

which is more sandy and with many small seams of fossils and cavities of calcite crystals.

Following the creek down 100 feet from the old abandoned dam, the following section occurs:—

- 1 foot clay drift;
- 2 feet limestone, many fossils and nodules. Brittle argillaceous at top and gray arenaceous at bottom.
- 1 foot brittle cherty limestone with small white streaks of chert.
- 5 feet gray brittle finely laminated freestone which has a few inches of black shale at its top.
- 4 feet sandstone of gray color in places, very probably due to weathering. No fossils.

A point 200 feet from the dam another section occurs, which, perhaps, is more of the sandstone of this series and has the following beds:—

- 3 feet clay drift from the surface.
- 3 feet gray hard limestone with a few fossils mostly concretions like quarry at Harmon City.
- 6 feet bluish thin bedded sandstone or freestone resembling some of the grindstones with a three inch layer of black shale at top of the bed.
- 8 feet, made up of 4-inch layers of bluish sandstone. Each bed in 4-inch layers.

TURNER.

All of the deeper wells which have been drilled in the village of Turner have penetrated a bed of more or less thickness of gypsum. The conclusions which have been reached from a few tests have been that the beds were too far below the surface to be of practical use in commercial workings. All of the shallow wells dug in the till contain large boulders of gypsum; out of one well nearly one-half ton of these boulders were taken, showing the abundance of gypsum within the till. The appearance here of these boulders is due to glacial action which scrubbed off masses of rock, in the region of the northeast, where the gypsum outcrops plentifully and were thus carried by the ice in the ground moraines and left in this place.

The water of most of the shallower flowing wells is strongly gypsiferous. The water from the flowing well at the schoolhouse, in Sec. 8, T. 20 N., R. 6 E., which is east of Turner and gives a strong test for gypsum and in drilling it three distinct beds of gypsum were found each three feet in thickness, and the test of this water indicates that the bottom of the well is still in the Michigan series.

Near the corner of Sec. 9, of this same town, Mr. Clukey drilled a 235-foot well and passed 8 feet of gypsum at 95 feet. In Turner, near the Detroit and Mackinac depot, is a well of 300 feet depth and a very strong flow. The record of the well shows gypsum of 5 feet thickness at 64 feet. Mr. M. H. Eymer of this place has a well of 105 feet depth and at 50 feet passed a 12-foot vein of gypsum.

The flowing well drilled on the property of Mr. Swartz penetrated a 15-foot bed of gypsum at a depth of 50 feet, the covering being drift and brown limestone. One mile north of the Swartz property, Mr. Applin drilled a well and obtained a strong flow at 250 feet, striking a 15-foot bed of gypsum at 25 feet.

Several years ago Albert Hann opened a 36-foot pit east of Turner, in the southeast corner of Sec. 8. The pit was opened with the expectation of obtaining a large bed of gypsum near the surface, but the work was finally abandoned for the reason that no bed was found near the surface of sufficient size to be of any value in working. The following strata are quite typical of the underlying rocks penetrated by the wells in this region:—

- 25 feet boulder clay filled with gypsum and occasional erratic.
- 3 feet blue, grayish arenaceous shale containing small grains of undissolved gypsum particles.
- ½ foot of gypsum interseamed with hard brown limestone.
- 7 feet consisting of hard flinty limestone with many cherty layers and small seams of gypsum.

COUNTY LINE.

Where the Detroit and Mackinac R. R. crosses the east side of Sec. 36, T. 20 N., R. 6 E., the Michigan series are exposed for nearly 200 feet in the sides of the track in the three foot cut made for grade of road bed. The outcrop is covered by the drift in all parts of the near vicinity. The land at this place is formed into a distinct low ridge crossing the R. R. track at right angles and its prominence is perhaps due to the fact that it consists of the hard calcareous sandstone which occurs just above the gypsum at the Keystone darn, Harmon City, and in the small test hole on the property of Albert Hann. The exposed gypsum here is a 6-inch layer and several other layers of hard cherty limestone. The cap of these formations is a hard brown sandstone of a foot in thickness. Along the top of this ridge, which is quite pronounced in direction, would be a place quite suitable for further exploration for the location of a bed sufficient for working on a commercial scale. The well records, especially those of Mr. Applin and Mr. Swartz, are good clues as to what may possibly be expected in the size of bed to be found.

West of the track, near the center of the rather broad, low east and west ridge, Mr. McLean dug a small experimental pit, and from the material thrown out, sandstone was found in abundance, and the gray smooth limestone, both of which closely resemble layers exposed at Harmon City on the shore of Lake Huron, and with these beds are associated a few small layers of gypsum. At the house of S. B. Dwyer, which is west of the R. R. and southwest of the low ridge, a dug well was made into six feet drift through 12 feet shelly brown sandstone and one foot of blue grayish shale.

AU GRES.

The gypsum beds can be clearly traced by wells to the south of the outcropping region as they dip to the center of the basin. This is especially noticeable in the deep wells of the townships of Au Gres and Whitney, in Arenac county. The well on the William French estate, in the northwest part of Sec. 6, T. 19 N., R. 7 E., has a record of 14 feet of gypsum at 100 feet in depth; also the well in Mr. Coles farm reaches gypsum at 80 feet in depth, while south of the village the wells of Mr. Ullman and Mr. Silly penetrate a bed of gypsum at 100 to 115 feet. In the above village some of the shallow wells, like those on the properties of Mr. Grimore, Mr. Bradley, Mr. Badour, show small streaks of gypsum at a depth of 50 to 60 feet.

HARMON CITY.

In Arenac county the point of contact in the Maxville limestone and the Michigan series is on the shore of Lake Huron, 500 feet north of the northeast corner of Section 24, T. 20 N., R. 7 E., and north on the shore of Harmon City. At this point the banks are 15 to 20 feet high. The entire ledge shows the effect of the lake action and the following section is well exposed:

- 4 feet clay or till.
- 3 feet red clay, with particles of lime.
- 1½ feet white clay.
- 3 inches cherty limestone.
- 5 inches of cherty limestone and sandstone closely interstratified.
- 1 inch shale and brownish limestone.
- 8 inches limestone.
- 6 inches brown sandstone.
- 4½ feet bluish gray sandstone.
- 10 inches arenaceous limestone.
- 5 feet bluish sand.

The strata are quite irregular as the thickness of the limestone varies and, as Winchell has noted, the dip from the point seems to be north and south.

WHITTEMORE TEST HOLE.

Going north 1-8 of a mile on the lake shore from the above outcrop, to the old Whittemore test shaft, we find the limestones are blended into brownish sandstones and the layer of bluish arenaceous sandstone in the stratum of 1½ feet thickness, which is crumpled and folded with thick seams of argillaceous limestone. In this shaft a 10-foot seam of gypsum was reported to have been found, but the project was given up, because of the inflowing water. From this point north on the shore to Alabaster, the lake sand covers all evidences of outcrops. Off shore from this point in 15 feet of water, are seen white beds of gypsum, being part of the lower bed worked at Alabaster and the one penetrated by wells at Au Gres and Turner.

The following are the railroad elevations of this district above tide:

MICHIGAN CENTRAL, MACKINAW DIVISION.

(Old Jackson, Lansing and Saginaw R. R.)

White Feather.....	604
Saganing or Worth.....	622
Standish	625
Deep River.....	657
Sterling	743
Dunham	764
Quinns	784
Alger	782
Culver	787
Summit	829

DETROIT AND MACKINAW RAILROAD.

Station.	Distance from Bay City.	Elevations.
Bay City, Saginaw Bay and North-western Branch of the M. C. R. R.	18.6	593.33
Saganing	25.7	592.58
Pine River.....	29.4	595.58
Omer	34.2	610.94
Twining	39.2	638
Turner	41.5	632
Emery Junction	48.8	672
McIvor	50.6	664
Marks	54.3	644
Tawas City	59.7	587.5
East Tawas	61.0	587.5
Oscoda	74.3	601.5
Alpena	126.0	601.5

May 30, 1901, the lake level was 7.5 feet below track grade at the East Tawas station.

An old profile at the Engineer's office of the Detroit and Mackinac R. R. states that the elevation of grade on the south bank of the Rifle river below Omer is 25.36 feet which equals 20.94 feet carried from Emery Junction. Thus the datum of the line north from Bay City is 4.42 feet higher than from Emery Junction to Omer. This may be accounted for by the fact that the datum from Emery Junction south was five feet lower than the datum of the line from East Tawas to the Junction which was built first and continued to Alger by the Michigan Central. The line from East Tawas to Alger was referred to 580 A. T. (the level of Lake Huron at East Tawas in 1880, and gives Alger, according to the D. & M. profile an elevation of 781 feet which checks with elevation obtained by the Michigan Central for the same place. The line from Bay City north was evidently referred to 580 A. T., a very meager record of this fact is made in one of the field books of the railroad office and some point of Saginaw River was used as a datum. All of the above elevations are based upon the datum of 580 A. T., for Lake Huron.

DETROIT, BAY CITY AND ALPENA RAILROAD.

This road is now abandoned from Alger to Prescott, the remainder of the original line from Prescott to East Tawas has been consolidated with the Detroit and Mackinaw railroad.

Stations.	
Alger	781
Moffat	769
Shearer	796
Prescott	768
Mills	794
Whittemore	777
Emery Junction	672

The elevations are referred to the datum of Tawas Bay on May 30, 1901, which was taken as 580 A. T. This line of the Bay City and Alpena at one time connected with the Mackinaw Division of the Michigan Central at Alger. The elevation of Alger on the profile of the old line is 781 A. T., which checks with that given to Alger by the Michigan Central.

§ 8. Huron County.

The strata of the Alabaster district pass southeast into Huron county.¹ The sub-carboniferous limestones of the Upper Grand Rapids found in Arenac county are also found with nodules and geodes of chert and quartz and interstratified lenses of coarse sandstone on the Charity Islands and around Wild Fowl Bay. Underneath them are the beds of the Lower Grand Rapids Group, mainly shale with some dolomites and some gypsum, as shown in the geological column of the county given in Figure 10, a reproduction from Plate I, of Vol. VII, Part 2. Upon the geological map of the county, Plate VII, the course of the point where one gypsum bed comes to the base of the drift is outlined. This appears to be well marked by the character of the well water.

Generally, however, there are from 20 to 30 feet of drift. Probably the best chance of striking gypsum tinder a reasonable cover is along the valley of the Pinnebog near Soule. Compare the wells on Sections 7, 8, 16, and 36 of Chandler Township. Beside these references on pages 182 and 185, see the records at Caseville, pp. 189, 179; Wisner, p. 164, 167; around Tarry in Fairhaven, pp. 161-161, and p. 226. Gypsum evidently extends down into Tuscola county, but I think that going southwest from Huron county we come toward a ridge or anticlinal in the Marshall sandstone which was probably formed during the early carboniferous time before the formation of the gypsum, and served to limit the extent of the gypsum on the southeast side of the coal basin. Here and there are patches of strongly saline shallow wells, but on the whole wells from Vassar and Flint to Bellevue show but little sign of the gypsum formation.

¹See report on Huron county, Vol. VII, Part II of these reports.

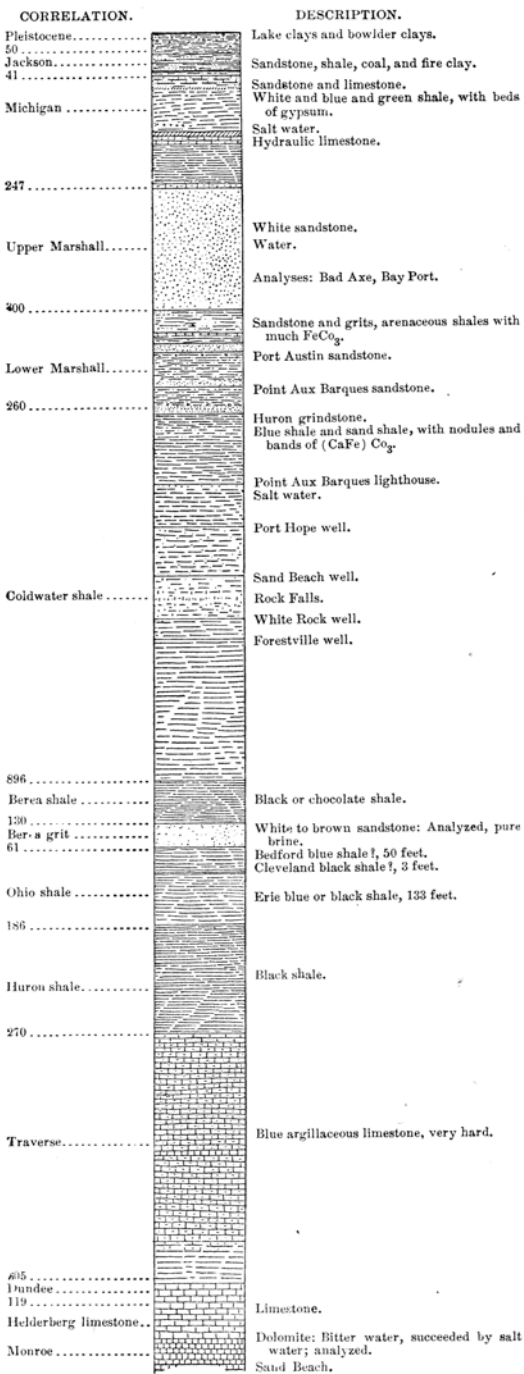


FIG. 10. Geological Section of Huron County

[10. Geological Section of Huron county]

CHAPTER V.

GYPSUM DEPOSITS OF ST. IGNACE.

§ 1. Historical.

The town of St. Ignace is located in Mackinac county on the northern peninsula of Michigan across the straits from Mackinaw City. The narrow peninsula extending southeast from Upper Michigan, terminates in the point of St. Ignace just below the town of the same name. Small capes jut out on the east and west sides of this peninsula, and are known as points. The prominent ones on the west side are, Point Aux Chênes and Point Labarde; and on the east, Gross Point and Rabbit's Back Peak. Plates XXI and XXII.

The narrow gravel and sand beach rises rather abruptly to the upland bluffs covered with pine and poplar timber. The area is traversed by the Duluth, South Shore, and Atlantic railroad, which terminates at the Point and there is connected by ferry with Mackinaw City of Lower Michigan.

The town of St. Ignace extends along the shore and a short distance on the bluffs above. Its history dates far back to the early days of the Jesuits. This place was an early missionary outpost and here is the grave of that famous priest, Pere Marquette.

The bluff above and around the city north and south is composed of heavy ledges of limestone of the Monroe series, which in geological age is Lower Helderberg or Salina. The rocks are covered near the town by a mantle of drift which has disappeared in many places through erosion. It has been an important lumber center and attempts have been made to develop a salt industry. St. Ignace is reached by steamers from Chicago, Detroit, and other lake ports. The distance from Chicago is 330 miles.

An early account of the gypsum deposits at St. Ignace is given by Dr. J. J. Bigsby (the eminent geologist, after whom the Bigsby Medal was named). Dr. Bigsby was surgeon at Fort Drummond and in a paper read Feb. 1st, 1823, entitled "Notes on the Geography and Geology of Lake Huron," published in the Transactions of the Geological Society (p. 193) he says: "At the isles of St. Martin, however, we find a large deposit of gypsum. It is an extensive bed of the granular kind, white, gray, and brown, interspersed with frequent masses of red, white, and brown selenite, occurring in shapeless lumps, in veins, or in small and very thin tables, having three or more sides and sharp angles." This account is the first found of the occurrence of gypsum in Michigan.

In the 50's there was a gypsum quarry opened on the west side of the peninsula, seven miles west of St. Ignace near Point Aux Chenes, and a dock was built for loading the gypsum on boats carrying the rock to Chicago, where it was calcined. A scourge of smallpox caused a temporary abandonment of the work, and

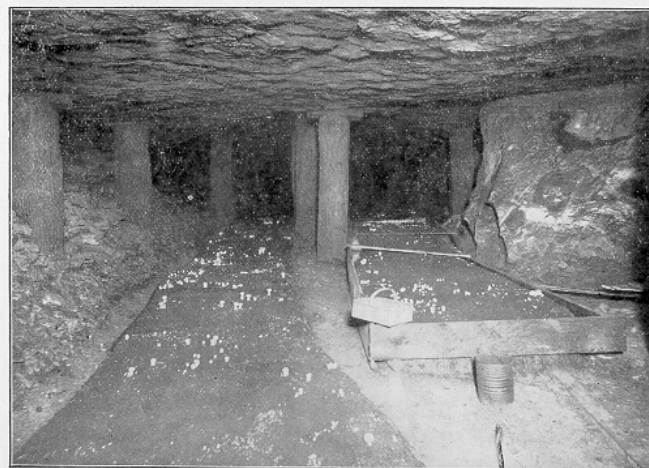
water in the quarry was a continual source of trouble. It was worked in an interrupted way for a number of years, until an ice gorge carried away the dock and the quarry was abandoned. The property is now owned by Chicago parties, but no work has been done for many years.

Geological Survey of Michigan.

Vol. IX Part II Plate X.



A. CAR OF GYPSUM COMING OUT OF MINE.



B. ABANDONED ENTRY WITH MUSHROOM BEDS.

[X. A. Car coming out of Mine
B. Mushrooms in Gypsum Mines]

About 1894 the Keystone Plaster Co. of Chester, Penn., drilled some test holes two miles west of the old quarry. The records of this work seem to have been lost, but it is stated by some of the men engaged on that work that 60 feet in all of gypsum were found in these wells, and the first ledge of a few feet in thickness was struck under a light cover. No development has followed this drilling.

§ 2. St. Ignace Wells.

In 1888 the Mackinac Lumber Co.. drilled a well at the edge of the town of St. Ignace, which was 919 feet deep, and no gypsum was recognized in the upper layers.

Mackinac Lumber Co. Well.¹

15		sawdust, clay.
485	500	red and blue shales (probably gypsiferous, L.).
400	900	limestone, traces of gypsum.
19	919	sandstone.

The shales, 500 feet thick, belong to the Monroe, and the 400 feet of limestone belong to the Niagara, with possibly the Medina or Hillsboro sandstone below.

A few years ago a new well² was drilled two miles north of the old one. This is located in Section 31, T. 41 N., R. 1 E., and about 600 feet north of the town line close to the lake.

The record may be summarized as follows:

Pleistocene	{	34	Surface.
	{	11	45 gravel with gypsum.
	{	129	174 dolomite and shales.
	{	13	187 gypsum.
	{	68	255 red and blue shales.
Monroe	{	5	260 gypsum.
	{	69	329 red and blue shales, gypsum at 300.
	{	97	426 blue shales, some gypsum.
	{	18	444 gypsiferous dolomite.
	{	66	510 dolomite.
	{	510	1020 dolomite (water flowing).
Niagara	{	90	1110 limestone.
	{	56	1166 dolomite.

Some gypsum was found at 35 feet, and 13 feet of gypsum were found at 174 feet, 5 feet at 255 feet depth, and more or less gypsum at other points.

¹Mich. Geol. Survey. Vol. V, Plate LXIII.

²Annual Report of Mich. Geol. Survey, 1901, pp. 227, 228.

§ 3. Rabbit's Back.

Four miles north of St. Ignace is a prominent spur of limestone bluffs extending into the lake and known as Rabbit's Back. It is clearly visible from the town from which it is separated by a half moon bay. Plate XXII. The bluff, composed of a magnesian limestone, which appears to be unfossiliferous, rises over 200 feet above the lake water, and shows marked effects of erosion. There is practically no drift cover, though granite boulders are common at the foot of the bluffs and on the slopes. A few years ago two kilns were operated here making lime from the stone above.

In 1892, Mr. Chamberlin, the owner of this land, had five holes drilled with a diamond drill under the supervision of Mr. Wm. S. Chalker, who has furnished me with the records of this work.

In well No. 2, the following rocks were found:

23 feet	clay, limestone and some gypsum.
9 "	limestone.
21 "	white gypsum.
3 "	shaly limestone.
9 "	gypsum.

These wells were drilled on the land below the bluffs in an area of 70 acres, and about 10 to 15 feet above the

water level in the lake. They all showed about the same order and thickness of the rocks. The gypsum in this point outcrops near the water's edge and can be seen under the water near the shore. At other places it is covered by about 14 inches of dirt.

