"Methods of Quarrying and Dressing"

(pp. 285-331 & other photographs and images from the book)

Excerpts from

The Collection of Building and Ornamental Stones in the U.S. National Museum: A Hand-book and Catalogue

By George P. Merrill, Curator,
Department Lithology and Physical Geology,
pp. 277-351

From
Annual Report of the Board of Regents of the Smithsonian Institution…Year ending June 30, 1886, 1887

Note: This book, *The Collection of Building and Ornamental Stones in the U.S. National Museum: A Hand-book and Catalogue, is* available on Google Books at this link: https://books.google.com/books?id=bdsOAAAAYAAJ&dq=%22collection+of+building+and+ornamental+stones+in+the+us+national+museum%22&source=gbs_navlinks_s

After the images of the "Methods of Quarrying and Dressing" section of this document, you will find the "Table of Contents" and the "List of the Illustrations" from this book. In this document, I have included all of the images, although I've only included the text for the "Methods of Quarrying and Dressing" section of the book.

This excerpt, which begins on the next page,
is presented on the Stone Quarries and Beyond web site.
http://quarriesandbeyond.org/

Peggy B. Perazzo
Email: pbperazzo@comcast.net
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F.—METHODS OF QUARRYING AND DRESSING.

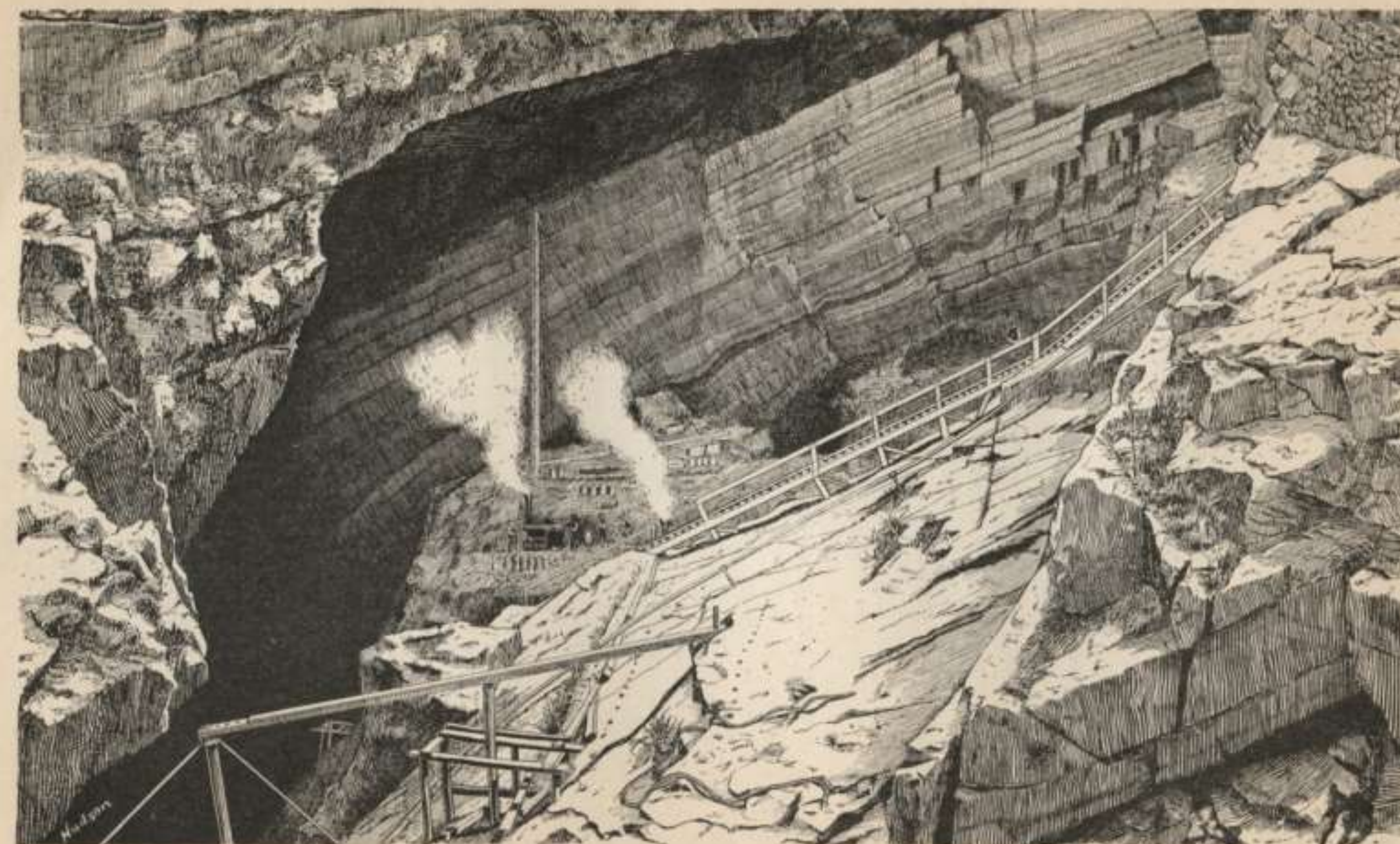
(1) JOINTS IN ROCKS AND THEIR UTILITY IN QUARRYING.

All rocks, whatever their origin, are traversed by one or more systems of natural seams or cracks, called joints. These vary greatly, according to the nature of the rock in which they occur, sometimes being so fine as to be almost imperceptible, or again perfectly distinct and capable of being traced for many yards, or even miles. In stratified rocks (limestones, sandstones, schists, etc.), according to Professor Geikie, the joints, "as a rule," run perpendicular, or approximately so, to the planes of bedding, and descend vertically at not very unequal distances, so that the portions of the rock between them, when seen from a distance, appear like so many wall-like masses. An important feature of these joints, as mentioned by this authority, is the direction in which they intersect each other. In general they have two dominant trends, one coincident on the whole with the direction in which the strata are inclined from the horizon, and the other running transversely at a right angle, or nearly so. The first are called "dip joints" or "end joints" by the quarrymen, since they run with the dip or inclination of the rock, while the last are called "strike joints," since they conform in direction to the strike of the rock. These last are also called "back joints."

In massive rocks like granite and diabase, joints, though prevalent, have not the same regularity of arrangement as in the stratified formations; nevertheless, most rocks of this class are traversed by two intersecting sets, whereby the rock is divided into long, quadrangular, rhomboidal, or even polygonal masses. Frequently, also, there exists a third series of joints running in an approximately horizontal direction, or corresponding more nearly with the bedding in stratified rocks. These are called by quarrymen "bottom joints," since they form the bottom or floor of the quarry. In some instances, as at the Hallowell (Maine) granite quarries, these bottom joints are so pronounced that no artificial means are required to start the rock from its bed after being freed at the sides and ends.

The cause of these joints has never been fully and satisfactorily explained. By some they are supposed to be due to contraction caused by cooling, and by others it is supposed that they are simply fractures produced by earthquakes. Obviously, the matter can not be discussed here, and the reader is referred to the various text-books on geology. But whatever may have been their origin, their presence is a matter of great importance to quarrymen, and, indeed, the art of quarrying has been well stated by Professor Geikie to consist in taking advantage of these natural planes of division. By their aid large quadrangular blocks

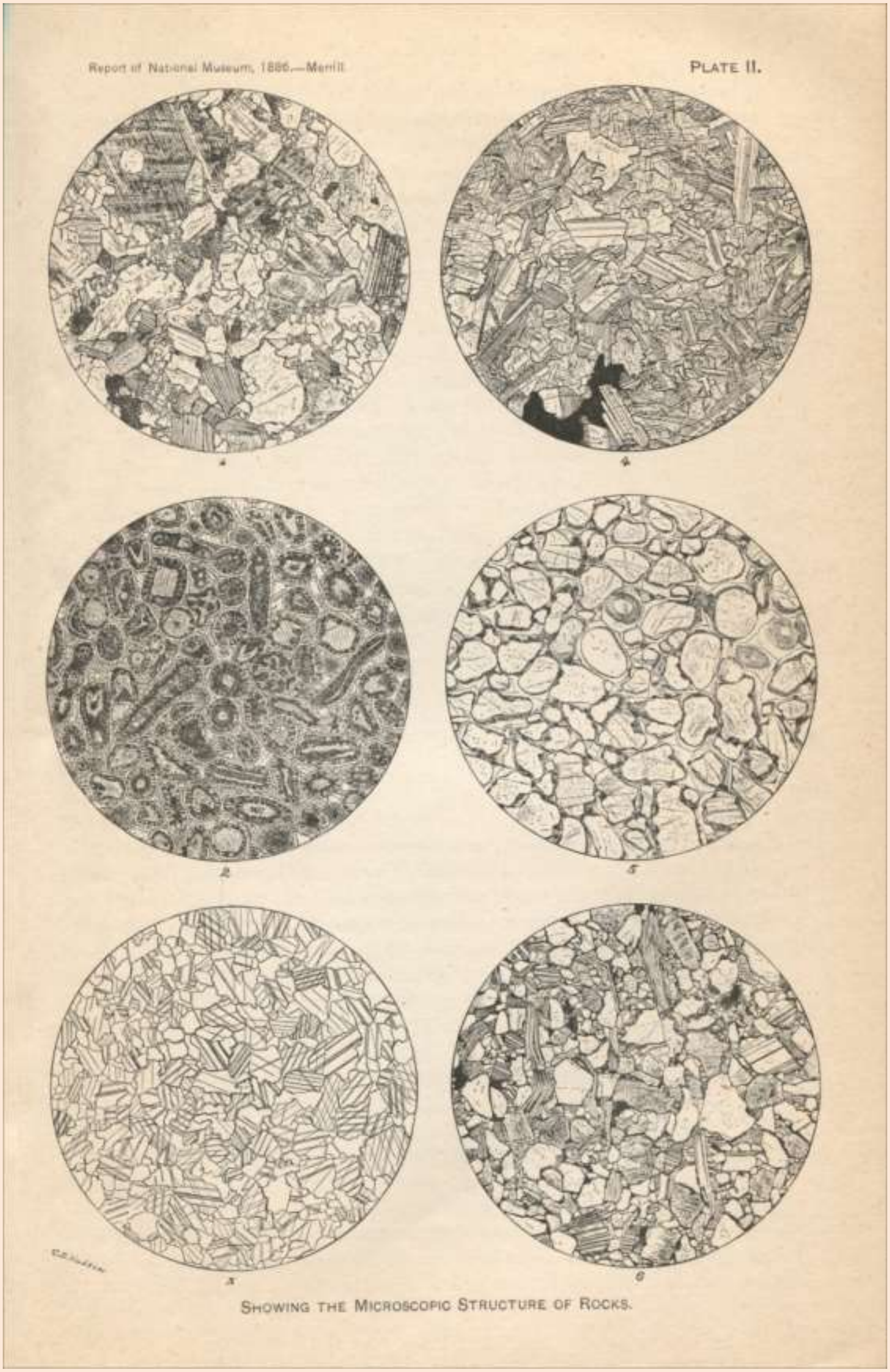
PLATE I.



INTERIOR VIEW OF MARBLE QUARRY, WEST RUTLAND, VERMONT. (See p. 387.)

