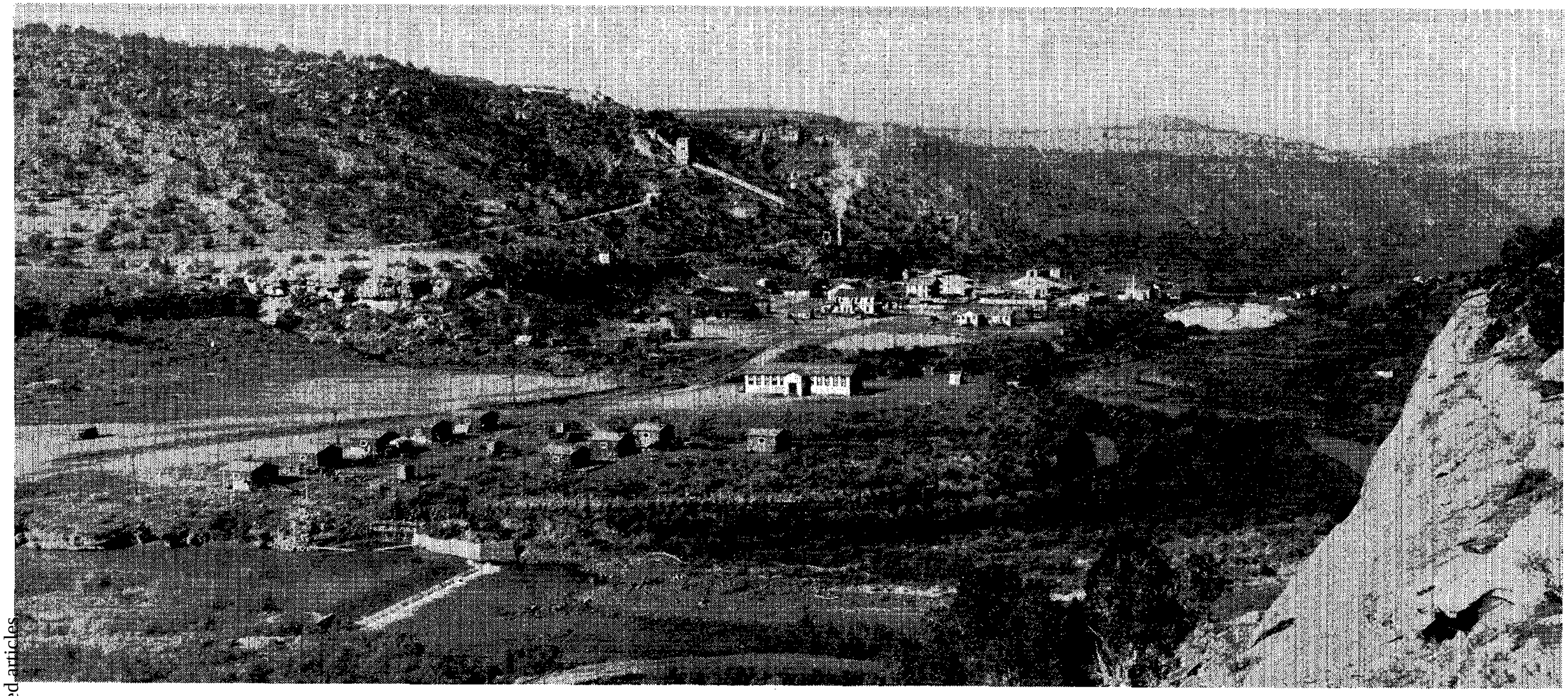

VANADIUM MINE AND PLANT AT URAVAN, COLO. *Courtesy, U. S. Vanadium Corporation*

STRATEGIC RAW MATERIALS

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UNEQUAL geographical distribution of raw materials has created national monopolies. Monopolies cause international irritations, and irritations long continued lead to war. Those nations which become involved in war have double need for raw materials to maintain efficient military and industrial machines. Nations at peace also suffer from lack of industrial raw materials because trade with the belligerents becomes impossible. The purpose of this article is to examine the raw materials imported into the United States, both as to need and quantity, and to point out what is yet to be done toward attaining independence of foreign suppliers. Those nations with great quantities of necessary raw materials have the greatest possible chance of protecting these possessions, unless some vitally strategic imports are shut off. If this happens to any nation, human resourcefulness in developing and adapting substitutes may often assure continuance of supplies.

In this study imports will be examined to see whether the United States is dependent for any material which, if the foreign supply were stopped, would cripple industry. Industrial rather than military requirements are stressed in this analysis since armed forces depend to a great extent upon normal commercial developments. By comparing the years 1926 and 1937 (Table I) the change over twelve years may be analyzed, and an attempt is made to explain the varying dependence.

Tables II, III, and IV show the three classifications of important raw materials. Table II lists those principally imported, and each is given a separate analysis. The Army and Navy munitions boards list several other materials which have not been included here but are considered by them to be strategic. They are coconut shells, coffee, hides, manila fiber, mica, optical glass, quartz crystal, silk, and wool. These have been developed as short paragraphs in the body of the article and no statistics are quoted, for normally statistics of these materials are either too small to be significant, or are misleading unless broken down into special cases.

ANTIMONY

Industrially, antimony is important through its use in many alloys—type metal, britannia metal, Babbitt metal, battery plates, hard lead, and white metal alloys. Military importance comes from its use in shrapnel, primers, lead shot, and tracer bullets. As a sulfide, antimony is used as a range finder in gunnery, for upon the explosion of shells containing it, dense clouds of white smoke are formed.

Table II indicates that our dependence for antimony is almost complete and is increasing slightly. This is not so alarming in 1937 as it was in 1926, for in the latter year our main supplier was China; in 1937 it proved to be Mexico. China still ships us more regulus or metal than any other country, but the antimony content of the ore we receive from Mexico for smelting here is about 60 per cent of our total consumption. The total amount of antimony from ore and metal received from China is only 5 per cent of our consumption. Latin American countries are becoming important producers, and in 1937 the antimony content of ores shipped to us from Latin America was: Mexico, 18,220,000 pounds; Chile, 3,414,000; Bolivia, 2,094,000; Argentina,

TABLE I. IMPORTS, EXPORTS, AND PRODUCTION FOR 1926 AND 1937 (IN THOUSANDS OF POUNDS) (*19–25*)

