually the case with the so-called "intrusive pyrite deposits." The ore-deposits consist of two types—(1) mineralized bands of schist and (2) great lens-shaped masses of very pure sulphide ores. Of the latter there are two main ore-bodies. The average silver content, according to Peters, was estimated at 3 oz. per ton. Actual work has proved that the ore treated up to the end of September 1902, viz. 1,320,131 tons, yielded an average of 2·74 oz. silver per ton. The 1918 and 1919 outputs were 320,344 and 266,864 oz. respectively.

Middlesex and Mount Claude Districts [52].—These districts are situated in the southern part of the county of Devon, which occupies the north central part of Tasmania. Stated in very general terms, the area consists, geologically, of a mass of Devonian granite, intrusive into Silurian limestone, and pre-Silurian conglomerates and slates. In addition there are rocks of a felsitic affinity, as well as lavas and tuffs of Tertiary age.

Lodes carrying argentiferous galena and chalcopyrite occur at Round Hill, at Wilmot Valley, near Bell Mount, and at the Thistle, Union and other mines in the vicinity of Lorinna.

The silver content of the lead ores in the district is varied. A range has been observed from ¼ oz. to 10 oz. of silver per unit of lead, the higher ratios being yielded by ore verging on tetrahedrite. The gold content ranges from a trace up to 25 dwt. per ton. In some of the lodes of the region silver is found in association with wolfram.

The Round Hill mine is owned and operated by the Round Hill Silver and Lead Mining Co. The ore consists dominantly of galena, with abundant chalcopyrite and a little pyrite, blende and siderite as common associates. The following table gives the statistics of the production of the mine from 1907, when operations were first commenced by the present company [53]:

Period of Production.	Net Dry Weight.	Silver.
	Tons.	Oz.
1907 to March 31, 1918	2,913	133,227
April to September, 1918	234	6,625
Total	3,147	139,852

Victoria

According to the Annual Report of the Secretary for Mines for 1918 the whole of the silver produced since 1900 has been extracted from gold at the Mint in Melbourne. No silver-lead ore has been raised in Victoria since that date.

The total amount of silver extracted from gold at the Mint in Melbourne up to the end of 1918 was 1,424,299 fine oz., valued at £215,123, and the total amount derived from other sources amounted to 30,577 fine oz., valued at £7,880. The total quantity of silver-lead ore raised to the end of 1918 was 793 tons, valued at £5,760.

In the year 1917 it is stated that 7,669 fine oz. of silver, valued at £1,406, were extracted from gold at the Mint [54]. The year 1918 produced 6,333 fine oz. (value £1,319).

Western Australia

Apart from the gold and silver tellurides of the Kalgoorlie goldfield, silver minerals have only been recorded on rare occasions in Western Australia. The small annual production of the metal is practically all obtained as a by-product from the metallurgical treatment of gold, and to some extent of copper ores.

Up to the end of 1919 the total value of the silver production in the State amounted to £496,812, which appears particularly insignificant when compared with the total gold production of £140,729,627.

Kalgoorlie Goldfield [8].—It is stated that the average Kalgoorlie ore contains about 1 oz. of silver for every 2 oz. of gold. The silver is combined with the gold, or, in rare instances, exists as chloride. The effects of weathering have been the complete oxidation of pyrite and other sulphides, and the oxidation of all the tellurides with liberation of free gold and silver.

In the unoxidized ores, gold and silver occur as free native gold carrying a little silver, as pure telluride of gold (calaverite), as pure telluride of silver (hessite), and as tellurides of both gold and silver (petzite, sylvanite and krennerite).

Silver production of Western Australia, obtained as By-product and exported

Year.	Silver in Bullion.		Silver-Lead Ore.	
	Fine Oz.	Value.	Quantity.	Value.
		£	Tons.	£
1908	168,455	18,877	727	6,914
1909	176,843	18,778	440	3,520
1910	176,139	18,777	—	—
1911	169,043	18,333	—	—
1912	165,371	19,725	—	—
1913	188,020	23,420	126	1,757
1914	193,057	23,227	715	9,807
1915	222,159	24,295	299	4,429
1916	173,012	22,258	68	554
1917	222,075	38,339	—	—
1918	109,830	22,711	237	3,461
1919	223,332	55,342	215	3,116

Phillips River Mining District [56].—The Phillips River mining district lies within the boundaries of the Oldfield district, which comprises part of the south-western portion of the State. The lodes consist of fairly regular bodies of copper ore, carrying small amounts of gold and silver. The country rock is chiefly gneissic granite with some dioritic gneisses.

Yilgarn Goldfield [57].—The gold of the Mount Jackson and Greenmount and probably other mining centres in the Yilgarn goldfield, carries small amounts of silver. Thus the total yield of fine silver up to 1908 from the Mount Jackson centre was 2,305 oz., and from the Greenmount centre 664 oz.

Kanowna District in N.E. Coolgardie Goldfield [58].—Up to 1908 the Kanowna mining centre produced a total of 2,412 oz. silver, and the Gindalbie 38 oz. silver.

Silver-Lead Deposits

It is reported [59] that a lode containing silver-lead ore was discovered in the country lying between the Davis and Oakover rivers, at a point 90 miles from Marble Bar and 60 miles from Wallwal, on the seaboard. The lode is stated to have been traced for 9 miles. A parcel of about 3 tons of ore assayed 50 % lead, 6·85 oz. silver, and 2·62 % copper per ton, valued at about £21 per ton.

New Zealand

Practically the whole of the output of silver in New Zealand results from the metallurgical treatment of the gold occurring in the Waihi-Tairua and Thames goldfields, situated in the Hauraki Peninsula, North Island.

Silver ores proper apparently have not been discovered in commercial quantities in New Zealand, although there are several places at which important deposits of silver-bearing lead and copper are stated to occur.

Quantities and Values of Silver exported from New Zealand for various Years since 1902 [60]

Year.	Oz.	£	Year.	Oz.	£
1902 . .	674,196	71,975	1915 . .	957,541	95,583
1907 . .	1,562,603	169,484	1916 . .	900,000[1]	—
1912 . .	801,165	84,739	1917 . .	787,152	105,299
1913 . .	975,616	103,866	1918 . .	879,383	171,456
1914 . .	599,162	62,085	1919 . .	453,567	103,037

In the Waihi goldfield the unoxidized ore consists of quartz, manganiferous calcite and mineralized porphyrite, with a varied percentage of pyrite, blende, galena, chalcopyrite and argentite. The gold-fineness of the electrum from the ore of the Waihi mine is 0·645. This electrum is found in the veinstones either in a very fine state of subdivision enclosed in the various sulphides, or is sparsely disseminated through the oxidized ore. Tellurides of gold and silver occur in the Silverstream, Old Maratoto, and other mines at Maratoto. These consist mainly of hessite, with probably some admixture of petzite. Argentite occurs throughout the sulphide ores of Waihi, Golden Cross, Maratoto, Komata and Khargamata. Other minerals are pyrite, with chalcopyrite, galena, blende, rhodochrosite, pyrolusite, etc.

Thames Goldfield [61].—The Thames goldfield is situated

[1] Estimated.

in the Hauraki Peninsula, Auckland, North Island. Throughout the field silver occurs alloyed with gold in the form of electrum, and also as tellurides. According to Fraser, it is difficult to estimate the production of silver; probably £85,000 represents the minimum value of silver produced from the opening of the field, in 1867, to the end of 1908.

Quartz and pyrite are the main gangue minerals of the gold-silver veins. Sometimes calcite, rhodochrosite, galena, blende and chalcopyrite are found in close association with these.

CHAPTER III

SOURCES OF SUPPLY OF SILVER ORES—*continued*

(*b*) FOREIGN COUNTRIES

EUROPE

Austria

In *Styria*, to the north of Graz, are argentiferous lodes which contain blende and galena, with sulphides of copper and iron, quartz and other minerals. The galena carries about 0·06% of silver. The country rock consists of calcareous, chloritic and argillaceous slates.

At *Pfunderrerberg* the lodes contain galena and sulphides of copper, iron and zinc. The galena contains 0·3 to 0·6% of silver, while the copper and iron sulphides are auriferous. The district is made up of gneiss and slates traversed by intrusions of diorite, aplite and micropegmatite.

Czechoslovakia

At *Przibram*, in Bohemia, is a silver-lead district which includes the towns of Przibram and Birkenberg on the left bank of the River Moldau, to the south-west of Prague. The country consists of Lower Silurian slates and sandstones, which about 2 miles to the south-east of Przibram give place to granite and phyllite. These rocks are intruded by numerous dykes and bosses of greenstone, with which the lodes are intimately associated. The lodes are of the lead-silver type, and the principal ore consists of argentiferous galena with blende, siderite and pyrite in a gangue of calcite, dolomite, quartz and barytes. Silver minerals also occur in places. The earliest available records of mining operations at Przibram date from the beginning of the sixteenth century. In 1910 the output amounted to 47·7 tons of fine silver, 3,390 tons of soft lead, 596 tons of antimonial lead, 155 tons of zinc ore and 50·5 tons of antimony ore [10/p. 705].

According to the *Engineering and Mining Journal*, the silver production of Bohemia amounted to 1,478,000 oz. for the year 1915, all of which was obtained from the mines at Przibram.

To the west and south of *Pilsen*, in eastern Bohemia, lead and zinc ores occur, with quartz and subordinate amounts of barytes and fluorspar, or calcite and dolomite. The silver content of the galena varies between 0·05 and 0·2 %.

At *Kuttenberg* and *Budweis*, in Bohemia, there occur lodes of galena and blende, with quartz, dolomite, pyrite and sulphide of arsenic. Native silver and red silver ores also occur in subordinate amounts. The districts contain gneiss overlaid by Cretaceous rocks and invaded by granite, pegmatite, and mica trap.

France

The Saint Sébastien d'Aigrefeuille Deposit [10/p. 1179].—The argentiferous lead deposit of Saint Sébastien d'Aigrefeuille occurs near the village of Générarques in the department of Gard. The ore-bearing beds consist of Upper Triassic conglomerate and sandstone, some 11 yards thick, and rest directly upon granite, and are overlaid in parts by Lias and Dogger. The ore consists of galena and pyrite, which fills the spaces between the pebbles over large areas of the conglomerate. The payable masses have very irregular outlines. The maximum lead content of the ore-bodies is 30 %; their average content 6 to 10 %, while the whole bed may contain 2 to 4 %. The amount of silver found with the lead is very varied, but on an average amounts to 58 oz. per ton of lead.

In the *Auvergne* important lead lodes carry argentiferous galena, with sulphides of zinc, iron and copper, and antimonial compounds in a quartz and barytes matrix. These lodes chiefly occur in gneiss and other metamorphic rocks traversed by veins of fine-grained granite and quartz-porphyry, and are contemporaneous with the older of the Tertiary volcanics, which are overlaid by later extrusives.

In the departments of *Cantal, Haute-Loire* and *Puy-de-Dôme,* some of the antimonial lodes carry silver. These lodes occur in gneiss, mica schist and granite. The now abandoned argentiferous galena district of *Pontgibaud,* in the department of Puy-de-Dôme, produced important amounts of silver chiefly from 1760 to 1780.

Germany (including Silesia)

Mansfeld District [10/p. 1121].—In the *Kupferschiefer* (bituminous marl-shale bed) of the Zechstein formation, copper occurs principally as chalcopyrite, chalcocite and bornite, and with a varied amount of silver. In the Mansfeld district the average is 0·55 parts of silver to 100 parts of copper, but in Reichelsdorf and Westphalia, the silver contents only amount to about one-fifth and one-twenty-fifth of the above respectively. Very little silver exists in Thuringia, where the silver is associated with pyrite as well as with copper.

Between Gerbstadt and Eisleben, in the Mansfeld district, the Kupferschiefer contains 2 to 3% of copper and 180 oz. of silver per ton of copper.

Freiberg District (Saxony).—The total production from 1163 to 1896 is given as follows:

	Oz.
1163–1523	63,171,300
1524–1835	56,598,201
1836–1896	49,315,861

The formation consists of granite-gneiss surrounded by a contact-aureole of mica schists and other metamorphosed sediments. Quartz-silver lodes occur containing argentite, pyrargyrite, proustite, etc., and silver-lead lodes with dolomite or with barytes. The silver seems to have been associated with the grey gneiss, and lodes become poorer on entering red gneiss or mica schist.

Altenberg District (Saxony).—The best-known lode is the Bergmannstrost, which carries arsenopyrite with galena, blende, tetrahedrite, etc.

Other lodes may be described as gold-silver lodes, and contain copper minerals as well. The Bergmannstrost and Lüschwitzgrund lodes contain traces of gold only, and 5 and 1½ oz. of silver per ton respectively, whilst the Maria-Förderung, Olgar-Wunsch and Wender-Hoffnung lodes contain 10, 2 and 17 dwt. of gold, and 6, 2 and 7 oz. of silver per ton respectively (Beyschlag and Vogt).

The formation consists of dark-coloured slates (probably Silurian), with intercalated porphyry and diabase, and some small intrusions of porphyry and olivine-kersantite.

Upper Erzgebirge (Saxony).—This region includes the districts of Schneeberg, Johanngeorgenstadt, Annaberg, Marienberg and Scheibenberg-Oberwiesenthal. Silver only occurs to a limited extent in Schneeberg with cobalt-bismuth ores. At Johanngeorgenstadt silver-bearing lodes contain ores of bismuth (principally), cobalt and uranium. The other districts were renowned for their cobalt-silver ores. Ores of tin, copper, lead, zinc and iron were also mined.

Clausthal District (Harz Mountains).—The formation of the Clausthal plateau, 11 miles long and 5 miles wide, chiefly consists of Culm and Devonian beds. The silver-lead lodes are fault-fissures of considerable width, the hanging-wall being disturbed and undefined. The principal ore is galena carrying 0·01 to 0·3 % of silver. Blende is common, whilst chalcopyrite, tetrahedrite and bournonite also occur. Quartz is the prevailing gangue. In 1908 eight mines produced 265,000 tons of argentiferous galena and blende, valued at £202,000 at the mine.

The copper and mixed ores of the pyrite deposit at Rammelsberg, on the N.W. border of the Harz, contain 0·015 % of silver.

St. Andreasberg District (Harz Mountains).—The ore-bodies of the silver-lead-zinc lodes were discovered in 1521, and reached a maximum of prosperity during the latter half of the sixteenth century; then followed a period of quiescence, but mining operations were resumed about the middle of the seventeenth century, and continued until 1910, when the ore-bodies had become exhausted. The lodes, rich in silver, carried galena, blende, and ores of silver, arsenic, etc.

Tarnowitz-Beuthen District (Silesia).—The metasomatic silver-lead-zinc deposits of this district occur interbedded in Muschelkalk limestone (Triassic), and contain galena, with from 0·025 to 0·048% of silver, blende, zinc carbonate, zinc hydrosilicate and marcasite. Mining began in the sixteenth century. In 1897 the production in Upper Silesia amounted to 510,686 tons of zinc ore, 35,847 tons of lead ore and 268,400 oz. of silver.

Goldberg District (Silesia).—This was once an important district. The cupriferous Zechstein, from 1866 to 1883, produced 58,000 tons of ore, with some 110,500 oz. of silver.

Berg District (Rhine Province).—Numerous argentiferous lead-zinc lodes occur in Devonian rocks. The Lüderich lode can be followed for a distance of 2½ miles. The ore consists chiefly of compact, fine to coarse-grained galena, carrying from 6 to 16 oz. silver, and sometimes as much as 225 oz. per ton. Blende, carrying cadmium, is abundant, and there are small amounts of chalcopyrite, pyrite and siderite in most places.

Holzappel District (Wiesbaden).—The formation consists of Devonian rocks considerably altered by a variety of tectonic disturbances. The lode-system appears to be a composite strike-fault consisting of a main lode, three branch lodes and a transverse lode. The principal contents are argentiferous galena with an average of 2 oz. of silver per ton, blende, siderite and chalcopyrite, with quartz as the chief gangue. The silver content amounts to 0·15% in the compact and fine-grained varieties.

From 1905 to 1910 the silver in the lead ore varied from 2 to 2½ oz. per ton.

Ems District (Wiesbaden).—The formation is Lower Devonian. The ore consists mainly of argentiferous galena, blende, siderite and chalcopyrite, with quartz as the principal gangue. In the main lode at Friedrichssegen, galena and blende are present in roughly equal proportions. The silver content of the clean galena (65% lead) is about 16 oz. per ton.

Ramsbech District (Westphalia).—The formation consists of Devonian rocks, with numerous narrow but persistent silver-lead-zinc lodes. Galena, with from 0·027 to 0·065% of silver, and blende are the principal constituents. Pyrite, chalcopyrite and siderite also occur. The gangue is quartz.

Munsterthal (Black Forest).—The lodes are associated with porphyritic dykes in biotite gneiss, and contain blende and galena, with some pyrite, silver, antimonial and arsenical ores. The gangue consists of quartz, fluorspar, calicte, siderite and barytes.

Schapbach District.—The lodes contain galena, copper, bismuth and other ores in a gangue of quartz, barytes, fluorspar, calcite, etc.

Greece

Laurion District [10/p. 746].—In the Laurion or Ergastiria district, situated in the extreme south-eastern corner of Attica, metasomatic silver-lead-zinc deposits occur in crystalline limestone (Upper Marble) and dolomite and calcareous schists (Lower Marble). Between the Upper and Lower Marble there is a bed of mica schist (the Kæsariani mica schist) which has played an important part in determining the position of the metalliferous deposits. These deposits are of an irregular bed-like form and consist of argentiferous galena, blende and oxidized ores of zinc. According to von Ernst, the galena, which is usually very compact, has a high percentage of lead and is rich in silver, 60 oz. per ton often being obtained. It is stated that the slags forming part of the dumps resulting from mining and smelting activities in ancient times, contain 13 to 14% lead with 16 to 100 oz. of silver per ton of lead. In 1912 the Laurium Mines Co. produced 10,253 tons of argentiferous lead.

The islands of *Milos, Pharos, Santorin*, etc., in the Grecian archipelago, contain argentiferous lead deposits.

Hungary [10/p. 535]

The Hungarian silver production is derived from gold-silver lodes, which are geographically as well as genetically closely associated with a series of Lower and Middle Miocene eruptives. The most important mining districts are those of Schemnitz-

Kremnitz, Nagybanya-Felsöbanya-Kapnik, and the Transylvanian Erzgebirge. In 1907 the various silver-mining districts contributed the following amounts of silver to the Hungarian production: Schemnitz, 146,447 oz.; Kremnitz, 2,515 oz.; Nagybanya, 55,212 oz.; Felsöbanya, 59,888 oz.; Kapnik, 53,245 oz.; Transylvania, including Nagyag, 6,289 oz.

Schemnitz and Kremnitz.—At Schemnitz, mining operations date back to some time prior to the year 750. About the year 1600 there were more than 400 mines in operation. However, since the fall in the price of silver in 1900 they have been worked at a considerable loss, the average yearly loss during the period 1903–1907 having been about £46,000.

