Asbestos

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Asbestos

Its sources, extraction, preparation, manufacture and uses in industry and engineering.



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Preface.

This little book, which the firm of Becker & Haag, Asbestos merchants presents to its friends, has a double purpose. First it would make the great number of persons who work asbestos in any form, or deal in asbestos products, more familiar with its properties, thus pointing out new possibilities for its use, and stimulating its utilization in fields hitherto unrecognized. Second it would offer to the far greater number of laymen who, for scientific or technical reasons wish to inform themselves of the origin, extraction, and practical utilization of asbestos, a brief and comprehensive exposition of these points.

The educated layman has some measure of information about the substances with which life brings him into daily contact, such as metals, textiles, colors, porcelain, etc. He will likewise, to keep pace with the triumphant progress of applied science have to concern himself more and more with asbestos, and to inform himself of its qualities as a raw material which grows daily more important and indispensable.

Various materials have long been known, but not until they were worked in certain definite ways or combined with other materials did they acquire certain qualities which have influenced or even created whole branches of engineering. A case in point is aluminium, which, in combination with newly tried alloys, opened up new paths in the entire field of engineering. To this class also belongs "Asbestos", whose advantages have been recognized for a comparatively short time only, and whose technical development must be considered as far from completed.

If this book is helpful in explaining the various points indicated, and in informing a larger number of persons, it may perhaps at the same time be of direct service to those branches of trade and industry which are in any way interested in Asbestos. Thus it will have attained its aim.

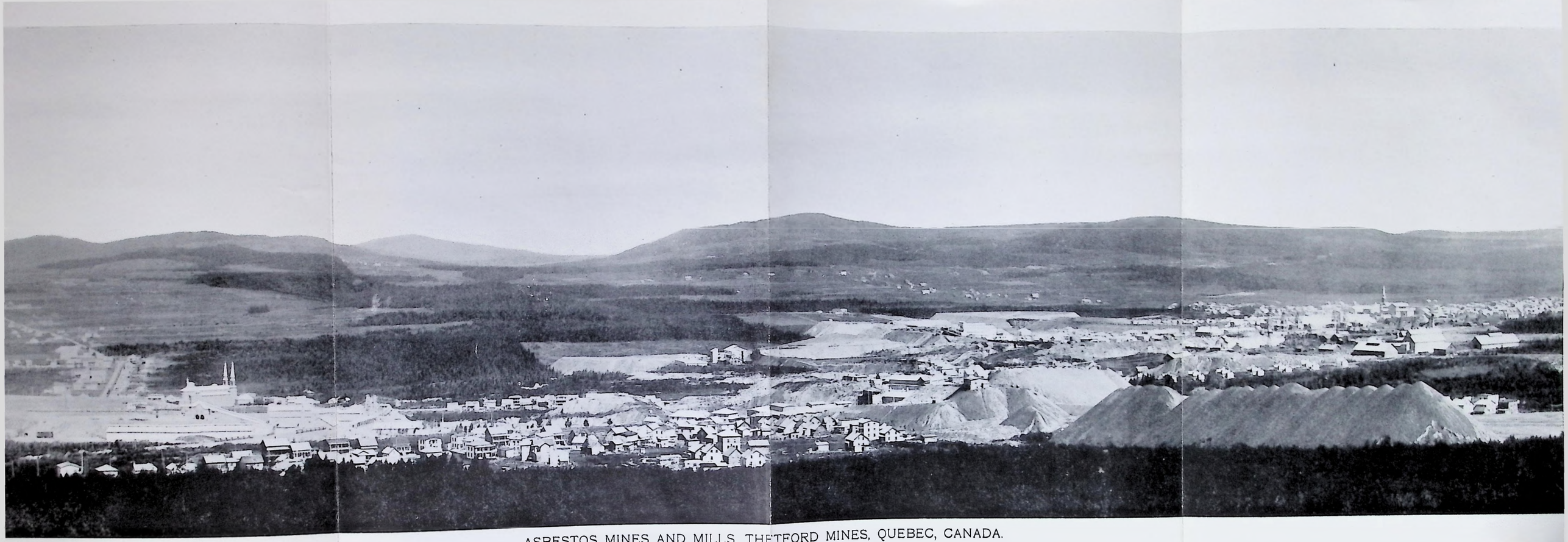
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ASBESTOS MINES AND MILLS, THETFORD MINES, QUEBEC, CANADA.

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I. The Mineralogy of Asbestos.

What is the nature of the material which is known and used all over the world today under the name of Asbestos? It is surprising to find this question often answered incorrectly, not only by most laymen but also by many asbestosusers. There is a widespread opinion that Asbestos is a vegetable fibre. Despite its remarkably cotton or silk-like appearance, it is, in fact a pure mineral fibre, heat and fire resistant, and non-decaying. It occurs mainly in veins or pockets embedded in a matrix.

The technical name "Asbestos" which is used mainly in Germany (Asbest), Canada, Africa and Russia, whereas "Amiant" is used in other countries, such as Italy, Greece, France and the Near East, does not distinguish between its types as they appear in nature, any more than do the names "pierre a coton" (cotton stone), used in France especially for Canadian asbestos, or such others as mountain flax, mountain leather, mountain wood, or mountain cork, etc.

Asbestos does, however, exhibit two types sharply differentiated both chemically and mineralogically: Serpentine and Hornblende asbestos. The mineralogical differences result from the varieties of matrix in which asbestos originates, and in which it is exclusively found. Serpentine asbestos is of the greatest importance. It is, as we shall see, by far the most suitable for industrial utilisation, and also the kind most frequently found.

Chemically, asbestos must always be regarded as a silicate of magnesia, but one in which considerable variations occur, mainly in the percentage of lime, which may even be entirely absent. A unique position is occupied by South African (Cape) asbestos, which is distinguished by its blue color, due apparently to a high percentage of iron.

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This may be so high that the percentage of magnesia is completely pushed into the background, and the chemical nature of the mineral quite altered. With this exception, asbestos from all other sources consists of a more or less calcareous silicate of magnesia.

Chemical analysis can then determine correctly the natural difference between the two kinds of asbestos. But they differ from one another in their physical qualities as well. By the nature of the matrix, as we have said, we distinguish between Hornblende and Serpentine or Chrysotile asbestos. Hornblende asbestos, sometimes called amphibole or actinolite has the following chemical composition: $Mg_3CaSi_4O_{12}$ and consists principally of 28,84% of magnesia, 13,46% of lime and 57,70 % of silica. Its hardness is 5—6, its specific gravity 2,5—3,3. It is light gray with a greenish or brownish tinge. Its resistance to acids is comparatively great, especially when contrasted with that of chrysotile asbestos. Its resistance to heat, on the other hand, that is to say its valuable industrial quatily, is very much lower, as it melts at 1150 ° C.

Chrysotile asbestos, found in serpentine or olivin, contrasts strongly with hornblende asbestos in that most of its varieties contain very little lime or almost none. Its chemical composition is expressed by the formula: $H_4Mg_3Si_2O_9$. It consists then of 43,48 % of magnesia, 43,48 % of silica and 13,04 % of water. Its hardness is only 3—4.

This asbestos, then, used almost exclusively in manufacture, not only because it is found more frequently but also because of its more valuable qualities, usually contains practically no lime, but more magnesia than its cousin of the hornblende group, and a high percentage of water. Its specific gravity also is consequently lower, namely only 2,3 to 2,5. Its fibres are somewhat shorter. Its color ranges from pure white or light gray through a reddish or yellowish white to a grayish green. It is, to be sure, corroded by mineral acids, but this shortcoming is more than compensated by its high melting point of about 1550°, which makes it a much more fireproof material than hornblende asbestos.

Chemically, Picrolith, also called bastard asbestos, is very closely related to chrysotile asbestos, and often occurs especially with Canadian asbestos. It is likewise long-fibred, but is very brittle, so that is must be regarded as actually defiling the valuable chrysotile asbestos, and is therefore frequently removed in the preparation.

Mineralogy distinguishes many other varieties of asbestos, which it designates by different names according to the system in which their crystallisation occurs in nature. In the following table the kinds of asbestos which are of the greatest practical importance are classified according to their qualities and their places of deposit:

Mineral group		Variety	Chemical Composition	Qualities	Most important Deposits
Serpentine (Olivin)		Chrysotile	Hydrated silicate of magnesia	Greatest flexibility and heat resistance; less acid proof	Canada Rhodesia Russia (Siberia)
		Picrolith	dtto 2 water, 3 magnesia, 2 silica	dtto	Insignificant
Amphibole (Hornblende)	Rhombic	Anthophyllite	magnesia silicate of calcium	brittle	U. S. A. Massachusetts
		Tremolite	dtto	more brittle than chrysolite, less heat resistance but acidproof	Italy Africa Balkan States America
	Monoclinal	Actinolite	Ferric magnesia silicate of calcium	dtto	North America
		Crocidolite	Ferric silicate of sodium	(blue) flexible, little heat resistance acid-proof	Cape Colony
		Amosite	Highly ferric Silicate, also argillaceous earth, magnesia, calcium, sodium	long fibres, fit for spinning	Transvaal

Talc is a silicate of magnesia almost like asbestos, which has to be eliminated as far as possible in the preparation of asbestos. It often occurs with serpentine, but because of its finely divided parts and squamous form, it is quite useless where fibrous material is required. From certain fibres containing chromic iron the complete removal of talc is, however, not successfully achieved.

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The mining of asbestos is restricted to the two kinds we have mentioned, and, as we have also seen, they are known commercially under the greatest variety of names. Sometimes, when heat-resistance is not greatly needed, hornblende asbestos is required; but when great heat-resistance is needed, especially if tensile strength and fitness for spinning are also necessary, the demand is always for chrysotile.

How, then, did this unique mineral, this paradox of nature, as one scientist called it, originate? Can we at this late day fathom the methods of operation in nature's workshop, and follow them up with sufficient certainty? It may now be acknowledged with a definiteness open to no scientific objection that the primitive stone is of volcanic origin; i. e. chiefly olivin, a ferrous silicate of magnesia, which frequently occurs as a mixture of basaltic eruptive stone. From this olivin there came into existence, by metamorphosis, the matrix of asbestos, serpentine, which often occurs still showing interstratifications and inclusions of remnants of olivin and related substances. Hornblende ores also have been similarly transformed, but in so summary a view as the present, we shall, for the sake of brevity, confine ourselves to the first and for us most important example. This metamorphosis or so-called serpentinizing has, in the course of time — a million years is a short span in the process —, transformed the rock into the well-known greenish substance with its appearance of silk fibres.

To this extent research believes that it has obtained the secrets of nature's process of manufacture, and established them by the finished product. But as to the origin of asbestos proper, which traverses its matrix in irregular, comparatively thin veins and deposits, and whose unique fibrous form causes it to appear as an organic formation, we can present only surmises. These surmises, however, backed by comparative studies and experiments, have taken shape as wellfounded hypotheses. Of these we shall here elaborate, only the one which has thus far met with the most general recognition.

This is the theory which was first presented in 1905 by George Merrill, and which other specialists like Cirkel, Einicke and others have adopted in consequence of their own investigations and studies. According to it, as indicated above, olivin rock was completely transformed to serpentine. This serpentinizing brought with it an

increase of about 33% in volume, the primitive rock swelled when it was transformed into a colloidal form. Hereupon, in the course of further development, shrinking took place in that the water-content of the swollen gelatinelike substance decreased, causing the appearance of cracks and crevices, just as when a mass of washed clay dries slowly.

From the sides of these crevices there then took place very gradually, with the further recession of the walls, a growth of fibres, set free from the watery solution — asbestos itself. This process seems plausible for the additional reason that something similar is known in the development of fibrous gypsum, which is, hard, brittle, but incapble of being spun. Its long-fibred variety also originates in crevices. Furthermore the chemical composition of both the asbestos and the gypsum fibres is exactly the same as that of the matrix in which they are respectively found.

For the distinction of differences in chemical composition, we here give analyses of the most important kinds of asbestos:

1. Canada.

a) Thetford:

Silica	39 —43 %
Alumina	1,5— 3,5%
Ferric oxide	0,2— 2,5%
Magnesia	40 —41,5%
Water	14 —14,5%

b) Danville:

Silica	41,8—42,8%
Ferric oxide	2,2— 3,7%
Magnesia	39,5—42 %
Water	14 —14,5%

2. Russia.

a) Ural:

Silica	42,5—43,5%
Alumina	traces to 0,5%
Ferric oxide	traces to 0,15%
Magnesia	41,8—42,6%
Water	14,3—15,3%

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b) Siberia:

Silica	41,5—42 %
Ferric oxide	6 — 7 %
Magnesia	35,1—36 %
Water	16 —16,5%

3. Rhodesia.

Silica	40 —43 %
Alumina	0,6— 1,7%
Ferric oxide	traces to 4,5%
Magnesia	38,2—39,6%

4. Cyprus.

Silica	40,6%
Alumina	1,0%
Ferric oxide	4,9%
Magnesia	39,0%
Water	14,5%

5. Amphibol Asbestos (Hornblende).

a) Cape (Blue asbestos):

Silica	50,5—51,5%
Ferric oxide	35,5—36 %
Magnesia	0 — 3 %
Alkalines	7,5— 9 %
Water	3,5—4 %

b) Transval (Amosit):

Silica	49 —53 %
Alumina	5,7— 9,4%
Ferric oxide	34 —44 %
Magnesia	0,7— 6,2%
Alkaline & lime	0 — 2,5%
Water	2,2— 3,0%

The composition of the varieties of hornblende asbestos is extraordinarily different. They all contain a preponderance of silica (51—62%), but their content of iron varies from 1,5 to 36%, that of lime from 0 to 18%, alumina 1 to 4%, magnesia 0 to 30%, alkali to 9% and water to 20%. It is interesting to compare these analytical figures, and to determine that Canadian (Danville) and Siberian chrysotile asbestos are not very greatly different. Siberian asbestos

is richer in iron, but this difference is too slight to cause any considerable difference in the industrial qualifications of the two kinds.

On the other hand, hornblende asbestos, besides containing a considerably higher quantity of iron, almost always contains considerable alumina and a great deal more silica at the expense of the magnesia content. Its resistance to fire is, as we have said, considerably less than that of chrysotile asbestos.

A unique position from the chemical point of view is held by the blue asbestos from South Africa, which is sometimes invaluable, and sometimes along with other kinds as an addition to white asbestos. It represents in a measure the end of the road which nature took when she reduced the magnesia content of the Canadian and Siberian varieties in favor of the content of iron and silica. Here, in the South African asbestos, the magnesia content has become almost negligible. It does, however, contain besides the alkali which is lacking in other kinds, more than 35% of iron. This iron, which probably causes the beautiful blue color of the asbestos, and which is present in the form of protoxide, changes, when heated in the open air, to oxide, and the mineral then becomes yellow or reddish brown and brittle. In its natural state it is, however, as capable of being spun as other good varieties of asbestos.

To grow more or less brittle upon prolonged heating at high temperatures is common to all varieties of asbestos, and is due to the loss of chemically latent water. Even in their natural state the brittle fibres contain less water than the softer and more flexible ones. In a soft fibre of high yield from Black Lake, Dr. F. T. Donald found, on analysis, 14,38% of water, whereas a brittle fibre contained only 11,70%. In his report (in the Journal of the General Mining Association, Quebec 1891), he says it is well known that a soft fibre, heated to a temperature which evaporates the latent water, is transformed into a substance so brittle that one can pulverize it by rubbing it between one's fingers. The connection between the water content and the flexibility of asbestos may therefore be considered proved.

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II. The History of Asbestos.

Among all the minerals of the world asbestos occupies a peculiar position. For among all the mineral products, even those — and there are many — which Nature has built up out of other elements analogously to asbestos, not one has the fibrous, flax-like structure, which strongly suggests, even to the superficial observer, that this is a raw material for the textile and other related industries.

Its resistance to high temperatures asbestos has in common with many other minerals. These are, however, not adapted to most of the purposes which asbestos serves, because they lack that peculiar quality: fibrous structure. This advantage led men from of old to work this mineral inorganic product as an organic, vegetable or animal fibre.

The oldest traditions would have it that even the earliest civilized nations, the Chinese as well as the Egyptians, used cloth and mats of woven asbestos. Certain it is that the Romans in ancient times found many uses in spinning and weaving for the asbestos found in Italy and Cyprus, which was sometimes very fine, with a silk-like sheen and long-fibred formation. In the collections of the Vatican, as in many museums, there are said to be pieces of such weaving, which served as shrouds for cremations, as well as for fabrics in daily use, such as table cloths, etc.

The Romans did not recognize the mineral character of the fibres, but considered them a product of the organic world. Yet, in cremations, they took advantage of the uninflammable character of the material, in that they thus obtained, sharply distinguished from the ashes of the fuel, the actual remains of their dead, which were to be set aside in urns. Asbestos cloth was naturally not an every day affair, but, as Pliny tells us, was used for shrouds only at the cremations of most distinguished patricians and of kings, and was con-

sidered a great extravagance. Because of the difficulty caused by the shortness of the fibres, the ancients worked the "immortal linen" (linum vivum) by adding vegetable fibre, just as we still do today. In the fire the vegetable fibres were then consumed, and the pure asbestos fabric remained.

In ancient temples, asbestos was used to protect the fires on the altars, and the lamps of the vestals had asbestos wicks, which were continually fed with oil, and thus maintained a perpetual flame. In this connection we first find in Plutarch the name ἄσβεστα, the everlasting, unquenchable flame, from which the impermeable material itself later obtained its name. These wicks were made of asbestos from Cyprus, which is still intensively mined, and is suited to the preparation of certain goods not requiring first class material. The Romans called the mineral amiantus, a word which we find today in the name amiant for asbestos.

In later times, we find only sporadic references to articles of asbestos. Charles V, for instance, is said to have astonished some of his less cultivated guests by throwing a table-cloth of asbestos into the fire, and recovering it whiter and cleaner than before. These playful surprises, especially with a table-cloth and napkins, recur frequently in literature. On the whole, however, articles of asbestos were made and owned mainly as curiosities. A more general and serious utilization was not even thought of, for the very reason of the high value of the rare long-fibred mineral, which alone was usable. And so, in the dark Middle Ages, this strange material was hardly known; at least, it was not used in European industry.

About 1250, the famous traveller Marco Polo, who explored the great Tartar Empire, which now forms a part of Eastern Siberia, reports that textiles were shown him, which resisted the might of fire, and of which superstitious people told him that they were made of the skin of salamanders. These, as is well knwn, were almost universally considered impervious to fire, and were used by alchemists of the Middle Ages, and even later, as the symbol of fire. Marco Polo was much too conscientious, and scientifically too experienced, not to recognize the actual origin of the fibres. He continued his research, and gradually learned so much that he was able to gain a correct impression of their extraction and preparation. His report on this subject is so accurate that we can affirm the funda-

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mental conformity of the ancient Tartar method of operation with that still used for long-fibred asbestos in Italy at the beginning of the 20th century.

Today we are also exactly informed as to the places of deposit and the quality of the asbestos present in several beds in the empire of the great Khan.

As we have said, knowledge of asbestos and of the articles made of it was practically lost in the centuries that followed. Until about the last quarter of the past century we have only sporadic reports of its manufacture, even from the countries where it could be mined in open cuttings.

About 1700, a certain Professor Bruckmann had his writings printed on uninflammable paper made of asbestos; the main object of this — to create imperishable documents. Experience, however, must have shown that the "paper" did resist fire in several conflagrations, but not so the writing and printing, so that the inexpediency of the idea soon allowed it to lapse into oblivion. Later, about the middle of the last century, a Florentine priest, Guiseppe della Corona, prepared strong asbestos boards as book covers, and shortly thereafter another Italian, Albonico, tried in vain to bring about the manufacture of asbestos bank notes by the Italian government. But the government realized better than this "inventor" that the tensile strength of such notes would be very slight, and that this very quality is more important than incombustibility.

In the meantime we find descriptions of several attempts to make articles of clothing, partly as curiosities, and partly for the express purpose of using the for firemen at fires. These experiments also met with no permanent success, since experience in serious cases showed that incombustibility alone is worthless if not combined with protection against smoke and suffocation.

Not until the seventh decade of the 19th century did the followers of rapidly developing science rediscover and recognize asbestos as an industrial raw product. The reason for this may well be found in the discovery of the largest and most valuable deposits of the world — these in Canada.

III. The Exploitation of Asbestos Deposits.

In recognizing the fact that various kinds of asbestos differ chemically and technically from one another, we also notice that these variations depend upon the geographical position of the beds of deposit. The asbestos of Canada, Rhodesia, South Africa, Russia, as well as that of the lesser beds in Italy, Cyprus etc., each has its specific composition, its special individual mechanical qualities; and the expert, who has examined on all counts a sample of asbestos submitted to him, is in a position, when he has established its properties, to tell also in what part of the world its source may be found.

In view of this interesting fact, we shall describe in the following chapters the locations of the most important asbestos beds, and consider some of the mining methods which are specially adapted to its peculiarities.

A. The Large Deposits.

a) Canada.

Canada is still the most important asbestos producing territory in the world. The asbestos mined there is the standard for the whole industry, not only because of the abundance in which it is found, but especially because of the uniformity of its external structural form and of its internal composition. With it all other asbestos is compared to determine its quality in any respect.

As we gather from the reports of the Canadian Department of Mines, Sir William Logan, as early as 1847, when he was Secretary,

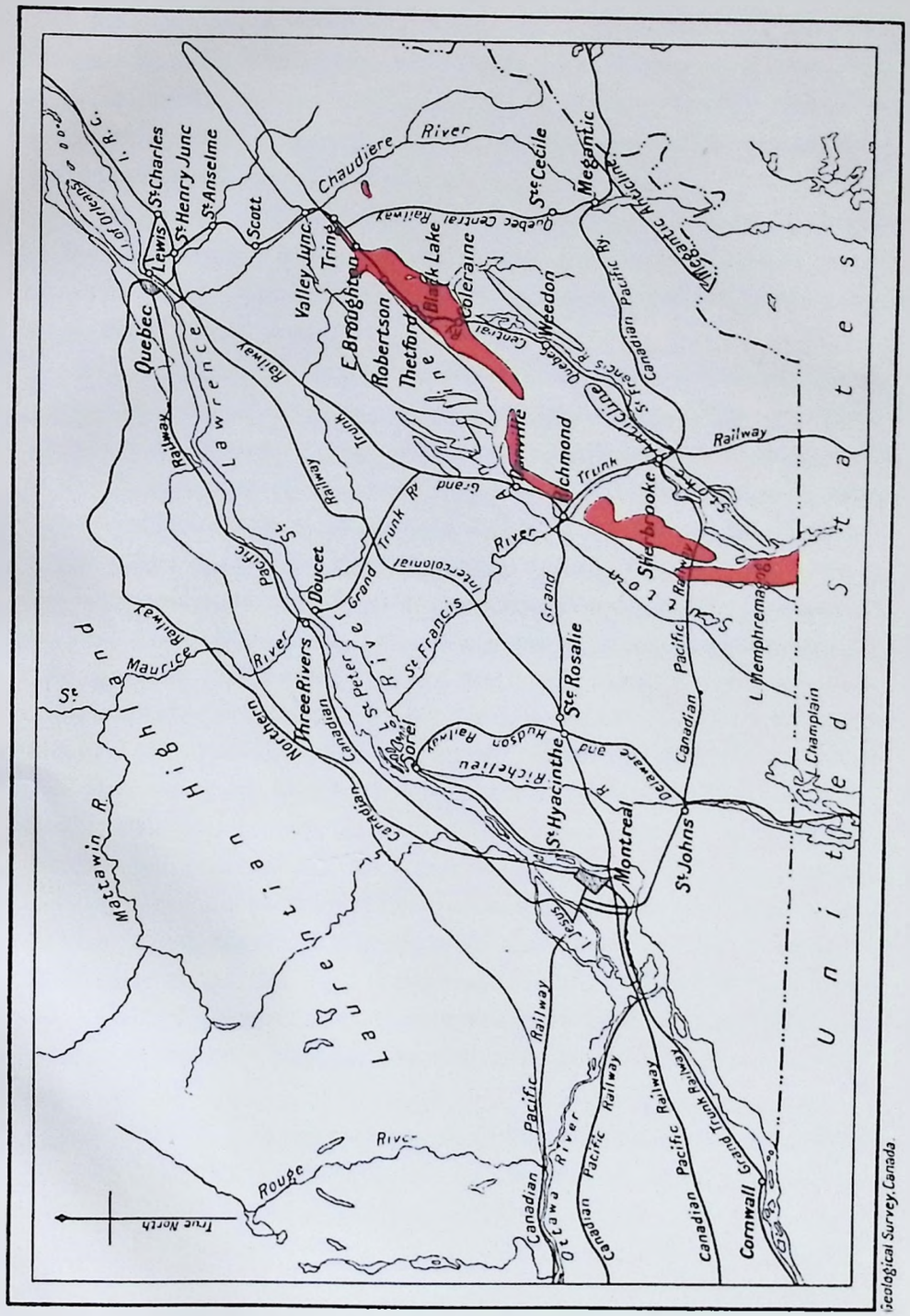
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of the Department, mentions the discovery of asbestos deposits in the eastern districts of the Province of Quebec. His reports were embodied in the book on the Geology of Canada which appeared in 1863, and which described the distribution in the country of serpentine and similar rock. But not until thirty years after the first statement by Logan, did the importance of this mineral for the country's trade and industry become evident. For in 1877 the great deposits at Thetford and Coleraine were discovered, the working of which was made possible and expedited by the construction at that very time of the Quebec Central Railroad. Not quite two years later, work was started in the mines at Danville, Black Lake and East Broughton. With this began the development of Canadian asbestos production, confined generally to the Province of Quebec, which has grown to such an extent that Canada now supplies the greatest portion of the world's demand for asbestos — 84% in 1907, and 75% even today.

The principal beds in which work was then begun, formed the actual foundation upon which the outstanding mines, King, Bell and Johnson, were later developed. All these mines were originally worked by hand with the most primitive methods, and the discarded rock still contained considerable portions of medium length and short fibres, which could not be extracted without mechanical equipment.

With the installation of mining machinery, then, the enormous quantities of rejected asbestos ore, accumulated during many years, were gradually worked over.

The mining operations of these most essential deposits are restricted to a relatively limited area, and the mines, belonging to three different owners, lie close together. The rock of the Thetford mines is all about the same, hardly varying even in color. It is without doubt the most important district for Canadian asbestos. In connection with it are developed less prominent mines: that of Black Lake, where, by infiltration from adjoining chromite mines, the asbestos has a more reddish brown appearance; and, a little to the south, those of the Coleraine district, where operations have been begun during the last ten years. To the north of Thetford lie the asbestos mines around Broughton, producing rock largely converted into tale, containing only a small percentage of short fibres, and no long fibres at all. About a hundred miles from these lie the Danville



mines with serpentine rock similar to that at Thetford, not so rich in long fibres, but with a preponderance of medium and short ones.

All these mines are operated mainly in open cuts, and the rock is removed either by cranes or through tunnels sloping up from the base of the cut to the mill or dumping ground. In the course of intensive operations the mining level of the various cuts has reached a depth of five hundred feet and more.

The general technical details of the equipment will be discussed in the chapter on extraction and mining. We must, however, mention here some typical fundamental differences displayed by the principal mines of the world.

In Canada, open cutting, confined to a relatively limited space, is chracteristic. From it the rock is carried by machinery — either by cables or by narrow gauge railroads through tunnels — to the mill or dump. The rock is extraordinarily hard, and the work of preparation consists mainly in drilling holes, preparatory for blasting. Three times a day this blasting occurs tearing down from three to four thousand tons of rock in each mine. The rock thus loosened is assorted at the base of the mine into dead rock and asbestos bearing rock suitable for the mill. Then too, large open veins containing crude asbestos are taken out by hand, so as not to be in any way damaged by contact with machinery. The number of workmen needed is relatively small, because the mechanical method is exceedingly well developed. In this connection we must mention the typical equipment of the Canadian King mine, which, by avoiding the slightest unnecessary delays, makes it possible to connect the work of one department directly with that of another by an entirely mechanical procedure. An uninterrupted flow of work is thus secured, all the departments working constantly hand in hand from the time when the rock reaches the mill and the asbestos is completely extracted.

Contrary to Canada are the working methods in Russia, where the open-cast workings are laid out in typical large terraces, in order to utilize large quantities of manual labor. But even there mechanical methods are to be introduced, as will be described later on.

Different again are the conditions prevailing in Rhodesia, where the most prominent mine at Shabani is situated on the top of a hill

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and mining operations are consequently facilitated. Besides, that large quantities of native labour are available and will be adapted for handcobbing and grading. Nevertheless mechanical equipment is largely introduced in order to increase the production and to become more independant of manual labor.

Asbestos from this great Canadian district is of an astonishing uniformity in its chemical composition, and hence in its industrial qualities. Two kinds of fibres are distinguished from one another by their external formation — "cross fibres" and "slip fibres." The first is the typical form of the fibres, appearing as long veins embedded in serpentine rock, and found in Thetford, Black Lake, Coleraine and Danville. From it are first taken the fibres for spinning, leaving about 70% of short fibres for the manufacture of tiles and bords. The length of the fibre is as much as 6 centimeters. The second kind of fibre, found mainly in the serpentine rock of East Broughton, does not form regular, long veins; the talc-like rock in certain places consists of silky and shiny fibres, pressed flat. The „slip fibres" are usually shorter than the "cros fibres," and therefore usable for inferior purposes only.

Except for the material consisting of fibres long enough to be extracted by hand, no other asbestos was brought to market during the first fifteen years of the operation of the great mines. All the remaining asbestos stone was simply dumped. Only since the middle of the nineties of the last century, when the working of the mines and the preparation of the raw material began to be done by machinery, were the less easily extractable long fibres, the medium and short ones, as well as the powdery material (asbestic) available for manufacture. We shall see later that whole industries are built up on the utilization of these fibres of lesser length.

According to its quality, asbestos fibre which is capable of being spun, is designated as "Crude" No. 1 or "Crude" No. 2, and the material coming from the mills (mill stock) is also classified according to its long, medium and short fibres. Its length and quality determines the use of the product in manufacture. The percentage of long fibre asbestos is naturally very small in comparison with the short fibre.



