GEOLOGICAL
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DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

PAPER 62-2

RAW MATERIALS OF CANADA'S MINERAL INDUSTRY

W. D. Mc Cartney S. C. Robinson
H. R. Steacy R. J. Traill
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Compiled by R. J. Traill

Price 50 cents

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RAW MATERIALS OF CANADA'S MINERAL INDUSTRY

This booklet comprises short descriptive notes on many of the more important minerals, ores, fuels and rocks that are the raw materials of the mineral industry of Canada. They are described under 76 product headings in alphabetical order, from "Abrasives" to "Zirconium". Information given for each product includes abridged data, if applicable, on:

(a) use of product and status of the industry;
(b) mineralogy and geochemistry of the raw materials;
(c) types of deposits and geographic distribution; and
(d) future outlook and potential sources.

The main purpose of these notes is to accompany a collection[1] consisting of 120 specimens, arranged so far as possible in alphabetical order of the principal economic product (e.g. abrasives, aggregates, aluminium, etc.). Raw materials are arranged alphabetically under each product rather than in any systematic mineralogical order. In instances where one raw material is the source of more than one product (e.g. pumice is used as an abrasive and an aggregate), only one specimen is included in the collection and it is placed under the more important product heading.

The collection serves to illustrate in part the raw materials described in the reviews that comprise the annual report on the Canadian Mineral Industry, issued by the Mineral Resources Division, Department of Mines and Technical Surveys. However, there are a number of other products for which there are potential sources in Canada, and a selection of the more important of these is also included.

The notes in this booklet have been derived from many sources. Under each product heading one or two of the most comprehensive of these references are given. The following three references are of such general use that they are listed by letter only:

A. "The Canadian Mineral Industry" by the Mineral Resources Division, Department of Mines and Technical Surveys; available from the Queen's Printer, Ottawa, price $1. Revised annually.

B. "Mineral Facts and Problems - 1960 Edition", U.S. Bureau of Mines, Bulletin 585; available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, U.S.A., price $6.

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[1] Obtainable (price $25) from the Director, Geological Survey of Canada, Ottawa. Prepayment of order is required and should be made by money order or cheque payable to the Receiver General of Canada. Collections will be delivered postpaid but may only be sent to addresses in Canada.

C. "Industrial Minerals and Rocks", 3rd Ed., 1960; published by the American Institute of Mining, Metallurgical and Petroleum Engineers, New York, price $11.75

In addition to the work of the compiler and the other principal authors, written contributions were made by G.A. Gross, E.D. Kindle, B.A. Latour, A.S. MacLaren and B. MacLean.

Some decisions as to the products and raw materials that should be included in this collection were arbitrary. Moreover, new sources of raw materials are constantly being developed and others are being abandoned. The Geological Survey would welcome criticism of the contents of the collection and booklet.

CONTENTS

Page	Product	Raw Material	Specimen Number in Collection
1	ABRASIVES	Corundum	1
		Garnet	2
		Bauxite*	6
		Diatomite	31
		Feldspar (plagioclase)	33
		Pumice	4
		Quartzite	89
		Sand (silica)	90
		Sandstone	91
2	AGGREGATES (Lightweight)	Perlite	3
		Pumice	4
		Shale	5
		Clay	23
		Vermiculite	115
3	ALUMINIUM	Bauxite	6
		Anorthosite	95
		Clay	23
		Nepheline syenite	20
		Shale	5
4	ANTIMONY	Stibnite	7
		Antimony-lead ore	8
5	ARSENIC	Arsenopyrite	9
		Skutterudite ore	25
		Niccolite	69
6	ASBESTOS	Chrysotile (long-fibre)	10
		Chrysotile (short-fibre)	11
		Chrysotile (iron-free)	12
		Amphibole (fibrous)	13
7	BARITE (Barium)	Barite	14
8	BENTONITE	Bentonite	15
9	BERYLLIUM	Beryl	16
10	BISMUTH	Bismuthinite	17
		Molybdenite ore	68
11	CADMIUM	Lead-zinc ore	18

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*Raw materials which are indented in this column appear in the collection under another product heading. For example, the bauxite specimen in the collection appears as an ore of aluminium.

Page	Product	Raw Material	Specimen Number in Collection
12	CAESIUM	Pollucite	19
		Beryl	16
		Lepidolite	87
13	CALCIUM	Limestone	56
14	CEMENT	Clay	23
		Limestone	56
		Shale	5
15	CERAMICS	Nepheline syenite	20
		Pyrophyllite	21
		Barite	14
		Clay	23
		Feldspar (microcline)	32
		Kaolinite	24
		Talc ore	103
17	CHROMIUM	Chromite	22
18	CLAY PRODUCTS	Clay	23
		Kaolinite	24
		Shale	5
19	COBALT	Skutterudite ore	25
		Copper-nickel ore	29
20	COPPER	Chalcocite ore	26
		Chalcopyrite	27
		Copper (native)	28
		Copper-nickel ore	29
		Copper-zinc ore	30
21	DIATOMACEOUS EARTH	Diatomite	31
22	FELDSPAR	Microcline	32
		Plagioclase	33
23	FLUORITE	Fluorite	34
24	FUELS	Coal (bituminous)	35
		Coal (sub-bituminous)	36
		Coal (lignite)	37
		Peat	38
		Bituminous shale	73
		Petroleum	74
		Tar sand	75
27	GEMSTONES	Agate	39
		Amazonstone	40
		Jade (nephrite)	41
		Labradorite	42
		Sodalite	43

Page	Product	Raw Material	Specimen Number in Collection
29	GERMANIUM AND GALLIUM	Sphalerite ore	119
30	GOLD	Gold (vein-type)	44
		Gold (placer)	45
31	GRAPHITE	Graphite	46
32	GYPSUM	Gypsum	47
33	INDIUM	Sphalerite ore	119
34	INSULATING MATERIALS	Chrysotile (short-fibre)	11
		Diatomite	31
		Muscovite	63
		Perlite	3
		Shale	5
		Sand (silica)	90
		Vermiculite	115
35	IRON	Hematite (hard, admixed goethite)	48
		Hematite (specular)	49
		Limonite (goethite)	50
		Magnetite	51
		Pyrrhotite	52
		Siderite	53
		Pyrite	101
36	LEAD	Galena ore (coarse)	54
		Galena ore ('steel')	55
		Antimony-lead ore	8
37	LIMESTONE	Limestone	56
		Marble	65
38	LITHIUM	Spodumene	57
		Lepidolite	87
39	MAGNESIUM	Brucite	58
		Dolomite	59
		Sea water	-
40	MANGANESE	Manganese ore (pyrolusite)	60
41	MERCURY	Cinnabar	61
42	MICA	Biotite	62
		Muscovite	63
		Phlogopite	64
		Lepidolite	87

Page	Product	Raw Material	Specimen Number in Collection
43	MINERAL FILLERS	Barite	14
		Bentonite	15
		Chrysotile (short-fibre)	11
		Clay	23
		Gypsum	47
		Limestone	56
		Marble	65
		Muscovite	63
		Pyrophyllite	21
		Talc	103
		Wollastonite	116
44	MINERAL PIGMENTS	Marble	65
		Ochre	66
		Umber	67
		Barite	14
		Ilmenite	107
		Stibnite	7
45	MOLYBDENUM	Molybdenite	68
46	NICKEL	Niccolite	69
		Pentlandite ore	70
		Pyrrhotite (nickeliferous)	71
47	NIOBIUM	Pyrochlore ore	72
48	PETROLEUM AND NATURAL GAS	Bituminous shale	73
		Petroleum (crude)	74
		Tar sand	75
50	PHOSPHATE	Apatite	76
		Phosphate rock	77
51	PLATINUM METALS	Copper-nickel ore	29
52	POTASH	Sylvite	78
53	QUARTZ CRYSTAL	Quartz	79
54	RARE EARTHS	Brannerite-uraninite-monazite ore	111
55	REFRACTORIES	Andalusite	80
		Kyanite	81
		Magnesite	82
		Sillimanite	83
		Brucite	58
		Chromite	22
		Pyrophyllite	21
		Sand (silica)	90

Page	Product	Raw Material	Specimen Number in Collection
57	ROOFING GRANULES	Basalt	84
		Rhyolite	85
		Slate	86
58	RUBIDIUM	Lepidolite	87
		Pollucite	19
59	SALT	Halite	88
60	SAND AND GRAVEL	-	-
61	SELENIUM	Copper-zinc ore	30
62	SILICA	Quartzite	89
		Sand (silica)	90
		Sandstone	91
63	SILVER	Silver-lead-zinc ore	92
		Silver (native)	93
64	SODIUM SULPHATE	Mirabilite	94
65	STONE (building)	Anorthosite	95
		Granite (grey)	96
		Granite (rose)	97
		Limestone (Tyndall)	98
		Sandstone (Nepean)	99
		Limestone (grey)	56
66	STRONTIUM	Celestite	100
67	SULPHUR	Pyrite ore	101
		Sulphur (native)	102
		Natural gas	-
68	TALC	Talc ore	103
		Pyrophyllite	21
69	TANTALUM	Columbite-tantalite	104
70	TELLURIUM	Copper-nickel ore	29
71	THALLIUM	Copper-zinc ore	30
72	THORIUM	Brannerite-uraninite-monazite ore	111
		Uranothorite-uraninite ore	113
73	TIN	Pyrrhotite-cassiterite ore	105
		Stream tin (cassiterite)	106
74	TITANIUM	Ilmenite	107
		Titaniferous magnetite	108

Page	Product	Raw Material	Specimen Number in Collection
75	TUNGSTEN	Scheelite ore	109
		Wolframite ore	110
76	URANIUM	Brannerite-uraninite-monazite ore	111
		Pitchblende ore	112
		Uranothorite-uraninite ore	113
77	VANADIUM	Vanadiferous sediment	114
		Pitchblende ore	112
		Titaniferous magnetite	108
78	VERMICULITE	Vermiculite	115
79	WATER	-	-
80	WOLLASTONITE	Wollastonite	116
81	ZINC	Sphalerite ('Black Jack')	117
		Sphalerite (yellow)	118
		Sphalerite ore	119
82	ZIRCONIUM	Zircon	120
		Uranothorite-uraninite ore	113

ABRASIVES

Reference: A

Many minerals and rocks of diverse composition and hardness are used as natural abrasives. Natural high-grade abrasives, however, have been largely supplanted by artificial abrasives made in turn from natural products. Natural abrasives are of three types: (a) high-grade abrasives which include, in order of hardness, diamond, corundum, emery and garnet; (b) siliceous abrasives such as sandstone, quartzite, flint, chert, quartz, sand, tripoli, diatomite and pumice; and (c) miscellaneous abrasives, including buffing and polishing powders such as feldspar, magnesite, chalk, lime, iron oxides and talc. Canada produces no high-grade natural abrasives, and small amounts only of sand (90)*, sandstone (91), and quartzite (89) for local sandblasting use, feldspar (33) for use in scouring soaps and cleansers, and bog iron ore for use in jewellers' rouge. Canada, however, is the world's leading manufacturer of crude artificial abrasives with a production in 1959 of 152,319 tons of fused alumina and 86,248 tons of silicon carbide from eight plants in Ontario and Quebec.

Industrial diamonds include carbonado or black diamond, and bort, which includes small stones, fragments and badly coloured or flawed rejects from the gem industry. Corundum, Al_2O_3, (1) ranks second to diamond on the mineral scale of hardness. Emery, originally a mixture of corundum, magnetite, hematite and spinel, named from an occurrence at Cape Emeri, Greece, may be high in spinel content and lacking in corundum. Garnet (2) is a group name for seven different species with similar crystal structures but different compositions. Almandite, $Fe_3Al_2(SiO_4)_3$, is the one generally used as an abrasive. Diatomite (31) and tripoli are nearly pure, fine-grained silica. Pumice (4) is a frothy siliceous volcanic lava and pumicite is volcanic ash.

Corundum is found associated with quartz-free igneous rocks such as nepheline syenite, as in the Bancroft area, Ontario, and in border zones of pegmatite dykes intruding basic igneous rocks. Deposits of the latter type are mined for corundum in South Africa. Garnets are widely distributed in schists, gneisses, and contact metamorphic zones in calcareous rocks, but commercial deposits are few. The Barton mine in Warren county, New York State, is probably the world's largest producer of garnet. The chief mineral products used in the manufacture of artificial abrasives are: bauxite (6), silica (91), carbon and boron and tungsten minerals. Silicon carbide (SiC), known under such trade names as 'Carborundum', 'Crystalon' and 'Carbolon' is made by fusing coke and silica sand. Fused alumina, sold under the trade names of 'Alundum', 'Aloxide', etc., is made by fusing bauxite with coke and iron. Boron carbide, the next-hardest substance to diamond, is an electric-furnace product made from coke and boric acid.

In the high-grade-abrasives field it is unlikely that natural abrasives can compete economically with the artificial products. Garnet is a possible exception, and a garnet industry might find a place between low-cost, soft, siliceous abrasives and high-cost, harder, artificial products. The value of deposits of low-grade abrasives will depend to a large extent on their proximity and ease of shipping to industrial consumers.

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*Figures in parentheses refer to specimen numbers in collection.

AGGREGATES (Lightweight)

References: A, C

Mathews, W.H. (1949): Expansible Perlite in British Columbia; B.C. Dept. Mines.

Preliminary Reports on Coated Lightweight Aggregates from Canadian Clays and Shales; Mines Branch, Dept. Mines, Tech. Surv., Memo. Ser. Nos. 117, 120, 121, 122, 126 and 128.

Canada produces annually between three and four million dollars worth of lightweight aggregates for use mainly in non-residential types of construction. When substituted for sand, gravel and crushed rock, lightweight aggregates reduce the weight of concretes by as much as two thirds. The materials used include clay, shale, slag, perlite and vermiculite, which are expanded by heating, and pumice, which is used in the natural state. Clay, shale and slag are produced from domestic sources; all other raw materials are imported, chiefly from the United States. Although production has been increasing steadily in recent years, lightweight aggregates are bulky commodities of low unit-value and only those deposits located close to transportation facilities and markets are likely to be competitive.

Perlite (3) is a volcanic glass that is characterized by an onion-skin fracture. It contains from 2 to 5 per cent water and when heated it expands quickly to form a light cellular product. Pumice (4) is a light, highly-cellular volcanic glass. It is commonly intermixed with volcanic ash (pumicite). Clay (23) and shale (5) are the most abundant domestic sources of lightweight aggregates. Vermiculite (115) is described under its own heading.

Shale and clay are widely distributed throughout the populated parts of Canada. Beds of perlite several hundred feet thick are quarried in the United States. In Canada, large deposits of perlite are known near Francois and Uncha Lakes and in Empire Valley, British Columbia. Major sources of pumice are the United States and Italy but lump pumice occurs over an extensive area in the Bridge River district, British Columbia. A promising Canadian occurrence of vermiculite is being developed near Perth, Ontario.

Commercial deposits of perlite and pumice should be sought in areas of Tertiary or Quaternary strata because deposits of earlier age appear to have been partly or completely destroyed, by devitrification and alteration.

ALUMINIUM

References: A, B

Canada produces about 12 per cent (nearly 1 million tons) of the world's supply of aluminium, entirely from imported ores. Canadian production is made possible by large sources of hydro-electric power on tidewater, at Arvida, Quebec, and Kitimat, British Columbia. Raw materials are imported by ship, principally from British Guiana, Surinam and Jamaica. Aluminium is one of the most widely used metals. Industries that consume major quantities of aluminium are: building and construction, transportation, durable consumer products, containers and packing, and electrical equipment.

The principal ore of aluminium is bauxite (6) which is a residual product of weathering under tropical conditions of aluminium-rich rocks that are low in free quartz. Bauxite is a mixture of aluminium oxides and hydroxides including boehmite, $AlO(OH)$, diaspore $HalO_2$, and gibbsite $Al(OH)_3$. It is commonly stained brown by traces of iron oxides. Minerals associated with bauxite are principally oxides and hydroxides of iron and, less commonly, manganese. Bauxite normally contains nearly 60 per cent alumina and is virtually free from silica.

As noted above, bauxite forms most readily as a result of near-surface weathering of rocks high in alumina and low in silica. Many of the laterite deposits of the tropics are rich in bauxite. Usually, however, the best ores are products of resorting and/or intense leaching under warm and humid conditions which remove alkalies, silica and most of the iron. Major sources of bauxite are found in the Guianas, Guinea, Jamaica, France, Hungary, United States, and the U.S.S.R. A small deposit of bauxite is known in Canada at Sooke, British Columbia. As a result of almost complete glacial scouring, it is improbable that important deposits of bauxite will be found in Canada. It is possible that 'fossil' deposits may be found buried by later sediments but it is likely that they will have been contaminated by silica in the process of burial.

Potential sources of aluminium in Canada are anorthosite (95), nepheline syenite (20), clay (23) and shale (5). During the war when it was possible that supplies of bauxite would be cut off, methods of recovery of alumina from these sources were investigated. Although recovery is possible, it is not economically competitive with recovery from bauxite. Anorthosite is a rock composed almost entirely of calcic plagioclase feldspar near $CaAl_2Si_2O_8$. Large bodies of anorthosite occur in southern Quebec, and Arvida is situated on one of them. Nepheline, $NaAlSiO_4$, from nepheline syenites in the Bancroft-Peterborough district of Ontario is another possible source. Clay and shale are abundant in many parts of Canada.

ANTIMONY

References: A, B

About 50, 000 tons of antimony are produced annually throughout the world. China is the most important producer with a production of 17, 000 tons, followed in importance by South Africa, Bolivia and Mexico. Canada produces about 750 tons of the metal annually. Sole production, in the form of antimonial lead, is by the Consolidated Mining and Smelting Company of Canada, from Sullivan mine ore and custom ore from other mines in British Columbia. Antimony is used to harden and strengthen lead. It is used in the manufacture of storage batteries, cable coverings, bearing metal, type metal, and solders, and is an important ingredient in flame-proofing paints and coatings.

Stibnite (7), Sb_2S_3, is the common ore-mineral of antimony. Relatively large percentages of antimony are also present in certain sulphosalt minerals, commonly associated with lead, as in zinkenite (8), $PbSb_2S_4$, boulangerite and jamesonite.

Stibnite usually occurs in shallow-seated deposits as veins in fissures, shears or joints, and as irregular replacement deposits. Most of the Chinese deposits are of this type. Although similar types of deposits are known in Canada in the Appalachian and Cordilleran regions, none so far have responded profitably to exploration and development. Antimony-bearing sulphosalts are commonly associated with lead or lead-zinc-silver ores, and the antimony may be extracted during smelting of the ores for recovery of the major products. Canadian production of antimony is obtained entirely as a by-product in the processing of lead ores.

An increased demand for antimony could be met in large part by an increase in by-product production.

ARSENIC

References: A, B

The United States and Sweden produce about half of the world's supply of refined arsenic trioxide, or white arsenic, estimated at 40,000 tons annually. In the late fifties, Canada produced from 700 to 1,700 tons annually, consumed about 250 tons, and exported the balance chiefly to the United States. Canadian production came entirely from the Deloro Smelting and Refining Company where white arsenic was recovered and refined as a by-product from the treatment of cobalt-nickel-silver ores from the Cobalt-Gowganda area. About 80 per cent of the arsenic consumed in Canada is used as a decolorizer in the glass industry. Smaller amounts are used in lead and copper alloys, and in the preparation of various chemicals. Its use in herbicides and pesticides has declined in recent years owing to competition from organic chemicals.

Arsenopyrite (9), FeAsS, is the most common arsenic-bearing mineral in Canada. It is found in many gold ores, and may have to be removed by roasting to permit maximum recovery of the gold. The crude white arsenic so produced must be collected from the flue gases and stored in a safe place because of its poisonous nature. Arsenic recovered as a by-product from the smelting of cobalt-nickel-silver ores is combined with cobalt and nickel in several minerals of which skutterudite (25) and niccolite (69) are the most abundant.

Production of crude white arsenic in Canada far exceeds present and foreseeable future demands.

ASBESTOS

References: A, C

Canada is the world's leading producer of asbestos. In 1959, Canada supplied 1,042,000 tons or about 45 per cent of the estimated world production. Of this, all but 28,000 tons was exported. About two thirds of the total exports was shipped to markets in the United States. The increased marketing and growing production capacity of the second largest producer, U.S.S.R., is a major but uncertain economic factor. The use of asbestos in asbestos-cement mixtures is increasing. Uses depend on the grade of fibre and include heat-resisting cloths for varied purposes, asbestos-cement pipe, sheeting, shingles, roofing tile, millboard, thermal insulating paper, pipe covering, floor tile, clutch and brake components, reinforcing in plastics and many others.

Chrysotile (10, 11, 12), $H_4Mg_3Si_2O_9$, comprises 93 per cent of the world's production of asbestos, and is the only variety produced in Canada. Asbestiform varieties of the amphibole group of minerals, namely crocidolite, anthophyllite, tremolite and actinolite (13), account for the remaining 7 per cent. Chrysotile provides the finest and most flexible fibres, but some amphiboles are more suitable for certain specialized uses, such as acid-resisting gaskets.

