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New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 143

GYPSUM DEPOSITS OF NEW YORK

BY

D. H. NEWLAND

AND

HENRY LEIGHTON

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1910

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New York State Education Department
Science Division, March 8, 1910

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SIR: Among the more important mineral resources of this State is gypsum. A large capital is invested in its development and its annual production is of growing moment. The actual development however, of this industry is far within the possibilities and it has, therefore, seemed wise to summarize the statistics of the gypsum industry and to indicate the lines along which its development may be profitably prosecuted.

Accordingly I submit to you herewith a treatise on the *Gypsum Deposits of New York,* which has been prepared by D. H. Newland, Assistant State Geologist, assisted by Henry Leighton, and recommend this for publication as a bulletin of the State Museum.

Very respectfully
JOHN M. CLARKE
Director

State of New York
Education Department
COMMISSIONER'S ROOM

Approved for publication this 9th day of March 1910

A. S. Draper

Commissioner of Education

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GYPSUM DEPOSITS OF NEW YORK

BY

D. H. NEWLAND

AND

HENRY LEIGHTON

INTRODUCTION

Gypsum has been mined in New York for the last century. The present development of the industry dates back, however, scarcely more than a decade. During this interval the production has grown to many times its former proportions, and from a relatively insignificant position the State has advanced into prominence with regard to both the mining and manufacture of gypsum. The basis of this progress is supplied by great natural resources combined with unexcelled market advantages.

The field investigations in connection with this report have extended over the whole area within which workable deposits are known to exist. Some of the occurrences visited have not been noted hitherto; the recent extensions of productive operations, moreover, have permitted a more detailed study of the deposits and their distribution than was possible a few years ago.

Acknowledgment is due the mining companies and others for many courtesies received by the writers. The privilege of inspecting the workings and plants was freely granted, and records of

exploration and other information were furnished, without which the report could not have been prepared.

The field notes have reference mainly to conditions in the summer of 1909. They were made by Mr Leighton.

HISTORY OF THE GYPSUM INDUSTRY IN NEW YORK

Statistics of production

The discovery of the gypsum deposits must have been practically coincident with the first permanent settlement of central and western New York, which followed close upon the termination of the War of the Revolution. The earliest mention that is still a matter of record relates to an occurrence on lot 90, Camillus township, Onondaga co., said to have been discovered by W. Lyndsay in 1792. In 1808 a stock company was organized to exploit this deposit for land plaster. The beds in Sullivan township, Madison co. were worked during the War of 1812 and the output was shipped to the Hudson river and as far away as Philadelphia. It appears that gypsum was quarried at Union Springs as early as 1811 and by 1822 several thousand tons are reported to have been shipped each year from that place to Pennsylvania. The sole use of the product was as agricultural plaster.

At the time of the first geological survey (1836–41) the quarrying of gypsum was actively pursued along the Salina belt from Madison to Genesee county. The reports of that survey mention operative quarries in the towns of Wheatland, Leroy, Seneca Falls, Union Springs, Phelps, Manlius, Camillus and Sullivan; and their output was then nearly as large probably as at any time in the succeeding 50 years.

Though the deposits were under active exploitation long before those of Michigan, Ohio and the Middle Western States had become productive, they have played little part in the development of the trade in calcined plasters or their technology. It was only after this branch of the industry had become firmly established in other parts of the country and American practice had become fairly perfected that the local deposits began to receive attention as a source of material for calcined plaster. The first production of plaster of paris was reported in 1892 and amounted to 75 tons. With the successful issue of the early undertakings the natural advantages of the State for manufacture and marketing have contributed a powerful impetus to this branch of the business, which is now the most important of all.

The production of gypsum and gypsum plasters, so far as statistics are available, is shown in the accompanying table. The figures for the years 1889 to 1903 inclusive are taken from the annual volumes of *The Mineral Resources*, while those subsequent to the latter year are abstracted from the bulletins of the New York State Museum. The total for 1843 is an estimate based on information given in the early reports of Hall and Vanuxem.

While the production for the years previous to 1889 can not be stated definitely, it is estimated that the aggregate output since the beginning of the industry in the State has been between 4,000,000 and 5,000,000 tons. A total approximating the truth may be derived by using the known figures for the period 1889–1908 and by

Production of gpysum and gypsum products in New York State

YEAR	TOTAL OUTPUT		SOLD AS LUMP GYPSUM		SOLD AS LAND PLASTER		SOLD AS CALCINED PLASTER	
	Short tons	*a*Value	Short tons	Value	Short tons	Value	Short tons	Value
1843	33 000	....	....	....	....	....	....	....
1889	52 608	$79 476	21 537	$21 642	31 071	$57 834	....	....
1890	32 903	73 093	3 072	2 858	29 831	70 235	....	....
1891	30 135	58 571	6 730	5 058	23 405	53 513	....	....
1892	32 394	61 100	7 887	5 661	24 407	55 039	75	$400
1893	36 126	65 392	10 979	8 198	22 802	49 221	1 813	7 973
1894	31 798	60 262	10 554	7 885	16 804	36 993	3 335	15 384
1895	33 587	59 321	12 182	6 492	16 765	36 664	3 480	16 165
1896	23 325	32 812	10 256	6 177	13 069	26 635	....	....
1897	33 440	78 684	5 394	3 516	15 826	34 368	9 200	40 800
1898	31 655	81 965	2 243	1 353	17 112	40 066	9 275	40 550
1899	52 149	105 533	1 900	1 677	13 924	25 290	26 443	78 566
1900	58 890	150 588	1 402	1 122	21 444	47 292	27 979	102 174
1901	119 565	241 669	11 678	10 908	33 591	61 093	55 273	169 668
1902	110 364	259 170	9 153	15 184	25 981	43 750	60 184	200 236
1903	137 886	462 383	9 304	15 439	37 850	77 392	75 613	369 552
1904	151 455	424 975	9 768	14 652	33 712	62 438	88 255	347 885
1905	191 860	551 193	27 980	34 095	19 815	39 014	130 268	478 084
1906	262 486	699 455	34 626	58 076	20 656	46 094	163 451	595 285
1907	323 323	751 556	91 060	179 432	15 441	38 859	145 684	533 265
1908	318 046	760 759	95 146	171 747	5 712	14 255	160 930	574 757

a Value is based on the marketed products.

estimating the previous production according to reasonable averages. The estimate for the year 1843 and the reported outputs for several years after 1889 show that until late years there was a fairly steady market for the gypsum as land plaster material. It is probable that the production did not average over 10,000 tons a year previous to the opening of the Erie canal, for until then the facilities for shipment were limited. From the year of its opening (1826) until 1889 the average was probably about 35,000 tons. For the period 1810–88 the production may be estimated accordingly at

2,400,000 tons, while the actual output in the period 1889–1908 has been 2,063,995 tons. The combined total in round numbers is 4,464,000 tons.

The production and imports of gypsum for the United States during the period 1890–1908 are given in the table herewith.

A comparison of the statistics in the two tables shows that New York has held its place in the general industry of the country which has increased its output over 800 per cent since 1890. The local output in 1908 was approximately 18 per cent of that recorded for the United States in the same year. There is little doubt that the use of gypsum in this country will continue to expand during the immediate future, though most likely at a slower rate than that exhibited in the last few years.

Production and imports of gypsum for the United States

YEAR	PRODUCTION *a*		IMPORTS *b*	
	Short tons	Value	Short tons	Value
1890	182 995	$574 523	178 857	$229 859
1891	208 126	628 051	119 817	226 319
1892	256 259	695 492	187 936	308 011
1893	253 615	696 615	167 663	211 924
1894	239 312	761 719	164 527	196 060
1895	265 503	797 447	195 844	237 231
1896	224 254	573 344	183 561	215 526
1897	288 982	755 864	165 865	195 714
1898	291 638	755 280	169 039	199 865
1899	486 235	1 287 080	199 844	239 853
1900	594 462	1 627 203	212 990	249 057
1901	633 791	1 506 641	238 310	258 067
1902	816 478	2 089 341	309 014	208 167
1903	1 041 704	3 792 943	269 484	324 163
1904	940 917	2 748 325	297 516	332 582
1905	1 043 202	3 029 227	403 119	423 204
1906	1 540 585	3 837 975	440 586	487 546
1907	1 751 748	4 942 264	445 890	499 030
1908	1 721 829	4 138 560	302 047	327 627

a The figures of production are based on the crude gypsum, while the values are for the marketable products.
b Includes crude and calcined gypsum, but not manufactured plaster of paris.

COMPOSITION AND CHARACTERS OF GYPSUM

Chemical and mineralogic characters. Gypsum is a hydrated calcium sulfate with the formula $CaSO_4 . 2H_2O$. Its ideal composition is represented by the following percentages by weight: lime

(CaO) 32.5; sulfuric acid anhydrid (SO_3) 46.6; water (H_2O) 20.9. The crystallized variety of gypsum may show a close approach to these percentages, but the ordinary rock and earthy gypsum employed in the industries contains a variable proportion of foreign matter which amounts generally to several per cent of the whole mass.

The crystals of gypsum belong to the monoclinic system and are usually formed by a simple combination of faces. According to the relative development of the latter, they may be tabular or flattened, prismatic, or elongated into acicular individuals. They are sometimes twinned so as to yield arrowhead forms. The common types of crystals are represented by the accompanying figures. The

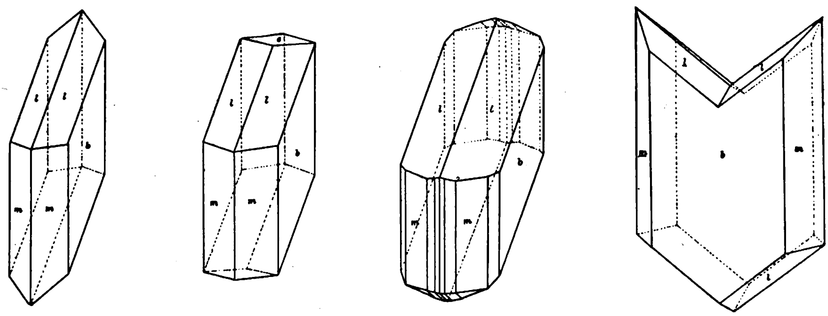

FIG. 1 Crystals of gypsum. At the right a twinned form. (H. P. Whitlock, del.)

crystals are characterized by an easy cleavage parallel to the principal plane (face *b* in figures). Thin flakes so produced are flexible, but not elastic like mica to which they bear some resemblance. If bent sharply they break in a diagonal direction with the production of fibers.

The cleavage plates of gypsum can be distinguished from foliated talc by their greater hardness, which is inferior, however, to that of anhydrite or calcite. Gypsum occupies the second place in the Mohs scale of hardness, according to which certain minerals are selected as standard and numbered in order of increasing hardness from 1 to 10. In this scale talc is 1 and calcite 3. The specific gravity of gypsum when pure is 2.3.

Gypsum is only slightly soluble in pure water (one part dissolving in 415 parts of water at 32°F. and in 368 parts of water at 100.4°F.) but its solubility is considerably increased in the presence of salts of the alkalis, such as sodium and potassium chlorids. Concentrated acids are generally poor solvents, sulfuric having no effect; dilute hydrochloric acid is the common solvent for laboratory purposes.

Gypsum parts readily with its water of crystallization. By partial dehydration it is converted into the half hydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$), which is plaster of paris. In ordinary practice of plaster manufacture where the dehydration is performed in closed receptacles, the temperature is not allowed to exceed about 400°F. If the temperature is maintained above that point for any length of time, complete dehydration results and the product then has the composition of the mineral anhydrite ($CaSO_4$). This mineral is insoluble and useless for plaster, but the artificial product, if certain conditions are observed in burning, is capable of uniting with water and enters into special grades of plaster. The dehydration of gypsum can be accomplished at temperatures much lower than those in manufacturing practice under the influence of hygroscopic materials like concentrated acids or currents of dry air.

Varieties of gypsum. Crystallized gypsum is commonly known as selenite. It is colorless and transparent in pure condition. It finds limited application in optics and has been used in the past as a substitute for glass for some purposes.

Satin spar is the name given to the fibrous variety, which is really an aggregate of parallel or radiating acicular crystals. It ranges from white to colorless, has a pearly luster and is often found in veins which intersect the larger bodies of massive gypsum and its inclosing rocks.

Rock or massive gypsum is the usual gypsum of commerce. It is generally made up of an intricate intergrowth of small crystals. The white or delicately tinted variety of even texture is the alabaster used for sculptures and objects of art. More often the rock gypsum has a dark color such as gray, drab, brown or nearly black, according to the character and amount of impurities present. These include organic matter, lime and magnesia carbonates, clay, iron oxids and silica. The actual proportion of gypsum in rock from different localities ranges within wide limits, from as low as 50 or 60 per cent up to 97 or 98 per cent in exceptionally pure types.

Still another variety of gypsum, known as gypsite or gypsum earth, is common in some parts. It is an incoherent surface deposit consisting of small gypsum crystals mixed with quartz, lime carbonate and organic matter. It occurs in the Middle Western States, where it is used to some extent for plaster manufacture, and in Europe.

Anhydrite. This mineral is mentioned here on account of its close relation to gypsum. It differs chemically in the absence of any water of crystallization and like overburned plaster lacks the property of setting when mixed with water. If exposed to weathering influences for a long time, however, it will absorb moisture and change to gypsum, a process that has probably taken place frequently in nature. The change involves an increase of 60 per cent in volume. The reverse reaction — the change of gypsum to anhydrite — may also occur under the influence of heat and pressure superinduced for instance by the burial of gypsum beds beneath a great thickness of overlying strata.

Anhydrite crystallizes in the orthorhombic system and cleaves in three directions normal to each other. Cleavage fragments are thus rectangular. Its hardness is from 3 to 3.5, noticeably greater than that of gypsum.

Beds of anhydrite occur frequently in association with gypsum, as might be expected from their similar origin. From a solution of calcium sulfate which is saturated with sodium chlorid either anhydrite or gypsum may be deposited according to the temperature.[1]

THE USES OF GYPSUM

Crude and ground gypsum

Ornamental and building stone. Alabaster, the semitranslucent white gypsum, which comes mostly from England, Italy and Spain, finds a demand for ornamental uses, less in this country than abroad. Very little gypsum is now used for ornamental or building purposes in the United States. According to the Iowa Geological Survey,[2] the gypsum around Fort Dodge was quite extensively quarried at one time for various kinds of structural work and for sidewalks. The stone has a tendency, it is said, to bleach and crack on the surface when exposed to the sun though it does not actually disintegrate to any harmful extent.

Agricultural plaster. The most important use of raw gypsum is as a soil amendment, for which purpose the rock, pure or impure as it may be, is simply crushed and ground to a powder. The employment of land plaster is of very ancient origin, going back at least to Roman times, and its beneficial influence has been advocated repeatedly by prominent writers on agriculture. But of late

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[1] Van't Hoff, J. H. & Weigert, F. Sitzungsber. Akad. Berlin. 1901. p. 1140. The deposition of anhydrite from sea water takes place at a temperature of 25° C. or 70° F.

[2] An. Rep't. 1895. v. 3, pt 2, p. 293.

there is manifest a decided decrease in the land plaster industry, which seems to indicate a growing uncertainty among agriculturists of the positive value of gypsum as a general fertilizer. The enormous development of the trade in calcined plasters, however, may have had something to do with bringing about this decline by diverting the attention of the producers to a broader, if not more remunerative, outlet.

The literature on the subject of land plaster is so voluminous that it can hardly be summarized profitably in a few pages. In fact the real action of gypsum on soils appears even now to be little understood. Storer,[1] one of the more recent writers, ascribes the effects to a combination of chemical and mechanical processes. According to him ground gypsum acts mechanically in flocculating loose soils and disintegrating stiff clay soils. In a chemical way it releases part of its oxygen to combine with nitrogenous and carbonaceous substances in the soil and also decomposes silicates like feldspar, from which it sets free potassium sulfate available for assimilation by the plant roots. The last reaction is thought to be the more important. Aside from the possible benefit of the contained lime, gypsum appears thus to add no direct fertilizing element to land.

Gypsum in portland cement manufacture. According to E. C. Eckel[2] gypsum is universally employed as a retarder in portland cement manufactured by the rotary kiln process, such cement being characterized by a high lime content and rapid set. From 2 to 3 per cent of gypsum is added usually to the clinker before grinding, in order to insure thorough incorporation. Besides its function in retarding the set of portland cement, the gypsum seems to exert a strengthening influence, at least in the early stages of setting. The addition is more often made in the form of raw gypsum than as calcined plaster, though of course the latter is more effective weight for weight. The lower value of raw gypsum, however, more than counterbalances the increased quantity necessary, as compared with calcined plaster.

Miscellaneous uses. Raw white gypsum is ground and made into crayons which are said to be superior in some respects to chalk crayons. The American Crayon Co. of Sandusky, O. manufactures such crayons along with a variety of similar materials.

Finely ground white gypsum is sold under the name of terra alba for various purposes. It is a common basis of cheap white

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[1] Chemistry of Agriculture. 1887. 1:206.

[2] Cements, Limes and Plasters. 1905. p. 534 et seq.

paints and has been found in food stuffs. Its more legitimate uses are in the preparation of insecticides and pharmaceutical supplies.

A peculiar use of gypsum is found in the wine-growing districts of Spain and Greece, where it is said to be added to red wines to hasten their ripening before bottling and to give them a more fiery color.[1] The process is called "plastering." The gypsum unites with the tartar or argol to form tartrate of lime which precipitates and clears the wine, while the soluble potassium sulfate that is formed reacts upon the phosphates releasing phosphoric acid which enhances the color intensity.

The presence of small amounts of gypsum in waters used for brewing is said to be advantageous.

Various processes have been devised for hardening blocks of crude gypsum so as to imitate marble and other materials. The blocks after being dehydrated by heat so as to render them porous are treated with chemicals such as ammonia, ammonium sulfate, copperas etc. A cheap substitute for meerschaum is made in this way with the use of stearic acid or paraffin.[2]

Uses of calcined gypsum

Molding and casting. The ordinary calcined gypsum, or plaster of paris, has a great number of uses. A very familiar one is as a material for making casts and molds. The value in casting objects is due largely to its property of swelling slightly as it sets, thus filling out the mold perfectly. The pottery industry consumes large quantities of plaster of paris annually in the form of molds for casting china and porcelain wares; the porous nature of such molds is an important advantage, permitting the water of the clay to escape.

The manufacture of plate glass likewise calls for large quantities of plaster. The glass sheets are imbedded in the plaster during the process of grinding and polishing. It is estimated that over 40,000 tons are consumed each year in the United States by the glass industry.

Building and construction. Stucco and staff are but other names for plaster of paris; the former in its application to interior decorations and as a white coating for wall surfaces and the latter to building construction and exterior decorations.

A related use of plaster of paris, first introduced in Germany but of rapidly growing importance in this country, is in the manufac-

[1] Scientific American Sup. 1907. 63:26033.
[2] Mich. Geol. Sur. An. Rep't. 1904. 9:206.

ture of plaster boards or blocks for the construction of walls and floors. The boards or sheets are built up in alternating layers of plaster and some supporting material such as paper, excelsior, fibrous talc, etc. They are nailed directly to the studdings and joists of buildings and are then covered with a fresh coat of plaster. Further details of their manufacture are given on page 45.

The employment of gypsum wall plasters in the place of lime plasters has developed rapidly of late years and now represents the most important single application of gypsum, at least in this country. Wall plasters consist of plaster of paris and some fiber-like hair or wood with the addition of a retarder. Their advantages over lime plasters are many, including more rapid set, greater spreading power, less shrinkage on drying, and ability to unite with coloring agents so as to produce any desired tint. On the other hand they are somewhat more expensive than lime and inferior to it in deadening sounds. A special preparation of plaster, glue and pigments is sold under the name of alabastine for the tinting of walls.

The manufacture of anhydrous plasters, of which Keene's cement and flooring plasters ("Estrichgips" of the Germans) are examples, is not carried on to any extent in this country. They are characterized by slow setting and superior hardness. Keene's cement, which is representative of a number of materials sold under special brands for hard finishing of walls, is made by calcining gypsum at red heat, after which the dehydrated plaster is immersed in a solution of alum and again ignited at high temperature. "Estrich" gypsum is the soluble form of artificial anhydrite prepared by calcination of gypsum at a temperature of about 500° C. for a period of not more than four hours. Further details concerning these plasters are given in another chapter.

Gypsum mortar can be made by using plaster ground to about the size of building sand and mixing with five to eight parts of water.[1] Tests prepared with German plaster show a crushing strength which for a number of different mixtures averages 11.1 kilograms per square centimeter, higher than the results obtained with lime mortar and exceeded only by those for cement mortar.

In mixing plaster for wall plaster or mortar it is pointed out that the plaster should be added to the water, the lumps quickly broken and the mass stirred as little as possible.[2] The plaster

[1] Scientific American Sup. 1907. 64:18.
[2] Scientific American Sup. 1907. 63:26207.

attains its greatest hardness with small amounts of water, 33 per cent being sufficient, of which 22 per cent remains in the hardened plaster. Plaster made with a large excess of water, as much as 200 per cent being often used, must necessarily be porous and less coherent as the crystals are not so tightly interlaced. It is also more absorbent of moisture and more liable to disintegration under change of temperature.

Other uses. Plaster of paris is also used in various printing processes.[1] Gypstereotyping is the process for the production from movable types of a solid printing plate of type metal. The printing form to be cast is secured in a metal frame or "chase," the type metal oiled and the space above it filled with plaster paste struck off even with the upper edge of the frame. After allowing it to set 15 minutes there remains a plaster mold into which the molten type metal can be poured.

In galvanoplastic work plaster molds saturated with stearin or wax and coated with graphite are used, and in rubber stamp making the rubber substance is pressed into a plaster mold and vulcanized.

GENERAL GEOLOGY

Occurrence of gypsum in New York State

The workable gypsum deposits are restricted to the Salina stage of the Upper Siluric or Ontaric system. The Salina includes also the rock salt beds of the State and is the equivalent practically of the Onondaga salt group as described in the early reports by Hall and Vanuxem. According to present nomenclature it is the basal subdivision of the Cayugan group, the uppermost of the three groups which together constitute the Upper Siluric succession in this region.

The Salina strata occupy two main areas within the State. The larger area contains the original sections which have become the types for comparison, and is the more important from an economic standpoint. It is represented by a belt that extends with uninterrupted continuity from Albany county on the east through central and western New York to the Niagara river and thence into the Province of Ontario. Its approximate limits are shown on the sketch map [pl. 1].

The belt terminates within or near the town of Knox, Albany co. by the thinning out of the strata, which in this part consist of only a few feet of shale. From Albany county westward the Sa-

[1] Scientific American Sup. 1907. 63:26033.

lina beds follow the range of hills that borders the Mohawk valley on the south, their outcrop being at first well up the slopes and at a distance of about 15 miles from the river itself. They parallel the Mohawk as far as Oneida county, where, owing to increased thickness of the members and the flatter topography, they begin to spread out so as to occupy a surface from 1 to 3 miles wide. Their course thus far is quite sinuous due to the numerous deep north and south valleys tributary to the Mohawk which produce long upstream deflections. Beyond Oneida county their outcrop rapidly broadens; it is about 12 miles wide at the west end of Oneida lake and fully 20 miles on the line of Cayuga lake where it attains the maximum width for the State. The outcrop in western New York is more regular, maintaining an average of from 7 to 10 miles and running almost in a straight line parallel to the shore of Lake Ontario.

The Salina of this area is mainly a shale formation. The other elements are gypsum which occurs in the upper shale beds; salt near the middle of the section; and an impure limestone which forms a thin capping to the shale in the central and western parts and discontinuous bands within the shale itself. The great mass of shale, except for a few feet at the base, is devoid of fossils; therefore, in subdividing the Salina, use is made of these elements which have a fairly constant horizon. The detailed stratigraphy of this belt will be discussed later under a separate head.

The second area within which the Salina beds appear is in southeastern New York and here they show a quite different development. They are found in two principal belts, one of which begins in Ulster county near the Hudson and follows the Shawangunk mountain uplift in a southwesterly direction across the State line into New Jersey and the other is in Orange county beginning near Cornwall and running parallel to the first along the Skunnemunk ridge. It may be remarked that the true sequence of the strata in this region has only recently been established. Our knowledge of the wide development which the Salina here shows has come largely through the work of C. A. Hartnagel[1] whose conclusions derived from stratigraphic evidences have been fully confirmed by study of newly discovered fossil-bearing sections. The main members of the Salina are conglomerate at the base, shale and sand-

[1] Notes on the Siluric or Ontaric Section of Eastern New York. N. Y. State Pal. An. Rep't. 1903. p. 342 et seq. Also Upper Siluric and Lower Devonic Sections of the Skunnemunk Mountain Region. N. Y. State Mus. Bul. 107. 1907. p. 39 et seq.


MAP OF NEW YORK
SHOWING THE
DISTRIBUTION OF SALINA STRATA
BY
D. H. NEWLAND
Scale of Miles
LAKE ONTARIO
ONTARIO
LAKE ERIE
VERMONT
MASS.
CONN.
NEW JERSEY
LONG ISLAND SOUND
ATLANTIC OCEAN
ADIRONDACK MOUNTAINS
CATSKILL MOUNTAINS
ROCHESTER
BUFFALO
Syracuse
Albany
Kingston
Binghamton
Elmira
Poughkeepsie
Watertown
Oswego

stone, with some limestone at the top. The conglomerate is the well known Shawangunk grit which was formerly regarded as the equivalent of the Oneida conglomerate of central New York. The shales (High Falls) are a minor feature of the northern sections of the area, though they gain in strength progressively toward the south and on the New Jersey border have a thickness of several hundreds of feet, so as to predominate over the other members. They are of reddish color, pyritic, and in places graduate upward into sandstone. With their exception, the strata of the region present a coarser phase of sedimentation than that inherent to the Salina of the type localities.

The variation in the character and sequence of the strata composing the two areas is explainable by their accumulation in separate basins which received land drainage from different parts of the Siluric continent. This condition is indicated by the diagram [fig. 2] which shows the relations of the Upper Siluric formations of central New York. The Salina beds of this region were deposited in the interior or Mississippian sea which received the drainage from the continental lands to the north. To the east the sea was shut off from the Atlantic basin by a barrier of Lower Siluric and earlier formations which extended along the Appalachian protaxis and which had been augmented just previous to the opening of Upper Siluric time by the Taconic uplift. During the whole of the Salina age there seems to have been no free communication between the two basins, so that the sediments formed on the Atlantic side of the barrier must have come from the adjacent Appalachian highland. The detritus was brought down to the sea probably by short swift streams; whereas in the interior basin there was a much more gradual slope from the Adirondack and Canadian highlands owing to the existence of a wide coastal plain that had been in process of construction from the early Paleozoic times, and the slower moving tributary rivers were able to transport only the finer materials to their outlets.