CANADIAN ASBESTOS MINES

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In 1910, for instance, the total Canadian production amounted to:

Crude No. 1 and No. 2 . . . . . 5%
Long and medium 64%
Short 31%

In 1923, the total production showed the following percentages:

Crude No. 1 and No. 2 . . . . 1,8%
Long and medium 12,7%
Short 85,5%

The increase in production since the opening of the mines in 1877 may be gathered from the following tables, taken largely from the reports of Canadian authorities.

Anno	Crude & Fibre
1878	70
1879	300
1880	380
1881	540
1882	810
1883	955
1884	1 141
1885	2 240
1886	3 458
1887	4 619
1888	4 404
1889	6 113
1890	9 880
1891	7 279
1892	6 082
1893	6 331
1894	7 630
1895	8 756
1896	10 892
1897	13 202
1898	16 124
1899	17 790
1900	21 621
1901	32 892
1902	30 219

Anno	Crude	Millstock Nr. 1 u. 2	Millstock Nr. 3
1903	3 134	27 995	
1904	4 410	31 201	
1905	3 767	46 902	
1906	3 841	56 920	
1907	4 327	57 803	
1908	3 345	63 202	
1909	3 074	60 275	
1910	3 740	45 106	22 070
1911	5 062	59 668	31 572
1912	4 749	58 394	39 616
1913	5 025	82 036	45 505
1914	4 061	74 506	29 101
1915	3 986	63 682	38 890
1916	5 958	55 638	71 743
1917	5 364	57 269	64 609
1918	3 704	45 971	92 700
1919	4 094	83 632	48 135

Anno	Crude	Spinning & Shingle	Paper & Other
1920	3 856	30 862	145 186
1921	944	15 022	71 509
1922	2 372	16 326	141 631
1923	3 779	27 572	185 455
1924	4 643	31 368	172 751

	Crude	Spinning & Shingle	Paper	Other
1925	5 169	46 080	93 935	128 338
1926	ca. 4 200	50 000	100 000	130 000

In 1885, the Canadian asbestos industry employed 350 men in seven mines; in 1925 it employed, in twenty mines, more than 3000

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men, and supported a total number of about 15 000 persons. The tables show clearly how greatly the production was increased by the working of the medium and short fibres, which are unfit for spinning, and which, before the middle nineties, were not used at all.

The Canadian mines furnish chrysotile asbestos almost exclusively, although there are found mixed with it traces of hornblende asbestos. This is, however, neglected. For, even for certain unimportant purposes where it might be used, chrysotile replaces it, since the short, powdery waste of the more valuable product can be used as well, for the same purposes.

As we have seen, the upward turn in Canadian production began with the discovery of the great serpentine asbestos deposits in the Province of Quebec. The asbestos mined there surpasses that from most other sources in its industrial qualities. It is, to be sure, usually not quite so long-fibred as certain other kinds, and not of such a silky gloss as, for example, that of Northern Italy, but its tensile strength, elasticity, cleavability, and suppleness are greater than that of any other extensively mined variety. Its resistance to heat is also especially high. The fibres are of a peculiar silky character, and possess a great smoothness. At first the technical difficulty of spinning this otherwise excellent product was almost insurmountable. But since this has been overcome, Canadian asbestos is considered the best for all uses. Its color varies with the percentage of iron contained, and with the color of the serpentine matrix, from a greenish to a brownish tinge: The Thetford product is greenish-white, that from Black Lake brownish white, and that from Coleraine of a fairly deep brown. The percentage of water contained, and its fitness for spinning, vary slightly. The continued weathering of this relatively loose mineral, sensitive to atmospheric influences, entails a loss of elasticity and tensile strength.

A particularly pure and fine-fibred asbestos comes from the mines at Thetford, which with those at Black Lake and Danville represent the principal asbestos mines of the world. Here the asbestos-bearing rock, rising to a height of 500 feet, and enclosing the mines, is the chain of serpentine rock, which, with an almost unbroken length of 155 miles, runs from the northern part of the United States to the Chaudiere River. In the centre of this range



CANADIAN ASBESTOS MINES, HAULING TOWERS AT THE KING MINES

the principal mines are located. They are all close together, and frequently overlap. (See map.) It is not only by their immeasurable wealth of valuable raw material that these mines have given Canada the first place in supplying asbestos to the world. There are other contributing factors, as, for instance, the comparative ease with which this valuable material can be mined.

Even though the mining has recently been carried on in open cuttings, and even though the mineral is transported through tunnels and inclined adits, the depth to which these penetrate is usually not so great as to be termed a true mine. In 1924 the deepest point of the King pit was about 300 feet below the earth's surface. Similar conditions prevail in the neighboring Bell mine, which is almost as large. All the other mines have recently been merged under the leadership of the Asbestos Corporation Limited, which is a consolidation of various Asbestos Companies in the Thetford Mines, Black Lake, East Broughton and Coleraine Districts of the Province of Quebec.

Prior to 1907 numerous Companies were operating as separate entities. In the early part of 1908 steps were taken to consolidate some of them and a new Company was formed under the name of the British-Canadian Asbestos Company Limited.

In 1909 the Amalgamated Asbestos Corporation Limited was created and the interests of the British-Canadian Asbestos Company Limited, the Standard Asbestos Company Limited, the Dominion Asbestos Company Limited, of Black Lake, as well as the King Asbestos Mines Limited and the Beaver Asbestos Company Limited, located at Thetford Mines, were absorbed. In addition to these, the Fraser Mine at East Broughton was also joined to the new Company.

This year also saw the formation of a number of other Asbestos Companies:

The Black Lake Asbestos & Chrome Company was organized, this Company having purchased the Southwark Asbestos Company Limited, the Imperial Asbestos Company Limited and the Union Asbestos Company Limited.

The Jacobs Asbestos Mining Company Limited, of Thetford Mines, also came into being that year.

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At Coleraine the Belmina Asbestos Company Limited was formed.

At Robertson the Robertson Asbestos Company Limited, and the Beaudoin & Audette Asbestos Company Limited (later on known as the Federal Asbestos Company Limited), as well as the Berlin Asbestos Company Limited, were organized.

At East Broughton the Boston Asbestos Company Limited (afterwards known as Asbestos Mines Limited) was created.

In 1911 the Martin-Bennet Asbestos Company Limited was formed and commenced operations at Thetford Mines.

In 1912 the Amalgamated Asbestos Corporation was reorganized under the new title of Asbestos Corporation of Canada Limited.

In 1917 the interests of the Jacobs Asbestos Mining Company were acquired by certain capitalists and a new Company was formed under the name of Consolidated Asbestos Limited, to which were linked up the Belmina Asbestos Company, of Coleraine; the Federal Asbestos Company and the Berlin Asbestos Company, of Robertson.

About this same period the Maple Leaf Asbestos Corporation Limited, of Thetford Mines, made its appearance.

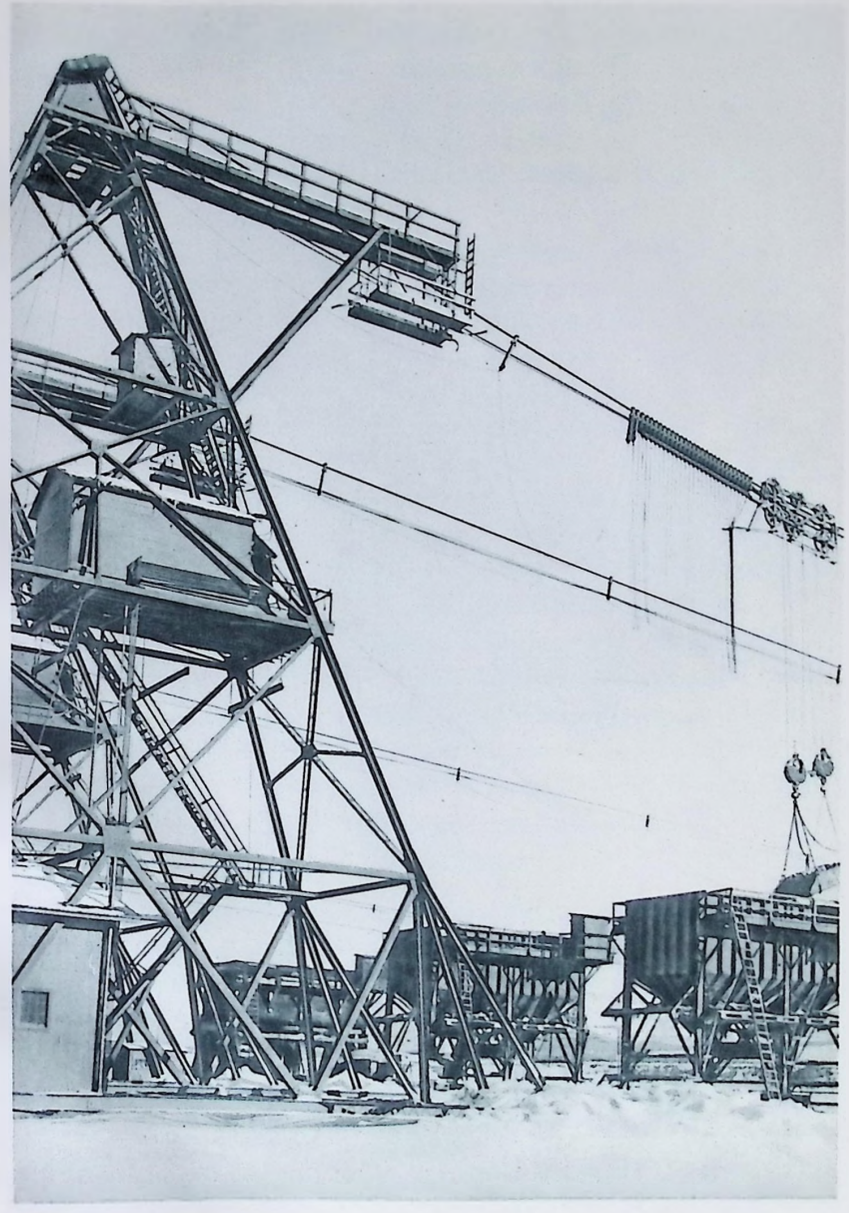
The Martin-Bennett Asbestos Company changed its name to that of the Bennet-Martin Asbestos & Chrome Mines Limited, and commenced operations on a larger scale and opened up at Coleraine what is known as the Vimy Ridge Mine.

The Robertson Asbestos Company, which had been closed down for a number of years, was also reorganized under the name of the Pennington Asbestos Company Limited, and operations were resumed.

Due to the heavy calls for asbestos occasioned by the War and also to heavy demands which continued until the end of 1920, most of these ventures carried on with greater or lesser success.

In 1925 steps were taken to bring under one head all of these various units and on the 1st of February, 1926, Asbestos Corporation Limited was formed and all of the above mentioned properties were brought under one management and control.

This Company now owns or operates the following mines, which at one time during the last twenty years were separate entities:



CANADIAN ASBESTOS MINES, HAULING TOWERS AT THE KING MINES

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Thetford Mines:	King Asbestos Mines Limited, Beaver Asbestos Company Limited, Martin-Bennet Asbestos Company Limited, Jacobs Asbestos Mining Company Limited, Maple Leaf Asbestos Corporation Limited,
Black Lake:	American Asbestos Company Limited, United Asbestos Company Limited, Manhattan Asbestos Company Limited, Glasgow & Montreal Asbestos Company Limited, Standard Asbestos Company Limited, Dominion Asbestos Company Limited, Southwark Asbestos Company Limited, Union Asbestos Company Limited, Imperial Asbestos Company Limited,
Coleraine:	Belmina Asbestos Company Limited, Bennet-Martin Asbestos & Chrome Mines Limited, Vimy Ridge Mine.
Robertson:	Pennington Asbestos Company Limited, Federal Asbestos Company Limited, Berlin Asbestos Company Limited,
East Broughton:	Asbestos Mines Limited, Fraser Mine.

A further natural advantage which the Canadian mines possess over their competitors in Rhodesia, Russia, and Siberia, which have recently made great progress in the methods and quantity of their production, is their favorable location for commerce with all parts of the world. The railroads traverse the entire Canadian asbestos producing territory. The raw material can be directly loaded into the cars. The distance to Quebec is only 75 miles, to Montreal 167, to Boston about 300, and to New York 470 — all very short stretches from the American point of view. In the summer raw asbestos is carried to the ports of the St. Lawrence River, near Montreal and Quebec. The distances and expenses for freight are therefore incon-

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siderable, compared with those in other great asbestos producing regions.

These natural advantages of the Canadian mines, due to lucky accidents, are practically favored to an extraordinary degree by the use of perfectly modern equipment. Each of the important mines has extensive railroad facilities, which transport the mined rock — such of it as bears asbestos — to the crushing plant, whereas the dead rock is cast aside. We shall later describe the mining equipment proper, which carries the raw material through the various stages from the first crushing of the rock to the preparation of carefully assorted wares, ready for shipment. We merely wish to mention here, in view of the selection of the King mine as our model, that this and similar mines have special engineering equipment for hauling up from the depth of the pit the rock which has been blasted. Along the railing that surrounds the pit are mighty elevator towers with winches that draw up the rock in ten-ton cars. In this way 3000 tons of rock, and more, are moved daily. In the King mine the lifting cables reach a length across their pit of more than 1000 feet.

Recently the Canadian mines have driven broad tunnels into the mountains, in which machines are set up, and where men can work comfortably. These tunnels, as well as the customary drilling holes, serve in the search for ore, and when asbestos is found, additional adits can be driven in. Thus during the long severe Canadian winter, when work in open cuts must often come to a standstill, development operations can be continued to some considerable extent in the tunnels. In the Bell mine especially, the inclined tunnels are much used in carrying off the rock. Operations are so carried on in the great mines that, during excavation, the fibres are being constantly tested. This facilitates enormously the movement of the product into the department of extraction to which it belongs.

b) Russia.

In the enormous territory, covering one-sixth of the surface of the earth, which comprised the former Russian Empire, there lie such extensive and mighty asbestos deposits as to justify the presumption that Russia will in the future regain her position as one of the most productive countries of the world, especially for European



RUSSIAN ASBESTOS ROCKS

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consumers. Before the World War, Russia stood second among the asbestos producing countries of the world, by reason of the very extensive and abundant mines in the Ural mountains, which are the oldest known asbestos deposits of Russia. There are also deposits in Turkestan and Siberia, which we shall discuss in a separate section, and some in the Caucasus, which are, however, of little consequence both as to quantity and quality.

The yield of asbestos from the Urals, amounting to almost 23 000 tons in the last year before the war (1913), and mined even during the war for military purposes, was still as little as 3000 tons in 1922. Since then the mines have done all they could to increase the production so as to reach the pre-war figures, and will probably surpass them.

The extraction of the mineral, and the use of its fibres, can be traced back, as far as the Ural deposits are concerned, to the beginning of the 18th century. At that time the great landowner, Nikita Demidoff, was already mining asbestos, which he worked sufficiently to set up some manufactures of textiles, gloves, baskets, etc. These were, however, used to supply only a limited district. Real trade did not then exist. Systematic mining of the mineral on a large scale began toward the end of the 19th century.

The most abundant deposits lie in the Ural where a beautiful, yellowish-white asbestos is found. Until 1913 this district furnished from 95 to 96% of the total Russian asbestos production. From the following table of the exportation of Russian asbestos we gather its great importance, taking into consideration also that the domestic consumption is largely supplied by asbestos from the Urals.

Exported

from	1899	to	1903	an annual average of		2 750	tons
	1904	„	1908	„	„	„	6 100	„
	1909	„	1913	„	„	„	11 200	„
	1919	„	1923	„	„	„	2 600	„
during	1923-1924			4 800 tons				
	1924-1925			about 7 600	„			
	1925-1926			„ 10 000	„			

The length of the asbestos-bearing zone is about 11 miles, with an average width of about half a mile. Since 1886 mining has been carried on there on open terraces which have now reached a depth

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of as much as 120 feet. Asbestos occurs in the serpentine of that region in strips several hundred feet wide. The natural supply of asbestos in the district, known in some places to reach a depth of 500 feet, is estimated at about 20 million tons.

Compared with these figures the production of other deposits in the Ural district is entirely unimportant. To the north of the Urals there are presumably still larger deposits. Furthermore there are mines near Alapajewsk and Newjansk, at the river Miass — where asbestos similar to that of Newjansk is found —, and between Orsk and Orenburg. All these mines, which together furnish only a small fraction of the main production, contain pure serpentine asbestos like that of the greater district. In spite of its somewhat slighter softness and silkiness, it equals Canadian asbestos in industrial and commercial value. Upon analysis it differs from this standard asbestos in containing a somewhat higher percentage of iron.

Ural serpentine rock, under present mining methods, contains about from 2 to 4% of asbestos. The yield of long-fibred varieties has varied greatly in the course of time. During the last twenty years it has averaged about one-third of the mined asbestos, as against two-thirds of the short fibred variety. It must here be noted that the Russian ore is comparatively rich in long fibres.

The existing old equipment of the Ural mines is for the most part antiquated and delapidated, and new mechanical equipment can be acquired but slowly. In the meantime the further exploitation of the mines is being planned.

As for the work of extracting the asbestos: this was formerly done entirely by hand, but has become largely mechanical, especially since the great number of peasants, once temporarily available as miners, are now lacking. For this reason hand-work is dropping off more and more, and there is need above all for the installation of mechanical hauling equipment to carry the rock from the mines to the dumping ground and the mill. Furthermore a systematic examination of the entire asbestos-producing region has been made by boring holes in all directions, so as to be able to concentrate the work at the best and most productive places.

In the preparation of the ore new methods have been introduced. For example, crushers have been installed, which break up the rock



RUSSIAN ASBESTOS MINES

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containing thin veins, and then carry off the broken pieces on travelling belts. The asbestos bearing rock is then assorted by hand. In this way a considerable quantity of rock which could hardly be properly treated by hand, is now mechanically prepared so that, when concentrated by the ensuing crushing process, it yields about 10% of medium and short fibres. Considerable progress has also been made in the process of preparation by the installing of new machinery, opening possibilities for increased production. It is planned to build more large plants, to intensify the exploitation of the mines, and thereby at the same time to reduce the overhead expenses of production. Considerable improvement in the methods of transportation will also be achieved by a narrow gauge railway, which has begun to operate between the mines and the railway station.

Altogether, it may be said that the Russian mines will do away with the former system of manual labor, at least for the medium and short varieties, which will be prepared by machinery, and that with the installation of new grinding machines, the production capacity of the mines will possibly increase. At the same time, the demand for asbestos in the Russian market itself will grow more and more as time goes on.

The Russian spinning fibres are being more and more appreciated for their peculiar qualities: great resistance to pressure and friction. The darker, short varieties are an unsurpassable material for the growing rooftile industry. Russian asbestos is therefore gaining an increasing significance for asbestos industry in general. Moreover, the demand for asbestos in the domestic Russian market is growing all the time.

c) Africa.

In South Africa three provinces of the "Union," namely: the Transvaal, Natal and the Cape, but specially Southern Rhodesia, are rich in asbestiform minerals.

1. The Union of South Africa.

The exploitation of asbestos deposits within the Union dates from about 1893, when a Company started developing deposits of fibre known as "Cape blue" or "crocidolite," found in the

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northern parts of the Cape Province. The year 1905 marks the first attempt to exploit chrysotile occurrences, near Carolina in the eastern Transvaal; more recently the same variety has been proved to occur in large quantities in the Barberton District, where it is being vigorously exploited to-day. In 1907 a third variety of fibre, known as "amosite," was located in the Lydenburg District, and has been under active exploitation since that year.

The less valuable forms of asbestos, like tremolite and anthophyllite, are also found within the Union, one of them, locally known as "asbestic," being available in very large quantities.

The following kinds of fibre occur in the Union under conditions satisfying the commercial requirements of quantity and quality, enumerated in approximate order of importance:—

(1) Chrysotile or "withe" asbestos, the well-known and valuable hydrated silicate of magnesia. (Transvaal and Natal.)
(2) Crocidolite or Cape "blue," a lavender-blue ferrous silicate hornblende. (Cape and Transvaal.)
(3) Amosite, an ash-grey ferrous silicate hornblende. (Transvaal.)
(4) "Asbestic" (so-called), a mass fibre variety of anthophyllite. (Transvaal.)
(5) Tremolite, silicate of lime. (Natal.)

(1) Chrysotile.

This variety is known from several localities in the Natal and Transvaal Provinces. The best developed occurrences are east of Carolina and in the Kaapsche Hoop section of the Barberton District.

East of Carolina, some twenty-five miles from the railway, chrysotile of excellent quality has been recovered at intervals on a modest scale since about 1906. The deposits are in the form of a series of sub-parallel cross-fibre seams lying in gently inclined serpentinized dolomite directly above an intrusive sheet of basic igneous rocks. The fibre length ranges from the very rare maximum of 7 inches down to microscopic dimensions, but the average run of mine is in the neighbourhood of one-quarter to half an inch.

Working conditions have not so far proved favourable, so that production has remained low and intermittent.

Kaapsche Hoop Area.—About three or four miles from the little village of Kaapsche Hoop in the Barberton District, and some



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fourteen miles from Godwan River Station on the eastern line, is an important occurrence of chrysotile which is being actively exploited and is at present the most productive source of chrysotile in the Union; the asbestos lies in serpentine.

The fibre from this source is of excellent quality and is now well established in the market. The character of the chrysotile is well maintained down to the lowest depth reached — 400 feet vertically below the surface.

The ease with which the fibre comes off the country rock, not only during milling, but also during development, the high percentage of recovery, together with the very large number of seams of superior quality fibre, combined with low mining costs and proximity to the railway, are the most valuable economic features of these occurrences. Their yield is steadily rising and now exceeds 1000 tons a month.

Natal. — At the Sitilo Mine in the Tugela Valley, between Eshowe and Krantzkop Station, some twenty-five miles from the latter, a deposit of chrysotile has been worked at intervals. This occurs as a series of parallel vertical seams in serpentine up to within a few feet from a contact with a vertical vein of aplite; the ruling fibre length is from one-quarter to half an inch, and the asbestos is of very good quality.

Several other occurrences of this asbestos are known in Natal, but have not yet reached a permanently productive stage.

(2) Crocidolite.

This variety has been known and worked longer than any other asbestos in the Union, and from its lavender blue colour is known in the market as Cape "blue." It was first produced in the Cape Province, but during the last few years additional deposits have been opened up in the north-eastern Transvaal.

Cape Province. — Here the crocidolite is found in the banded ironstones of the Lower Griqua Town Series in the northern parts of the Province over a very extensive belt of country from south of the Orange River, near Prieska, in a general northerly or north-north-easterly direction through Kuruman at least as far as the Mashowing River in British Bechuanaland, and most probably beyond that in the district of Vryburg and Mafeking. The eastern portion

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of the belt coincides with the hilly tract known as Asbestos Mountains.

The total length of the Cape asbestos country is not less than 240 miles, with a variable width from 30 miles downwards. It is the most extensive stretch of asbestosbearing formation known; as a source of crocidolite it holds the record.

The chief centres of activity are at Keikamspoort (a few miles south of Prieska), at a number of localities close to the latter village, at Koegas and Westerberg, at Danielskuil and district, and round Kuruman, etc.

Throughout this belt crocidolite has been found at a very large number of points, always as cross-fibre seams interbedded in the banded ironstones; much of this fibre satisfies commercial standards, and the present production is capable of almost indefinite expansion.

The southern section of these asbestos fields extends from the extreme south across the Orange River to about Griqua Town, and includes all the workings of Elandsfontain, Blackridge, Keikamspoort, and others. Most of them depend on the Upington-Prieska-De Aar line for railway connection.

The northern section embraces a large number of more recent workings, scattered between Griqua Town in the south and Tsenin, north of Kuruman.

The most thoroughly opened up and also the oldest mine is Westerberg, which now produces the major portion of the company's output. This is the only locality in the whole field where the development of the fibre deposits proceeds after the manner of a mine regularly laid out along underground workings. Two distinct sets of interbedded seams exist on Westerberg, each made up of from three to seven parallel seams. At the deepest point so far reached—some 230 feet below the surface—the usual hard banded ironstone becomes distinctly softer, but there is no deterioration in fibre quality.

As usual, the length of fibre varies, but the bulk of the seams are between half an inch and one inch thick.

The methods of market preparation are simple, and comprise hand cobbing and sieving by inclined hand-worked sieves, the product of which passes through a machinedriven classifier.

In the other workings of the southern as well as over the northern section the geological conditions under which the seams

occur are essentially the same. Most of the producers of the latter area have to rely on Vryburg, Taungs, Kimberley, etc., as their railheads, and are to some extent handicapped by distance from the railway line, which in some cases is over 100 miles distant. Fibre is found on a very large number of farms, and development proceeds practically by opencast workings only; the output is maintained not so much by the exploitation of a few rich deposits as from many small quarries, some farms having as many as 30 working places. Though the yield from any one of these places is comparatively small, this combined output is substantial and could be very largely increased as soon as improved market conditions become reestablished.

In the southern section more systematic underground mining is going on, partly because some of this work has been kept up for a longer period; moreover, the selection of mnie ground and its methods of exploitation are more under the direct control of the management than is the case in the northern section, where the contract system of labour—which often leaves the methods of mining to the natives—is applied.

Transvaal Province.—Here crocidolite is restricted to the north-eastern part of the Province, situated east of Chuniespoort, and embracing the southern portion of the Haenertsburg goldfields at an average distance of sixty miles from Pietersburg, the nearest railway station. The seams of crocidolite occur interbedded in the basal portion of the Pretoria Series, close to the underlying dolomite, in ferruginous slates indistinguishable from the banded ironstones of the Cape asbestos belt, and consist of the same lavender-blue fibre with sensibly the same average length. These deposits have only been opened during the last few years, so that production is still low, but undoubtedly capable of a substantial increase on the return of more favourable market conditions.

(3) Amosite.

In the northern portion of the Lydenburg District, and continuing northwards into the Pietersburg District for not less than sixty miles, a new variety of asbestos was discovered in 1907, and is now under active exploitation. It is an ash-grey ferrous silicate hornblende, containing either no soda or only a very small amount; its geological

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conditions of occurrence are, however, identical with those associated with crocidolite.

Amosite* is found over some sixty miles along both banks of the Olifants River from the junction of that stream and the Steelpoort River, generally northwards to Malips Drift in the Haenertsburg goldfields. The deposit forms cross-fibre seams interbedded in banded ironstones, which most probably correspond to the same horizon in which the crocidolite of the Cape asbestos field occurs.

The main mine has now been opened up for some 2,500 yards along the outcrops, and has reached a depth of 400 feet. Very large quantities are available; thus in section B alone, where the continuity has been demonstrated for more than 300 feet on the dip, some 25,000 cubic feet of fibre are available between two levels.

There are three groups of deposits, each consisting of several parallel seams. Their most extraordinary features are their great regularity in distribution, which has enabled a regular system of drives and levels to be made out, and the phenomenal fibre length, in which respect this field is unique. Unlike other varieties of fibre, amosite maintains its great length over long stretches in the principal horizon. The maximum length observed is 11 inches, but in the great majority of cases the fibre is between 4 inches and 7 inches long, so that the entire output is easily maintained at that standard. The average length is certainly not overstated at 6 inches. Indeed, it has been found necessary, to cut the fibre up into 1-inch material for certain consumers.

Market preparation is simple, since grading does not depend on fibre length (the entire output being spinnable), and consists of sieving and hand cobbing. The criteria of the three grades depend upon colour, flexibility, etc.

The quality of amosite is different from that of any other asbestos. In texture, the mineral, though very delicately fibrous, tensile, and readily fiberized, is harsher to the touch than Cape "blue" or chrysotile, but the fibres are quite as strong and to a certain extent elastic. Difficulty was at first experienced in marketing amosite, but it has now been taken up both in America and Europe. Since it can be put on the market at a very much lower

*) The name is built up from the initial letters of "Asbestos Mines of South Africa", one of the producers of this fibre.

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PANORAMIC VIEW OF THE RHODESIAN ASBESTOS MINES
SHABANIE MINE

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price than other classes of spinnable fibre and also occurs in unlimited quantities, it should eventually come into its own.

The following Table shows the production of asbestos for the several Provinces.

Production of Asbestos in the Union (Short Tons).

Year	Cape Province Production	Transvaal Production	Natal Production	Total-Union
1917	4,033.6	4,592.9	39.5	8,666
1918	2,875	258.2	11.0	3,144.2
1919	3,087	802	122	4,011
1920	3,227.8	3,585	71	6,883.8
1921	3,745	1,540	101.4	5,386.4
1922	3,440.7	1,667.8	7	5,115.5
1923	4,169	4,020	—	8,189
1924	3,001	4,239	—	7,240
1925	2,641	8,067	—	10,708
1926	4,234	11,315	—	15,549

3. Rhodesia.

Although civilization began to penetrate Rhodesia as early as the end of the eighteen-eighties, the gold fever long retarded the search for other mineral deposits in the country. Only in 1908 were the first asbestos fibres discovered in the southern part. In the Shabanie and Mashaba district, where the peculiar formations forced themselves on the visitor's notice, the first discoveries were made, and in these districts to this day lie the main sources of the excellent Rhodesian asbestos.

In 1909 the report of the Department of Mines first mentions asbestos production. Since then the amount of production has risen steadily with one slight interruption caused by special difficulties in transportation. It has lately taken such strides that, considering the high quality of the fibres, the hope of Rhodesian mine owners to have their country become proportionately the greatest exporter of long-fibred asbestos, does not seem excessive. The figures thus far published are as follows:

1908 . . . . . 55 tons
1909 . . . . . 272 „

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1910	332	tons
1911	460	„
1912	—	
1913	290	„
1914	487	„
1915	2 010	„
1916	6 157	„
1917	9 562	„
1918	8 574	„
1919	9 799	„
1920	18 823	„
1921	19 529	„
1922	14 249	„
1923	20 364	„
1924	26 141	„
1925	34 349	„
1926	33 344	„
1927	33 176	„

The quality of the mineral, especially from the two above mentioned districts and from a number of others, such as Victoria and Belingwe, is quite exceptional. The country is traversed in a northeasterly direction by the Norit range, about 400 miles long, in whose immediate neighborhood innumerable chrysotile veins are found. There occur strata as thick as 260 feet, reaching a considerable depth. Their extent has not yet been conclusively ascertained, since the abundance of the visible mineral does not make this necessary. Then too, the quality is so very fine that the sum of the production and the export can not be compared with the corresponding Canadian figures. For by far the greatest part of the Canadian product consists of short fibres, unsuitable for spinning, whereas about 40% of the Rhodesian is spinning material. In a short time when mills that are planned and partly erected, and also connecting railroads begin to operate, the Rhodesian production will presumably advance by leaps and bounds. This may also increase considerably the percentage of short fibres. Even now the mines can scarcely supply the demand for their product, and the enlargement of the plants is urgently required.