Drawn from a photograph.

(photo caption) Plate I. “Interior view of marble quarry, West Rutland, Vermont. (See p. 387.) Drawn from a photograph.” (pp. 278)



“Showing the microscopic structure of Rocks.” Fig. 1. Muscovite-biotite granite (26335*), Hallowell, Maine. Fig. 2. Oolitic limestone (37955*), Litchfield, Grayson County, Kentucky. Fig. 3. White marble (25733*), West Rugland, Vermont. Fig. 4. Diabase (26199*), Weehawken, New Jersey. Fig. 5. Sandstone (26268*), Potsdam, New York. Fig. 6. Sandstone (26077*), Portland, Connecticut.”

can be wedged off which would be shattered if exposed to the risk of blasting.*

(2) GRANITE QUARRYING.

The methods of quarrying naturally vary with the kind and quality of the material to be extracted. In all the object aimed at is to obtain the largest and best shaped blocks with the least outlay of time and money, and this, too, so far as possible, without the aid of explosives of any kind, since the sudden jar thus produced is extremely liable to develop incipient fractures and so shatter as to ruin valuable material.

In quarrying granite there is less to fear from the use of explosives than in either sandstone or marble, while, at the same time, the greater hardness of the stone renders the quarrying of it by other means a matter of considerable difficulty and expense.

In the leading quarries of Maine and Massachusetts no machinery is used other than the steam drill and hoisting apparatus. By means of the drills a lewis† hole or a series of lewis holes is put down at proper intervals to a depth dependent upon the thickness of the sheets. These are then charged, not too heavily, and fired simultaneously. In the Hallowell quarries, where the sheets of granite are entirely free from one another, this is all that is necessary to loosen the blocks from the quarry, and they are then broken up with wedges. In many quarries, however, where the sheets are thicker or the bottom joints less distinct, it is necessary to drill a series of horizontal holes along the line where it is wished to break the rock from the bed and then complete the process with wedges.

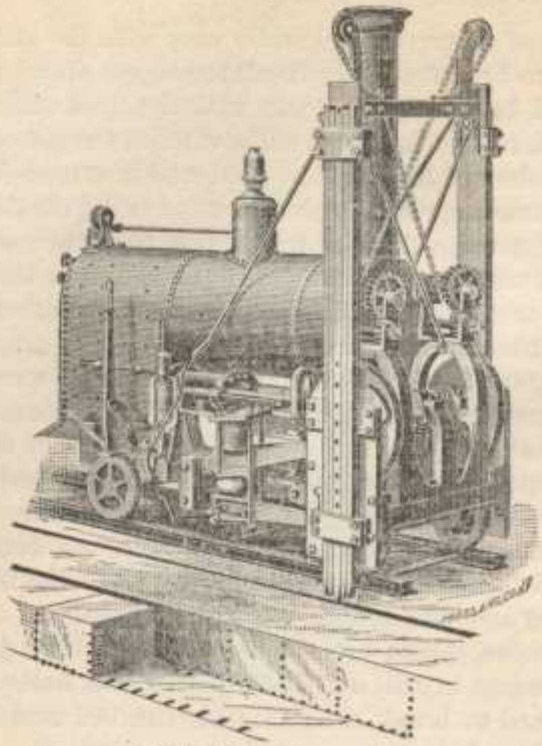
(3) MARBLE QUARRYING.

In quarrying marble and other soft rocks, channeling machines are now largely used. These, as shown in the illustration (page 312), run on narrow tracks, back and forth over the quarry bed, cutting, as they go, vertical channels some 2 inches in width and from 4 to 6 feet in depth. After the channels are completed a series of holes from 8 inches to 2 feet apart are drilled along the bottom of the block, which is then split from its bed by means of wedges. This under drilling is called by quarrymen "gadding," and special machines, which are known as "gadding machines," have been designed for the purpose. (See figures on pages 325 and 326.) At the Vermont marble quarries both the

* A good illustration of the utility of jointed structure as an aid to quarrying sedimentary rocks is offered in the Primordial conglomerates about Boston. These consist of a greenish gray groundmass, in which are embraced a great variety of pebbles of granite, quartzite, melaphyre, and felsite of all shapes and sizes. The beds are traversed by two series of vertical joints which cut the rock and its included pebbles, granite, quartz, melaphyre, and felsite alike, with almost as sharp and clear a cut as could be made by the lapidary's wheel. The joints are very abundant, and in many cases quarrying would be a practical impossibility without them. Whenever smooth walls are required the stone is laid on its bed with the joint face outward.

† I find the word also spelled *louis*. For description see Glossary.

Sullivan diamond-pointed drill and the Ingersoll impact drill are used for gadding. The bottom holes are usually drilled to a depth equaling



Wardwell channeling machine.

about one-half the width of the block to be extracted, though this depth, as well as the frequency of the holes, must necessarily vary with the character of the rift of the rock.

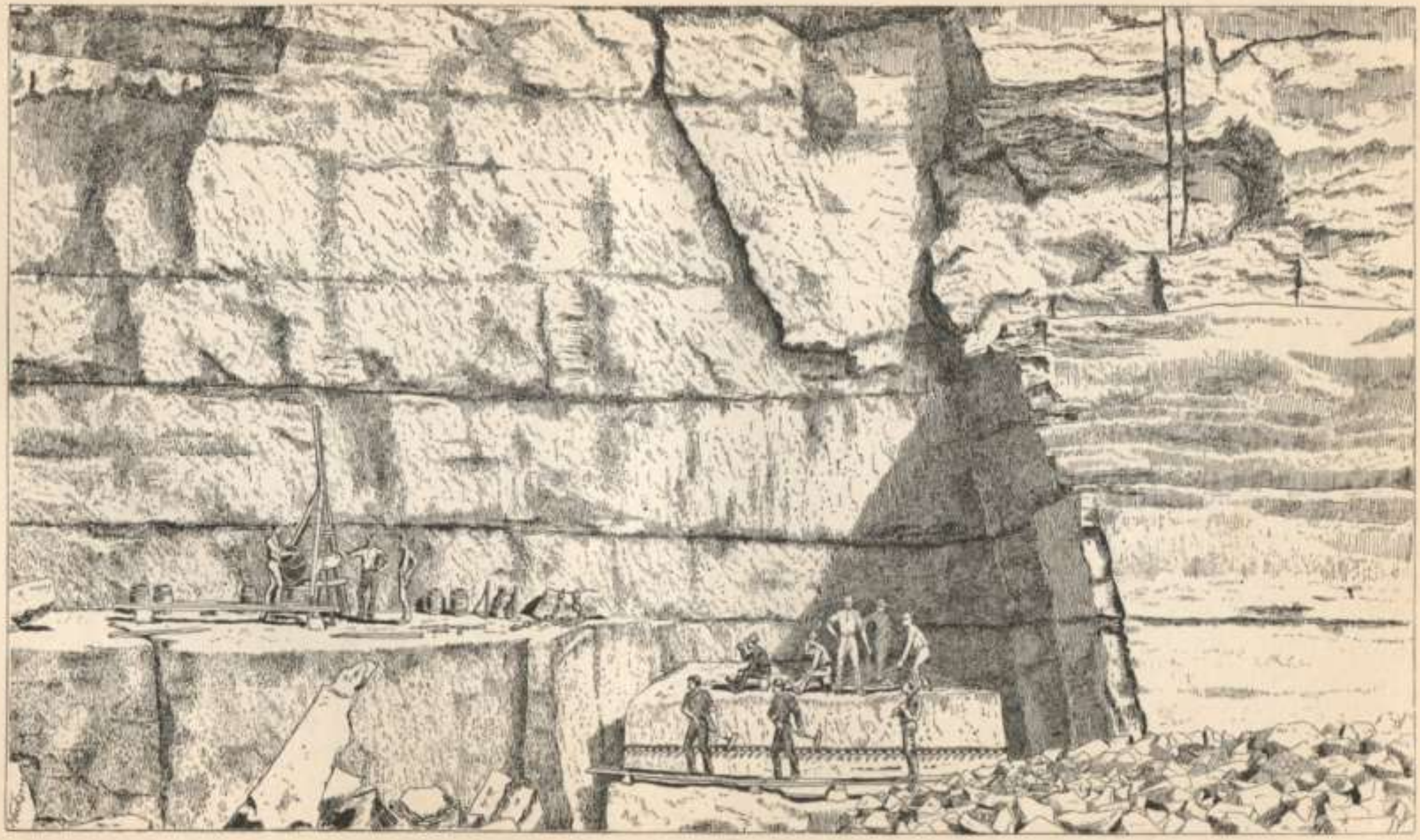
(4) SANDSTONE QUARRYING.

In the quarrying of the Triassic sandstones at Portland, Conn., the channeling machine is also used to some extent, but the prevailing method of loosening large blocks is by deep drill holes charged with heavy blasts of powder. These holes, which are made by a crude machine driven by cranks, like an ordinary derrick, are 10 inches in diameter and about 20 feet deep. Into these are put from 25 to 75 pounds of powder, contained in a flattened or oval tin cannister, with the edges unsoldered and closed at the ends by paper or cloth. This is placed in the hole in such a position that a plane passing through its edges is in line with the desired break, and fired. In this way large blocks are freed from the quarry, and these are then broken to any required size, as follows: The workmen first cut with a pick a sharp groove some 4 to 8 inches deep along the full length of the line where it is desired the stone shall break. Into this groove are then placed, at intervals of a few inches, large iron wedges, which are then in turn struck repeated

(photo caption) “Wardwell channeling machine.”

Report of National Museum, 1886.—Merrill.

PLATE III.



QUARRYING SANDSTONE AT PORTLAND, CONNECTICUT.

Drawn from a photograph.

(photo caption) Plate III. “Quarrying sandstone at Portland, Connecticut. Drawn from a photograph.”
“Splitting out stone with wedges, Portland, Connecticut.” (pp. 313)

blows by heavy sledge-hammers in the hands of the quarrymen until the rock falls apart. This process will be made plain by reference to Plate III. In some of the quarries of softer sandstone no machines at all are used, the channeling being done entirely with picks and the stone forced out by means of iron bars alone, or split out with plug and feather. To allow of this, however, the stone must be evenly and thinly bedded, and the different sheets adhere to one another with but slight tenacity, as is the case with certain of the New York "bluestones" and Berea grits of Ohio. In the New York quarries the vertical joints are said to be so numerous as to practically do away with the necessity of channeling.*

Powder is still largely used in most of the smaller quarries, and in all those of granite rock for throwing off large masses. If properly used with these harder varieties, it is doubtful if any serious harm results, but in the quarrying of marble and other soft stones, its use can not be too strongly condemned. As suggested by Sperr† the rapid disintegration of the Carrara marble is no doubt caused in part by the incipient fractures induced through the crude methods of quarrying employed. Excepting when, as in the case of granite, no other means can be employed, explosives of all kinds are to be avoided. When necessary, they should be used in a lewis hole, whereby direction may be given to the force of the discharge and the shock distributed over large surfaces.