Drilling was also done on the tract adjoining the Chamberlin land and gypsum was found. It was estimated that the gypsum area in this region would include about 160 acres. Gypsum was found at Gross Point four miles north of Rabbit's Back, and its outcrop is seen near the shore from this point on to the east for several miles. The gypsum is fairly white, and in places it is spotted with dark selenite crystals rounded in outline.

Similar crystals were found included in some of the Kansas rock gypsum, and their formation was thus explained by Haworth:¹

"The existence of such phenocrysts (or crystals) indicates that the ocean water was at one time evaporated very slowly, and under the most favorable conditions for the production of individual crystals. Later there was a slight freshening of the water by surface drainage entering the concentrated lake, so that a partial redissolving of the crystals was effected, as shown by the rounded edges of the crystals. Still later there was a rapid evaporation of the water, precipitating the massive gypsum, and an agitation of the shallow water sufficiently vigorous to mix the crystals already formed thoroughly with the new precipitated gypsum, forming the whole mass as it now appears."

¹University Geol. Survey of Kansas, Vol. V, p. 59.

§ 4. St. Martin Island, etc.

Some gypsum exploration was carried on a few years ago on St. Martin Island to the east of Rabbit's Back, and the rock shows in the water and was found in shallow wells over a large portion of the southern part of the island. The rock by analysis shows 98 per cent of gypsum, and so contains very little impurity. The records at hand would indicate good deposits which could be worked to advantage if the water could be kept down in the mines at a reasonable cost. The rock on St. Martin Island is stated to be three feet thick in the ledge close to the surface, with other layers further down.

The objections to the St. Ignace gypsum deposits, that they are in thin veins and of poor quality, are apparently untrue. The evidence at hand does not accord with these rumors. The price of fuel might prevent the manufacture of plaster in this section of the State though water transportation is available, but the gypsum might be mined and shipped to other points further south. At the present time there is no development of these gypsum fields. [It is probable that gypsum occurs not far beneath the surface in the northern islands of the Beaver Island group. I have seen many indications of it. L.]

CHAPTER VI.

A STUDY OF WELL BORINGS.

§ 1. Preliminary.

A large number of wells have been drilled in this State in search for water, salt, oil, and gas. Many of the records of these wells have not been preserved, but a considerable number have been printed in the reports of the State survey. In these reports it is not always possible to identify the formation. An examination of published records shows the Michigan series identified in 24 wells.¹

A comparative study of the records preserved will throw some light on the distribution of the Michigan group of rocks, and the places where gypsum² is to be found and at what depth. A study of the underlying sandstone will throw light upon the nature of the floor of the old sea, from which the salt and gypsum were precipitated.

The gypsum deposits of Michigan at Grand Rapids and Alabaster are found in the Grand Rapids division of the Michigan group, which is Carboniferous in age. The deposits at St. Ignace are in the Salina formation. In the wells in Monroe county and some others in the State gypsum is found in this same formation. The first division of this chapter will be devoted to the study of the gypsum in the Carboniferous, and the second to the deeper deposits of the Salina.

In most of the wells, the first formation on the surface is the drift, consisting of sands, clays, and gravel. The records which follow have been taken mainly from the published reports of the Michigan survey, but have been condensed and adapted to the present purpose. The levels given are railroad levels of the nearest points, and so are not always accurate for the top of the well.

¹Viz.: Alma, Vol. V, Pt. 2, p. 45. Vol. VIII, Pt. 2, p. 175; Bay City, Vol. V, Pt. 2, Plate VI, and annual for 1901: Caseville, Vol. V, Pt. 2, p. 53; Vol. VII Charlotte V, Pt. 2, VIII; Corunna V, Pt. 2, Plate XII; East Saginaw V, Pt. 2, p. 55; South Saginaw and the Bliss well, VIII, Pt. 2, p. 176; Grand Rapids V, Pt. 2, p. 61; Kawkawlin V, Pt. 2, p. 65; Midland V, Pt. 2, p. 69, VIII, Pt. 2, p. 163; Sebewaing VIII, Pt. 2, p. 172; St. Charles VIII, Pt. 2, p. 192; St. Johns VIII, Pt. 2, p. 196; Durand VIII, Pt. 2, p. 199; Mason VIII, Pt. 2, p. 217.

²It is worth noting that microscopic observations lead me to believe that all the calcium sulphates below, say 500 feet, is really in the denser form of anhydrite and water rather than gypsum. This is to be understood in reading the description. When anhydrite is mentioned it is because I have actually recognized it as such under the microscope. I have also inserted some newer data regarding Mt. Pleasant, Detroit, Wyandotte, Milan, Ludington, Muskegon, etc. L.

§ 2. Carboniferous (Grand Rapids Group) Gypsum.

The distribution of the Grand Rapids group below the surface cannot be described over very much of the State of Michigan on account of the small number of well records available. The farthest north this group is found in recorded wells is at Grayling in Crawford county, 125

miles northeast of Grand Rapids. The formation in the Grayling well consists of sandstone, limestone, shales, and gypsum, 175 feet thick as compared with 177 feet in the Lyons well at Grand Rapids. The gypsum is 408 feet from the surface, where the level above tide is about 1,135 feet. It is reported as 132 feet thick, but there is but one sample, and this is doubtless incorrect and the thickness includes shales. This record would place the gypsum 727 feet above sea level, while at Grand Rapids it is 530 feet in the Lyons well. At Grayling the Grand Rapids group rests on the Coldwater shales.

A general theoretical section of the Lower Michigan rocks is as follows:

	Feet.
Drift.....	3 to 60
Saginaw (Jackson) Coal Group (Upper Carb.).....	50
Parma.....	100
Grand Rapids Group.....	300
Marshall sandstone.....	75
Coldwater shales, etc. (Waverly).....	800
Berea sandstone.....	65
Antrim shales (Devonian).....	225
Traverse Group (Hamilton).....	350
Dundee limestone (Devonian).....	100
Monroe beds (Lower Held. and Salina).....	700

The Grayling well record may be summarized from the Annual Report of Michigan Geological Survey, 1901, page 232, as follows:

Drift	365 feet	drift gravel, etc.
Lower Grand Rapids	380 "	15 calciferous sandstone.
	408 "	28 dark limestone.
	540 "	132 gypsum and shales.
	960 "	420 blue shale.
Coldwater	1150 "	190 limestone.
	1540 "	390 blue shale.
Berea (?)	1590 "	50 red and blue shales.
Devonian	2750 "	1160 shales and limestone.

On the eastern side of the Lower Peninsula are found the records of the East Tawas well, those of Huron county already referred to, and the group of Port Huron wells at New Baltimore, St. Clair and Marine City. In the Port Huron group of wells, the Pleistocene rests on the Devonian, with no traces of the Carboniferous strata. The gypsum (anhydrite) comes from the Monroe (Salina) rocks. At East Tawas 50 feet of drift rests on the Marshall sandstone with no traces of the Grand Rapids group. In the Sebewaing well of Huron county, 56 feet of drift rests on 44 feet of the coal measure sandstone and shales. The Grand Rapids group, 100 feet below the surface, consists of shales and limestone with no gypsum beds, and rests on the Marshall sandstone, which is 248 feet below the surface. (See the Huron county report, Volume VII, Part 2.) But the wells for Terry, the next station, and thence north, show more or less gypsum.

In the Saginaw and Bay City area there have been numerous wells drilled in search for salt, and out of the large number a few records are available. At Bay City the Grand Rapids group lies below 100 feet of drift and 465 feet of Jackson coal shales. It consists of limestone, sandstone, shales, and gypsum in a 12 to 15 foot layer. The gypsum is 712 to 720 feet below the surface and 128 feet below sea level. Below the Grand Rapids

group comes the Marshall sandstone and Coldwater shales.

The Bay City well record (a newspaper record) given in Volume V, is as follows; down through the Grand Rapids series:

Drift	120	120	
Saginaw coal measures	444	565	
Grand Rapids series	{ 20	585	limestone, 85% brine.
	{ 50	635	sandrock.
Lower Grand Rapids or Michigan	{ 25	660	sandy shale.
	{ 40	700	blue shale.
	{ 12	712	gypsum, ¹ white 6-inch casing to 722 feet. ²
Marshall, upper	{ 108	820	blue shale.
	{ 10	830	hard limerock.
	{ 80	920	sandstone, brine 100. ^o
Marshall, lower	135	1055	red and white shale and so on down to 2865 feet.

¹Or anhydrite.

²Compare with Saginaw wells, like Whittier's No. 3, which when about 740 feet deep was cased down to 551' 2".

The well at the North American Chemical Co.'s works, So. Bay City, was given in the Annual Report for 1901, p. 224, as far down as the Marshall, and is as follows, revised:

Drift	105	105	sand, clay, etc.
Saginaw coal measures	385	490	shale, quicksand, and salt.
Parma ?	50	540	sandstone pyrite at top.
Upper Grand Rapids	{ 80	620	limestone.
	{ 5	625	sandstone.
	{ 5	630	limestone.
	{ 30	660	shale.
	{ 10	670	gypsum, etc.
	{ 30	700	limestone 10, shale 10, sandstone 10.
	{ 7	710	gypsum (compare 712 of 1st well).
Lower Grand Rapids	{ 10	720	" and limestone.
	{ 10	730	" shale.
	{ 70	800	shale and limestone.
	{ 10	810	limestone, gypsum shale.
	{ 20	830	limestone and shale.
	{ 20	850	pyritic limestone.
Upper Marshall, Napoleon	120	970	water-bearing sandstone.
Lower Marshall	225	1295	sandstone and shale largely red.
Coldwater.	2050	760	shales.
			Goes on down to 3508 feet.

It appears that beside other gypsum beds, one near the bottom, there is a quite persistent bed 130 feet or so above the bottom. A bed in a similar position is found in Huron county, at Midland, Alma, and Mt. Pleasant, so that it is probably quite persistent.

At Kawkawlin, just north of Bay City, the drift is 100 feet thick and the Jackson Coal group 300 feet. Gypsum was found at 400 feet and the thickness of limestone and gypsiferous shales was 100 feet. This record is incomplete, but probably shows the Marshall sandstone below. The gypsum is 196 feet above sea level, and farther north at Alabaster it is about 600 feet above the sea.

Abstract of Kawkawlin Well, Bay County. Michigan Geol. Survey, Vol. V, p. 65.

Drift	100	drift.
Jackson Coal Measures	400	300
Grand Rapids Group	{ 500	100
	{ 700	200
Marshall ?	800	100
		shale, sandstone, coal seams.
		limestone, shales, gypsum at 400 feet.
		gypsiferous shales.
		sandstone.

Abstract of South Saginaw Well. Michigan Geol. Survey, Vol. VIII, p. 176.

Drift	340	Drift.
Saginaw Coal Measures	493	153
Upper Grand Rapids Group	{ 525	32
	{ 555	20
Lower Grand Rapids or Michigan	{ 570	75
	{ 665	95
	{ 690	25
Marshall	715	25
		sandstone, shale.
		sandy limestone.
		impure sandstone.
		calcareous green shale.
		green shale.
		argillaceous dolomite.
		sandstone.

At South Saginaw the Grand Rapids group is 493 feet below the surface or 95 feet above sea level and consists of limestones and shales, and the same order seems to hold in the East Saginaw well, where the group is 398 feet below the surface and consists again of sandstone and shales, with some limestone and no beds of gypsum mentioned.¹

¹Though from the casing down to cut off the gypsum bearing brines it is probable that more or less is present, and Mr. John Coryell tells me that such is the case. For instance the Whittier well at Florence 740' 11" deep was cased with an offset down to 551' 2" to keep out the gypsum, or gypsiferous brine. L.

East Saginaw Well. Michigan Geol. Survey, Vol. V, p. 55.

Drift	92	drift.
Saginaw Coal Measures	398	206
Grand Rapids Group	{ 462	64
	{ 634	172
Marshall ?	{ 797	163
	{ 800	3
		alternating sandstone and shale.
		alternating limestone and sandstone.
		alternating shale and sandstone.
		sandstone.
		bright red shales.

In the next county of Midland, west of Bay City, a five and one-half foot layer of gypsum was found in the Sanford well 134 feet below the surface. An occurrence similar to that at Sanford appears to be that at Fremont township in Saginaw county. The age and occurrence of this Sanford gypsum and that of Fremont are very uncertain. I am tempted to believe they may be boulders in the drift, but it is also possible that they may represent interglacial or preglacial deposits derived from the erosion of Alabaster gypsum deposits. It is worth noting that boulders of gypsum are not uncommon southwest of Alabaster, as at Alma and Mt. Pleasant, and water of wells in the drift are very strong of sulphates.

Wells in Fremont and Brant townships, towns. 9 and 10 N. R. 2 E. also often show gypsum. The following records were collected by W. F. Cooper. "Mr. D. Steele, on the half of the west side of Section 33, Fremont township, has flowing wells 70 to 80 feet deep. There was said to be 25 feet and more of gypsum in this well. The record was also given by A. McPhee, the driller, as:

Clay	7	7
Clay and boulders	25	32
Sand and gravel	25	57
Hard pan (till)	12	69
Clay and gravel	1	70
Gypsum	18	88

Mr. A. McPhee, opposite on the east side of Section 32, reports a flowing well 107 feet deep with 7 feet of gypsum, at the bottom, till above. These wells were started as coal tests, and I have seen samples of the

gypsum obtained, and also talked with the intelligent business men F. G. Benhain, Barnes, Linton, etc., of Saginaw, for whom they were drilled. Two or three of the wells were put down and they are of the opinion that the gypsum is continuous, but a part of the drift. Of course, without a roof and in an artesian basin it is not mineable." A few miles to the south in the Midland well, the gypsum bed described as nearly pure anhydrite, 80 feet thick,¹ was 970 feet below the surface. In the later well the Grand Rapids group was 285 feet thick and consisted of limestone, calcareous shale, and anhydrite resting on the white sandstone of the Marshall formation.

¹But samples are not numerous.



MULES IN GYPSUM MINES.

[XI. Mules in Gypsum Mines]

Sanford Well.

Michigan Geological Survey, Vol. VIII, p. 164.

Drift	134	alternate sand and clay.
Grand	{ 139½	5½ gypsum.
Rapids Group	{ 240	100½ alternate sand and clay.
Marshall	254	14 white sandrock.

Midland Well.

Michigan Geological Survey, Volume VIII, p. 163.

Drift	285	drift.
Saginaw Coal	{ 920	635 sandstone, shales.
Measures	{ 970	50 limestone.
Grand	{ 1050	80 plaster red, fairly pure anhydrite.
Rapids	{ 1130	80 calcareous shale.
Group	{ 1205	75 limestone.
Marshall	1305	100 white sandstone.

To the south of Saginaw, in Shiawassee county, there are three records available. In the Owosso well the Grand Rapids group was found 473 feet below the surface and 272 feet above the sea. It consists of 83 feet of limestone, shales and thin beds of limestone, and it contains salt water but no beds of gypsum. In the Corunna well the Grand Rapids group was found at 649 feet, or 127 feet above sea level, and included 152 feet of sandstone and shales with no beds of gypsum.

Corunna Well.

Michigan Geological Survey, Volume V, Plate XII.

Drift	30	drift.
Saginaw Coal		
Measures	225	255 alternate shales and sandstone.
Parma	649	394 sandstone.
Grand	{ 706	57 sand, shales.
	{ 738	32 blue shale.
	{ 743½	5½ sandstone.
	{ 744	1½ black shale.
Rapids	{ 745	1 shale.
	{ 755	10 sandstone.
Group	{ 765	10 shale.
	{ 800	35 sand, blue shale.
Marshall ?	907	107 sandstone, shale.

Owosso Well.

Michigan Geological Survey, Volume V, Plate XLV.

Drift	100	drift.
Saginaw Coal		
Measures	{ 301	201 clays, shale, sandstone, coal.
Parma	{ 473	172 sandstone.
	{ 476	3 limestone.
Grand	{ 533	57 blue shale.
Rapids	{ 536	3 brown limestone.
Group	{ 541	5 salt (water ?).
	{ 556	15 soft shale.
Marshall	601	45 sandstone and salt water.
Coldwater	{ 716	115 shale, sandstone, salt water.
	{ 1000	284 shales.

The Durand Well, given in Volume VIII, Part II, p. 199, is not safely to be interpreted. No gypsum was recognized by the drillers. It is said to be mainly shale below the drift.

West of Saginaw, in Gratiot county, at Alma, the Grand Rapids group is found in 790 feet and consists of 225 feet of shales and shaly limestone with beds of blue and white gypsum at 860 feet or 105 feet below sea. This is the second record showing the gypsum below sea level, the other being the Bay City well described above. Calcium sulphate occurs at Mt. Pleasant and St. Louis, being probably anhydrite in all these wells. An analysis of the drillings from the Mt. Pleasant well gave M. A. Cobb of the Lansing high school:

	Per cent.
Fe ₂ O ₃ , Al ₂ O ₃	1.4
Ca C O ₃	2.83
MgO.....	.2
CaSO ₄	87.15
SiO ₂ , CO ₂ and }	8.42
Moisture	
	100.00

Alma Well.

Michigan Geological Survey, Vol. VIII, p. 175.

Drift	475	drift.
Saginaw Coal		
Measures	790	315 shales, sandstone, some coal.
Grand	{ 860	70 blue and black sandy shales.
Rapids	{ 895	35 blue and white (anhydrite) gypsum.
Group	{ 1015	120 argillaceous limestones.
Marshall	1500	485 sandstone and shale.
Coldwater	2250	750 shales.
Berea shale	2300	50 black shales.
Berea grit absent.	2360	60 blue shales.
Antrim shales	2750	390 black shales.
Traverse	2861	111 limestone and shales.

Good samples of the new wells for bromine of the Midland Chemical Co., at Mt. Pleasant, were saved. The elevation of the well is about 770 A. T., and the anhydrite is most abundant from 450 to 600 feet down, the record of the well being:

Drift.		
80	80	gravel, glacial overwash.
20	100	blue till.
20	120	quicksand.
160	280	blue till.
74	354	porous bed with water, coarse gravel on top, fine sand below.
26	380	red clay.
55	435	ground moraine till with broken coal measures.
Saginaw Coal Measures.		
185	620	black shale with streaks of coal (410', 435', 460') sandstone, limestone, or carbonate of iron and fire clay, mostly less than five feet thick.
90	710	Fine white sandrock with mineral water.
80	790	gravelly sandrock with a strong flow of water, not so salt.
30	820	shale and red limestone.
Parma and Maxville.		
30	850	white limestone.
120	970	white sandstone with very salt water.
55	1025	white limestone fiercely effervescing.
Lower Grand Rapids or Michigan Series.		
5	1030	shale.
20	1050	sandstone.
75	1125	dolomite and shale.
100	1225	anhydrite and dolomite.
45	1270	" nearly pure (gypsum).
103	1373	dolomite, shale and anhydrite.
8	1381	sandstone.
5	1386	shale.
4	1390	sandstone.
15	1405	shale.
160	1565	sandstone, dark with heavy brine.

To the south of Charlotte, in Eaton county, I recognize, in Vol. V, the Grand Rapids group, with some doubt. Only a few samples were saved, and those do not show any typical beds, though the Upper Grand Rapids or Maxville limestone crops out just south at Bellevue. It may be absent, for we are approaching the margin of the basin where there are variations due to irregular erosion.

A deep well at Assyria, 917 A. T. (Sec. 4 T. 1, N., R. 7 W.) shows two samples which were supposed to represent the rock from the bed rock surface at 162 feet to 240 feet, which are typical of the Michigan series, dark colored dolomites, with greenish shale and some selenite.

The reference of part of the Ann Arbor well to the Michigan series, by A. Winchell,¹ is certainly erroneous, and I am inclined to think that in the records of Jackson wells, given in Vol. V, the Grand Rapids group may be really absent, the heavy sandstone beneath the coal measure representing the shoreward coming together of the Marshall and Parma, as explained in Vol. VIII, Part 2, pp. 39 to 40.