From these considerations, it is apparent that the geographic features which were conducive to the deposition of salt and gypsum in the first region may have been wholly wanting in the other. The available evidences are, however, scarcely sufficient to warrant the assumption that these minerals do not occur in southeastern New York. The Salina of this region has been so recently recognized that little attention has been given to its exploration and the descriptions are based wholly on surface exposures. It is highly improbable that any valuable deposits occur in the northern sections, where conglomerates and sandstones are the prevailing strata. If present at all, they will be found in the extreme southern part near the New Jersey border, in association with the shales which, as before stated, are here much thicker and even become the predominant member of the series.

In so far as the climatic factor may be concerned in the formation of the salt and gypsum, conditions must have been very similar in the two regions. The long continued concentration of the Salina seas by evaporation was widespread throughout the northeastern section of the interior basin as shown by the occurrence of one or both minerals in the Salina of Ontario, Ohio and Michigan, and there is no reason for believing that the climate was essentially less arid or otherwise different in the nearby part of the Atlantic basin, especially as the intervening barrier had undergone steady submergence during the epoch and was to disappear wholly before the close of Siluric time.

The colors of the strata in both regions are very similar. Deep red shales which some geologists regard as indicative of arid climatic conditions are a prominent feature of the sections in southern Orange county as well as of the Lower Salina of central New York.

Salina stratigraphy

The Salina stage as developed in central New York is divisible into five parts. The different members are seldom sharply delimited by physical features and owing to the scarcity of fossils throughout the beds their demarcation on the map is only possible in a general way. They are usually connected by zones of gradation; or sometimes the transition from one member to another is marked by a sequence of alternating layers. The latter is the condition, for example, of the passage from the waterlime that caps the formation, to the underlying shale.

The full series is found only in the part of the belt that lies west of Madison county. To the east they overlap upon the lower formations and gradually thin out to disappearance. The general relations of the members are shown in the accompanying diagram [fig. 2].

Bertie waterlime. This is an argillaceous, more or less magnesian limestone which forms the top member of the Salina stage. It is a persistent formation of quite uniform character. It extends from the Province of Ontario, where the type locality is found,

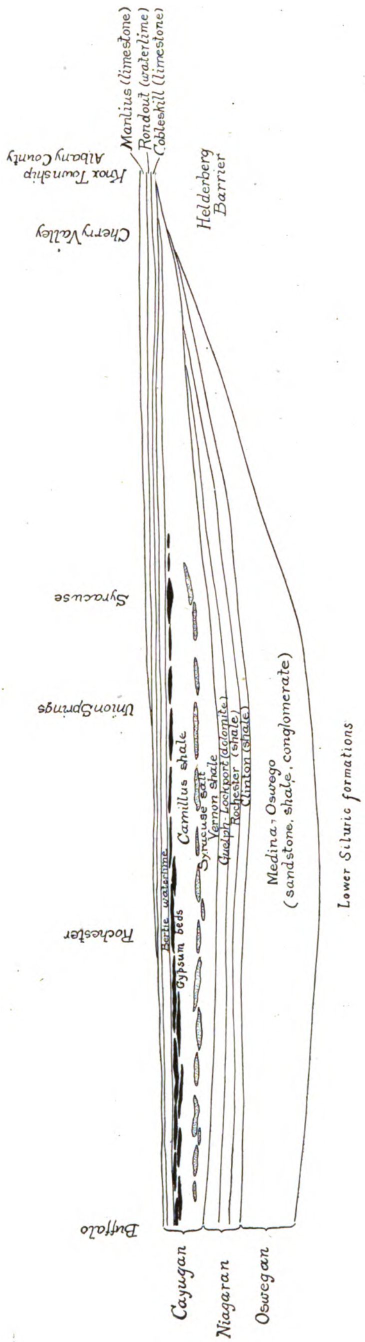

FIG. 2 Diagram indicating relative position and linear extent of the Upper Siluric strata in New York State

eastward as far as Schoharie county. In field exploration it serves as a very useful indicator, since the gypsum horizon lies just below, in the shales.

The limestone carries an eurypterid fauna which is also characteristic of the Pittsford shale at the base of the Salina. The intervening beds, however, are almost devoid of fossil remains, due undoubtedly to the unfavorable conditions for life that prevailed in the highly saline waters in which they were laid down. A common physical feature of the limestone is conditioned by the presence of numerous small cavities, which may so abound as to lend the appearance of a porous lava or slag. The cavities or cells are rounded or irregular in shape, sometimes elongated like worm tubes, and are frequently lined with a calcareous deposit. The structure was considered by some of the early writers to be of organic nature and the limestone was commonly designated the Vermicular limerock. This view of the origin of the cells was controverted by Vanuxem who pointed out the fact that they are often accompanied by hopper-shaped casts and impressions that have the clear outlines of rock salt crystals. There is little doubt but that they are due to the former presence of rock salt deposited with the limestone and afterward dissolved away.

The limestone possesses hydraulic properties and has been burned for hydraulic cement. The natural cement industry which was carried on for many years at Buffalo and Akron made use of this limestone which was employed to some extent also by the plants in Onondaga county. Its thickness varies from 60 feet in Canada and 50 feet in Erie county to 10 feet or less in eastern New York.

Camillus shale. Underneath the waterlime occurs a bed of soft shale, containing intercalated layers of magnesian limestone. The workable gypsum beds are found in this shale, at varying horizons, but mainly near the top. The color of the shale is commonly drab or gray with variations to olive-green and sometimes red. There are no fossils, except one or two species found in the intercalated limestones.

The thickness of the shale, together with the gypsum beds, averages perhaps 300 feet in the central part. Its outcrop is usually found just north of the line of ridges (known as the Helderberg escarpment in the eastern part of the State) formed by the great beds of overlying limestone and spreads out as a flat more or less swampy surface, physically continuous with the area of the Vernon shales. In the central section the outcrop is 2 or 3 miles wide.

The gypsum deposits are seamed more or less with shale which divides them into separate beds, though there is little regularity in the number or thickness of the beds from place to place. The shale intercalations range all the way from mere films to layers several feet thick. While the main body of gypsum is usually found near the top of the Camillus shale, in some places directly beneath the waterlime, there are nodules, veins and layers of gypsum distributed all through the mass.

The limestone layers accompanying the shale represent transition stages toward the Bertie waterlime and are more abundant in the upper part. They show the same porous structure and hopper-shaped casts due to halite and contain varying percentages of magnesia. They are inclined to be more argillaceous than the characteristic waterlime, as might be expected, and on that account disintegrate rapidly when exposed to the weather.

The whole body of shale is impregnated more or less with lime and is often called marl in the reports of James Hall. The lime, however, is not of organic origin, but a precipitate probably from infiltering waters subsequent to the consolidation of the beds.

Syracuse salt. This is a very variable member composed of alternating beds of rock salt and shale, occupying a position between the Camillus and Vernon shales. There is no definite plane of demarcation at the top or bottom, and some geologists consider it a part of the Vernon shale rather than an independent unit, inasmuch as the presence of rock salt constitutes the only criterion for its recognition. Even that feature does not hold along the outcrop, for the salt has been removed in solution wherever the covering is less than about 1000 feet thick.

From the records of deep wells, the salt horizon is recognizable in the Salina from Madison county westward to Erie county. At Morrisville, Madison co. a single bed of salt about 12 feet thick occurs.[1] In Onondaga county there are as many as four beds of salt separated by shale and the extreme thickness of the salt and included rock is not less than 300 feet. At Ithaca seven beds of salt aggregating 248 feet and six beds of included shale with a total thickness of 222 feet are shown in a well record. In the Genesee valley, at the Retsof mine, the salt beds include 15 feet of rock and measure altogether 124 feet. In the Oatka valley of Genesee county the salt-bearing strata are from 100 to 135 feet thick. In Erie county they appear to range between 100 and 200 feet thick.

[1] The data relating to the thickness of the salt deposits are taken from Luther's "Geology of the Salt District." N. Y. State Mus. An. Rep't 50, v. 2. 1896.

Vernon shale. The thickest member of the Salina beds is the Vernon shale. It is a soft shale which by its usual deep red color can be distinguished more or less readily from the shales above the salt horizon. The strong ferric-oxid color is particularly prevalent in the eastern section where the beds can be traced across the country by the red, greasy clays that result from their decomposition. In the western part they are banded with greenish and grayish layers and bear some resemblance to the Medina shales. They are exposed from Herkimer county westward across Oneida, Madison, Onondaga and Cayuga counties, but beyond the Genesee river are generally buried under the drift, and as their color is no longer uniform, their line of outcrop is not so readily determined in that part. Thin layers of limestone also appear in the western counties, as shown in well sections.

The thickness of the Vernon shale reaches a maximum in Onondaga and Cayuga counties, where it probably averages about 500 feet. At Syracuse the salt well section shows 525 feet. Toward the east the shale thins rather rapidly and apparently disappears entirely in Herkimer county. Westward its thickness also diminishes, but from the information afforded by the few wells that have penetrated the Salina the shale seems to persist as far as Erie county at least. At Gardenville, in that county, a well record shows 200 feet of shale below the salt horizon. Most of the salt wells and shafts do not go below the lowest salt, though in one well at Warsaw the shale has been penetrated for a little over 100 feet.

The absence of any extensive deposits of gypsum in the Vernon shale is a noticeable feature, and one which seems to detract from the validity of the usually accepted view that the salt and gypsum beds are due to evaporation of sea water. If the sea during Siluric times approximated in composition the ocean of the present day as regards saline constituents — and the evidences strongly indicate a similarity of conditions — there should be a considerable deposit of gypsum below the salt beds. It is fairly certain, however, that the salt and gypsum do occur in their normal order. In some of the deep wells, as for instance at Attica and Aurora, gypsum was found below the salt, while there may be a large amount of gypsum in the aggregate disseminated through the mass of the Vernon shale, as has been suggested by Hartnagel.[1] It can only be said that the conditions generally were less favorable for the deposition of large and continuous beds of gypsum in the Vernon shale than later in

[1] Geologic Map of Rochester and Ontario Beach Quadrangles. N. Y. State Mus. Bul. 114. 1907. p. 30.

the period represented by the Camillus shale. This may have been due to the influx of fresh waters at frequent intervals, to which the great body of silt may be attributed.

Pittsford shale. In a few localities, the base of the Salina series is marked by a bed of dark shale which rests upon the Lockport dolomite. Though of no great thickness, the bed is given an independent position in the stratigraphic column on account of its fauna, most interesting of which are the eurypterids, found also in the Bertie waterlime. The Pittsford shale is a local phase of the Salina, first recognized a few years since from exposures at Pittsford near Rochester.

General structure of the Salina beds

The Salina strata which outcrop from Albany county to the Niagara river have been little disturbed since their emergence from the sea. They are nowhere involved in local folds and if at all faulted the displacement must be so slight as to escape general observation. They dip uniformly toward the south, the direction ranging from due south to a few degrees east or west of south.

Within the central and western parts their inclination averages about 40 or 50 feet to the mile, or roundly 1 foot in 100. This is probably no more than the slope of the sea floor on which they were laid down. In the eastern section the dip is somewhat higher, owing to the fact that the beds here experience in some measure the influence of the Appalachian disturbance, which came at the close of the Paleozoic era.

If the whole belt be considered as a unit it becomes apparent that the uplift has been accompanied by a certain amount of differential movement. This is well shown by a comparison of altitudes at different places along the outcrop. The following approximate elevations have reference to the outcrop of the gypsum beds in central and western New York. The localities are given in order from west to east.

LOCALITY	ALTITUDE Feet
Akron, Erie co	640
Oakfield, Genesee co	735
Wheatland, Monroe co	570
Garbutt, Monroe co	560
Victor, Ontario co	500
Seneca Falls, Seneca co	400
Union Springs, Cayuga co	460
Martisco, Onondaga co	600
Jamesville, Onondaga co	580
Lyndon, Onondaga co	640
Clockville, Madison co	650

In tracing the beds farther east, the gypsum disappears as a prominent feature, but the top of the Salina is found at about 900 feet at Clinton, Oneida co. and between 1400 and 1500 feet in Herkimer county. Beyond Herkimer county the elevation drops off rather rapidly so that in Schoharie county the single member of the series outcrops at about 600 feet.

The lowest point of outcrop is nearly on line with Cayuga lake where the belt is widest. There is a rise of about 300 feet between that point and Genesee county and of over 1000 feet in the interval between Cayuga lake and southern Herkimer county. The main part of the belt has thus the structure of a broad shallow syncline with an axis running north and south and with its eastern wing rising well above the western.

Nature of the gypsum deposits

The gypsum forms regularly stratified beds which are usually heavy and range from several inches to 5 feet or so thick. The impure argillaceous gypsum is, however, rather thinly bedded, the individual layers being separated by shale intercalations. The strata are not, of course, absolutely continuous along the Salina belt, but have the shape of elongated lenses which succeed each other along the strike and dip, perhaps after intervals occupied only by the accompanying shale and limestone. The workable deposits are thus separated into more or less well defined areas, on the borders of which the gypsum diminishes or entirely disappears.

The lenticular form of the deposits is well illustrated by the area near Akron which has been fairly well delimited by exploration underground and by numerous test holes [*see* map facing p. 50]. The bed averages about 4 feet thick and extends for nearly 2 miles in an east-west direction before it thins out. On the north or outcrop side it apparently diminishes very slightly and then terminates abruptly, a feature which is due probably to removal of the gypsum by erosion. The extension of the bed on the dip has not been thoroughly explored, though the available evidences indicate a gradual thinning in that direction.

In surface exposures the beds may exhibit local modifications of the lenticular form. Several occurrences illustrative of such irregularities have been described and sketched by Hall[1] with considerable detail. Two of his sketches are reproduced herewith [fig. 3, 4]. In explanation of the features shown in figure 4, Hall expresses the

[1] Survey of the Fourth Geological District. 1843. p. 119 et seq.

opinion that they are attributable to the removal by underground waters of the shale along the contact which has caused it to subside and to fill in the hollows between the gypsum masses. He does not give, however, any explicit reasons for the peculiar shapes assumed by the gypsum and one might even conclude that he considered such masses to occur very generally throughout the Salina belt.

The significance of these irregular discontinuous deposits has been misinterpreted in some descriptions, owing to which the sedimentary origin of the gypsum seems to have been seriously questioned by geologists. There can be no reason to doubt that they are of superficial distribution and represent the remnants of former lenses of normal type partly dissolved away by ground waters. If followed along the dip of the strata, they would be found probably to lose their irregular form and merge into the usual bedded deposits. The solvent effect of ground waters upon the gypsum is shown in numerous places on the outcrop; the joint and bedding surfaces are often deeply pitted, and secondary veins of gypsum may be observed extending into the shales.

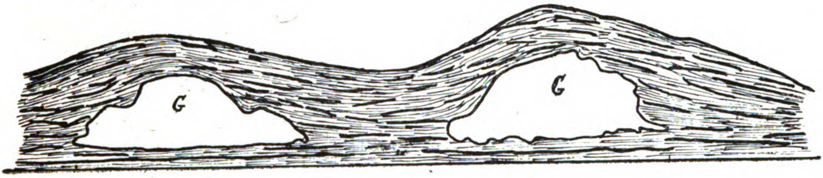

FIG. 3 Irregular bodies of gypsum resulting from solution of a once continuous bed. (After Hall)

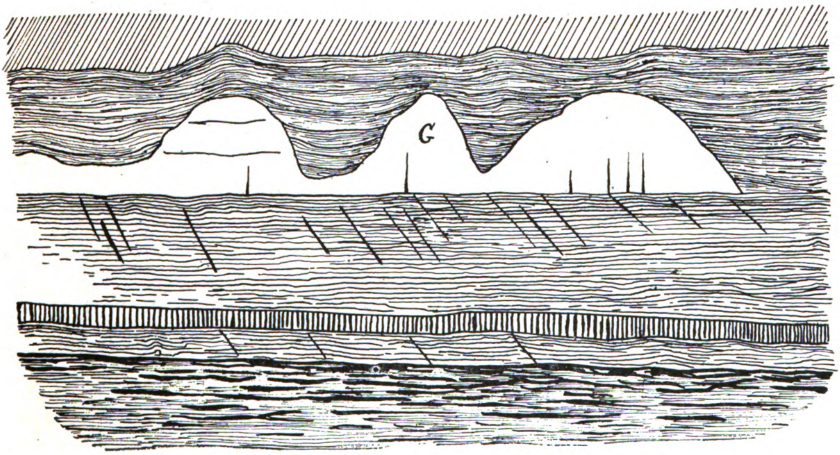

FIG. 4 Bed of gypsum partly dissolved away. (After Hall)

DETAILS OF THE DISTRIBUTION OF GYPSUM IN NEW YORK: WITH DESCRIPTION OF MINES, QUARRIES AND MANUFACTURING PLANTS

Herkimer county

The most easterly occurrence of gypsum that was ever worked commercially is a deposit in southeastern Herkimer county. It was discovered previous to 1837 in an adit run into the hillside on the James Crill farm in the western part of Starke township. The opening was intended to explore a supposed silver vein. The gypsum is said to have been found in a roundish mass and to have had a white color. Some 20 or 30 tons were removed by Mr Crill. Present interest is chiefly connected with its situation so far east and with the fact that it is described by Vanuxem as occurring in a white sandstone of Clinton age which at this point immediately underlies the Camillus shale and can be seen in outcrop a little north of the opening. It seems probable that the deposit is of secondary character, derived from scattered inclusions of gypsum in the shale above.

Oneida county

The Salina shales have a small areal distribution in Oneida county and there are no records to show that gypsum has ever been worked within its limits, though the occurrence of small deposits seems very likely, specially toward the western boundary of the county in Vernon, Augusta and Kirkland townships.

Madison county

The gypsum beds of Madison county, so far as known, all lie near the upper or southern part of the Salina outcrop in a belt running east and west across the northern portion of the county. The townships included are Lenox, Oneida, Lincoln, Sullivan, with a possible occurrence in the valley regions of northern Cazenovia, Fenner, Smithfield and Stockbridge townships.

The gypsum occurs in the form of lenses, pockets, or irregular masses in the Upper Salina shales, frequently immediately underlying beds of waterlime. The pockets are rarely very extensive, seldom exceeding 25 feet in length and a depth of 10 or 20 feet.

The gypsum consists of a mixture of clear selenite plates and a loose, earthy, dark colored mass consisting of clay and organic material. The selenite plates are rarely larger than 2 or 3 inches across and are so intermingled with the earth as to make the mass friable and easy of extraction. The clear, pure, nature of the selenite gives to the beds an appearance of high quality which is at once dispelled by a glance at the analysis below which is based on an average sample taken from a 50-ton lot from the bed of Mr Duane Clock at Clockville, and analyzed by Prof. F. E. Englehardt.

Gypsum ($CaSO_4 . 2H_2O$)	70.6421
Calcium carbonate ($CaCO_3$)	6.9073
Magnesium carbonate ($MgCO_3$)	7.1891
Iron oxid (Fe_2O_3) } Aluminum oxid (Al_2O_3) }	4.9200
Insoluble (SiO_2 etc.)	5 9000
Moisture and organic	4.4415

The quarrying and grinding of gypsum for agricultural uses have been carried on in the county from early times. In the first part of the 19th century it was a much more important industry than now. Some of the quarries then in operation were those of Cobb, Merrill and Wright along Cowaselon creek in the town of Lincoln (formerly Lenox); those of Judge Seeler and Mr Lawrence on Clockville creek; and the old Sullivan bed to the east and north of Chittenango which was worked during the Revolution and its plaster shipped as far as Philadelphia. Also the Van Valkenburgh quarry south of Chittenango, Bull's and Brown's quarries between Sullivan and Clockville, and doubtless many others were in operation about 1840. In recent years pockets of gypsum have also been worked intermittently at Hobokenville, where is situated the Tuttle quarry and mill, and about 1 mile south of Cottons where the mill and quarry owned by R. D. Button are located.

The gypsum bed at Clockville, now owned by Duane Clock, is as favorably situated as any in the county for extraction and shipment. The bed, some 100 feet long and 5 to 7 feet thick, outcrops along the Elmira, Cortland and Northern Railroad about ¼ mile northeast of the Clockville station, 200 feet north of the railroad bridge crossing the creek. Another bed outcrops just south of the bridge while the surrounding hills contain numerous other deposits. The gypsum is the typical friable admixture of selenite and impure gypseous clay. It is underlain by Salina shales and overlain by clay. It contains on the average about 70 to 75 per cent gypsum and can be easily and cheaply mined and loaded directly on cars.

About 5 miles farther west are gypsum beds owned by Cyrus Worlock and R. D. Button which are of similar character and are also easily accessible. Other deposits are found near the Erie canal, such as those between Chittenango and Sullivan. They are in many cases very heavily topped with a shale and limestone cap which must be stripped in quarrying, since it appears too badly broken up to allow tunneling methods.

Owing to their somewhat irregular character and to their relatively low percentage of gypsum, the more inaccessible deposits in this region have little present value, while even the more favorably situated and larger lenses are of limited utility.

Onondaga county

The Salina shales outcrop in Onondaga county in an east-west belt varying in width from 10 to 12 miles. The lower beds, known as the Vernon red shales, outcrop in the northern portion in Lysander, Van Buren, Clay, Salina, Cicero and Manlius townships. They are described by Luther[1] as including many layers of green shales and mottled red and green shales. "The red color is, however, very pronounced, a strong brick-red; the green is a light but generally distinct pea-green. Some of the upper layers near the contact line are olive. Red is the predominating color in the lower beds, and green toward the top. The shale is very soft and clayey, crumbling into dust on exposure, if dry, or turning to clay, if wet. Some of the green and olive layers are fissile to a slight degree."

Overlying these shales and outcropping to the south are a series of peculiar, cellular, broken limestones containing hopper-shaped cavities, seams and irregular cavities. These are accompanied by dark gypsiferous or olive colored shales. This is supposed to be the horizon of the salt beds of the State and at the surface, along the outcrop, numerous salt springs were once abundant. Above this horizon and to the south lie the gypsum or Camillus shales. They occupy a belt 2½ to 3 miles in width and are bounded on the south by the ridge which is a prolongation of the Helderberg escarpment. They also extend in long tongues to the south through the escarpment in the valleys of Limestone, Butternut, Onondaga, Marcellus and Skaneateles creeks. The gypsum series consists of gray, drab or mottled shales with interstratified layers of fine-grained platten dolomite, and contains many thick beds of grayish to black gypsum and gypsiferous shale. Between the two chief gypsum masses, according to Luther,[2] there lies a 40 to 50 foot course of dolomite or clayey limestone, containing numerous cells and cavities and formerly known as "vermicular limerock." The gypsum beds

[1] N. Y. State Geol. Rep't 15.1898. 1:250.
[2] *Ibid.* p. 264.

seem to be most persistent where overlain by the escarpment of Bertie waterlime, Cobleskill, Manlius and Onondaga limestones and for this reason are found mainly in the low hills capped by these limestones and along the stream valleys cutting through the escarpment.

The beds of massive gray gypsum occur beneath small hills between Fayetteville and Jamesville. The first area is a series of wooded hills ranging in hight from 40 to 100 feet. These lie 2 miles southwest of Fayetteville or 1 mile south or southeast of Lyndon, a station on the trolley line. They are capped by Helderberg limestone and the gypsum beds outcrop on the sides of the hills, forming a belt around each hill. The capping of resistant limestone seems to have served as a protection against the removal of the gypsum by percolating waters.

Clifford Miller quarry. This quarry is situated 1 mile directly south of Lyndon, to the east of the road. It has been worked from early times. It is also known as the Heard or Severance quarry. The gypsum bed is about 60 feet thick and consists of a number of alternating layers, varying in purity, color and grain, the individual layers having local names such as the "cap rock," the "9-foot," the "11-foot," etc. They range in color from very light drab in the cap rock to dark or almost black, and at times have a brownish color from the presence of iron. Despite its varied appearance the rock runs rather uniform in gypsum, and no attempt is made to sort the material in the quarry operations.

The gypsum here is overlain by 2 feet of marlite or weathered shale, followed by 5 feet of thinly bedded blue limestones (Bertie) then 15 or 20 feet of massive porous Cobleskill limestone full of cavities, with a varying thickness of glacial drift and soil as capping to the whole. The heavy mass of overburden becomes more troublesome as the quarry is carried farther into the hill and the stripping problem becomes a difficult one. The overlying marlite is usually blasted out until, by caving, the whole overburden falls into the quarry excavation and work is resumed on the new face of gypsum. Both hand and machine drills are employed. Black powder is used in blasting. The broken gypsum is loaded by hand into large 20-ton side dump wagons which are drawn from the quarry by a traction engine a distance of over 2 miles to the canal. The grade is mostly downhill and the road is in good condition. The installation of traction haulage is a new feature in the district and seems to be giving satisfaction. At the canal dock, the rock is dumped down a small embankment, and from there loaded by six men into a steel bucket which is swung by a boom derrick to the canal boat and dumped. The gypsum is all shipped in crude state to Mr Miller's plant in New York city where plasters of various kinds are made.

Quarry of the National Wall Plaster Co. This quarry is situated south and west of the Miller quarry on the same knoll. The gypsum bed is continuous with that in the Miller quarry but is not quite so thick. The property includes about 15 acres underlain with gypsum. Quarrying is carried on intermittently and at present no work is being done. The overburden is similar to that of the other quarry but stripping is accomplished by excavating the gypsum in such a way as to undercut the limestone beds and the latter are then allowed to fall into the vacant space. The rock was formerly hauled to the canal and to the mill but the latter now stands idle. The equipment of the mill consists of a Sturtevant jaw crusher, a set of Hoagland rolls, Cummer kiln and cooling bin, two 10-ton kettles, and a buhrstone mill. The rock was first crushed, then passed through the Hoagland rolls which reduced it to the size of corn. A large quantity of it was shipped in that state to cement manufacturers. Some of this crushed rock was passed through the Cummer kiln at a temperature of 340° and shipped without grinding. Some was also ground in the buhrstone mill and calcined in the kettles. The future of this company is still an unsettled question.

Quarries at Fayetteville. To the east of these quarries are those of H. H. Lansing, now idle; and also idle quarries formerly owned by the Adamant Wall Plaster Co. and C. A. Snooks, but now controlled by Clifford Miller.

Large amounts of a similar grade of gypsum are found in all of these quarries and extending into the several hills. What is most needed at present is an outlet for shipping, such as would be furnished by a railway switch now being contemplated, or by aerial tramways or bucket carriers to the railroad or the canal. Another improved method, not yet introduced in the region, is mining by means of adit tunnels driven into the hillsides. This would obviate the necessity of closing down in bad weather and would do away with the expense now incurred in stripping.

At Fayetteville there are mills owned by Bangs & Gaynor and F. W. Sheedy. Each is equipped with jaw crusher, nipper and buhrstone mills, and grind gypsum. Their mineral is purchased from the neighboring quarries. The ground gypsum is sold as land plaster or to fertilizer companies.

