CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

ABRASIVES

PRODUCTS OF CANADA
TECHNOLOGY AND APPLICATION

Part I

Siliceous Abrasives

Sandstones, Quartz, Tripoli, Pumice, and Volcanic Dust

BY

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OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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TABLE A

Natural Abrasives and Their Uses

HARD ABRASIVES

- **Diamond**
  - Crystals — Wheel truing, cutting and boring
  - Dust — Gem polishing, etc.
- **Corundum**
  - Manufacturing wheels — Some metals
  - Coated papers and cloths — Some metals and hardwood
- **Emery**
  - Manufacturing wheels — Snagging metals
  - Coated papers and cloths — Metals and hardwood
  - Loose grain
    - Coated on flexible wheels — Semi-finishing and polishing metals
    - Glass grinding
- **Garnet**
  - Coated papers and cloths — Hard woods, paint, and varnished surfaces
  - Loose grain — Glass grinding, etc.

SILICEOUS ABRASIVES

- **Quartz and Flint**
  - Burrstones — Grinding grain, paints, etc.
  - Pebbles — In cylindrical mill for grinding ores, etc.
  - Small slabs — Hand-operated, fine sharpening stones
  - Crushed: coated paper or cloth — Soft wood
- **Sandstone and Sand**
  - Natural grindstone — File, knife, saw, etc., grinding
  - Pulpstone — Wood for pulp making
  - Sharpening stones — Hand-operated, coarse sharpening stones
  - Crushed as loose grain — Sand blasting, glass grinding
- **Pumice**
  - Blocks — Rubbing paint and varnish surfaces
  - Loose grain — Glass grinding, scouring powders, etc.
- **Volcanic dust and pumicite**
  - Loose grain — Scouring powders, cleansers, etc.
- **Diatomite**
  - Powder — Metal polish, dental powder, etc.
- **Tripoli**
  - Powder — Buffing composition, metal polish, etc.
- **Siliceous clay, silt, and rottenstone** — Scouring powder, varnish rubbing compounds

SOFT ABRASIVES

- **Feldspar, Rottenstone**
  - Powder — Scouring and cleansing powder, bath bricks, etc.
- **Dolomite (lime)**
  - Calcined unhydrated in form of grease compound — Buffing of metals, mainly nickel
- **Metallic oxides, such as iron, chromium, zinc, tin, etc.**
  - As red and green rouge, crocus, putty powder, etc., either loose or in form of grease compounds
    - Plate glass, stone, etc., polishing
    - Buffing of metals

GENERAL PREFACE

Abrasives may be divided into two general classes—*Natural* and *Artificial.* The former includes all rocks and minerals which are used for abrasive purposes without chemical or physical change, other than crushing, shaping, or bonding into suitable forms. Artificial abrasives are those made either by heat or chemical action from metals or raw mineral materials, and in recent years they have largely replaced natural abrasives, particularly for metal grinding.

Natural abrasives are found in many parts of the world. Roughly, the list includes all minerals capable of abrasive action, but the use of many of these as an abrasive is insignificant compared to their other uses. The principal natural abrasives in order of their hardness are corundum, emery, garnet, and various forms of silica, the chief of which is sandstone. Diamond, which is the hardest known natural substance, is, on account of its rarity, seldom used as an abrasive. The accompanying table (Table A) gives a list of the natural abrasives, the forms in which they are used, and their principal uses.

WORLD'S PRODUCTION OF NATURAL ABRASIVES

The accompanying table (Table B) which is produced without alteration from "Abrasive Materials in 1923"[1], shows the producing countries, the type of abrasives, and the quantities of each produced. In dealing with an individual abrasive throughout the reports the output and value of the mineral have also been tabulated and in several instances there may be a few minor alterations of the above general table, due to more recent information.

[1] Katz, F. J.: U.S. Geol. Surv., Min. Res. U.S., pt. II, p. 336 (1925).

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TABLE B

World's Production of Natural Abrasives, 1913-23*

(In Metric Tons)

—	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
Corundum:											
Australia, Western (exports)	(a)	(a)	(a)	(a)	(a)	(a)	1	(a)	(b)	(a)	(a)
Canada	1,068	497	238	61	171	124	....	178	366	....	....
India, British	404	120	63	1,898	2,105	2,046	718	213	65	....	....
Madagascar	1,099	556	327	914	734	178	812	521	285	186	421
Russia	(a)	(a)	(a)	(a)	(a)	(a)	(a)	63	7	2	(a)
Union of South Africa	12	11	62	685	2,385	3,515	162	236	112	1,836	2,554
United States	....	....	....	....	744	(c)	....	....	....	....	....
Diatomaceous earth:											
Algeria	(a)	(a)	(a)	(a)	(a)	(a)	1,000	1,500	800	2,480	10,000
Australia—											
New South Wales	25	25	40	239	142	20	89	390	209	489	523
Victoria	152	1,016	278	....	762	142	159	1,016	....	....	....
Chosen (Korea)	(a)	(a)	(a)	(a)	(a)	(a)	30,054	28,820	24,313	38,904	....
France	1,725	(a)	(a)	(a)	(a)	(a)	2,500	3,800	4,580	(a)	(a)
Italy	20	20	20	....	....	....	15	25	875	175	420
Sweden	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	600	322	(a)
United Kingdom	156	....	....	....	....	....	....	....	....	....	....
United States	5,975	9,990	(d)4,167	(d) 2,468	(d)2,751	(d)2,690	38,684	56,174	50,016	40,606	59,722
Emery:											
Germany (Bavaria)	(a)	260	80	90	50	50	170	140	243	420	400
Greece	5,560	16,112	14,338	19,871	16,440	12,600	9,300	11,089	12,709	13,000	21,626
Russia	(a)	(a)	(a)	(a)	(a)	(a)	676	511	(a)	(a)	(a)
Turkey	42,437	19,110	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
United States	868	440	2,779	13,864	14,801	(e) 9,455	2,360	2,111	277	1,332	2,074
Garnet:											
Madagascar	....	....	....	....	....	....	....	....	....	10	5
Spain	(a)	(a)	(a)	(a)	(a)	(a)	801	198	5	(a)	982
United States	4,815	3,838	3,902	5,598	4,531	4,260	4,485	4,968	2,765	6,399	8,170
Grinding pebbles and tube-mill lining:											
Denmark	(a)	(a)	(a)	(a)	(a)	(a)	(a)	11,162	13,000	15,726	20,914
France	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
United States	....	....	....	(f)	13,653	11,312	8,571	9,910	897	2,866	4,129
Grindstones and pulpstones:											
Canada (grindstones)	4,388	3,607	2,341	3,155	2,289	2,787	1,833	2,217	1,162	912	1,354
Italy (grindstones)	913	150	161	1,025	806	710	1,340	1,410	860	875	960
United States	(g)	(h) 43,791	(h) 38,667	(h)46,120	(h) 49,380	59,274	42,515	48,520	23,895	24,062	42,247

Millstones:											
France	29,994	(a)	(a)	(a)	(a)	(a)	24,742	19,240	19,300	19,105	(a)
Greece (sales)	(i)5,618	(i)5,874	(i)5,423	(i) 1,321	(i)4,070	(a)	(i)9,200	(i)2,728	(i)14,348	(i)5,324	(i) 2,400
Italy	3,701	4,584	3,794	2,204	1,453	1,153	1,858	1,857	1,934	1,885	2,220
Jugoslavia (exports)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	334	(a)	(a)	(a)
United States	(j)	(j)	(j)	(j)	(j)	(j)	(j)	(j)	(j)	(j)	(j)
Oilstones, scythestones, etc.:											
Belgium (whetstones)	(i)125,800	(i)77,440	....	(i) 1,900	....	(i) 3,000	(i)31,800	(i)67,800	(i)77,550	(i)68,930	(i)207,950
France (whetstones)	628	(a)	(a)	(a)	(a)	(a)	440	500	850	778	(a)
Germany (Bavaria) (whetstones)	(a)	15	5	....	5	12	14	15	29	43	42
United States	(l)	(l)	(l)	(l)	1,647	916	1,327	1,038	754	922	1,109
Pumice:											
Italy—											
Crude	14,973	14,376	10,242	9,287	11,312	4,473	13,210	25,200	10,968	21,036	30,473
Ground	....	....	....	....	5,705	7,900	8,450	9,325	....	....	....
New Zealand	2,726	2,464	1,940	4,129	2,195	2,298	1,054	2,889	2,992	3,068	3,776
United States	22,283	25,030	25,136	30,227	32,017	27,793	32,705	37,955	33,664	41,061	51,324
Tripoli:											
Canada (tripolite) (1)	562	590	288	562	544	454	513	236	309	199	118
France	29	(a)	(a)	(a)	(a)	(a)	34	54	(a)	(a)	(a)
Spain	....	....	....	....	....	....	110	597	494	524	869
United States	18,867	15,620	27,860	39,242	23,649	18,127	22,037	36,499	11,195	27,401	24,568

(a) Data not available.
(b) 25 kilograms.
(c) Corundum included under "Emery".
(d) Exclusive of considerable production for special uses upon which the Survey is not at liberty to report.
(e) Exports from Syria.
(f) Grinding pebbles only, valued at $42,500. Weight not recorded.
(g) Weight not recorded. Output valued at $855,627.
(h) Grindstones only. Pulpstones not recorded by weight but by pieces, as follows: 1914, 697; 1915, 696; 1916, 1,066; 1917, 2,325.
(i) Pieces.
(j) Weight not recorded but value was as follows: 1913, $56,163; 1914, $43,316; 1915, $53,480; 1916, $44,559; 1917, $43,489; 1918, $92,514; 1919, $66,972; 1920, $63,325; 1921, $24,524; 1922, $20,853; 1923, $22,229.
(k) Recorded as 46 stones; weight not given.
(l) Weight not recorded but value was as follows: 1913, $207,352; 1914, $167,948; 1915, $115,175; 1916, $154,573.

(1) This material mined in Canada is not tripoli, and should be included under diatomaceous earth.

* Katz, F. J.: U.S. Geol. Surv., Min. Res. U.S., pt. II, p. 336 (1925).

CONTENTS

TABLES

ILLUSTRATIONS

Photographs

Drawings

INTRODUCTORY

In recognition of the importance of the abrasive industry and the many inquiries concerning the uses, sources of supply, preparation, and markets of the numerous minerals and materials included under the heading of Abrasives, the writer has made an investigation resulting in a series of bulletins embracing the subject in all its phases.

The following publications dealing with abrasives are issued as separate bulletins.

Part I. Siliceous Abrasives: Sandstones, Quartz, Tripoli, Pumice, and Volcanic Dust.

Part II. Corundum and Diamond.

Part III. Garnet.

Part IV. Artificial Abrasives and Manufactured Abrasive Products and their Uses.

Up to the present there has been very little collected information on Canadian sources of supply of abrasive silicas, although brief references to, and descriptions of isolated deposits have appeared in many Government reports and other periodicals. The writer has, therefore, endeavoured to collect and sort out this information and bring it up to date by local inquiries and field investigations. Most of the field work was done during the years 1923-24-25. A brief description of the principal deposits, production, and methods of treatment of the foreign materials have been also included.

PART I

SILICEOUS ABRASIVES

TYPES OF SILICA USED FOR ABRASIVES

Silica in many forms is used for abrasive purposes. These forms include flint, quartz and quartzite, chert, sandstone, sand, silt, amorphous silica, tripoli, diatomite, rottenstone, and siliceous clays. These materials depend mainly upon the free silica and sharpness of the grains for their abrasive properties.

The abrasive uses and the common forms of silica have been briefly tabulated by R. B. Ladoo.[1]

Abrasive Uses	Types of Silica Used
As grindstones, pulpstones, and sharpening stones.	Massive sandstone from very fine to moderately coarse-grained.
Tube-mill grinding pebbles.	Rounded flint pebbles.
Tube-mill lining.	Chert, flint, and quartzite in dense, solid blocks.
In sand blast work.	Quartz, quartzite, sandstone, and sand crushed into grains of uniform size.
For sawing and polishing marble, granite, etc.	Sharp, clean sand graded into various sizes.
In sandpaper.	Quartz, quartzite, flint, sandstone, and sand; coarsely ground and coarsely sized.
Lithographers' graining sand.	Medium to fine sand or coarsely ground silica, and tripoli.
Wood polishing and finishing.	All forms of silica ground to medium fineness.
In scouring and polishing soaps and powders.	Quartz, quartzite, flint, chert, sandstone, sand, tripoli, and diatomaceous earth; all in finely ground state.
Metal buffing, burnishing, and polishing.	Ground tripoli, and other forms of ground silica.
In tooth powders and pastes.	Various forms of pure silica, finely ground.

GRINDSTONES

Natural grindstones are made from certain sandstones which occur throughout the world. The proper selection of the sandstone is of the greatest importance and depends on the use to which finished grindstone is to be applied.

[1] Ladoo, R. B.: Non-Metallic Minerals, p. 525 (1925)

PRESENT STATUS OF THE INDUSTRY

During the latter part of the last century the grindstone industry was at its height, but for the past two or three decades there has been a gradual decline in tonnage production. This has been caused mainly by the use of artificial grinding wheels, which, owing to their superior cutting qualities, uniformity, ease of manipulation, and all-round efficiency, have replaced the natural stone for most general purposes. To-day, the demand is only for the larger stones of over 5 feet in diameter, a market which limits the production to deposits of large, thick, and uniform beds.

In Canada, the original cause of the decline was due to the opening up of the grindstone quarries in Ohio and other places in the United States, which are comparatively close to the larger markets. The decline was further aided by adverse tariffs and the introduction of artificial abrasives. However, the uniformity and good qualities of the stones produced from a few Canadian localities, particularly at Stonehaven, northern New Brunswick, have held part of the market.

It is very doubtful, however, if grindstones will ever recapture the market held by the artificial abrasives, for not only the practical, but also the personal element must be considered, as workmen do not like to use grindstones on account of the dirt and danger accompanying their use. However, manufacturers of saws and thin-edged tools still use the natural stones.

REQUIREMENTS OF GRINDSTONE MATERIAL

A sandstone suitable for grinding purposes, must be of uniform hardness, possess a sharp and even grain, and be free from clay or other impurities. The hardness is important, for if the stone be too soft it wears away rapidly, causing coarse and uneven grinding; if it be too hard it glazes and cuts so slowly as to be useless. The grains of silica should be cemented together in such a manner as to have sufficient tenacity to impart the necessary strength to the stone but at the same time crumble away with sufficient rapidity when exposed to friction to prevent glazing as well as to present continually fresh, sharp grains. The size of the grit determines the ultimate use of the stone since the coarser the grit the faster will be the cutting, although the work will be rougher.

Cementation

The bond or cement which consolidates the sand particles has an important bearing on the quality of the grindstone. The cements are usually limonite, clay, calcite, and quartz. These may occur individually as the sole constituent, or be mixed in varying proportions forming an argillaceous matter. Limonite is usually the cement of the more highly coloured sandstones. Stones having too much clay are inferior for grinding purposes since they crumble too easily and absorb water readily, resulting in a "mud." Calcite-cemented sandstones quickly weather and disintegrate since the atmospheric carbon dioxide dissolves the calcite. If the cement contain an excess of silica the stone is liable to be too hard.

FORMATIONS SUITABLE FOR GRINDSTONES

Although there are many deposits of sandstone, only a few are suitable for the production of grindstones. Carboniferous sandstones appear to be the most productive of the formations, as the producing quarries in the Maritime Provinces of Canada, Ohio in the United States, and the Newcastle area in England, are all Carboniferous in age. Most of the Canadian stones have been quarried from the Millstone Grits of the Middle Carboniferous, and a few from the Upper or Permo-Carboniferous of the Pictou area, Nova Scotia.

The thickness of the bedding as well as the closeness and uniformity of the cross-jointing further determines the suitability of the sandstone. No matter how good the physical properties of the stone may be, the deposit is useless unless the beds are sufficiently thick and the joints far enough apart to ensure that large grindstones or pulpstones can be cut and dressed from the quarried blocks.

QUARRYING AND MANUFACTURE OF GRINDSTONES

Quarrying

The old methods employed in the early days for quarrying and handling stones, many of which are still in use, are outlined under Canadian History.

The methods of quarrying sandstones for grindstones and pulpstones vary somewhat and depend largely on the nature of the sandstone—the ease with which it splits, bedding- and joint-planes—and the size of stones required. The usual practice, after removal of the overburden, is to drill a series of short holes and explode them with a light charge of black powder in order to break the beds into blocks. The blocks are then raised by means of special wedges, called "gads," which are driven about 4 inches apart, parallel to the bedding. Gads are also driven across the grain and serve to split the blocks into the desired size. The blocks are then roughly shaped by means of pick and chisel, either in place, or after removal by derrick to a prepared site or flat car.

The ordinary quarrying implements consist of hand tools, air or steam drills, and derricks. Channels or cuts of almost any desired length or depth are made either with a rock drill and bar by drilling a series of closely connected holes along a line, or by diamond boring machines travelling on an adjustable track. The direct-acting channelling machine consists essentially of a truck travelling on rails and carrying a number of specially-designed air or steam drills which deliver a series of powerful blows as the machine slowly moves back and forth along the rails. The drills are usually mounted on a swivel joint which enables them to cut at any angle. The drills, which are single bitted, are placed so that the outer and middle bits are at right angles to the channel and the intermediate ones, diagonal. There are a number of different makes of these machines.[1]

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. 100, pp. 84-86 (1912).

Manufacture of Grindstones

Grindstones are manufactured either by hand-shaping the rough blocks or by cutting a circular stone directly from the face of the bedrock by means of a channeller; in either case the stones are dressed on lathes.

The method used for the dressing of grindstones is very simple and varies little from that employed a century ago. The dressing tool consists of a long, iron bar having a broad, curved end, through which is inserted a short, square chisel-edged bit. The bit is pressed against the side of the rough stone block which is mounted on a revolving shaft. The diameter of the stone is gauged by inserting the bar between two of a series of pins mounted on a wooden frame, close to, and parallel to the centre of the side of the block. A channel is thus cut on either side of the stone and the outer pieces are broken off with hammers while the stone is at rest. The stone is then dressed, both side and face, by means of the same tool, but using a different shaped bit.

Gang saws, diamond-tooth saws (both circular and straight), planing machines, rubbing beds, etc., are employed in quarries which also produce slabs and building material.

CANADIAN METHODS OF MANUFACTURE

Read Stone Company, Stonehaven, Chaleur Bay, New Brunswick

The quarry is equipped with a number of derricks and a travelling crane which is worked in combination with a channeller. A 50 h.p. steam boiler operates the hoisting machinery for the quarry derricks. Another 50 h.p. boiler drives the pumping machinery and steam channeller, and a 100 h.p. boiler operates the mill. The mill machinery consists of an air compressor for hammer drills used in the quarry, hoisting and pumping machinery, three gang saws, eight lathes, two scythestone grinders, and a shingle mill for making scythestone boxes.

The crude blocks of stone are partly shaped by hand and finished in lathes. The method by which the company makes scythestones is described on page 54.

Miramichi Quarry Company, Quarryville, New Brunswick

Power is derived from two steam boilers and engines giving about 75 h.p., and a 40 h.p. crude-oil engine, which is used as an auxiliary.

The cutting machine consists of iron bands 12 feet long, 18 inches in depth, and $\frac{3}{16}$ inch thick, placed at intervals in a heavy frame, and is operated by a special device for regulating the swing and length of stroke. Steel shot is used as an abrasive and the machine cuts about 12 inches an hour irrespective of length of stroke.

The blocks are roughly squared by a straight cut reciprocating, diamond-tooth saw having a 3-foot stroke. The squared blocks are placed on a travelling platform and surfaced by means of planers having two adjustable bits and a 16-foot movement with quick return motion. The centre hole and outside of the pulpstone or grindstone are then cut by means of cylindrical diamond-tooth saws, an operation which takes about three-quarters of an hour for a 5-foot stone. The machinery is illustrated in Plate VII. Trimming of the grindstones is done by a bar and bit lathe.

The quarry equipment consists of an air compressor, steam drills, derricks, and a large 8-ton crane mounted on rails.

The Mic Mac Quarry Company, Woodburn, Nova Scotia

The company has a small steam plant, drills, derricks, etc. The blocks are removed from the quarry face to a convenient place nearby and roughly shaped by hand into grindstones which are then finished on lathes by the usual methods.

UNITED STATES METHODS

In Ohio, grindstones are made by several methods. In the northern quarries the stone is usually sawed off to the required thickness and then broken by chisels into squares the approximate size of the grindstone desired; for the larger stones the corners are scabbled off. A hole is cut in the centre, either square by means of a pick, or circular by a rotating drill. The stone is then fastened to a rotating shaft and is made circular and true by means of a soft steel bar, having a sharply bent end, which is held in position against the side of the revolving slab. The circular trench so produced is repeated on the opposite side and when it has reached the necessary depth the outside is knocked off leaving the circular piece. The face of the rotating stone is then smoothed and the sides trued with the same tool.

A common practice in the southeastern quarries is to cut a circular trench in the solid rock, by means of an air-drill or ditcher and thus produce a number of blocks of the desired diameter at a single operation. The ditcher is supported by tripod legs and by a vertical bar which fits into a 4-inch square hole in the rock surface. The drilling machinery, which is rotated by a worm gear, is attached to one end of a heavy iron bar and a counterbalance weight is attached to the other end. The diameter of the circle to be cut is varied by bolting the drill attachment in different holes in the bar. The channel is cut by means of a four-pointed, star-shaped drill, and for the large stones the steel is changed every six inches in depth, each successive drill being about $\frac{1}{4}$ inch smaller on account of the loss of gauge by wear.[1] To free the stone along the floor a series of holes are made by an air-drill which slides on a horizontal bed and is kept in position by the operator by means of a hinged handle and crossbar. The explosive used is black powder. The circular block is then removed, the square hole in the centre completed, and after careful examination the rough stones are sent, if satisfactory, to the finishing mill where they are sawed to the proper thickness, turned in the lathe, and finally inspected.[2]

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[1] Bowles, Oliver: U.S. Bureau of Mines Bull. 124, p. 47 (1917).

[2] Stauffer, C.R., and Schroyer, C.R.: Geol. Surv., Ohio, 4th Series, Bull. 22, pp. 149-150 (1920).

CANADIAN GRINDSTONE INDUSTRY

EARLY CANADIAN HISTORY[1]

The quarrying and manufacture of grindstones is one of the oldest industries in Canada. There are in northwestern Nova Scotia and southeastern and northeastern New Brunswick probably upwards of a hundred old sandstone quarries which have at some time been worked for grindstones.

The grindstone industry had its beginning at the head of Chignecto bay, near Minudie, Cumberland county, Nova Scotia, about 1750, when the sandstone beds were worked by the French. For a number of years, activities were confined along the coast at "The Joggins" now called Lower Cove, 6 miles to the south of Minudie. These quarries which were first worked by the English in 1790, eventually became the largest on the bay of Fundy, and were operated almost continuously until 1906. About 1764, Joseph Des Barres, Governor of Prince Edward Island, secured a Crown grant of the Minudie-Joggins territory and leased various sandstone ledges to the farmers, who for many years made rough grindstones by hand.

Old records between 1800 and 1830[2] showed that an enterprising storekeeper by the name of William Harper used to make periodic rounds in his schooner, the "Weasel," visiting Dorchester, Hopewell, Grindstone island, Sackville, and Joggins, and exchange food, clothing, and other necessities for the grindstones made in these places. Cargoes of 40 to 60 tons of stones were frequently collected and distributed to local users; he also found a ready market for large quantities of stones at "Quoddy" (Passamaquoddy) which was then on the disputed International Boundary. There were several other traders besides Harper, who engaged in this business.

During the years 1815 to 1830, Messrs. Joseph Read and John T. Seaman acquired control of the Lower Cove quarries from the Des Barres' estate and made regular shipments of grindstones to the United States by means of small vessels. These shipments went only as far as the frontier port of Eastport where they were transferred into United States vessels for Boston and other places. In 1824, a branch office was established at Boston by Joseph Read, 2nd, which was continually maintained by him and his successors until 1888.

Between 1830 and 1833 the Des Barres' estate was purchased by Amos, youngest brother of John T. Seaman, and he and his successors, except for short leases, continued the business at Lower Cove and the near vicinity until about 1895. After Amos Seaman obtained control of the Lower Cove quarries in 1833, Joseph Read, 2nd, opened sandstone quarries at Ragged Reef, on the Chignecto Bay shore, some 6 miles to the south. He also had grindstones made by contract at other places in the bay where suitable rock was bared by the tides, principally at Sand cove, Sand River, and around the mouth of the Apple river, along a distance of about 25 miles of shore-line. Stones from the latter quarries, exported to the United States, were often shipped in Parrsboro schooners, which accounts for the shipments of grindstones from Parrsboro mentioned in old reports.[3]

[1] Historic information mainly supplied through the courtesy of Mr. H. C. Read.
[2] Steeves, H. Harper: Moncton's First Store and Storekeeper, Pub. by J. and A. McMillan, St. John, N.B.
[3] How, H.: Mineralogy of Nova Scotia, p. 176 (1868).

Operations in this area were barely profitable after 1860 owing to increased difficulties in quarrying operations, to the abrogation of the Reciprocity Treaty in 1866, to the imposition of high duties by the United States in the sixties, and to the opening of large quarries in Ohio.

Old Methods of Quarrying

In the early days of the industry advantage was taken of the great tides in the bay of Fundy which bared the ledges of rock twice daily. At low tide large slabs of rock were loosened and fastened to barges ("Joggins boats") by cable chains, so that when the tide rose the barges lifted up the blocks of sandstone and floated them to convenient coves, where, after the tide had fallen enough, workmen shaped the stones by hand into the various sized grindstones required by the trade. When a sufficient quantity had accumulated at any one place, a vessel would come for them, grounding in a prepared berth nearby, and the grindstones would be hoisted on board by hand. Owing to the crude methods at first employed, the larger stones of 3 tons weight were handled with great difficulty, but later, oxen and horses were used.

Old Grindstone Plants

The first plant to employ lathes for making grindstones was erected, about 1850 by a man named Bevere, on the Scadouc river, about 5 miles south of Shediac, Westmorland county, New Brunswick. After operating five years the quarries were abandoned owing to the grit being unsuitable. The machinery was bought by the Read and Seaman Company, and moved to their quarries on Chaleur bay. The first steam plant used in Canadian grindstone quarries was installed on Chaleur bay, Gloucester county, about 1860, by the Read Company, and in 1865 the first gang saws were used. The early steam plants were erected in the following order: Chaleur bay, Weston point, Lower Cove, Quarryville, Slack cove, and Squaw cap, all of which, with the exception of the first and Quarryville, are near the entrance of Cumberland basin.

Unit of Measurement

At first grindstones were made by contract work at so much per "stone" which was an arbitrary unit represented by a grindstone 24 inches in diameter by 4 inches thick and was supposed to weigh 160 pounds or 14 stones to the long ton. The number of stones was ascertained by multiplying the square of the diameter by the thickness and dividing by 2,304. About 1880 the unit was changed to the short ton of 2,000 pounds.

Price of Grindstones

Old records show that the average price of grindstones, between 1800 and 1830, was about 5 to 6 shillings per "stone" or between 70 and 80 shillings per ton. There are, however, many instances of poor quality stones selling for 9 shillings per ton and one case is cited of 60 tons being sold at 7 shillings per ton. In 1860 the average price was about $13 per ton. From 1874-79 the price dropped from $16 to $13 and maintained an average of $12 until 1888 when there was a further decrease in price until the beginning of the Great War; the actual annual price since 1886 will be found in Table I.

Freight rates on grindstones by schooner, in 1830, to Boston were about $3.50 per ton.

Table I shows the production of grindstones, pulpstones, and sharpening stones in Canada since 1886. Table II shows the exports and imports for the same period.

TABLE I

Grindstones, Pulpstones, and Sharpening Stones Produced in Canada since 1886

Year	Grindstones				Total		Average value per ton	Pulpstones (a)		Sharpening stones		Polishing grit		Total abrasive materials	
	Nova Scotia		New Brunswick												
	Tons	Value	Tons	Value	Tons	Value		Tons	Value	Tons	Value	Tons	Value	Tons	Value
		$		$		$	$		$		$		$		$
1886	1,765	24,050	2,255	22,495	4,020	46,545	11·58	....	....	....	....	....	....	4,020	46,545
1887	1,710	25,020	3,582	38,988	5,292	64,008	12·10	....	....	....	....	....	....	5,292	64,008
1888	1,971	20,400	3,793	30,729	5,764	51,129	8·87	....	....	....	....	....	....	5,764	51,129
1889	712	7,128	2,692	23,735	3,404	30,863	9·07	....	....	....	....	....	....	3,404	30,863
1890	850	8,536	4,034	33,804	4,884	42,340	8·67	....	....	....	....	....	....	4,884	42,340
1891	2,161	21,600	2,499	22,787	4,660	44,387	9·53	....	....	....	....	....	....	4,660	44,387
1892	2,462	27,610	2,660	22,226	5,122	49,836	9·75	60	900	....	....	101	450	5,283	51,186
1893	2,112	21,000	2,368	15,979	4,480	36,979	8·25	120	1,400	....	....	....	....	4,600	38,379
1894	1,543	15,217	2,124	16,000	3,667	31,217	8·51	90	1,500	....	....	....	....	3,757	32,717
1895	1,400	14,000	1,995	16,652	3,395	30,652	8·93	80	1,280	....	....	....	....	3,475	31,932
1896	1,450	14,500	2,203	17,910	3,653	32,410	8·82	60	900	....	....	90	450	3,803	33,760
1897	1,407	17,500	3,065	23,240	4,472	40,740	9·11	100	1,600	....	....	....	....	4,572	42,340
1898	1,422	12,350	3,313	28,240	4,735	40,590	8·59	200	3,200	33	985	....	....	4,968	44,775
1899	1,377	10,300	2,735	24,965	4,112	35,265	8·58	375	7,000	24	1,000	....	....	4,511	43,265
1900	1,421	12,600	3,758	34,690	5,179	47,290	9·14	360	6,160	....	....	....	....	5,539	53,450
1901	358	3,200	3,676	34,075	4,034	37,275	9·25	547	8,415	....	....	....	....	4,581	45,690
1902	1,074	8,118	3,309	31,900	4,383	40,018	8·72	250	4,100	....	....	....	....	4,633	44,118
1903	1,337	9,562	4,086	36,900	5,423	46,462	8·51	115	1,840	....	....	....	....	5,538	48,302
1904	1,029	7,332	3,480	33,490	4,509	40,822	9·04	140	1,960	....	....	....	....	4,649	42,782
1905	1,020	10,200	4,440	49,700	5,460	59,900	10·95	68	1,875	12	600	....	....	5,540	62,375
1906	1,023	9,680	4,282	48,634	5,305	58,314	10·95	40	600	18	900	....	....	5,363	59,814
1907	551	4,480	4,833	54,396	5,384	58,876	10·91	....	....	30	1,500	....	....	5,414	60,376
1908	473	4,803	3,185	37,250	3,658	42,053	11·42	158	4,725	27	1,350	....	....	3,843	48,128
1909	312	3,204	3,690	43,170	4,002	46,374	11·59	240	6,640	33	1,650	....	....	4,275	54,664
1910	387	3,496	3,400	38,000	3,787	41,496	10·92	125	3,700	36	1,800	25	200	3,973	47,196
1911	380	3,382	3,952	43,450	4,332	46,832	10·83	160	3,960	54	2,000	20	150	4,566	52,942
1912	374	3,760	3,830	42,700	4,204	46,460	11·03	125	4,000	38	1,300	45	330	4,412	52,090
1913	350	4,900	3,658	40,400	4,008	45,300	11·32	100	3,400	74	2,425	20	200	4,202	51,325
1914	350	5,270	3,433	43,577	3,783	48,847	12·88	40	4,000	115	1,254	38	403	3,976	54,504
1915	285	5,300	1,994	26,667	2,279	31,967	13·93	....	....	281	3,615	20	186	2,580	35,768
1916	273	5,800	2,959	44,175	3,232	49,975	15·42	....	....	224	2,614	22	193	3,478	52,782
1917	375	9,875	1,794	28,827	2,169	38,702	17·88	47	2,750	307	4,302	....	....	2,563	45,754
1918	256	8,000	2,550	62,745	2,806	70,745	24·32	180	8,400	56	3,500	30	360	3,072	83,005
1919	283	9,000	1,648	47,344	1,931	56,344	28·85	14	420	45	3,392	30	360	2,020	60,516
1920	211	8,440	2,051	65,679	2,262	74,119	32·75	125	10,000	56	3,987	1	30	2,444	88,136
1921	183	6,990	881	33,647	1,064	40,637	38·20	200	22,000	17	1,430	....	....	1,281	64,067
1922	102	3,692	735	26,600	837	30,292	36·20	150	12,000	18	1,450	....	....	1,005	43,742
1923	254	7,906	1,463	43,577	1,717	51,483	30·00	260	25,100	35	3,500	....	....	2,012	80,083
1924	338	12,525	1,693	56,586	2,031	69,111	34·00	624 (b)	58,113	36	3,600	....	....	2,691	130,824
1925	439	16,723	1,296	45,061	1,735	61,784	35·60	781 (b)	57,781	46	4,600	....	....	2,562	124,165
1926	455	18,016	1,202	43,850	1,657	61,866	37·3	936 (b)	72,206	27	2,700	....	....	2,620	136,772
Total...	36,235	445,465	116,596	1,474,840	152,831	1,920,305	12·56	6,870	341,925	1,642	55,454	442	3,312	161,825	2,320,996

(a) All from New Brunswick.
(b) 200 tons during 1924 from Vancouver island, B.C., valued at approximately $19,000, and 480 tons valued at approximately $27,800 in 1925.