Name	1926 Imports	1926 Exports	1926 U. S. production	1926 U. S. consumption[1]	1926 Production, % of consumption	1926 Dependence on imports, % of consumption	1937 Imports	1937 Exports	1937 U. S. production	1937 U. S. consumption	1937 Production, % of consumption	1937 Dependence on imports, % of consumption
Antimony	43,638	...	4,766[2]	48,404	10	90	29,724	874	2,532[3]	31,382	8	92
Asbestos	516,000	2,210	2,716	516,506	...	100	614,376	6,008	27,792	636,160	4	96
Asphalt	284,000	76,500	...	8,656,000	...	...	1,920,002[p]	417,514[p]	5,608,242[p]	7,110,730[p]	98	2
							57,326[n]	37,012[n]	970,768[n]	991,082[n]	98	2
Bauxite	630,000	196,000	880,000	1,324,000	67	33	1,110,000	271,000	926,000	1,765,000	53	47
Camphor	2,018[c]						1,912[c]	0	0	1,912	...	100
	1,170[r]	...	...	6,132	...	100	1,016[r]	0	0	1,016	...	100
	2,944[s]						1,828[s]	...	...	...	...	...
Cement	1,210,000	366,000	62,000,000	62,844,000	98	2	680,000	142,000	44,500,000	45,038,000	99	1
Chrome ore	481,178	...	316	481,404	...	100	1,215,000	0	5,140	1,220,140	0	100
Cinchona bark	3,906	...	...	3,906	...	100	84	0	0	84	0	100
Cobalt	875	...	...	875	...	100	1,661	0	0	1,661	0	100
Copper	779,441	965,685	1,750,000	1,563,756	112	...	574,724	691,168	1,675,540	1,559,096	108	0
Cryolite	17,000	7,834	...	9,166	...	100	36,600	0	0	36,600	0	100
Fluorspar	152,000	...	257,314	409,314	63	37	74,126	916	362,460	435,670	83	17
Graphite	32,387	810[4]	10,939[5]	39,042	28	82	59,186	2,028	...	...	...	...
Iodine	711	...	...	711	...	100	1,785	0	299	2,084	14	86
Iron ore (million lb.)	5,700	1,940	151,500	155,200	97	3	5,330	2,760	160,000	162,570	98	2
Lead	310,722	142,481	1,391,660	1,559,901	89	11	71,806	40,182	886,284	917,908	97	3
Magnesite	185,092	...	267,000	452,092	59	41	107,638	0	406,874	514,512	80	20
Manganese	800,000[1]	...	456,000[1]	1,263,600	36	64	982,000[1]	0	338,000	1,320,000	26	74
Mercury	2,146	9	572	2,709	21	79	1,438	35	1,250	2,653	47	53
Molybdenum	...	...	1,371	1,371	100	...	7	14,709	29,419	14,717	200	0
Nickel	45,500	3,138	615[2]	42,977	1	99	108,871	8,947	438[3]	100,362	0	100
Opium	144	...	...	144	...	100	183	0	0	183	0	100
Phosphate rock	38,900	1,671,000	7,200,000	5,567,900	129	...	29,500	2,330,000	9,400,000	7,099,500	134	..
Platinum (troy oz.)	114,968	13,471	286[2,6]	103,661	0	100	148,809	62,441	9,997[3,6]	96,365	10	90
Potash	532,560	...	46,732	579,292	8	92	702,234	65,742	567,000	1,201,492	48	52
Quinine sulfate	97	...	...	97	...	100	83	...	...	83	0	100
Rubber	980,000	50,000	...	930,000	...	100	1,287,105	106,316	...	1,180,789	0	100
Salt	121,455	317,816	14,800,000	14,360,729	104	...	102,082	140,222	18,483,128	18,444,988	100	0
Sulfur	...	1,302,000	4,250,000	3,948,000	108	...	875	1,470,000	6,030,000	4,560,000	132	0
Tin	173,516	4,320	16[2]	169,180	0	100	194,000	690	[3]	193,310	...	100
Tungsten ore	6,190	29	2,766	8,927	31	69	10,190	...	7,000	17,190	41	59
Vanadium	1,940	...	661	2,601	25	75	1,259	...	1,086	2,345	46	54
Vanadium ore	16,800	...	43,200	60,000	72	28	14,806	...	262,160	276,966	94	6
Zinc	29,295	304,238	1,223,982	939,039	130	...	76,372	17,042	1,102,330	1,161,660	95	5

[1] Estimated.
[2] Does not include secondary recovery: antimony, 37,400,000 pounds; nickel, 6,100,000; tin, 64,000,000; platinum, 38,795 troy ounces.
[3] Does not include secondary recovery: antimony, 24,680,000 pounds; nickel, 4,800,000; tin, 59,718,000; platinum, 55,926 troy ounces.
[4] Exported 3,474,000 pounds of synthetic graphite.
[5] Manufactured 21,164,000 pounds of synthetic graphite.
[6] Includes Alaska.
[c] Crude. [n] Natural. [p] Petroleum. [r] Refined. [s] Synthetic.

TABLE II. MATERIALS NORMALLY IMPORTED TO A MAJOR EXTENT

Material	% Dependence on Imports 1926	1937	Material	% Dependence on Imports 1926	1937
Antimony	90	92	Mercury	79	53
Asbestos	100	96	Nickel	99	100
Bauxite	33	47	Opium	100	100
Camphor	100	..	Platinum	100	90
Chrome ore	100	100	Potash	92	52
Cinchona bark	100	100	Quinine	100	100
Cobalt	100	100	Rubber	100	100
Cryolite, natural	100	100	Tin	100	100
Graphite, natural	82	..	Tungsten ore	72	59
Iodine	100	86	Vanadium	75	54
Manganese	64	74	Vanadium ore	28	6

TABLE III. MATERIALS NORMALLY IMPORTED TO A MINOR DEGREE

Material	% Dependence on Imports 1926	1937	Material	% Dependence on Imports 1926	1937
Asphalt, natural	..	2	Iron ore	3	2
Asphalt, petroleum	..	2	Lead	11	3
Cement	2	1	Magnesite	41	20
Fluorspar	37	17	Zinc	0	5

TABLE IV. MATERIALS NORMALLY EXPORTABLE

Material	Production, % of Consumption 1926	1937	Material	Production, % of Consumption 1926	1937
Copper	112	108	Salt	104	100
Molybdenum	...	200	Sulfur	108	132
Phosphate Rock	129	134	Zinc	130	95

1,962,000; Peru and Panama, minor amounts. The output of Bolivia is capable of greater expansion which makes our situation more comfortable from an economic and military standpoint.

The extent of reserves in the United States is not certain, and the quantity produced domestically, mostly from crude lead, is too small to satisfy our requirements. Recovery of secondary antimony is large and almost equals the consumption of virgin metal.

Experiments are now in progress for the utilization of complex antimony ores containing precious metals, but there is still a question as to whether the natural reserves are extensive enough to guarantee independence, even under favorable economic conditions.

ASBESTOS

No change in our dependence upon imports of asbestos has occurred in the past decade. In 1926 we produced 0.5 per cent of our consumption and in 1937 we supplied only 4 per cent. Our reliance upon outside sources is a matter of economics; it is cheaper to import from Quebec than to ship from our principal deposits which are in the Southwest. These reserves are probably large (*12*), and there are a number of potential mines. But they are not being operated because the material is not as clean or desirable as that obtained from the Canadian deposits, and the long haul to market adds to the cost. The Quebec belt of asbestos, mainly chrysotile, extends into Vermont, and most of the asbestos produced in the United States comes from there. The utilization of this deposit is becoming increasingly important, for the material is of the same quality as that in Canada. Proved resources which from time to time have produced asbestos for domestic use exist in Arizona, California, Maryland, Montana, Idaho, Washington, and Georgia.

The principal uses of this material are in asbestos-cement products, asbestos paper, millboard, brake linings, high-temperature insulation, and to a smaller extent, in woven materials. The past decade has seen a change from the woven brake linings to the molded type. Total consumption of asbestos has not altered through this practice, for it is used in both types of brakes. The molded types utilize a shorter fiber, and in this manner our dependence on long-fiber asbestos, which is imported from British Africa, may be reduced.

