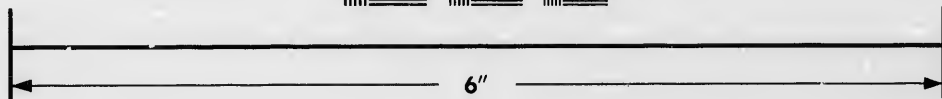
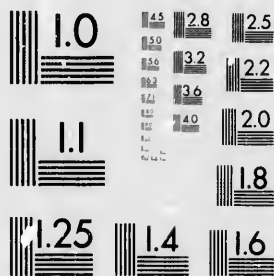
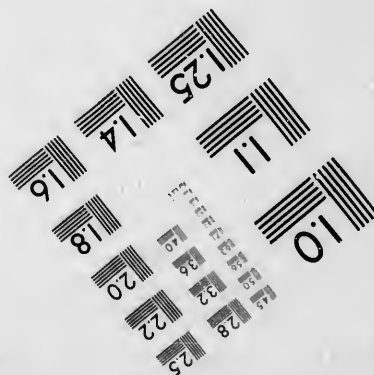
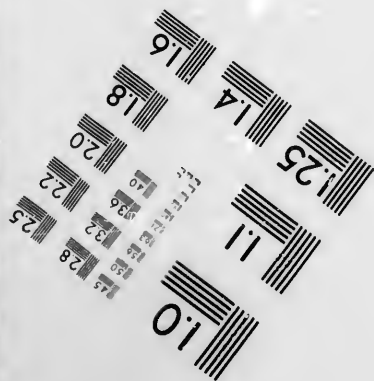


**IMAGE EVALUATION  
TEST TARGET (MT-3)**



6"



**Photographic  
Sciences  
Corporation**

23 WEST MAIN STREET  
WEBSTER, N.Y. 14580  
(716) 872-4503

1.5  
2.0  
2.2  
2.5  
2.8  
3.2  
3.6  
4.0  
4.5

**CIHM/ICMH  
Microfiche  
Series.**

**CIHM/ICMH  
Collection de  
microfiches.**



Canadian Institute for Historical Microreproductions / Institut canadien de microreproductions historiques

10

**© 1981**

Technical and Bibliographic Notes/Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- Coloured covers/  
Couverture de couleur
- Covers damaged/  
Couverture endommagée
- Covers restored and/or laminated/  
Couverture restaurée et/ou pelliculée
- Cover title missing/  
Le titre de couverture manque
- Coloured maps/  
Cartes géographiques en couleur
- Coloured ink (i.e. other than blue or black)/  
Encre de couleur (i.e. autre que bleue ou noire)
- Coloured plates and/or illustrations/  
Planches et/ou illustrations en couleur
- Bound with other material/  
Relié avec d'autres documents
- Tight binding may cause shadows or distortion along interior margin/  
La reliure serrée peut causer de l'ombre ou de la distortion le long de la marge intérieure
- Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/  
Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- Additional comments:/  
Commentaires supplémentaires:

- Coloured pages/  
Pages de couleur
- Pages damaged/  
Pages endommagées
- Pages restored and/or laminated/  
Pages restaurées et/ou pelliculées
- Pages discoloured, stained or foxed/  
Pages décolorées, tachetées ou piquées
- Pages detached/  
Pages détachées
- Showthrough/  
Transparence
- Quality of print varies/  
Qualité inégale de l'impression
- Includes supplementary material/  
Comprend du matériel supplémentaire
- Only edition available/  
Seule édition disponible
- Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image/  
Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below/  
Ce document est filmé au taux de réduction indiqué ci-dessous.

|                          |                          |                          |                                     |                          |                          |
|--------------------------|--------------------------|--------------------------|-------------------------------------|--------------------------|--------------------------|
| 10X                      | 14X                      | 18X                      | 22X                                 | 26X                      | 30X                      |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12X                      | 16X                      | 20X                      | 24X                                 | 28X                      | 32X                      |

The copy filmed here has been reproduced thanks to the generosity of:

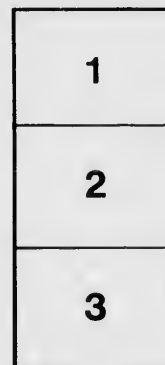
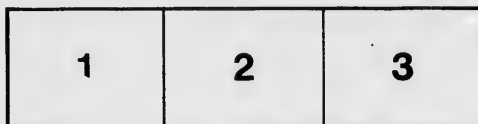
Bibliothèque nationale du Québec

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol  $\rightarrow$  (meaning "CONTINUED"), or the symbol  $\nabla$  (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:



L'exemplaire filmé fut reproduit grâce à la générosité de:

Bibliothèque nationale du Québec

Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole  $\rightarrow$  signifie "A SUIVRE", le symbole  $\nabla$  signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.

P 553.64  
18914

*THE APATITE DEPOSITS OF CANADA.*

BY T. STERRY HUNT, LL.D., F.R.S., MONTREAL, CANADA.

(Read at the Cincinnati Meeting, February, 1884.)

THE presence of apatite in the Laurentian rocks of North America has long been known to mineralogists, and within a few years so much interest has been excited by the economic importance of deposits of this mineral found in certain parts of Canada, that a brief history of our knowledge of these deposits may not be unacceptable to the members of the American Institute of Mining Engineers. It was in 1847 that the present writer was shown by a local collector of minerals some large crystals, which had been called beryl, found in North Burgess, in Ontario. These were at once recognized as apatite; and after a visit to the locality, this was described in the report of the geological survey of Canada for that year as likely to furnish an abundant supply of a valuable fertilizer; the opinion being then expressed that the fact of "the existence of such deposits as these will prove of great importance."

Specimens of apatite from this locality, collected by the writer, were shown among the economic minerals of Canada at the great exhibitions of London and Paris in 1851 and 1855, and the mineral had already been found by explorers at several other points in the same region previous to 1863. In the *Geology of Canada*, published in that year, the writer resumed the results of his further studies of these deposits, and described the apatite as occurring in the Laurentian rocks, both distributed in crystals through carbonate of lime, and in "irregular beds running with the stratification and composed of nearly pure crystalline phosphate of lime." This was further said to occur in North Burgess, in several parallel "beds interstratified with the gneiss."\*

In a subsequent report of the geological survey, in 1866, I again noticed the occurrence of the apatite in beds in the pyroxenic rocks often found associated with the gneiss. It was said, "the presence of apatite seemed characteristic of the interstratified pyroxenic rocks

\* Loc. cit., pp. 592, 761.

P 553.64  
14914

of this section, in which it was very frequently found in small grains and masses, alike in the granular and the micaceous schistose varieties." In these rocks, the apatite was said to mark the stratification, and to form, in one example, a bed, in some parts two feet thick, which was traced 250 feet along the strike of the pyroxenic rock. I at the same time described the occurrence of apatite, often with calcite, in "true vein-stones, cutting the bedded rocks of the country;" alike gneiss, pyroxenite, and crystalline limestone. These latter deposits were farther spoken of as well-defined veins, traversing vertically, and nearly at right angles, the various rocks; as often banded in structure, and including besides apatite both calcite and mica, occasionally with pyroxene, and more rarely with hornblende, wollastonite, zircon, quartz, and orthoclase. These veins were said to be very irregular, often changing rapidly in their course from a width of several feet to narrow fissures. It was added, "it is evident that this district can be made to supply considerable quantities of apatite;" and while the uncertainties arising from the irregularities of the veins were mentioned, it was said, that "some of the deposits might probably be mined with profit."\*

Before following farther this history, it may be stated that there are two districts in Canada which have, within the past few years, been found to contain deposits of apatite of economic importance; one in the province of Ontario, in which the above observations were made by the writer previous to 1866, including parts of the counties of Lanark, Leeds, and Frontenac; and the other, since made known, in the province of Quebec, chiefly in Ottawa county. In both cases it is found in the rocks of the Laurentian series, consisting of granitoid gneisses with bands of quartzite, of pyroxenite, and of crystalline limestone. These ancient and highly inclined strata, with a northeast strike, rise from beneath the horizontal paleozoic rocks near Kingston, and again pass beneath them near Perth. These overlying strata, belonging to the Ottawa basin, hide, moreover, to the eastward, the apatite-bearing gneisses of this district; which, a short distance to the westward, are again concealed by the Taconian and other overlying pre-Cambrian groups in Hastings county. The gneissic belt is here seen chiefly in the townships of Loughborough, Storrington, Bedford, North and South Crosby, and in North Burgess, where the apatite was first discovered.