Chrysotile forms veins in serpentinized ultrabasic rocks with the fibres parallel (slip-fibre) or perpendicular (cross-fibre) to the vein walls. Serpentinized peridotites are mined on a very large scale in the Eastern Townships of Quebec, and similar deposits are in production at the Munroe mine, Ontario, and the Cassiar mine, northern British Columbia. The deposit at Baie Verte, Newfoundland, is at an advanced stage of development. Other deposits are being sought and examined in the belts of ultrabasic rocks. Chrysotile also occurs in serpentinized dolomite adjacent to diabase in Transvaal and Arizona, but only small tonnages of low-iron chrysotile have been produced. Crocidolite and other amphiboles in the order of 100,000 tons per year are mined from metamorphosed iron-rich argillite or quartzite in South Africa, and crocidolite is produced in Transvaal and western Australia. Small occurrences of crocidolite have been found in Labrador and northern Quebec.

BARITE (Barium)

References: A, B, C

Ross, J.S. (1960): The Barium Minerals Industry in Canada; Mines Branch, Dept. Mines, Tech. Surv., Info. Circ. No. 126.

The major use of barite is as a heavy, inert component of drilling muds in oil and gas development. Lesser amounts are used in heavy concrete aggregate and in the manufacture of paints, glass, rubber, oilcloth and ceramics. Canadian production of about 239,000 tons in 1959 ranks third in the world and could be increased to meet further demands. The market for barite is dominated by the needs of the oil-well-drilling industry. About 90 per cent of Canadian production is exported, principally in crude form.

Barite or barytes (14), $BaSO_4$, relies for industrial application on its high specific gravity, colour (mainly white or colourless), composition, and low cost. It occurs in metalliferous veins associated with quartz, galena, sphalerite, chalcopyrite, fluorite and various manganese and iron minerals; and also in pockets and lenses in crystalline limestone associated with celestite, calcite, fluorite and scattered sulphides.

Barite occurs in fissure veins at Madoc, Ontario, and as replacement deposits in limestone at Liard Crossing, northeastern British Columbia, and at varied locations in Carboniferous beds in Nova Scotia and Newfoundland. The largest producing deposit, at Walton, Nova Scotia, is of the latter type. Producing mines in southeastern British Columbia comprise fissure veins and replacement deposits of barite associated with quartz. Large tonnages of barite gangue have been discarded at Buchans, Newfoundland.

The effectiveness of barite aggregate, especially when used in barite cement, in shielding atomic radiation, could lead to modest increased consumption in the construction of fallout shelters and atomic installations. Oil-well drilling, however, may demand appreciably less barite as drilling techniques change and more drilling muds are economically recovered. Because transportation costs commonly exceed the value of crude barite, Canadian deposits in remote areas such as Little Cornwallis Island in the Canadian Arctic, and northeastern British Columbia, would enjoy a transportation advantage should local demands for drilling muds develop or increase. The recent development of asphalt-barite mixtures for road- and runway-surfacing could create new demands for ground barite.

BENTONITE

Reference: A

The principal world source of bentonite is the United States; deposits also occur in Mexico, New Zealand, South America, Africa, Japan, U.S.S.R., Italy, Germany and other European countries. Annual consumption of bentonite in Canada ranged from 23,000 to 35,000 tons during 1950 to 1958, much of this being imported from the United States. Some domestic production comes from extensive deposits in Western Canada but recent production figures are not available. Two types of bentonite are used commercially. Swelling bentonites, which expand up to 15 times their volume when soaked in water and form permanent colloidal suspensions, are used mainly in well-drilling fluids and foundry sands, and are becoming increasingly important as bonders in the pelletizing of iron-ore concentrates. Non-swelling bentonites have strong absorptive properties and are used mainly for the filtering and decolorizing of animal, vegetable and mineral oils, and other liquids.

Bentonite (15) is a bedded clay material that is composed largely of clay minerals of the montmorillonite group. These minerals strongly exhibit the property of base exchange, the exchangeable cations usually being sodium and calcium. It is this property that largely determines the distinctive characteristics and uses of bentonites.

Bentonite is formed by the devitrification and alteration in situ of deposits of wind-borne volcanic ash. It occurs in beds from a few inches up to 20 feet thick, interstratified with shale and sand and, occasionally, lignite and coal. Surface outcroppings are fairly easily recognized as they have a crinkled, coral-like texture, and are almost devoid of vegetation. Also, after rains, they are covered with a soapy mass several inches thick. Non-swelling bentonite is quarried from the Vermilion River Formation in the Thornhill-Miami area of Manitoba and north of Pelly, Saskatchewan. There is also a large deposit of 'semi-bentonite' at Knollys, Saskatchewan, in the Butler Formation. In Alberta, swelling bentonite in the Edmonton Formation is being produced at Rosedale and Onoway, and has been produced intermittently from a deposit near Drumheller. In British Columbia a bed of non-swelling bentonite 14 feet thick is exposed in Tertiary rocks south of Princeton. Numerous deposits occur elsewhere in these provinces. Thin bentonite seams have been recognized in the Ordovician in Ontario.

BERYLLIUM

References: B

Mulligan, Robert (1960): Beryllium Occurrences in Canada; Geol. Surv., Canada, Paper 60-21, 40 pp.

Vokes, F.M. (1958): Beryllium in Canada, Metallogenic Map; Geol. Surv., Canada, Map 1054A-M2.

World production of beryl in 1958 was 7,000 short tons, the chief producers being Belgian Congo, Brazil, Argentina, Union of South Africa, India, United States and Mozambique. The United States, which produced only 463 tons, consumed a record high of 6,002 tons. Although beryl has been stockpiled at several Canadian deposits no shipments were recorded in 1958 and 1959. Pure beryllium and beryllium oxide have important uses in the nuclear-energy field and in the missile, aircraft, electronics and scientific-equipment industries. Beryllium is also used as an alloying agent with copper, nickel, iron, aluminium and magnesium. Beryllium oxide is a super-refractory, having a melting point of 2,570°C.

Beryl (16), $Be_3Al_2(SiO_3)_6$, is the most common beryllium mineral, and accounts for nearly all commercial production. It occurs in granite pegmatites and high-temperature or pegmatitic quartz veins. In pegmatites, beryl is mostly concentrated with quartz and commonly with muscovite and albite. Tourmaline and molybdenite are common associates, and topaz, wolframite, and cassiterite may occur under similar conditions. Other beryllium-bearing minerals of possible economic significance include: chrysoberyl, $BeAl_2O_4$; phenacite, Be_2SiO_4; helvite and danalite, the end-members of a complex silicate-sulphide series; and gadolinite, a silicate of beryllium, iron and rare earths.

Beryllium in Canada occurs mainly in pegmatites, high-temperature and pegmatitic quartz veins and disseminations in granite, and to a lesser extent in contact-metamorphic deposits. Possible sources of beryllium may therefore be expected in all regions of deformed bedded rocks invaded by igneous rocks. Known occurrences appear to be confined to the following metallogenic provinces: the northeastern marginal belt of the Western Cordilleran region; northeast of Great Slave Lake; northwest of Lake Winnipeg; southeastern Manitoba; western Ontario; eastern Precambrian among Keewatin-Timiskaming and Grenville-type basement rocks; and associated with Devonian granitic intrusions in the Appalachian region. Only a very small amount of gem-quality beryl has been found in Canada and none of the known occurrences appear favourable as gem deposits.

A considerable expansion of the beryllium industry is to be expected in the future. The increasing consumption of beryl from foreign sources by industries in the United States provides an incentive to develop Canadian sources.

BISMUTH

References: A, B

Canada produces about 200 tons of bismuth annually as a by-product recovered in the treatment of lead, molybdenum, silver and copper ores. Most of this production is exported to the United States and Britain where it is used in low-melting-point alloys, and medicinal and cosmetic preparations. The United States consumes about 750 tons of the annual world production of about 2, 500 tons of bismuth. Canada ranked second to Peru in 1958 in output of bismuth.

Bismuth occurs in nature mainly as the metal and as the sulphide bismuthinite, Bi_2S_3 (17). Large deposits of these minerals are uncommon and most of the world's supply of bismuth is obtained from the treatment of lead, copper, molybdenum, gold, silver, tin and tungsten ores which contain small amounts of bismuth minerals.

The main sources of bismuth in Canada are: lead-zinc-silver ores refined at Trail, British Columbia; molybdenite-bismuth ore (68) processed at the Lacorne mine, Quebec; copper ores treated at Gaspé Copper Mines Limited, Murdochville; and silver-cobalt ores from the Cobalt district, Ontario, smelted at Deloro, Ontario.

CADMIUM

References: A, B

World production of cadmium is close to 20 million pounds annually. The United States is the largest producer, and Canada, South West Africa, Mexico and Belgium also produce important amounts. Canadian production in the last 10 years has ranged from 800, 000 to 2, 400, 000 pounds and consumption from 170, 000 to 250, 000 pounds annually. The balance is exported, chiefly to the United States and Britain. A considerable proportion of Canadian cadmium production goes unrecognized in the form of zinc concentrates exported for treatment elsewhere. Cadmium is used as a coating on iron and steel and on other alloys, and competes with zinc particularly in the coating of intricately-shaped small articles where the higher price of cadmium is relatively less important. It is used also in low-melting alloys and in pigments. Recent developments indicate possible increasing use in atomic-reactor shields and in the production of electrical energy directly from light (solar batteries).

Greenockite and hawleyite, two structural forms of cadmium sulphide, are the only noteworthy minerals in which cadmium is an essential constituent. Neither of these minerals is found in commercial quantities. Cadmium occurs in small amounts in the sphalerite or many zinc ores (18) from which it may be extracted as a profitable by-product.

Cadmium is recovered as a by-product of the treatment of zinc concentrates at the zinc smelters at Trail, British Columbia, and Flin Flon, Manitoba. Concentrates from the Sullivan mine and other mines in southern British Columbia and the Yukon are treated at Trail. These vary in grade from 0.14 per cent cadmium in Sullivan concentrates to as much as 0.8 per cent in concentrates from Mayo in the Yukon. Concentrates from mines in Manitoba and Saskatchewan, containing about 0.12 per cent cadmium, are treated at the Flin Flon smelter.

CAESIUM

Reference: B

Only a small market for caesium exists at present. World production in 1958 amounted to 100 tons of ore mined in Africa. The United States and Western Germany consumed about 15 tons of ore, and the remainder was stockpiled at the mines. Caesium, the heaviest and most reactive of the alkali metals, has a single valence electron in its atomic structure and is the most readily ionized of all the elements. Caesium is the active agent used to convert light into electricity in such devices as photomultiplier tubes, and in infrared lamps, telescopes and binoculars. Caesium and its compounds are also used in vacuum tubes and scintillation counters, as microwave-frequency and time-signal standards, in glass and ceramics, as an absorbent at gas-purification plants, as a catalyst in hydrogenation and polymerization processes, and as a scavenger in metallurgy. Two potentially important uses for caesium still in the development stage are caesium vapour as the fuel for ionic-drive rocket engines, and caesium as the active agent in thermionic converters to convert heat to electricity.

The only caesium mineral which has been found in commercial quantities is pollucite (19), a hydrous caesium-sodium aluminium silicate which may contain as much as 40 per cent caesium oxide but commonly contains about 25 per cent. A few other minerals, notably lepidolite (87) and beryl (16), may contain up to 3 per cent caesium oxide.

The heavy alkali metals—caesium and rubidium—are closely associated in nature and tend to be concentrated in granitic rocks. Concentrations of caesium-bearing minerals are rare and have been found only in sodium-lithium pegmatites as at Bernic Lake, Manitoba; Karabib, South West Africa; and Bikita, Southern Rhodesia. A small amount of caesium is associated with the carnallite deposits of Stassfurt, Germany, and Solikamsk, U.S.S.R.

Although caesium is still considered a rare element it may well become a tonnage commodity in the future. The United States has no established reserves of caesium, and the Canadian deposits at Bernic Lake (with reserves estimated at more than 150,000 tons) may eventually become of considerable strategic importance.

CALCIUM

Reference: A

Canada is one of the world's leading producers of calcium metal. Production in 1959 mounted to 76,610 pounds. In comparison, 25,227 pounds was produced in 1958; 221,225 pounds in 1957; and 895,203 pounds in 1948. Because of its high reactivity, calcium is used mainly as a reducing agent in the metals industry, notably in the production of uranium, thorium, titanium, zirconium, and chromium. The world's largest producer, Dominion Magnesium Limited (DOMAL), is the only producer of calcium in Canada. Export markets consume most of the domestic output.

Calcium is widely distributed in extensive sedimentary deposits as the carbonate, sulphate and phosphate; it is also a major constituent in many rock-forming silicate minerals. Raw commercial sources of the metal are limestone (56) and brines containing calcium chloride. The more important of these is limestone—a rock that is ideally composed of calcium carbonate but which usually contains some magnesia, alumina, silica, and other impurities; all gradations exist between limestone and dolomite. Silica, magnesia, strontium, barium, and particularly, the alkali metals, are all undesirable impurities.

Limestones occur in rocks of all ages and are widespread throughout the world, but only a small percentage are of acceptable purity as sources of metallurgical-grade lime. Calcium chloride has been recovered from brines in the United States. Limestone is abundant in many parts of Canada and is being exploited for many purposes. However, additional deposits of exceptional purity would be of possible commercial interest.

CEMENT

Reference: A

Canada produces between 6 and 7 million tons of cement annually, with a value of about $100 million. This places her in about tenth position among the world producers, the United States being the largest. Production of cement in Canada has shown a fairly consistent increase since 1933, the average annual gain since 1944 amounting to 336,000 tons. In 1959, cement occupied ninth position in Canada's mineral output. Prior to 1957, about 10 per cent of Canada's consumption was imported, but since then our imports have dwindled to a relatively small quantity, mainly of special types, whereas our exports have increased. Exports now account for approximately 5 per cent of our production, almost all of this going to the United States. Most cement produced is of the common portland variety which is used in concrete for all general forms of construction. Masonry, air-entraining, oil-well and other types of cement are also produced in Canadian plants.

The essential ingredients required for portland cement are lime, alumina, silica and iron oxide. The principal commercial sources of these for the cement industry are limestone (56), shale (5), and clay (23), although as many as 27 other raw materials are used as sources in Canada and the United States. For use in portland cement, limestone must contain less than 3 per cent magnesia; this eliminates the dolomitic varieties and, as magnesia is a common impurity, it rules out many accessible sources of the rock. Unless present in excessively large amounts, argillaceous (clayey) matter is not deleterious in limestones and may be beneficial. Certain argillaceous limestones, for example, contain almost the exact proportions of lime-alumina-silica for the cement industry and are appropriately named 'cement rock'.

Canada is self-sufficient in the raw materials of the cement industry. There is no nation-wide shortage of suitable deposits of limestone, clay and shale but we are faced with local shortages of one or more in certain areas. Because of this, and because cement and its raw materials are low-cost bulky commodities, the industry's concern is not one of reserves but of locating suitable deposits in close relation to established, newly-created or potential cement-consuming centres. At the end of 1959, eighteen plants were producing cement clinker in Canada, with one or more located in all provinces except Nova Scotia and Prince Edward Island.

Because cement is an essential commodity for which there is no substitute, its production may be expected to increase with increase in population.

CERAMICS

References: A, C

Canadian Institute of Mining and Metallurgy (1957): Pyrophyllite and Nepheline Syenite; Geology of Canadian Industrial Mineral Deposits; Congress Volume.

Clay (23), nepheline syenite (20), feldspar (32), and smaller amounts of talc (103), pyrophyllite (21), spodumene (57), and barite (14) are used in the manufacture of ceramics. Of these materials, nepheline syenite and pyrophyllite are discussed here and the remainder are described under their mineral name.

Nepheline-syenite production, dominated by Canada and the U.S.S.R., has grown especially rapidly in the past 10 years in Canada—to about 249, 200 tons in 1960. About 80 per cent is exported to the United States. Domestic and export markets have largely been won at the expense of feldspar, particularly in glass manufacture. About 20, 220 tons of pyrophyllite was produced and exported for ceramic use in 1960. Other uses include insecticide diluent, refractories, asphalt filler, rubber, and paint. Consumption in North America appears to be increasing at about the normal rate, suggesting that no new markets are being exploited, and that competition from talc and other substitutes is balanced.

Nepheline syenite (20) is a rock similar in origin and appearance to granite but deficient in silica, generally composed of nepheline ($NaAlSiO_4$), microcline, albite, and with undesirable accessory minerals such as hornblende, mica, magnetite, corundum and garnet. Nepheline pegmatites have been mined, but this production ceased as production from Blue Mountain, Ontario, increased. The high ratio of alumina, soda, and potash to silica makes the rock desirable in glass manufacture, and in many ceramic applications it is superior to feldspar despite a higher soda-to-potash ratio. High soda and lime, or corundum and iron oxide not amenable to removal by simple milling processes, or non-uniform distribution of material in the quarry, detract from many nepheline-syenite deposits. Pyrophyllite (21), $H_2Al_2(SiO_3)_4$, is similar in crystal structure, and hence in physical properties, to the more familiar talc. It normally occurs as irregular lenticular deposits with quartz and sericite as dominant gangue minerals.

Nepheline syenite is fairly common in central Canada and the United States. Major bodies of this rock occur in the Haliburton-Bancroft district, in the Sudbury district, and near Port Caldwell in Ontario. Large bodies are known in Quebec and in eastern British Columbia. The producing deposit of pyrophyllite in southeast Newfoundland was formed by intense alteration of rhyolitic volcanic rocks along shear planes near a granite contact. This origin is typical of other occurrences. Very large tonnages of low-grade, and adequate quantities of good-grade material are available.

The popularity of nepheline syenite is expected to increase in present uses. Should bauxite supplies be restricted, nepheline or possibly nepheline syenite can be used as one of the more expensive sources of alumina. Nepheline so used in the U.S.S.R. yields soda, potash, and cement as by-products.

It is commonly difficult to market ceramic materials because any proposed changes of the manufacturer's raw materials must be extensively tested by production, thus a uniform long-term supply is generally of greater importance than short-term price variations. Normally, the cost of raw materials is a small part of the total cost of ceramic products.

CHROMIUM

References: A, B

The principal producers of chromite are U.S.S.R., South Africa, Rhodesia and Nyasaland, Turkey, and the Philippines. The United States is the world's largest importer and consumer. Canada's consumption of chromite, all of which is imported, is largely dependent on the marketing of stainless and alloy steels, and has fluctuated between 36,000 and 129,000 tons annually during the period 1949 to 1959. Industrial uses of chromite in order of consumption are: as a component of ferro-alloys used in making alloy steels; in refractory products for lining and repairing furnaces; and, in the chemical industry, for producing various chromium compounds.

Chromite (22), the only important ore mineral of chromium, has the theoretical composition $FeCr_2O_4$, corresponding to 68 per cent chromic oxide. Commercial chromite ores, however, seldom contain more than 50 per cent chromic oxide due to replacement of part of the iron by magnesium and some of the chromium by aluminium. The variation in composition is important because the Cr_2O_3 content and the Cr:Fe ratio in the concentrate determines the grade under which it can be marketed. Specifications for metallurgical-grade chromite require a Cr_2O_3 content of 45 to 50 per cent and a Cr:Fe ratio of 2.8 : 1 or higher. For refractory-grade chromite, the combined Al_2O_3 and Cr_2O_3 content must exceed 57 per cent but the Cr:Fe ratio is less important. Specifications for chemical-grade chromite are less exacting; typical ores contain about 44 per cent Cr_2O_3, less than 15 per cent Al_2O_3 and 20 per cent FeO, and have a Cr:Fe ratio of about 1.5 : 1.

Chromite occurs in various ultrabasic rocks and in serpentine derived from them. It also occurs in commercial amounts in stream sands derived from serpentine areas. The Appalachian ultrabasic belt which extends in Canada from the Eastern Townships of Quebec through Gaspé to Newfoundland contains numerous small chromite deposits, some of which were mined during World War II. Similar types of deposits occur in the Cordilleran region of British Columbia and the Yukon, and in places are accompanied by low platinum values. The largest known Canadian deposit, in the Bird River area, Lac du Bonnet, Manitoba, unfortunately is low grade (26 per cent Cr_2O_3; Cr:Fe, 1.4 : 1). Other occurrences are known in the Precambrian in northwestern Ontario and in the Coppermine River area of the Northwest Territories.

Because of the importance of chromium in the steel industry and the exceptional characteristics of high-chromium alloys, consumption of chromite ores is expected to increase. The approaching depletion of the world's high-grade ore reserves has stimulated development work on the utilization of lower-grade ores. Improved technology may make production of low-grade Canadian deposits economic. The possibility of finding high-grade chromite deposits in Canada should not be overlooked.

CLAY PRODUCTS

References: A

Phillips, J.G. (1956): Clays and Shales of Eastern Canada; Mines Branch, Dept. Mines, Tech. Surv., Info. Circ. No. IM-3.

Clay products, as defined by J.G. Brady in reference A, include such materials as fire-clay refractories, common and face brick, structural tile, partition tile, drain tile, quarry tile, sewer pipe, conduit, flue lining, electrical porcelain, sanitary ware, dinnerware and pottery. Somewhat more than $100 million worth is consumed annually in Canada, of which 60 to 65 per cent is represented by imported products or products manufactured here from imported clays. Canada produces about $45 million worth of clay products from domestic sources. Except for 1957, production has shown an average annual increase of about 10 per cent during the years 1949 to 1959.