The matrix of Rhodesian asbestos is serpentine in which talcous slate is embedded, lying immediately above a layer of quartz. The extensive quartz streaks are a distinct indication of the presence of the asbestos veins. These are worked in quarry-like pits picked in the usual way, and mechanically prepared. The main mine, in Shabanie, is located on a hill, so that the rock can be easily removed. Large numbers of black workmen can be used in sorting it by hand. Still, in order to increase production, the methods of work are growing more and more mechanical, and independent of manual labor. The fibrous parts are easily separated from the rock, and are sorted into three classes according to their length (which is as much as 2½ to 3 inches), their color, and their technical uses. The principal markets have been Europe and the United States.

B. The Smaller Beds.

a) Arizona.

Asbestos production in the United States of America is increasing in quantity, and improving in quality. There was no considerable production until about 1903, although valuable asbestos was discovered as early as 1872 in the Ash Creek District, where the largest American asbestos mine is now situated. There are several smaller deposits in the States of Georgia, Virginia, North Carolina, Wisconsin, Vermont, New Jersey, Wyoming and California; but the most productive are still those in Sall Mountain, White County, Georgia, and in Gila County, near Globe City, Arizona, Recently the production in California has also increased.

Sall Mountain, like most of the smaller beds, produces amphibole asbestos, which is mined in great quantities. But because of its slight industrial value, it can be used for inferior purposes only, and is not greatly in demand in international trade. Arizona, however (where the first beds were discovered in 1903), produces a fine chrysotile asbestos with fibres as long as 3 inches. In almost all the Arizona mines the asbestosbearing serpentine is embedded in lime stone. The fibres are white and of good quality. The domestic production of chyrsotile asbestos in the United States was:

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1915	316	tons
1916	649	„
1917	1116	„
1918	396	„
1919	502	„
1920	1245	„
1921	438	„
1922	25	„
1923	69	„
1924	90	„

These small figures of production are due principally to the fact that the American deposits are located in very remote districts (Indian Reservations) with no railroad facilities, so that the mining and transportation are very difficult. To them must be added a certain amount of hornblende asbestos. It is, however, evident that the part played by domestic asbestos in the United States is quite insignificant in comparison with the enormous quantities which it consumes. It is therefore not surprising that the greatest portion of the Canadian asbestos produced is exported to its immediate neighbor.

The asbestos mined in the United States is of several varieties, differently named according to certain variations in their chemical composition. In Arizona, as we have said, there is found the best and most valuable chrysotile, which is a pure silicate of magnesia. From this we distinguish the so-called anthophyllite, found in Sall Mountain. This contains iron, is harder and more brittle than chrysotile, and therefore produces only very short fibres of little value. Another variety of anthophyllite is the Transvaal anosite. This contains some sodium, and the percentage of magnesia is almost completely replaced by iron, which causes it to resemble the blue Cape Colony asbestos.

As we have said, of the deposits in the United States, only those are of industrial value, which yield chrysotile asbestos. The other beds enumerated above, are not of economic interest. Imports of asbestos into the United States are published by the American government as follows:

1913	97,145	tons
1914	71,886	„
1915	93,516	„

1916	116,162	tons
1917	134,108	„
1918	137,700	„
1919	135,270	„
1920	167,558	„
1921	72,463	„
1922	149,427	„
1923	212,420	„
1924	183,250	„

These figures show that the chrysotile asbestos mined in the United States constitutes only a very small fraction of the raw product consumed in that country. Even if the domestic mines constantly increase their output, America will always remain very dependent upon imports from her neighbor, Canada.

b) Cyprus.

Excepting the Italian deposits, which we shall discuss later, the asbestos beds on the island of Cyprus are the oldest ones known in history. Even Plutarch and Pliny the Elder tell of them, as well as of the Greek beds on the Island of Euboea. The shrouds of kings, as we have seen, and the wicks of the ever-burning lamps of Vesta's temples, were made of this asbestos. The beds known to the ancients on both islands seem soon to have been depleted, for there is no mention of them in later accounts. Mention is made of the discovery, between the end of the 16th and the end of the 17th centuries, of smaller deposits on Cyprus. These were, however, not intensively worked.

Only after 1900 were the new deposits discovered, lying in the serpentine rock that forms the upper regions of the Trodos mountains. The most important mines were exploited by an Austrian syndicate from 1908 until 1918. The mines are located on the eastern slope of the range, about 500 feet above sea level. The beds interesting because of the existence of several zones differentiated geologically, and also by the quality of their asbestos. In the primary zone there is pure chrysotile, claimed to be of the very finest quality, and to exist in inexhaustible layers. In the so-called "roll-deposits," subjected to the shifting and compression of the hills, a less fine variety,

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the cheap "Lefka" asbestos, is found. As there are almost no long fibres, the preparation is so handled from the first as to produce only very few varieties of short fibres. The fibres show sufficient resistance to the felting and interweaving which takes place in the course of manufacture. The ore contains 1% of asbestos, very impure raw material, to be sure.

To this day mining on Cyprus is done in open cuttings, along terraces on the slopes of the mountain. Nature has here prepared more comfortable facilities than almost anywhere else. Before the ore is loaded into baskets, it is freed by hand of the larger stones. Until very recently this work was done by women, as was also the further sorting. With such cheap labor, manual labor could be extensively used, and several grades of raw material of varying fibre lengths were mined. The separation was effected by hammering the rock propped on hard supports. The fibres were then assorted according to length either by hand or with sieves.

Since 1925 several medium grinding and separating machines of the American pattern have been under construction, so as to further the exploitation of the mines, and the operations in general.

c) Finland.

To the inhabitants of Finland asbestos rock, its technical usefulness, and its resistance to fire have been known since ancient times. The main deposits are near Rikkavesi, and in the territory of Lake Juojaervi on the border of Karelien. The inhabitants have used the ore for the construction of baking ovens and baths, and have kneaded the weathered fibres with clay, using them as fire-proof mortar or for the manufacture of earthenware.

All Finnish asbestos is, however, so-called actinolite, a hornblende product, which, in consequence of the shortness and brittleness of the fibres, is not fit for spinning, and can generally be used only when mixed with other varieties. This is due to the high content of silica, which the following analysis shows:

SiO_2	62,02%
MgO	27,20%
FeO	3,54%

Al_2O_3	2,08%
CaO	0,71%
loss in annealing	5,04%

In 1900 the first company was formed to mine these deposits, of which the best in quality was found on the Paakkilanniemi estate. This was, however, dissolved in 1911, after wearisome efforts, partly because the transportation facilities for carrying the raw material were then too unfavorable, and partly because the inferior material could neither compete with Russian and Canadian asbestos, nor establish any demand for itself.

In the meantime the question of transportation has been solved by the canalizing of the Juojaervi River, which has made a direct connection with Saima Lake, and thus with the sea. In addition came the great scarcity of asbestos, which the Central Powers experienced by their isolation during the war, and which made the mining even of inferior asbestos seem worth while. In 1918 operations were resumed by a newly formed company. At first, besides small quantities of prepared fibres, it was chiefly asbestos ore that was exported. As almost 70 % of the mineral is waste, the preparation of it in the country was undertaken as soon as possible. The following table shows the number of tons exported since then as "Fibres":

1919	33 tons
1920	252 „
1921	750 „
1922	785 „
1923	787 „
1924	1227 „
1925	ca. 1500 „

Since 1922 a domestic asbestos factory has been manufacturing tiles and asbestos boards of Finnish material, but only in conjunction with Canadian and Ural asbestos. The very insignificant waste is then utilized for flooring, paints, and similar minor purposes.

d) Australia.

Australia has long been known as a producer of asbestos. It is quite usual to think of the land as a homogeneous unit, and to overlook the fact that it is a continent not much smaller than Europe.

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Numerous older asbestos mines are known, producing absolutely different varieties, some of very fine quality, and others designated as inferior. To the latter belonge the asbestos originating in the serpentine zones of Queensland, whose fibres are rather short and difficult to spin. There occur here many pieces, colored by their content of iron, and very brittle.

In West Australia also, are found numerous beds of an asbestos similar to the actinolite of North America, an amphibole asbestos of great brittleness in spite of the great length of the fibres. This is suited only for insulating purposes, and as an added ingredient for paper and boards. On the other hand, valuable deposits of chrysotile have been discovered in this same western half of the continent. First, about ten beds were found in Pilbara, reaching from the coast far into the interior, in the neighborhood of Soanesville, Lionel, and other places. These seem to be very productive of long-fibred material. The serpentine rock is said to be as much as 25 feet thick, and to be traversed by mumerous asbestos veins of considerable width. The operations have to be carried on by means of adits driven into the mountain; work in open cuttings, like those in Canada, is hardly possible. The length of the fibres is from 1 to 4 inches; the percentage of spinning fibres in the mined rock is very high. Consequently several mills have already been established in Soanesville and Lionel, which furnish the prepared raw material for inland consumption. Small quantities of the longer fibred kind are occasionally exported.

The composition of this asbestos is that of pure chrysotile:

Silica	43,0%
Alumina	0,4%
Oxide of Iron	1,9%
Magnesia	39,9%
Water	14,8%

In New South Wales, in southeastern Australia, there is also found, besides inferior amphibole asbestos, a very fine chrysotile, ranging from a reddish color to pure white, with long, firm fibres well suited for spinning.

Finally, in Tasmania also, asbestos has been found, of a quality worth mining. This has hardly been exported, but is used for domestic purposes only.

On the whole, production was not strenuously carried on in Australia until 1918. Because of the great distances, the raw product there requires a more difficult and expensive preparation than does that from the large beds of other countries. In 1918, however, production began to rise, so that of the 500 to 900 tons mined during the past few years, a part has already been exported.

e) Siberia.

A recent report on Siberian mineral resources and their industrial significance declares that the asbestos industry has hitherto been of a casual nature, but that the supply is large and the quality good chrysotile. This characterizes excellently the present and the future of the natural asbestos stores of Siberia. The endless distances, and the relatively slight transportation facilities and meagre means of communication account for the small extent to which the mineral resources in the interior of this rich country can be utilized. Even the report of the Russian government says that only Ural asbestos is in demand for export purposes, while the working of the Siberian beds is still inchoate. Nevertheless the most important mines of the country, containing a great wealth of valuable asbestos, have been rather thoroughly explored, and their exploitation may develop in due time.

The most important and largest beds lie near the Yenisei, and along it, south and north of Minussinsk, in the Uryanchai district, and along the Iltschir River; then too, near the Mongolian frontier in the Altai Mountains, along the river Katun. Iltschir asbestos is at present considered the most valuable. Asbestos was first discovered in the Katun district, named from the river in the Altai mountain range, as a number of expeditions were undertaken to explore the mineral resources there, gold having been found in the neighborhood. Such expeditions were undertaken between 1895 and 1899, by Professor Saposchnikow, of the University of Tomsk, who discovered very excellent asbestos. Systematic exploitation of the beds was, however, carried on intermittently only, the owners as well as the lessees changing frequently in the course of time. The technical difficulties are great because of the mountainous location, and considerable time will still pass before Siberian asbestos, which

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is in no way inferior to Ural asbestos, will figure prominently in the markets of the world.

Smaller asbestos beds, still unexplored, lie to the west of Lake Baikal, in the neighborhood of Vladivostok, and on Kamtschatka.

f) China.

In this immeasurably large country only inconsiderable asbestos beds have been found. Recent reports give the total area of the Chinese deposits as above 3100 acres. Of these about 80 % are in the province of Chili; the rest are distributed in the districts of Pekin, Jehol, Mukden and Shensi. The Lih-Cheng mine, near Pekin, is the only one that is regularly worked, beeing kept in operation partly by an English firm. Its production is very small — only a few tons a month for the domestic market.

In spite of the inferior quality of Chinese asbestos, which makes it usable only for the manufacture of tiles and boards, it is more expensive than foreign products because of the lack of modern means of transportation.

In the Japanese concession of Kuantung in Ho shang t'un, there is another systematically operated mine, that delivers its produce to a Japanese company. The production amounted to: —

1920	22	tons
1921	72	„
1922	79	„
1923	63	„

The asbestos is said to be of medium quality.

Only a small part of the Chinese product is prepared there. The manufacture of the finished product by the Tientsin Company was: —

1918	ca.	7,0	tons
1919	„	7,0	„
1920	„	3,9	„
1921	„	12,8	„
1922	„	9,3	„

g) Alpine Beds.

1. Italy.

Among the oldest asbestos deposits, worthy to be mined and industrially prepared because of their quality and abundance, are those on Mount Cenis, in Lombardy, and in the Val d'Aosta. They produce hornblende asbestos, which is of course not so resistant to fire, and not so flexible as the serpentine variety. It does, however, offer sufficient resistance to the temperatures formerly required in manufacture, and a still greater resistance to the inroads of chemicals. As we have seen, before the 19th century, the industrial utilization of asbestos was resticted to the manufacture of a few occasional articles. The middle of the 19th century was the earliest time at which one could really speak of manufacture, as such.

In consequence of its hornblende origin, the Italian asbestos, even though it has long fibres, it not so usable as the softer, finer Canadian asbestos. It is uncommonly tough and coarse, and is worked almost exclusively in a mixture with Canadian asbestos, or for special purposes.

The material mined in the mountains is carried down unsorted and unworked into the valleys. It is then partly prepared in the country, or shipped to England, where it is graded and further prepared for special uses. Italy herself supplies from Canada the larger part of her own demand for asbestos. This sufficiently proves that the Italian hornblende production — used chiefly for filters, so-called "cross-fibre" and boards — plays a very small part in the world market.

The United Asbestos Company, formed in London in 1880, has, since the beginning of the actual industrial exploitation, managed almost all the Italian mines. Because of the difficulty of work in the mountainous country and the laborious transportation, Italian asbestos was very expensive before the discovery of Canadian asbestos, especially as the better grades were not often found. The long-fibred silky variety occurs almost exclulively in the high mountains, and the thin short asbestos in the valleys.

Near Turin, at San Vittore, there is a recently developed bed, which produces short-fibred asbestos suited to the manufacture of boards and tiles. Here, in the high Alpine Val d'Aosta, mining on a

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considerable scale, for Italy, has been carried on for about two years. Asbestos there occurs in flat strata, compressed by the weight of the mountains, furnishing rather short fibres suited to the manufacture of tiles and boards. The percentage of crude asbestos in the rock seems to be small. But the raw product is easily mined, since the beds lie along a rather precipitous wall, offering easy transportation to the preparation plant in the valley. Large plants, similar to those in Canada, have therefore been erected there by the contractors. It is, however, too soon to predict whether the development of the enterprise will be so favorable as to make the mining permanently profitable.

2. Smaller Beds.

The countries of the former Austro-Hungarian monarchy possess some asbestos deposits in Lower Austria, Styria, and Salzburg, which should be classified as Alpine beds. But they are so insignificant that, although they are operated, they do not supply the demand of any domestic industry.

In Switzerland there are also numbers of beds — in the Puschlaver valley, near Sils in the Engadine, in the Valais near Zeneggen, and near Poschiavo — where several hundred tons of asbestos were mined during the world war. Here, however, as in Italy, all the workable deposits produce hornblende asbestos.

This is true also of the asbestos found in the French Alps, in the Chamonix valley, which, like the other French deposits in Dauphiné and the Pyrenees, are interesting mineralogically, but economically unimportant.

C. Unexploited Deposits.

Besides the above-mentioned smaller beds, whose products have at least lokal importance, there are a great many asbestos deposits in the world, which either for economic or for technikal reasons, are still not mined. Some of these may be productive in the future. Some contain material too unimportant to make their product of any consequence for the world market, and are therefore neglected. We shall briefly describe these beds.

In the southeast corner of Europe several beds have been discovered. They were tested and partly worked during the war, when imports from the great supply countries were cut off. Among these are several beds in the Balkan peninsula and states bordering upon it: In Greece and Macedonia, where hornblende as well as chrysotile asbestos was found; in Bosnia, Servia, Bulgaria, along the Schipka and near Kustendil.

Richer beds, furnishing comparatively usable material lie on the island of Corsica. The asbestos there is, like the Italian, of hornblende origin. It is, however, less valuabla, as its fitness for spinning is very slight. Its average yield is only 10 % of long fibres, very brittle because of the high content of alumina. Nevertheless, aside from the question of quality, the mine is so rich that this type of asbestos was formerly used instead of oakum, etc., as a packing material. Recently an English company has taken over the mining of the usable material, but without important results. The color is white, and the resistance to heat (melting-point 1245° C) and acids satisfactory. The product can, however, be used for unimportant purposes only.

Among the countries of the former Austro-Hungarian monarchy, which we have not included under the heading "Alpine beds", Hungary and Czechoslovakia (Bohemia and Moravia) must be mentioned, as sporadic beds of asbestos have been found there. Lately Tschopau in the Hungarian Erzgebirge, which fell under the jurisdiction of Czechoslovakia after the world war, and is now called Dobschina, has been much talked of. There, along the Sajo River, lie asbestos beds mentioned even two hundred years ago. They are apparently good deposits of chrisotile, which have been mined from time to time and then again abandoned, because of the difficulties of transportation. Since the world war, a company has taken over the mining of this raw material of the useful chrysotile variety.

Analysis:

Silica	41,5 %
Alumina	1,3 %
Oxide of iron	2,7 %
Magnesia	39,9 %
Water	14,2 %

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At present it is used only for the manufacture of asbestos slates and boards, but the company has undertaken the construction of a larger plant for preparing the mineral, so that the future production will presumably be greatly increased.

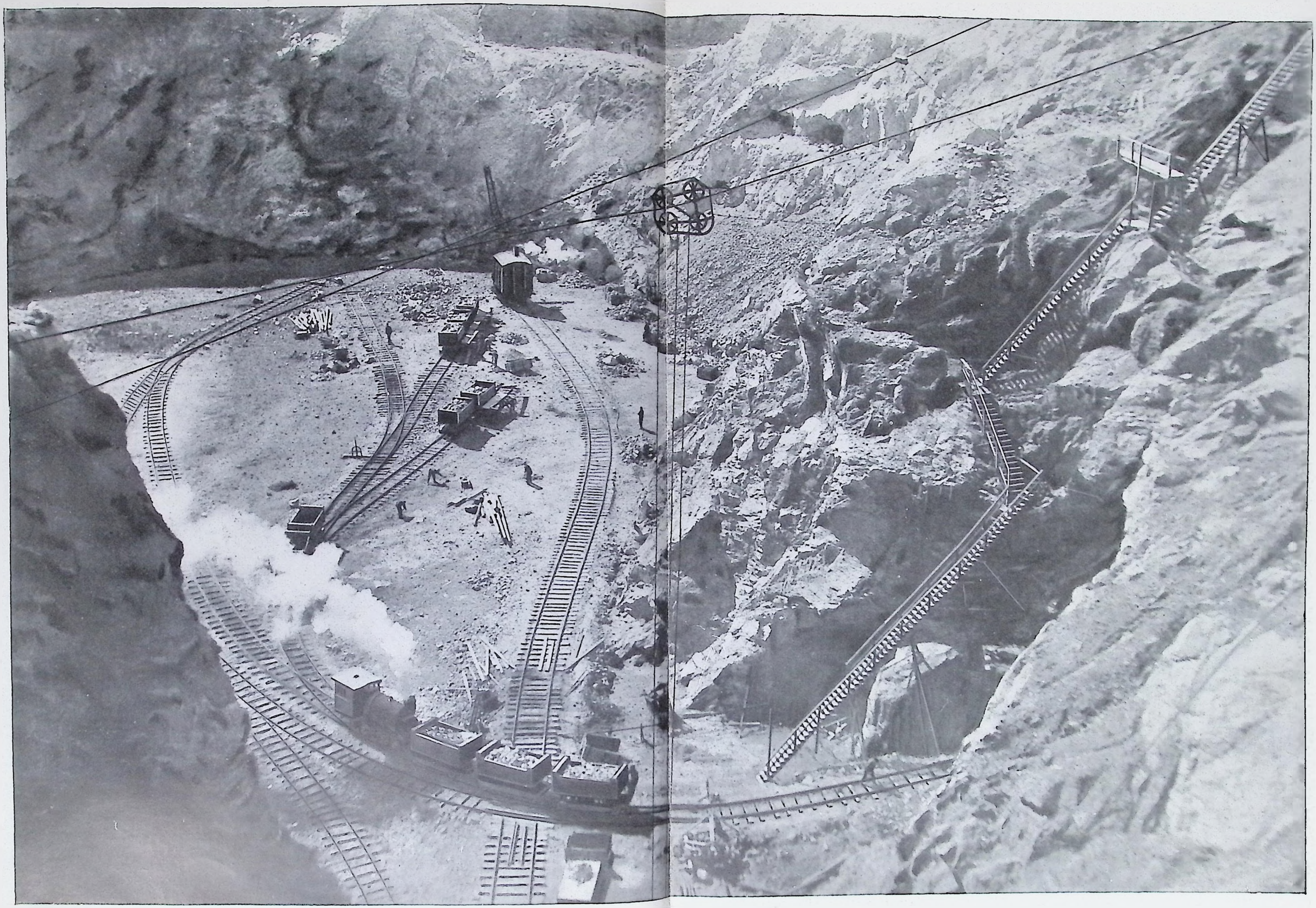
German asbestos beds were scarcely known or exploited before the war. During the war, older deposits of hornblende asbestos, which had been known to mineralogists, like the one near Zoeblitz in the Erzgebirge, or those in Thuringia and the Reuß Oberland, were first worked or opened. Asbestos was also found in the Vogtland and near Hof, in northern Bavaria. Systematic operations in these and some other places were temporarily carried on during the war. German asbestos is generally short-fibred, so that it can not be spun. It is suitable only for the manufature of asbestos boards, and was thus used as long as Canadian asbestos could not be procured. During the war, after the complete exhaustion of the imported stock of asbestos, German asbestos was drawn into use as a substitute, for every conceivable purpose. But after the reestablishment of international commerce, this use ceased entirely.

Small deposits have also been discovered in Spain, Sweden, and Greenland, but have not been worked. For the crude asbestos was too thoroughly interstratified with masses of rock to allow of profitable mining.

Outside of Europe, besides the large beds that supply the whole world with their products, many others are known, which are hardly worked. In Asia, for example, aside from the large Siberian mines, there are many small widely scattered beds, some perhaps worth operating, but not thought of for general competition because of the desolateness of the country. Such places have been found in India, in Borneo, in the Philippines, Mongolia, south of Lake Baikal, and in Japan.

The American continent, besides the enormus Canadian distrikt and the beds in the United States, contains several deposits of much less importance, but well worth operating. At the close of the last century, deposits of apparent promise were discovered in Newfoundland. They lie in a great mountain mass 125 miles long, and reaching a height of 2000 feet, consisting mainly of serpentine rock with asbestos infiltrations. The asbestos is of fine fibre, as much

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as 2 inches long, and well suited to spinning. It is, in other words, like the Canadian product.

Asbestos of the hornblende variety has been found in Mexico. With a content of 20% of alumina, it is, however, of little practical use. It is not highly resistant either to acids or to high temperatures.

In Brazil, two fairly large asbestos beds are known, both in the province of Minas Geraes. One consists of a kind of actinolite of hornblende origin, containing much iron and silica. The product of the other, near the city of Caethe, is considerably more valuable. Here a white, silky, long-fibred asbestos has been mined. But the quantity produced is not large enough for Brazilian asbestos to play an independent part in the world's commerce.

In Argentine, in the Sierra de San Luis, asbestos has been found, which can not be spun, but is highly resistant to heat. There are also beds in Venezuela and Peru, where small but easily prepared products are mined, and in Chile, where it is rather a by-product.

In Afrika, besides the great mines in the south which we have described in detail, there are small beds in the Congo and German East-Africa; but they have never been mined in spite of their apparently fine quality.

On the other hand, a deposit of seemingly fine chrysotile has recently attracted attention. Although it was known to the profession since the late eighteen-eighties, its exploitation seemed uneconomical because of its extreme inaccessibility. The bed is located on the Takaka River, near the city of Nelson in New Zealand. Here, at a height of about 3300 feet, lies a mine that can be reached only by difficult mule-tracks. The asbestos, embedded in serpentine, is thought to constitute from 10 to 25 % of the rock. The fibres are as much as 3 inches long, of a greenish white color, and of a quality alleged to be fine. Systematic exploitation has hitherto not been carried on to any considerable degree.

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IV. The Manufacture of Asbestos.

A. Extraction and Preparation.

Let us now consider the percentages which determine the mining qualifications of asbestos-bearing minerals, i. e.: the proportion of pure asbestos which a rock like serpentine must contain in order to make mining profitable. This calculation is a condition precedent to the whole question of extraction.

If the ore contains too low a percentage of pure asbestos, even if the quality is of the finest, mining is not profitable. In Canada, in open, easily worked mines, three percent of asbestos can keep a mine alive. In general, however, with few exceptions, a content of five percent is accepted as the lowest estimate for profitable mining. But, whenever possible, beds, with at least 8 %, and normal in other respects, are sought. The richest deposits, those of Rhodesia, contain as much as 15%. In Canada 6 to 12% occur, in Russia and Cyprus 5 to 10 %. Most other mines do not attain 10 %.

The asbestos extracted from the rock itself contains only a small percentage of fibres fit for spinning; — in Canada, for instance, about one-twelfth. The rest consists of medium and short fibres, which can be used for the manufacture of boards, tiles, slates, insulating material, etc.

As for the technical process of mining, there is, as everyone knows, the fundamental distinction between underground mines and open cuttings. Most of the treasures which men extrakt from the earth, they are forced by Nature to obtain at a monstrous expense of money and labor, by building passages into the depths of the earth. For examples of this, consider the most important minerals, such as coal or iron ore. Fortunately, where asbestos is concerned, con-

ditions are very different. Only in a few places, e. g.: in Canada, where the extraction is rather difficult, is deep mining occasionally resorted to in order to obtain a larger quantity of the desired ore. Almost always, the asbestos or its matrix lies plainly in view, or is so easily accessible that a real mine with pits and shafts is not required. The reason for this lies in the nature and inner construction of the mineral itself. The peculiar cobweb-like ramified and cloven veins of asbestos, and the inconsiderable depth of the workable strata seldom demand the construction of adits and shafts. In fact such construction in most cases prevents the transportation of the ore. Herein lie decided advantages. For work in the open is more easily surveyed, and, not requiring the erection of props and walls, is simplified and made less expensive. On the other hand, since only a small portion of the mined material can be utilized, enormous dumping grounds for the dead rock must be provided. This inconvenience would also arise, but in a lesser degree, if the mining were carried on in a deep shaft.

The exterior configuration of asbestos mines varies according to the greater or less difficulties of operation, and also according to the method of preparing the matrix. If the mineral appears on a mountain slope, it can be extracted in the simplest way: as in a quarry, in terraces hewn into the rock, or in caves. The work in the open then progresses step by step along perpendicularly sunken levels, divided into terraces. This comparatively easy method of mining was found applicable in the rich deposits of Russia, Rhodesia and Cyprus, where labor is also cheap. The mined rock is here subjected to a first rough sorting by hand before it leaves the place of its extraction. Here too, as far as possible, adherent, unusable rock is chopped off; then the product is conveyed to a central point to be properly assorted according to the purity of the material, — the pure fibres being more carefully separated from those attached to dead rock — and according to its quality, i. e.: according as the fibres are long, short, or very fine. In the end six kinds usually emerge; three grades of each of the two varieties — the pure fibres, and those adhering to rock. There then remain the dead rock and a fine waste of inferior quality. Such a classification can of course be undertaken only where it is justified by the length of the fibres. Where we have only very short fibres, or asbestos that can be se-

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parated from its ore only by great force, the entire production is often carried to the mill. Where labor is cheap, sorting and preparing by hand is profitable; it pays to have the long fibres picked out, for their value is very much higher than that of asbestos prepared in a mill.

Naturally the method of the rough sorting and preparation is adapted to local conditions. In Canada, where the greatest mechanical aids are at the disposal of the mines, the equipment has an entirely different appearance from that used in any other asbestos producing country.

We have seen that the mining is simplest when the rock lies on a mountain slope. As we have said, this is a most favorable condition, and one that seldom occurs. As a matter of fact, in the two countries which, next to Rhodesia, chiefly supply the world, — Canada and Russia — asbestos beds are often found on entirely level ground. In such places mines are begun in round or angular, more or less regular surfaces, and are deepened in open cuttings, like amphitheatres, without any previous knowledge of where the greatest depth will be reached. This depends not only upon the deposit of asbestos itself, but also upon the possibility of overcoming the technical difficulties of conducting water, mining the rock, and transporting the mined mineral without endangering the profitableness of the enterprise. The most common appearance of such a mine is that of a pit surrounded by towers between which stretch strong wire cables running in all directions over the whole area. Trolleys run back and forth along the cables, carrying buckets or baskets of the mined mineral, with a capacity as great as 20 tons. The dimensions of such a mine are from 650 to 1000 feet by 250 to 350 feet, with a depth varying with the abundance of the mineral, and sometimes reaching more than 350 feet. The height of the steps, laid out in terrace formation, varies greatly, and their shape is most irregular. It is sometimes 6 feet, and sometimes 36.

On the whole, the method of extracting the raw material is always fundamentally the same. The technical appliances differ according to the size of the mine. Let us consider then the mechanical preparation, and the equipment needed for it.