The district contains Triassic limestones and quartzites, Eocene nummulitic beds, a series of Miocene lava flows, chiefly andesites, intrusive diorites, and a post-mineralization eruption of Pliocene basalt. By far the greater number of the lodes are found in andesite. In the adjacent sedimentary strata they quickly split up and disappear. Propylitization of the andesite and alteration of the other rocks have generally occurred in the immediate neighbourhood of the ore-bodies. The most important minerals are argentite, stephanite, galena, polybasite, pyrargyrite, proustite, tetrahedrite, etc. Quartz is the most important gangue mineral, but calcite and other carbonates are also found.

At Kremnitz the lodes likewise occur in propylitized andesite. Among the ore-minerals pyrite and stibnite are common, while galena is rare. Quartz is the principal gangue-mineral.

Nagybanya, Felsöbanya and Kapnik.—Felsöbanya lies about 5½ miles, and Kapnik about 21 miles to the east of Nagybanya, a town near the north-western border of Transylvania. At Nagybanya the lodes consist chiefly of auriferous quartz with silver minerals, particularly pyrargyrite. At Felsöbanya silver-lead lodes carrying some gold occur, whilst at Kapnik the lodes are of the silver-lead-zinc type and contain comparatively little gold.

Transylvanian Erzgebirge.—An area on the north side of the River Maros, in western Transylvania, includes such important gold- and silver-producing localities as Nagyag, Offenbanya, Verespatak, Zalatna and Ruda. It consists of

Jurassic, Cretaceous and Tertiary sediments. With the last are associated Tertiary igneous rocks, chiefly andesite and dacite, and to a less extent rhyolite, forming a number of small detached occurrences. The lodes are found for the most part to lie within andesite and dacite. The native gold, which generally contains a relatively high proportion of silver, is accompanied by pyrargyrite, proustite, stephanite, native silver, pyrite, galena, tetrahedrite, arsenopyrite, etc. Quartz is the predominant gangue-mineral, although calcite is often abundant, and the frequent occurrence of manganese minerals is characteristic.

Italy and Sardinia

Sardinia—The Iglesias District [10/p. 749].—In the Iglesias mining district in south-western Sardinia are extensive argentiferous galena and blende deposits of metasomatic origin. By far the greater number of these lie within Silurian limestones and appear to be genetically connected with certain granitic intrusions partly exposed within the area under consideration. The most productive localities, as far as galena is concerned, are those of Montevecchio, San Giovanni, San Benedetto, Malacalzetta, Nebida and Monteponi. The lode-series at Montevecchio includes three argentiferous galena lodes. In depth, blende becomes more common. At San Giovanni and the other localities mentioned above, galena, often rich in silver, is also mined. During 1889 these deposits yielded a total output of galena amounting to 25,910 tons, of which 12,100 tons was contributed by the Montevecchio lodes. It is interesting to note that the more irregular deposits carry most silver, and that the silver content decreases in depth, whilst the amount of blende increases.

In Sardinia, silver ores proper were first discovered in 1870 at the Monte Narba mine on the eastern coast of the island, where the metal occurs native, as sulphide and as chloride. Silver ores occur at the mines of Monte Narba, Giovanni, Bonu, Bacu Arrodas and Correboi. At Monte Narba the lode traverses Silurian slate in the vicinity of porphyry [12].

Italy.—In Tuscany lodes containing argentiferous galena, sulphides of zinc, iron and copper in a gangue of quartz and calcite, occur in Palæozoic slates. A well-known deposit is the Bottino mine, near Florence.

Norway

Kongsberg District [10/p. 660].—The silver lodes at Kongsberg, some 50 miles west of Christiania, are distributed over an area about 20 miles long and 3 to 6 miles wide. The area is occupied by a pre-Cambrian complex of gneisses and schists, and the very numerous lodes vary in thickness from that of paper to 4 in. Often several parallel veins are bunched together. Their strike is mostly at right angles to that of the crystalline schists. By far the most important constituents of these veins are native silver and calcite, although argentite, fluorspar and quartz are to be met with in much smaller amounts. It has long been observed that the silver is almost exclusively confined to those parts of the veins which intercept portions of the schists impregnated with iron and copper sulphides—the fahlbands. The two principal mining areas are Overberget and Unterberget. Since 1622, when the silver was discovered, some 150 mines have at different times been worked. Most of the mines belong to the State. From 1624 to 1815 the output amounted to 18,042,000 oz. of silver, and from 1816 to 1909, 13,548,000 oz. The net profit received by the State from 1830 to 1890 was 1·1 million sterling. Since the drop in price of silver in 1892–1893, the production has practically only covered the cost. The production is now very small.

Near *Vefsen*, Helgeland, argentiferous lead lodes occur in gneiss, schist and older Palæozoic rocks, which are intruded by gabbro and soda-granite. The principal ore is galena, containing 0·2 to 0·8% of silver. In addition, the sulphides of zinc, iron, copper and antimony are found.

At *Dalane*, in Kvitseid, situated in the Telemarken district of South Norway, an impregnation of native copper with native silver occurs. Telemarken contains Late Archæan slates, conglomerates and quartzites intruded by later pre-Silurian granite. The Norwegian pyrite occurrences are widely distributed over the country, and at several points contain notable amounts of silver. At *Sulitjelma*, in Nordland, where the most important deposit is situated, the Bessemer copper contains 0·0448% of silver. The deposits at *Röros* and at *Meraker* show similar proportions.

Portugal

The most important lead-mining area in Portugal is that of Mertola, near the Guadiana. The galena occurring in this district is said to contain 24 oz. silver to the ton [12].

Spain

Cartagena and Mazarron Districts [10/p. 547].—In the neighbourhood of Mazarron and Cartagena, situated on the Mediterranean coast of south-eastern Spain, there are lodes carrying argentiferous galena. At both localities the ore-bodies are found in close association with Tertiary extrusions of andesite and dacite. At *Mazarron* the lodes occur within an area about 8 km. long and 3 km. wide, partly in dacite and partly in the surrounding metamorphic series. The principal ores are galena, blende, pyrite and marcasite. The gangue consists of siderite, calcite, dolomite, some barytes and quartz. The galena generally carries 48 oz. of silver per ton, and, exceptionally, as much as 95 to 190 oz. In 1904, the mines at Mazarron produced more than 30,000 tons of lead ore with 58% of lead. The mineralized district around *Cartagena* has a length of about 10 km. and a width of about 5 km. The lodes, which traverse propylitized andesite as well as the adjacent sediments, carry chiefly galena, containing on an average 32 to 48 oz. of silver per ton, together with blende, copper sulphides and pyrite. In 1904 the production at Cartagena amounted to 80,000 tons of lead ore alone.

Linares District [10/p. 709].—This important argentiferous lead district lies on the northern side of the town of Linares, which is about 260 km. south of Madrid. Within this area are several exposures of granite surrounded by Cambrian and Silurian sediments. The principal country rock is granite and the ore-deposits are most numerous in the Linares granite mass. Others occur in the granite mass at La Carolina and at St. Elena, and still others in a similar intrusion at Arquillos. The most important ore is galena, which contains on an average 6 oz. silver per ton. Blende, pyrite and chalcopyrite are also present. Quartz is the principal gangue. The most important mine is that of Arrayanes, near Linares. Here the galena carries up to about 3 oz. per ton. The lodes at La Carolina and St. Elena contain galena which has a silver content of 20 to 30 oz. per ton. This district reached its zenith in 1889 with an output of 118,325 tons of lead. In 1909 the production was 78,848 tons.

At *Ciudad Real*, 96 km. north of Linares, the lead contains 0·4 to 0·5% of silver.

Guadalajara.—The silver-bearing veins of Hiendelaencina have been described by Vicente Kindelán [62]. The most important veins belong to the oldest system, striking E.–W. The silver ores include native silver, argentite, stephanite and ruby silver. Galena, blende, bournonite, pyrite and chalcopyrite are only accidentally present. The gangue of the richest veins consists of barytes and hyaline or amorphous quartz, or quartz in a state of agate. The formation is gneiss and mica schist.

A barren zone occurs from a depth of from 200 to 300 metres, but is succeeded by a rich zone which has been followed to a depth of 600 metres, which appears to be the limit of payable silver ore in that region. The Segunda Santa Cecilia veins from 1904 to 1907, inclusive, produced 787,600 oz. of silver from the lower rich zone. From 1844 to 1870, 9,649,800 oz. of silver were extracted from the Rico lode alone, and since that date the silver output from Hiendelaencina has been almost exclusively from that lode.

In *Andalusia* argentiferous lead and copper ores are accompanied by barytes, strontianite and siderite. Secondary ores of silver are found in the upper parts of the lodes. In *Seville* native silver and silver ores are associated with cobalt ores and siderite. The famous pyrite deposits of the *Huelva* or *Rio Tinto* district, in southern Spain, usually contain about 1 oz. of silver per ton, representing a relation of 1,000 to 1,200 of copper to 1 of silver.

Sweden

In the *Åmmeberg* district in Orebro, situated about 100 miles south-west of Stockholm, blende with some argentiferous galena occurs in the form of beds and fahlbands. The country rock is Archæan granulite, associated with which are gneisses, limestone and various igneous intrusives. The ore is intergrown with microcline, some quartz, subordinate plagioclase and biotite, and more rarely, pyroxene, hornblende and garnet. The principal ore-bed may be followed almost without interruption for a distance of 3 miles. Of this, however, only a number of lenticular swellings, which in places may reach 12 to 15 m. in thickness, are payable. The deposit may probably be regarded as of the contact-metamorphic type. From 1857 up to and including 1909, altogether 1,968,729 tons of picked and of milling ore were produced. The lead ore contains about 72% of lead and 26 oz. of silver per ton [10/p. 677].

At *Sala*, which lies about 60 miles north-west of Stockholm, there occurs a metasomatic silver-lead deposit in dolomite, which, however, is now practically exhausted. Mining began in the year 1500 and reached its zenith in the first half of the sixteenth century. From 1510 to 1600, some 200 tons of silver were obtained; from 1601 to 1700, 63 tons; from 1701 to 1800, 37 tons; and from 1801 to 1908, 87 tons [10/p. 771].

At *Fahlun* large quantities of copper have been obtained, but the production latterly has considerably declined. The "soft ore," consisting of pyrite with chalcopyrite, quartz, etc., contains about ½ oz. of silver per ton. Silver was also present in the pyrite deposits of Åtvidaberg.

ASIA

Asia Minor

The following data concerning the silver-lead deposits of western Asia Minor have been derived from an article written by Penzer in August, 1919 [63].

The chief mines in western Asia Minor which yield silver-lead are those of Balia-Karaïdin in Brusa, and Bulgar-Maden in Konia. The mines of Balia-Karaïdin date from very ancient times. In 1901 there were about 1,600 men employed, and the production was 7,000 tons of argentiferous galena, containing 70% of lead and 0·125% of silver, as well as blende and calamine. In 1910 the output was 12,000 tons of lead and 3,000 to 4,000 tons of blende. In 1913 the output amounted to 13,076 tons of lead and 5,000 tons of zinc ore. The mines are furnished with a modern smelting and refining plant.

The Bulgar-Maden mines, situated a few miles south of the Konia-Adana line in the vilayet of Konia, have been worked by the peasants for nearly eighty years, in a primitive fashion. The deposits occur in the neighbourhood of the contact between micro-granulities and Palæozoic limestones. Two separate zones have been noticed extending all along the metalliferous formation from Bulgar-Maden to Kizil Tepeh.

The annual yield is about 103,000 oz. of silver, 225 oz. of gold and about 400 tons lead. In 1892 the ore extraction was 20,000 tons, containing 20% of lead and 209,000 oz. of silver, and 19 to 26 dwt. of gold to a ton of lead. These figures increased just before the war, and the mines yielded ore containing 75% of lead and from 1½ to 3½% of silver.

In the vilayet of Aidin, silver-lead mines occur in Balia, which from 1911 to 1913 yielded an average of 14,000 tons of lead.

In Angora, silver-bearing lead ore is found at Ak-Dagh-Maden, Denek-Maden and Elma-Dagh; all these mines are State-controlled, but the last-named was abandoned many years ago.

In Castamouni, the argentiferous lead mine at Kurré has been abandoned owing to insufficient means of transport and communication.

In Adana, besides the silver-lead mines of Bulgar-Maden, are those of Karalar and Hadjin, while silver, lead and zinc occur at Iotape. There are probably other deposits in the northern part of the vilayet, but owing to the lack of communications and transport, no exploitation has been carried on.

Recent reports have been received of two lead mines (probably argentiferous) 24 miles north-east of Bulgar-Maden. One is at Delik Tash, 15 miles due east of Bereketli Maden, and the other 9 miles north-west of Delik Tash.

Silver-lead mines also occur at Kebah Maden.

It is reported that in 1916 the Germans obtained seventy concessions for the workings of silver-lead mines in Asia Minor, probably in Brusa and Aidin.

Edwards states [64] that most of the lead mines in the (former) Ottoman Empire contain appreciable amounts of silver, and have been considerably exploited at shallow depths by the ancients.

Before the war, an English company, the Asia Minor Mining Co., was working silver ores at Lidshisi, and producing about 3,000 tons of ore per year, and important mines were being opened on the Kessenderé peninsula [12/p. 558].

Lead and silver, with a little gold, are also mined by the State at Bulgardegh, where about 48,000 oz. of silver are produced annually [12/p. 558].

China

In Chi-li and North Shansi (North China) silver is obtained from deposits of argentiferous galena. At Ten Yung Shang, in the Je-hol district of Mongolia, a vein occurs in limestone near the contact with metamorphic schists. It is worked by the Chinese. The vein strikes E.–W. and dips N.50°–70°. The galena carries 300 to 500 oz. of silver per ton, and blende, also present, 12 to 18 oz. per ton. In the Qu-San-Tzu mines, seven miles east of the last, galena with tetrahedrite carries 100 oz. of silver per ton, and occurs in a vein with the same strike and dip and in a similar formation [12/p. 618].

In Sze-Chuan (one of the south-western provinces) the Maha gold mine is said to carry a considerable amount of silver. At Loku-Te-Tye are veins bearing free gold and lead ores high in silver (300 oz. per ton). At Ma-Ta-Sa is a vein of silver-lead, which is said to produce 122 oz. per ton, and another vein bears argentite. At Ta-Chien-Lu are the Government silver mines producing 75 to 90 oz. of silver per ton. The vein is 4 feet wide and is worked along its strike for over

10 miles. This vein contains complex ore carrying copper, silver and lead, but it is only worked for its silver content. Near Yer-She are veins of gold, silver and copper ore, and in the south-eastern district are veins carrying silver-lead.

At Fukea are numerous veins containing copper and silver ore. These mines supplied the greater part of the silver used in the Tang dynasty. Near Hui-Le-Chao are numerous veins of gold, copper and silver ores, which are worked extensively by the aborigines. In the Yen-Yuan district are veins carrying gold, silver, lead, copper, zinc and also mercury [65].

In the Hunan province, Central China, is the Shui-Ko-Shan zinc and lead mine. The country is limestone (probably Carboniferous) overlaid by red sandstones and shales of Cretaceous or Tertiary age. Large irregular-shaped bodies of ore, composed of blende and galena with pyrite and chalcopyrite, are developed in the limestone at and near its contact with syenite. The latter has small crystals of chalcopyrite disseminated through it. The deposit was the direct result of the metasomatic action of the mineral-bearing solutions emanating from the magma. Lead concentrate contains from 9 to 38 oz., and zinc concentrate from 2·5 to 15 oz. of silver per ton [66]. The only other deposit with an important output is that of Kungshan in Tungchwan (Yunnan province), where the principal ores are carbonates. The production from the Wei-hung-chow district, Kweichow, is chiefly silver.

The amount of silver produced in China in 1914 was insignificant, and probably did not exceed 50,000 oz. [67].

For 1917 the production is given as 63,900 oz., and that of 1918 as 70,000 oz. (U.S. Bureau of the Mint).

Dutch East Indies

Borneo

A vein near Budok, Dutch Borneo, contains sylvanite (a telluride of gold and silver).

In the Kahajang mine, of the central auriferous district of Dutch Borneo, there is some silver in the ore [69].

Celebes

The sulphide gold ores at Palehleh, on the north coast, contain 12 oz. of silver per ton [69].

Sumatra

In the Redjang-Lebong lodes the ratio of silver to gold in the bullion is often as high as 10 to 1. In 1906 and 1907, the mine produced 248,240 and 327,584 oz. of silver respectively [69].

In Western Sumatra, from Tjalang to a point on the coast opposite the island of Poolo Raja, garnet and wollastonite lenses occur in ancient schist, which carry copper (as bornite), gold, silver and some platinum—silver being by far the chief product [70].

JAPAN

Silver-mining in Japan dates from a very early period, the oldest records referring to the discovery of silver ore in the island of Tsushima, in the year A.D. 674. From then until the year 1896 many deposits were opened up, but during the course of the next few years a number of these had to be abandoned on account of the fall in the price of silver.

The production of the metal gradually increased from 1874 to 1895, but from 1895 to 1904 remained nearly stationary, in spite of the rapid progress made by the gold and copper industries. In 1905 there was a considerable increase in the production owing to the conspicuous development of the Kosaka mine and the general increase of the silver production in the gold and copper mines. The great increase in 1908 was due to the development of the Tsubaki mine, and the total output for that year was more than 17 times the output in 1875, and $2\frac{1}{2}$ times that in 1900. Generally speaking, the production of silver extracted from silver ores proper is declining, but the total output is maintained or increased by the increasing amounts of the metal obtained as a by-product in the treatment of gold and copper ores [71] [72] [73].

Production of Silver in Japan, 1880 *to* 1919

Year.	Troy Oz.	Year.	Troy Oz.
1880 . . .	332,406	1915 . . .	5,120,293
1890 . . .	1,699,029	1916 . . .	5,805,700
1900 . . .	1,890,716	1917 . . .	7,111,700
1910 . . .	4,581,613	1918 . . .	6,600,400
1913 . . .	4,649,910	1919 . . .	5,163,068
1914 . . .	4,836,228		

(U.S. Bureau of Mint.)

Production of Silver by the Principal Japanese Mines in 1919

Mine.	Locality.	Troy Oz.	Mine.	Locality.	Troy Oz.
Hitachi .	Ibaraki	1,355,857	Sado .	Niigata	171,252
Saganoseki .	Ōita	902,029	Ikuno	Hyōgo	171,146
Ashio .	Tochigi	581,304	Yoshioka .	Okayama	132,637
Kosaka .	Akita	559,991	Abeshiro .	Aomori	132,616
Kamioka .	Gifu	222,796	Other mines		752,660
Mitsui-kushikino	Kagoshima	180,780	Total .		5,163,068

[68]

The production of the twenty most important mines during the five years prior to 1908 aggregated 85·2% of the total output. The greater part of the silver produced by these mines came from argentiferous lead ore; 18·6% from normal or dry silver ore, and 15·7% from argentiferous copper ore. It is to be noted, however, that there is a tendency for the output of silver from copper ores to surpass that derived from dry silver ore.

The silver deposits, whether in the form of veins, impregnations, or metasomatic replacements, are practically confined to Tertiary volcanic flows of liparite and andesite and tuffs of the same age. On the other hand, the economically unimportant contact-metamorphic deposits are restricted to the region occupied by pre-Tertiary rocks.