TABLE II

Canadian Exports and Imports

Year	Exports	Imports	
	Grindstones (*a*)	Grindstones and pulpstones	Burrstones (*b*)
	$	$	$
1886	24,185	12,803	4,062
1887	28,769	14,815	3,545
1888	28,176	18,263	4,753
1889	29,982	25,564	5,465
1890	18,564	20,569	2,506
1891	28,433	16,991	2,089
1892	23,567	19,761	1,464
1893	21,672	20,987	3,552
1894	12,579	24,426	3,029
1895	16,723	22,834	2,172
1896	19,139	26,561	2,049
1897	18,807	25,547	1,827
1898	25,588	22,217	1,813
1899	23,288	27,476	1,759
1900	42,128	34,382	1,546
1901	29,130	39,068	5,762
1902	24,489	40,838	2,559
1903	27,659	53,388	586
1904	35,612	46,039	35
1905	24,868	49,747	2,607
1906	31,978	59,627	2,661
1907	32,534	40,780	245
1908	19,721	65,125	3,396
1909	13,942	56,692	1,141
1910	23,502	71,394	854
1911	29,206	123,356	1,642
1912	26,535	112,020	1,409
1913	54,867	145,247	1,784
1914	24,407	98,872	16
1915	36,234	79,391	314
1916	44,942	122,291	648
1917	31,304	185,607	910
1918	47,148	297,287	1,571
1919	38,682	281,066	3,421
1920	41,705	312,672	1,655
1921	27,601	448,055	4,844
1922	17,018	319,941	910
1923	38,291	482,340	6,908
1924	50,710	593,670	791
1925	62,223	661,352	584
1926	75,374	828,250	450

(*a*) Including stone for the manufacture of grindstones.
(*b*) Burrstones in blocks, rough or unmanufactured, not bound up or prepared by binding into millstones.

The following are the Tariff Duties established in 1922.

Import duties into Canada—

	General	Intermediate	Preferential
Grindstones and pulpstones not less than 36″ in diameter	15 p.c.	12½ p.c.	10 p.c.
Grindstones mounted or n.o.p.	25 p.c.	22½ p.c.	

Import duties into the United States—

Grindstones and pulpstones finished or unfinished $1.75 per ton.

PRINCIPAL GRINDSTONE AREAS IN CANADA

NEW BRUNSWICK

Albert County

Mary Point and Grindstone Island. Between the years 1800 and 1850 the grindstone industry flourished in the vicinity of Grindstone island. In 1830 the island was rented for a period of years for £30 per year, but no stones appear to have been produced here since 1850.

The Mary Point sandstone beds strike almost due east and west and dip 30 degrees to the south. The whole series consists of different coloured sandstones of variable bedding, interlaminated with shales and cut by cross-jointing and irregular fracturing. In the southwest part of the area a red stone occurs but false-bedding and many concretions render it useless. Eastward the stone becomes grey in colour; it is about 200 feet thick and rests on an underlying bed of shale.[1] The best stone seems to occur near the shale, and massive beds of good olive-grey stone from 2 to 6 feet thick were worked.[2] Immediately opposite Grindstone island, beds of laminated, red and grey stone are again seen, and farther around in the mouth of Shepody bay the sandstones are thin-bedded and soon disappear beneath the drift.

The stone used for grindstones is a brownish grey colour and is an even-textured, medium fine grit with an argillaceous cement bond. There are also beds of a coarser grit similar to the Rockport stone.

Quarries have been opened up at Mary point for over half a mile along the coast. The quarries of Grindstone island are situated on the north shore and are an extension of the same beds as those worked at Mary point.

Although all the easily accessible stone along the shore has been removed, a cliff about 50 feet high, a short distance inland along the strike of the old quarries opposite Grindstone island, affords a good working face.

Westmorland County

A great number of quarries have been opened up in the Millstone Grits of Dorchester and Sackville districts, as far north as Upper Dover, 15 miles up the Petitcodiac river, and south on the peninsula between this river and the Memramcook; on the southern part of Rockport peninsula, and up the north shore of the Cumberland basin as far as Wood Point. For the last few years no grindstones have been made at any of these places, except at a new quarry opened recently at Rockland. Information concerning the principal districts is briefly reviewed below.

Dorchester Area

Boudreau and Fort Folly. Between 1835 and 1885 a large number of quarries were opened up and operated in the southern part of the peninsula between Petitcodiac and Memramcook rivers. The grindstones were mostly shipped to the United States for file and spring grinding purposes. Most of the quarries are at a considerable elevation above the river although there are many scattered workings along the face of the bluffs. The lowest

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. 203, p. 52 (1914).
[2] Geol. Surv., Canada, Rept. 661, Min. Res. of New Brunswick (1898).

bed, which is 25 feet below the surface, is about 12 feet thick, contains numerous minor bedding-planes, and irregular horizontal cracks, causing a large proportion of waste material. The stone is somewhat fine-grained and of a brownish to blue-grey colour. The Boudreau quarries have been abandoned for 40 years.

Beaumont. This quarry which is south of the old Boudreau quarries and at a much lower elevation, was opened up in 1899 by Mr. A. D. Richards of Fort Folly, who operated it for six years. It was worked by Mr. F. Dobson for the Dorchester Stone Works, Ltd., from 1909 until it was closed down in 1919. About 730 tons of grindstones, mostly of large size suitable for spring and file grinding, and 1,050 tons of pulpstones were shipped.

The workings are not large but at one point there is a face of 50 feet. There are three beds of solid blue-grey sandstone, 6, 7, and 8 feet thick respectively, overlain by about 30 feet of overburden and badly shattered stone.[1] The grit consists of medium-grained, rounded quartz fragments bonded by clay with a small amount of calcium and magnesium carbonates.

There is a steam plant on the property as well as a lathe, hoist, pump, and drills.

Rockland. Work was started in 1923 by Mr. F. Dobson for the Read Stone Company, on a deposit of medium-grained, yellow-grey sandstone on the top of the hill north of the Beaumont quarries. The beds are about 5 feet thick and are a continuation of the ridge of the old Caledonia quarries. Several pulpstones and grindstones have been shipped for experimental purposes.

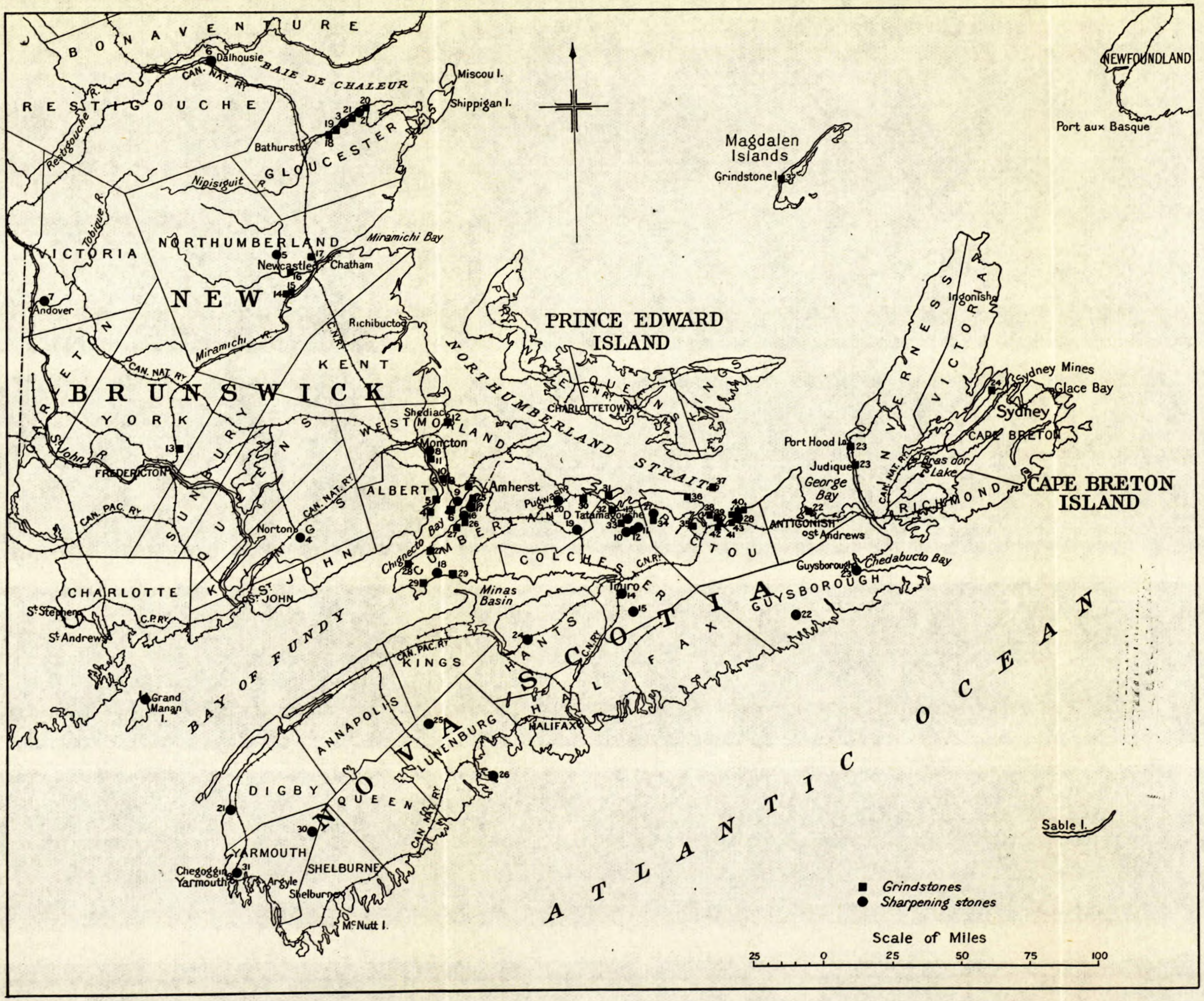
Sackville Area

Rockport Peninsula. Grindstones have been produced from the Millstone Grits on both shores of the peninsula, from 4 miles north of cape Maringouin on the west to Peck cove, 3 miles up the east coast. Operations were started at Rockport (then called North Joggins) in 1815. In the earlier days the stones were cut by hand from reefs, which were covered by high tide. Later two steam plants were erected on the southern shores at Rockport and Ward point. These quarries were worked for many years by the Read Company under contracts with Messrs. Tower, Ward, Seaman, and others. Most of the stones cut since 1890 were shipped in a crude form to the plant at Wood Point for finishing.

Wood Point. The sandstone reefs along the coast in the vicinity of Wood Point have been worked for many years, at first mainly for building stones, although prior to 1880 small tonnages of grindstones were made. After the quarries were taken over from the Atlantic Brownstone Company in 1896 by the Read Company, about 200 or 300 tons were produced annually for the next ten years. However, during the next decade, the annual output was increased to 800 to 1,000 tons. No grindstones were produced after 1918.

In the main quarry, which is about 100 yards back from the shore, massive beds 4 to 10 feet thick overlain by 20 feet of overburden have been exposed to a depth of 50 feet. The quarry is about 150 feet across

[1]Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. 203, p. 58 (1914).



Numbers on map correspond to numbers listed in Tables III and XI.

Figure 1. Grindstone and sharpening-stone localities in New Brunswick and Nova Scotia

and is almost continuous with a line of quarries extending along the coast. The sandstone is of a purple tinge when freshly quarried but rapidly turns to a reddish brown colour. The stone from the lower beds is harder than the upper and makes the best grindstones.

The stone is coarse-grained and is composed of quartz, feldspar, and a little mica, as well as greenish, decomposed volcanic rock matter. The cementing material, which is argillaceous, is not abundant; the porosity is, therefore, high and the stone breaks down under freezing.[1]

The quarry was well equipped for dressing the grindstones and also handled stones from Rockport. The plant has been partly dismantled.

Shediac Area

Scadouc River. In the Millstone Grits about 5 miles south of Shediac there are some old extensive quarries which were first opened up in 1850. Most of the beds are quite thick, the lower being of finer grit than the upper. The stone is composed of angular quartz fragments, which vary greatly in size, and considerable amounts of decomposed feldspar. The cementing material is clay with a small amount of carbonate of lime.[2] The quarries were worked for building material; and a few grindstones were also made, but they were not satisfactory.

A few pulpstones are said to have been made from the lower beds of E. G. Smith's quarry a short distance to the north. The stone is readily worked when green and seasons remarkably well. Mr. W. B. Deacon is said to have also made a few grindstones from stone in this area.

Northumberland County

Grindstones have been produced since 1870 at various points along the Miramichi river in the vicinity of Newcastle. The Read Stone Company operated over twenty different quarries in this area. However, with the exception of the quarries mentioned below, operations ceased when Ohio grindstones were placed on the New England markets.

Derby Parish

Miramichi Quarry Company, Quarryville. Sandstones have been extensively quarried on both banks of the Indiantown brook, a tributary of the Southwest Miramichi river, 8 miles southwest of Newcastle. The quarry was first opened up in 1897 for building stone by William Hood; and in 1905 the Miramichi Quarry Company was formed.

The sandstone which is olive-brown in colour, occurs in beds, from 1 foot to 10 feet thick, of medium-fine to medium-coarse grits; the beds are interlain by thin plant-bearing beds and shales. In places the remains of old trees which have been partly turned into coal are found; in other places hard, round nodules, caused by the local crystallization of carbonate of lime, occur. The jointing is not clearly marked; but in some beds it is curved, which causes undue waste. However, about 70 per cent of the product is marketable material.

The green stone weighs 140 to 150 pounds per cubic foot and loses about 3 pounds per cubic foot on seasoning. In the lowest beds, so far

[1] Parks, W. A., Mines Branch, Dept. of Mines, Canada, Rept. 203, p. 62 (1914).
[2] Op. cit., p. 47.

exposed, the quartz grains, which are for the most part angular, constitute about one-third of the rock and average $\frac{1}{3}$ mm. in diameter. Semi-decomposed feldspar grains are almost as numerous as the quartz grains.[1] The cementing material is argillaceous matter.

The Miramichi Quarry Company work the beds on the west bank of the brook. The quarry extends for about 400 feet and is worked back for about 200 feet, the total depth exposed from the top of the ridge to the lowest workings being approximately 100 feet. The quarry is worked in two sections, the upper 50 feet consisting of finer grits and thin beds which are mainly used for building stone. In the bottom of the lowest workings a good solid bed 10 feet thick is exposed, from which pulpstones are made.

The pulpstones which are produced in sizes up to the 5-foot magazine grinders have been used in numerous Canadian pulp mills and have apparently given satisfaction. The company has been a steady producer of pulpstones since 1905. Although the quarry furnishes the largest number of pulpstones in the Dominion, its main output is building stones. The grindstones are suitable for axe and coarse tool grinding, but only a few hundred have been made, mainly between 1918 and 1920.

The company has an up-to-date plant for the cutting and finishing of grindstones and pulpstones.

The Read Stone Company, Quarryville. This quarry is situated on the east side of Indiantown brook, directly opposite the workings of the Miramichi Company. The quarry was opened over 40 years ago for building stone; and after being closed for some time was re-opened in 1916 by the Read Stone Company and worked, under the management of Mr. Holt, until 1922.

The beds are an easterly continuation of those of the Miramichi Company, described above, but the top beds of the latter appear to be missing. The beds are not so thick and are more broken up than those of the neighbouring quarry, consequently there are only a few places where blocks large enough for grindstones or pulpstones can be quarried.

The texture and colour of the stone is very similar to that of the Miramichi quarry but there is less variety of grits.

The quarry has been worked in steps exposing a face about 40 feet high. A grab dredging machine was used to remove the overburden and loose drift, and the stones were dressed in the usual cutting and finishing plant. The plant is now partly dismantled.

During the period of operations several hundred tons of grindstones and pulpstones were made.

Newcastle Parish

French Fort or Fish Quarries, Newcastle. Extensive beds of olive-green sandstone occur on the east bank of a steep ravine about 2 miles northeast of Newcastle. Quarrying operations, which were first started in 1885, by Mr. C. E. Fish, have exposed rock faces up to 50 feet high in the upper part of the ravine for a distance of about a quarter of a mile, and outcrops have been traced for over 3 miles. The lower beds show the sandstone strata to be over 120 feet in thickness. The main beds which have been opened up in the upper part of the ravine are irregular and range in thickness from a few inches to about 10 feet; the thickest, which also contain

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. 203, pp. 28-33 (1914).

the coarsest grit, being at the bottom. Between the beds are seams of clay, vegetable matter, and sand, and in many places within the beds there are concretions or "bulls" and pockets of softer material. The main joints which are well developed strike east and west and are from 1 to 10 feet apart. The upper 30 feet is mostly overburden and very thin broken beds, but towards the northeast where the most of the work has been done, there is less thin stone on top, the overburden being about 7 feet thick. The first 25 feet of the beds consists of olive-green stone suitable for building purposes; underlying this is 30 to 40 feet of grey stone, in beds 4 to 10 feet thick, which is suitable for grindstones and pulpstones.

For the first fifteen years about 130 tons of grindstones were made annually. Pulpstones were first produced in 1891, the last shipment being in 1903. The total output of the latter was about 1,700 tons.

Gloucester County

Chaleur Bay Area

Grindstone quarrying was first started on the south shore of Chaleur bay about 1844 by a Mr. Sutherland who later sold his property to Sprague, Soule, and Company of Boston. Read and Seaman bought and leased quarries here about 1855, and the Read Company has been continuously operating in this area ever since. A number of quarries were opened up along the coast for a distance of 10 to 15 miles, all of which are now idle except the Stonehaven quarry which is the largest in the Dominion. The Chaleur Bay district is noted for its production of good quality grindstones.

Dr. Parks[1] describes the stone on this area as follows:—

> The whole mass of the formation as exposed along the coast and as revealed by borings, consists of red and greenish shales, with bands of impure sandstone and occasional thin seams of coal. The thickness of the whole series is at least 700 feet. The formation dips southeast at a low angle—40 feet to the mile. The valuable layer appeared to be lenticular in habit, thinning out and re-appearing in the exposure along the shore, where its maximum thickness is 15 feet. A bore hole, $1\frac{3}{4}$ miles inland and southeast from Clifton, revealed the bed at a depth of 110 feet with a thickness of 31 feet.

The Hoodnett Quarries at New Bandon and Pokeshaw. The sandstones are 12 to 15 feet thick and since they extend into the bay can be worked only at low water. The old quarries were operated by Mr. A. A. Hoodnett in 1888, and by Foley and Company in 1891, after which they were abandoned. Only a few tons of small stones could be produced annually, as the beds are badly fractured. A bar lathe driven by water-power was used to dress the grindstones.

The Knowles Quarries, Clifton. The Clifton ledges, which were originally granted to Mr. W. R. Knowles in 1831, were first leased and worked by the Read Company between 1856 and 1880. From that time until they were abandoned in 1916 they were under the Knowles management and produced grindstones fairly continuously on a small scale.

The reef of blue freestone which is about 12 feet thick, is overlain by 30 feet of shales and underlain by clay beds and narrow coal seams to the water's edge, and extends inland a considerable distance from the shore. The sandstone beds occur at a height of 70 feet above sea-level and there is an available thickness of about 10 feet of stone suitable for grindstone manufacture.

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. 203, p. 24 (1914).

The output of these quarries during the early days of operation amounted to 500 to 1,000 tons of grindstones annually and later about 50 to 150 tons. A steam shovel was employed for removing the overburden, and steam-operated gang saws and lathes were used for cutting and finishing the grindstones.[1]

The Lombard Quarries, Clifton. Lombard quarry was worked many years ago on a large scale by Lombard and Company, Boston, Mass. The deposit consists of horizontal strata of grey sandstone, 12 feet thick, overlain by 40 feet of shales and clay.

Previous to the early eighties the annual output amounted to about 1,000 tons of grindstones, but during the decade previous to its shutting down in 1899 the output averaged only 300 tons annually. Grindstones from 1 to 7 feet in diameter were produced.

Grande-Anse. In 1900 most of the machinery from the Clifton quarry was moved to the Grande-Anse quarries, 10 miles farther east along the coast. The quarries were operated by Messrs. McGill and Company for Lombard and Company, until they were abandoned in 1905.

Exposures occur for about half a mile along the shore and form a cliff 15 to 25 feet above high water. The Grande-Anse stone is a deeper yellow than the Stonehaven or Clifton varieties. The material is fine-grained and easily worked. The average annual output of the Grande-Anse quarries was about 200 tons of grindstones.

New Bandon. In 1906, Lombard and Company moved the plant to New Bandon, 7 miles west of Grande-Anse, and re-opened a quarry formerly operated by the Read interests. A small output was maintained up to about 1912, but since that time the plant has been idle.

The Read Stone Company, Stonehaven. The Stonehaven quarries have been in continuous operation since 1863, when they were purchased by the Read Stone Company from Messrs. Sprague, Soule and Company, of Boston, who first opened up the area in 1844. The bulk of the Canadian grindstone production for the last thirty years has come from the main Stonehaven quarry.

The overburden consists of about 40 feet of chocolate-brown shales and 10 feet of hard, broken calcareous sandstone. About 10 feet of the grindstone beds are above high tide. The sandstone is medium- to fine-grained, blue-grey in colour, and of even texture. The beds are almost horizontal, dipping to the southeast at a low angle. The valuable stone at present determined, is 10 feet thick at the western end, 25 feet at the centre, and about 20 feet at the eastern end. The individual beds are 1 to 4 feet thick. The main joints are well defined and vertical.

The quartz grains, which vary from one-third mm. in diameter to considerably less, are generally angular; they comprise from one-third to one-half the whole rock. Some decomposed feldspar and minute scattered flakes of mica with a considerable amount of green-blue chloritic matter are also in evidence. The grains are closely cemented by argillaceous matter which constitutes about one-third of the stone.

Several quarries, extending about half a mile along the shore, have been worked by the company. Owing to the heavy overburden the main quarry was first opened up on the beach. After all the available stone above high water had been removed, operations were carried on at low

[1] Geol. Surv., Canada, Rept. 971, p. 87 (1907).

water and the blocks floated in by pontoons at high tide; later a large dam was built out in the bay. In all about one mile of dams have been constructed of timber rip-rapped with waste rock, and made water-tight by the use of puddled clay.

The quarry is operated for four or five months in the year, but is flooded in winter in order to preserve the stone from the frost. The quarry has been worked in a series of steps to a depth of from 15 to 25 feet below the water-level (*see* Plates I, II, III A, and IV B).

The rock is quarried to the required size by the use of steam channellers, drills, powder, and wedges, and the blocks are hoisted to the dump where they are roughly shaped by the stone cutters before being dressed and finished in the plant. (*See* description under methods of dressing stones.)

Grindstones are made in all sizes from 8 inches to 7 feet in diameter and 1- to 14-inch face. The smaller stones up to 30 inches in diameter are used by farmers and in lumbering operations. The 30- to 50-inch stones are used in machine shops. The large stones, for which there is now the greater demand are mainly used for grinding edge tools, files, machine knives, saws, scythes, skates, and for granite-cutting. Previous to the introduction of artificial grinding wheels the large stones were also extensively employed for agricultural implement and axe grinding.

Records published since 1886 show an output of grindstones valued at one million dollars, which is probably less than half the total.

A number of scythestones are also produced annually from a neighbouring ledge of very fine-grained, blue stone.

NOVA SCOTIA

Cumberland County

Lower Cove. The sandstones at Lower Cove near Joggins and those a few miles up the coast at Minudie were the first to be worked for grindstones in Canada, having been operated by the French about 1750. About the middle of the nineteenth century, there was for many years a very thriving industry, and, at that time, these quarries, under the management of Read, Seaman and Company, produced from 4,000 to 5,000 tons annually. The regime of the Seaman family was brought to a close about 1898 when Rufus Seaman Hibbard, grandson of Amos Seaman, sold the Lower Cove property to Harry Heustis of Providence, who formed the Atlantic Grindstone Company. At the time of closing down in 1906 the company was re-organized as the Atlantic Grindstone, Coal, and Railway Company, under which name it is known at present.

The old mill buildings, which were first erected in 1860 and enlarged in 1874, still contain the remains of the elaborate turning machinery, consisting of a Corliss engine, saws, tables, gang saws, and boilers. The mill had a capacity of 10,000 to 15,000 tons of grindstones and scythestones annually.

The cessation of operations was mainly due to increasing difficulties of extraction, in that the beds pitch steeply into the ground so that mining costs became very heavy; another troublesome factor was the presence of "bulls" or hard nodules which caused many an otherwise good stone to be discarded.

The sandstones are light grey in colour and of medium coarse to fine grit. The beds dip steeply to the south with an east and west strike and range in thickness from a few inches to about 5 feet. They are, however, badly broken in a number of places and contain concretions or hard nodules.

The quarry was started at the water's edge and extended inland until it reached a distance of about a quarter of a mile from the shore and a depth of about 60 feet. Tunnelling operations were also employed. Grindstones of all sizes, from 5 inches to 7 feet in diameter, and varying in width from $\frac{3}{4}$ inch to 15 inches, were made from five different grits, the coarsest being used for grinding axes, the medium for scythes and hay-knives, and the finest for cutlery.[1]

Previous to 1886 a large number of scythestones were made, most of which were sold locally. Oilstones were produced from a tidewater quarry at Mill cove about 5 miles to the north.

A considerable number of grindstones have been made at numerous places along the Cumberland coast of Chignecto bay, as far south as Apple River. At the latter place the formation consists of red and grey sandstones overlain by varying thicknesses of conglomerates. These quarries were last worked about 1901.

Pictou County

Between 1840 and 1865 the firm of Read and Seaman tested out and operated many sandstone deposits in the Millstone Grit and Permo-Carboniferous formations in the vicinity of Pictou and Merigomish harbours. These deposits include the old quarries at the extreme west end of Big Caribou island; the southwestern and eastern shores of Pictou island, the west end of Roy island; several quarries on the northwest and northern shores of Merigomish island; and Quarry island. About 1865, the business was taken over by Robert McNeil, who confined operations to quarries bordering on Merigomish harbour near New Glasgow and sold the output to Read, Stevenson Company. Between 1870 and 1879 a few grindstones were also made, intermittently, by Alex. Robertson at Roy island, from previously worked ledges on the north of Merigomish island, and on the mainland near McDonald gut.

The Millstone Grits have been worked in the vicinity of French river, at Oldings point one mile north of Quarry island; in the Middle Carboniferous at Granton, in the vicinity of Beggs gut, Pictou harbour, 7 miles northwest of New Glasgow, as well as from various points in the vicinity of Chance harbour.

In 1890 some of the Merigomish Harbour quarries passed into the hands of James Stevenson, a partner of the Read Company. The business is now carried on by the Mic Mac Grindstone Company whose main deposit is east of Woodburn. This is the only company in Nova Scotia producing grindstones to any extent, although a few stones are still obtained annually from Quarry island.

Merigomish Harbour

Mic Mac Grindstone Company. The quarry, operated by the Mic Mac Company, is situated at the east end of a small peninsula between Blackhall and Pine Tree guts, east of Woodburn. The sandstone reef was first

[1] Geol. Surv., Canada, Rept. 971, p. 86 (1907)

worked over 50 years ago. The quarry was taken over in 1913 by the present company from the Mohawk Grindstone Company, and to date has produced about 200 to 300 tons of grindstones annually. It is the second largest grindstone-producing quarry in Canada.

There is about 20 feet of overburden underlain by 8 feet of thin, flat beds of sandstone followed by 12 feet of beds, each 2 to 5 feet thick. The stone is soft, of medium fine grit, the top beds being a yellow-brown colour and the lower are grey. The formation dips at a low angle to the north. There is considerable waste from the thin beds, since the sale of small stones is almost negligible. The crude stone from the thin beds was at one time shipped to the United States to be made into scythestones, but it was found that on account of its brittleness, it was only suitable for the large oval-shaped stones.

The stone is quarried by means of wedges and black powder. The powder is loaded into a series of long holes and fired electrically. Derricks remove the blocks, which are roughly shaped by hand, and then finished by lathe. Grindstones 4 to 6 feet in diameter are produced. (*See* Plate III B).

The stones are shipped from a siding one mile west of the quarry. There is a local market for about 20 tons of small stones annually, and the remainder which amounts to between 200 and 300 tons per year is shipped to the United States for saw and machine knife grinding.

The president of the company is Mr. P. B. Stanley of the Stanley Rule and Metal Company, and the quarry is managed by Mr. J. Munroe, a grandson of the original owner.

Quarry Island. Grindstones have been made from the sandstones of Quarry island for the last sixty years. This island which is one mile north of the Mic Mac quarry is connected with the mainland by road. The quarries were operated for a great number of years by Messrs. Robert McNeil and James Stevenson, although for the past twelve years the reefs on the southeast shore of the island have been worked by Mr. J. Sutherland.

About 15 to 20 feet of greenish slate is underlain by about 30 feet of sandstone beds, 3 to 8 feet thick, which dip flatly to the north and into the bank, so that only the shore exposures can be conveniently worked. The sandstone is yellowish brown in colour and is very similar, both in texture and appearance, to the upper beds of the Mic Mac quarry but is slightly softer. The material is said to produce grindstones of good quality for certain purposes.

Records between 1870 and 1914 show an average annual production of 200 to 300 tons of grindstones from various quarries on the island and the immediate vicinity. The annual output for the last decade has been 15 to 20 tons of small stones, which are disposed of locally.

The old plant and machinery installed in 1891 has fallen into disuse, and only a few stones are now shaped by hand, the greater number being sent to the Mic Mac Company plant for finishing.

Colchester County

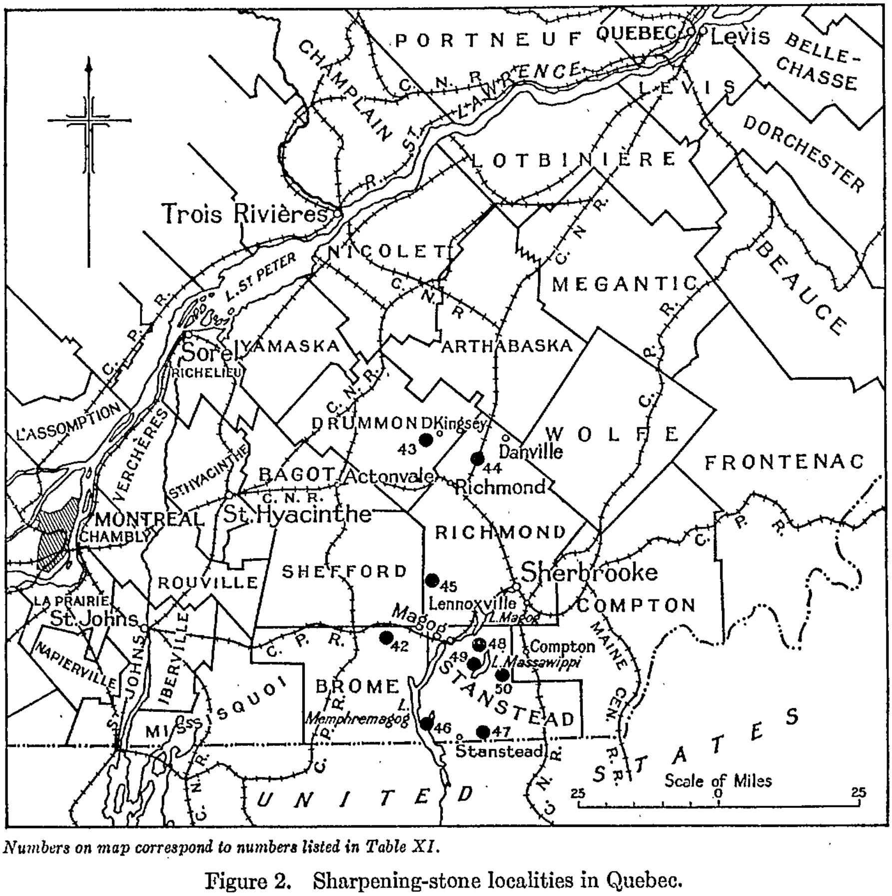
On Yellow brook, about one mile south of Waugh River on the Tatamagouche river, fine and medium-coarse sandstone in horizontal beds, 2 to 3 feet thick, are exposed. Two small quarries have been recently opened up by Logan Murphy on the hill-side near the road, exposing faces 8 and 10 feet high. A few tons of stones, 1½ to 3 feet in diameter, are made by hand and sold locally. The small stones weigh about 70 pounds and the larger ones about 350 pounds.

In the bed of the brook, below Murphy's farm, fine-grained grey sandstones are exposed from which a few scythestones for local use are made.

About 25 years ago a few stones were made by Tom Simpson from the grey sandstones of the French river, west of Tatamagouche, but the quality was poor.