The Ludington well, given as Plate XXIX of Vol. V, is an error. Mr. E. D. Wheeler says it is merely his correlation of their Manistee well. It may have been used in Ludington as a guide to the driller in putting down their well. A well was recently put down by the J. S. Stearns Lumber Co., and a good set of samples saved for us. A limestone facies like that of the Grand Rapids occurs between 576 and 650 feet, but similar rocks with some selenite occur in Muskegon wells, for instance, that of the Central Paper Co. from 625 to 850 feet down, which appears to be distinctly in the Coldwater series. I take it,

therefore, that there were forerunners of the Michigan series formed somewhat earlier along the margin of the Michigan basin, as a facies of the Coldwater series.

¹Vol. V, pt. 2, p. 48

§ 3. Well Records Near Grand Rapids.

In the area near Grand Rapids there have been in past years a number of wells drilled in search for salt. Most of these wells start on the Grand Rapids group or pass into this formation through a shallow drift cover. These wells were drilled from 1840 to 1860, and the records carefully preserved by Prof. Winchell. In the so-called artesian well the plaster rock was found 57 feet below the surface and mixed with clay shales. The Lyons well record is given in a very detailed section and shows alternating shales, sands, and gypsum of the Grand Rapids Group resting on the Marshall sandstone. In the State well the gypsum was 40 feet below the surface. In the Scribner well the stratum appears to be replaced by gypsiferous shale and the same is true in the Powers and Martin wells, one-half mile north of the Scribner well.

Artesian Well Co. Well. Michigan Geological Survey, Vol. V, Plate XX.

Drift	{ 10		drift.
	{ 57	40	black shale.
Grand Rapids Group	128	71	plaster rock, shale.
Marshall	259	131	sandstone.
Coldwater	1175	916	shales, sandstone.
Berea	1205	30	sandstone.
Antrim	1708	503	shales.
Traverse	1885	177	shales 67 feet and dark limestone.
Monroe	{ 2200	315	limestone, light above, dark below.
	{ 2.20	20	gas, marl, limestone, brine.

A record of the same well furnished by the Godfrey Estate.

10		gravel, clay.
127	118	gypsum and shales.
145	17	limestone.
240	95	sandstone.
259	19	"
271	12	blue clay shale.
400	129	sandstone.
702	302	shales.
712	10	limestone.
1155	443	shales.
1175	20	red clay.
1205	30	sandstone.
1775	570	shales.
2220	445	limestone.
2340	120	limestone, sandstone, with salt.

State Salt Well. Report of Winchell, 1860, p. 144.

Drift	40		drift.
Grand	{ 47	7	gypsum.
Rapids	{ 48	1	limestone.
Group	{ 61	13	clay, shale.
Marshall	473	412	clays, shale, sandstone.

Grand Rapids No. 2 or Lyons Well.
Michigan Geological Survey, Vol. V, Plate XXI.

Grand Rapids Group	{	14	hard gray limestone.
		20	6 sandstone.
		30	10 blue clay.
		41	11 clay with gypsum.
		59	18 clay shale.
		63	4 gypsum.
		65	2 clay shale.
		71	6 gypsum.
		74	3 clay shale.
		82	8 blue sandstone.
		100	18 blue clay.
		107	7 sand and clay.
		117	10 limestone ^e , gypsum.
		124	7 gypsum.
		133	9 clay shale.
		140	7 sandstone, clay.
		147	7 gypsum.
		153	6 clay shale.
		172	19 gypsum shale.
Marshall	{	175	3 gypsum.
		180	5 clay, sand gypsum.
		191	11 clay rock.
		265	74 sandstone.

Scribner's Salt Well.
Winchell Report, 1860, p. 146.

Grand Rapids Group	{	51	limestone.
		52	1 compact shale.
		54	2 blue limestone.
		204	150 shales, lime, sandstone, gypsiferous.
Marshall		315	111 sandstone.
		325	10 clay.
		380	55 sandstone.

Powers and Martin Salt Well.
Winchell Report, 1860, p. 147.

16	surface.
56	40 limestone.
97	41 shale, clay.
98	1 clay, streaks of gypsum.
116	18 shale gypsiferous.
120	4 shale.
136	16 gypsiferous shale.
138	2 sandstone.
156	18 shale with gypsum.

Indian Mill Creek Salt Co.
Well. Winchell Report, 1860, p. 149.

Drift	{	81		gravel, sand.
		84	3	white gypsum.
		92	8	clay, shale.
Grand	{	96	4	hard rock.
		130	34	clay.
Rapids	{	137	7	sandstone.
		141	4	clay.
Group	{	157	16	gravel.
		161	4	sandstone (bottom of Power's well).
		203	42	gypsum, clay.
		319	116	sandstone.
		334	15	clay and shale.
Marshall ?	{	424	90	sandstone.
		434	10	clay, sandstone.

Butterworth Salt Well.
Winchell Report, 1860, p. 148.

Grand	{	12	limestone.
Rapids		5	sandstone.
		1	limestone.
Group		1	clay shale.
		24	5 limestone.
		27	3 calcareous sandstone.
		57	30 clay, limestone.
		61	4 brown limestone.
		122	61 shales with gypsum.
		184	55 lime. gypsum.
Marshall ?	293	109 sandstone.	
	303	10 shale.	
	431	128 sandstone, shales.	
	490	59 shales, sandstone.	

Windsor Salt Well.
Winchell Report, 1860, p. 150.

Drift	{	43	drift.
		64	21 limestone.
		72	8 dark shale.
		76	4 sandstone.
		88	12 shale, gypsum.
Grand	{	89	1 sandstone.
		99	10 shale, gypsum.
Rapids	{	108	9 greenish clay, shales.
		132	24 gypsum, shales.
Group	{	152	20 blue and black shales.
		156	4 gypsum.
		166	10 black shale.
		179	13 gypseous clay, very salty.
		183	4 black hard rock.
		240	57 dark flint clay, gypsum.
		248	8 pyritiferous rock with gypseous clay.
Marshall	{	327	79 sandstone.
		349	22 clay, sandstone.
		423	74 sandstone.
		446	23 argillaceous sandstone.

Beyrich Brewery Well.
Michigan Geological Survey, Vol. III, p. 110.

Drift	{	35		drift.	
		36½	1½	limestone.	
		43½	7	blue shales.	
		45	1½	gypsum.	
		124½	79½	shales, pyritiferous rock.	
Grand Rapids		129½	5½	sandstone.	
		134½	5	gypsum.	
		135	½	sandstone.	
		137½	2½	shale.	
		142½	5	gypsum.	
		Group	147	4½	blue shale.
			147½	½	hard flinty rock.
			153½	6	gypsum.
			158	4½	blue shale.
			166	8	pyritiferous rock.
221			55	white sandstone.	
227			6	blue shale.	

In the Windsor well north of the city about 30 feet of gypsum in all was found and the first was struck at 76 feet or 529 feet above sea level. In the Butterworth well in the city, the first gypsum was found at about 70 feet or 533 feet above sea. In the Lyons well in the city 40 feet of gypsum were found and the first at 545 feet above sea. The wells south of the city, the State Salt well and the Godfrey well, reached the gypsum at 596 and 620 feet A. T.

These wells, studied in connection with the quarry exposures of gypsum, show that the gypsum surface is exceedingly irregular. It is highest north of the river and lowest in the city and north of the city. South of the river the gypsum dips northeast about 40 feet from the quarries south of the city to the wells in the city, or about

25 feet to the mile. The gypsum surface in the city and north beyond the city limits in the Windsor well appears to be almost level. If it ever seemed advisable to mine this gypsum in this area there would be trouble with water which would have to be removed by strong pumps.

§ 4. Drilling by the Pittsburg Plate Glass Company.

In the spring of 1902 the Pittsburg Plate Glass Co., having secured a tract of land north of the Grand River and west of Grand Rapids, drilled six wells in search for the gypsum rock (see Plate XVII). The Results of this work have been kindly furnished to the writer by this company, and the following account is based on the careful notes of their engineer, Mr. J. J. Mears of Grand Rapids.

The work demonstrated the existence of a good stratum of gypsum suitable for the manufacture of plaster, but the company decided not to develop the tract at the present time. The well records show the clay, shales, limestones, and some sandstone of the Grand Rapids series.

Well "A."			Well "B."		
78		sand and clay.	77		sand, clay, gravel.
80	2	shale.	78	1	shale.
85	5	flinty clay.	82	4	gypsum.
88	3	gypsum.	83	1	clay.
91	3	shale.	85	2	gypsum.
94	3	sandstone.	89	4	shale.
95	1	shale.	90	1	gypsum.
105	10	gypsum.	95	5	shale.
110	5	shale.	96	1	gypsum.
114	4	gypsum.	100	4	shale.
115	1	sandstone and gypsum streaks.	101	1	gypsum.
121	6	gypsum.	103	2	shale.
123	2	shale.	104	1	flint.
130	7	gypsum.	108	4	sandstone.
135	5	shale.	117	9	gypsum.
			119	2	limestone.
			123	4	shale.
			135	12	gypsum.
			136	1	blue clay.
Well "C."			Well "D."		
64		sand and gravel.	68		gravel, sand.
67	3	shale.	71	3	shale.
69	2	gypsum.	72	1	gypsum.
75	6	shale.	84	12	shale, some gypsum.
77	2	gypsum, limestone. (abandoned)	86	2	gypsum.
			98	12	shale, some gypsum.
			99	1	limestone.
			103	4	shale.
			117	14	gypsum.
			130	13	shale, some gypsum.
Well "E."			Well "F."		
24		sand.	106		sand, gravel.
61	37	shale.	115	9	shale.
64	3	sandstone.	122	7	gypsum.
69	5	shale.	123	1	clay, pyrite.
74	5	sandstone.	136	13	gypsum.
77	3	shale.	138	2	shale.
92	15	gypsum.	141	3	gypsum.
92½	4	inches, shale.	143	2	shale.
96	4	gypsum.	147	4	limestone.
98	2	sandy shale.	149	2	gypsum.
104	6	gypsum.	150	1	limestone.
	6	inches shale.			
107	3	gypsum.			
110	3	sandstone.			
112	2	shale.			
116+	4+	gypsum.			

In well "A" the ten foot ledge of gypsum was found at 95 feet or 574 feet above tide. In well "B," about 100 yards east of "A", the 12 foot vein was 123 feet below the surface, or 613 feet A. T.

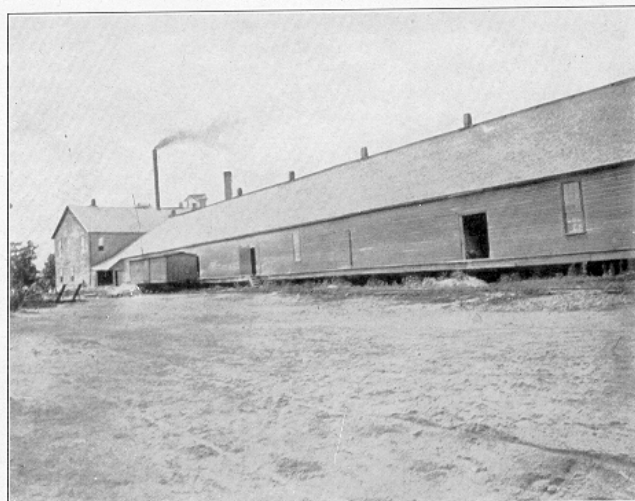
In well "D," one-fourth of a mile north of "A," the 14 foot stratum of gypsum was reached at a depth of 103 feet or 594 feet A. T. In well "E," 200 yards southwest of "A," the 15 foot ledge was struck at 77 feet or 565 feet A. T. In the well "F," one-half mile north of "B," the 13 foot gypsum stratum was found at 123 feet or 609 feet A. T.

These records give a dip of four feet north in one-half mile or eight feet to mile from "B" to "F." The extremes of variation are shown in wells "B" and "E," giving a difference of 48 feet in about 600 feet.

These drillings prove the gypsum to extend over the area to the west and northwest of the gypsum mines now opened north of the river. This field will doubtless be opened before many years, adding to the production of the plaster in the Grand Rapids area.

Geological Survey of Michigan.

Vol. IX Part II Plate XII.



A. DURR PLASTER MILL, GRANDVILLE.



B. GYPSUM QUARRY OF DURR MILL, AT GRANDVILLE.

[XII. A. Durr Gypsum Mill at Grandville
B. Gypsum Quarry of Durr Mill at Grandville]

§ 5. Gypsum in Wells Reaching the Silurian.

The gypsum deposits in the Monroe or Salina near St. Ignace are the only ones in this formation in Michigan found near enough to the surface to afford any encouragement for working. Possibly the northern islands of the Beaver Island group would find it a short way down. In most of the deep wells of the State around the border of the coal basin, gypsum or rather anhydrite is found in this same geological formation.

In the Niles well in Berrien county, in the southwestern part of the State, a 20 foot stratum of anhydrite and gypsum was found in the Monroe formation at 615 feet from the surface down to 720 feet. At the east gypsiferous shales were struck at, 648 feet in the Port Huron well.

Gypsum, or rather anhydrite, occurs in the Benton Harbor well at 81.5 feet, and in the Kalamazoo well at 1,500 feet, in the Manistee well at about 1,800 feet, in the Marine City well at 1,400 feet, in the Mt. Clemens well at 980 feet, in the Muskegon well at 2,350 feet. Gypsum occurs in the wells of the Edison Illuminating Co., near Ft. Wayne, Detroit, on down from 900 feet, in the Wyandotte wells from 590 feet down (especially at 750 feet), near Trenton from 690 feet down, at Ludington about 2,050 feet, at St. Clair at 1,510 feet, at Milan, 1,050 feet (at 1,210 feet very solid). All these deposits were in the Monroe or Salina formation.

The total quantity of calcium sulphate in the rocks of Michigan, from the surface Carboniferous to the deep Niagara, must be very great, but the deep strata of anhydrite are of only scientific interest and not of present economic importance.

§ 6. Conclusion.

A comparative study of these well records, from the various localities of the Lower Peninsula, shows that the gypsum is found in the wells on the eastern and western sides of the interior coal basin and at the north in the Grayling well. In the wells in the interior gypsum is replaced by anhydrite. The gypsum was evidently deposited on the borders of the old interior sea.

The depth of the anhydrite in most of these wells (Bay City, 700 feet; Kawkawlin, 400 feet; Midland, 970 feet; Alma, 895 feet; Mt. Pleasant, 1,125 feet), would be too great to make any mining profitable. Moreover it is a question just what treatment would be needed to make anhydrite (which corresponds to a dead burnt plaster) set.

The industry will be confined to the eastern and western parts of the Peninsula, to Alabaster and vicinity at the east, and to the area around Grand Rapids at the west. New borings and extensions will doubtless increase the productive areas in these two localities as illustrated by the recent work of the Pittsburg Plate Glass Co. at Grand Rapids.

§ 7. Total Quantity of Gypsum Available in Michigan.

On account of the irregular distribution of gypsum, being cut out here and there, and the uneven thickness, and the few borings recorded, it is impossible to give any accurate figures as to the amount of gypsum present in the two localities where it is now worked.

There are approximately six square miles of gypsum area near Grand Rapids, with an average thickness of 10 feet. A cubic foot of gypsum weighs 140 pounds, so this area would yield nearly 118,000,000 tons of gypsum, which would make about 100,000,000 tons of plaster. This quantity would supply the whole United States for 170 years or more at the present rate of consumption. The Alabaster field would yield about 20,000,000 tons, not counting unprospected areas west. But little can be said as to the areas in Huron county and around St. Ignace. The amount of gypsum or anhydrite shown by the deep drill records would have to be reported in billions of tons. While these figures may be too high, they are yet of value in giving some idea of the quantity of available supply, even if the actual prospecting work should cut them down.

CHAPTER VII.

MICHIGAN MINES AND MILLS.

§ 1. Grand Rapids District.

THE ALABASTINE COMPANY.

The gypsum mine of the Alabastine Co. was opened in 1876, at the present locality, two miles south and one mile west of the center of the city of Grand Rapids. It is just outside of the city limits in the northwestern quarter of section 2, Wyoming township, three-quarters of a mile south of the Grand river and on the Pere Marquette and Pennsylvania railroads, Plate V.

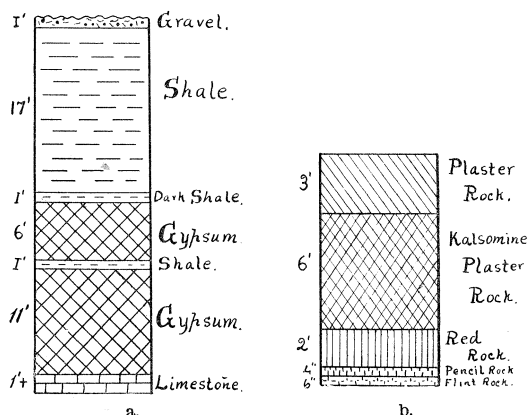


FIG. 11. Section in Alabastine quarry, also (b) one showing uses.

[11. (a) Section Alabastine Quarry]

[11. (b) Section Alabastine Quarry Showing Uses]

A geologic section at the mine is represented in Figure 11. The gravel cover is usually shallow and will average about one foot over the bluish shales which weather to a buff color and are 12 to 17 feet in thickness. Between this shale and the six foot ledge of gypsum is one foot of dark shale of very different character from the buff shale which makes poor brick and cement. As the buff shale is used for cement manufacture, this dark shale represents the waste in stripping. The six foot gypsum layer is separated from the so called 12 foot layer (in reality 11 foot) by about one foot or less of shale. The bottom rock of the quarry is a compact bluish gray limestone which in places is distinctly banded and on weathering becomes soft and shaly. It seems to contain a considerable amount of alumina or clay.

The gypsum is worked in an open quarry by stripping off the overlying shales, and the lower 12 foot ledge is the one used at the present time. This ledge while slightly furrowed by solution on the top is approximately level and has probably been protected from marked solution by the overlying gypsum and the compact shale. The ledge is marked by two thin clay seams, one about three feet from the top and another about two feet below this, which run into slightly wavy lines through most of the quarry and represent a slight change in conditions at the time the gypsum was deposited, a slight interruption in the precipitation, possibly by inflowing water bringing a

slight amount of sediment, or by the action of the currents distributing some foreign material.

The base of the gypsum for two feet from the bottom is colored red or pink and rests on a peculiar *cone in cone* red gypsum layer four inches thick, called pencil rock by the quarryman. In many quarries crystals of selenite are found, but in this quarry I found no traces of crystals, though some imperfect crystals have been found but these are rare. No specimens of white fibrous satin-spar were found, though the cone in cone structure may represent a variation of the fibrous satin-spar, as explained in the section on the Grandville quarry. A well defined jointing plane runs east and west through the south side of the quarry and stands out clearly on account of its very smooth face exposed for a distance of 200 feet. Minor jointing faces extending a short distance are also found in the quarry.

At the north side of the quarry the gypsum is entirely cut out for a space of 100 feet east and west and running off to the north. The space is filled with clays similar to those found above the gypsum. No stratification is seen in the clay, and it has probably settled as the gypsum was removed by solution. The gypsum abutting this clay is worn into furrows and ridges of irregular course, several inches in depth, clearly the result of water action. In no part of the quarry are evidences of solution more marked. It would seem as though there must have been at a former time an underground water channel running through this part of the quarry to the north, but there is no evidence of its existence to the south in this quarry. Further evidence of the existence of this channel is found near the mill. In constructing the foundation for the large brick stack, one-half was built on gypsum rock, and the north half on clay with no trace of rock. Drillings made to the south of the quarry and on the hill to the east of the mill show a good gypsum ledge. To the north of the quarry and west of the mill, borings fail to find gypsum. To the northeast across Plaster creek is the Godfrey quarry, where the gypsum is found in good thickness. Another possible course of this underground channel is suggested from the experience in the old quarry.

It is said that the lower edge of gypsum disappeared to the west in the working of the old quarry near the Grandville road in 1876, and caused the abandonment of that quarry and the opening of the new one. This old quarry is now filled with water so this account was not verified by the writer. Borings on the west side of Plaster creek between the two quarries are reported to show no gypsum. Granting the truth of these observations, the failure to find gypsum may represent the discovery of an old water course passing to the northwest from the old to the new quarry and then turning to the northeast past the mill. Not enough boring records are available to map in detail such a water course, or even to prove its existence beyond a possible doubt.

