

(c) Some swires, and also valleys which are now permanent water-courses (to which, however, the streams in them are often obviously not adjusted) were directly formed by streams flowing from the ice-margin, whose load of sediment was deposited as a Kaim. The Burners Hills, already noticed as occurring on the Cotherstone Moor, have drainage channels connected with them, and the trench now occupied by the How Beck is the course of the escaping glacial waters. Dr. Smythe has also noticed the association of Kaims with dry valleys in Northumberland.<sup>1</sup> The glacier-streams in such cases did not flow directly into lakes, and hence sometimes developed wide and deep trench-like slacks.

(11) One of the most striking features of the superficial deposits of these two counties is the great amount of erosion and reassortment of glacial material that has taken place along the main valleys of the Tyne, a feature which was first clearly pointed out by Lebour.<sup>2</sup> The river terraces formed from the Drift in this valley between Bardon Mill and Haydon Bridge by the Glacial and Postglacial streams can be traced as high as the 300 feet contour-line. This is in distinct contrast with the apparently small denudation of the kaims, drumlins, and other surface features of the Drift out of the line of the main valleys, but this may be deceptive as these mounds and ridges may be much reduced in size, although their original contour is still preserved.

(*To be continued.*)

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### **The World's Copper Production.**

By F. H. HATCH, Ph.D., M.Inst.C.E., Past-President of the Institution of Mining and Metallurgy.

THE following article originally appeared in the *Times Trade Supplement* of August 28 last. It is here reprinted with some small additions by the courtesy of the proprietors of that Journal.

The world's consumption of copper at the beginning of the nineteenth century was some 15,000 tons<sup>3</sup> per annum. By the end of the century it had increased to over 600,000 tons per annum, and it reached a million tons by the year 1912. In 1917 it was close on one and a half million tons.

This era was one of continually growing engineering activity, and the high consumption of copper in the latter part of the period was chiefly due to the great demand for that metal for purposes of electric power generation and transmission, while during the late

<sup>1</sup> *Glacial Geology of Northumberland*, p. 102.

<sup>2</sup> *Geology of Northumberland and Durham*, p. 15, and "Certain Surface Features of the Glacial Deposits of the Tyne Valley": *Nat. Hist. Trans. Northumberland, etc.*, vol. xi, pt. iii, 1893.

<sup>3</sup> Metric tons throughout.

War a considerable use was made of the metal and its alloys in the manufacture of war material.

Such remarkable increases in consumption demanded fresh sources of supply, which did not fail to be discovered. During the nineteenth century new deposits of copper ore were developed, at first in South America and in Cuba, and, later on in the century, in the United States, Australia, South Africa, and Canada. Another source of supply from the sixties onward was the copper smelted at British ports from the cupriferous pyrites imported in vast quantities from Spain and Portugal for its sulphur content.

In the following table will be found the world's production of copper for every fifth year from 1803 to 1918.<sup>1</sup>

TABLE I.  
WORLD'S PRODUCTION OF COPPER FOR EVERY FIFTH YEAR.

Year.	Metric Tons.	Year.	Metric Tons.
1803	15,000	1863	96,000
1808	16,000	1868	110,000
1813	17,000	1873	122,000
1818	19,000	1878	154,000
1823	23,000	1883	199,000
1828	27,000	1888	262,285
1833	31,000	1893	310,704
1838	36,000	1898	441,868
1843	42,000	1903	609,985
1848	52,000	1908	790,238
1853	63,000	1913	1,002,300
1858	78,000	1918	1,395,160

At the beginning of the nineteenth century the world's copper consumption of some 15,000 tons per annum was easily covered by the production of the United Kingdom, Russia, (Bogoslovsk), Japan, Chile, Sweden (Falun), Norway (Röros), and Germany (Mansfeld), together with small amounts from other countries. This order is that of the importance of the contribution. The chief producer—the United Kingdom—furnished nearly a half of the whole world's production from mines in Cornwall, Devonshire, Anglesey, and Ireland.