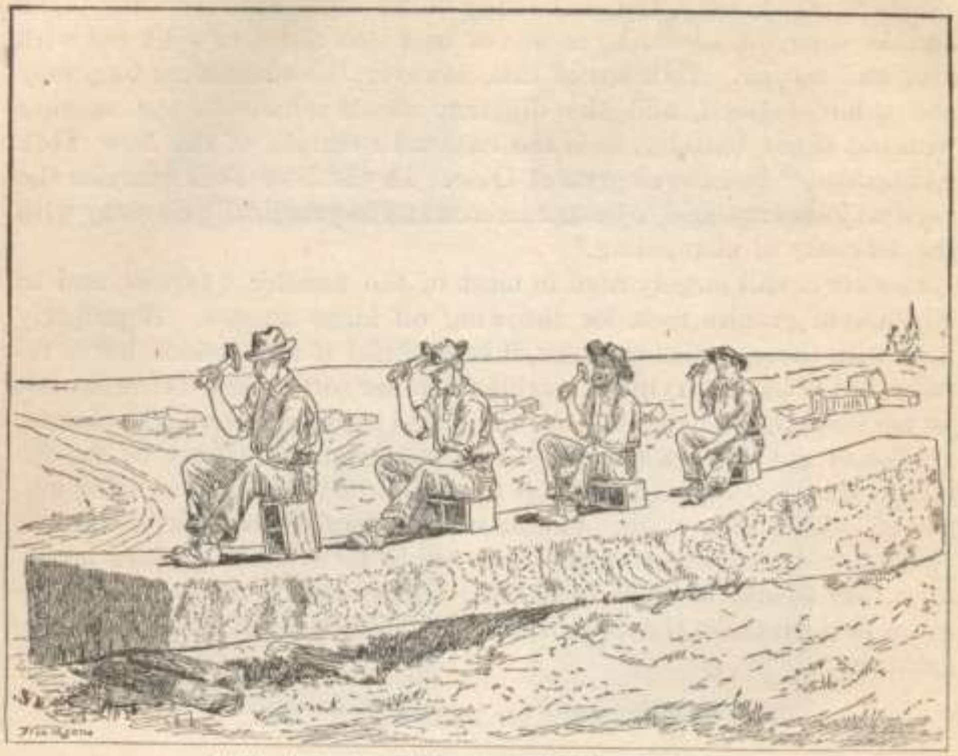
(5) CUTTING AND DRESSING STONE.

In cutting and dressing stone the same slow hand processes that were in vogue hundreds of years ago are still largely employed. There have been, it is true, many machines invented for this purpose, but the majority of them are far from satisfactory in their working qualities, or the cost of running them is so great that they can be used only by the larger and wealthier firms. After a large mass has been split from the quarry bed it is broken into blocks of the required size and shape by means of wedges. A series of holes, three-fourths of an inch in diameter and a few inches deep, is drilled along the line where it is desired the stone shall break, and into each of these two thin half round pieces of soft iron called "feathers" are placed, and a small steel wedge or "plug" placed between. The quarryman then moves along this line striking with his hammer each wedge in its turn till the desired strain is produced and the stone falls apart.

There is a chance for a greater display of skill in this work than may at first appear. Nearly every stone, however compact, has a distinct grain and rift, along which it can be relied on to split with comparative ease and safety. To know the rift and be able to take proper advantage

* F. W. Sperr. Report Tenth Census, p. 37.
†*Op. cit.*, p. 38.

of it is an important item, and it is astonishing how readily an experienced workman will cause a stone to take the desired shape through a knowledge of this property.



Drilling holes for splitting stone with plug and feathers.

This process of splitting stone with wedges is said* to have been first brought into general use in this country by a poor mechanic named Tarbox, of Danvers, Mass. Through the influence of Governor Robbins, who stumbled upon samples of his work by the merest accident, this man was induced in 1798 to go to Quincy and teach his art to the quarrymen of that place. So much did the adoption of this simple method facilitate granite working that the price of the cut material dropped within the space of a few months over 60 per cent. Prior to this time the stone after being blasted from the quarry in irregular blocks was squared down to the proper size by cutting a groove along a straight line with a sharp-edged tool called an axhammer, and then striking with a heavy hammer repeated blows on both sides of the groove until the rock was broken asunder.†

* Proceedings American Academy, Vol. IV, 1859, p. 353.

† In Pattee's History of Old Braintree and Quincy occurs this passage: "On Sunday, 1803, the first experiment in splitting stone with wedges was made by Josiah Bemis, George Stearns, and Michael Wilde. It proved successful, and so elated were these gentlemen on this memorable Sunday that they adjourned to Newcomb's hotel, where they partook of a sumptuous feast. The wedges used in this experiment were flat, and differed somewhat from those now in use.'

As to who can justly claim to be the first to bring this method of splitting into

(photo caption) "Drilling holes for splitting stone with plug and feathers."

This method is said to have been introduced into Quincy somewhere about 1725–'50, by German emigrants, and, crude as it may seem, was a vast improvement over that used in preparing stone for the construction of King's Chapel, erected in 1749–'54, on the corner of School and Tremont streets, Boston. Here we are told the stone was first heated by building a fire around it and then broken by means of heavy iron balls let fall from a considerable height.

With such difficulties as these to contend with it is not surprising that the building should have been considered a wonder when completed, and that people coming to Boston from a distance made it a point to see and admire this great structure. The wonder, however, was not that the granite could be broken into shape by such methods, but "that stone enough could be found in the vicinity of Boston fit for the hammer to construct such an entire building. But it seemed to be universally conceded that enough more like it could not be found to build such another."

After a block is broken from the quarry bed it is trimmed to the desired size and shape by means of a variety of implements, according to the hardness of the stone and the character of the desired finish.

In dressing granite and other hard stone the tools ordinarily used are the set or pitching chisel, the spalling hammer, peau hammer, bush hammer, hand hammer, chisel, and point. With the set the rough

general use the author has no means of ascertaining. That none of the above can justly claim to have *invented* the process is evident from the following:

"I told thee that I had been informed that the grindstones and millstones were split with wooden pegs drove in, but I did not say that those rocks about this house could be split after that manner, but that I could split them, and had been used to split rocks to make steps, door-sills, and large window cases all of stone, and pig-troughs and water-troughs. I have split rocks 17 feet long and built four houses of hewn stone split out of the rocks with my own hands. My method is to bore the rock about 6 inches deep, having drawn a line from one end to the other, in which I bore holes about a foot asunder, more or less, according to the freeness of the rock; if it be 3 or 4 or 5 feet thick, 10, 12, or 16 inches deep. The hole should be an inch and a quarter diameter if the rock be 2 feet thick, but if it be 5 or 6 feet thick the holes should be an inch and three-quarters diameter. There must be provided twice as many iron wedges as holes, and one-half of them must be fully as long as the hole is deep and made round at one end, just fit to drop into the hole, and the other half may be made a little longer, and thicker one way, and blunt pointed. All the holes must have their wedges drove together, one after another, gently, that they may strain all alike. You may hear by their ringing when they strain well. Then with the sharp edge of the sledge strike hard on the rock in the line between every wedge, which will crack the rock; then drive the wedges again. It generally opens in a few minutes after the wedges are drove tight. Then, with an iron bar or long levers, raise them up and lay the two pieces flat and bore and split them in what shape and dimensions you please. If the rock is anything free you may split them as true almost as sawn timber, and by this method you may split almost any rock, for you may add almost any power you please by boring the holes deeper and closer together."

(From letter of John Bartram to Jared Elliot dated January 24, 1757. See Darlington's Mem. of Bartram and Marshall, p. 375.) The precise date at which these four stone houses were built is not stated, but the work above quoted contains an illustration of John Bartram's house, near Darby, Delaware County, Pa. This house, block is trimmed down to a line. Then the irregular surface is worked down by the point, which is driven by the hand hammer. After pointing, are used the pean and the patent or bush hammers in turn, beginning with the 4-cut and thence working down with the 6-cut, 8-cut, 10-cut, and 12-cut, or until the desired surface is obtained. The condition of the hammered surface at the completion of one of the hammerings should be such that each cut in the hammer traces a line its full length on the stone at each blow.

The single cut or pean hammer should leave no unevenness exceeding one-eighth of an inch, and each finer cut reduces the unevenness left by the preceding.

The 12-cut should leave no irregularities upon the surface of the stone other than the indentations made by the impinging of the plates in the hammer. The lines of the cut are made so as to be vertical in exposed vertical faces when the block is in position. On horizontal and unexposed faces they are cut straight across in any convenient direction. With sawn surfaces of course much of the preliminary work is done away with, as the surface is already sufficiently smooth. It is at present customary to saw only such stone as are designed for polishing or some kind of smooth finish.

In preparing a stone for polishing the surface is first made smooth as possible by sawing or by the means above designated. It is then fur-

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which is of stone, was erected about 1730. Hence we must conclude that the art of splitting stone in this manner was known to some at least as early as this date.

It is stated (Grueber, Die Baumaterialien-Lehre, pp. 60, 61) that in Finland, even at the present day, granite is split from the quarry-bed through the expansive force of ice. A series of holes, from a foot to 15 inches apart and from 2 to 3 feet deep, according to the size of the block to be loosened, is driven along the line of desired rift after the usual custom. These holes are then filled with water and tightly plugged. The operation is put off until late in the season and until the approach of a frost. The water in the holes then freezes, and by its expansion fractures the rock in the direction of the line of holes. Blocks of 400 tons weight are stated to be broken out in this way. A more ancient method consisted in simply plugging the holes with dry wooden wedges and then thoroughly saturating them with water, the swelling wood acting in the same way as the freezing water. Another ancient and well-known method consisted in building a fire around the stone, and when it was thoroughly heated striking it with heavy hammers or throwing cold water upon it. In splitting stone the ancient Romans are said to have sprinkled the hot stone with vinegar, though whether they thereby accelerated the splitting or caused the stone to break along definite lines is not known. Quartz rocks, it is stated, can be made to split in definite directions by wetting them while hot, or laying a wet cord along the line it is desired they shall cleave. The wet line gives rise to a small crack, and the operation is completed by striking heavy blows with wooden mallets. According to M. Raimondi, the ancient Peruvians split up the stone in the quarry by first heating it with burning straw and then throwing cold water upon it. To carve the stone and obtain a bas-relief, this writer contends that the workmen covered with ashes the lines of the designs which they intended to have in relief, and then heated the whole surface. The parts of the stone which were submitted immediately to the action of fire became decomposed to a greater or less depth, while the designs, protected by ashes, remained intact. To complete the work the sculptor had but to carve out the decomposed rock with his copper chisel.

ther reduced by means of wet sand and emery of varying degrees of fineness. Small blocks are now usually ground on a revolving iron bed, on which the abrading material is shoveled and kept wet by a stream of water from overhead. With larger blocks a heavy slab of stone is drawn by the workmen back and forth across the surface on which the wet sand has already been placed. On the finer grades of white marble emery is not used, as it stains; fortunately, owing to the softness of these stones, it is readily dispensed with. After being ground, the surface is rubbed by a sharp, evenly gritted sandstone called a "hone," and then with pumice-stone.