ONTARIO AND QUEBEC

Grindstones have not been produced in Ontario for over half a century, and even at that time the output was insignificant when compared with that of the Maritime Provinces.

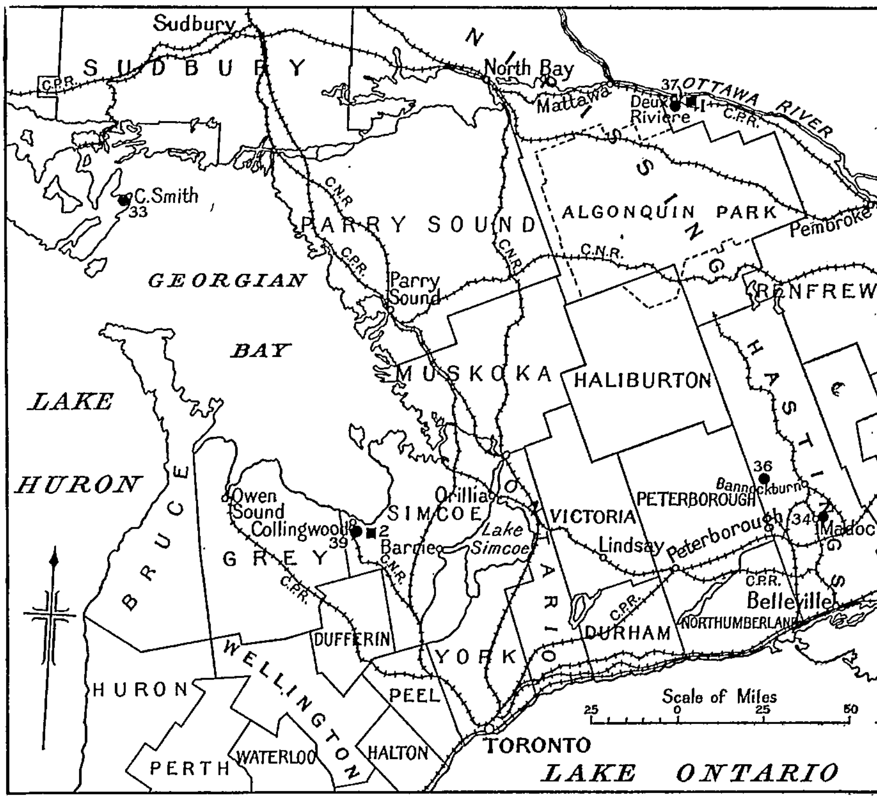


Numbers on map correspond to numbers listed in Table XI.

Figure 2. Sharpening-stone localities in Quebec.

The only recorded production from Quebec is from Grindstone island, the centre island of the Magdalen group, due north of Prince Edward island, where many years ago the grey sandstones, on the east side of the island, were worked by the French inhabitants.

Although sandstone deposits are common in both provinces there is not likely to be any production of grindstones from these provinces, on account of the unsuitability of the stone.



■ *Grindstones*
● *Sharpening stones*

Numbers on map correspond to numbers listed in Table XI.

Figure 3. Grindstone and sharpening-stone localities in Ontario.

ONTARIO

About fifty or sixty years ago grindstones and scythestones were made in Dufferin and Simcoe counties from sandstones of basal Silurian age. The formation has been traced from Colpoy bay, on the southwest side of Georgian bay, through Grey county to the shores of lake Ontario, near Port Credit, and thence west doubling around the head of the lake near Dundas, and along the south shore east to Niagara river.[1]

The sandstone at the top of the formation is a grey colour and is known as the grey band. Grindstones were produced from this band in

[1] Min. Res. of Ontario, Rept. of the Royal Commission, p. 43 (1890).

the vicinity of Orangeville and northwards along the east side of Dufferin county, where in places the formation is about 20 feet thick. A few grindstones were also obtained a few miles south of Collingwood in Nottawasaga township, Simcoe county. The stones were made roughly by hand and sold locally.[1]

Renfrew County

Clara Township

Deux Rivières. Between 1870 and 1875, grindstones, which were stated to be of excellent quality, were made from the sandstone which borders the Ottawa river some two miles west of Deux Rivières portage. The beds are thin and are suitable for the production of small stones or scythestones.

The following is an account by A. E. Barlow[2]:—

> Some of the material contained in portions of the beds of coarse sandstone and grit, found near the base of several of the Palæozoic outliers, would probably be suitable for the purpose of making grindstones. A quarry was opened many years ago on one of these arenaceous beds exposed above Deux Rivières which furnished some excellent grindstones. Where the layers are not thick enough for this purpose, they would furnish whetstones of very fair quality. Where too hard and compact, these stones answer only for a short time, when first used, soon becoming too much polished.
>
> Portions of the very fine-grained, banded slates and greywackes, too frequently met with throughout the northern and northeastern part of the district, may probably afford material suitable for hones and whetstones.

[1] Geol. Surv., Canada, Rept. of Progress, 1863, pp. 316-317, also p. 809.
[2] Barlow, A. E.: Geol. Surv., Canada, Ann. Rept., vol. X, pt. I, p. 157 (1897).

TABLE III

Grindstone Localities in Canada

Ref. No.	County or district	Location	Description	Date when quarried	Approximate tonnage produced	References	Remarks
			ONTARIO				
1	Renfrew........	Clara tp., Deux Rivières.	Thin-bedded sandstones.	1870-5...........	A few hundred tons	*See* Report.........	Small grindstones and scythestones of good quality.
2	Simcoe.........	Nottawasaga tp., con. X, lot 24.	Grey sandstones of basal Silurian age.	1860-70.........	A few hundred tons.	*See* Report.........	
			QUEBEC				
3	Gulf of St. Lawrence.	Magdalen islands, Grindstone island.	Grey sandstones....	About 1830......	Small..............	N.S. Inst. Sci., Vol. VIII, p. 45 (1904).	Made by French inhabitants for local use.
			NEW BRUNSWICK				
	Chignecto Bay Area						
4	Albert..........	Grindstone island and Mary point.	Different coloured sandstones of variable bedding, interlaminated with shales.	About 1820-70..	Very considerable. No records.	*See* Report.........	Numerous quarries opened up on the island, also on coast near Mary point for a continuous line of over ½ mile. All shore ledges worked out, but good cliffs of sandstone inland.
5	"	Hopewell cape......	Olive-green, coarse to medium grit sandstones	1856-64..........	A few hundred tons	*See* Report.........	Worked by Seaman-Read for a few years. Shore deposits exhausted. Good exposures inland, quarry west of Curryville has 50-foot face.

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TABLE III

Grindstone Localities in Canada—Continued

Ref. No.	County or district	Location	Description	Date when quarried	Approximate tonnage produced	References	Remarks
			NEW BRUNSWICK—*Continued*				
6	Westmorland...	Sackville parish, Rockport peninsula, Rockport, cape Maringouin, Slacks cove, Ward point.	Yellow-brown medium grit sandstones. Beds 5 feet thick dip 45 degrees west, but usually much broken.	1815-1912.......	About 10,000 tons since 1886.	*See* Report.........	Several quarries worked by Seaman - Read under contracts. Stones in later years shipped crude to Wood Point for finishing. Three small steam plants.
7	"	Wood Point, 4 miles south of Sackville.	Olive-grey to brown, medium to coarse grits.	About 1870-1918.	About 12,000 tons since 1890.	*See* Report.........	Extensive quarrying by Read Company. Large steam plant now partly dismantled.
8	"	Dorchester parish, Boudreau, Fort Folly point.	Fine-grained, grey-brown sandstones, somewhat hard, numerous joint-planes and cracks. Beds up to 12 feet thick.	1856 and 1864 to about 1875.	Considerable. No records.	*See* Report.........	Majority of quarries high above river. Much waste material due to cracks and joint-planes.
9	"	Beaumont..........	Blue-grey, medium grit beds of 6, 7 and 8 feet thick, overlain by 20 feet of overburden and shattered beds.	1899-1919.......	About 730 tons of grindstones and 1,050 tons pulpstones.	*See* Report.........	Old steam plant and equipment.
10	"	Rockland..........	Yellow-grey medium grit beds, 5 feet thick.	1860 and 1923 to date.	A few pulpstones and grindstones for trial.	*See* Report.........	Old quarry recently re-opened by Read Company on top of hill between Rockland and Boudreau.
11	"	Steeve creek, Upper Dover.	Thin, flat beds of soft, fine-grained, brown sandstone, and thin beds of very fine, hard, blue stone.	1880-90.........	Small stones and scythestones.	....	Operated by Steeve Bros. Hand-made stones trammed to scows on river shore ¼ mile to west. Blue stone, good for scythestones.

	Northumberland Strait—						
12	Westmorland...	Scadouc river, Shediac.	Medium-grained, olive-green sandstones.	1850-55 and 1898-9.	A few tons; 55 tons at latter date.	Mines Branch, Rept. 203, pp. 45-8 (1914).	Grit not suitable for grindstones.
	Central N.B.						
13	York..........	Newcastle river, Penniac and Nashwaak, 12 miles north of Fredericton.	Grey sandstones....	1840............	Very few...........	Geol. Surv. of New Brunswick, p. 99 (1842).	The quality of stone stated to be good for grindstones.
	Miramichi Area						
14	Northumberland.	Quarryville, Miramichi Quarry Company.	Olive-brown, medium to coarse grits Beds extensive, 1 to 10 feet thick.	About 1905 to date. Previously for building stone.	About 30 tons of grindstones and 1,800 tons of pulpstones.	*See* Report.........	Extensive quarry worked in two ridges of different grits over a total height of 100 feet. Largest Canadian producer of pulpstones. Modern stone cutting and finishing equipment. Connected by short spur line to railway.
15	"	Quarryville, Read Stone Company.	Olive-brown, medium to coarse grits. Beds extensive, 1 to 10 feet thick.	During the war and in 1922. Previously for building stone.	About 250 tons of grindstones and 200 tons of pulpstones.	*See* Report.........	Easterly extension of above. Grit finer and beds more broken.
16	"	Whitney, Adam Hill quarry.	Non-continuous beds of well-jointed, yellow-green sandstone.	1909-11.........	Very few grindstones, mostly building stone.	Mines Branch, Rept. 203, p. 33 (1914).	Beds contain mica, bulls and coarse streaks. Not suitable for grindstones.
17	"	Newcastle, French Fort (Fish) quarry	Extensive beds of olive-grey sandstone of variable grit.	1885-1903.......	About 2,000 tons of grindstones and 1,700 tons of pulpstones.	*See* Report.........	Quarter mile of quarry exposing about 50 feet of beds of variable thickness and colour.
	Chaleur Bay Area						
18	Gloucester.....	Clifton, Knowles quarry.	Twelve feet of blue sandstone underlain by clay and slate.	1855-1916.......	4,000 tons since 1887.	*See* Report.........	Beds exposed along shore-line and extend inland.

TABLE III

Grindstone Localities in Canada—Continued

Ref. No.	County or district	Location	Description	Date when quarried	Approximate tonnage produced	References	Remarks
			NEW BRUNSWICK—*Concluded*				
19	Gloucester......	Clifton, Lombard quarry.	Blue-grey, soft, medium grit sandstone overlain by 40 feet of shales.	1850-1901........	5,000 tons since 1886.	*See* Report..........	Grindstones 1 to 7 feet diameter. Good for machine shop and edge tools. Small plant.
20	"	Grand Anse, Lombard quarry.	Olive-grey, fine-grained sandstones. Exposed for ½ mile.	1902-12..........	2,000 tons...........	*See* Report..........	Plant moved from Clifton.
21	"	Stonehaven, Read Stone Company.	Uniform medium and fine grit blue sandstones in beds 1 to 4 feet overlain by 40 feet of shales	1844 to date.....	80,000 tons of grindstones since 1886 and 1,500 tons of scythestones.	*See* Report..........	Largest producer. Grindstones up to 7 feet in diameter. Quarries later worked by means of a dam below sea-level. Extensive and up-to-date plant. Stone excellent for edged tool grinding.
			NOVA SCOTIA				
22	Antigonish......	Monk head..........	Extensive exposures of yellow-brown sandstone.	About 1860-5....	Small..............	Mines Branch Rept. 203, p. 89 (1914).	Uniform beds up to 18 inches in thickness.
	Cape Breton						
23	Inverness.......	George bay (east shore) Port Hood, Judique.	Fine, grey and yellow sandstones.	About 1860-5....	A few hundred tons	Mines Branch Rept. 203, pp. 98-101 (1914).	These sandstones outcrop in the Coal Measures behind Judique. Stones were made for local use.
24	Cape Breton....	Boularderie island, Black Brook.	Fine, grey, homogeneous and non-calcareous sandstones, and blue sandstones.	About 1860-5....	About 100 tons......	Mines Branch Rept. 203, p. 91 (1914); also Geol. Surv. Can., p. 416 (1877).	These sandstones occur along the southeast shore of the island. Grindstones were also made from the blue-green sandstones of East Sydney.

	Chignecto Bay Area						
25	Cumberland....	Joggins area, Minudie.	Grey, medium grit sandstones.	About 1750-1800	Considerable.......	*See* Historical Report.	Several quarries worked by French. All hand-made stones.
26	"	Lower Cove........	Fine to coarse, greyish sandstones in beds up to 5 feet and exposed to depth of 75 feet.	1790-1906.......	Output in old days up to 4,000 tons per year. 25,000 tons since 1886.	*See* Report.........	Worked by Seaman-Read and was for many years largest producer of grindstones and scythestones. Two or three extensive quarries. Large plant now in ruins.
27	"	Sand cove, Sand River, Ragged Reef point.	Red and grey sandstones. In many places overlain by conglomerates.	1840-1901.......	Considerable.......	Geol. Surv., Can., vol. VI, pt. A, p. 62 (1895).	25 miles of shore-line between Ragged Reef and Apple River were worked intermittently by Seaman-Read and contractors.
28	"	Pudsey point and Apple River.	Grey sandstones interbedded with shales and overlain by thick conglomerate beds.	1840-1901.......	Considerable.......	Geol. Surv., Can., vol. VI, pt. A, p. 62 (1895).	
	Minas Channel						
29	Cumberland....	Greville bay, Spencer Island and Fox point.	Grey, fine-grained sandstones.	1836...........	Small..............	Geol. Surv., Nova Scotia, p. 113 (1836).	A few stones were made at various points between Spencer Island and Diligent River.
	North Shore						
30	Cumberland....	Wallace river, below Wallace bridge.	Grey, fine-grained sandstones.	....	Small..............	....	A few stones for local use many years ago.
31	"	Malagash, Gravois point.	Grey-blue, fine grit sandstones dipping 50 degrees north, overlain by red sandstone.	About 1860.....	Very small.........	Geol. Surv., Can., Mem. 121, p. 10 (1920).	A few grindstones were made from the exposed beds.
32	Colchester......	French river, west of Tatamagouche.	Grey sandstones....	1900...........	Very small.........	....	Stones were of poor quality.

TABLE III

Grindstone Localities in Canada—Concluded

Ref. No.	County or district	Location	Description	Date when quarried	Approximate tonnage produced	References	Remarks
			NOVA SCOTIA—*Concluded*				
33	Colchester......	Tatamagouche river, Waugh River, Yellow brook.	Two to three-foot beds of fine and medium grit sandstone.	1920 to date.....	A few tons annually.	*See* Report..........	A few small hand-made grindstones and scythestones are made by Logan Murphy.
34	Pictou..........	West Branch River John, Mine brook.	Thin beds of grey sandstone interlaminated with beds of soft brown stones are exposed for 1 mile along west shore. Dip 30 degrees N.	1895-1903........	A few grindstones but chiefly scythestones.	Geol. Surv., Can., vol. V, pt. P., p. 116 (1890).	Beds of the grey stone have been quarried for grindstones and scythestones by Dan Beckworth and Peter Holt.
35	"	Pictou harbour, Granton, Beggs gut.	Greenish grey, thickly bedded sandstones underlain by red and grey shales.	1840-74..........	Small...............	Geol. Surv., Can., vol. II, pt. P., p. 97 (1887).	A few stones quarried intermittently by R. E. Chambers.
36	"	West end of Caribou island.	Reddish grey and mottled crumbly sandstones and shales.	1845-55..........	A few hundred tons.	Geol. Surv., Can., vol. V, pt. P., p. 135 (1893).	Worked intermittently.
37	"	Pictou island, West point and Seal point	Fine grey and coarse rusty sandstones in thick flaggy beds full of plant remains. On east side grey-green sandstone, cliffs 20 feet high.	1860-87..........	Small...............	Trans. N.S. Inst. Sc., vol. VIII, pp. 80-3 (1894).	The best showings of the grey beds were quarried intermittently, mainly about 1885.
38	"	Between Pictou and Little harbours, McKenzie head and Roaring Bull point.	Grey sandstones....	1860............	Small...............	Geol. Surv., Can., vol. II, pt. P., p. 126 (1887).	

39	Pictou........	West end of Roy island.	Grey, false-bedded sandstones 10 feet thick; some of it defective; 20 feet overburden.	1840-74..........	Small..............	Geol. Surv., Can., vol. II, pt. P., p. 98 (1887).	Quarried intermittently from several places on the west end of the island.
40	"	West end and north shore of Merigomish island.	Thick and thin, crumbly, false-bedded layers of grey sandstone interstratified with shales and plants, 8 feet of good stone with 15 feet overburden at west end.	1860-88..........	Small..............	Geol. Surv., Can., vol. II, pt. P., p. 95 (1887).	Some suitable beds worked intermittently for grindstones. Used for saw and cutlery grinding.
41	"	Southeast end of Quarry island.	Yellow-brown, medium grit, soft sandstone overlain by greenish slates. Considerable overburden.	1856 to date.....	About 3,000 tons since 1870.	*S* Report..........	Formerly worked by Read, McNeil and Stevenson, with an annual output of 250 tons. For last decade by Sutherland with output of 20 tons annually.
42	"	Woodburn, Oldings point (Mic Mac Company).	Yellow-brown and grey sandstones, 20 feet thick.	Since 1865......	About 13,000 tons since 1913.	*See* Report..........	Worked by McNeil and Stevenson; since 1913 by Mic Mac Company. Now second largest producer.
43	"	French river, McDonald gut.	Shales and red sandstone containing grey bands. Thickness 10 to 15 feet.	1865-80..........	Small..............	Geol. Surv., Can., vol. II, pt. P., p. 91 (1887).	Quarried intermittently from thick, grey beds.

FOREIGN LOCALITIES

UNITED STATES

Grindstones were first produced from the state of Ohio almost a century ago when the early settlers of Cuyahoga county, in the vicinity of Berea on Rocky river, made stones to take the place of those imported from Canada. John Baldwin who was the pioneer of the industry started manufacturing stones in 1828, and in 1830 began shipping them to Canada. In 1833 he was the first producer on the continent to use a hand lathe for turning the rough stones, and from that date, the output increased annually. Although grindstones were also produced in West Virginia and Michigan, 85 per cent of the total output has been from Ohio.

Ohio

The Berea sandstones from which the grindstones are obtained occur throughout the state. The northern and western limits stretch easterly from the northeast corner of the state along and close to Lake Erie shores as far as Norwalk, 70 miles west of Cleveland, and thence south till they reach the Ohio river on the southern border of the state.

The sandstones in Washington county, are known as the Dunkard series and rank amongst the most important sources of grindstones. They are blue-grey to yellow in colour, are of loose, medium-fine grits, being slightly finer than the celebrated stones from Newcastle, England, which otherwise they resemble. They are principally used for grinding machine-knives, saws, and thin steel tools. In the southern area a large output of grindstones is maintained by four or five producing companies in the vicinity of Marietta on the north bank of the Ohio river.

Berea in Cuyahoga county, west of Cleveland, in the northern part of the state, is the centre of the grindstone industry. There are numerous quarries within a radius of 15 miles, the majority of which are now operated by the Cleveland Stone Company. The stone is yellow-grey in colour, of a coarse grit, and usually contains over 90 per cent silica. The principal quarries are at Amherst, Elyria, Constitution, West View, and Euclid, in Cuyahoga and Lorain counties. At present no grindstones are quarried at Berea, but raw material from many localities is sent there to be made up into grindstones.

The Amherst quarries are the largest that are at present being operated in the district. The stone is of a buff colour, friable, and soft. It is specked with iron, oxidized to limonite, which is loosely contained between the grains of quartz. The solid individual grindstone beds are about 8 feet thick with a total thickness of about 40 feet. The best stone occurs in huge lenses or "boulders" sometimes several hundred feet long and a hundred feet thick. The Constitution grit furnishes a medium light grey, friable stone, possessing a variety of textures. The Euclid stone is made from a very hard, fine-grained, blue grit. It occurs in beds of about 20 inches and is used mainly as whetstones, or as a polisher for removing scratches made by the ordinary grindstones, and for grinding shoulders of knives. Other sandstones which have been quarried in the past for grindstones are: the Independence grit which is coarse and sharp, used for spring and file grinding; the Massillon grit from Stark county is similar to the Independence; the Tippecanoe grit from Harrison county is fairly loose and hard and is used for grinding springs, files, and heavy forgings.

West Virginia

Grindstones are now produced only to a small extent from the southerly extension of the Ohio sandstones of the Dunkard series in the vicinity of St. Mary's. There are, however, many abandoned quarries on the south bank of the Ohio river. The sandstone occurs in blue and brown layers and in many places contains considerable mica.

Michigan

Grindstones are produced at Grindstone City and Port Austin in the Huron district, from fine-grained, uniform, blue-grey beds of sandstone containing numerous flakes of silvery mica. At one time the Huron grit was extensively used for grinding mowing-machine knives, cutlery, and tools requiring a fine edge.

GRINDSTONE PRODUCTION IN THE UNITED STATES

The following table shows the United States grindstone production since the war. These stones are produced by ten or twelve firms:—

TABLE IV

Grindstone Production in United States

Date	Short tons	Value
1918	56,554	$ 1,262,602
1919	40,755	993,959
1920	44,832	1,239,990
1921	16,310	477,259
1922	21,367	574,900
1923	37,384	1,008,899
1924	28,991	852,260
1925	28,970	864,637

BRITISH ISLES

The English grindstones and pulpstones have been quarried for several centuries, and are recognized as being among the best in the world.

VARIETIES AND OCCURRENCES[1]

In the trade the stones appear to be roughly divided into three classes, referred to as (a) Newcastle stones, (b) Derbyshire or Peak stones, and (c) Yorkshire stones. These designations, however, do not necessarily indicate the locality of origin of the stones.

Newcastle

The Newcastle grindstones are obtained from thick-bedded, light grey and yellowish sandstones of the Coal Measures at various localities near Newcastle-on-Tyne in the north of England. These stones are the most siliceous of the three classes. The rock is characterized by uniformity of texture, keenness of "bite," and compactness. The fine-grained varieties are in great demand for edge-tools and glass bevelling, for which latter purpose they are largely exported to America.

The principal producing centres are Springwell, Sheriff Hill, and Gateshead. Some of the largest and oldest quarries at Springwell, 3 miles from Newcastle, formerly owned by Mr. J. Elliot, were purchased during the latter part of 1924 by Messrs. Richard Kell & Co., Ltd. These

[1] Information mainly supplied by the courtesy of the Imperial Institute, London, England.

quarries are stated to be amongst the best in the country for grindstones and pulpstones. Grindstones from 1 foot to 6 feet or more in diameter are produced.

Derbyshire

Derbyshire or Peak stones, which are coarse sandstones, are largely used for pulpstones. They are obtained from the Millstone Grits, especially the Lower or Kinderscout Grit. However, grindstones suitable for heavy work, such as grinding locomotive and heavy textile machine parts, heavy edge-tools, etc., are made from the coarsest Derbyshire stones. The principal producing centres are Rowsley and Matlock.

Yorkshire

Yorkshire stones, typified by the Ackworth stone, generally have finer and sharper grits than the Derbyshire stones. They are usually light brown or buff, rather soft, fine-grained, thickly-bedded sandstones. The best stones are obtained from the top of the Middle Coal measures. The stones are used for grinding cutlery, saws, and fine-edged-tools.

The grindstones are chiefly quarried from near Leeds, Pontefract, Rotherham, Normanton, Wickersley, and Sheffield.

Analyses of three well-known Yorkshire sandstones used for grinding cutlery are given.

—	Silverwood	Brincliffe	Ackworth
	per cent	per cent	per cent
Silica	80·00	74·32	81·45
Alumina	10·86	12·77	8·61
Iron oxide	2·28	4·03	2·90
Titanium oxide	0·48	0·70	0·38
Lime	0·44	0·54	0·35
Magnesia	0·55	0·87	0·39
Potash and soda	2·55	2·70	3·08
Loss on ignition	2·84	4·07	2·84

Other Producing Centres

The Bilston quarries (Staffordshire) supply grindstones, scythestones, rubstones, and oilstones, but the finer grits are becoming scarcer. The Hollington and other stones are obtained from near Uttoxeter, Staffordshire. They are fine-grained, compact sandstones, of very sharp grit cemented by iron oxide. Three kinds of stone are quarried: red, white, and mottled. Although principally quarried for building stones, they are also used for grindstones.

The sandstone from Billings near Wigan, Lancashire, yields a stone which is largely used as a fine grindstone by cotton-machinery makers for spindles and fliers; it is also specially suitable for glass cutting, bevelling, and polishing.

Supplies of some of the stones which formerly enjoyed a wide reputation are now almost exhausted. Among these is the Craigleith stone of Edinburgh, which is a delicate drab-coloured, fine-grained, slightly calcareous sandstone from the Calciferous sandstone series (Scotland), and which was highly esteemed for glass cutting on account of its fine, sharp grit. It is now obtainable only in small quantities from Ravelstone quarry, Edinburgh.

CONSUMPTION AND STATUS OF THE INDUSTRY

The grindstones produced in England are chiefly consumed in Sheffield and other large towns where cutting tools, engineering materials, and machine parts are made, but large quantities of stones are exported to all parts of the world. It has been estimated that in 1923, about 2,500 natural stones were in use in Sheffield, of which only 100 were being used for dry grinding, and it is said that this city, even under the present depressed conditions of trade, consumes at least 50 tons of stones per week.

A large percentage of the English pre-war output was taken by Russia. A quantity of stones are annually exported to Portugal for grinding tobacco knives, and to Italy for coral grinding. Owing to the competition from artificial stones the natural grindstone trade in Great Britain, as elsewhere, has declined. During 1924 the British output was also seriously decreased owing to the competition from Swedish and German stones which were, on the average, 40 per cent below the pre-war prices at Newcastle, and the English trade with Belgium, Italy, and France was supplanted largely by German and Swedish stones. However, there always has been a demand for the larger stones for pulpstones, and fine grits for glass bevelling, so that those quarries able to produce such stones were operating full time. There was a decided improvement in the grindstone industry during 1925.

Statistics covering the annual output of English stones are not available.

OTHER EUROPEAN COUNTRIES

Grindstones are produced in Belgium, Bavaria, France, Greece, Italy, and Sweden. The Bavarian stone is coarse and hard and is used principally for razor grinding.

Statistics of the various natural abrasives produced in these countries are rarely separated. A few isolated cases are hereby given.

TABLE V

European Grindstone and Millstone Production

Country and Product	Year	Unit	Quantity
Belgium (Grindstone)	1923	Piece	68,930
Bavaria (Sandstone)	1923	Short ton	57,432
France (Millstone)	1922	Short ton	433,892
Greece (Millstone)	1921	Piece	14,348
Italy (Millstone)	1923	Short ton	2,428
(Grindstone)	1923	Short ton	1,049
Sweden (Millstone)	1923	Short ton	184

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PULPSTONES

Pulpstones are made from sandstones having a somewhat similar texture to that used for grindstones; and in some places the same quarry furnishes both types of stones, but invariably from different beds. The sandstone bed must be at least 3 feet thick to make even the smallest pulpstones.

In order to produce the necessary wood fibres for paper-making, the previously cut short lengths of barked wood are fed into a wood-grinding machine, where they are pressed by hydraulic pressure against the rotating face of the pulpstone.[1] There are usually three of these feed points or pockets on each stone, so that grinding occurs in three separate places on the face of each stone at the same time. The stones revolve from 200 to 225 r.p.m. with a feed pressure of 60 to 125 pounds per square inch. Since the average stones used weigh from 2 to 4 tons each, and are subjected to enormous and unbalanced stresses and strains, the greatest care in the selection of the type of stone with the requisite physical properties is of the utmost importance.

REQUISITE QUALITIES OF A PULPSTONE

A good pulpstone should cut fast, produce fibres neither too coarse nor too fine, be of medium hardness, possess a long life, wear evenly, and withstand the strain. In order to produce the long thin fibres the stone should tear and not cut, hence sandstones comprised of sub-angular grains are desirable. If the grains are too rounded there is a tendency for the stone to glaze, thus producing inferior fibre. Coarse-grained stones cut faster than finer grained, but the pulp from the former is coarse and of poorer quality. The bonding material holding the grains together should be soft enough to wear away so as to leave the harder silica grains protruding. The stone should be uniform throughout, otherwise it will wear unevenly. If too hard it is liable to glaze and require too frequent regrinding of the face; if too soft it wears away too quickly. The ideal pulpstone must give a satisfactory number of grinding hours under severe conditions; high daily production; long life—that is, installations must be kept low; and be such that it is not necessary to dress or "jig" the stone too frequently.

The usual size of a pulpstone is 26- or 27-inch face and 54 inches in diameter, but a variety of sizes up to the magazine grinders of 54 by 62 inches are used.

Sandstone deposits possessing beds of the requisite thickness and the above physical qualities are rare.

GENERAL SITUATION

Pulpstones have been produced in Canada since 1891 but the annual output is small. There is a big demand for these stones in Canadian pulp mills and approximately 4,500 tons, valued at over half a million dollars, are used annually, only about 10 per cent of which is now produced in Canada. (*See* Table VII.) In order to ascertain the cause for this small consumption, the opinion of a number of Canadian pulp-mill owners was sought in 1924, from which the following deductions were made: That the

[1] For full details see "The Manufacturer of Pulp and Paper", vol. III, pp. 18-41 (1922).

Canadian stones were somewhat soft and of fine grit, many contained mud cracks and flaws and were liable to break and were as a rule poorly seasoned; the material was good but that their failure was due mainly to their being unseasoned and to lack of careful inspection and selection.

Some years ago soft sandstones were used for making pulpstones, but with the increased speed and high pressure now prevailing in the mills a much stronger and harder rock is required.

MANUFACTURE OF PULPSTONES

The flat bed of the rock from which the stone is to be made is cut out to the required dimensions, after which the block is removed, placed in a gang saw and cut to the approximate thickness. The squared block is then placed under circular saws where the external diameter is cut to within a half inch of the required dimensions, and the centre hole is also cut out by a small saw, after which the stone is sent to a semi-automatic finishing machine, which cuts the face and sides very accurately. After the stone has been inspected the hole is bored out to the required shape and size, and the edges of the face are bevelled to guard against accidental chipping.

Careful inspections in all stages of the operations are necessary, and if any cracks develop or soft or hard spots are exposed, the stone is discarded. The methods employed by the Miramichi Quarry Company, which, until 1924, was the largest pulpstone producer in Canada, are very similar to the above. The machinery employed is illustrated in Plate VII.

In the quarry at Newcastle island, Nanaimo, British Columbia, the stones are cut in place, by means of circular steel cylinders of exactly the same internal diameter as the finished pulpstones, and about 1 foot longer. Each cutter is rotated on its vertical axis and is pushed downward by an automatic feeder which regulates the rate of boring to about 2 feet per hour (for a 64-inch by 6-foot cylinder). Split steel shot is used as the cutting medium. The whole machine is mounted on wheels in a wooden frame, so that it can travel on rails laid on the wide benches of the rock. (*See* Plates IX A and IX B.) The surface of the rock immediately under the cutting edge is levelled with plaster-of-Paris before commencing operations. The stone cylinders are freed by drilling a number of small horizontal holes at the bottom of the bench and splitting by means of light charges of powder. They are then lifted by derrick, loaded into barges, and shipped to the McDonald Stone Company at Vancouver where the centre holes are bored and the stones cut to the required length. Although this method is employed elsewhere for making grindstones, it is believed to be the only locality in which pulpstones are cut in place from the solid rock. It is claimed that the advantages over the cubical block method are minimum waste of good stone, a saving of labour in trimming, and a considerable saving in freight charges.

The method employed by one of the largest pulpstone producers in the United States is as follows: The corners of the cubical block are broken off by means of small air-hammers, after which the stone is worked into a more cylindrical shape by means of the same tool, and the top face roughly finished off. The stone is then turned over and the other face worked in the same way, after which the whole stone is gone over carefully with the air-hammer. The eye is then made by drilling 9 holes through the centre and reaming them out with an air-hammer, it is then finally squared for mounting on the lathe shaft. In order to finish the stone it is lined up in the square shaft and held in position by wedges, one end of the shaft being free and unsupported so that the stone can be quickly and easily removed. The finishing operations are similar to those already described under grindstones, the turning tool being a 6-foot bar fitted with a forged drill-steel bit. The stone is made to revolve about 20 r.p.m. and each bit is renewed after 8 to 10 revolutions of the stone. The sides of the stone are finished first and then the face, and finally the corners, and after removal from the table the centre hole is finished by air-hammers using different length tools.