Raw materials of the clay-products industry include common clays and shales, stoneware clay, china clay, ball clay, and fire clay. The last three are high-grade refractory clays and are largely imported. Clay (23) is a fine-grained earthy material that is usually plastic when wet. It is always of secondary origin, resulting from the weathering or hydrothermal alteration of other rocks. It occurs as residual deposits or, more commonly, as transported sediments that have been laid down in bodies of marine or fresh waters. Clays are composed of one or more clay minerals with varying proportions of quartz and various other non-clay constituents. The principal clay minerals are the illites, chlorites, montmorillonites and kaolinites (24)—all hydrated silicates of magnesium, aluminium or iron. They are exceedingly fine grained and are distinguished from one another mainly on the basis of their atomic structure. Shale (5) is a consolidated form of clay and usually has a thinly laminated structure. China clay is composed essentially of the clay mineral kaolinite (24), $Al_2O_3 . 2SiO_2 . 2H_2O$. The crude material generally contains quartz and other impurities and must be beneficiated for commercial use. Ball clays, fire clay and stoneware clay are composed mainly of kaolinite and quartz. They generally contain less alkalies and alkaline materials than the common clays and are not ordinarily beneficiated.

Common clays and shales used for the manufacture of brick and tile, are the principal raw materials available in Canada. They are found in most parts of the country but only those near large markets are exploited. China clay occurs in small deposits near St. Remi, Quebec, in the Whitemud Formation, Saskatchewan, and in British Columbia. Ball clays, fire clay and/or stoneware clays are known in the Whitemud Formation of Saskatchewan, on Sumas Mountain, British Columbia, Swan River, Manitoba, and in Nova Scotia.

The better grades of clay would probably find a market if found in the settled parts of Canada but exploitation of common clays is likely to be restricted to the vicinity of large markets or along major waterways. Consumption of clay products will increase with growth of population.

COBALT

References: A, B

Jones, R.J. (1954): Cobalt in Canada; Mines Branch, Dept. Mines, Tech. Surv., Pub. No. 847.

Cobalt production in Canada in recent years has been in the neighbourhood of 3 million pounds annually. For 20 years after the discovery of the rich silver ores of the Cobalt-Gowganda area, Canada was pre-eminent in world production, but since 1926 Canada has fallen behind the Congo and recently has dropped further, to fourth place behind United States and Rhodesia-Nyasaland. The Congo currently produces about 60 per cent of the world's cobalt and Canada about 10 per cent. Of this Canada uses less than 10 per cent and exports the remainder, chiefly to the United States. Recent expansion in world productive capacity has put cobalt in potential oversupply. Current problems are to expand markets and at the same time keep the price of cobalt down so as to meet the challenge of nickel, the chief competitor, which sells for less than half the price of cobalt. Cobalt is used chiefly in the production of high-speed steels, high-temperature alloys, and permanent magnet alloys. Lesser quantities are used in bonding porcelain enamels to metal, as driers in paints, and in animal feeds.

In Canada the principal cobalt minerals occurring abundantly enough to be recognizable to the ordinary observer are the arsenides and sulpharsenides such as smaltite $(Co, Ni)As_2$, skutterudite $(Co, Ni)As_3$ (25) and cobaltite, CoAsS, which are found at the silver camps of Cobalt-Gowganda and in the uraniferous veins of Great Bear Lake.

In Canada, as elsewhere in the world, cobalt is a by-product of other metal mining. About 90 per cent of the cobalt produced in Canada comes from the refining of copper-nickel ores (29) derived from the Sudbury area of Ontario, and the Lynn Lake area of Manitoba, where cobalt occurs in small amounts in the sulphide ores. Cobalt-Gowganda still makes a substantial contribution—about 10 per cent—to Canadian cobalt production.

COPPER

References: A, B

Killin, A.F. (1959): Survey of the Copper Industry in Canada in 1959; Mineral Resources Div., Dept. Mines, Tech. Surv., Bull. M.R. 47.

In 1959 Canada produced nearly 400,000 tons of copper from 35 mines, to rank fifth among copper-producing nations in the world, behind the United States, Chile, U.S.S.R., and Northern Rhodesia. Consumption of copper in Canada was approximately 130,000 tons. The remainder was exported, mainly to the United States and Britain. The present (1961) small oversupply of copper on world markets has adversely affected development of several potential deposits. However, there is an annual increase in demand for copper and it is estimated that present Free World consumption of 4 million tons annually will rise to 6 million by 1970.

Chalcopyrite (27), $CuFeS_2$, is by far the most important ore mineral of copper in Canada. Bornite, Cu_5FeS_4, and chalcocite (26), Cu_2S, locally enrich many deposits in the Cordillera. Tetrahedrite, $Cu_{12}Sb_4S_{13}$, is also an important ore mineral or copper, particularly in deposits containing lead, zinc and silver. Although supergene copper minerals such as cuprite, Cu_2O, native copper (28), malachite, $CuCO_3.Cu(OH)_2$, and azurite, $2CuCO_3.Cu(OH)_2$, occur widely on weathered outcrops, they are not economically important in Canada because intense glaciation has removed the upper oxidized parts of most deposits. Copper sulphides are commonly associated with sulphides of iron, nickel (29), cobalt, lead and zinc (30).

Deposits of many types have been mined for copper in Canada. Current production comes largely from massive sulphide replacement bodies where the copper may be accompanied by gold, as in the Noranda area of Quebec; by zinc, as at Flin Flon, Manitoba, Normetal, Quebec, Manitouwadge, Ontario, and Britannia, British Columbia; or by lead and zinc as at Buchans, Newfoundland. The nickel-bearing sulphide deposits associated with basic rocks at Sudbury, Ontario, and Lynn Lake and Thompson, Manitoba, produce more than one third of Canada's copper. Sulphide replacement veins in the Chibougamau area and the Eastern Townships of Quebec, have produced significant amounts of copper. In Quebec's largest copper mine at Murdochville in the Gaspé Peninsula, disseminated sulphides form the ore, as they did also at Copper Mountain, a former large producer in southern British Columbia. These last two deposits show some of the characteristics of contact-metamorphic skarn deposits. Smaller higher-grade deposits of this type have produced from time to time in southern British Columbia and on Vancouver Island.

Large deposits of copper ores of lower grade are available in Canada and will be mined when demand and price increase. Very large replacement deposits near Bathurst, New Brunswick and huge reserves in producing camps are capable of greatly increased production.

DIATOMACEOUS EARTH

References: C

Eardley-Wilmot, V.L. (1928): Diatomite, Its Occurrence, Preparation and Uses; Mines Branch, Canada Dept. Mines, Pub. 691.

Diatomaceous earth is a lightweight porous material that is used principally as an industrial filtrant and as a filler and extender for paints, plastics and other products. Canada imports about 30,000 tons annually, chiefly from the United States which is the world's largest producer. Domestic production is negligible.

The terms 'diatomaceous earth', 'diatomite' (31) and 'kieselguhr' are all applied synonymously to marine or fresh-water sediments that are composed essentially of residual siliceous shells of diatoms, which are microscopic flowerless plants. Under certain conditions sediments form consisting almost entirely of these fossil diatoms. Such sediments in the process of formation today are of limited economic importance. The largest commercial diatomite deposits occur as earthy to compact beds of chalk-like material ranging in age to the Upper Tertiary, when diatom growth appears to have been especially prolific. The great diatomite beds in California are of Miocene and Lower Pliocene age. Large deposits are commonly associated with volcanics. Crude diatomite contains abundant free water and usually alumina, iron oxides and lime; specifications vary according to its uses but pre-drying is always necessary. It is due to the porous nature and inertness of the minute diatom structures that diatomite finds important applications as a filtering medium.

Major producers of diatomite are the United States, West Germany, Denmark, France, Algeria and England. In Canada, diatomite occurs mainly in British Columbia and in the Maritimes. The largest deposits are in rocks of Tertiary age in the Quesnel River region, British Columbia, where compact beds up to 60 feet thick are exposed along the valleys of the Fraser and Quesnel Rivers. Numerous small deposits underlying lakes or in marshy ground occur in Nova Scotia and New Brunswick. Other deposits are known in Ontario, Quebec and Newfoundland.

Diatomite has many industrial uses, and large high-grade deposits close to markets would be of economic interest.

FELDSPAR

References: A, C

Spence, H.S. (1932): Feldspar; Mines Branch, Canada Dept. Mines, Pub. No. 731.

Production of feldspar in Canada has averaged about 19, 000 tons annually since 1952. About half of this is exported, mainly to the United States, and the remainder is consumed in Canada in the manufacture of pottery, clay products, glass and, to a lesser extent, scouring powder and porcelain enamel. Numerous deposits, potential overproduction, and competition from other products, have kept the selling price of feldspar low. Pottery manufacturers must evaluate each new supply of feldspar by means of exhaustive tests, and reliable delivery of a uniform product over long periods of time is essential for many markets.

Microcline (32), $KAlSi_3O_8$, and to a lesser extent albite (33), $NaAlSi_3O_8$, are the feldspar minerals that are used industrially. These are of value in the ceramics and glass industries because of their alumina, potash and soda contents, and their relatively low firing-temperatures. Feldspars find use as scouring powders because of their suitable hardness and the angular shape of the fragments.

Although feldspars are among the most abundant minerals of the earth's crust, only coarse pegmatites from which individual crystals or zones of feldspar can be selectively mined or hand sorted are of commercial interest. Almost all of the feldspar produced in Canada has come from granite pegmatites in southeastern Ontario and southwestern Quebec. Production in recent years has been largely confined to the area near Buckingham, Quebec. Some feldspar is produced as a by-product from lithium operations near Val d'Or, Quebec, and some electrostatically beneficiated, glass-grade feldspar has been shipped from Baie Johan Beetz in eastern Quebec.

Nepheline syenite (20) is finding increasing use as a substitute for feldspar in the manufacture of ceramics and glass. Its principal advantages include a lower firing-temperature, higher content of alumina, absence of free quartz, and a generally more uniform product. Talc (104) and pyrophyllite (21) have also captured former feldspar markets. Feldspar production in Canada is not expected to increase to any large extent in the future.

FLUORITE (Fluorspar)

References: A

Wilson, M.E. (1929): Fluorspar Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 6.

Fluorite is consumed as a flux in steelmaking, in ceramics, and as the raw material for the growing fluorine chemical industry. In aluminium production, about 150 pounds of fluorite is consumed in preparing artificial cryolite and aluminium fluoride for each ton of aluminium produced. Canadian production in 1960, valued at about $2 million, was derived mainly from St. Lawrence, Newfoundland, with some production from Madoc, Ontario. Production could be increased if further markets could be developed in competition with Mexican fluorite.

Fluorite (34), CaF_2, commonly occurs as attractive cubic or octahedral crystals of varied colours, usually blue, green, or purple. It may also occur in cleavable, granular and even fibrous masses.

Fluorite deposits comprise two main classes; namely veins in granite, and veins and replacement deposits in limestone. The first class is represented by deposits in southeast Newfoundland and the Rock Candy mine in southern British Columbia. These deposits have a quartz gangue and were probably formed at fairly high temperatures. Fissure veins and replacement deposits in limestone, on the other hand, were probably formed at low temperatures and the fluorite is normally accompanied by calcite, barite, celestite, galena, sphalerite, and pyrite. Fissure veins of this class occur at Madoc, Ontario; replacement deposits are known near Liard Hot Springs and elsewhere in northeastern British Columbia. Low-grade fluorite deposits are known near Lake Ainslie, Cape Breton Island.

The rapid increase in world consumption of fluorite suggests that as high-grade deposits are exhausted, lower-grade material will be used and more effort will be made to recover the large tonnages of fluorine compounds now wasted during the treatment of phosphate rock. Consumption of fluorite per ton of steel and aluminium produced will probably continue to decline as technical improvements are made, but the increasing demands of the fluorine chemical industry are expected to continue.

FUELS

References: The Coal Mining Industry; Dom. Bur. Statistics, (published annually).

Coal Reserves of Canada; Geol. Surv., Canada.

Current coal production in Canada is some 10 million tons—3 million tons less than the amount imported, chiefly from the United States. From a high of 19.1 million tons in 1950, coal production steadily decreased to 10.6 million tons in 1959, where it appears to have levelled off. This decrease has been mainly due to loss of markets to oil and natural gas. Major markets that coal has retained include: fuel for thermal power plants; for conversion to metallurgical coke; and heating plants for light and heavy industry. Most forecasts predict that coal will continue to compete successfully in these markets and this should result in an increased consumption and production of coal for at least the next 25 years. These predictions are tempered somewhat by the uncertainty as to when and to what extent nuclear energy will be able to compete in the same markets, especially that of thermal power plants.

Coal is classified according to the degree of alteration that it has undergone from the original peaty material (38). There are four main classes that range upward from the lignitic class (37), through the sub-bituminous (36) and bituminous classes (35), to the anthracitic class. The lower-class coals (lignitic and sub-bituminous) are termed 'low rank' and the higher-class coals (bituminous and anthracitic) are termed 'high rank'. The low-rank coals have a greater moisture-and-volatile-matter content and a smaller heat value than do the high-rank coals. Rank is not an indication of quality. High-rank coals may be poor in quality because of a high ash or sulphur content whereas some low-rank coals may be of very high quality. It is possible to beneficiate a coal and improve its quality but it is impossible to alter its rank. Each coal must be properly sampled and tested in a laboratory before its rank can be determined.

Coal reserves in Canada are estimated to be some 94 billion tons. The three western provinces of Saskatchewan, Alberta and British Columbia contain 95 per cent of the reserves, with Alberta alone accounting for 51 per cent. Nova Scotia, with only 3 per cent of the reserves, accounts for about 50 per cent of the production. The more readily accessible coal in Nova Scotia has been mined and the remaining reserves are mainly under the sea, which makes it increasingly more difficult and costly to recover. Reserves in Western Canada are ample to fill needs there for a long time to come. Unfortunately for Canadian coal producers in both the east and the west, the greatest coal-consuming area in Canada (southern Ontario) finds it more economic to use American coal than Canadian coal.

Coals of all ranks occur in Canada. The seams are contained in sedimentary rocks ranging in age from Devonian to Tertiary, but no deposits older than Pennsylvanian are known to be economic. The chart that follows shows the age and distribution of the various coalfields and coal areas in Canada.

Class	Province	Age	Coalfields or Coal Areas
Anthracitic	Alberta	Lower Cretaceous	Canmore area (small pockets in an otherwise bituminous deposit)
	British Columbia	Lower Cretaceous	Groundhog area, Kathlyn Lake area
		Upper Cretaceous	Graham Island (very small deposits)
Bituminous	Nova Scotia	Pennsylvanian	Sydney, Pictou, Springhill, and west coast of Cape Breton Island
	New Brunswick	Pennsylvanian	Minto
	Alberta	Lower Cretaceous	Extending through the Foothills and mountain belts
		Upper Cretaceous	In Foothills belt and Lethbridge area
	British Columbia	Lower Cretaceous	Crowsnest Pass area, Peace River area, and Telkwa area
		Upper Cretaceous	Vancouver Island and Graham Island
		Tertiary	Merritt and White Lake
	Yukon Territory	Lower Cretaceous	Whitehorse, Laberge, and Carmacks areas
	Northwest Territories	Carboniferous to Tertiary	Several occurrences in the Arctic Islands
Sub-bituminous	Alberta	Upper Cretaceous	Throughout most of Plains area
	British Columbia	Tertiary	Princeton area
	Northwest Territories	Carboniferous to Tertiary	Moose River, Pond Inlet, and several other scattered occurrences, especially in the Arctic Islands

Class	Province	Age	Coalfields or Coal Areas
Lignitic	Ontario	Lower Cretaceous	Onakawana
	Manitoba	Tertiary	Turtle Mountain
	Saskatchewan	Tertiary	Estevan and other large areas in south of province
	British Columbia	Tertiary	Hat Creek and Graham Island
	Yukon and Northwest Territories	Tertiary	Several scattered occurrences

GEMSTONES

Reference: B

A wide variety of rocks and minerals are regarded as gemstones. The precious gems—diamond, ruby, sapphire, emerald, and opal—are not known to occur in Canada. Statistics are not available on Canadian production of semi-precious gemstones as these are, in effect, mined by thousands of 'rockhounds' who collect, cut and polish gems, and manufacture jewelry as a hobby. Most gems are used for decorative purposes, mainly in jewelry, but to a smaller extent for vases, statuettes and other art objects, and for exhibit in collections. Low-quality gem diamond is also sold for abrasive purposes. Gem tourmaline has been used as a piezoelectric material, and agate is made into mortar and pestle sets, knife edges for balances, textile rollers, and spatulas. Gemstones are prized for their beauty, durability, and rarity. The beauty may lie in the stone's colour or play of colours and/or in its brilliancy or 'fire'. Colour is the chief attraction in the semi-precious stones and brilliancy or 'fire' is the more important feature in precious stones. Durability or resistance to abrasion is obviously important. Rarity is essential for a precious stone, but as in the case of diamond the rarity may be more apparent than real.

Although more than a hundred minerals have been used as gemstones, only five of common use in Canada will be mentioned here. Agate (39) is perhaps the most popular gemstone found in Canada. Its commonly delicate banding results from intermittent deposition of silica from solutions in irregular cavities in rocks. Other varieties of cryptocrystalline quartz include: chalcedony, the pale-coloured variety; carnelian and plasma, the red and green varieties; chrysoprase, the apple-green variety; jasper, mostly red and brown; and onyx and sardonyx, the black-and-white and red-and-white banded agates. Amazonstone (40), the apple-green microcline, and labradorite (42), with its iridescent blues and greens, are species of the feldspar group from which gems are cut and polished. Jade (41), the most mystical of the gemstones, was first used in China at or about 2600 B.C. It ranges in colour from white through all shades of green, and even to red; a peacock-feather green is the most precious. Two mineral varieties of jade are: jadeite, the sodium aluminium pyroxene; and more commonly, nephrite, a compact fine-grained tremolite or actinolite variety of amphibole. Sodalite (43), a sodium aluminium silicate containing some of the chloride radical, makes an attractive blue to lavender-blue gem.

Agates are generally found as pebbles along the shores and bottoms of rivers and on beaches. Fine specimens are found at many localities in British Columbia, and along the north shore of Lake Superior and in the Bay of Fundy area. Fine specimens of amazonstone have been obtained in the past from a number of pegmatites in eastern Ontario and adjoining Quebec. Most of these deposits have been mined out and few new sources have been found. Nephrite jade is a product of metamorphism and is found associated with gneisses, schists, serpentines, and metamorphosed limestones. It is more resistant to weathering and abrasion than its enclosing rocks and is generally recovered by collectors as water-worn pebbles and boulders. The Fraser River Valley in British Columbia yields hundreds of pounds of jade to collectors annually. Labradorite is named for its occurrence in eastern Labrador where it is found as large cleavable masses in anorthosites. The best gem material comes from Tabor's Island where a quarry was operated for a number of years by the Grenfell Mission. Sodalite occurs only in silica-deficient nepheline rocks, the principal locality being the Princess quarry and other deposits in the Bancroft-Haliburton area of Ontario. Good specimens have also been found in nepheline syenites in the Kicking Horse Pass and Ice River areas of British Columbia.

GERMANIUM AND GALLIUM

Reference: B

Although neither of these metals is produced in Canada they are regarded as possible products of the mineral industry. No reliable statistics are available concerning world production of germanium and gallium. In 1959, an estimated 45,000 pounds of germanium was consumed in the United States, mainly in the electronics industries where its main use is in the manufacturing of transistors, diodes, and power rectifiers. Gallium is produced intermittently in the United States. Production reached a maximum of 200 pounds in 1948, and it is estimated that a production of 100 tons per year could be readily attained. Gallium has numerous uses but they involve very small quantities of the metal and for all of them there are other metals that can be substituted.

The principal mineral in which germanium is an essential constituent is germanite—a complex sulphide-arsenide which also contains copper, iron, zinc and gallium. The main occurrence of germanium, however, is as a minor constituent in several minerals of which sphalerite (119) is the most important. Gallium occurs in the earth's crust in about the same proportion as lead but is less favourably concentrated in deposits. In addition to being found in germanite, small amounts of gallium have been detected in many minerals, and the metal may be extracted as a by-product from ores of aluminium (6), copper, tin, and zinc (119). Both germanium and gallium have been found in coal ashes and have been recovered from the ashes from power-plants in Britain.

Germanite is relatively abundant in the copper ores of Mansfeld, Germany, and occurs in highest concentrations in the copper-lead-zinc ores of Tsumeb, South West Africa. In the United States, germanium and gallium have been recovered as by-products of the refining of zinc ores from the Tri-State district of Missouri-Kansas-Oklahoma.

The outlook for germanium and gallium is highly speculative, and a bright future depends on development of new major uses for these metals. The by-product relationship between these metals and zinc suggests that an adequate production level could be attained if demand should increase.

GOLD

References: A, B

Cooke, H.C. (1946): Canadian Lode Gold Areas; Geol. Surv., Canada, Econ. Geol. Ser. No. 15.

Reflecting the effects of a fixed price and continued postwar inflation of costs, the relative importance of gold mining in Canada has declined in recent years. In 1959 it had fallen to sixth place in value among Canada's mineral products. Since the price of gold in effect varies inversely as the price of everything else, periods of deflation stimulate gold mining. During the great depression of the thirties gold ranked second only to wheat as the most important single item in Canada's economy.

For the past 10 years, annual gold production in Canada has been in the neighbourhood of 4,400,000 ounces, with a value of some $150 million. By producing 10 per cent of the world's gold, Canada is second to South Africa in Free World production.

