

"Some months ago we anticipated the formation of a company to exploit certain arsenide and oxide deposits of cobalt on the farm Kruisrivier, in the Middleburg district, which has been favorably reported on by Mr. W. F. H. Dudgeon, A.R.S.M. In view of the fact that the market value of the concentrates to be produced was not definitely known, a small private company, Cobalt (Proprietary), Ltd., has been formed to test this point. A small plant has already been put up, and it is expected that a trial shipment will be ready before the end of the present month. The deposits contain, in addition to arsenide and black oxide of cobalt, appreciable values in gold and some platinoids. Although nothing more than rumors of this activity can have reached Europe, considerable interest has already been evinced, judging from the letters of inquiry already received through consuls, trade commissioners, and other sources. This interest suggests that the views we have previously expressed as to the value of cobalt ores of fair content are not unduly optimistic."³³

Another well-known occurrence of cobalt is at Laatsse Grift No. 82, a few miles west of Kruis River. At Waaikraal, cobalt is found in appreciable quantities at the mine of the Edwards Goldfields, in the Rustenburg district, about 25 miles northeast of Rustenburg and about 42 miles northwest of Pretoria. In 1926 the main shaft at the property was down 160 feet on the incline, and work had been done along the strike for a distance of 450 feet. Assays of this ore showed a range in cobalt content from 3.95 per cent to 9.7 per cent. The ore is arsenical, the cobalt probably being in the form of smaltite, and some of it contains as much as 53 ounces of gold. Other occurrences of cobalt have been reported on the farm Wenzam Leid, situated some 2 miles south of Balmoral station on the Pretoria - Delagoa Bay Railway and in small amounts in the central part of the Bushveld igneous complex.

MARKET GRADES

Cobalt metal is marketed in three forms - rondelles, shot, and anodes. The production of anodes for cobalt plating is small and only a small amount of the highest-grade metal is produced as water-formed shot. Practically all of the metal is cast into rondelles, which are slugs about 1 inch in diameter and three-fourths inch thick. These rondelles are often shipped in bags but they are also packed in small casks, particularly for export trade.

Cobalt oxide is marketed either as black or gray oxide; the black oxide contains about 70 per cent cobalt metal, and the gray about 75 per cent. Gray oxide is made by roasting the black oxide slightly in a reducing atmosphere in a reverberatory furnace.³⁴

³³ Money and Mines; Cobalt Activity: South African Min. and Eng. Jour., vol. 40, Aug. 10, 1929, p. 657.

³⁴ Dominion Bureau of Statistics, Annual Report on the Mineral Production of Canada, 1926: Ottawa, 1928, p. 136.

The following table listing the customary brands of cobalt compounds with their cobalt content has been taken from Drury:³⁵

Table 6. - Brands of cobalt compounds, showing their cobalt content

Brand	Special designation	Chemical formula	Percentage cobalt content
F F Ko ...	Finest cobalt oxide (superior oxide).	CoO	1/ 78
G K O ...	Grey cobalt oxide, Ia	CoO	1/ 76
F K O ...	Grey cobalt oxide	CoO	1/ 75
R K O ...	Black cobalt oxide, Ia	Co ₂ O ₃	1/ 70
S K O ...	Black cobalt oxide	Co ₃ O ₄	1/ 66
A K O ...	Cobalt arsenate	Co ₃ As ₂ O ₈ ·8H ₂ O	29
K O H ...	Cobalt carbonate	CoCO ₃	50
P K O ...	Cobalt phosphate	Co ₃ (PO ₄) ₂ ·8H ₂ O	34

1 Theoretically CoO, Co₂O₃, and Co₃O₄ contain 78.8, 71.1, and 73.4 per cent cobalt, respectively.

The oxide, since it is a powder, is shipped in barrels; special tin containers holding 5, 10, and 25 pounds are required for the Japanese trade. According to Bateman:³⁶

"The marketability of cobalt ores depends not only upon the grade but upon the other associated minerals. Arsenic is an important and desirable constituent of the ore, but the higher the nickel content, the less desirable the ore is, as the nickel must be separated, and the expense is generally greater than the value of the metal recovered. This applies to practically all associated minerals, with the exception of arsenic and silver. On this continent it is almost impossible to market an ore for cobalt if such ore contains any considerable quantity of lead, zinc, and copper. An ore containing less than 4 per cent of metallic cobalt is not acceptable to the smelters.