Several of the principal mines exploit dry silver ore as well as argentiferous lead and copper ores, which occur as lodes traversing eruptive and sedimentary rocks of Tertiary age. Of considerably less importance are argentiferous lead and copper ores which occur as impregnations in Tertiary rocks. With regard to deposits of the metasomatic type it is stated that, although great numbers of such deposits exist, the only one actually explored is the so-called Kuroko deposit. The Kuroko deposit was worked in conjunction with the Tsubaki mine, which in 1908 yielded the greatest output of silver of any mine in Japan.

Numbers of deposits of the contact-metamorphic type are known, but only a few are important, such as those at Kamioka and Hiragane in Hida. These occurrences are very commonly situated at or near the contact between igneous intrusions and Palæozoic or pre-Cambrian strata.

The Tsubaki mine, opened in 1889, no longer produces. The country rock consists of Tertiary shales and andesites. The ore is the so-called "kuromono" or "black ore," a mixture of argentite, blende, galena, pyrites, chalcopyrite, barytes, quartz and calcite. It contains generally 0·07% of silver, but the richer parts yield 0·15% to 0·3% of the metal. The Kosaka mine was opened in 1866, and is one of the most important in Japan. The ore is of the kuromono type and yields copper, silver and gold, and occurs as a large mass in Tertiary tuff near its contact with dacite. The Ikuno mines are said to have been started in 807, although it was not until 1542 that they were worked on anything like a large scale. There are two principal mines, namely the Tasei and the Kanagase, which yield copper, silver and gold. The country consists of Tertiary tuffs, liparite and associated rocks, and the ore is made up of argentite, native gold and silver, with chalcopyrite, pyrite, galena, blende, pyrargyrite, stibnite, quartz, calcite and rhodochrosite. These minerals occur in a series of veins. The Kamioka deposit is said to have been discovered about 1,200 years ago, and yields silver, copper and lead. The rocks are hornblende gneiss with limestone and intrusive quartz-porphyry, and the deposits, which consist of argentiferous galena, chalcopyrite, blende, actinolite, epidote, with calcite, quartz, pyrite, etc., occur as lodes.

Siberia

The silver-lead mines of Western Altai, Government of Tomsk, were important in the early part of the nineteenth century. In Central Altai the deposits lie for the most part in Carboniferous limestone and occur as lodes carrying silver-bearing lead ores mixed with a large proportion of barytes. Silver tellurides are also mentioned as occurring in these deposits. The mines have been worked out to depths of 700 feet, and operations did not apparently pay in depth. The deposits in the Salair Mountains are very similar in their mineral contents, as likewise are those in the Kolybane district, but are stated to be much richer. The Zmeeff mine near Kolyban Lake, south of Barmaoul, exploited a particularly rich shoot of ore. Another rich group of mines is the Rydirsk group [74].

In 1845 the silver production of the Altai is given as 26,331 oz. [74] and in 1891 as 313,462 oz. [12].

NORTH AMERICA

The primary silver deposits of the American continents have been formed during, or shortly after, certain epochs of igneous activity, either of the intrusive or of the volcanic type. They are thus intimately connected with occurrences of igneous rock, and in general are found either within such rocks, or at their contact with the intruded sediments, or within sedimentary strata not far removed from the intrusive rocks. The American silver deposits date from two widely separated ages. The first period belongs to the pre-Cambrian or early Palæozoic; the second period belongs to the late Mesozoic and the Kainozoic. The older silver and gold deposits of the first-named type occur at various points in the wide stretches of the two land-masses on the eastern side of the American Cordillera. In North America silver is obtained from the copper deposits of the Lake Superior region, but a much larger amount is yielded by the Cobalt district in Ontario. Considering the vast extent of the eastern lowlands in North America it is extraordinary how localized and highly concentrated these deposits are.

In South America the region east of the Andes is geologically very similar to the corresponding region in the northern part of the continent, but here the silver production is insignificant.

The younger deposits, belonging to the second period, were formed during the great igneous activity which accompanied the building of the Cordilleras, and are thus confined to the western or Cordilleran part of the continents where deposits of the first period are either rare or else concealed by newer sediments or igneous flows. From Cape Horn to Alaska these younger silver deposits occur under similar geological conditions, and were formed during a period dating from earliest Cretaceous times. Throughout the interior part of the Cordilleran region of North America are numberless intrusions of granitic or dioritic rocks and porphyries of later Mesozoic or Tertiary age. Aureoles of silver-bearing veins surround these intrusions. Contact-metamorphic deposits have been commonly formed where the intruded rock is limestone. In Mexico there are countless, though small, intrusive masses of diorite or porphyry in Cretaceous limestone, around which argentiferous veins or contact-metamorphic deposits have formed. In addition to this type of silver deposit there is another which comprises ore-bodies occurring in lava flows. These include such celebrated deposits as those at Comstock, Tonopah and Cripple Creek. They are best represented in Nevada, Arizona, Utah and Colorado. Few of these are found north of the Canadian boundary, and none of them along the main Canadian or American coast. In Mexico the most celebrated silver occurrences belong to the same type. In South America the most prominent formations of the Andes are the Cretaceous sediments. During Jurassic and Cretaceous times there was considerable volcanic activity, unattended, however, by mineralization. In this respect there is a difference from North America, where mineralization is connected with large plutonic intrusions of the same age. In the Cordilleran region of South America the principal and almost the only period of mineralization seems to be that of the early Tertiary, when igneous intrusions occurred on a large scale. Of less importance are ore-bodies associated with late Tertiary lava flows. The poverty of the eastern front ranges of the Andes is paralleled by the lack of precious metal deposits in the eastern or Rocky Mountain range of Canada.

Guatemala

According to Réné Guerin [75], blende and argentiferous galena abound in limestone in the department of Chiquimula, sometimes being associated with copper carbonate. The ore on an average contains from 64 to 96 oz. of silver per ton. Silver was formerly coined from the mines of Alotepique to the value of 60,000,000 pesos. The San Pantaleón mine, worked by an English company from 1854 to 1868, produced silver to the value of 44,000,000 pesos.

Honduras

The republic of Honduras is the largest silver-producer in Central America. The greater part of the production comes from the gold-silver mine of Rosario, near Tegucigalpa, where the lodes are connected with " rhyolitic " intrusions traversing Triassic sandstones and limestones.

The following account of the silver-mining in Honduras is based on information supplied by Thacer in a paper published in 1891 [76].

The Opoteca mine is perhaps the most important in Honduras. The ore is free-milling and carries native silver and argentite in addition to gold. The deposit has been extensively worked in the past. The assay value of the ore is given as about $20 silver and $1 gold per ton of 2,000 lb. An ore-body consisting mainly of argentiferous galena, with blende and pyrite in small amounts, is situated about 3 km. from the town of Valle de Angeles and 32 km. from Tegucigalpa, and is worked by the Animas and California companies. The assay value of the ore is given as about $60 of silver and 30% lead.

Silver- and gold-bearing quartz veins, some 1 to 4·5 metres in width, occur about 3 km. from the village of San Juancito, near Tegucigalpa. The foot-wall consists mainly of " volcanic greenstone," and the hanging-wall chiefly of siliceous slates.

The Yuscaran mining district, comprising the mountains of Yuscaran and vicinity, is situated 72 km. south-east from Tegucigalpa and 144 km. from San Lorenzo on the Pacific coast. The lodes, which traverse igneous rocks, carry sulphides of silver, copper, zinc, lead, iron, etc., together with antimonial sulphide of silver, in a quartzitic gangue. Sulphides of silver carrying some gold occur in the department of Choluteca, district of Aramicina, near a town of the same name, 48 km. from the Pacific coast and about 137 km. from Tegucigalpa. The Guasucaran mine, a celebrated silver mine and one of the oldest in Honduras, lies 96 km. from the Pacific and 48 km. south-west of Tegucigalpa. Argentite and blende occur in a gangue of quartz and barytes. The country rock is stated to be a highly siliceous trachyte. The San Bartolo mines lie 90 km. north of San Lorenzo and 80 km. south-west of Tegucigalpa. The ore is free-milling quartz carrying sulphide and chloride of silver. The mines of San Andres are situated upon San Andres Mountain, north-west of Tegucigalpa in the department of Copan. The ore is said to be free-milling. Another group of silver mines lies about 15 km. from Tegucigalpa, and in 1891 was worked by the Suyape Silver Concession, Ltd. The ore is argentiferous galena with blende and quartz.

Ore carrying silver and gold occurs near the village of San Juan, in the district of Corpus, department of Choluteca. In the district of Santa Lucia, department of Tegucigalpa, lodes are worked by the Victoria, Zopilotiera and Santa Elena mines. The Zopilotiera lode carries argentite, and in the Victoria lode the silver-bearing minerals are arsenical and iron pyrites.

Antimonial silver ore, associated with more or less gold, occurs in the department of Tegucigalpa, 120 km. from the city, and at about 144 km. from the same city, near a small village called Langue, ores carrying silver and lead occur. At San Marcos, 80 km. from San Lorenzo and near the town of Sabana-Grande, a free-milling ore carrying argentite and gold is said to occur. The Santa Lucia mines lie 14 km. east of Tegucigalpa. The lodes carry pyrite, argentite, brittle and ruby silver, and a trace of gold. The ores require a preliminary roasting and are not adapted to free milling.

The silver from the whole of the Central America States in 1918 amounted to only 2,900,000 oz., an average of 483,000 oz. per annum for each of the six countries forming those States. The total yield for 1919 is estimated at 3,000,000 oz.

Mexico

The silver-producing States of Mexico, arranged alphabetically, are as follow:

Aguascalientes [77]

At Asientos de Ibarra the country is hornblende-andesite or diorite. Other formations are limestone, schist and rhyolite. The principal veins strike N.60°–70°W. and dip N.E. or S.W.80°. According to Miguel Velazquez de León, the silver ores are argentite, pyrargyrite and polybasite, with argentiferous galena, blende, pyrite, chalcopyrite and bornite. The gangue is quartz. Other veins in the district run N.–S. or E.–W.

Tepezalá, with similar formation, is a copper district, but the copper oxides and sulphides of some of the veins are silver-bearing.

Chiapas

The Santa Fé mine is interesting, as, according to E. T. McCarthy [78], the ore occurs in it in irregular courses or channels in a large mass of wollastonite (lime silicate) surrounded by limestone. The principal useful minerals are argentiferous bornite and chalcopyrite, carrying more or less free gold, associated with tetrahedrite, enargite, pyrite, galena, blende, with copper carbonate minerals as incrustations in the vicinity of "blow" or "vent" holes. The ore carries from 6 to 8 oz. of silver per ton. The ore-bodies are usually regarded as contact deposits.

Chihuahua

The Santa Eulalia camp of the Iturbide district lies 28 km. south-east of Chihuahua city. It was discovered in 1703. The formation consists of folded Cretaceous limestones largely covered by an unconformable mantle of dacitic tuff. The ore-bodies, which are irregular in shape, are metasomatic replacements of limestone, mainly along bedding-planes, but partly along fractures. The richest ores, consisting chiefly of cerussite, galena and oxidized ores of iron, occur at depths of from 400 to 457 metres.

In the Parral camp of the Hidalgo de Parral district, strong and well-defined veins in porphyry have been worked to a depth of 366 metres.

According to Waitz, the area between Parral and Minas Nuevas consists essentially of a foundation of schists, upon which rests, and through which penetrates, a series of Tertiary volcanic flows and minor intrusive rocks. The schistose formation, of unknown age, consists principally of siliceous schists, which are considerably folded. The Tertiary igneous rocks are made up of felspar-porphyry, andesites, rhyolites and tuffs and basalt, arranged in their order of appearance. The felspar porphyry occurs as intrusive rocks cutting through the schists and sending out apophyses in all directions. The andesites occur as surface flows. They are, for the most part, considerably altered. The extrusion of the andesitic rocks was followed by the appearance of rhyolites and tuffs, and afterwards by the formation of dykes and surface flows of basalt.

Santa Barbara, 6 km. south-west of Parral, was discovered in 1547. The ore-deposits occur as lodes cutting through indurated grey shales and porphyries, which break through and overlie them. Generally speaking, the ores consist of galena, with pyrite and blende, in a gangue of quartz. When Weed examined the district in 1900, the Moctezuma Mining and Milling Co. was exploiting two lodes, carrying ore of the following average composition: lead, 7·5; zinc, 6·5; copper, 0·27; iron, 5·0; lime, 8·0; and silica, 50·0%; silver, 6 oz.; and gold, $1·40 per ton.

Minas Nuevas is 12 km. north-west of Parral. The most important lode is the Veta Grande, on the Veta Colorada, which was located in 1645. At 305 metres in depth it is from 4·5 to 5·5 metres thick, and carries about 46 oz. of silver per ton.

According to Robles, the more important system of lodes trends N.28°W. and traverses rhyolitic rocks. A second system has a direction N.43°E. and traverses andesites. The first system includes the Veta del Refugio, Santa Ana, Veta Colorada, and Veta Negra lodes. The principal minerals occurring in the Veta Colorada are argentite, pyrargyrite, native silver, anglesite, cerussite and galena in a gangue of quartz, with which is associated a small amount of fluorspar. The lodes cut through all rocks with the exception of the basalt, and Robles considers that mineralization probably took place in Pliocene times.

In the Andres del Rio district, the Urique mines were discovered in 1630. N.–S. veins dipping E. traverse Middle Cretaceous limestones and slates. Polybasite, pyrargyrite, argentite, pyrite, galena and blende occur in a gangue of quartz, calcite and gypsum. Veins with a similar strike and dip traverse Tertiary diorite. The gangue is quartz, and the ores are polybasite, miargyrite, pyrargyrite, pyrite and galena. Iron oxides and blue and green copper carbonates are found in the oxidized zone. The mines of Batopilas were discovered in 1632. N.–S. lodes course through diorite and contain an abundance of native silver, argentite, pyrargyrite, miargyrite, proustite, pyrite and galena in a gangue of quartz and calcite.

In the Arteaga district (W.N.W. of Batopilas), a vein, at the Rio Plata mine, according to H. J. Baron [77/p. 547], strikes N.25°W. in diorite. The vein, from 1·2 to 1·8 metres thick, carries argentite, bromyrite and native silver in a gangue of bluish quartz. The ore, which occurs in shoots from 2·5 to 30·5 cm. thick on the hanging-wall side, carries from 200 to 4,000 oz. of silver per ton. At the Palmarejo mines the ores are argentite, with some stephanite in a siliceous gangue, carrying disseminated pyrite. The principal bonanza, according to T. H. Oxnam [77/p. 547], occurred at the intersection of an E.–W. vein with one coursing N.51°30W. At Chinipas the veins occur in diorite and hornblende-andesite, The strike is N.E., or in some cases N.W. The vein-filling is quartz with argentite, pyrite, oxides of iron and dendritic manganese.

Ocampo, in the Rayon district, was discovered in 1821.

The country is porphyry, and the ores are siliceous, carrying silver and some gold. At Pinos Altos (north of Ocampo) the principal vein is 6 metres thick, and the silver values are greater than the gold values.

In the Sahuayacan district (48 km. west of Ocampo) there is a narrow band of shale impregnated with argentiferous pyrite, with an intrusion of andesite near by. The veins are numerous and well-defined. Guadalupe y Calvo, of the Mina district, is a gold mine, but the ores contain about 16 oz. of silver per ton. The veins at Cerro Colorado form a network of altered hornblende-andesite. The gangue is calcite and quartz, carrying free gold, pyrite and chalcopyrite rich in silver. At San José de Gracia the lodes, which have a N.–S. course, and traverse hornblende-andesite, carry auriferous pyrite, galena, blende and silver sulphides in a gangue of quartz.

Coahuila

The Sierra Mojada mines, discovered in 1878, are in the southern part of the State. The occurrence is very similar to that of Santa Eulalia (Chihuahua). The formation is Cretaceous limestone. A volcanic breccia, consisting of angular fragments of felsite and granite rocks, cemented by a siliceous matrix, rests unconformably upon the limestone. The ores —lead carbonates, copper ores and silver chloride—occur as replacement and impregnation deposits within the limestone, at and near its contact with the volcanic breccia. However, the most valuable ore-body ever mined in the camp—the San José copper-stope—was apparently an impregnation of the siliceous breccia with silver chloride and copper oxide, and occurred chiefly at the contact. The ore, considered as a whole, carries varying amounts of lead, silver, silica, iron, and sometimes copper, zinc, barium sulphate, sulphur and gypsum.

Durango

In Guanacevi, according to A. F. J. Bordeaux [77/p. 556], there is a stockwork in hornblende-andesite impregnated with pyrite, and elsewhere, an altered rhyolite with intrusions of andesite dykes containing fragments of rhyolite, forming a breccia, and reticulated with veinlets of argentite, etc. The minerals are pyrite, argentite, ruby silver, native silver, chalcopyrite with some arsenopyrite, galena, and blende in depth. The gangue is quartz and calcite. A little north of the town of Guarisamey, the formation, according to E. Halse [79/p. 248], is eruptive quartz-hornblende-andesite, andesite breccia, and porphyrite with interbedded sheets and intrusive dykes of felsite of the rhyolite group. The main lode strikes N.W. and dips N.E. The ore is argentite, argentiferous pyrite, chalcopyrite, galena and ruby silver (rare). Some of the ore consists of wavy black layers alternating with lighter ones and having a conchoidal texture. This ore has frequently much resemblance to the fluidal structure of the felsite country, and may be regarded as evidence of the replacement of the latter by quartz and argentite [80].

In the Candelaria mine, at San Dimas, the main vein strikes N.55°E., dips N.W.50°, and is from 1·8 to 2·4 metres thick in brecciated felsite. The ores are argentite, proustite, native silver and argentiferous pyrite in quartz and calcite.

At Promontorio, which was discovered in 1880, the formation, according to F. C. Lincoln [77/p. 557], consists of rhyolite-porphyry with inclusions of andesite and dacite and segregations (?) of binary granite. The vein strikes N.55°W. and dips S.W., cutting the joint-planes of the country at an acute angle on both strike and dip. The primary minerals are quartz, galena and blende, less pyrite, a little chalcopyrite, and minute quantities of bornite, chalcocite and covellite. The secondary enrichment consists of native silver, chalcocite and a little chalcopyrite. Small amounts of copper minerals indicate a high silver content. The ore is arranged in shoots, which pitch south-east or follow the dip of the cross-fractures (N.E.–S.W., dipping steeply to the S.E.).

At Mapimi, which was discovered in 1598, the formation, according to J. D. Villarello [77/p. 558], consists of Middle Cretaceous sedimentary rocks and a Tertiary eruptive rock (hornblende-andesite). The primary minerals are arsenopyrite, galena, blende and pyrite, with calcite as gangue ; boulangerite, chalcopyrite, fluorspar and barytes are less abundant, while stibnite, pyrargyrite, tetrahedrite and quartz are rare. The above occur in chimneys. The Ojuela chimney is 40 metres in diameter, between 800 and 500 metres in depth, and descends almost perpendicularly to 650 metres. La Paloma chimney at a depth of 470 metres is horizontal, then descends vertically 600 metres.