On granites it is often customary to give a "skin coat" by rubbing the block, after the final emerying on the smooth, wet grinding bed, without any abrading material, until a perfectly smooth surface and dull polish is obtained. When this point is reached—and the surface must be quite free from scratches and blemishes, or a good polish is impossible—the polish is produced by means of polishing putty (oxide of tin) rubbed on with wet felt. In cheap work it is customary to use oxalic acid in connection with or entirely in place of the polishing putty. This enables the production of a polish with less labor, but it is also less durable.

A high grade of polish can only be produced by skilled workmen, and each one has his own peculiar methods, varying in trifling particulars from that given above. In many of the larger works where steam power is used, it is said to be customary to mix a quantity of very finely ground metallic lead with the putty. By this means a higher gloss is produced, and also one that is very durable. All the larger works now use machinery in both grinding and polishing. Descriptions of these will be given in the following chapter.

Sundry attempts have been made to utilize the sand-blast process, so extensively used in glasswork, for carving on stone; but so far, with few exceptions, these attempts have met with but poor success. In 1875-'76, Messrs. Sheldon & Slason, of West Rutland, having a large Government contract in preparing head-stones for soldiers' graves in national cemeteries, introduced the system with considerable success. The process consisted in covering those parts of the stone to be left uncut with an iron shield, while letters and figures of chilled iron were placed upon those portions which were to stand out in relief. The blast then being directed against the stone cut away very quickly the unprotected parts. By this means the name, company, regiment, and rank of soldiers, could be cut on a stone in less than five minutes, and two hundred and fifty-four thousand stones thus lettered and having dimensions of 3 feet in length, 10 inches in width, and 4 inches in thickness, were placed in the national cemeteries at a cost of but $864,000. The sand-blast process has also been used with good results on the hard red quartzite of Sioux Falls, as will be noted later.

(6) QUARRYING AND SPLITTING SLATE.

In quarrying slate the methods vary greatly according to the disposition of the beds, and no attempt will be made here at a detailed description. Ordinary blasting powder is employed in loosening the blocks, and great skill and sagacity is shown by experienced quarrymen in so manipulating the blast as to produce the desired effects of freeing the rock from the quarry bed without shattering the stone. After a block is removed from the quarry it is subject to special treatment according to the purpose to which the stone is to be put. If for roofing-slate, the block according to Mr. Sperr* is taken from the quarry to the splitters' shanty, where it is taken in charge by a splitter and his two assistants. The first assistant takes the block and reduces it to pieces about 2 inches in thickness, and of a length and breadth a little greater than those of the slates to be made. This is done by a process called "sculping," which is as follows: A notch is cut in one end of the block with the sculping chisel, and the edge of this notch is trimmed out with a gouge to a smooth groove extending across the end of the block and perpendicular to the upper and lower surfaces; the sculping chisel is then set into this groove and driven with a mallet until a cleft starts, which by careful manipulation is guided directly across the block. The upper surface of the block is kept wet with water so that the crack may be more readily seen. If the slate is perfectly uniform in shape and texture, and the blows upon the sculping chisel are directed straight with the grain, the crack follows the grain in a straight line across the block. Almost invariably, however, the crack deviates to the right or left, when it must be brought back by directing the blow on the sculp in the direction in which it is desired to turn the break, or by striking with a heavy mallet on that side of the block toward which it is desired the crack shall turn. Some slates can be sculped across the grain, but nearly all must be broken in this direction. From the first assistant or "sculper" the block goes to the splitter who by means of a mallet and broad thin chisel splits it through the middle, continuing to thus divide each piece into halves until the desired thinness is obtained. It is necessary to keep the edges of the blocks moist from the time they are removed from the quarry until they are split. From the splitter the thin but irregularly shaped pieces pass to the second assistant who trims them into definite sizes and rectangular shapes. This is done either by hand or by machine. To trim by hand a straight edged strip of iron or steel is fastened horizontally upon one of the upper edges of a rectangular block of wood some 2 to 4 feet in length. The trimmer then lays the sheet of slate upon the block allowing the edge to be trimmed to project over this strip, and then by means of a long heavy knife with a bent handle cuts off the overlying edge, thus reducing it to the required size and shape. Two kinds of

* Report Tenth Census, Vol. x, p. 39.

machines for doing this work are now in use. In general they may be said to consist of an iron frame-work some 2½ feet high, with a horizontal knife-edge upon its upper edge. Against this knife is made to work by means of a treadle another knife, curved in outline, which is thrown upward again by means of a spring, after being brought down by the treadle-movement. At right angles to this knife-edge, on one side of the machine, an iron arm projects toward the workman; this arm has notches cut into it for the different sizes of the slate. The difference between the two kinds of machines is said to consist chiefly in the arrangement of the cutting-knife, one working as stated above, while the other revolves on an axle something in the manner of an ordinary corn cutter.

Slates are sawn by means of an ordinary circular saw, such as is used in sawing lumber, and are planed by machines such as are used in planing metals, as are other soft stone. Some of the hard slates used for tiling have to be cut by means of circular saws with teeth of black diamond.*

(7) KINDS OF FINISH.

The more common kinds of finish applied to stone are described below; the figures on Plate IV being drawn from samples in the national collections.

(1) *Rock face.*—This is the natural face of the rock as broken from the quarry, or but slightly trimmed down by the pitching tool. As in this and all the figures given, it is frequently surrounded by a margin of drove work.

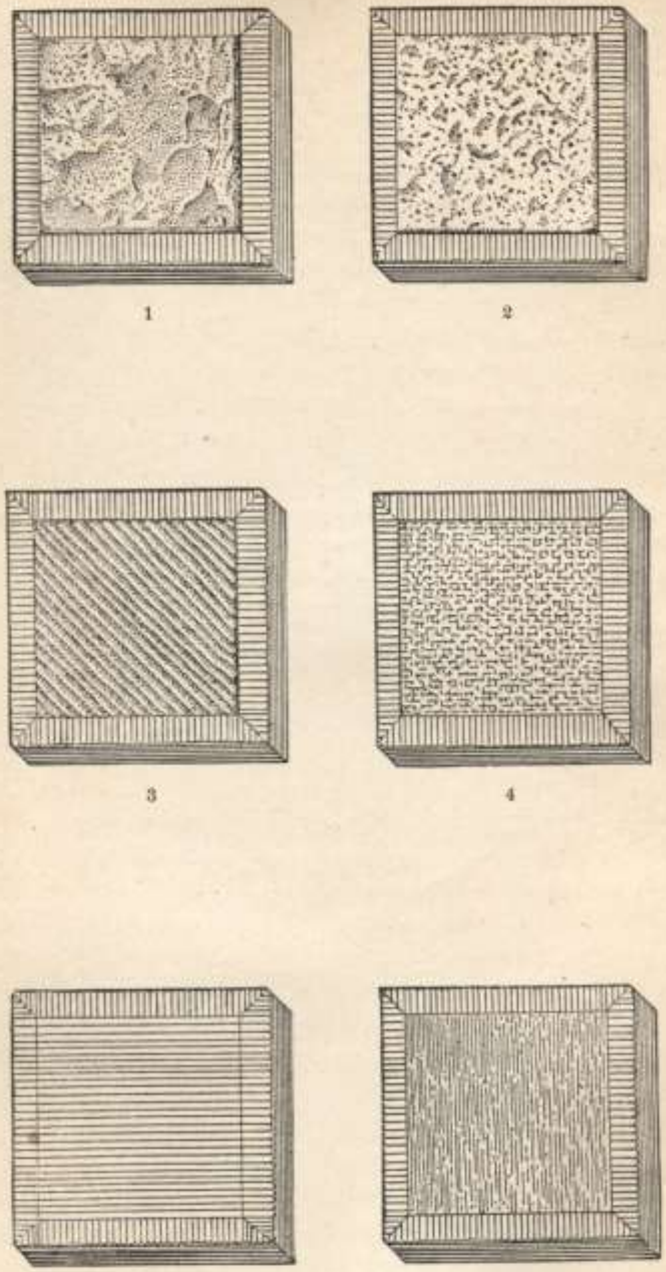
(2) *Pointed face.*—In this finish the natural face of the rock has been trimmed down by means of the sharp-pointed tool called a point. It is used principally for exterior work, as in the walls of a building. Two common styles of pointing are shown.

(3) *Ax-hammered face.*—This finish is produced by striking upon the surface repeated blows with a sharp-faced hammer, called an ax or pean hammer. It closely resembles the next, but is coarser. Used in steps, house trimmings, and other exterior work.

(4) *Patent hammered.*—This finish is produced by striking repeated blows upon the smooth surface of the rock with the rough-faced implement called a patent hammer. Five grades of fineness are commonly recognized, the 4-cut, 6-cut, 8-cut, 10-cut, and 12-cut surfaces, made by hammers composed of four, six, eight, ten, and twelve plates, respectively. A very common finish for the finer kinds of exterior work.

(5) *Bush hammered.*—This finish resembles closely the tooth chiseled or very fine pointing. It is used mostly on soft stone. (See descriptions of bush and patent hammers on p. 329.)

* Detailed and very closely resembling accounts of the methods of working slate are given by F. W. Sperr, in Report Tenth Census, Vol. x, pp. 38–42, and E. Prince, jr., report D 3, Vol. I, pp. 138–143, 2d Geol. Survey, Pennsylvania. To these the reader is respectfully referred.



KINDS OF FINISH.

FIG. 1. Rock face.
FIGS. 2, 3. Pointed face.
FIG. 4. Tooth-chiseled.
FIG. 5. Square drove.
FIG. 6. Patent hammered.

(photo caption) Plate IV. "Kinds of Finish. Fig. 1. Rock face. Figs. 2, 3. Pointed face. Fig. 4. Tooth-chiseled. Fig. 5. Square drove. Fig. 6. Patent hammered." (pp. 319)

(6) *Square drove.*—The square-drove surface is made with a wide steel chisel with a smooth edge, called a drove. It is quite common to use this style of finish as a border to the rock-face or pointed surfaces in many kinds of exterior work.

(7) *Tooth chiseled.*—This finish is produced by means of a wide steel chisel with an edge toothed like that of a saw. This and the square drove are used principally upon limestones, marbles, and sandstones, the granites being too hard to be cut in this manner.

(8) *Sawed face.*—This is the surface of the rock as left by the saw; the saw used for the purpose being a thin smooth blade of soft iron fed with sharp sand or chilled iron. This and the following styles, although possessing distinctive characteristics easily recognizable by the eye, are of such a nature that their likenesses can not be well reproduced on paper. Hence no attempt at illustration has been made.

(9) *Fine sand finish.*—To produce this finish the chiseled or sawn surface of the marble is rubbed smooth by means of a block of stone and fine wet sand or on the machines yet to be described.

(10) *Pumice finish.*—This is a very smooth but unpolished surface produced by smooth rubbing with pumice or Scotch hone.

(11) *Polished surface.*—Two kinds of polished surfaces are made—the acid gloss and the putty gloss. For either the surface of the stone is made as smooth as possible by means of sand, or emery, and pumice, or hone, after which it is rubbed with moist woolen cloth and oxalic acid, or polishing putty. The latter produces the best and most lasting gloss, but requires more labor. Frequently the two methods are combined, especially in tombstone work.