"Cobalt ore is being marketed in America in four different forms:

1. Hand-sorted silver ore and sand-table concentrates, carrying high silver values and running generally between 5 and 8 per cent metallic cobalt.
2. Massive cobalt ore carrying low silver values and running between 6 and 12 per cent metallic cobalt. Ores of this sort contain approximately 60 per cent arsenic.
3. Residues from the cyanide treatment of high-grade silver ores and concentrates, carrying 5 to 8 per cent cobalt, and up to 50 ounces of silver.

55 Drury, Charles W., Cobalt, its Occurrence, Metallurgy, Uses, and Alloys: Rept. Ontario Bur. Mines, 1918, vol. 27, pt. 3, p. 84.

36 Bateman, G. C., Marketing of Cobalt Ores and Metal: Eng. and Min. Jour., vol. 116, Dec. 22, 1923, pp. 1076-1077.

4. Speiss from American smelters, treating silver-cobalt ores and generally containing large percentages of iron, copper, and lead."

PRICES

The prices of cobalt metal and oxide are fixed at infrequent intervals by a few producers acting virtually in agreement and in accordance with general trade conditions. Drastic reductions in prices have followed the advent of each new producer into the market but as these successive increments of supply are absorbed equilibrium is reestablished more or less promptly. In recent years demand has increased rapidly and fairly steadily, but not yet does it appear to be of a character that will respond readily to changes in price. It is reasonable to suppose that a large increase in price would tend seriously to curtail consumption, but it does not follow that a sudden drop in price would tend rapidly to increase demand. In any event the history of the industry reveals the policy of producers in recent years to adjust the supply to meet the demand, keeping prices meanwhile at as nearly a uniform level as possible.

Formerly very rare and expensive, cobalt compounds became relatively cheap when the new Caledonian ore came upon the market. In the eighties cobalt oxide, 170 per cent, generally sold at about \$2 a pound, and for many years the price remained between \$1.60 and \$2 a pound. In 1909 it jumped to \$2.50 only to drop to \$1.40 in 1909, and as larger and larger quantities of cobalt recovered from the silver ores of Ontario came upon the market some oxide was sold as cheap as 50 cents a pound in 1912. The magnitude of this second upheaval in the supply situation is evident from the fact that in 1910 the estimated world consumption of cobalt oxide was in the neighborhood of 300 tons, whereas fully 1,500 tons could have easily been recovered from the silver ores mined in the Cobalt camp in that same year. Cobalt remained a drug on the market until after 1915. Conditions improved as a substantial demand began to be created for the metal, and in consequence the price of the oxide advanced from around 90 cents in 1915. In 1917 black oxide advanced from \$1.05 a pound to \$1.50 a pound and gray oxide from \$1.15 to \$1.65. These prices were fairly well maintained, despite the advent of production from the Missouri Cobalt Co., until 1920 when the price rose to \$2 and finally at the height of the boom to \$4.10. In 1921, in spite of a weak demand, the oxide was quoted at approximately \$3; the price declined, in the following year to about \$2.25, where it has virtually remained ever since. In the early part of 1930, according to the Engineering and Mining Journal, black oxide, 70 per cent, was quoted at \$2.10 a pound, f. o. b. Canadian works, and the London quotations were 8s. (\$1.95) for black oxide and 8s.10d. (\$2.15) for gray. Black oxide has generally ranged in price from \$2 to \$3 a pound.