EDUCATION DEPARTMENT
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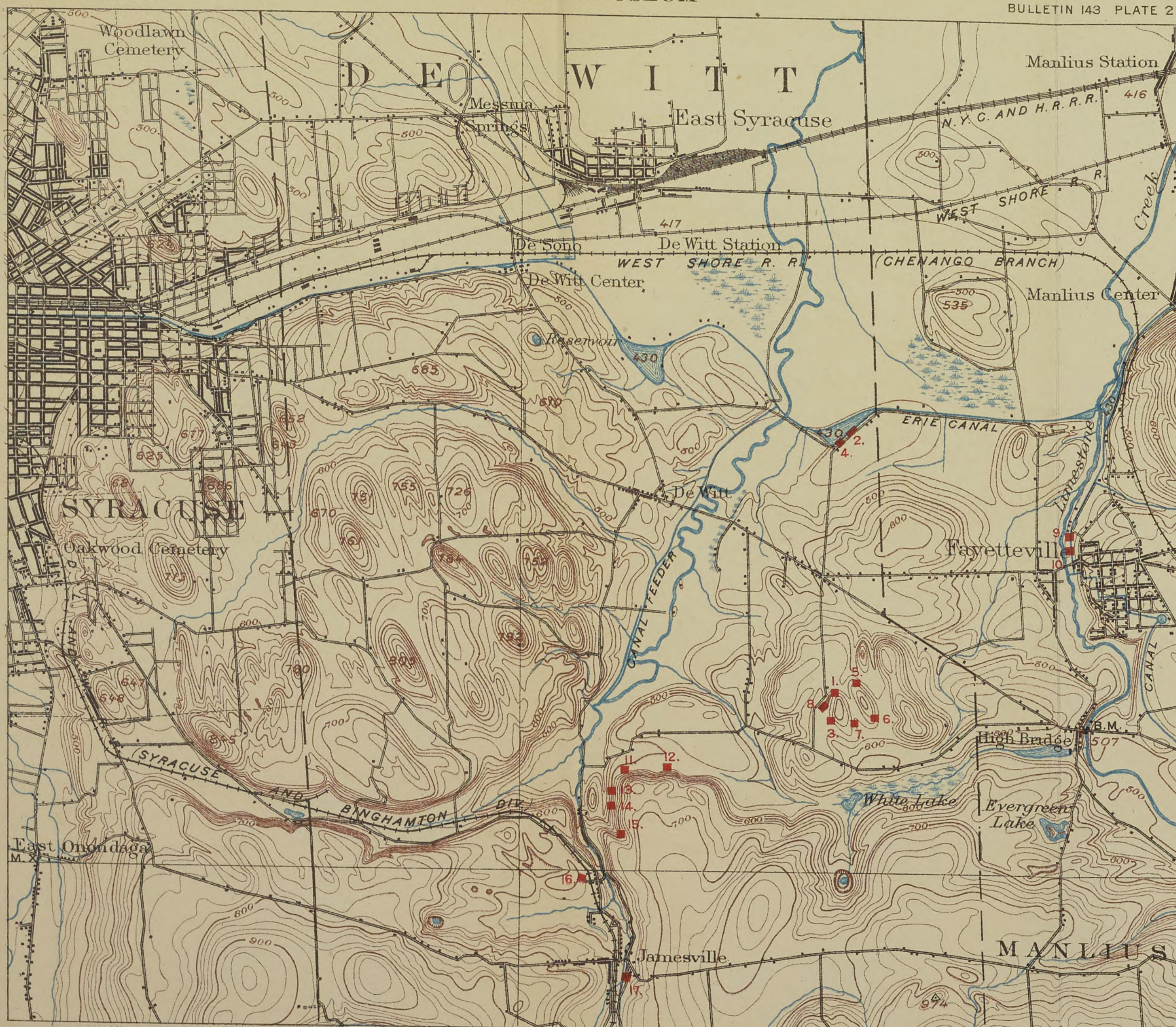
STATE MUSEUM

BULLETIN 143 PLATE 2



MAP OF JAMESVILLE-FAYETTEVILLE DISTRICT

LIST OF WORKINGS

1. Quarry,
2. Dock,
   Clifford Miller Co.
3. Quarry,
4. Mill,
   National Wall Plaster Co.

5-8, 13-15. Abandoned workings.

9. Mill,
   T. W. Sheedy
10. Mill,
   Bangs & Gaynor
11. Mine
16. Mill,
   Thomas Millen Co.
12. Mine
17. Mill,
   E. B. Alvord Co.

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Quarries at Jamesville. The second area in which active operations have been conducted is 2 miles north of Jamesville and east of the road leading to Dewitt (Orville). As in the other quarries the gypsum outcrops on the slope of a hill capped with Helderberg limestones. The north and west faces of this hill are abrupt slopes of which the lower portion is gypsum.

The quarry of Thomas Millen Co. is situated about ½ mile east of Reals station on the Jamesville trolley road. The gypsum is very similar to the Lyndon product and occurs in the same manner. It averages about 30 feet in thickness and is overlain by 50 feet of limestone. Until two years ago quarrying was carried on in the usual manner, but now the gypsum is excavated underground by means of a tunnel driven along a 6-foot layer of the best rock. In the fall of 1908 the workings extended 150 feet into the hill and 100 feet to the west. Much timbering is needed. The rock is drilled by electric drills, and the mine equipped with electric lights. The broken rock is loaded into 1-ton side dump metal cars which are hauled by wire cable from the working face to the entrance and up an inclined trestle, the cable being operated by a small engine and drum. Owing to the grade of the tunnel, the cars return to the face by gravity. From the cars the rock is dumped directly into 3-ton wagons and hauled by a team to the mill. The mill is situated about ½ mile north of Jamesville station, on the Delaware, Lackawanna & Western Railroad. No plaster of paris is made, the rock being shipped crude or after a preliminary crushing in a Butterworth & Lowe jaw crusher.

One half mile east of Millen's mine, on the same escarpment, is the mine of E. B. Alvord & Co. The gypsum is overlain by a few feet of thin shale, 15 feet of massive limestone and 20 feet of thinly bedded limestones. The company has recently begun mining the rock by means of a tunnel driven in an old quarry. A 5-foot layer is worked. The mine is lighted by electricity and the drills operated by the same power. No mine cars or track are used, but the wagons and horses are driven directly into the mines and to the working face. This necessitates wide gangways and large rooms, but no trouble is experienced with the roof. The mill of this company is situated at Jamesville, across the river from the post office. The power is furnished by a 70-horsepower turbine and the equipment consists of a jaw crusher, cracker and buhrstone mill as well as an unused kettle. The rock is sold crude, or with only preliminary crushing, to cement factories, or is ground in the buhrstone mill and sold as land plaster.

The gypsum bed appears at several places around the western flank of the hill where there are abandoned quarries, and in an abandoned tunnel near Fiddler's Green, a station on the Jamesville trolley line.

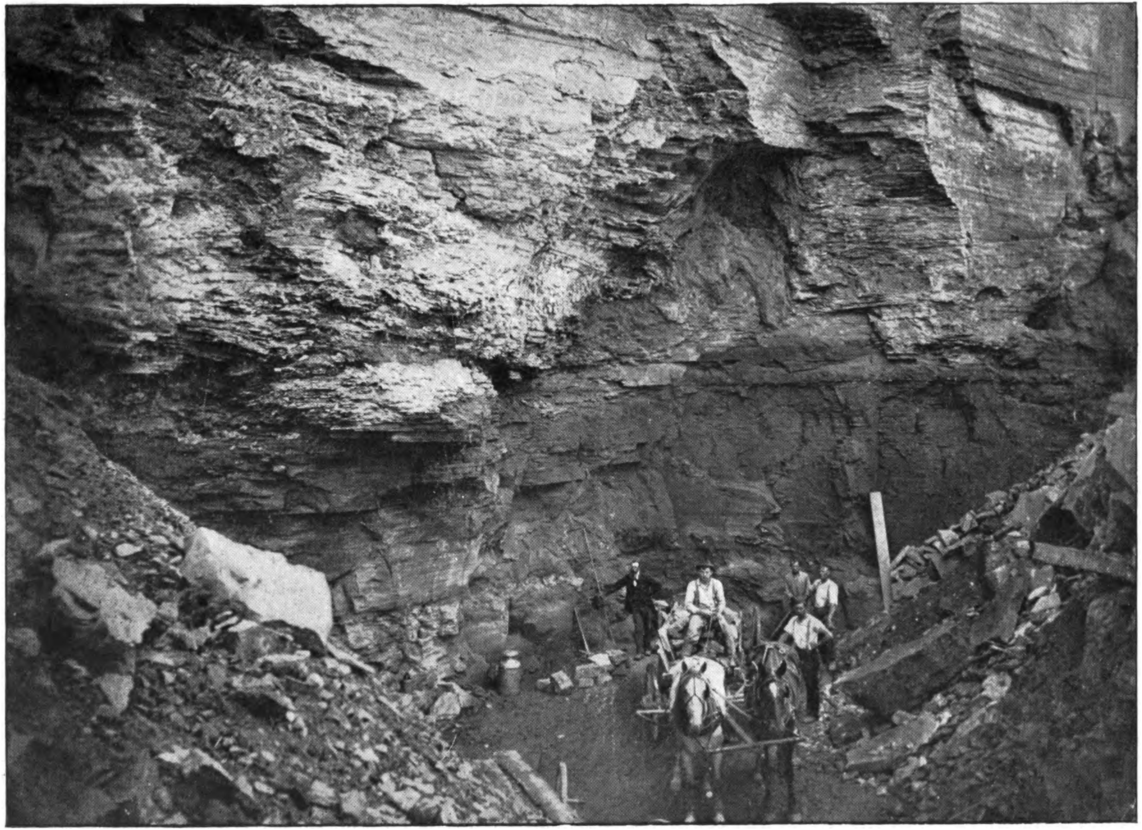
The close proximity of the railroad to this area is a feature that should bring about its greater development. The track is now only a mile from the mines, but there is a difficulty in the way of extending the switch because of the steep valley of Butternut creek.

Other quarries in Onondaga county. The deposits in other sections of the county are mainly of the pockety type and consist of mixtures of white gypsum, selenite flakes and crystals and fibrous gypsum veins with shale. As in Madison county, they rarely run over 10 feet in thickness and 25 feet in diameter. They are usually surrounded by shales and layers of impure limestone and occur both immediately under the Bertie waterlime or in the shales farther to the north.

In the eastern portion of the county the deposits are quite numerous in the town of Manlius, the hilly area between Chittenango, Mycenae and Fayetteville containing many such deposits. Many of the knolls have been opened up from time to time and the gypsum worked for land plaster, but at present no production is made. Westward there are no beds, with the exception of those in Dewitt township, already discussed, until the Onondaga valley is reached. The heavily glaciated area between Butternut creek and Syracuse probably contains gypsum beds, but as yet they are uncovered.

Two and a half miles south of Syracuse, A. E. Alvord formerly quarried a gypsum deposit. Vanuxem in his third annual report [p. 256] mentions the working of gypsum deposits along the railroad from Syracuse to Split Rock, and no doubt there are many small deposits in that section.

In the construction of the railroad from Syracuse to Auburn large quantities of gypsum were unearthed along the south side of Nine Mile creek between Camillus and Martisco (formerly Marcellus station). Thousands of tons of the material were taken out and the deposits attracted great attention. The gypsum bed consists of a mixture of limestone, shale and selenite or at times a whitish gypsum with wavy markings. At no part of the extensive cut was gypsum in pure masses observed, and if quarrying were undertaken the whole impure mass would need to be excavated and the percentage of gypsum would run low. The ease of mining and its accessibility to the railroad may render it of some value in the future. Other outcrops occur farther to the west, at Martisco.



Quarry face in gypsum, near Lyndon, Onondaga co.

One outcrop is at the prominent point or hill northwest of the station where a 10-foot layer has been quarried. The material is similar to that already described. Following south up a branch of Nine Mile creek another outcrop is seen just south of the station (Martisco) on the Marcellus Falls Railroad. It is about 20 feet in thickness and extends for some 150 feet along the road.

A few miles to the west the Auburn Railroad runs through a steep sided valley, and on either bank gypsum deposits are frequent. Probably the purest deposit of gypsum noted in the county was encountered in this ledge in an old quarry about half way between Halfway and Martisco. The quarry is now the property of Fred Chapman of Martisco and Monroe Hill of Elbridge. It is situated just off the road about ¼ mile south of the Auburn track on the face of an escarpment. The gypsum bed appears at an elevation of about 100 feet above the railroad. The quarry shows about 15 feet of gypsum in all, of which 4 feet is of much better grade than the average for Onondaga county. It is a grayish to white crystalline mass dotted with brown cleavable crystals and resembles the rock found at Oakfield, Akron and Garbutt. It is overlain by 20 feet of limestone, and the expense of stripping is the probable cause of idleness. No other outcrops were found in the vicinity, so that no idea of the extent of this stratum could be formed. It seems, however, a deposit well worth investigation, since a few test holes back on the ledge and along the outcrop would soon fix the boundaries of the good rock. Its favorable situation for working and its accessibility are evident. Some form of gravity tramway or aerial bucket tram could easily be constructed, a tunnel driven into the hillside, and the rock shipped on the Auburn road. The quarry was formerly owned by Abner Taylor and the rock was ground by Dwyer & Canear in their mill, long since abandoned.

The abundance of gypsum outcrops on the sides of the deep cut valleys between Camillus and Halfway would seem to indicate the former presence of a persistent and continuous gypsum bed over that region and it is probable that underlying the Helderberg limestones on most of the hills, gypsum beds would be found. From Halfway on to the western boundary of the county no gypsum deposits have been recorded, although there seems no reason to doubt their existence in that section.

Cayuga county

The area covered by Salina rocks in the county varies from 14 to 20 miles in width and falls within the towns of Conquest, Cato, Montezuma, Mentz, Brutus, Throop, Sennett, Springport and Aurelius. The Cobleskill limestone which forms the southern boundary of the area, immediately overlying the Salina, extends across the county as follows: Beginning at a point near Skaneateles falls the outcrop follows directly west to a point about a mile south of Sennett, where it crosses the New York Central tracks, turns southwest and crosses the northeastern corner of the city of Auburn, thence southwesterly to Hills Branch, and then south to Howland point and Frontenac island near Union Springs.

The topography of the northern portion of the Salina permits of but few outcrops. The area bordering the Seneca river is low and marshy while outcrops in other areas are completely obscured by a heavy covering of glacial drift, usually taking the form of drumlins. On this account very little is known as to the gypsum deposits in that portion of the county. About 1½ miles north of Throopsville, along the river, pockets of gypsum were worked in 1837, the owner being N. Marble of Port Byron. Other impure deposits have been reported in the vicinity of Montezuma.

Along the southern border of the Salina and immediately underlying the Salina waterlime and Cobleskill are the important gypsum beds of the county, in early times the most important in the State. These beds are exposed at three localities: in the town of Springport north of Union Springs; at Cayuga Junction, ½ mile east of Cross Roads station; and on the boundary of the township 1½ miles north of Cross Roads. The gypsum in these localities varies from 10 to 40 feet in thickness, and is of a gray or bluish color, firm and massive, with plates and veins of selenite coating some of the blocks or mixed with the more impure material. In a few places it is overlain by waterlime rock but usually has an immediate covering of glacial soil varying from a few feet to 25 feet in thickness. The occurrence, as well as the character of the rock, is very similar to that of Jamesville and Lyndon. The stratigraphy of the Union Springs region has received the close attention of many geologists and much has been written concerning it. The points involved seem to have no direct bearing, however, on the present treatise and will not be discussed.

In the early days many quarries were in operation in the Cayuga Junction area, 2 miles north of Union Springs (then Springport) and the plaster was shipped by canal all over the country. Mr Yawger is quoted by Vanuxem as stating that plaster was used there as early as 1811 while by 1842 the quarries were producing 10,000 tons yearly, the price delivered by boat to Ithaca being $1.50 to $2 per ton. From Ithaca it was transported by the Ithaca-Owego Railway and Susquehanna river to points in Pennsylvania. In 1840 five quarries were in operation, owned by Richardson, Partenheimer, Cresis, Howland and Yawger, while the Cross Roads quarry was owned by Mr Thompson.

At the present time and for some years back the only active quarry has been that of the Cayuga Plaster Co., of which C. T. Backus of Union Springs is president. The mill and quarry of this company is at present leased and operated by the United States Gypsum Co. The mill is situated along the Ithaca branch of the Lehigh Valley Railroad, about 2 miles north of Union Springs at Cayuga Junction. It is equipped with a Sturtevant cracker and nipper and five buhrstone mills. The rock is sold in lump or ground form to cement factories and others; none is calcined. The quarry is situated about ⅛ mile back from the mill. The gypsum varies from 20 to 30 feet thick and is overlain by as much as 25 feet of glacial drift that contains many waterlime boulders. Stripping is effected by means of a steam shovel, and the earth is carried to a convenient dumping place at one side. The gypsum is worked at the present time by quarry methods and by means of a tunnel driven into the lower course of the gypsum. Steam drills are used and on the open face the rock is blasted off in benches. The tunnel has been only recently opened and extends but a few feet into the face. The rock is loaded on cars and transported to the mill on a narrow gage cable railway.

An analysis of the plaster as quarried in 1903 showed the presence of 80 per cent lime sulfate.

The future of this field depends upon the uses which can be found for rock of this grade. Transportation facilities are good, the deposits are large, and mining could be carried on cheaply. Although the cement firms at the present time are demanding, generally, a higher grade of gypsum, which is supplied by the beds of western New York, the low cost of production and the advantages for shipment are favorable to an increased development at Union Springs, and in time the once flourishing industry may be revived.

Another gypsum deposit was formerly worked at Cayuga Bridge (now Cayuga), the gypsum occurring both above and below the bridge. This deposit was in small pockets, however, and was soon abandoned for the better material south of it.

Seneca county

The area in Seneca county covered by the Salina shales lies in the townships of Junius and Tyre with a small outcrop in the town of Seneca Falls. In the two former townships outcrops are rare. The soft character of the Vernon and Camillus shales rendered them susceptible to speedy erosion during the glacial period and there has been formed a broad shallow east-west depression bounded by the more resistant limestones on the north and south. This area is heavily blanketed with glacial deposits, kames, drumlins etc. and is frequently marshy. It is almost devoid of rock exposures. Where the Seneca river has cut its channel through the Cobleskill and Bertie waterlimes, however, the Camillus shales have been uncovered and their gypsum masses exposed. The Camillus shale series according to Luther[1] "is composed in the lower part of thin dolomitic limestones and thin layers of soft shale and at the top has a bed of gypseous shale 35 feet thick, some parts of which are of sufficient purity to have, when pulverized, some economic value as land plaster and wall plaster. Gypsum was quarried about 1840 near Black brook west of Nichols corners and the bed has been penetrated in wells of that vicinity. It is not exposed along that stream now."

The exposures of gypsum along the Seneca river have been described by John Delafield,[2] as follows: "The greatest exposures of the rock are on the north bank, on the farm of Mr Frederick Swaby, and also on the ground of Mr Cady. The rock on Mr Swaby's farm was extensively worked at one period, and before he purchased the property; but, owing in some degree to the limited size of the beds, but chiefly to the neglect of the parties who worked the quarries, they are not productive. The difficulty seems to have arisen from the omission of separating the rock from the shales and marly limestone which surrounds it. . . . The hight of the cutting is about 40 feet and the upper bed of rock, the drab colored limestone (*Bertie waterlime*) is covered by a few feet of soil; it is about 6 feet thick."

He speaks of the plaster as occurring in large unconnected masses in the shale, one being 15 feet high and 35 feet broad. Gypsum occurs on the south side of the river in the bluffs but is not exposed. It is again exposed farther east on the north side of the river at the railroad bridge; and it was uncovered on the south

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[1] N. Y. State Mus. Bul. 128. 1909. p. 7.
[2] N. Y. State Agric. Soc. Trans. for 1850. 1851. 10:441–42.

side, in a cut made by the railroad company for the purpose of filling in low ground, the gypsum occurring in courses 4½ and 2½ feet in thickness and very accessible. At one time, as mentioned by Mr Delafield, the plaster industry along the Seneca river was an important one, and the output amounted to 5000 tons annually. It has been abandoned for a long period, however, and there is little prospect of its resumption. The deposits are all, no doubt, of the impure "mixed" type, while any that might be encountered under the drift of Junius or Tyre townships would require shaft mining and that too under unfavorable conditions such as wet ground and the like.

Wayne county

Only the northern or lower portion of the Salina shales outcrops in Wayne county and that only along the southern border in a belt averaging perhaps 6 miles wide. Although the contact between the Camillus and Vernon shales is not sharply defined, we may infer from the thickness of the Salina shales in the county that the exposed part lies below the Camillus and in the main perhaps below the horizon of the salt beds. Wells drilled in Clyde show the Salina to be 840 feet thick at that point, and at Alloway it is 580 feet thick.

Gypsum is said to be exposed at various places along the line of the canal and the New York Central Railroad. At Clyde it is found in wells at a depth of 25 feet, at Lyons at 40 feet, and at Palmyra at the same depth. Gypsum was at one time quarried at a point 2 miles west of Newark, where the railroad and canal pass between two hills. North of the canal, on lot 85 owned at that time by Winslow Heth, quarries were opened as early as 1832 and by 1839, 2000 to 3000 tons had been extracted. The gypsum is described by Hall[1] as being "mostly lamellar, transparent and of that variety which receives the local name of isinglass plaster." It was said to occur with varicolored gypseous marl and to have the form of "large rounded, irregular masses."

South of the canal was Blackmar's quarry which was worked at the same time and contained plaster of similar quality. Gypsum has also been quarried around Port Gibson [*see* descriptions under Ontario county] and undoubtedly many similar pockets underlie the area northeast of Port Gibson in Wayne county. Occurring as they do in the lower Vernon shales, the deposits are not likely to

[1] Geol. Rep't 4th Dist. (1837) 1838. p. 326.

prove of commercial value. The gypsum is all of the quality known as "mixed," i. e. consisting of selenite plates, reddish, granular and fibrous gypsum interstratified and seamed with clay shales, marlites, impure shaly gypsum, etc.; and it is found in small irregular deposits.

Ontario county

The Salina group is represented throughout the county by frequent exposures of Camillus shale, Bertie waterlime, while the overlying Cobleskill waterlime and in the eastern part of the county the Rondout waterlime are also encountered. Of these the Camillus shale is the only one of present interest and in it are found all the gypsum deposits. This shale occupies the entire northern portion of the county, and varies in width from 6 miles in the eastern portion to 2 miles in the western. In character it varies but little from its general type, a greenish or dark shale becoming light gray on exposure and containing interstratified platten dolomites at intervals. Where exposed, it frequently contains the pockety beds of gypsum so characteristic of the beds to the east. In the greater portion of the area, however, actual exposures are rare, owing to the heavy drift mantle.

Beginning in the eastern part of the county, the first exposures of gypsum are those brought to light by the Canandaigua outlet between Phelps and Gypsum. Of these the best grade of rock is represented by the beds of the Empire Plaster Co., owned by Mr A. D. Miller of Phelps. Mr Miller's main quarry lies on the northern bank of the outlet 1 mile north-northeast of Phelps Junction, near the bridge. The rock is a gray, impure gypsum, heavily seamed with fibrous white gypsum varying from ¼ to 1½ inches in width. It occurs in masses of 100 up to 3500 tons in weight and is gotten out by blasting. The material is hauled by wagons to the mill, located near the bridge, 1 mile west on the outlet. This mill is equipped with a cracker, nipper and buhrstones and is run by water power. The mill has been idle for two years but formerly carried on an active business in land plaster.

Across the road from the mill is an abandoned quarry from which Mr Miller formerly extracted gypsum masses from 25 to 3000 tons in weight. In early times many mills were in operation in and around Phelps and Gypsum, and the annual production of land plaster in the early forties along the outlet was 6000 tons.

From Manchester on to Victor the Salina beds are heavily covered or swampy, and no gypsum has been reported although well drilling may bring some to light. The various cuts made by the Ganargua creek northeast of Victor have uncovered several gypsum masses of the pockety type, and quarrying was at one time undertaken. A mill and quarry were operated on the C. M. Conover farm 1½ miles east of Victor on the north side of the creek. The gypsum, for its kind, was of good grade, 40 feet thick, and had a large sale for land plaster. The quarry has been idle for 15 years. In the later years of quarrying, stripping became such a troublesome feature (there is 30–40 feet of drift) that a tunnel was driven at the base of the hill, with a breast of 14 feet. Gypsum was also quarried at one time in the Goose Egg, an oval hill about 1¼ miles north of the Conover farm.

On the Conover farm there have been found by core drilling two layers of gypsum resembling in appearance that seen at Garbutt, Akron and Oakfield. This is the most easterly occurrence of such pure beds in the State and is, accordingly, of great interest. The series of core drill holes were put down in the flat area near Ganargua creek about two years ago under the supervision of Mr C. L. Tuttle; after going through 19 feet of soil and 16 feet of waterlimes, the first gypsum vein, 8 feet thick, was encountered. At 104 feet, a second seam was struck, its width being 6 feet thick. The cores were examined by the writers and the gypsum appeared to be of good quality, the lower vein being light colored and fine textured, resembling the Oakfield gypsum, while the upper one was less pure and dark colored, though firm and massive, resembling the Garbutt rock. An analysis of the material made on chips taken along the whole gypsum portion of the core shows 96 per cent gypsum according to Mr Tuttle. Calcining tests show the lower vein to burn and set to a whiter color. The Victor Gypsum Co., of which Mr C. L. Tuttle of Rochester is president, controls this deposit, having an option on the Clara Conover, the Eliza Conover and the Mark Gourley farms, in all amounting to 365 acres. Plans have been completed for a switch from the main line of the Lehigh Valley Railroad to the proposed shaft house, but the actual operations have been delayed for two years. If the deposit should prove extensive, a large industry could probably be established, since the Lehigh Valley Railroad passes right through the district and connects directly with the large portland cement factories of Pennsylvania.

The Lehigh Valley Portland Cement Co. attempted to locate gypsum on the hill nearby and it is stated that they struck 5 or 6 feet of medium grade gypsum but decided not to work it. Other reports indicate that they simply drilled through the 40 feet of mixed gypsum on the hill and struck limestone, not going as deep as did Mr Tuttle. The Atlas Co. is also said to have drilled neighboring farms without success. Conflicting opinions as to the extent and value of these deposits, as well as a lack of information as to several well records, make it impossible to arrive at any definite conclusions concerning the deposits. Judging by the more western areas we feel sure, however, that deposits of good gypsum will be discovered along the line of the Lehigh Valley Railroad, both to the east and to the west. The Bertie waterlime which, exclusive of the surface soil and drift, is the surface rock of the region averages 40 feet in thickness, so that in prospecting for the gypsum, one might have to pass through a heavy drift mantle and perhaps the whole 40 feet of waterlime before encountering the Camillus shale in which the gypsum lies.

Irregular pockets of gypsum occur near Port Gibson and have been worked for land plaster for years but are no longer productive. The most recent working has been that of Mr Ezra Grinnell who owns a water-power plaster mill along the creek and who obtained his gypsum from an 18-foot deposit near the mill. The gypsum in the area is said to occur under beds of argillaceous limestone in low knolls and hillocks, in the form of flattened spheroidal masses. It is fine grained, compact and contains no selenite veins.