The upper gypsum ledge, six feet thick, is exposed for several hundred feet in the south side of the quarry, but disappears both to the east and west within the limits of

the quarry. To the west where it has disappeared as a well marked ledge, boulders of gypsum, very much water worn, are scattered through the clay shales. On the west and north sides of the quarry, no trace of the upper ledge is seen, though it again appears in the Godfrey quarry, less than a mile to the northeast, and it is found in the workings north of the river. The gypsum in this area south, of the river shows in this marked degree the effects of past solution through water action, so that the quarry men follow the rule that "gypsum is only found where you find it."

The work in the quarry at the present time is at the western and northwestern ends. The overlying shale was formerly burned into brick in the company's brick plant located to the east of the gypsum mill. This made a very good quality of red brick, some of which was used in the construction of the new mill. As the quarry was worked farther and farther west, the hauling of the clay became more expensive; and as the new Portland cement mill at Newaygo found, this clay and shale especially adapted to their work, they made arrangements to obtain it and ship the clay to their plant, 30 miles north on the Pere Marquette railroad.

This shale is plowed and then taken in wheel scrapers to the switch and dumped into railroad cars through a chute opening in a bridge over the track. The gypsum rock is drilled vertically and blasted with dynamite. The larger blocks thrown out by the blast are broken with sledges and loaded into self dumping mine cars. These cars are hauled to the end of the 320 foot incline by horse or mule, and there attached to a cable which hauls the cars to the top near the mill where they are dumped. The rock is hauled from under the incline track on one horse dump carts a short distance into the mill. A large quantity of rock is piled up at the end of the incline to be used in bad weather and through the winter.

In the earlier history of the quarry, the eleven foot ledge was sorted for different uses, and the parts of the layer were so classified. The upper three feet of the stratum were used for calcined plaster and was called the plaster rock. The next six feet, supposed to be purer in composition and so better adapted to the manufacture of finer plasters and especially for the manufacture of Alabastine wall finish, was called the Alabastine plaster rock; and the lower two or three feet of red gypsum, considered as impure, was used for land plaster, and called the land plaster rock, as indicated in Figure 11 b.

At the present time these different parts are all used for the same purpose and there is no sorting of the rock for ordinary uses. Some of the whiter and more compact blocks are separated and hauled in wagons to the covered store sheds to the southeast of the mill, to dry or season as it is termed, and are then used for the manufacture of Alabastine finish.

The quarry rock is mainly compact, without the saccharoidal or sugary texture, but has dark seams here and there branching irregularly. The seams are caused by dark clay particles and are small in proportion to the

white gypsum and do not give a high clay percentage in an average analysis of the rock. The crushed rock is snow white and makes a fine white plaster.

Analysis fails to disclose the cause of the color of the red gypsum as it is as pure as the white rock and shows no higher iron percentage, and when crushed the powder is snow white.

So far there has been but little trouble with water. The small springs in the mines are readily drained away. The level of the floor of the quarry is about 10 feet above the water in the river three-quarters of a mile to the north. The top of the gypsum is approximately level and gives no clue to the dip. As compared with the levels of the Godfrey quarry, the gypsum dips 16 feet to the mile toward the northeast.

The Alabastine Mill.

The mill of the Alabastine company consists of a central brick structure two and three stories high (Pl. VI.) 215 feet long and 55 feet wide with two frame wings 105 and 75 feet long to the east and west. The mill is located about 450 feet north of the quarry. The brick building is used for the grinding and calcining machinery. The frame to the west is the land plaster department, and the west portion of the brick building is the mixing room for the hard plaster (Plasticon). The long frame building to the east is the plaster of Paris department and the ware room.

The engine and boiler house is constructed of brick and located to the south of the center of the main building, and thus removes in part the danger of fire. It is equipped with two 100 H. P. boilers and a 150 H. P. engine. The store room, office, and rock storage shed, are located to the south of the mill. The buildings on the left of Plate VI, belong to the old plant and the quarry is off to the left of the picture. Plaster creek is back of the mill.

At the center of the large building on the ground floor are located two Butterworth and Lowe jaw crushers right and left of the entrance, with the crackers just below them. North of the crushers in the same room are four runs of four foot buhr stones for grinding the rock for calcined plaster, and one vertical emery stone mill with a capacity equal to two runs of stone used for grinding land plaster.

The coarsely ground rock is carried by elevators from the crackers to storage bins on the second floor, from which it passes by spouts into the hoppers above the buhrs and the emery mill. The flour-gypsum is carried from the stones by screw conveyors to the east room and elevated to bins above the kettles.

The kettle room, also built of brick, is three stories high with the storage bins on the third floor and the kettles extending from the first floor up into the second. The bins extend down into the second story with a long V shaped base which opens into a wooden trough or spout carrying the gypsum into the kettles. There are four ten-foot kettles, each of which will hold nearly ten tons of gypsum. Two of these kettles are connected with the

large brick stack and two are connected with separate vapor stacks through which the water passes off. The fuel is added below the kettle on the first floor, and the finished plaster is dumped into fire proof bins on this floor. After cooling for a short time the plaster is taken by long screw conveyor to an elevator at the end which carries the plaster above and over by another conveyor to the west end of the brick building to another set of storage bins. From there it passes down into the mixing rooms where it goes into the Broughton mixers in which a certain amount of retarder is added to form the Plasticon wall plaster, or the plaster is carried, to the east ware room and sacked without retarder as plaster of Paris. The plant has a capacity of 135 tons in ten hours.

The Alabastine mixing plant is located on the Grandville road on the bank of Plaster creek and is the original Granger & Ball gypsum mill remodelled and enlarged. It is a two to four story frame building 400 feet long and 200 feet wide, with two frame warehouses 40 by 100 feet attached on the north side. On the ground floor are located the power plant, the packing machinery, and the secret machinery designed for the manufacture of this wall finish. One room is used for the manufacture of paper boxes and another for wrapping and packing. On the second floor are eight runs of 30-inch buhrs for regrounding the product prepared from material received from the other mill. On the third floor are the color mixing appliances designed by the company.

Alabastine finish is plaster of Paris treated to give its proper working qualities and mixed with dry colors. The mixture is reground to the finest powder in the buhrs and packed in barrels and other bulk packages, or in five pound boxes. The capacity of the mixing plant is about ten tons a day and the product is sent to all parts of the country.

The Godfrey Mine and Mill.

The Godfrey mine is located nearly a mile to the east of north of the Alabastine mine and was opened in 1860 and worked until about 1898. The workings are now filled with water up to the level of the top of the upper ledge. The bank above the gypsum shows some variations from the section given for the Alabastine mine. There is practically no gravel covering, but the top as exposed shows (Fig. 12) three feet of shale and then half a foot of limestone separated from a thin eight inch layer of gypsum by 30 inches of shale. Below the gypsum come 46 inches of shale, the lower six inches showing an incrustation of alum. This shale rests on another three inch ledge of limestone followed by 32 inches of black shale and a foot of red streaked gypsum and a four inch ledge of limestone. Forty-six inches of shale separate this limestone from the six foot stratum of gypsum at the water level.

A short distance east of this quarry, a section of the Taylor brick yard shows similar conditions to the Alabastine mine with the absence of the six foot gypsum ledge. Here are found in a boring seven feet of gravel

and 31 feet of shale and clay used for the manufacture of brick, resting on an 11 foot stratum of gypsum. Following the record down below this gypsum, there are 12 feet of shale and 18 inches of hard rock, probably limestone, and then 20 feet of gypsum.

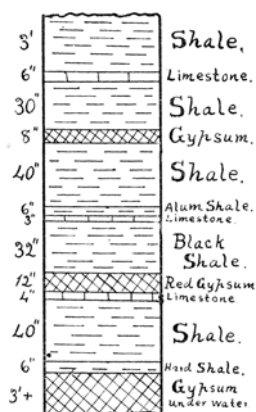


FIG. 12. Section of the Godfrey quarry.

[12. Section of Godfrey Quarry]

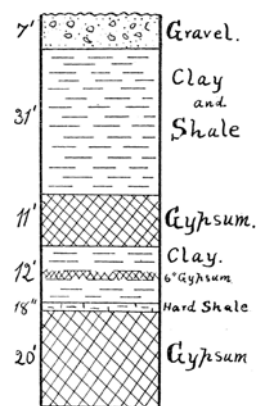
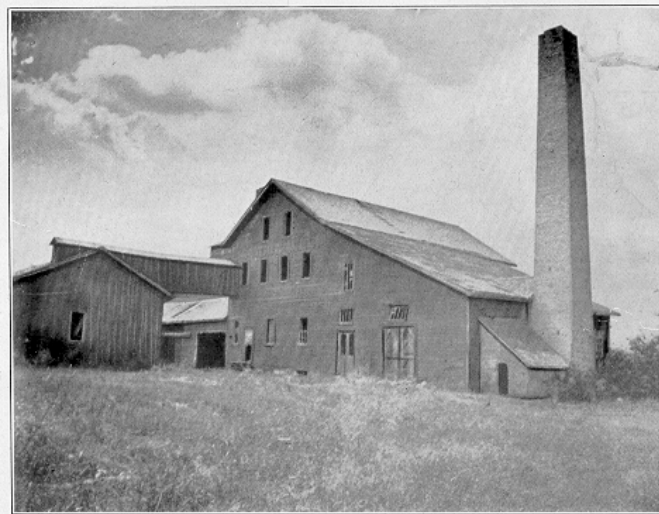


FIG. 13. Section at Taylor brick yard.

[13. Section at Taylor Brick Yard]

Geological Survey of Michigan.

Vol. IX Part II Plate XIII.



OLD RED GYPSUM MILL AT GRANDVILLE.

[XIII. Old Red Gypsum Mill at Grandville]

The old work at the Godfrey mine was on the 11 foot ledge which has been removed over a large area extending from the wagon road at the east to the railroad switch to the mill at the west. The rock as far as we can judge from the fragments scattered around the quarry and from the account of the former foreman, Mr. A. J. Wright, was of the same general character as at the Alabastine mill.

A large portion of the old mill is still standing to the northwest of the quarry. It was a two and one-half story frame building equipped with a Godfrey double nipper and cracker for crushing the rock, and with two vertical disintegrators made by Butterworth and Lowe, for the fine crushing and a single run of buhr stones. The mill was run by water power from Plaster creek. A separate building contained two ten foot kettles and the storage bins, but this was destroyed by fire a couple of years ago. A large roofed storage shed was built just south of the quarry and the rock was hauled in dump carts to the mill. The property is now idle and is owned by the Godfrey estate.

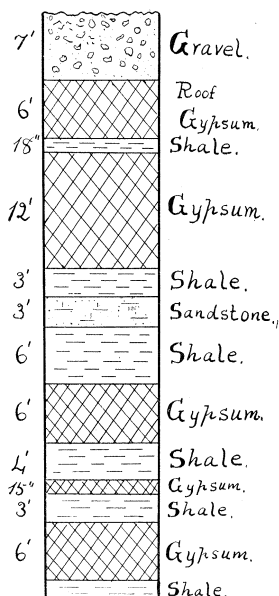


FIG. 14. Section at Powers' shaft.

[14. Section at Powers Shaft Nine]

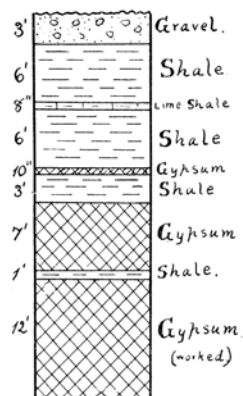


FIG. 15. Section Grand Rapids Plaster Co. mine.

[15. Section Grand Rapids Plaster Co. Mine]

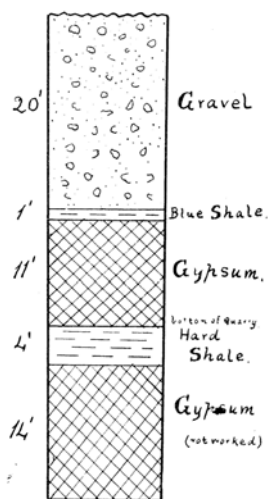


FIG. 16. Section Durr Mine.

[16. Section Durr Mine]

Powers Mine and Mill.

This property is located within the city on the west bank of the Grand river about midway between the Pearl and Fulton street bridges. Mr. Wm. T. Powers organized the company and sunk the shaft in 1896. The mine goes 50 feet below the bed of the river and the framework of the shaft is built up 35 feet more to the floor of the mill. The record of the shaft has been lost and the section represented in Figure 14, is given from the memory of Mr. Powers of the boring made to the roof gypsum and 60 feet below it. The company owns 30 acres of this gypsum land. The upper ledge six to eight feet thick is left for a roof and the mine is worked on a room and pillar system with rooms about 50 feet square and the pillars 20 feet.

It is estimated that by this system about three-fourths of the gypsum can be removed.

The mill was built on the bank above in 1898, and was burned in the spring of 1903, and the company is known as the Gypsum Products Co. The frame mill was built in an L shape, 130 feet long east and west, and 25 to 50 feet wide with a storage shed built to the east 20 by 20 feet. The wareroom to the west was two stories high and the wider portion was three stories. On the second floor were placed the nipper and cracker and the buhrs below them in two sets, one of 36-inch for ordinary grinding, and a pair of 30-inch buhrs for regrinding. A part of the flour gypsum was carried by conveyors to the west part of the room and sacked for land plaster, and part was elevated to the third story over the kettle placed in the north part of the L extension. The gypsum then passed into the Powers patent kettle which was ten feet in diameter with a new design of flues described in the chapter on Technology, and it was heated by a wood fire. The finished plaster was dumped into fire brick bins and elevated to bins over the Broughton mixer where it was mixed with retarder to form wall plaster.

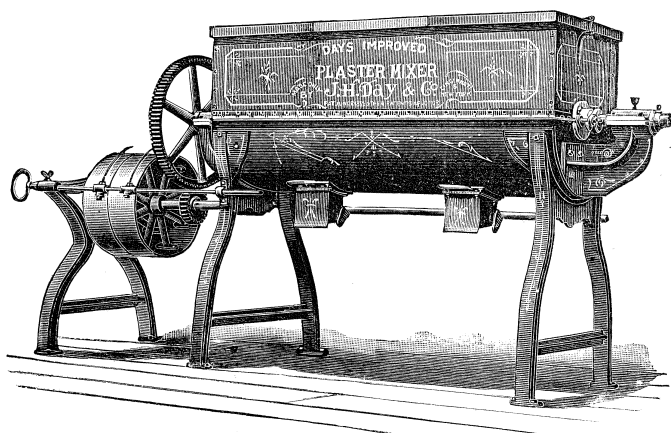


FIG. 17. Day's Lightning Plaster Mixer.

[17. Day's Lightning Plaster Mixer]

A special feature of the manufacture at this mill was the granite wall plaster, a sanded mixture ready to be mixed with water and applied to the wall. For this purpose there was on the basement floor a revolving cylinder sand dryer heated with wood fuel. The dried sand and retarder were mixed with the plaster of Paris in a Day's Lightning Plaster Mixer. as shown in Figure 17.

Grand Rapids Plaster Company Mines and Mills.
(Plates X, XI, XV.)

On the north side of the river the gypsum is obtained from under the hill by an inclined hillside double entry tunnel. The Grand Rapids Plaster Co. have two double entry mines, one at each of their Eagle mills, known as mine No. 1 and mine No. 2. The main entry runs north and starts into the hill about the top of the 12 foot ledge. The section of the hill for 26 feet above the entry is given in Figure 15, a section which extends from the fence down, in Plate XV. About three feet of gravel are underlaid by 12 feet of shale separated at the center by eight inches of shaly limestone. Below the shale is a ten inch layer of gypsum seen in the photograph above the entry, and separated by three feet of shale from the six to seven foot upper ledge of gypsum. One foot of shale divides the upper from the 12 foot gypsum rock. The hill extends above to the wagon road 40 to 45 feet above the entry, and north of the road the hill rises 100 feet higher though not shown in the photograph.

The seven foot ledge is left for a roof and the 12 foot ledge is quarried for plaster rock. This is worked by a room and pillar system with rooms about 40 feet square and is mined by drilling holes in the upper half of the face of the rock and blasting down with dynamite. This leaves a bench or ledge six feet high which is then drilled vertically and blasted; all of the mining is carried on by this drift and bench system without any undercutting.. Pillars of gypsum are left to support the roof, 15 to 20 feet in diameter and between the pillars intermediate timber posts are placed making the mines or caves as they are locally called, perfectly safe. No accidents from caving roof have ever occurred in mine No. 1. In No. 2 there has been no caving of the roof since 1881. At that time the roof covering about five

acres fell in one night. The cause was in the placing the pillars too far apart, and the lack of sufficient intermediate posts. Since that time water has been somewhat troublesome in this mine, and about 150,000 gallons are pumped out in a week.

Mine No. 2 is similar to mine No. 1, and now the two are connected, and in all about 45 acres have been worked out. The character of the gypsum is about the same as in the quarries south of the river, showing a compact rock cut by numerous dark seams and with the red rock and the pencil rock at the bottom.

The Eagle mill No. 1 is a short distance south of the mine entry and consists of a group of frame and brick buildings connected by overhead enclosed bridges which are for the conveying of material from one department to the other.

The rock is hauled in mine cars by cables up an incline track to the second floor of the frame machinery building and is crushed in a nipper and cracker, the rock is further crushed to flour in the four runs of buhrs on the same floor as the nipper. The fine gypsum is then elevated to the third floor where the material for land plaster is carried through the overhead bridge to the west to the land plaster warehouse. The material for calcined plaster is carried to the east through another overhead bridge into storage bins in the two story brick calcining building. There are three ten-foot Powers kettles, which are connected with the high brick stack. The calcined plaster is carried to the east room into the large ware room 225 by 40 feet with a bulk capacity of 5,000 barrels, and sacked or placed in barrels as wanted. The engine and boiler house built of brick one story high is at the side of the machinery building. The land plaster warehouse is a one and half story frame to the west.

This mill and the No. 2 mill are located on the L. S. & M. S. R. R. track about two and one-half miles west of the city of Grand Rapids. The Eagle mill No. 2 is located a short distance west of mill No. 1 and is equipped with a Godfrey double nipper and Lowe cracker and the fine grinding is done in three runs of vertical emery stone mills and the re-grinding of very fine plaster in two runs of 30-inch buhrs. There are three ten-foot kettles arranged similar to the plan of the No. 1 mill.

The English Mill and Mine.

The English mill of the United States Gypsum Co. is located to the west of the mills last described. It is a three story frame building 40 by 50 feet with a mixing and grinding room to the east 60 by 40 feet. The rock is brought in mine cars from the shaft down a slight incline to the second floor of the mill where the nipper and cracker are located. The broken rock is then elevated to bins above the two runs of buhrs, and one vertical emery stone mill, where the rock is ground to flour which is carried by a screw conveyor and elevated to the third floor above the two ten-foot kettles. The mill is also equipped with three sets of regrinding buhrs for the finer plaster.

The hot calcined plaster is dumped into fire proof bins and then elevated and carried by conveyors to the ware room; at the east where it is sacked for the market. This mill was erected in 1900 and has a daily capacity of 150 tons.

The gypsum rock is obtained from under the same hill that is worked to the east by the Grand Rapids Plaster Co., but it is reached by a vertical shaft on the hillside, 62 feet deep. The shaft is six by eight feet in section, containing double elevators and an independent air shaft. The elevators work alternately and are operated by electricity. The cars carry 2,500 pounds. The drilling in the mines is done by electric drills and the mine is lighted by electricity. The area now worked out is about three acres. This is one of the best equipped mines of gypsum in the country.

The first rock worked in this shaft is a 12-foot ledge, and the six-foot upper ledge is left for the roof. The characters of the rock are similar to those in the other mines of the Grand Rapids area.

§ 2. Grandville Area.

The gypsum quarries of the Grandville area are three-fourths of a mile south of the town. The location is four miles west and five miles south of Grand Rapids, or seven miles by the Pere Marquette railroad. The mines are located in the northwest quarter of section 20 and in the northeast quarter of section 19 in Wyoming township. The old Red mill is located in the corner of section 19 and it is now filled with water and has been abandoned for 20 years.

Across the road in section 20 is the quarry of the White mill, now idle, and to the north in the next field is the quarry of the Burr mill. Both of these quarries have large areas worked out. They are worked by stripping off the surface covering of gravel and so are open quarries.