First the material is roughly broken up in stone crushers such as are generally used in the preparation of ores. These are either

of the jaw type — with heavy crushing jaws worked by springs — or of the centrifugal type, equipped with conical grinders. After this, the material is dried. In the primitive plants of earlier times, this was often done in the open air, with sheds as a protection from direct rain, and with a frequent turning over of the pieces by hand. Thus is done in the Urals and on Cyprus. In more modern plants, equipped with every modern contrivance, the drying is done by means of mechanical devices: dryers with steam jackets which rotate, and, owing to the inclined position of their longitudinal axis, automatically move the material slowly forward. Others have movable arms, which transport the product, and at the same time automatically load the dryer.

In well-equipped plants, the dried material is next taken to large storage warehouses. The King mine possesses one capable of storing almost 30,000 tons. Next it is taken either to the so-called dissipator mill, where it is caught up and brooken by rollers revolving in opposite direktions; or to a grinding mill, where two hardened rollers with ridged surfaces pack and crush it; or to a crushing mill. In this the crude asbestos is pressed and crushed so that the rock is broken and separated from the fibres, and the consistency of the fibrous mass itself is relaxed. As a result of many years of experience and experimentation, modern machines are so designed and operated that the asbestos fibres themselves are spared to the greatest possible extent, and that fibres of the first grade may not be destroyed and thus become suitable only for the manufacture of asbestos boards. The saving of the long fibres combined with the highest attainable production is one of the most important problems for the designer of asbestos preparing machinery.

After the preparation in the mill, the ore itself is already so crushed and crumbled, and the separation of the fibres from the rock has gone so far that it is ready for a final forcible separation of the fibrous asbestos from the stone. This occurs in the fibre opener, a large drum-shaped container, in which revolves a shaft with a number of arms bearing long sharp-edged teeth or knives. As the shaft turns at a great rate of speed — about 10 revolutions per second — the fibrous mass is freed from the small remnants of rock, which it still contains, and at the same time separated and spilt up into fibres — "opened".

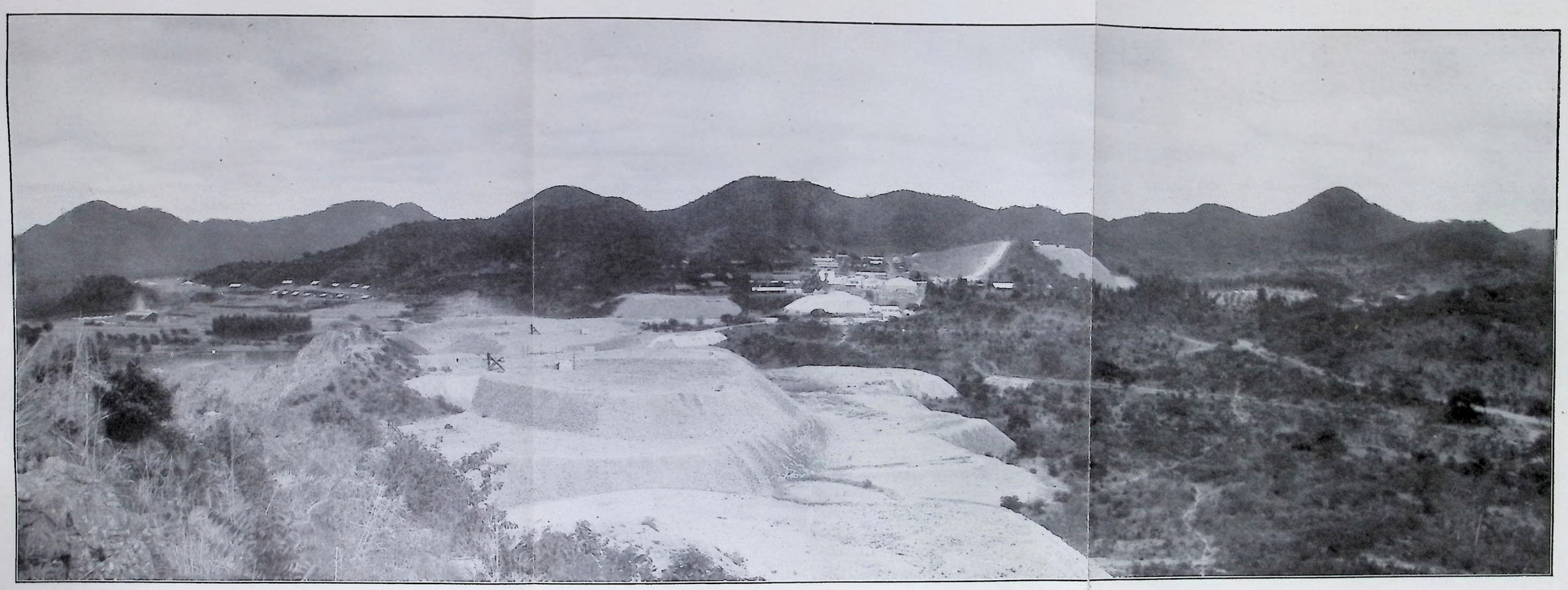
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When this process is finished, a division into three parts is usually made by means of a shaker sieve. The material dropping through the sieve is useless stone reduced by the foregoing mechanical operations to the size of a grain of corn. This is taken to the dumping ground, and forms the inevitable waste in this industry. In the course of years there have arisen in the great Canadian mines whole mountain ranges built up out of this waste material.

The dust arising during the separation of the fibres from the crushed ore is extremely troublesome. The Canadian works, by the use of every modern industrial appliance, — which they can afford to use to a greater extent than the more primitively worked mines of other countries — have succeeded in separating the mineral dust from the asbestos fibres, and in carrying it so far from the reach of human lungs that it is no longer troublesome. The most effective means to this end is compressed air, the use of which is important in the further extraction and separation of the mined product.

A mixture of long fibres, rough pieces of crude asbestos, and some hard pieces of unbroken rock would remain on the separating sieve, were there not on its surface a blower or other such contrivance, to blow the light, pure fibres into a collecting bin. The rock, about ¾ of an inch to 1¼ inches in diameter, still contains some fine-fibred asbestos, which can be well utilized for many industrial purposes, when extracted in the form of very short fibres only. This extraction takes place in a so-called Cyclone-opener, which is a very important part of a mill's machinery. A large box of heavy steel plate, provided with a charging hopper and a discharge vent, bearing on opposite walls two fan blowers, rotating in opposite directions at a speed of several thousand revolutions per minute. The rock of the above designated size, falling into this box, is completely crushed, and, in so far as it still contains asbestos, is ground almost to powder. In the course of the process the material is carried by a current of air from the box, and winnowed into fine asbestos fibres from the remaining rock. In some plants a shaker sieve is introduced between the "Cyclone-opener" and the winnower. In any case, the finest fibres are sucked up by air and carried away, while the heavy powdered rock falls to the bottom of the box. If further grinding is not profitable, the worthless waste and the residue in the box go to the dumping ground. The fine fibres go into the collector, which

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RHODESIA ASBESTOS MINES

PANORAMIC VIEW OF SHABANIE MINE TAKEN FROM BIRTHDAY ROCK PLANT SITE,
SHOWING POWER PLANT ON EXTREME LEFT, RIGHT UP TO THE COMPOUND ON EXTREME RIGHT.

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already contains the longer fibres from the knife-equipped opener. A Cyclone-opener of this type prepares as much as 5 tons per hour, depending upon the hardness of the rock.

The collector now contains the total product of asbestos, with the possible exception of especially valuable spinning fibres that may have been previously extracted. The whole quantity is now classified into several grades according to the length of the fibres and their uses in different branches of industry. This is accomplished in so-called classifying drums, long rotating cylinders whose walls are pierced with holes corresponding in size to the desired length of the fibre. The number of differentiated kinds varies at different mills. In any case, the asbestos falling through the classifying drums, reaches winnowing sieves by which the longer spinning fibres are sucked up by air, while the short-fibred and powdery material is carried away. If the material is very rich in yield, a second grade of shorter spinning fibres is sorted out. This second class of spinning fibre may then be mixed with the short fibre falling from the drums, while all the leftovers are kept together. But even these are again separated, mostly on finer shaker sieves, into very short fibres not suitable for spinning purposes.

The whole classifying process, then, furnishes one or two grades of spinning fibres, and medium or short fibres not suitable for spinning. The very short fibres serve in the manufacture of coarse boards, paint, etc. where there is need of a raw material which, when mixed with liquids, can be worked as a homogeneous mass. The shorter fibres not suitable for spinning, can be formed into a felt-like mass, well suited to the manufacture of astbestos tiles, paper, packing material, etc.

It is evident that the classification and grading may be continued, subdivided, and repeated according to the requirements of various articles whose manufacture depends upon certain definite qualities. The size of a plant may be gathered from the fact that in one, such as we have described above, 80 to 100 tons of raw asbestos can be prepared in a day. Out of this, from 9 to 10% of pure asbestos is mined. If, for instance, the daily output of one of the larger Canadian mines is 100 tons of pure asbestos from 1200 to 1500 tons of ore, it is due to the fact that three of the systems we have described are working there simultaneously.

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Of course, the method of preparation depends entirely on the natural character of the ore. There are deposits, like those in East Broughton, containing only very fine-fibred, almost powdery asbestos. Such material is worked much more simply than long fibred asbestos. Either it is immediately taken to the mills, or it is all ground in crushers to the finest grade. It supplies only short asbestos for asbestos boards or fillers, or for insulating purposes. In most mines, however, rock is mined containing all kinds of asbestos from the spinning fibre to powdery waste, being prepared by the systematic method described above.

We have pointed out how important industrially and ecconomically is the systematic arrangement and continuous operation of a mine's preparation equipment. In this respect the plant of the Canadian King mine, newly erected after its great fire, may serve as a model. Let us therefore briefly describe once more its organization and process of operation.

Directly connected with the main crushing plant, where heavy crushing machines break up the mined rock into pieces the size of a fist or smaller, is a storage shed for the crushed rock. This is then carried by conveying belts, over a covered road to the mill. The fibre mill, which can produce about 200 to 300 tons of fibre daily, contains crushers on the ground floor, on the next floor winnowing sieves, and on the third floor dust-collectors and grading machines, which suck in the fibres and assort them according to the desired qualities. The whole installation is unexcelled, as to the smoothness of operation and as to the prevention of dust, which would be harmful to health, and also cause material losses.

B. Manufacture.

Before describing the separate fields of industry in which asbestos and its products are chiefly used, let us consider briefly the natural properties which make asbestos so valuable for industry in general. For the nature of the raw material determines the branch of manufacture to which it may be adapted. We shall discuss, then, the methods of testing and determining scientifically the technically important qualities.

The most outstanding and remarkable, hence also the most commonly known characteristic of asbestos and its products, is its resistance to high temperatures. It must be conceded that this fireproof quality does not go as far as is often supposed, that it does not fall in with the conception which the so-called "fireproofing" industry ordinarily connects with the word. In fact asbestos should not be used for the products of this and of related industries. As a rule it is sufficient for it to withstand the temperature of superheated steam, or the melting temperature of the most commonly used metals and alloys.

We have already mentioned a quality that sharply distinguishes chrysotile from the hornblende asbestos, namely that hornblende strongly resists acids which completely destroy chrysotile. This adapts hornblende asbestos to certain purposes, although it is far less resistant to heat and much less fit for spinning than its competitor.

When we touch the silky, remarkably smooth and soft fibres of any variety of asbestos, we notice another quality — its slipperiness. This suits it more than any other inorganic product, to the manufacture of packing and stuffing material for steam engines, wherever friction needs to be avoided or lessened, and where at the same time, resistance to great heat and to high pressure (even that of chemically effective gases) are required. These three requirements are answered by no other material in the same degree as by Asbestos.

To its capacity to withstand heat, asbestos unites the important quality of being a poor heat conductor. The two traits are not always combined. Aside from the metals of high melting point, there are also a number of other fire-proof products, e. g.: graphite, which conduct heat more or less rapidly. The low heatconductivity of asbestos is probably due in part to its structure of small cells and to its content of air. This makes it an ideal material suited equally to retain heat and cold. Herein may also lie the reason for its not being a conductor of electricity, a quality which has established it as a valuable insulating material in electrical industries.

The well known asbestos gloves, aprons and suits, which have proved so advantageous in blast furnace work, but which, because of accompanying circumstances, are not so useful for the fire department, have been found extremely practical in the operation of high voltage currents.

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The uncommonly fine subdivisions of the small fibres also make asbestos useful in the manufacture of a number of other products, where the quality depends upon the ability to combine the natural properties of asbestos with those of other materials, which are then either absorbed by the asbestos or mixed with it in the varying proportions. Thus, by saturation with different water-repelling chemicals, a water-proof asbestos is made into tiles, coverings, felt, building material, etc. — products whose manufacture and value we shall have to consider in detail at another place.

Finally, the specific gravity of asbestos is so low (2,3 to 3,3), that this also is an advantage not to be underestimated.

The expert, confronted with a sample of asbestos prepared for manufacture, or with a finished asbestos product, must examine the qualities of the raw material and determine whether the material offered meets his particular requirements. When it is a question of crude asbestos or asbestos that is completely prepared, the analysis is comparatively simple. It is restricted to external qualities, — the structure and kind of the fibres, their strength, fineness, flexibility and slipperiness, — and to chemical and physical questions, such as the chemical analysis and specific gravity. The length of the fibres, and the percentage of fibres of a given length, are frequently determined in sieve machines. These machines contain a number of sieve boxes in which the sample is shaken for a certain time, whereupon the quality of the product is judged by the amount left in each compartment. The contrivances used for such tests, and the rules applied are based on agreements that have been generally adopted as standards in the industry.

Quite different and more difficult are the tests of finished asbestos products. For here the expert must determine the possible additional ingredients, consisting of foreign matter — not only the permissible, indispensable materials, well-known and in general use, but also others which must be thought of more or less as adulterants. If the asbestos is woven or spun, that is, if long-fibred asbestos has been used, the expert can more easily judge the quality than if the article has been moulded, pressed, or prepared by some such method. For then it generally contains some non-asbestos ingredients or binders.

But even for the testing of finished products, chemical analysis may be an important aid, especially in ascertaining the content of

magnesia and silica. These two ingredients decide the usefulness of products which have to be exposed to high temperatures or to vapors or acids. The specific gravity is a further criterion for certain technical qualities in the articles and for the discovery of adulterations. Hand in hand with these tests, possible only with the aid of scientific methods, there goes, first of all, an examination of the exterior of the manufactured product. This is, of course, not undertaken only with the naked eye, but with the microscope as well. Certain interstratifications, inlays, and additions to the raw material — such as metal wire or cloth, organic layers of fibres and single threads — may be determined by the unaided eye. With a magnifying glass or microscope the expert can easily and definitely determine the length of the fibre in the prepared asbestos, and whether the vegetable fibres originate in cotton, hemp, flax, rubber, or other plants. If the sample to be examined may be destroyed, the percentage of organic matter may be found quantitatively by drying and heating, always taking into consideration the quantity of water of crystallization.

It is by no means always a question of adulteration, but of threads in the weft, fastening threads, reinforcing wires or bands, which give the product a chemical or mechanical resistance or some other quality necessary in unusual cases, and which pure asbestos does not possess. There are additional ingredients without which the manufacture of certain asbestos products would not be possible at all. In cases of real adulteration, or of ingredients usable in themselves, but present in an inallowable degree, all branches of science must be drawn upon, and yet great care must prevail, before a definite suspicion may be uttered. Often the water content of the prepared raw material may have been abnormally high, so that thorough drying at a high temperature must precede actual heating. In most cases the microscope in the hands of an experienced judge is the most successful detective, for paper, pulp, and similar fibres are plainly distinguished from asbestos. On the other hand we know that certain admixtures are indispensable. Asbestos boards, sheets, etc. contain quite varied binding and gluing materials, such as resin and similar impregnations, waterglass, gum, starch, etc. Organic products like these may often be extracted in solutions, and their kind and quantity be determined. Sometimes there occur mineral adulterations, e. g.: barytes or zinc oxide, which are traceable by chemical

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analysis. The problem is, however, especially difficult when the adulterants originate in materials related to asbestos itself, i. e.: when they have a very similar chemical composition, as has talc, for instance. Then physics, optics and chemistry must cooperate with the full acumen of the analyst to attain the goal. Besides inquiries into the quality of merchandise to ascertain its fitness for certain purposes, and the searching out of adulterants, the equally important question arises whether certain varieties of crude or even of prepared asbestos are in themselves suitable, even under definite limited conditions. This often forms the basis of searching tests and examinations.

Here the test is usually based upon the resistance of the material to definite temperatures. It is essential to know whether the sample in question possesses tensile strength sufficient to resist the temperatures that are required, or that may possibly arise. Upon the result of such an important test and the care with which it is carried out, the life of a man in industry may often depend. The articles or raw materials are exposed gradually, and for a definite time to rising temperatures, and at every stage are carefully examined for any change in their quality. In asbestos boards and similar moulded or pressed merchandise, made of very short-fibred or powdery raw 'material, the decrease in quality caused by heat is rapid. Here the so-called bursting strength and tensile strength are the first things to be tested, for the boards become brittle and pliable if exposed to high temperatures for any length of time, and finally crumble to pieces. All such products must be gradually heated to the temperatures at which they are to be permently used. With spun merchandise or textiles, which are known beforehand to consist chiefly or only of pure asbestos, the tests are intended rather for selecting the most suitable variety of asbestos. Only experience and practice can decide this. They show, for instance, that white Canadian asbestos is incomparably more valuable for use at constantly high temperatures than is the blue African asbestos. But the insulating power of both, even against electricity, is about the same. The more brittle African asbestos contains a larger quantity of air between its cells and fibres, and this is in many respects the best insulator.

These examples go to prove that it is, generally speaking, neither possible nor profitable to establish basic rules for the utilization of

this or that variety of compound. Even in this great field, experience is the best teacher, and if an expert sometimes seems to solve these problems rather unceremoniously, he is after all doing so on the basis of his own or of other people's experience.

We shall now consider in greater detail the branches of manufacture built up exclusively or principally on the use of asbestos, and in which its different varieties are worked. Let us examine the operations in the sequence used in preparing and classifying the different kinds, turning first to manufactures which use long-fibred material — asbestos spinning and weaving.

a) Spinning and Weaving.

It is evident from the foregoing that the manufacturer of a finished product must consider carefully several questions: whether he can and will mix with his asbestos any foreign substances, to what extent he will do so, and to which variety of asbestos he shall give the preference, or whether the product he wishes to manufacture must have qualities obtainable only by an exactly calculated mixture of several kinds of asbestos.

Such are the problems of the man who wishes to spin or weave asbestos. Cotton is often mixed with asbestos. Even when the long-fibred Canadian variety is used, about 2% of cotton is added, but with shorter grades of fibre as much as 10% is added. In most cases, moreover, the manufacturer can not restrict himself to a single variety of asbestos, but must prepare a mixture of different varieties corresponding to the uses and practical requirements of the finished article, bearing in mind such economical questions as the cost of raw material and of ease of manufacture, and, of course, the possible selling price.

Plants with a background of long experience know that all crude asbestos must first go through the crusher, whereas not every asbestos fibre need be subjected to this process. The different kinds of asbestos required for a given product are arranged, with or without the addition of cotton, in superimposed layers, to be carried to the shredder or mixer. Having been opened and mixed, the fibres are ready for the various spinning processes. They are then either carded by a carding machine, or are immediately transformed into rove by a carding comb. In modern carding machines, especially

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those used for fine threads, the carder is connected with the roving machine by conveying bands, which carry the carded fibres directly to the roving machine. During the carding process, the opened fibres are more finely shredded and are laid parallel to one another by the cards. At the same time any remaining impurities, and fibres too short for spinning, are removed, and the longer fibres are united into a web. The machines used for this purpose are the same as those generally used in ordinary textile industries, which is not always so in the later stages of preparation.

The carding process is as follows: The material, evenly distributed on the feeding table, is pushed by it on to a roughing cylinder, which spreads it on a drum. Here the carding and combing take place. Small impurities are eliminated, and at the same time a loose thin web is made of the longest possible fibres. Cotton, instead of being added to the asbestos during the mixing process, may be added during carding. The quantity fixed upon as an addition to the asbestos mixture in question is weighed and likewise carded, with the result that the carded cotton leaves the machine, not as fibre or roving, but as a web or fleece. The cotton fleece is then led to the spinning card so that it is laid as a cover over the layer of asbestos on the feeding table. The percentage of cotton in the asbestos is kept exactly as previously decided upon. Next the asbestos and the cotton run together over the combing cylinders, and, as a single web, go to the stripper, which cuts the broad web into narrow strips. In the ensuing steps of the process, these strips are changed to loose threads, called roving, which are wound either singly on bobbins, or many threads together on cylinders. This roving has no strength. This it obtains only in the spinning process. Since spinnable asbestos fibres are generally only as long as the fibres of cotton waste, the machinery for spinning asbestos is similar to that for spinning yarn from cotton waste. The required strength which the asbestos roving lacks, is now supplied by twilling in the spinning machine. Asbestos roving, like any other spinning fibre, is drawn taut and twilled. As compared with cotton fibres, those of asbestos permit of very little working. It is not possible, as with cotton, to produce a fine yarn from heavy roving. Asbestos yarns always contain, according to specifications, a layer either of cotton yarn or of thin metal wire. This is called asbestos with a cotton or metal core.

After the preparation of the yarn, if it is not to be used simply as such, it is next twisted, i. e.: several threads are twisted together on a twisting machine so as to form a single twisted thread. In commerce there is a demand for single or twisted threads, and for twisted cords, made on cording machines. From a number of cords of gradually increasing heaviness, rope is made by the same process as that used in the manufacture of hemp ropes. Several operations have to be combined to guarantee the evenness of the twisted threads or cords. The asbestos threads must be tightly and closely united, must be of a uniform size, and while they are being put together, must be maintained at uniform tension, so that the finished product may have the same shape and strength throughout its entire length. When it has been spun and twisted, the yarn which is not sold or utilized as yarn, is woven into fabrics.

Before turning to this branch of manufacture, let us say a word about the quality of the yarns made from different kinds of asbestos. We have already seen that pure asbestos fibres from a single source are spun rarely and for special purposes only, and that vegetable fibres, such as cotton, are usually added. If the finished product is to have special qualities, like resistance to acids or high temperatures, special varieties of asbestos and mixtures without cotton are generally used. The white or silvery Canadian asbestos is best suited to high temperatures. Its long, soft and silky fibres are easily prepared and readily spun. South African hornblende asbestos is most highly resistant to acids, but its fibres are not so soft, and the yarns made oft it are rough and brittle without any great tensile strength. Siberian asbestos has a place between these two varieties. Its fire-proof quality does not quite equal that of Canadian asbestos, while its fibres are shorter and less soft; its specific gravity is somewhat lower, but it has slightly more resistance to acids. This shows how important it is to be thoroughly familiar with the chemical and physical qualities of the various kinds of asbestos, and to select the raw material best suited to a given purpose.

For weaving, as we have said, single as well as twisted yarns are used, and fabrics of the most varied density, strength, and consistency are produced. A fabric is, of course, woven by the combination into a pattern of single threads laid cross-wise, in which the vertical threads are called the warp and the horizontal ones the woof. The

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arrangements of looms now make possible the most varied combinations in weaving, which it would take too long to describe here.

Asbestos yarn is used not only for the weaving of fabrics but also for manufacturing packing and insulating cords for steam engines and pipes. These are produced by so-called bobbin and braiding machines. The space between the single threads or cords may be filled, according to its intended purpose, with fine asbestos, or with other materials, such as infusorial earth, wax, talc, oil, fat, graphite, etc. Such packing and insulating material is made in many finishes, and for the most varied industrial requirements. For its mechanical strengthening other threads or fine metal filaments are often introduced. The material is delivered in round, rectangular or square shapes, and cut into pieces of uniform size.

b) Boards.

We shall now turn to the working of the very short fibres — the waste fibres that arise in the extraction of asbestos. We have already seen that unspinnable fibres and the dust-like waste particles of asbestos represent by far the greatest portion of the raw product. The asbestos board and paper industry therefore uses the largest quantities of the raw mined asbestos. The third field for its utilization is that of building materials.

For the manufacture of asbestos boards an important prerequisite is the careful preparation of the raw material, which must be of a homogeneous fineness, and free from all impurities or foreign substances. Where these conditions are not met at the outset, where, for instance, the waste from the spinning mills is not used, the material has to be specially prepared in grinders. Here the remaining particles of rock and impurities are removed from the fine asbestos particles.

After the raw material has attained the required fineness and purity, it reaches the pulp-mill, where it undergoes the most important part of the process. The apparatus is the same as that generally known and used in the manufacture of paper. It is directly connected with the preparatory work of the crusher, and is not only a mixing but also a grinding machine, which accomplishes a final and most thorough-going preparation of the material. This is necessary

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in Canada

CANADIAN ASBESTOS MINES
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because asbestos fibres do not have the inner softness of other fibres used for making fine paper. The drum of the pulp mill carries wide steel blades about $^3/_8$ of an inch thick and revolving 500 to 600 times per minute. It is adjustable, so that the distance between it and the so-called ground work, — a box, with blades inserted in it, — may be changed. This is done whenever it is expedient during the process, so that the sets of blades on both sides are finally approached within 1 mm. of each other, and the pulp is ground extremely fine.

The composition of the mass varies according as ordinary commercial boards or fine asbestos boards are wanted, and also according to the desired degree of incombustibility or resistance to fire. The commercial quality usually consists of from 75 to 80% of asbestos, some 3% of binding matter, and a filler, which is mainly caolin. The "chemically pure" asbestos boards contain 97 to 98% of asbestos and only 2 to 3% of binding matter. For this vegetable glue is used almost exclusively, either collodin, made of potato starch, or some other vegetable product. Without a binder, boards can not be made.

From the pulp mill the mixture passes into the mixing vat, a trough with about three times the capacity of the pulp-mill, where the mass is considerably diluted with water, in order to obtain a greater degree of smoothness. It is estimated that 550 lbs. of water are needed for the production of 2,2 lbs. of finished boards. These vats are now made of concrete, and are smoth inside. The base slopes a bit toward the scooping-wheels, so that the material flows automatically into scooping buckets, placed at either side of the front of the vat. In the centre is a shaft bearing two paddles, each with three forged iron rakes, revolving 6 or 7 times per minute.

The buckets now lift the carefully mixed mass into the regulator, or exhaust-box. The discharge is regulated by a sliding valve through which the material passes to sand-catching and knot-removing machines, built either separately or in combination with one another. In them the remaining particles of soil or mineral are sorted out and retained on a kind of grate. Then, by means of an oscillating mixer, the mass is carried in perfectly uniform layers to a plate, pierced at regular intervals by slits through which it still has to pass. These intermediate steps all serve a single purpose: to make the mass as homogeneous as possible, and to take it in this state to the board machine. Even in the pipes through which the material flows into

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the machine there are rotating screws to prevent any undesirable separation of the solid and liquid portions.

The board machine is constructed like those for the manufacture of ordinary pasteboard, although in individual parts special arrangements have developed to adapt them to their special purpose. The machine consists, as it were, of three groups of apparatus: the sieve, the press, and the mould.

The sieve portion consists of large tanks containing rotating perforated cylinders, — the most important part of the whole machine. The watery mass, still constantly stirred and agitated so that the heavy portion shall not settle at the bottom, runs toward the tanks. The rotating cylinders must be of extraordinary accurate workmanship, and most carefully adjusted in their bearings, as the slightest irregularity would cause unevenness in the thickness of the boards. Special care must be taken by testing, and, if necessary, by readjusting the bearings, to keep a constantly uniform distance between the circumference of the cylinder and the wall of the box (i. e. between the bottom and the circular sieve), and also to keep feeding the matter to the sieve continuously. Even the occurrence of eddies in the flowing, watery mixture would cause the mass to be taken up unevenly by the cylindrical sieves. We need not consider the details of construction which sciences has in the course of time devised to obviate faults and overcome difficulties; it suffices to indicate them to make clear even to the layman how greatly the manufacture of boards depends upon this single machine.

The second part of the sieve machinery is the pressing board. It serves by its pressure to squeeze as much water as possible out of the layer of asbestos, which has settled on the sieve. It also pushes it on to a conveyer of felt, which takes it up and carries it to the press. The pressing board too must be adjusted with great accuracy so that it may press away everywhere equal quantities of matter.

The material next goes to the press, whose purpose is quite clear. The running mass, still saturated with water, must be pressed dry. Carried by porous felt, it therefore passes between rollers, whose great pressure effects a thorough draining.

Over the press the mould is placed. Between the two runs the endless felt belt with the sheet of pasteboard, moved solely by the friction of the two sets of rollers, of which only those of the press are

power-driven. When the pasteboard has been removed, the carrying belt continues over guiding and stretching rollers until it again reaches the sieves to take up a new layer of asbestos. When the pressed material touches the moulding rollers, it sticks to them, separating itself from the felt. About the cleaning, washing and further treatment of the felt belt during its return to the sieves, we need say nothing here, however important it may be for the smooth execution of the process.

The forming-rollers or moulds, the last part of the board machine to be used, determine the desired thickness of the sheet. The rollers are usually of cast iron of a circumference equal to the single or double width of commercial boards. In the casing is a groove into which a knife or cutter is inserted to cut and lift off the board. Recently mechanical contrivances have been designed to cut the board at intervals with a sharp steel knife, and to remove it automatically from the roller. Here, as in any discussion of mechanical equipment, we can explain its character and purpose only in the large, for, owing to the present rapid industrial development, such accounts are necessarily incomplete, and may be antiquated even at the moment of their appearance in print. This paper purposes to give only a general survey of the nature and industrial importance of asbestos, not directions for the construction and setting up of machinery for its utilization.

The naked eye can naturally not determine the moment when the board mixture on the moulds has attained the desired thickness. An ingeniously constructed system of signals has therefore been installed, which causes a bell to ring at the proper time.