Seasoning

The proper seasoning of pulpstones is of the utmost importance. The freshly quarried stone is saturated with water which takes a considerable time to evaporate. As the moisture passes through the pores of the stone a process of cementation takes place that forms a hard binder as the stone dries out. The finer the grit and the larger the stone, the longer the drying out process takes. The smaller stones should be seasoned for one year and the larger ones for about two years. In a poorly seasoned stone the cementation is not complete, the binder is soft and only the outside is hardened, consequently after a short time in operation the stone wears away rapidly or even fractures under the strain. The tying up of capital resulting from the stocking of a variety of stones valued at $200 to $1,000 each, presents a very serious problem, and because of lack of capital, or rush orders, the length of proper seasoning is very often not so long as it should be. Many experiments have been tried to shorten this period of seasoning by artificial means, but none appear to have been a real success. Amongst these is a process by which the stone is soaked in melted sulphur and allowed to cool whereby the crushing strength is increased from two to three times the original. Although this is advantageous when the stone is to be used for building purposes, it does not appear to be successful for pulpstones. Another method of hastening seasoning is to steam-heat the stones to about 180° F. in a closed chamber for several hours and then allow them to cool slowly and age for about two months.

Care of Pulpstones

In order to preserve the life and efficiency and obtain the full benefit of a pulpstone, it is necessary to treat it with care from the time it is cut out of the solid rock until it is finally discarded from the pulp mill. Great care must be exercised to prevent chipping of the face edges when handled by the cranes or if rolled over an uneven surface. It should be crated for shipment and every endeavour should be made to eliminate the possibility of moisture and frost getting into the stone during transportation in winter. Whole carloads have not infrequently been ruined from neglect of this latter care. The rough handling of stones in quarry or transport often gives rise to the formation of fissures, which are the main causes of the breaking of a stone during operations.

LABORATORY TESTS

Although the small-scale tests on certain sandstones to determine their suitability for the manufacture of pulpstones, do not duplicate the actual conditions in the mill, nevertheless, a comparison with standard good quality pulpstones indicates to a large degree the suitability or otherwise of the sandstone under trial.

The methods used by L. H. Cole[1] were carried out on several Canadian sandstones and the accompanying table (Table VI) embodies several of Mr. Cole's deductions and eliminates those sandstones which were considered unfit.

Granulometric Analysis

A portion of the material to be tested was very carefully crushed by hand in a mortar in order to completely free the individual grains without actually fracturing them. A 100-gramme sample was then screened through a set of Tyler standard screens of 28 to 200 mesh, the quantity retained on each screen being separately weighed and recorded (for various meshes see Table VI). The average fineness is obtained by multiplying the weight of the material passing through each screen by the mesh of the screen passed through, totalling all the results and dividing by 100.

Hardness Test

Cores, one inch in diameter, of the stone to be tested were obtained by means of a diamond drill, and were fitted into a holder which was weighted to 1,250 grammes. The protruding end of the test piece was made to rest on the horizontally revolving plate of a Dorry hardness machine. The plate, upon which 40-mesh standard quartz sand was continually fed, revolved for 500 revolutions at about 35 r.p.m. The test pieces, which were run in duplicate, were weighed before and after grinding and the loss in weight recorded.

Toughness Test

One-inch diameter cores, exactly one inch in length of the material to be tested, were treated on a Page impact machine. In this machine a blow from a 2-kilogram hammer, dropping from heights increasing by one centimetre after each blow, is transmitted to the test pieces by a steel plunger having a spherical end resting on the sample. The height of the blow which cracked the test piece was the figure taken as representing the resistance to shock.

In the hardness and toughness tests several samples, both thoroughly dry and saturated with water, were taken; the latter test did not show an appreciable difference, but in the hardness test the difference between the wet and dry samples was often considerable. The wet test is probably nearer the actual working conditions.

The structure and nature of the grain and bond were determined by the microscope and chemically.

The results are given in Table VI.

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[1] Cole, L. H.: Mines Branch, Dept. of Mines, Rept. 466, pp. 10-16 (1917).

TABLE VI

Physical Properties of Some Canadian and Imported Pulpstones

Ref. No.	Place of origin	Colour	Character of grains	Composition of grains	Composition of matrix	Granulometric Analyses							Average fineness	Hardness. Loss in grms.		Toughness. Drop in cms.	
						28	35	48	65	100	200	-200		Dry	Wet	Dry	Wet
1	English (Booth Co.).........	Pale brown.....	Semi-angular crystalline.	Quartz and some hornblende.	Calcareous.........	1·6	16·3	42·3	14·3	7·7	6·2	11·5	61·7	17·1	23·5	4·5	4·0
2	English (Eddy Co.)..........	Pale brown.....	Semi-angular....	Quartz and some feldspar and mica.	Siliceous...........	....	1·5	22·3	29·9	19·8	12·0	14·3	77·8	24·5	35·1	4·0	....
3	English (Laurentide Co.)....	Pale brown.....	Granular........	Quartz, feldspar, mica and iron specks.	Siliceous...........	9·5	14·8	27·2	16·3	17·5	8·0	6·5	56·8	11·9	6·8	6·0	4·6
4	American (Booth Co.).......	Creamy white..	Semi-angular....	Quartz and a few iron specks.	Siliceous...........	7·8	17·6	34·9	15·1	8·0	5·9	10·6	59·1	19·1	26·3	4·5	4·0
5	American—Empire, Ohio....	Greenish white.	Semi-angular....	Quartz and a little feldspar and mica.	Siliceous...........	3·6	14·7	40·8	12·1	9·3	8·8	11·4	63·0	30·9	38·1	3·7	....
6	American—West Virginia....	Creamy white..	Semi-angular....	Quartz and a little mica.	Calcareous.........	2·9	9·0	43·1	18·6	10·0	6·1	10·1	60·9	20·8	20·6	4·3	4·0
7	Hill quarry, Whitney, N.B...	Yellow-green....	Angular to semi-angular.	Quartz, feldspar and mica.	Argillaceous........	....	4·1	24·8	30·1	20·2	10·3	10·5	70·3	29·5	....	3·0	....
8	The Miramichi quarry, Quarryville, N.B.	Greenish brown	Angular to semi-angular.	Quartz, feldspar and mica.	Argillaceous........	9·7	21·6	36·9	12·4	6·3	5·6	7·2	52·3	21·0	....	4·0	....
9	The Read Stone Co., Quarryville, N.B.	Greenish brown	Angular to semi-angular.	Quartz, feldspar and mica.	Argillaceous........	....	33·3	36·5	11·5	6·5	4·8	7·5	52·5	20·8	....	2·7	....
10	Fish quarry, Newcastle, N.B	Greenish brown	Semi-angular to rounded.	Quartz, feldspar and mica.	Argillaceous........	1·9	14·8	43·4	19·1	8·7	5·8	6·3	51·7	19·0	20·6	3·1	2·3
11	Read quarry, Rockland, N.B.	Brownish green.	Semi-angular to rounded.	Quartz, feldspar and mica.	Argillaceous........	0·5	9·9	33·8	25·8	15·4	6·3	8·3	59·9	10·8	16·1	3·5	3·0
12	Smith quarry, Shediac, N.B.	Light greenish..	Angular.........	Quartz, altered feldspar and chlorite.	Argillaceous and slightly calcareous	3·8	14·8	43·0	17·0	8·0	6·5	6·5	54·0	30·8	....	4·0	....
13	Stake Road, N.S...........	Pale brown.....	Semi-angular to rounded.	Quartz, feldspar, little iron and mica.	Siliceous and slightly carbonaceous.	8·2	40·6	18·4	14·3	4·2	10·4	7·9	64·0	23·5	....	4·0	....
14	Lake Superior, Ont..........	Pinkish buff....	Semi-angular to rounded.	Quartz, feldspar.....	Siliceous and calcareous.	0·7	8·1	21·8	22·9	17·6	1·4	27·5	87·5	2·2	2·7	8·7	9·0
15	McDonald quarry, Nanaimo, B.C.	Speckled grey...	Semi-angular....	Quartz, magnetite, hornblende, and mica.	Siliceous and slightly ferruginous and argillaceous.	1·0	3·2	25·7	29·7	17·2	11·2	12·0	70·7	6·8	21·4	9·0	....

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TABLE VII

Details of Pulpstones Used in Canadian Mills in 1924

—	Diam. Face	Diam. Face	Diam. Face	Diam. Face	Diam. Face	Diam. Face	Diam. Face
Principal sizes of stones in inches.*	54 x {26, 27, 28}	54 x {32, 33}	54 x {35, 36}	60 x 27	60 x {33, 35, 36}	60 x 54	62 x 54
Number of each size....	782	88	152	104	25	89	91
Percentage of each size..................	58·8	6·6	11·4	7·8	1·9	6·6	6·9
Average weight of each stone in tons..........	2·6	2·8	3·0	3·2	4·0	6·3	7·0

*Stones of odd sizes are included in the nearest sizes listed.
Number of mills in operation:—Ontario 19; Quebec 24; Maritime Provinces 9; British Columbia 2. Total, 54.
Total number of stones used:—1,331.
Total weight of stones used:—4,576 tons.
Total value of stones used:—$548,197.
Approximately 30 per cent of the above mills report that they have never tried Canadian stones.

CANADIAN LOCALITIES

Pulpstones were first produced in Canada in 1892. (*See* general table of production, Table I.) Most of the stones have been made from four quarries in New Brunswick, detailed descriptions of which will be found under the heading of Grindstones. Further brief accounts of these and of additional quarries will also be found below.

French Fort Quarry, Newcastle, New Brunswick. Pulpstones are recorded as having been first manufactured in 1891 by Mr. C. E. Fish from the French Fort quarry, near Newcastle, N.B. About 1,600 tons of stones were produced before the quarry was abandoned in 1903. At the time these stones were used, over 20 years ago, they were reported to have been satisfactory, although the stone is somewhat soft, and it is doubtful whether they would stand up under modern conditions of high speed and high pressure grinding. There are, however, in the lower beds of the formation, some thick beds which are harder than those previously used. (No. 10, Table VI). It is stated that negotiations are now under way to recommence the production of pulpstones.

Read Stone Company, Miramichi River, Quarryville, New Brunswick. A few hundred tons of pulpstones, most of which were made in the two years before the quarry closed down in 1922, have been intermittently made from this quarry. The beds are, however, too broken up for the economic production of pulpstones, but mill owners who used them after being well seasoned, spoke favourably of them, although their life was somewhat short. (No. 9, Table VI).

Miramichi Quarry Company, Quarryville, New Brunswick. Pulpstones have been produced continually from this quarry since 1905; it is the largest producer in Canada, about 2,000 tons of finished stones having been shipped. The lower beds of the yellow-brown sandstone from which some good quality stones are being produced, are up to 10 feet in thickness. However, the grit is somewhat fine, the stone soft, and the presence of mud cracks and hard and soft spots necessitates careful selection and frequent inspections of the stones during manufacture. The company has an up-to-date quarry equipment and pulpstone manufacturing machinery. (*See* photographs of quarry and plant, Plates IVA, VII; also No. 8, Table VI.)

Dorchester Area, New Brunswick. Between 1899 and 1903 pulpstones were produced from the quarries in the vicinity of Beaumont by Mr. A. D. Richards, and later at intervals between 1909 and 1919 by the Read Company under the management of Mr. F. Dobson. Altogether, approximately 1,000 tons of stones were produced. During 1923 the Read Company re-opened one of the old quarries at the top of the hill between Beaumont and Rockland. Several stones which were shipped for trial, are said to be giving satisfaction. (*See* Plate IVB; also No. 11, Table VI.)

Adam Hill Quarry, Northwest Miramichi, New Brunswick. This quarry, near Whitney, about 9 miles west of Newcastle, has, in the past, produced building stone. The beds, which vary from 6 inches to 4 feet in thickness, are not uniform in quality. Some of the beds contain hard and soft spots, coarse streaks, and mud cracks, but parts of the beds might yield good pulpstones. There is, however, no record of any production. Tests made by L. H. Cole[1] on this stone showed that although they were below the general standard of toughness and of somewhat finer grain, they compared favourably with the best American stones. (No. 7, Table VI.)

Smith Quarry, Shediac, New Brunswick. One mile west of Shediac station a quarry of light greenish-coloured sandstone was opened up many years ago for a distance of about 200 feet along the east bank of the Scadouc river. The face is exposed for about 75 feet, but only the lowest beds are thick enough for the manufacture of pulpstones. The stone is soft and medium coarse-grained throughout, but hardens considerably on seasoning. It is stated that a few pulpstones were at one time produced, but no records are available. The physical tests compare favourably with the imported stones.[2] (No. 12, Table VI.)

Hickey Property, Stake Road, Malagash, Nova Scotia. A pale brown-coloured sandstone, which occurs on the Hickey farm one mile north of Stake Road, was tested by L. H. Cole[3] and gave favourable results. No work appears to have been done on the property, and only 3 feet of the beds which dip 60 degrees to the south are exposed. The beds appear to be very uniform in character. (No. 13, Table VI.)

Lake Superior, Sibley Peninsula, Ontario. A somewhat hard, pinkish-coloured, fine-grained sandstone occurs at intervals outcropping along the west shore of the Sibley peninsula, 20 miles east of Port Arthur. The best exposures upon which there is practically no overburden, occur due south of Pass Lake station, and north near Loon lake. Small samples submitted to a pulp mill were favourably reported upon and negotiations are said to be under way to produce stones in the near future. (No. 14, Table VI.)

Newcastle Island, Vancouver Island, British Columbia. A deposit of sandstone was recently opened up in the Protection formation of Newcastle island about one mile northeast of Nanaimo, by Messrs. J. A. and C. H. McDonald of 1571 Main street, Vancouver.

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[1] Cole, L. H.: Mines Branch, Dept. of Mines, Canada, Rept. 466, p. 7 (1917)
[2] Op. cit., p. 9.
[3] Op. cit., p. 9.

Even-grained, grey sandstone, having a "pepper and salt" appearance, is exposed on both sides of Echo bay on the south end of the island. Some work has been done on a ridge 900 feet inland from the west shore of the bay, but the main operations are confined to the southern end of the east shore. At this point the overburden is from 1 to 2 feet of soil and 3 feet of thin, broken beds. Solid beds of 3, 6, and 7 feet in thickness are exposed in the quarry workings. (*See* Plates IX A and IX B). The formation has a gradual dip to the southeast and the east shore of the bay rises towards the north forming at its upper end a 60-foot bluff, which exposes solid beds of 7 to 10 feet thick. In some instances the bedding-planes, which are thin coal and sand seams, disappear.

The island is covered with bush so that very few outcrops are exposed except near the shore. Good pulpstone material occurs for several hundred yards from the workings but at the north end of the island the sandstone is soft and seamy. Good material can also be obtained from the western quarry.

The stone is decidedly hard and tough and compares very favourably with the imported stones. (No. 15, Table VI.)

The grit consists mainly of even-grained, sub-angular quartz particles with some feldspar, black mica, hornblende, and a little magnetite. The proportion of the cementing material is comparatively low and is mainly siliceous with ferruginous matter, some alumina and magnesia.

Pulpstones were first produced in 1923 and since that date about 700 or 800 tons have been shipped, consisting mostly of smaller sizes, although a few magazine grinders have been produced. The latter, the owners claim, can be economically made because of the very thick solid beds. The reports from some of the mill owners using these stones are very favourable and the stones are claimed to be equal to the best imported, to have a long life, and are said to require no seasoning. Stones have recently been shipped to several eastern Canadian and United States mills.

The old quarry about one mile farther north, opposite Penbury point, which was at one time leased from the Western Fuel Company, is in the same formation but is full of coal spots, and is very seamy; it would probably not furnish pulpstones.

Fort Steele Mining Division, British Columbia. In the extreme southeast corner of British Columbia, in the vicinity of Cabin creek, a tributary of the Flathead river, the formation is made up of sandstones, shales, and coal seams. The sandstones are fairly fine-grained and are speckled grey in colour. According to J. D. Mackenzie[1] the sandstone consists of 30 per cent quartz grains between 0·15 mm. and 0·30 mm. in size and are sub-angular, the cementing material being limonite. The sandstones are usually thick-bedded and in some cases are as much as 9 feet thick. The area was not visited by the writer, but from descriptions furnished, some of the sandstone may be suitable for pulpstones. However, these sandstones are somewhat remote from transportation being about 25 miles by air-line east of Gateway station on the International Boundary where it crosses the Kootenay river.

[1] Mackenzie, J. D.: Geol. Surv., Canada, Mem. 87, pp. 21, 27 (1916).

FOREIGN LOCALITIES

UNITED STATES

Pulpstones are now produced by seven companies in Ohio, five in West Virginia, and one in Washington. The principal Ohio centres are at Steubenville, Elyria, Lisbon, Marietta, and East Liverpool; the Washington production comes from the vicinity of Tacoma; and the West Virginia, from Empire and Littleton, and from the Morgantown sandstone beds along the Monongahela river.

At East Liverpool near the eastern Ohio boundary, the stone is a light buff-coloured, coarse-grained, thick-bedded sandstone, overlain by broken beds of the same material and shales. There is a considerable overburden in the centre of the deposit, but at the edges it is only about 10 feet. About 30 feet of the thick beds are used for pulpstones, and about 25 per cent of the total stone quarried is utilized for their manufacture. A definite system of benching is not employed owing to the irregularity of the joints and thickness of beds, but each block is quarried separately. Unmounted air jack-hammers are used, since only short holes are drilled. The holes are partly filled with slow black powder which is tamped on top of a light wad placed part way down the hole in order to leave a large open chamber. By this means and by the aid of wedges, the blocks break square and straight.[1]

A general description of the types of sandstone will be found in the section dealing with grindstones in the United States since many of the grindstone quarries also produce pulpstones. The physical properties of a few of these stones will be found in Table VI.

The following table shows the United States pulpstone production since 1918.[2]

TABLE VIII

Pulpstone Production in the United States

	Short tons	Value
1918	8,785	$ 513,680
1919	6,110	342,056
1920	8,652	467,014
1921	10,030	750,063
1922	5,157	445,286
1923	9,186	680,416
1924	9,193	814,409
1925	8,370	841,302

ENGLAND

At present the English pulpstones are regarded by Canadian mill owners as being the best on the market. They are characterized as being hard, durable, the least likely to contain flaws, and are always well crated. As such they command a higher price than any other stones.

The principal districts from which pulpstones are obtained are Darley Dale and Grindleford Bridge, Derbyshire; near Newcastle and Gateshead; Northumberland; Bilston, Staffordshire; and Keighley, Yorkshire.

[1] Weigel, W. M.: Private correspondence, U.S. Bureau of Mines, March (1925).
[2] Figures mainly derived from "Mineral Industry."

The Darley Dale stone[1] is a compact, close-grained micaceous, light drab-coloured sandstone obtained from the Millstone Grit. The stone has the following composition and characteristics:—

	Per cent
Silica (SiO_2)	96·40
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1·30
Water (H_2O)	1·94
Calcium carbonate ($CaCO_3$)	0·36
Weight per cubic foot	148 pounds
Crushing strength per square foot	670·3 tons

The output of the quarries amounts to about 1,000 pulpstones per annum. The company is believed to be the largest exporter in Great Britain.

It is claimed that the Darley Dale pulpstones are particularly suited to the needs of the Canadian and Newfoundland pulp industries; they are also exported to Norway, Sweden, and Finland. A variety of this stone is also used for glass bevelling.

Another important pulpstone is the well-known P. J. Turner "Stoke" stone from Grindleford, Derbyshire. This is a drab and brown-coloured, mottled, coarse-grained sandstone. According to F. H. Brindley[2] an analysis of a specimen from the Stoke quarry had the following percentage composition:—

	Per cent
Silica (SiO_2)	86·70
Alumina (Al_2O_3)	7·59
Ferric oxide (Fe_2O_3)	1·36
Lime (CaO)	0·20
Water, etc. (H_2O)	1·45
Alkalis	2·61
Crushing strength, per square inch	8,795 pounds

The Upper Coal Measures of the Newcastle district also supply large quantities of pulpstones which are mostly exported to the United States and Japan (and formerly to Russia). The stone is yellowish brown in colour, and varies considerably in texture. Analyses of two of these stones, supplied by Messrs. Richard Kell and Co., Ltd., are as follows:—

	Springwell per cent	Windy Nook per cent
Water	0·30	0·60
Organic matter	1·70	2·10
Silica	86·04	84·80
Iron and alumina oxides	8·80	9·70
Calcium oxide	1·67	0·58
Magnesium oxide	0·19	0·18
Alkalis	2·30	2·04
Sulphuric anhydride	None	None
Carbonic anhydride	None	None

The Keighley district of Yorkshire supplies large quantities of pulpstones. Pulpstones are also obtained from the Bilston quarries (Staffordshire) and are exported to Scandinavia, Canada, and the United States.

[1] "The Stancliffe Estates, Darley Dale," Stone Trades Jour., pp. 464-7 (May 1925).
[2] Brindley, F. H.: Quarrying for Pulpstones, Quarry Managers' Jour., vol. 6, pp. 350-2 (June 1924).

The Lombard Company, who at one time produced stones from Chaleur bay, New Brunswick, has extensive quarries in England, and an agency in Boston, Mass.

No record of the English pulpstones production is obtainable.

ARTIFICIAL PULPSTONES

The Norton Company of Worcester, Massachusetts, has recently introduced an artificial pulpstone, which is composed of a double row of specially shaped segments.[1] Silicon carbide is used as the abrasive. For certain kinds of pulp, good results are claimed and although the price is high, the life of the artificial stone is said to be very much longer than that of the natural stone. Further details will be given in the bulletin dealing with Artificial Abrasives.

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[1] Pulp and Paper Mag. of Canada, Artificial Pulpstone, p. 193 (Feb. 19, 1925); also Greenwood, W. W.: "Grits and Grinds," Feb. 1925, also Nov. 1926, issued by the Norton Company (full details and photos).

BURRSTONES

The true burrstone is a white to grey or slightly yellowish form of chalcedonic silica. The stone has a coarse cellular structure, the holes being frequently due to the dissolving out of calcareous fossils. It has about the same hardness as flint, but is not so brittle and possesses a straight fracture. The rock is of chemical origin—that is it results from the precipitation of silica from solution, presumably through the action of organic matter.[1] Its sharp cutting power is due to the toughness of the rock and its numerous pores and cavities.

It was originally used as horizontal, circular "millstones" for grinding grain, but is now also used for a variety of other purposes such as in grinding of paint, cement, fertilizers, etc., and in the preparation of graphite or other minerals. Its use is, however, declining, particularly on the American continent, where it is being largely replaced by artificial wheels and more modern types of grinding equipment.

CANADIAN LOCALITIES

A true burrstone or cellular chert occurs in Quebec in Argenteuil district, Grenville township, range VI, lot 1, on the farm of James Lowe, about one mile northeast of Rawcliffe. The deposit consists of two parallel veins, 4 to 6 feet wide, about 100 yards apart, which extend to range V, lot 3. The country rock is syenite. The chert consists of grey, yellowish and brown parallel bands in which the cells are irregularly distributed, some parts being devoid of cavities whereas in other places they vary from the size of a pin's head to 1 inch in diameter.

Over sixty years ago two or three small pits were dug in the chert and some small burrstones of excellent quality are said to have been made from the cellular part of the vein.[2]

The Canadian imports of burrstones will be found in Table II.

FOREIGN LOCALITIES

The best burrstone is produced in France. It is a freshwater, cellular quartzite or flint of Tertiary age, possessing great strength and toughness. It is said to be a limestone which has been replaced by silica. The best stone comes from the top of the Lower Oligocene of the Paris basin from a bed called the "Calcaire de Brie," which stretches from Vernon to Rheims and from Laon to Fontainebleau. The principal quarries are at La Ferte-sous-Jouarre. The stone occurs in large masses and is worked in open quarries and usually sold in irregular blocks. The blocks are shaped to the required dimensions and sold as solid stones, or else fitted together and bonded into solid wheels. The stone finds markets all over the world, and in 1922 about 434,000 short tons of burrstones and millstones were produced.[3]

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[1] Merrill, G. P.: "The Non-metallic Minerals," Smithsonian Institution, p. 217 (1901).
[2] Geology of Canada, p. 808 (1863): Geol. Surv., Canada, Ann. Rept., vol. IV, pt. K, p. 154 (1890).
[3] Imp. Min. Res. Bureau, London, England. Private information.

MILLSTONES

The term millstone, which now includes the true burrstone, is somewhat loosely applied to include circular stones revolved on a horizontal plane as well as those run on edge. They may be made from any hard and suitable rock varying from a sandstone, basalt, granite, to a quartz conglomerate.

The stones are used for similar purposes to burrstones and vary in diameter from 18 inches to 6 feet and with a face of from 1 to 2 feet. However, like the burrstones they are being replaced by artificial stones and other forms of grinding, such as steel rolls.

CANADIAN LOCALITIES

Millstones have not been produced in Canada for many years, and the value of those used, as shown by the imports, amounts to about $1,000 annually, whereas 45 years ago the imports were about $15,000 annually.

They were formerly produced from a band of quartz conglomerate which occurs on the contact of the Trenton and the Laurentian formations below Quebec. On the Chaudière river between St. Joseph and St. Francis, a granitoid gneissic rock associated with serpentine was once successfully used for the manufacture of millstones. Other localities[1] in Quebec are: at Crooked falls in the Saguenay district, from a stone composed of a red orthoclase and mica; along the north shore of the Ottawa river, from a red, coarse-grained gneiss; in the parish of St. Cuthbert, from an 8-foot band of hard conglomerate in beds from 1 to 2 feet thick. Millstones were also made from one of the layers of conglomerate occurring in Vaudreuil seigniory, north of the Cascades. Near White cape at Murray Bay, the quartzose conglomerate in the Trenton formation has also furnished good millstones. Good millstones for grinding grain were also produced from the Oriskany sandstones at DeCewville, near Cayuga, Ontario.

About 40 years ago several ship loads of Whitehaven granite were taken from Millstone island, near the southeast extremity of Guysborough county, Nova Scotia, and made into millstones.[2]

FOREIGN LOCALITIES

UNITED STATES

At present about $20,000 to $25,000 worth of millstones are produced annually in the United States, which is only about one quarter of that produced 40 years ago. The largest output comes from New York state, particularly from the Shawangunk conglomerate in Ulster county, and is known under the name of Esopus stone.

Millstones have also been produced from a fine-grained quartzite at Brush mountain, Montgomery county, Virginia; from a quartz conglomerate at Parkewood, Moore county, and from a granite at Faith in Rowan county, both in North Carolina; from a quartz conglomerate, Lancaster county, Pennsylvania; from the Dutton sandstones of Jackson county; from a quartz conglomerate of similar texture to the Esopus stone, near Fair Haven, Rutland county, Vermont; and from a white variety of the Berea sandstone at Peninsula, Summit county, Ohio.[3]

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[1] Geology of Canada, p. 808 (1863).
[2] Geol. Surv., Canada, Ann. Rept., vol. II, pt. P, pp. 149, 163 (1887).
[3] Ladoo, R. B.: "Non-Metallic Minerals," p. 9 (1925).

EUROPE

Millstones have been employed in England from very early times and the value of some of the coarser British grits for this purpose was well known to the Romans. They imported into Britain stones of Niedermendig lava from Germany for use as a top stone above a stone of English Millstone Grit.

At one time the supplying of millstones for grinding grain was an important industry and some of the coarser British sandstones were highly esteemed for this purpose, so much so that the geological formation from which these were principally obtained was named the Millstone Grit by G. S. Greenough. This formation formerly supplied many millstones, but at present it is only quarried in Derbyshire and Yorkshire (West Riding), and its principal use is for pulpstones. For milling wheat, natural millstones have been superseded by steel rolls, although some mills use artificial stones or French burrs. However, many millers prefer to employ stones of Millstone Grit for grinding Sussex oats, rice, and maize. A silicified encrinital limestone, from near Halkin, has been used for the milling of flour; it is said to closely resemble the imported French burrstones. White quartzites from Banffshire and Argyllshire have also been used as millstones.

French millstones are obtained from the Middle Tertiary rocks of Eperon (Eure et Loire) and also from Cinq-mars-le-Pile in the Loire basin. A quartzite used for grinding clay and other soft minerals is obtained in the Dordogne.

There are several localities in Germany from which millstones are produced, the principal of which is the Niedermendig stone at Andernach, 10 miles northwest of Coblenz. It is a porous trachyte-tuff. Other millstones are obtained from porous rhyolites found in the Odenwald, Thuringia, and the Fichtelgebirge district. The Ziltan millstone is a coarse conglomerate in a sandy matrix obtained from southeast Saxony.[1]

A total annual production of 2,000 tons of millstones comes from Italy, Greece, Jugoslavia, and Sweden; the largest producer being Italy.

CHASER STONES

These are large, circular stones, run on edge, usually in pans paved with blocks of conglomerate or some hard material and are used mainly for grinding minerals, chiefly feldspar, quartz, and barytes. They are made from a similar rock to those from which millstones are produced, but being larger are used for heavier work.

In the English "chaser" mills used for grinding spices, both Cornish and Aberdeen granites are employed; probably many other local igneous rocks could be so used, but lately it has been found more economical to import Italian granite for this purpose. In the Staffordshire potteries, two distinct varieties of chert were employed in grinding mills, the lower stone being a chert which was obtained from the base of the Millstone Grit at Halkin mountain, Flintshire, Wales. The upper was a cherty limestone obtained from Bakewell and Longstone Edge, Derbyshire.

[1] Imp. Min. Res. Bureau, London, England. Private information.

GRINDING PEBBLES

Extremely hard and tough, rounded pebbles, usually of flint, are used in cylindrical or conical mills for grinding of ores and minerals. Steel balls have now largely replaced pebbles, so that the use of the latter is declining.

CANADA

Granite grinding pebbles have for a number of years been produced by the Canada Pebble Co., Ltd., and latterly by C. W. Todesco from the vicinity of Santoy near Jackfish on the north shore of lake Superior. In 1920, 560 tons was produced but during the last two years a total of about 170 tons was shipped valued at $9 per ton. These pebbles are largely used for clinker grinding and in cement mills.

During 1922, the Hedley Gold Mining Company used pebbles from Hedley, Similkameen district, B C. These pebbles are stated to have given satisfaction and cost $4 per ton as against $35 for the imported Danish.

A considerable deposit of pebbles suitable for grinding purposes occurs on the north shore of Gabarus bay, Cape Breton county, Nova Scotia. The best pebbles come from McIsaac beach, east of Eagle head, and from the east end of Lever head. The pebbles from the former beach are composed of blue-grey rhyolite of very dense structure and show structural planes visible as closely packed rings encircling them. The Lever pebbles are composed of quartzite, pink, fine-grained quartz porphyry, green syenite porphyry, green rhyolite, and fine-grained andesite. Series of tests were carried out by K. A. Clark of the Mines Branch, Department of Mines, Ottawa, and compared with standard imported pebbles. The following table shows the results of these tests[1]:—

TABLE IX

Abrasion Tests on Samples of Imported and Gabarus Bay (Nova Scotia) Pebbles.

Sample No.	Number of pebbles.	Average weight of pebbles, grms.	Total weight grms.	Loss in weight in grms.			Per cent wear		
				First run	Second run	Total	First run	Second run	Total
1 (a)	55	93	5,114	22	20	42	0·42	0·39	0·81
(b)	52	95	4,948	(4)*	24	....	....	0·49	....
(c)	53	96	5,053	29	23	52	0·57	0·47	1·04
(d)	56	90	5,061	27	23	50	0·53	0·47	1·00
2 (a)	11	470	5,152	5	2	7	0·10	0·04	0·14
(b)	18	280	5,068	5	0	5	0·10	0·00	0·10
(c)	28	180	5,025	2	2	4	0·04	0·04	0·08
3 (a)	10	440	4,417	6	2	8	0·14	0·05	0·19
(b)	16	320	5,128	6	2	8	0·12	0·04	0·16
(c)	20	250	4,909	3	2	5	0·06	0·04	0·10
4 (a)	....	....	5,076	5	2	7	0·10	0·04	0·14
(b)	....	....	5,011	10	7	17	0·22	0·14	0·36
(c)	....	....	4,982	4	5	9	0·08	0·10	0·18
5	10	300	3,055	6	2	8	0·20	0·07	0·27
6	18	270	4,799	9	7	16	0·19	0·15	0·34

* Apparently a mistake.

No. 1. Four samples of flint pebbles used in the Mines Branch Ore Dressing plant, secured from a New York dealer.
No. 2. McIsaac beach, Nova Scotia, 3 samples of different average weights.
No. 3. McIsaac beach, Nova Scotia, 3 samples of different average weights.
No. 4. Average across McIsaac beach, unselected: (a) over 200 grms., (b) between 200 and 100 grms., (c) under 100 grms.
No. 5. Lever beach, Nova Scotia, east end.
No. 6. Lever beach, Nova Scotia, centre of east end.

[1] Hayes, A. O.:Geol. Surv., Canada, Sum. Rept., pt. F., pp. 23-27 (1917).

It will be seen from the above that these pebbles showed better wear than the imported flint pebbles. Although no survey was made to carefully estimate the available tonnages Dr. Hayes states that—

> A rough approximation indicates that several thousand tons similar to sample No. 4 could be easily loaded on a vessel and many thousands of tons could be sorted from Lever beach and loaded by means of small boats, as the water is shallow in the vicinity of this bar.