Gold occupies a unique place among mineral products because of its monetary status. Most of the gold produced goes directly to governmental institutions to provide stability for paper currencies and to be used in settling international trade balances. Some gold is used in jewelry, and in scientific instruments where extreme resistance to corrosion is required.

Almost 85 per cent of the gold mined in Canada is found in auriferous quartz veins (44); more than 13 per cent comes as a by-product of base-metal mining operations; and the remaining 2 per cent is derived from placer deposits (45). Significant placer production is now virtually restricted to the Yukon. With increased base-metal production, by-product gold has increased in importance in recent years. Virtually all gold occurs as the native metal, alloyed with various amounts of silver. In some camps—Kirkland Lake and Rouyn for example—a significant amount of gold occurs as tellurides such as sylvanite, $(Au, Ag)Te_2$, and calaverite, $AuTe_2$.

Auriferous quartz veins are widely distributed in Canada. They are found in all the geologically more complex parts of the country—in particular the Canadian Shield, the Western Cordillera, and the Acadian region. The veins range from relatively simple fracture-fillings to complex vein-swarms and stock-works with extensive carbonate wall-rock alteration. Most of the important groups of deposits, or gold camps, belong in the second category. A spatial relationship, either genetic or structural, between veins and granites or acid intrusive bodies, is common.

GRAPHITE

References: A (1957), C

Spence, H.S. (1920): Graphite; Mines Branch, Canada Dept. Mines, Pub. No. 511.

Graphite is classified for industry by grain size and physical character, into lump, amorphous, or flake grades. Principal uses include foundry facings, steel production, lubricants, crucibles, batteries, pencils, and carbon brushes for small electric motors. Canada has produced no natural graphite since 1954 when the Black Donald mine was closed after 58 years of almost continuous operation. Artificial graphite is produced at Welland, Ontario. Canadian imports are mainly derived from Mexico, United States, Norway, and Ceylon.

Carbon crystallizes as either tightly bound atoms in the isometric system (diamond) or loosely bound hexagonal plates or layers in the hexagonal system (graphite). This structural difference accounts for the divergent physical properties of the minerals. Graphite (46) has a perfect cleavage, feels greasy, is soft and sectile, is inert to most reagents, and is a good thermal and electrical conductor.

Graphite occurs in metamorphosed gneisses and marbles, in veins, and in some meteorites. Major Canadian deposits are in Grenville rocks and are metasomatic replacement deposits in silicated marble at contacts with quartz-rich beds. At the Black Donald mine, Renfrew area, Ontario ore was extracted from a conformable graphite zone up to 70 feet thick and grading from 22 to 80 per cent graphite. Disseminated graphite in siliceous gneiss or marble is common, but only large lenses of above-average grade are normally mined. Contact-metamorphic deposits in altered marble are less common, but are represented in Ontario and Quebec. Fissure veins in the Buckingham district, Quebec, are not known to be of economic value. Bedded deposits formed by the metamorphism of coal are important in Italy and elsewhere, and graphitic anthracite occurs at Lepreau Harbour, New Brunswick.

Very large world reserves of graphite are known. Although some promising deposits are known in Canada, no production seems imminent. Uses for graphite are not notably increasing, but graphite is not likely to be replaced by alternative materials.

GYPSUM

References: Collins, R.K. (1959): The Canadian Gypsum Industry; Mines Branch, Dept. Mines. Tech. Surv., Info. Circ. 114.

Goodman, N.R., Campbell, C.O., Zaskalicky, M.F., Hunt, G.R., Baird, D.M., Brownell, G.M., et al. (1957): "Gypsum" in Geology of Canadian Industrial Mineral Deposits; Can. Inst. Min. Met., Congr. Vol., pp. 110-137.

Gypsum, when heated, loses most of its water and becomes plaster of paris or calcined gypsum. In this form, about 70 per cent of the gypsum consumed in 1958 in Canada was used in wallboard, lath, plasters, and other building products. Most of the remainder was used as uncalcined gypsum added to portland cement in amounts from 3 to 6 per cent, to retard setting and increase strength. Canadian gypsum production of almost 6 million tons in 1959, valued at $8.9 million, represents a remarkable increase since World War II. Nova Scotia contributed about 85 per cent of this production. Although about 81 per cent of the crude gypsum in 1959 was exported to the United States, the value of gypsum products manufactured in Canada in 1958 was almost $37 million. Consumption of products depends on the demands of the domestic building industry.

The occurrence of gypsum (47), $CaSO_4.2H_2O$, and anhydrite, $CaSO_4$, as evaporite beds in limestone is discussed more fully under "Salt". Massive, fine-grained to sugary textures are most common, and coarse crystals (selenite) and fibrous varieties (satin spar) are seldom of economic value. Commercial deposits of gypsum are normally found within a few hundred feet of the surface and are commonly underlain by anhydrite. Similarly, beds of gypsum when traced to deeper levels are transitional to anhydrite. Anhydrite, clay and limestone, and glacial debris introduced from the surface into sink-holes and channels are common impurities. Deposits commonly show internal structural complexities caused by the increase in volume when anhydrite was hydrated to gypsum.

In Canada, gypsum has a similar distribution to salt, but is more widespread. The Maritime beds are Mississippian in age, those in southern Ontario are Silurian, those producing in southern Manitoba are thought to be both Jurassic and Silurian or Devonian, and abundant anhydrite exists in the Middle Devonian of the Prairie Provinces. In southeastern British Columbia, producing gypsum beds are Middle Devonian. Piercement domes in the Canadian Arctic expose gypsum and anhydrite.

Future outlook for gypsum relates to the demands of domestic building construction and export markets. Maritime deposits are well qualified for competitive export trade, and deposits such as those on the Magdalen Islands, Quebec, may eventually be called on. In common with many industrial minerals, the low unit-value makes transportation cost a major factor in the economics of gypsum.

INDIUM

References: A, B

Ludwick, M.L. (1950): Indium; Indium Corporation of America.

Indium somewhat resembles tin in its properties and its uses are still under development. Chief applications at present are in transistors, sleeve-type bearings and special low-melting alloys. The United States is the main consumer, having found markets for an estimated 20 tons of indium in the peak year, 1957. In the same year, the Consolidated Mining and Smelting Company of Canada, Limited, produced an estimated 13 tons and exported most of it to the United States and Britain.

Although indium occurs in the earth's crust in about the same abundance as silver it is considerably more dispersed and no deposits have been found that are rich enough to mine for indium alone. Sphalerite (117, 118, 119), the principal ore mineral of zinc, is the commercial source of indium.

Canada's production of indium comes entirely from the refining of zinc ore at the Sullivan mine in southeastern British Columbia.

The outlook for continued growth of the indium industry is favourable.

INSULATING MATERIALS

References: C

Goudge, M.F. (1932): Raw Materials for the Manufacture of Rock Wool in the Niagara Peninsula, Ontario; Mines Branch, Canada Dept. Mines, Rept. No. 727, pp. 93-106.

Various minerals, rocks and by-products are used in natural or processed forms for thermal insulation against heat and cold, for acoustic insulation against noise, or for electrical insulation. Thermal and acoustic insulators find their greatest market in the building industry. They also have many industrial applications. Canada, with its extreme temperatures, is a major consumer of thermal insulators. In 1960, for building insulation, Canada produced about 8 million cubic feet of loose and granulated mineral wool, about 160 million square feet of 2-inch mineral-wool batts, several millions of square feet of batts of other thicknesses, and between 300, 000 and 400, 000 cubic yards of expanded vermiculite. Asbestos is well known for its fire-retardant properties, and large quantities are employed in the manufacture of fire-resistant paper, sheeting, cloth, etc. Diatomite is used in refractory and general insulating blocks, and expanded perlite in acoustic plaster and tile and as loose insulation. Mica (63, 64) is used as an electrical insulator.

Mineral wool consists of delicate fibres of silicate glass which are produced by directing a blast of steam or air at a stream of silicate melt and driving it off in tiny globules which develop hair-like filaments in their flight. Mineral wool includes rock wool, slag wool, and glass wool. Inexpensive accessible sources of silica, lime, alumina and magnesia are the essential ingredients. Combinations of limestone, dolomite, shale and sandstone, as well as a variety of other substances may be used for rock-wool manufacture. Some impure limestones and dolomites have nearly the correct chemical composition and are termed 'wool rock'. Since about 1946, rock wool has been largely replaced by slag wool, slag being preferred because of its easier melting qualities. Slag wool is produced from iron blast-furnace slag, which produces a white wool, or from lead- and copper-refining slags, which because of their high iron content produce a greyish wool. To achieve the desired SiO_2 content in slag wool, gravel, granite chips or waste silica rock may be added to the melt. Glass wool, as the term would imply, is made from a glass melt, the ingredients being essentially those used in the manufacture of glass. Principal among these is glass sand. Sand, sandstone, limestone, dolomite and shale are also used.

IRON

Reference: A

Canada was fifth in world production of iron in 1959 and produced nearly 22 million tons worth $186 million. Consumption in Canada was nearly 6 million tons, part of which was imported from the United States. Most Canadian production was exported to the United States with lesser amounts to Britain, European countries, and Japan. When the Labrador deposits were opened in 1955, production jumped from 6.5 to 14.5 million tons in one year. It is estimated that Canadian production will at least double in the next decade.

Iron ores are classified as direct-shipping type, requiring at most to be dried and screened before shipping; and low-grade beneficiating type that requires extensive concentration before shipping. Principal minerals are: hematite, Fe_2O_3, which varies from the red earthy type (48) of direct-shipping ore, to the crystalline specular type (49) in iron-formations; goethite (50), $HFeO_2$, yellow hydrated iron oxide also known as limonite; magnetite (51), Fe_3O_4, a good source of iron when free from titanium; siderite (53), $FeCO_3$; pyrite (101), FeS_2, and pyrrhotite (52), FeS; and ilmenite $FeTiO_3$.

Most known types of iron-ore deposits are represented in Canada. Massive oolitic-textured hematite-siderite-chamosite beds interbanded with black slate, crop out at Wabana on Bell Island, Newfoundland, and are mined 3 miles under the sea. Iron ranges, similar in many respects to those south of Lake Superior, extend almost continuously for 750 miles along the western side of the Labrador geosyncline from Hudson Strait southward to Wabush Lake and westward beyond the Mushalagan River. About 45 ore deposits are located in the central part of this belt in the Schefferville-Knob Lake area. Pockets of rubbly hematite and goethite ore have been derived from fine-grained cherty iron-formation through leaching of the silica and redistribution of the iron by ground waters. Iron deposits being developed in the Wabush Lake-Mount Wright and Jeannine Lake area of Labrador and Quebec, consist of highly metamorphosed iron-formations composed of coarse-grained hematite, magnetite, and quartz that can be easily concentrated. Steeply dipping, tabular to lenticular masses of hematite and goethite associated with carbonate beds and volcanic rocks form large deposits of ore in the Steep Rock iron ranges in Ontario. Bands and lenticular masses of widely banded to massive siderite iron-formation have been mined for more than 20 years in Michipicoten, Ontario.

Canada has very large potential reserves of iron ore. The largest are the metamorphosed iron-formations in the southern part of the Labrador belt and others west of Ungava Bay. Four beds of Keewatin- type iron-formation have been selected for development from more than 100 of this type in south-central Canada, and substantial reserves of fine-grained iron-formation are known in the Albanel Lake region, Quebec. Vast amounts of iron are present in the complex magnetite-ilmenite-hematite differentiates within large masses of gabbro and anorthosite in Eastern Canada. These will be mined when extraction processes are perfected. Large amounts of direct-shipping ore are available in the Steeprock Range and there are extensive reserves of siderite ore in Michipicoten. Small deposits of oolite-siderite ore in the Foothills of Alberta are important because of their proximity to fuels. Magnetite bodies in British Columbia provide iron for export to Japan. Finally, iron is now a potential by-product of large copper, nickel and lead-zinc mines containing abundant pyrite and pyrrhotite.

LEAD

References: A

Alcock, F.J. (1930): Zinc and Lead Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 8.

In recent years Canada has ranked fifth among world lead-producers. Production in 1959 was 186,495 tons, two thirds of which was exported. The United States, Britain and West Germany in that order were the principal buyers. Important uses of lead are in storage batteries, anti-knock compounds for gasolines, and cable coverings. Recently developed uses in radiation shielding for nuclear reactors as well as sound and vibration control in jets and air-conditioning machinery act to offset declining consumption in some of the older uses, as for instance the substitution of plastics in cable coverings.

The principal ore mineral of lead is galena (54, 55), PbS, characterized by its silvery colour and cubic cleavage. Very commonly it is associated with sphalerite—the principal zinc mineral—and most lead mines produce some or a great deal of zinc as well. Galena commonly occurs with silver minerals, and much lead is produced as a by-product of silver mining. Lead-antimony sulphides (8) are the only other ore minerals of importance in Canada, although cerussite (the lead carbonate), and anglesite (the sulphate), may occur in the weathered zone of lead deposits and have formed valuable deposits elsewhere in the world.

The bulk of Canadian lead production comes from the Sullivan mine in southeastern British Columbia—a large bedded sulphide replacement deposit in metamorphosed argillaceous sediments. Lead has been produced from complex copper-zinc-lead sulphide replacement bodies in sheared volcanic rocks at Buchans, Newfoundland, and Tulsequah, British Columbia. Similar replacement bodies in mixed volcanic and sedimentary terrains in New Brunswick, Yukon and northeastern Ontario contain considerable reserves of lead. Silver has been the principal metal of value in certain complex sulphide replacement veins at Mayo, Yukon, and Slocan, British Columbia, from which large quantities of lead have also been produced. Replacement deposits of galena and sphalerite in relatively undisturbed dolomitic limestones are probably the most common type of lead deposit throughout the world; very large reserves of this type exist at Pine Point on the south shore of Great Slave Lake.

Very large deposits of lead are available in Canada to meet the foreseeable demand for many decades. Because there is a current oversupply of lead, attempts were being made in 1961 to reduce output on a voluntary basis. It seems probable, therefore, that new production of lead in Canada in the near future is likely to be as a by-product of copper, zinc or silver mining.

LIMESTONE

Reference: Hewitt, D.F. (1960): The Limestone Industries of Ontario; Ont. Dept. Mines, Industrial Circ. No. 5.

The principal uses of limestone, as illustrated by Ontario production in 1957, are: crushed stone for construction (68 per cent), cement manufacture (14 per cent), the lime industry (7 per cent), and metallurgical flux (6 per cent). Minor uses are in the pulp and paper industry, in agriculture, in glass manufacturing, as a whiting substitute, and as a filler. Canada is fortunate in having ample supplies of limestone in regions of dense population. The supply of high-purity calcium limestone for chemical uses, although adequate, is limited; there is a continuing search for sources of high-quality limestone.

Limestone in its purest form is calcite (56), $CaCO_3$, but it generally contains varying amounts of magnesia, alumina, and other contaminants. Specifications and prices vary for the many different uses to which it is put; it is advisable therefore, to check physical and chemical properties of limestone from each quarry, and in some areas, from different strata within the quarry.

Limestone is a sedimentary rock that has generally formed under marine conditions. Much of the limestone used in the Prairies and Eastern Canada is of Palaeozoic age and has not been subject to metamorphism. Marble (65) is a metamorphic equivalent of limestone that varies greatly in composition, colour and grain size. Marl is an unconsolidated aggregate of calcareous loam, clay, or sand, used primarily in agriculture.

Limestone is abundant in Canada, yet we import from the United States more than we export. This is due in part to the fact that it enters Canada free of duty, whereas a duty of 1 1/4 cents per 100 pounds is imposed on limestone entering the United States. Limestone is imported into Canada in places like Saskatchewan, Sault Ste. Marie and Trail, where stone of suitable quality is closer at hand south of the border. It is apparent that prospecting for limestone—of the type that can meet modern specifications for various uses—is justified, particularly in the areas in which limestone is imported.

LITHIUM

Reference: A

A young and promising lithium industry in Canada is currently (1961) undergoing a period of reappraisal following cancellation of contracts for shipments of spodumene concentrates to the United States. Reserves of lithium ore at two major Canadian deposits are estimated at 20 million tons containing 1.15 per cent Li_2O, and 9 million tons with a grade of more than 2 per cent Li_2O, respectively. The United States is the world's largest manufacturer of lithium compounds, metal and alloys, and in the past has supplied all of Canada's requirements of these products. A small amount of lithium lubricating grease has been produced in Canada, and the first chemical treatment plant for the production of lithium compounds began operating in 1960. Consumption of lithium compounds in the manufacture of ceramics, special glasses and multipurpose greases has increased rapidly in recent years. Other uses for lithium compounds include: electrolyte in alkaline storage batteries; dry-cell batteries for operation at very low temperatures; carbon-dioxide absorbers in submarines and respirators; air-conditioning and refrigeration plants; fluxes for welding aluminium; crystals for optical and X-ray equipment; and activators for certain phosphors. Lithium metal is still relatively unknown in industry but its use in metallurgy as an alloying element and scavenger is increasing.

The chief ore minerals of lithium are: spodumene (57), $LiAlSi_2O_6$, containing 4 to 8 per cent Li_2O; lepidolite (87), a mica containing 3 to 5 per cent Li_2O; and amblygonite, $LiAlFPO_4$, containing 8 to 10 per cent Li_2O. Less important lithium-bearing minerals commonly associated with the ore minerals are: petalite, a lithium-aluminium silicate; triphylite-lithiophylite, phosphates of lithium, iron and manganese; and zinnwaldite, a lithium mica. A large part of the United States production is in the form of lithium sodium phosphate recovered from the crude brines of Searles Lake, California, as a by-product of the salt industry.

Canada's main lithium deposits, in Lacorne township, Quebec, and at Bernic Lake, southeastern Manitoba, are pegmatites which contain spodumene as the main ore mineral, smaller amounts of lepidolite and amblygonite, and minor amounts of other lithium-bearing minerals. The Bernic Lake deposit also contains the world's largest concentration of the caesium-rich mineral, pollucite (20). Lithium-bearing pegmatites are also known in the Yellowknife-Beaulieu area, District of Mackenzie, and the Thunder Bay district of Ontario.

MAGNESIUM

Reference: A

Magnesium, with a density of 1.74, is the lightest of the structural metals. It is used mainly in the production of lightweight alloys and to a lesser extent as a reducing agent in the production of zirconium, titanium, beryllium and uranium. World production of magnesium in 1959 was estimated to be 104,300 tons. Of this, Canada produced 5,817 tons, or 5.5 per cent, of which most was exported. Major world producers of magnesium are the United States, Norway and the U.S.S.R.

The chief commercial source of magnesium is raw sea-water (0.13 per cent magnesium); other important sources are evaporite deposits and natural brines. In Canada, dolomite (59), $CaMg(CO_3)_2$, is the principal source of magnesium. Dolomite theoretically contains 21.9 per cent MgO and only those sources approaching this figure are likely to be of commercial importance as ores of magnesium. Magnesite, $MgCO_3$, and brucite (58), $Mg(OH)_2$, have also been used for the production of magnesium; but while they continue to represent important sources they are now used mainly for refractories. Other possible sources of magnesium are carnallite, $KCl.MgCl.6H_2O$, serpentine, $H_4Mg_3Si_2O_9$, and olivine, $Mg_2Fe_2SiO_4$. Scrap metal provides a secondary source.

Sea water represents the largest exploitable source of magnesium in the world. Dolomite occurs in rocks of all ages and deposits of it are widespread throughout the globe. In Canada, dolomite and brucite are the only raw materials that have been used for the commercial production of metal. High-purity dolomite is in abundant domestic supply, particularly in Ontario and Manitoba. One extensive deposit, averaging nearly 21 per cent MgO, is quarried near Haley Station, Ontario as the ore for the nearby plant of Dominion Magnesium Limited (DOMAL). Deposits of brucitic limestone and dolomite occur in Quebec, Ontario and British Columbia. In these, the brucite typically occurs as granules 1 to 5 mm in diameter. Until suspension of its operations in 1959, the Magnesium Company of Canada Limited (MAGCAN) produced magnesium at Arvida, Quebec, from brucite obtained at its deposit near Wakefield, Quebec.

The other potential and possible sources of magnesium in plentiful supply in Canada (additional to sea water) are: deposits of magnesite and hydromagnesite in British Columbia and the Yukon; magnesitic dolomite in Quebec; serpentine in Quebec, Ontario and British Columbia; olivine in Quebec and British Columbia; and carnallite in Saskatchewan. Magnesium chloride and magnesium sulphate occur in some alkali lakes in Saskatchewan, associated with sodium sulphate. Canada therefore, has abundant natural sources of magnesium, in many forms. However, apart from sea water, dolomite and possibly brucite are likely to constitute the only competitive domestic sources in the foreseeable future. There seems to be little incentive to search for dolomite deposits, but brucite would merit attention if only for its use as a refractory.

MANGANESE

References: A, B

Hanson, G. (1956): "Manganese in Canada" in Symposium Sobre Yacimientos de Manganeso; XX Internat. Geol. Congr., vol. 3, pp. 9-14.

Canada has produced no manganese in recent years, and domestic production in the United States, despite strong federal measures to encourage development, comprised only 1 per cent of her consumption in 1959. About 13 pounds of manganese, mainly in the form of ferromanganese, is used in producing each short ton of steel. Slightly more than 95 per cent of the total American consumption is used in producing steel and manganese alloys and metals. The balance is consumed in chemicals, batteries, and minor uses. Canadian imports of ore have fluctuated in the 1950-1960 period from extremes of 222,082 tons in 1951 to 42,060 tons in 1958. Major world producers of manganese are the U.S.S.R., India, Union of South Africa and Brazil.