At Copalquin the ore-deposits are contained in quartz-diorite. At Topia the veins extend N.E. and contain galena, blende, a small amount of pyrite, argentite and pyrargyrite, in a gangue of quartz and calcite.

Guanajuato

The mining district of Guanajuato is one of the oldest and most extensive in Mexico, and has yielded immense quantities of silver, as is shown by the following figures:

Value of Silver Production, 1701 *to* 1903

	$ (Pesos)
1701–1800	279,690,689
1800–1900	231,137,013
1900–1903	6,235,204

($10 = £1 approximately.)

The most productive years were 1791, 1804, 1849, 1850 and 1852.

The researches of Villarello, Flores and Robles on the geology of the Sierra de Guanajuato have given the following results:—The oldest rock-group is formed of highly contorted argillaceous, calcareous and carbonaceous schists and conglomerates, identical in petrological characters with those of Zacatecas. Into this metamorphosed sedimentary series were intruded, with attendant metamorphism, gabbros and olivine- and quartz-diabases. After a period of erosion there then followed a series of Tertiary extrusions in the following order:

(1) Andesite rocks with tuffs. (2) Rhyolites with rhyolitic tuffs and breccias. (3) Hypersthene and augite-andesites; these were succeeded by the deposition of the "Red Conglomerate," after which there appeared rhyolitic tuff, dykes of comptonite, and an outpouring of the Cerro Cubilete

basalt. Mineralization is believed to have been coincident with the extrusion of the Cerro Cubilete basalts.

The lodes have been grouped into three zones, viz. the Central Zone, the Eastern Zone and the Western Zone. The Central Zone, which includes the Veta Madre, which was discovered in 1558, is divisible into three systems. The famous Veta Madre lode occupies a brecciated zone lying chiefly between the " Red Conglomerate " and the schists. In depth it traverses the schists where they are intruded by diabases. The Veta Madre is really a composite lode of considerable complexity, and frequent variations in dip and strike have been brought about by the variations in the nature of the rock traversed. Similar variations are to be observed in the Sta. Lucia and Sta. Inés veins within the " Red Conglomerate." At Esperanza, Protectora and La Cebada, the ore-bodies traverse schists and diabases. As example of the second system of the Central Zone there is the Cedro lode which traverses rhyolitic breccia and the hypersthene- and augite-andesites, and the veins of the Flores de Maria group, the S. Vicente, Sta. Anita, Canales and El Conejo lodes, which occur in rhyolites and rhyolitic breccias and the " Red Conglomerate," are examples of those belonging to the third system. The Eastern Zone comprises the districts of Sta. Rosa, San Nicolas del Monte, Peregrina, Villalpando, Cubo and El Nayal, and the Western Zone extends from San Cayetano to the district of La Luz.

The predominant minerals occurring in the lodes of the Sierra de Guanajuato are polybasite, stephanite, argentite and pyrite in a gangue of quartz with some calcite. The zone of oxidation is very superficial.

Guerrero

Tasco is one of the oldest and one of the most important mining camps of the district of Hidalgo.

The formation is calcareous schist and limestone cut by Tertiary eruptives. At Tehuilotepec (which forms part of the Tasco camp) the formation is mainly limestone cut by andesite and rhyolite.

According to J. O. Aguilera [77/p. 567], the veins of Tasco are related to these eruptives.

According to E. Halse [81], the veins run (1) N.N.W.–S.S.E., dip E.S.E. (prevalent); (2) N.W.–S.E., dip N.E. (prevalent); (3) N.–S., dip E. The veins usually meet at acute angles on the line of strike, and rich branches or shoots of ore occur at the points of intersection. The filling consists of marcasite, pyrite, blende, galena, chalcopyrite, argentite and proustite in a gangue of quartz and calcite.

In Tetipec (including Poder de Dios, Pregones and Xocotitlan) the "country," filling and structure of the veins are similar. The principal direction of the veins is N.W.–S.E., as in Tasco.

The lodes of the Rosario mines and the San Nicolas del Oro mine are in hornblende-andesite. They course N.W. and sometimes N.E., and contain, below the zone of oxidation, argentite, ruby silver, pyrite and a small quantity of chalcopyrite. The gangue is quartz carrying gold.

At Tlalchapa the lodes have a N.W. course and dip to the N.E. The vein-filling is quartz with argentite, pyrite and blende. Occasionally calcite, galena and chalcopyrite occur.

The veins worked by the Coronilla mines are in rhyolite, and contain argentite, ruby silver and pyrite in a gangue of quartz.

At the Tepantitlan mines the veins traverse red conglomerate of Tertiary age. They have a N.W. course and dip to the N.E. or to the S.W. The gangue is quartz, containing argentite, ruby silver, blende, arsenopyrite and a small amount of chalcopyrite.

In the Campo Morado range of the Aldama district, large masses of pyrite occur in sedimentaries of Archæan (or possibly Palæozoic) and Cretaceous ages, in relation to a dioritic dyke. According to Luis Hijar y Haro [82], the outer shell of one enormous prism consists of oxidized ores, cerussite, anglesite, iron oxide, etc., with the gold and silver contents about equal. The prism probably contains on an average 0·25 % silver and 0·005 % gold. The deposit is a primary one.

Hidalgo

Pachuca and Real del Monte are nearly 5 km. apart and about 100 km. north of the City of Mexico. The Pachuca district lies on the western slope and Real del Monte on the eastern slope of the Pachuca range of mountains, which bounds the great Valley of Mexico. From 1522, when Pachuca was discovered, to 1901, more than 3,500 tons of silver, worth about £31,000,000 sterling, are said to have been extracted, principally from the immense bonanzas.

The Pachuca Range is built up of Tertiary andesite, rhyolites and basalt, probably of Miocene age. The outpouring of andesite, which forms the principal rock-type, was followed by rhyolite, with associated obsidian, pitchstone and tuffs, and finally by basalt. The lodes, usually found in andesite, are younger than the rhyolite, but older than the basalt. The country near the lodes is kaolinized, impregnated with silica, and otherwise considerably altered [83].

The veins, according to Aguilera and Ordoñez, belong to one E.–W. system of fractures only, but secondary veins branch off from and sometimes diagonally unite the E.–W. veins at angles seldom exceeding 30°. The veins are fissure veins with a quartz gangue.

There are five main groups of lodes, namely, the Vizcaina, El Cristo, San Juan Analco, Santa Gertrudis and Palo Norte. The width of the lodes seldom exceeds 7 metres, but they are remarkably persistent along the strike.

The upper oxidized (*colorado*) zone consisted of quartz, oxides of iron and manganese, and chlorides and bromides of silver, which were capable of treatment by the cold amalgamation or *patio* process (invented in Pachuca in 1557 by Bartolomé de Medina). Exploitation is now confined to the lower sulphide (*negro*) zone, which consists of pyrite, galena, argentite and rhodonite.

Sometimes stephanite and polybasite occur. Blende is rare. The gangue is milky quartz, with, in places, bluish, greenish and purplish varieties. Calcite occurs only in small amounts as a later infiltration.

Native silver is found at all depths. Dark ruby silver (pyrargyrite) is rare, and light ruby silver (proustite) appears to be entirely absent from the Pachuca veins. In Pachuca, bonanzas have occurred more frequently in the lower than in the upper zone. The San Rafael bonanza produced nearly $14,000,000 in ten years, whilst that of Rosario produced $28,000,000 in thirty years (1853 to 1883).

At Real del Monte N.–S. veins intersect the E.–W. veins. At a depth of 400 metres the filling of the Vizcaina vein is quartz, coarse blende, fine-grained argentiferous galena, pyrite, chalcopyrite and rhodonite. The Santa Inés (N.–S.) vein has been worked to a depth exceeding 400 metres, and has two shoots of rich ore in the sulphide zone which appear to pitch south [84].

Jalisco

At Hostotipaquillo, the lodes are formed by the siliceous replacement of brecciated andesite. According to S. J. Lewis [20/p. 523], the primary filling consisted of metallic base sulphides with some silver, the gangue being calcite, a little quartz and rhodochrosite; then followed siliceous solutions containing more of the precious metals; this was followed by oxidation and enrichment. Here and there, through step-faulting, the quartz has been shattered, displaced from 3 to 6 metres, and leached. Rich ore occurs to a depth of 200 metres; from 200 to 300 metres the ore shows little secondary influence, but can still be worked at a profit.

The Amparo mine, near Etzatlán, is in augite-andesite (basic rock).

In the opinion of S. J. Lewis [20/p. 526], the San Juan lode, striking N.S. and dipping W.70°, was first formed, the primary low-grade filling consisting of lead, zinc, iron, and copper sulphides, and abundant rhodochrosite in a gangue of calcite. This vein was subsequently cut through and displaced 90 metres by the Dulces Nombres vein, trending N.W.–S.E. and dipping E.70°. Owing to the draining of the ground and the re-opening of the channels, this section of 300 ft. in length became much enriched by a siliceous solution containing gold and silver. Finally there was a great fault movement in the southern portion of the San Juan vein; the rock breccia was ground up into impalpable powder by the up and down movement, and a gouge (*flucan*) from 30 cm. to 1 m. in thickness was formed in the fault zone, which acted as a check across the ore-channels, thereby causing heavy ore deposition on both sides of the fault. There are two ore-bodies, one of which goes to a depth of 300 metres. The ore contains an average of 5 dwt. gold and 9·6 oz. silver per ton.

Territory of Lower California

In the Cacachilas district the veins are in a granitic rock. The gangue is quartz. In the upper zone are oxides of antimony and iron, chloride and bromide of silver, and carbonate of lead; in the sulphide zone are galena, tetrahedrite, sulphides of silver, berthierite, jamesonite, pyrite and blende.

In the San Antonio district, according to Santiago Ramirez, N.E.–S.W. veins, dipping S.E., occur in granulites and diorites. The sulphide ores are similar to those of the Cacachilas district [86/p. 343].

In the Virgenes district (32 km. east of La Paz) the formation is tourmaliniferous granite traversed by dykes of pegmatite (?). According to Santiago Ramirez the veins course N.20°W. and dip E. The ores are silver-bearing tetrahedrite and galena, accompanied by copper minerals. The gangue is quartz or heavy spar [86/p. 346].

At the Pihuamo mines the lodes course E.10°N. and dip N.10°W.65°. The gangue is calcite, and the ore is silver-bearing galena and blende. The ore-bodies lie at the contact between slates and limestone of the Lower Cretaceous above, and granulites below.

Mexico

At El Oro, the formation consists of calcareous shale (Cretaceous), from 500 to 900 ft. in thickness, overlying intrusive andesite of about 1,000 ft. in thickness. At a depth of 2,200 ft. shale again appears, and may possibly prove to be ore-bearing. The veins strike N.10°–20°W. and dip W. 63°–70°. S. J. Lewis [25] gives the history of the lodes as follows: After the fracturing of the shale by the andesite, the primary mineralization was performed by alkaline solutions —no doubt aided by the carbonaceous matter in the shale— and calcite was the gangue carrying little of the precious metals ; then followed cross-faulting and the entry of a siliceous solution far richer in the precious metals (pseudomorphs of quartz after calcite occur) ; finally, owing to the wearing away of the surface cap of andesite, circulation of the surface waters in the cross-channels has produced enrichment of the ore-bodies, forming them into the *bonanzas* that are being mined to-day. The free gold, which occurs in a fine state of division, is alloyed with silver, and is mixed with minute proportions of argentite, proustite and pyrargyrite.

At Sultepec, the Cretaceous shale, from 300 to 600 metres thick, is underlaid by intrusive andesite, in which the lodes become impoverished.

According to E. Halse [87], the country is a green talcose schist, often accompanied by andesite dykes. The ores are pyrite, marcasite, argentite, pyrargyrite, proustite (occasional), stephanite (rare), miargyrite (rare), galena and blende, accompanied by chalcopyrite, stibnite (rare) and arsenopyrite. The gangue is quartz, calcite, dolomite, fluorspar and barytes (rare).

At Zacualpan, the principal lodes strike N.–S. in andesite with inclusions of Cretaceous shale, which has an adverse effect on the lodes. The pay-ore, in the opinion of S. J. Lewis [26], is largely a matter of secondary enrichment, which will probably prove to reach to 450 metres in depth.

Two systems of veins occur in Temascaltepec—E.–W. (the best) and N.W.–S.E. (low grade). According to Dollfus and Montserrat [88], the country is a blackish schist with calcite, and is near a mass of quartzose porphyry. The veins, as regards filling, are very similar to those of Sultepec.

In the Ilaltaya group, according to Hoppenstedt, the ores form contact-deposits between andesites and Tertiary volcanic conglomerates.

Michoacán

The principal veins at Tlalpujahua, according to Joseph Burkart [85/p. 75], strike N.25°W. and dip E. The country is a metamorphosed schist or slate. The filling consists of native gold and silver, argentite, polybasite and pyrargyrite, with pyrite and occasionally calcite. The usual gangue is quartz. Dos Estrellas, one of the richest mines of the Republic, geologically forms part of the El Oro district (*see* State of Mexico). The ore milled contains 7 or 8 dwt. of gold and from 4 to 6 oz. of silver per ton. At Angangueo the veins are fissures in eruptive rock. The silver occurs mainly as argentite, with galena, blende and chalcopyrite. The gangue is quartz and calcite.

Nuevo Leon

The ores in this State are principally silver-bearing galena and blende. According to J. O. Aguilera [77/p. 596], the Iguana ore-deposits are bedded veins carrying quartz, galena, pyrite and silver sulphides in limestone near diorite.

Oaxaca

According to E. Halse [89/p. 372] the country at Taviches is hornblende-andesite (Tertiary), traversed by dykes of diorite, trending, like the veins, in a general N.W.–S.E. direction, and which are metalliferous in places. Pyrargyrite is the principal silver ore. It is frequently associated with auriferous pyrite, and is occasionally accompanied by polybasite, argentite and stephanite. Stibnite, galena, chalcopyrite and blende are also found. The gangue is quartz, with calcite and gypsum occasionally. Dark ruby silver (pyrargyrite) occurs in spots (*moscas*) and little bunches (*ojos*), and sometimes forms the centre of quartz, having a radiated spherical texture (*rueda*), which appears to have filled cavities in the rock [80].

Gold-bearing ores, carrying some silver, occur at Peras and at Peñoles in granitic rocks, and argentiferous lead-ore deposits are found at Tehuantepec.

Puebla

In the Teziutlan and Tlatlaquitepec districts, contact copper-bearing deposits occur between gneiss and mica schist. On an average the ores carry 3 oz. of silver and 1 dwt. of gold per ton.

Querétaro

At Cadereita, the old mine of San Juan Nepomeceno (or Mina Grande del Doctor) produced a large quantity of silver during the Colonial period. In the seventeenth century it is said to have paid more than 18,000,000 pesos as the King's fifth. According to C. B. Dahlgren [90], the vein strikes E.–W. and dips S.60° in limestone. The ore now being worked in the upper levels is siliceous, and contains both silver and gold.

The Ajuchitlan mine, in the Mineral de las Aguas, is, according to S. J. Lewis [55/p. 448], a true contact deposit, consisting of tongues of intrusive porphyrite in Cretaceous calcareous shale. The latter was shattered by the eruptive mass, primary mineralization of gold-silver ores from a siliceous solution followed, and quartz-breccia ore-bodies were formed by replacement. This stage was accompanied by settling and was followed by cross-faulting, while enrichment has succeeded the latter.

San Luis Potosí

The Barreno mine in the San Pedro district is a true contact deposit of Cretaceous limestone overlying intrusive diorite-porphyrite (probably Miocene). The lead-silver-gold ores were deposited in immense fractures in the limestone. S. J. Lewis [55/p. 444] regards the lodes as having been built up as follows: (1) A deposition of primary iron sulphides from a siliceous solution with low precious-metal contents; (2) a considerable shattering of the limestone, which preceded and accompanied the entry of siliceous solutions carrying lead, mercury, antimony, arsenic, zinc and other base metals, with an increase in gold and silver (pseudomorphs of galena after pyrite occur); and (3) the oxidizing enrichment of the iron-sulphide ore-bodies by atmospheric and circulating agencies, which has reached a depth of 300 metres.

Catorce was discovered in 1772. The veins traverse limestone and porphyry dykes, and are themselves cut by more recent porphyry dykes. The general strike is N.W.–S.E., the dip S.E. or N.W.60 to 65°. The *negros* zone contains proustite and other rich silver ores, with sulphide of antimony and arsenic, chalcopyrite, pyrite, galena and some blende. The gangue is more quartzose than in the *colorados* or oxidized zone.

At Santa Maria del Rio, according to J. P. Manzano, the country is Cretaceous slate [77/p. 611]. The veins vary in strike N.40° to 75°W. and in dip from N.68° to S.67°. The ore consists of tetrahedrite, argentite and pyrargyrite, accompanied by pyrite and chalcopyrite in a gangue of quartz and steatite. At Charcas the formation is limestone, and the ores contain copper, zinc and antimony, with some silver. At Ramos, La Cocinera vein, discovered in 1796, produced silver to the value of 21,000,000 pesos from 1801 to 1809. The country is an argillaceous schist.

The ores are native silver, polybasite, cerargyrite, argentite and proustite, accompanied by tetrahedrite, chalcopyrite, pyrite, galena and blende in a gangue of quartz and clay.

Sinaloa

At Fuerte, silver-bearing veins occur in porphyry and syenite. Palmerito, about 48 km. north of Culiacan, is in the district of Mocorito. Here, according to W. H. Weed [77/p. 614], there is a breccia reef of decomposed trachyte, striking E.–W. and dipping N.30°, and from 41 to 46 metres thick. The hanging-wall is quartz-syenite, and the footwall is altered trachyte. Argentite and galena are the principal ores. The whole ledge is said to average 15 oz. of silver per ton. The output amounted to between 4,700 and 6,000 oz. per month in 1900. At Cosalá the country is andesite, carrying much lime. All the ores carry silver, gold and some copper. The gangue is quartz. About 25% of the value of the content is in silver. At Santa Cruz de Alayá, 48 km. north of Mazatlán, the formation, according to E. Halse [79/p. 243], is limestone, probably of Middle Cretaceous age, containing thin bands of chert and intercalations of schist. The principal veins course N.–S. and dip W. The ore consists of argentiferous blende, with some pyrite, chalcopyrite and arsenopyrite, and occasional spots of argentite and ruby silver in a gangue of quartz and calcite.

The veins are of the replacement type and often consist of bands of ore separated by limestone. The ores carry from 19 to 40 oz. of silver per ton.

The vein of the Jocuistita mine, district of San Ignacio, strikes E.–W. and dips N.83°. The formation is porphyry and trachyte.

At Copala, district of Concordia, the formation consists of Tertiary eruptive rocks. The veins strike N.–S. and dip E. The filling is quartz, which carries small quantities of argentite and native silver, with a little pyrite, galena and gold.

The Tajo mine, district of Rosario, was worked by the Spaniards. The vein strikes E.–W., and the ore consists of argentite, native gold and silver, galena, pyrite and blende in quartz [90/p. 92].