Cobalt metal as far back as 1901 was purchased by Krupp at prices ranging from 7s.6d. to 10s.6d. a pound (\$1.83 to \$2.56).³⁷ Subsequently, in view of the fact that reduced oxide was imported into the United States in order to evade the

³⁷ Merry, F. L., Testimony before Ontario Nickel Commission: 1917, Appendix, p.

the duty of 25 cents a pound on oxide,³⁸ it is evident that the metal, at least in this form, was about as cheap as the equivalent weight of oxide, and for a time after Canadian metal began to make its appearance it was sold for about \$1 a pound. In 1917, however, the price rose rapidly from \$1.25 to \$2.25, and in 1920 it advanced from \$3 to \$6 a pound. After remaining around \$3 a pound from 1921 to 1923, it receded gradually to \$2.50. Early in 1930 this was the nominal price quoted by the Engineering Mining Journal for shot or rondelles (97 to 98 per cent) f. o. b. Canadian works. Contract sales, of course, are booked at discounts, down to about \$2.10 and under special circumstances perhaps below \$2 a pound. The London quotation has remained at 10s. (\$2.43) a pound almost continuously since 1923.

Quotations for cobalt and cobalt oxide have appeared with sufficient regularity to permit of tabulation only in recent years. The available figures are presented in the following table:

Table 7. - New York and London prices per pound of cobalt metal, gray oxide, and black oxide 1929¹

	NEW YORK			LONDON		
	Metal	Gray oxide	Black oxide	Metal	Gray oxide	Black oxide
1913	(2)	(2)	(2)	(2)	(2)	(2)
1914	(2)	-	-	-	-	-
1915	(3) \$1.60-\$1.70	(2)	(2)	-	-	-
1916	1.25- 1.50	(2)	(2)	-	-	-
1917	1.25- 2.25	\$1.15-\$1.65	\$1.05-\$1.50	-	-	-
1918	2.25- 2.50	1.65 -	1.50 -	-	-	-
1919	2.50- 3.00	1.65 -	1.50 -	-	-	-
1920	(4) 2.50- 6.00	-	(5) 2.00- 4.10	-	-	-
1921	3.00- 6.00	-	2.00- 4.10	-	-	(2)
1922	3.00- 3.25	-	2.00- 2.10	(2)	(2)	(6) 11s.-12s.
1923	2.65- 3.00	-	2.00- 2.25	11s.-12s.	10s.	9s. -
1924	3.00- 3.50	-	2.10- 2.25	10s.-11s.	-	9s. -
1925	2.50- 3.00	2.25- 2.35	2.10- 2.25	10s. -	(7) 8s.10d.	8s. 9s
1926	2.50- 2.75	2.20- 2.35	2.10- 2.20	10s. -	8s.10d.	8s. -
1927	2.50- 2.60	-	2.10 -	8s.6d.-10s.	8s.10d.	8s. -
1928	2.50- 3.00	-	2.10 -	9s.6d.-10s.	8s.10d.	8s. -
1929	2.10- 3.00	-	2.10 -	10s. -	8s.10d.	8s. -

1 Prices for the years 1915-1919 are quoted from the Mineral Industry as also for 1925 and 1926 for gray oxide. For the years 1920-1929 prices are quoted as follows: Metal, shot or rondelles, 96 and 98%, f.o.b. Canadian works; black oxide, 70%, f.o.b. Canadian works, from the Engineering and Mining Journal.

2 Not quoted.

3. Quotation in August, 1915.

4 Quotations from April to December, 1920.

5 Quotations from May to December, 1920.

6 Quotation for month of December, 1922.

7 Quotations from August to December, 1925.

³⁸ As noted under "Imports" on p. 13.

The market for cobalt-bearing ores and residues has improved markedly in the last two or three years. The principal sources of cobalt shipped to Deloro, Ontario, is still the high-silver ore and concentrates. On this class of material the shipper is paid for 98 per cent of the silver and, provided the ore assays over 5 per cent of cobalt, for the total contents of cobalt metal. The price paid for the cobalt is 2 cents per unit per pound, equivalent for a 5 per cent ore to 10 cents a pound and for a 10 per cent ore to 20 cents a pound of cobalt content. The smelter charge is \$20 a ton, and a further deduction of one-half cent an ounce of silver is made for refining. Freight charges are paid by the shipper.