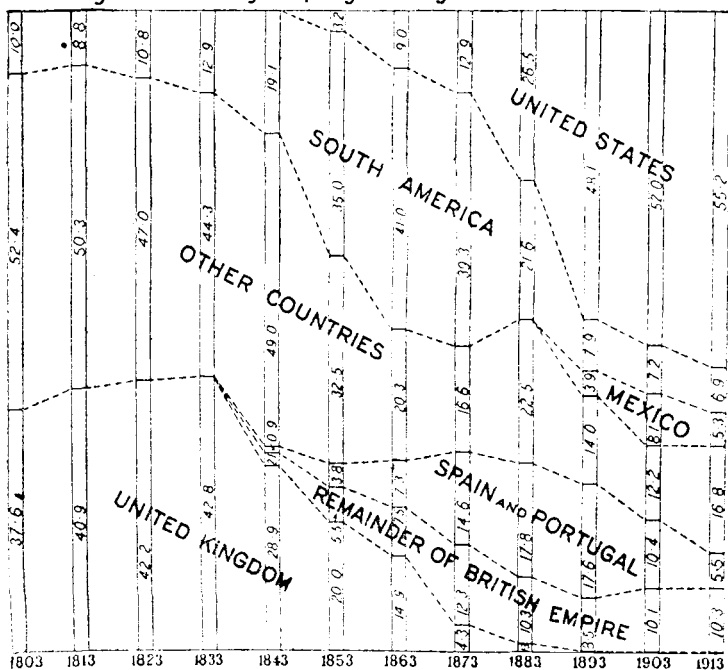
The introduction of copper sheathing for wooden ships was responsible for a gradual but not rapid increase in consumption until the forties, when it reached close on 40,000 tons per annum. The United Kingdom was still the largest producer (accounting for a third of the whole), followed by Chile, Russia, and Japan.

<sup>1</sup> The figures for 1803 to 1883 have been estimated from the world's decennial production given in Messrs. Nicol Brown & Turnbull's *A Century of Copper*. Subsequent figures up to the year 1908 are from the Chief Inspector of Mines' Report, part iv. The figure for the year 1913 is from Merton's Tables, and that for 1918 from the *Engineering and Mining Journal*.

The expansion of the engineering trades then caused a more rapid increase of consumption, and by the middle of the century it reached close on 60,000 tons per annum. British Colonies (Australia and the Cape) and the United States now began to take part in production, but the United Kingdom maintained its lead, furnishing a quarter of the whole. The countries next in importance were Chile, Cuba, Russia, and Japan. The Chilean output was from rich oxide ores, which were imported into the United Kingdom for smelting in Swansea. Large quantities of similar ores were brought

#### COPPER FROM HOME ORES.

Diagram of Percentage Output by Producing Countries from 1803-1913.



from Cuba; but imports from this source ceased about 1870. The British Colonies contributed 5 per cent of the total, mainly from the Kapunda and the Burra-Burra mines, discovered in South Australia in the forties; while the United States' contribution of two per cent was derived almost entirely from the Lake Superior native copper mines, which began to produce in 1845.

For the next twenty years the consumption maintained a fairly uniform rate of acceleration, being about 85,000 tons in 1860 and 115,000 tons in 1870. The increase was met by an expansion of production in Chile, which now exported a considerable proportion of its copper in the form of metal (Chile bars) and regulus; whereas,

previously, high-grade ores had been sent to the United Kingdom for smelting at Swansea. The change was due to the high toll charged by the Swansea works, which drove the Chileans to establish their own local smelters. In 1870 Chile furnished half the total world's production, and thus became the leading producer. The United Kingdom occupied the second place, being followed in order by Spain and Portugal, the United States, Australia, Japan, and Cuba. In 1863 the United States produced 9 per cent and in 1868 10 per cent of the whole. The production of the United Kingdom was 15 per cent of the whole in 1863, decreasing to 9 per cent in 1868. On the other hand, that of the British Colonies rose from 7 per cent in 1863 to 10 per cent in 1868. This was in large measure due to the working of the rich oxide-ores of the Wallaroo and Moonta mines of South Australia, discovered in 1845; but the Great Cobar and other mines in New South Wales contributed, and Newfoundland began to ship ore from Tilt Cove in 1864.