A section of the Durr mine is given in Figure 16, and shows 20 feet of gravel and one foot of blue shale over the 11-foot ledge of gypsum which rests on a four foot layer of hard shale which forms the bottom of the quarry. Borings show a 14-foot gypsum ledge below this. The lower ledge is not worked as water is a source of trouble at the present level of the quarry and must be kept down by pumps.

The upper gypsum ledge at the Grand Rapids quarries appears to be absent in these quarries, and the upper surface of the 11-foot ledge is very uneven and shows in a marked degree the effects of solution. The gravel cover coming down almost to the gypsum is in marked contrast to the Grand Rapids quarries. The lower part of the 11-foot ledge is of red color and the cone in cone layer reaches six inches in length and is in places free from the red color.

The origin of such cone in cone structure in clay materials has been much discussed, but never satisfactorily explained. Dana regarded such a structure in clay shales as due to the concretions formed under

pressure. I have found in western gypsum quarries a layer of satin spar needles on the under surface of the gypsum ledge in the same position as these cones, and the fibres standing vertical as they do in these cones.

The origin of the satin spar in the Kansas gypsum seemed to be due to gypsum waters percolating downward and depositing gypsum in needles which are thus secondary in origin. It is possible that the preceding suggestion of Dana in the cone in cone structure in clay may explain the origin of this gypsum structure; that pressure acting at the same time as the formation of the secondary spar, might cause a consolidation of the needles and form the cone in cone structure as seen in the Michigan quarries. The Michigan gypsum is more compact than the Kansas deposits and so appears to be more firmly consolidated.

The gypsum rock is taken from the Durr quarries in cars and hauled by horses or mules along a T-rail track a little over one-half mile northwest to the mill. A shaft has been excavated near the mill, down through the 32-feet of gravel to the gypsum. This proved a troublesome operation on account of the caving of the gravel, but the shaft has now been firmly timbered, and the mine will be opened and equipped with electricity, and made equal to the English mine at Grand Rapids. When this is completed the quarry will be abandoned.

The Durr Mill. (Plate XIIA.)

The rock from the quarry is stored in two long sheds and hauled from these into the mill on the ground floor where it passes through the nipper and cracker and is hoisted by chain elevators to the second floor. It here passes through four four-foot buhr stones and the rock flour is conveyed and elevated to the bins above the kettles which are three in number, two of these are eight feet in diameter and one is ten feet.

The crushing and calcining machinery are in the three story building at the south end of the long mill. This portion of the mill is connected with the three story mixing plant at the north end, by a ware room, giving a storage capacity of 900 tons.

The calcined plaster is elevated from the bins below the kettles and carried by a long overhead screw conveyor through the ware room to the mixing plant. The plaster of Paris is taken out at various points in the ware room where it is sacked. In the mixing plant the plaster of Paris and retarder are mixed in Broughton mixers.

A special feature of the work at this plant is the manufacture of Adamant wall plaster. The sand for this mixture is dried in three Perfect sand dryers built like a large stove with hopper on the top into which the sand is shoveled and coal is fed in below. The capacity is ten yards a day for each dryer. A cylindrical rotary sand dryer has been installed to take the place of these stoves, and it has a capacity of 60 tons a day.

The dried sand, plaster of Paris, and retarder, are mixed in one of the two Broughton mixers and then sacked in 130 to 140 pound sacks, while the ordinary plaster, also

made in this mill is placed in 100 pound sacks. The patents for Adamant plaster are owned by the United States Gypsum Co., and it is made at a number of their plants.

White Mill. (Plate XIV.)

The White mill, named from the color of the building, is located near the Durr mill quarry and has now been idle for four years. It is owned by Mr. Dummer of Chicago. The mill though idle is kept in good condition and is under the care of a watchman day and night.

In the center of the building is the power plant with a 150 H. P. Allis engine, steam pump, and small compound engine. The room just south contains the two boilers, and south of the boiler room is the kettle room with four ten-foot kettles with fire brick bins below. The fuel for the kettles and the boilers is added at the east end of this room, and the kettles are so arranged that they can be readily reached and repaired from any side.

The rock was brought from the quarry in large boxes carried on an overhead cable operated by a large drum and engine in the upper part of the building. The cable was supported by two towers, one near the mill and the other on the opposite side of the quarry. The gypsum was dumped in a room to the north of the engine room and was thrown into a Lowe nipper and cracker; then hoisted by an elevator to a half floor above where it passed through four runs of 36-inch buhr stones. The gypsum flour was elevated and carried to the south to bins over the kettles.

The calcined plaster was elevated from the fire proof bins and carried by a screw conveyor to the north of the engine and crushing rooms into the sacking and storage room. This long room is divided into a series of smaller rooms or bins, and from these the sacks or barrels were loaded on the cars on the switch built on the west side of the building.

The Red mill (Plate XIII.) across the wagon road from the White mill is one of the oldest mills standing. It was dismantled a number of years ago and is now passing into rapid decay.

§ 3. Alabaster.

The Alabaster mine and mill are located six miles south of Tawas City and three-fourths of a mile back from Saginaw Bay, and the bottom of the quarry is about 15 feet above the water in the bay. The quarry is located in the northwest corner of section 27 of Alabaster township in Iosco county. A large area has been worked out during the past years of its history, and over a half mile of face is now exposed. Probably no gypsum quarry in the United States turns out as much rock in a year as this one which has an annual output of a hundred thousand tons. The workings show a solid ledge of gypsum 18 to 22 feet in depth covered toward the bay by five to eight feet of clay with gravel through it, and toward the west by 12 to 16 feet of stiff boulder clay which is stripped by means of a steam shovel with a

capacity of 840 cubic yards a day. The clay is loaded into small dirt cars and hauled by a small steam engine and dumped into the abandoned parts of the quarry.

The rock is drilled to a depth of 16 feet and blasted with dynamite, and the larger masses from the blast are broken with sledges and loaded into small ballast cars and hauled by a second steam engine to the mill or to the wharf.

The rock is compact and more or less streaked or banded with darker streaks composed of clay and dark gypsum. Selected masses are snow white without a trace of dark color. The lower one and one-half feet of the ledge are red in color and near the bottom are composed of nodules of reddish or white gypsum surrounded by impure clay gypsum. On weathering the nodules separate and the dark portion crumbles. This portion of the ledge is thrown to one side and is not used at the mill. The floor of the gypsum is a fine grained, bluish sandstone.

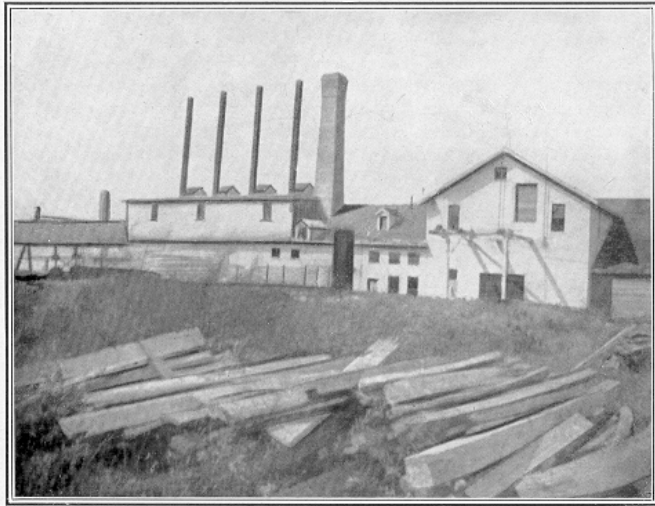
It is stated that an old shaft was put down in the quarry 65 feet below the level of the basal rock and passed through a total of 25 feet of gypsum. According to Mr. Gregory, in the earlier history of this quarry, there were two layers of this gypsum separated by a layer of hard fossiliferous limestone and a small stratum of shale, but upon working into the deposit the shale and limestone have entirely disappeared. The mine and mill are connected by a five mile switch with the Detroit and Mackinac R. R.

The mill is built about half way between the quarry and the bay. This consists of a group of buildings, the main one being 40 by 52 feet and contains the grinding machinery and the three ten-foot kettles built with the four interior flues on a line. An extension has been made to the machinery building which is 24 by 64 feet and reaches out to the railroad track. The upper part of this building is the storage room for the bulk plaster and this is sacked below and loaded directly on the cars.

A shed 200 by 28 feet has been erected to store sacks and the finished product, with an extension 40 by 100 feet which adds 1,500 tons storage capacity. The rock shed is 40 by 200 feet and will hold 3,500 tons of rock stored for winter use. The two story carpenter shop was used at the old mill for the manufacture of barrels and nearly 30,000 of these were used every year, no material being sent out in sacks. In the new mill, built in 1892, sacks have been used, and only about 7,000 barrels are needed a year. These are made in the carpenter shop which is also used to store parts of machinery, lumber, and the like.

In addition to the mill buildings, the company has erected 40 houses to accommodate the workmen, a two story hotel 70 by 80 feet, and an office building and store 60 by 60 feet. The rock which is shipped by water is hauled in cars by the small engine out on the 600 foot pier and loaded directly into sailing vessels holding 450 to 700 tons, or it is stored in a two story warehouse 40 by 100 feet, built on the end of the pier. The rock is hauled up

an incline to the second story and loaded through iron chutes. The finished product is hauled into the lower part of the warehouse and loaded by hand trucks on the boats.



THE WHITE MILL AS SEEN FROM THE QUARRY, GRANDVILLE.

[XIV. White Gypsum Mill at Grandville, as seen from quarry]

In the Alabaster mill grinding machinery is on the first floor and consists of a Lowe nipper not used at the present time, and a large cracker into which the rock is now thrown as it comes from the quarry. The gypsum is then ground in a Stedman disintegrator or in three runs of buhr stones. Two sets of 36-inch buhrs are used for regrinding the rock flour for superfine plaster used especially in the plate glass works. The mill is equipped with one Raymond machine, formerly used for grinding this extra fine plaster, but it has been out of use for some time. The gypsum flour is elevated in double bucket elevators and carried in screw conveyors to bins over the kettles. The calcined plaster is elevated and conveyed to the store houses by long conveyors one of which is 150 feet long. In the ordinary plaster the retarder is added in two Broughton mixers. Power is furnished by a 150 H. P. engine and the capacity of the mill is 200 tons in 24 hours.

Other Gypsum Deposits in the Alabaster District.

West of Alabaster Point, according to Winchell,¹ the gypsum formation can be found for a distance of 30 miles near the surface on all the head branches of the Au Gres river.

"In township 21, range 5, section 12, is another similar exposure of rich gypsum deposits, and numerous smaller deposits are noticed in the beds of creeks between that locality and the lake."

Prof. W. M. Gregory² has made a, very careful study of the geology of this region, and his account of the distribution of the gypsum is given in § 6 of Chapter V.

"The outcrops of this formation have a limited area in this region and no evidence of gypsum in the Grand Rapids group outcropping has been found north of the

line connecting Tawas City and West Branch and south of a line connecting West Branch and Au Gres. Gypsum is found in the deep wells of the Saginaw valley, but the above statement refers to a region in which a search might reveal the rock in suitable condition for practical working.

Judge Sharp, of West Branch, is the authority for the statement that three and one-half miles east of West Branch on the Rifle river is an outcrop of gypsum, which several years ago caused much excitement for its size and purity. No careful exploration of this bed has been made and at present it is undeveloped."

¹Geol. Survey of Mich., Vol. III. p. 107; 1876.

²Geol. Survey of Mich., Annual report for 1901, pp. 16-18.

CHAPTER VIII.

TECHNOLOGY OF GYPSUM AND GYPSUM PLASTERS.

§ 1. General Process of Manufacture.

Gypsum rock as described in the chapter of Chemistry is a mineral composed of sulphate of lime and water ($\text{CaSO}_4, 2\text{H}_2\text{O}$). When this rock is heated to the proper temperature it loses part of the water and is then known as plaster of Paris (CaSO_4)₂. H_2O , a compound capable of taking up water when it is added to it, forming the set plaster.

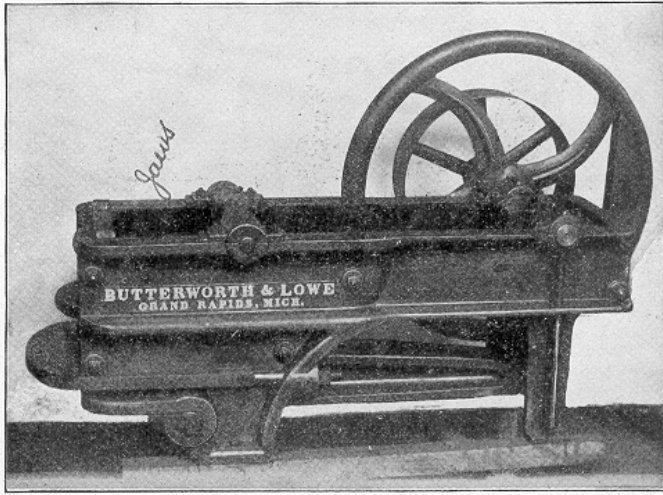


FIG. 18. Jaw Crusher for Crushing Gypsum.

[18. Jaw Crusher for Grinding Gypsum]

The essential parts of the process of manufacture are the proper grinding and proper burning, and it is the aim of this chapter to present the methods used in reaching these results.

In a number of the foreign countries, especially in France and in some of the English mills described in an earlier chapter, the gypsum rock is burned and then reduced to powder. The practice in the Michigan mills and practically all the mills of this country, is to crush the rock and burn the rock flour in kettles or cylinders.

Most of the material in the United States is prepared in mills and kettles of the same general type; but there are some variations regarded by many of the plaster men as improvements, and there have been some attempts at improvement which have proved to be failures.

§ 2. Crushing of the Rock.

In the typical Michigan mill the gypsum is treated according to the following plan: On the second floor of the mill are placed the jaw crusher, the nipper and the cracker. The nipper as shown in Figure 18 has a corrugated face plate of chilled iron forming the end of the machine, and a swinging apron of the same pattern which forms a V shaped box. The apron is driven

against the fixed plate by an arm which moves with an eccentric motion on the shaft, so as to give a backward and forward movement, and the shaft is moved by steam or water power. Such a machine weighs about 6,000 pounds and has a capacity of seven to eleven tons per hour. Mr. Godfrey invented a double swinging apron jaw crusher which gave an increased capacity, but it is only used in two mills in the State.

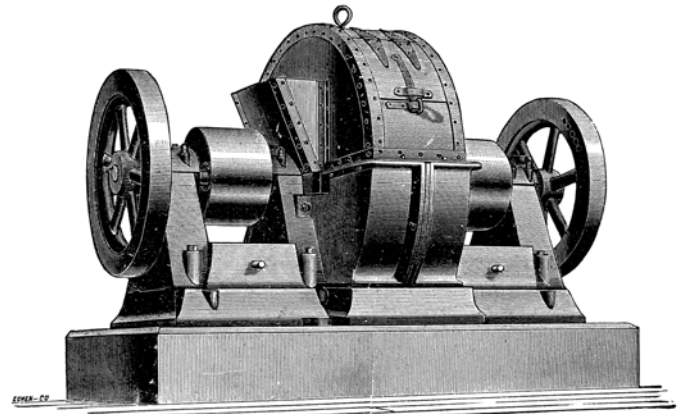


FIG. 19. Gypsum Disintegrator, made at Aurora, Indiana (closed).

[19. Gypsum Disintegrator. (Closed)]

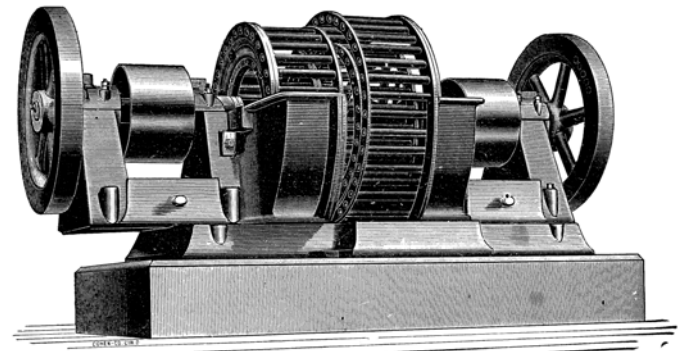
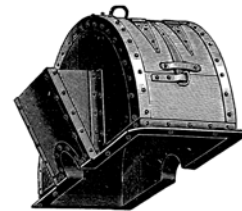


FIG. 20. Gypsum Disintegrator, same as Fig. 19 (open).

[20. Gypsum Disintegrator. (Open)]

Blocks of about 50 pounds weight are thrown into the jaws of these machines and are crushed into pieces about the size of a man's hand. The small masses drop from the crusher into the cracker set in the floor just under the crusher. This machine has a conical corrugated shell in which revolves a shaft with a corrugated iron shoe, working like a coffee mill. Three sizes of this type of machine are made, with a capacity of three, seven, and twelve tons per hour, the usual size is the medium one which has a weight of 3,300 pounds. The cracker was originally patterned after the old corn mills which ground the cob and corn in one mass.

The gypsum is further crushed in the cracker into fragments of the size of small gravel, which fall into the buckets of a chain elevator whereby they are raised to storage bins on the floor above. From this bin the gypsum particles pass down by gravity through spouts into ordinary buhr mills or emery stone mills, where they are ground into flour.

The two buhr stones are arranged as in a flour mill usually with upper runners, and ranging in diameter from 32 to 42 inches. Most of the buhrs in Michigan are French stones obtained from old flour mills. They are cut in radiating furrows and when ground smooth by the friction of the gypsum particles must be redressed. This operation requires skilled labor and usually one man is employed at the mill for this purpose. It is also necessary to have an extra set of buhr stones as in a large mill one set is out of use most of the time.

To increase the capacity and avoid the expense of dressing the buhr stones, other types of machines have been invented, and used to some extent in the Michigan mills. One of these is the lime disintegrator, invented and made by the Stedman Foundry and Machine Works of Aurora, Ind. One of these disintegrators is used in the Alabaster mill and in the Chicago mill of the U. S. Gypsum Co. This machine as shown in Figures 19 and 20, consists of two cages with short cross bars. These cages travel at high speed in opposite directions. In the Alabaster mill, the disintegrator runs at a speed of 800 revolutions per minute. The gypsum is carried by a spout into a hopper at the side and passes to the center of the cages where the centrifugal force carries the particles between the bars of the cage. These bars passing in opposite directions beat the rock into powder by the impact against the bars, and by the striking of the gypsum particles against each other. There is no danger of choking or clogging of the machine and the action is rapid. The capacity of a 50-inch disintegrator is 60 to 75 tons in ten hours.

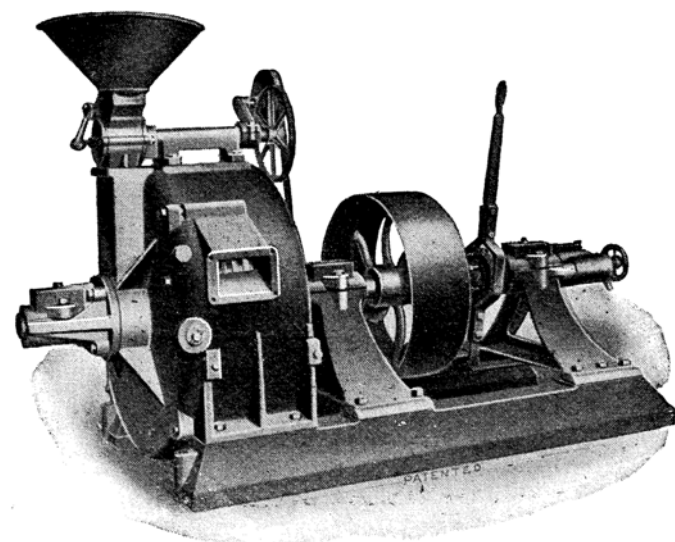


FIG. 21. Sturdevant Emery Mill.