In order to encourage the mining of low-silver high-cobalt ores, the Deloro company issued in 1928 a special tariff covering ores containing 8 per cent or more of cobalt and less than 500 ounces of silver per ton. In ores containing under 100 ounces of silver no payment is made for the silver, the price for the cobalt is \$90 a ton, provided the ore contains over 8 and less than 9 per cent of cobalt. As there is no separate smelting charge, this works out to about 50 cents a pound of metallic cobalt contained in the ore; but for each additional 1 per cent of cobalt, the price advances \$15 per ton (gross weight) or 75 cents per pound of cobalt content. On ores containing between 100 and 500 ounces of silver per ton, 20 per cent of the silver content is paid for, and the cobalt is paid for at the rate of 3 cents per unit per pound. In the latter case, therefore, payment per pound of cobalt content is at the rate of 24 cents for an ore containing 8 per cent and 30 cents if it contains 10 per cent.

No payment is made for the arsenic, although this is recovered as a by-product in the smelting operation.

Since the Ontario ores contain silver, nickel, and arsenic as well as cobalt, they have to be treated by a relatively complicated series of processes, and for that reason the price paid for the cobalt contents by the Canadian smelting company is lower than that offered by European smelters for less complex ores. At present (May, 1930) as much as \$1 a pound of metallic content would be paid by certain dealers f. o. b. New York for ore containing even as much as 5 per cent of cobalt and relatively free from objectionable elements such as nickel or arsenic. Even the arsenical ores from Cobalt, Ontario, command as much as \$400 a ton or \$1 a pound of cobalt content, provided they carry as much as 20 per cent of the metal. One ore containing 15 per cent has been sold for \$225 a ton or \$0.75 a pound of metal content, f. o. b. Cobalt.

NORTE AMERICAN BUYERS OF COBALT ORES OR RESIDUES

Deloro Smelting and Refining Co., Deloro, Ontario, Canada.
Harshaw Chemical Co., Cleveland, Ohio.
Charles Hardy, Inc., 122 East 42d Street, New York, N. Y.
Metal & Ore Corporation, Woolworth Building, New York, N. Y.
Electro Metallurgical Co., 30 East 42d Street, New York, N. Y.
Hugo Falck & Co., 25 Broadway, New York, N. Y.
Jungmann & Co., Inc., 3 Desbrosses Street, New York, N. Y.
Shepherd Chemical Co., Highland Avenue, Norwood, Cincinnati, Ohio.
J. A. Samuel & Co., 220 Broadway, New York, N. Y.
Simonds Saw and Steel Co. (F. B. Lewis, Manager), 85 First Street,
Portland, Ore.

BRITISH BUYERS OF COBALT AND COBALT SALTS³⁹, LONDON

W. Adolph & Co., (Ltd.), 135 Upper Thames Street, E.C.4.
A. Boaks, Roberts & Co. (Ltd.), 100 Carpenters Row, Stratford, E. 15.
Chance & Hunt (Ltd.), 61 Grace Church Street, E.C.3.
The General Commercial Co. of London (Ltd.), 114 Cannon Street, E.C.4.
Hickie, Borman & Woods (Ltd.), 36 Lime Street, E.C.3.
Leopold Lazarus, 11-13 Creechurch Lane, E.C.3.
Edward Le Bas & Co., Dork House, Billiter Street, E.C.3.
Sanders, Page & Co., 90 Fenchurch Street, E.C.3.
Donald A. Scott & Co. (Ltd.), 10 Arthur Street, E.C.4.
Metal Traders (Ltd.), 7 Grace Church Street, E. C. 3.

³⁹ As furnished by the Chief Canadian Trade Commissioner in 1922. Published by the Mines Branch, Ottawa, Canada. Paper No. 8.