Mineral substitutes such as rock wools, slag wools, and rock corks have been on the market for a number of years and are used in low-temperature insulation. Glass wool cloth is being developed to replace asbestos in electrical appliances but has not found extended use. No substitute has yet appreciably altered our consumption of asbestos.

Replacements for brake linings are not known, but reserves of asbestos for production of the molded type are available in the United States; reserves of spinning fibers, our smallest item of consumption, are located in Arizona and Maryland. There is no great hope for future development of the large southwestern deposits, for prices, freight costs, and requirements of evenness of quality form an economic burden too heavy to shoulder in the present market.

BAUXITE

Our dependence upon extraterritorial deposits of bauxite for about 40 per cent of our consumption has changed little over the past twelve years and only the comparative richness of the foreign ores leads us to import at all. Like many of the materials imported into our nation a slight price increase would make our many marginal and submarginal deposits workable without necessitating major technological changes in manufacturing operations (*12*).

The aluminum industry is the largest single consumer of bauxite, using about 50 per cent of our yearly supply. The manufacture of chemicals, abrasives, cements, and refractories accounts for the other 50 per cent (*32*).

Strategically our only concerns are the supply of cryolite and the present production capacity of aluminum plants. Aluminum consumption has increased rapidly, and despite the recession in 1937 more aluminum was used in the United States during that year than ever before. Totals for 1937 rose above those of 1929 in primary and secondary production, almost a fourfold increase in consumption over the low of 1934. Only by increasing output through additional production units could we meet emergency demands, and because aluminum manufacture requires an immense amount of electrical energy, the time necessary for the completion of power plants becomes the critical factor (*36*). At present, expansion programs are under way in the aluminum industry which will probably eliminate plant capacity as a vital strategic problem.

CAMPHOR

The most important and certainly the most strategic essential oil is camphor. Japan has a monopoly on the natural product "obtained by distilling the wood of an evergreen tree of the laurel family found in Formosa, Japan proper, and southern China." The price and production are controlled by the Japanese Government (*35*), and only the success of Germany early in the twentieth century in producing synthetic camphor relieved the world of sole dependence upon Japan and attendant high prices. The price of natural camphor has steadily dropped in an unsuccessful attempt to discourage synthetic producers.

In 1932, with the price of natural camphor about 29 cents a pound, and with tariffs of 1 cent per pound for crude and 5 cents for refined and synthetic, production of the synthetic material began in the United States (*7*). This industry, which owes its life to the efficiency of modern chemical engineering, has to date successfully kept pace with the lowering price of natural and imported synthetic camphor.

The Tariff Act of 1930 (page 51) states: "If at the end of three years after the enactment of this Act, the President finds that during the preceding six months the domestic production by quantity of synthetic camphor did not exceed 25 per centum of the domestic consumption thereof by quantity, or, at the end of four years .... that during the preceding six months such domestic production did not exceed 30 per centum of such consumption, or, at the end of five years..... that during the preceding six months such domestic production did not exceed 50 per centum of such consumption, he shall by proclamation so declare, and, after six months thereafter, the rate on synthetic camphor shall be 1 cent per pound."

A committee reported to the President on each occasion and for each period when domestic industry, working under a duty of 5 cents a pound to offset high American labor costs, met the requirements. Production figures for synthetic camphor are not available, but annual output is believed to be well above 1,500,000 pounds.

Camphor's most important use is as a plasticizer in the manufacture of nitrocellulose plastics, at one time utilized in laminated glass as well as in molded arti-

Packing Synthetic Camphor after Flaking

Courtesy, E. I. du Pont de Nemours & Company, Inc.

cles and films. The present trend is toward plastics which do not require camphor; although the production of nitrocellulose products is not decreasing, other raw materials—notably cellulose acetate, cellulose ethers, and synthetic resins—are being used in most of the recent plastic applications. Strategically camphor can no longer be considered important.

COBALT

All American requirements of cobalt, a cartel-protected material, are imported. Ordinarily this would be serious, but our total consumption for 1937 was less than 2,000,000 pounds, so this metal, on a tonnage basis, is relatively unimportant. Leading sources are Canada, Union of South Africa, Belgian Congo, and Australia. Future consumption may grow if the price falls, for the steel industries are making valuable industrial cobalt alloys and the decrease in cost would encourage use. The principal outlets of cobalt-iron combinations are for metal cutting tool steels and permanent magnets, although nickel aluminum magnets are replacing cobalt types to some extent.

The chief use of this material is the production of color in pottery and glass. Depending on the amount added, light blue to deep blue tones are obtained, and in flint glass, small amounts act as decolorizers (*30*). This element is relatively new to industry and experiments now in progress with plating, glazing, and mordanting may increase its fields of application.

CRYOLITE

The Danish State owns and controls the one known commercial supply of natural cryolite (*32*). Only at Ivigtut, Greenland, is it mined (*8*), and shipments are made to two distributors, one in Copenhagen and the other, the Pennsylvania Salt Manufacturing Company, in the United States. The latter used cryolite to manufacture soda and alum as early as 1865, and although cryolite is no longer used for this purpose, the company has maintained its contract.

The principal consumers are the aluminum industry, which uses cryolite as a solvent for bauxite in its electrolytic process, and the ceramic industry, in which cryolite is the base of an opaque glass resembling porcelain, for use in ceramic ware and vitreous enamels on steel. The 100 per cent dependence of the United States for its supply of this natural material is not critical or important, for the aluminum industry is now using artificial cryolite satisfactorily (*9*, *26*), and synthetic resins are being used to produce porcelainlike effects on metallic surfaces.

FERROUS ALLOYS

The importance of chromium, manganese, molybdenum, nickel, tungsten, and vanadium is due primarily to their use in ferrous alloys. Our dependence upon external producers for these metals is critical, for only tungsten and molybdenum are produced to any extent in the United States; the other alloying elements, silicon, zirconium, titanium, and copper, are either used in small amounts or are not strategic since they are produced in the United States.

The present tendency has been toward an increased use of alloying materials, nor is there any indication of a change in this trend. Therefore, in this section emphasis will be placed on the military nature of such materials.

CHROMIUM. We are practically 100 per cent dependent for chromium. A small amount is produced in the United States, but relatively low-grade ores make it impossible for domestic producers to compete with foreign suppliers who have the advantage of richer deposits.

Iron-chromium alloys are necessary for production of such equipment as bearings, cutlery, crusher parts, valve steels, armor plate, and in applications where resistance to corrosion, especially at high temperatures, is necessary. The steel industry, which uses the greatest amount of chromium, requires a product containing 50 per cent or more chromic oxide (*12*), and it is unlikely that the mines of the United States could produce enough material of such quality to care for our normal requirements. The alloy-type ores come from Africa and New Caledonia; of our 1937 imports, Africa supplied 52 per cent, Cuba 12 per cent, and New Caledonia 11 per cent. The Cuban ore ought to be important strategically, but because its chromium content is low it cannot be used for alloying. Such ores are used in the manufacture of refractories and, next to steel, this industry is our largest consumer of chromium. Chemical manufacturing accounts for 13 per cent of our consumption, the compounds produced being used in electroplating, dyeing, and tanning (*27*).