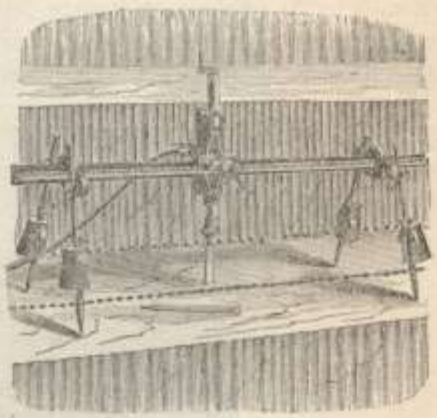
G.—MACHINES AND IMPLEMENTS USED IN STONE WORKING.

DRILLS AND DRILLING MACHINES.

Of the many machines that have from time to time been invented for working stone we can here mention only the principal ones that are to-day in actual use.

Drills.—The old-time method of drilling by means of a flat pointed drill called a "jumper," which is held by one workman while others strike upon it alternate blows with heavy hammers, although still in use in many quarries, has been largely superseded by steam-drills of various kinds. A simple form of the steam-drill, and one now in very general use, is that shown in the accompanying figure (page 321). The drill proper is fastened directly to the piston, which can be inclined at any angle, thus fitting it for ordinary quarrying or for tunneling. It is driven either by steam or by compressed air. A different adaptation of the same principle is employed in the channeling and gadding machines used in getting out dimension stone. Figures of these are also here given. The drill and cylinder are attached to the horizontal bar by

Eclipse Rock Drill.



Improved Quarry Bar.

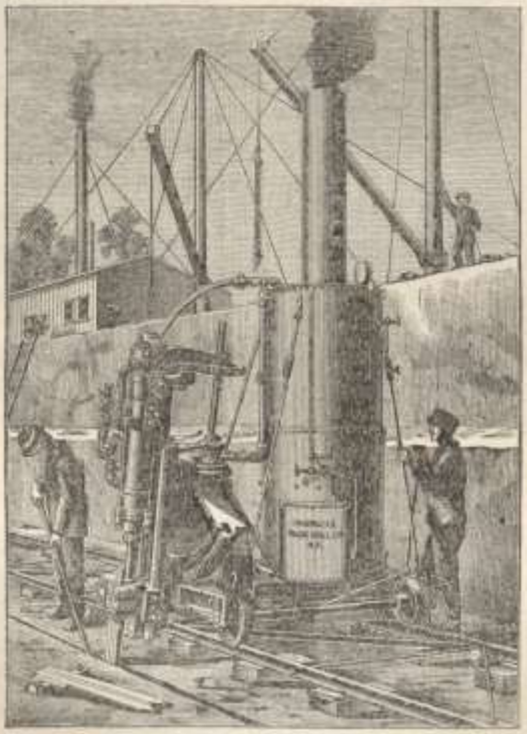
means of a clamp, which can be loosened or tightened at will. By this means a dozen or more holes can be cut by simply sliding the drill along the bar and without moving the entire machine.

(2) CHANNELING MACHINES.

The channeling machine shown on page 312 was invented by George J. Wardwell, of Rutland, Vt. The first successful machine was built by him in 1863, in connection with the Sutherland Falls Marble Company, and that original machine has been at work there constantly until within a few months (1885). These machines are now in operation in all the important quarries of sandstone, limestone, and marble in the country, and it is calculated that over 5,000,000 square feet have been cut by them. The channeler is essentially a locomotive machine driven by power, usually steam, moving over a steel rail track which is placed on the quarry bed. It carries a single gang-drill on one side, or two such drills—one on each side. These are raised and dropped by a lever and crank arrangement. The gang of cutters forming the drill is composed of five steel bars, 7 to 14 feet in length, sharpened at the ends and securely clamped together. Of the five cutters, two have diagonal edges; the other three have their edges transverse. The center of the middle largest extends lowest, so that the five form something like a stepped

(photo captions) (left) “Eclipse Rock Drill. (right) “Improved Quarry Bar.”

arrangement, away from the center. The drill, lifted, drops with great force and rapidly creases a channel into the rock. The single-gang machine is operated by two men, the double by three. As it runs backward and forward over the rock the machine is reversed without stopping, and as it goes the cutters deliver their strokes, it is claimed, at the rate of one hundred and fifty per minute. The machine feeds forward on the track half an inch at each stroke, cutting half an inch or more every time of passing. The single machine will cut from 40 to 80 square feet of channel per day in marble or limestone and at a cost of from 5 to 20 cents per square foot. The double machine will do twice the amount of work. A good workman would formerly cut from 5 to 10 feet, that is, a groove 1 foot deep and from 5 to 10 feet long per day.



Saunders Channeling Machine with boiler attached.

For this he would receive from 25 to 30 cents per foot.* Another machine for doing the same work as that just described is the Saunders channeling machine shown in the illustration, and which has recently come into use in the Vermont quarries. This differs from the Wardwell in several important particulars, prominent among which are these: (1) The cutting tool is attached rigidly to the piston, so that the blow is dealt directly by the steam pressure in the cylinder and without the intervention of any cranks, levers, or springs. (2) The cutting tools are

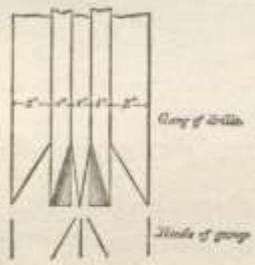
* The Marble Border of Western New England, p. 43.

(photo caption) "Saunders Channeling Machine with boiler attached."

made adjustable at any angle—to the right, left, forward, or backward. The machine is thus capable of making transverse and sidehill cuts, and does what is known as "cutting out the corners" in quarrying; and (3) it can be used in chambers where the distance between the floor and roof is but 6 feet and can be used in tunnels and headings.

Saunders Channeling Machine making sidehill cuts and with boilers detached.

The machine carries five drills in the gang, with three straight points and two diagonal ones. These are arranged as seen in the accompanying cut:



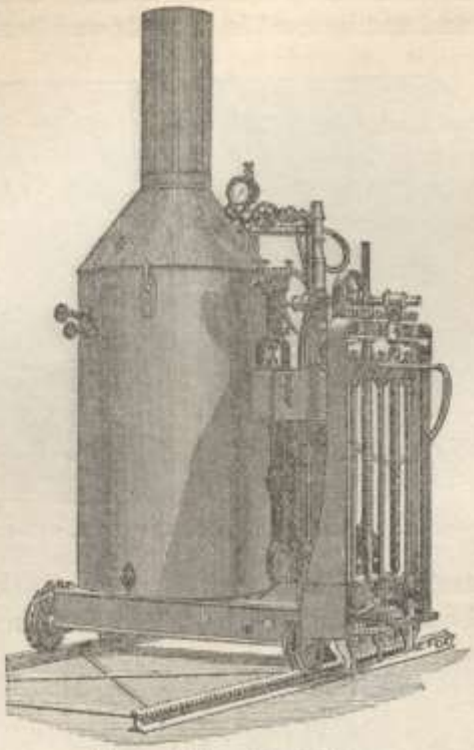
The average capacity of the machine, as claimed by the company's circular, is as follows:

In marble, 80 to 100 square feet of channel in ten hours.
In sandstone, 150 to 200 square feet of channel in ten hours.
In limestone, 120 to 150 square feet of channel in ten hours.

The diamond channeling-machine is shown in the figure on page 324. According to the company's circular this machine employs 1¾-inch drill-bits, which are attached to drill-rods of varying lengths, adapted to any required depth of channel up to 9½ feet. The channel may be made open or partly closed, the latter by leaving slight spaces between the holes, to be afterward chipped out. But the whole operation of a clear cut is made simultaneously with the boring by means of an intercutting guide, which answers this purpose very well. The drill can be made to

(photo captions) (top) "Saunders Channeling Machine making sidehill cuts with boilers attached."
(bottom) Diagram of a drill in the Saunders Channeling Machine.

vary in direction from perpendicular to 50 degrees slant for putting down the tunnel and angle cuts. If necessary the boiler can be left at a distance from the machine, the steam being conveyed by hose.



Diamond Channeling Machine.

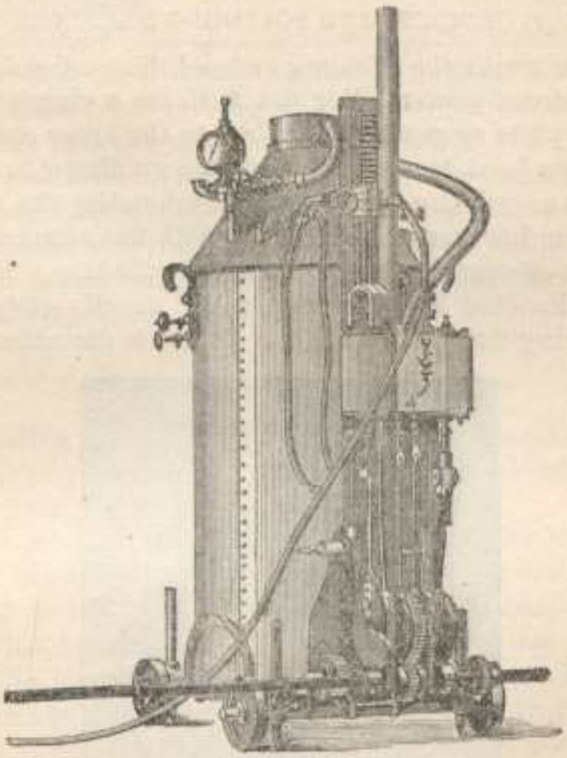
(3) GADDING AND GADDING MACHINES.

The diamond gadder is shown on page 325. According the company's circular the machine takes its name from the class of work for which it was especially designed and which is known among quarriers as "gadding." When the requisite channel cuts are made about a block of marble to be removed, it is necessary to undercut the block in order to release it. This is usually accomplished by drilling a series of holes beneath it, and then, by wedges, the block is split from its bed.

The machine is placed upon a platform on trucks arranged to run upon a track. When adjusted for work it may be braced by the pointed legs shown. The boring apparatus is attached by a swivel to a perpendicular guide-bar. This guide-bar is secured to the boiler behind it, which forms the main support of the machine. Upon the guide-bar the boring apparatus may be raised or lowered at pleasure, for the purpose of boring a series of holes in a perpendicular line if desired. Upon the swivel the boring apparatus may be turned, so as to bore in any direction within the plane of the swivel-plate.

(photo caption) "Diamond Channeling Machine."

The illustration shows the drill-rod or spindle placed near the base of the machine, and so as to bore horizontally. At one end of the spindle is the drill-head, armed with carbons, and supplied with small apertures or outlets for water. At the other end of the spindle is attached a hose for supplying water to the drill-head. A rapid revolving movement is communicated to the drill-spindle by the gears shown. The speed and feed movement may be regulated by the operator with reference to the hardness or softness, coarseness or fineness, of the material to be bored; and the feed movement may be instantly reversed at pleasure. The machine is so constructed that the drill-spindle may be re-



Diamond Gadder.

moved and another inserted in the same holder, adjusted to bore in the opposite direction, the boring apparatus being driven by a double-cylinder engine. A continuation of one of the piston-rods through the cylinder forms the plunger to a small pump placed above the cylinder, which supplies water to the boiler and forces water through the drill spindle and head. These jets of water wash out all the borings made, and keep the drill-head from heating. The usual feed of this drill in marble is from 4 to 5 inches per minute.