The country presents a succession of small, isolated, rounded, rocky hills, alternating with numerous small lake-basins, hollowed

\* Loc. cit., pp. 204, 224, 229.

UNIVERSITY OF TORONTO  
LIBRARY

out of the gneiss, and sometimes out of the interstratified limestones; the general trend both of the hills and the lakes being coincident with the strike of the rocks. These, though concealed in the valleys by considerable depths of alluvial soil, are seen in the hills to be hard and undecayed. These geographical features, as I have elsewhere pointed out, were apparently determined by sub-aërial decay previous to the erosion which removed from them the softened and disintegrated portions, leaving the present outlines.\*

When, after cutting the forest-growth which covers these hills of granitoid gneiss, fire is allowed to pass over the surface, destroying the undergrowth, the comparatively thin layer of soil is laid bare, and is soon washed away by the rains; leaving the bald, rocky strata exposed in a manner singularly favorable for geological study, but rendering the region sterile. To prevent this process of denudation it has become the practice in some parts of the country, after burning over the hillsides, to sow them, without loss of time, with grass-seed, which, at once taking root, protects the soil from the destructive action of rains, and transforms it into good pasture-land. This system, which has been adopted to a considerable extent in parts of Frontenac county, Ontario, is worthy of record and of imitation in other regions.

The similar apatite-bearing gneisses, which are found to the north of the river Ottawa, a little northeast of the city of that name, are in Ottawa county, Quebec, and chiefly in the townships of Buckingham, Templeton, and Portland. They reproduce all the characteristics of the first-mentioned district, and may be looked upon as a prolongation of it beneath the northwestern limb of the paleozoic basin already mentioned. Later observations, both in Ontario and in this latter district, where mining operations have been carried on within the past few years, have been recorded by Messrs. Broome and Vennor, and by Dr. Harrington,—the latter up to 1878. They have, however, added little to our knowledge of the conditions of occurrence of the mineral beyond what had already been set forth in 1863 and 1866.

I have, within the past few months, examined with some detail many of the apatite-workings in Ontario, which have served to confirm the early observations, and to give additional importance to the fact, already insisted upon in previous descriptions, that the deposits of apatite are in part bedded or interstratified in the pyroxenic rock

\* See the author's paper on "Rock Decay Geologically Considered."—*Amer. Jour. Sciences*, Sept., 1883.

of the region, and in part are true veins of posterior origin. The gneissic rocks, with their interstratified quartzose and pyroxenic layers, and an included band of crystalline limestone, have a general northeast and southwest strike, and are much folded; exhibiting pretty symmetrical anticlinals and synclinals, in which the strata are seen to dip at various angles, sometimes as low as  $25^{\circ}$  or  $30^{\circ}$ , but more often approaching the vertical. The bedded deposits of apatite, which are found running and dipping with these, I am disposed to look upon as true beds, deposited at the same time with the inclosing rocks. The veins, on the contrary, cut across all these strata, and, in some noticeable instances, include broken angular masses of the inclosing rocks. They are, for the most part, nearly at right angles to the strike of the strata, and generally vertical, though to both of these conditions there are exceptions. One vein, which had yielded many hundred tons of apatite, I found to intersect, in a nearly horizontal attitude, vertical strata of gneiss; and in rare cases what appear, from their structure and composition, to be veins, are found coinciding in dip and in strike with the inclosing strata.