Sonora

The Babicanora camp, district of Arizpe, was discovered in 1780. The country is porphyry. The principal lode strikes N.52°W., and dips W.75°. The ores are sulphide of silver with gold and pyrite. According to the late Edmond Fuchs [91], one vein of the Carmen mine carries proustite, argentite and polybasite, with a little gold, associated with pyrite, a little galena, chalcopyrite and tetrahedrite (rare). The gangue is quartz and a little calcite. Some silver is found in the ores of the Cananea copper deposits.

The Chipioneña mine lies 26 km. north of Matapé, in the district of Ures. According to E. Halse [89], the vein strikes N.W.–S.E. and dips N.E.45° in granite. The ores are silver-bearing galena, pyrite and blende. The ore occurs in shoots pitching N.W. or following the cross-joints in the country.

The silver-bearing veins, worked by the San Javier, Los Bronces and La Barranca companies, traverse sandstone and slate, and contain chalcocite, tetrahedrite, pyrite, chalcopyrite, blende and a small amount of galena, and complex sulphides of silver in a gangue of quartz and calcite.

Tamaulipas

In the Victoria district the ores carry silver-lead-copper. San José is a copper district, but the ores contain some silver.

Territory of Tepic

Rich gold-silver veins occur in the municipalities of Santa Maria del Oro, Acaponeta and Santiago Ixcuintla, with or without copper and lead.

El Zopilote mine, in the last municipality, has veins with a N.W. course consisting of quartz, blende and pyrite, sulphides of silver and small amounts of galena. The Castellana mines, to the north of Ixtlán del Rio, have lodes with a N.50°W. course. They contain quartz, pyrargyrite, polybasite and a small amount of argentite. Native silver occurs in the oxide zone. At Barranca del Oro, in Ahuacatlán, the veins are in granulites cut by dykes of diorite and hornblende-andesite. The lodes have an E.–W. course, and contain quartz, pyrite and a little galena.

Zacatecas

The Zacatecas district was discovered by Juan de Tolosa in 1546. The extension is 14 km. from north to south, and 12 km. from east to west.

Values of Production in the Zacatecas District

	$ (Pesos)
1548–1810	588,041,956
1810–1818	20,060,363
1818–1825	17,912,476
1825–1832	30,028,540

Among the mines famous for their remarkable output of silver may be mentioned La Gallega, San Acacio, San Borjas, Asturiana and San Francisco, all in the Veta Grande lode, Quebradilla, Rondaneva and Guadalupe, on the Mala Noche lode, and the mines exploiting the San Luis and Santo Tomas veins.

According to Burckhardt and Scalia, the oldest rocks in the Zacatecas region are ancient, highly-contorted sericitic schists. Of later origin, and unconformable to the above, are quartzites, grits and siliceous and argillaceous schists of Upper Triassic age, exposed only at two points, and folded or highly-inclined.

Exposed over a considerable area to the west of the town of Zacatecas is an upper and lower series of spilites (altered shaly-olivine-basalts) intercalated with the Triassic sediments and folded with them. The upper series rests unconformably upon both the ancient schists and the lower series of spilites. The outpouring of the upper spilites was followed by a lengthy period of erosion during which the *roca verde* grits and breccias were laid down. Afterwards came the Bufa rhyolites and rhyolitic tuffs and breccias as extensive surface flows, but now represented by a few uneroded remnants, and, finally, quartz-porphyry and rhyolite, as unimportant dykes traversing schists and spilites, now represented by occasional outliers at elevated points.

Flores distinguishes three principal mineralized zones—the middle zone, which includes the mines working the Veta Grande lode; the north zone, including the mines of Panuco; and the south zone close to the town of Zacatecas. The south zone may be grouped into several systems. The first includes Cantera, Mala Noche, El Bote, Magistral, Sierpe and Plata, all of whose lodes strike E.–W.

The Cantera group is located for the most part between the *roca verde* breccia and the spilites; the Mala Noche lode lies mostly within the spilites, and the El Bote and Magistral groups traverse the ancient schists.

The N.W.–S.E. system of lodes include the Quebradilla, San Luis, Santo Tomas, San Vicente and Dolores groups. The predominant primary minerals of these lodes are argentite, proustite, polybasite, galena, blende, pyrite, chalcopyrite and bornite in a gangue of quartz with calcite. The secondary minerals include oxides of iron, argentite, native silver and copper, and the oxides of copper. Cerargyrite, bromyrite, cerussite and the oxide of manganese are rarer.

According to E. Halse [92], there is a gold-silver-bearing group of veins to the south of the town. The strike varies from N.14°W. to N.28°W., and the dip is easterly from 55°

to 80°. The country is a highly altered schist, often chloritic, with diorite (?). The veins, about 1 metre thick on an average, have a banded structure, the filling being characterized by alternate layers of quartz and calcite, with ribbony bands of silver sulphide and native gold deposited preferably in the quartz. The veins carry from 6 to 38 oz. of silver and from 9 to 60 dwt. of gold per ton.

The mines at Fresnillo are about 64 km. south-west of Zacatecas City. According to B. Silliman [77/p. 644], the deposit is a stockwork of some sixty veins resting in the N.E. and S.W. slopes of the Cerro de Proaño Mountain. The formation consists of Cretaceous limestone with dykes and intercalations of rhyolite. The veins average 60 cm. in thickness, and the walls for 90 or 120 cm. are impregnated with pyrite, cerargyrite, native silver and argentite (*azulaques*). The gangue is white quartz. The sulphide ores are argentite, pyrite, etc. The lodes cut diorites, and, according to Arenas, rhyolite also.

Sombrerete was discovered by Juan de Tolosa in 1555. The veins strike E.–W. and dip S.80° in compact limestone, slate and porphyry. Proustite is the characteristic ore, arsenopyrite is abundant, and the gangue is quartzose.

Aranzazú, formerly known as Mazapil, was discovered in 1530. Here strata of Cretaceous-Jurassic age are, according to Ordoñez [84] intruded by quartz monzonite of Tertiary age. Mineralization is confined to the contact zones in limestone against the igneous rock. The ore-bodies consist of chalcopyrite, pyrite, tetrahedrite, with small amounts of blende and galena, in a gangue of calcite, garnet with tremolite and quartz. The ore-bodies therefore possess the characteristics of contact-metasomatic deposits.

The chief mine is Albarradón; the vein strikes N.E.–S.W. and dips S.85° in felspathic porphyry, near limestone and slate. The ores, principally cerussite and galena, contain 40 oz. of silver per ton, but rich copper ores, as well as some gold occur also. The geological formation of the ore-bodies of Santa Rosa and Concepción del Oro is very similar.

At Penón Blanco the veins cut Cretaceous limestone. They contain quartz, calcite and barytes and, in the zone of oxidation, native gold and silver, carbonates of copper and silver sulphide. In the sulphide zone are found argentite, stephanite, polybasite, stromeyerite, pyrargyrite, galena, pyrite, chalcopyrite and arsenopyrite. The lode at Mezquital del Oro, in the Juchipita district, has a N.E. course and dips N.W. In the oxidized zone are quartz, iron oxide and free gold and, in the sulphide zone, quartz, chalcopyrite, pyrite and sulphides of silver. The country is rhyolite.

Mexico produced 63,656,000 oz. of silver in 1920.

United States

During the year 1919 the production of silver in the United States amounted to 56,682,445 fine oz., having a value of $63,533,652 (valued at $1·12 per oz.). Compared with the output in 1918 this indicates a reduction amounting to 11,127,694 oz., and represents the smallest output since 1913.

Below are given the more important statistics relating to production, value, imports and exports of silver for the United States.

The following table gives the amounts and values per ounce of silver produced in the United States from the years 1913 to 1920, inclusive, compared with some previous years:

Year.	Quantity.	Average Price in New York, per Fine Oz.	Year.	Quantity.	Average Price in New York, per Fine Oz.
	Fine oz.	$		Fine Oz.	$
1883 .	35,732,800	1·11	1914 .	72,455,100	·55
1888 .	45,792,700	·94	1915 .	74,961,075	·52
1893 .	60,000,000	·78	1916 .	74,414,802	·66
1898 .	54,438,000	·59	1917 .	71,740,362	·82
1903 .	54,300,000	·54	1918 .	67,879,206	1·00
1908 .	52,440,800	·53	1919 .	56,682,445	1·12
1913 .	66,801,500	·60	1920 .	56,564,504[1]	1·00

[1] By the terms of the Pittman Act and U.S. Mint regulations domestic silver produced and reduced in the United States after Jan. 17, 1920 is saleable to the Director of the U.S. Mint at $1·00 per fine oz. (*Min. Jour.*, Jan. 29, 1921).

The following table gives the output of silver by States for the years 1916 to 1920. The figures for 1920 represent a joint preliminary estimate by the Bureau of the Mint and the Geological Survey.

Silver Produced in the United States 1916–20, *in Fine Ounces*

—	1916.	1917.	1918.	1919.	1920.
Alaska . .	1,266,317	1,207,164	796,836	690,151	792,751
Arizona . .	6,680,252	6,962,257	6,771,490	5,702,911	6,098,251
California .	1,936,910	2,107,107	1,555,417	1,153,614	1,513,495
Colorado . .	7,551,761	7,291,495	6,982,313	5,966,606	5,572,407
Georgia . .	—	—	43	8	140
Idaho . .	11,570,399	11,402,542	10,188,056	5,933,078	7,531,253
Illinois . .	5,782	7,116	8,939	6,000	8,500
Maryland .	153	538	164	—	—
Michigan. .	759,068	684,225	491,939	425,610	510,601
Missouri . .	128,860	63,344	40,948	75,991	123,219
Montana . .	14,046,054	14,555,034	15,341,793	15,012,258	13,583,164
Nevada . .	13,682,067	11,217,654	10,113,405	7,045,395	7,392,689
New Hampshire	935	—	—	—	—
New Mexico .	1,729,917	1,535,807	763,758	851,821	764,586
North Carolina	1,738	590	9	19	11
Oklahoma .	606	—	—	—	—
Oregon . .	221,887	172,152	150,207	236,620	182,558
Philippine Is. .	17,643	12,715	12,597	15,715	21,917
South Dakota .	210,100	190,382	165,865	122,068	84,351
Tennessee .	93,837	106,975	131,931	97,554	112,595
Texas . .	664,319	587,945	612,436	539,483	524,212
Utah . .	13,545,802	13,360,905	13,439,811	12,542,623	11,564,155
Vermont. .	1,964	403	5,117	2,200	—
Virginia . .	508	4,500	2,967	8	—
Washington .	294,516	266,112	302,446	258,270	183,437
Wyoming .	3,407	3,400	719	300	72
Total . .	74,414,802	71,740,362	67,879,206	56,682,445[1]	56,564,504

[1] Including 4,144 oz. from Maine.

The table on p. 112 gives figures relating to the imports and exports in the year 1919.

As regards the manner of occurrence and mineral contents of the very numerous silver-bearing deposits in the United States, space will only permit of a brief survey with the object of demonstrating their more important characteristics. With this in view one cannot do better than summarize the opinion held by Waldemar Lindgren, a recognized authority on the gold and silver deposits of America [93].

Value of Silver Imported and Exported for Year Ended Dec. 31, 1919

(Figures furnished by the Bureau of Foreign and Domestic Commerce.)

—	—		Excess of	
	Imports.	Exports.	Imports.	Exports.
	$	$	$	$
Contained in domestic ore and base bullion	—	6,693	—	6,693
Contained in foreign ore and base bullion	74,073,322	1,252	74,072,080	—
Domestic bullion refined	—	186,533,723	—	186,533,723
Foreign bullion refined	8,382,030	23,644,997	—	15,262,967
United States coin	1,057,135	21,224,827	—	20,167,692
Foreign coin	5,897,521	7,609,559	—	1,712,038
Totals	89,410,018	239,021,051		
Excess of exports over imports	—	—	—	149,611,033

On the basis of geological occurrence, Lindgren distinguishes three types of silver-bearing deposits, viz.:

I. Veins contained in granitic rocks or accompanied by porphyries consolidated at considerable depth. The normal gangue is white massive quartz through which the sulphides are sparsely disseminated.

II. Veins contained in volcanic surface flows, such as rhyolite, andesite and basalt. The gangue is prevailingly very fine-grained, chalcedonic, or drusy, and in many places it contains adularia. The metallic constituents consist of argentite, accompanied by very small amounts of lead, zinc and copper sulphides.

III. Metasomatic deposits in limestone, generally in connection with granite, diorite, monzonite or porphyry. Both quartz and calcite appear in the gangue. Almost without exception the ores contain lead and usually also copper and zinc. Native silver and cerargyrite (horn silver) are abundant.

Deposits of the first type are apt to be rich near the surface, where secondary sulphides and sulphantimonites have formed, but generally they are disappointing below the water level, where the primary ore is reached. Many examples of this type may be found in Montana, Idaho, and other States. A subdivision of this class is formed by veins which contain more abundant sulphides, among which galena generally predominates, and may be successfully worked by concentration even below the surface zone of enrichment. Examples occur in Clear Creek County, Colorado.

Deposits of the second type, by oxidation and secondary deposition of sulphantimonites, have undergone great enrichment in their upper parts. Illustrations of this are found in the Tonopah and Comstock ores of Nevada, the Mogollon ores of New Mexico, and the Silver City ores of Idaho.

The upper parts of many deposits belonging to the third type are extremely rich, as exemplified at Leadville and Lake Valley.

Geological Classification of Silver derived from Various Ores in the United States for 1906 [93]

Type of Deposit.	Silver Ores with much Lead and Copper.	Silver Ores with little Lead or Copper.	Silver-gold Ores.	Silver Ores.	Total.
	Oz.	Ox.	Oz.	Oz.	Oz.
From replacement deposits in limestone and shale genetically connected with intrusives . .	4,600,000	1,305,000	—	574,000	6,479,000
From fissure veins in various rocks genetically connected with intrusives . .	1,323,000	712,000	314,000	—	2,349,000
From fissure veins in Tertiary volcanic flows .	1,408,000	900,000	7,500,000	466,000	10,274,000
	7,331,000	2,917,000	7,814,000	1,040,000	19,102,000

The classification of the silver ores of the United States is most satisfactorily based on metallurgical considerations. Lindgren recognizes two main groups, *dry or siliceous ores* and *silver base metal ores*. The siliceous ores include the silver-lead-copper ores, the silver-gold ores, and the true silver ores, and comprise those which contain little or no copper, lead or zinc. In the main they are siliceous ores containing only gold and silver. The value of the silver is equal to or greater than that of the gold, and the copper and lead are below 2½ % and 4½ % respectively. The silver-gold ores contain gold ranging from 0·5 to 3 oz. per 100 oz. of silver. The true silver ores contain less than 0·5 oz. of gold per 100 oz. of silver. Among the silver base metal ores, those containing 2½ % or more of copper, equivalent to 50 lb. per short ton, are designated copper ores, whilst those with over 4½ % of lead, or 90 lb. per ton, are called lead ores.

The following tables give the relative proportions and actual production of the chief classes of ore produced during the years 1916 to 1918 in the United States:

Sources of Silver in United States

(From different classes of ores.)

	Per cent. of Total.		
	1916.	1917.	1918.
Dry or siliceous silver and silver-gold ores.	31·2	30·4	31·7
Copper ores	31·1	28·8	30·1
Lead ores	24·4	27·0	26·9
Lead-zinc ores	10·9	12·2	10·7

The productions from the various classes of ore for the year 1918 are in fine oz. as follow:

Placers	89,494
Dry or siliceous ores . . .	21,564,982
Copper ores	20,462,597
Lead ores	18,291,243
Zinc ores	135,676
Copper-lead and copper-lead-zinc ores	224,580
Lead-zinc ores	7,290,380
Total	68,058,952

The following are additional details concerning the sources from which the various classes of ore were derived during the year 1918.

Dry or Siliceous Ores.—About 42% of the total production came from Nevada (chiefly from the Tonopah district), 22% was from Colorado (mainly from Leadville, Upper San Miguel, and Sneffels districts), and 18% from Utah. Montana and Arizona each produced more than 900,000 oz. of silver from this source, and New Mexico nearly 380,000 oz. Ninety-nine per cent. of the silver produced in Texas was from siliceous silver ores.

A large part of the silver from silver-gold siliceous ores is obtained with the gold by amalgamation and cyanidation in the mills, and the silver is recovered by refining the mill bullion. The remainder is produced by smelting the richer ores and refining the copper or lead bullion produced.

Copper Ores.—Silver is obtained from most of the copper ores, which are mainly sulphides, by the electrolytic refining of lake and blister copper produced by smelting.

Lead Ores.—The principal yield of argentiferous lead ores comes from Idaho and Utah. The yield in Idaho is mainly from the silver-lead ores of the Cœur d'Alene, and in Utah from the Park City and Tintic districts. Colorado ores of this type are derived from Aspen and Leadville. Most of the output is from the desilverization of lead bullion derived from the smelting of western ores and concentrate.

Zinc, Lead-Zinc and Mixed Ores.—The silver from argentiferous zinc ores is obtained mainly as refinery by-products from the smelting of zinc concentrate from Colorado, California and Nevada.

The silver from lead-zinc ores comes chiefly from concentrate from the Cœur d'Alene in Idaho, the Butte district in Montana, and the Park City region in Utah.

Copper-lead and copper-lead-zinc ores were, during 1918, mainly derived from Utah, New Mexico, Colorado, California and Arizona.

Having obtained a general idea of the silver-bearing deposits in the United States as a whole, attention may now be turned to a more detailed consideration of the several States from which silver is obtained.

Montana

This State is the leading silver producer in the United States, but records a decrease in 1919 compared with the production in 1918. As in past years, much of this silver came from copper ores, but a large part of the increase resulted from residues from zinc ores, both those smelted in the East and those treated in the electrolytic plant at Great Falls. The principal contributors of silver in 1919 were the combined Anaconda properties with the Butte and Superior, the North Butte, the Elm Orlu, the Davies Daly and the East Butte. In 1918 the copper ores yielded 10,521,219 oz. (an average of 1·64 oz. per ton), of which Silver Bow County (Butte) supplied 10,480,556 oz. The lead-zinc ores produced 4,532,034 oz., of which Silver Bow County supplied 4,261,041 oz., and Lincoln County supplied 156,887 oz. The dry or siliceous ores produced 1,028,443 oz., of which Granite County supplied 465,631 oz.

At the town of Butte, in south-western Montana, both copper and silver lodes occur. The latter, which are no longer worked, contain silver sulphide ores, with some native silver, blende, pyrite, galena, quartz, rhodochrosite, rhodonite and hübnerite. They have a marked banded structure. The copper lodes contain quartz as a gangue, whilst the metalliferous portions consist on an average of about 60% of chalcocite, 30% enargite, 8% bornite, and 2% chalcopyrite, covellite and tetrahedrite. The mineral region is made up of Tertiary igneous rocks intruded into Cretaceous metamorphosed limestones, etc., and is partly covered by rhyolite. The most important lodes are found in quartz-monzonite, the "Butte granite." Into the quartz-monzonite were intruded, as later differentiated products, a granite-aplite, the "Bluebird granite," and a quartz-porphyry, the "Medoc porphyry." The rhyolite constitutes the latest phase of igneous action. Mineralization pre-dated the volcanic phase. The lodes, which are divisible into three groups, cut the aplite and quartz-porphyry dykes, but are older than the rhyolite. The formation of extensive oxidation and cementation zones are of great economical importance.