Still another style of gadding-machine is used in the Vermont quarries, and which is but an especial adaptation of the eclipse drill shown on page 326. It is claimed that this machine will "put in holes close to the

(photo caption) "Diamond Gadder."

bottom of the quarry, in a horizontal position along the bench, into the roof, or perpendicularly into the floor, as desired."

Plain quarry frame in position for undercutting or gadding.

(4) GRINDING AND POLISHING MACHINES.

In the larger works the grinding and polishing already described is now done by steam power. For flat surfaces a circular, horizontally revolving iron plate or grating, attached to the lower end of a vertical shaft, with elbow joint, is used, the workman guiding it to any portion of the surface he may desire by means of the handle; the abrading substance being sand or emery, as before. With felt attached to the plate the same form of machine is also used for polishing. Blocks of such size as can be handled by the workmen are usually ground upon horizontally-revolving iron beds some 8 or 10 feet in diameter.

Ingersol Standard Gadder at work.

In making straight or only slightly-curved moldings the form is first carved out with the chisel, and then a plate of cast-iron, fitted as accurately as possible, is made, by means of a long arm, to travel back and forth over the stone with sand or emery, or putty powder and felt, as the case may be. These are called pendulum machines. The actual labor is thus greatly reduced, and a higher and more lasting polish obtained than is possible by the old hand methods.

(photo captions) (top) "Plain quarry frame in position for undercutting or gadding."
(bottom) "Ingersol Standard Gadder at work."

(5) LATHES AND PLANERS.

For turning posts and pillars lathes are now very generally used for granite as well as for softer stone. In easy working varieties, as sand stone, limestone, or serpentine, the cutting tool is a simple chisel, much like that used in turning metals, and held in a clamp in the same manner. With the harder rocks, like the granite, however, this method is ineffectual, and the cutting tool is in the form of a thin steel disk some 6 or 8 inches in diameter, which is so arranged as to revolve with the stone in the lathe when pressed against it at a sharp angle. By this means large and beautiful columns can be made at far less cost than by the old hand processes.

A monster machine of this character, seen by the writer in the Vinalhaven quarries in 1880, is capable of taking a block 25 feet in length and 5 feet in diameter and turning it down to a perfect column.

With the softer varieties of stone a plain surface, sufficiently smooth for flagging, is produced by means of planing-machines similar to those in use for planing metals. For doing the same work on hard material like granite a planer, with revolving cutting disks of chilled iron, similar to those used in the lathes, has been devised. This machine is shown in the accompanying figure, page 328.

(6) MACHINES FOR SAWING.

In sawing marble and other soft stones the same method, with some modifications, is employed as was in use, according to Professor Seeley,* three hundred years before the Christian era.

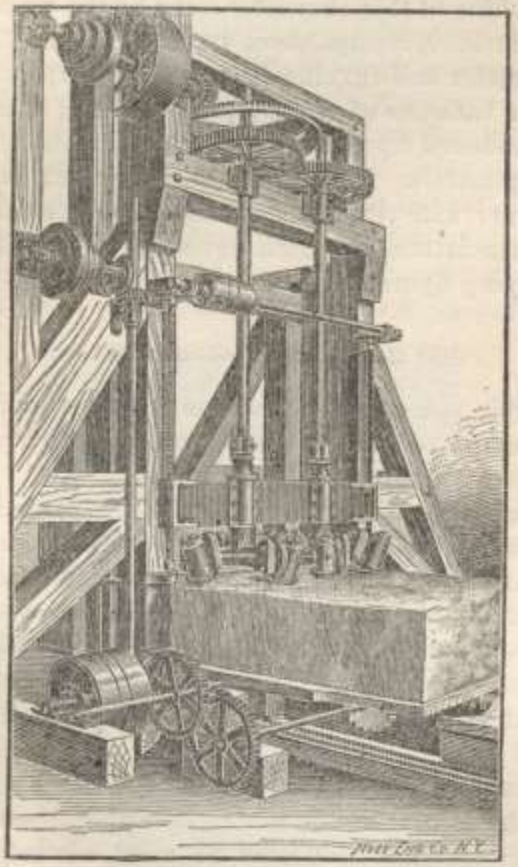
The principle consists simply of a smooth flat blade of soft iron, set in a frame and fed with sharp sand and water. The saws are now frequently set in gangs of a dozen or more in a single frame, and several gangs are tended by one man, who shovels on the wet sand as it is needed, while fine streams of water from overhead wash it beneath the blade as it swings backward and forward in its slowly deepening groove. Some attempts at automatic feeders have been made, but they are not as yet in general use.

This method has been found inapplicable to cutting granite, owing to the greater hardness of the material. Recently a sand composed of globules of chilled iron has been used to good advantage. The great drawback to the use of this material, so far as the author has observed, is the care necessary to avoid staining the stone by rust from the wet globules during the time the machine is not running. This is done by wetting down the stone and globules in the saw frame with a thick solution of lime-water (whitewash) prior to leaving the saws for the night. Circular saws, with diamond teeth, have been used to some ex-

* The Marble Border of Western New England. Proc. Middlebury Hist. Soc., Vol. I, Part II, p. 28.

tent, but have been found too expensive for ordinary work. In sawing slate circular saws are used, such as are employed in sawing lumber. Philo Tomlinson, who was engaged in marble sawing at Marbledale, Conn., near the date 1800, is stated by Professor Seeley* to have been one of the first to successfully apply the gang-saw system in this country.

For sawing circular apertures in the tops of wash-stands or getting out tops for small tables a saw made of plates of soft iron bent into the form of a cylinder and revolved by a vertical shaft is used. Sand emery, or globules of chilled iron form the cutting material, as in the saws just mentioned.



McDonald Stone Cutting Machine.

A recent European invention for sawing stone consists of a twisted cord of steel, made to run around pulleys, like a band-saw. The cord is composed of three steel wires loosely twisted together, but stretched tightly over the pulleys, and is made to run at a high rate of speed. The swift successive blows from the ridges of the cord, delivered along the narrow line, disintegrates the stone much more rapidly, it is claimed, than the iron blades fed with sand, the usual rate of cutting in blocks of

*Op. cit., p. 29.

(photo caption) "McDonald Stone Cutting Machine."

soft limestone being at the rate of about 24 inches an hour, and in Carrara marble a little more than 9 inches an hour. Brittany granite is cut at the rate of nearly 1¼ inches an hour, and even porphyry can be worked at the rate of eight-tenths of an inch an hour. In certain Belgian marble quarries the saw is said to have been used to advantage in cutting the rock from the quarry bed. In thus utilizing it the floor is first cleared as for channeling machines, and then, by means of large cylindrical drills, fed with metallic sand, a shaft 27 inches in diameter is cut to the desired depth, the cores being removed entire, as in the common tubular diamond drills. Two of these holes are sunk at proper distances apart and guides set up in them, on which move frames carrying pulleys of a diameter somewhat less than that of the holes; over these pulleys the cord-saw is stretched; motion is then imparted to the pulleys by a simple system of transmission, and the saws cut without interruption until the bottom of the drill-pit or shaft is reached.* A great saving of time and material is claimed for this invention, but although it seems to promise well none are at present in use in this country, nor has the author ever had opportunity for examining one.†

(7) THE SAND BLAST.

As already noted, the sand blast has been utilized to some extent in the work of lettering head-stones, and for producing delicate tracings on the Sioux Falls quartzite. That the process is still so little used is due, as I am informed, to the opposition of trades-unions, and not to any deficiency of adaptability in the process itself.

(8) HAND IMPLEMENTS.

Face hammer.—This is a heavy square-faced hammer, weighing from 15 to 25 pounds, and used for roughly shaping the blocks as they come from the quarry. It is sometimes made with both faces alike or again with one face flat and the other drawn out into a cutting edge (Fig. 10, Pl. V). The cavil differs only in having one face drawn out into a pyramidal point.

Ax or pean hammer.—A hammer made with two opposite cutting edges, as seen in Fig. 13, Pl. V. The edges are sometimes toothed roughly, when it is called the toothed ax.

Patent or bush hammer.—A hammer made of four, six, eight, ten, or more thin blades of steel, bolted together so as to form a single piece, the striking faces of which are deeply and sharply grooved. This hammer is said to have been invented by Mr. Joseph Richards, of Quincy, Mass., about 1831–'40. As first constructed the head was composed of a single piece, instead of several, as now (see Fig. 12, Pl. V). In some works this is called the bush hammer.

*Am. Arch. and Build. News, Nov. 7, 1885.

†This apparatus is figured and described in the Scientific American for March 6, 1886, p. 147.

Crandall.—This consists of a bar of malleable iron, about 2 feet in length, and slightly flattened at one end, through which is a slot three-eighths of an inch wide and 3 inches long. Through this slot are passed ten double-headed points of one-fourth inch square steel, 9 inches long, which are held in place by a key.*

The writer has never seen this instrument in use.

Hand hammer.—A smooth-faced hammer, with two striking faces, weighing from 2 to 5 pounds. It is used for hand-drilling, pointing, and chiseling in the harder kinds of rocks (see Fig. 16, Pl. v). The usual form has both faces alike.

Mallet.—This is a wooden implement, with a cylindrical head, used in place of the hammer in cutting the softer stones, as marbles and sandstones (Fig. 15, Pl. v).

Sledge or striking hammer.—A heavy, smooth-faced hammer, weighing from 10 to 25 pounds, used in striking the drills in hand-drilling or in driving large wedges for splitting stone, Fig. 11, Pl. v.

Pick.—An instrument resembling the ordinary pickax used in digging, but somewhat shorter and stouter. It is used on the softer varieties of stones for rough dressing or for channeling prior to wedging.

Pitching chisel.—A steel chisel, the cutting face of which is rectangular in outline and with sharp angles or corners. It is used for trimming down the edges to a straight line. See Fig. 7, Pl. v. The chipper (Fig. 6) is used for very similar purposes.

Chisel or drove.—This is a steel chisel, the cutting edge of which is drawn out wide and thin as shown in Fig. 2, Pl. v. It is used principally on the softer varieties of rock in producing the so-called "drove work."

Splitting chisel.—A steel chisel, made as shown in Fig. 8, Pl. v, and used for splitting and general cutting on hard stone like granite. Other forms of chisels, used only on soft stone and driven with the wooden mallet, are shown in Figs. 3 and 9.