[21. Sturdevant Emery Mill]

Another type of machine for crushing the gypsum gravel from the cracker to flour is the Sturdevant emery-stone mill, made by the Sturdevant Co., of Boston. This mill, as shown in Figure 21, is made after the pattern of buhr stones set to run in a vertical direction. Its grinding surface is composed of large blocks of emery stone as it comes from the mine, set in a metal frame. These blocks are so arranged that the grain of the emery runs at right angles to the face of the stone, giving the maximum cutting power. It is made of large pieces fitted as closely as possible and the crevices filled in with smaller emery. A special composition metal is then poured in from the back making a solid casting, and the whole is strengthened by steel bands. The center of the mill stone (Figure 22) is made of buhr stone in order to produce a more even wear on the surface, as the speed and consequent wear is greater toward the border than near the center. The bed stone is bolted to the mill frame and does not have to be removed till the stone wears out. These emery mills are said to reduce the cost of grinding nearly one-half, and can be dressed in much shorter time than ordinary mill stones, and they can be run at much higher speed. Such mills are made in sizes from 30 to 54 inches in diameter. The 30 inch emery stone mill weighs 3,500 pounds and will grind one to four tons per hour, requiring from 18 to 20 H. P.

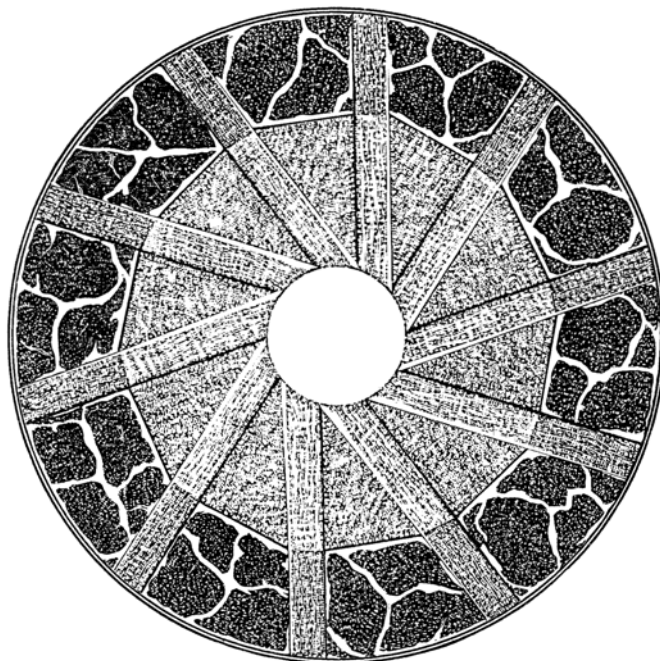


FIG. 22. Sturdevant Emery Mill Stone.

[22. Sturdevant Emery Mill Stone]

§ 3. Calcining.

After the gypsum is ground to flour by some of the methods described above, it passes into a screw conveyor, and is elevated directly to the floor above and then conveyed into storage bins located over the kettles.

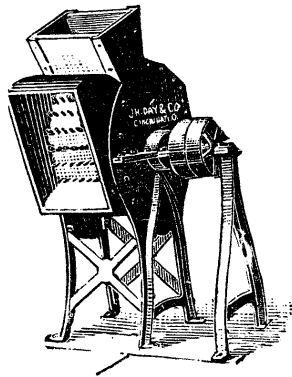


FIG. 23. Day Fiber Picker.

[23. Day Fiber Picker]

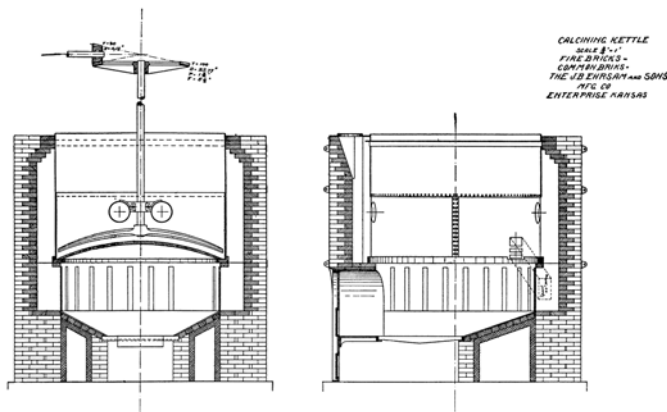
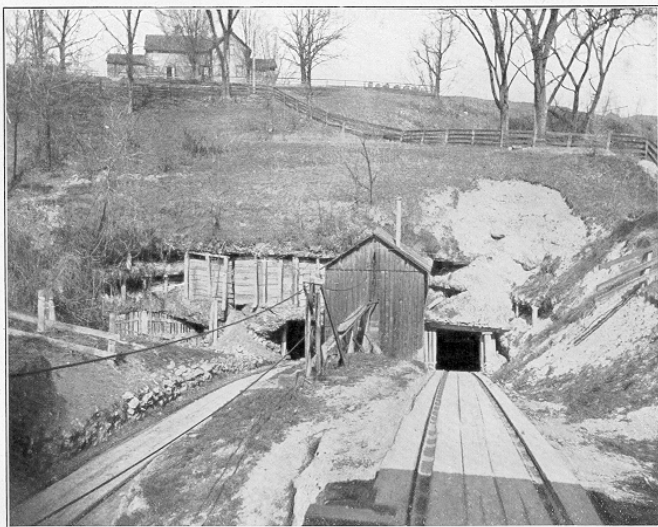


FIG. 24. Ehsam Calcining Kettle.

[24. Ehsam Calcining Kettle]

Geological Survey of Michigan.

Vol. IX Part II Plate XV.



ENTRANCE TO GYPSUM MINES.

[XV. Grand Rapids Plaster Co. Gypsum Mine, entrance to]

The ground gypsum flour is allowed to run by gravity from the storage bin into the calcining kettles. All of the kettles in Michigan are constructed after the same general plan, a plan introduced from New York by Mr. Godfrey. The kettles are constructed in the form of a hollow cylinder made of boiler steel three-eighths of an inch thick and are about as deep as wide, ranging from eight to ten feet, and the latter is the usual size in Michigan. The cylinder sets on an iron ring and on this ring inside of the kettle is placed the convex bottom made of such a mixture of irons that it will have a low shrinkage, even as low as 3-64 of an inch in passing from the molten to the cold stage. This bottom is made convex upward and about $\frac{5}{8}$ of an inch in thickness fitted with small rings at the top which enable one to fasten chain and tackle to it and so place the bottom in the kettle where it is firmly fastened to the cylinder with moulder's cement. Sectional kettle bottoms have been invented and are made by the Des Moines Mfg. and Supply Co. On account of the uneven contraction and expansion in different parts of the kettle resulting in the warping or buckling of the plates, it is claimed at the Michigan mills that it is very difficult to fit in the single pieces. This type of kettle bottom is used in a number of Iowa and Kansas mills and they are said to be satisfactory in those mills. They are made in six radial sections and one center piece. A ten foot kettle bottom weighs approximately 4,400 pounds.

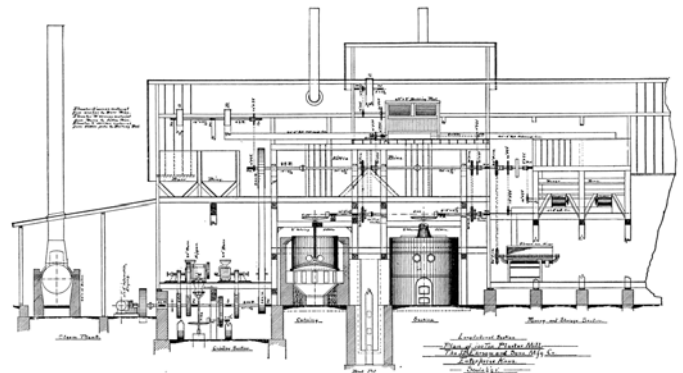


FIG. 25. General plan of Plaster Mill, showing Calcining Kettles and other machinery in place.

[25. General Plan of Plaster Mill]

The kettle is set like a boiler upon a brick base and surrounded by a wall of brick $12\frac{1}{2}$ to 17 inches thick separated from the kettle by seven to ten inches of air space. The grate bars were formerly placed four feet and now seven feet below the kettle bottom. The fire place is about four and one-half by three feet, though in one Michigan mill the grate is six by four feet. It requires about 3,300 fire brick and 19,000 common brick to set such a kettle. Figure 24 shows the plan of a four-flue kettle set in position.

Figure 25 shows the general plan of a plaster mill with kettles, elevators, storage bins, etc.

In the old style of kettles no flues passed through the kettle, but in the kettles now in use, there are two to four flues passing through the kettle about the center. In the Michigan kettle four flues are used, two above the center and two below, as shown in Figure 26. In the

Butterworth & Lowe kettle there is a division between the two sets so that the heat passes up in the open space on one side and through the lower two flues, then back through the other set and out through the chimney flue. In the Iowa type of kettle and in a few of the Michigan kettles the four flues are on a line. The kettle flues have been gradually increased in diameter from 7 inches to 16, and are 36½ inches apart on the horizontal line in a ten-foot kettle, and are ten inches apart up and down.

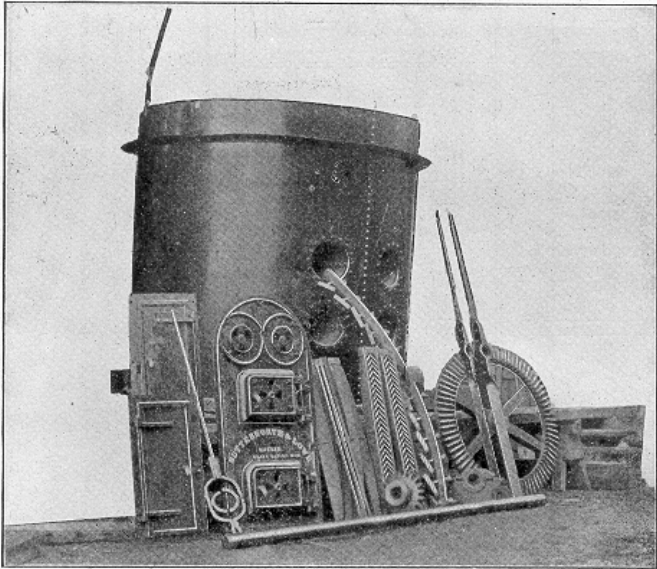


FIG. 26. Four Flue Gypsum Calcining Kettle.

[26. Four Flue Gypsum Calcining Kettle]

The experiment tried on the amount of fuel required to calcine plaster in two kettles, one with the four flues on a horizontal line, and one with the flues arranged two above and two below, appears to show an advantage in favor of the latter arrangement. The results of this experiment are given in the following table kindly furnished by Mr. Lowe of Grand Rapids.

The kettles were properly set and with good draft. The gypsum was ground so that 85 per cent would pass through a 40 mesh sieve. The experiment was watched on the second batch after the kettle had been fully heated. The material was discharged after the second settling and was fully calcined, and the weight of plaster was eight and one-fourth tons, with a water percentage of five and one-half.

Type of four-flue kettle.	Condition of rock.	Pounds of bitum. coal.	Time in hours.	H. P. required.
Direct, flues 0000.....	Green	1,030	3 7-12	12
Return, flues 00 00	"	880	3 8-12	13
Direct, flues 0000.....	Dry.....	850	2 10-12	10½
Return, flues 00 00	"	730	2 11-12	11½

The material in the second experiment was discharged at the end of the first settling and total weight of plaster was eight and one-half tons, with a water percentage of eight. In the direct arrangement the heat passes through flues and out. In the return the heat passes through two flues then back through other two and out.

Type of four-flue kettle.	Condition of rock.	Pounds of bitum. coal.	Time in hours.	H. P. required.
Direct, flues 0000.....	Green	765	2 9-12	12
Return, flues 00 00	"	660	2 10-12	13
Direct, flues 0000.....	Dry.....	600	2 1-12	10½
Return, flues 00 00	"	520	2 2-12	11½

These kettle flues are arranged with openings in the brick work, closed by doors which can soon be opened and the flues cleaned from time to time.

The gypsum flour is constantly stirred on the bottom of the kettle by a convex revolving arm with a length equal to the diameter of the kettle, and with small cross pieces projecting below and set at an angle so as to reach all portions of the bottom. The arm is fastened to a four inch vertical shaft which is driven by a five foot horizontal cog crown wheel, set in motion by a one foot vertical pinion wheel attached to the power shaft. Above and below the flues two stirring rods are also attached to the vertical shaft. It requires 10 to 25 H. P. to run this stirrer, and sometimes if the plaster is run too fast into the kettle, the resistance is sufficient to break the teeth or cogs from the pinion wheel. The stirrer makes about 15 revolutions per minute. A ten-foot kettle will calcine three and one-fourth tons of ground gypsum per hour, and a two kettle mill with the necessary machinery for taking care of the rock will require 85 H. P. when emery mills are installed. A complete ten-foot kettle with bottom and vapor stacks weighs 19,000 pounds. The kettle is covered with a sheet iron cover, with an opening or door which can be shifted so as to see the interior.

In the Powers patent kettle 40 three-inch flues are built around the circumference of the inside of the kettle, each forming a segment of an oval. This arrangement gives more clear space in the kettle and is claimed to make a considerable saving in fuel. In the Powers mill at Grand Rapids, ten tons of plaster can be made in a ten-foot kettle in one batch.

In an hour after the gypsum kettles are filled the temperature reaches 230° F., and the mass is seen to be boiling vigorously, as the water is driven off and out through the vapor stacks above. When the temperature increases to 270° F. (132° C.) the gypsum settles down solid leaving 16 inches or more of vacant space at the top, and the steam almost ceases to rise. At 280° or 290° F. (138° to 143° C.) the mass comes up again, often throwing a part of the material over the top of the kettle. When the temperature of 350° to 370° F. is reached, the plaster is readily withdrawn through a gate near the bottom controlled by a lever above, into a fire brick bin on the ground, and the kettle is then refilled.

In some mills these temperatures are carefully watched and a dial thermometer with long rod, or a thermometer attached to a long stick, is thrust through the door at the top of the kettle and the temperature read. Gypsum plaster is a good non-conductor of heat, and it clings to the cooler thermometer bulb or tube placed in the mass,

and so causes the instrument to record a lower temperature.

In most of the Michigan plants the expert calciners who have spent years watching the plaster, learn to tell the stages of the burning by the appearance of the boiling plaster or by the amount of steam passing out through the vapor stacks, and even by the creaking sound of the machinery caused by the settling down of the plaster throwing more strain on the cogs, and when the strain is relieved by the final boiling of the mass, the creaking sound ceases. Some calciners with little experience attempt to calcine plaster without a thermometer, and then are apt to work by guess, making a plaster of variable quality, but such workers are few in the Michigan mills, especially at the present time when competition among the mills requires the best plaster that can be manufactured.

In the earlier days of the plaster industry the plaster was withdrawn at the end of the first settling, and in recent time this method has been followed to save fuel and increase capacity, but such plasters are of lower strength and are often rejected by the plasterers.

The whole process of calcining, after the kettles are heated to the proper temperature, requires two and one-half to three hours, and there is a loss in weight of 12 to 14 per cent due to the loss of water. Three kettles are burned in a day, requiring about 1,200 pounds of coal in dry rock, and as high as a ton of coal in moist rock. Where wood is used it requires one-fourth cord of slab wood, costing \$1.90 a cord, to burn ten tons of plaster. The favorite coal used is the Ohio and Indiana block.

The great objection to the present kettle system of calcining is the great amount of heat required to calcine the mass of cold gypsum thrown into a kettle with thick bottom, and a considerable amount of heat is wasted by radiation from the kettle. This has been lessened by the arrangement of flues in the interior of the kettle. Another objection is the large horse power required to stir this mass of gypsum and so keep it from over-burning on the bottom. The great heat at that place tends to warp and burn out the kettle bottoms which are heavy and expensive to replace.

In the early history of the Michigan industry attempts were made to avoid these troubles by using rotating cylinders as described in the historical chapter. Various forms of cylinders have been invented, but with one exception, to be described, these have attracted little attention. Butterworth and Lowe purchased one of these patents and improved it, but have now ceased to manufacture them.

The objection given to the cylinder method of calcining is the difficulty of determining when the plaster is properly calcined. The expert calciner cannot see plaster boiling in the enclosed cylinder, and all of his tests of the appearance of the boiling mass, the rising steam, the creaking machinery, have disappeared or are so modified that he can no longer recognize them. He is at a loss to determine the time to draw the finished product.

If he depends on a time limit of a certain number of hours or parts of an hour, the rock may vary in amount of contained moisture and so have to be drawn at different times. This might be determined by the thermometer, but this method of determining temperatures does not appeal to men skilled in kettle methods. These objections have prevented the rotating cylinders from being adopted in any of the Michigan mills, and the method is generally condemned in this State.

Plaster machinery has improved very slowly in comparison with machinery in other lines of rock product manufacture, and it is hoped that new and better methods will be invented and that prejudice alone will not stand in the way of their adoption.

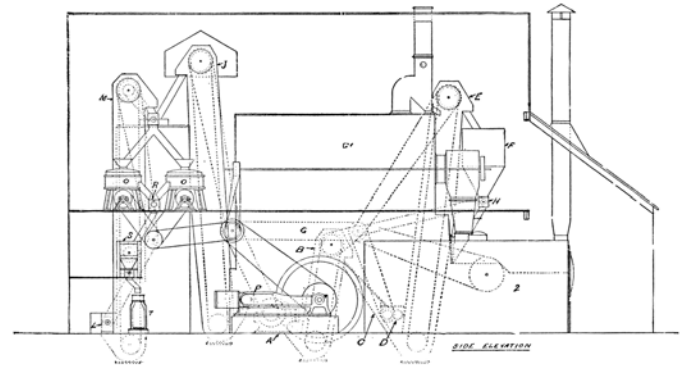


FIG. 27. Cummer Continuous Calcining Kettle (sectional view).

[27. Cummer Continuous Calcining Kettle. (Sectional view)]

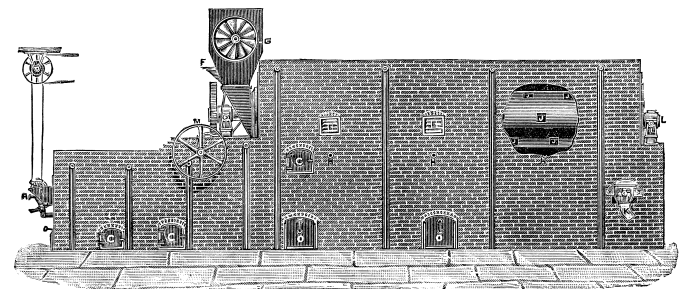


FIG. 28. Cummer Continuous Calcining Kettle (outer view).

[28. Cummer Continuous Calcining Kettle. (Outer view)]

§ 4. Cummer Rotary Calciner.

A year or more ago the F. D. Cummer Co., of Cleveland, Ohio, invented a rotary cylinder for calcining plaster, and has installed these in several plants. At the present time this is the only company in this country which is meeting with any success in this line of gypsum machinery. From the experience in the Portland Cement mills, this method would seem to be the logical method of calcining such plaster, it could be proved that the plaster could be made of good and uniform quality, and this the Cummer Co. claim to be doing, and are willing to guarantee.

The Lycoming Calcining Co. of Williamsport, Pa., is using the Cummer process in a plant of a capacity of 50 tons of plaster in 11 hours, using slack coal as fuel, and they claim there is a large saving in horse power and

labor over the kettle method, and that the plaster is of a high strength and is satisfactory to the trade.

The gypsum blocks are crushed in a jaw crusher, A, (Figure 27) and by rolls, D, so as to pass through a one inch ring screen, C, and the material is then fed into the rotary calciner, G, from the storage bin, F. This cylinder is 27 feet long and four feet in diameter set at an incline and slowly revolved. It has a large number of hooded openings, J, (Figure 28) so arranged that heated air and gases are drawn in from the chamber around the cylinder. The material is constantly raised and dropped in the cylinder by means of the lifting blades. The heated air traverses the cylinder in the opposite direction of the material. In Figure 28, A, is the stoker front, C, C, are cleaning doors, K, is the discharge for the calcined product, H, H, are holes in the masonry in which the pyrometers for measuring the temperature may be placed, M, is the driving pulley, F, is the hopper, and G, is a fan for controlling the flow of the gases and heated air.