From a military standpoint an accumulated supply of high-grade ore is a necessity. Recently the Navy commissioned a domestic producer to supply 2000 short tons of metallurgical-grade ore. This stock will be held in reserve for emergency use.

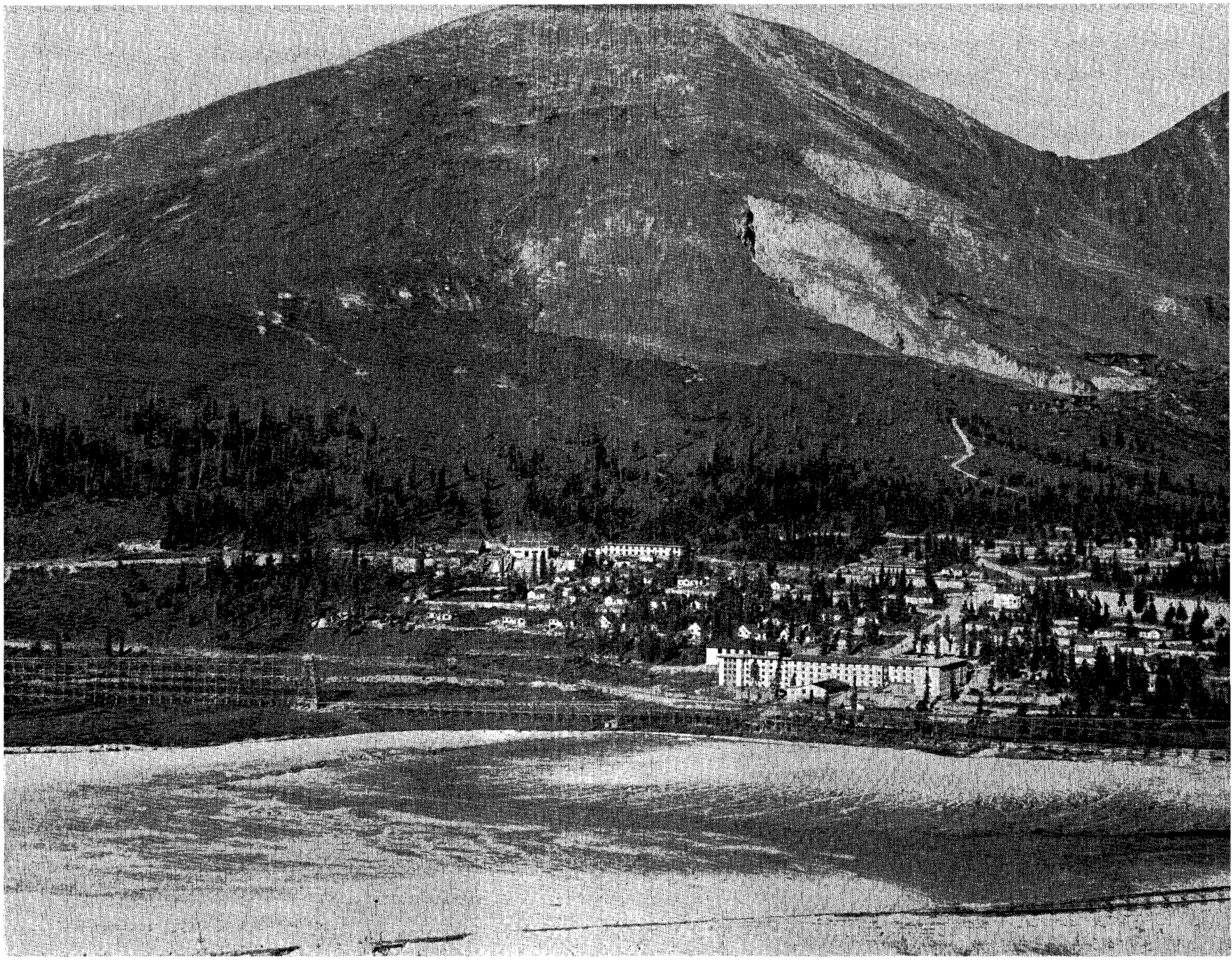
Partial substitutes for chromium are known, and molybdenum alloys are being used for high-temperature and high-pressure applications. However, substitutes (for many purposes there are none) will not make us independent of foreign chromium.

MANGANESE. The steel industry uses manganese as an aid in removing undesirable impurities from the molten steel and as an alloying element. It helps to desulfurize and deoxidize the furnace charge, and few pounds of steel are produced which have not been processed with manganese. In view of our great production of steel products, this metal is important. It would be desirable to have the major part of our consumption produced in this country, but the domestic sources are unable to produce manganese concentrates from our low-grade ores which will compete economically with the imported material. In an attempt to encourage domestic production, Congress imposed a tariff of 1 cent per pound of manganese in 1922. This was later reduced in the Brazilian trade agreement of 1935 to 0.5 cent per pound. The tariff aid was not successful because from 1922 to 1935 domestic industry produced only 5 per cent of American requirements for metallurgical-grade ore (*6*). In 1926 domestic production was 36 per cent of consumption and by 1937 this had dropped to 26 per cent.

There is an intense interest in the manganese problem of the United States, and many surveys have been made by individuals and societies. The American Institute of Mining and Metallurgical Engineers acknowledged the importance of the problem in 1925 and suggested a program designed to relieve the shortage an emergency could create (*1*).

Reserves of low-grade ore in the United States are large, and economical methods of extraction would eliminate manganese from the list of strategic materials. Leith and Liddell (*12*) estimated that the reserves of Spiegel in the Cuyuna Range of Minnesota alone are equivalent to the amount of ore which industry would consume in 36 years. From a military standpoint our domestic sources of high-grade ore are probably great enough to ensure a five-year supply.

Most of our manganese comes from Russia, the African Gold Coast, Brazil, and India. In 1937 Russia supplied about 41 per cent of our consumption, Africa 29 per cent, and Brazil and India each about 8 per cent. Cuba sent 13 per cent, an increase over the 4 per cent supplied in 1936 which was made possible through technological improvements.



Mountains of Molybdenum

Industry has been busy on the problem of developing an independent manganese supply, and processes of leaching manganiferous iron ores are now on the border line of being economical.