Considerable quantities of quartzite pebbles, suitable for grinding, occur in the Cypress hills of Saskatchewan. These hills are capped by a gravel bed varying in thickness up to 50 feet.[1] South of Maple Creek, the slopes of the north side of the hills are covered with pebbles, which are particularly well exposed in road cutting in the vicinity of Coulee and to the south of Elkwater lake. The Canadian Pacific railway track is ballasted for a considerable distance east and west of Gouverneur with quartzite pebbles obtained in the immediate vicinity. The pebbles vary from 1 inch to 6 inches in diameter but the greater number would probably average 3 inches.

FOREIGN OCCURRENCES

Most of the flint pebbles are obtained from deposits in Greenland, Belgium, and from the sea coast of France between Havre and St. Valery-sur-Somme. The Greenland stones are sent to Denmark and are known as Danish pebbles, and are, on account of their great hardness and toughness, recognized as the standard. Since the war the annual production of Danish pebbles has varied from 12,000 to 23,000 tons.

Flint pebbles are also produced in England and Norway; and various types of grinding pebbles have been exported from Germany, Italy, Labrador, Newfoundland, and Japan.[2] In the United States grinding pebbles are produced from Rock county, Minnesota; Manhattan, Nye county, Nevada; and from the beaches of San Diego county, California. The United States production for the last two or three years was between 2,000 and 4,000 tons annually, valued at $30,000 to $50,000.

Artificially rounded pebbles are made from some quartzites and chalcedonized rhyolites, such as occur near Sioux City, Iowa. The cubes of stone are broken out of the solid rock and in some cases are used angular, since they quickly become round in the operation of the ball mill.

The standard market sizes represented by Danish flint pebbles are as follows:[3]

TABLE X

Sizes of Danish Flint Pebbles

Size No.	Range in inches
1	1 to 1¾
2	1¾ to 2⅛
3	2⅜ to 3½
4	3⅛ to 4⅓
5	4⅓ to 5⅓
6	5⅓ to 6¾
7	6¾ to 7⅛

[1] Davis, N. B.: Mines Branch, Dept. of Mines, Canada Sum. Rep 1916, p. 122.
[2] Ladoo, R. B.: "Non-Metallic Minerals," p. 7 (1925).
[3] Op. cit., p. 8.

SHARPENING STONES

Under the general heading of sharpening stones are included whetstones, scythestones, honestones, razor hones, oilstones, and waterstones. Their nomenclature is somewhat confusing as the difference between these stones is not clearly marked and they grade from one into another.

TYPES OF SHARPENING STONES

Scythestones

This division, as its name implies, constitutes all stones used for sharpening scythes and sickles. The grit is also suitable for kitchen and butcher knives and similar articles. They are the coarsest of the whetstones and are usually made from the finer beds of sandstones from which grindstones are obtained. The better grades of scythestones are usually fine-grained, highly siliceous argillites or mica schists which in many cases contain, in addition to the quartz, innumerable minute crystals of some hard mineral such as garnet or magnetite.

Razor Hones

Razor hones embrace all stones used for sharpening razors and delicate instruments. At present razor hones are largely made from artificial abrasives, although there is still quite a demand for the natural Belgian honestone.

Oilstones

These stones, as the name indicates, are those very fine grit stones from which the most satisfactory service is obtained by the use of oil. There is a big demand for artificial oilstones, although large quantities of the opalescent, siliceous novaculites from Arkansas, are annually used.

Waterstones

Water is used with these stones, although very satisfactory results are obtained with oil. The best varieties are the Hindostan stone from Indiana and the Queer Creek stone from Ohio.

Holy- or Rubbing-stones

These stones, which are made from blocks of close-grained sandstone, were at one time extensively used for rubbing down ships' decks and the name "holy-stones" is said to have originated from the fact that the work was done in a kneeling position. The stones are now used to some extent for rubbing down rough surfaces on which a fine finish is to be applied, particularly for automobile bodies, furniture, and for concrete work.

PRESENT SITUATION

The demand for natural scythestones has decreased owing to the increasing competition from artificial abrasives, and to the increased use of agricultural machinery over the old hand-operated tools. Even the fine-grained, natural oilstones are now largely supplanted by artificial products.

Most of the world's output of scythestone material comes from the Pike Manufacturing Company's quarries in New Hampshire and Vermont; oilstones are obtained from Arkansas in the United States. A considerable production of razor hones is maintained from Belgium and Scotland.

SELECTION OF STONE

The proper selection of sharpening stones depends on the class of tool to be sharpened; the tools being divided into coarse-, medium-, and fine-edged tools.

Coarse-edged Tools

Almost all the tools of this class are knives and do not require a very fine edge as they are always used with a drawing motion, and as the slight coarseness of the edge gives them a saw-like effect it adds to the cutting efficiency. When natural stones are employed, any of the ordinary types of scythestones made from the compact siliceous schists to the fine-grained sandstones may be used. The smaller or finer knives are usually finished on an oilstone.

Medium-edged Tools

These require a smooth edge and may be classified broadly under carpenters' tools. The best results are obtained by first sharpening on a coarse stone and finishing on a fine stone, rather than sharpening in one operation on a medium grit stone. For this reason a combination stone with a coarse grit on one side and a fine grit on the other is the most convenient.

Fine-edged Tools

These embrace all tools and delicate instruments used for highly specialized purposes, mainly in the professions such as surgery and dentistry, also by metal engravers, furriers, and leather workers. These tools are made sharp by medium to fine grit stones, the final edge being put on by an oilstone.

Sharpening

In sharpening tools the best results are obtained by *sharpening against the edge,* that is with the edge of the tool working against the stone, the exceptions being when sharpening on leather, or when the tool itself is held still while the whetstone or grindstone is moved. Tools sharpened in this manner show less tendency to form a "wire-edge."[1]

CARE OF OILSTONES

The three main considerations in the care of an oilstone are: to retain the original life and sharpness of its grit; to keep its surface flat and even; and to prevent its glazing. For the first, the stone should be always cleaned after using and kept moist, as exposure to a dry atmosphere tends to harden it. A new natural stone should be soaked in oil for a few days before using and then always left covered. The surface may be kept flat by sharpening tools on the edge of the stone, as well as in the middle. A flat surface can be restored by applying the stone to the flat side of a grindstone.

[1] Pike Manufacturing Co., Pike, N.H.: "How to Sharpen" (June 1, 1923).

Glazing is prevented by the proper use of oil or water, otherwise the steel particles become embedded in the grit. Oil should always be used on fine-grained natural stones, such as the novaculites, and on all artificial stones, since water is not thick enough to keep the steel out of the pores. The dirty oil or water should always be removed as soon as possible. Glazing can usually be removed by a good cleaning with gasoline or ammonia, but if this does not suffice the stone should be scoured with sandpaper. Coarse grit stones do not require oil or water.

MANUFACTURE OF SHARPENING STONES

Machinery Employed

The principal types of machines employed in the manufacture of whetstones are the band saw, by means of which the crude blocks of stone are cut into narrow strips, and the rubbing bed on which the strips are ground down to the required dimensions.

Gang or Band Saw

These saws consist essentially of a number of long bands of malleable iron set parallel in a heavy frame which oscillates backwards and forwards. The length of stroke or swing is variable and the method by which the pressure or rate of cutting is regulated varies in different mills. In some instances it is controlled by an adjustable ratchet movement which lowers the frame a fraction of an inch at each swing; screw-feed gangs are fed downwards by gears. In the rope-feed system the frame is counterbalanced by means of weights whereby a steady pressure is applied.

The gang frames vary in width depending on the size of the block to be sawed, and some have a sliding head so that they can be adjusted. The length of stroke is generally governed by a pitman and can be varied. The successful cutting of 30 or 40 one-inch strips out of a large block at one time requires careful adjustment and manipulation of feed.

Abrasives Used

The abrasive commonly used is sharp sand, as it leaves a smooth surface and causes no staining. Crushed steel or shot is sometimes used, and cuts at least 25 per cent faster but leaves a much rougher surface. A mixture of the two has been successfully employed. Carborundum powder increases the rate of sawing considerably, but rapidly pulverizes and becomes so fine as to be useless.

The abrasive is fed into the distributor above the gangs by pumps, either centrifugal or Frenier type, an air lift, or sometimes by means of conveyer belts. Unless the mill is close to a suitable sand deposit, the sand, or, in any case, the artificial abrasive, is returned through the circuit and used again.

Rubbing Bed

This machine consists of a horizontal, circular table or plate made of iron or thick wood studded with iron nails driven flush with the surface. The average diameter of the table is about 6 feet and the speed is from

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40 to 50 r.p.m. The abrasive used is common sand which is distributed and returned through the circuit in a manner similar to that employed for the gang saws. Water is freely used throughout both operations.

CANADIAN METHODS OF SCYTHESTONE MANUFACTURE

The Read Stone Company, Stonehaven, New Brunswick

This company is the only producer of scythestones in Canada. The crude blocks of stone are cut by multiple-blade gang saws which consist of malleable iron strips $\frac{1}{4}$ to $\frac{1}{8}$ inch thick, 10 inches wide and about 12 feet long. A number of these blades are set at various intervals in a heavy frame which reciprocates under regulated pressure against the surface of the stone. Local sand from Pokeshaw, or sometimes steel shot, is used as the abrasive. The rate of cutting is from 10 to 12 inches per hour. The slabs which are $1\frac{1}{2}$ inches in thickness are then cut into pieces $1\frac{1}{2}$ inches by 1 inch, and about 10 inches long. The pieces are then placed on the rubbing bed and rubbed to a smooth finish. The oval stones are finished by hand.

UNITED STATES METHODS OF WHETSTONE MANUFACTURE

New Hampshire and Vermont Scythestones

For the making of scythestones, such as are produced by the Pike Manufacturing Company from the fine-grained, siliceous schists of New Hampshire and Vermont, the rough slabs or "timbers" of the selected material are split at the quarry by means of knives and hammers, into approximately the required shape. They are then conveyed to the mill and placed on the rubbing beds where they are ground to a uniform size. They are then reversed until the required thickness is obtained after which they are done up in bundles of 50 and the ends trimmed to the required length. Each stone is then finished separately by hand on the bed, the edges and ends being bevelled. They are finally smoothed off by hand by means of a piece of hard stone, after which they are labelled and packed in boxes. Local sand is used as the abrasive to grind the stones and is fed to the bed by means of a Frenier pump.

Arkansas Oilstones

The Arkansas novaculite from Hot Springs and the more porous Washita stone come from the mines in relatively small lumps. The lumps are built up in layers into a large block using plaster of Paris as the cement. When dry, the whole mass is sawn vertically by band saws into 2-inch slabs, after which the block is then sawed in a horizontal direction. The separate long strips are then laid flat and again built up into a block with plaster and cut by the saws to the required length of about 8 inches. The finishing is done by laying the pieces, after being freed from the plaster, on to the revolving face of a 5- to 6-foot diameter, horizontal iron wheel, using sand as the abrasive. The water absorbed by the Washita stone during the sawing or rubbing processes gives it a bluish green colour, which is considered objectionable, so that after drying they are rubbed or "cleaned" with pumice to restore their original white colour.

The discards and small slabs resulting from the sawing operations are set evenly with plaster of Paris on the face of a small disk which is placed face downwards and rests on the rubbing wheel. There are four of these disks to one wheel. Both the rubbing wheel and the disks containing the cemented stones revolve, resulting in a double grinding action. The process is repeated for the reverse side and for the ends. These disks and the small odd pieces are made up into numerous forms and shapes requisite for the trade. Thin disks of novaculite used by jewellers, dentists, etc., are cut by diamond-toothed cylinders. Any other pieces that are not made up are ground into a powder and used by watch and razor blade makers for polishing and grinding.

Manufactured Sharpening Stones

For some purposes sharpening stones are made up artificially from a mixture of natural grits, such as a fine sand, crushed siliceous schist, and a clay bond. The ingredients in certain proportions and size of grit are thoroughly mixed together with water and silicate of soda, pressed into various shaped moulds and baked. A typical stone of this type is fitted with a handle and used for domestic knife sharpening.

WORLD'S SUPPLY OF SHARPENING STONES

CANADA

There are a large number of fine-grained sandstones and siliceous argillites and mica schists in Canada that are suitable for whetstones, but for a number of years none have been produced other than a small annual output by one or two grindstone producers. There was a large output about a century ago from Whetstone island, Memphremagog lake, in the Eastern Townships of Quebec, and 50 years ago there was a big production annually from Lower Cove, Cumberland county, Nova Scotia.

Scythestones are now produced only by the Read Stone Company from their quarry at Stonehaven, Chaleur bay, New Brunswick. The company has been manufacturing these stones, which are of good quality, from a very fine grit and even-textured, blue sandstone since about 1880. The stones which are made in several patterns are shipped under the trade names of "Canada Red end," flat; "Bay of Chaleur," oval; "English round," round tapered; and are packed in boxes containing one-quarter gross. Probably about 1,700 tons of these scythestones have been produced to date, but in recent years the output has been only about 35 tons annually. These stones are nearly all sold in the Canadian markets, but in the past a considerable tonnage of rough blocks was shipped to the United States to be made into scythestones. The "Acme" stone is made from a finer grit quarried at New Bandon. This same stone was at one time shipped as rough blocks for marble polishing. Crude blocks have also in recent years been shipped to the United States from the Mic Mac Quarry Company, Nova Scotia, to be made into scythestones, but on account of the brittleness of the sandstone it is mainly used for the large oval-shaped stones. A small quantity of this stone, known as "Brown grit" is used for hand rubbing marble.

References and brief descriptions of many of the Canadian localities from which whetstones were produced are embodied in the accompanying tabulation (Table XI). The annual output since 1886 will be found in Table I.

TABLE XI

Sharpening-Stone Localities in Canada

Ref. No.	County or District	Location	Description	References	Remarks
			NEW BRUNSWICK		
1	Charlotte............	Grand Manan island, Cameron cove.		Handbook for Emigrants to N.B. (1857).	Oilstones said to be equal to the Turkish stone were quarried about 1850, from the north of the island.
2	Gloucester...........	Chaleur bay, Stonehaven.	Fine, even-textured, blue sandstone.	*See* description under Grindstones.	Considerable tonnage of scythestones. Present output about 35 tons annually.
3	"	Clifton..................	Fine, even-textured, blue sandstone.	*See* description under Grindstones.	Scythestones have been produced from various localities in this vicinity, but none in recent years other than at Stonehaven.
4	Kings................	Moosehorn brook near Norton station.	Fine-grained, blue sandstone.	Geol. Surv., Can., vol. X, pt. M., p. 115 (1899).	Quarried many years ago and stated to have produced excellent whetstones.
5	Northumberland......	Northwest Miramichi river, Sevogle river.	Fine-grained, blue sandstone.	Geol. Surv., Can., vol. X, pt. M., p. 115 (1899).	Quarried many years ago and stated to have produced excellent scythestones.
6	Restigouche..........	Mouth of Restigouche river, cape Bon Ami, near Dalhousie.	Tuffs and calcareous shales	Geol. of N.B., p. 128 (1865).	The hard and tough layers were used for hones and exhibited at Halifax exhibition in 1851.
7	Victoria.............	Perth parish, Tobique river, ½ mile above The Narrows.	Red, green, and bluish argillites with calcareous bands containing fossils and very fine bands of greenish, siliceous, argillite.	Geol. of N.B., p. 131 (1865).	Over 60 years ago excellent honestones were made for local use from the finer textured bands.
8	Westmorland	Dorchester parish, Petitcodiac river, Steeve creek.	Thin beds of hard, fine-grained, blue sandstone.	*See* table under Grindstones (No. 11).	Good quality scythestones made for local use over 40 years ago. Some crude rock shipped to U.S., for manufacture.
9	"	Sackville parish, Rockport peninsula.	Fine-grained, yellow-green sandstone.	*See* description under Grindstones.	Scythestones made at various times many years ago from certain beds of the peninsula. Quality not very good.
			NOVA SCOTIA		
10	Colchester...........	Earltown, McDonald brook, 3 miles west of Earltown.	Patch of Devonian formation in granite.	Geol. Surv., Can., vol. V, pt. P., p. 191 (1893).	Quarried for local use about 50 years ago.

11	Colchester............	John McKay's old dam, 1 mile south of East Earltown, Nabiscump brook	Bluish grey, flaggy, fossiliferous argillites on contact of conglomerate and Silurian rocks.	Geol. Surv., Can., vol.V, pt. P., p. 14 (1893).	Quarried for local use about 50 years ago.
12	"	Hills, 2 miles northwest of Earltown.	Fine, grey bands of sandstone.	Geol. Surv., Can., vol. V., pt. P., p. 191 (1893).	Quarried and made into whetstones for local use. They should be kept wet or oiled.
13	"	Tatamagouche river, Waugh River.	Fine-grained, grey sandstone.	*See* description under Grindstones.	A few scythestones now made annually for local use by Logan Murphy.
14	"	Hilden, 4 miles south of Truro.	Fine, grey argillites in Devonian formation.	Cat. Ind. & Colonial Exhib., London, p. 157, (1886).	
15	"	East brook, Birch Hill, near Cloverdale.	Fine-grained, grey sandstone occurring in Carboniferous limestone.	Geol. Surv., Can., vol. V, pt. P., p. 191; also pt. A., p. 60 (1893).	Said to have produced excellent scythestones.
16	Cumberland..........	Chignecto bay, Lower Cove.	Fine-grained, grey-brown sandstone.	*See* description under Grindstones.	Large quantities of sharpening stones of all grits were made. Special plant erected. Stones shipped to U.S., Europe, and for local use.
17	"	Mill cove..................	Red sandstones with fine, grey and green stripes and spots.	Geol. Surv., Can., vol. IX, pt. S., p. 11 (1898).	Oilstone well suited for hones, quarried about 1890-96.
18	"	Minas basin, DeWolf brook, at Brookville.	Slaty pebbles and quartzites interstratified with layers of argillaceous shales.	Geol. Surv., Can., vol. V, pt. AA., p. 53 (1893).	The shale was used locally for whetstones when the slaty coal seams were opened up in 1876.
19	"	Wallace river, Whetstone brook, ½ mile northwest of Wentworth station.	Hard, grey Silurian slates.	Geol. Surv., Can., vol. I, pt. E., pp. 39 and 52 (1885).	A few whetstones made for local use over 50 years ago.
20	"	Pugwash river, opposite Pugwash River village.	Hard, grey sandstones....	....	A few scythestones for local use.
21	Digby................	Meteghan, on coast, 1 mile south of Meteghan.	Fine-grained, grey sandstone.	....	A few stones used locally many years ago.
22	Guysborough.........	St. Mary bay, 1 mile south of Sherbrooke.	Blue-black layers of the upper graphitic slates.	Geol. Surv., Can., vol. II, pt. P., p. 163 (1887).	Large quantities of slate for making whetstones shipped to U.S. about 40 years ago.
23	"	Chedabucto bay, near Crow harbour.	Quartz schistose rock that readily splits into long prisms.	Econ. Min. of N.S., Halifax Exhib., p. 54 (1906).	A good scythestone material which was at one time sold locally in the semi-rough condition.
24	Hants................	Kennetcook river, ½ mile north of Scotch village.	Grey sandstone..........	Geol. Surv., Can., vol.VI, pt. AA,. p. 66 (1895).	Quarried about 1890 and used as whetstones for saw sharpening.

TABLE XI

Sharpening-Stone Localities in Canada—Continued

Ref. No.	County or District	Location	Description	References	Remarks
			NOVA SCOTIA—*Concluded*		
25	Lunenburg...........	New Germany, Whetstone lake.	Bands of very fine-grained, hard, greenish and grey siliceous slates.	Geol. Surv., Can., Sum. Rept., p. 253 (1910).	Two pits sunk in 1901, ¼ mile west of lake in 6-foot band of slates. The valuable portion is the green band of 3 to 6 inches wide. Strikes east and west and traced for over 1 mile. Excellent quality hones but require careful sorting. Small plant partly erected.
26	"	Heckman island, 4 miles east of Lunenburg.	Fine-grained, dark grey, highly siliceous limestone.	....	Whetstones quarried for local use about 50 years ago.
27	Pictou...............	West Branch River John, Mine brook.	....	*See* table under Grindstones (No. 34).	
28	"	Merigomish island, west of Smashem head.	Fine-grained, reddish, hard shaly sandstones.	Geol. Surv., Can., vol. II, pt. P., p. 126 (1887).	Scythestones made about 1880 from the shaly sandstones west of the head; said to be of good quality.
29	Queens...............	Pleasant river............	No information..........	How's Min. of N.S., p. 177 (1868).	In Provincial Exhibition of 1854, and said to be good quality honestones.
30	Yarmouth...........	Roseway river, 35 miles up river at Whetstone lake and at Schoodic lake.	Grey slates and greenish quartzites.	Geol. Surv., Can., vol. IX, pt. M., p. 44 (1898).	Whetstones, said to be of good quality were made from the slates from several places on the Yarmouth-Shelburne boundary.
31	"	Yarmouth, Butterwell's farm at Brooklyn.	Fine-grained, dark grey, siliceous mica schist.	....	Said to have produced good scythestones and were one time in great demand locally and were known as "Pitman grit."
			ONTARIO		
32	Algoma..............	Plummer tp., cons. I to III. Ottertail lake.	Massive, white quartzites and conglomerates of the Huron series separated by layers of fine-grained, greenish grey, siliceous slates.	Geol. Surv., Can., pp. 56 and 809 (1863).	Hone and whetstones suitable for razor and delicate instrument sharpening were made from the siliceous slates about 1860.

33	Manitoulin...........	Manitoulin island, cape Smith.	Fine-grained sandstone layers in the Hudson River marls.	Geol. Surv., Can., p. 178 (1866).	In the Utica formation, consisting of massive, black bituminous shales; suitable for whetstones.
34	Hastings.............	Madoc tp., cons. V and VI, lots 4-5.	Blue, fine-grained, argillaceous mica schists with good parallel cleavage.	Geol. Surv., Can., pp. 32 and 809 (1863,; also p. 157 (1870).	Extensively quarried for scythestones about 1860.
35	"	West of Bridgewater, Elzevir tp.	Calcareous hornblende slate on contact of crystalline limestone.	Geol. Surv., Can., p. 107 (1866).	Portion of the slate suitable for whetstones.
36	"	Lake tp., cons. III and IV, lots 6, 8, and 18, Mud Turtle and Whetstone lakes.	Thin-bedded, fine-grained felsitic slates carrying rutile, hornblende and carbonaceous specks. Intruded by volcanic and calcareous rocks.	Geol. Surv., Can., Mem. 6, p. 176 (1910).	A few whetstones made many years ago for local use from south end of both lakes.
37	Renfrew.............	Clara tp., Deux Rivières..	Thin-bedded, fine-grained sandstones resting on gneiss.	*See* description under Grindstones.	Scythestones were made about 1870.
38	"	Ottawa river, west of Ottawa. At Chats falls, and at Allumette falls.	Sandstone beds of the Chazy formation.	Geol. Surv., Can., p. 809 (1863).	Whetstones for carpenters' tools and axe sharpening were made about 1860-81
39	Simcoe...............	Nottawasaga tp., cons. X, XI, lot 24, Collingwood.	Fine-grained sandstones of the Hudson River formation and the grey bands of the basal Silurian formation.	Geol. Surv., Can., p. 809 (1863). *See* description under Grindstones.	Coarse-textured whetstones were made from various localities along with the grindstones.
40	Algoma	Missinaibi river, Staunton tp., Sharp Rock portage.	Siliceous, grey mica schists overlain by greenish quartzites.	Geol. Surv., Can., p. 333 (1877).	
41	Kenora..............	Near Kenora............	Fine and compact-textured felsites or micro-granites and mica schists.	Geol. Surv., Can., vol. I, pt. CC., p. 150 (1885).	Used locally as whetstones, particularly amongst the Indians, about 1880.

TABLE XI

Sharpening-Stone Localities in Canada—Continued

Ref. No.	County or District	Location	Description	References	Remarks
			QUEBEC		
42	Brome...............	Bolton tp., range VI, lot 23, Libby pond.	Fine-grained mica schists.	Geol. Surv., Can., p. 809 (1863).	Whetstones made locally about 1860 on west shore of Libby pond.
43	Drummond..........	Kingsey tp., range II, lot 7, Mastine's farm, 2 miles north of Trenholm.	Argillaceous mica schists.	Geol. Surv., Can., p. 809 (1863).	Quarried from east bank of St. Francis river and produced good grade hone and razor stones. Small plant erected 1860 by Mr. Jackson.
44	Richmond...........	Cleveland and Shipton tps., between Melbourne and Danville.	Micaceous slates.........	Geol. Surv., Can., p. 809 (1863).	There are several places over the 12-mile ridge of slates between Melbourne and Danville that have been quarried and used locally for whetstones.
45	Sherbrooke..........	Orford tp., range XVIII, lot 9, Fraser lake.	Slate near contact with serpentine.	Geol. Surv., Can., p. 809 (1863).	Honestones said to be of excellent quality were quarried from the slate near Fraser lake many years ago.
46	Stanstead............	Stanstead tp., range II, lot 10, Memphremagog l., Whetstone island.	Bands of very fine-grained, greenish brown argillaceous schists on contact with black and grey limestones. Extends over distance of 12 miles.	Am. Jour. Sci., vol. V, p. 406 (1822); Geol. Surv., Can., p. 809 (1863); vol. IV, pt. K., p. 154 (1890); vol. VII, pt. J., p. 42 (1896).	In 1820 several mills were erected on the island and east shore of lake. Very large quantities of scythe-stones were made from the coarser schists, and oilstones said to equal the Turkish, from the fine beds.
47	"	Stanstead tp., range IX, lots 4-6, Stanstead plain, Verdun's farm.	Fine-grained, well-banded argillaceous schists having a flat dip to the west.	Geol. Surv., Can., vol. IV, pt. K., p. 154 (1890).	Used locally by farmers. The argillite outcrops in numerous places in area of several square miles and would make good scythe-stones.
48	"	Hatley tp., range VI, lot 15, Kateville, Kezars farm.	Fine-grained, blue and grey argillaceous schists	....	Used locally about 15 years ago as a whetstone. The blue stone is said to be excellent for sharpening tools. Covers an area of about 5 acres.
49	"	Hatley tp., range IX, lot 5, S.W. Massawippi lake, H. Norton's farm.	Fine-grained, blue-grey argillaceous schists.	....	A 2-foot seam of rock was worked for whetstones many years ago. Creek was dammed and material taken from its bed.
50	"	Also same on range II, lot 7, near Hatley.	....	....	....

UNITED STATES

TYPES AND DESCRIPTIONS OF VARIOUS SHARPENING STONES PRODUCED

The largest output and the best quality sharpening stones come from the United States, by far the largest producer being the Pike Manufacturing Company, with factories at Littleton and Pike, New Hampshire.

The following varieties are produced:—

Novaculite

Novaculite is a very fine-grained and compact white, quartzose rock, supposed to be a consolidated siliceous slime. It consists almost entirely of chalcedonic silica (over 99 per cent) and is of sedimentary origin. The rock is quarried principally from the vicinity of Hot Springs, Garland county, Arkansas. There are two varieties, the true novaculite (Arkansas stone) which is white, and the Washita (Ouachita) stone which in many instances has a yellowish or rusty red tint.

The *Arkansas stone,* which is very dense, possesses a conchoidal fracture and waxy lustre. It occurs in massive beds of a few inches to 15 feet thick in the novaculite formation which has a total thickness of 500 feet and includes thin layers of shales and sandstones. As a result of pressure the brittle novaculite has in many places been crushed and split. In addition to this, many fine quartz veins intersect the rock in all directions, some being so thin as to be invisible to the naked eye. Since these are detrimental, very careful sorting is necessary, and the amount of waste is out of all proportion to the material eventually used. Large blocks of even apparently pure stone are not shipped, but are broken up into pieces weighing up to five pounds. Freezing also has an injurious effect on this stone as its denseness does not allow for its expansion.

The Arkansas stone, which is produced in "hard" or "soft" grades, is especially suitable for sharpening fine-edged instruments and small tools and is mainly used by surgeons, dentists, engravers, jewellers, etc.

The *Washita stone* has approximately the same composition as the above but is less dense and more porous, possesses a sub-conchoidal fracture and resembles unglazed porcelain. It is freer from defects than the Arkansas stone; quartz veins are not so numerous, but cavities or "sand holes" are much more common. On account of its greater porosity freezing does not have an injurious effect. Long drying is, however, inadvisable as it seems to cause loss of easy fracture and to make the stone tough and hard. The stone is less expensive than the Arkansas and is a faster cutting stone, but is used for coarser work.

The Washita stone is shipped in blocks of 50 to 1,000 pounds in weight. It is found in much larger quantity than the Arkansas stone and the demand for it is also much greater. It is claimed that these novaculites give a much smoother and longer lasting edge than do the artificial stones.

A description of the novaculite quarries which are now mainly operated by the Pike Manufacturing Company will be found in various bulletins dealing with the non-metallic mineral resources of the United States.[1]

[1] Phalen, W. C.: Min. Res. of U.S.A.; pt. II, pp. 842-5 (1911); also Merrill, G. P.: Smithsonian Inst., pp. 466-69 (1901).

Mica Schists

Fine-grained, dark grey, highly siliceous, laminated mica schists are quarried by the Pike Company at Pike, Grafton county, New Hampshire. The quartz grains occur in definite layers separated by thin layers of mica. That part of the rock containing coarse, irregularly scattered quartz and argillaceous matter is discarded. There is a regular system of cross-jointing at right angles to the bedding-planes, so that after blasting, slabs or "bents" are easily pried out. The irregular slabs are first roughly trimmed, and these in turn are further reduced and stacked.

These quarries have been producing scythestones for over a hundred years.

At Lisbon, also in Grafton county, the Pike Company produces the "chocolate" stone from a bluish chocolate-coloured schist. The demand for this stone has died out in late years, so that a few weeks' quarrying provides enough for several years. It is mainly used by fishermen along the coast.

The Pike Company also operates a quarry at Evansville, Orleans county, Vermont. The rock is of a more massive formation than the Pike, and does not occur in layers.

Sandstone

Amongst the better known is the *Hindostan* or Orange stone from French Lick, and Northwest township, Orange county, Indiana. Some of the crude material is shipped to the Pike Company at Pike or Littleton for manufacture. It is a fairly soft, fine-grained, low-priced waterstone used mainly by mechanics and for domestic use.

Scythestones have been manufactured by several of the Ohio grindstone companies, particularly from the Berea and Euclid grits. The Queer Creek stone is a hard, dark grey, medium coarse sandstone, which is used as a waterstone for coarse sharpening. The Euclid is a blue, very fine grit stone used mainly for butcher and pocket knives. The Berea grits are used for the coarsest work, and the Huron for medium.

The *Deerlick* stone is produced at Chagvin Falls, Cuyahoga county, Ohio.

The *Labrador* stone, which is somewhat similar to the Ohio sandstones, is produced to a small extent near Labrador lake, Cortland county, New York.

Rubbing Stones

There are a number of sandstones of various grits, known as brown, blue, and red, that are extensively used for honing or rubbing marble or granite by hand. Other types of compact micaceous stone used for this purpose are the *American Black Hone*, and the *Kentucky Caron Hone* from Louisville.

PRODUCTION

The average annual production of whetstones in the United States for the last five years has been about 1,000 tons valued at approximately $260,000. For details see Non-Metallic Mineral Resources of the United States.[1]

[1] Katz, F. J.: U.S. Geol. Surv., Min. Res. of U.S.; pt. II, p. 337 (1925).

EUROPE

BRITISH ISLES[1]

A great many of the finer-grained sandstones already described under English grindstones are used for hone and oilstones, especially those from Bilston, Newcastle, and from many parts of Yorkshire. The Gwespyr sandstone from Talacre, Flintshire, is used for scythestones. It is a light greyish buff, slightly micaceous sandstone, massive, compact, fine-grained and homogeneous.

The most important type of whetstone is the *Scotch hone*, sometimes called *Water-of-Ayr*, *Snakestone*, or *Tam O'Shanter*, obtained from Bridge of Stair, near Dalmore, Ayrshire, Scotland. It is a mottled, pale grey, very compact, Carboniferous shale which has been hardened by igneous intrusions. It is used as an ordinary whetstone, also for a lithographic stone and for burnishing pulpstones.

Another good hone is the Charley Forest or *Whittle Hill* stone from Leicestershire. This is an exceedingly fine-grained, hard tuff from the Blackbrook series, the lowest member of the Precambrian series in this district. The *Idwal* or Welsh oilstone, and the *Cutler's Green* from Snowdon, Wales, have also been extensively used. The so-called "Ragstones" obtained from Scotland and elsewhere, consist of siliceous mica schists having a twist along their length which gives a sharp "bite."