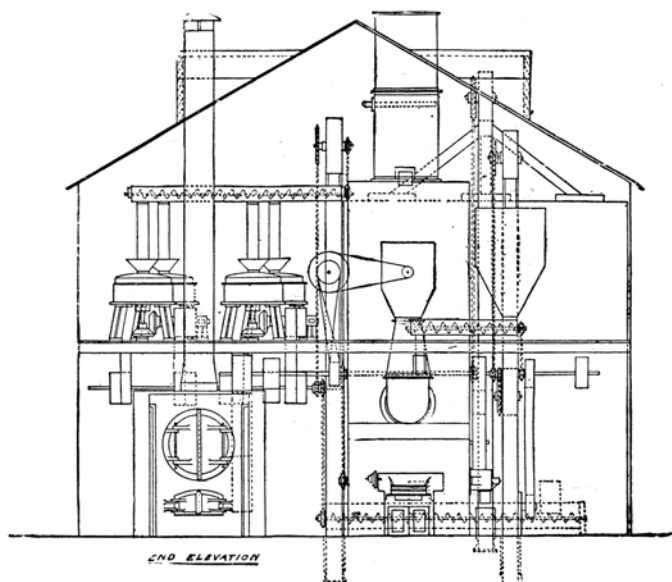


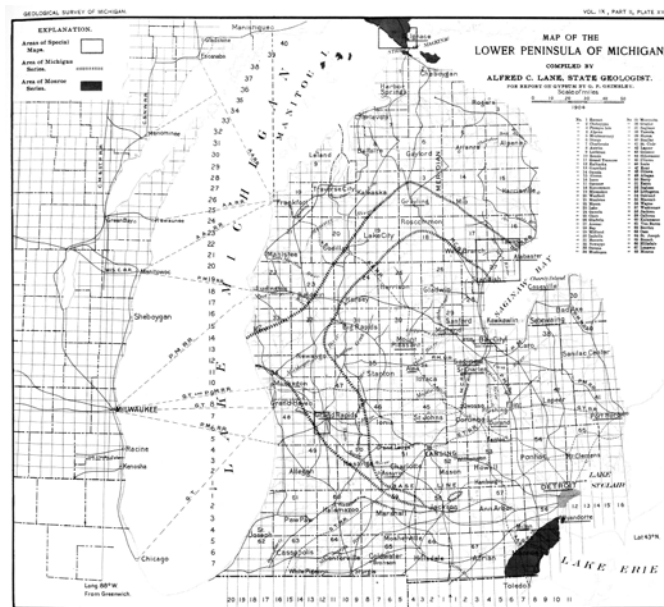
FIG 29. Cummer Continuous Calcining Kettle (end elevation)

[29. Cummer Continuous Calcining Kettle. (End elevation)]

The material delivered from the rotary calciner is steaming and heated to from 350° to 400° F. Elevators carry the plaster to the three specially constructed brick calcining bins, 30 feet long, six feet wide, and 29 feet deep, where the resident heat of the plaster completes the process of calcination and the material is cooled in about 36 hours. The cooled plaster rock is mechanically discharged into the elevator, M, (Figure 27) which, carries it into small bins placed over the grinding mills, O. From these mills the conveyor delivers the pulverized material to the screen, S. The finished product is sacked at T. The end elevation of a Cummer mill is shown in Figure 29.

In the kettle method, the calcined plaster after remaining in the fire proof bins a time to cool is taken by conveyors and elevators to an upper floor and passed over screens. The screens by means of double eccentrics

have a shaking motion and are usually about three and one-half by four and one-half feet in size covered with wire cloth sieve, and are set at a sloping angle. The fine plaster passes through and the coarse particles or tailings are conveyed back to the buhrs for regrinding. In the western United. States plaster mills, the sieves are 30 to 35 meshes to the square inch. In Michigan and Ohio they are usually 35 to 45 meshes to the square inch, and in New York 40 to 55 mesh sieves are generally used.



[XVI. Map of Michigan Showing Location of Wells]

In some plaster mills the plaster is screened by passing into a horizontal cylindrical reel 40 inches in diameter and 10 feet long, slanting downward three-eighths of an inch to the foot, and made of 40 mesh wire cloth. The screenings in both of these methods average about one per cent of the total.

The screened plaster is conveyed into bins on the second floor of the mixing room where it may be run into sacks of 100 pounds weight or into 265 pound barrels, and sold for plaster of Paris, or as it is called in Michigan, stucco. This word stucco is used in the United States in a variety of ways. In Kansas it usually refers to plaster made from earthy gypsum (gypsite). In other sections, and this is the correct use of the term, it refers to a plaster of Paris with glue or some retarder added to it to delay the time of setting.

The retarder was formerly added to the plaster in the kettle a short time before drawing the product, but this method produced uneven results. It is now added in correct proportion in a mixing machine of the type of the Broughton mixer shown in Figure 30. This machine is made of iron or steel with a receiving hopper below constructed of wood, and the machine is adapted for continuous operation.

While one charge is being sacked, another is being mixed, and the third is filling the hopper above, which holds 1,000 to 1,400 pounds. The capacity of a five bag

machine is 300 to 400 barrels per day of ten hours, requiring 8 to 12 H. P., and with a weight of 4,750 pounds.

The finished plaster some years ago was always placed in barrels with a weight of 300 pounds. At the present time some of the material is placed in barrels of 265 pounds weight, but most of the plaster is sold in sacks of 100 pounds weight. These sacks cost about eight cents each in wholesale lots and are charged against the customers who receive a rebate of the amount paid when the sacks are returned.

§ 5. Progress in Technology of Gypsum Plaster.

In the early days of the Michigan plaster industry, the calcining was done in cauldron kettles holding a few barrels and stirred by hand. A little later several of these kettles were set in an arch similar to the plan now used in the kettle block system of making salt from brines. This crude method was improved by Mr. Freeman Godfrey, by the construction of a six foot calcining kettle with a stirring appliance moved by water power. These kettles were increased to eight feet and then to ten feet in diameter, and one company has even considered a 12 foot kettle. Experience seems to show that in economy of fuel and power, the most profitable kettle is the ten foot size, and this has now come to be the standard size in gypsum mills.

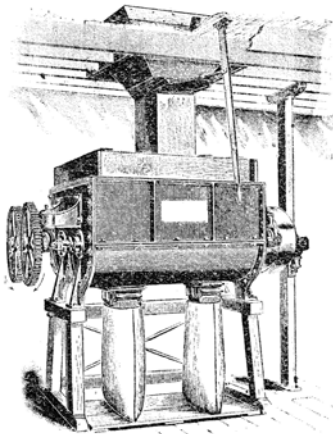


FIG. 30. Broughton Plaster Mixer.

[30. Broughton Plaster Mixer]

The interior flue system enabled the plaster to be calcined with less fuel than without, and in many of the western mills two Hues are considered as good as four and give greater capacity to the kettle. If no partition is added in the air space around the kettle to separate the two sets of flues, there seems to be no advantage in the extra two flues. The Iowa plan of four flues on a horizontal line seems to require more fuel than in the arrangement of two above and two below, as indicated in the table given under that section of this chapter.

The size of the flues has been increased from 5 to 16 inches in diameter, and this is regarded as the maximum size for economical working of plaster, though there is

some difference of opinion on this point. The size of the grate has been increased and most plaster men agree that a fire place four and one-half by three feet is the most economical.

Progress, then, in calcining plaster in Michigan in the past 30 years has been in enlarging the capacity of the kettle and in the saving of fuel. In the early days when wood was abundant and was the only fuel used in this work, there was no incentive to improvements which would save fuel.

In the present day of active competition and occasional cutting of prices, it is important to save expense at every turn and to improve the product as much as possible.

The improvement in product has been in the more complete removal of water in the gypsum rock. The old plasters were removed at the end of the first settling as fully calcined. Such plaster would scarcely sell today at any price in competition with plaster removed after the second settling.

Another improvement has been along the line of fine grinding and increase in capacity of grinding machinery. Some mills today are turning out a plaster so finely ground that there is scarcely a trace of grit in the mass. The Stedman disintegrator, and the Sturdevant emery mill give a greater capacity for the power required and cost less for repairs than the old style buhr mill, but many plaster manufacturers claim, the resulting plaster is not so fine in grain. With the use of these machines, when a very fine ground plaster is needed for any special kind of work it may be reground in a small buhr mill. For ordinary wall plaster work it is very doubtful whether such fine plasters are any better than the coarser grades.

This progress in improvement in grinding machinery has only come in the last few years and is so new to many plaster men that they are not ready to adopt them. No machine appears to the plaster men so valuable for crushing the coarse rock as the old, nipper and coffee mill cracker used for over 30 years. In some of the New York mills Blake crushers have displaced the old type of crushers, but the number is as yet small.

It is but natural that appliances used for so long a period of time, which make a plaster of high strength and uniform quality, and by which in past years the owners of mills have accumulated comfortable fortunes, should be displaced only with great difficulty by new methods, theoretically improvements, but practically in use but a short time.

The early experience, filled with failure in the use of rotating cylinders at Grand Rapids and Alabaster has not been forgotten, so new methods reported as successful in New York and Pennsylvania are looked upon with suspicion by the practical operators in this State who are familiar with the past history of these early Michigan cylinders. This experience of opposition to new methods is seen in many lines of industry. It was prominent some

years ago when rotary kilns were invented for use in Portland cement manufacture.

The buildings in the Michigan plant are built in a substantial manner of brick or heavy frame. The older mills are built compact with the different rooms under one large roof, or grouped close together. The new plants have separate buildings and if not built of brick, have at least the engine room so constructed. Fire has destroyed many of the gypsum mills and every precaution is used to avoid the danger of fire.

§ 6. Use of Retarders,

Plaster of Paris made from gypsum rock will set in a few minutes, but if a retarder can be added, it will delay the set for a longer time according to the amount added. In ordinary cases enough retarder is mixed with the plaster in the Broughton mixer to delay the set about two hours and occasionally by special order, the set is delayed six to eight hours. The retarder a few years ago was always added in the kettle which gave uneven and unsatisfactory results.

Various substances have been used for this purpose. In the earlier history of cement plasters, glue water was added by the workman as he used the material; but this was troublesome and often resulted in poor work from neglect to use the proper amount or failure to thoroughly mix the parts. The trade demanded a plaster already retarded in a way that would give uniform results. This has led to the invention and manufacture of patent retarders in large numbers.

These retarders have a base of some glue compound or hair treated with chemicals, and are organic in composition. The popular brands now in use are the Challenge, Webster City, Wymore, Binn's, Ohio, retarders. In Michigan the Wymore retarder is in common use. It is made of a mixture of organic compounds not patented, but the formula is carefully guarded, and it is made at Wymore, Nebraska.

Among the ancient Romans, blood was used to retard the set of plaster of Paris, and today the organic material of the tankage from packing houses is found to give the desired results and is used to a very considerable extent as a retarder. Among the numerous patents issued for retarders the following may be of interest:

Patent number 286,650 was issued to cover a mixture of plaster of Paris, saw dust, hair, and water.

Patent number 291,508 is for a mixture of plaster of Paris, weak glue water, glycerine, sawdust, and slaked lime.

Patent number 301,459 is a mixture of plaster of Paris and glue.

Patent number 445 211 calls for a mixture of a solution of the substance of hair.

Patent number 446,604 is a mixture of beans, peas, and lentils, with slaked lime, carbonate of soda, and alkaline earth.

Patent number 452,346 covers a mixture of plaster of Paris with glue dissolved in water, lime slaked in glue water, and sand.

Patent number 391,889 is for a mixture of plaster of Paris, sawdust, sugar, carbonate of soda, slaked lime, sand, pumice stone.

Patent number 397,297 is for a mixture of hydraulic lime, animal gelatin, and vegetable glutinous matter.

Patent number 321,620 covers the mixture of plaster of Paris and resin-de-lac dissolved in caustic soda.

Patent number 420,008 is a mixture of plaster of Paris, serum and hair mixed, carbolic acid and air slaked lime.

Patent number 479,060 is a mixture of plaster of Paris, glue, seed meal, sulphate of zinc, cut rope or hair.

Patent number 523 658 is for the mixture of fermenting and decomposing organic matter in water mixed with quick lime dried and powdered.

Patent number 558,435 gives a complex mixture of plaster of Paris, furnace slag, slaked lime, hydraulic cement, flour of grain, and fibre.

Patent number 502,096 gives plaster of Paris, sanegal gum, sugar, silicate, carbonate of soda, alum, clay, salt cake, and ground China meal.

An examination of these specifications will show considerable resemblance in composition, and part of the materials included would appear to be only needed to add to the complexity of the mixture and enable one to secure a patent. Plaster of Paris is a common ingredient. Of the 40 patent specifications in my possession, 20 have a base of glue, and five of prepared hair, seven contain sawdust.

The cause of the retarding influence of such mixtures has never been fully determined. The set of plaster, as will be shown in another section, is due to the formation of a crystal network. This ordinarily takes place as soon as water is added to the calcined gypsum. The retarder delays in some way this crystallization, possible by holding the water, as dried organic tissues have a strong affinity for water. The water would then be given up slowly to the plaster and the crystallization be delayed.

In the laboratory crystals may be seen forming out of solution and then gradually increase in size. This is seen in some substances better than in others, but the cause of the phenomena has been a subject, of speculation from the days of the early mineralogists of the time of Haüy at the beginning of the last, century, but so far the explanation of the exact causes of crystallization has eluded the students of crystallography. Until the causes of crystal formation are understood, it will be extremely difficult if not impossible to explain the action of substances which act as retarders to crystallization.¹

The force which produces crystals has been termed the crystallizing force and while this is a useful handle for grouping the observed facts, it lacks an explanation and definition. It seems without doubt to be a molecular force and is exerted in different ways in different substances, and different ways in the same substance under different conditions.

¹Glues increase viscosity hence retard circulation. The growing crystal soon exhausts its immediate neighborhood and new material is only slowly fed in. See Rosenbusch p. 28, *Microscopische Physiographie*.

The retarder as added to plaster is in proportion of 4 to 6 pounds to the ton, or in 1 pound there would be about 1-30 of an ounce, and this is sufficient to delay the set 3 or 4 hours.

If the retarder holds the water as suggested above, the plaster would not be injured by such addition of foreign material in small amount, as it would only delay the time of the formation, and the resulting crystal network would be as strong as though no retarder was there, but experiments show that the plaster is weakened, and there must be some other result in addition. A series of experiments was made to determine the effect of the retarder on the strength of the plaster. The following table shows the tensile strength in pounds per square inch of plaster of Paris plus Wymore retarder after 30 days.

Mixture.	Pounds of retarder to ton.	Initial set.	Final set.	Average strength.	Maximum strength.
A.	0	2 min.	48 min.	595	667
B.	2	3 "	1 hour	558	578
C.	4	1 hour	49 min.	343	458
D.	10	23 min.	7 hours.	325	495
		1 hour	43 min.		
		35 min.			

With an addition of two pounds of retarder to the ton, the strength of the plaster is decreased over 6 per cent. This would indicate a direct effect of the retarder on the crystal arrangement preventing a perfect crystallization of the plaster. The reduced strength even with the addition of 10 pounds of retarder to the ton, would still give a plaster stronger than is really necessary for a wall, as it would never be subjected to a strain of 325 pounds to the square inch. But the excess of retarder, would through disintegration probably greatly weaken the plaster in course of time.

The proper treatment would be to use as little retarder as is necessary and, to use the best that is made. The gelatins to which group glue belongs are composed of carbon, hydrogen, nitrogen, and oxygen, in very complex proportion, but they represent fairly stable compounds. Some of the refuse matter used for retarder is of very different character and in nature passes through the stages of decay and it seems but natural that they would alter even plaster.

Particles of foreign material added to plaster of Paris appear to act as accelerators, but when some of these are heated with the gypsum they act as retarders. The table shows a portion of an extended series of experiments on influence on set of plaster through the

use of a variety of substances. The clay used was ordinary fine ground clay with a considerable percentage of moisture. This clay burned with the gypsum rock held back the set. The dried clay seems to be a retarder and in that condition would have a strong affinity for water.

Mixture of plaster of Paris.	Initial set in minutes.	Final set in minutes.
Pure plaster of Paris.....	7	21
water acidulated with HCl.....	2	6½
" " " H ₂ SO ₄	1½	4
with sodium carbonate.....	9	16
" " sulphate.....	4½	10
" concentrated sugar solution.....	5	12½
" borax.....	4½	12
" wood charcoal.....	7	12½
" limestone.....	7	16
" one-third sand.....	7	15
" 1% limestone.....	11	23
" 6% ".....	13	24
" 10% ".....	10	19
" 2% clay.....	5	14
" 8% ".....	5½	15
" 10 ".....	5	15

An inspection of this table shows that the different proportions of clay and even of limestone make but little difference in the time of setting. Acids and sulphates when added in nearly saturated solutions hasten the set. Sugar solutions were formerly added for retarder, but in nearly saturated solution they hasten the set.

§ 7. The Set of Plaster.

When water is added to plaster of Paris, it sets in a solid mass. This is all that it is necessary for the plasterer to know in order to do his work, but to many of these men the subject of the true nature of the set is an interesting and puzzling problem. Just what is the process of setting of plaster?

Lavoisier Theory.

As far as we can learn from the chemical and physical literature, this question was first answered by that famous French chemist, Lavoisier, who in 1765 described the results of his experiments in the following words, translated from the French.¹

"I took the calcined plaster, as has been described before, and which hardens readily with water. I threw it into a considerable amount of water, in a pan or large dish. Each molecule of plaster, in passing through the liquor, seized its molecule of water of crystallization, and fell to the bottom of the dish in the form of small brilliant needles, visible only with a strong lens. These needles, dried in the free air or with the aid of a very moderate heat, are very soft and silky to the touch. If placed on the stage of a microscope, it is perceived that what was taken under the lens for needles are also parallelepipeds, very fine, so they are described as thicker, or many times thinner, and many more elongated. The plaster in this state is not capable of uniting with water, but if it is calcined anew, these small crystals lose their transparency and their water of crystallization, and become again a true plaster, as perfect as before. One may, in this fashion, successfully calcine and recrystallize the plaster even to infinity, and consequently give it at will the property of seizing water."

This explanation of the set of plaster through the formation of a crystalline network was verified a number of times later, and was given by Payen in 1830 as his first principle in the chemistry of plasters.

¹Quoted by Landrin. Annales de Chimie, pp. 431, 435; 1874.

Landrin's Theory.

The next important contribution to the chemistry of plaster was by Landrin in 1874, who divided the set of plaster into four periods.

"1. The calcined plaster, on contact with the water, united with this liquid and takes a crystalline form.

"2. The plaster dissolves partially in water, which becomes saturated with this salt.

"3. A part of the liquid evaporates, due to the heat set free in the chemical combination. A crystal is formed and determines the crystallization of the entire mass; a phenomenon which is analagous to that which takes place when a piece of sulphate of soda is placed in a saturated solution of this salt.

"4. The maximum hardness is reached when the plaster gains enough water to correspond exactly with the formula $\text{CaOSO}_3 \cdot 2\text{H}_2\text{O}$; this maximum being to the remainder in proportion to the quantity of water added to the plaster to transform it into mortar."

*Chatelier's Theory.*¹

Chatelier in 1887 showed that plaster would set in a vacuum flask, so that evaporation was not a necessary step in the set of plaster, as Landrin maintained in his third principle above.

According to Le Chatelier, the plaster of Paris compound (CaSO_4)₂, H_2O dissolves in part in the added water, which diminishes the solubility, and the solution becomes therefore supersaturated and $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, or gypsum, crystallizes out. In other words, the plaster of Paris dissolves, and becomes hydrated, then crystallizes out as gypsum, every particle of the plaster goes through these steps.

¹Academic des Sciences 1887.

Grimsley Theory.