The distinction between the beds and the veins of apatite is one of considerable practical importance,—first, as related to the quality of the mineral contained, and second, as to the continuity of the deposits. The apatite of the interbedded deposits is generally compactly crystalline, and free from admixtures, although in some cases including pyrites, and more rarely magnetic iron-ore, with which it may form interstratified layers. Many will recall in this connection the bands of magnetite, with an admixture of granular apatite, found interstratified in parts of the great magnetic ore-deposit known as the Port Henry mine, near Lake Champlain, in Essex county, New York; where, in certain layers formerly mined, the apatite made up about one-half the bulk. I have seen an example of a similar association of magnetite and apatite from Frontenac county, Ontario. The latter mineral is, however, for the most part found included in the beds of pyroxene rock, already mentioned, which is generally pale green or grayish green in color, sometimes containing quartz and orthoclase, and distinctly gneissoid in structure.

The veins present more complex conditions; while they are often filled throughout their width by apatite as pure and as massive as that found in the beds, it happens not unfrequently that portions of such veins consist of coarsely crystalline, sparry calcite, generally reddish in tint, holding more or less apatite in large or small crystals, generally with rounded angles, and often accompanied by crys-



tals of mica, and sometimes of pyroxene and other minerals. Occasionally these mixtures, in which the carbonate of lime generally predominates, will occupy the whole breadth of the vein. These *lime-veins*, as they are called by the miners, sometimes include cavities from which the carbonate appears to have been dissolved by infiltrating waters, leaving free the inclosed crystals of apatite. In some cases, however, these veins present cavities which have apparently never been filled with solid matter, and exhibit drusy surfaces, with quartz, and more rarely with barytine and zeolites. These calcareous veins often carry so much carbonate of lime as to be valueless for commercial purposes, unless some cheap means for separating the apatite can be devised. It may be said, in general terms, that while some of these true veins, throughout portions or the whole of their breadth, yield good and pure apatite, others are of comparatively little value. The bedded masses, on the contrary, are free from carbonate of lime, and although they may occasionally contain small quantities of mica, pyroxene, hornblende, or pyrites, these are seldom present to an injurious extent.

The question of the continuity of these deposits of both classes is an important one. Veins filling fissures that have been formed in rocks are sometimes continuous for great lengths and to great depths, but experience shows that their extent varies very much for different regions and for different rocks. Inclined beds, which were once horizontal sheets, inclosed in strata that have since been folded, should be as persistent in depth as they are in length; and when traced in the outcrop for many hundreds of feet, may be expected, under ordinary circumstances, to continue downwards as far, unless a turn of the inclosing strata brings them up again to the surface. The inclosed beds of apatite in the regions already noticed are often traced for 500 to 1000 feet and more, and there is reason to believe that they are continuous for long distances. The workings upon them have, however, as yet been very superficial, generally from twenty to forty feet, and rarely exceeding 100 feet. The deepest mine, which is in Ottawa county, is now about 200 feet.

The ordinary thickness of the bedded masses of apatite may be said to vary from one to three and four feet, though not unfrequently expanding to eight and ten feet, and even more, and sometimes contracting to a few inches; the same layer being subject to considerable variations. In some cases the apatite in a bed is found to thicken and then to diminish, or to be divided by the interposition of the accompanying pyroxenic rock. The condition of the apatite in these

cases recalls the thickening and thinning sometimes observed in a layer of coal among disturbed strata, where, as the result of great pressure attending the movements of the harder inclosing rocks, it is alternately attenuated and swollen in volume; in which case a thinning in one part is necessarily compensated for by a thickening of the parts adjacent.

The thickness of the veins also, as above stated, is very variable, and the same vein in a distance of a few hundred feet will sometimes diminish from eight or ten feet to a few inches. We have already noticed the variable nature of the contents of these veins, which are sometimes filled with solid and pure apatite, and at other times present bands or layers of this mineral, with others chiefly of calcite, of pyroxene crystals, or of a magnesian mica, occasionally mined for commercial purposes. While these veins have yielded in many cases considerable amounts of apatite, they have not the persistency of the beds. Their study presents many interesting facts in paragenesis, which I have described in detail in the report of the geological survey for 1866, already quoted, and more briefly in my *Chemical and Geological Essays* (pp. 208-213).