In consequence of the increased demands of the engineering trades, especially in shipbuilding and marine engineering, followed later by the very extensive use of copper in electric power generation and transmission, the world's consumption of copper now began to rise more rapidly; by 1873 it was 122,000 tons per annum, in 1883 close on 200,000 tons, and in 1893, 310,000 tons. This rapid growth in consumption was met by large increases in the production of the United States and of Spain and Portugal: in Spain the Rio Tinto (taken over by an English company in 1876) enlarged its scale of operations and other pyrites mines in the Huelva district of Spain and the neighbouring territory of Portugal became great copper producers. In 1873 the order of contribution was as follows: South America (chiefly Chile), British Empire (17 per cent of the whole, Spain and Portugal (Rio Tinto and Tharsis), United States (13 per cent of the whole), Germany, Japan, and Russia. By 1883 the United States had passed the British Empire (the respective proportions being 26 per cent and 12 per cent), and from that period the production of the United States went up by leaps and bounds. This was brought about, not only by improving the methods of mechanical concentration and smelting, but also by very largely increasing the scale of operations, notably in the rich sulphide mines of Montana, in the native copper mines of Michigan (Lake Superior), and in the large porphyry contact deposits of Arizona.

During this period the output of the United Kingdom (one per cent in 1883) dwindled to insignificance, owing chiefly to the gradual deepening of the Cornish mines and the downward change from copper to tin which characterizes the lodes.<sup>1</sup> The contribution of the British Empire as a whole, however, showed a substantial increase in consequence of the important mining developments which then took place in Australasia, Canada, and South Africa.

<sup>1</sup> The present copper production of the United Kingdom is derived mainly from "precipitate" got by treating water from the old Parys and Mona mines in Anglesey.

The increase in the output of Australasia was due to the development of the Mount Lyell mine in Tasmania; that of Canada to the working of nickel-copper mines at Sudbury in Ontario, gold-copper mines at Rossland in British Columbia, and silver-copper mines at Nelson in the same province. In South Africa copper mines were worked by the Cape Copper Company and the Namaqualand Copper Company in Little Namaqualand, the ore being sent to Swansea partly in the form of matte, partly as a high-grade concentrate.

Table II gives the production of the world, the United States and the British Empire for every fifth year, from 1888 onward.

TABLE II.

Year.	World's Total.	United States.		British Empire.		U.K. alone.	Other countries.
	Tons.	Tons.	% of World's.	Tons.	% of World's.	Tons.	% of World's.
1888	262,000	103,000	39.1	24,000	9.3	1,456	51.6
1893	310,000	149,000	48.1	26,000	8.5	425	43.4
1898	442,000	239,000	54.0	34,000	7.7	640	38.3
1903	610,000	317,000	52.0	62,000	10.1	531	37.9
1908	790,000	427,000	54.1	79,000	10.0	579	35.9
1913	1,002,000 <sup>1</sup>	555,000	55.2	91,000 <sup>2</sup>	9.1	421	35.9
1918	1,395,000 <sup>2</sup>	848,000 <sup>2</sup>	60.8	—	—	182 <sup>3</sup>	—

The order of production and the proportion produced by each contributor at the beginning of the twentieth century (1901) were as follows: United States (51½ %), British Empire (11½ %), Spain and Portugal (10 %), South America (8 %), Mexico (6 %), Japan (5 %), Germany (4½ %), Russia (1½ %), Norway (½ %), and Italy (½ %).