Livingston county

No gypsum beds have been recorded in the county, due to the fact probably that they are heavily covered with limestone. The northern border of the county is occupied by the drab colored limestone of the Bertie formation, which overlies the gypsum beds. The Garbutt and Wheatland gypsum bed lies at an elevation of about 570 feet A.T. With an assumed dip of 40 feet to the mile, a fair average inclination, the bed on the border of the county would lie at about 490 feet A.T., so that at a surface elevation of 600 feet the bed would be pierced at 110 feet. There is reason to believe, however, that in the region between Caledonia and Mumford and in the area north and northeast of Maxwell, the horizon of the gypsum approaches nearer to the surface. Though the prospect of finding gypsum within these regions seems good, it will require exploration with the drill to determine the matter definitely, since in all probability the beds are not absolutely continuous with the Camillus shale.

Monroe county

The Camillus shale crosses the county from east to west, outcropping in southern Perinton, northern Mendon, southern Henrietta, northern Rush, southern Riga and Chili, and the greater part of Wheatland townships. Its northern limit is uncertain owing to the heavy drift covering and to its merging gradually into the Vernon shale below. Its southern limit is the outcrop of Bertie waterlime beds.

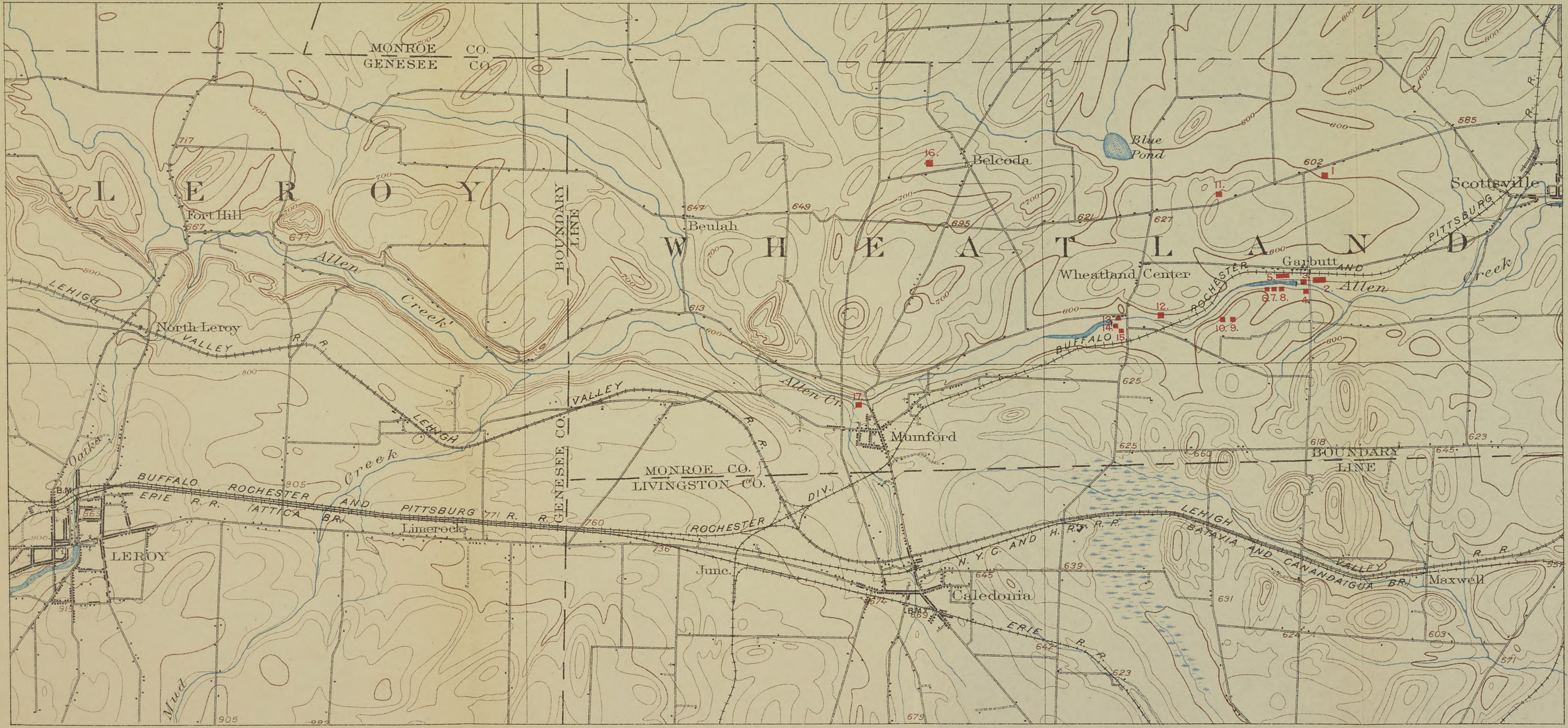
The gypsum deposits of value seem to be limited strictly to the town of Wheatland in the southwestern corner of the county. Here the Bertie beds, underlain by gypseous shales and the gypsum layers, are exposed for a distance of several miles along Allen's creek between Garbutt and Mumford; while small gypsum deposits have been exploited along its banks as far west as Fort Hill in Genesee county. The Wheatland township deposits are among the most important of the State. The area at present worked occupies about 3 square miles.

The gypsum at present developed, occurs in two continuous layers below 40 or more feet of soil and waterlimes. The upper layer lies at a horizon above the level of the stream while the lower layer is probably at the stream's level. The upper layer varies in thickness from 5 feet to 7 or 8 feet, but rarely can good rock be obtained with a thickness of over 5½ feet. The second layer, or "second bottom" as it is locally termed, has been found in practically all the workings. It is separated from the upper layer by a hard, bluish limestone varying in thickness from 6 to 12 feet. The gypsum in this layer varies also from 5 to 7 or 8 feet in thickness and in some mines contains from 1 to 2 feet of whiter gypsum than that of the upper layer. Its general average would probably run about the same. At present, the upper layer alone is being developed, although the lower layer has been exposed and its qualities are known. The descriptions of the individual properties follow.

Empire Gypsum Co. This company owns the most eastern mill of the group, situated southeast of Garbutt station and east of the north-south highway. The mine is situated west of the road, entrance being made to it by a slightly inclined tunnel, opening on the road. The gypsum averages 5 feet, 5 inches in thickness of which the middle 2 feet appears to be of the best quality, and the lower 2 feet is harder. The layer is overlain by a good limestone roof and underlain by 10 feet of limestone, below which is a second gypsum bed not yet developed.

The labor employed in the mines is mainly Italian. Drilling is done with hand auger drills, and blasting with dynamite. The workings extend about ¼ mile in a southwest direction and are based on a room-and-pillar method. The mine at present is lighted only by torches, but the management is considering the installation of electric haulage and lights. The rock is loaded on wooden mine cars and hauled by mules to the surface and then across the road over a trestle to the mill. At the mill the rock is crushed with a jaw crusher and then by one of the usual nippers. It then passes into a rotary drying cylinder, is dried and then ground in a Universal pulverizer, a unique method in New York gypsum mills. After grinding, the dust is collected by a fan which saves screening the whole product. The remainder is screened on inclined shaking screens. The ground material is then calcined at a temperature of 280° to 350° in three 11-ton kettles with solid bottoms. Material calcined at this temperature is said to be "first settling" and is "greasier and smoother" than that calcined at a higher temperature. Some of the material is calcined at 450° or second settling, and is then sold to the Pittsburg Plate Glass Co. for bedding plate glass. The mixing room is equipped with two 5-compartment Broughton mixers; two 12-tube bagging machines and a fiber shredder of the type in which the log of wood is pivoted and the knives revolve against it. This machine is capable of grinding 2500 pounds per day. The fiber is blown by a blast of air into the bins, the aeration also separating the dust from the fibers and loosening the mass. The wood used is mainly willow and basswood. Some of the crude rock is shipped directly, being dumped from the mine cars on the trestle into the gondolas below; a switch runs directly under the trestle, from the Buffalo, Rochester & Pittsburg Railroad. This plant is superintended by Mr G. J. McEntyre.

Garbutt Gypsum Co. This company, one of the oldest in the district, has a mill west of the Empire mill on the west side of the road, and on the north bank of the creek. The mines are located about a mile southeast of the mill, on the top of the south bank of the creek, and are reached from the mill by the roads to the south and west. In former days entrance was had to the gypsum bed by a tunnel driven into the north face of the hill, but this has been abandoned and at present the bed is reached by two small shafts. One of these was sunk four years ago to a depth of 70 feet, and the other, 100 feet to the west, was sunk in October 1908 to the depth of 68 feet. The covering consists of 40 feet of soil and 22 feet of limestone, the gypsum layer being from 5 to



LIST OF WORKINGS

1. Abandoned adit, McVane farm
2. Mill,
4. Mine, Empire Gypsum Co.
3. Mill,
9, 10. Shafts, Garbutt Gypsum Co.
5. Mill,
6, 7, 8. Mines, Lycoming Calcining Co.
11. Gypsum deposit, M. Rogers farm
12. Shaft and Crusher, Monarch Plaster Co.
13. Adit,
14. Mill,
15. Shaft, Consolidated Wheatland Plaster Co.
16, 17. Abandoned workings

MAP OF WHEATLAND DISTRICT

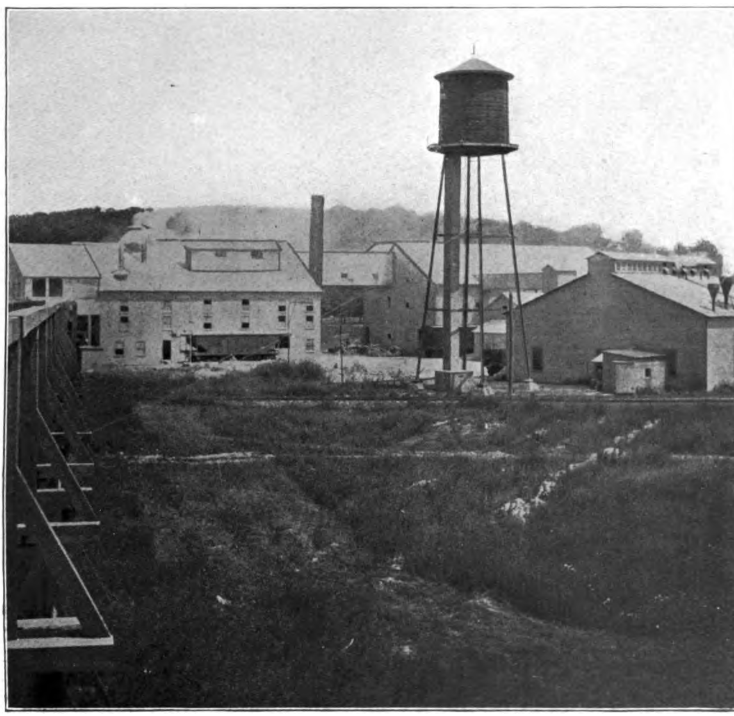
8 feet thick. The gypsum appears to be of remarkably good quality for the region and resembles the Genesee and Erie county rock. The purest, whitest layer occupies about 2 feet in the middle of the face. The new shaft, now worked, is a two-compartment shaft, one compartment being occupied by the stairway and the other by the bucket. Mining is carried on by two men in the mine, the rock being simply gophered out with little system and wheeled or carried to the shaft. Here it is loaded on a scoop or square bucket and hoisted to the surface by a cable and derrick operated by a small donkey engine. The bucket is swung around to the wagon and dumped or, in case the wagon is full, it must be dumped on a reserve pile and later loaded by hand on the wagon. Two men operate the engine and hoist.

The purity of this rock warrants a larger equipment and a more systematic, scientific mining and handling of the product. It is said that they mine all that can be handled in the mill. Further exploration ought to reveal similar deposits on nearby properties, and with better equipment and a mill location more easily accessible to the mine, it seems possible that the area south and west of the mine could be developed. If a way could be opened up to transport the rock down the slope to the north and west, either by gravity, railroad or areal tramway, and a mill be located along the railroad at a convenient point, an important economy could be effected.

The rock is now hauled by wagons over the road more than a mile to the mill. The mill is equipped with one 15-ton kettle, one Butterworth & Lowe nipper and cracker, a buhrstone mill for grinding the gypsum, and a Broughton mixer. Power is furnished by a steam engine. Originally water power was used and later that was supplemented by a gas engine. Calcining is carried on at 38° and to calcine a kettle takes about four hours.

Lycoming Calcining Co. The mines of this company are located west of the Garbutt mill on the south bank of Allen's creek. Previous to 1900 the bed at this point was worked by means of a vertical shaft on the top of the bank, but when the property was acquired in 1900 by the present company a tunnel was driven into the side of the creek bank about one half way up and after drifting some distance through "ashes" or shaly decomposed material, the firm "vein" was disclosed. The bed is now worked by three tunnels, the two nearest the trestle being connected, while the newer third tunnel will be connected with the others in six months' time. The bed of gypsum varies from 6 to 7 feet in hight. The rock is a light gray to brown gypsum with thin fibrous gypsum veins running through it. The lower 2 feet are harder and of poorer quality. The mine has a good limestone roof, separated from the gypsum by a thin parting of shaly rock known as rotten rock. The second "bottom" or layer of gypsum is 12 to 15 feet below the first and is separated from it by limestones. It appears to be of a grade equal to the upper rock. The mining operations have been conducted systematically, with pillars left every 21 feet. The mine workings now extend about 2500 feet into the hill. Mine no. 1, or that nearest the trestle, is about worked out. The mines are equipped with electric lights. Drilling is done with new auger coal drills and blasting with low grade dynamite. The whole face of gypsum is utilized, with no sorting, but care is taken to so arrange the cars that the poor and good grades alternate at the mill. At present the ore is hauled in steel cars by mules to the scale house, and then strings of cars are hauled across a wooden trestle to the mill by a horse. At the time of our visit in August, tunnel no. 3 was being opened out at its mouth so as to permit of a straight-away switch being laid, and they were preparing to instal a system of electric haulage, to abandon mine no. 1 and haul the product of nos. 2 and 3 out of no. 3. Mine no. 3 is less troubled with water and contains the best quality of gypsum. The electric system will necessitate a new trestle over the creek to the mill. Waste rock in the mine is utilized in banking up the sides of the gangways and very little needs to be removed from the mine. In mine no. 1 a shaft has been sunk through the limestones to the lower layer, and enough of the gypsum removed to prove that it is of good quality. By lowering the floor of the no. 1 tunnel an incline could be built and the lower layer easily worked. Some such plan is under consideration at present. After crossing the trestle, the cars are drawn up an incline by cable to the second floor of the mill and automatically dumped. The rock passes through a Butterworth & Lowe cracker and nipper, there being two of each, and is thus ground to ½ inch. It is then elevated and fed by a screw feed into two Cummer kilns equipped with American automatic stokers and with a Bristol recording thermometer, which records on a paper in red ink the time and temperature. The dust is separated in the furnaces by an air blast, and is said to make a high grade of land plaster. From the kilns the steaming gypsum is carried by screw conveyors to the large bricked-in cooling bins where it is allowed to finish cooking for 24 hours or so. The kilns can each calcine about 11 tons an hour.

Plate 5



Plant of the Empire Gypsum Co., Garbutt

It is then ground by four vertical Sturtevant "rock emery" mills and is ready for mixing or for shipment as stucco.

The prepared wall plasters are mixed in the west end of the building by the Diamond Wall Plaster Co., the materials used being cottonwood fiber, hair, sand and stucco. One mixture contains two parts sand to one of stucco with a small proportion of hair and retarder. The sand is obtained from Wheatland Center, 2 miles west, between the farms of Frank Kingsbury and Albert Mudge. Before use it must be dried and screened.

The Sackett Wall Board Co. occupies a large building adjoining this plant on the north. The company manufactures the large thin slabs of plaster board used so extensively for interior walls. The stucco is obtained from the Lycoming mill. It is mixed with water and placed by special machinery between many sheets of paper and the whole rolled into a cardboardlike sheet which when dried becomes the plaster board.

Monarch Plaster Co. The next mill in order is that of the Monarch Plaster Co., a little over a mile west along the Buffalo, Rochester & Pittsburg Railroad. The mine and mill are situated just north of the creek and railroad track near the railway bridge. The mine consists of a tunnel driven into the hill to the north. Drilling is done by auger electric drills and the mine is lighted by electricity, power being furnished by a gasolene engine in the mine. The gypsum bed is 6 feet thick, but owing to poor quality the lower 2 feet is left as a floor and only 4 feet of gypsum extracted in the rooms. The cement companies, it is stated, do not care to purchase the bottom rock. The mine is dry and the roof solid so that large rooms can be made, and open spaces 30 feet square are frequent. Mule haulage is employed. Six feet below the bottom rock is a second layer of gypsum which is 6 feet in thickness, 1 foot of which is of exceptionally white gypsum. Nothing has as yet been done with this lower layer.

At present the cars are hauled up a slight incline from the mouth of the tunnel and the material dumped into a small jaw crusher and cracker and the crude crushed rock sold to cement manufacturers. The company is installing, however, a large up to date crushing plant, in which the cars can be drawn by a cable directly from the mine to a considerable hight above the track and the rock dumped into the largest of Sturtevant jaw crushers, and from it into the bin and thence through a chute into the cars. The power will be furnished by a gasolene engine. The steel scales will be placed in front of the chute at the loading place.

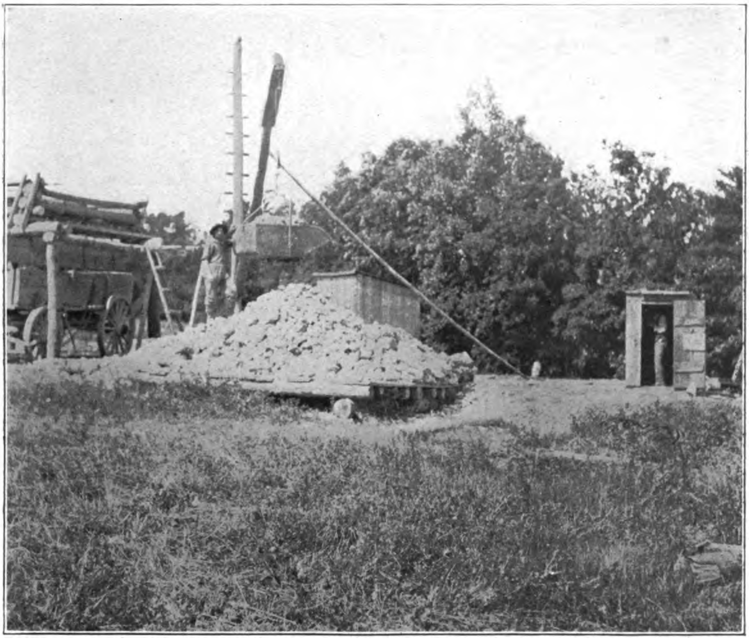
This company is said to control a larger tract of land south of the creek which may be worked at some future time. The product is all sold as 1 inch or ½ inch material to cement factories.

Consolidated Wheatland Land Plaster Co. A short distance west, along Allen's creek, is the property of the Consolidated Wheatland Land Plaster Co. The old mine consisted of a tunnel driven from the north bank of the stream; a 6-foot layer was mined and the product hauled across a bridge to the mill. During the past year, however, a shaft has been sunk a short distance southeast of the mill. The shaft is 35 feet deep and by it access is gained to the same 6-foot layer that is mined by the Monarch. As in the Monarch, the layer consists of 4 feet of gray streaked gypsum with 2 feet of "bottom" rock which is of lower grade. The mine cars are run on a platform hoist and are hoisted to the surface by a drum and engine overhead. They are then run over a track directly to the mill. There is also a lower layer 6 feet below, which is 6 feet thick and has a 1-foot white layer. In the mill the rock is crushed by a jaw crusher, ground in two 4-foot buhrstone mills, of Turkey Hill, Pa., stone, made by the Monroe Burr Co., and is then calcined. at 380° in two solid bottom kettles. The sales include crude crushed rock, land plaster, stucco and wall plaster, the latter made with patent retarder and purchased wood fiber from Massachusetts. Some of the stucco is sold to the Rock Board Co. who have a small plant nearby. The plant is operated by steam or water power, according to conditions.

Possible occurrences of gypsum elsewhere in Monroe county. The known deposits of gypsum in the region around Garbutt and Wheatland are largely controlled by the operating companies and a few other companies not now operating. Prospecting for new deposits must now be carried on south of the creek on the uplands. The beds here lie under a heavy covering of soil and rock, and would be found at a depth of from 50 to 100 feet.

Aside from the localities described, the gypsum beds have not been much explored in the county. To the north of Allen's creek, pockety impure gypsum has been found at Beulah, on the Harman farm near Belcoda and on the Rogers and McVean farms 1 mile north of Garbutt. In the Rogers farm the gypsum was found at a depth of 40 feet, being overlain by 27 feet of soil and 13 feet of limestone. On the McVean farm gypsum was at one time extracted from the hill by a tunnel, now abandoned, and from appearances there is a possibility of its future utilization. Gypsum was also encountered in a well on the farm of Mr Clapp in North

Plate 6



Shaft of the Garbutt Gypsum Co., Garbutt

Rush. In the region south of the outcrop, gypsum has been encountered in various wells at Mumford and Caledonia at 60 feet depth, and Mr Jenkins, a well driller of Scottsville, states that an apparently good belt of gypsum runs from Wheatland to Maxwell, 4 miles southeast and that it lies about 45 feet deep across the whole belt. He also states that gypsum was encountered in a well at the State Industrial School.

Opportunities for further prospecting are afforded along the northern boundary of the Bertie waterlime north of Mendon Center; in the area between Rush and North Rush; in the hilly region between Garbutt and Maxwell, and in the hills north and northwest of Mumford.

Genesee county

The northern half of the county is occupied entirely by the Salina shales, and as yet these have not been differentiated into the Vernon and Camillus shales. Succeeding the shales are the waterlime beds with their attendant gypsum bodies, while above and to the south the Onondaga limestones and underlying waterlime beds stretch across the county in a well marked escarpment, called locally the "ledge."

According to Hall[1] the shales in the center of the towns of Bergen, Byron, Elba and Alabama are gray or ash colored and contain thin seams of fibrous gypsum, selenite and occasionally small masses of granular gypsum. Succeeding the shales are a series of bluish, slaty and drab colored impure limestones which, he says, embrace large beds of gypsum. These gypsum deposits, so important in former days, are no longer quarried, and their location is almost forgotten. They have interest, however, as sources of supply for the future.

Near the eastern boundary of the county, gypsum beds have been uncovered on the banks of Allen's creek, and at one time large quantities of plaster were quarried near Fort Hill.

About 3 miles northeast of Fort Hill, or about midway between Fort Hill and South Byron, on lots 118, 144 and 182 large amounts of gypsum were formerly quarried. The deposit on lot 118, according to Hall, belonged to Mr Hughes and Mr Cash and was "a *white* gypsum free from seams and intermixture of clay." It was covered by a bluish limestone with shaly seams. On lots 144 and 182 the gypsum was "clay colored" and was overlain by a drab limestone containing species of Avicula. These quarries be-

[1] Geol. N. Y. pt 4. 1843. p. 464–65.

longed to Messrs Bannister, Collins and Clifford. The plaster sold at 50 cents a ton at the bed and for $3.50 a ton, ground. The three lots furnished in all almost 3000 tons annually.

The next locality mentioned in the early reports is that of Oakfield, or as Hall[1] says "Gypsum is also found in the western part of Elba, near the junction of the Pine Hill road with the Batavia-Lockport turnpike." Since western Elba is now Oakfield township, the locality mentioned must be in the vicinity of Oakfield. The masses were small and were 8 feet below the surface. They were never extensively quarried.

No further mention of gypsum localities in the county is found in literature until the records relating to the discovery of the large deposits at Oakfield and later at Indian Falls and Akron on the Erie county border.

The pioneer in the Oakfield district was Mr Olmstead who for some years previous to 1892 carried on a business in land plaster. In 1892 he installed a kettle, the first one in the State and began the manufacture of calcined plaster. For comparison with the present development of the Oakfield beds we quote the following from Merrill[2] in regard to the industry in 1893. Speaking of the two active shafts of Mr Olmstead, he says:

> The most easterly pit is worked by four men. The shaft is 8 by 12 and 31 feet deep. A former owner ran a tunnel to the north which is now closed up. There are two tunnels at present, one 75 feet long, the other 55 or 60 feet long. These are separated 80 or 85 feet at the ends. The 55-foot tunnel is at present being worked. The deposit is only about 4 feet thick, not so much as this in many places. The only timbering is a few short stulls. The rock is very much the whitest plaster seen in New York, and when ground is like flour. The material is loaded in flat cars running on a track made by laying stringers and nailing cross pieces and covering with hoop iron. This lessens the labor of handling and increases the output. At the bottom of the pit the material is loaded into an iron bucket fastened to an iron chain which is operated by a horse whim and derrick at the surface. . . The capacity of Mr Olmstead's pits is about 15 tons per day.

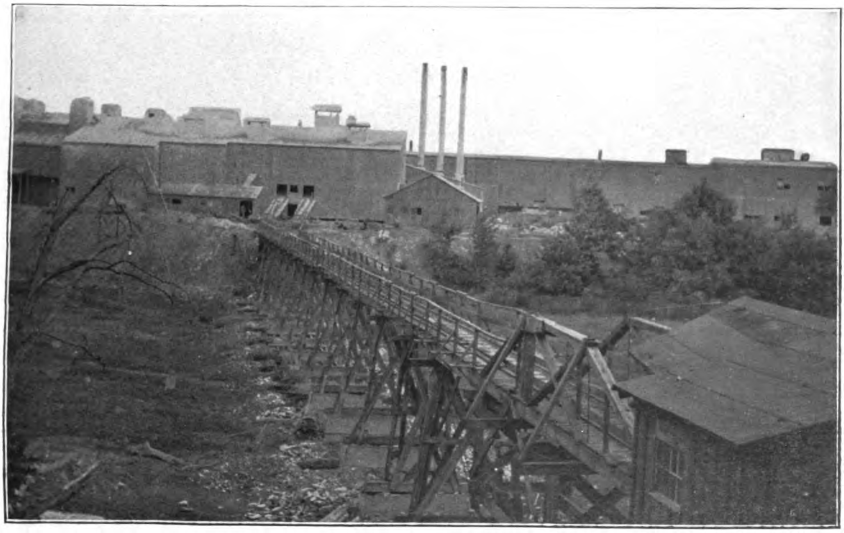
From this period on, the industry has shown rapid growth. The Olmstead property was purchased by the English Plaster Co., and a mill was erected and equipped with a Blake crusher, nipper and five kettles and five buhrstone mills. The Genesee Plaster Co. in 1901 erected a mill with three calcining kettles, and to this mill

[1] Geol. N. Y. pt 4. 1843. p. 464.
[2] N. Y. State Mus. Bul. 11, p. 77.