BIBLIOGRAPHY

- Andrews, E. C. Notes on the geology of the Broken Hill district. Econ. Geol., vol. 17, No. 6, Sept., 1922, pp. 470-290.
- Barclay, W. R. Is cobalt an impurity in nickel? Chem. and Met. Eng., vol. 34, Sept. 1927, p. 581.
- Beder, Roberto. Breve recopilacion de los yacimientos de materias explotables de la Republica Argentina, con especial atencion a los ultimos descubrimientos. Dir. Gen. de Minas, Geol. e Hidr., bol. 26, 1921, 32 pp.
- Bell, J. Mackintosh. South Lorrain silver district, Ontario. Trans. Am. Inst. Min. and Metall. Engrs., vol. 70, 1924, pp. 1043-52.
- Bertrand, Gabriel, and Mokrnagatz, --. Sur la presence du cobalt et du nickel chez les vegetaux. Compt. rend., vol. 175, 1922, pp. 458-460. (Quotes various authorities who have found Co and Ni in the ashes of several plants.)
- Sur la presence du cobalt et du nickel dans la terre arable. Compt. rend., vol. 175, 1922, pp. 112-114.
- Bolivia Mineralogica--petroleos y minas. Vol. 2, No. 15, July 15, 1922, pp. 26-30. (Location and mode of occurrence of tin, wolfram, nickel, cobalt, chromium, vanadium, platinum, etc.)
- Bremhorst, A. Preparation of metallic cobalt from cobaltiferous smelter residues. Metall. u. Erz, vol. 24, 1927, pp. 7-8; Chem. Zentralb., 1927, p. 1518; Chem. and Ind., Brit. Chem. Abs., vol. 46, Oct. 14, 1927, p. 783.
- Darstellung metallischen Kobalt aus kobalthaltigen Huttenruckstanden. Metall. u. Erz, vol. 24, 1927, pp. 7-8.
- Bugge, Carl, and Foslie, Steinar. Norsk Arsenmalm og Arsenikfremstilling. Norges Geologiske Undersokelse, Nr. 106, Kristiania, 1922.
- Bulletin of the Imperial Institute of Great Britain. Cobalt. Vol. 14, No. 3, London, 1919, p. 417.
- Byers, Horace G., and Thing, Curtis W. Passivity of cobalt. Jour. Am. Chem. Soc., vol. 41, 1919, pp. 1902-1908; Chem. Abs., vol. 14, Feb. 10, 1920, p. 239.
- Canadian Pacific Railway. Cobalt situation in Canada. Leaflet. (An updated report describing occurrences, sources, uses, market, etc.; it gives 1924 production and export figures.)
- Carnatesco, R., and Vascautamu, Mrs. E. Determination of cobalt as cobalto-cobaltic oxide in a stream of oxygen. Ann. sci. univ. Jassy, vol. 15, 1928, pp. 69-70; Chem. Abs., vol. 22, July 10, 1928, p. 2337.
- Glennell, J. E. The estimation of cobalt by the nitrosobetanaphthol method. Min. Mag., London, vol. 36, No. 5, 1927, pp. 270-273.
- Colvocoresses, G. M. Cobalt mining in New Caledonia. Eng. and Min. Jour., vol. 76, 1903, p. 816.
- Compton, R. H. New Caledonia and the Isle of Pines. Geograph. Jour., vol. 49, Feb., 1917, pp. 81-106.
- Cooper, C. S. Peru's rich resources. Pan Am. Union Bull., vol. 55, No. 1, July, 1922, pp. 56-63.
- Crocq, J. Cobalt in the sands of Woluwe-Saint-Lambert. Jour. Chem. Soc., vol. 70, Pt. 2, London, 1896, p. 434.
- Deichman, G. F. (American Consul, Valparaiso, Chile.) Cobalt production in Chile. Consular File No. 9662, Section of Foreign Minerals.