Psilomelane, colloidal MnO_2, and pyrolusite (60), MnO_2, are the principal manganese oxides of commercial ore, but manganite, $MnO(OH)$, and many other oxides are represented as well as braunite, $3MnMnO_3.MnSiO_3$. Rhodochrosite, $MnCO_3$, is a minor ore but has usually been oxidized or altered by metamorphism in major world deposits. Phosphorus and excessive iron, silica, and aluminium are undesirable impurities. The average grade of ore imported into the United States in 1959 was 47.7 per cent manganese. No large tonnages of such material are known in Canada.

Glaciation in Canada has greatly reduced the possibility of finding large, deeply oxidized and enriched manganese deposits derived from underlying manganiferous silicate and carbonate beds or veins. On a small scale, shallow oxidation of beds in volcanic rocks forms small deposits of surface ore near Cowichan Lake, British Columbia. Sedimentary deposits of manganiferous carbonate and shale form basal Middle Cambrian beds in southeast Newfoundland, and Silurian sediments in southwestern New Brunswick and similar beds in Nova Scotia are all low-grade, large deposits of possible future value. Bog deposits are numerous in Eastern Canada and British Columbia. Oxidized replacement and related weathered residual deposits in Windsor limestone are sporadic but have yielded most of Canada's small production at various points in Nova Scotia and New Brunswick. Vein deposits of manganese oxides were formerly mined at New Ross, Nova Scotia.

Because there are no commercial deposits known at present in Canada and because manganese is of strategic importance to Canada and the United States, extensive research is being directed toward the exploitation of low-grade domestic ores. Present technical developments indicate that ferromanganese, silicomanganese, and probably electrolytic manganese could be produced from low-grade Canadian ores. Beneficiated ore of high grade has been experimentally produced. Future developments may lead to commercial exploitation of Canada's large, low-grade deposits.

MERCURY

References: A, B

Armstrong, J.E. (1942): The Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 42-11.

Mercury was produced in Canada during the war years 1942-1944 but production ceased as soon as shipments from Spain could be resumed. Major producers are Spain, Italy and the U.S.S.R. Canada ranks seventh in the world in reserves, but deposits are rather low grade. Mercury is used as a cathode in the preparation of chlorine and caustic soda; in electrical apparatus and control instruments; in various laboratory applications; for precision casting; in insecticides and other agricultural applications; and in a host of other industries. Its prime uses are due to the fact that it is the only metal that is liquid at ordinary temperatures, and therefore for many purposes it has no possible substitute. Supply of mercury is assured at the present rate for the foreseeable future from existing sources. Demand is rising, but only slowly.

Mercury occurs primarily as cinnabar (61), HgS, and less commonly as native mercury; as coloradoite, HgTe; as tiemannite, HgSe; and in various less common minerals.

Mercury deposits are formed at relatively low temperatures and generally near the surface. Most of them are impregnations in sandstone, shale, etc. in areas of recent volcanic and hotspring activity. They are not found in old Shield areas. Principal deposits are at Almaden, Spain, at Monte Amiata, Italy, and in Yugoslavia, the U.S.S.R., United States and Mexico. In Canada, deposits at Pinchi Lake and Takla in northeastern British Columbia produced substantial amounts of mercury from brecciated zones in limestone, dolomite and quartzite adjacent to the Pinchi Lake fault.

If the demand for mercury were to increase very greatly, it might be possible to reopen mines in British Columbia.

MICA

Reference: Hoadley, J.W. (1960): Mica Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 19, 135 pp.

From 1886 to 1920 Canada was the world's chief source of sheet phlogopite mica. Thereafter, production declined due to competition from Madagascar phlogopite and changing economic conditions. A brief resurgence occurred during World War II when Canada became a major producer of sheet muscovite. In 1959, Canadian production of mica was the lowest since 1932, most of the production coming from an operation near Cantley, Hull township, Quebec. The possibilities of a resurgence of the industry are not great because it is almost impossible to produce mica in Canada at prices which will compete successfully with the prices of mica produced in countries where labour costs are much lower. The physical properties of mica, which are the basis of its commercial value, are: perfect basal cleavage which permits a crystal to be split into sheets as thin as one thousandth of an inch; the tough, flexible and elastic nature of mica sheets; and extremely low conductivity for electricity and heat. Sheet mica is used mainly as an electrical insulator. Ground mica is used in the manufacture of roofing products, paint, rubber, plastics, and wallpaper.

The mica group of minerals are essentially silicates of aluminium containing varying proportions of alkalis, magnesium, iron, etc. The most common commercial micas are muscovite (63) or white mica, a potassium-aluminium silicate; and phlogopite (64) or amber mica, a potassium-magnesium-aluminium silicate. Biotite (62), the iron-bearing mica, is of little industrial value. The lithium-bearing micas, lepidolite (87) and zinnwaldite, and a vanadium-bearing mica, roscoelite, are of value for their lithium and vanadium contents and not for the same purposes as the micas already mentioned.

Sheet mica deposits are of two general types: muscovite deposits associated with granite pegmatite; and phlogopite deposits associated with metamorphic pyroxenite, generally in or near calcareous sedimentary rocks. Throughout the world most pegmatites that have been mined successfully for muscovite occur in mica schists and gneisses and in mica-bearing quartzites. The host rocks, however, may be hornblende schists and gneisses, granite, granitic gneiss and, in at least one instance, norite. Phlogopite deposits occur in areas of highly metamorphosed sedimentary rocks that have been intruded by pegmatite-rich granitic rocks. They are always associated with diopsitic pyroxenite and are commonly associated with crystalline limestone.

MINERAL FILLERS

References: A, C

Mineral fillers are added to many products to provide body or reinforcement, to increase stiffness or strength or otherwise modify the physical properties of the products, and in many instances to reduce their costs. Major consumers are the paper, rubber, asphalt, plastic and paint industries. Statistics on the total production and consumption of fillers in Canada are not available, and are difficult to compute because most substances used as fillers are also used in other industries, generally in greater quantities. However, their importance is evidenced by the fact that the United States consumes more than 7 million tons of mineral fillers annually, valued in excess of $100 million. More than one million tons is required there for the paper industry alone.

A large variety of minerals and mineral substances are used as fillers. The more important ones include pulverized limestone (56), slate (86), silica (89, 90, 91), clay (23), asbestos (11), mica (63), talc (103), pyrophyllite (21), barite (14), and diatomite (31). Among others of less importance are feldspar (33), nepheline syenite (20), wollastonite (116), gypsum (47), vermiculite (115), perlite (3), pumicite (4), and bentonite (15). Actually, most industrial minerals in finely divided form and many rock flours may serve as fillers, the main considerations being their availability, cost, and their physical suitability to the processes and to the finished products. The physical properties of particular importance are density, particle size and shape, absorption, porosity, thermal behaviour, and surface characteristics, as well as abrasiveness, which depends both upon the hardness of the mineral and the shape of the particle. Specifications for mineral fillers may be found in reports of various standards assocations, such as the American Association for Testing Materials; some of the large consumers have their own specifications.

The principal mineral fillers used in Canada are pulverized limestone, china clay, asbestos, talc, soapstone, barite, whiting and whiting substitute, although most if not all the others mentioned above are also employed to some extent. Canadian production of talc, soapstone and shorter-fibre grades of asbestos is consumed largely as fillers; production or imports of the others have wider applications in other industries, i.e. nepheline syenite in ceramics and glass, barite in oilwell drilling, etc. (The modes of occurrence, sources, and other uses of all the above-mentioned substances are dealt with in separate or more appropriate sections, which may be ascertained from the index.)

MINERAL PIGMENTS

References: A, C

The principal natural substances used as pigments or extender pigments in paints and other products include the so-called 'mineral earth pigments' such as barite, chalk, and marl, together with natural forms of calcium carbonate to which the terms 'whiting' and 'whiting substitute' are applied. Mineral earth pigments containing iron oxide as their colouring medium have the widest industrial applications, though they must compete with synthetic iron oxides. The paint industry annually consumes about 2,000 tons of synthetic and natural iron-oxide pigments, 1,000 tons of barite, and 15,000 tons of chalk, whiting and whiting substitute. Natural iron-oxide pigments and whiting are discussed below. Barite is described under its own heading.

Naturally occurring iron-oxide pigments are composed essentially of limonite (50), FeO(OH), or hematite (48), Fe_2O_3, with varying proportions of clayey matter; the principal ones are ochre (66), sienna and umber (67). Ochres, which contain more clay than the others, are commonly yellow or red; siennas are yellowish to yellowish brown; and umbers are generally brown. The yellow colours are due to limonite and the reds to hematite; brown umbers are characterized by the presence of considerable manganese. Hues may be darkened or enhanced by calcining. Some highly prized reds are obtained from nearly pure forms of soft hematite. Iron-oxide pigments are generally noted for their covering power, opacity to ultra-violet light, and stability. They are a low-cost product and only large deposits of suitable purity would be of industrial importance, although small deposits could be used locally. The most important properties desired for their use in the paint industry include mass colour, tinting strength, particle size, oil absorption, opacity and chemical composition. The term 'whiting' was originally applied to finely ground chalk, a soft friable limestone. The industrial use of the term has now been extended to include such substitutes as powders derived from marl, marble (65), limestone, and chemically precipitated calcium carbonate. Marble is metamorphosed limestone; marl is an earthy limestone found in lakes, ponds or marshes.

In Canada, deposits of naturally occurring iron-oxide pigments are found in bogs or in swampy or low-lying areas where they have evidently been formed by the precipitation of iron from instreaming waters which have leached their iron from neighbouring rocks. The principal deposits occur near Three Rivers, Quebec, and have been worked almost continuously since 1888. Some production in the past has also come from deposits in Colchester county, Nova Scotia, Portneuf and Labelle counties, Quebec, and from near Westminster, British Columbia. Other occurrences of pigment-grade ochre have been reported from Ontario, Manitoba, Saskatchewan and British Columbia. It is possible that three pigments might be obtained at or near iron-ore deposits or other large concentrations of iron minerals. Ground marble is produced as a whiting substitute from a deposit near Bedford, Missisquoi county, Quebec.

MOLYBDENUM

References: A

Vokes, F.M. (1958): Molybdenum in Canada, Metallogenic Map; Geol. Surv., Canada, Map 1045A-M3.

The United States produces about 80 per cent and consumes about 55 per cent of the world's output of molybdenum. The molybdenite deposit at Climax, Colorado, is the largest single producer, and most of the remainder of the world's production (excluding Russia) is obtained as a by-product of copper mining in the United States and Chile. Production of molybdenite and molybdic oxide in Canada in recent years has averaged about 400 tons of contained molybdenum annually, valued at about $1 million. Most molybdenum is used by the iron and steel industries in the production of ingots and castings. Molybdenum is valued not only because of its own alloying properties, but because it intensifies the effect of, and can partly or wholly replace, other alloying elements such as tungsten, nickel, chromium and vanadium. In addition to its metallurgical uses, molybdenum is used as a refractory metal; and molybdenum compounds are used in lubricants, pesticides, special pigments, dyes, and as a catalyst in the petroleum industry.

The principal ore mineral is molybdenite (68), MoS_2. Molybdenite generally occurs in flat plates or short prisms. Its form, lead-grey colour, and metallic lustre much resemble graphite. Molybdenite, unlike graphite, gives off sulphur-dioxide fumes on heating and has a bluish to greenish grey streak. Other possible ore minerals are: the lead molybdate, wulfenite, $PbMoO_4$; and the hydrated ferric molybdate, molybdite, $3MoO_3.Fe_2O_3.7H_2O$.

Molybdenite occurs either as disseminated grains or tabular crystals in pegmatites, quartz veins, along cracks and joints in granitic rocks, and in contact-metamorphic deposits. Ores are usually of low grade and most of the world's production is from deposits containing less than 1 per cent molybdenite. The minerals wulfenite and molybdite are usually found in the oxidized zones of molybdenite deposits and are not by themselves of commercial importance. Canadian production in 1959 came entirely from molybdenite deposits in the Preissac-Lacorne area of Quebec. Ore reserves in this area are estimated at more than 2 million tons grading more than 0.4 per cent molybdenite. Other areas in which exploration for molybdenum has centred in recent years are the Williams Lake area, British Columbia; DesRosiers township, northwest of Gogama, Ontario; northwest of Beardmore, Little Long Lac area, Ontario; and on upper Sheep Creek, Yukon Territory.

Although known reserves of molybdenum are adequate to meet the needs of Canadian industry in the near future, demand for the metal is likely to increase and new deposits may become of economic importance.

NICKEL

References: A, B

Canada in recent years has produced more than two thirds of the nickel supply of the Free World and for many years produced more than 90 per cent. New Caledonia, and to a lesser extent, Cuba and the United States have produced most of the remainder. Free World production in 1958 was 190,000 tons. Electroplating consumes between 10 and 15 per cent of all nickel produced in the Free World. Most of the remainder is used in alloys, to which nickel contributes toughness and resistance to corrosion. The percentages of nickel consumed in the various types of alloys in 1959 are as follows: stainless steels, 29; high-nickel alloys such as chromel and inconel, 16; nickel-alloy steels, 15; foundry products, 12; and copper-nickel alloys, 4.

Nickel deposits are associated with basic or ultrabasic rocks and may be divided into three types—sulphide, silicate, and laterite ores. Sulphide ores are the only ones of importance in Canada. In these, the principal ore mineral is pentlandite (70), $(Fe, Ni)_9S_8$—a brassy metallic mineral commonly closely associated with the iron sulphide, pyrrhotite, and to a lesser extent with the copper-ore mineral, chalcopyrite. Nickeliferous pyrrhotite (71) is commonly associated with pentlandite and contributes substantially to the nickel content of some ores. Niccolite (69), NiAs, and skutterudite (25), $(Co, Ni)As_3$, are minor ore minerals of nickel.

The world's largest deposits of nickel—at Sudbury, Ontario—are mostly steeply-dipping tabular bodies of massive to disseminated sulphides grouped around the basic outer margin of an oval-shaped compound intrusive body that is nearly 40 miles long. Some orebodies are in contact with the main intrusive mass, others are within a few miles of it. Many show textures suggesting replacement of breccia or rubble dykes. At Lynn Lake, Manitoba, massive sulphide and breccia replacement bodies are associated with faults in, and close to, two steeply-dipping cylindrical masses of basic rocks. At Rankin Inlet, District of Keewatin, disseminated nickel-sulphide ore occurs on the foot-wall side of an ultrabasic sill. A similar but smaller deposit has been found at the Wellgreen prospect in the Yukon. Nickel ore is being produced near Hope, British Columbia, from disseminated sulphide deposits which are roughly pipe-like bodies enclosed in ultrabasic rocks. The most important recent development in nickel production is the opening of the Thomson mine in northern Manitoba, where reserves are estimated to be one-third as large as those of the Sudbury camp. The deposits are in gneisses near bodies of ultrabasic rocks. Gravimetric data suggest that a potential metallogenic province for nickel lies parallel to the Hudson Bay railway in northern Manitoba.

Areas in which nickel may be found are those immediately adjacent to basic or ultrabasic rocks. In such areas nickel is commonly associated with massive or disseminated pyrrhotite, particularly where it is associated with chalcopyrite. Although there is currently an ample supply of nickel, demand for the metal is increasing, and new deposits are likely to be important to Canada's economy.

NIOBIUM (Columbium)

Reference: Rowe, R.B.: Niobium (Columbium) Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 18.

Niobium's economic importance stems from its increased use in high-temperature steel alloys. It is used in amounts of up to 1 per cent to stabilize carbon in chromium steels and to prevent creep at high temperatures. Improvements in metallurgy of steels and an apparent shortage of niobium combined to reduce demand in the decade 1950-1959. However, new uses and adequate supplies have now reversed the trend and prospects for niobium are improving. The price for concentrates declined sharply when the United States ceased stockpiling in 1955 but has remained fairly stable since 1956. The improved status is reflected in the decision taken in 1960, to produce niobium at Oka, Quebec, at a milling rate of 400 tons of ore per day.

The principal ore minerals of niobium are columbite and intermediate members of the columbite-tantalite solid solution series (104), $(Fe, Mn)Nb_2O_6$ - $(Fe, Mn)Ta_2O_6$. Pure columbite contains 82.7 per cent Nb_2O_5. This mineral is commonly associated with others typical of granite pegmatites—albite, lithium silicates, tourmaline, beryl, cassiterite, etc. The pyrochlore (72) series, approximately $(Ca, Na)_2Nb_2O_6.nH_2O$, contains on the average 50 per cent Nb_2O_5 and variable amounts of U, Th, rare earths, and Ta. Betafite is pyrochlore containing more than 15 per cent uranium. Rare-earth concentrates may be a useful by-product from pyrochlore ores. It is only recently that satisfactory methods for economic extraction of Nb_2O_5 from this series were developed. There are many other mineral series containing niobium and tantalum, such as fergusonite, euxenite-polycrase, samarskite, etc., but methods of extraction from these will probably not be studied until large concentrations are found. It should be noted that niobium and tantalum are closely allied geochemically and are often associated with titanium and zirconium. A slightly better price is paid for concentrates containing more than ten parts Nb_2O_5 to one part TaO_5, than for those containing more tantalum. Uranium, thorium and rare-earth elements commonly substitute for Ca, Na, etc. in these minerals. Studies have indicated that the Nb content of bauxite, developed from niobium-rich syenites, is too low to be economic.

Columbite-tantalite is recovered primarily from alluvial deposits of tin in Nigeria (85 per cent), the Belgian Congo (7 per cent) and Malaya. It has also been mined in small amounts from granite pegmatites in Mozambique, Brazil, and the United States. Very large tonnages of pyrochlore are available in carbonatite rocks of East Africa and important tonnages have been proved in Norway and at Oka, Quebec, and on Lake Nipissing, Ontario. Deposits of pyrochlore are being mined at Saxe, Norway, and are being developed for production at Oka, Quebec. Underground development has been done also at Lake Nipissing, Ontario.

In Canada, deposits of pyrochlore in carbonatites associated with alkaline rocks are the most promising sources of niobium. A belt of such rocks extends from Oka, Quebec, to near Chapleau, Ontario. Other deposits are near Manson Creek and Blue River, British Columbia. The only placer occurrences of niobium in Canada are in streams draining the Horsethief and Bugaboo granite stocks northwest of Inverness, British Columbia. Placer deposits in the cordilleran region of British Columbia and the Yukon are a possible source of niobium. Columbite occurs sparsely in pegmatites of the Canadian Shield, but due to recent glaciation it is unlikely to be concentrated in placer deposits there.

PETROLEUM AND NATURAL GAS

Reference: Annual Estimate of Canada's Mineral Production (1960); Dom. Bur. Statistics.

During 1959 Canada produced 185 million barrels of crude oil and 417 billion cubic feet of natural gas with a value of about $460 million, to rank third among the oil-producing nations of the western hemisphere and eighth in the world; although it contributed only about 2.6 per cent of the world's oil output. The location of the principal productive areas far inland has led Canada to export oil and gas to the northern and western United States and to import oil, mainly by tanker, at Atlantic coast and St. Lawrence River ports. The output of natural gas in Canada increased nearly two and one-half times during the period 1956 to 1959 as a result of the completion of major pipeline-construction projects linking productive areas with both domestic and export markets. Further significant increases may be expected upon completion of pipeline projects presently planned or under construction.

Petroleum (74) has many uses, not only as a fuel and a source for lubricating oils and greases, but also in the petrochemical industry in the production of such items as synthetic rubbers, fibres, plastics, and chemicals. Natural gas is utilized primarily for heating, but processing of gases containing hydrogen sulphide and condensate yields by-products of sulphur, propane, butane, and other liquid petroleum gases. Of the petroleum products used in Canada, motor gasoline constitutes 35 per cent; middle distillates comprising light heating oils, diesel fuel, kerosene, and aviation turbo fuel constitute 36 per cent; heavy fuel oil, 17 per cent; and all other products including aviation gasoline, lubricating oil and greases, waxes, and petrochemical fuel stocks, 12 per cent.

The petroleum industry in Canada is centered in Alberta, southern Saskatchewan, southwestern Manitoba, northeastern British Columbia, and southwestern Ontario. There is minor production from Norman Wells, Northwest Territories, and New Brunswick. Alberta ranks first in output of oil and of natural gas, and the four western provinces produce 99 per cent of Canada's petroleum and 96 per cent of the natural gas. Reservoirs of oil and gas occur in rocks ranging in age from Cambrian to Upper Cretaceous. Present production is entirely from oil and gas wells, but the Athabasca oil sands (75) constitute a very large potential source of petroleum, and bituminous shales (73) are another possible source. Proven reserves of liquid hydrocarbons in Canada, exclusive of the Athabasca oil sands, were estimated to be in the order of 4 billion barrels at the end of 1959. In contrast, reserves in the Athabasca oil sands are estimated to be between 100 and 300 billion barrels of oil. Proven recoverable reserves of natural gas have been estimated to be in excess of 26 trillion cubic feet.