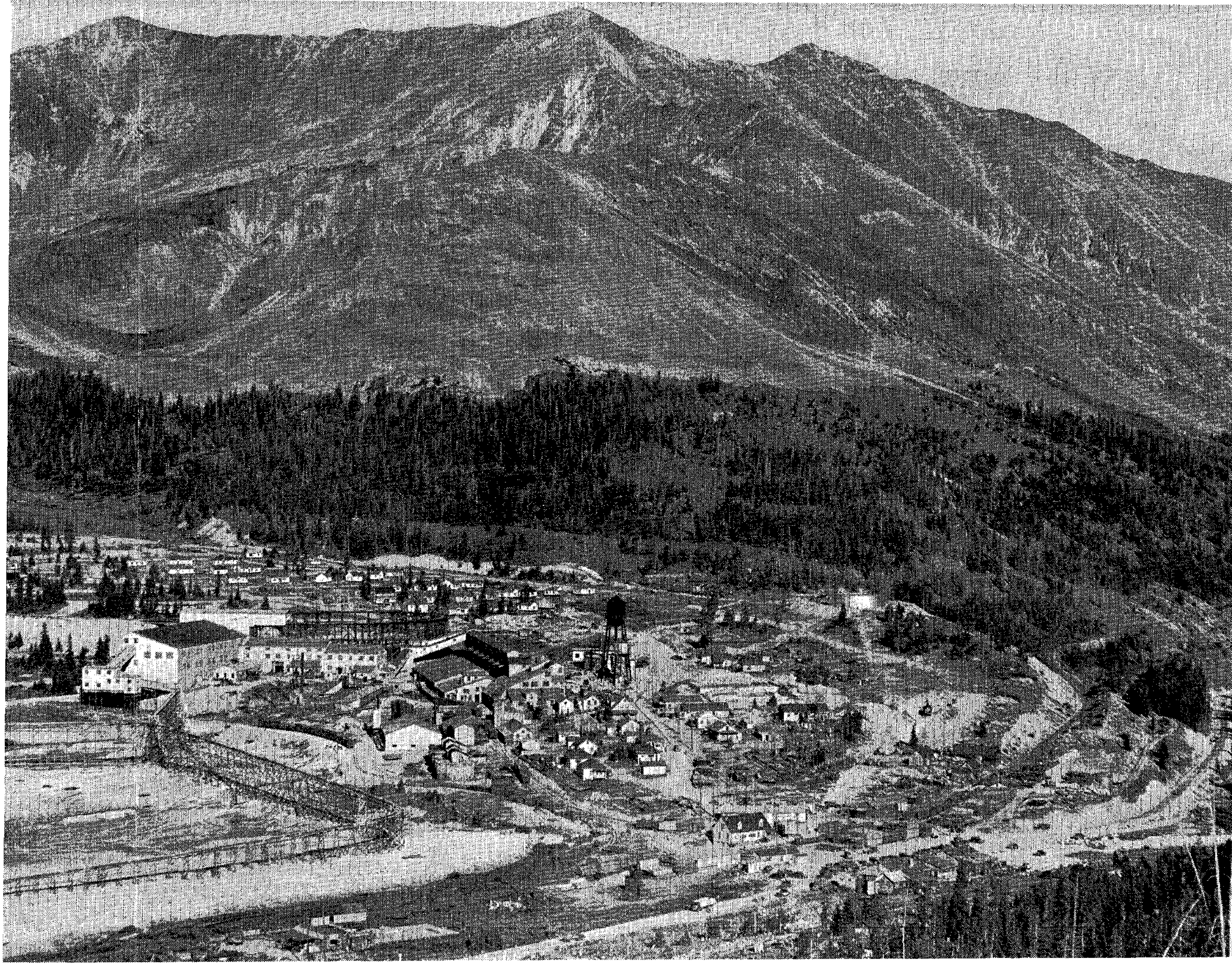
The United States Bureau of Mines has experimented with and developed an electrolytic process of recovering manganese in metallic form (*12*). This may prove to be economically sound, but until such processes are commercially feasible the United States will continue to be dependent upon foreign sources.

A continuing supply of manganese during an emergency is quite necessary with present steel-treating techniques, but variations are possible and they would undoubtedly be practiced. Increased costs due to war conditions would force manufacturers to substitute spiegel (*10*), silicon-manganese, and other manganese alloys for ferromanganese as they did during the World War. The committee of the A. I. M. M. E. (*1*) estimated that perhaps 15 per cent of our metallurgical needs could be supplied by low-manganese pig iron, and that from 15 to 50 per cent of our needs could be supplied by spiegel.

Steel manufacturers know how to use slag piles for the recovery of manganese, and this technique only awaits an emergency to become a source of supply (*28*). The use of low-manganese pig iron as the original charge in the furnace will provide another method of saving; it has even been suggested (*28*) that increasing the basicity of the slag by the inclusion of additional quantities of fluorspar would reduce the manganese compounds in the slag to metal. Germany and England have been using soda ash to desulfurize steel batches, and aluminum compounds have been employed as deoxidizers.

In an emergency the supplies of manganese from Cuba and Brazil may acquire vital importance; but before domestic production, plus that of Brazil and Cuba, could equal the amount of ore necessary for a wartime steel industry, a stringent shortage would occur. In view of this, a bill was introduced in the Senate recently to encourage storage of quantities of high-grade foreign ore within our borders. In this way our wartime steel industry could draw upon such reserve supplies while other sources were increasing their output.

Nickel. The only large supply of nickel the United States ever had was a mine at Lancaster Gap, Pa., which in 1891 became uneconomical to operate in competition with the high-grade ores produced at the Sudbury Mine in Canada and the mines in New Caledonia. Since 1909 (*12*) no nickel has been mined in the United States. Although some is



Courtesy, Climax Molybdenum Company

produced every year as a by-product of copper refining, the United States is entirely dependent on imports.

In 1937, 108,871,000 pounds of nickel were imported; exports in the form of Monel metal, bars, sheets, rods, etc., were 8,947,000 pounds, and world production was probably not greater than 250,000,000 pounds. Therefore in 1937 the United States consumed about 40 per cent of the world's nickel; in 1926 this figure was 59 per cent. In these same years we produced about 0.5 per cent of the amount we consumed.

Our chief source of nickel is Canada, a friendly country, and it is difficult to imagine conditions which would shut off our supplies. However, in its surveys the Army considers only the United States as a source of material; for strictly military uses, consideration of normal stocks, secondary recovery, and domestic production has led Emney (*5*) to conclude that we could last through a state of seige of at least two years without imports.

The percentages of nickel used in various industries are as follows (*17*):

Nickel steels	55	Heat and electrical resistance	3
Monel, Inconel	12	Nickel, brass, bronze, and castings	3
Nickel-copper alloys	10	Nickel-iron alloys	1
Electrodeposition	10	Miscellaneous	1
Nickel cast iron	5		

It has been reliably estimated that over a period of time most of our nickel steels could be replaced by other materials. There is no known substitute for nickel in stainless alloys, but distinct savings of the metal could be effected by nickel plating.

The relative nearness of nickel deposits makes this metal less critically strategic than substances shipped from long distances, such as tin, manganese, and chromium; and it is possible to substitute nickel in several applications now consuming tin and chromium.

TUNGSTEN. Production of tungsten in the United States is apparently increasing, for in 1926 domestic sources supplied 31 per cent of our needs, and by 1937 this had increased to 41 per cent. American mines are aided by a tariff of 50 cents a pound and, as the table on the following page shows, price affects the amount produced (*11, 29, 30, 32*).

Reserves of high-grade ore are estimated as equivalent to an eight-year supply, and although low-grade deposits are extensive no economical process of recovering the tungsten content is available.

Most of the tungsten imported into the United States comes from China, where the ore is plentiful, from the Malay Peninsula, and from Australia. China leads by far in the amount shipped to us, sending 68 per cent of the total imported; the Malay states and Australia account for only 18 and 6 per cent, respectively. Tungsten is used in the manufacture of steel for high-speed tools as the alloy is able to keep its cutting edge when heated, in electric light filaments, in magneto steel, in radio tube filaments, and in a few chemical applications. By far the largest use is in alloys, estimated at 90 per cent.

PINE CREEK TUNGSTEN MINE NEAR BISHOP, CALIF.