Nearly all the silver-lead ores in Montana occur in fissure veins in or about the contacts of intrusive quartz-monzonite stocks, and a few deposits are contained in limestone.

Utah

Most of the silver produced in Utah is a by-product obtained in the smelting of copper and lead ores.

In 1918 the largest production came from Juab County, credited with 4,994,806 oz., mainly from lead ores. Salt Lake County had the next largest output, amounting to 3,022,638 oz., from copper, lead and zinc-lead ores. Of the Salt Lake County output of silver, the Bingham district produced 81%. The Tintic district, in Juab and Utah counties, yielded 6,681,644 oz., mainly from lead ores. The Park City region, in Summit and Wasatch counties, produced 2,572,586 oz., mainly derived from lead and lead-zinc ores. Altogether, the lead ores of Utah yielded 6,672,725 oz. of silver in 1918, the copper ores 1,445,559 oz., the lead-zinc ores 1,243,638 oz., and the dry or siliceous ores 3,987,068 oz. The crude ore smelted in 1918 contained 10,612,588 oz., and concentrate contained 2,316,766 oz.

At Bingham Cañon contact-metasomatic copper deposits occur in limestone in the neighbourhood of late Mesozoic or early Tertiary monzonite. Lodes accompanied by impregnation zones also occur in monzonite.

The silver base metal ores of Tintic and Park City are derived from replacement deposits in limestone associated with intrusive rocks.

Idaho

The output of Idaho showed a decrease of 38% in 1919 compared with the figure given for 1918. Decreases amounting to 300,000 oz. or more were shown by the Hercules, Morning, Hecla, Tamarack and Custer mines. Smaller decreases were reported by the Bunker Hill, Caledonia and Gold Hunter. The largest silver producer in the State was the Bunker Hill and Sullivan mine, followed by the Hecla mine at Burke. Other important silver producers were the Morning, Tamarack and Custer, Gold Hunter and Caledonia. The mines in the Cœur d'Alene district produced about 4,800,000 oz., or about 84% of the total output of the State. In 1918 lead ores contained 88% of the total output of silver, and lead-zinc ores 9%. Crude ore shipped, which averaged 15·61 oz. of silver a ton, supplied nearly 32% of the silver, and concentrate, which averaged 19·66 oz. of silver a ton, contained more than 67% of the total silver.

The silver-lead deposits of the Cœur d'Alene district in northern Idaho consist of argentiferous galena, siderite, blende, pyrite, etc., in a gangue of quartz with some barytes. The district is composed of Algonkian slates and quartzites pierced by a large syenitic intrusion. The lodes are later than the syenite, but, with the exception of the Hecla lode, older than a series of intrusive basaltic rocks which traverse it.

The siliceous silver-gold ores of Silver City in Owyhee County occur in connection with surface flows of lavas. In the Wood River district galena-tetrahedrite veins cut through limestone. The Gold Hunter deposit of silver base metal ores occurs in quartzite.

Nevada

During the year 1919 the largest output of silver, or about 3,535,000 oz., was produced in the Tonopah district, where the principal contributors were the Tonopah Extension, Tonopah Mining, Tonopah Belmont and West End. Large quantities of silver also came from the Nevada Wonder, in Churchill County, and the Rochester mines, in Humboldt County. Smaller outputs came from the Yellow Pine, Nevada Packard, Prince Consolidated, Elko Prince, and several properties at Virginia City. The Comstock district produced about 240,000 oz., and several properties at Rochester produced about 575,000 oz. In 1918 dry or siliceous ores yielded all but 848,223 oz. of the output of silver, and nearly 88% of this yield was recovered by cyanidation.

The silver-bearing lodes at Tonopah occur in a series of Tertiary eruptive rocks. There are younger lodes containing silver minerals in a quartz gangue traversing rhyolite-dacite, and there are older lodes found in andesite. This latter set of lodes contains argentite, polybasite, stephanite, etc., with some chalcopyrite, pyrite, and a little galena and blende in a gangue consisting principally of quartz. The country rock in the neighbourhood of the lodes is greatly propylitized.

The famous Comstock lode, in the Washoe district, is situated principally in propylitized augite-andesite. The chief veinstone is quartz, and the metalliferous contents were concentrated in a series of large bonanzas. The most important silver minerals of these bonanzas were argentite, stephanite and argentiferous galena. Mining operations were suspended in 1892. Since then, except for a little sporadic work, the mines have been idle.

The main ore-bodies in the Eureka district are due to replacement of a limestone along its faulted plane of contact with impervious quartzite. The primary ore consists of galena associated with pyrite. Within the oxidation zone these give place to various carbonates, sulphates, arsenates, molybdenates and chlorides, which are rich in gold.

Colorado

In 1918 there was an increase of silver contents in ore marketed direct from the mines, the decrease in silver and lead being due to a decrease in lead concentrate from lead-zinc ores. Lake County, chiefly Leadville, but including Lackawanna Gulch, Sugar Loaf, St. Kevin, and Wortman lode districts, and the Arkansas River dredge district, produced 2,348,000 oz. of silver. San Miguel mills, treating ore from both San Miguel and Ouray counties, produced 1,170,000 oz. of silver. Owing to various difficulties connected with labour, etc., there was a falling off in the production of the San Juan region. Dolores County also showed a small decrease, but in Mineral County there was an increase of over 100%. Decreases are recorded from Cripple Creek and Boulder and Chaffee counties. Pitkin County (Aspen) yielded 570,000 oz. of silver. In 1918 siliceous and dry ores yielded 67% of the silver recovered, lead ores 21%, lead-zinc ores 8%, and copper ores 2%. The remainder came from placers, zinc ores and copper-lead ores.

The silver-lead occurrence at Leadville represents a metasomatic deposit in blue-grey dolomitic limestone, of Carboniferous age. The ore-bodies occur chiefly as flats at the junction of the limestone and microgranite. The ores are mostly made up of anglesite, cerussite, galena and pyromorphite. The deposits at Aspen are also of the replacement type in limestone.

In the Cripple Creek district a series of related Tertiary intrusive rocks occur in pre-Cambrian granite and slate. The lodes occur principally in breccia and phonolite, but to some extent also in other rocks. Considerable alteration of the country rock in the neighbourhood of the veins has taken place. The ore consists of tellurides of gold, silver and lead, and pyrite. In addition, tetrahedrite, stibnite, and small amounts of galena, blende, molybdenite, etc., occur. The gangue consists of quartz, fluorspar and dolomite.

Fissure veins connected with intrusive rocks occur at Clear Creek, and also in Park, Gunnison and other counties. Fissure veins contained in volcanic surface flows occur in Mineral County (Creede), and also in San Miguel, Custer, Hinsdale, Ouray and San Juan counties.

Arizona

A large decrease in output was recorded for 1919 resulting from a falling off in shipments of lead ore, which contains considerable amounts of silver. Of the 6,686,152 oz. of silver produced in 1918, 5,347,618 oz. came from copper ores, 913,973 oz. from dry or siliceous ores, 362,182 oz. from lead ores, 36,208 oz. from lead-zinc ores, and smaller quantities from zinc, copper-zinc and copper-lead ores. Cochise County produced 2,315,518 oz., of which 1,693,598 oz. came from copper ores and 426,019 oz. from siliceous ores. Yavapai County produced 2,502,968 oz., mainly derived from copper ores. Bullion recovered from gold and silver ores, almost all by cyanidation, yielded 158,476 oz. of silver. Concentrate contained 1,119,510 oz., and crude ore shipped to smelters contained 5,372,505 oz., or more than 80% of the total output of silver.

The silver base metal ores are derived from imperfectlyknown districts in Gila, Mohave, and Santa Cruz counties, and in part probably represent oxidized and enriched ores.

In 1906 the largest part of the siliceous silver-lead-copper ores produced in Arizona was contributed by the Tombstone mine, working veins and replacements in limestone, quartzite, and shale near bodies of intrusive rocks.

The siliceous silver-gold ores are derived from fissure veins in volcanic flows, principally rhyolite or dacite, and the larger part of it comes from Cochise County.

The siliceous silver ores seem to be largely oxidized ores from veins connected with intrusive rocks, in the Cerbat Range, Mohave County, also from Globe, and from mining districts in Yavapai County.

California

In 1919 the silver was derived mainly from copper and lead ores, although an appreciable quantity was also mined with the gold. Owing to the rise in the value of the metal some few old silver mines in the southern part of the State have been reopened, but none on any large scale. In 1918 more than 47% of the output, or 669,711 oz., came from copper ores. Zinc and silver-lead ores yielded 499,759 oz., siliceous ores 228,332 oz., and placers the remainder. The only counties producing more than 100,000 oz. of silver in 1918 were Shasta, Inyo and Plumas. About 69% of all the silver was recovered from crude ores sent to smelters.

Alaska

In 1918 the copper mines produced 719,391 oz., siliceous ores yielded 90,064 oz., and the placers 38,334 oz., out of a total of 847,789 fine oz. silver.

New Mexico

The Fanney cyanidation mill and the Ernestine mill, both at Mogollon, yield the bulk of silver produced in New Mexico.

In 1918 the total output amounted to 782,421 oz., of which Socorro County produced 352,878 fine oz., or 45%, chiefly from siliceous ores from the Mogollon district, the remainder from mixed ores of the Magdalena district. The output from Grant County amounted to 338,833 oz., and most of this yield came from the Lordsburg and Central districts. Dry and siliceous gold and silver ores, chiefly from Grant and Socorro counties, yielded 48% of the total; copper ores, chiefly from Grant, Socorro and Santa Fé counties, yielded 32%. The remainder of the production was from lead-zinc and copper-lead ores, mainly from the Central, Cook's Peak, Victoria, and Magdalena districts.

The Mogollon deposits belong to the second type recognized by Lindgren and are associated with volcanic flows.

Texas

The greater part of the silver comes from the Presidio silver mine and cyanidation mill in the Shafter district, Presidio County.

Michigan

In 1918 the copper mines at Michigan produced 509,067 fine oz. of silver. The silver was mainly derived from the electrolytic treatment of 56,127,000 lb. of copper. The average recovery of silver per ton of "rock" treated was 0·18 oz. Of the total output of silver, 453,957 oz. came from mines in Houghton County. The ore consists of native copper in an amygdaloid and conglomerate gangue.

Washington

In 1918 about half the silver came from copper ores, and most of the remainder from Republic ores. In 1918 Ferry County produced 101,376 oz., mainly from siliceous ores, and Stevens County 168,669 oz., mainly from copper ores, out of a total of 310,093 oz.

South Dakota

The output of silver in 1918 in South Dakota, which was mainly derived from refining gold bullion, was 159,202 oz.

Domestic Exports of Refined Silver Bullion from United States[1]

In ounces.

—	1913.	1914.	1915.	1916.	1917.	1918.	1919.[2]
To British countries:							
United Kingdom	76,863,366	59,907,488	70,051,650	72,474,513	65,882,912	21,285,266	12,138,296
Canada	876,103	755,137	211,875	476,633	1,318,490	1,404,604	3,433,878
British Guiana	4,660	4,805	7,650	11,197	7,470	8,150	2,850
India	2,998,484	417,236	—	1,124,920	14,865,512	71,706,081	104,573,267
Hong Kong	12,602,762	14,556,806	11,436,311	11,159,587	6,473,263	13,570,859	6,837,715
Total, British countries	93,345,375	75,641,472	81,707,486	85,246,850	88,547,647	107,974,960	126,986,006
To foreign countries:							
France	11,646,203	11,375,109	3,382,439	2,425,619	570,878	2,988,342	5,578,302
Russia in Europe	—	—	—	184,992	—	—	—
Russia in Asia	—	—	—	—	—	6,329,862	—
Switzerland	—	—	8,000	17,000	—	—	160,498
Mexico	57	50,000	—	—	—	—	—
Argentina	12,271	6,473	5,139	844,001	16,365	201,369	3,215
Peru	—	—	825,659	1,228,955	474,039	—	—
China	3,610,067	2,257,527	425,792	4,287,784	10,255,260	17,031,911	37,136,233
Costa Rica	31,326	—	—	—	—	—	—
Denmark	—	—	580,047	—	—	—	556,110
Germany	—	—	—	—	200,114	—	—
Italy	—	—	451,752	—	—	—	—
Netherlands	—	482,591	1,472,374	—	—	—	1,636,632
Japan	—	—	—	—	250,983	—	3,464,902
Norway	—	—	402,687	—	64,776	44,158	1,076,159
Sweden	—	—	—	—	9,647	48,675	157,846
Other countries	100	350	17,162	3,761	15,729	971	24,250
Total, foreign countries	15,300,024	14,172,050	7,571,051	8,992,112	11,857,791	26,645,288	49,794,147
Grand total	108,645,399	89,813,522	89,278,537	94,238,962	100,405,438	134,620,248	176,780,153
Value $	66,811,027	52,180,453	45,469,371	52,944,518	72,923,403	126.034,247	186,533,723

[1] For years ended on June 30.

[2] Calendar Year.

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Imports of Refined Silver Bullion into United States[1]

Values in dollars.

—	1913.	1914.	1915.	1916.	1917.	1918.	1919.[2]
From British countries:							
United Kingdom	17,578	17,584	12,013	25,329	996	2,844	—
Canada	1,394,764	153,149	850,104	1,975,618	1,599,791	2,215,359	3,361,145
West Indies, etc.	—	—	—	—	—	700	158
Australia	168,647	96,137	21,965	961	—	—	—
South Africa	—	—	—	—	—	36,266	—
Total, British countries	1,580,989	266,870	884,082	2,001,908	1,600,787	2,255,169	3,361,303
From foreign countries:							
Costa Rica	261,545	439,385	48,105	42,503	102,408	90,466	53,945
Honduras	815,120	907,696	992,165	782,271	910,641	1,466,037	1,674,713
Mexico	12,800,054	11,094,492	14,456,518	14,393,862	5,377,764	13,572,247	2,989,801
Chile	198,682	645,965	631,706	273,447	160,451	467,000	18,418
Colombia	88,780	22,163	78,576	192,531	157,253	239,680	140,904
Peru	2,083,776	2,675,200	2,667,924	1,249,015	14,258	5,332,466	120,569
Spain	131,376	95,510	—	—	—	—	—
Japan	158,467	109,957	184,781	95,880	—	—	—
Portuguese Africa	—	—	—	17,474	—	32,694	—
Salvador	—	109,915	269,719	—	—	—	—
German Africa	—	26,184	—	—	—	—	—
Germany	18,115	66,282	—	—	—	—	—
Other foreign countries	178,994	89,594	110,804	206,468	30,292	352,808	22,377
Total, foreign countries	16,734,909	16,281,343	19,440,298	17,253,451	6,753,067	21,553,398	5,020,727
Grand total	18,315,898	16,548,213	20,324,380	19,255,359	8,353,854	23,808,567	8,382,030
Grand total . . oz.	30,825,572	28,387,924	39,683,771	36,770,040	12,248,550	26,985,607	7,990,171

[1] For years ended on June 30.

[2] Calendar year.

Imports of Silver Ore and Base Bullion into United States[1]

Values in dollars.

—	1913.	1914.	1915.	1916.	1917.	1918.	1919.[2]
From British countries:							
United Kingdom	28,335	46,482	2,857	12,633	55,016	123,477	45,647
Canada	6,481,110	5,355,424	4,322,536	3,025,563	3,337,431	6,169,690	2,998,993
British W. Indies	—	11	—	—	2,268	—	—
British E. Indies	—	—	—	—	—	2,892	—
British S. Africa	—	17,297	—	—	4,173	2,295	76,822
Australia	7,843	9,130	5,845	18,302	—	—	1,566[3]
Total, British countries	6,517,288	5,425,344	4,331,238	3,056,498	3,398,888	6,298,354	3,123,028
From foreign countries:							
Honduras	14,051	36,151	1,862	305,713	354,405	107,519	178,479
Panama	7,596	2,231	12,155	20,573	36,363	55,171	2,924
Salvador	—	—	—	350,696	354,528	125,972	379,051
Mexico	11,865,605	5,741,068	2,003,680	5,380,391	10,768,418	27,550,579	57,183,527
Cuba	232	1,818	18,420	31,767	99,368	25,915	82,595
Bolivia	—	—	—	—	137,779	—	130,266
Chile	964,015	135,638	230,077	681,653	1,515,037	1,544,335	1,886,631
Colombia	1,054	7,656	25,559	10,522	17,975	26,906	90,624
Peru	81,385	17,825	157,135	2,549,144	6,720,682	839,726	8,719,647
Dutch E. Indies	—	—	—	—	710,101	1,202,409	1,773,584
Japan	—	—	—	97,200	74,690	—	—
German Africa	66,580	15,788	—	—	22,932	—	—
Portuguese Africa	—	—	—	17,580	34,196	—	68,698
Other foreign countries	56,417	52,904	13,167	68,710	37,011	227,089	454,278
Total, foreign countries	13,056,935	6,011,079	2,462,055	9,513,949	20,883,485	31,705,621	70,950,304
Grand total	19,574,223	11,439,423	6,793,293	12,570,447	24,282,373	38,003,975	74,073,332

[1] For years ended on June 30. [2] Calendar year. [3] New Zealand.

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Oregon

In 1918 the total output in Oregon was 107,323 fine oz., of which 77,031 oz. came from siliceous ores, 26,161 oz. from copper ores, and 4,102 oz. from placer bullion.

Southern Appalachian States

These include Alabama, Georgia, Maryland, North Carolina, South Carolina, Tennessee and Virginia.

In 1918 the total production of silver in Tennessee and Virginia was 95,478 oz. Only 44 oz. came from siliceous ores and placers, and 95,434 oz. from copper ores.

Wyoming

Silver is obtained partly from the siliceous ores of the Seminole and Elk Mountain districts, in Carbon County.

SOUTH AMERICA

Bolivia

Potosi.—Silver was discovered in the Potosi Mountain in 1544 [95]. The mountain consists of a cone of porphyritic rhyolite surrounded by conglomerates, shales and tuffs. These rocks are traversed by hundreds of approximately parallel veins and the intervening country rock is considerably mineralized. In the oxidized zone the silver occurs as cerargyrite and native metal, whilst within the sulphide zone the upper portion is characterized by an abundance of pyrargyrite and at lower levels by tetrahedrite. Cassiterite is also to be included as one of the constituents. Pyrite is practically the only gangue, although small amounts of barytes and quartz are present.

The Bolivian output of silver from 1553 to 1910 is said to have been 48,800 tons, of which the mines of Potosi are stated to have contributed no less than 30,000 tons. At present Bolivia and Chile yield about 125 tons per annum. A large part of this comes as a by-product from the tin mines, whilst another part is derived from the mine near Huanchaca.