It is worthy of remark, that some of the first attempts at mining apatite in Canada were upon these veins, and that their irregularities contributed not a little to the discouragement which followed the early trials. The larger part of the productive workings are upon the bedded deposits. These, however, as already noticed, are for the most part opened only by shallow pits; a condition of things which is explained by the peculiar character and the frequency of the deposits, and also by the economic value of the apatite. This mineral, unlike most ordinary ores, is, in its crude state, a merchantable article of considerable value, and finds a ready sale at all times, even in small lots of five or ten tons. Like wheat, it can be converted into ready money, at a price which generally gives a large return for the labor expended in its extraction. Hence it is that farmers and other persons, often with little or no knowledge of mining, have, in a great number of places throughout the district described, opened pits and trenches for the purpose of extracting apatite, and at first with very satisfactory results. So soon, however, as the openings are carried to depths at which the process becomes somewhat difficult from the want of appliances for hoisting the materials mined, or from the inflow of surface-waters, which in wet seasons fill the open cuts, the workings are abandoned for fresh outcrops, never far

off. In this way a lot of 100 acres will sometimes show five, ten or more pits, often on as many beds, from twelve to twenty feet deep; each of which may have yielded one or more hundred tons of apatite, and has been abandoned in turn, not from any failure in the supply, but because the mineral could be got with less trouble and cost at a new opening on the surface near by.

These conditions are scarcely changed when miners, without capital and unprovided with machinery for hoisting or for pumping, are engaged, as has often been the case, to extract the mineral at a fixed price per ton. These, having no interest in the future of the mine, will work where they can get the material with the least expenditure of time and labor, and often will quit the opening for some one which is more advantageous. The very abundance and the value of the mineral mined has thus led to its careless, wasteful, and unskilful exploitation. It is the working of these causes, in the way just explained, which has thrown undeserved discredit on this mining-industry, and, more even than the injudicious schemes of speculators and stock-jobbers, has retarded its legitimate growth.

It is evident that the proper development of these deposits will require regular and scientific mining in place of the crude plan of open pits and trenches, which, from causes already explained, has hitherto, with few exceptions, been followed. As a basis for calculation in mining, it becomes necessary to establish some data as to the production and the value of the apatite-layers which we have described. The specific gravity of the mineral, as deduced from many specimens of massive Canadian apatite, is from 3.14 to 3.24. If we assume 3.20, this will give for the weight of a cubic foot of apatite almost exactly 200 pounds. A fathom of ground, carrying a bed or vein of apatite one foot in thickness, will thus contain thirty-six cubic feet, or 7200 pounds of apatite; equal to a little over three and one-fifth tons of 2240 pounds each. Allowing the fractional portion, equal to nearly seven per cent., for loss in mining (it will be noted that coarse and finely-broken apatite are equally merchantable), we shall have as the net product of a layer of apatite for a fathom of ground mined, three gross tons for each foot in thickness.

The apatite of these deposits is generally greenish in color, often clear sea-green, but more rarely reddish-brown in tint. The massive varieties are sometimes coarsely crystalline and cleavable, but sometimes finely granular. The veins often yield crystals of large size.

The mineral is essentially a fluor-apatite, containing not over two

or three thousandths of chlorine, and in its purest state about 92.0 per cent. of tricalcic-phosphate. The analysis of a selected specimen gave me 91.2 per cent. of phosphate, but it is generally mingled with small portions of foreign matters, chiefly insoluble silicates. The analyses of seven specimens from different Canadian mines, published by Mr. C. G. Hoffman in 1878, showed from 85.2 to 89.8 per cent. of phosphate.