Courtesy, U. S. Vanadium Corporation

Year	U. S. Production, 1000 Lb.	Av. Price per Unit	Year	U. S. Production, 1000 Lb.	Av. Price per Unit
1926	2766	$11.10	1932	792	$ 9.20
1927	2328	10.37	1933	1790	9.58
1928	2416	10.40	1934	4098	14.57
1929	1660	13.13	1935	4790	13.37
1930	1404	12.09	1936	5224	14.83
1931	2808	11.02	1937	7000	19.50

An important substitute, or rather alternative, that is being used as an alloying element is molybdenum. Domestic reserves of this element are large. If necessary it could replace most of the tungsten used in steels. For example, Germany has limited the use of tungsten by edict and with apparently no difficulty has substituted molybdenum. In 1925 the subcommittee on tungsten of the A. I. M. M. E. (*1*) reported that "molybdenum steel, once made, has very desirable qualities. The difficulty is in making the steel. Molybdenum volatilizes, does not mix uniformly with steel; the steel is red-short, making an enormous scale loss." However, the decarburization of the steel was at that time overcome by the use of borax. The modern method utilizes heat treatment, and today molybdenum is being used successfully in considerable quantities.

From a military standpoint our tungsten resources should be conserved, and yet the mines must be kept operating so that war supplies will be available. A possible solution is the creation of huge military stock piles of foreign ore and tariffs favoring producers in Bolivia and Mexico. In this way South American mines will be available in case the Pacific Ocean shipping lanes to Asia are closed.

VANADIUM. Although we imported only 6 per cent of the vanadium ore we consumed in 1937, we were dependent for 54 per cent of our supply of this metal. In other words, 94 per cent of the ore used was produced domestically and supplied only 46 per cent of the metal, and the 6 per cent of ore imported produced 54 per cent of the metal. In 1937 imported concentrates contained about 9 per cent vanadium; United States carnotite ores contained on an average about 2 per cent vanadium, and lower grade ores brought the percentage of contained vanadium even lower. Dependence upon foreign ores is apparently economic, for in 1936 we imported 71 per cent of the metal consumed. Activity of domestic producers reduced this amount to its present figure and indications are toward a continuing increase in production. Chief external sources are Peru and Africa. Peru has produced most of the world's supply for many years.

Vanadium is used principally to increase the elastic limit, yield point (*31*), and impact strength of steels. The effects produced by small amounts of vanadium are out of all proportion to the amount added, compared to other alloying materials. Vanadium oxide is a catalyst of increasing usefulness, particularly in the manufacture of sulfuric acid.

Amounts of vanadium consumed are small, but it is an important metal since no substitutes for it in alloys are known. Strategically the deposits of Peru are readily accessible, and domestic deposits are now greatly increasing their production.

The position of the United States in regard to ferrous alloys may be summed up in the following quotation (*2*): "While it would not be entirely proper to say in these days of resourcefulness that anything is indispensable, it is nevertheless true that without ferro alloys certain of our major industries would be set back at least a generation in their development."

IODINE

Prior to 1932 the world's supply of iodine came from Chile and Japan. The Chilean industry, which had a virtual world monopoly, derived its iodine from the nitrate deposits; Japan's source was the iodine contained in seaweed. There was no production of iodine in the United States, and consumers were forced to pay the pegged price of about $4.50 a pound. A monopoly-controlled production is always a shining mark for the chemist, and the discovery of a high content of iodine in certain petroleum well waters of the West Coast provided the opportunity for an American iodine industry. Production started in 1932, and for about a year the Chilean price stayed the same. Domestic producers would soon have captured the entire market of the United States, but prices were drastically lowered and by 1936 were less than $1.00 a pound. Even with this low price domestic producers supplied 30 per cent of our needs. We produced 65,000 pounds more in 1937 than in 1936, though this amounted to only 14 per cent of our consumption. Imports increased more than threefold which accounts for our lower percentage of production. The savings to consumers, due solely to the resourcefulness of this particular American chemical industry, is enormous, and prices are unlikely to rise again to their once exorbitant levels. If competition and low prices cause domestic producers to cease operations (a fear which led Army officials to keep iodine on their strategic list), a proved source of iodine will still exist in this country to ensure against foreign control.

MERCURY

The ratio of imports to consumption of mercury has decreased during the past decade. In 1926, 70 per cent of our mercury was imported, and by 1937 this had been reduced to 53 per cent. In order to compete with the foreign product, mercury production in the United States requires a protective tariff and relatively high prices. The duty amounts to $19.15 per flask which, using the average 1936 price, is equivalent to 25 per cent ad valorem.

Mercury comes from Spain, Italy, and Mexico, and the chief producing states are California, Oregon, Arizona, and Texas. Spain and Italy have a virtual monopoly on mercury production, and in 1936 a cartel agreement between the two countries was abolished. The price, however, is independent of the cartel, for production of both countries is sold through one source.

Domestic ores are not rich (*12*), and production is a matter of price. Our problem consists of ensuring a native supply for emergencies without unduly penalizing consumers during normal periods.

Mercury's chief uses are in drugs (*34*), chemicals, fulminates used in detonators and ammunition, electrical apparatus, thermometers, the manufacture of vermilion and felt, and to a minor extent in mechanical devices.

In equipment applications the use of mercury is increasing, but this cannot be said of other fields. Vermilion is being replaced by other pigments. Synthetic organic compounds are replacing mercury compounds as detonators, the use of felt is decreasing in men's wear, and organic synthetics are making great inroads into the amount of mercury used in drugs.

OPIUM AND QUININE

Opium and quinine are not produced in the United States, and we are solely dependent upon outside sources for these medicinal substances.

Quinine production is a matter of absolute advantage to certain countries, climatic conditions being favorable to the cinchona tree in limited areas only. Ninety per cent of the world's cinchona bark comes from the Netherland Indies where production and manufacture are controlled by bureaus of both planters and manufacturers (*36*). Quinine is used in the treatment of malaria and, until the recent advent of two synthetic substitutes, was the only drug known which had desirable inhibitory effects upon this disease. The synthetic compounds are atabrine and plasmochine. The latter has been reported as being more potent than quinine (*33*). Although the essential chemicals necessary for the manufacture of the substitutes are imported from Germany (*36*), there is no reason why American chemical manufacturers could not produce them, during an emergency, in quantities sufficient to supply our needs.

The poppy plant, from which opium is derived, depends on a national comparative advantage of cheap labor and localized demand, legal and illegal, in the Far East. The cheapness of labor is amply illustrated by the fact that the financial reward to a poppy grower in India is estimated at 25 shillings (about $6.00) for six months of labor (*4*).

The League of Nations has continuously made ineffective gestures toward control of this drug but as yet with little effect. It is possible that the only solution to this great social problem lies in synthesizing morphine, opium's most important constituent. Most of the alkaloids have already been synthesized, notably nicotine and papaverine. Codeine, which is prepared by the methylation of morphine, awaits only the synthesis of that compound.

The chief sources of opium are Great Britain and the Netherlands, who between them supply 89 per cent of our consumption.