- DeRubies, S. Pina. Presence of nickel and cobalt in chromites. Soc. espan. fis. quim. Anales, vol. 15, 1917, pp. 61-65; Chem. Abs., vol. 11, Oct. 20, 1917, p. 2760.
- Detrez, L. Metallurgy in Kantaga. Chim. et Ind., Special Number, May, 1927, pp. 119-139.
- Dhein, Ferdinand. The arc spectrum of cobalt according to international morals. Z. Wiss. Phot., vol. 19, 1920, pp. 289-335; Chem. Abs., vol. 14, 1920, p. 2751.
- Drury, Charles W. Cobalt, its occurrences, metallurgy, uses and alloys. Report of Ontario Bureau of Mines, 1918, vol. 27, pt. 3, sec. 1, Toronto, 1919, 122 pp. ----- Cobalt. Min. Ind., vol. 26, 1917, pp. 480-483; Chem. Abs., vol. 12, Dec. 10, 1918, p. 2519.
- Dudgeon, W. F. H. Important gold-cobalt occurrences. South Africa Min. and Eng. Jour., vol. 40, pt. 1, Johannesburg, 1929, p. 113.
- Dupouy, Gaston. Etudes mineralogiques sur l'Indochine Francaise. Paris, 1913, p. 43. Gives a description of the minerals found in French Indo-China, etc.
- Dyson, G. Malcolm. The extraction and utilization of cobalt. Chem. Age, vol. 19, Nov. 3, 1928, pp. 33-35.
- Engineering and Mining Journal. Developments in the Mount Cobalt Cloncurry district. Vol. 114, Oct. 14, 1922, p. 694.
- Fehlmann, H. Der Schweizerische Bergbau wahrend des Weltkrieges Schweiz. Volkswirtschaftsdepartment Abteilung fur industrielle Kriegswirtschaft Bergbaubureau, Bern, 1919. (The cobalt minerals are in sericite and chlorite gneiss, rich in horn-blende.)
- Fletcher, Mark. Note on cobaltiferous mispickel from Sulitjelma, Norway. Proc. Univ. Durham, Newcastle-upon-Tyne, vol. 2, 1904, pp. 183-184.
- Fraser, P. Cobalt: Lancaster County, Pa. Sec. Geol. Survey of Pennsylvania. CCC, 1880, pp. 163-176.
- Frebald, George. Ore deposits of the Harz, II Berzelianite, Au_2Se , and a new occurrence of cobalt selenide. Centr. Min. Geol., 1927-A, pp. 196-199; Chem. Abs., vol. 22, Jan. 10, 1928, p. 44.
- Friend, J. N. Cobalt, nickel, and the elements of the platinum group. A testbook of inorganic chemistry, vol. 9, pt. 1, Charles Griffin & Co., London, 1920, pp. 18-77.
- Gee, L. C. E. Cooke's cobalt mine. A Review of mineral operations, State of South Australia, for half-year ending Dec. 31, 1908, No. 9, Adelaide, 1909, p. 28.
- Gregory, J. W. The nickel-cobalt ore of Talnotry, Kirkcudbrightshire. Inst. Min. and Met., Bull. 277, London, 1927, pp. 1-5.
- Halse, Edward. Cobalt ores, Monograph on mineral resources, with special reference to British Empire, Imp. Inst. Great Britain, 1924, 54 pp.
- Hantzsch, A. The nature of cobalt halide solutions. Ztschr. anorg. Chem., vol. 166, 1927, pp. 237-243; Chem. Abs., vol. 22, March 10, 1928, p. 737.
- Hayden, H. H. Cobalt. Records of the Geol. Survey of India, vol. 44, pt. 1, 1914, p. 19.
- Henda, Kotaro. Some physical constants of iron-cobalt alloys. Sci. Repts., Tohoku Imp. Univ., vol. 8, 1919, pp. 51-58; Chem. Abs., vol. 13, Sept. 20, 1919, p. 2190.
- Howarth, W. E. On the occurrence of linnaeite in the coal measures of South Wales. Geol. Mag., vol. 65, No. 773, London, 1928, pp. 517-518.