BELGIUM

The well-known *Belgian razor hone*, sometimes called *"soapstone"* or *"petrified woodstone"* is a damourite slate containing innumerable garnets, more than 100,000 in a cubic millimetre.[2] The stone occurs in the form of 2- to 3-inch, white to yellowish bands in a blue-grey slate (phyllade). These bands are parallel with one another and with the grain of the slate, into which they sometimes gradually merge, but in most cases there is a sharp line of demarcation. Since the slate possesses abrasive qualities also, the stones are usually double-faced, with the yellow damourite on one side and the grey slate on the other. The chemical composition consists of less than 50 per cent total silica and is high in manganese and alumina, and having less than 2 per cent iron oxides with a trace of lime, the garnets are probably the manganese-aluminium-silicate, or spessartite variety.

These hones are quarried at Lierraux, Salm-Chateau, Bihau Sart, and Recht in the Belgian Ardennes.

OTHER COUNTRIES

The *German water hone* from Sonneberg is a hard, fine-grained, bluish green argillaceous schist. *The Ratisbon hone*, which is similar to the Belgian stone described above, occurs as a yellowish band from 1 inch to 18 inches wide in a blue slate.

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[1] Information mainly supplied through the courtesy of the Imperial Institute, London.
[2] Merrill, G. P.: Smithsonian Inst., U.S. Nat. Museum; pp. 470 (1901).

Whetstones are also made in Bavaria, Italy, and Sweden. In 1923 the Bavarian production was 45 tons and the Italian, 490 tons. The Swedish production for 1923 was valued at 27,890 krona.

ASIA

TURKEY

The Turkey oilstone from Smyrna in Asia Minor is, in nearly all respects, similar to the Arkansas novaculite, but is not so uniform. It is, however, drab in colour and carries an appreciable amount of free calcium carbonate and other impurities. Before the discovery of the Arkansas stone, it was regarded for several centuries as the best oilstone for mechanical tools.

SILICAS USED AS MEDIUM HARD ABRASIVES

FLINT

True flint, which is a chalcedonic variety of silica (SiO_2), is extremely hard, light to dark grey in colour, and possesses a prominent conchoidal fracture.

When found as rounded pebbles it is used for grinding purposes in cylindrical mills. The flint pebbles found in the chalk deposits of the southeast coast of England, after crushing and grading, are used for making abrasive cloths and papers. It is because of this use that the English market for garnet remains small, since the flint, which is plentiful in the British Isles, is a cheaper material, and is almost as hard as garnet. Flint also occurs abundantly in the chalk deposits of France and Belgium.

True flint is not found in commercial quantities in Canada and the material so-called by the trade, is quartz.

QUARTZ AND QUARTZITE

Quartz is a very common, hard, brittle mineral having a conchoidal fracture but no cleavage. It occurs in many forms and colours, but is usually white, and is transparent to opaque. It has a hardness of 7 and a specific gravity of 2·64. Quartzite is a metamorphosed sandstone in which the individual grains are not easily identified.

A very small percentage of the quartz and quartzite mined is used for abrasive purposes. Part of the output of some deposits is crushed and graded for use as sandpaper. The finer material is used as an ingredient in scouring powders, soaps, etc. Crushed and graded quartz is also used in glass-grinding, though for this purpose it has been largely replaced by other materials such as pumice, garnet, and artificial abrasives. Very finely crushed quartz is used as a metal-buffing compound in the form of a grease brick.

Quartz is not adapted to grinding-wheel manufacture although it is in some cases mixed in small quantities with other abrasives in making open cutting-wheels for knife-grinding.

A small tonnage of Canadian quartz is mined by the Orser-Kraft Company from quarries near Christie Lake and Maberly in Lanark county, Ontario, and shipped to Canadian abrasive paper manufacturers. Approximately 150 tons was used during 1924-1925. There are many other deposits from which suitable material could be obtained if required. Large masses of pure glassy quartzite, which might be suitable for abrasive purposes, occur from 1 to 3 miles east of Rutter station on the Canadian Pacific railway, about 30 miles southeast of Sudbury, Ontario. Details of the Canadian silica deposits will be found in L. H. Cole's monograph.[1]

In the United States the main sources of quartz for sandpaper are Maine, Maryland, and Wisconsin.

[1] Cole, L. H.: Silica in Canada; Mines Branch, Dept. of Mines, Canada, Rept. 555, 126 pp. (1923).

CHERT, HORNSTONE, AND NOVACULITE

Chert is a compact, chalcedonic silica of organic or precipitated origin. It has approximately the same composition as flint, but is coarser and less homogeneous and as a rule contains more oxide of iron and lime. It occurs distributed throughout limestones, affording cherty limestones, and is especially common in certain Carboniferous rocks, particularly those of southwest Missouri, U.S., at Bakewell in Derbyshire, at Reeth in Yorkshire, England, and at Holywell, Wales. In the British Isles it is locally known as malmstone, hearthstone or firestone, and it is used in the potteries for paving the flint mills.

Chert occurs in numerous parts of Canada, but is classified with flint in its use for grinding-pebbles, tube-mill linings, etc. A large deposit of a dark variety of chert occurs as one of the gangue rocks in the Sullivan lead-zinc mine, East Kootenay, British Columbia, and large quantities are now lying on the dumps. As it is very hard and breaks with a sharp fracture it might be employed as a cheap abrasive, although the dissemination of iron pyrites throughout the mass would be somewhat detrimental.

Hornstone is an impure flint with a splintery fracture; it is more brittle than true flint.

Novaculite is an opaque white, fine-grained quartoze rock supposed to be a consolidated, siliceous slime of sedimentary origin. It occurs extensively in Arkansas, and considerable quantities are used to make whetstones. The material, which is not known to occur in Canada, is fully discussed under Sharpening Stones.

SANDSTONES AND SAND

The principal abrasive uses of sandstone are for making grindstones, pulpstones, sharpening stones, etc., which are dealt with separately under their own headings. Other abrasive uses are as follows:—

Sandblasting

The principle involved in sandblasting is the forcing of dry, clean sand grains by means of air in a special device on to the rough surfaces of various castings, metals, stone, etc., whereby they are made comparatively smooth. Sandblasting was first used as a means of "frosting" glass and later its use was applied to metals.

Both bank and sea sand, but usually disintegrated or crushed sandstone, are employed for sandblasting. Some difference of opinion exists as to the relative merits of sharp angular grains and rounded grains, but recently there appears to be a decided preference for the latter. It is claimed by some that although the sharp grains cut faster, it is the impact of the grain against the surface that does the work; that in the rounded form the grains touch at only one point, and if of uniform size they make more dents per given area, which are more uniformly spaced than with the angular grains, and therefore give a better finish. The round particles are less liable to split under impact and consequently have a longer life. Under the microscope the grains should have the appearance of round, semi-transparent pearls of uniform size and colour. The speed and thoroughness with which they clean are governed more by the velocity and the number of individual grains or granules striking the work than by the size of the grains.

All quartz grains have about the same hardness, but there is considerable difference in the toughness or ability to resist crushing and shattering.

In application, the sand must be absolutely dry, and free from dust or loam. The sand can usually be used over and over again, until the grains are broken too fine. The waste sand can be used for several purposes such as, in foundry work, linings between the brick flooring of annealing furnaces, etc.

The following ranges of sizes of grain for sandblasting are suggested:[1]

Sand No. 1—	Through	20	mesh on	35	mesh.
Sand No. 2—	"	10	"	28	"
Sand No. 3—	"	6	"	10	"
Sand No. 4—	"	4	"	8	"

No. 1 sand is used for light work and where a comparatively smooth finish is desired such as for automobile castings, finishing brass, frosting glass, and removing paint. No. 2 is used for similar work but of a heavier character. Nos. 3 and 4 are used for the heaviest cast iron and steel work only.

The use of metallic shot and grit for heavier work as well as the types of machines used in blasting are described in the bulletin on Artificial Abrasives.

Production Centres. No Canadian sand or sandstone appears to have been used for sandblasting. In the few instances in which it has been tried out it was found that the material was either too fine in grain or else fractured too easily. However, some of the beds of the basal members of the Potsdam sandstones of southern Ontario along St. Lawrence river, particularly in the vicinity of Kingston, as well as those along the St. Lawrence and Ottawa rivers in Quebec, may be found to be suitable for this purpose.

The main production centres in the United States are New Jersey, Ohio, and Illinois. The first named are lake and beach sands, whereas the Ohio and Illinois sands are generally obtained from sandstones.

Glass-surfacing Sand

Pure, clean, beach and river sands, or Illinois sand, are used almost universally for the preliminary or coarse surfacing of plate glass. The crude sand is water-graded into a number of grades at the glass plants and fed to the surfacing machines. Approximately 3 tons of sand is required to surface 1 ton of plate glass. A fine grade called "banding" sand is sometimes used for bevelling glass, and is prepared by screening the fines from sandblast or glass sand. The process of glass surfacing and machines used are described in the bulletin on Artificial Abrasives.

[1] Weigel, W. M.: Abrasive Industry, p. 309 (Dec. 1924).

Cutting Sand

Clean sand possessing sharp, solid, quartz grains is extensively used as an abrasive for sawing stone. It is usually an ungraded coarse sand about equivalent in mesh to a No. 1 sandblasting sand.

Burnishing Sand

Burnishing sand is a fine-grained, tough, clean, silica sand, with grains as nearly rounded as possible. It is used mainly in rolling down and burnishing gold decoration on chinaware and porcelain. It should be uniform in size and between 65 and 100 mesh.

MINING AND PREPARATION

The sand used for any of the above purposes is usually quarried by steam shovel, or by hydraulic dredging. The sand is always prepared by washing over screens of suitable sizes to remove clay, vegetable matter, and other impurities adhering to the quartz grains. It is then dried in rotary steam or revolving driers. The large sizes are usually taken out by means of trommels of coarse wire cloth, and the finer sizes are separated on shaking or vibrating screens. If the sand is obtained from sandstone, the rock is first crushed and then treated in a manner similar to that already described. The very friable, non-coherent sandstone such as occurs in the vicinity of Ottawa, Illinois, is blasted with dynamite and then disintegrated by powerful hydraulic jets instead of being crushed.

The United States production of grinding and polishing sands averages one million short tons annually.

The Silico Limited Sandstone Quarry, St. Canute, Quebec. Sandstone is sometimes used indirectly for abrasive purposes when it supplies the silica necessary for the manufacture of the artificial abrasive, silicon carbide.

In this connexion, the Silico Limited is operating a deposit of Potsdam sandstone, one mile east of St. Canute, in the Lake of Two Mountains district, Quebec.

The sandstone occurs as a dome-like mass rising to a height of about 40 feet above the surrounding country. The rock is very white, fine-grained, and easily crushed. The company has opened up a quarry face about 300 feet long and about 30 feet high. The sandstone, which occurs as horizontal beds 1 to 3 feet thick, is mined by the bench system. (Plate X.)

The material is trammed to the mill on the property. The mill equipment consists of a 12- by 20-inch jaw crusher, and a 9-foot chaser mill with two 10-mesh trommel screens. The crushed and screened product passes through the washing plant composed of 10 long, narrow troughs fitted with screw conveyers. The overflow goes to settling-tanks where the fines are collected and the heavier material from the washers is conveyed to the top of the building where it is drained, after which it is shovelled into the boot of an elevator which conveys it to a steam drier. The dried material is then elevated to revolving trommel screens. In all, four grades are produced, the first three being used respectively for glass sand, manufacture of silicon carbide, and for foundry work. There is at present very little market for the overflow fines.

During 1924-25 over 20,000 tons of graded sand from this quarry was used in Canada for the manufacture of silicon carbide.

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SILICAS AND OTHER MATERIALS USED AS SOFT ABRASIVES

DIATOMITE

Diatomite (tripolite, kieselguhr, diatomaceous earth, etc.) is composed of myriads of minute siliceous skeletons of aquatic plants of marine or freshwater origin called diatoms. It has the appearance of chalk when dry, but is extremely light in weight, and when pure contains up to 96 per cent silica in the form of the diatom skeletons. Microphotographs of samples of Canadian diatomite are shown on Plate XIII C and D.

It has a great many uses, the most important of which are for filtration and for insulation against heat, cold, and sound. As an abrasive it is used in paste and liquid metal polishes, in dental powders, and for polishing finger nails, etc.

It occurs extensively in Canada, particularly in the Maritime Provinces, as deposits in lakes or marshes; these deposits rarely attain a thickness of more than 6 feet. The largest deposits so far found in Canada are in British Columbia, where, in the vicinity of Quesnel, it occurs over many square miles in compact beds 40 feet thick, in some places hundreds of feet above the present rivers.

Diatomite is mined in Canada by one firm only, the Oxford Tripoli Company, Oxford, Nova Scotia.

The material consumed by Canadian industries is mainly obtained from the large California deposits. Upwards of 100,000 tons are produced annually in the United States. The uses and demand for diatomite are continually increasing. The price varies from $8 to $15 for the crude; $30 for straight calcined; and up to $120 per ton for finest air-float.

Further details regarding this material will be found in a separate report on Diatomite.

TRIPOLI AND AMORPHOUS SILICA

Tripoli is a form of silica which closely resembles diatomite, but is of entirely different origin. The material was first quarried at Seneca, Missouri, about 1872, and on account of its close outward resemblance to the substance occurring at Tripoli, north Africa, it was called tripoli although the African product is true diatomite. However, since that time the use of the term has been reserved for the Seneca material and other siliceous materials of similar origin and physical properties, and it is now regarded more in the nature of a trade name. Rottenstone is sometimes classed, though erroneously, with tripoli.

General Description and Composition

Tripoli is generally regarded as a chalcedonic variety of silica. It is soft, friable, porous, and double refracting. Under a high magnification the grains have a subangular and minutely globular or spongy appearance, by which it can be distinguished from the plain or striated, sharp, glass-like fragments in volcanic dust or pumicite, or from diatomite by its absence of all diatom structure. (Plates XIII and XIV).

The apparent density of tripoli is considerably higher than that of diatomite which will at first float on water, whereas tripoli immediately sinks. The combined water of the pure material is 0·5 per cent (diatomite 5·0) and is usually high in silica content (96-99 per cent). The crude rock has an absorption of 38 and the powder, 52 per cent. It has a fusion point of 3200° to 3300° F.

Difference between Tripoli and Amorphous Silica

There has been much controversy as to the origin of tripoli due to the fact that, until recently, there have been two types of so-called tripoli, one of which may be termed the Missouri-Oklahoma type, and the other, the Illinois-Tennessee type. Although the general appearances of these two materials are similar in many respects, it has been proved that they differ in origin. Under the microscope, both show the spongy, globular clusters of the grain formation, but in the Missouri type it is more evident (Plate XIII A and B). According to G. V. B. Levings[1] the two types can be distinguished by a microscopic examination, using polarized light with a purple-green colour screen and crossed nicols, which reveals the double refraction of the Missouri material. Since the Missouri variety was the first to be discovered, the term tripoli would strictly apply only to that material, so that the Illinois type is now usually known as amorphous silica, though it is more of a cryptocrystalline nature. Cherty material and siliceous limestone occur in, or in the immediate vicinity of both types of deposits.

At one time tripoli was thought to be an altered chert or a residual product from the decomposition of siliceous limestone. The Missouri material, however, according to Levings, is an altered form of Arkansas novaculite, which originally contained alkaline salts. The salts were removed by percolating surface waters leaving the siliceous grains which were ultimately re-deposited, probably as a colloidal gel. Although tripoli occurs in a limestone formation, the siliceous particles in the limestone do not show the same character as the tripoli, nor even in the decomposed parts underlying the tripoli beds. The nodules and horizontal layers of chert found within the beds were probably deposited along with the tripoli.

On the other hand, there appears to be no doubt that the Illinois silica is a decomposition product of the Clear Creek cherts of the Devonian age and was possibly carried down while in the crystalline form to the district where it is now deposited, and gradually changed to the cryptocrystalline structure—a change which evidence has shown to be still in progress. The Illinois-Tennessee silica varies in structure from the noncoherent of the Tennessee phase to the hard, compact, dense and absorbent in the Illinois phase. In colour it is usually pure white, but parts of the deposits are in many places stained by iron oxides to creamy yellow or rose. It occurs in extensive thick beds usually mixed with unaltered chert.

[1] Butler, P. B., and Levings, G. V. B.: The Metal Industry (January 1924).

USES

Tripoli is used for similar purposes to diatomite, but the number of these uses is considerably less. The main uses for tripoli are as a parting-medium in foundries, filtering, mild abrasives, and fillers.

Abrasives

Tripoli and amorphous silica are extensively used as mild abrasives for polishing, buffing or burnishing, for which purpose about 30 per cent of the United States production of tripoli, or 5,000 tons are used annually. Its high porosity and absorption powers make it possible for tripoli to form a very strong bond with stearic acid, tallow, paraffin, petrolatum, etc., with which it is mixed to form the "Tripoli grease bricks" and "Tripoli compositions" of the trade.

Tripoli is also used in the manufacture of scouring and cleansing powders and soaps; for the rubbing down of painted surfaces, particularly as the final rub on the Duco finish of automobile bodies. Due to its absorbent properties it is used to a considerable extent in washing powders in which it acts as a mechanical cleanser with soap and other ingredients, and since it absorbs calcium salts it has a tendency to soften water.

The Illinois material is also extensively used in grease bricks and is now recognized by the users as "silica" and is employed for different purposes than tripoli, since its action is different on the buffing wheel. The finest powders are used in grease compositions such as the "white diamond" of the trade for white "colouring" operations on high-class work.

Parting Sand

True tripoli has found increased use as a prepared parting sand in foundry work and about 60 per cent of the total output is now used annually for this purpose, considerable quantities being used by Canadian makers of foundry facings.

Filters

The massive forms of tripoli are largely utilized for the manufacture of filter stones for domestic filtering installations. They are cut from the compact beds and made in a variety of sizes from flat disks up to 12 inches in diameter by 1 inch thick to cylinders up to 6 inches in diameter and 8 inches thick.[1]

Fillers

The largest use for both tripoli and amorphous silica as a filler is in the paint industry where they are known as "soft silica" as distinguished from "hard silica" made by crushing quartz, flint, etc. They are also used in the manufacture of rubber, particularly hard rubber, in refractory cements, and as a carrier for the active ingredients in insecticide dusts.

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[1] Ladoo, R. B.: U.S. Bur. of Mines, Reports of Investigations, Serial No. 2190 (Nov. 1920); also Butler, P. B., and Levings, G. V. B.: The Metal Industry (January. 1924).

DISTRIBUTION

No tripoli or amorphous silica of the Illinois type has been found in Canada. Although it is reported under the heading of tripoli as being produced from France, Spain, and Germany, no details are available. However, none of these, with the possible exception of the German variety, are similar to the Missouri material.

UNITED STATES

The following shows the production in United States since 1913:[1]

TABLE XII

Tripoli* Production in the United States

(Metric Tons)

1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
18,867	15,620	27,860	39,242	23,649	18,127	22,037	36,499	11,195	27,401	27,082	28,476	29,388

* This also includes amorphous silica, the production of which is slightly the greater.

Tripoli

The main deposits are distributed over an area of less than 100 square miles in the vicinity of the Missouri-Oklahoma boundary, of which Seneca, Newton county, Missouri, is the centre. The best deposits, which are all within two or three miles of Seneca, are horizontal, and occur along the crests of ridges in uniform beds from 2 to 20 feet in thickness with an average of 10 to 12 feet, overlain by an average of 6 feet of overburden.

By far the largest producer in the Seneca district is the American Tripoli Company,[2] whose annual output is almost 12,000 tons.

Amorphous Silica

This silica is more widespread than the Missouri tripoli and deposits exist in Illinois, Tennessee, Georgia, Alabama, Mississippi, and Nevada. The largest deposits occur around Tamms, Elco, Jonesboro, and Wolf Lake, in Alexander and Union counties, Illinois, from which an average annual output of about 15,000 tons is maintained.

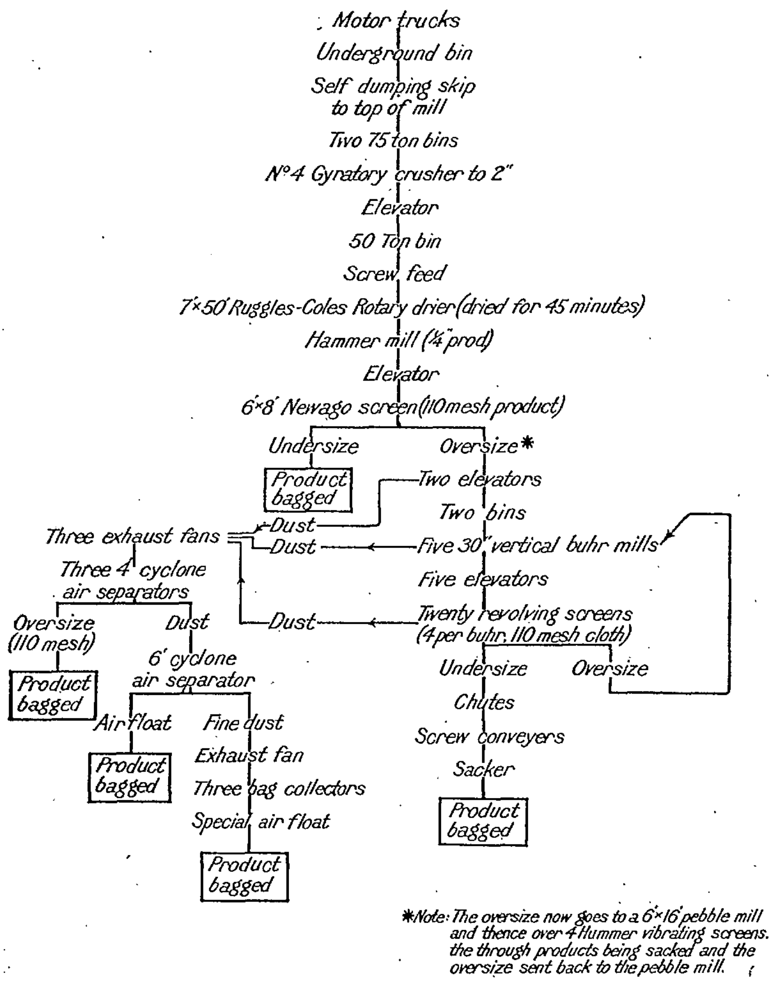
In Illinois the silica occurs as a nearly pure white, hard material, with considerable overburden. The largest deposits are worked by the Tamms Silica Company at Tamms, Illinois, but there are eight or more other producers in the state, amongst which are the International Silica Company at Elco, and the Innis, Speiden Company at Murphysboro and at Wolf Lake.

[1] Katz, F. J.: U.S. Geol. Surv., Min. Res. of U.S.; pt. II, 27, p. 337 (1925.)
[2] For detailed description see Butler, P. B., and Levings, G. V. B., The Metal Industry (January 1924).

In Tennessee the silica occurs as a thick, tilted series of beds several hundred feet in thickness and of unknown depth. The deposits are located in a narrow strip, extending southwesterly from Cleveland, Bradley county.

MINING AND MILLING

The mining of tripoli is very similar to that employed for any soft, bedded material. In some instances where the overburden is thick, under-



From report by R. B. Ladoo, U.S. Bureau of Mines, No. 2190, Nov. 1920.

Figure 4. Flow-sheet of mill of the American Tripoli Company, Seneca, Mo., U.S.

ground mining by the room and pillar methods is employed. Care is taken to make use of the joint- and bedding-planes so that as large blocks as possible are removed without breaking. This is done by means of the ordinary plug-and-feather method, or else by a special system of channels, cut by a hand-channelling machine, and the holes drilled are filled with unslaked lime and tamped. The swelling of the lime from the moisture in the material causes the blocks to break off.

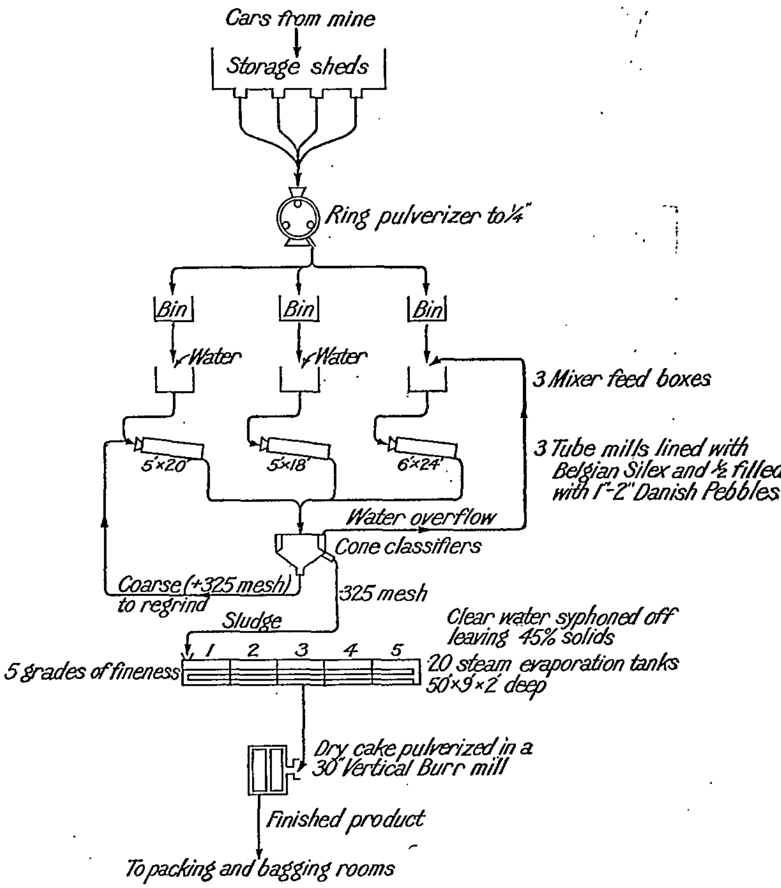


Figure 5. Flow-sheet of silica mill of Tamms Silica Company, Tamms, Ill., U.S. Capacity 50 tons per 24 hours.

The milling methods employed for Missouri tripoli consist of a somewhat intricate system of driers, pulverizers, screens, and air separators. Details of the methods employed by various companies are given in R. B. Ladoo's report No. 2190,[1] the flow-sheets from which are hereby produced and are self-explanatory. (Figure 4).

[1] Op. cit., also "Non-Metallic Minerals," p. 648.

The Illinois silica is treated wet and the flow-sheet for its recovery is much simpler than that used for the Missouri material which is graded by dry methods. (Figures 5 and 6).

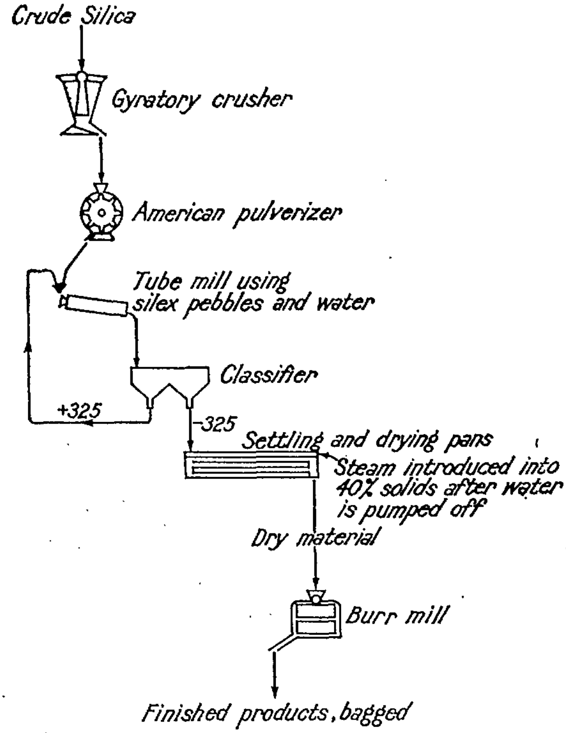


Figure 6. Flow-sheet of silica mill of the Innis, Speiden Company, Murphysboro, Ill., U.S.

MARKETS AND PRICES

The markets are indicated in the list of uses. The prices for the latter part of 1926 are as follows:

Missouri tripoli, per short ton, burlap bags, paper liners, per minimum carload of 30 tons, f.o.b. mills:

Crude...$5 to $7.50
Once ground through 40 mesh (85%-200 mesh)
Rose and cream coloured..........................$14
Double ground through 110 mesh (96%-200 mesh, of which 90%-325 mesh)
Rose and cream coloured..........................$17
Air-float through 200 mesh (99·5%-325 mesh)
Rose and cream coloured..........................$25
Mill run...$15
Super air-float—About $10 per ton higher than above.

The demand for air-float is very small, the largest demand being for the double ground.

Illinois silica, water-ground and floated, per short ton, in bags, f.o.b. mills:

450 mesh	$31	200 mesh	$20
350 mesh	$26	100 mesh	$8

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SILT

Silt is a common, fine-grained, siliceous material which has been formed by the disintegration of siliceous rocks, and which has been washed down to lower levels by water, in the process of which most of the soluble ingredients have been leached out. In composition it is variable, depending on the original rock constituents and the intensity of the water action, the main constituents being silica 50 to 75 per cent and alumina 12 to 25 per cent. Chemically, it resembles volcanic dust, but it is rarely as pure. The grains are somewhat rounded and are unlike the flat angular particles which are characteristic of volcanic dust deposits. Striations of the grains are also absent. (*See* Plate XIII E.) It differs from clay in that it is "short." In colour it is seldom pure white, but usually grey, buff, or brown, depending on the amount of iron present.

Some silts have been successfully used as an ingredient in cleansing powders and hand cleaners and occasionally as a metal polish.

CANADIAN DEPOSITS

Numerous deposits of silt have in the past been used on a small scale, purely for local use, and about which little or no information is available.

At Black harbour, about 6 miles south of St. George, New Brunswick, a deposit of fine, light grey silt varying in thickness from a few inches to two feet and covering an area of several acres has been worked. The silt is put up in cardboard cartons by the Connors Brothers and sold under the trade name of "Black's Infusorial White Polish." (*See* analysis, Table XIII, No. 1; and microphotograph, Plate XIII E.)

In concession X, lot 19, Chaffey township, Muskoka, Ontario, beds of pale yellow silt occur along both banks of the Little East river, about 8 miles north of Huntsville. In places the deposit has a thickness of 25 feet and extends about 20 feet from the river banks. It is stratified with sand and layers of silts of varying coarseness. Messrs. Tynan and Southby have recently been working this deposit on a small scale and putting the material on the market in the form of scouring powders and cleansers. It is understood that they intend to erect a treating plant in the near future.

In British Columbia, particularly in the wide river valleys of the interior, there are vast quantities of fine siliceous material, which have been deposited by water and which attain a thickness of over a hundred feet. The silica content, however, is rarely as high as 70 per cent and it is doubtful whether any of these silts are pure enough to be of commercial value (*see* analyses).

TABLE XIII

Analyses of Canadian Silts

—	1	2	3	4	5	6
SiO_2	70·40	64·10	57·80	62·70	61·40	68·00
Al_2O_3	17·53	14·53	20·05	15·95	19·19	17·04
Fe_2O_3	3·47	7·71	6·95	6·47	5·21	3·16
CaO	nil	3·96	6·60	6·65	4·35	0·56
MgO	1·88	2·50	1·31	1·45	1·49	1·96
Na_2O and K_2O	n.d.	6·32	n.d.	n.d.	n.d.	n.d.
H_2O at 105° C	3·57	n.d.	5·50	2·52	4·26	3·85
CO_2 and organic matter	1·99	1·10	1·01	2·28	4·14	2·57
	98·78	100·22	99·22	98·02	100·04	97·14

1. Black harbour, south of St. George, N.B.
2. Chaffey tp., Muskoka, Ont.
3. Todd hills, east of Kamloops, B.C.
4. High silt banks, 5 miles west of Kamloops, B.C.
5. Junction of Elk and Kootenay rivers, 3 miles south of Waldo station, Fort Steele mining division, B.C.
6. Lockhart creek, Boswell, Kootenay lake, B.C.

BATH BRICK

Bath bricks are made of river silt which is moulded, dried, and burned at a dull red heat. It is one of the earliest known made-up forms of natural abrasive and is used extensively (particularly in Europe) for scouring steel utensils, and when finely ground is used for rough polishing, either in the form of a paste or liquid.

The name originated in England and the brick is made from a very fine, highly siliceous silt which occurs along the banks of the Parret river at Bridgewater, Somerset, England.

Some of the Canadian silts might be prepared and used in a similar manner.

ROTTENSTONE

Rottenstone is a residual product derived from the weathering and decaying of a siliceous, argillaceous limestone, the calcium carbonate and other impurities having been leached out leaving a siliceous skeleton. It occurs as a soft, friable, very fine-textured, earthy mass of light grey to brownish or olive-grey colour. It is sometimes erroneously classed as tripoli, but is more impure and less siliceous than the Missouri tripoli.

It varies considerably in chemical composition. Analyses show silica 80 to 85 per cent, alumina 4 to 15 per cent, carbon 5 to 10, iron oxides 5 to 10, and small amounts of lime.

It is used for polishing wood and metal and, recently, in the form of a paste for rubbing down paint and varnished surfaces, and as a filler, particularly for phonograph records. In Europe it is used more extensively than on the American continent and forms one of the abrasive bases in some English paste and liquid metal polishes.