The great mineral belt of Bolivia lies in the chain of mountains which forms the eastern border of the high plateau of that country, a region of Palæozoic folded slates with cores of diorite and granite, together with porphyritic intrusions. Lava flows are generally absent. The characteristic ore-bodies are those containing both silver and tin. The most important districts are Carabuco, Avicaya, Milluni and Huayna-Potosi, Monte Blanco in the Quimza-Cruz mountains, Colquiri, Oruro, Morococha, and Huanuni, Llallagua, Colquechaca, Potosi, Porco, Pulacayo, Huanchaca, Chocaya, Tasna, Chorolque, etc. The primary silver minerals are principally antimonial tetrahedrite, with pyrargyrite, proustite and stephanite. Cassiterite and a large variety of other minerals also occur. The most important gangue-mineral is quartz, which is occasionally accompanied by some calcite and barytes.

The upper parts of these lodes carry native silver, cerargyrite, pyrargyrite, proustite, etc. The wonderfully rich silver veins of Potosi change in depth to pyritic tin-bearing veins.

At *Corocoro* extensive deposits of native copper, with some native silver, domeykite, certain silver ores, etc., occur as an impregnation in sandstone.

Chile

Mineral deposits of commercial value are practically confined to northern Chile. Here the Jurassic and Cretaceous formations are strongly developed with contemporaneous lava flows of great volume. Into these are intruded granite porphyries and diorite porphyries in smaller stocks, as well as many batholithic masses of granodioritic rocks. The great majority of mineral deposits are associated with these intrusives, although a certain number occur in late Tertiary lava flows. Möricke classifies those ore-deposits containing silver into the following groups:

I. *Silver-copper deposits.*—Deposits containing argentiferous copper ores in basic plagioclase-augite rocks or in Mesozoic sediments, especially limestones, penetrated by the igneous rocks. The chief gangue-minerals are calcite, barytes and quartz. Deposits containing silver, but with only a subordinate amount of copper, occur at Tres Puntas, Cabeza de Vaca, Los Bordos, Chañarcillo, San Antonio in Atacama, Algodones, Rodeito, Argueros, Quitana in Coquimbo, etc.

II. *Silver lodes with a high gold content.*—These occur in both basic and acid igneous rocks. Free gold as well as silver chlorides occur, e.g. at Lomas Bayas in Atacama, and Condoriaco in Coquimbo.

III. *Deposits containing galena, blende, tetrahedrite, enargite, etc.*—Examples of such argentiferous deposits occur at Cerro Blanco and La Coipa in Atacama, Las Hediondas, Vacas Heladas and Rio Seco in Coquimbo.

The principal silver-bearing provinces are in the northern portion of Chile. Proceeding from north to south they are as follow:

Tarapacá.—The Huantajaya mines, in the Coast Mountains, east of Iquique, are amongst the oldest in Chile and have yielded an enormous amount of high-grade ore. The formation consists of metamorphosed limestone and schist. The veins are productive only in the limestone, and carry abundant native silver, cerargyrite and embolite. The new mineral *huantajayite* (approximately 20NaCl + AgCl) was found in the partly-cemented superficial débris.

In the Cordillera, east of the Pampa of Tamarugal, are various veins which carry argentiferous galena and blende in a quartz gangue. At Mina there are veins which carry about 8 oz. silver and 2 dwt. gold per ton. They occur in diorite intruded by porphyry, gabbro and basalt dykes (99/pp. 274–6].

Antofagasta.—The Caracoles silver district, in the department of El Loa, is the most important in this province. It was discovered in 1870, and was extensively worked for some years. Black marls of Jurassic age, dipping south, have been intruded by dykes of quartz-porphyry and diorite-porphyry. Masses of porphyry also occur in the sedimentary rocks. The main lode (Resurrección) strikes N.–S. and can be traced for 2 km. The thickness varies from 2 to 6 m., and the filling at and near the surface consists of barytes with some calcite and iron oxide. At a depth of 50 m. the first bunch or shoot of ore was found, several metres in length and height and with a pitch to the south. Where the shoot occurred the country was more compact and of darker colour than nearer the surface, and there were numerous cross-veins. A second ore-body was discovered at a depth of 100 m. which was 90 m. in length and 15 m. in height. A series of veins formed a junction with the main vein at this point. The metalliferous minerals met with included native silver in wire form, proustite, pyrargyrite, cerargyrite, argentite, highly argentiferous galena and pyrite. The gangue consisted of calcite, barytes and altered country. The average silver content was about 320 oz. per ton.

At a depth of 137 to 155 m., a number of pockets of ore were met with, all pitching south, containing native silver, ruby silver, argentite, cerargyrite and iodyrite in a gangue of calcite, barytes and country rock altered through silicification, etc. Nodules of sulph-arsenide of silver and iron were found above the pockets, and masses of porphyry were also met with, in which argentite predominated in leaves or was disseminated therein. The total depth reached was 200 m. The mines are no longer being worked [100]. They produced in the best years 120 tons of silver.

At El Inca, 32 km. north of Calama, are veins which carry silver chlorides to a depth of 152 m.; in others, argentiferous galena is the principal ore. At Guanaco, 129 km. N.E. of Taltal, are gold mines, which carry some silver in enargite, and other copper ores. Below 121 m. the gold and silver contents became negligible, and the mines were worked for copper [99/p. 276].

Atacama.—The department of Copiapó is especially rich in silver mines. The famous mines of Chañarcillo were discovered in 1831 or 1832, and for half a century produced a large quantity of silver. The isolated mountain of Chañarcillo lies about 80 km. inland from the Pacific, between the ports of Taltal and Chañaral, and has an altitude of 1,220 m. The formation consists of a bluish limestone of Jurassic age interstratified with various intrusive or highly metamorphosed rocks. Four beds of limestone, known as the first, second, third and fourth limestones, and three beds of olivine-basalt or dolerite, known as the first, second and third "greenstones," have been penetrated by the mine workings.

Several layers in the limestone (termed sheets of porphyrite by F. Moesta) are impregnated with ore [101]; thus the one known as the *Manto de Ossa*, which really forms the roof of No. 1 limestone in the northern parts of the Colorado mine, is from 1 to 6 m. in thickness, and has a vesicular structure, and, especially where calcite and limonite abound, the rock was found to be impregnated with granules, filigrees, leaves, plates and veins of native silver, mixed with argentite, cerargyrite and some embolite. About 55 m. below this, a thin band of "ferruginous limestone" (? porphyrite), a few inches thick, had many small cavities encrusted with embolite, and filled with calcareous clay [102].

The sterile rock, interstratified with the limestone, is, according to Henwood [102/p. 79], composed largely of felspar, quartz and hornblende. A more recent writer—Nicomedes Echegarai—calls them sheets of melaphyre (altered olivine-basalt) and dolerite [103]. At Colorado a pair of parallel dykes of augite-porphyrite, striking N.W. and dipping N.E., traverse all the strata.

The principal lodes strike N.E. and dip N.W., and are metalliferous only in the limestone. According to M. H. Gray, some lodes dip S.E., and, although many of them have been explored to a considerable depth, they have, generally speaking, been found to give unsatisfactory results [12]. Deeper still, the proportions of blende, galena and arsenopyrite increase. Calcite is the principal gangue in the limestone, with brownspar (a variety of dolomite) and barytes. The lodes were richest where they united with minute veins (*cruceros*) oblique both in direction and dip.

When Henwood wrote his memoir, the workings on the Colorado lode were at a vertical depth of 414 m., and in the third bed of limestone. Since then the bottom levels of the Delirio and Constancia mines penetrated a fourth bed of limestone, in which the ore in the veins was abundant but not of high grade [104].

Portions of all the lodes have been enormously rich, e.g. at about 180 m. deep in the first limestone, the Candelaria lode for a length of 64 m. averaged upwards of 720 oz. silver per ton. The rich bunches pitched uniformly S.W., but they were of course generally surrounded by much larger bodies of inferior ore. In 25 years, ending 1856, the principal mines of Chañarcillo have produced silver to the value approximately of £6,140,000 [102/p. 124], and from 1830 to 1853, or in 23⅓ years, the production of the department of Copiapó alone amounted to upwards of 1,100 metric tons of silver [102/p. 153].

Henwood, referring to the lower grade ore, says: "Of this there remains, either still unbroken in the lodes or rejected at the surface, almost incalculable quantities" [102/p. 93]. Echegarai points out that the Descubridora lode is completely virgin in the third zone, having been exploited only in the first and second zones for a length of 1½ km. The suspension of the deeper mines is said to have been solely due to the abundance of water met with in depth.

The above statements, provided they are correct, would appear to warrant the reopening of some of the old mines of Chañarcillo.

In the department of Vallenar several rich veins containing much native silver and some gold and copper were discovered in the beginning of the last century.

In the Vicuña district, 104 km. east of Chañaral, quartz veins carry argentiferous ores of copper and lead in syenite and porphyry [99/p. 277].

At present the silver production of the Atacama province comes mainly from the Elisa de los Bordos mine.

Coquimbo.—Numerous very rich silver mines were formerly worked in the department of La Serena, but the richest ores are exhausted, and the mines are practically all idle now.

The Arqueros deposits were discovered in 1825. The formation consists of Jurassic limestones traversed by porphyries. The filling of the lodes comprises native amalgam, native silver, pyrargyrite, cerargyrite, stephanite, smaltite, tetrahedrite, bornite and chalcopyrite [12/p. 875].

The Rodeito silver mines have also been highly productive, as well as those of the Algodones district of the department of El Qui [99/p. 278].

According to Alberto Herrmann, silver ore was first discovered and worked in Chile in 1692, and from that time to the end of 1902 the country has produced 8,824 metric tons of metal [105].

COLOMBIA

Silver ores proper occur principally in the departments of Tolima, Cauca and Antioquia.

In the first, the Frias mines of Guayabal are the only ones at present being worked for silver alone. The Frias veins contain no gold. The silver ores occur along the line of intersection of two veins, which meet at an angle of 57° on the line of strike. The country is hornblende-schist. The ores are argentite, ruby silver and native silver with abundant pyrite, a little blende and galena. The gangue is quartz with some carbonate of lime.

South of Guayabal are the Líbano and Venadillo mines. The ores are principally gold-bearing, but contain from 3 to upwards of 20 oz. of silver to the ton.

In the Mariquita district, several old silver mines are found, which were formerly worked by the Spaniards, viz. Bocaneme, which has an E.–W. vein at the contact of andesite and schist, the ores being argentite and ruby silver, and Plata Vieja with an E.–W. nearly vertical vein, 60 cm. thick, of pyritic quartz, carrying ruby silver and, occasionally, native silver. The Santa Ana mine of the Santa Ana district was also formerly worked by the Spaniards, and was reopened about sixty years ago, but was abandoned in 1874. The vein strikes N.10°E. in schist, and is nearly vertical. Both gold and silver occur in pyrite, blende and galena. The Calamonte mine is in schist. The ores are pyrite and blende, occasionally rich in silver, and native silver. The gangue is quartz. The vein also carries gold.

In the Marmato district of the department of Cauca, several silver veins are known. In the Marmato gold mines the ores carry from 10 to 20 oz. of silver per ton. In the Echandia district, a few km. south of Marmato, vertical veins from 30 to 150 cm. thick occur in hard rhyolite near schist, and close to a dyke of diorite. The ores are pyrite, galena, blende, chalcopyrite, arsenopyrite, native silver and gold. The gangue is quartz and calcite. In 1900 the annual production of Echandia was 230,000 oz. of silver and 2,000 oz. of gold [96/p. 123].

In Antioquia, Caramanta is the only district which is principally argentiferous. An E.–W. vein occurs in a porphyritic rock near " trap." The ores are galena, blende, tetrahedrite, argentite, ruby silver and native silver (scarce). The gangue is quartz. Some free gold is found at and near the surface.

In Manizales, the Diamante mine has a lode from 91 to 122 cm. thick of soft breccia, composed of trachyte and rhyolite, and traversed by small quartz veinlets 1·25 to 4 cm. thick, carrying free gold, auriferous pyrite, argentite and a little chalcopyrite. With increasing depth the tenor of the lode in silver increases greatly [69/p. 622].

In Volcanes, a vein in mica-schist strikes N.–S., dips W. and is 60 cm. thick. It shows native gold with tetrahedrite (freibergite) and ruby silver. In Morisca the country is rhyolite, and the gold is associated with dark ruby silver and brogniartite [96/p. 142].

The famous Zancudo mine, near Titiribi, is a contact vein at the junction of hornblende-schist with overlying conglomerate, having diorite near. The sulphides are arsenopyrite, chalcopyrite, blende, galena, stibnite and dyscrasite, with some nickel, cobalt and manganese ores. The gangue is quartz and calcite. The ores average 17 dwt. of gold, and 18 oz. of silver per ton.

The fineness of the bullion from the important Remedios gold district averages about 600 gold and 350 silver, and that of the vein-gold of the whole of Antioquia is said to average 698 gold and 302 silver, and that of the placer gold, 834 gold and 136 silver [97].

Peru

Peru is the leading silver-producing country in South America, the greater part of the output being derived from the copper mines of Cerro de Pasco. A small amount comes from lead bullion, and the remainder from silver or gold-silver deposits. The districts in which silver-bearing deposits occur are very numerous and are generally situated in the Western Cordillera in the departments of Cajamarca, Libertad, Ancachs, Huanuco, Junín (Cerro de Pasco), Lima, Huancavelica and Arequipa.

In Peru and Chile, along the coast and Central Cordilleras, there is a strong development of Jurassic and also of Cretaceous sediments, folded and in part overturned towards the east. These Mesozoic sediments contain interbedded lava flows of the same age, which, however, do not appear to be of importance as regards mineralization. The great majority of Peruvian deposits are in close genetic connection with numerous intrusions of dioritic or monzonitic porphyries, probably of early Tertiary age. Thus the Cerro de Pasco deposits occur at or near the contact of an intrusion of a dioritic prophyry with the surrounding Cretaceous sediments. Formerly, the lodes carried very rich silver ores in their upper parts, but in depth these give place to low-grade copper ores.

The production of silver in Peru during the year 1918 amounted to 9,781,733 oz., compared with 10,864,624 oz. in 1917.

The principal silver-bearing departments, proceeding from north to south, are as follow :

Cajamarca.—In the district of Hualgáyoc (altitude about 3,650 m.) in the province of the same name, silver-bearing veins proper are associated with andesite, and copper-bearing veins, containing more or less silver, with diorite. The primary ore of the latter is enargite. Cerro Jesús is the centre of the silver mineralization, and contains four systems of veins striking N.67°E., N.45°E., N.80°E. and N.20°W., of which the first is the most important. The filling consists of the common sulphides of copper, lead, zinc and iron, and native silver, argentite, pyrargyrite, stromeyerite, bournonite, tetrahedrite, enargite and some native gold, in a gangue of quartz, calcite and barytes. The oxidized ores, now exhausted, were rich in silver.

The Cerro Chilete (altitude 1,340 m.), in the province of Cajamarca, is built up of diorites and amphibole porphyries. Several veins traverse these rocks. The sulphide zone consists of antimonial argentiferous galena and blende, in a gangue of quartz, but cerargyrite and native silver occur in the oxidized zone.

At Sayapullo, in the province of Cajabamba, limestone, overlaid by sandstone and shale, strikes E.–W. and dips N. The veins, 125 cm. in thickness, striking N.W. and dipping

30° to 35° S.W., contain argentite, tetrahedrite, enargite, chalcopyrite, pyrite, blende and quartz. The filling of the veins at Algamarca is similar, but enargite and blende appear to be absent. The veins strike N.E. and dip 60° to 70° S.W. in shales and quartzite. They are from 80 to 120 cm. in thickness [99/pp. 447–9].

In other districts of the department silver occurs in lead or copper ores, or in both, and although, in many instances, silver ores may occur in the oxidized zone (forming *pacos*), they are more or less rare in the sulphide zone.

In 1917 the province of Cajabamba produced 100,200 oz. of silver contained in copper ingots, and the province of Hualgáyoc yielded 116,800 oz. from leached sulphides.

Libertad.—In the district of Quiruvilca, province of Santiago de Chuco, copper ores—enargite, tennantite and tetrahedrite—predominate, and contain under 16 oz. silver per ton, but the veins of Llacapuquio are rich in silver (800 to 1,000 oz. per metric ton), and carry only 4 or 5% of copper. It is noteworthy that red blende in small crystals and barytes generally accompany the shoots of ore rich in silver, and that when the copper content increases, the silver content diminishes, and *vice versa.* Enargite when pure carries 45·5% copper and 11 oz. silver per metric ton [106].

In the Aguiñuay district the country is augite-andesite, and the ores are galena and blende with spots of tetrahedrite rich in silver. At San Miguel the ores are similar, with the addition of bournonite, rich in silver; and at Santa Rosa the sulphide region is characterized by argentiferous and ferriferous jamesonite with much pyrite and spots of tetrahedrite. Blende is rare. At Mundo Nuevo, when slate forms the country, argentiferous lead and zinc ores predominate, but when it is quartzite, copper ores prevail [107].

In 1917 the province of Otuzco yielded 129,100 oz. of silver from silver ores, and the province of Santiago de Chuco, 51,000 oz. silver from lead ores. "La Guardia" mine in Otuzco produced ores very rich in gold and silver.

Ancachs.—In the Macate district, province of Huaylas, both lodes and bedded-veins (*mantos*) occur in shale and sandstone intruded by mica-diorite. The minerals are native silver (in small quantity), argentite, pyrargyrite, tetrahedrite, galena and pyrite, and their oxidation products, in a gangue of quartz. The ore of these districts is also essentially argentiferous galena, including, in addition to the minerals already mentioned, chalcopyrite, blende, bournonite and siderite.

Recuay is the most important district of the province of Huaraz. The Anglo-French Ticapampa Co., Ltd., owns mines in Collaracra. There are two mineralized zones, one of galena and one of complex sulphides, with a high silver content and some copper. The former diminishes, and the latter increases in depth. The production amounted to 591,000 oz. silver in 1917.

In the San Luis and Chacas district, province of Huari, the formation is quartz-diorite, upon which rests in succession contact metamorphosed black shale, sandstone and coal-bearing strata. The veins strike N.W., N. or N.E. The minerals, in order of abundance, are galena, blende, stibnite, pyrite, chalcopyrite, tetrahedrite and some stephanite, polybasite, bournonite and arsenopyrite. The blende contains from 20 to 45 oz. silver, and the leanest galena over 90 oz. silver per ton.

At Tulla, three veins, coursing N.–S. and dipping W.53°, are cut by a vein striking E.–W. and dipping S.45°. The country is slate and gneiss cut by igneous rocks. The thickness varies from 0 to 120 cm., and the average ore contains from 40 to 60 oz. silver per ton. The ore consists of galena, blende, auriferous pyrite, with small amounts of tetrahedrite, ruby silver and native silver, in a gangue of quartz, calcite, siderite and fragments of wall-rock.

In the Auquimarca district, of the province of Cajatambo, veins, 2 m. in thickness, are found in dioritic country. The filling consists of native silver in threads and dendritic forms in quartz, tetrahedrite, galena, chalcopyrite and pyrite, and the ore contains from 130 to 550 oz. silver per ton. In the Quichas district the formation is limestone and sandstone. The ore is tetrahedrite with pyrargyrite, realgar and pyrolusite in a gangue of calcite and grossularite, and averages 70 oz. silver per ton. Pure tetrahedrite has as much as 900 oz. silver per ton. The ore in the Socorro mine, in the Chanca district, is banded; the successive layers from the centre to the walls are quartz and calcite, sprinkled with pyrargyrite and tetrahedrite, fine and coarse pyrite, thin bands of quartz and calcite, and thick bands of pyrite. Galena, blende and chalcopyrite also occur [99/pp. 451–4].