PLATINUM

In 1917 the United States Government, with the help of the War Department and the Russian Embassy, smuggled 21,000 ounces of platinum out of Russia. This incident illustrates the need for platinum during a war period when a potential shortage for commercial use made this action necessary. Seemingly unimportant in commercial applications, platinum's many uses in chemical industry as a catalytic agent, in crucibles, rayon spinnerets, sulfuric acid spraying jets, and electrical instruments such as thermocouples, contact breakers, and switches, make it an important raw material.

However, the picture has changed considerably since 1917 when the main source of platinum was Russia. Today Canada, Colombia, and the United Kingdom supply us with most of our platinum. Canada ships platinum ore to England, and she, in turn, ships us the refined metal.

Other substances are being used in place of platinum (*3*, *15*): vanadium catalysts in chemical industry, alloys of cobalt and silver in the electrical field, and alloys of nickel and of palladium for dental work. It has even been suggested that glass may replace platinum in rayon spinnerets. Platinum's use continues as one of convenience or necessity, for its high price has made it a metal for which substitutes are actively being sought. The speculative nature of the price of platinum has been important in recent years because the metal has been hoarded, instead of gold, as a hedge against inflation.

Strategically we are comparatively safe, for the platinum from the ores of Canada could, in an emergency, be extracted by our own refiners.

POTASH

Since 1926, when we produced only 8 per cent of our consumption, newly discovered potash deposits have increased this figure to 48 per cent. The discovery of these deposits is the result of a patient search conducted by the Geological Survey, the Bureau of Mines, and several private groups (*18*, *31*, *32*). Indicated reserves are large, and future developments are expected to add substantial amounts.

The most important consumer of potash is the American farmer, for it is vital to plant life. He uses about 95 per cent of our supply (*24*). The other 5 per cent is utilized by our chemical industries for such materials as caustic potash, potassium chloride, potassium carbonate, etc.; in these and other forms, potassium is used for the manufacture of soft soap, glass, and explosives.

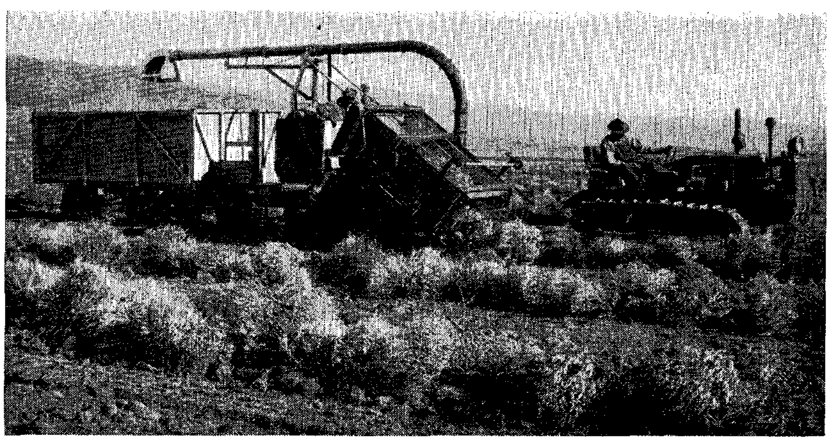
Of the amount imported, Germany accounted for 66 per cent and the Netherlands shipped us 14 per cent. Material sent from the Netherlands probably originated in either France or Germany, so that the major amount of our imports are of German origin. However, American industry is capable of expansion to supply all of our needs in an emergency, and American farmers will never again face a shortage of potash through embargoes on imports.

RUBBER

The United States will probably never produce natural rubber, and its dependence upon importation will continue as long as it is economical to use Nature's product. Largest imports come from the Malay States and the Dutch East Indies, and minor amounts are supplied by Ceylon and Brazil. The major production of rubber is therefore under British and Dutch protectorate.

In the depression year of 1932 rubber sold for an average price of 3 cents a pound. Producers claimed this was below production cost and sought a method of protection. On July 1, 1934, the English, Dutch, French, Siamese, and Borneans entered into a five-year protective agreement, with options for renewal at the end of the period. The plan is evidently working, for prices have risen, and the average prices for three years were: 1934, 13 cents; 1937, 19.4 cents; 1938, 16 cents (approximately). The agreement has recently been extended for another five years (*16*).

The search for synthetic rubber has evolved several useful materials, Neoprene, Thiokol, Buna, and Soyprene among them. It would be too costly to replace the plantation product with that of the factory, but should an emergency arise which would cause the price to rise and remain at an exorbitant level, synthetic rubber would capture a large part of the market.



Courtesy, Intercontinental Rubber Company

HARVESTING 4-YEAR-OLD CULTIVATED GUAYULE SHRUBS, A SOURCE OF DOMESTIC RUBBER

Another source of rubber is the guayule shrub which grows wild in Central Mexico and has been cultivated to a limited extent in California. Results of the domestic venture are said to be technically successful but not commercially attractive at present. The wild plant requires about seven years to reach its rubber-producing stage, though this can be reduced to four under cultivation. The rubber produced contains about 20 per cent of resin, and although methods of extraction are known, uses today do not require its removal. Consumption of guayule rubber in the United States now amounts to about 6,000,000 pounds from uncultivated Mexican shrubs, and about 800,000 from domestic sources.

The principal use of rubber is in the manufacture of automobile tires, and attempts are being made to adapt the synthetic material to this use. The man-made product is already supplanting natural rubber for gaskets, laboratory equipment, and various other applications where its stability is useful.

Strategically America is in a critical condition because a leaf disease, which ultimately kills the tree, prevents the creation of South American plantations. As a natural material, adapted to the temperate zone, we have only the guayule shrub, and this, together with synthetic rubber and secondary recovery, must answer our emergency needs.

TIN

The production of tin in the United States (Table I) is almost entirely secondary and is recovered from metals, alloys, and chemicals. During 1937 Alaska produced about 380,000 pounds, the United States about 5760 pounds. In thirty-six years the United States has produced 291 long tons; in the past decade the minimum yearly consumption of primary tin was 35,478 long tons (*24*). The United States has no known suitable deposits or reserves. The British Straits Settlements are our largest suppliers, and in 1937 we received 86 per cent of the amount they produced, which was 76 per cent of our imports. Bolivia sent to us about one thousandth of our consumption, yet they produced about 38 per cent as much as did the Straits Settlements. However, Bolivia exports ore because she does not have the fuel for conversion, while most of our importation is tin that has already been refined. The United States smelts very little tin, and if our supplies of metal were shut off, necessity would require the building of an American tin-smelting industry. Strategically, though probably not economically, a tin-refining industry should be a part of the industrial structure of our United States.

The uses of tin are varied. The ubiquitous tin can uses almost half of our consumption, and solder, Babbitt and other alloys, foil, tubes, and chemicals make up most of the other 50 per cent. Military uses include tin metal in shrapnel and compounds of tin in flares and smoke producers (*5*).

Substitutes for tin are growing in importance. In bearing metals and bronzes, nickel may sometimes be used in place of tin. Recently bearings of synthetic resins, lubricated with water instead of oil, have shown promise abroad. For foil, cellophane is used, and tubes are now being made of aluminum. In the tin-plating industry possible substitutes are nickel and aluminum. We need only to examine the list of substances which are not suitable for packing in tin-lined cans to wonder why tin substitutes have not already come into more general use. Mantell (*13*) listed forty-eight foodstuffs which were packed in tin cans, and for twenty of them the container proved unsuitable. Resin linings are now used in beer cans, but because resins are injured by the high heat required for sterilization, they cannot be generally used for foodstuffs. However, this application is too new for its possibilities to have been exhausted. Enamel-lined cans have been in use many years for canning substances which cannot be packed in tin, and glass will continue to be an important, satisfactory food container.