True rottenstone comes from Hull and from the Yoredale rocks of Derbyshire, England; also from Wales and Belgium. In the United States the material produced at Antes Forte, Lycoming county, Pennsylvania, is not true rottenstone and is not so good as the English product. It contains about 60 per cent silica, 17 per cent alumina, 8 per cent alkalies, and 9 per cent iron oxides with some water, lime, and magnesia, and is probably a ferruginous and siliceous shale. It is much heavier than the true stone which is very light.

The fine grades, 250 mesh, are sold for $28 to $29 per ton in carloads, f.o.b. mill; the coarser grades sell for about $24 per ton. The English stone is almost double the price of the American.

True rottenstone has not been found in Canada.

CLAY

Clays are used to a small extent as a mild abrasive in some polishes, cleansers, and cleaning soaps, etc. Only clays containing a large percentage of very finely divided quartz, and therefore almost silts, are suitable. They are, however, cheap and inferior abrasives which take the place of the more superior ground pumice, volcanic dust, diatomite, or other forms of silica. On the other hand, certain highly burned clays which have afterwards been finely ground and levigated, make a good abrasive and are often used by English metal polish makers.

Various clays are used in the manufacture of the numerous types of grinding wheels. These clays are slip clay, fireclay, stoneware clay, etc. All clays used by Canadian grinding-wheel manufacturers are imported from the United States. About 0·5 per cent of the total clay produced in the United States is used in the manufacture of grinding wheels.

SILICATES

Certain silicates are extensively used for abrasive purposes, particularly the glassy volcanic rocks or obsidians such as pumice and volcanic dust. Feldspar is sometimes used as a mild abrasive ingredient in cleansing powders.

PUMICE

Pumice is a highly cellular glassy volcanic rock or lava usually of a certain acid variety known as liparites and has the same composition as normal rhyolites.

It occurs in the vicinity of volcanoes as porous blocks of a white or light grey colour. Owing to its cell-like structure it will float on water. The cutting or abrasive quality of this material is mainly due to the thin partitions of glass composing the walls between the cells.[1] (Microphotographs of the grains of ground pumice are shown in Plate XIV A.)

Composition

Lump pumice varies in composition according to the locality in which it is found. It contains impurities such as feldspar and hornblende which diminish the value as an abrasive as these tend to scratch articles being polished. A good pumice contains 65 to 75 per cent silica, 12 to 15 per cent alumina, 4 to 5 per cent soda, and the same amount of potash, with a small percentage of other minerals. The silica is mainly in the form of glass or silicates of the other minerals present. Typical analyses are as follows:—[2]

TABLE XIV

Analyses of Pumice

—	1	2	3	4	5	6	7	8
SiO_2	67·39	76·91	61·07	73·91	73·70	63·94	64·84	70·80
Al_2O_3	15·99	12·18	17·55	13·30	12·27	16·34	19·70	13·18
Fe_2O_3	0·56	0·48	2·13	2·46	2·31	3·57	3·24	3·52
FeO	1·99	0·92	4·13	....	....	....	....	....
MgO	0·77	nil	2·26	0·37	0·29	1·38	1·45	0·50
CaO	1·63	0·92	6·28	0·54	0·65	3·18	3·44	2·20
Na_2O	4·74	4·17	3·50	3·63	4·25	8·39	2·54	3·67
K_2O	4·80	3·15	0·98	4·18	4·73		4·65	1·92
H_2O	2·06	0·90	1·60	1·01	1·22	2·75	....	3·85
TiO_2	....	0·18	0·47	....	....	0·45	....	....
Total	99·63	99·81	99·97	99·40	99·42	100·00	99·86	99·64

1. Mono lake, California.—U.S. Geol. Surv. Bull. 150, p. 148.
2. Katman volcano, Alaska, 1912 eruption.
3. Mt. Pelee, May 1902 eruption.—Nat. Geog. Mag., Vol. 13, p. 285.
4. Mt. Shasta, Siskiyou county, California.
5. Capo di Costagna, Lipari islands, Italy.—Non-Metallic Minerals, Smithsonian Inst., p. 471 (1901).
6. Bridge river, Lillooet, B.C.—Anal. by M. F. Connor, Mines Branch, Ottawa, Can.
7. " " " " " "
8. Firth Pumice Company, North island, New Zealand.

[1] Merrill, G. P.: "Non-Metallic Minerals," Smithsonian Inst., p. 471 (1901).
[2] Figures obtained from various sources.

Volcanic dust or pumicite, which will be discussed in detail later, is a material of somewhat similar composition, but occurs as a fine powder.

USES

The main use for lump pumice is as an abrasive. The best grades are used in lithographic work and for polishing of various metals before plating; also for rubbing down wood and metal surfaces, leather finishing, paint and varnish finishes such as coach and automobile bodies, etc., and smoothing oilcloth. It is used by manufacturers of pianos, furniture, cutlery, surgical instruments and fine tools; by art metal workers; for cleaning and polishing stone, and for cleaning buffing wheels. A small amount of fine lump is used as a toilet article. There is a considerable consumption in the finishing of automobile bodies.[1]

In localities where pumice occurs, the blocks are sometimes used as a building stone and as light weight concrete aggregates. The quantity of lump pumice used is comparatively small, in the United States the amounts range from 100 to 400 tons annually.

Ground pumice is used for polishing compounds; particularly for producing a burnished brass effect on various metals; as the abrasive ingredient in cleansers and scourers; as an abrasive in rubber erasers; for the polishing or cutting down of hard rubber, fibre board, stone, and almost universally for glass bevelling; for rubbing down of painted and varnished surfaces, etc. Coated on paper it is known as "pouncing paper" and is employed in the manufacture of hats.

OCCURRENCES

CANADA

Lump pumice occurs in the Bridge River district, Lillooet mining division, British Columbia. The material, which is a yellowish grey, cellular, andesite pumice, is distributed over an area of at least 100 square miles on both sides of the Bridge river. Its easterly end is at Tyaughton creek, about 50 miles northwest of Lillooet, where it occurs in pea-sized lumps, but which gradually increase in size toward the west. The pumice covers the surface of the country under the grass roots for an average depth of about one foot, except where it has been washed away by rivers, and on the steep mountain sides.

Its westerly limits have not been determined; but lumps up to two inches in diameter occur in the vicinity of Gun lake about 20 miles west of Rexmount, also in the valley of the south fork of Bridge river, west of Ferguson creek, where it, in places, attains a depth of 3 feet. The northerly and southerly limits are approximately at Gun creek and the Hurley river respectively, giving a total width of about 8 miles.

Analyses of the material (Table XIV, No. 6 and No. 7) show it to be lower in silica than the imported pumice, and small lumps of vitreous glass and feldspar are visible in the material. According to C. W. Drysdale[2] the age of the deposit is Recent Quaternary.

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[1] Jacobs, F. B.: Abrasive Industry, p. 211 (July 1923).
[2] Drysdale, C. W.: Geol. Surv., Canada, Sum. Rept. 1916, p. 75.

An interesting section is revealed at Pearson pond which is situated on a plateau 250 feet above and about one mile up the east side of Gun creek. A ditch cut some years ago, drained the pond and in doing so the water cut a deep gorge down to the level of the creek, thereby exposing 1½ feet of marl underlain by 1 foot of pumice, which in turn is underlain by about 7 feet of marl which on the west end rests on about 240 feet of boulder gravel (*see* Plate XI A). The underlying marl is finer and more compact than the more recent deposit on top of the pumice, but both contain many pea-sized shells.

The area can be reached from Shalalth station on Seaton lake, 8 miles west of Lillooet, and then by road north over the divide via Mission pass and down into the Bridge River valley.

No use has been made of the material except locally for insulating buildings. The difficulties of transportation and the shallowness of the deposits are somewhat detrimental to its commercial development.

A sample of lump pumice, recently submitted by Mr. G. B. Grandy of Winnipeg, was stated to have come from a deposit 12 miles east of Kenora, Ont., but no details are at present available.

ITALY

The most important and largest deposits of high-grade lump pumice occur on the island of Lipari, near the north coast of Sicily, about 40 miles from the Italian mainland, and is known commercially as Italian pumice. These deposits have been worked for many generations and the material was formerly obtained from the shores and at comparatively low elevations, but the highest grade pumice at these low levels has been worked out.

The best material now comes from an area of about 3 square miles at Monte Chirica, in the northeast of the island, where it occurs overlain by white tuff. It is mined by means of tunnels and drifts into the mountain side at an elevation of about 1,500 feet above the port of Canneto. The pumice is brought down on donkeys, and after drying is carefully sorted into various sizes and lumps, freed from foreign substances, and bagged for shipment. The largest deposits are owned by the Van Amringe Company who ship the material to their United States mill at Mamaroneck, New York, and by the J. H. Rhodes Company whose warehouses are at Dutchkill canal, New York.

UNITED STATES

The most of the so-called pumice produced in the United States is a volcanic dust or "pumicite," but there are several deposits of true lump pumice. The grade is, however, inferior to the best Italian since it is not uniform and contains hard impurities, and is also mixed with silt.

There was, during the war, a considerable output of lump pumice when the Italian product was cut off, but at present operations are confined to one locality, 9 miles west of Calipatria, near Salton sea, Imperial county, California. The material which is a fibrous pumice embedded in a fine silt is mined from the crater of an old volcano. There are other deposits in northern California, near Klamath, but they are at high altitudes and are covered by snow for the greater part of the year. Pumice stone was at one time mined from several localities near mount Shasta in Siskiyou county, where the crude material averages about 10 to 15 per cent recoverable pumice. In one of these deposits the pumice varies from sand size to lumps of 1 foot or more in diameter and the deposit ranges from 15 to 100 feet in depth.[1] Lump pumice also occurs at Kanosh, Utah, and in several localities in Nevada.

In 1919 the United States output of lump pumice was about 2,000 short tons, in 1921 about 400, and in 1924 about 800 tons, all of which came from California.

JAPAN

A variety of pumice stone known locally as *koka Seki* is reported as occurring on the Niijima islands off the coast of the Idzer peninsula, 90 miles south of Tokio. It is said to possess high tensile strength and high-heat resisting qualities (1300°C) and is used for boiler and furnace construction and for heat insulation.[2]

NEW ZEALAND

Large quantities of pumice, mainly in the form of water-transported material, are distributed over the central part of North island. At the centre of origin, around lake Taupo, very large lumps are common. The deposits are operated by the Firth Pumice Company. (Analysis, Table XIV, No. 8).

PREPARATION

Lump Pumice

In Italy, grading of the pumice into various sizes and qualities is nearly all done by manual labour. The lump is made into three sizes: (1) *grosse* or large lumps from 3 to 8 inches, (2) *corrente* or medium, and (3) *pezzame* or chips and small pieces from 2 inches downwards. The *grosse* is in turn sorted by quality into three grades named *fiore, quasifiore,* and *mordenti.* The fiore grade is dressed with files in order to remove corners and rough spots and is classified into *bianche, dubbiose,* and *nere.* The large lumps are named *rotonde* (round) and *lisconi* (flat). Each lump of the highest quality is wrapped separately in paper and packed carefully in casks for shipment. Another common variety known as *Alessandrina,* which is mined at Castagna, is cut into brick-shaped pieces and used for smoothing oilcloth.

During the past few years there has been an increase in the annual production of Italian pumice which now amounts to about 34,000 short tons. Part of this, principally the *pezzame* and inferior grade lump, is ground locally, but the product is so poor and irregular that it sells in America at a lower price than the unground material.

Impure material such as occurs in California is treated by passing the crude lumps through a system of trommel screens and classifiers, and over picking-belts.

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[1] Ladoo, R. B.: Non-Metallic Minerals, p. 460 (1925).
[2] Raw Material, p. 65 (Feb. 1921).

Ground Pumice

In preparing powdered pumice stone the crude material is first dried and then crushed, after which it passes through a series of mechanical separators, and is finally bolted through numerous silk screens, whereby four grades of uniform size are produced, namely F, FF, FFF, and FFFF. Practically all this ground pumice is produced from chips or from the small sizes; the large and medium sizes being sold as lump.

PRICES

During 1925, the average New York prices of imported lump per pound in casks varied from 3 to 5½ cents per pound; selected lump in barrels, 6 to 8 cents; domestic lump in barrels, 5 to 5½ cents; and domestic ground in barrels, 3 to 5 cents per pound. In 1926 the prices were about one cent lower.

VOLCANIC DUST AND PUMICITE

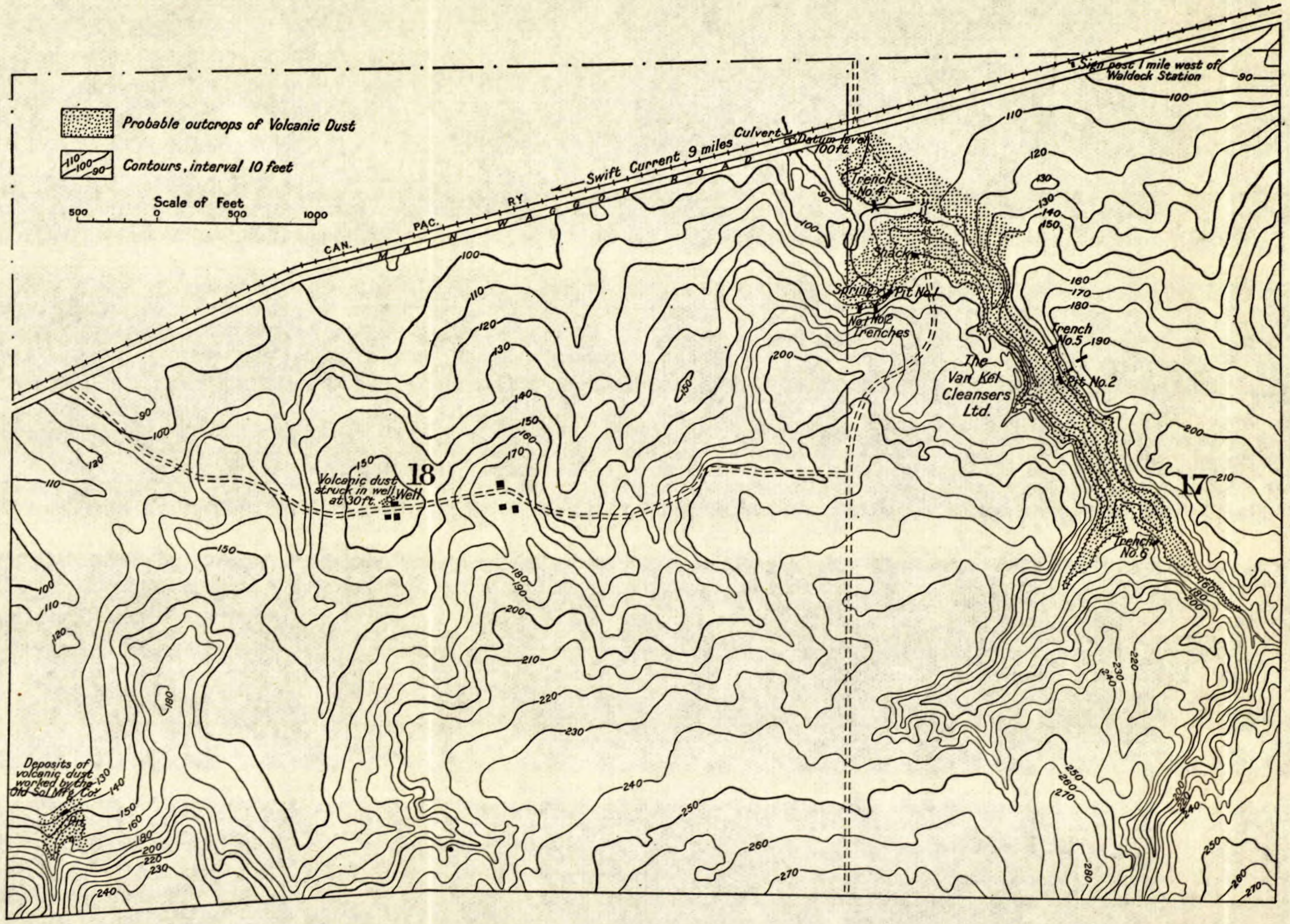
Volcanic dust is a natural glass or silicate, atomized by volcanic explosions and thrown into the air in great clouds which ultimately settle, forming beds of varying thickness, in many cases hundreds or even thousands of miles from its original source. In many instances the dust has been washed down from the higher levels and re-deposited by the agency of waters, in which case the beds are stratified or mixed with foreign substances. In other instances the dust has fallen into ancient lakes or seas and has remained undisturbed. The dust occurs as a finely divided powder of a white to grey or yellowish colour, composed of small sharp angular fragments of highly siliceous volcanic glass. Many of these fragments are striated, a condition which serves to distinguish the volcanic material from other forms of silica or silicates (Plate XIV).

The term volcanic ash by which it is commonly known is somewhat misleading, as it is not, according to E. H. Barbour[1], the product of combustion, but is a powdered, glassy rock. Pumicite is the name by which this material is known in the United States, where it occurs in immense quantities, mainly in Nebraska.

COMPOSITION

The composition of volcanic dust is very similar to that of pumice and is necessarily variable, but a good grade material contains about 70 per cent silica, 13 to 15 per cent alumina, and low in iron. The silica, as in pumice, is in the form of silicates, but there may be some free silica. The analyses of different dusts are given in the accompanying table.

[1] Barbour, E. H.: "Nebraska Pumicite;" Neb. Geol. Surv., vol. 4, pt. 27 (1916).



Field work and topography by L. H. Cole, 1922.

Figure 7. Map of volcanic dust deposits, near Waldeck, sections 17 and 18, township 16, range 12, west of the 3rd meridian, Saskatchewan.

TABLE XV

Analyses of Volcanic Dust and Pumicite

—	1	2	3	4	5	6	7	8	9	10	11
SiO_2	71·80	70·12	68·49	64·82	69·76	67·20	68·64	71·00	68·10	60·50	71·00
Al_2O_3	15·48	15·80	21·35	21·64	15·56	13·78	13·05	12·31	14·31	19·22	14·90
Fe_2O_3	0·80							5·69	5·69	3·21	1·70
CaO	1·42	0·52	....	2·25	2·20	2·44	2·11	1·40	1·81	2·30	1·40
MgO	0·53	0·23	0·39	2·77	0·90	0·57	0·40	1·30	0·23	0·35	tr.
Na_2O	5·89	4·43	3·49	....	....	1·40	0·91	3·47	4·56	n.d.	2·20
K_2O		3·05	4·17	....	....	6·49	7·40	1·42	1·85	n.d.	
H_2O+105°C	4·08	6·42	2·10	8·52	11·58	7·80	7·28	2·20	3·10	7·82	8·80
Organic matter.								1·08	0·18	5·01	....
Total	100·00	100·57	99·99	100·00	100·00	99·68	99·79	99·87	99·83	98·40	100·00

1. Orleans, Harlan county, Nebraska, U.S., pumicite. E. H. Barbour, Neb. Geol. Surv., vol. 4, pt. 27.
2. Okemah, Oklahoma, U.S. E. H. Barbour, Neb. Geol. Surv., vol. 4, pt. 27.
3. Gallatin county, Montana, U.S. E. H. Barbour, Neb. Geol. Surv., vol. 4, pt. 27.
4. Waldeck, Swift Current, Saskatchewan, Canada. Buff material, No. 1 pit. L. H. Cole, Mines Branch Summary Report, 1922.
5. Waldeck, Swift Current, Saskatchewan. White material, No. 1 pit. L. H. Cole, Mines Branch Summary Report, 1922.
6. 20 miles southwest of Swift Current (fine, compact, white).
7. " " " " (coarse, friable, white).
8. Carrolls Landing, Arrow lakes, B.C., Canada. Analysis by E. A. Thompson, Mines Branch.
9. " " " " " " "
10. Haig, British Columbia, Canada. Analysis by E. A. Thompson, Mines Branch.
11. Deadman river, British Columbia, Canada.

USES

Volcanic dust being almost the same as ground pumice, is used for similar purposes. The uses are classified into abrasion and scouring; construction and non-conduction. The material for the first-named purpose often replaces ground pumice for finishing and polishing woodwork, painted and varnished surfaces, glass, metal, and stone. The finest grades are used in metal polishes.

Its most important use is for scouring compounds such as "Old Dutch Cleanser." (Microphotograph, Plate XIV B.). It is used by many soap manufacturers and put up in the form of pumice soaps. In this connexion the volcanic dust is sometimes utilized by firms having waste vegetable oils, especially cotton-seed oil. For example in whip and shoe-string factories, quantities of cotton seed remain in the process of carding and spinning. The oil is extracted from the cotton seed, saponified, and then mixed with the volcanic dust thereby producing a good hand-cleaning soap.

Because of its fineness and innumerable air spaces, some volcanic dust, particularly that possessing a high percentage of striated grains, is well suited for heat insulating purposes. It is also sometimes used as an ingredient in Portland or hydraulic cement, and as a filler for paint.

OCCURRENCES

CANADA

Volcanic dust occurs in many localities in central and western Canada. In many instances deposits of silt, particularly in eastern Canada, very closely resemble volcanic dust both in colour and composition, and it is difficult to differentiate between these two materials of different origin, especially when the true dust has been re-deposited by water action and is contaminated. The geographical and geological conditions are usually a guide, as well as the nature and angularity of the glass or silica fragments when examined microscopically.

ONTARIO

There are no records of commercial beds of volcanic dust in Ontario, but in the Timagami area, on the west side of the southern stretch of Anima-Nipissing lake, the hills are composed of erupted material and fine-grained tuffs representing the consolidation of the volcanic dust beds.

SASKATCHEWAN

Extensive beds of volcanic dust occur in the vicinity of Waldeck on the Canadian Pacific railway, 11 miles northeast of Swift Current. Part of these beds occurring on the west half of section 17, township 16, range 12, west of 3rd meridian, are now being operated by the Van-Kel Cleansers, Limited, of Swift Current. The deposit was first discovered in 1918.

The deposit consists of a loosely compacted, finely divided material, the majority of which is light buff in colour, but there are parts that are white and more powdery. The beds, which in places have been proved to have a thickness of 37 feet, are in many places exposed in coulées or beds of ancient streams. The deposit, except where exposed, is overlain by overburden varying from 1 to 15 feet of hard and compact boulder clay and in places by highly weathered, brownish grey to chocolate-coloured shales. The dust beds appear to have a slight dip to the north, the northerly exposures being at an elevation of about 100 feet and the southerly at 140 feet. The outcrops are shown on the contoured sketch. (*See* Figure 7, also Plate XII). According to L. H. Cole,[1] who made a survey of the property in 1922, there are approximately 200,000 tons in an area 250 feet wide and 500 feet each way from pit No. 2 on the large coulée. It is probable, however, that the dust also underlies a considerable area at the levels indicated on the map.

Nature of the Waldeck Dust

Owing to the presence of diatoms in the original samples, the deposit was thought to be impure diatomite, but these samples were taken from the immediate vicinity of a spring, the sediments of which first drew attention to the deposit. However, diatoms are not found in the material

[1] Cole, L. H.: Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1922, pp. 15-20.

outside the influence of the spring. (Analyses are given in Table XV, Nos. 4 and 5.) Under the microscope the material shows as thin, angular, glass fragments, many of which, especially the white-coloured dust, have parallel striations. (Microphotograph, Plate XIV C.).

When first quarried the dust readily breaks up into powder in the hand, but blocks can be cut out which dry into comparatively hard lumps. It has high absorption qualities, which, along with its abrasive qualities, make it a good material for domestic cleansers. It has been successfully used at Calgary and Winnipeg as a fuller's earth for purifying lard and tallow.

Exploitation

Several prospecting trenches have been dug and pits sunk on the property, and during the last two or three years material amounting to several hundred tons has been taken out. The company, however, has temporarily abandoned this deposit in favour of the whiter material in the vicinity of Webb.

The Van-Kel Cleansers, Limited, have erected a small plant at Swift Current, the flow-sheet being on the same lines as those recommended by the Mines Branch. (*See* Figure 8.) They are marketing their products in the form of cleansers and hand cleaners. The power of absorption of the dust is still retained after being burned at a comparatively low temperature, a feature that is taken advantage of by the company, who markets small bricks soaked with kerosene as fire-lighters.

The Old Sol Manufacturing Company is operating an extension of the Waldeck deposit about one mile west of the above and also puts up cleansers under their own name. Approximately 350 tons of the dust has been extracted since they started operations in 1923.

Three miles east of Waldeck on section 11, township 6, range 12, there is another outcrop of volcanic dust showing a particularly good grade of pure white material, which is very similar to the Nebraska pumicite. (*See* description under United States.) The same type of material occurs in section 19, township 13, range 15, south of Webb, 20 miles southwest of Swift Current, but there appears to be a variety of even-textured beds, in one of which the grains are considerably coarser than the average. (*See* analyses, Table XV, Nos. 6 and 7; and Plate XIV.) It resembles the different beds of the Deadman deposit described below. This is now being operated by the Van-Kel Cleansers, Limited. Another reported occurrence is in the vicinity of Victor, section 2, township 6, range 12, 50 miles south of Swift Current.

Very little prospecting has been done, but it is probable that large areas of commercial material will be found in this region.

BRITISH COLUMBIA

Volcanic dust, varying from pure white to deep yellow occurs in many localities in British Columbia.

Deadman River. A pure white material occurs in the Deadman River region, about 25 miles north of Savona. At this point the Deadman valley is wide and contains a chain of several lakes. The whole country on either side of the lakes consists of decomposed, yellow volcanic tuffs and agglomerates, overlain by amygdaloidal basalts, which form bluffs rising 300 to 400 feet above the lakes. Within these tuffs three or four horizontal beds of pure white, highly siliceous material, 8 to 12 feet thick, and separated from one another by 30 to 100 feet of tuffs, are exposed. The beds can be traced on the east side of the river, north from Last Chance creek for a distance of several miles. Exposures can be seen in an easterly direction up Last Chance creek for at least a quarter of a mile. In places the weathering of the tuffs has left isolated pinnacles 30 to 50 feet high, in some of which the white beds form the top and base. (*See* Plate XI B.) The white beds are of similar composition, but of different texture. The lower bed, which is exposed near the mouth of Last Chance creek, is the finest material and has the appearance of pure white chalk. (*See* screen analysis.) The upper beds are considerably coarser. The bed at the mouth of Last Chance creek has been staked and is known as the Last Chance claim. About a ton of material was taken out and transported by pack horses to Savona. The white beds have been reported as kaolin, diatomite, and volcanic ash, but the alumina content is too low for kaolin and there are no diatoms present. A microscopic examination shows the material to consist mainly of angular glass fragments which are characteristic of volcanic dust. (Microphotograph, Plate XIV F.)

A small deposit of diatomite mixed with shell marl occurs on the east shore of Skookum lake, about one mile north of Last Chance creek, and this may have been the material which became confused with the main deposits.

These well-stratified deposits must have originally extended across the valley and were evidently laid down in deep water. A general description and geology of the region will be found in W. F. Ferrier's report.[1]

The following table shows the analyses of the different beds of volcanic dust as well as the underlying and overlying tuffs:—

TABLE XVI

Analyses of Volcanic Dust and Tuffs, Deadman River, B.C.

—	White volcanic dust				Yellow volcanic tuffs		
	1	2	3	4	5	6	7
SiO_2	73·10	71·70	70·10	70·80	67·60	68·70	67·80
Al_2O_3	12·46	13·88	14·31	11·95	15·84	13·14	13·34
Fe_2O_3	1·74	1·82	2·69	2·05	3·16	3·16	3·86
CaO	nil	nil	1·60	1·15	2·00	2·40	2·20
MgO	0·46	0·38	0·47	nil	0·39	nil	0·38
Na_2O	2·98	1·80	1·64	n.d.	0·36	n.d.	3·41
K_2O	3·46	3·09	2·66	n.d.	2·95	n.d.	1·36
$H_2O+105°$ C	1·90	3·10	4·30	5·22	5·00	6·00	3·00
Organic matter	3·86	4·01	2·27	7·78	2·42	5·40	4·92
Totals	99·96	99·78	100·04	100·79	99·72	98·95	100·27

1. Finest material, Last Chance claim (80 per cent—200 mesh).
2. Medium fine material, Last Chance claim.
3. Coarsest bed ¼ mile east of Last Chance claim.
4. Lowest bed 2 miles north.
5. Tuff overlying No. 1.
6. Tuff from centre of deposit 100 feet from top of Last Chance claim.
7. Tuff from centre of deposit at Skookum lake, 1 mile north of No. 1.

Analyses by E. A. Thompson, Mines Branch, Ottawa.

[1] Ferrier, W. F.: Min. Res. Com., Canada, p. 37 (1920).

It will be noted that the tuffs are of similar composition to the white material, but are coarser in texture.

The following shows a screen analysis of a sample from the finest bed:—[1]

		Per cent
Retained on	35 mesh	
"	48 "	0·10
"	65 "	0·30
"	100 "	0·60
"	150 "	0·80
"	200 "	14·50
Through	200 "	83·60

As will be seen from the above analyses over 80 per cent passes through 200 mesh, which product should be suitable for a polishing compound. For cleaning and cleansing compounds it would have to be mixed with some of the material from the coarser beds.

The property is approached by fairly good road from Savona, on the Canadian Pacific railway, up the Deadman river to Walter's ranch, a distance of 17 miles, and thence by rough trail for 10 miles north to Last Chance creek. Transportation difficulties are a disadvantage to commercial production.

Arrow Lakes. A grey buff-coloured dust occurs on Messrs. Sutherland and Gettie's farm at Carrolls Landing, north of Burton about 25 miles south of Nakusp on the east shore of Upper Arrow lake. The deposit outcrops on a wide bench 50 feet above the lake and consists of stratified beds from 3 to 6 feet thick of volcanic dust, clays, and silts of the following sequence:—

Feet	Inches	
0	6	Soil and grass roots.
3	0	Grey, very fine-textured volcanic dust. Table XV, No. 8.
4	0	Light buff, fine-textured volcanic dust. Table XV, No. 9.
6	0	Grey clay and silt.
6	0	Stratified beds of clay, silt, and volcanic dust.
30	0	Coarse, iron-stained, stratified silts and sand to lake level.

A microscopic examination of the grains shows that the majority are thin and angular, many of which exhibit close parallel striations. (Microphotograph, Plate XIV E.). The deposit was traced over several acres under Sutherland's orchard and farm buildings, and probably extends considerably farther in a northerly direction, since the topography and soil are similar and uniform for a mile or two along the shore. (*See* analyses, Table XV, No. 8 and No. 9.) A small amount of material has been taken out and shipped to Vancouver for use in scouring soaps. There is a Government wharf alongside the property.

Haig. A small bed of dark yellow volcanic dust occurs on the north side of the Canadian Pacific Railway track, 1 mile west of Haig station or 2 miles northwest of Hope. The material occurs as a shallow basin-shaped deposit, about 350 feet in diameter and with a maximum thickness of 2 feet. It is exposed in the side of a small ravine about 50 yards north of the track and is overlain by about 15 feet of clays and gravels. The contacts above and below the dust are sharp and distinct.

[1] Cole, L. H.: Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1918, p. 161.

Under the microscope the grains exhibit well-striated, sharp and angular fragments, the majority of which will pass through 200 mesh. The silica content is somewhat low and the alumina high. (*See* analysis, Table XV, No. 10.) The material dries to a cream-yellow colour.

During 1923 the Tillson Company of Calgary worked the deposit and shipped about a carload to Calgary for use as a scouring material. Although the deposit is very conveniently situated for transportation, the mining of it would necessitate the removal of considerable overburden. Moreover, its yellow colour is a disadvantage.

Elko. Beds of pale grey volcanic dust occur on the property owned by E. J. Richards of Elko, situated at the junction of the Elk and Kootenay rivers, 3 miles south of Waldo station. The beds are exposed on the steep banks of the river and are underlain by silts. (*See* analysis under Silt.) An analysis of the dust shows it to contain: silica 68·3 per cent; iron oxides 5·1 per cent, and alumina 14·3 per cent. The grains show characteristic striations under the microscope.

Canadian Consumption

The Canadian import statistics include pumice stone, ground pumice, pumicite, and volcanic dust. For the five years previous to the war the imports were fairly constant, being about $18,500 annually. The following shows the value of the imports under the heading of pumice from 1915: $18,814; $34,554; $34,162; $36,938; $29,910; $57,068; $21,528; $26,405; $28,222; $28,127; $27,581; and in 1926, $32,005.

UNITED STATES

Large quantities of volcanic dust, which goes under the name of "pumicite" are produced in the United States. The production now amounts to over 40,000 tons, having an average value of over $40 per ton. The main sources of supply are Nebraska and Kansas, although California produces small quantities. The pumicite is generally regarded as having its origin in the extinct volcanoes of the Rocky mountains and the dust has been transported and re-deposited by wind or water action. The beds vary in thickness from a few inches to almost 100 feet and are usually covered by overburden averaging 15 to 25 feet thick and sometimes as much as 50 feet.

Under the microscope the glass grains of pumicite show an angular, scaly structure, many of which, have parallel striations and capillary tubes. The best commercial material is that which contains a high percentage of the striated grains.

Nebraska

Pumicite covers almost the whole of Nebraska,[1] the coarsest material being found in the western part, where some beds are coarse enough to show grains visible to the naked eye. Farther east the texture becomes increasingly fine. The majority of the beds are wind deposits, the pumicite

[1] Barbour, E. H.: Nebraska Geol. Surv., vol. 4, pt. 27 (1916).

having been dropped on the lee side of knolls and ridges. In some cases the pumicite was dropped into the lakes of that period, and on settling was stratified and laminated.