The ores of the province of Pallasca are characterized by high silver content as compared with their lead and copper contents.

Tetrahedrite in Ancachs generally carries tin [108].

In 1917 the department produced 743,300 oz. of silver.

Huanuco.—A silver-copper-lead belt traverses the province of Dos de Mayo. The ores of the Huallanca district consist principally of argentiferous pyrite and tetrahedrite in a quartz gangue. In the Chonta district are three bedded veins (*mantos*), interstratified in sandstone and quartzite, consisting of pyrite, blende, galena, cinnabar and tetrahedrite, which were formerly worked for the mercury content [99/p. 454].

All the silver in this department is extracted as a by-product from the treatment of copper ores.

Junín.—The silver-lead-copper deposits of this department occur in a belt less than 50 km. wide in its western part. The northern half of the zone includes the well-known districts of Cerro de Pasco, Colquijirca and Morococha.

The Cerro de Pasco district, in the province of the same name, was discovered in 1630, and has produced a large quantity of oxidized ores, or *pacos*, containing silver, but, since 1898 it has been worked mainly for copper. The country consists principally of rhyolite agglomerates and tuffs. There has been a concentration of silver and a leaching of copper in the oxidized zone. Low-grade pyritic ores occur below this zone, but, here and there, are portions so enriched with enargite and famatinite that they can be worked at a profit. The copper ores contain silver.

In the Colquijirca district of the same province, there are two beds of ore intercalated in the limestone series, which represent replacements. In some places the *manto* consists almost wholly of chert, and in others almost entirely of pyrite. Galena and barytes are present when the deposit is richest in silver, with, here and there, a little chalcopyrite and tetrahedrite. Magnificent specimens of native silver in wire-form occur in the oxidized or partially oxidized ores. Its most common habitat is in the spaces between the interlocking tabular crystals of barytes, where it may be found alone or adhering to some of the sulphides, very commonly to the tetrahedrite.

In the Vinchos district, north of Cerro de Pasco, there are veins in limestone, which has been intruded by igneous rock. The filling consists of galena, pyrite, arsenopyrite, chalcopyrite, tetrahedrite, bournonite, pyrargyrite and native silver. The silver content varies from 70 to 300 oz. per ton, and the lead from 25 to 30%. The thickness of the veins varies from 20 to 50 cm. There are ore-shoots at the intersections.

In the Huaillay (sometimes called Huancavelica) district, south of Colquijirca, veins in micaceous dacite yield enargite and tennantite in quartz. In the sedimentary rocks (Cretaceous-Jurassic sandstones and marls metamorphosed in contact with dacite) there is less copper and more lead and zinc in the ore, and the gangue is more calcareous than in the eruptive rocks.

In the Morococha district, province of Yauli, the formation consists of porphyry and peridotite; argentiferous copper ores are now being worked and are yielding a large output of copper and silver, but silver-lead ores also occur in the district; they are not being mined at present [99/pp. 454–5 and 476–8]. On the Cerro San Marcelo, sulphides and complex sulphides of silver (*pavonados*) with oxidized ores (*pacos*) occur in veins in metamorphosed limestone, which appear to have favoured the precipitation of silver, for where the limestone is little altered, the silver present is very small in quantity.

"Flats" occur, having a floor of highly siliceous limestone, and a roof which appears to be a friction-breccia. At Cerro Alpamina, highly argentiferous galena, sometimes accompanied by oxidized or sulphide silver ores, occurs in the marls and limestone [109].

In the Yauli district, of the same province, native silver and argentite, with small quantities of blende, pyrite and galena, occur in the uppermost part of the veins. In depth argentite gives way to pyrargyrite; this in turn to sternbergite, with native silver becoming very rare. Galena, blende, and especially pyrite, show progressive increase in amount with depth. Still lower are geodes with small amounts of native silver, pyrite first becomes cupriferous and argentite again appears, followed by tetrahedrite and the almost complete disappearance of the rich silver minerals [99/p. 455].

At Carahuacra, iron oxide is very abundant, and rich ores occur in shoots. This region is deemed to have a great future before it. At Andachagua, galena, tetrahedrite, native silver, blende and iron oxide predominate.

In 1917 the department of Junín produced 5,707,700 oz. silver, 5,499,000 oz. of which resulted from the smelting of copper ores in the province of Cerro de Pasco, and 121,900 oz. from lead ores produced in the province of Yauli.

Lima.—The Casapalca district is being worked for its argentiferous copper ores. The veins are for the most part in andesite. The San Antonio is the only mine in the district that contains ruby silver and gold in any quantity.

Huancavelica.—In the Lircay district of the province of Angaraés, pyrite, chalcopyrite, galena, occur in the country rock, with siderite, barytes and ocasionally quartz. There are three varieties of tetrahedrite : (*a*) silvery in colour, with from 600 to 650 oz. silver and 5% copper ; (*b*) silvery-grey, found below this, with from 450 to 500 oz. silver and 15% copper, and (*c*) reddish, found at still greater depth, with from 300 to 400 oz. silver and 20% copper. The Acchilla vein runs N.W. and dips N.E. in dark porphyritic rock. The filling consists of galena, tetrahedrite, arsenopyrite, and much ruby silver and argentite. The ordinary ore contains 300 oz. silver per ton.

In the Vizcachas region (10 km. east of Lircay), the Vizcachas vein, 15 cm. in thickness, strikes N.–S. and dips W. in porphyritic rock. It contains native silver in plates and filaments in a gangue of calcite and some quartz. Sulphides of copper and lead are accessory.

The silver-lead-copper region of Huachocolpa (province of Huancavelica) and Carhuapata (province of Angaraés) is found in the porphyritic facies of the Mesozoic. In the famous Quespesisa mine, which lies at an altitude of 5,000 metres, galena and blende are the most abundant minerals, and they are associated with native silver, argentite, pyrargyrite, proustite, stephanite, pyrite, chalcopyrite and stibnite. The gangue is quartz, and some barytes. The Candalosa vein contains galena, blende, bournonite, chalcopyrite, pyrite, stibnite and tetrahedrite (with 5 dwt. gold per ton). There are three varieties of tetrahedrite in this mine: (*a*) crystallized, brilliant silvery, with 270 oz. silver and 15% copper; (*b*) crystallized, steel-colour with blue and yellow shade, 200 oz. silver and 25% copper; (*c*) amorphous, 53 oz. silver and 30% copper. The mine is in the zone of rich sulphides. Quespesisa has probably yielded three times more silver and gold than Candalosa, although statistics are lacking, and is regarded by some as still being above the rich sulphide zone.

The silver-lead regions of Nañantuyo, Sapralla and of Totoral Grande y Chico should also be mentioned, as argentiferous galena is the principal ore of each [110] [99/pp. 455–9].

In 1917 the department produced about 32,000 oz. of silver.

Cuzco.—Silver-bearing galena and tetrahedrite occur in veins in the Lares district of the province of Calca. In the Vilcabamba district of the province of La Convencion, four systems of veins occur in sedimentary rocks (probably Carboniferous), having an intrusion of porphyry, with which the mineral deposits no doubt bear some genetic relation, viz.: (1) N.–S.; dip W.; argentiferous tetrahedrite, with argentite and native silver in calcite—country metamorphosed limestone and red porphyritic sandstone; (2) N.–S.; dip E.; argentiferous galena and some tetrahedrite with calcite in limestone; (3) E.–W.; dip S.; the principal ore is niccolite (NiAs) in calcite, accompanied by gerdorffite (NiAsS), and occasionally smaltite ($CoAs_2$). The niccolite is sometimes associated with pyrite, argentiferous tetrahedrite, galena and arsenic; (4) N.E.; dip N.W.; copper ores, with argentiferous tetrahedrite as a rare constituent.

In the Chimboya district, on the summit of the Eastern Cordillera, at an altitude of 4,600 metres, the principal sulphides from the surface down, are pyrite, galena, blende and stibnite. The gangue is quartz, calcite and barytes, and the country a red porphyry which has been highly altered by propylitization. The galena is usually fine-grained and rich in silver.

In the province of Paruro, there is a replacement vein of highly argentiferous galena in white quartzite. In the province of Chambivilcas, veins of argentiferous galena are found in patches of limestone, resting on a laccolite of quartzose diorite, and, in the Furgani region, the same mineral is found in limestone which rests on limestone-conglomerate, which in its turn lies on quartz-diorite [111].

Apurimac.—In the Challhuanca district of the province of Cotabambas, there are lodes at Pisti which carry pyrite, silver sulphides and iron oxides. The veins are in granite and are 0·5 m. in thickness. The sulphides of silver yield about 58 oz. silver per ton. North of Lake Tunicre (altitude 4,460 m.), there occurs a vein in quartzite, which consists of a number of stringers; these occasionally unite and form a vein 0·3 m. in thickness. This vein carries silver sulphides [112].

The silver produced in this department is a by-product of the gold industry.

Puno.—At Santa Lucia (altitude 4,370 m.), in the province of Lampa, very irregular mineralizations occur in limestone. They sometimes constitute large bunches, and sometimes appear as little veins, and may be regarded as impregnations or replacements of the limestone. The deposits are rich in iron and manganese, and contain silver and copper, and, here and there, pure polybasite occurs, containing 3,215 oz. silver per ton and 25% copper. Until a few years ago, the deposits were worked by the Lampa Mining Co., Ltd., which owned a 30-ton per day smelter. The future of the mine depends on the economic winning of the large ferruginous masses assaying 1·5 to 2% copper, with from 27 to 35 oz. silver per ton [113].

In 1917, the province of Lampa yielded 72,800 oz. silver from copper ores.

The plateau region of southern Peru, west of Lake Titicaca, is built up of Palæozoic shales and limestone, Mesozoic and Tertiary sandstones and acid eruptive rocks. Silver-bearing lodes occur in the igneous rocks, and, to a lesser extent, in the Palæozoic limestone. The silver lodes usually carry a little gold, and a considerable amount of chalcopyrite, galena, blende and pyrite. In general, the sulphides of copper, zinc, lead and iron are present in roughly equal proportions, forming an ore difficult to treat. The gangue consists of barytes, calcite, rhodonite and quartz. The copper ores in the Tertiary sandstones contain, as a rule, much smaller amounts of silver than when they occur in the Palæozoic sedimentaries.

Arequipa.—In the Quequeña and Cerro Verde mining regions numerous copper-bearing veins occur in diorite and carry some silver [113].

The first silver mines of the Caylloma district (altitude 5,000 metres), in the province of the same name, were worked by the Spaniards in 1630, and, prior to that time, by the Incas. The veins occur in andesite, and contain pyrargyrite, argentite and native silver, which, in depth, are largely replaced by polybasite and argentiferous galena. Tetrahedrite, rich in silver, occurs occasionally, and blende, pyrite and chalcopyrite are also present. The gangue is rhodonite and quartz with a little calcite and occasionally rhodochrosite, barytes or wavellite. Even the purest samples of rhodonite and quartz have yielded from 1½ to 3 oz. silver per metric ton. The outcrop of the principal vein now worked is traceable for nearly 4,000 m. From 1890 to 1905 the Caylloma Silver Mining Co., Ltd., produced 5,542,000 oz. of silver. In 1906 a new (Chilian) company—Consolidada Sociedad Explotadora de Caylloma—was formed. Its monthly output averages 110 tons of concentrate assaying 190 to 280 oz. silver per ton, together with gold and lead [114] [115].

In 1917 the province of Caylloma yielded 225,000 oz. silver from silver ores, etc., and the output of the province of Arequipa amounted to 13,300 oz. silver from copper ores. Practically the whole of the production came from the mines owned by the Caylloma company [113].

The tables on page 143 give productions of silver in Peru classified according to the nature of the products and as regards the outputs of the departments respectively.

The nature of the products which carry silver, together

Production and Value of Silver in Peru, 1903–1917

Year.	Nature of Silver-bearing Products.							Total.	
	Copper Ingots.	Silver Ingots.	Lead Ingots.	Copper Matte.	"Lixiviation Sulphides."	Minerals and Concentrate.	Other Products.	Production.	Value.
	Kg.	Kg.	Kg.	Kg.	Kg.	Kg.	Kg.	Kg.	Lp.
1903 .	—	19,651	2,682	45,661	31,890	70,722	198	170,804	579,963
1906 .	2,812	8,686	4,855	39,002	27,473	147,466	—	230,094	972,958
1909 .	54,817	14,097	2,786	76,213	20,963	37,673	107	207,656	639,650
1912 .	98,287	7,813	4,700	121,989	34,755	56,746	62	324,352	1,233,407
1913 .	93,801	8,075	2,553	115,441	27,156	50,746	1,360	299,132	1,131,150
1914 .	170,611	4,489	2,617	50,125	28,244	29,493	1,021	286,600	997,973
1915 .	192,078	8,264	2,966	37,963	28,235	23,700	1,219	294,425	930,189
1916 .	233,319	3,944	1,891	48,652	21,036	24,674	2,013	335,529	1,332,249
1917 .	279,652	2,719	1,830	6,840	22,206	23,167	1,514	337,928	1,641,205
Total .	1,125,377	77,738	26,880	541,886	241,958	464,387	7,494	2,486,520	9,458,744
Total oz.	36,181,658	2,499,331	864,211	17,422,014	7,779,119	14,930,367	240,937	79,917,637	—

[98]

Annual Productions of Silver in Peru, 1913–1917, by Departments

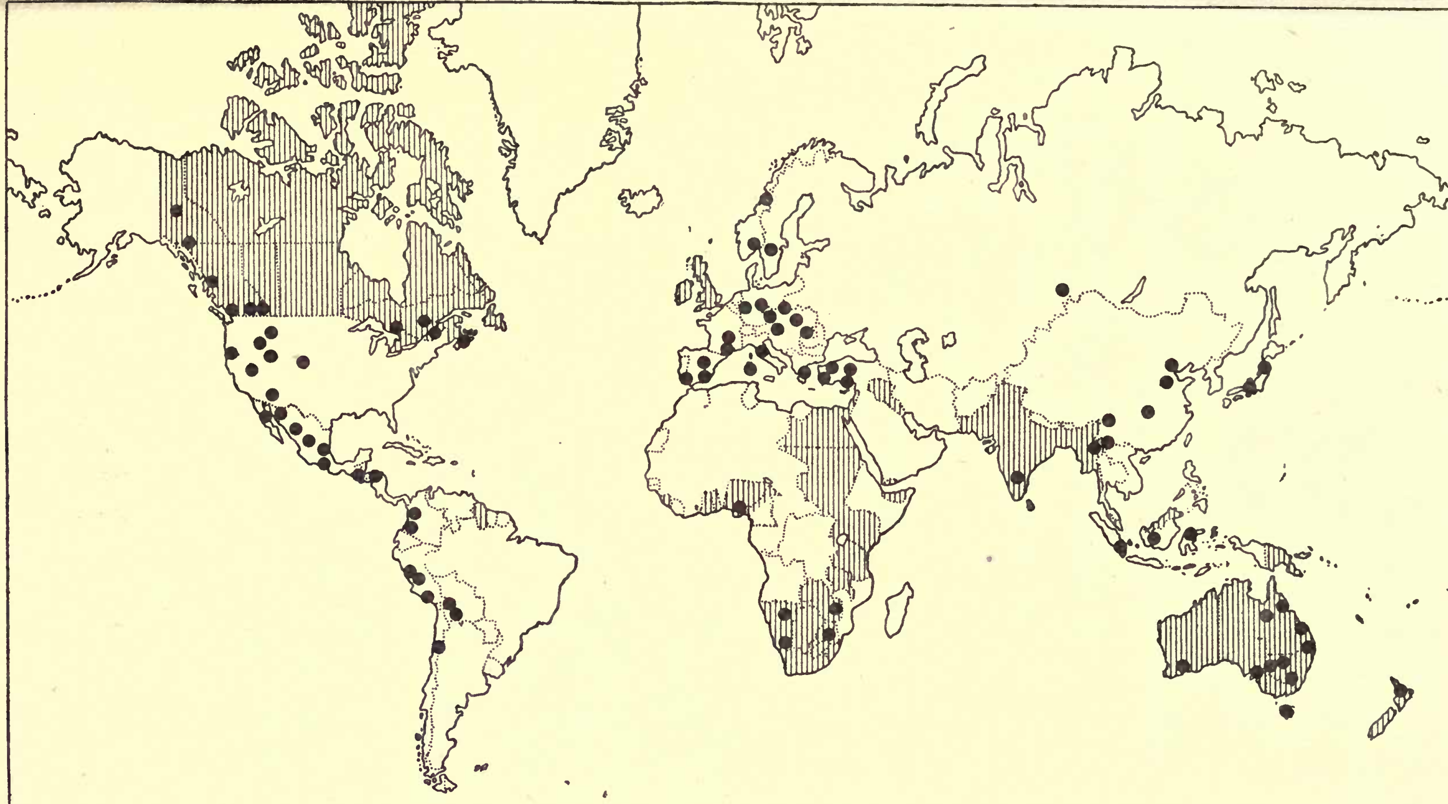
Fine Silver, kg.

Year.	Junín.	Lima.	Ancachs.	Arequipa.	Cajamarca.	Huánuco.	Libertad.	Puno.	Apurímac.	Huancavelica.	Various.
1913 .	180,814	63,118	29,026	2,269	8,960	6,860	2,690	699	137	4,544	15
1914 .	139,645	92,687	26,348	2,918	8,106	8,398	3,933	1,664	—	2,875	26
1915 .	148,325	89,653	30,155	3,094	6,901	6,655	3,463	4,331	220	1,628	—
1916 .	180,625	101,973	25,118	6,443	4,461	4,089	4,431	5,596	364	2,006	423
1917 .	177,529	109,206	23,119	8,351	7,258	1,854	5,878	2,272	1,125	1,000	336

with the amounts of silver contained in these products, is summarized as follows:

Nature of Silver-bearing Products and their Content in Silver, 1917

Products.	Silver Contents.		
	Weight.	Percentage of Total.	Value.
	Kg.		£
Copper ingots	279,652	82·76	1,403,183
" Lixiviation sulphides "	22,206	6·57	98,176
Silver minerals	11,386	3·37	44,956
Copper matte	6,840	2·02	23,692
Lead minerals	4,961	1·47	16,149
Copper minerals	3,418	1·01	11,994
Silver concentrate	3,239	0·96	10,774
Silver ingots	2,719	0·81	12,358
Lead ingots	1,830	0·54	7,666
Cyanidation precipitates	1,497	0·44	5,644
Lead concentrate	126	0·05 (Lead concentrate to Leady slag)	397
Bismuth minerals	33		119
Cement copper	15		68
Copper concentrate	4		19
Leady slag	2		10
	337,928	100·00	1,641,205



MAP SHOWING THE SILVER-PRODUCING DISTRICTS REFERRED TO IN TEXT
(British Empire shaded).

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