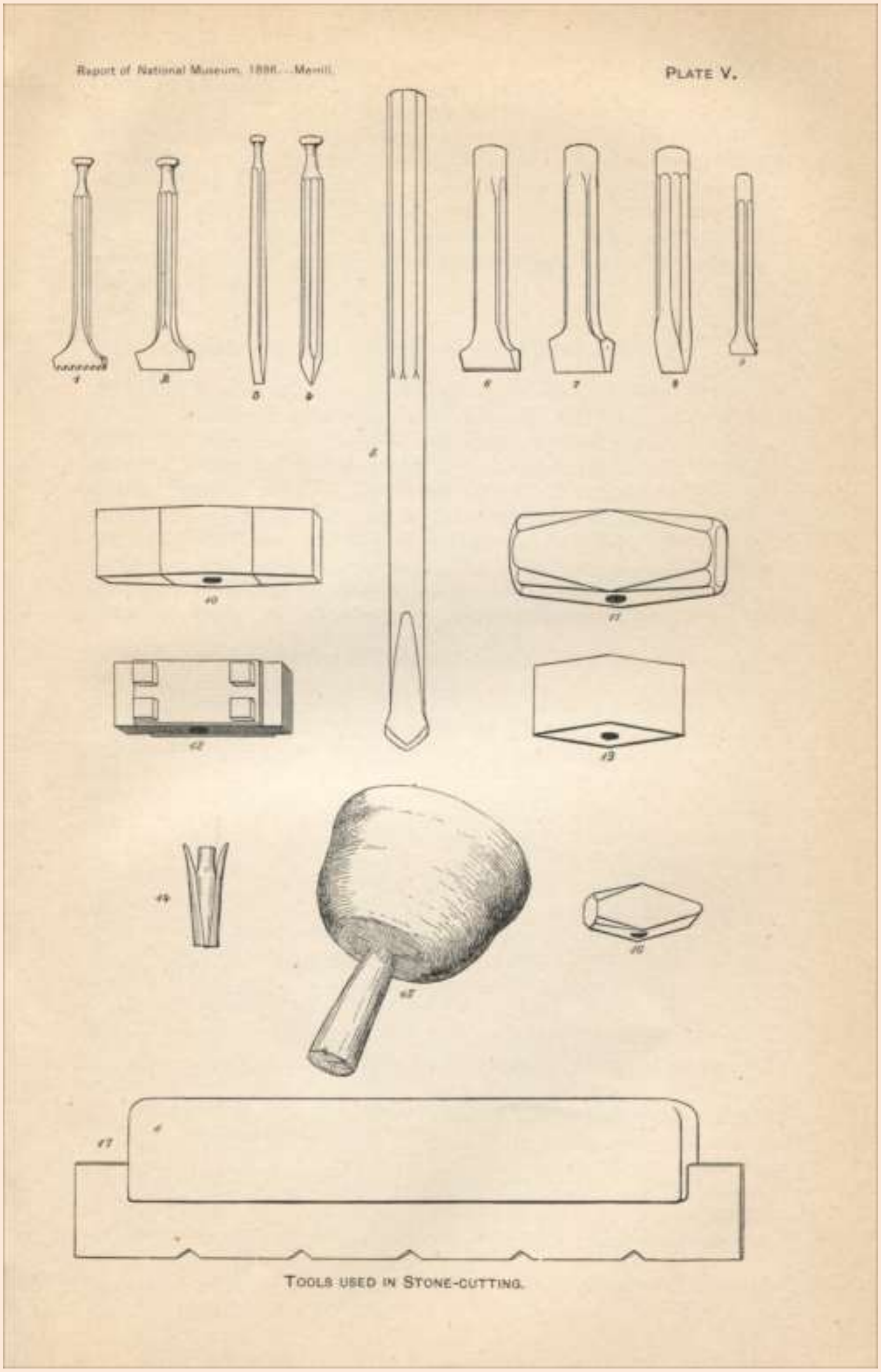
Tooth chisel.—A chisel like the drove chisel, but with the edge toothed like a saw (see Fig. 1, Pl. v), used only on soft stones like marble and sandstones.

Point.—A steel implement, with the cutting end in the form of a pyramidal point (see Fig. 4, Pl. v), used in the production of the finish known as point work and also in the smoothing down of rough surfaces prior to using the ax or some other tool for fine work. Points for use on hard stone and driven by the hammer have the upper end finished as shown in Figs. 6 and 7.

Wedge or plug.—Steel wedges vary greatly in size. Those used in the process of splitting, called plug and feather (Fig. 14, Pl. v), are but two or 3 inches in length, while those used in quarrying for splitting off large blocks are often a foot or more long and correspondingly large.

Hand drill.—A small steel drill from 8 to 15 inches in length, held in

* Man. and Builder, Feb. 1885, p. 38.



(diagram caption) Plate V. “Tools used in stone-cutting.” “Hand implements used in working stone”
Fig. 1. Tooth chisel. Fig. 2. Drove chisel. Fig. 3. Chisel for soft stone. Fig. 4. Point. Fig. 5. Hand-drill. Fig. 6. Chipper. Fig. 7. Pitching tool. Fig. 8. Chisel for granite. Fig. 9. Chisel for soft stone (marble, etc.). Fig. 10. Face or sledge hammer. Fig. 11. Striking hammer. Fig. 12. Bush or patent hammer. Fig. 13. Ax or pean hammer. Fig. 14. Plug and feathers. Fig. 15. Mallet. Fig. 16. Hand hamer. Fig. 17. Grub saw. (pp. 330)

one hand and driven by the hand-hammer (Fig. 5), used in making holes for "plug and feather" splitting and other light work.

Grub saw.—A saw for cutting stone by hand. It consists of a plate of soft iron from one-twentieth to one-tenth of an inch in thickness and from 6 inches to 4 feet in length; the blade is notched on the lower edge and fitted with a wooden back for convenience in handling and to prevent bending. Sand or emery is the cutting material, as with the steam saws (Fig. 17, Pl. V).

H.—THE WEATHERING OF BUILDING STONES.

The term weathering, as applied to stone, includes the series of physical changes induced by alternations of heat and cold, or by friction, as well as the more complex series of chemical changes, such as may be comprised under the heads of oxidation, deoxidation, hydration, and solution. Since a stone exposed in the walls of a building may be subjected to the influence of any one or the combined influences of several of these agencies, whereby serious consequences, as of discoloration or disintegration may result, it is important to consider, in more or less detail, their comparative energies under varying conditions and upon the various kinds of stone commonly employed for structural purposes.

(1) PHYSICAL AGENCIES.

Heat and cold.—It is safe to say that none of the conditions under which a stone is commonly placed are more trying than those presented by the ordinary changes of temperature in a climate like that of our Northern and Eastern States. Stones, as a rule, possess but a low conducting power and slight elasticity. They are aggregates of minerals, more or less closely cohering, each of which possesses degrees of expansion and contraction of its own. In the crystalline rocks these dissimilar elements are practically in actual contact; in the sandstones they are removed from one another by a slight space occupied wholly or in part by a ferruginous, calcareous or siliceous cement. As temperatures rise, each and every constituent expands more or less, crowding with resistless force against its neighbor; as the temperatures decrease a corresponding contraction takes place. Since with us the temperatures are ever changing, and within a space of even twenty-four hours may vary as much as forty degrees, so within the mass of the stone there is continual movement among its particles. Slight as these movements may be they can but be conducive of one result, a slow and gradual weakening and disintegration.

This constant expansion and contraction is often sufficient in amount to be appreciable in stone structures of considerable size. Thus Bunker Hill Monument, a hollow granite obelisk, 221 feet high by 30 feet square at the base, swings from side to side with the progress of the sun during

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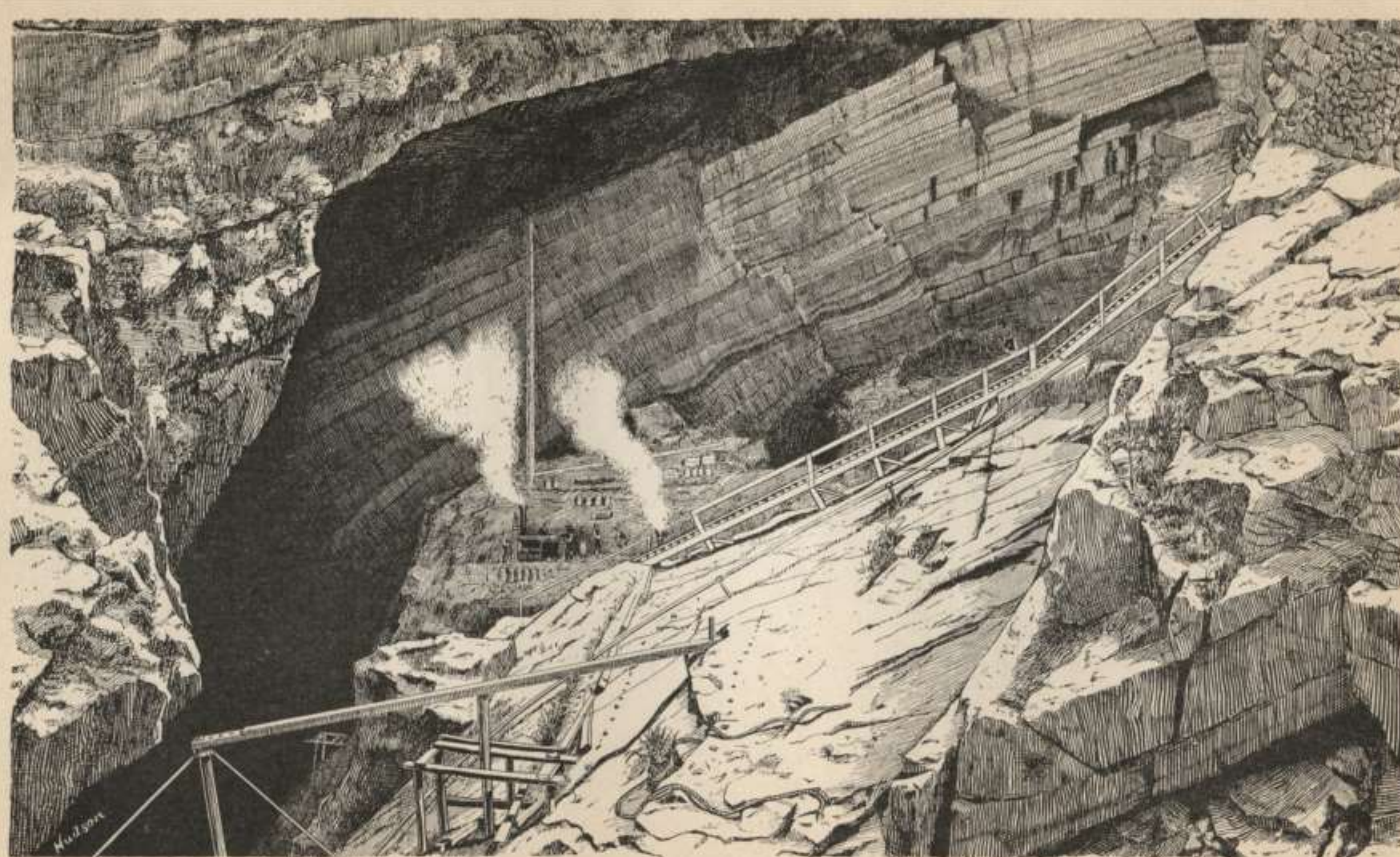
This concludes the section of the book entitled, "Methods of Quarrying and Dressing."

On the following pages, I have included the rest of the images presented in the book along with the "Table of Contents" and the "List of Illustrations."