The total production of the world for the nineteenth century has been estimated<sup>4</sup> at 10,240,000 tons, the chief contributors being: the United States (29 %), South America (20 %), Spain and Portugal (13 %), the United Kingdom (8½ %), Japan (6 %), Germany (4½ %), Australia (4½ %), Russia (4 %), Norway and Sweden (2 %), Mexico (1½ %), Cuba (1½ %), South Africa (1½ %), Canada (½ %). The British Empire as a whole produced 16 %. (See Table III.)

The first decade of the twentieth century saw a production of 7,333,000 tons. During this decade the following countries practically doubled their production: United States, South America (where the biggest increase was in Peru), Mexico, Japan, and Norway. This great advance in production was largely brought about by improvements in the methods of mechanical concentration, which made it profitable to lower the grade of the material mined, and

<sup>1</sup> Merton.<sup>2</sup> *Mineral Industry.*<sup>3</sup> Home Office.<sup>4</sup> By Nicol Brown & Turnbull in *A Century of Copper.*

thus to attack vast bodies of disseminated ore hitherto untouched, especially in the American States of Arizona, Utah, and Nevada. Other new producers were Serbia and German South-West Africa; Cuba also started work on its sulphide ores.

TABLE III.

THE PRODUCTION OF COPPER IN THE NINETEENTH CENTURY, ARRANGED ACCORDING TO COUNTRIES (STATISTICS DERIVED FROM NICOL BROWN AND TURNBULL'S "A CENTURY OF COPPER").

	Tons.	Tons.	Per cent.
UNITED STATES . . .		2,993,540	29.3
SOUTH AMERICA.			
Chile . . . . .	1,886,405		18.3
Bolivia . . . . .	54,210		.5
Peru . . . . .	34,135		.3
Venezuela . . . . .	113,850		1.1
Total . . . . .		2,086,600	20.2
BRITISH EMPIRE.			
United Kingdom . .	864,660		8.5
Australasia . . . .	470,219		4.6
South Africa . . . .	175,580		1.7
Canada . . . . .	69,870		0.7
Newfoundland . . .	46,527		0.5
Total . . . . .		1,626,856	16.0
SPAIN AND PORTUGAL.		1,328,965	12.9
JAPAN . . . . .		604,200	5.9
GERMANY . . . . .		472,520	4.6
RUSSIA . . . . .		420,920	4.1
SCANDINAVIA.			
Norway . . . . .	103,500		1.0
Sweden . . . . .	106,680		1.1
Total . . . . .		210,180	2.1
MEXICO . . . . .		142,360	1.4
CUBA . . . . .		139,880	1.4
OTHER COUNTRIES . .		211,468	2.1
Total . . . . .		10,239,489	100.0

The production of the present decade will exceed ten million tons, that is, it will be more than the whole production of the last century. The widespread use of the flotation method of concentration and the introduction of new processes for leaching the ores direct, brought fresh sources of supply into being at a time when production was being greatly stimulated by urgent war demands. With the coming of peace, however, a temporary fall in consumption was inevitable, and this began to show its effect on production in the year 1919, and will be accentuated in the present year (1920).

It is doubtful, however, whether consumption has reached its highest point. The ever-spreading use of electricity for power, light, and heat means a *per capita* increase of consumption throughout the world, especially in countries such as Russia and China, where hitherto electricity has not come into general use.

TABLE IV.

WORLD'S PRODUCTION OF COPPER, ACCORDING TO COUNTRIES, FOR FIRST DECADE OF TWENTIETH CENTURY, DERIVED FROM HOME OFFICE RETURNS.