The material was first mined in 1885 and called "geyserite" as it was at that time thought to have originated from geyser action. From that date, when its value as a scouring and cleaning ingredient was proved, the production increased rapidly and now almost a quarter of a million dollars worth is mined annually.

One of the largest producers is the Cudahy Company, the manufacturer of "Old Dutch Cleanser," who is mainly responsible for the practical development of the American pumicite industry. The company owns mines in different parts of the state, the largest being near Orleans in Harlan county. At this mine the beds are from 6 to 10 feet thick and covered by overburden of 15 to 25 feet. (*See* analysis, Table XV; microphotograph, Plate XIV B.) This overburden is removed by heavy ploughs and scrapers. In some instances a layer of about one foot of dirt is left as a protective covering. The pumicite is so soft and friable that the banks are easily undermined and broken down by shovels. The Cudahy Company at one time mined extensively at Ingham, Lincoln county.

Highly laminated beds as much as 25 feet thick occur in the United States Pumice Company's mines at Ingham and are overlain by 6 to 12 feet of overburden, although in places it is 50 feet. The pumicite varies in colour from white to yellow and blue, but the discoloration is stated not to be detrimental.

In recent years, Furnas, Lincoln, and Harlan counties have been the most important producers. Other properties which have been operated are: near Endicott, Jefferson county; near Edison, Furnas county; near Arnold, Auster county; Scotia, Greeley county; Atkinson, Holt county, and others.

Other Producing States

Since 1916, the state of Kansas has been the largest producer of pumicite. Deposits are now being worked at Quinter, Gore county; Meade, Meade county; Woodruff, Phillips county, and in Harper and Morton counties.[1]

Although pumicite occurs in many places in Oklahoma the deposits are not so extensive nor so pure as those of Nebraska or Kansas. The largest known deposit in Oklahoma is on the boundary between Harper and Beaver counties.

NEW ZEALAND

From 2,000 to 4,000 tons of volcanic dust is produced annually from southeastern New Zealand, mainly from the Gisborne district around Poverty bay. Beds of the dust up to 20 feet in thickness occur, and are interbedded with mudstone and argillaceous sandstone. The material is probably derived from the volcanoes of the Taupo zone. An analysis of the "finely divided pumice"[2] shows it to contain: SiO_2, 70·0 per cent; Al_2O_3, 12·0; CaO, 1·2; Na_2O and K_2O, 6·5 per cent.

[1] Ladoo, R. B.: Non-Metallic Minerals, p. 460 (1925).
[2] N. Z. Dept. of Mines, Bull. 21, p. 55 (1920).

About 30 miles farther north, similar material has been mined from the vicinity of Tolaga bay in the Uawa district. The main deposits are operated by the Firth Pumice Company, on the Waikato river, 58 miles south of Auckland. The loose, fine material is dredged, air-dried, calcined to remove organic matter, and roughly classified by screening. The coarse product is used as heat-insulating material (for freezing chambers), and the finer material is used in the manufacture of hand-soaps, etc.[1]

PREPARATION FOR MARKETS

The crude volcanic dust or pumicite is first dried, usually in revolving driers, and after pulverizing is passed through a series of screens and air-float machines. The coarse products are further pulverized and passed through the circuit with the finer material. The degree of fineness and the proportion of each size of grain to one another is a matter of importance and depends largely on its ultimate uses. The demand for sizes are approximately as follows: plus 40 or plus 80 mesh respectively, but by far the greatest demand is for minus 120 mesh; a considerable quantity is used by glass-grinding companies for the minus 200-mesh product.

Experiments by the Mines Branch

Experiments on grading the volcanic dust from Swift Current, Saskatchewan, were recently conducted by the Mines Branch with the following

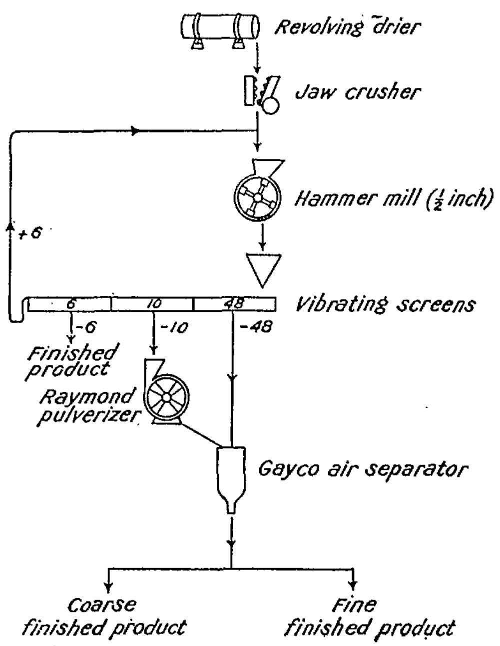


Figure 8. Experimental flow-sheet of mill to treat volcanic dust from Waldeck, Saskatchewan.

[1] Private information, N. Z. Geol. Surv.

results. After drying in a revolving drier and crushing in a jaw crusher, the product was further reduced by means of a hammer mill. It was found that this machine gave better results than rolls, because the material cakes up in the latter and will not pass through the screens. After screening to three sizes the fines were treated in a Raymond grinder of the beater type. It was found that the Raymond suction product was 8 per cent plus 48 mesh, 8 per cent minus 48, and 84 per cent minus 100. This product was then further sized by means of a Gayco air separator. From these tests the accompanying flow-sheet was devised. (*See* Figure 8.)

The volcanic dust is very porous and absorbs a quantity of moisture and being difficult to dry, a large capacity drier should be installed. In using the above flow-sheet the following proportion of grades would be expected: 25 per cent of 6 and 10 mesh, possibly suitable for oil filtering; 1·0 per cent of air-separator coarse, for hand cleaners; 74 per cent air-separator fines, for household cleansers, etc.

For metal polishes, the air-separator fines would have to be passed over a second air-separator so as to bring them to minus 200 mesh or finer.

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FELDSPAR

Feldspar belongs to a group of minerals which are aluminium silicates of potassium, sodium, and calcium, either combined or separate. Its colour varies, but is usually buff or pink. For abrasive purposes its chief physical property is its hardness which is 6 to 6·6 or next below quartz on Moh's scale, and is hard enough to mark glass. Feldspar when crushed breaks with a parallel cleavage and under the microscope the powder is characterized by its many parallel-sided grains (Plate XIII F.). It is used as a mild abrasive to replace the harder silica in some scouring soaps and cleansers. Ground feldspar is employed as the abrasive ingredient in the well-known "Bon Ami" cleanser.

In the United States about 2·5 per cent of the total feldspar consumed is used for various abrasive purposes.

CANADIAN FELDSPAR USED FOR ABRASIVE PURPOSES

Commercial feldspar is widely distributed in Canada throughout Ontario and Quebec, from which some of the world's purest material is exported for ceramic purposes. Almost any of these Canadian deposits could produce a grade of spar suitable for an abrasive, provided it is light-coloured, low in quartz, and free from harmful impurities. In 1923 about 500 tons of the feldspar mined from the Quebec shores of the gulf of St. Lawrence, near Anticosti island, is stated to have been used in the manufacture of cleansing powders. During 1925 the Masson feldspar property on lot 47, range IX, Aylwin township, Hull district, Quebec, was operated by the Bon Ami Company of Montreal; part of the crude spar was shipped to the parent company, the Orford Soap Company, Manchester, Conn., U.S., for grinding; the remainder being used in the Canadian plant. In the same year approximately 2,000 tons of Canadian feldspar from the Masson, O'Brien and Fowler, and other properties was utilized for cleanser materials, which was increased to about 3,000 tons in 1926.

Only a small part of the finely ground feldspar used by the grinding-wheel manufacturers in Canada, is of Canadian origin. This is, however, mainly due to the fact that almost all the feldspar mined in Canada is exported in the crude condition to the United States where it is pulverized, and although it may be shipped back as ground spar, its identity is usually lost.

An account of the Canadian feldspar deposits will be found in a number of reports.[1]

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[1] de Schmid, H. S.: "Feldspar in Canada;" Mines Branch, Dept. of Mines, Canada, Rept. 401 (1916).
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NON-SILICEOUS SOFT ABRASIVES

Although minerals and other substances that are softer than silica or feldspar are not usually recognized as true abrasives, nevertheless any material, if continually applied, will in time abrade a harder substance than itself.

There are a number of comparatively soft materials which are commercially used for the final polishing of various metals, stone, glass, rubber, ivory, etc. These include chalk or whiting, lime, china clay, several metallic oxides, such as some iron oxides—crocus, rouge, black rouge, also chromium oxide, green rouge, manganese dioxide, putty powder, and others.

Chalk is a soft, compact, fine-grained, white limestone composed of the calcareous remains of small marine shells, and when pure consists entirely of calcium carbonate ($CaCO_3$).

Small quantities of pure chalk, usually ground and called "whiting," are sometimes used, as a very mild abrasive, for hand polishing of nickel, gold, silver, or plate ware, also for polishing buttons, ivory, celluloid, hard rubber, etc. Whiting is used indirectly as an abrasive when it is employed as a drying agent in the manufacture of silicate grinding wheels.

China clay (kaolin) and some of the finer pipe clays have been successfully used in polishing powders. The latter was at one time largely used for polishing naval and military tunic buttons.

NON-SILICEOUS BUFFING MATERIALS

Buffing is the final stage of polishing. It is performed by means of a rapidly revolving flexible wheel or buff, made of canvas, cotton, muslin, or leather and coated with an abrasive.

The buffing materials are, in order of their hardness, very finely powdered emery, tripoli, pumice, amorphous silica, which have already been described, the mild non-siliceous Vienna lime, and the artificially prepared metallic oxides, such as crocus, red, green, and black rouges. Tripoli has the largest field and is the most universally used.

These abrasives are made up in the form of grease bricks or compounds which have the combined advantages of readily adhering to the buffing wheel, being dustless, and easily handled. The bonds employed are stearic acid, petrolatum, tallow, and paraffin. The manufacture of buffing wheels and compounds is described in the bulletin on Artificial Abrasives.

Vienna Lime

Description and Composition

Vienna lime is a calcined, unhydrated magnesium limestone or dolomite, and is composed of the oxides of calcium and magnesium. The dolomite used is a greyish white, fine-grained rock which occasionally displays certain characteristic fossils and is composed of about 55 per cent carbonate of calcium and about 43 per cent carbonate of magnesium, with traces of iron, silica, and alumina. For buffing purposes the lime and magnesia content should, approximately, be in the above proportions, as otherwise poor results are obtained. There are, however, many dolomites of this composition that would not be suitable since the fossil content of the rock appears to impart certain necessary physical properties.

Uses and Action

Vienna lime is used extensively for the buffing of numerous materials such as brass, copper, bronze, steel, pearl, celluloid, etc., but by far its most important use is for nickel and the lime is now recognized as the standard composition for the "colouring" of nickel after plating, as it gives it a deep "under surface" blue peculiar to the metal. Vienna lime cuts faster than crocus and has almost entirely replaced it for all classes of work. Vienna lime should not be used on aluminium as it attacks it chemically.

The action of Vienna lime in buffing is not clearly known, but it is believed that the heat generated on the buff causes a caustic action due mainly to the lime, and the magnesia does the work as it helps to "drag" and create the necessary friction, but excess of lime would cause it to slip too readily. As soon as the lime becomes hydrated it ceases to function and also attacks the grease compositions.

The total consumption in the United States and Canada probably does not exceed 1,800 tons annually and the price of the crude lime, f.o.b. mines, is about $30 per ton.

Preparation

The detailed process of making Vienna lime is kept secret but the quality largely depends on the correct burning and the fuel used, since the saps of some woods used in the burning will destroy the colouring qualities already referred to. The calcined dolomite is then cleaned and ground to a certain fineness, packed in sealed containers and shipped to the various manufacturers of buffing compounds. The finished lime grease bricks have also to be stored in sealed containers since the buffing action is destroyed if the lime becomes hydrated.

Occurrences

This lime originally came from the Solenhofen mines in the vicinity of Vienna, Austria, hence the name by which it is still known to the trade. In America it has been almost entirely superseded by the lime made from the dolomite at Francis Creek and Manitowoc in Wisconsin, U.S. It is claimed that better results are now obtained from the American material and that the manufacturing costs are less owing to the greater absorption of grease by the imported products. The types of the dolomite used in the Manitowoc district are described by Miss M. E. Squire.[1] It appears that in these deposits the ultimate use can now be determined by inspection of the coral or fossil remains. The Vienna lime fossil is a gastrapod.

[1] Squire, Miss M. E.: "Fossils Tell What Lime is Good For," Rock Products, p. 18 (Dec. 1, 1923).

Possible Canadian Sources

Vienna lime has not been produced in Canada, but there are, within the Dominion, pure dolomite deposits of similar appearance and composition to those now being used. A probable source would be the Lockport and Guelph dolomites which stretch from Niagara Falls in a northwesterly direction as far as Manitoulin island. There are in the Guelph dolomites several localities where the gastrapod fossils occur. Numerous outcrops occur in this zone and several quarries are being operated for the manufacture of lime for building and other purposes.

METALLIC OXIDE BUFFING MATERIALS

The manufacture and various applications of these metallic oxide abrasives are described in the bulletin on Artificial Abrasives, but are briefly outlined below.

Crocus or crocus martis is a hard, purple red, hydrated iron oxide. It is made by calcining either iron pyrites direct, or the material obtained as the by-product of the sulphuric acid plants. The crocus grain is sharp and harsh. The English crocus is slightly softer than the American.

It is used in the form of a grease compound for the buffing of tin, steel, cutlery, and other iron and steel surfaces requiring a high finish. The English crocus produces a better finish than the American. The use of crocus is declining as it is being replaced by Vienna lime and green rouge, but is still used for tin and Britannia metal.

Rouge is another highly hydrated oxide of iron made by calcining ferrous sulphate (green vitriol or copperas) in special furnaces or crucibles. After the sulphur has been driven off, the material turns varying shades of red, depending on the temperature and oxidation. The darker the colour the harder will be the rouge. The grains of rouge are rounded and thus differ from crocus.

The palest red or soft rouge is largely used for the buffing of precious metals and in delicate finishing operations. The largest use is in the powder form with water, when it is almost universally employed for the final polishing of plate and bevelled glass.

Black rouge (glassite) is magnetic oxide of iron made by chemically precipitating ferrous sulphate with caustic soda. It is used for buffing and sometimes in the powder form on a felt wheel for the final polishing of plate and bevelled glass. It is not extensively used as it is difficult to remove the black from the pores of the skin.

Green rouge is an oxide of chromium and is a comparatively recent buffing medium; its main use is for buffing platinum and stainless steels. The brilliant lustre now produced on stainless cutlery knife blades is obtained by this oxide.

Satin rouge is lamp black, and is not a metallic oxide, but is included here for convenience. It is sometimes used in the form of a brick for silverware or for the polishing of very thin plating such as are used on coffins, also for polishing black or dark celluloid and bone materials such as buttons.

Manganese dioxide, although a good polishing medium, is avoided because of the dirt as in the case of black rouge.

Putty powder, an oxide of tin, was at one time extensively employed in the powder form as a polishing medium, particularly for stone glazing, but being of a poisonous nature, its use is declining.

25074—10

Read Stone Company's grindstone quarry, Wood Point, Westmorland county, N.B. General view, looking west.

PLATE III

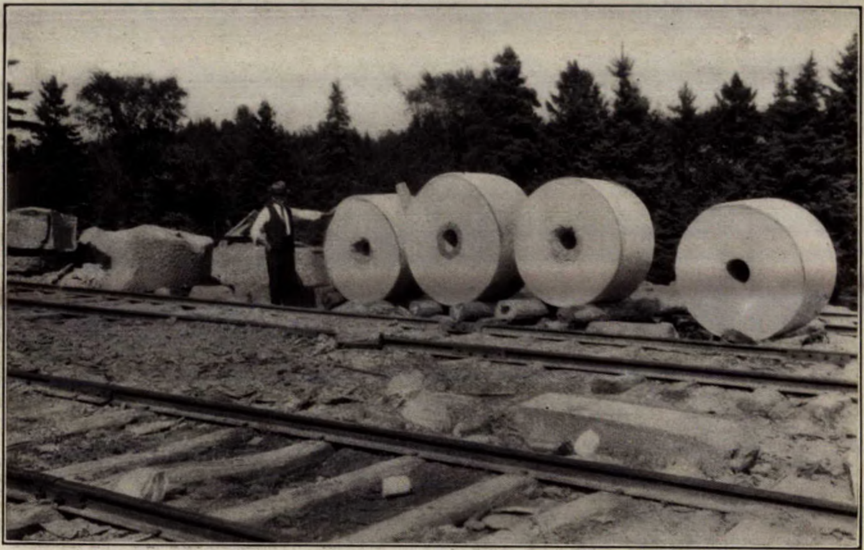
A. Read Stone Company's grindstone quarry, Stonehaven, N.B. General view of quarry and dam, looking northwest.

B. Mic Ma Grindstone Company's quarry, Woodburn, N.S. View looking southwest.

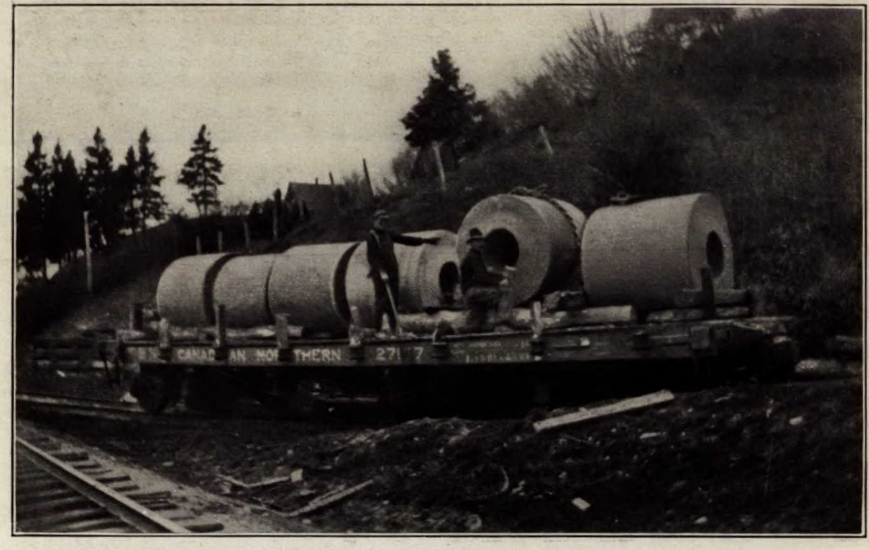
A. Quarry of Miramichi Quarry Company, Quarryville, N.B., showing thick, basal beds from which pulpstones are made.

B. Read Stone Company (Dobson quarry), Rockland, N.B. Lifting out a grindstone slab.

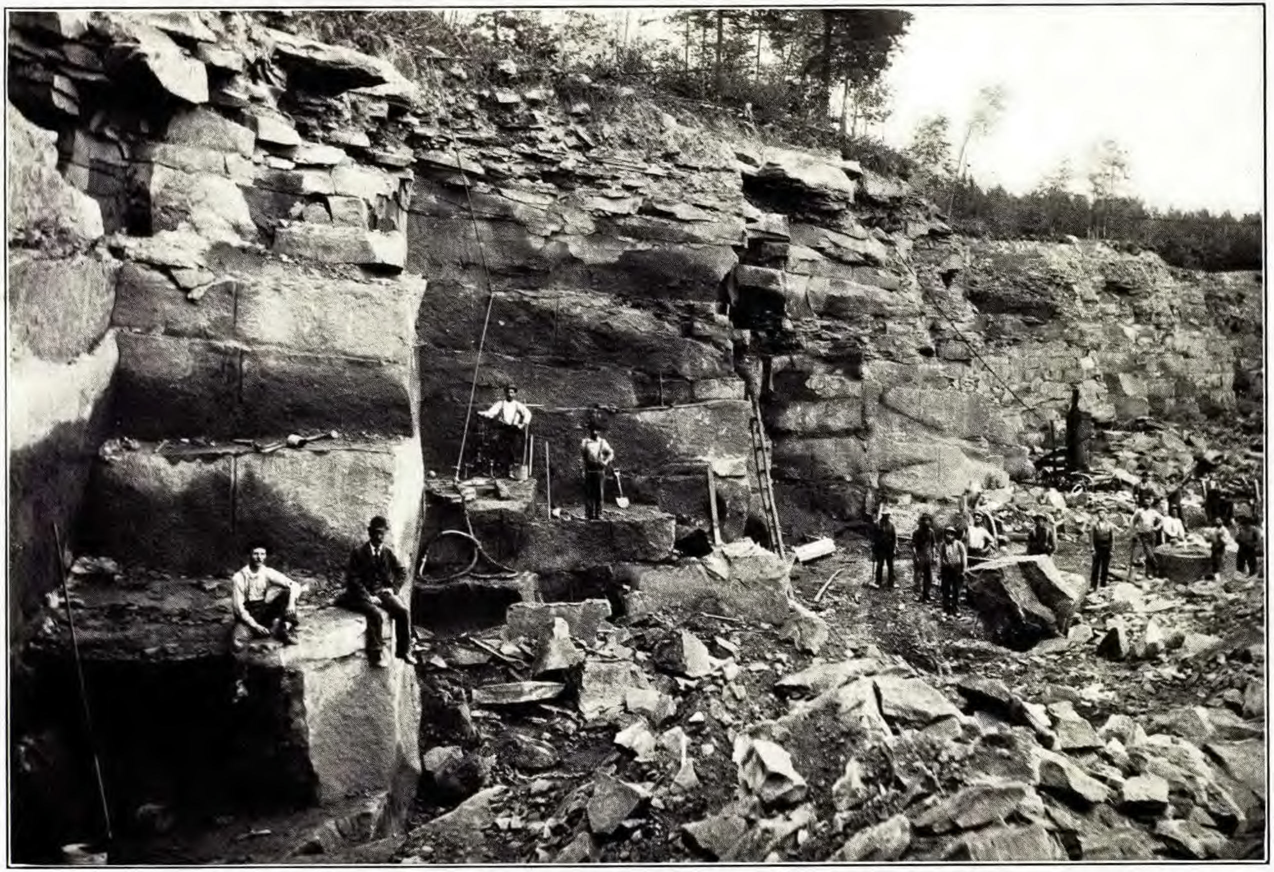
PLATE V



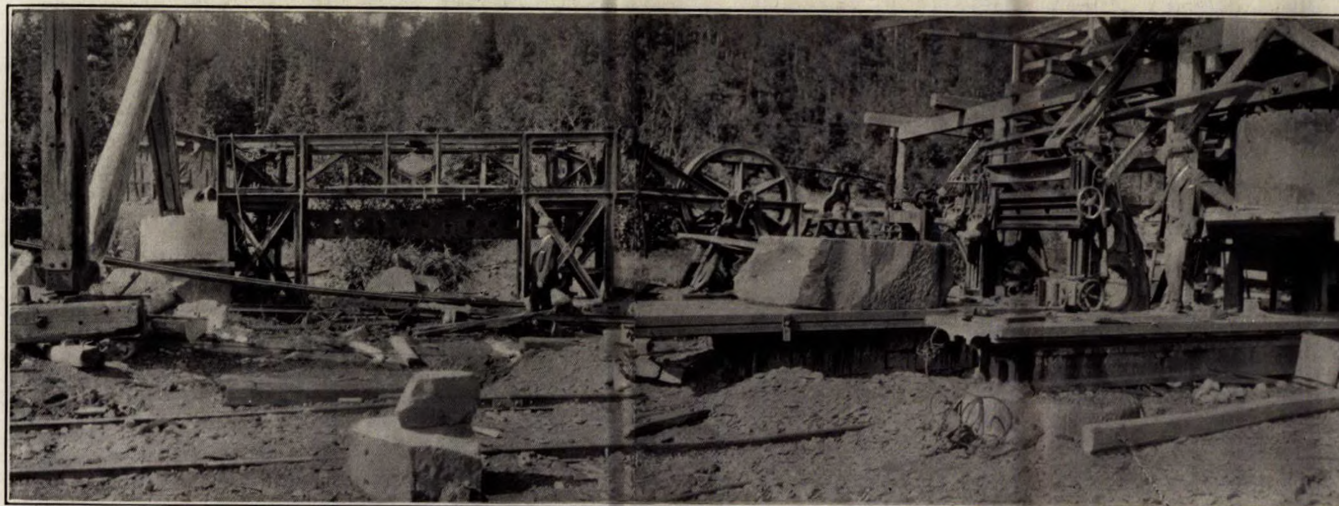
A. Pulpstones ready for shipment, Miramichi Quarry Company, Quarryville, N.B.



B. Magazine pulp grinders, Miramichi Quarry Company, Quarryville, N.B.



French Fort grindstone and pulpstone quarry, Newcastle, N.B., (1897). Looking east, showing basal grindstone beds 9 feet thick.



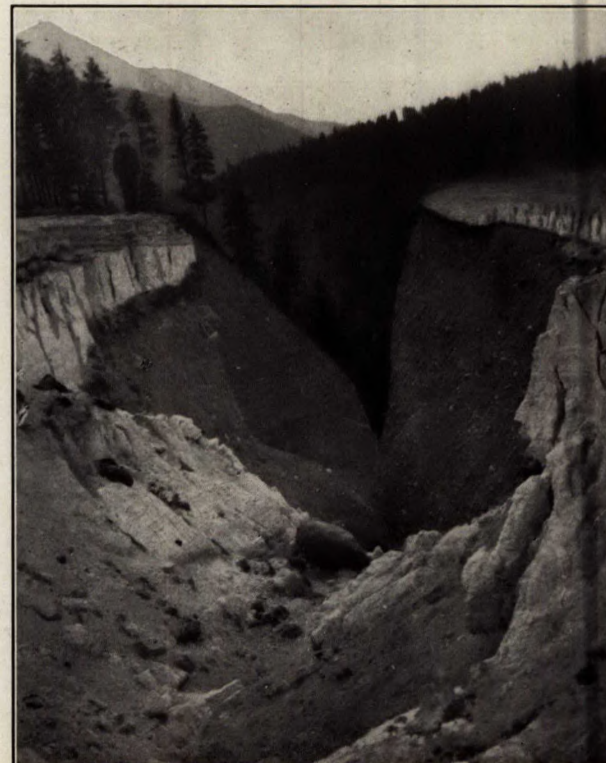
Plant of the Miramichi Quarry Company, showing circular saw, planer, and diamond-tooth saw.

French Fort quarry, Newcastle, N.B., (1897). Finished pulpstones and semi-finished grindstones.

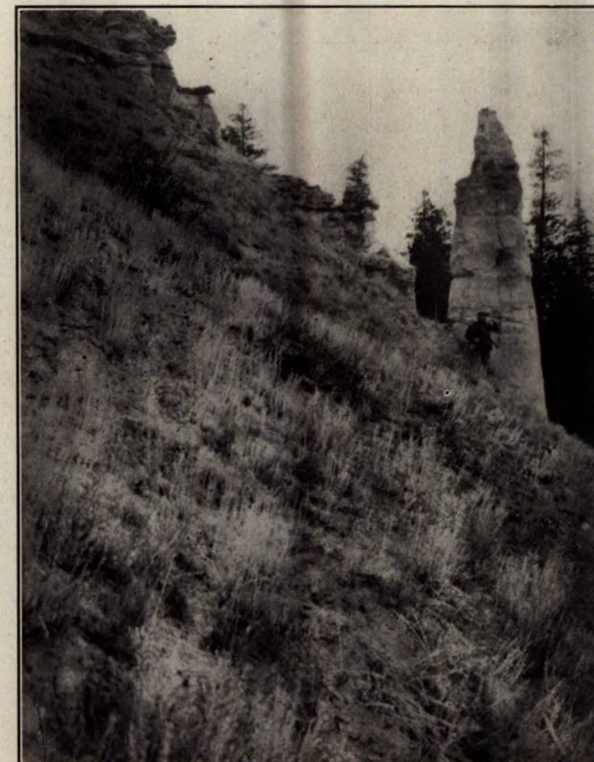
A. The McDonald pulpstone quarry, Newcastle island, B.C., showing cylindrical cutter and driving gear.

B. The McDonald pulpstone quarry, Newcastle island, B.C., showing 6-foot bed from which circular stones have been cut.

Sandstone quarry of Silico Limited, St. Canute, Que.



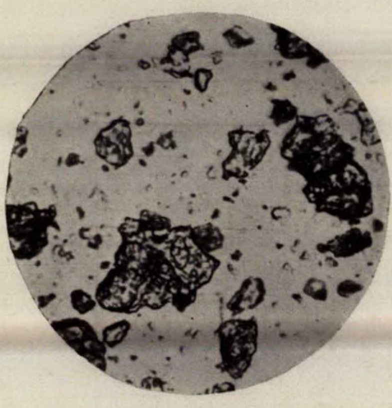
A. Pumice, Pearson's pond, Bridge river, B.C., looking west towards Gun creek, showing one foot of pumice overlain and underlain by marl.



B. Volcanic dust, east shore of Snohoosh lake, Deadman river, B.C., showing pillar of tuff with bands of white volcanic dust at top and near bottom.

Volcanic dust, general view of the Waldeck deposits, Saskatchewan, looking north toward Canadian Pacific Railway tracks.

PLATE XIII



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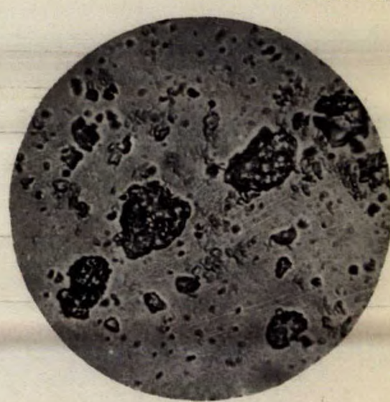

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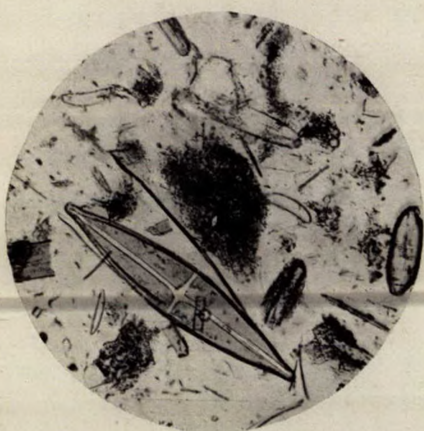

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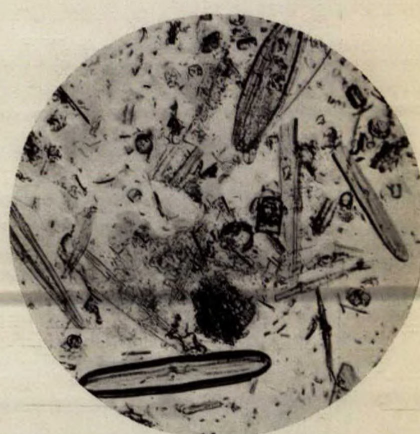

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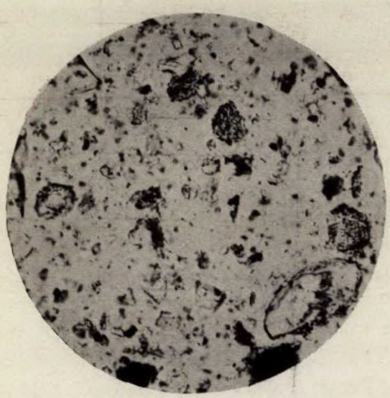

E

F

PLATE XIII

A.	Pink tripoli, Seneca, Mo., U.S. Showing spongy appearance of grains......	X 325
B.	Amorphous silica, Murphysboro, Ill., U.S. Showing spongy appearance of grains and their similarity to tripoli................................	X 325
C.	Diatomite, Chaffey township, Muskoka, Ont. The large boat-shaped cross diatoms occur in nearly every Canadian diatomite deposit..............	X 200
D.	Diatomite, Simon lake, Allen's Mills, Que................................	X 200
E.	Silt, Black harbour, southwestern New Brunswick. Showing rounded grains and non-siliceous impurities (black spots)............................	X 200
F.	Feldspar, near Perth, Ont. Showing characteristic paral el-sided grains.....	X 200

PLATE XIV

A. Pumice, Italian, ground in U.S. Showing characteristic striations of the grains.......... X 200

B. Pumicite, Orleans, Nebraska, U.S. Grains washed from a sample of "Old Dutch Cleanser".......... X 150

C. Volcanic dust, Waldeck, Sask. Showing mixed fine- and coarse-textured, angular and striated grains.......... X 200

D. Volcanic dust, Webb, Sask. Showing fineness and uniform texture of grains, a few of which are striated.......... X 200

E. Volcanic dust, Carrolls Landing, Upper Arrow lake, B.C. Showing striated grains.......... X 200

F. Volcanic dust, Deadman river, Savona, B.C. Showing grains of the finest bed highly magnified.......... X 650

PLATE XIV

A

B

C

D

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F

INDEX