Plate 7

Entry to mine of Lycoming Calcining Co., Garbutt

Plate 8



Mill of Lycoming Calcining Co., Garbutt

there was later added the equipment of the Big Four Plaster Co. The entire equipment consisted of one Blake crusher, one nipper, eight buhrstone mills, four kettles, two shaking screens, one single mixer, one triple mixer and one sand drier. The Oakfield Plaster Co. at about the same time was operating three mines and a mill that contained one Blake crusher, two buhrstone mills, one bolter, and two kettles of 10-ton capacity.

At present the industry is in control of two firms, both of whom are working on a good sound basis.

United States Gypsum Co. This company, which owns gypsum mills and mines in several states, entered the Oakfield district about 1903 and bought up or leased the properties of a number of the former companies. The company abandoned all but one of the many shafts, consolidated the mill equipment and installed electric power.

The present mines and mill are situated about 1½ miles west of Oakfield on the West Shore Railroad. The mill formerly belonged to the Genesee Plaster Co. and has already been described. The company also operates the mill of the Oakfield Plaster Co. a short distance to the west. The mine shaft which is situated about ½ mile north of the mill is equipped with a two-compartment electric hoist. The rock is automatically dumped into large hoppers, is weighed and then falls into a steel lined storage bin from which it is loaded directly by chutes into large cars which are drawn by a locomotive to the mill.

Niagara Gypsum Co. The mill and mine of this company are situated ½ mile west of the United States Gypsum Co's plant, or 2 miles west of Oakfield Station, on the West Shore Railroad. The manager is Mr M. A. Reeb. The shaft at present operative is situated about ½ mile north of the mill. Entrance is made through a two-compartment shaft, 45 feet in depth. Transportation underground at present is by means of hand labor. An electric hoist raises the rock from the mine to a level above the switch, where the rock is either dumped directly into cars or on a supply pile. The gypsum is conveyed to the mill on cars drawn by a 12-ton electric locomotive. A second shaft nearer the mill has just been completed. This is 51 feet in depth and will ultimately connect with the other mine, when all the rock will be conveyed underground by electric haulage to the new shaft. Here an electric hoist will be installed, together with a crusher and cracker also electrically driven. At the mill the rock is crushed first by a large rotary cracker, elevated by a bucket elevator, passed through two crackers and again elevated to the bins over the calciners. From the bins it passes into two large Cummer rotary calciners each with a capacity of 15 tons per hour. The dust from the calciners is collected in overhead bins and with the finished product from the calciners is elevated and passes into the brick-inclosed cooling bins. After remaining in these bins 24 hours the material is ground in four Sturtevant rock emery mills. It is then elevated and carried to the mixing room in the west end of the building. This is equipped with two three-compartment Broughton mixers, a large stucco bin, a fiber machine and a hair picker. Power for the mill is furnished by a 300-horsepower Allis-Chalmers motor. The mill and mine are operated day and night with a capacity of 500 tons for each 24 hours.

Additional occurrences in Genesee county. West of Indian Falls and 8 miles west of Oakfield, gypsum outcrops along the banks of Tonawanda creek. The stream cuts down through the escarpment and exposes the limestones and the underlying gypsum beds. A 6-foot layer of gypsum is exposed along the creek from 1 to 2 miles west of Indian Falls and about 30 feet above the creek, while above it lies an 8-foot layer of a more impure and harder gypsum.

The deposits are included within the Indian Reservation; in 1901 the Standard Plaster Co. secured the mineral right to the whole tract and began mining operations. Tunnels were driven into the 6-foot layer, using Howell's twist drills and black powder. The rock mined was loaded on flat mine cars and pushed by hand to the tunnel entrance where the good gypsum was loaded on cars and the waste rock thrown on the dump. From the mines the rock was carried by a railroad switch to the main line of the West Shore near Alabama, the switch being 3 or 4 miles long. The rock was then sent to Black Rock where the company had a mill equipped with a gyratory crusher and screen, one Cummer calciner, one cooling bin and five Sturtevant emery mills. The power was electric. The mines are now completely abandoned. Underground water and the presence of mud pockets are said to have been the main difficulties in the way of success. Similar trouble is encountered in nearly all gypsum workings, and it seems plausible that the conditions in the latter respect at least would have improved with the extension of the tunnels for some distance under the hill. The beds could also be worked through shafts.

The known gypsum beds of the Akron district begin 2 miles west of this locality. These will be discussed under Erie county.

LIST OF WORKINGS

1. Mill,
2. Shaft,
   Akron Gypsum Co.

3, 4. Shafts,
   American Gypsum Co.

5, 6. Test holes.

7. Abandoned workings
   Standard Plaster Co.

8, 9. Shafts,
10. Mill,
   Niagara Gypsum Co.

11, 14. Shafts,
12, 13. Mills,
   U. S. Gypsum Co.

The proven gypsum territory near Akron is shown by dotted area.

MAP OF OAKFIELD AND AKRON DISTRICTS

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It seems probable that large quantities of gypsum as yet uncovered must lie near the surface in Genesee county. They are likely to be found from Fort Hill westward through South Byron and Newkirk to Oakfield, north of the limestone escarpment; thence following the escarpment in a westerly direction to Alabama and southwesterly to Akron. There is also room for development to the south of the outcrop of the dolomites, but these areas constitute a reserve for the future after the exhaustion of the beds near the surface.

Erie county

Entering Erie county at a point 2 miles northeast of Akron the escarpment formed by the Onondaga limestone and underlying waterlimes passes through Akron southwesterly to Clarence, thence westward parallel to and ½ mile north of the Clarence-Williamsville road. It continues through Williamsville and follows rather closely the road from Williamsville to Buffalo. Within the city of Buffalo its limits are as follows:[1]

It follows the general direction of Main street from the Almshouse to near the New York Central Railroad belt line at Rodney and Fillmore avenues. After crossing Main street, it passes near the corner of Oakwood and Woodward to Oakwood and Parkside and enters the park at the stone quarry, crossing from there into the cemetery at the corner of the iron fence near Agassiz place. From here it sweeps around in a curve to Scajaquada creek at Main street bridge and passes out of sight beneath the drift on the left bank, about 300 feet below the bridge.

Of the escarpment Bishop says: "The hydraulic limestone is usually visible at the base, or north side, of this escarpment as a stratum of variable thickness in the face of the cliff but occasionally forms a terrace ranging from a few feet to 200 yards in width and approximately parallel to the escarpment. This terrace is most conspicuous between Williamsville and the Buffalo city line."

Very few exposures of the Salina shales north of the escarpment are recorded. The area is very flat and uniformly drift-covered. A small outcrop on the southern end of Grand Island and an outcrop along the Canadian bank of the Niagara from near the International bridge to a point opposite Strawberry island show the Camillus shales to be "soft light gray or olive gypseous shales."[2] Borings would seem to indicate an absence of the Ver-

[1] Bishop, I. P. N. Y. State Geol. An. Rep't 15. 1895. p. 312.
[2] Luther, D. D. N. Y. State Mus. Bul. 99, p. 8.

non shales, and Luther places the entire thickness of Salina shales at 333 feet. The overlying Bertie waterlime has a thickness of 53 feet at the Buffalo Cement Co's quarry, while the Cobleskill above varies from 7 to 9 feet near Buffalo to 12 feet at Falkirk near Akron.

Although gypsum beds of good quality no doubt occur below the Bertie waterlime, no definite information can be obtained of such deposits with the exception of the important ones at Akron and those encountered in the wells of the Buffalo Cement Co. at Buffalo.

Many gas wells drilled in Buffalo and to the eastward along the escarpment report varying amounts of "gypseous shales," "gray and white gypsum," etc., but careful examination of such records fails to lead to any definite knowledge. They were all drilled by churn drills in search of *gas* not *gypsum,* and little dependence can be placed on the data relating to the latter, either as to its quality, thickness or its depth from the surface.

The occurrence of gypsum at Buffalo was well established by the work of the Buffalo Cement Co. described by Ashburner.[1]

The Buffalo Cement Co. drilled a series of wells near the Main street crossing of the belt line in search for gas. Well no. 1 was drilled to a depth of 490 feet 6 inches with a diamond drill. Well no. 2 was drilled 6 feet from well no. 1 with a 5⅝ jump drill to a depth of 1305 feet. The core of well no. 1 is in the possession of the Buffalo Academy of Natural Sciences. The record of no. 2 as given by Ashburner is as follows:

DEPTH Feet	MATERIAL
1–25	Shale and cement rock in thin streaks
25–30	Tolerably pure cement rock
30–43	Shale and cement rock in thin streaks
43–47	Pure white gypsum
47–49	Shale
49–61	White gypsum
61–62	Shale
62–66	White gypsum
66–73	Shale and gypsum, mottled
73–131	Drab colored shale with several layers of white gypsum, measuring 18 feet in all
131–33	Dark colored limestone
133–37	Shale and limestone
137–40	Dark colored compact shale
140–720	Gypsum and shale, mottled and in streaks
720–25	Limestone
725–60	Soft red shale
760–85	White solid quartzose sandstone, very hard
785–1305	Soft red shale

[1] Ashburner, C. A. Petroleum and Natural Gas in New York. Am. Inst. Min. Eng. Trans. 1888. 16:924–27.

Plate 10

Shaft of U. S. Gypsum Co., Oakfield

At 1305 feet the drill was stopped. Permanent water was struck at 43 feet; gas of fair quality as well as quantity, at 452 feet; salt water, leaving on evaporation about 12 per cent of salt, was found at 555 feet. A shaft 20 feet square, was sunk on the premises later, for the purpose of determining the feasibility of mining the gypsum, but the rush of water through the gypsum layer at 43–47 feet, was so strong that a pump with a capacity of 2000 gallons per minute failed to make any impression upon it, and the attempt was abandoned.

Since then no further effort to exploit the gypsum has been made, though by reason of its quality and situation it seems to offer an attractive field which would warrant more thorough investigation than has been given to it.

The Akron gypsum "basin," as it is locally termed, is situated northeast of the village of Akron or 20 miles west of Buffalo. The productive area lies south of the West Shore Railroad, with which connections are made by long switches.

The boundaries of the workable bed or beds of gypsum have been rather well defined by the sinking of various shafts and the putting down of a number of core drill holes. On the northern side the boundary seems to follow rather closely along the Bloomingdale road running northeast from Akron, beginning at a point a little west of the Akron Gypsum Co's shaft and running northeasterly about 2 miles. The drill holes put down by the various interested parties in the vicinity and an unsuccessful shaft north of the road on the Akron Gypsum Co's property indicate an abrupt termination of the gypsum deposit north of the road and a large amount of unconsolidated material. There is a possibility that this low lying area represents a channel formed during the glacial period and subsequently buried or filled up with glacial till, and that the scouring out of such a channel has robbed that area of large amounts of gypsum.

In width the basin ranges up to over a mile. The whole area could be represented as pear-shaped with the small end lying just west of the Akron Gypsum Co's shaft and the large end east of the American Gypsum Co's plant.

The southern boundary is the least well defined, since the beds extend on toward the south under the escarpment of Helderberg and Onondaga limestones, which rises to a hight of 100 feet above the low lying flat on which the plants and mines are situated. It is said that a test boring drilled through the limestones on the "ledge" directly south of the Akron Co's shaft gave but a foot of good gypsum, while two recent drillings made on the Newman property along Murder creek just south of Akron showed the presence there of but a small amount of gypsum. These would seem to define the limits of the western end of the basin. The boundaries of the eastern end under the ledge south of the American Gypsum Co's shaft have received but little attention, and nothing could be learned concerning them. The bed of gypsum as mined consists of a 4 to 5-foot bed of light colored crystalline or granular gypsum. It is overlain by from 25 to 50 feet of thinly bedded impure limestones, and these in turn are rather heavily covered by a mantle of glacial clay varying from a few feet up to 25 feet in thickness. The section at the new (no. 2) shaft of the American Gypsum Co. is as follows:

MATERIAL	THICKNESS	
	Feet	Inches
Drift clay	18	......
Rock (waterlime)	3	4
Clay	3	......
Rock (waterlime)	3	8
Clay, water-bearing	4	......
Rock (waterlime)	21	......
"Ashes"	......	4
Gypsum	1	......
Rock (waterlime)	2	......
Rock, roof (waterlime)	2	......
"Ashes"	......	8
Gypsum	4	......

Other sections in the vicinity are very similar, so that the above might be taken as typical. The clay beds below the drift are evidently a series of soft weathered shales and are frequently a serious source of annoyance to mining operations on account of the large amount of water they contain. They are often so thoroughly saturated with water as to be veritable "mud seams" of soft fluid clay. Above the main gypsum bed so called "ashes" (an impure shaly gypsum or a mixture of selenite and shale) and even more massive gypsum rock is found in small layers.

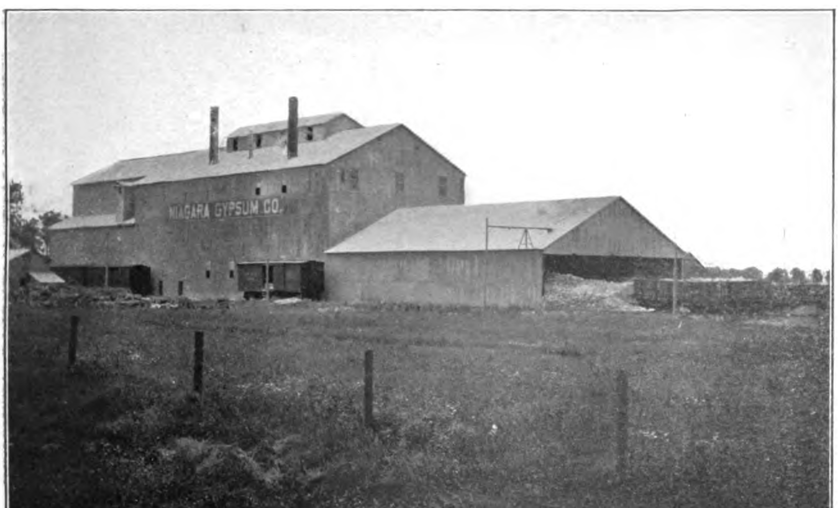
The acreage known to be underlain with gypsum is controlled mainly by three companies, the American Gypsum Co., the Akron Gypsum Co. and the United States Gypsum Co., of which the two companies first mentioned are engaged in the mining and milling industry, while the United States Gypsum Co. does not at present work its property. The whole field is comparatively new, the first development work having been done in 1903.

American Gypsum Co. This company operates a large crushing plant and mines 2½ miles northeast of Akron on the boundary line between Genesee and Erie counties, the lands on which it owns mineral rights being situated on both sides of the line. En-

Plate 11

Shaft of the Niagara Gypsum Co., Oakfield

Plate 12



Mill of the Niagara Gypsum Co., Oakfield

trance is had to the mine by means of a shaft 60 feet deep. This shaft is divided into three compartments, one 5 by 8 feet for air passage and stairway; one 6 by 8 feet for passenger elevator; and one 6 by 8 feet accommodating the bucket elevator. Mining is carried on underground much as in coal mines, the most approved methods being employed to secure economy and safety. The gang-

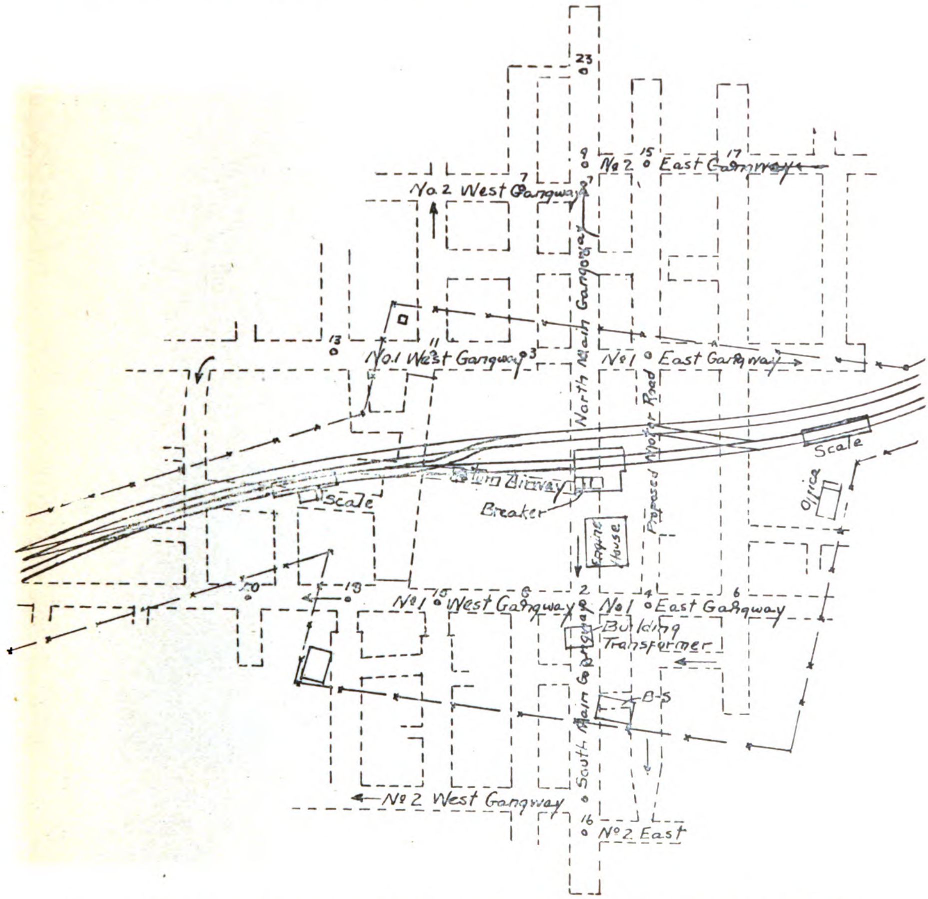


FIG. 5 Map of the surface plant and underground workings of the American Gypsum Co., Akron

ways are carried 6 feet high and are wide enough to admit of using the 2 feet of barren rock taken from below the gypsum bed for a supporting wall on either side of the gangway. The rooms are driven 24 feet wide by 300 feet long and their hight is simply the thickness of the vein, or 4 feet. Pillars 24 feet wide and alternately 40 or 60 feet long are left, each being separated by a 20-foot cross cut. Good ventilation is afforded by the use of a 9-foot Buffalo Forge Co's exhaust fan operated by a 9½-horsepower motor. Excavation is done by contract, the miner buying his blasting materials and hiring his assistant who loads the cars. For drilling, Howell's no. 2 air drills are used. The air compressor is driven by an 85-horsepower motor. This compressor also furnishes power for the pump at the bottom of the shaft.

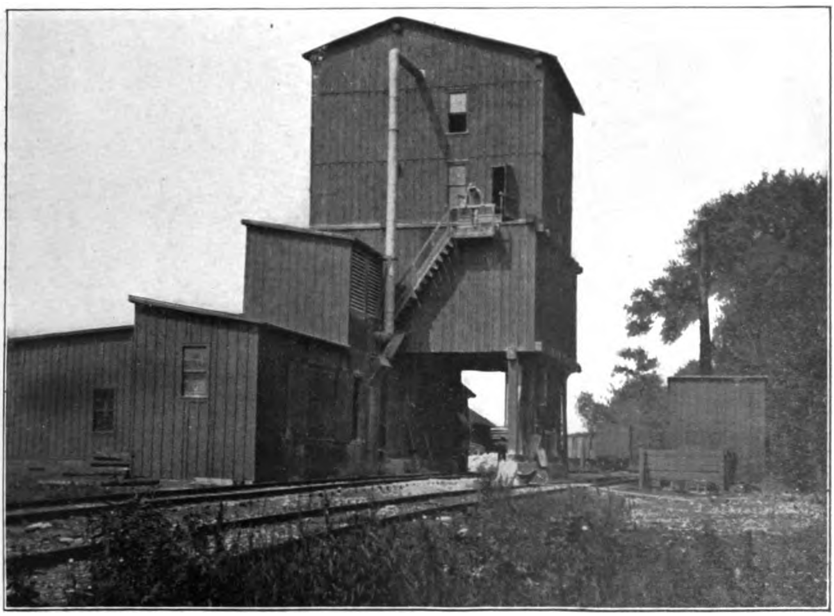
At present the cars are drawn from the rooms to the shaft by means of mules, but the managers are planning a system of electric haulage which will do away with all mule haulage in the gangways. The mine is well lighted by electric lights, well ventilated and kept dry. At the foot of the shaft the mine cars, holding about one long ton, are dumped by a side dump into a steel hopper which carries the rock to a point where it is picked up in the buckets of a vertical bucket elevator which hoists it to the mill overhead. This elevator is 110 feet long, contains 175 buckets and travels 80 feet per minute.

The rock is thus hoisted into the mill built directly over the shaft, is discharged into a 36-inch by 42-inch Jeffrey crusher where it is immediately crushed and then screened, all material over 1 inch in size being reelevated to the crusher. The crushed rock is then ready for shipment, the whole product being sold crude to cement factories. The dust arising from the grinding is carried by suction through pipes into a series of long vertical cloth sacks where the air escapes and the dust remains on the inner surface of the sack. At intervals the bags are shaken and the dust allowed to collect at the bottom. No use is being made of the dust at present, though it seems adapted for certain purposes by reason of its fineness and nearly pure white color.

All the machinery in both mine and mill is driven by electric power from Niagara Falls. The current furnished at 11,000 volts over a 3-phase 25-cycle line, is taken to a concrete transformer house where it is stepped down to 440 volts. It is then supplied to an 85-horsepower motor for an Ingersol-Rand compressor, to a 100-horsepower motor for the Jeffreys crusher and bucket conveyor, and to a 9½-horsepower motor driving the 9-foot ventilating fan. For the electric lighting, the current is passed through a 5-kilowatt transformer.

At the time the plant was visited in June 1909 a second shaft 64 feet deep had been sunk 1420 feet west of the working shaft, and preparations were under way to erect a breaker and extend the

Plate 13



Shaft and mill of the American Gypsum Co., Akron

railroad switch to that point. A sketch map of the underground workings is shown in figure 5, page 55.

There is a large flow of water into the workings, as in all the shafts of this field, but drainage is accomplished satisfactorily.

Akron Gypsum Co. The mill of this company is situated 1 mile northeast of Akron on the Bloomingdale road. The mine is situated southeast of the mill and is connected with it by a narrow gage gravity railroad. Mine and mill are comparatively new, active operations having begun in the fall of 1908. Mr George Ralph is manager. Entrance is had to the mine by a 6 by 12-foot shaft divided into two 6 by 6-foot compartments, and is 84 feet deep. Mining is conducted by the company itself and not under the contract system. The men are divided into gangs, each consisting of a machine man operating the drill and doing the blasting, a helper and two muckers. A large number of Indians from the nearby Tonawanda Reservation are employed in the mines and are giving very good satisfaction. Drilling is done by compressed air. The mining system in vogue is based on the old method of extraction by means of radiating gangways which center at the shaft. Pillars are left 30 feet apart and about 10 feet thick. The mine cars are pushed to the bottom of the shaft by hand, each man being required to push 30 cars a day and receiving a bonus for all additional cars. The gypsum bed as mined varies from 4½ to 5 feet thick, so that with the present methods of handling the cars, it is unnecessary to excavate any bottom rock. When first opened, 4000 gallons of water a minute were pumped from the shaft and although the flow has since been greatly reduced, a 4-inch pump is still kept in operation most of the time and the mine is quite wet. No forced ventilation is employed, a small airway on the east side of the shaft giving sufficient air. The mine cars brought to the bottom of the shaft are run directly on the platform of the hoist and are raised to the surface by a small drum hoist working in balance and driven by a steam engine. The cars are raised to a level above the ground and are dumped either directly into 2-ton steel cars on a gravity track or are dumped on the reserve pile. The cars are run by gravity to the mill and are hauled back in a string by a horse. At the mill which is situated just north of the Bloomingdale road the cars are hauled up an incline and dumped automatically into a Butterworth & Lowe jaw crusher. From this crusher the material passes directly to a "cracker" of the usual type, which reduces it to pieces no larger than hickory nuts. It is then elevated and distributed to five 42-inch French buhrstones, where it is ground to a fine powder. This is then screened on 60-mesh brass shaking screens inclined at a 45° angle, and all material above 60-mesh is returned and reground. Screw conveyors carry the ground material to Butterworth & Lowe kettles, three in number. These have a capacity of 10 tons each and have nonsectional bottoms. They are fired by bituminous coal and use about a ton of coal a week, the calcining being carried to the point of second settling. The use of a blast of natural gas and compressed air in firing the kettles is being contemplated. The dust arising during calcining is caught in steam-filled chambers and returned to the kettles. From the kettles the plaster is conveyed to a large storage bin holding 900 tons. Some of this 60-mesh stucco is sold to outside companies for mixing, while some is reground on three 36-inch Munson buhrstone mills so that it is practically of 100-mesh and is thus sold for fine finishing plaster. The plant is equipped with two five-compartment Broughton mixers and makes various wall plasters with hair and wood fiber. They manufacture their own supply of wood fiber, obtaining their wood, mostly poplar, willow and basswood, from the neighboring farmers. The wood is shredded on a Hoover improved wood fiber machine, made at Perrysburg, O. The hair used is washed goat's hair and is purchased in bales. The sand is obtained from the company's own pit situated close by the mill. The wood fiber made is mixed in the following proportion: 1 ton stucco, 30 pounds wood fiber and 10 pounds retarder. The wall plaster containing hair is mixed in the proportion of 1 ton of stucco to 3 pounds of hair, when it is then ready for the sand. Raw ground gypsum from the buhrstones is also sold as land plaster to nurseries, experimental stations and to fertilizer firms. Power for the entire mill is furnished by three Bessemer gas engines no. 3146, speed 180 revolutions per minute, 125 horsepower, developing altogether 400 horsepower. A Rand compressor engine no. 10 also is operated by gas and furnishes compressed air for the mine and for a small machine used in dressing the buhrstones, each of which requires redressing about every three weeks. The natural gas used is furnished by the Akron Gas Co. through a direct pipe line from Alden. It comes in under a pressure of 125 pounds but is throttled down to 8 ounces for use. The gas costs 25 cents a thousand feet and about 40,000 feet a day are used, bringing the total cost up to $10 a day for fuel. The capacity of the mill is 300 tons of plaster a day.

Plate 14

Mill of the Akron Gypsum Co., Akron

CHARACTER OF THE GYPSUM IN NEW YORK; CHEMICAL ANALYSES

Within the long stretch of Salina strata from Madison to Erie county are included gypsum deposits of different physical and chemical characters. These variations are conditioned mainly by the relative proportions and nature of impurities present and to a lesser extent by the different conditions in which the gypsum itself is found.