The boards cut off from the forming-rollers, still containing a great deal of water, are now laid between felt or cloth presses, or between metal pressing plates, and with these are put under a press, hydraulically worked in modern plants, and exerting a pressure of 20 to 35 tons per square inch. Here the greater part of the water is pressed off. The boards are next carried in cars to drying rooms. These are of very different types: sometimes a canal-like passage through which the hanging boards are transported, sometimes a cylindrical drying apparatus. The temperature in the canal-like passage — the most frequently used method — rises to about 80 ° C. The heating is done by a powerful fan blower which sucks up air,

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and drives it over a heater into the passage. Through such dryers the boards pass on wagons. The heat is increased from 20° or 25° C to 80° C, so that, in a regularly rising temperature, the boards retain their shape and are perfectly dry on leaving the passage.

The completely dried boards must still attain the shape necessary for their destined use. If they are to be used as boards of the usual commercial form, they are trimmed in a cutting machine with board scissors. Or, if they are to be used for making rings or pieces of other shapes, they are placed in stencilling machines, which, with different stencils, can cut out any desired form. Both the cutting and stencilling machines are constructed like those used for ordinary boards, but the toughness and hardness of asbestos demands machines of an especially solid construction. The waste material from these last operations, which is very great in stencilling, is again handled as raw material in the crusher and grinder, and is carried anew through the process.

c) Paper.

The manufacture of asbestos paper is basically the same as that of asbestos boards. The mixture is the same in both cases, the only difference being that to make paper the materials must in special cases be more finely ground. The machinery is also the same; only in the last stages of the process do we find essential variations from the board machines.

The finely ground paper pulp flows from the grinder into the stirring tank below, is thoroughly mixed there, and is scooped out by means of a bucketwheel. To remove the tiniest impurities, or any lumps of the material itself, an elimination that is even more important here than in the manufacture of boards, the pulp-solution, or "milk-matter," is taken to the sand catching and knot-removing machines. Thence, a pure and homogeneous mass, it flows into the sieves. A band of the material forms on the revolving sieves, from the surface of which it is removed and taken to the press by a woolen felt carrying belt. The mould required for the manufacture of boards is not needed here. The layer of paper is naturally of an even, very slight thickness, and there is no necessity for a piling up of layers to reach a definite and regular thickness. The presses also are quite differently constructed, since the fineness of the layers for

paper admits of a more thorough-going mechanical draining off of water, and thus facilitates the final drying by artificial heat.

For this purpose two wet presses are provided. The first, exactly like that used for boards, drains off 30% of the water. From it the paper roll is carried by guiding rollers and a felt conveying belt to the second. Here the further draining is done mechanically. The paper roll is carried between two strips of wet felt or rollers, which absorb the water from both surfaces, and carry it off. Thus the thin layer of paper is rather thoroughly drained. The cast iron rollers of the press are covered with rubber in order to exert an elastic, effective pressure.

The roll of paper now reaches the dryers. These consist of hollow cylinders, warmed by steam, and encased in a felt band which is moved as an endless belt by the rotation of the hot cylinders themselves. Any remaining humidity is absorbed on the way by the endless belt, and is evaporated by the heat from the cylinders. Consequently paper leaving the dryer can be wound by reels or rollers, and carried away in finished rolls. If necessary it may still go through a trimming machine to be cut or trimmed to sizes in commercial demand.

The uses for asbestos paper are not so manifold as those for boards. It serves to warp goods needing protection from heat or fire, such as explosives, etc. It is used as an insulating material for covering pipes and other objects, for which, because of its greater pliability and softness, it is often more suitable than boards or loose insulating material. For special purposes the paper is made waterproof, or with other special qualifications, and it is also colored. Then the required ingredients, such as resin, waterglass, paint, etc. are usually added to the pulper, but sometimes not until a later stage of the process.

d) "It-sheets" and Similar Packing Material.

The modern steam engine works under a degree of pressure which was not dreamed of a few years ago, and which is constantly rising. The use in a boiler of 750 lbs. of steam is no longer startling; 900 or 1200 lbs. lie within the bounds of possibility. This gives rise to temperatures at which tin becomes as liquid as oil, lead melts, and organic matter carbonizes.

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Among the parts of a steam plant which must meet the most exacting requirements, the packing material, in the shape of plates or rings, is of the first rank, and except in certain industries, which no packing material satisfies, and which have adopted the use of finely ground conical fittings, asbestos alone, reinforced by metal, has sufficient resistance. For pressures now considered moderate, of 175 to 300 lbs., creating temperatures as high as 200° C, asbestos was first proposed to replace the rubber packing previously used. The first firm to manufacture asbestos sheets, Richard Klinger of Vienna, called them "Klingerit." After their splendid success, other factories soon put similar sheets on the market, calling them by names ending in "IT," and thus creating the common name of "It"-sheets for these products.

Although asbestos forms the main bulk of the "It"-sheets, two other substances are united with it: a mineral or other filling material (such as clay, barytes, oxide of iron, cellulose), and binding matter (gum solutions, resin, lac, etc.).

For the manufacture of sheets, which are to satisfy all requirements, a good well-cleaned and opened asbestos fibre is used. The flossy, loose material is thoroughly mixed in a hermetically closed container, equipped with stirring apparatus, into which it is put with the ingredients needed for specific purposes, and with the properly dissolved binding material. Upon the uniform mixing of all the ingredients and the quality of the raw material depend the quality and usefulness of the finished plate. The average proportions for the contents of a first class "It"-sheet are about two parts of asbestos to one part of a filler — (oxide of iron, magnesia) — and rubber dissolved in benzine.

This mixture is worked in a moulding machine to sheets of the desired thickness. Finished sheets are also sometimes glued together with solutions of gum, and then pressed into a single stronger sheet by pressing rollers. Such specially pressed sheets are said to have met with great success. From these finished sheets insulating rings are stencilled or cut.

Sometimes ordinary It-sheets do not possess the heat resistance or the strength required for certain modern industries. In such cases, layers of metal gauze or thin foils of lead have been introduced between the sheets, before gluing several together. Recently the

requirements have become so exacting that the use of organic matter, such as rubber, not being able to withstand the attacks of heat and steam expansion, must be completely avoided. Now asbestos rings covered with copper-foil or electroplated with copper are used, whose soft metal covering serves as packing under the enormous pressure between the asbestos and the steel. Graphite has been successfully used as an additional ingredient. Under all circumstances, however, asbestos is the only possible raw material to meet certain conditions in the manufacture of packing for steam pipes, which mean life or death to modern engineering. When, in an American article, asbestos is spoken of as the most important mineral of the world, this seemingly exaggerated statement cannot be contradicted in view of certain definite uses such as that which we have just described.

e) Asbestos Shingles or Tiles – Eternit.

The production of asbestos tiles, known all over the world under the patented name of "Eternit," is a technical and industrial field whose importance in our industry and daily lives is just beginning to attract widespread attention. In the preface of his book, published just before the war, K. A. Weniger might well say of asbestos shingles: "We are at the beginning of the asbestos shingle industry, and the future will undoubtedly bring new applications of which we cannot even think today."

And yet the invention of Eternit has had its 25th anniversary. The history of its manufacture is indissolubly connected with the name of its inventor, Ludwig Hatschek.

The inventor had set himself the task of manufacturing hydraulically pressed artificial stone tiles of great mechanical strength and with a high resistance to cold, to water, and, if possible, to heat. He solved his problem by adding a certain percentage of asbestos to his binding material — i. e. to the cement which he liked best to use. This idea was not in itself new, nor did its practical execution in the form then available promise any special advantage. Cement, mixed with fibrous matter, even with asbestos, had already been made into building material, without yielding an extraordinarily valuable product. This was due to the shortness of the time allowed the cement for settling.

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Hatschek's invention, resulting in a hitherto unknown product with the above mentioned qualities, was based on new knowledge. By working the cement and asbestos mixture with extremely great quantity of water, the possibility of hardening the binding material was not destroyed, and decomposition did not occur; on the contrary, there ensued a peculiarly solid union, a sort of bubbling up of the mixture in a gelatinous mass, which happily delayed the settling and hardening of the cement. There remained plenty of time to drain the product of water, to mould it into plates or other forms, and then to let these half-finished articles harden gradually.

Once the knowledge was acquired, there was no machinery so well-suited to the execution of the new process as that used in board mills. Here too the pulp mixed with large quantities of water is kneaded and opened, and then washed again in plenty of water, to be drained later in cylindrical sieves, carried to the moulding machine, cut to the proper thickness, taken off and moulded to any form. The use of this apparatus for a perfectly analogous process is Hatschek's second basic invention. His fortunate solution may seem obvious. At that time, as a matter of fact, the plan of working a board mill with a mixture of rapidly settling materials was so audacious that it could be denied neither public recognition nor patent protection.

The importance of Eternit from the very first may be measured by the increase in the consumption of the product manufactured by Hatschek during the years before the patent was granted. He himself gives the following as the quantities (in round numbers) used in Austria:

1900	34,600	square meters	
1901	190,000	"	"
1902	841,000	"	"
1903	1,117,000	"	"
1904	1,675,000	"	"
1905	3,000,000	"	"
1913	11,500,000	"	" (Last year before the war.)

A great many imitations and competitive products, some themselves patented, were put on the market, but none has succeeded in supplanting Eternit, the simplest in composition and in manufacture.

Eternit, as we know, consists of only two materials: cement and asbestos. The cement comes from the factory in the form of fine powder; the asbestos, on the other hand, still contains some slight impurities, and its fibres are not sufficiently opened for the manufacture of so homogeneous a pulp as that required for Eternit. It is therefore worked in two different machines, a crushing mill and a scutching machine. The crushing mill, with its heavy rollers, presses and grinds at the same time. The asbestos fibres, still closed in sheaves, are squeezed and thereby separated; the foreign substances are ground away. If the grinding were overdone — its duration depends upon the quality of the asbestos — the fibres would be ground to powder and killed. The scutching machine next opens the compressed fibres. At the last the asbestos is like fine spun cotton, and is blown by exhaust fans into storage bins. In some plants further sorting is carried on at this point by revolving sieves.

Next comes the pulper, which does the chief work of the whole process. It is a large tank of iron or concrete, with a capacity of three or more cubic meters, in which a blade-bearing shaft rotates at a circumferential speed of about 100 meters per second. Here the mass of cement together with from 10 to 20% of asbestos, is mixed over and over again with great quantities of water, until it reaches that uniform consistency required for work on a board machine. The fibres are, so to speak, fully dissolved, and constitute a uniform mass with the thin cement juice. The contents of a tank of these dimensions are 700 to 800 kilograms of cement, a corresponding portion of asbestos, and sometimes some mineral coloring matter. This is next transferred to a stirring vat, a large storage vessel, usually of concrete, of about two or three times the capacity of the tank. It is equipped with a strong mixer to prevent the cement from settling, which it has a strong tendency to do. From this mixer the pulp is scooped into another mixing vat, in which the thick mass has enough water added to it and stirred into it to prepare it for the board machine.

By the addition of large quantities of water, the material is now of such consistency as to be worked by cylindrical sieves. The board machine and the hydraulic press must next drain off all the superfluous water. The design of these machines is the same as that of standard paper and board machines. They consist of cylindrical

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sieves and a flat carding machine. Generally speaking the process is the following: The sieve portion consists of boxes in which circular sieves rotate. These take up the pulp, while the water runs off trough the meshes. From the sieve, a felt belt, pressed between rollers, carries off the fully formed fleece to a sucking apparatus, where the greater part of the water is sucked off by means of an air pump.

Now, before it is pressed further, the fleece is placed in the moulding roller, which is adjusted to a definite thickness, and takes off pulp from the roller until this thickness is reached. Then it is cut from the roller and taken over a table to a stencilling machine to be stencilled to the desired size. Thence, piled up and packed with intervening sheets of metal foil, the material is taken to a hydraulic press, which presses out all the remaining water that can be mechanically removed.

The pressed asbestos shingles are put aside to set. After a time they are finished by having their corners cut, holes pierced, or other desired work done. They then remain in the store-house from 2 to 4 months until their mass is fully and completely hard.

In broad outline, this is the process which has developed in the course of 25 years. It is naturally accompanied by a number of fundamentally unimportant, but economically very considerable, methods for avoiding the loss of raw material and waste, which are valuable and capable of being used over again — as, for instance, a second using of the great quantities of water.

In the manufacture of Eternit, as it was at the time of the granting of the patent, no changes have taken place. In the course of time there were invented and carried out many new processes for making asbestos tiles, representing more or less clever evasions of the two characteristic features of Eternit. The processes — about two dozen all told — are divided into two classes, those using circular sieves as Hatschek does, and those operating without them.

The process of A. Oesterheld is typical of the first class. This differs from Hatschek's in that the pulp tank is charged with asbestos alone, and the fleece of asbestos formed on the sieves mechanically sprinkled with dry cement, which, in the later stages of the process, lies between two layers of asbestos. On the upper layer cement is again sprinkled. This piling up of layers of cement and fibrous

material, and then uniting them by pressure, is said to be very successful. We may forego a description of the other variations of Hatschek's process, since, with slight deviations in apparatus or chemical composition, they all strive to be as close to their model as possible, without encroaching upon its patent protection. This they often perilously approach.

The systems operating without circular sieves almost all replace them by presses into which the thoroughly worked mixture of cement and asbestos is led from the tanks, to be drained there and pressed into tiles.

The weight of Eternit tiles is comparatively little — only about one-fifth of that of roof tiles of the same area, which are, of course, much thicker. Because of their mechanical solidity, Eternit tiles only 4 mm. thick (1/6 inch) may be used. They are fully fire and frost proof. This last quality is due to their great density and very slight porosity; they absorb no water, which during a frost might cause cracking. They have sufficient elasticity to resist storms or other great strains of pulling or pressure. Their rather unprepossessing appearance is made pleasing by the addition of color, — black, red, brown, etc.

The field for which all these qualities best suit Eternit is roofing. Here, since the beginning of its manufacture, it has been chiefly used. Individual manufacturers have special forms of tiles and systems of roofing, which it would take us too far afield to mention here. Suffice it to say that A. Oesterheld, whose process we have described above, has invented a chain construction for tiling the roofs of sheds, in which the asbestos tiles are attached to light chains that constitute the entire roof structure. A square meter of such roofing with tiles 6 mm. thick is said, including all its metal parts, to weigh only 19 kilograms (42 lbs.).

Recently, corrugated tiles have been made, which, because of their powers of insulation against changes in temperature, have in many instances already replaced corrugated iron. The corrugations are formed when the large flat tiles leave the board machine. Just as it is possible to corrugate the still flexible tiles, and then allow them to harden, it is also possible to give them a closed form, i. e.: to use them for making pipes.

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In such pipes the good qualities of Eternit show to special advantage. Its tensile strength in every direction is even more obvious in this closed form than in that of a flat board; added to this is its complete resistance to liquids and acids, which could otherwise be carried off only in pipes of ceramic manufacture. Because of its high insulating capacity Eternit is furthermore an ideal material for all branches of electrical engineering — a side of its industrial value quite apart from its mechanical properties.

It is not the purpose of this book to enumerate all the possible fields in which asbestos cement boards might replace materials hitherto used; we must repeat the statement at the opening of this chapter that the development of this material has only just begun, and that the future will open fields still unknown. The statement, made more than ten years ago, is true even now. The outstanding qualities of the mineral are known. On the basis of these, science will surely find more and more uses to show its worth and prove its value.

Hatschek's important invention, through its practical possibilities, has given rise to many similar factories in every great country. These are continually developing further, and are numbered among the chief consumers of so-called board fibres. Until the invention of Eternit, the mines had no sufficient demand for short fibres, although in quantity they formed the main bulk of the product. The manufacture of asbestos tiles opened great new possibilities for the utilization of these fibres. The economic growth of many mines actually dates from that time. By the new impetus thus received, they were enabled to enlarge and modernize their plants in order to fit their production to the demands of the tile industry.

On the other hand, new fields for the use of asbestos tiles were continually found. In consequence of their great adaptability they have entered upon a triumphant march over all the world. And this is not yet over. For the number of asbestostile plants in all civilized lands is still constantly growing, and will grow all the more when gradual re-building causes a further increase of building operations. Hatschek's invention has certainly enriched the building industry to an extraordinary degree, by creating an unsurpassable roof and wall covering for domestic use, and a material for general building purposes in tropical and colonial countries.

f) Asbestos in Electrical Industries.

Serpentine, the matrix of asbestos, it itself widely used in electrical industries for the manufacture of boards, insulators, plugs, etc. as it has high insulating capacity and is of good appearance. Asbestos, with the same chemical composition as serpentine, is even more valuable than its matrix for electrical purposes, because of its fine fibrous structure and its adaptability, with or without a binding material, to moulding.

Pure asbestos, to be sure, may be used only within definite limits, because of its readiness to absorb humidity. But this very quality suits it for impregnation with high insulating substances, such as lac, asphalt, etc., and thus makes it all the more useful in the electrical field. Usually asbestos is here used either as yarn (in a web), or as a board (in a pressed shape).

Insulators of asbestos for resistance wires are made in various ways. Either the bare metal wires are passed parallel through a coarse-meshed net of asbestos threads or cords, or each wire is itself encased in asbestos, and then worked into a web of definite form. The latter method is also used in currentcarriers that need to resist high temperatures. Then, too, insulated conduits, so-called rubber-cores, sometimes have asbestos woven or wound around them to shield them against heat from without.

Asbestos boards serve the double purpose of insulating against electricity and heat, and are therefore used for lining the walls of boxes, parts of apparatus, stoves or switch-boards — in short for any kind of insulating. Eternit is commonly used for high tension switch-boards, for partitions with switches, wherever there is danger of strong sparking or arcs of light. As we have said, asbestos in loose form, combined with other insulating substances such as resin, turpentine, tar, asphaltum, rubber, etc., pressed either cold or warm, is made into insulating articles of all kinds. Besides having resistance to electricity and heat, these possess great tensile strength, resisting breaks and tears. Of such material are made handles for tools and shutters as well as plugs, switches, fuses, and boxes for accumulators; anything, in short, that can be made in mass production by pressing, cutting, sawing, milling and turning. Some of the material is so homogeneous, so solid and thick, that it can be ground or planed, and

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polished. The core of all these articles, in so far as they answer all requirements with regard to insulation and mechanical strength, is asbestos in one form or another.

g) Asbestos in Chemical Industries.

We shall not deal here with the general requirements and needs of chemical industries. These, possibly more than the industries of any other field, require in their mechanical apparatus a reliable material for caulking various containers, conduits, and tanks, subjected to more or less high pressure, so as to prevent the slightest leakage or escape of poisonous gases into rooms used by human beings. In chemical works this requirement is of special importance. For a small leak in a steam pipe or faulty heat insulation in a boiler usually shows itself in a loss of mechanical work, and may be expressed in financial terms. A very slight defect in the caulking of apparatus whose contents, such as gases, chlorine, sulphuric acid, or ammonia are subjected to high pressure, might endanger the health and life of workmen. Lack of insulation against heat may also sometimes prevent the beginning or continuation of a chemical reaction on the result of which the entire operation of a plant may depend.

It is clear then that the machinery of chemical plants requires special consideration with regard to the general applications of asbestos. But the special demand of chemical industry lies in other directions, of which we may distinguish three — the laboratory, the factory, and means of transportation.

In the chemical laboratory, asbestos is used in various forms and for many purposes. Asbestos boards of various thickness serve the chemist as heating plates on which he brings to a boil over a gas burner liquids that need to be carefully heated. Containers and pieces of apparatus that are especially delicate or need to be cooled slowly, may be wrapped or lined either with asbestos paper or with a solution of fine asbestos fibres in water. Pulp of this kind may be smeared on the surface of the vessel, and when it has dried, adheres to it as an insulating layer. In the same manner, bowls and glasses may be protected from the too sudden heating of a direct flame, and wire netting improved and made more durable by having its meshes filled with a mass of asbestos. Long-fibred asbestos is used for filter-

ing liquids, such as strong, hot acids and corrosive lyes, which would destroy any other filtering material, paper above all. Here asbestos does splendid service. Sometimes the vessels, — funnels, etc. — used for filtering, are lined with fine, long-fibred or soft asbestos, and sometimes asbestos is mixed with the liquids that are to be filtered, and put with them into the funnel.

This use of asbestos takes us directly into the great field of chemical manufacture. For, on a large scale also, the filtration of acids, lyes, and other corrosive liquids is carried on with the help of asbestos as a filtering material. Large pieces of apparatus, filters, etc. are lined with asbestos fibres, and the filter-presses, so much used in chemical industries, contain filtering cloths of asbestos weave for the pressing through of strongly corrosive liquids.

In this connection sugar factories and refineries may not pass unmentioned, although they do not specifically belong to the chemical industries. Cloths in the filtering presses of sugar factories, which are known to use solutions of lime, are best when made of asbestos, since cloth made from organic fibres cannot resist the lime for any length of time.

In electro-chemical industries, asbestos cloth, boards, and even loose fibres are used to a great extent as so-called diaphragms. They serve as nonconducting, yet ion-pervious partitions between the anode and the cathode space in electrolytical cells, to keep separate from each other the decomposition products of the electrical current. For this asbestos must possess not only a certain porosity and impermeability to gas, but also chemical resistance to the reaction of the products of decomposition. This is particularly true in electrolytical water decomposers. In modern electrolytical cells for manufacturing chlorine and dry potash (Siemens-Billiter, Nelson, etc.) there takes place through the asbestos diaphragm not only a passing of ions, but of the whole electrolytical current. The consumption of asbestos in electrolytical industries is not inconsiderable, as the life of a diaphragm is naturally limited.

Finally, as an important example of the manifold uses of asbestos, we must mention a field of large scale modern chemical industry: the preparation of asbestos, covered with finely divided platinum for use as a so-called contact mass in the making of sulphuric acid. For this the very best asbestos is used. It is saturated with a

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solution of platinum, and annealed, — a process whereby the pure metal attaches itself to the fibres in the finest possible particles. This contact substance, long known in the form of ignition capsules for lighting gas, serves in the manufacture of sulphuric acid to transform the passing sulphurous acid. In chemical industries, this process, called catalysis, uses considerable quantities of first class asbestos. The united German "Farbenfabriken" yearly consume a large quantity the highest grade of asbestos for this purpose.

The use of asbestos in the Welsbach light industry is of equal importance but of much lesser consumption. The fastening of the mantles to the carriers, hooks and pins of the burners is done exclusively with asbestos thread. All attempts to substitute other materials have proved that for this purpose asbestos is indispensable.

In speaking of the use of asbestos in sugar refineries, we entered the field of food products. We must also mention the wine press. Asbestos plays an important part in all wine-producing countries, for, in a purified state, it is made into filters to clear the acid-containing juices. There is no wine-grower or dealer in Germany today who does not clear his wines by means of asbestos filters in order to obtain the best results. The same is true of France, Italy, Spain, Austria, South America, and even of the less cultivated wine-producing countries, such as the Caucasus and Algiers. These filters allow as much wine to pass through in half a day as did the old cellulose filters in a week. Furthermore the asbestosfiltered wine is clearer, and has no taste of foreign matter.

Of course there are a great many other special chemical cases where asbestos in one of its forms may be used for filtration or heat-insulation, or as an acid or lye-proof substance, for instance in the manufacture of caustic hydrate of soda, chloride of lime, etc. But these offer no new points of view. We merely wish to show that the chemical and food industries, fields of human endeavor so important and so valuable use asbestos for innumerable purposes, the number of which will doubtless increase in time, and that they can substitute nothing else for it.

h) Asbestos as a Heat-Insulator.

The resistance that asbestos offers to the penetration of high temperature makes it a most valuable insulating material in two

respects: first to retain heat which is present or purposely produced, and second to hold off undesired heat. The first purpose is usually effected by lining rooms or apparatus in which high temperatures have been created and must not be lost, viz: fire-places, blast and melting furnaces, electrical stoves, etc., or by covering steam pipes, etc. whose inner heat must be uniformly maintained. For this there is no material like asbestos, and where its comparatively high price prohibits its use without an admixture of foreign substances, as much of it as possible is still taken in all mixtures for insulating purposes. All steam boilers not fully set in masonry, especially locomotive and ship boilers, are either surrounded by insulating material containing more or less asbestos, or covered with asbestos sheets. There are innumerable recipes for preparing paste of this kind, all consisting of short fibred asbestos and organic or inorganic binding material. It is applied to the sides of the boiler, and hardens there. When the covering is made of finished asbestos sheets, the body to be insulated is best covered with them while they are still damp, and they may be fastened with wire. This has the advantage that the covering may be easily removed and used again.

To line furnaces, stones are made of asbestos with other mineral additions, such as clay, infusorial earth, magnesia, etc., and a binding material — usually waterglass. These are set inside of the furnace, and bound with a mortar of similar components. As an example of such mixtures we may mention the familiar Uralit, containing asbestos, chalk and waterglass. Silicic acid is eliminated from the mass, which is fused and cemented by the high temperature in the oven. Instances of the uses of asbestos for insulation might be multiplied ad libitum, but these suffice to show the great value of asbestos for this branch of general industry, whose mechanical strength still rests chiefly on coal, fire and steam. And even after we are able to use the sun's rays to create steam, asbestos insulation will be more indispensable than ever.

If, on the other hand, protection is sought against heat from without, the number of possible uses for asbestos in all forms, such as fabrics, sheets, etc., as flexible and hardening mass, or as loose powder, is equally unlimited. It seems beyond doubt that the increased production of asbestos, and the discovery and further

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development of old and new deposits, will make it more and more accessible, and bring it more into use, in this field.

i) Floor and Wall Coverings, etc.

The general utilization of asbestos, both of short and of long fibres, either as a main or as a secondary substance in finishing the interiors of buildings, is based principally upon its capacity as an insulator against changes in temperature, and upon its fire-proofness.

We must here distinguish between two kinds of mixtures: these consisting of other mineral matter, in which asbestos is used to give the mass solidity and mechanical resistance, but where its other qualities are merely a welcome adjunct; and those in which asbestos is the principal ingredient, where its natural advantages are used in every way, while other materials appear only in small quantities, as binders or coloring matter.

To the first class belong hydraulically hardened products, various kinds of cement, mortar, gypsum and magnesia cement — the so-called Stonewood. To the mixture, consisting of magnesia and chloride of magnesia, are added a great variety of fibres and fillers — cork, peat, wood-pulp, shavings, etc. But the addition of greatest technical value is asbestos, which is best suited by its chemical composition and color for combining with cement of magnesia.

Of "stonewood," floors and walls can be made without seams, tight, hard and of a firm consistency. As a rule they are made of two layers that combine solidly with each other, since they have the same composition. The lower layer usually contains coarser fillers — sand, peat-scraps, saw-dust, etc., while to the top layer, the smooth one, asbestos of more or less short fibres is added. The asbestos gives to the mixture a firm consistency, and its well-known good qualities all come into play.

Widespread uses have been found, since the end of the eighteen-nineties, for a product, which is really waste from the mines, and which, in some Canadian plants, had piled up mountain high. This product, there called asbestic, is a mixture of ground serpentine and very short, irrecoverable asbestos fibres. As the chemical composition of both is essentially the same, they are equally valuable for the manufacture of building boards.

Sometimes asbestic is used alone, mixed with water, and made into a fine pulp. It is then pressed, for use as a floor covering, or, with wire reinforcements and webs, for wall-partitions and ceilings. Sometimes a binding material, usually waterglass, is added to promote quicker and better setting. As it is a solution of silicate, it combines very thoroughly with asbestos, and with it changes into a stone-like mass, which can bear great weights. The same mixture is used to cover columns, beams, etc., insulating them against all changes of temperature.

Waterglass is also frequently used in solution for soaking asbestos cement tiles to be used for floor or wall covering. Its well-known capacity to insulate against heat or cold, sound, and chemical agents, gives it value for building purposes.

Asbestic, or any asbestos powder, finds a similar use in the production of paints. It is thinned with waterglass or another suitable binding material, and with mineral colors. Then it is applied to the desired surfaces of a building.

k) Brake Bands.

One of the sore spots in the present technique of transportation, and one of its main problems, is the production of a reliable and durable material for the brakes of fast and powerful motor cars. Everyone hears of so many serious accidents caused by a more or less complete refusal to function on the part of the brakes, that it hardly seems necessary to urge the importance of achieving technical perfection for these parts.

In asbestos, nature has provided this industry with a raw material, recognized even now as indispensable and ideal, and one which is consequently more and more used for brakes. Its tensile strength against friction, and its absolute resistance to the high temperatures which are suddenly created in moments of danger by abrupt braking and which rise to the melting point of ordinary metals, make it increasingly indispensable as the automobile industry develops.

The form in which asbestos is here used is almost exclusively that of impregnated fabrics or pressed articles. The industry has taken out a number of patents for mixtures capable of special resistance, but many firms keep secret the exact compositions of

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mixtures they have found specially successful — which is quit comprehensible because of the difficulty of proving illegal imitations

In most brake bands, however, impregnated asbestos fabrics often reinforced by thin brass wires, are used without other additions The manufacture of good products requires the greatest care throughout the process, and the use of the very best materials. The finest quality of long-fibred pure chrysotile asbestos yields the most reliable product. Large American firms, controlling their own asbestos mines, have some of the most valuable fibres especially spun for this branch of manufacture. Rhodesian and Russian asbestos, with their great tensile strength, are also well adapted to the making of brake bands.

When heavy demands are to be made upon it, the yarn, after it is spun, is woven with the addition of brass wires into bands of varying widths and sizes. The usual commercial dimensions are: from 2 to 15 cm. wide, and from 3 to 10 mm. thick. Heavier bands are usually not produced directly by weaving, but by the folding over, and combination under heavy pressure, of several thin layers. By impregnation, the finished fabric is made impervious to oils, fats, and water; at the same time its mechanical resistance to the friction caused by braking is maintained and increased. The chemicals used in the process are not fully and generally known. Most manufacturers, however, probably use bituminous, or asphaltic substances.

These bands, used as coverings for brakes and for couplings, have qualities which clearly cannot be attained by mixtures without asbestos. Besides the advantages we have mentioned, bands containing asbestos do not become so easily heated by the friction of braking or coupling. This is probably because, in consequence of the natural slipperiness of asbestos fibres, friction sets in gradually and softly, increasing only with high pressure. There is a consequent saving in oil, and the parts of the car that rub against each other with their asbestos coverings are very slowly worn.