Many large areas of the Western Canada sedimentary basin require further testing, including partly tested areas of the Foothills belt and northeastern British Columbia; and virtually untested areas of the Arctic Islands, and much of the Yukon and mainland Northwest Territories. Drilling has taken place in other areas of potential oil- or gas-bearing strata, principally the Maritimes region, St. Lawrence Lowlands and Gaspé areas of Quebec, the Queen Charlotte Islands, and the lower mainland of British Columbia. Of these, only New Brunswick has so far yielded oil or gas in commercial quantity. The Athabasca oil sands (75) of northeastern Alberta, the world's largest known bituminous sand deposit, constitute a very important potential source of petroleum. Investigations into the sands and possible methods for economic recovery of the oil are being actively carried on. Bituminous shales (73) also constitute a possible source of petroleum. Such shales are widely known in Canada, but there is no current development.

PHOSPHATE

References: A

Spence, H.S. (1920): Phosphate in Canada; Mines Branch, Canada Dept. Mines.

For several generations the phosphate rock used in Canadian industry has been imported, although during the 1880's a considerable part of the world production came from the apatite deposits of eastern Ontario and southern Quebec. Imports into Canada, which have amounted to 800,000 tons annually, have come almost entirely from the United States. Most of the phosphate rock is used in the manufacture of fertilizers. A small part goes into the preparation of phosphorus and its compounds which are used largely in the production of detergents.

Fluorapatite (76), the fluorine-bearing phosphate of calcium, is the principal source mineral. In appearance it ranges from the large well-formed hexagonal crystals found in the pegmatitic deposits of Eastern Canada, to the fine colloform varieties (77) composing the phosphorite nodules of sedimentary deposits.

Most of the world's phosphate reserves are in sedimentary deposits such as the land-pebble phosphates of Florida and the bedded deposits of the Phosphoria Formation of Montana and Idaho. In essence they are chemical sediments deposited along the margins of ocean basins in areas of deep water relatively free of normal clastic sediments. Canada has thin sub-economic deposits of this type in the southern Rocky Mountains which are extensions of much thicker deposits in the adjoining United States.

In northern British Columbia and the Yukon some potential may exist for the discovery of phosphate associated with other chemical sediments such as the cherts of the Lower Palaeozoic. Segregations of apatite in alkaline intrusive complexes are an important world source of phosphate, particularly in Russia, which, in the Khibine deposits of the western Arctic, has the largest deposits of this type in the world. Some deposits of this type are known in Canada near Nemegos in northeastern Ontario. The historically important deposits in southern Quebec and eastern Ontario are pegmatitic in character and form irregular pockety masses in pyroxenite associated with metamorphosed limestone. Revival of production from them on anything but a small scale seems unlikely.

PLATINUM METALS

References: A, B

For 20 years until 1953 Canada was the leading world producer of the platinum metals. Since then South Africa has taken over first place with U.S.S.R. probably a close third. Colombia and the United States also produce small quantities. Total world production in recent years has approached 900,000 ounces annually, of which Canada has produced in excess of 300,000 ounces. Resistance to chemical attack, high conductivity, and superior catalytic action are the qualities of the platinum-group metals upon which their usefulness in industry depends. Thus platinum is used in laboratory equipment, and in chemical industrial equipment such as spinnerets in the rayon industry. It is used as a catalyst in the production of ammonia, nitric acid, and high-octane gasoline. Palladium is particularly useful in low-amperage electrical contacts. Both platinum and palladium are used in jewelry. The minor platinum-group metals—iridium, rhodium and ruthenium—are used principally alloyed with the major metals of the group.

Platinum-group metals occur in association with ultrabasic and basic rocks. The native metal occurs with chromite in dunites, which may form the source of placer deposits, such as those of Tulameen River, British Columbia, and Dezadeash, Yukon. The sulphide and arsenide minerals, such as cooperite, PtS, and sperrylite, $PtAs_2$, are found disseminated among copper and nickel sulphides (29) at Frood and other mines near Sudbury, Ontario.

Canadian production is a by-product of the refining of the copper-nickel ores at Sudbury, which contain an average of .025 oz/ton of the platinum metals. The association with ores of this type is world-wide, and an increasing amount of the world's platinum is coming from such sources. The balance is derived from placers, such as those of the Ural Mountains and Colombia.

The possibilities of placer production in Canada appear to be limited to the placer areas of British Columbia and the Yukon. So far there have been only nominal quantities produced, principally from the Tulameen River area. Further production of platinum in Canada therefore is likely to be closely related to that of nickel.

POTASH

References: A

Bannatyne, B.B. (1960): Potash Deposits, Rock Salt, and Brines in Manitoba; Manitoba Dept. Mines, Natural Resources, Pub. 59-1.

Tomkins, R.V. (1957): "Potash" in Geology of Canadian Industrial Mineral Deposits; Can. Inst. Min. Met., Congr. Vol., pp. 198-202.

Mining from one of the world's largest and best-grade deposits of potassium minerals began in Saskatchewan in 1958. As an essential fertilizer, especially in long-established farm areas, world potash consumption is expected to steadily increase. Most potash is used in fertilizers, but about 5 per cent of American consumption comprises chemical and industrial use in detergents, soaps, glass, ceramics, dyes, and many other products and processes. Most future Canadian production will be exported. Potash, K_2O, is neither found in nature nor produced, but is the common measure used in reporting the potassium content of various ores and compounds. The dominance of control of the present active companies by foreign potash producers reflects the high proportion of export anticipated.

The commercial beds of potash in Alberta, Saskatchewan, and southwestern Manitoba contain sylvite (78), KCl, admixed with halite, NaCl, and carnallite, $KCl.MgCl_2.6H_2O$. Sylvite contains 63.1 per cent of readily available potash equivalent, whereas carnallite contains only 17.0 per cent. Proportions of sylvite, halite, and carnallite, as well as undesirable clay impurities, are variable over the large areas investigated. These minerals are soluble, hence when encountered in drilling for oil, using water-based muds, the core recovery is normally poor.

Potassium minerals have been dissolved from beds above depths of 2,800 feet in the Prairie Provinces. Tomkins estimates that reserves of potash in the upper part of the Middle Devonian Prairie evaporites at depths less than 3,500 feet are 5,000 million tons, grading between 25 and 35 per cent potash. Mining is complicated by the deep shafts which must be sunk through incompetent, commonly water-bearing rock, but the expected grade is higher than that of New Mexican deposits. German deposits are being mined at similar and shallower depths and average 10 and 12 per cent potash. Some companies are studying the feasibility of extraction through drill-holes as brine.

QUARTZ CRYSTAL

References: B, C

Oscillator plates cut from natural or synthetic quartz crystal (79), SiO_2, are used for accurate frequency control in radio transmitters and many other electric devices. In 1958, 170,000 pounds of quartz crystal of electronic grade, representing 270,000 pounds of raw imported quartz, was consumed in the United States. Consumption in World War II averaged 1 million pounds per year. Brazil, the only producer of large amounts of natural electronic-grade quartz crystal, has supplied the United States requirements for many years. Synthetic quartz crystals are now being produced in the United States but domestic production is still a small percentage of the total consumption.

The Brazilian deposits are deeply weathered quartz veins and blanket deposits of milky quartz in which the clear quartz crystals occur in vugs and pockets. Individual deposits are small and irregular and are distributed over a wide area. A number of small quartz-crystal occurrences in Leeds county, Ontario, were examined during World War II as possible domestic sources. The deposits are associated with brecciated quartzites intruded by pegmatitic and granitic dykes. Small amounts of good crystals have been recovered from one of these deposits and, more recently, from a deposit in Shefford county, Quebec.

The Brazilian supply of natural quartz crystal is believed adequate to meet peacetime requirements of the Free World for many years. It is expected that United States industry will establish a competitive supply of synthetic crystal. Good sources of fusing-grade quartz may be of economic interest in the future to supply raw materials for the synthetic-quartz industry. Deposits of quartz crystal would have to be large, and the crystals of exceptional size and quality to be economically exploited.

RARE-EARTH ELEMENTS

References: Ellsworth, H.V. (1932): Rare-Element Minerals of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 11.

Rose, E.R. (1959): Rare Earths of the Grenville Sub-Province, Ontario and Quebec; Geol. Surv., Canada, Paper 59-10.

The rare-earth elements are generally divided into the cerium (light) group and the yttrium (heavy) group. The cerium group is in more plentiful supply than the yttrium group. Mischmetal is the common commercial alloy of the cerium rare earths. Annual United States consumption of these rare metals is about 3,800 tons; this is used principally in magnesium and aluminium alloys, in carbon arc lighting, as lighter flints, in glassmaking and ceramics, and in the electronics industry. It is probable that their uses will increase as their price is reduced. Rare-earth metals are produced in part as by-products of thorium and niobium and there is currently an adequate supply.

The primary ore mineral of this group of elements is monazite—a phosphate containing roughly 55 per cent light rare-earth oxides, 5 per cent heavy rare-earth oxides, and 6 per cent thoria. Another mineral that has recently become important is bastnaesite—a barium, cerium-group fluo-carbonate containing up to 69 per cent cerium-group oxides. Allanite which is locally abundant in Canada contains up to 21 per cent cerium-group oxides. Yttrium-group oxides are most abundant in euxenite, xenotime, gadolinite, and cenosite, which occur very sparsely in Canada. The rare-earth elements are usually associated geochemically with thorium and uranium in such minerals as uraninite, pyrochlore, perovskite, betafite, niocalite, and britholite.

Although monazite occurs widely as an accessory mineral in granitic rocks and their apophyses, it occurs in commercial concentrations only in detrital sands of Brazil, India, United States and Ceylon, and in a large vein in South West Africa. Bastnaesite is plentiful in vein and replacement deposits of California and New Mexico. Other rare-earth minerals are found in pegmatites and in placer deposits derived from them. Cenosite is usually in vugs in pegmatitic granites. In Canada, rare earths associated with uranium and thorium occur in the buried placer deposits of the Blind River area, in the pegmatitic granites of the Bancroft district, and in contact-metamorphic deposits in limestone at Oka, Quebec, Lake Nipissing and Chapleau, Ontario, and Blue River, British Columbia.

It seems probable that rare earths will be produced as a by-product of production of niobium at Oka, Quebec, scheduled to start in 1961. Monazite in considerable quantity is found in parts of the ore-bodies of the Blind River uranium camp (111) and might yield rare earths as a by-product. In the Bancroft uranium camp, rare earths occur sparsely in uranium minerals and might be recovered as a by-product. If current research on use stimulates demand for rare-earth elements, by-production from uranium and niobium producers in Canada is probable. Present indications are that no rare-earth deposits known in Canada at present could compete as primary producers with detrital deposits elsewhere.

REFRACTORIES

References: A (1959): Reviews 7, 33, 36, 41, 50.
C: Chapters 4, 8, 11, 12, 20, 25, 43, 44.

Canadian Institute of Mining and Metallurgy (1957): Geology of Canadian Industrial Mineral Deposits; Congr. Vol.

Refractories comprise materials that retain their shape and chemical identity at high temperatures. For highly diverse uses, a wide range of materials are used which are grouped by chemical composition, mainly by the silica-and-alumina content or by the magnesia content. Special applications are filled by graphite, zircon, topaz, carbon, and other minerals. (Only the basic refractories—magnesite and forsterite—and the alumina-silica refractories—kyanite, andalusite, and sillimanite—are discussed below. Fire clay, silica (90), brucite (58), graphite (46) and dolomite (59) are discussed elsewhere in this booklet.) Magnesite is used to produce magnesia bricks or granules and caustic-calcined magnesia. The latter is used in the production of heavy-duty flooring cement, refractories, insulation, and in the chemical and paper industries. The proportion of magnesia refractories used in heavy industry has been increasing. Canadian production of magnesite and brucite in 1958 was valued at $2 1/2 million. Forsterite and sillimanite-group minerals are not currently produced in Canada.

Magnesite (82), $MgCO_3$, is commonly massive with the appearance of unglazed porcelain, and may also be coarsely crystalline. Forsterite, $2MgO.SiO_2$, is the magnesium-rich olivine which normally contains some fayalite, $2FeO.SiO_2$, in solid solution. The sillimanite group, for refractory purposes, refers to those minerals having a high alumina-to-silica ratio, which, when heated, form mullite, $3Al_2O_3.2SiO_2$. They comprise kyanite (81), andalusite (80), and sillimanite (83), all of which have the same composition— $Al_2O_3.SiO_2$—and dumortierite, $8Al_2O_3.B_2O_3.6SiO_2.H_2O$, and topaz, $Al_2(F, OH)_2SiO_4$. The last two minerals are desirable because they contain almost 70 per cent alumina on heating, and dissociate at relatively lower temperatures.

Principal modes of occurrence of magnesite are as bodies in crystalline carbonate rocks, as a cryptocrystalline alteration product of serpentine, and as vein fillings. The origin of magnesite as original sediment or altered dolomite or limestone is seldom clear, but both origins appear to have been demonstrated in various deposits. Canadian deposits include dolomitic magnesite lenses with disseminated serpentine which replace marble at Kilmar, Quebec; bedded crystalline magnesite enclosed in Cambrian quartzite in British Columbia; and magnesite derived from serpentinized peridotite in western Newfoundland. The last-named has quartz as an undesirable impurity. Forsterite is not mined in Canada, although ultrabasic rocks have been evaluated in the Gaspé Peninsula, and further investigation of dunite bodies seems warranted in ultrabasic rocks elsewhere in Canada. Sillimanite, kyanite, or andalusite form in argillaceous sediments during intense metamorphism. Kyanite is the most important of the group and is normally disseminated in kyanite schists and gneisses or may form segregations in contact-metamorphic zones, pegmatites, and quartz veins. Kyanite gneiss with several kyanite-rich lenses is found at Crocan Lake, Mattawa area, and in central Dryden township, Ontario. These deposits are being investigated as possible orebodies, and other gneisses are known in Clarendon township, Ontario, and in west-central British Columbia. Andalusite is mainly restricted to argillaceous rocks adjacent to granitic or dioritic intrusive rocks, and as lenses in pegmatites. Andalusite schists are reported in eastern Nova Scotia but no production in Canada seems imminent. Sillimanite in gneisses is known in many localities, but no deposit of commercial promise is known to be under investigation.

ROOFING GRANULES

Reference: A

Roofing granules are coloured particles of rock or slag that are used to provide a protective and decorative coating on asphalt shingles and siding. Their consumption in Canada reached an all-time high in 1958, amounting to 141,736 tons, of which approximately 81 per cent was artificially coloured. Domestic consumption has been largely met by imports from the United States, but in recent years the proportion of imported granules has been diminishing; in terms of volume it declined to 62.9 per cent in 1959, as compared to 81.7 per cent in 1955.

Rocks of diverse types and origin are used for the production of roofing granules. The principal ones finding acceptance today are basalt (84), diabase, syenite (20), porphyry, rhyolite (85), slate (86), argillite, quartzite (89), greenstone, and chert. Although all are fairly common rocks the selection of suitable deposits is influenced by many economic factors, such as size, proximity to markets, and ease of quarrying; and also by the nature of the rock and by specifications for the granules which are expected to provide a protective surfacing for at least 20 years. The chief desirable characteristics of the rock are: uniformity in colour and physical properties, to provide a continuous, uniform product; toughness, to withstand handling and to produce a minimum of fines in processing; opacity, so that the resulting granules will protect the asphalt from deterioration by the sun's ultra-violet rays; high resistance to mechanical and chemical weathering; and low porosity. Also, the granules produced must be of a desirable shape for maximum coverage and bonding, and, if required, must be amenable to artificial colouring processes. Most of the naturally coloured granules today consist of black slag, obtained from steam-generating and steel plants. Blends of various colours of granules are becoming increasingly popular.

The United States produces nearly 2 million tons of roofing granules annually from sources in twelve different states. In Canada, production is centered around Marmora and Madoc in Ontario, where granules are produced from basalt, slate and pink rhyolite. Schist, slate and greenstone in British Columbia are reported to have been used as roofing granules.

Because the annual consumption of roofing granules is closely related to the volume of residential construction it may be expected to fluctuate from year to year, but will probably show a gradual upward trend with the economic growth of the nation. Domestic sources are therefore likely to become increasingly important. Because igneous and metamorphic rocks dominate the desirable sources, deposits should be sought in areas underlain by such rocks, respecting the factors already mentioned. Probably the most promising area, all factors considered, is along and within the southern perimeter of the Precambrian Shield extending throughout central Ontario and southern Quebec. Other potential areas would appear to be in southern British Columbia, New Brunswick, Newfoundland and Nova Scotia.

RUBIDIUM

Reference: B

Rubidium is a costly and little-known alkali metal produced in small amounts as a by-product of the lithium industry in the United States. The amount produced in 1958 amounted to about 1,000 pounds. Rubidium has similar properties to caesium and may be used for many of the same applications. Rubidium, for example, has been used as a getter in vacuum tubes, as the active agent in photoelectric cells, as a scavenger in chemical and metallurgical applications, and as a catalyst in the synthesis of ammonia and in various hydrogenation and polymerization processes. It has also been tested as a propellant for ionic-drive rocket engines, as a heat-exchange medium in small nuclear power plants, and in plasma thermocouples.

Rubidium does not occur as an essential constituent of any known mineral but is commonly present as a minor element in many minerals and is, in fact, more abundant than lead in the earth's crust. Lepidolite (87), a lithium mica, may contain up to 3.5 per cent rubidium oxide and is the best present commercial source of rubidium. Pollucite (19), the ore mineral of caesium, may contain 1 to 2 per cent rubidium oxide and is a second important source. Other possible rubidium-bearing minerals are carnallite, microcline (32) and biotite (62). Commonly, rubidium is associated with one or more of the other alkali metals—Na, K, Li and Cs—which occur in greatest abundance in granitic rocks.

The only deposits of economic importance at present are sodium-lithium pegmatites containing lepidolite and/or pollucite as ore minerals, from which rubidium may be recovered as a by-product. In Canada the deposit at Bernic Lake, Manitoba, is estimated to contain more than 1,800 tons of rubidium in pollucite and lepidolite.

SALT

References: A

Heywood, W.W. (1955): Arctic Piercement Domes; Trans. Can. Inst. Min. Met., vol. 58, pp. 27-32.

Sanford, B.V., Bancroft, M.F. (1957): "Salt" in Geology of Canadian Industrial Mineral Deposits; Can. Inst. Min. Met., Congr. Vol., pp. 208-218.

Salt (NaCl), as an essential dietary need, has been a valued commodity since man's earliest history. In 1958, some 30 pounds of salt was used in industry for each pound sold as table salt in the United States. The principal consumer is the chemical industry, notably the producers of chlorine and soda ash. Salt is also used for highway treatment, meat packing, cattle feed, water softeners, and a host of other applications. Vast reserves are known, and the oceans could provide unlimited quantities. Canadian production has increased rapidly to 3,206,164 tons in 1960, second in value in Canadian industrial minerals only to asbestos, with production dominated by Ontario deposits. Nearly half of Canada's production was produced as brine, and about 38 per cent was exported to the United States.

Halite (88), NaCl, is soluble in water to the extent of about 35 to 40 parts per 100 of water, has a lower density than common rock minerals, and massive halite or rock salt can flow somewhat like asphalt when subjected to high pressure. These properties control the geological occurrence of salt deposits as brines, evaporite deposits formed when evaporation exceeded inflow of ocean waters in restricted seas or coastal depressions, and as salt domes formed when pressure forced salt from deeply buried beds to flow toward loci of structural weakness and to rise through overlying rocks toward the surface as large domes or columns. At the time of deposition, with increasing salinity of the residual solutions being evaporated in enclosed seas, calcium sulphate deposition as anhydrite or gypsum was normally followed by deposition of salt and, at extreme salinity, by deposition of potassium salts. Thus salt is commonly associated, but not admixed in commercial deposits, with gypsum, anhydrite and, where conditions were suitable, with carnallite and sylvite.

Canada has abundant commercial reserves, principally in southern Ontario, Nova Scotia, and the three Prairie Provinces. These are brines and evaporite beds of varying ages—Silurian in Ontario, Carboniferous in the Maritimes, and Middle Devonian, with associated potash deposits, in the Prairie Provinces. Other salt beds are known or suspected in New Brunswick, Newfoundland, and at great depth in Prince Edward Island. More than 40 dome-like structures, some of which are capped with gypsum and anhydrite, are known in the Canadian Arctic. Of these, many probably represent the surface exposure of buried salt domes, and for the present are of principal interest as possible structural traps for petroleum and natural-gas accumulation.

The ability of rock salt to flow and seal fissures commonly makes unused underground openings in salt beds dry and non-porous. These openings have some promise as safe repositories of radioactive waste products from controlled nuclear reactions, and for petroleum storage.

SAND AND GRAVEL

References: A, B

The sand and gravel industry exceeds all non-fuel mineral industries in tonnage produced. Production in Canada in 1959, from more than 8,000 pits by more than 2,000 operators, totalled 165 million tons. Because the average price per ton is less than one dollar, transportation must be minimized and production is almost always from local sources. Production has risen nearly 50 per cent since 1955. More than 90 per cent of production is used as aggregate in the construction industry with or without binders such as cement or asphalt. Minor uses for sand include moulding, glass-making, and as engine, ballast and abrasive sands.

Sand is defined as the granular product of the natural disintegration of rock coarser than 200 mesh (0.003 inch) and finer than 1/2 inch. Gravel is similar material coarser than 1/4 inch and finer than about 6 inches. Sharp-edged or angular sand is a better aggregate than rounded sand. Sand is commonly composed of quartz particles, and for concrete must be free from clay. Gravel for concrete should contain quartz and hard silicate or limestone pebbles; it should be free from shales, argillites, ochers, argillaceous limestone or sandstone.