While the deposits all belong to the general class of rock gypsum, from the descriptions of the individual deposits already given it is possible to distinguish two types that seem to be separate in their occurrence and may have originated under somewhat different conditions. The first of these is represented by the dense firm gypsum in which the impurities are evenly distributed so as to give the appearance of a more or less homogeneous mass. This is the usual rock gypsum which forms the basis of the calcined plaster industry in New York and in most places elsewhere. It consists of a ground mass of finely divided gypsum fibers or elongated acicular crystals in felted arrangement, with occasional larger individuals that stand out prominently by their brilliant cleavage surfaces. The other type is characterized by a loosely cemented aggregate of gypsum and shale, the two constituents being plainly discernible. The gypsum is usually in large crystals or crystal aggregates which by themselves are transparent and quite free from impurities. The deposits of this type are built up of successive thin layers of the selenite and shale. When the mass is exposed to the weather, the shale decomposes quickly and falls away from the gypsum so that in outcrops it may have the semblance of a high grade deposit. This type is known to the gypsum miners as "ashes," owing probably to the grayish color and powdery nature of the shale. It was quite extensively worked at one time for land plaster, but is evidently unsuitable for calcination.

The chemical composition of the gypsum found in different sections of the Salina outcrop is shown by the accompanying detailed analyses of samples which were collected during the recent field work. The samples represent the run-of-mine gypsum as now utilized, having been collected from the stock bins of the different mills. The analyses were made by George E. Willcomb.

	1	2	3	4	5	6
SiO_2	.51	1.03	.40	2.93	8.31	4.00
Al_2O_3	1.19	.41	2.97	1.92	4.53	1.74
Fe_2O_3	.79	1.27	.77	1.10	1.34	1.11
CaO	30.62	30.74	30.76	26.27	21.50	29.36
MgO	1.20	2.01	1.53	8.29	7.20	2.81
SO_3	43.59	42.39	43.78	33.83	30.47	35.79
CO_2	1.02	2.20	2.80	11.02	9.50	6.38
H_2O	20.52	18.19	17.53	14.87	14.53	17.93
	99.44	98.24	100.54	100.23	97.38	99.12
Gypsum calculated	93.74	91.27	94.26	72.84	65.49	77.06

1 Akron, Erie co.
2 Oakfield, Genesee co.
3 Oakfield, Genesee co.
4 Garbutt, Monroe co.
5 Lyndon, Onondaga co.
6 Lyndon, Onondaga co.

The following incomplete analyses are from the paper by Arthur L. Parsons,[1] with the exception of no. 8 which is taken from *The Mining and Quarry Industry of New York State for* 1907.[2]

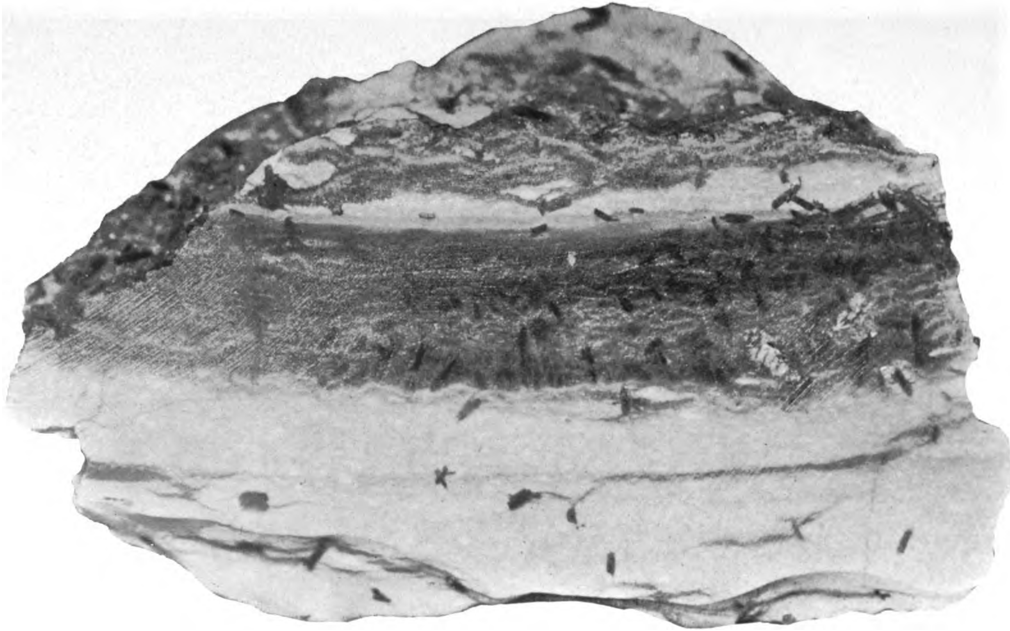
	1	2	3	4	5	6	7	8
Gypsum	82.5	70.3	94.03	74.09	64.53	73.92	82.66	87.48
Silica & insol.	....	....	.....	6.05	11.17	4.62	3.86	3.34
Other matter	17.5	....	5.97	19.86	24.27	21.44	13.48	8.93

1 Wheatland, Monroe co. Under "other matter" are included $CaCO_3$ 1.75; $MgCO_3$ 3.6.
2 Wheatland, Monroe co. Analysis furnished by Iroquois Portland Cement Co.
3 Wheatland, Monroe co. Analysis furnished by Consolidated Wheatland Plaster Co.
4 Union Springs, Cayuga co.
5 Fayetteville, Onondaga co.
6 Fayetteville, Onondaga co.
7 Cottons, Madison co. "Other matter" includes Al_2O_3, Fe_2O_3 1.84; $CaCO_3$ 6.57; $MgCO_3$ 5.07.
8 Jamesville, Onondaga co. "Other matter" includes Al_2O_3, Fe_2O_3 2.92; $CaCO_3$ 3.33; $MgCO_3$ 2.69.

The analyses indicate that the gypsum content of the rock ranges between the general limits of 64 or 65 per cent and 95 per cent. The grade apparently improves toward the western end of the section, in Genesee and Erie counties, where the average is above 90 per cent. The rock in this part is also the lightest in color and yields nearly white plaster.

[1] N. Y. State Geol. An. Rep't 23. 1904.
[2] N. Y. State Mus. Bul. 120. 1907.

Plate 15



Rock gypsum showing banding and porphyritic crystals, Akron

The impurities of the rock are such as might be expected from the stratigraphic associations. The principal foreign ingredients are lime and magnesia carbonates, clay and quartz. The iron shown by the analyses is mostly present probably in the clay. The high percentage of magnesia in the rock of the eastern section is a striking feature, since it appears to be greatly in excess of the proportions found in dolomites. The presence of free carbonate is thus indicated.

PERMANENCE OF THE GYPSUM SUPPLY

There are no sufficient data on which to base an estimate of the available gypsum supply, but in view of the magnitude of the known deposits it would be a gratuitous task to attempt any formal calculation. The production of 4,000,000 or 5,000,000 tons in the past is insignificant as compared with the amount that still lies on the surface. It represents an equivalent of 40 or 50 acres of the thickest beds, such as are found in Onondaga and Cayuga counties, or about 400 acres of one of the 4-foot beds in the western section. The existing mines and quarries could maintain the present rate of production of 350,000 tons a year for an indefinite time. The extension of the workings in depth or the opening of additional areas on the outcrop will bring new supplies, as they are needed, into the zone of exploitation.

METHODS OF PROSPECTING AND EXPLOITING THE GYPSUM DEPOSITS

There are certain facts and inferences bearing upon the distribution of gypsum in the New York Salina beds that may be found useful in the conduct of exploratory work.

The main deposits occur in the upper Salina shales, and therefore their horizon of outcrop is near the southern border of the belt as traced on the map. Little is known of the character of the gypsum which belongs to the salt-bearing shales proper, and if represented anywhere in the present workings its identity has not been established.[1] The pockets of impure gypsum that are described from the eastern section of the belt quite likely occur at different horizons, since they are probably due to solution and redeposition of the gypsum rock, but they have little industrial importance.

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[1] The deposits once worked at Port Gibson, Ontario co. seem to lie at a lower horizon than the other occurrences in the State and may be below the Camillus shale. The present investigation, however, did not uncover any definite evidence of their association with the rock salt series.

The best indicator of the position of the gypsum is the Bertie waterlime, which is found above the deposits in exposures along the sides of valleys or hills, or to the south of them when the surface is flat. It is much more resistant to erosion than the Salina shales, and together with the overlying limestones can often be traced in outcrop by the character of the topography. A very noticeable escarpment formed by the limestones extends across Erie, Genesee and Monroe counties, where it is known as the "ledge." The Salina shales occupy the plain between this escarpment and the parallel one to the north formed by the Niagaran limestones.

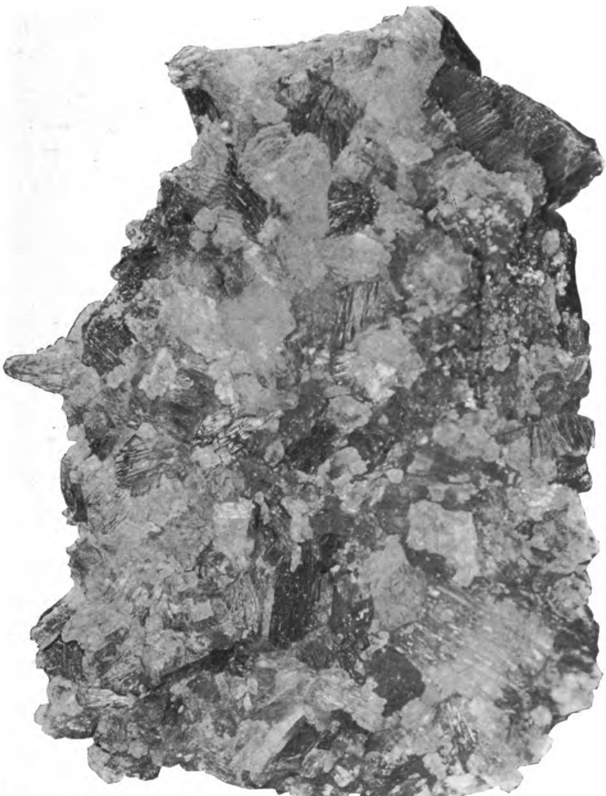
The absence of a protecting cover of limestones leaves the gypsum open to the attack of weathering agencies which may result in the partial or complete removal of surficial deposits. This seems to be the prevailing condition in the western section where the gypsum is very rarely seen in outcrop.

The sampling of gypsum must be conducted with care and intelligence. The successive layers or strata may show wide variations in purity, and it is generally better to sample each separately so that the series of analyses will reveal their individual character. Sometimes it may be found practicable to work only certain beds, leaving the poorer material in the roof or floor of the mines. In sampling the pocket deposits of friable shaly gypsum, close attention is required that the mass of fibers or crystals may not be unfairly sorted from the impurities.

The beds of rock gypsum can be explored to best advantage by core drilling. It is difficult in most cases to form an accurate estimate of their quality and thickness from exposures, except where these result from previous quarrying or mining operations. The sites of the drill holes should be selected with due allowance for weathering and solution of the gypsum near the surface. Besides affording accurate samples for analysis the cores will give valuable information as to the character and thickness of the covering.

The core drill is absolutely essential for exploration in Genesee and Erie counties, since the surface in that section is almost level and the deposits lie at depths of from 40 to 80 feet. Its advantage over the churn drill is so obvious and decisive that there can be little excuse for the continued use of the latter for such work. After the glacial material is once passed, no difficulty need be anticipated in securing cores of the limestones, shales and gypsum with a 2-inch diamond drill. As a rule the glacial drift of western

Plate 16



Selenite from shaly deposits, Onondaga county

New York can be penetrated without much trouble, as boulders are usually scattered and of no great size.

The extraction of gypsum by open cutting is necessarily confined to the eastern and central sections. The pocket deposits are worked only in a small way after the simple methods of early days. More systematic operations are carried on in connection with the rock gypsum of Onondaga and Cayuga counties. The beds are exposed along the sides of hills with a thickness of from 20 to 60 feet. The quarries at Lyndon, Jamesville and Union Springs are opened on such natural exposures. The overlying limestones and drift are stripped off or allowed to fall into the excavation left by the removal of the gypsum. As the work advances into the hill an increasing amount of overburden is encountered and in the course of time becomes a serious problem necessitating a change to underground mining or the abandonment of work altogether. There are many abandoned quarries around Fayetteville. At Union Springs the drift covering is stripped by steam shovels, and the material loaded on cars for removal to a dump. The breaking of the gypsum rock is effected by drilling and blasting with black powder or dynamite. Both hand and power drills of the percussion type are used in the quarries, the latter having perhaps less than the usual advantage over handwork on account of the soft nature of the material.

In the western section the gypsum is mined underground, and this practice has also been introduced recently in some of the quarries around Fayetteville to obviate the handling of the overburden. Entrance to the workings is had through an adit where the gypsum approaches sufficiently near the surface, otherwise a vertical shaft is used.

The main adits which serve for haulage are driven from 5 to 8 feet high and from 6 to 10 feet wide. The larger dimensions refer to the mines near Jamesville, where the gypsum is excavated in large rooms and removed by two-horse wagons that are loaded directly at the working face. With thin beds the rock is hauled out on mine cars attached to a cable. In some cases a foot or so of the floor rock is removed to provide the necessary head room, but this is generally unnecessary. The size of the rooms ranges up to 30 feet square. The overlying limestone makes a firm roof and little support is needed in addition to that given by the pillars; timbering or backing is only rarely necessary.

The mines at Akron and Oakfield, as well as those of the Consolidated Wheatland Co. at Wheatland and the Garbutt Gypsum Co. at Garbutt are entered through vertical shafts from 50 to 70 feet deep. The shafts have either two or three compartments, one of which serves for a ladder and airway. The underground workings follow the room and pillar system but are more regularly planned than these of the adit mines and are based on accurate surveys. The early methods of extending the drifts radiately from the shaft or in a haphazard manner are no longer pursued to any extent. The mines are often electrically lighted, ventilated by forced draft and when necessary are drained by pumps which raise the water from a sump at the shaft bottom. Gas, electricity and steam are used for power purposes, the former being supplied from the natural gas belt of western New York. Electric locomotives have been recently introduced for underground haulage, but in most mines the cars are either pushed by hand or drawn by mules. The hoisting is accomplished in various ways. At the Garbutt mine a derrick and boom raise the rock which is loaded into a metal scoop. The American Gypsum Co. has installed at Akron a bucket elevator. Single and balanced platform hoists which raise the gypsum in the mine cars are most generally employed.

The rock is broken by drilling and blasting. Auger drills are used in some mines and percussion drills in others, the former being employed when the rock is sufficiently soft. With hard or tough rock they are apt to become heated and to bind in the holes. Some companies prefer to let the mining on contract, while others maintain the wage system. The miners represent all nationalities but are mainly from southern Europe. A few Indians from the New York reservations are employed.

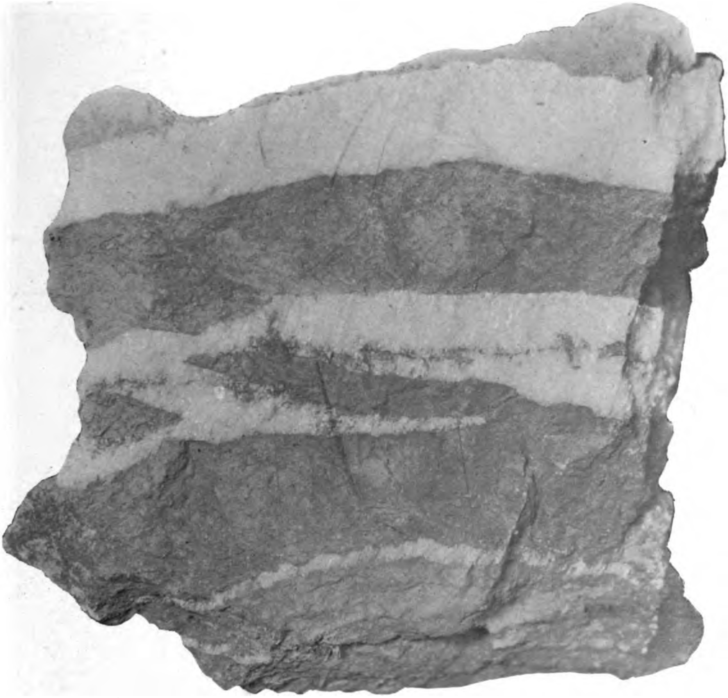
The mines are usually connected with the milling plants by tracks. In the Fayetteville district, however, the rock is teamed, except in one case where a traction engine is used to draw a 20-ton wagon, and the haulage is here an important item of the working costs. Much of the output of this section is shipped in lumps or ground form to cement and plaster mills outside the district.

ORIGIN OF GYPSUM

General principles and theories

Gypsum is formed by the combination of sulfuric acid with lime in the presence of water. The sulfuric acid need not necessarily be in free state, since almost any soluble sulfate may react upon lime

Plate 17



Satin spar in veins formed by secondary deposition in shale,
Ontario county

minerals, specially the carbonates, to produce an interchange of bases. Wherever a source of sulfuric acid exists in nature, the formation of gypsum may be expected under ordinary circumstances, as the other essentials are nearly always at hand.

The derivation of sulfuric acid can be traced most commonly to the oxidation of the sulfur occurring in metallic sulfids. The iron sulfids — pyrite, marcasite and pyrrhotite — are particularly widespread both as rock-forming minerals and in ores. When exposed to atmospheric influences they are subject to rapid decomposition, yielding such compounds as hydrogen sulfid, sulfurous and sulfuric acids, ferrous sulfate and iron oxids. The presence of hydrogen sulfid in the spring waters that issue from the shales and sandstones of western New York is an illustration of the decomposition of iron sulfids which are disseminated in the shales. In the Oak Orchard spring at Byron, Genesee co. sulfuric acid of similar derivation exists both free and combined with lime, magnesia and the alkalis. Another source of the acid is from the decay of organic matter, which yields hydrogen sulfid in the first instance. This gas, as well as sulfur dioxid, is also given off by volcanos, fumaroles and hot springs, and gypsum is frequently deposited near their vents by the action of the acid vapors and waters upon lime minerals.

With the supply of sulfuric acid that is made available in these ways the formation of gypsum takes place very generally throughout the zone of weathering and ground-water circulations. Under some conditions the gypsum may accumulate directly in sufficient amount perhaps to have economic importance, as when acid solutions from the decomposition of pyrite come in contact with beds of limestone. But more generally it is carried in solution until the waters reach the surface and are concentrated by evaporation. Though gypsum dissolves rather slowly in pure water, its solubility is greatly increased in the presence of salts of the alkalis, specially sodium chlorid, so that sea water for example is a much better solvent than fresh water. It is by concentration of the surface waters held in some inland basin, lake, or arm of the ocean that the valuable deposits of gypsum are usually formed.

Deposition of gypsum from sea water. The deposits that result from the evaporation of sea water have been investigated by J. Usiglio, Van't Hoff and others. Usiglio in 1849 carried out a series of laboratory experiments which outline very well the general conditions of their formation, though his results have been amended in some respects by the later works of Van't Hoff and his associates. The experiments were based on samples of water taken from the Mediterranean, which has a slightly higher content of solid matter than the open ocean, but which does not differ noticeably in the relative proportions of the several ingredients.

By evaporation of the water, which at the start had a density of 1.02, no marked deposition took place until the specific gravity of 1.05 was reached, when the volume had been reduced to 53 per cent of the original. Between this density and that of 1.13, the iron oxid and calcium carbonate were precipitated. Then, with a volume of only 19 per cent of the original, the solution began to deposit gypsum which continued to come down until the density reached 1.26. At a density of 1.214, when only 9.5 per cent of the solution remained, salt was deposited along with magnesium sulfate and chlorid. Further concentration brought down the more soluble salts in variable order, but sufficient details have been given for the present purpose.

The sequence of deposits from sea waters accordingly is first limestone and ferric oxid, next gypsum, and then salt and magnesium compounds. Gypsum is precipitated when 81 per cent of the water is evaporated and salt when a little over 90 per cent is removed.

The formation of gypsum beds in association with limestones and salt deposits is thus a simple process. But the evaporation of a relatively shallow lake or an arm of the sea alone would scarcely afford any considerable thickness of gypsum. Of the total solid matter in sea water, amounting to 3.5 parts in 100, only about 3.6 per cent consists of calcium sulfate. The extensive accumulations of salt and gypsum are to be explained, probably, by some such method as that advocated by Ochsenius. According to his theory the deposition occurred in nearly inclosed arms of the sea or lagoons. If a bay or lagoon is connected with the sea by a narrow and shallow channel, evaporation will cause the denser brine formed at the surface to sink and concentrate at the bottom while its diffusion will be prevented by the shallow opening seaward. Surface currents may enter from the sea, however, to maintain an equilibrium with evaporation. Provided there is little land drainage in the bay, the salinity of the water will increase until saturated, and deposition of the constituents will then occur in regular sequence. The process may be interrupted of course at any time by an unusual influx of water, or there may be periodic fluctuations of supply so as to produce an alternating series of deposits. That this method of concentration affords an explanation for many of the salt and gypsum beds is made probable by the fact that there are present day examples of its operation. Some of the bays on the shores of the Caspian sea are now depositing salts, while the waters of Kharaboghaz, which are almost shut off from the sea by long spits that leave only a shallow channel between them, are in process of concentration and are fed by a surface current that is estimated to bring 350,000 tons of salt a day into the gulf.

According to this theory the evaporating basin is in effect a continuous salt pan and the thickness of the deposits that might be formed is limited only by its depth.

Formation by conversion of limestone in place. Where ground waters are supplied more or less constantly with available sulfuric acid, from pyritic shales for example, it is not improbable that they may convert large masses of limestone into gypsum during the course of time. The gypsum would retain perhaps the bedded structures of the limestone and would thus closely resemble the deposits from sea water. Just what importance is to be placed upon this method in relation to stratified deposits in general can not be stated, though some geologists have advocated its application to extensive occurrences, including those of New York State.

There is no doubt that this process operates in a small way. Scattered masses and crystals of gypsum formed by the reaction of acid solutions upon lime are found in the clay beds along the Hudson river. The indurated shales upon which the clays rest are impregnated with pyrite, which affords a source of sulfuric acid, while the clays themselves contain lime carbonate to the amount of several per cent. The gypsum is often well crystallized in detached individuals but has no economic value.

Gypsum deposited by ground waters. Ground waters holding calcium sulfate in solution may come to rest in joints, fissures or other openings in rocks, where evaporation may bring them to the point of saturation. The gypsum usually separates in the form of selenite or in the fibrous aggregate known as satin spar. The gypsum strata with their inclosing rocks are frequently veined and seamed by such secondary deposits. The cavities thus filled may have been very narrow at first, but were widened gradually by solution and possibly as well by the expansive force of the growing crystals. The force of crystallization is regarded by some geologists as an important factor in the formation of cavities occupied by minerals deposited from solution. Though its magnitude is not definitely established, it is considered in general to be measurable by the crushing strength of the minerals themselves. If such be the case, it is apparent that large masses of gypsum might be built up within cavities of originally small compass, such as joints and the openings along bedding planes.

An example of the accumulation of salt and gypsum by the work of ground waters is found according to G. D. Harris[1] in the so called "Five Islands" or "Salt Islands" of Louisiana which rise as dome-shaped hills above the low coastal plain of the gulf. The domes are not due apparently to differential erosion but have been actually uplifted *en masse*, so that the strata dip away from their centers on all sides only to become horizontal as the plain level is reached. Their uplift has been ascribed previously to different agencies, including gas pressure, water under a great head, and to deep seated igneous masses which are working toward the surface. Harris finds that the domes occur at the intersections of master faults and thinks the faults have served as channels for the ascension of saline waters from great depths. With temperatures corresponding to their source in the interior at the start the waters would rise throughout the faulted strata and be compelled to precipitate their salts as they become cooler on their way. The solvent power of water for sodium chlorid decreases most rapidly between the temperature of 180° and that of 120° C. so that the precipitation of this salt would take place in greatest amount at considerable depths. The tendency therefore is to form a cone which, slender at first and pressing against the surrounding strata, would grow broader and longer by deposition at the base. The force of crystallization, it is thought, might move the mass upward spreading out the strata on all sides. With the deposition of salt the power of holding calcium sulfate in solution increases until the salinity is reduced to about 14 per cent, after which it rapidly decreases. Cooling of the solution down to about 40° C. also increases the solubility. The formation of gypsum would take place accordingly near the surface, and it is noted that the gypsum of Louisiana and Texas usually occurs above the salt.

This hypothesis involves a striking, if not a novel, application of the force of crystallization to the origin of such deposits. It seems, however, to meet the peculiar conditions that surround the occurrence of salt and gypsum in the gulf region (as well as in a few localities elsewhere) conditions which are difficultly explainable by the more common method of deposition from sea water. While there is, thus, much in its favor from a geologic standpoint, there is also need of more knowledge of the physical principle on which its validity ultimately depends.

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[1] Econ. Geol. 1909. 4:12.

Mode of origin applicable to the New York deposits

There is no doubt that the gypsum of the Salina beds has been deposited by evaporation of surface waters and is an integral part of the stratified succession. This view is advocated or tacitly implied in most descriptions of the New York deposits that have already been published, though it has not escaped criticism. The evidences which form the application of this method to the exclusion of other theories may be summarized under the following heads:

1 Form and structure of deposits
2 Associations of the gypsum
3 Biologic conditions in Salina time

1 The occurrence of the gypsum in thin lenses which are of the same degree of continuity as the inclosing strata indicates an accumulation concordant with the salt, shales and limestone of the Salina. The lenses, in most instances at least, thin out very gradually, showing only moderate changes of thickness as they are traced from place to place and few irregularities not common to sediments in general. If the gypsum were formed by the reaction of acid waters upon limestone, variations in form like those found in replacement deposits of metallic minerals would be expected. The type of deposits in which the gypsum occurs as nodular masses with a thickness nearly equal to the horizontal dimensions — as figured by Hall and represented in Dana's *Manual* — is certainly the exception and not the rule and is the result probably of solution of the larger masses by underground waters. Such deposits are illustrated in figures 3 and 4 on page 25.

The undisturbed condition of the beds as generally observed is also against any theory of secondary deposition either by reaction upon limestone or by precipitation from ground waters. The change from limestone to gypsum involves an increase of 90 per cent in the volume, which would hardly occur without general disturbance of the adjacent strata. The beds, also, are not faulted or fractured so as to permit the easy circulation of waters in vertical direction.

2 The close relation of the gypsum to the salt deposits is such as would be expected from the evaporation of sea water. While the fact that the salt underlies the main gypsum beds, whereas the reverse is the natural order, seems to controvert this view, an explanation for it may be found without recourse to extraordinary conditions of evaporation and supply of the sea waters. If the

waters of that time held approximately the same relative proportions of salts in solution as the ocean of the present day, their evaporation would afford one part gypsum to something over 20 of salt. As gypsum occurs interbedded with the salt and probably distributed more or less through the Vernon shale below the latter, this relative amount may well be present in its normal order. The relations indicate, however, that the process of evaporation while the first gypsum and salt were laid down was subject to frequent vicissitudes from the influx of new supplies of sea water into the basins. After the salt had been precipitated by repeated evaporations the process was suspended for a time, during which the basins were probably invaded by land drainage and shales were accumulated in considerable thickness. A renewal of the early conditions with a fresh supply of sea water started the precipitation of gypsum again, but this time the process was not continued long enough apparently to bring down salt, or if it were precipitated it was redissolved before the overlying strata were formed.