Country.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	Total 1901-1910.
UNITED STATES .	273,173	299,151	316,631	368,564	409,103	416,314	394,174	427,547	495,760	489,937	3,890,374
BRITISH EMPIRE .	(63,874)	(52,208)	(61,865)	(64,395)	(70,947)	(73,421)	(75,267)	(78,705)	(72,704)	(78,914)	692,300
Australia .	29,500	25,128	31,410	29,765	35,280	38,771	41,103	38,220	37,680	41,000	
Canada .	18,575	17,767	19,632	19,491	21,590	25,868	25,640	28,895	23,811	25,262	
Cape Colony .	12,443	6,120	7,523	10,654	10,397	5,121	5,631	87,746	8,606	10,415†	
Newfoundland .	2,799	2,703	2,753	3,984	2,879	2,688	1,700	1,567	1,155	1,480	
Sundry .	557	490	547	501	821	973	1,193	1,277	1,452	757	
SPAIN AND PORTUGAL .	(90,625)	(58,894)	(63,058)	(67,541)	(57,637)	(69,950)	(73,061)	(69,160)	(77,087)	(75,387)	672,400
Spain .	54,625	52,417	56,150	60,565	53,120	62,290	64,731	65,625	71,747	71,747	
Portugal .	6,000	6,477	6,908	6,976	4,517	7,660	8,330	3,535	5,340	3,640	
SOUTH AMERICA .	(39,970)	(37,990)	(42,723)	(41,427)	(45,895)	(46,328)	(52,377)	(64,816)	(65,176)	(72,677)	508,389
Chile* .	30,570	26,600	21,086	29,923	29,605	29,626	28,863	42,096	42,726	42,726	
Bolivia .	—	3,600	4,141	2,000	4,045	3,288	2,813	2,039	2,470	2,478	
Peru .	8,500	7,700	9,496	9,504	12,213	13,474	20,681	20,681	19,854	27,347	
Venezuela .	—	—	—	—	32	—	20	—	126	126	
MEXICO .	37,000	43,312	48,976	77,820	69,300	61,600	80,230	43,940	59,780	80,000	602,258
GERMANY .	31,376	30,578	21,782	22,562	24,480	22,000	22,838	22,790	24,719	29,000	252,085
JAPAN .	25,304	27,440	33,245	35,560	33,715	38,515	40,183	41,399	45,793	50,765	371,859
RUSSIA .	8,258	8,258	8,817	10,700	8,840	10,424	14,632	16,850	18,421	22,700	127,900
ITALY .	4,855	4,685	4,344	5,503	4,731	5,232	7,114	3,614	3,174	4,326	47,778
NORWAY .	4,684	4,996	4,180	5,701	7,200	7,613	8,585	7,134	9,900	9,570	69,563
GERMAN S.W. AFRICA .	—	—	—	—	—	26	3,804	6,058	6,671	6,482	23,041
SERBIA .	—	—	—	—	—	763	1,704	2,198	4,209	5,335	14,269
CUBA .	—	—	—	2,045	1,825	1,017	1,912	—	4,146	1,896	12,841
REMAINING COUNTRIES .	5,490	4,430	4,364	3,620	4,329	3,159	5,894	6,027	5,171	5,314	47,798
TOTAL .	553,769	571,852	609,985	705,378	738,202	756,362	781,955	790,238	892,711	932,463	7,332,855

\* Including Bolivia.

† South Africa.

The vital question is whether production will be able to meet such heavy demands as are here foreshadowed in view of the approaching exhaustion of some of the existing sources of supply. While the number of companies contributing to the world's production is well over three hundred, about half the total is derived from a score of mines only. Many of these big producers are in America. The United States contributes from its mines in Arizona, Montana, Michigan, Alaska, Nevada, New Mexico, and California over 60 per cent of the world's production; and there are big producers in Canada (Sudbury), Mexico (Cananea, Nacozari, Boleo), Chile (Chuquicamata), Peru (Cerro de Pasco), and Venezuela (Aroa). Japan also has some great mines (Ashio, Besshi, Hitachi, and Kosaka), and the Rio Tinto in Spain, the Mansfeld in Germany, and the Bogoslovsk, Dzansoul, Kyshtim, Sissert, and Spassky mines in Russia should be noted in this connexion. Although existing reserves may be large enough for the immediate future, it is quite certain that some of these large mines cannot have a very long life, and their shutting down would appreciably affect production unless fresh discoveries enable their places to be filled.