The market-value of apatite, which, as is well-known, is chiefly consumed for the production of soluble phosphate by the manufacturers of artificial fertilizers, varies greatly, other things being equal, with its purity. Thus, while at present the price in England is 1s. 2d. the unit for apatite giving by analysis 75 per cent. of tricalcic phosphate, there is paid an addition of one-fifth of a penny for each unit of phosphate above that percentage, so that a sample yielding by analysis 80 per cent. is worth 1s. 3d. the unit. The price in the English market is subject to considerable fluctuations, having within the last four years been as high as 1s. 5½d., and as low as 11d. the unit for 80 per cent. phosphate. The present may be considered as an average price.

The Canadian apatite shipped to England has yielded for various lots from 75 to 85 per cent., 80 per cent. being the average from the best-conducted mines, though lots from mines where care has been used in the dressing and selection of the mineral for shipment have yielded 84 and 85 per cent. Many of the smaller miners to which we have alluded, selling their product to local buyers, take little pains in dressing, and hence their product is apt to be lower in grade. It will be seen, from the rule adopted by foreign purchasers, that there is great profit in a careful selection and dressing of the mineral for market. The basis being 1s. 2d. the unit for 75 per cent., with a rise of one-fifth of a penny for each unit, it follows that while a ton of 75 per cent. apatite will bring only 87s. 6d., a ton of 80 per cent. will command 100s., and one of 85 per cent. 113s. 4d.

In the present state of the industry it is not easy to say what would be the cost of production. At the outcrop of the large masses of apatite, and in the open cuts and quarries already described, the cost of extraction and dressing is of course very variable, estimates in different deposits giving from \$2 to \$8 the ton. In Ottawa county, where, within the last four years, deposits have been opened and mined on a better system than heretofore, the figures of production and cost are instructive. According to the report of its

manager in July, 1882, the High-Rock mine, in Buckingham, yielded, in 1880, 2400 tons, and in 1881 2000 tons of apatite. An adjoining portion of land having been then acquired, the production of this company's mines in 1882 and 1883 is stated at 5000 tons annually; from eighty to ninety men being employed. The cost of the mineral is here given at \$4 the ton, dressed, at the mine; in addition to which \$3 is paid for carriage to the railroad or the river, and about \$1 additional to Montreal, the port of shipment. The mines in the Ontario district are for the most part in or near to the waters of the Rideau Canal, or some of the many lakes connected therewith, from which the freight to Montreal is \$1.50 the ton. I am informed by a merchant, who is a purchaser and shipper of apatite, and is also engaged in mining it both in Ontario and Quebec, that the average cost for freight from Montreal to England, with selling-charges, is 20s. the ton; which, for apatite of 80 per cent., now worth 100s. the ton, would leave 80s., or \$19.36. Deducting from this the cost of production and of transportation to Montreal, there remains a large profit.

The amount of apatite shipped from Montreal has gradually increased, and, according to published figures, attained, in 1883, 17,840 tons, of which, it is to be remarked that 1576 tons were delivered in Hamburg, and 650 in Stockholm, the remainder going to Liverpool, London, and other British ports. Of this about 15,000 tons were from Quebec, and the remainder from Ontario. It should be noticed that this was, with small exceptions, mined in 1882, and brought to the water-side during the winter season. It is estimated that the shipments of apatite for 1884 will equal 24,000 tons.

The methods of mining hitherto generally pursued in the apatite deposits of Canada, allow of many improvements which would materially reduce the average cost of production, and give a permanency to the industry which the present modes of working can never attain. The regularity and persistence of the bedded deposits, and of some of the veins, warrants the introduction of systematic mining by sinking, driving, and stoping, with the aid of proper machinery for drilling, as well as for hoisting and pumping. The careful dressing and selection of the apatite for the market is also an element of much importance in the exploitation of these deposits. The cost of labor in the apatite-producing districts is comparatively low, and there are great numbers of beds now superficially opened, upon which regular mining operations, conducted with skill and a judicious expenditure

of capital, should prove remunerative. It must be added, that the areas in question have as yet been very partially explored, and that much remains to be discovered within them, and also there is reason to believe in outlying districts ; so that in the near future the mining of apatite in Canada will, it is believed, become a very important industry.

UNIVERSITY OF TORONTO  
LIBRARY

e  
t  
n  
g  
t