Both the salt and main gypsum beds maintain a constant horizon throughout their extent. The main gypsum beds are found only in the Camillus shale and are generally limited to the upper section. In the western part of the State they are capped by limestone which shows no evidence of alteration by ground waters, and there are layers of unchanged limestone intercalated in the shale. There seems to be no sufficient explanation for any selective action on the part of the limestone whereby certain beds were more prone to alteration than others.

3 In the discussion of the stratigraphy of the Salina stage it was noted that the variations in the character of the strata are accompanied by marked fluctuations in the abundance of fossil remains. The preceding Niagara stage is characterized by a fairly prolific and varied fauna which has, however, a peculiar development that is connected by paleontologists with changes of physical surroundings. The Pittsford shale at the base of the Salina holds a very different fauna that is characterized by eurypterids. Throughout the succeeding intervals represented by the Vernon shale, salt and Camillus shales, there is little or nothing to be found in the way of fossil remains, and only with the Bertie waterlime, at the close of the Salina, do they reappear and are then represented by an assemblage related to that of the Pittsford shale. The lack of fossils in the gypsum beds may be explainable, perhaps, as the result of solution and breaking down of the strata by underground circulations, but this theory fails to account for their absence in the shales and un-

changed limestones which aggregate many hundreds of feet in thickness. This circumstance as well as the other facts regarding the fauna of Salina time becomes intelligible, however, when connected with the vicissitudes that life must encounter in sea waters of fluctuating salinity.

PROPERTIES OF GYPSUM AND THEORY OF ITS TRANSFORMATION TO PLASTERS

The composition and peculiar properties of gypsum have been the subject of frequent study by chemists since the development of exact methods of analysis. A brief review of the more important investigations will serve to show the intricate nature of the problems encountered and assist their explanation in the light of recent researches, so far as they may have been solved.

We are indebted to Lavoisier for the first definite data on the composition of gypsum.[1] He dissolved the mineral in water and found that its solubility was about one part by weight in 500 parts water. From the solution he was able to crystallize the gypsum out, and he therefore considered the mineral to be a chemical salt. Furthermore he determined the nature of the acid and base, as well as the presence of water of crystallization. By experiment it was found that the cooking of gypsum produced no new compound but simply drove off the water. In Lavoisier's opinion all of the combined water disappeared in the process, though he seems to have been familiar with the fact that commercial plaster of paris contained a small amount of moisture; consequently he was at loss to understand why plaster heated to a higher temperature than customary should be deprived of setting qualities.

Payen,[2] in 1830 found that gypsum heated at 80° C. in a current of dry air or 115° C. in a closed space "began to lose very slowly a part of its water of crystallization. This drying proceeds very rapidly as the temperature is raised, but beyond a certain point (200° C.) an important modification takes place. The sulfate of lime hydrates with difficulty, and when heated at 300–400° C. loses all power to take up water of crystallization."

In 1840 Berthier[3] showed that, contrary to the belief of Lavoisier and others, calcined plaster contained from 3 to 8 per cent of water, and his results were confirmed later by Landrin.

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[1] Acad. des Sci. Compt. Rend. Paris. 1765.
[2] Chimie Industrielle 1830 and Précis de Chimie Industrielle. Paris. 1851. ed. 2. p. 301.
[3] Ann. des Mines, 1840, ser. 3, 19:655.
[4] Ann. de Chimie et de Phys. ser. 5, 3:440.

It remained for Le Chatelier[1] to make the first accurate observations in relation to the changes involved by the calcination of gypsum. He noted that calcined plaster contained some 7 per cent water, as shown by his own experiments and by analyses made in L'Ecole des Ponts et Chausses. "M. Debray has demonstrated," says Le Chatelier, "that different hydrates of the same salt are characterized by different tensions of dissociation, greater as the proportion of water is greater. This results in the fact that the

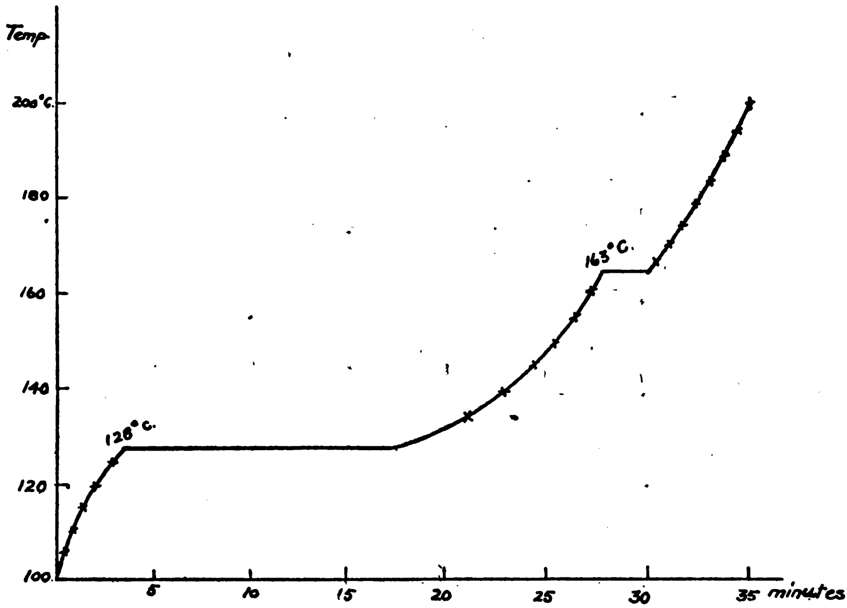


Fig. 6 Temperature gradient for the decomposition of gypsum. (After Davis)

temperature of decomposition of the different hydrates, under a given pressure will not be the same. In studying from this view the decomposition of gypsum, I have discovered that it took place in two very distinct periods of time."

To confirm this conclusion he placed two grams of powdered gypsum in a glass tube, which he heated gradually in a paraffin bath, recording by a thermometer the temperature every five minutes. Using the time as abcissa and the temperature as ordinates he constructed a curve. This curve did not rise regularly but contained two horizontal breaks in its regularity. The temperature after rising rapidly to 110° rose more slowly from 110° to

[1] Acad. des. Sci. Compt. Rend. 96, 1668. 1883.

120°, stood stationary a long time at 128° and then went on upward more rapidly between 130° and 140°; a second stop analogous to the first but less important took place at 163°. From the results of this experiment W. A. Davis[1] has plotted the following curve [fig. 6].

Le Chatelier then says, "These two halts in the rise of the thermometer were brought about by the absorption of heat which accompanied the elimination of the water. They indicate the existence of two hydrates having different temperatures of decomposition. To determine the composition of the intermediate hydrate, I heated 10 grams of gypsum at a temperature of 155° which from the above figures is intermediate between the decomposition temperatures of the two hydrates. The loss of weight was as follows:

TIME		GRAMS
Hours	Minutes	
....	15	.66
....	30	1.36
....	45	1.52
1		1.56
1	15	1.56

"The loss of weight at 155° tends then to a well defined limit of 1.56 grams which corresponds exactly to 1.5 molecules H_2O for 1 molecule of $CaSO_4$." This leaves us a material with a formula of $CaSO_4.\frac{1}{2}H_2O$ identical with "half hydrate" noted by Johnston[2] as found in the form of scale in a steam boiler heated to 121° C. and by Hoppe Seyler[3] as formed by gypsum in presence of water at 140–60° C.

The same sample was then heated to 200° C. with the following results:

TIME		LOSS OF WEIGHT
Hours	Minutes	Grams
....		1.56
....	15	1.78
....	30	1.98
....	45	1.98
1		2.08

This loss of 2.08 grams corresponds to two molecules of water to one of $CaSO_4$, that is, at 200° C. the dehydration is complete.

In summing up his results Le Chatelier says: "These experiments show that there exists at least one inferior hydrate of calcium sulfate having the formula $CaSO_4.\frac{1}{2}H_2O$ and that it

[1] Soc. Chem. Ind. Jour. 1907. 26:728.
[2] Phil. Mag. 1838.
[3] Pogg. Ann. 1866. 127:161.

contains 6.2 per cent water. The commercial plaster containing in the mean 7 per cent water is then almost exclusively made up of this hydrate."

In the past 10 years a number of chemists have taken up the question of the decomposition of gypsum, the formation of the half hydrate and the anhydrite and their mutual relationships. Among the number are Armstrong, Van't Hoff, Shenstone, Cundall, Cloez etc. [*see* Bibliography for references]. The most recent investigations are those by W. A. Davis[1] who, moved by the uncertainty and lack of uniformity in the results previously obtained, has carried out a series of careful experiments, which he presents along with a summary of the work performed by others. This very valuable contribution is presented herewith in abstract.

At the time Davis entered upon his investigations there were recognized, as derived from gypsum, the half hydrate, formed at 128° and decomposed at 163° [Le Chatelier]; the soluble anhydrite which according to Van't Hoff was formed directly by heating gypsum in a vacuum over concentrated sulfuric acid without the intermediate formation of the half hydrate, and natural anhydrite, which can be formed by strongly igniting the soluble anhydrite. The soluble anhydrite is very soluble in water and sets very rapidly to a hard mass.

Davis first heated a series of gypsum samples at temperatures between 98° and 130° C. and measured their successive loss in weight or loss in water and derived the following curves [fig. 7].

The influence of the state of division of the gypsum is clearly noticeable.

The striking feature in the curves, however, is that loss of water does not begin immediately after the material is heated. In one experiment a whole hour is shown to elapse before any water is given off. During this period the monoclinic gypsum is undergoing a crystallographic change to the orthorhombic system, or in other words $CaSO_4 . 2 H_2O$ is dimorphous, as are nearly all the hydrated sulfates of bivalent metals. Further proof of this is shown in the behavior of the half hydrate on setting. When the plaster first sets into a coherent mass, microscopic investigation has shown that all the crystals present have a straight extinction and are probably orthorhombic. Gypsum crystals subsequently appear because the orthorhombic form is labile at ordinary temperatures and, in from a few hours to a few days, changes to gypsum. This perhaps explains the fact that plaster when first set contracts (while the orthorhombic crystals are forming) and expands (at the change to monoclinic). At first sight the curves might suggest Van't Hoff's idea that no intermediate half hydrate is formed, but owing to the

[1] Soc. Chem. Ind. Jour. 1907. 26:727.

removal of water by the air the two dehydrations may go on side by side as follows:

$$CaSO_4 . 2 H_2O = CaSO_4 . \tfrac{1}{2} H_2O + 1\tfrac{1}{2} H_2O$$
$$CaSO_4 . \tfrac{1}{2} H_2O = CaSO_4 . + \tfrac{1}{2} H_2O$$

This view is further substantiated by the heating of gypsum at 98° in an open crucible with the formation of half hydrate in nine hours and no further loss or change with eight hours heating.

Commercial plaster, Davis considers to be made up mainly of the half hydrate, not soluble anhydrite as held by Cloez, since the water vapor in the mass would immediately hydrate any anhydrite formed, or at least the moisture from the air would soon alter it to the half hydrate. Bottled samples of freshly made plaster almost

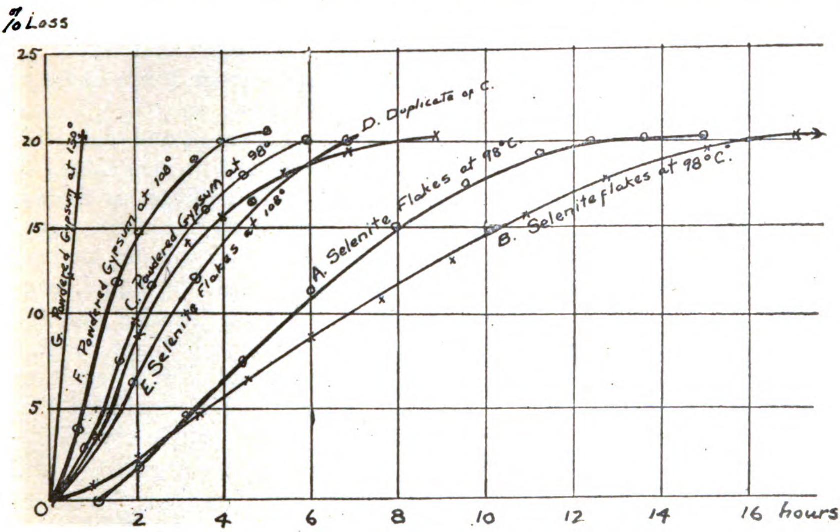


FIG. 7 Curves showing rates of dehydration of gypsum under different conditions. (After Davis)

always show 6 to 8 per cent water and are therefore the half hydrate.

In summing up then we may say that the change from gypsum to anhydrite is brought about as follows:

	LOSS IN WATER
1 $CaSO_4 . 2H_2O$ monoclinic to $CaSO_4 . 2H_2O$ orthorhombic........	none
2 $CaSO_4 . 2H_2O$ orthorhombic to $CaSO_4 . \frac{1}{2}H_2O$ orthorhombic......	$1\frac{1}{2}$ mols
3 $CaSO_4 . \frac{1}{2}H_2O$ to $CaSO_4$ (soluble) orthorhombic...............	$\frac{1}{2}$ mol
4 $CaSO_4$ (soluble) to $CaSO_4$ insoluble (natural anhydrite)......	none

Of these, the first two steps are carried out on calcining plaster and their reversal on the setting of plaster.

Davis classes freshly made plasters into four groups:

1 Those consisting mainly of the half hydrate, containing 6 to 8 per cent water.

2 Those containing soluble anhydrite and very hygroscopic, with less than 6 per cent H_2O.

3 Plasters containing more than 7.5 per cent H_2O and consisting of half hydrate mixed with some gypsum.

4 "Dead burnt" plasters containing less than 6 per cent water but not hygroscopic and setting slowly; these contain ordinary anhydrite.

Setting of plaster. The property of plaster, or the calcined gypsum, to set on mixing with water gives it its chief value. Gypsum calcined at temperatures varying perhaps from 100° C. to 500° C. and mixed with water will, after a period of from a few minutes to a day, take up water and become a hard mass.

The cause of setting has long been an unsettled and debatable theme, though the fundamental principle was laid down by Lavoisier in the investigations already noted. In addition to the experiments that have been described he carried on one more. Into a large vessel of water he threw some powdered plaster and allowed it to sink. He says, "In passing through the liquid, each molecule of plaster took back its water of crystallization and fell to the bottom of the dish under the form of small brilliant needles, visible only with a high power lens." Examined with a lens they proved to have the regular form of gypsum. He concluded that the setting with water "is nothing more than a simple crystallization"; gypsum, deprived of its water, reabsorbs it greedily and again becomes crystalline. Lavoisier thought that his investigations left no doubt as to the cause of the hardening of plaster, and that there remained "nothing to be desired in explanation of the problem." Though the change is caused primarily by a crystallization and the taking up of water, the chemical, crystallographic and physical changes in all their steps are far from clear; as stated by Mr Davis,[1] "the problem has proved to be one of extraordinary difficulty, and in spite of the investigations made by such well known chemists as Marignac, Le Chatelier and Van't Hoff, an amount of confusion exists with regard to the subject which is almost without parallel in inorganic chemistry."

Landrin[2] made an elaborate investigation into the setting of plaster and brought forward the theory that the plaster partially dis-

[1] *loc. cit.*
[2] Ann. de Chimie, 1874. p. 434.

solved in the water which became saturated with respect to it. The heat of the chemical reaction causes an evaporation of some of the water and a consequent crystallization of the saturated solution, the first crystal developed determining and hastening the crystallization of the whole mass. Le Chatelier later showed, however, that plaster would set in a vacuum so that evaporation was not the means of causing the crystallization.

Le Chatelier[1] in taking up the question utilized the observation of Marignac[2] that calcium sulfate in contact with water gives a supersaturated solution which allows the deposition of crystals of the hydrous calcium sulfate. With plaster cooked at 140° a solution is obtained containing 9 grams of $CaSO_4$ per liter, i. e. four times more than can normally exist in solution. Le Chatelier goes on to say that such supersaturated solutions, capable of uniting directly with water to form their hydrates are common, for example Na_2 SO_4 Na_2 CO_3 etc., all of which salts set when mixed with water. Finally he believes that the set is the result of two simultaneous phenomena: "On the one hand the masses of the plaster mixed with water dissolve themselves on hydrating and produce a supersaturated solution. On the other hand, this solution allows at the same time a deposition of crystals of hydrous calcium sulfate. They are added to little by little and bind themselves together."

G. P. Grimsley,[3] although agreeing with Le Chatelier and others that the set of gypsum is due to a formation of a network of crystals of gypsum crystallized from a saturated solution of the half hydrate, to account for the cause of the beginning of the crystallization advances this theory: "The effect of heat on gypsum in the burning of plaster as we have shown, is to remove a certain percentage of water, and to break up the small masses of the rock into finer and finer particles, microscopic and even ultramicroscopic in size. If the heat is not carried too far, certain particles through the mass may still possess their crystalline form and are true crystals though small. These minute crystals in the saturated solution would start the process of crystallization. . . If the plaster is underburned the gypsum is not reduced to the proper fineness and uniformity, and so would not permit the crystallization to go on in the way it would in a properly burned plaster. But of more importance, the hydrate represented by plaster of paris would not be formed. If the plaster is overburned, it will be so completely comminuted that no minute crystals will be left to start the crystal-

[1] Acad. de Sci. Compt. Rend. 96, 714. 1883.
[2] Ann. de Chimie de Physique Tome I, 279. 1871.
[3] Kansas Univ. Geol. Sur. 1899. 5:95.

lization. Where the plaster is slightly overburned, the crystals are extremely fine and crystallization goes on very slowly and imperfectly."

While the presence of any unburned gypsum may hasten or otherwise influence the setting of some plasters, it does not appear that the process is absolutely dependent upon that condition for its start. In the case of soluble anhydrite there is rapid setting on addition of water, which is hardly explainable by the view taken by Grimsley.

The approximate solution of the problem is undoubtedly to be found in the work of Davis. "It has always been assumed that the setting of plaster is due to the regeneration of gypsum by the action of water on the half hydrate. If, however, the setting of the half hydrate be carefully observed by means of the polarizing microscope, not a single gypsum crystal can at first be detected in the set mass; the cake of set material, during the first quarter of an hour after it has hardened to a coherent mass, which is only slightly indented by the finger nail, is made up of crystals showing a straight extinction only, and therefore probably orthorhombic. The first product of the setting of the half hydrate (or soluble anhydrite) is, indeed, the same orthorhombic dihydrate as is produced in the first stage of the dehydration of gypsum. Gypsum crystals subsequently make their appearance within the set mass, owing to the fact that the orthorhombic form of the dihydrate is labile at the ordinary temperature, and undergoes change more or less rapidly — during the course of several hours or several days, the time varying greatly — into the more stable form of gypsum. The series of changes

$$\alpha\ CaSO_4 . 2H_2O \rightleftharpoons \beta\ CaSO_4 . 2H_2O \rightleftharpoons CaSO_4 . \tfrac{1}{2} H_2O$$

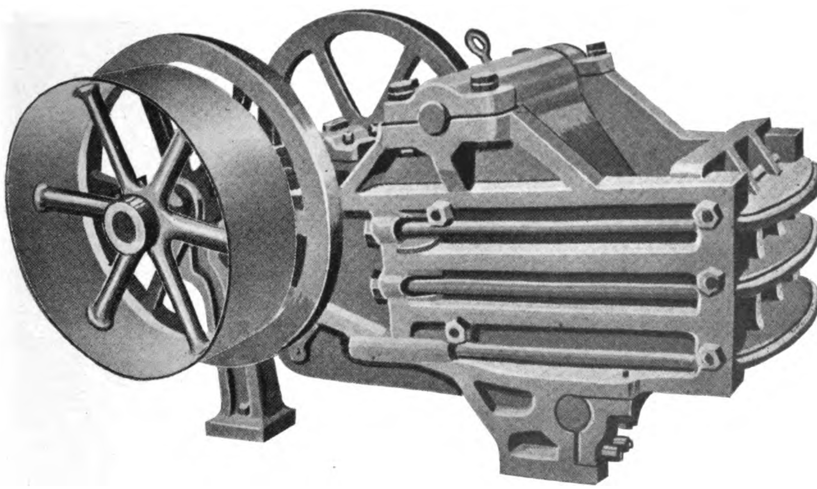
Gypsum (monoclinic) (orthorhombic) Half hydrate (orthorhombic)

is, indeed, strictly reversible. Before gypsum can undergo dehydration to form the half hydrate, it passes into the orthorhombic form of the dihydrate, and the latter is also the first product of the hydration of the half hydrate."

Some recent experiments have been made by Leduc and Pellet[1] on the relation of calcining temperature to the setting of plaster. They calcined for an hour or more pure alabaster at various temperatures and mixed the plaster formed with 85 per cent water. The results of their experiments are as follows:

[1] Le Genie Civil. 1906. 49:253.

Plate 18



Jaw crusher

CALCINING TEMPERATURE	SET BEGINNING AFTER	SET COMPLETE AFTER
	Minutes	
120°C	8	16 minutes
250°C	4	6 minutes
450°	4	over 5½ hours
500°	....	24 hours
600°	....	24 hours
650°	....	no set
700°	....	no set
720°	....	no set
1185°	....	no set

This indicates that the most efficient temperature for calcining is at about 250° C. (482° F.).

TECHNOLOGY OF GYPSUM PLASTERS

Plaster of paris and wall plasters

The manufacture of the different calcined plasters is based on similar methods, though there is considerable variance in the details of practice and equipment of the plants. In every case the crude gypsum from the mines or quarries must undergo the two operations of crushing and calcination.

The plasters made in New York and also practically all those manufactured in this country belong to the half hydrate class, i. e. their basis is plaster of paris. Their varied qualities depend mainly upon the proportion of impurities present in the original rock and upon the addition of artificial materials to hasten or retard the setting process. The anhydrous plasters which include the so called "cements" and the German flooring plasters form a distinct group that can best be considered under a separate head.

Crushing. The crushing of the material may be performed either before or after calcination. The general practice in this country is to make a partial reduction at least before burning, though abroad the crude rock is often calcined in arched kilns in a manner similar to the burning of limestone. With the kettle process, which is widely used in American plants, the rock is reduced to a fine powder before calcination. The introduction of rotary cylinders for calcining among the newer plants involves a change of the crushing process whereby the rock is subjected to a preliminary reduction to uniform size and after calcination is given a second treatment for pulverization.

The first step in reduction is performed in a coarse crusher, by which the rock of size convenient for handling is broken to lumps of about 1-inch diameter. The crushers commonly used are of the jaw or gyratory types, the preference in New York plants being given to the former. One form of jaw crusher or "nipper" specially devised for gypsum plants is shown in plate 18. The movable jaw, as well as the end plate, sometimes has a corrugated surface which prevents the soft material from clogging the outlet. The machine shown in the illustration weighs 13,000 pounds and will crush each hour from 15 to 30 tons of rock.

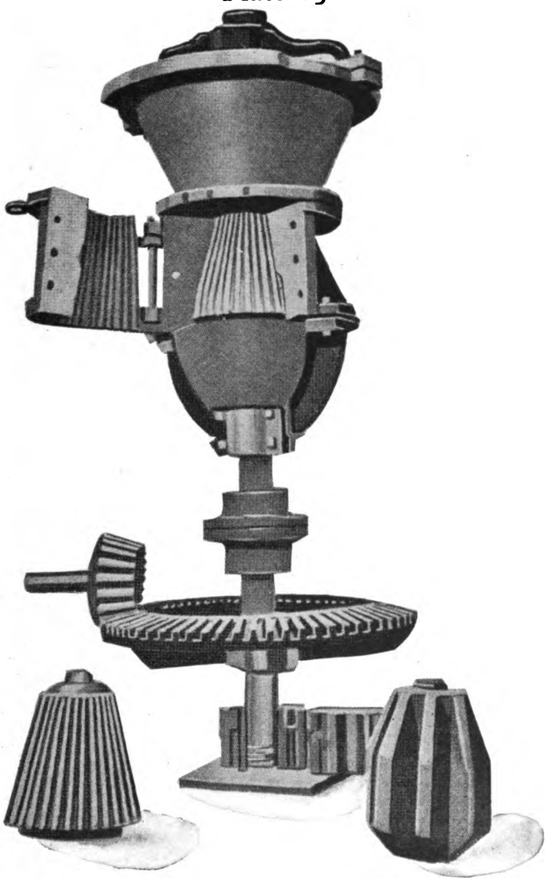
From the coarse crusher the gypsum passes into the "cracker." This machine works like a coffee mill, having a corrugated shell of inverted conical shape within which revolves a corrugated spindle [pl. 19]. The machines have a capacity of from 3 to 12 tons an hour and crush to about pea size.

After this treatment, the gypsum is ready for charging into rotary cylinders if these are used for calcination. For the kettle process, however, it is next run through a fine grinder of which there are several forms well adapted for the purpose. In the mills first erected the grinding was universally done by buhrstones, and this practice continues to be quite common, though it has been superseded in most of the modern plants by more improved methods. The stones are set the same as in flour mills and may be of French or domestic make. The small expense of such an oufit is its chief recommendation and is offset by the necessity of redressing the stones from time to time, an operation that requires a high degree of skill.

An improvement on the horizontal millstones for grinding gypsum is the use of a vertical mill which can be run at a higher speed. This type is common abroad. The Sturtevant Mill Co. of Boston manufactures a vertical mill of special construction that has been installed in several plants. The stones are built up of emery blocks set in a metal shell around a central disk of buhrstone. The emery blocks are held secure by metal filled in while molten. A 36-inch Sturtevant mill is shown in section in plate 20. The mill is supplied with an automatic feeder from which the gypsum is carried by a worm conveyor and forced between the stones.