Conclusion.

The following list of products for whose manufacture asbestos is exclusively or partly used, does not claim to be complete. It contains only a fraction of the fields of industry and classes of wares made of asbestos, and commercially handled. Practically every class comprises a more or less large number of varieties differing from one another in the quality of the asbestos, or in the addition of foreign substances.

One great Canadian firm alone, in its 1924 catalogue, enumerates 200 different articles offered to the engineering world. There is no mine, no blast furnace or steel factory, power station or gas-plant, no railroad or steamship company, no chemical or other factory anywhere in the world today, which does not carry on its books an account labeled "Asbestos." Mills and agricultural establishments, glass and ceramic works, laboratories, medical and hygienic research institutes and hospitals all use asbestos in different forms and mixtures. For them all, in many places and for many purposes, it can be replaced by no other material.

We should not like to close without taking a convincing survey of the asbestos-using industries, and stressing the fact that the industrial and scientific fields where it is indispensable are by no means known, nor yet capable of being estimated.

In all parts of the world where industrial and scientific work is being done, and where there is need of a material that insulates against both electricity and sound, that is also heat-proof, undecaying, resistant to water, acids or lyes, that is porous, flexible, and fit for spinning, asbestos or an asbestos product is the first thing to be tried. There are large and highly important fields such as road-building, where the application of asbestos is in its infancy. The combination of asbestos with the principal materials used in the construction of streets or roads, — either with asphaltum or other bituminous substances mixed with mineral fillers, or with cement and other hydraulic binders, — is a problem for the solution of which thorough experiments on large scale have recently been carried on. And it does not seem at all unlikely that this will open up new possibilities for the utilization and sale of the very short fibres, which are still found in large quantities.

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We mention this to show that there is hardly a branch of industry from which the thought of using asbestos to good advantage may be summarily excluded, and that new fields for it will surely be opened, and also to stimulate all engineers and research workers who share this interest, to continue for their own and the public's advantage to discover and disclose these further possibilities. Thus asbestos, in many ways so indispensable to commerce and industry, will be even better recognized and applied to the uses of mankind.

General uses of asbestos and its products:

Bands and covering for brakes, wheels, discs, blocks.
Boards.
Boiler coverings.
Boots.
Brushes for corrosive liquids.
Cork and asbestos mixtures.
Covering for radiators.
Door-sills and frames.
Electrical insulation. (Switch-boards and boxes, handles, cords, cables, covering for wires, vulcanized material, It-Boards.)
Felt and wool.
Filters.
Fire-extinguishing mixtures.
Flat-irons (handles and stands).
Floors.
Heating plates.
Insulation in film industries.
Insulating material for boilers and steam pipes.
Insulation of refrigerators.
Lining for furnaces (in factories and homes, drying-rooms, baking ovens).
Mattresses.
Packing material (counteracting chemical agents, dry and wet heat, high pressure steam, for pumps, air-brakes, etc.).
Painting material and colors.
Paper.
Paste and cement for building material.
Plaster for walls and ceilings.
Protectors of all sorts.
Road-building material.
Roofing materials (slate, tiles).
Rubs, vats, etc.
Sound-proofing material.
Textiles (clothing, draperies, covers, rugs, tablecloths, etc., tarpaulins, theatrical decorations, mats, belts).
Wall handings.
Wall paper.
Water-proofing with impregnated asbestos.
Wicks and torches.
Wood, artifical.

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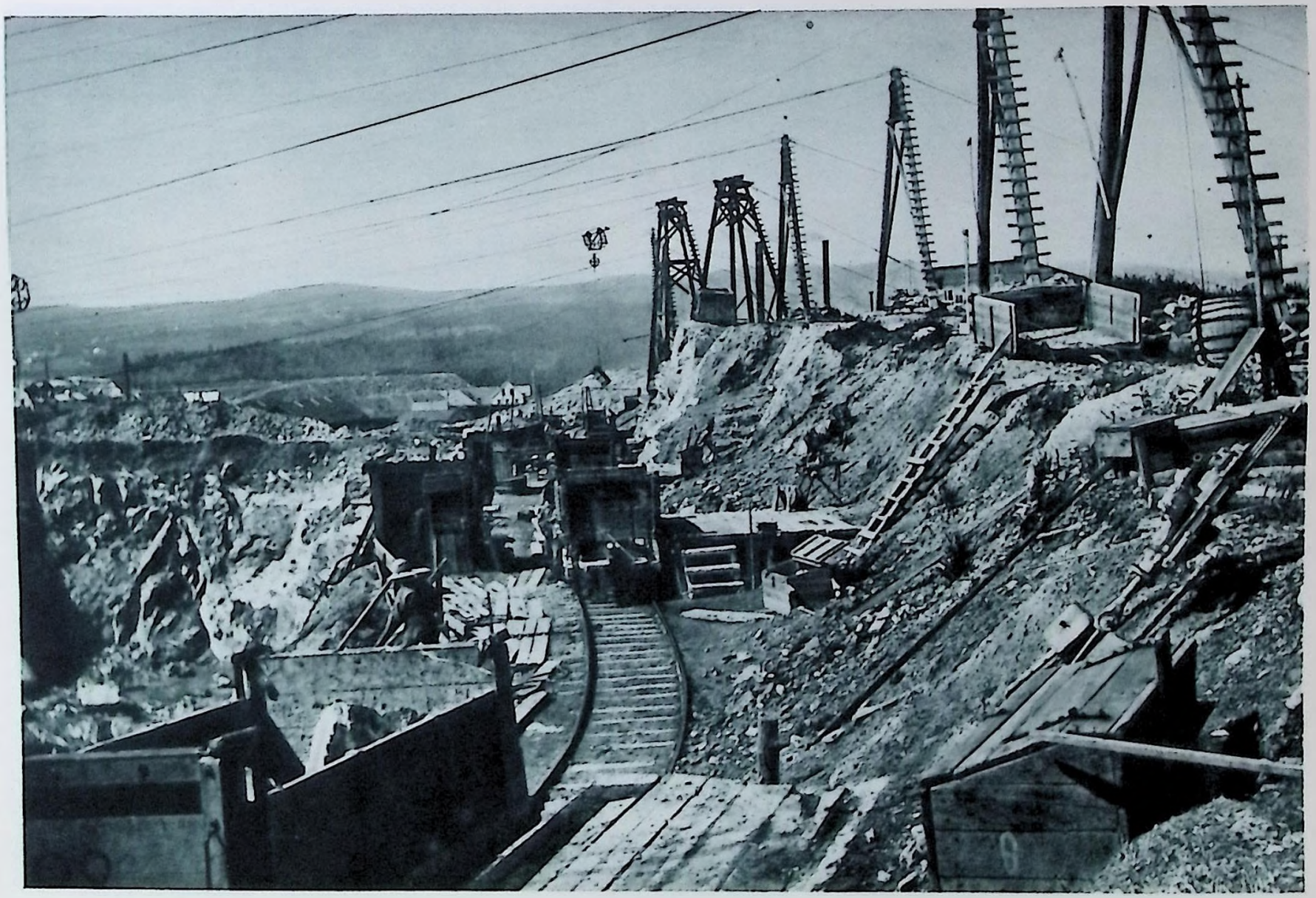
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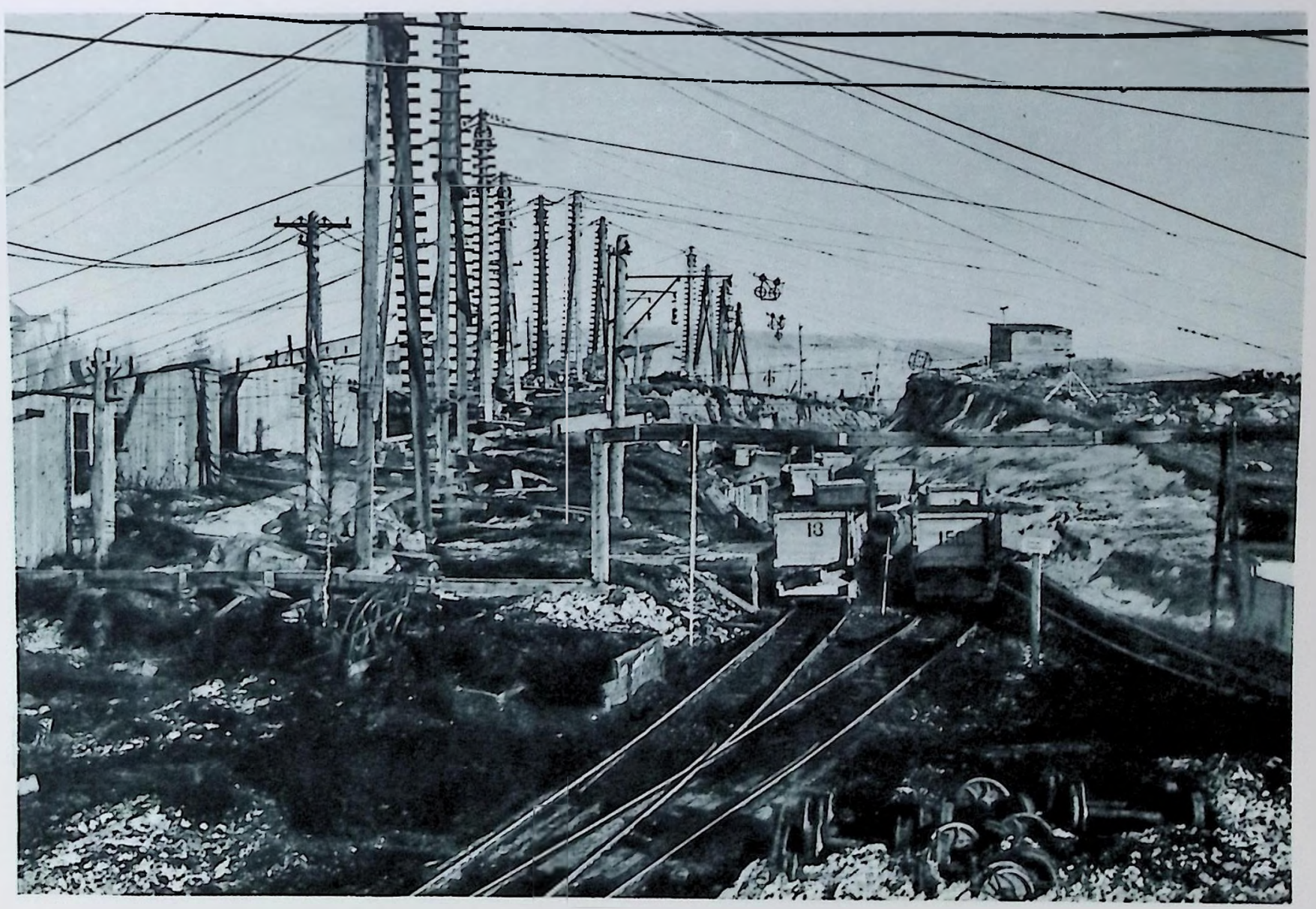
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CANADIAN ASBESTOS MINES, KING MINES WITH CRUSHERS

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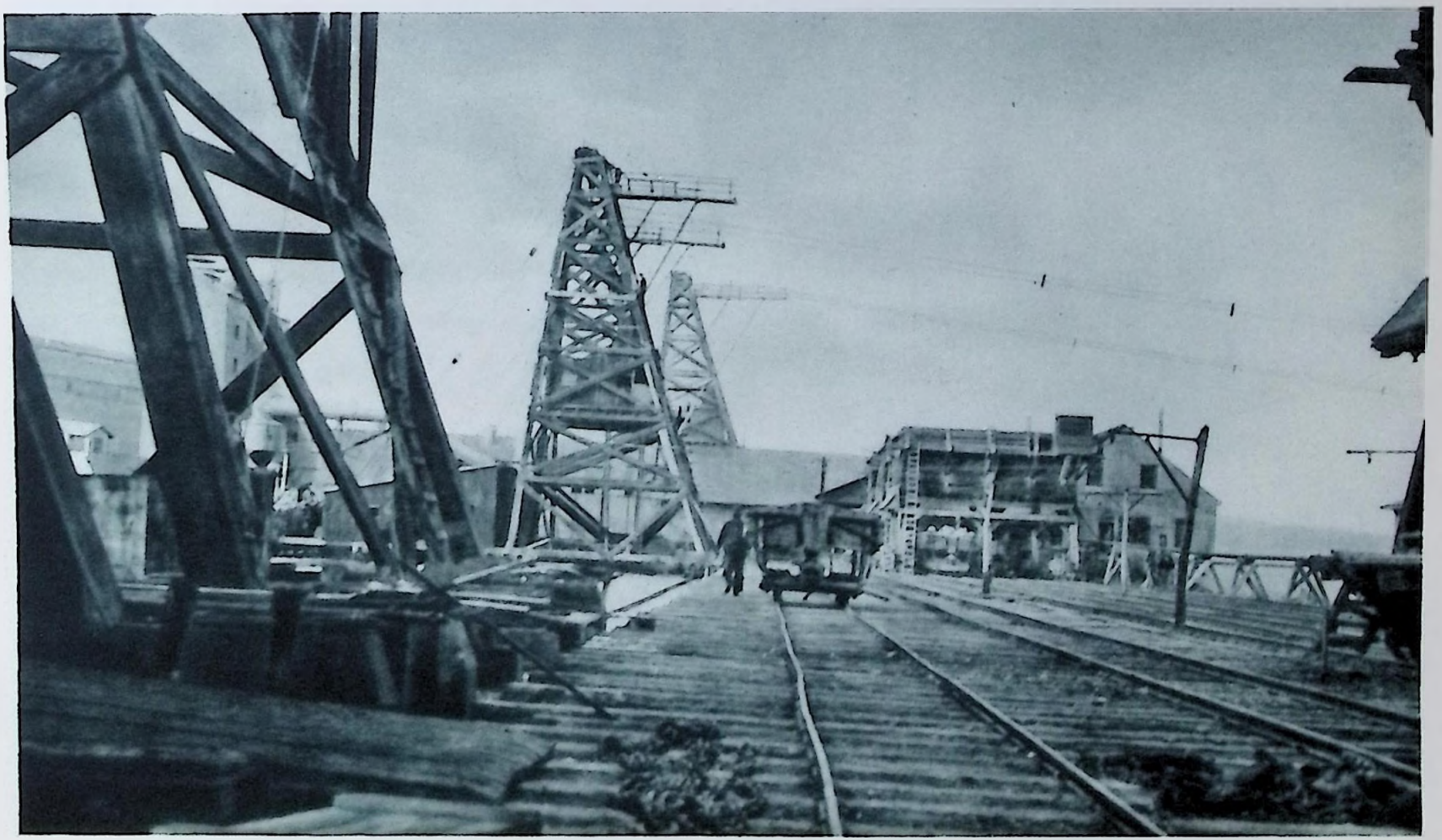
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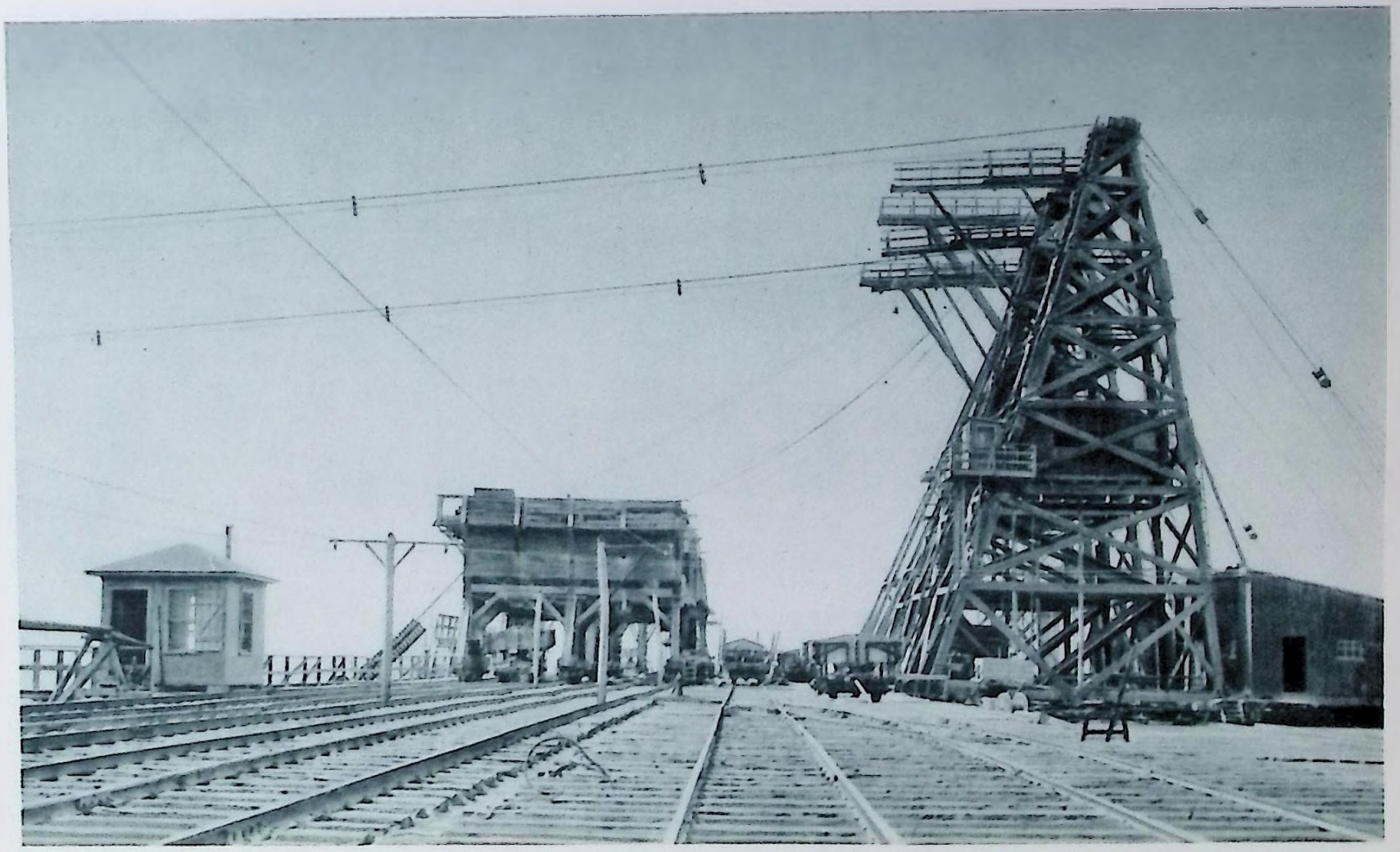
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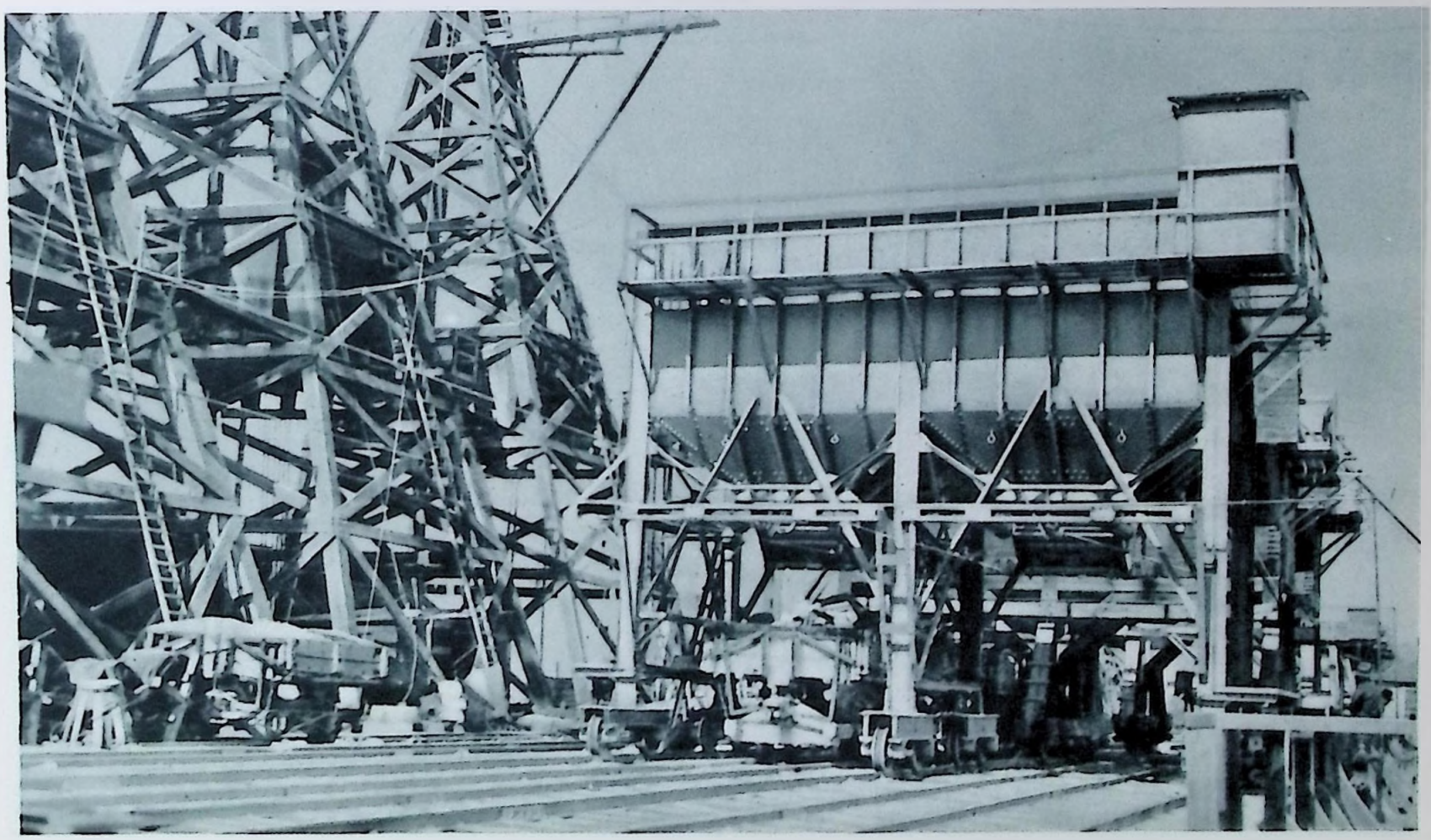
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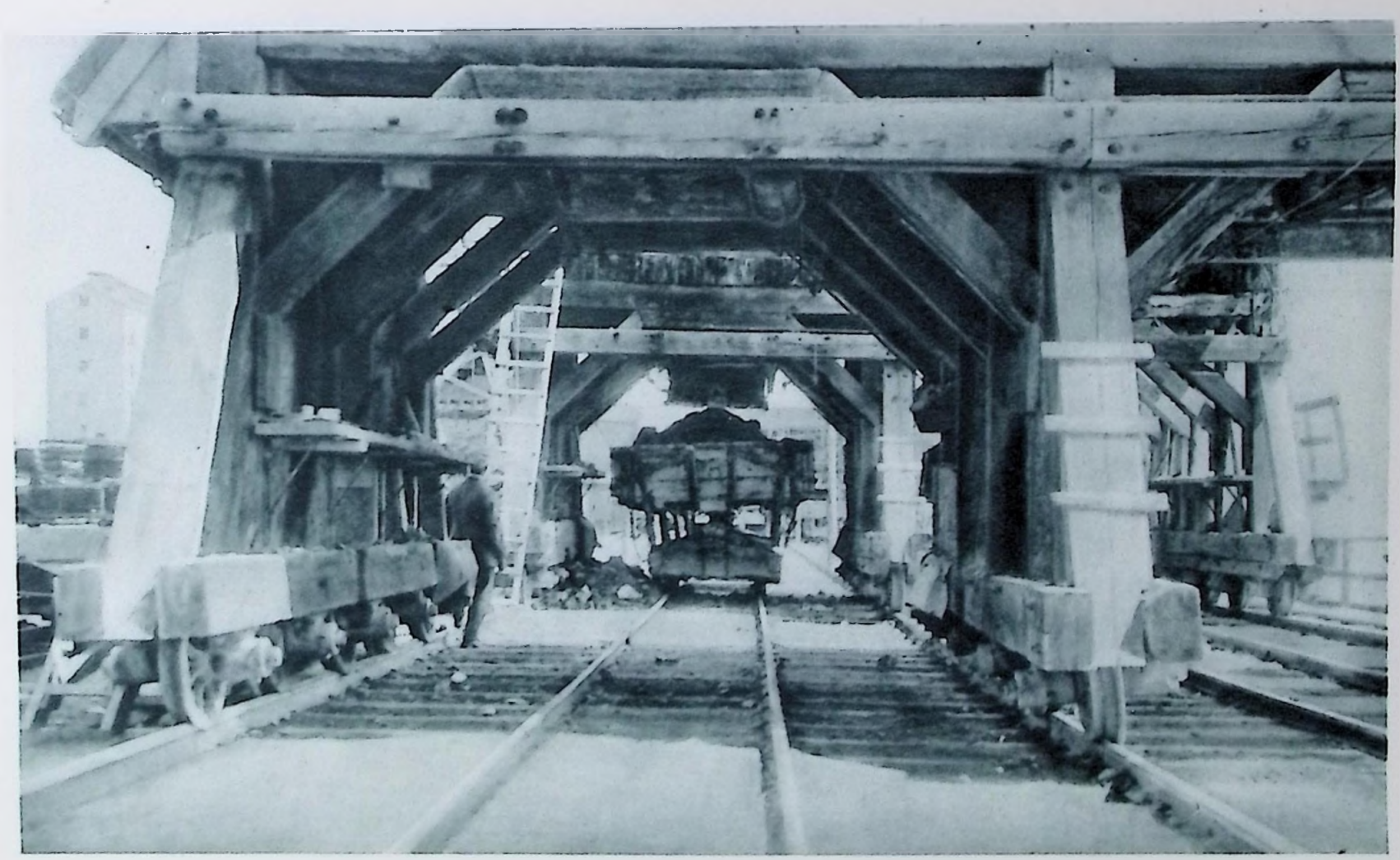
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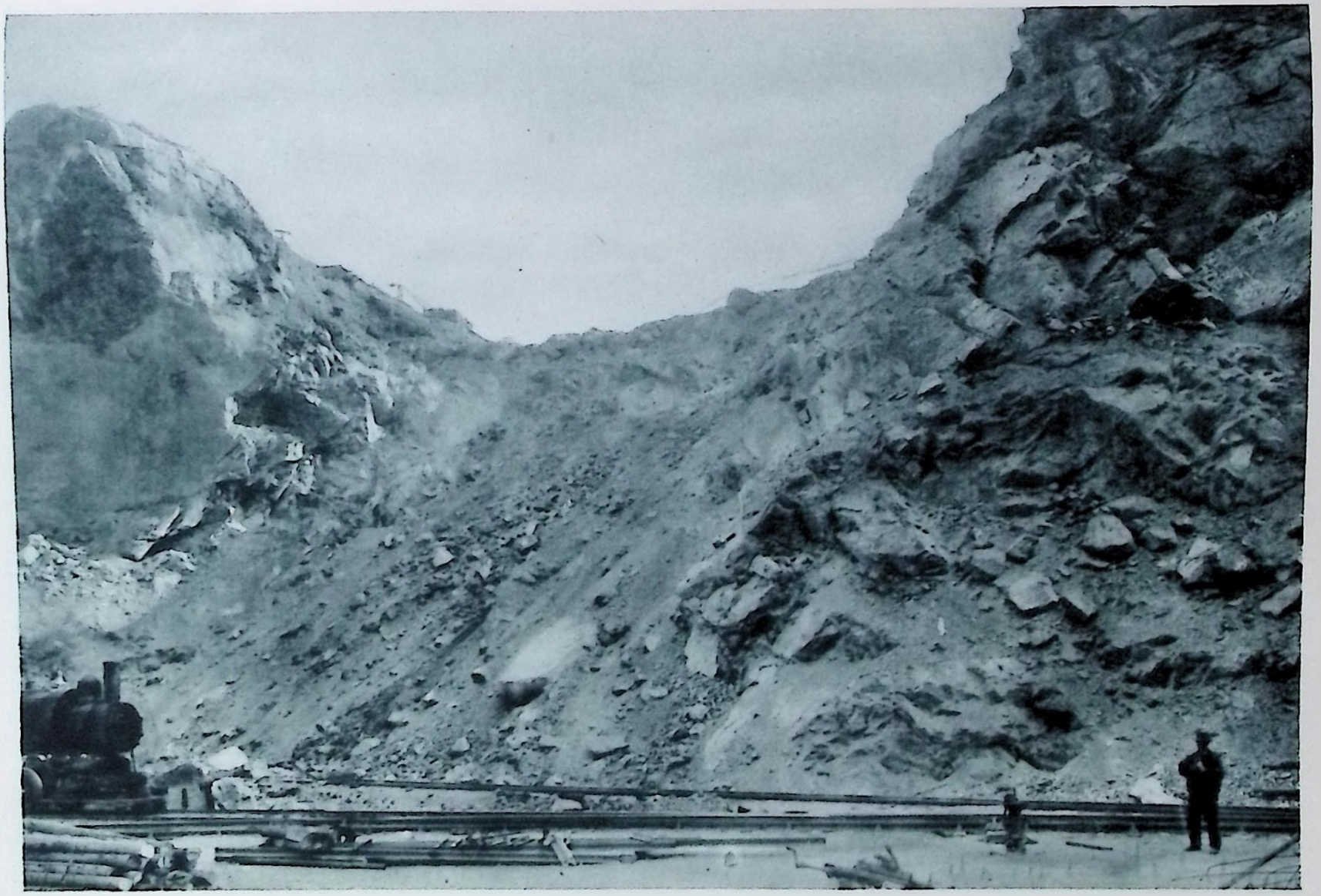
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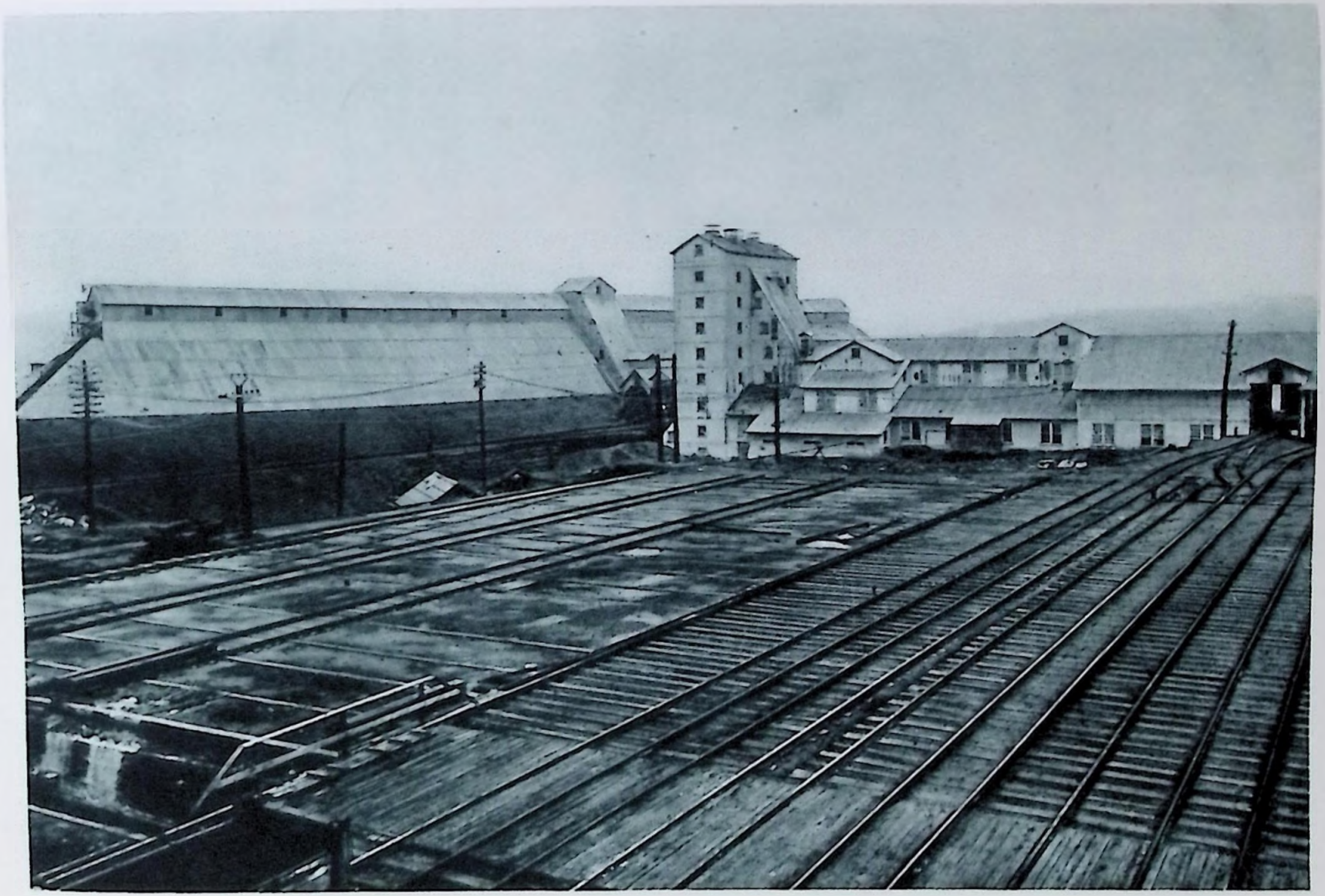
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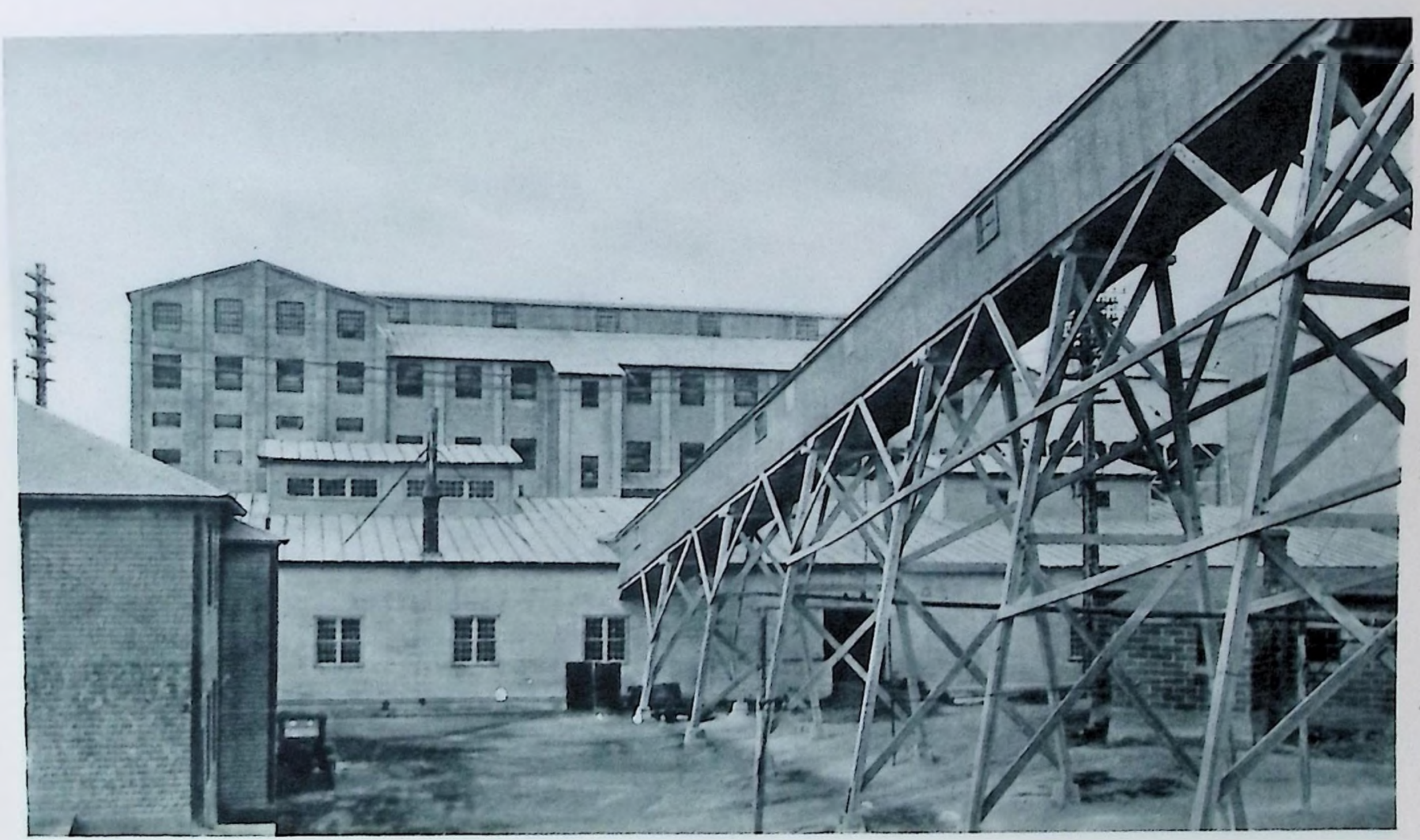
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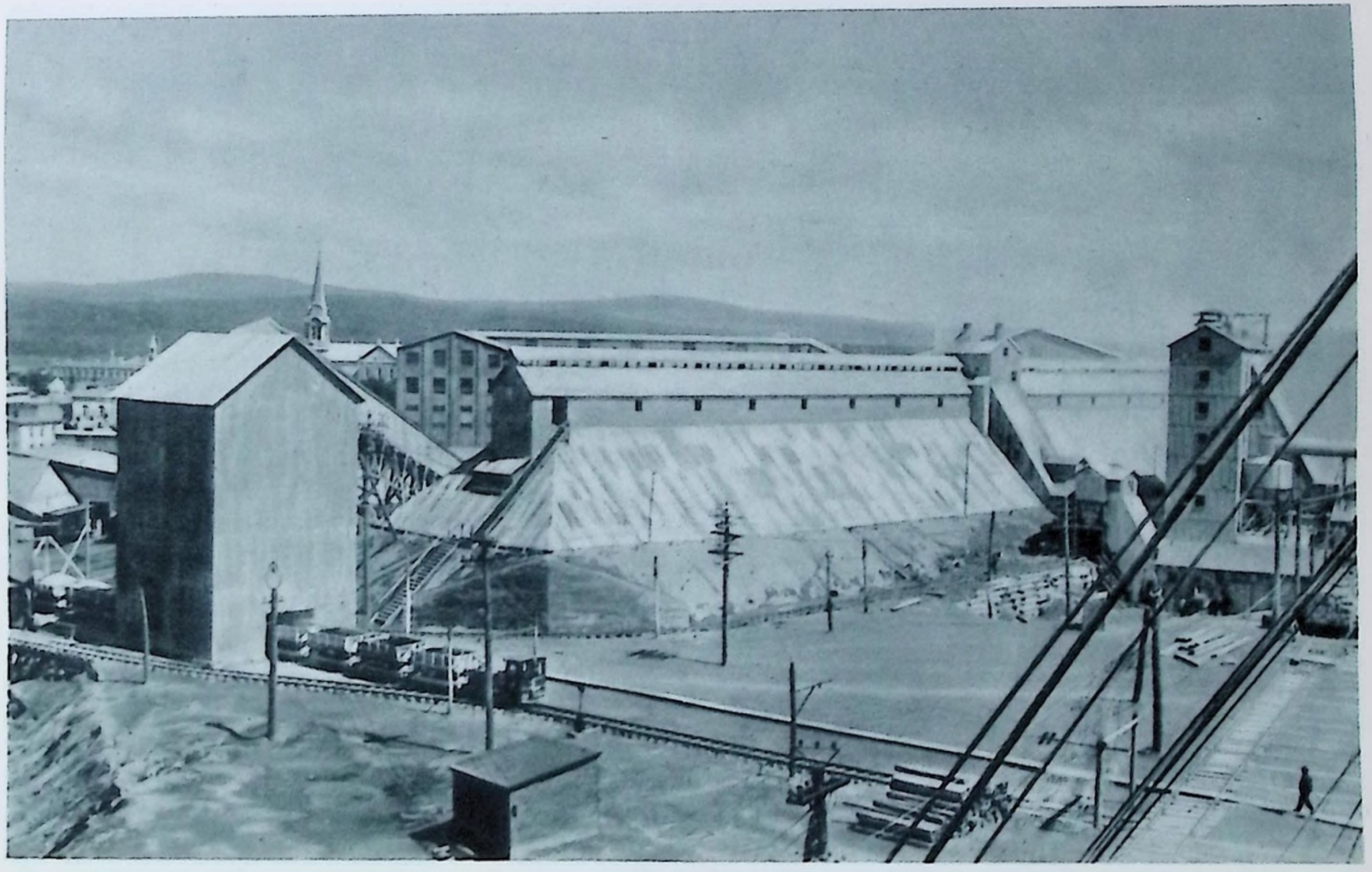
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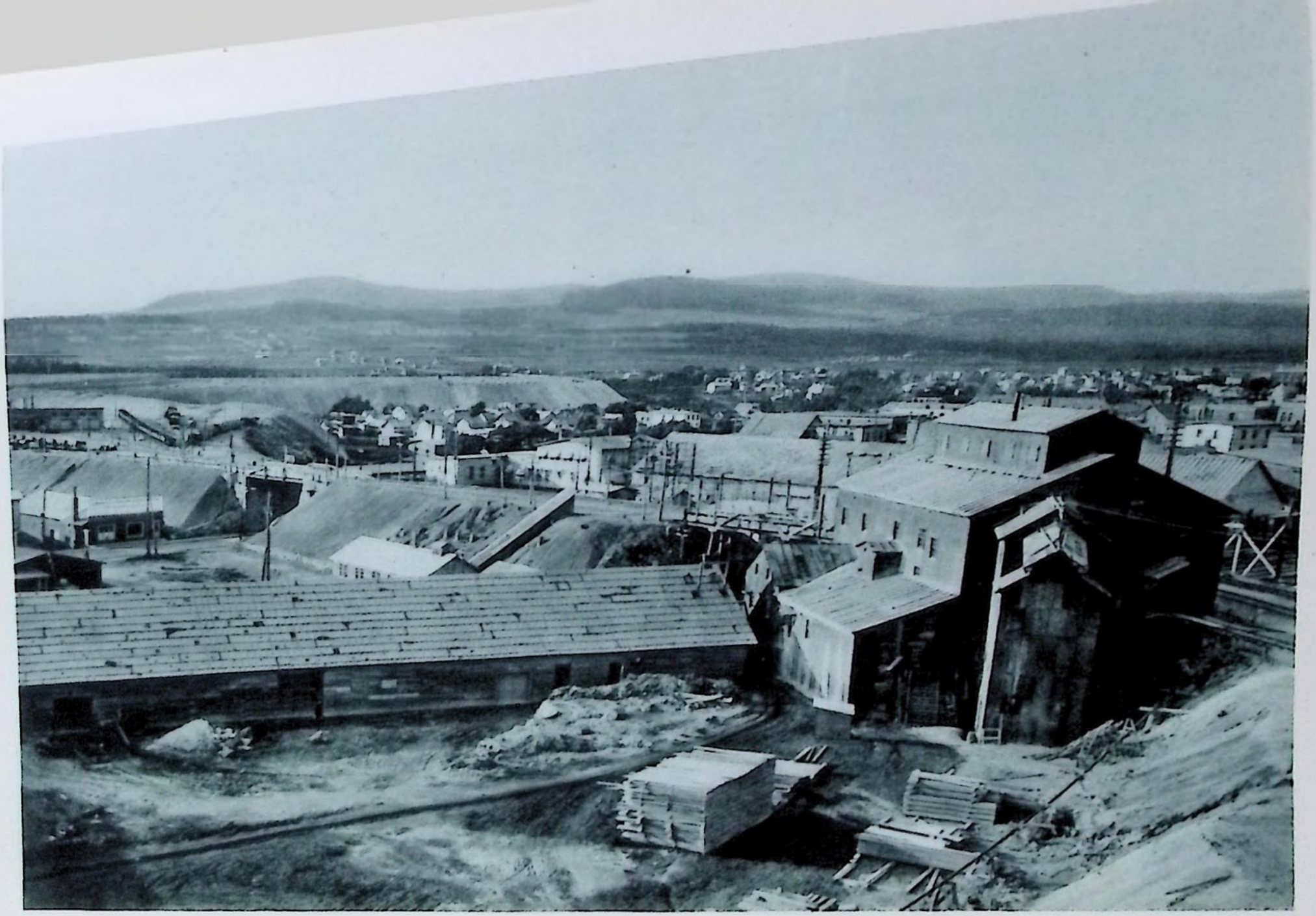
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CANADIAN ASBESTOS MINES, STONECRUSHER PLANT AT KING MINES