- Hess, W. M. On the occurrences of smaltite in Colorado. *Am. Jour. Sci.*, 3d ser., vol. 23, 1882, p. 380.
- Industrial Australian and Mining Standard. Cobalt in Australia. Vol. 67, Feb. 23, 1922, p. 361.
- Industrial Australian and Mining Standard. Cobalt at Selwyn. Vol. 62, Oct. 16, 1919, p. 752.
- Jaeger, F. M., and Blumendal, H. B. Spatial configuration and rotatory dispersion in optically active cobalt and rhodium salts. *Chem. Abs.*, vol. 22, Oct. 10, 1928, p. 3596.
- Jones, E. G. A method for the colorimetric estimation of cobalt. *Analyst*, vol. 43, 1918, pp. 317-319; *Chem. Abs.*, vol. 13, Jan. 10, 1919, p. 15.
- Kalmus, H. T., and Blake, E. S. Cobalt alloys with noncorrosive properties. *Can. Dept. of Mines, Mines Branch*, pt. 4, 1916, 37 pp. (Researches on cobalt and cobalt alloys, conducted at Queens University, Kingston, Ont., for the Mines Branch, Dept. of Mines.)
- Kalmus, H. T., and Harper, C. Physical properties of the metal cobalt. Reprint, *Jour. Ind. Eng. Chem.*, vol. 7, Jan., 1915, p. 6.
- Kalmus, H. T. Preliminary report of investigations at the research laboratory of applied electrochemistry and metallurgy. School of Mining, Queens Univ., Kingston, Ont., for the Mines Branch, Dept. of Mines, Jan., 1913. (Summary report, Mines Branch, Dept. Mines, 1912, Ottawa, 1913, pp. 92-107.)
- Preparation of metallic cobalt by reduction of the oxide. *Can. Dept. of Mines, Mines Branch*, No. 259, 1912, pp. 1-36.
- Kallogg, A. E. Cobalt in Jackson County, Oregon. *Eng. Min. Jour.*, vol. 112, Oct. 22, 1921, p. 650.
- Knight, C. W. Cobalt; its past and future. *Eng. and Min. Jour. Press*, vol. 113, 1922, pp. 761-768.
- Kowalke, C. L. Cobalt as an element for thermocouples. Advance copy of a paper to be presented at the 29th general meeting, *Am. Electrochem. Soc.*, Wash., D. C., April, 1916, pp. 213-220.
- Krusch, P. Die Untersuchung und Bewertung von Erzlagerstätten unter besonderer Berücksichtigung der Weltmontanstatistik, S. 659, Mit 133 Textabbildungen, Stuttgart, 1921. (Geology of ore deposits; character of deposits of metalliferous ores.)
- Kuter, E. P. The electrodeposition of cobalt. *The Foundry*, March, 1916, pp. 111-113. (Results of experiments carried out by Kalmus, Harper, and Savell; working under the direction of the Canadian Bureau of Mines.)
- Leemans, Joseph. Some Belgo-Congolese Industries. *Chim. et Ind.*, Special Number, May, 1927, pp. 87-100.
- Leitch, D. The metallic minerals of the Talnotty deposit. *Inst. Min. and Met.*, Bull. No. 277, London, 1927, pp. 6-9.
- Marshall, Henry. (Under Secretary.) Report of the Dept. of Mines, Queensland, for the year 1920 (Cloncurry District); also for 1921.
- Masumoto, Hakar. The magnetic, electric, and thermal properties of nickel-cobalt alloys. *Sci. Repts.*, Tohoku Imp. Univ., vol. 16, 1927, pp. 321-332.
- Masumoto, Hakar, and Nara, Sitisaburo. The coefficient of thermal expansion in nickel-cobalt alloys, and the magnetostriction of iron-nickel alloys. *Sci. Reports*, Tohoku Imp. Univ., vol. 16, 1927, pp. 333-334.