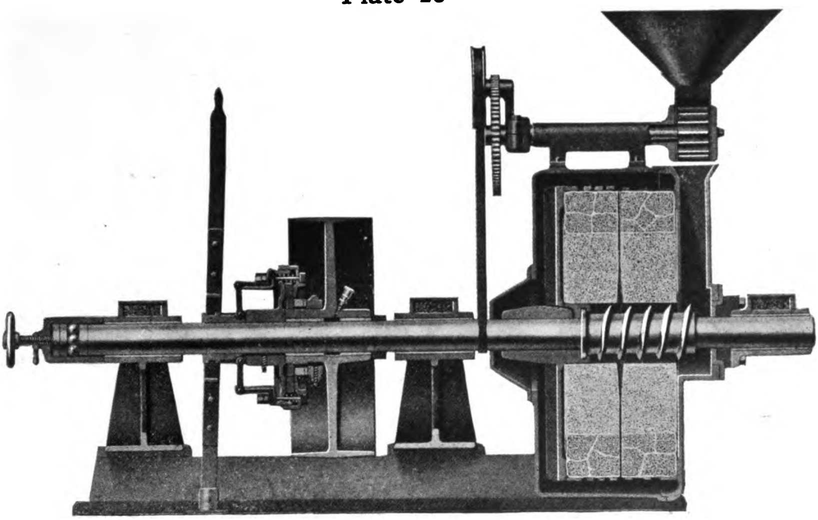
Another machine in use for pulverizing gypsum is illustrated in plate 21. It is made by the Williams Patent Crusher & Pulver-

Plate 19



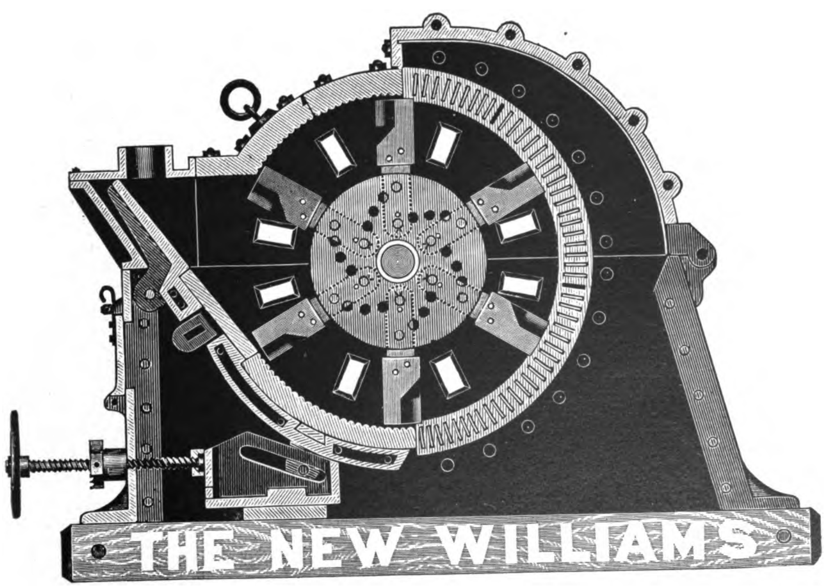
Type of cracker used in crushing gypsum

Plate 20



Section of Sturtevant mill

Plate 21



The Williams pulverizer

izer Co. of St Louis. The reduction is accomplished by means of hammers carried on a rapidly revolving horizontal axis and working against a corrugated breaker plate. The machine is said to take rock that will pass through a 2-inch ring and crush from 12 to 15 tons an hour through a 30-mesh screen.

The Stedman disintegrator, which is characterized by a series of concentric cages with steel crossbars, the adjacent cages revolving in opposite directions and crushing the rock by impact, is employed in some of the western plants. The roller mills in use for grinding flour is also said to be serviceable for gypsum.

There seems to be no standard of fineness for plasters, such as obtains in cement manufacture. The size of the particles, however, is not without influence upon the setting qualities, though within the moderate limits of variation in ordinary practice the degree of fineness does not appear to be very important. A series of sieve tests on marketable plaster from the middle western districts has been published by the Iowa Geological Survey,[1] the results of which show that an average of 70 per cent of the ground plaster will pass through a sieve with 74 meshes to the linear inch, about 60 per cent through a 100-mesh sieve and 44 per cent through a 200-mesh sieve.

Calcination. The chemical features of the calcination process are described elsewhere in detail. Though the process is simple in theory, as well as in its mechanical requirements, it demands a degree of experience and skill to insure a uniformly satisfactory product.

The common kettle method of calcination as used in this country is an adaptation of the earlier practice by which plaster of paris was made on a small scale in a cauldron kettle over an open fire. The modern kettles are cylinders of boiler steel, nearly square in vertical section, set upright on a brick foundation. Their diameters range from about 8 to 10 feet. The sides are constructed of sheet iron ⅜ to ⅝ inch thick, while the bottoms which must withstand extremes of temperature are usually cast from the best grade of scrap iron, and their thickness varies from ¾ inch at the edges to 4 inches in the centers. The bottoms are arched upward rising about a foot at the crown. Some kettles are made with sectional bottoms, so that in the case of breakage it is only necessary to replace the broken part instead of installing a new bottom. The cover is of sheet iron and has a trap through which the charge is introduced.

[1] An. Rep't 12. 1902. p. 162.

The kettle is inclosed nearly to the top by a brick wall with an open space between for the circulation of heat. The fire chamber below is a little narrower than the kettle and rises from 4 to 7 feet above the grate bars. The heated gases pass through ports into the open space at the base, then into flues which are placed horizontally in the kettle itself and out through a stack. The flues are built in sets of two or four. In a kettle of two flues they are placed parallel about 8 inches above the crown. The arrangement in a kettle of four flues is shown in plate 22 taken from a photograph furnished by Butterworth & Lowe, Grand Rapids, Mich. The kettle illustrated measures 10 feet, 4 inches across by 8 feet, 5 inches high and will calcine 10 tons of ground gypsum into plaster of paris at a single charge. The weight of the metal is about 10 tons.

The kettles are generally installed in line and worked in pairs with a feeding chute and a pit for the calcined product between each pair. In burning it is necessary to keep the gypsum in constant agitation, for otherwise the hot mass would soon destroy the kettle bottom. The agitation is accomplished by means of a vertical shaft to which paddles are attached and which is turned at the rate of 15 revolutions a minute by means of a crown wheel connecting with a pinion on the mill shafting. From 10 to 25 horsepower is required to maintain the agitation.

The arrangement of an installation in a kettle plant is shown in figure 8, which is reproduced from a drawing furnished by Butterworth & Lowe.

In operation, the kettle is charged with ground gypsum through the trap in the cover and is filled in about an hour. Heat is gradually applied during the process, and when the temperature reaches 220° or a little above, the mass begins to boil vigorously from the escape of the mechanically held moisture. After this is evaporated there is a noticeable settling, and the steam almost ceases for a time. With increasing heat a second ebullition begins between 280° and 290° F., causing the mass to rise to the top of the kettle. The steam now is due to water of crystallization which continues to come off as the heat is raised. When the boiling begins to slacken, the mass settles again and is ready for removal into the fire brick bins for cooling. The finishing temperature ranges between 350° and 400°, as there is no fixed point which marks the completion of the process. The experienced calciner relies chiefly upon the physical appearance of the plaster, the amount of steam given off and the creaking of the machinery during the settling as guides in the

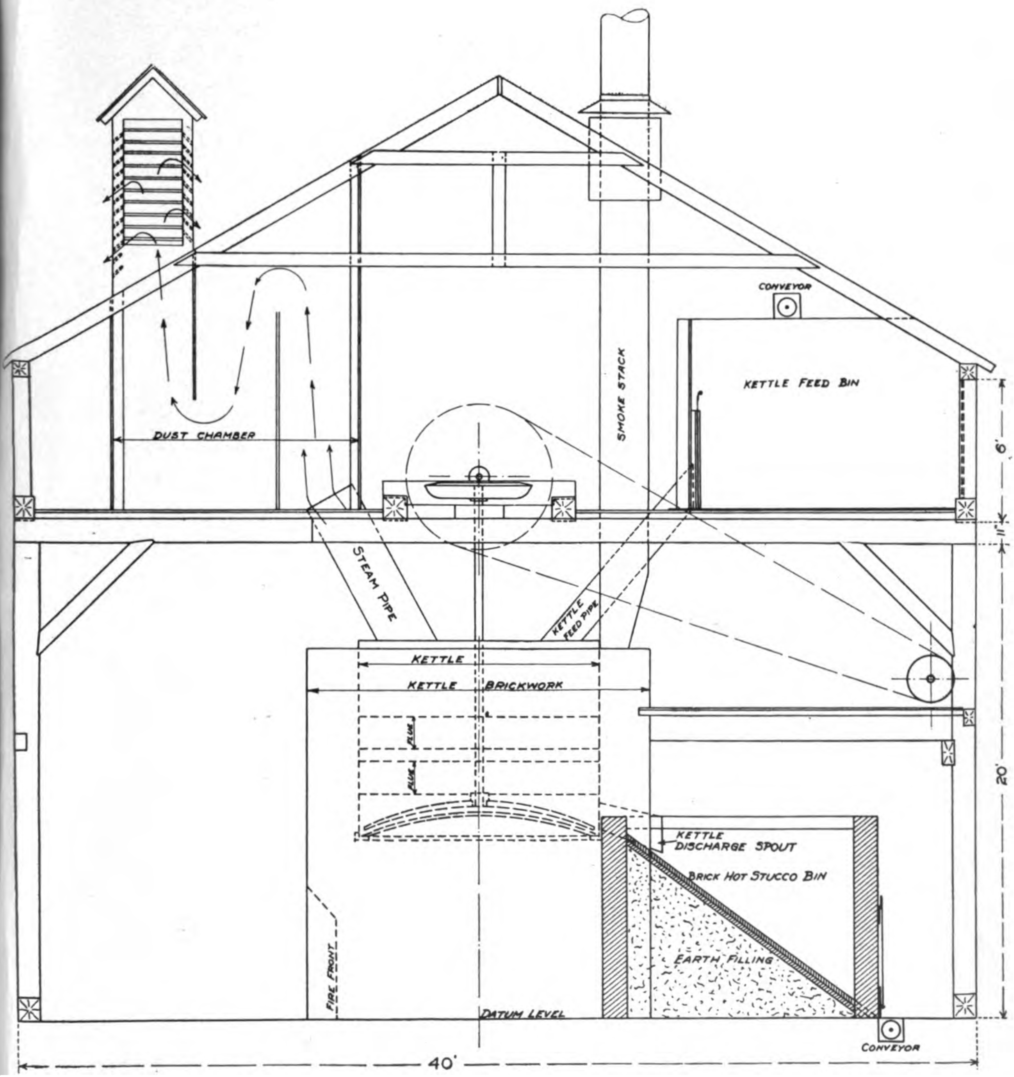


Fig. 8 Cross section of 10 ft kettle room

BUTTERWORTH & LOWE,
GRAND RAPIDS, MICH.

operation, though thermometers are used in some plants as a further check. The wide range of temperatures at which the burning is completed may be ascribed largely to the variation in the purity of the gypsum. According to Paul Wilkinson[1] the temperatures used in the manufacture of plaster of paris from the Kansas rock, which averages very high in gypsum, do not exceed 340° F., while they run about 396° F. as a maximum in the calcination of the impure earthy gypsum.

If the calcination is finished at too low a temperature the change to half hydrate will be incomplete; the plaster in that case will be deficient in strength. On the other hand, if the temperature is carried too high, there is danger of converting a part of the whole of the charge into anhydrite. Soluble anhydrite results when the overburning is continued for a short time only and insoluble anhydrite when it is of longer duration and at stili higher temperature. The presence of soluble anhydrite in plaster freshly burned is perhaps not uncommon, though the main ingredient is, of course, the half hydrate. According to Davis any soluble anhydrite in the product will take up moisture from the air to form half hydrate, so that its presence in small amount may have no detrimental effect.

The time required for the calcination of a charge ordinarily is from two and one quarter to three hours, depending on individual practice. The fuel consumption with bituminous coal averages from 200 to 300 pounds for each ton of plaster. After cooling in the pits the product is elevated to a revolving screen, which removes any coarse material for regrinding, and is then transferred to the storage bins.

The kettle process has been criticized frequently as uneconomical, and this is undoubtedly a serious drawback. Its simplicity and the fact that plaster makers have grown accustomed to visual methods of controlling the burning operation seem to be the main reasons for its continued favor. As compared with the rotary kiln the kettle consumes for each ton of plaster made, more fuel in calcination and more power in agitating the charge, while it is less efficient by reason of its interrupted operation.

The Cummer rotary kiln is the only continuous calciner in use in this country. It is made by F. D. Cummer & Son Co. of Cleveland. The apparatus as installed for operation is shown in plate 23.

The gypsum rock is not pulverized as in the kettle process but is crushed to pass through a ¾-inch ring and delivered to the storage bin over the feed spout of the kiln. This consists of a steel

[1] Am. Inst. Min. Eng. 1897. 27:516.

cylinder set on a slight incline and turned slowly on roller bearings by means of a large spur wheel at the upper end. The rock enters the cylinder at the same end and gradually works its way down as the cylinder revolves, being lifted and dropped by blades attached to the sides. The hot gases from the furnace are forced by a fan into the brick chamber surrounding the cylinder where they are mixed with sufficient air, admitted through the registers at the base, to give the desired temperature. From the co-mingling chamber the air and furnace gases are drawn by a fan through hoods into the interior of the cylinder which they traverse in a direction opposite to that taken by the material. The temperature of the interior is maintained between 400° and 600° F., according to the character of the rock and the desired product. As the rock remains in the cylinder only 10 minutes, there is little danger of overheating incident to the kettle method. A thermometer is placed in the discharge spout where the operator can watch it and regulate the flow of gases so as to give a uniformly heated product.

An indispensable feature of the Cummer process is the calcining bins into which the steaming material from the kiln is removed. Four bins are required for each cylinder. They are made of brick and lined with paving brick which have little absorbing power. The material remains in the bin for about 36 hours, during which time the free moisture not driven off in the cylinder is removed as well as a further part of the water of crystallization. While the calcination is going on in the bin, outside air is excluded, thus allowing the heat of the material to equalize itself throughout the mass. Small variations in temperature during the day's run of the cylinder have little or no influence on the character of the product so long as the average remains fairly constant. With the use of four bins the process is absolutely continuous; while one is being filled, calcination is going on in the second and third, while the fourth is being emptied.

The arrangement of a mill in which the Cummer process is used is shown in figure 9. The kiln is installed in the plant of the Lycoming Calcining Co. at Garbutt, which has a capacity of 50 tons of plaster in 11 hours. The fuel is soft coal. According to the manufacturers' circular the consumption of fuel, when a good grade of coal is used, averages about 70 pounds for each ton of calcined material, exclusive of that employed for driving the plant, which is a relatively small item.

Another continuous process is described by F. A. Wilder[1] as in

[1] Iowa Geol. Sur. 1902. 12:213.

Plate 22

Four-flue kettle for calcination of gypsum

use at Mannheim, Germany. The calciner consists of a fire box and automatic stoker opening into the chamber that contains the rotating cylinder. Above the cylinder and connected to it by a pipe is a chamber through which a spiral conveyor passes. The gypsum ground to a size not larger than a hickory nut is charged into the forewarmer, is conveyed by the spiral to the other end and dis-

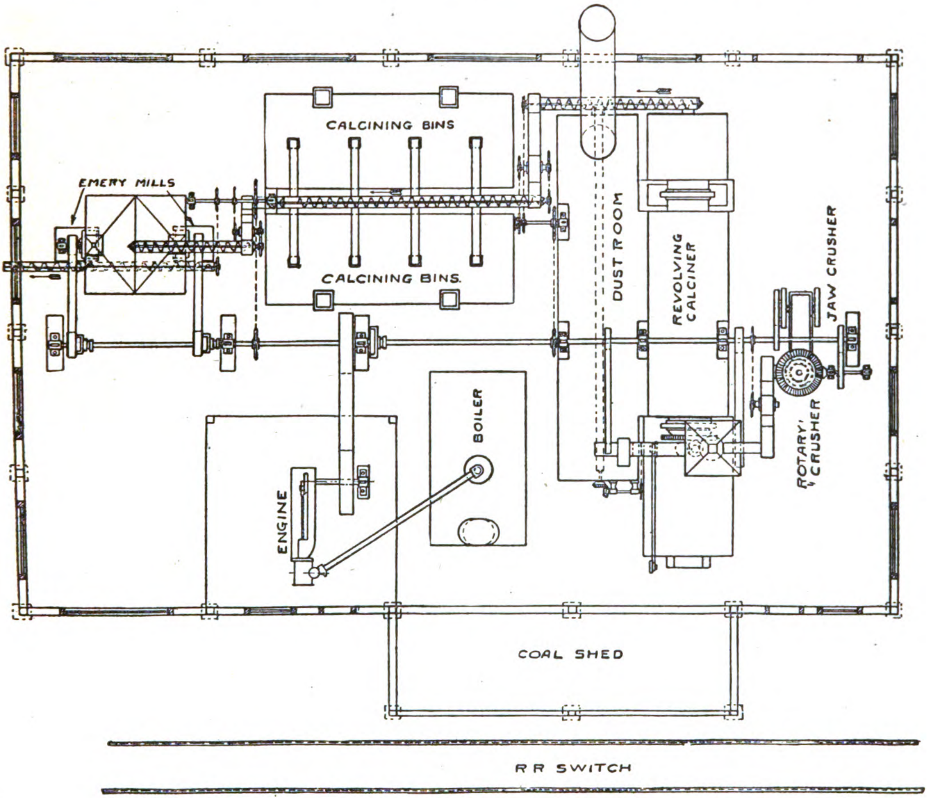


FIG. 9 Arrangement of installation for Cummer process

charged into the rotary cylinder. A fan forces the hot air and gases from the fire box into the cylinder and this calcines the gypsum and forces it toward the discharge end of the cylinder. The material is agitated by a continual lifting and dropping brought about by a series of shelves or buckets on the sides of the revolving cylinder. The larger lumps which would require a longer period of heating for calcination, owing to their weight, are moved most slowly toward the discharge point, and thus receive the most heat, while the fine powder which if allowed to remain long in contact with the heat would become dead-burned, passes quickly to the rear end of the cylinder under the blast of air. The gases and hot air pass out of the cylinder and into the forewarmer where whatever heat remains in them is utilized in heating the crude gypsum on its way to the cylinder. The gases and air, then with a temperature of but 80° F., pass into collecting chambers to recover any dust of plaster in them, and thence out through the stack.

In Europe gypsum is commonly burned in lump form in arched kilns, which are built of masonry and somewhat resemble the ordinary brick kiln of this country.[1] The heat from the central fire pit is conducted through radiating channels, which are constructed of the larger gypsum blocks, and then finds its way upward in the spaces between the lumps to issue finally through flues in the roof.

Plaster of paris used in porcelain and china ware manufacture requires careful preparation, as it must form a light, porous mass when set. This grade is made mostly in France and Germany. The calcination is often carried out in brick ovens, the gypsum being stirred frequently during the process. An improved type of oven that is now employed in Germany for making porcelain plaster takes the form of a long room constructed of brick into which the gypsum is carried on cars.[2] These have racks holding five or more shelves which are loaded with rock that has been previously crushed to 1-inch size or smaller. The room is heated by a furnace below, the gases passing through flues in the walls and not coming into contact with the gypsum. The temperature is maintained uniformly at 140° C. (284° F.). Three charges are burned in a week, and the output of each is about 8 or 9 tons of calcined plaster.

Resultant product. The product resulting from the operations just described is a finely divided calcined plaster. If a pure gypsum has been used it will consist of calcium sulphate plus a small residue of water, the amount depending upon the degree to which the calcination is carried. The ideal composition of plaster of paris is represented by the formula $CaSO_4 . \frac{1}{2} H_2O$ which calls for 93.8 per cent of calcium sulphate and 6.2 per cent of water. These percentages are approached in high grade plaster of paris, which finds special uses, but most wall plasters contain a considerable proportion of impurities due to the admixture of clay, lime, magnesia etc. with the gypsum.

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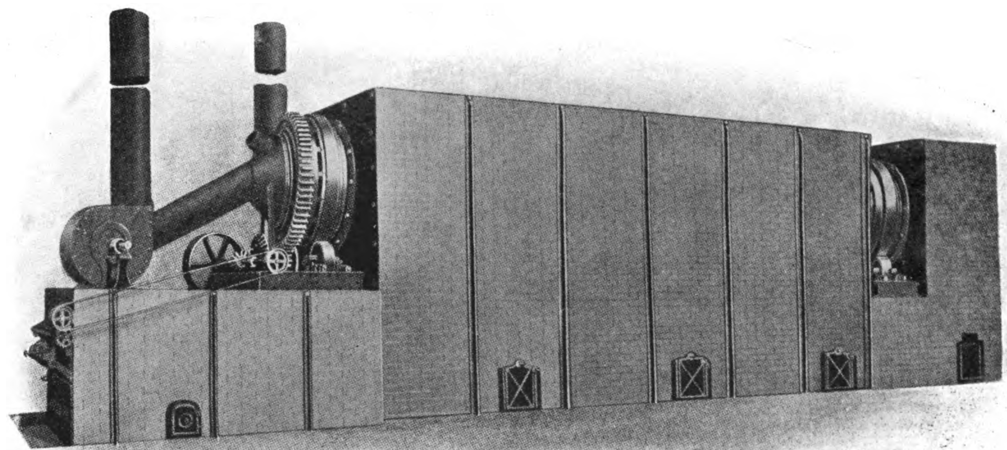
1 Grimsley, G. P. Technology of Gypsum. Mineral Industry. 1899. 7:390.

2 Wilder, F. A. The Gypsum Industry of Germany. Iowa Geol. Sur. An. Rep't 12. 1902. p. 217.

Plate 23



Cummer rotary calciner

The composition of the plaster, other things being equal, is an index of its setting properties. A pure plaster of paris of normal fineness when mixed with water will harden in about six minutes. This is known as the initial set.[1] Impure plasters, on the other hand, may require an hour or more to harden.

Addition of retarders. Plasters intended for wall and other structural purposes must be slow setting to avoid difficulty in manipulation. If this is not a natural property, which may be found in the impure sorts, it is necessary to induce slow setting by the addition of some foreign material. As a matter of fact practically all wall plasters, however impure, require treatment with a "retarder" by which the time of setting is prolonged to from two to four or five hours, according to need.

The retarders employed by manufacturers of wall plasters include such materials as glue, glycerine, chemically prepared hair, slaked lime, sawdust, and the tankage from packing houses. Most manufacturers have a preference for some particular material, the nature of which, as well as the proportions used, is generally carefully guarded. There are also several patented preparations on the market. The effect of the retarder is probably to decrease the solubility of the plaster and thus to extend the period of hydration and recrystallization.

The retarder is added to the cool ground plaster in amount varying from 2 to 15 pounds a ton and is thoroughly incorporated by the use of a mixing machine.

Wall plasters also contain some fiber — hair, wood or asbestos — which is added before mixing. From 1 to 3 pounds of hair to a ton of plaster is the general proportion. The hair must be previously teased out by a picker. The wood fiber is made from a soft wood like poplar, willow or basswood. The wood, cut into 20-inch lengths, is run between two revolving toothed cylinders which rapidly shred it. The mixing of the various ingredients is usually carried on in a mixing machine known as the Broughton mixer [pl. 24].

Anhydrous plasters

This class of plasters has as a basis the dehydrated product which results from calcination of gypsum at a higher temperature than is used in plaster of paris manufacture. Such plasters are

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[1] The set of plaster is determined in the same way as in the case of cements. The apparatus commonly used is the Gilmore needle. A sample pat having been made from the plaster, a needle of $\frac{1}{2}$ inch cross section loaded with a 4-ounce weight is placed on it. The initial set is completed as socn as the needle fails to make an impression.

characterized by slow setting when mixed with water and by a hardness superior to that of the half hydrate class. They are used more specially as material for floors and for hard finishing of walls, and corresponding to these uses two general varieties may be recognized — *Estrichgips* or flooring plaster which was first introduced in Germany, and the so called cements, of which Keene's cement is a common example.

The manufacture of flooring plaster is still centered largely in Germany. Its technology has been described briefly by Wilder.[1] The nature of the material is still not well understood, though an investigation by Van't Hoff and G. Just[2] has thrown some light on the subject.

According to Wilder, Estrich gypsum is prepared by calcination of rock gypsum at a temperature of about 500° C. The rock is not crushed, but taken directly from the quarry to the kiln. The kiln resembles that used in lime burning. The gypsum blocks are thrown in at the top and pass over an inclined grate which lies over a fireplace. They slowly work their way over the grate, through a constricted space, and finally, when calcined, fall into a cooling chamber. No attempt is made toward a close control of temperature.

Estrich gypsum has come into general use in Germany as a flooring material for office buildings, factories etc., where it takes the place of portland cement. It admits of coloring and polishing, so as to yield a good imitation of marble or other attractive stone.

Hard finish plasters or gypsum cements are made from anhydrous plaster by treatment with some chemical. The best known representative of these plasters is Keene's cement, which was first manufactured in England. The burning process is performed in a vertical kiln, somewhat similar to that just described, where the rock reaches a red heat. The dehydrated material is then treated with a 10 per cent alum solution, after which it is again burned at high temperature and ground for use. The action of the alum is perhaps to assist the solution of the dead-burned gypsum. The plaster sets slowly and when quite stiff can be softened again with water, without impairing its hardening power. The high temperature at which it is burned tends to oxidize any iron present so that a perfectly white product can be made only from rock gypsum that is practically free from such impurity.

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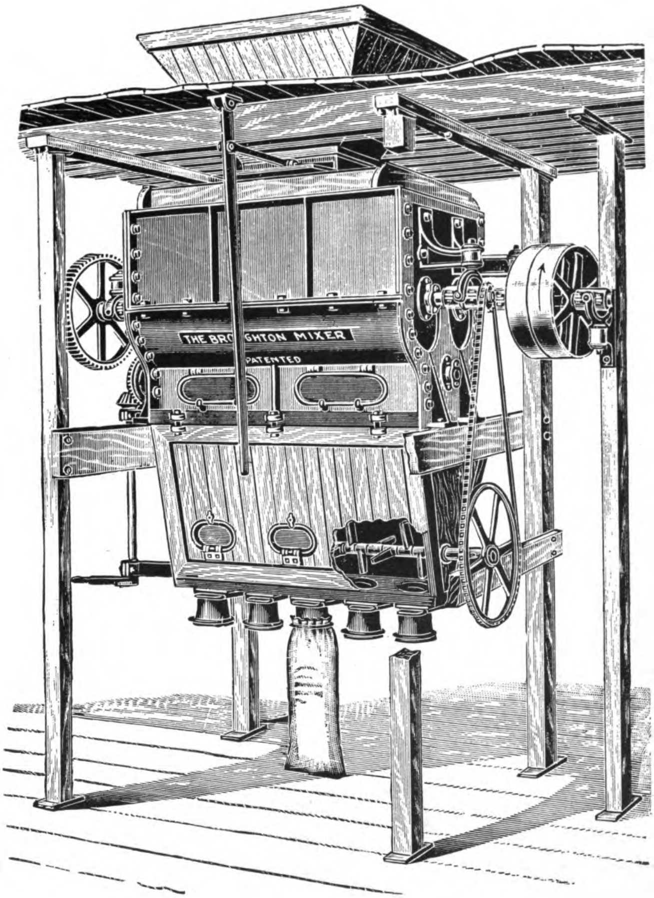
[1] *Op. cit.* p. 219.

[2] Kgl. Preuss. Akad. Wissensch. 1903. 1:249. A translation of this paper appears in E. C. Eckel's *Cements, Limes and Plasters.*

Plate 24



The Broughton mixer

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New York State Education Department

New York State Museum

JOHN M. CLARKE, Director

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Museum bulletins 1887–date. 8vo. *To advance subscribers, $2 a year or $1 a year for division (1) geology, economic geology, paleontology, mineralogy; 50c each for divisions (2) general zoology, archeology and miscellaneous, (3) botany, (4) entomology.*

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