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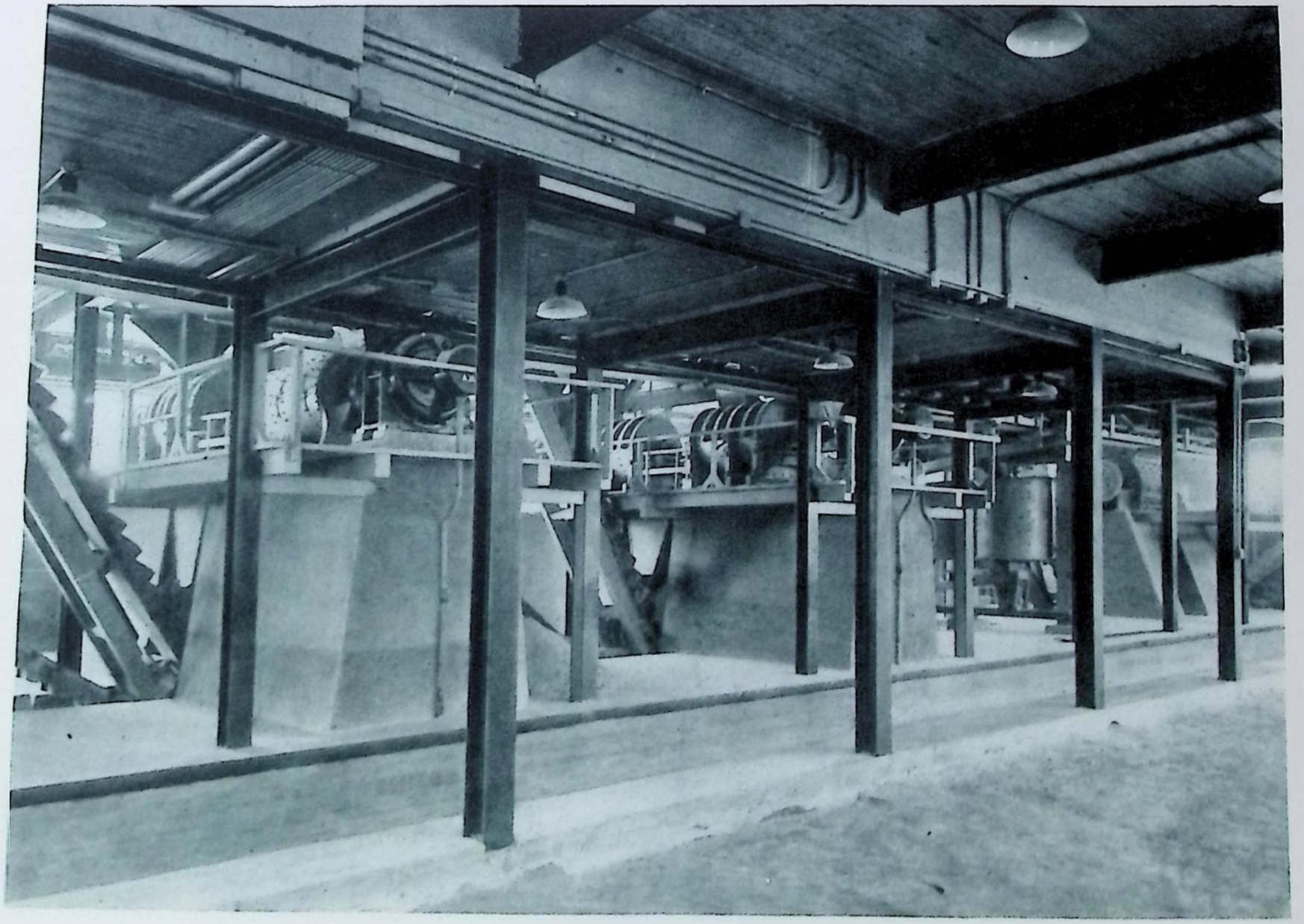
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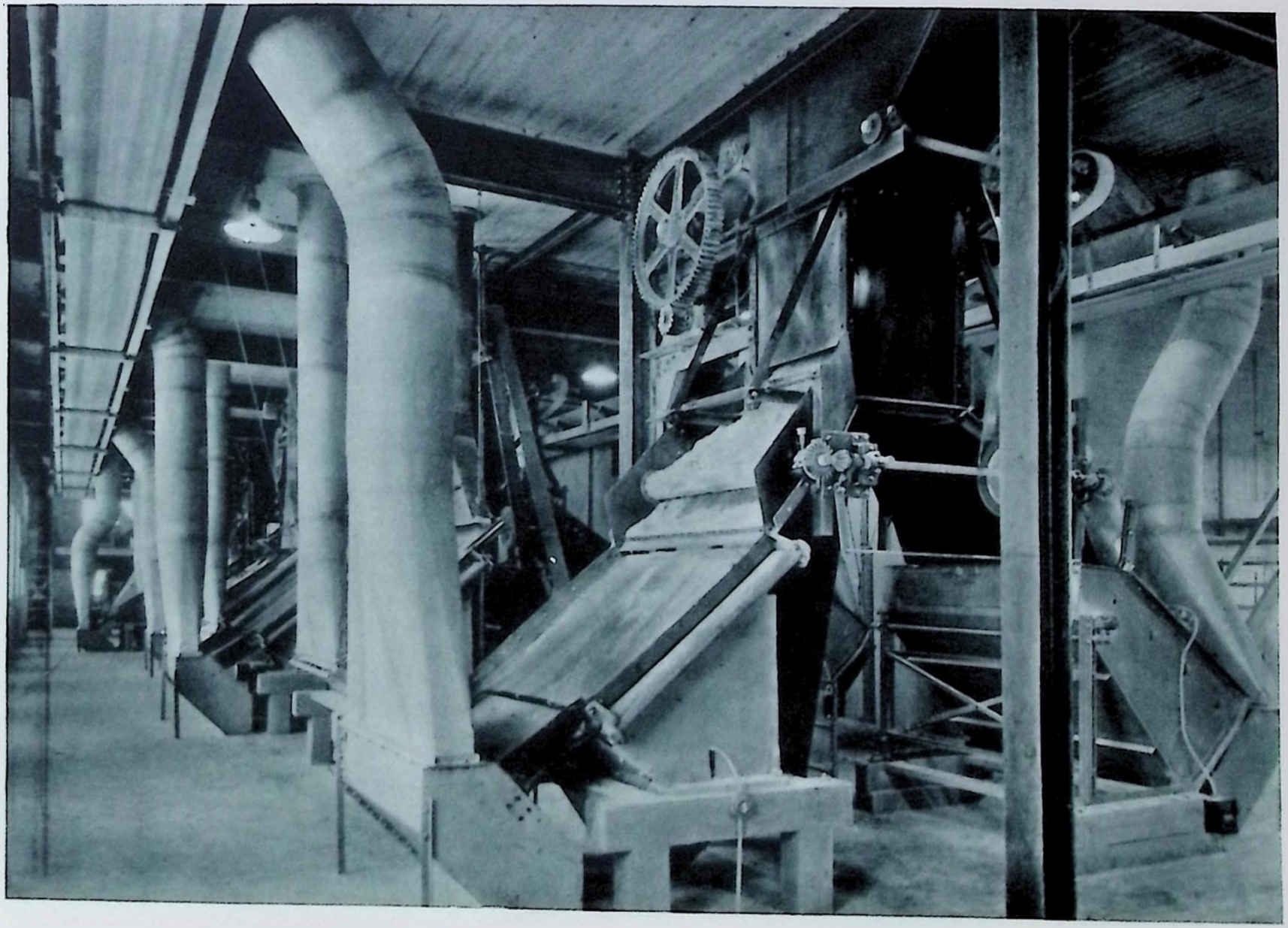
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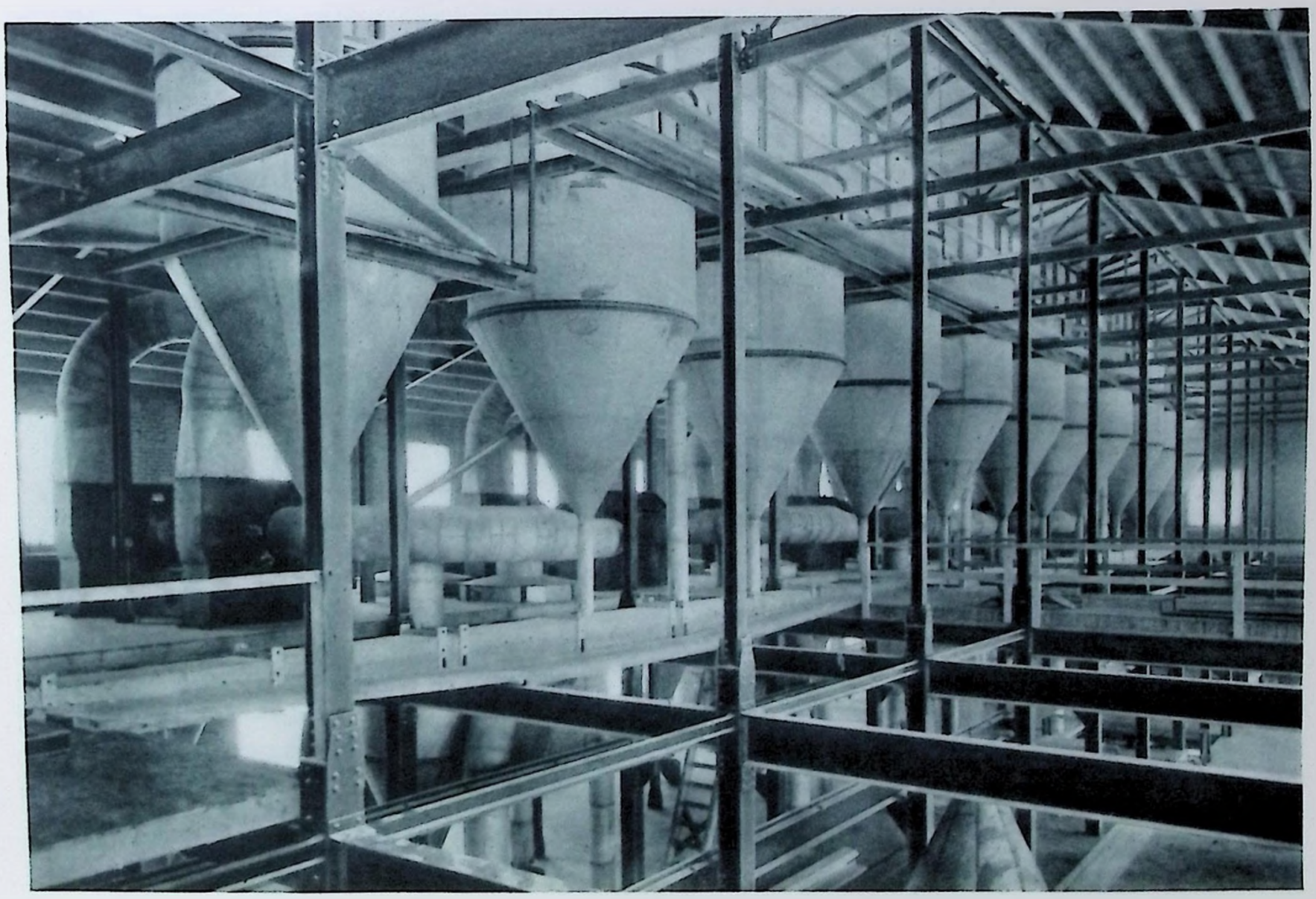
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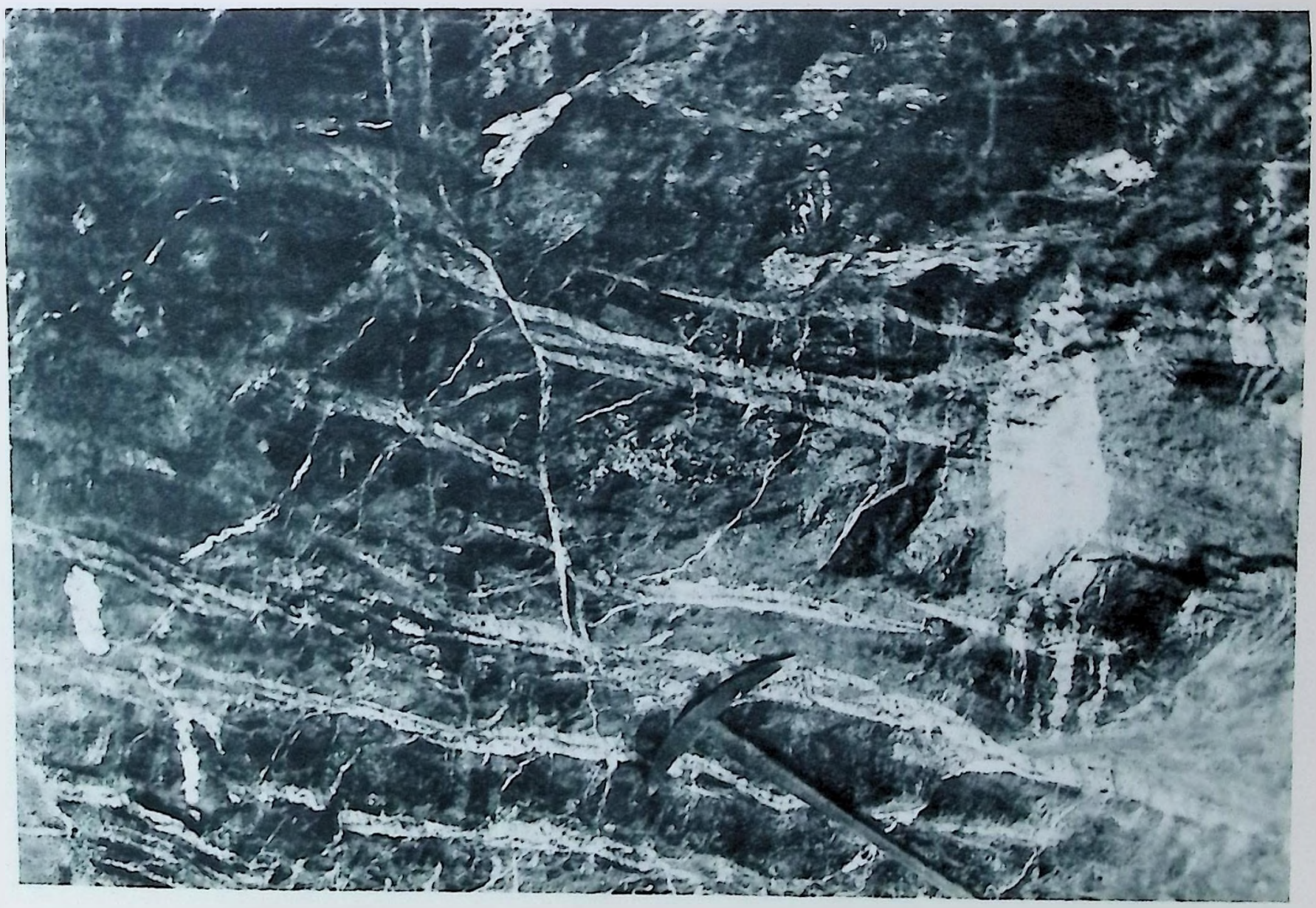
CANADIAN ASBESTOS MINES, ROCKING SIEVES AT KING MINES