Sand and gravel deposits are classed genetically as residual, fluvial, marine and lake, and glacial. Residual deposits generally contain much clay and soft material and are rarely used commercially. Fluvial deposits are generally poorly sorted as to size and are found as sand bars, in stream beds, in delta formations, and as terraces. Marine and lake deposits are commonly clean and well sorted by size along the shorelines. Glacial deposits are commonly an unsorted mixture of soft and hard materials varying widely in grain size. In Canada, useful deposits of sand and gravel mark the shorelines of old glacial lakes and the courses of streams emanating from old glaciers. Such deposits are composed of resorted glacial material and are generally of good quality.

Cinders and other porous aggregates and expanded mineral products are replacing sand and gravel for such purposes as lightweight aggregate in plaster, concrete blocks, and filters. Despite this, a constant growth in demand is evident and good sources of sand and gravel are in demand, particularly near metropolitan areas.

SELENIUM

References: A, B

Canada has two plants producing selenium and its salts. One, the world's largest, is near Montreal, and the other is at Copper Cliff, Ontario. Between them they produce annually more than one quarter of the Free World's selenium. Canada ranks second in world production after the United States, which produces about one half of the total. The largest consumer of selenium has been the electronics industry, although in recent years selenium has lost ground to germanium and silicon in one of its principal uses in this field—selenium rectifiers. It is used also in photoelectric cells although here also it is meeting competition from caesium. The chemical industry consumes one third of the selenium used; in pigments, as a catalyst in the production of cortisone; in fungicides, to improve the heat and abrasion resistance of rubber; and to produce bright-red glass.

Selenium is almost similar to sulphur in its properties and in its natural occurrence. Although many selenide minerals are known in Canada, selenium is most abundant substituting for some of the sulphur in sulphides.

All selenium is obtained as a by-product of the treatment of base-metal ores in which it occurs in trace quantities. In Canada it comes as a by-product of the refining of copper and copper-zinc ores (30) in northwestern Quebec, Gaspé Peninsula, Flin Flon, Manitoba, and Manitouwadge, Ontario, and from copper-nickel ores in the Sudbury district.

Present sources of selenium are more than adequate to fill the immediate demand. Its present position as a by-product does not appear likely to change in the near future.

SILICA

References: A

Collings, R.K. (1956): The Canadian Silica Industry; Mines Branch, Dept. Mines, Tech. Surv., Memo. Ser. No. 134.

In 1959 Canada produced 1,934,000 tons of silica, exported 147,000 tons and imported 792,000 tons. Silica is imported into Canada free of duty, whereas import duty into the United States varies from nil to $1.75 per long ton depending upon the type of material. Prices for silica vary from 50 cents to $3.00 per ton at the quarry. Obviously, therefore, location of the quarry relative to the market is critical. Transportation is generally by ship. The large volume of imports is composed primarily of exceptionally pure silica, lacking in Canada. Modern methods of beneficiation may make Canada more nearly self-sufficient. Principal uses of silica are: as a flux, in smelting, manufacture of ferrosilicon and silicon, silica brick, glass, silicon carbide, sodium silicate and other chemicals. It is used also in hydraulic fracturing of oil wells, as silica flour in the ceramics industry, and as an abrasive.

The raw materials of silica, SiO_2, are crystalline quartz (79), silica sand (90), sandstone (91), quartzite (89), flint, chert, diatomaceous earth, etc. Most silica is obtained by quarrying deposits of sandstone and quartzite, whose composition approaches 99 per cent SiO_2. Specifications vary widely for silica for different uses. Principal contaminants are iron, alumina, and calcium and magnesium carbonates. Iron is generally more objectionable than alumina. Carbonates can commonly be eliminated by acid washing.

Sandstone strata are commonly flat-lying and occur intercalated with other sedimentary rocks in most areas outside the Canadian Shield. Quartzite is found largely in the Shield and is more erratic in composition and structure. Sand may be of beach, fluvial, or fluvioglacial origin. Commonly, marine sands are purer than lake sands. Aeolian sands are rare in the populated areas of Canada.

The demand for high-quality silica is increasing in Canada. Larger demand, coupled with recent advances in beneficiating impure silica, may make it worth while to produce pure silica from deposits near the principal markets or from those on major water routes. It is possible, for example, that improved cleaning methods will permit exploitation of sand from dunes and beaches along the Great Lakes or on the sea-coasts.

SILVER

References: A, B

Silver is being produced from the three metalliferous regions of Canada—the Western Cordillera, the Appalachian Region, and the Canadian Shield. For the most part it is by-product silver; only in the Yukon and parts of Ontario and British Columbia are there deposits from which silver is the major metal produced. Canada's production in recent years has ranked third, with about 30 million ounces annually, or 15 per cent of the world total. Mexico and the United States are the two principal producers. Silver has been a monetary metal from ancient times and a large part of the silver produced is still consumed in coinage. In Canada almost half has been used in this way in recent years. Almost one third has gone into silverware and plating, with the balance consumed chiefly as photographic chemicals.

The principal ore minerals of silver are the native metal (93), the sulphide, acanthite (argentite) Ag_2S, and complex compounds containing arsenic and antimony such as the ruby silvers. Freibergite, $(CuAg)_{12}(SbAs)_4S_{13}$, is a common source of silver in lead-zinc-silver ores (92). Silver occurs in solid solution in galena and is commonly present in varying proportions alloyed with native gold.

Silver-bearing minerals are found in varying proportions associated with base-metal sulphides in veins and complex replacement bodies. At Mayo in the Yukon and at several places in British Columbia, notably Slocan, the proportion of silver-bearing minerals in the veins is high and the orebodies are mined principally for their silver content. In some places, as at Cobalt,Ontario, and Great Bear Lake, nickel and cobalt minerals are found in the veins with the silver. For some time after its discovery early in the 1900's Cobalt was the leading silver camp in the world, and it still accounts for one fifth of Canada's annual production. More than half of the silver produced in Canada is recovered as a by-product. A small proportion of this, about 2 per cent, occurs alloyed with gold, and as tellurides or other silver minerals, in gold-bearing quartz veins and placer deposits. The greater proportion, however, is derived from large base-metal sulphide deposits which contain only relatively small quantities of silver, in the order of 1 or 2 ounces per ton. These include lead-zinc and copper-lead-zinc deposits such as the Sullivan mine in British Columbia and Buchans in Newfoundland; copper and copper-zinc deposits as in northwestern Quebec, Gaspé, and Manitouwadge, Ontario; and copper-nickel deposits of the Sudbury area.

SODIUM SULPHATE

References: A, B

Cole, L. Heber (1926): Sodium Sulphate of Western Canada; Mines Branch, Canada Dept. Mines, Pub. No. 646.

Hamilton, J.B. (1957): Salt; Mines Branch, N.B. Dept. Lands, Mines, Info. Circ. 57-1.

Almost all the natural sodium sulphate used in Canada is consumed in the production of kraft paper, with minor amounts used in glassmaking, tanning, processing of textile fibres, and other uses Production in Saskatchewan has varied appreciably but has averaged about 150,000 tons per year for the past 13 years. About 40,000 tons was exported in 1958. This production could readily be doubled, and total reserves in Saskatchewan and Alberta are very large. Factors affecting production of sodium sulphate include major transportation costs to paper-making plants, the variation in production as a by-product of hydrochloric acid and rayon manufacture, and the increase in secondary recovery and decrease in amounts used per ton of pulp in pulp-and-paper manufacture.

Of principal interest in Canada is mirabilite (94), $Na_2SO_4.10H_2O$, or Glauber's salt. This soluble mineral can be harvested from brines either in natural undrained lakes or in artificial, adjacent ponds. Mirabilite may form temporarily, especially during cold weather, or may comprise permanent beds. These lakes are commonly fed by saline springs augmented by fresh-water springs and surface runoff. If natural evaporation is complete, the first-formed mirabilite is contaminated with magnesium sulphate, sodium chloride, calcium sulphate, and other impurities. Other important sulphates are thenardite, Na_2SO_4, and glauberite, $Na_2SO_4.CaSO_4$.

The saline lakes of Saskatchewan and Alberta extend into Montana and North Dakota. The sodium-sulphate content of percolating ground water is probably derived from bentonitic and pyritic shales containing scattered gypsum crystals which underlie much of the area and comprise large proportions of the glacial outwash and boulder clay deposits. Trona, $Na_2CO_3.NaHCO_3.2H_2O$, is mined from depths of 1,500 feet in Wisconsin. Glauberite has been intersected at depths of 1,440 to 1,700 feet near Weldon, New Brunswick. One section 8 feet thick contains about 30 per cent sodium sulphate.

STONE, BUILDING AND ORNAMENTAL

References: Hanes, F.E. (1960): Stone, Building and Ornamental; Mineral Resources Div., Dept. Mines, Tech. Surv., Rev. 52 (1959).

Carr, G.F. (1955): The Granite Industry of Canada; Mines Branch, Dept. Mines, Tech. Surv., Pub. 846.

Goudge, M.F. (1933): Canadian Limestone for Building Purposes; Mines Branch, Canada Dept. Mines, Pub. 733.

Parks, W.A. (1914): Report on the Building and Ornamental Stones of Canada; Province of Quebec; Mines Branch, Canada Dept. Mines, vol. 3, Pub. 279.

Wilson, A.E. (1936): Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec; Geol. Surv., Canada, Mem. 241.

Estimated production of all types of Canadian building and ornamental stone for 1959 amounted to 176,600 short tons, valued at $6,650,000. Estimated imports amounted to $2,749,390, which was 5.2 per cent higher than in 1958—(marble made up 42.7 per cent; granite products 25.8 per cent; slate 2.3 per cent; and other building stone, chiefly limestone, 29.2 per cent). Exports increased in value by 62.8 per cent—from $174,101 in 1958 to $283,356 in 1959.

The principal building stones quarried in Canada are: coarse-grained black anorthosite (95) composed mainly of labradorite (feldspar) containing minute inclusions which give it a black colour; grey even-textured granite (96); pink, fine- to medium-grained granite (97); grey and buff Tyndall limestone (98) that is characterized by a distinctive mottled effect in a branching network and by abundant fossils; uniform grey Queenston limestone (56), with traces of bluish dolomite and occasional pink crinoid stems; and cream-coloured Nepean sandstone that weathers grey with rust-coloured spots (this stone is used in the Parliament Buildings at Ottawa).

Anorthosite is quarried along the Canadian Pacific Railway line about 45 miles northwest of North Bay and in the Lake St. John region of Quebec. It is abundant from North Bay eastward through southern Quebec to the Atlantic coast. Most of the grey granites are quarried in the Eastern Townships of Quebec; the quarry at Stanstead has given its name to granites from this area. Rose to pink granite is quarried from a large dyke on the Mont Laurier line of the Canadian Pacific Railway, 140 miles north of Montreal. Tyndall limestone is quarried extensively in an area between Tyndall and Garson, Manitoba. The Queenston limestone comes from a very large quarry 2 miles west of Queenston, Ontario. These and other building stones have been quarried intermittently in many other parts of Canada.

Demand for building and ornamental stone varies greatly. It is difficult therefore to establish new quarries. It is essential that large quantities of stone that is uniform in colour and texture be available. Fashion varies in architectural use of stone and this is a major factor. Often it is cheaper to bring in stone of known colour and texture for a specific job from a foreign source than to open up a quarry to produce it locally.

STRONTIUM

References: Spence, H.S. (1922): Barium and Strontium in Canada; Mines Branch, Canada Dept. Mines, Pub. No. 570.

Schreck, A.E., and Arundage, J.C. (1959): Strontium A Materials Survey; U.S. Bur. Mines, Info. Circ. 7933.

Most production of strontium has come from England and Mexico. In Canada, small sporadic shipments have been made from Bagot township, Ontario. Strontium imparts a brilliant red flame to warning and distress devices, to fireworks and to tracer ammunition. Strontium is also used in welding-rod coatings, zinc refining, and luminescent paints. Strontium 90, a highly radioactive isotope, has some industrial and medical applications, but is a dangerous waste product of nuclear reactions.

Principal minerals of strontium are celestite (100), $SrSO_4$, strontianite, $SrCO_3$, and barytocelestite, in which some barium substitutes for strontium. Calcium also may substitute for strontium in these minerals in sufficient amount to prevent commercial exploitation. Strontium minerals are commonly associated with fluorite, barite, calcite, gypsum and rock salt.

In Ontario and Quebec, celestite and barytocelestite occur in narrow veins and in a replacement deposit in crystalline limestone and dolomite. In western Newfoundland, celestite occurs with barite in a large replacement zone in Carboniferous limestone, a deposit similar to commercial deposits in England and elsewhere. Celestite is known at Madoc, Ontario, and at Birch Island, British Columbia.

Should demand and prices rise, the Newfoundland deposit may deserve further evaluation.

SULPHUR

References: A, B

Consumption of sulphur in Canada has climbed in recent years to 500,000 tons annually. Pulp and paper manufacture, the chief consumer, has taken about half. Most of the balance has gone into the production of sulphuric acid, which is used in the treatment of uranium ores in addition to its traditional important role in the manufacture of fertilizers. Sulphur or the sulphur chemicals are essential reagents in the fabrication of a host of manufactured products, from alcohol to tires. Canada now produces enough sulphur to satisfy all her own requirements and is becoming an exporter of increasing importance. Current annual production, in excess of 800,000 tons, is expected to quadruple in the next decade.

Most sulphur in the United States comes from native sulphur (102). In Canada, production is primarily from pyrrhotite (52), FeS, and pyrite (101), FeS_2. A large and increasingly important source is natural gas.

In Canada, native sulphur is known in gypsum-anhydrite domes in the Arctic Islands. Pyrite-pyrrhotite deposits from base-metal mines in British Columbia, Ontario and Quebec accounted for half the total sulphur produced in Canada in 1959. About one third of the sulphur produced was recovered from smelter gases, and the remainder as a by-product of natural-gas production, mainly in Alberta.

Expansion of natural-gas exports will greatly increase production of sulphur. It has been estimated that production from this source will be of the order of 3 to 4 million tons within this decade. It seems improbable therefore that other sources of sulphur will be able to compete, except where the element is produced as a by-product near major markets or on tide-water.

TALC (Soapstone)

References: A, B

Talc is a mineral name which has been used by industry to describe all gradations from the pure mineral to impure talcose rocks that may contain less than 50 per cent talc. Talcose rocks are commonly referred to as soapstone. In recent years Canadian mines have produced 25 to 30 thousand tons of talc and soapstone annually, most of which has been consumed in Canada. In addition Canadian consumers import about 16, 000 tons of ground talc annually. About 75 per cent of the talc consumed in North America is used in the ceramics, paint, rubber, insecticide, roofing and paper industries. The remainder is used in toilet preparations; as a refractory mineral; and for a very large number of minor uses.

Talc (103) is a hydrated magnesium silicate having the theoretical formula $H_2Mg_3(SiO_3)_4$. It is characterized by its extreme softness, greasy feel, and foliated structure, with flexible but not elastic laminae. Its colour may vary from white to dark green. Common impurities in talcose rocks include quartz, calcite, dolomite, pyroxenes, amphiboles, serpentine, iron oxides and pyrite. In general, the objectionable impurities in talc are quartz, unaltered amphiboles and pyroxenes, iron oxides and pyrite. Pyrophyllite (21), a hydrous aluminum silicate, is physically very similar to talc.

Talc is a metamorphic mineral which occurs in commercial quantities as lenses in metamorphosed dolomites, schists, or gneisses, or as large bodies in altered ultrabasic rocks. Favourable regions for talc deposits in Canada are the Appalachian and Cordilleran regions, and the Grenville and other metamorphic regions of the Canadian Shield. Pyrophyllite is an alteration product of siliceous rocks and is produced largely from Newfoundland.

Canada's production of talc has remained constant for the past 20 years, whereas imports have steadily increased from 3 to 18 thousand tons per year. Many known deposits of talc in the Cordilleran region remain untapped due to lack of a western market and the high cost of shipping across Canada.

TANTALUM

Reference: Jones, R.J. (1957): Columbium (Niobium) and Tantalum; Mines Branch, Dept. Mines, Tech. Surv., Memo. Ser. No. 135.

Tantalum has been almost wholly replaced by niobium in steels and other major uses. Today it is used principally in the manufacture of acid-proof equipment, in the electronics industry and in surgery. United States imports of niobium ores were six times as great as those of tantalum ores in the decade ending 1953. It seems probable therefore, that tantalum requirements can be met as a by-product of niobium production. Use of tantalum has been restricted by shortage of supply. However, now that it is possible to recover niobium and tantalum from pyrochlore, the supply is improved and use is likely to expand. Due to North America's dependence upon imports, new discoveries in Canada would be strategically important.

The principal minerals from which tantalum is recovered are tantalite and intermediate members of the columbite-tantalite series (104), $(Fe, Mn)Nb_2O_6$ - $(Fe, Mn)Ta_2O_6$. Pure tantalite contains 86 per cent Ta_2O_5 and pure columbite 82.7 per cent Nb_2O_5. The pyrochlore-betafite-microlite series, approximately $(Ca, Na)_2 (Nb, Ta)_2O_6.nH_2O$, contains up to about 70 per cent Ta_2O_5 (in microlite). In Canada, however, most pyrochlore contains less than 10 per cent Ta_2O_5 and pyrochlore from Oka, Quebec contains roughly 3 per cent Ta_2O_5. There are many other minerals containing significant amounts of tantalum and niobium, which everywhere occur together. These minerals are mostly similar to pyrochlore in character and are complex in composition. Examples are fergusonite, samarskite, euxenite, niocalite and perovskite. These minerals also contain rare-earth elements and thorium and uranium in minor amount, and are therefore, possible by-products of niobium or tantalum production in Canada.

Columbite-tantalite occurs in granites and granite-pegmatites but is recovered economically with cassiterite mainly from placer deposits. Tantalum production from this mineral is largely from Brazil, Nigeria, Malaya, and Australia. Pyrochlore and similar minerals are found in large amount principally in carbonatites and other rocks associated with alkaline intrusives. Principal sources of these minerals are in East Africa and Canada. Production from Oka, Quebec, is scheduled for 1961 and important deposits are known at Nemegos and Lake Nipissing, Ontario, and Blue River and Manson Lake, British Columbia.

It is probable that tantalum will be produced in Canada only as a by-product of niobium.

TELLURIUM

References: A, B

The largest use of tellurium is in the rubber industry to improve aging of rubber and its resistance to heat and abrasion. It is also used in relatively minor amounts in alloys with copper, iron and lead and recently has shown promise in thermo-electronic applications both in direct production of electricity from heat and alternatively to conduct heat away in spot cooling. The United States produces 90 per cent of the Free World supply and Canada is the second largest producer.

Although tellurium is one of the rarer metals in the earth's crust, it is found as the native metal and forms rather a large group of telluride minerals. Tellurides are closely associated with the occurrence of gold and silver in some mines. Tellurium is commonly associated with selenium in base-metal ores.

Canadian production of tellurium comes from copper refineries at Copper Cliff, Ontario, and Montreal East, Quebec. It is derived from trace amounts present in copper-nickel (29), copper, and copper-zinc (30) ores mined at Noranda and Gaspé, Quebec, Sudbury, Ontario, and Flin Flon, Manitoba. Telluride minerals are characteristic of certain Canadian gold camps such as Kirkland Lake, Ontario, but no tellurium has been produced from these sources.

Present and potential supplies as a by-product of base-metal production are more than adequate to meet current demand.

THALLIUM

Reference: B

At present, thallium is a minor metal with limited commercial use. Most is consumed in the form of thallium sulphate in rat poisons, although an increasing use is being found in electronics.

Thallium occurs in such rare minerals as lorandite, $TlAsS_2$, and Crookesite, $(Cu, Tl, Ag)_2Se$, but its more common occurrence is as a trace component of base-metal ores. In nature thallium is geochemically associated with lead and zinc and it is found in galena, PbS, and in lead sulphosalts.

In Canada, thallium is recovered intermittently from flue dusts from the zinc ores at Flin Flon, Manitoba.

Potential supplies greatly exceed current demand. Research is being directed towards expanding its use.

THORIUM

References: Davidson, C.F. (1956): The Economic Geology of Thorium; Mining Mag., vol. 94, pp. 197-208.

Lang, A.H. (1952): Canadian Deposits of Uranium and Thorium; Geol. Surv., Canada, Econ. Geol. Ser. No. 16.

Thorium in small quantities is used in gas mantles, as a refractory, as a catalyst in chemical reactions, in glass manufacture, and in electrical filaments. The two promising uses of thorium that may require larger production are as a nuclear fuel (because thorium bombarded by neutrons produces fissionable uranium 233 in the so-called 'breeder reaction'), and as an additive to magnesium in light alloys that will stand elevated temperatures as in aircraft turbines, etc. Thorium production is closely allied to that of the rare-earth elements because both are recovered from monazite. To a large degree therefore, production of thorium has been dependent upon demand for rare earths. Monazite is abundant in beach sands on the coasts of India, Brazil, and the United States. Since 1951, a large vein deposit in South West Africa has accounted for more than half the world production of monazite. In 1959, production of thorium began in Canada as a by-product of uranium in the Blind River area of Ontario at a rate of 150 tons per year.

Thorium occurs in many minerals, in most of which it is associated with uranium and the rare-earth elements. Probably the most abundant high-grade source of thorium is the silicate-mineral series thorite-uranothorite (113), which contains up to 65 per cent ThO_2. It is found less commonly as an end member of the thorianite-uraninite series, ThO_2-UO_2. The principal ore mineral of thorium, however, is monazite, a phosphate of the rare-earth elements in which the thoria (ThO_2) content averages about 5 per cent. Thorium is also present in minor amount in such minerals as pyrochlore and brannerite, which are mined for niobium and uranium respectively. Uranium ore from the Blind River area (112) contains monazite, brannerite, and uraninite.