Tin's importance rests upon the fact that it protects iron and that the technology of making cans has reached its high efficiency upon tin-coated ferrous sheets. A switch to substitutes would require a definite change in technology which might involve higher costs and a decreased use efficiency.

Tin is one of the great problems and weaknesses in our military strategy, and a serious effort should be made to perfect the use of substitutes and actively to import and smelt Bolivian ores.

STRATEGIC MILITARY MATERIALS

The strategic materials listed by the Army and Navy munitions boards must be considered in a military sense. Coconut shells are considered strategic because they produce a superior charcoal for gas mask use. Sources are the tropical countries indicative of a lengthy water transportation.

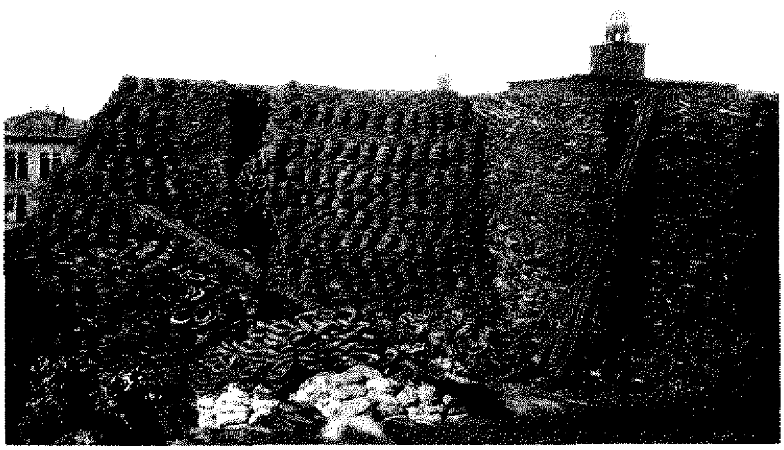
Coffee is a strategic material though it can hardly be classified as important or critical. Brazil is the world's largest producer. The only two reasons we would have to fear a shortage is war with Brazil, which is most unlikely, or a war which successfully throttles our Caribbean ocean transport. Any war which could shut off our supply of coffee would certainly bring with it a spirit of sacrifice capable of foregoing the pleasure derived from such a luxury.

Courtesy, E. I. du Pont de Nemours & Company, Inc

RUBBER MILL FOR WASHING A DOMESTIC SYNTHETIC RUBBERLIKE SUBSTITUTE

About one third of the hides consumed in the United States are imported, so that this item is not seriously strategic. Substitutes for leather are finding greater use, and if necessity dictated the change, our present consumption could be reduced.

The commercial source of Manila fiber is the Philippine Islands, so that its availability during emergencies depends on the United States defense system. Cotton is an acceptable substitute; like all of our imported fibers, the most strategic item is the time necessary to introduce the substitute successfully.



Courtesy, U. S. Rubber Reclaiming Company

RECLAIMED RUBBER IS A DOMESTIC SOURCE OF THIS RAW MATERIAL

Mica is an important insulation material and the United States has an ample supply of every form used except sheet mica. Imports of the other forms are great but only because of the cheap labor available in producing countries.

Optical glass and quartz crystal find outlets in scientific equipment, cameras, radios, etc. The United States manufactures about 50 per cent of its optical glass requirements and imports quartz crystal from Brazil.

Military uses of silk are in parachutes, insulation, and powder bags. Industrially it is a luxury which could be eliminated in extreme emergencies.

Wool is necessary for clothing, and the United States produces about two thirds of its consumption. It has few substitutes, but by curtailment of nonessential uses we could maintain our self-sufficiency.

In our analysis we have noted that certain of our strategic materials could be produced in the United States if price warranted. Such materials could be described as economically strategic to differentiate them from others which are not contained within our borders. As mentioned before, the munitions boards consider only the United States as a source of material during wartime. There is no consideration of possible imports or using sea lanes that are not at the mercy of the enemy. If during a war this were actually the case, economy would have no meaning, and many of the materials we now view as important strategically would be produced in sufficient quantities in the United States. In this category are the many processes, which are even now on the border line of being economical, for producing manganese from low-grade ores, the tendency of tungsten production to increase as price rises, and the recent drastic expansions in vanadium production.

Ferrous alloys are necessary for steel manufacturing, but it does not follow that a shortage of alloying material would bring a cessation of steel making. There are other methods and techniques which would be perfected and used as economic conditions warranted, though steel manufacture would become more complicated and costly. Strategically such practices ought to be perfected during normal periods, for in this manner changes brought on by emergencies can be made with a minimum of errors. The German program of *Ersatz* may not be economically sound but it is good military strategy.

Mercury is another substance which could be produced in much greater quantities in the United States if price warranted such expansion. Natural cryolite could be supplanted by the artificial product; and although it would mean an immense expansion of present domestic production capacity, asbestos could be produced in sufficient quantities.

Iodine is an economic strategic material to every country with access to the sea. If price warranted, iodine could be produced from kelp. Domestic production from petroleum brines is a matter of price. Bauxite and potash are also raw materials which a rising price would remove from our strategic list.

Three items now considered strategic may be removed by the combination of chemistry and efficiency. They are rubber, silk, and mica. At present it would take strained and unusual economic conditions to replace natural rubber with our chemical substitutes, but it is possible. Silk may be replaced by recently announced polymerization products for insulation and parachute uses, though there is no reason to believe that they are being considered for such applications, and by cotton and rayon for powder bags. Mica has an untried and new substitute in "Alsifilm", a coherent self-supporting film made from bentonite clays. Sheets may be produced in any size, and it is thought to use this material in place of sheet mica, the only mica product in which we are deficient.

The substances in which we are deficient or totally lacking are tin, nickel, chromium, antimony, platinum, rubber, silk, opium, quinine, Manila fiber, coffee, coconut shells, and sheet mica. It has already been noted how synthetic resins are being used for tin; domestic alloying materials for chromium and platinum, and organic substances for rubber, silk, opium, quinine, and Manila fiber. These substitutes, however, cannot totally replace the original materials, and to the problem of developing and perfecting such substitutes, American chemistry must devote unceasing attention.

The chemist and chemical engineer have in times past relieved the pressure created by lack of essential materials. In the last war, dyestuffs, coal-tar medicinals, potash, and nitrates were the critical materials. The United States now lacks none of these materials. Since the World War, America, with the help of chemical industry, has developed sources for the production of iodine and potassium. The chemical engineer has helped the chemist in the production of camphor and bromine.

The United States also has a program of *Ersatz*, but only because industry is free to challenge any economic setup it may choose, only because industry has not been standardized. If war should come it will find us a nation of immense resources both mental and physical. If war does not come the continuing process of change due to natural economic forces will steadily alter our dependence upon imported raw materials, creating thereby a strengthened industry.

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Crude-Drug Warehouse for Storage of Cascara Bark from the Pacific Coast (see Following Article on "The American Way in Pharmacy")