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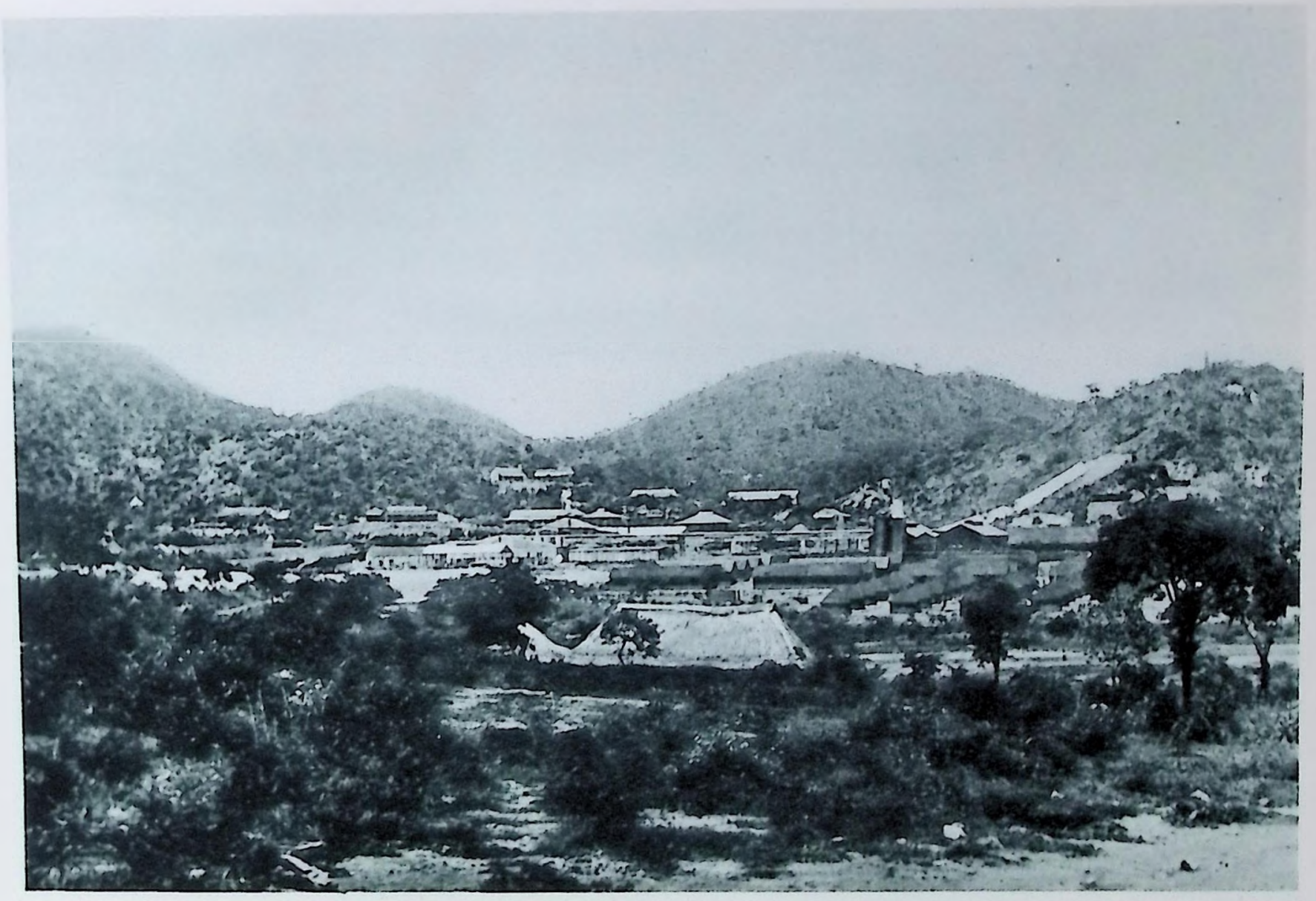
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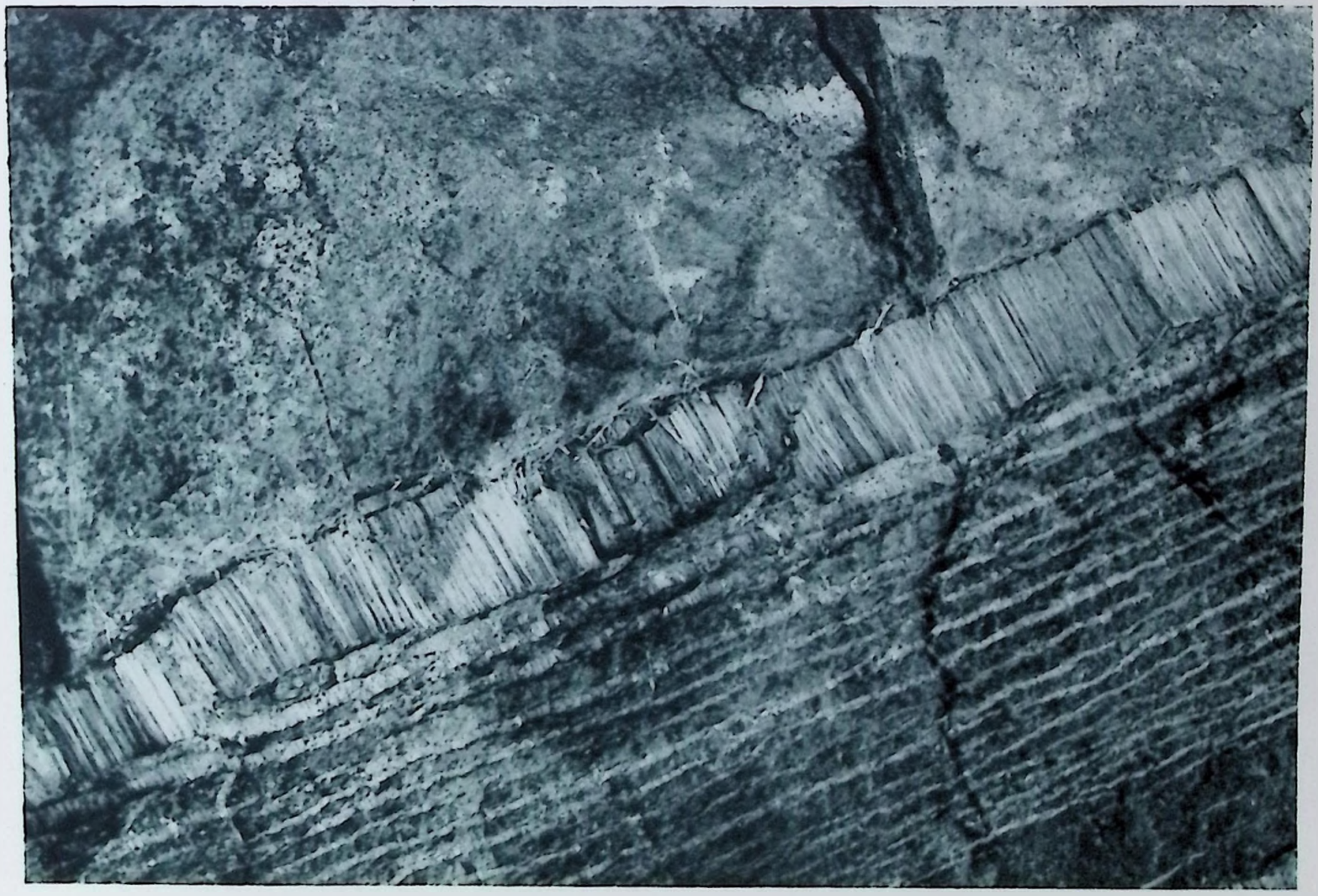
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RUSSIAN ASBESTOS ROCK, INTERSTRATIFIED WITH BROAD AND NARROW FIBRE VEINS

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RUSSIAN ASBESTOS MINES, HORSE HAULING PLANT IN FORMER YEARS

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RUSSIAN ASBESTOS MINES, PICTURE OF THE EARLY DAYS

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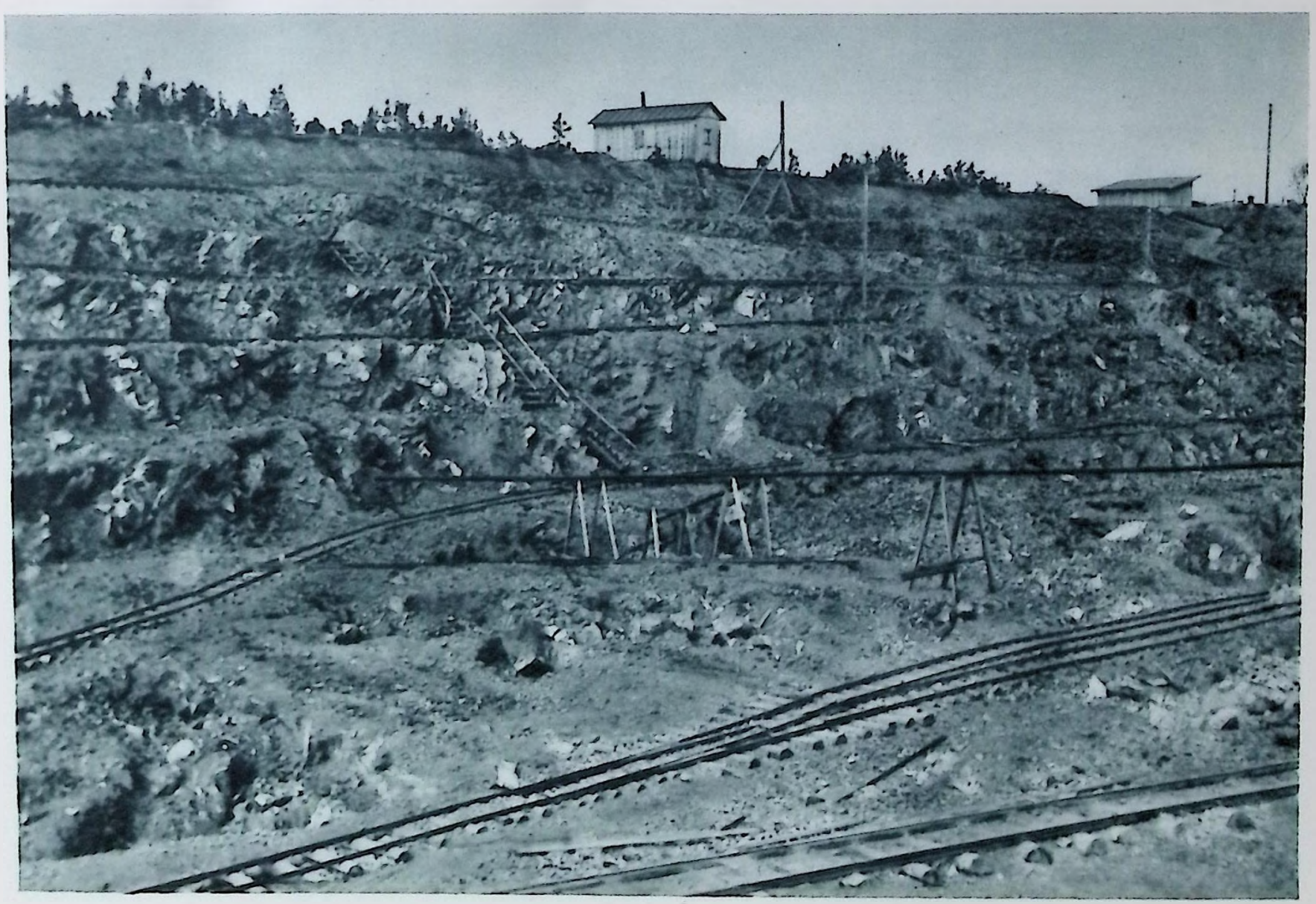
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RUSSIAN ASBESTOS MINES, WORKING OF THE MINES IN TERRACES

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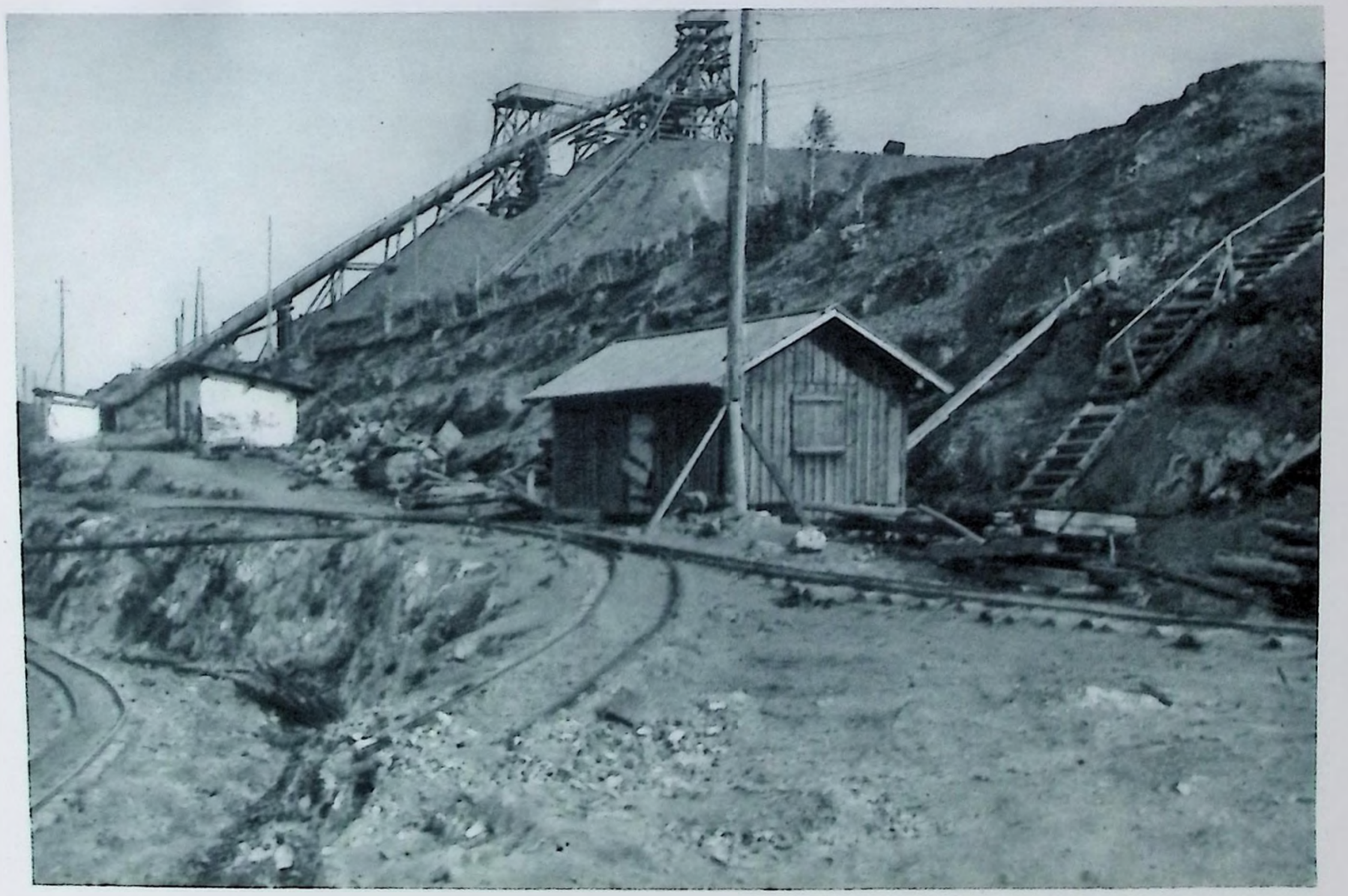
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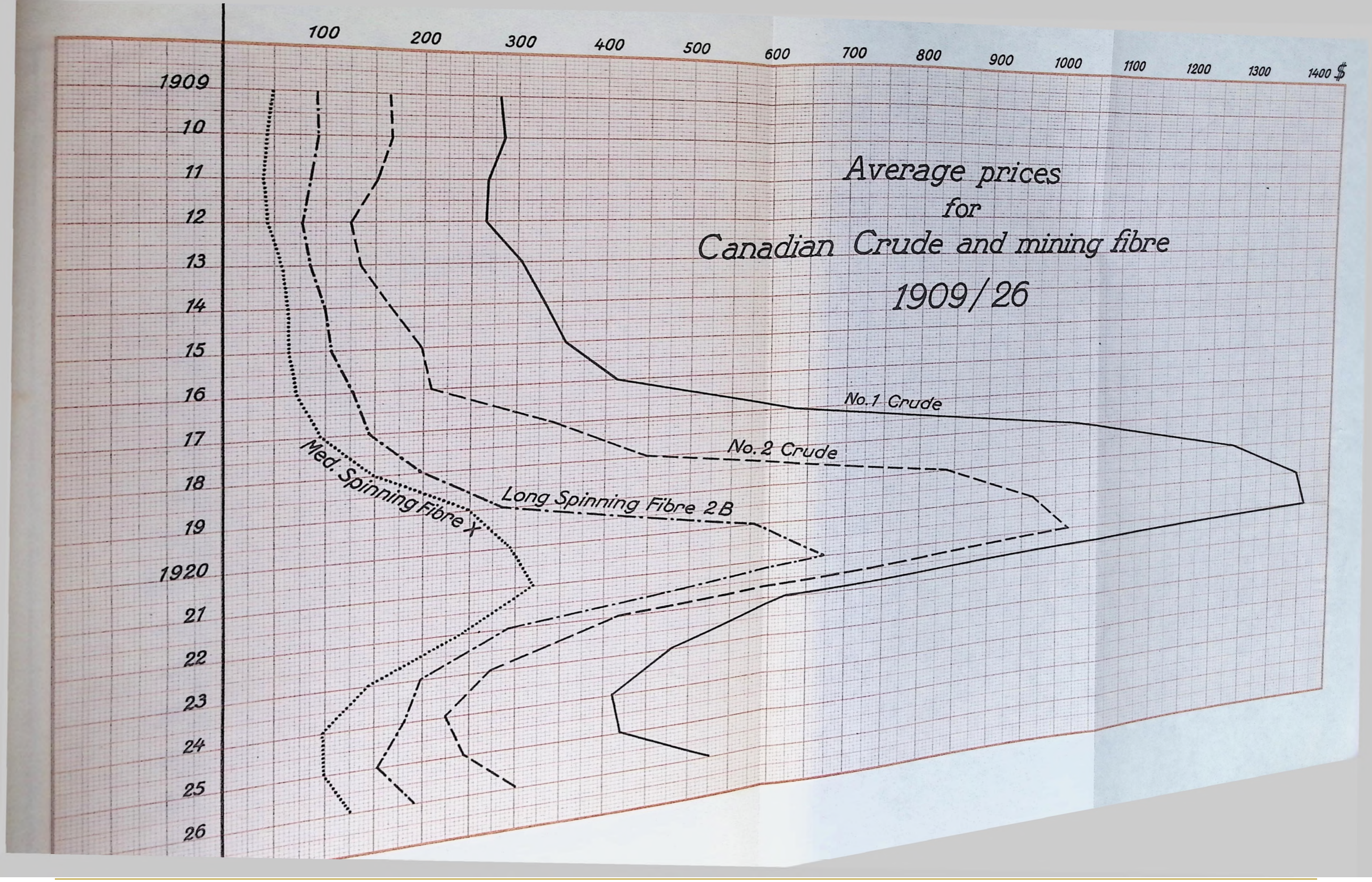
TRANSVAAL ASBESTOS MINES, AMOSITE MINES

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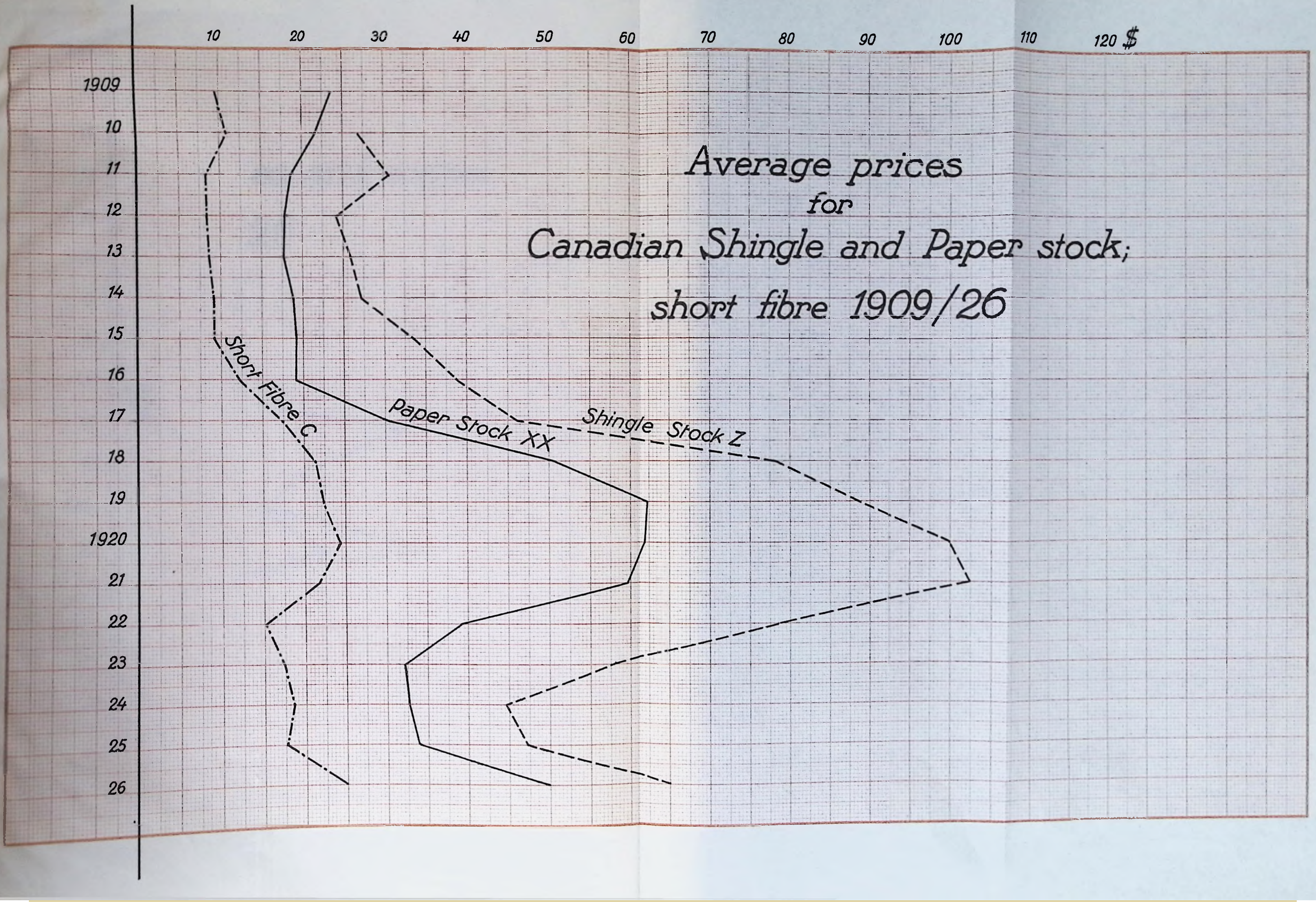


TRANSVAAL ASBESTOS MINES, AMOSITE MINES

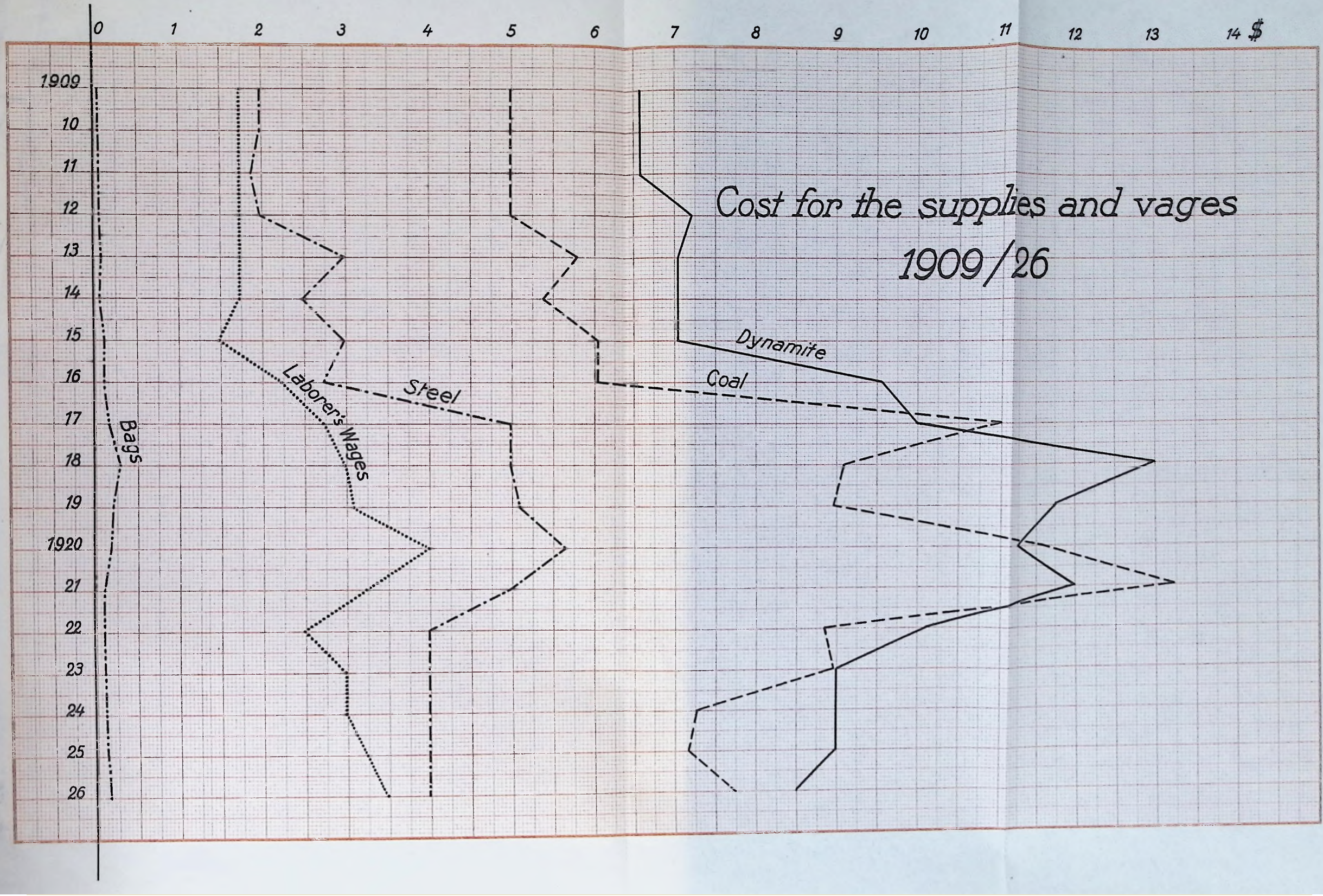
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ASBESTOS REGI

SCALE: 2 miles



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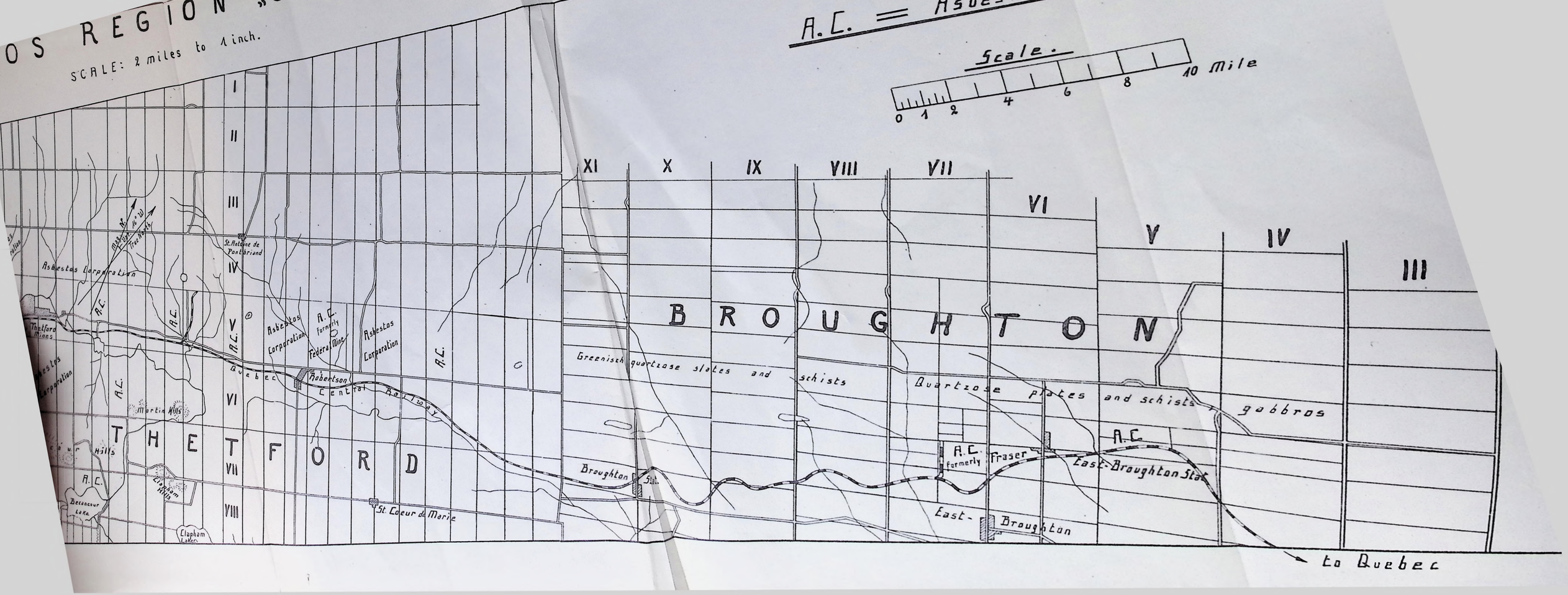
TOS REGION „QUEBEC"

SCALE: 2 miles to 1 inch.

A.C. = Asbestos Corporation.

Scale.

0 1 2 4 6 8 10 Mile



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