In primary deposits, thorium is found mainly in granites, pegmatites, carbonatites and pyrometasomatic deposits, in all of which it is closely associated with rare earths and uranium. It is not found with uranium, however, in hydrothermal and supergene deposits, nor is it present with rare earths in bastnaesite deposits.

If demand for thorium were to increase significantly, it could be readily obtained in larger amount as a by-product from the leach liquors of uranium in the Blind River and Bancroft camps. In some properties at Bancroft it is present (as uranothorite) in amounts exceeding the uranium content. Possibly these mines could be operated for thorium alone. Their tailing ponds should contain abundant thorium. Thorium might also be recovered as a by-product of niobium production from pyrochlore at Oka, Quebec, and in Africa. It is evident, therefore, that known sources of thorium are adequate to meet all demands that may be expected in the next decade or more.

TIN

References: A, B

Tin is so widely used in industry that demand for the metal is a good indicator of manufacturing activity. Its principal uses are in tin plate, solder, bronze, and bearing metals. Promising new uses are in the plastics and fungicide fields. For 10 years ending in 1952, tin was smelted at Kimberley, British Columbia, using cassiterite produced as a by-product from the Sullivan mine's lead-zinc-silver ore. Since then concentrates have been exported. The amount of tin produced has rarely approached 10 per cent of Canada's annual consumption—about 4,000 tons.

Cassiterite (106), SnO_2, is the principal ore of tin. It is a heavy brown mineral that is strongly resistant to corrosion and weathering and is therefore concentrated in placer deposits. Tin also occurs in a group of sulphosalt minerals which may be found in deposits containing antimony and arsenic associated with lead, silver and copper.

Economic tin deposits are generally associated with belts of granites and pegmatites. Cassiterite occurs in high-temperature veins, pegmatites, and contact-metamorphic deposits. Probably its most important occurrence is in placer deposits derived from these granite belts. In placer deposits tin is commonly associated with tungsten and in places with niobium. In Canada, tin is produced from the Sullivan mine where, as cassiterite, it is associated with pyrrhotite and some sphalerite (105).

Linear belts of tin occurrences are known in the Yukon and northern British Columbia (e.g. Dublin Gulch) and in New Brunswick near St. Stephen. Because tin must be imported to North America, deposits in Canada would have strategic importance.

TITANIUM

References: A, B

Canada has one of the world's largest reserves of titanium ore—sufficient for 400 years at the present rate of production—and is one of the largest producers of titanium concentrates. The Canadian industry is based on the production of titanium-dioxide slag containing 72 per cent TiO_2, most of which is exported to the United States and used for the manufacture of titanium-dioxide pigments. High-grade pig iron is produced as a by-product of the Canadian smelter process. The Quebec Iron and Titanium Corporation mined and smelted 559,205 tons of ilmenite ore in 1959 and produced 217,589 tons of titanium-dioxide slag and 145,990 tons of pig iron. Subsidiaries of two of the world's largest titanium-pigment manufacturers are commencing operations in Canada, and home consumption of titanium-dioxide slag should become an increasingly important part of the industry. Titanium-dioxide pigments have the desirable properties of high covering power, chemical inertness, and low specific gravity and are used extensively in paints, ceramics, papers, textiles, and cosmetics. A relatively small amount of Canadian ore is used as a heavy aggregate and in the manufacture of ferrotitanium alloys. Titanium, often called 'the wonder metal', has yet to reach its potentially important role in the structural-materials field.

The only titanium minerals of commercial importance at present are ilmenite (107), $FeTiO_3$, and rutile, TiO_2. Titanite or sphene, $CaTiSiO_4$, has been mined on a small scale in the U.S.S.R. Ilmenite, which supplies most of the world's demand, contains about 53 per cent TiO_2. It commonly occurs intimately associated with magnetite and hematite.

Two general types of deposit, namely beach sands and massive ilmenite deposits, are worked for their titanium content. Black sands are worked extensively for ilmenite in India, Australia, Malaya and in Florida, U.S.A. Rutile, zircon and monazite concentrates are recovered in the same operations. Massive ilmenite deposits are the main sources of titanium ore in Canada, Norway, and the United States. The Canadian deposits occur as magmatic segregations in the anorthosites of southern Quebec; the largest bodies are in the Allard Lake and St. Urbain areas. The ilmenite in these deposits is closely intergrown with hematite, and smelter operation is required to separate the iron from titanium. Ilmenite deposits in the United States and Norway consist of magnetite-ilmenite intergrowths (titaniferous magnetite) and have a much lower TiO_2 content than the Canadian deposits. In addition to the massive ilmenite-hematite deposits, Canada has even larger potential reserves of titanium in the form of titaniferous magnetite (108) and ilmenite disseminated throughout gabbroic rocks which are associated with, and commonly surround, the anorthosites.

TUNGSTEN

References: A, B

Little, H.W. (1959): Tungsten Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 17.

Tungsten is a brilliant white metal, rather inert chemically, with a very high melting point and tensile strength. It is used mainly in the manufacture of tungsten carbide, an extremely hard substance used as one of the components for coating the tips of cutting tools; and in the production of ferrous alloys. It is also used extensively in the manufacture of non-ferrous alloys, and as metallic tungsten it is virtually irreplaceable in some electrical applications. World production of tungsten concentrates in 1958 is estimated at 57,000 tons. China dominated production with about 20,000 tons, followed by U.S.S.R., North and South Korea, Bolivia, and United States in that order. Canada produced no tungsten concentrates in 1959 and has never produced more than 2 per cent of the annual world production.

The principal ore minerals are scheelite (109), $CaWO_4$, and wolframite (110), $(Fe, Mn)WO_4$. The latter mineral forms a series from ferberite, $FeWO_4$, to hübnerite, $MnWO_4$; the name 'ferberite' is commonly used for that part of the series containing up to 20 per cent $MnWO_4$, 'hübnerite' for the portion up to 20 per cent $FeWO_4$, and 'wolframite' for the remainder. Pure scheelite contains about 80 per cent tungstic oxide. The most common and undesirable impurity is molybdic oxide, for which penalties are imposed on scheelite concentrates. Other objectionable elements in concentrates are arsenic, antimony, bismuth, phosphorus and sulphur. Wolframite contains about 75 per cent tungstic oxide.

Most of the tungsten produced in the United States and in Canada has been obtained from scheelite deposits of contact-metamorphic origin. These deposits are invariably related to acidic intrusive rocks such as granite, granodiorite, quartz monzonite or quartz diorite, and the ore is most commonly formed in metamorphosed limestone. Typical examples are found in the Salmo district, British Columbia, and the Mayo district, Yukon. Scheelite is widespread in gold-bearing quartz veins throughout the Precambrian Shield and elsewhere, as in Nova Scotia, New Brunswick, British Columbia and Yukon Territory. Wolframite is closely associated with tin minerals in nature and scheelite may or may not be present. Wolframite-bearing quartz veins and pegmatites are found in Nova Scotia, New Brunswick and the Yukon Territory. Tin-tungsten-bearing placer deposits at Dublin Gulch, Yukon, are of possible economic importance.

Consumption of tungsten in the United States and Canada increased considerably in 1959 and this trend is expected to continue. Tungsten deposits, in general, are characterized by erratic distribution of ore values, and the main problem hindering the development of a Canadian tungsten industry is beneficiation of low-grade ores in competition with lower-cost foreign sources.

URANIUM

References: A

Lang, A.H. (1952): Canadian Deposits of Uranium and Thorium; Geol. Surv., Canada, Econ. Geol. Ser. No. 16.

Production of uranium in Canada rose from roughly 1,700 tons of U_3O_8 in 1955 to nearly 16,000 tons in 1959, but despite this increase, Canadian production dropped to second place below that of the United States. In consequence there is now an oversupply of uranium and the United States is not taking up its options to purchase Canadian uranium after 1962. Major demand for uranium will now depend almost wholly on such peaceful uses as a fuel for power plants and as an alloy in steels—uses that are currently being developed. As recently as 1955, possible shortage of supply of uranium inhibited development of peaceful uses. With the supply now assured it is probable that industry will take greater interest in new uses for the metal.

Of the very large number of minerals containing uranium, the majority are secondary products of weathering. Due to recent glaciation, these secondary minerals are of minor importance in Canada. Primary ore minerals of uranium are uraninite, including the variety pitchblende (112), and brannerite (111), davidite, and uranothorite (113). Many other primary minerals, such as betafite, allanite, euxenite and pyrochlore, contain uranium in sufficient quantity to be potential sources of uranium as a by-product of rare-earth or niobium production. The two most common secondary minerals in Canada are gummite and uranophane which contribute minor amounts of uranium to the ores of a few mines. Elements geochemically associated with uranium that are of possible economic importance are: thorium, rare-earth metals, vanadium, niobium, tantalum, zirconium, and phosphorus. Uranium is a possible by-product of production of these elements.

Uranium production in Canada has come from hydrothermal deposits at Great Bear Lake and Marion River, Northwest Territories, and Beaverlodge, Saskatchewan; from conglomerates (buried placers?) at Blind River, Ontario; and from pegmatitic granite dykes at Bancroft, Ontario. Other types of deposits that have received serious study are pegmatites near Bancroft and in central Saskatchewan and pyrometasomatic deposits at Charlebois Lake, Saskatchewan, Oka, Quebec, Nemegos and Lake Nipissing, Ontario, and at Birch Island, British Columbia. Other types of deposits in Canada analogous to those mined elsewhere are autunite-bearing sandstones at Middle Lake, Saskatchewan, and phosphate deposits of the Rocky Mountains. In the United States, principal production has come from the carnotite-pitchblende-coffinite deposits of the Colorado Plateau and adjoining regions. In South Africa, uranium is a by-product of the huge gold reefs of the Witwatersrand. In the Belgian Congo, uranium has come principally from the hydrothermal deposits of Shinkolobwe. In Eastern Europe, deposits are of the hydrothermal type associated with nickel and cobalt.

The industry must turn from guaranteed prices and markets to a highly competitive status. Canadian mines whose deposits are relatively low grade will have difficulty competing with those in other countries but have the possibility of producing associated elements such as thorium, rare earths, vanadium and zirconium as by-products.

VANADIUM

Reference: B

About 90 per cent of all vanadium produced is used in making tool and other steels, and wear-resistant cast iron. It is also used, in minor amount, as a deoxidizer, in permanent magnets, and as a catalyst. A promising new use for this metal is in a device for the prevention of fumes causing 'smog' in certain cities. This use could markedly increase consumption of the metal. In England, molybdenum is largely used in steels in place of vanadium. Vanadium is a by-product of uranium production in the United States, and in recent years, supply of 1,400 tons per year has exceeded demand. It is produced also in Finland and South Africa. It occurs in certain oil fuels and has been recovered from them in flue dusts. Although there has been surplus production of vanadium, there is now the possibility of significantly increased demand.

Principal minerals of vanadium are carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$, and vanadinite $Pb(PbCl)(VO_4)_3$. There are many other supergene vanadates. Patronite, VS_4, was formerly an ore mineral.

The famous carnotite deposits in the sandstones of the Colorado Plateau are the principal world source of vanadium as a by-product of uranium. It is also recovered as a by-product from phosphate beds in Idaho. Substantial production comes from an iron-titanium-vanadium mine in Finland. In Africa vanadium is produced from magnetite lenses in the Bushveld complex and as a by-product of lead from lead-vanadate ores of the Otavi region. Production of patronite from the famous hydrocarbon lens in shales at Mina Ragra, Peru, and from Northern Rhodesia has been suspended. In Canada vanadium occurs in significant amount in titaniferous iron deposits at Mine Centre and Mattawa, Ontario. As the primary mineral nolanite it is fairly abundant with pitchblende (112) in some mines at Beaverlodge, Saskatchewan. It is also found with hydrocarbon and chalcocite in sediments (114) intercalated with volcanic rocks on the coast of British Columbia. In small amount it occurs in the large titaniferous iron deposits (108) associated with anorthosite bodies along the southeastern margin of the Canadian Shield.

Probably the most readily available potential sources of vanadium in Canada are the uranium ores at Beaverlodge, Saskatchewan. The volcanic flows in the vicinity of Quadra Island and Menzies Bay, British Columbia, contain vanadium which, in small local concentrations, is quite high grade. Should the large bodies of titaniferous iron in the anorthosites be developed, it is possible that vanadium might be retained in the iron produced. The large deposits of tar sand near McMurray, Alberta, contain more than 200 parts per million vanadium, which might be recovered in flue dusts if this material were ever used as a fuel in large plants.

VERMICULITE

Reference: Hoadley, J.W. (1960): Mica Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 19.

Vermiculite is a hydrous, micaceous mineral whose importance is due to its property of exfoliating, or expanding, when heated suddenly at a high temperature. The expanded product is used chiefly for insulation and as a lightweight aggregate. Plants producing the expanded product are generally located close to marketing centres to which the vermiculite is shipped. Although one deposit is reportedly being readied for production near Perth, Ontario, all raw vermiculite exfoliated in Canadian plants to date (1961) has been imported from the United States and South Africa. Domestic production of expanded vermiculite has been increasing, and in 1959 it amounted to 344,430 cubic yards.

Although vermiculite (115) is a definite mineral species the name is commonly applied to any mica-like mineral that expands on heating. A volume expansion of about 8 to 12 times is generally possible in commercial ores. Vermiculite is formed by the alteration and hydration of micas and many so-called 'vermiculites' are actually interleaved mixtures of vermiculite and unaltered mica. The mineral is invariably associated with phlogopite and biotite, and appears to bear some relation to the presence of abundant apatite (76). Most deposits occur within bodies of basic to ultrabasic rocks that are cut by, or related to, syenitic intrusives.

The principal commercial sources of vermiculite are in the United States and South Africa, where the mineral occurs in large bodies of pyroxenite. Vermiculite in Canada occurs mainly in impure limy bands in metamorphic terrains. The most promising deposits appear to be in the Stanleyville area, about 15 miles southwest of Perth, Ontario, where vermiculite occurs with apatite, diopside, and other metamorphic silicates within bands of crystalline limestone. Large deposits of vermiculite rarely outcrop and surface indications are generally represented only by the presence of loose flakes in the overlying soil.

Because the demand for vermiculite is likely to continue, large accessible deposits of the mineral command attention. From the above it will be seen that promising areas in Canada so far appear to be those underlain by metamorphosed and silicated limestones. By analogy with certain foreign deposits, however, other potential areas would be those underlain by basic to ultrabasic rocks intruded by syenite or corundum-bearing aplite.

WATER

Reference: Canadian Municipal Utilities, vol. 98, No. 2, Feb. 1960.

Water is rarely considered as an economic mineral, yet of all minerals it is easily the most essential to man. Despite this, it is difficult to obtain statistics on its production and consumption. Daily consumption of water in cities and municipalities in Canada whose population exceeds 1,000 (published in the above reference) indicates that for this group, annual consumption is of the order of 5.5×10^{11} gallons. It is estimated that in 1956 this represented the consumption by 55 per cent of Canada's population. On a pro rata basis, total consumption is of the order of 1,000,000,000,000 gallons per year. However, it is improbable that the smaller communities consume as much water per capita as the larger communities in which major commercial and industrial plants are situated. To offset this, there are some major industrial users and irrigation districts who provide their own water supplies—users that would not be included in the above figures. On balance it is probable that total consumption exceeds 5 billion tons per year, possibly by a large margin.

It is impossible to list the uses of water because it enters into every facet of our lives. It is interesting, however, to indicate by three examples how much is needed in industry. The number of gallons of water used in producing 1 barrel of gasoline, 1 ton of paper and 1 ton of finished steel are respectively, 357, 39,000 and 65,000.

Other uses of water, such as power generation and transportation, require even greater volumes but they can hardly be listed as consumption because the water supply is largely regenerated and an extremely small amount is permanently consumed. The major problem today is redistribution of water. For example, communities drawing water from underground supplies and discharging it as waste into surface supplies may deplete underground aquifers faster than they are replenished by precipitation of rain and snow.

Of 1,754 municipalities and cities in Canada that have established waterworks, 481 draw their water from underground sources and 1,273 obtain water from lakes and rivers. A third but minor source of water in parts of the Prairies is rain from the roofs of buildings, collected in cisterns. Water supplies from underground sources in many areas are becoming seriously depleted. It is unfortunate that in many such areas, aquifers contain water too salty to use, but studies are being made of methods to obtain fresh water from saline water. There is some evidence of depletion of surface supplies due to quick runoff as a result of denudation of our forests. Glaciers are retreating and this too reduces our surface water supply, particularly in the dry summer months.

In heavily populated areas it is becoming necessary to pump water from distant lakes and rivers. In other areas the seasonal runoff is retained in storage dams. As a general water-conservation policy, reforestation and conservation of existing forest cover are increasingly important. Pollution of fresh-water sources is a problem of serious concern to the nation, particularly in areas where large industrial plants are located.

WOLLASTONITE

Wollastonite is a fairly soft non-metallic mineral that grinds to a brilliant white fibrous powder, in which form it is used mainly in the ceramics industry and as an extender for paints. It has also been investigated as a source of mineral wool. Current supply of the mineral is obtained from sources in the United States.

Wollastonite (116), $CaSiO_3$, occurs chiefly as whitish platy crystals or cleavable masses in crystalline limestones and other metamorphic rocks. Common mineral associates are garnet (2) and diopside. Large deposits of wollastonite are relatively rare and their value is affected in large measure by the amount of impurities they contain and the difficulties involved in separating them.

The principal known sources of wollastonite are at Willsboro, New York State, and in California. The mineral has been identified at several localities in western Quebec, Ontario and British Columbia, but not in commercially important amounts.

Because wollastonite is a common mineral, additional occurrences of it are to be expected. However, because it must compete in many of its uses with talc and other materials and because beneficiation is usually necessary to produce a clean product, only large and rich deposits are likely to be of interest.

ZINC

References: A, B

Zinc is exceeded only by steel, aluminium, and copper in world metal-production. In recent years Canada has produced approximately 400,000 tons of zinc annually and is a close second to the United States in world production. All provinces with the exception of Alberta and Prince Edward Island have produced significant amounts. Canada's reserves, 17 million tons, are the world's largest and comprise one fifth of the world total. Zinc is most widely used to prevent corrosion of steel; its value in this role is in the electrochemical, as well as the physical protection that it provides against oxidation. It is widely used in die casting, and is a major constituent of brass and many other alloys.

Sphalerite (117, 118), ZnS, is the only important ore mineral of zinc in Canada. It is very commonly associated with galena, chalcopyrite, pyrite and pyrrhotite in major base-metal deposits. Sphalerite is a deceptive mineral because it varies in lustre from metallic to vitreous and in colour from black through brown to honey-yellow, depending on the amount of iron substituting for zinc.

A common type of zinc deposit is comprised of pods and irregular replacement bodies in dolomitic limestone where it is associated with galena. In Canada, deposits of this type are known in the Salmo area, British Columbia, and along the south shore of Great Slave Lake near Pine Point. These are similar to the famous Tri-State deposits of the United States. Zinc, again associated with lead, occurs in a large single body of massive sulphides replacing sediments in Canada's largest producer, the Sullivan mine in southeastern British Columbia. More complex deposits of copper, lead and zinc sulphides occur in mixed sedimentary and volcanic terrains in the Yukon, northern British Columbia, Ontario, Quebec, and the Maritimes. Unlike lead, zinc is also commonly found in what are predominantly copper deposits—massive bodies of pyrite, chalcopyrite and sphalerite in volcanic rocks. Flin Flon on the Saskatchewan-Manitoba boundary is of this type and there are other important examples in north-central Ontario, northwestern Quebec, and British Columbia. Techniques for detecting concealed but electrically conductive sulphide bodies, developed by Canadians, have led to the discovery in recent years of large reserves of zinc ore, particularly in New Brunswick and Quebec.

ZIRCONIUM

References: B

Jones, R.J. (1954): Zirconium; Mines Branch, Dept. Mines, Tech. Surv., Mineral Resources Info. Circ. MR7.

Zirconium is used principally in moulding sand as the mineral zircon, and in the ceramics and refractory industries. It finds minor uses in steel-making, in chemistry and, because of its low neutron adsorption when hafnium is removed, in atomic research. World consumption, estimated to be about 80,000 tons of zircon annually, is readily met from known sources as a by-product of titanium production.

Zirconium is very closely associated geochemically with hafnium, and less closely with titanium. The principal ore mineral is zircon (120), $ZrSiO_4$, and a minor ore mineral is baddelyite, ZrO_2. Zircon generally contains about 4 per cent of Hf in solid solution. Although zircon is a very common accessory mineral in granites and similar rocks, it is recovered almost wholly from beach sands where it is associated with rutile, TiO_2, ilmenite, $FeTiO_3$, etc.

Principal beach sands from which zircon is recovered are in Australia and in the United States (Florida and California). No important placer deposits of zircon are known in Canada but noteworthy occurrences in rock in Canada are in east-central Ontario and southwestern Quebec. These deposits cannot compete economically with beach sands.

It is a remote possibility that zircon could be recovered as a by-product of uranium ores of the Blind River (111) and Bancroft (113) camps.

INDEX TO RAW MATERIALS