If you'd like to read this book, *The Collection of Building and Ornamental Stones in the U.S. National Museum: A Hand-book and Catalogue*, you will find it on Google Books at this link: https://books.google.com/books?id=bdsOAAAAYAAJ&dq=%22collection+of+building+and+ornamental+stones+in+the+us+national+museum%22&source=gbs_navlinks_s

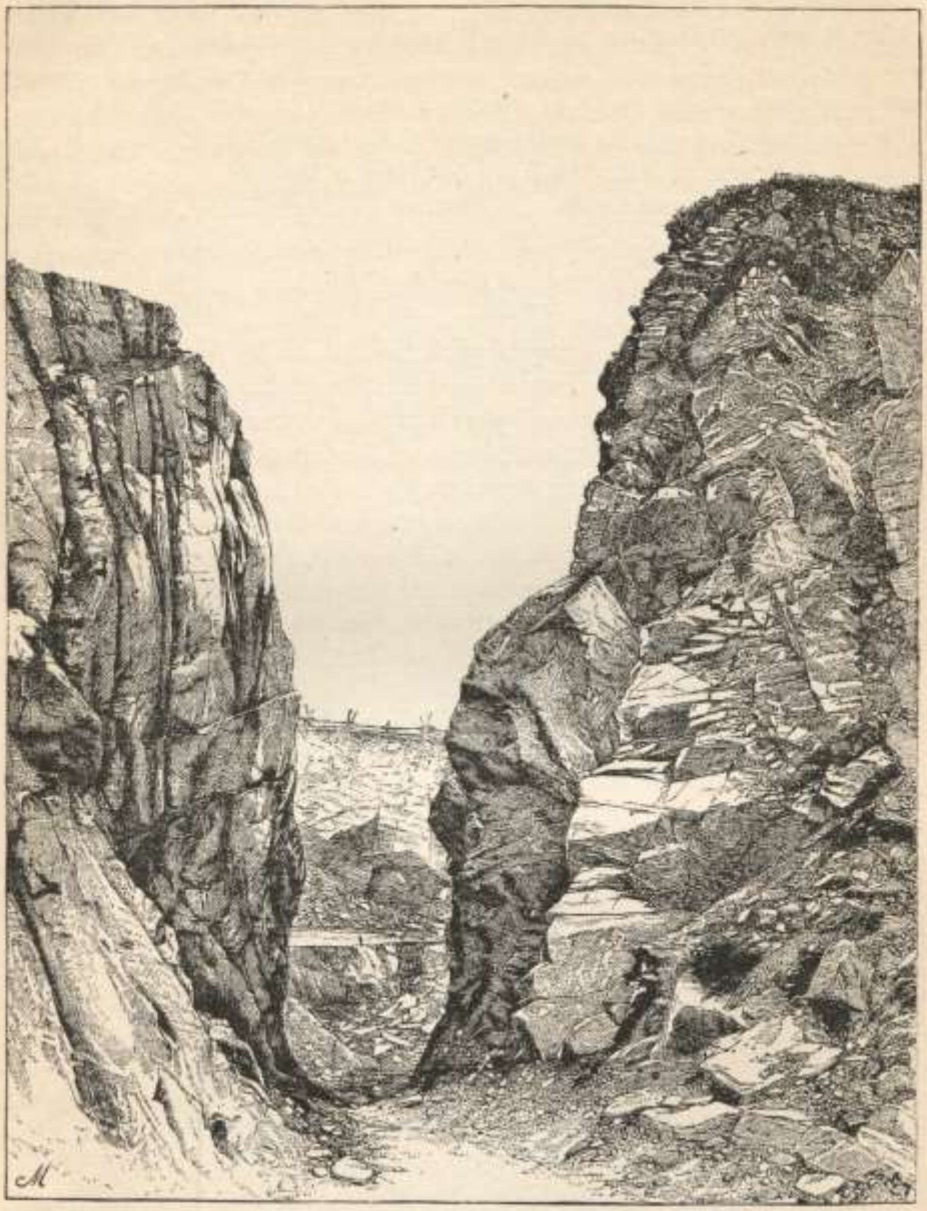
Peggy B. Perazzo, Stone Quarries and Beyond



INTERIOR VIEW OF MARBLE QUARRY, WEST RUTLAND, VERMONT. (See p. 387.)

Drawn from a photograph.

(photo caption) Plate I. “Interior view of marble quarry, West Rutland, Vermont. (See. P. 387.) Drawn from a photograph.” (pp. 277)



SERPENTINE QUARRY, CHESTER, PENNSYLVANIA.

(photo caption) Plate VI. “Serpentine Quarry, Chester, Pennvylania” (pp. 363)

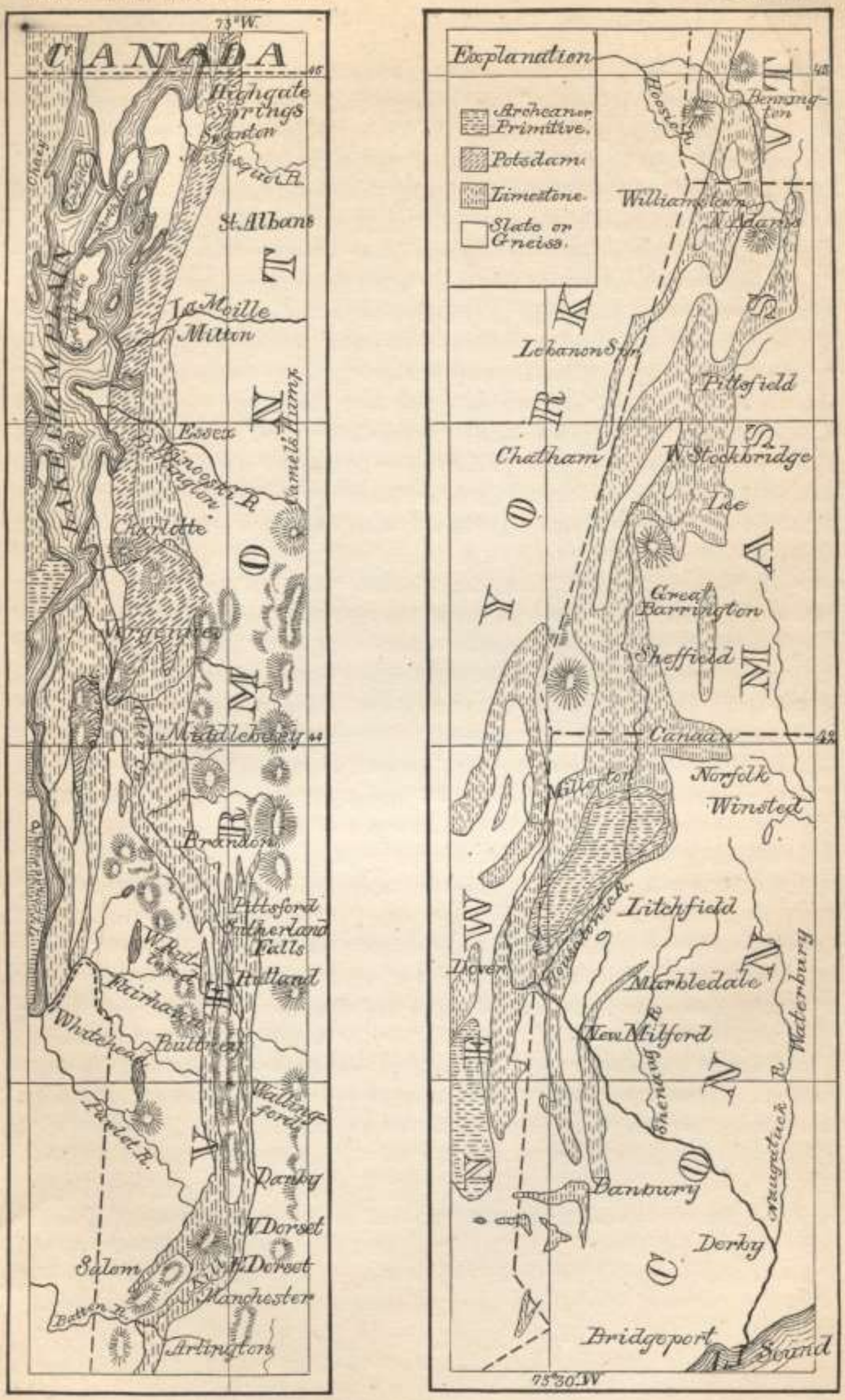
LIMESTONES COMPOSED LARGELY OF ORGANIC REMAINS.

Fossiliferous limestones.—Many limestones are made up wholly or in part of the fossil remains of marine animals, as is shown in the accompanying figure, which is drawn from a magnified section of a limestone of the Cincinnati group from near Hamilton, Ohio.

In some cases the remains are retained nearly perfect; again the entire fossil may have been replaced by crystalline calcite. In other instances stones are found which are made up only of casts of shells, the original shell material having decayed and disappeared, as in the Eocene limestone from North Carolina. Many of the most beautiful marbles belong to the group of fossil limestones, as, for instance, the red and white variegated Tennessee marbles. *Crinoidal limestones* are made up of fossil crinoidal fragments.

Shell limestones or *shell sand-rocks* as they are called by some authorities, are made up of shells usually much broken, though sometimes almost entire. The well-known *coquina* from Saint Augustine, Fla., is a good illustration of this variety. *Coral rock* is of the same nature, excepting that it is composed of fragments of corals. *Chalk* is a fine white limestone composed mainly of the minute shells of foraminifera.

(image caption) "Magnified section of fossiliferous limestone (25274), Hamilton, Ohio" (pp. 373)



MARBLE REGION OF WESTERN NEW ENGLAND.

(map caption) Plate VII. "Marble regions of western New England." (pp. 386)

Several outcrops of marble occur in Middlebury, and which have been worked for many years past; but in consequence of the thinness of the beds, their badly-pointed structure, and the interstratification of a magnesian state that produces numerous "rising seams," it is quite difficult to obtain perfectly sound blocks of large size.*

The quarries in Dorset are situated mostly upon the sides of Mount Eolus, or Dorset Mountain, as it is also called, a section of which (after Hitchcock) is here given.

(image caption) "Section of Mount Eolus (aka Dorset Mountain) after Hitchcock." (pp. 389)

GRANITE QUARRY, HALLOWELL, MAINE.

Drawn from a photograph.

(photo caption) Plate VIII. “Granite Quarry, Hallowell, Maine. Drawn from a photograph.” (pp. 417)

QUARRIES OF TRIASSIC SANDSTONE, PORTLAND, CONNECTICUT.
Drawn from a photograph.

(photo caption) Plate IX. “Quarries of Triassic Sandstone, Portland, Connecticut.” (pp. 447)

NOTE: The entire book, *The Collection of Building and Ornamental Stones in the U.S. National Museum: A Hand-book and Catalogue*, is available on Google Books at this link: https://books.google.com/books?id=bdsOAAAAYAAJ&dq=%22collection+of+building+and+ornamental+stones+in+the+us+national+museum%22&source=gbs_navlinks_s

Below is a transciption of the "Table of Contents" for *The Collection of Building and Ornamental Stones in the U.S. National Museum: A Hand-book and Catalogue*, available at the link above. (Also note that the sections in blue below are presented in the document above.) Peggy B. Perazzo, Stone Quarries and Beyond.

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Figures in the Text.

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* The numbers are those of the thin sections in the Museum collections from which the figures were drawn.