- McHargue, J. S. Significance of the occurrence of manganese, copper, zinc, nickel, and cobalt in Kentucky blue grass. *Jour. Ind. Eng. Chem.*, vol. 19, Feb., 1927, pp. 274-276.
- McKay, Robert J. Is cobalt an impurity in nickel? *Chem. and Met. Eng.*, vol. 34, 1927, p. 438.
- McLellan, J. C., Niven, C. D., and Wilhelm, J. O. The resistance of cesium, cobalt, and chromium at low temperatures. *Chem. Abs.*, vol. 23, Feb. 10, 1929, p. 558.
- Mellor, E. T. Note on the field relations of the Transvaal cobalt lodes. *Trans. Geol. Soc. South Africa*, vol. 10, 1907, pp. 36-43.
- Metal Industry, London, Cobalt in Canada. Vol. 31, 1927, pp. 8-9.
- Metal Industry. Canadian metallurgical plant expansion. Cobalt, bismuth and calcium. Vol. 33, London, Oct. 19, 1928, pp. 368-378.
- Mindalev, L. New reaction of cobalt. *Mitt. Techn. Arbeiten in der Republik (russ.)* vol. 13, 1925, pp. 57-59; *Chem. Abs.*, vol. 21, March 20, 1927, p. 874.
- Mineria y Metallurgia. Oficina Central de Estadística, anuario estadístico de la Repub. de Chile. Vol. 8, 1924, 55 pp.
- Mining Journal. The cobalt industry. Vol. 156, London, March 5, 1927, p. 200.
- Mining Magazine. Cobalt at Cloncurry. Vol. 27, Aug., 1923, p. 97. (The cobalt mine at Mt. Cobalt, Cloncurry District.)
- Mining Magazine. Gold and cobalt discovery. Vol. 39, Nov., 1928, London, p. 299. (In connection with the discovery of highly mineralized ore in the mine of the Edwards--Waaikraal--gold fields.)
- Morgan, G. T., and Main Smith, J. D. Separation of cobalt from nickeliferous ores by the purpleo-cobalt chloride process. *Jour. Soc. Chem. Ind.*, vol. 43, 1924, pp. 131-133-T.
- Oftedal, Ivar. The crystal structure of skutterudite and smaltite-chloanthite. *Ztschr. Krist.*, vol. 66, 1928, pp. 517-546; *Chem. Abs.*, vol. 22, July 10, 1928, p. 2340.
- O'Hara, Winthrop V. (American Vice-Consul, Barcelona.) Report on the mineral deposits and industries. Consular File No. 4193, April 28, 1922.
- Pardo, J. M. Cobalt, its uses, and Spanish deposits. *Ing. y Construcción*, vol. 6, Jan., 1928, pp. 8-14.
- Pisar, Charles J. (American Consul, Cape Town, South Africa.) Nickel and cobalt deposits--Areb, near Rehoboth. Consular File No. 4849, Sept. 18, 1922.
- Queensland Government Mining Journal. Other minerals. Vol. 29, April 14, 1928, p. 147. (Cloncurry district.)
- Queensland Government Mining Journal. Outlet for Queensland's cobalt. Vol. 34, Jan., 1928, p. 2.
- Rangel, Manuel, and Terrones, Alberto. Mineral resources of Durango. *Eng. and Min. Jour.*, vol. 112, No. 5, July 30, 1921, p. 173.
- Rice, W. N., and Foye, W. G. Guide to the geology of Middletown, Connecticut, and vicinity. *Conn. Geol. and Nat. History Survey, Bull.* 41, 1927, 137 pp.
- Saint-Smith, E. C. Queen Sally cobalt mine, Koolamarra, Cloncurry mineral field. *Queensland Govt. Min. Jour.*, vol. 26, July 15, 1925, p. 281.
- Cobalt near Cloncurry. *Min. Mag.*, vol. 33, 1925, p. 290.
- Schiffer, E. Determination of cobalt and other alloyed elements in cobalt metal, cobalt steel, and highspeed tool alloys. *Stahl u. Eisen*, vol. 47, 1927, pp. 1569-1571; *Chem. and Ind., Brit. Chem. Abs.*, vol. 46, Nov. 11, 1927, p. 845.