The copper recovered from the ore mined throughout the world probably does not exceed 45 lb. to the long ton or two per cent. Exact figures are forthcoming for the United States: in 1906 the average yield for all ores treated was 2.5 per cent; in 1903 it had fallen to 1.67 per cent, and by 1914 to 1.6 per cent; in 1916 it was 1.7 per cent.<sup>1</sup> There is, consequently, not the margin for increasing the available reserves by lowering the grade of the ore mined, such as obtains in iron-ore mining; and any increase in the supply of copper, or, indeed, the maintenance of the present rate of production, must depend in the long run either on the discovery of new deposits, or on the improvement of the treatment methods. During the last decade the world has been searched for new occurrences of copper-ore, and it is certain that the efforts of capitalists and mining engineers will not be relaxed in that direction. Metallurgists also will perfect the existing methods of extraction or find new ones whereby the yield will be increased. B. S. Butler states<sup>2</sup> that from 5 to 30 per cent of the copper content of the ore at present treated is lost, and if this be so there is room for improvement in this direction.

The United States, by its refineries on the Atlantic seaboard, controls a large proportion of the South American and Canadian output of the metal. Acting in conjunction with the large home production, the effect of this control has been to place the copper market of the world (which for the greater part of the nineteenth century was centred in Great Britain) practically in the hands of the United States. It may be that in view of an increasing consumption the copper magnates who control this market will use their power to limit supplies and drive up the price of copper. These

<sup>1</sup> *The Mineral Resources of the United States*, 1916, p. 642.

<sup>2</sup> *The Strategy of Minerals*, New York, 1919, p. 153.



considerations lead some to foretell a coming world shortage which will be little less than a famine.<sup>1</sup>

On the other hand, great reserves of unworked copper-ore undoubtedly exist in different parts of the world, and in course of time an increased production may be looked for from the resources of Mexico, Chile, and Peru in Central and Southern America, from the Altai, the Kirghiz Steppes, and the Urals in Russia, from the Belgian Congo in Central Africa, and from South-West Africa.

Whether future supplies will equal the demands there are not sufficient data at hand to determine.

### **The Representation of Stratigraphical Divisions by Shading.**

By Dr. J. W. EVANS, F.R.S.

**B**LACK and white shading is frequently employed in geological maps and sketches, but there is a remarkable absence of uniformity in the means by which different strata have been represented.

There are three purposes for which shading may be employed in geological maps, but these cannot as a rule be satisfactorily effected on the same map. It may be desired to express (1) the lithological characters of the rocks, (2) their stratigraphical position, and (3) their structural relations. For the first purpose it is convenient to use the same conventional shading as is employed in diagrams of sections. It is mainly with the second that I shall deal in the present article. For the third purpose little has yet been done, and I hope to consider the subject on another occasion.

I devised the system of denoting the different divisions of the geological succession, which I shall now describe, for the small scale geological maps published in the portion of the *Handbuch der regionalen Geologie* dealing with the British Isles. One of these is reproduced on a reduced scale in this issue of the *GEOLOGICAL MAGAZINE*. The geological boundaries were drawn by Dr. Morley Davies and the shading by Miss Reeks, Technical Artist to the Imperial College of Science and Technology.

In this system the pre-Cambrian rocks are distinguished by a north-east and south-west direction of shading (the Charnian strike), the older Palæozoic—Cambrian, Ordovician, and Silurian—by a north-east and south-west direction, the later Palæozoic—Devonian, Carboniferous, and Permian—by a north and south direction, that of the Pennine range, and the Mesozoic by an east and west direction (Hercynian).

The Kainozoic is indicated by crosses and the Quaternary or Anthropozoic by small circles or "birds" (~~). In the subdivisions of the strata expressed by each direction of shading, the older rocks are distinguished by continuous lines and the later by

<sup>1</sup> Sidney Brooks in the *North American Review*.