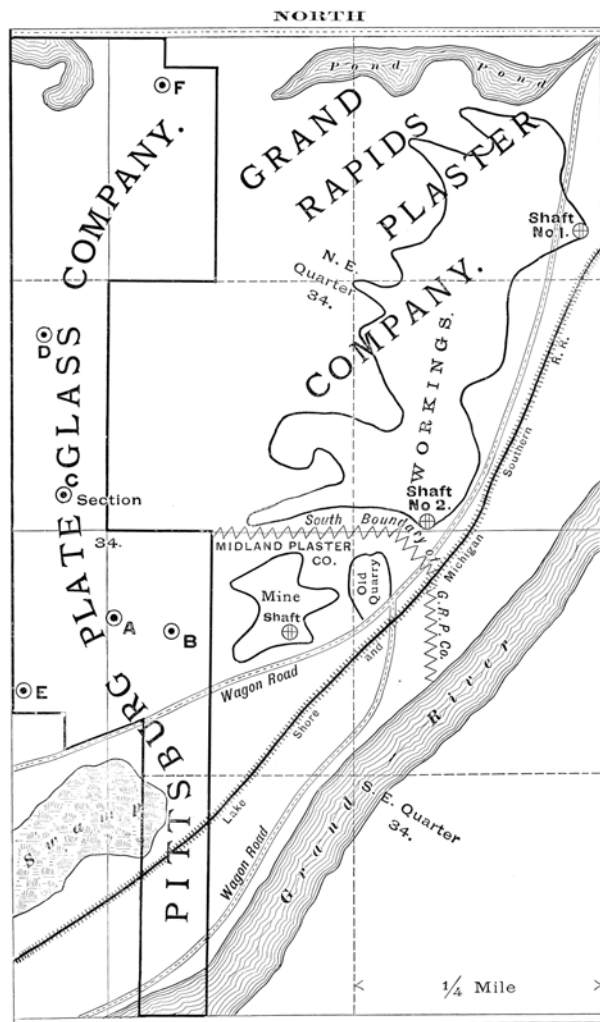
In Volume V of the University Geological Survey of Kansas, the writer outlined a theory to explain the setting of plaster. This theory was based on a number of laboratory experiments and on careful observation. Since that time a considerable amount of time has been devoted to this subject and the theory still appeals to me as a logical and plausible one, fully in accord with the observed facts.

Under the microscope the ground gypsum before calcination consists of rather large masses of varying size as shown in Figure 31. In comparison with the gypsum earth, the rock is seen to consist of more or less broken crystals, while the gypsum earth shows crystals of more regular shape. After calcination these larger

crystals are found to be broken into fine granules of nearly uniform size and shape. As the material is heated, the water is changed to steam throughout the crystal mass, and expanding, breaks the crystals into finer particles. There is thus a physical change as well as a chemical one. If the plaster has not been sufficiently calcined the grains are coarser and more irregular.

Geological Survey of Michigan.

Vol. IX Part II Plate XVII.



PITTSBURG PLATE GLASS COMPANY LANDS.

[XVII. Map of Land Controlled by the Pittsburg Plate Glass Co. at Grand Rapids]

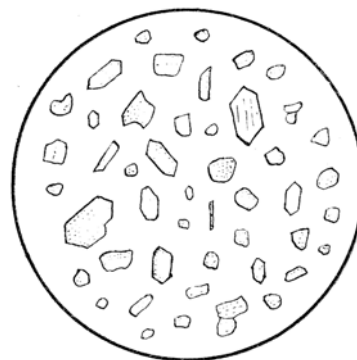


FIG. 31. Uncalcined gypsum earth, $\times 500$ diameters.

[31. Uncalcined Gypsum Earth $\times 500$]

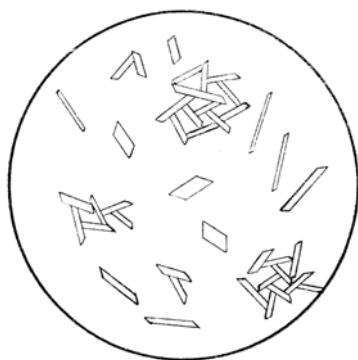


FIG. 32. Calcined gypsum earth from central Kansas, one-half hour after water was added to it, $\times 600$ diameters.

[32. Calcined Gypsum Earth $\frac{1}{2}$ Hour After Water Was Added to it $\times 600$]

Under the microscope when water is added to the calcined plaster, small needle like prisms are seen forming and shooting out here and there. As these become more and more abundant, they unite with one another and rapidly form a solid mass, in which the individual crystals can scarcely be distinguished. Open spaces are left in the mass apparently filled with water, and finally these are closed, and a firm solid mass results. The network formed by these crystals at first, is shown, in the drawing in Figure 32.

The treatment of calcined gypsum with water in the same way shows very little change, Figure 33. Gypsum crystallized from solution by evaporation shows crystals which are not needle shaped, but they are broader and show considerable irregularity. They are more or less twinned and they do not interpenetrate, but form a loose mass which readily crumbles. This crystallization is shown in Figure 34, which was obtained by evaporating a solution of uncalcined gypsum on a glass slide and then examining it under a high, power microscope.

Crystallization is aided by the small size of the grains or particles in the plaster, and the finer grained plasters set more rapidly than the coarser ones, as one may observe in the fine dental plasters as compared with ordinary plaster of Paris.

My own experiments agree then with those given by Lavoisier, Payen, Landrin, and Chatelier, in that the set of plaster is due to the formation of a crystalline network. The cause of the formation of this network of crystals, or the factor which starts the crystallization is the troublesome part to explain, and this has attracted less attention among investigators along these lines.

When gypsum is burned it forms, as Landrin showed and as analyses prove, the hydrate $(\text{CaSO}_4)_2, \text{H}_2\text{O}$. Marignac called attention to the fact that if the water is added in excess, this hydrate in part is dissolved, forming first a clear liquid which then becomes turbid, and crystals of $\text{CaSO}_4, 2\text{H}_2\text{O}$, or gypsum are thrown down. Now an examination of these formulas shows that three parts of water have been taken up by the hydrate.



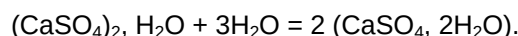
FIG. 33. Uncalcined ground gypsum in water, after standing three days.

[33. Gypsum Crystallized from Solution in Water after Standing Three Days $\times 500$]



FIG. 34. Gypsum crystallized from solution in water, after standing three days.

[34. Uncalcined Ground Gypsum in Water, after Standing Three Days $\times 500$]



So first the plaster dissolves partially in contact with the water, as Landrin pointed out in his second principle, and as accepted by Chatelier. Next, some changes take place whereby, according to Marignac's experiment, the liquid becomes turbid and crystallization begins. Landrin thought evaporation took place as a result of the heat formed by chemical combination, and that then a crystal was formed which started the crystallization through the entire mass. Chatelier showed by experiment that evaporation was not necessary and he argued that by the taking up of this water the solubility of the hydrate was decreased, and so, on account of the resulting supersaturation, crystallization ensued.

The solution of the hydrate in these experiments is certainly saturated, and all that is needed is something to start the crystallization. From a study of saturated solutions in the laboratory, it is well known that if crystals are introduced into such solutions crystallization will result and go on until the salt is crystallized out.

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 liner and finer particles, microscopic and ultra-microscopic in size. If the heat is not carried too far certain particles through the mass may still their crystalline form as shown in Figure 31, and so they are

true crystals though very small. These minute crystals in the saturated solution would start the process of crystallization. Their growth would cause the turbidity of the solution as noted by Marignac, and would result in the precipitation of small gypsum crystals, thus forming the crystal network which constitutes the set of plaster.

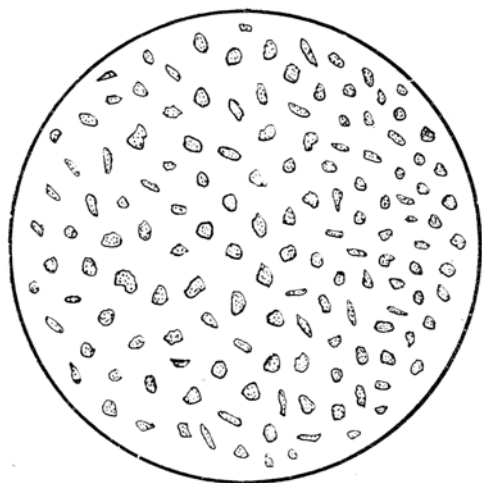


FIG. 35. Calcined gypsum earth from central Kansas, $\times 500$.

[35. Calcined Gypsum Earth from Central Kansas $\times 500$]

If the plaster is unburned 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 the properly burned plaster. But of more importance, the hydrate represented by plaster of Paris would not be formed.

If the plaster is overturned, the plaster will be so completely comminuted that no minute crystals would be left to start the crystallization. Where the plaster is slightly overturned, the crystals are extremely fine and crystallization goes on very slowly and imperfectly.

CHAPTER IX.

CHEMISTRY OF GYPSUM AND GYPSUM PLASTERS.

§ 1. Composition.

Gypsum was used in a variety of ways long before its real nature and composition were determined or even investigated. The first record of the composition of gypsum is found in a paper of Lavoisier presented to the Academie des Sciences in 1765. Lavoisier decomposed the gypsum rock by means of carbon, setting free sulphurous vapors which formed a sulphur deposit and proved the presence of sulphuric acid. He then decomposed a solution of gypsum in water by means of potash, showing the presence of lime. In this manner the qualitative analysis of gypsum rock was made and its elements determined.

Later quantitative analyses were made on various specimens of gypsum. One of these early analyses was made on pure crystallized gypsum from Mont-martre near Paris. This analysis shows a very low percentage of water, and indicates rather anhydrite.

	Per cent.
Silica	0.02
Lime sulphate	92.56
Lime carbonate.....	0.32
Water	7.10
	100.00

From this and other similar analyses, the theoretical composition of a pure gypsum was determined, and by later revision was given as,

	Per cent.
Sulphuric acid.....	46.60
Lime oxide.....	32.50
Water	20.90
	100.00

The percentage composition of water (20.9) and lime sulphate (79.1), divided, respectively by the atomic weights (water) 18, and (lime sulphate) 135, would give a proportion of the groups in the molecule, for water as 1.162 and for lime sulphate as .585, or a relation, of two parts of water to one of lime sulphate expressed by the chemical formula $\text{CaSO}_4, 2\text{H}_2\text{O}$. When the two parts of water are absent the mineral is called anhydrite.

A portion of the water in the gypsum is readily removed on application of heat, and observation accompanied by chemical analysis shows that about three-fourths of the water can be readily removed, and the other one-fourth only with difficulty; and further that the three-fourths so removed passes off at two different stages.

§ 2. Payen's Experiments.

The facts noted above were first determined by Lavoisier and confirmed by Payen¹ in 1830, who found that the gypsum began to lose at a temperature of 115° C., and that the loss rapidly increased up to 204° C. He determined the best temperature for the formation of plaster to lie between 110 and 120° C. (230 to 248° F.). In modern plaster manufacture a temperature of 100° or more higher than Payen's is used.

Payen's results are given in the following summary:

1. The set of plaster is due to a crystallization of hydrous sulphate of lime.
2. The lowest temperature at which plaster can be made is 80° C. (176° F.), but the material must be kept at this temperature for a considerable period of time.
3. A temperature of 110 to 120° C. is sufficient to deprive plaster of all its water and to calcine it completely.
4. Plaster in small particles favors drying.
5. Calcium sulphate heated to about 250° C. (482° F.) is dehydrated; at 300 to 400° C. (572 to 752° F.) it loses completely the properties of hydration, or the power of gaining again the water of crystallization, and resembles then the hydrated sulphate of lime found in nature. If heated higher, it may result in melting the sulphate of lime.
6. The hardening of plaster by alum is perhaps due to the formation of a double sulphate of potash and lime.

¹Chimie Industrielle, 1830, quoted by Landrin, Annales de Chimie, 1874.

§ 3. Chatelier's Experiments.

Chatelier² in 1887 conducted some very elaborate experiments on the effects of temperature on gypsum. He powdered the gypsum rock and placed it in a paraffin bath, and connected a thermometer in the bath with a chronograph. On applying heat up to 200° C. or 392° F., there was a constant rise in temperature, with two exceptions. The first halt occurred at 128° C. or 262° F., and the second at 163° C. or 325° F. The first one was the more pronounced, and Chatelier regarded these interruptions as due to an absorption of heat which accompanied the elimination of water. This would indicate the existence of two hydrates, whose decomposition took place at the temperatures indicated by the halts on the chronograph. Further the dehydration was found to be incomplete at 155° C. or 311° F., and complete at 194° C., or 381° F.

In order to prove the composition of the first hydrate, Chatelier heated a saturated solution of gypsum in a closed tube to a temperature between the two halts indicated, or between 130° C. (266° F.) and 150° C. (302° F.) and very delicate, long, rectangular prisms

were formed, which were thrown into alcohol and then analyzed with the following result:

	Per cent.
Water	6.70
Sulphate of lime.....	93.30
	100.00

This agrees very closely with the formula $(\text{CaSO}_4)_2, \text{H}_2\text{O}$, where there would be,

Water	6.20
Sulphate of lime.....	93.80
	100.00

In this compound it is seen that two parts of lime sulphate are united with one part of water, while in the original gypsum one part of lime sulphate was united with two parts of water. Chatelier also found that the incrustation in the boilers of ocean steamers, where salt water was used and where the temperature averages about 165° C. (320° F.), possessed nearly the same composition, as the hydrate given above. His analysis was as follows:

Water	5.80
Sulphate of lime.....	91.90
Carbonate of lime.....	0.30
Iron oxide.....	2.00
	100.00

Further experiments by Chatelier showed that if 10 grammes of powdered gypsum were heated for sometime at 155° C. or 311° F, intermediate between the temperatures necessary for the decomposition of the two hydrates, the loss in weight was uniformly 1.56 grammes which corresponds with one and a half equivalents of water so that the compound should contain about 6.2 per cent of water as shown by the formula given. Ordinary plaster of Paris usually contains about 7 per cent of water, so that it is a definite hydrate with the formula $(\text{CaSO}_4)_2, \text{H}_2\text{O}$.

The second halt, as has been given, took place at 163° C. or 325° F. From this temperature to 221° C. or 430° F. no change was noted in the plaster; but beyond this temperature, the plaster when mixed with water did not absorb it readily and only set after a long time. If the heat reaches 343° C. or 650° F., the plaster acts like anhydrite, it is said to be dead burned and will not set on addition of water. If the gypsum is heated further, the substance melts, forming a crystalline mass on cooling which cannot be decomposed by heat except in the presence of organic matter, when it changes into CaS. If this substance is acted upon by carbon dioxide gas (CO_2) and water, sulphuretted hydrogen will be formed.

The temperature of burning is thus seen to be all important, and calls for skill and experience on the part of the calciner. If overburned, the plaster sets very slowly. If underburned, the new hydrate is not formed, and the plaster will not set.

²Annales des Mines, p. 345, 1887.

§ 4. Chemistry of Foreign Gypsum.

In the various papers on foreign gypsum deposits so far as consulted, very few analyses are given. The gypsum of the Hartz¹ mountains is a pure variety containing but little silica and iron, while the analysis from the Philippines shows a higher percentage of the silica impurity.

	Wienrode Hartz by Jungst.	Osterode Hartz by Hampe	Albany Philippines by Trobe.
Silica and insoluble residue.....	2.80	0.15	6.43
Iron and alumina oxides.....	0.60	.....	0.64
Lime sulphate.....	77.63	79.05	73.60
Lime carbonate.....	.....	.....	.....
Water.....	19.90	20.74	20.18
	100.93	99.94	100.85

In New South Wales² the gypsum is not as yet used to any extent, and may be compared with the rock on St. Marcos island off the coast of California analyzed by the writer, and also with the analysis of the gypsum of Hawaii.

	Lake Tank, north of Bourke, New South Wales.	St. Marcos, by Grimsley.
Silica and insoluble residue.....	2.90	0.16
Iron and alumina oxides.....	0.60	0.31
Lime sulphate.....	75.66	78.60
Lime carbonate.....	.....	0.93
Water.....	20.20	20.31
Magnesia sulphate.....	0.61	.....
	99.97	100.31

¹Calculated from analyses given in Vol. V, Univ. Geol. Survey, Kans., p. 141.

²Minerals of New South Wales, p. 164, 1888.

The analysis from Hawaii¹ shows a very high percentage of lime, and would give about 76.04 per cent of lime sulphate, and leave about 7 per cent for water, i. e., anhydrite.

Silica and insoluble residue.....	4.00
Iron oxide (Fe ₂ O ₃).....	0.70
Lime oxide.....	43.40
Sulphuric acid.....	44.73
Magnesia oxide.....	0.50
	93.33

¹19 Annual Report U. S Geological Survey. Part VI, Cont., p. 685;1897-8.

§ 5. Canada Gypsum.

In Canada over four-fifths of the gypsum quarried is exported, and most of this rock comes to the United States. The leading district for the gypsum sent to this country is in Nova Scotia. Analyses² of this rock are given in the following table which shows the percentage of sulphuric acid and also the calculated percentage of the combined sulphate of lime plus water.

	No. 1.	No. 2.	No. 3.	No. 4.
Sulphuric acid	43.65	43.98	40.84	44.86
Water .....	.....	.....	18.47	20.02
Insoluble in acids.....	1.88	2.67	0.99	2.57
Undetermined	4.28	2.77	11.20	0.97
Sulphate of lime and water (gypsum).....	94.84	94.56	87.81	96.46
	101.00	100.00	100.00	100.00

²Report of Connecticut Exp. Station, p. 62; 1883.

§ 6. United States Gypsum.

The gypsum rock from eastern United States to the Pacific coast shows a considerable range in chemical composition. In the eastern part in New York state the composition is shown in the following analyses:

	Cayuga. ³	Onondaga. ⁴	N. Y. Rock, ⁵ Prof. Armsby.
Lime sulphate and water (gypsum).....	74.09	64.53 73.92	76.35
Insoluble matter.....	6.05	11.17 4.64	5.83
Other material chiefly CaCO ₃	19.86	24.27 21.44	17.82
	100.00	99.97 100.00	100.00

The average composition of the New York gypsum rocks is given by Merrill as,

	Land plaster. ⁶	Severance quarry. ⁷
Lime sulphate and water (gypsum).....	65 to 75%	80 to 90%
Insoluble material.....	6 to 8%	10% or less.
Lime carbonate.....	18 to 28%	Trace.
Magnesia carbonate .....	.....	5% or less.

³Report Connecticut Exp. Station, p. 75; 1884.

⁴ " of same station, p. 62: 1883.

⁵Advertising Circular, Marsh & Co., Sandusky, Ohio.

⁶Report Connecticut Exp. Station, p. 50; 1882.

⁷Bulletin New York State Museum, Vol. III, p. 81; 1893.



[XVIII. Buhr Stone Mills Grinding Gypsum; Grand Rapids Plaster Co.]

OHIO.

Going farther west, the gypsum industry is seen to center in a small district near Sandusky in Ohio. This rock, according to the late Professor Orton, has the following composition:¹

	Average sample.	Surface rotten rock.	Land plaster.
Silica and insoluble material.....	0.68	0.46	0.91
Iron and alumina oxides.....	0.16	0.29	0.60
Lime sulphate.....	77.45	78.54	78.73
Lime carbonate.....	1.12	0.75	.....
Water	20.14	20.00	19.70
Magnesium oxide.....	0.56	0.03	0.54
	100.11	100.07	100.48

¹Calculated from Geol. Survey of Ohio, Vol. VI, pp. 696-702; 1888.

FLORIDA.

An analysis of a gypsum deposit in Florida is given by Dr. David T. Day, as,²

	Per cent.
Silica and insoluble material.....	0.07
Iron and alumina oxides.....	0.01
Lime sulphate.....	77.79
Lime carbonate.....	0.52
Water.....	21.39
	99.78

²Calculated from U. S. Geol. Survey, Vol. XX, Part VI Cont., p. 662; 1899.

IOWA.

The composition of the Iowa gypsum is given in the following analyses by G. E. Patrick:³

	Selected sample.	Top.	Middle.	Bottom.
Insoluble residue.....	0.65	.....	.....	.....
Lime sulphate.....	78.44	78.37	78.54	78.44
Water (calculated)....	20.76	20.75	20.79	20.76
	99.85	99.12	99.33	99.20

³Iowa Geological Survey, Vol. III, p. 291; 1895.

KANSAS.

In Kansas a very complete chemical examination was made by Prof. Bailey of the gypsum rocks and plasters. From these a few are selected to show the range in composition of the gypsum rock, and a second series gives the composition of the gypsum earth so much in demand in that section for the manufacture of plasters.⁴

	Blue Rapids.	Dillon.	Medicine Lodge.
Silica and insoluble material.	0.65	0.35	0.19
Iron and alumina oxides.....	0.17	0.12	0.10
Lime sulphate.....	79.30	78.40	77.46
Lime carbonate.....	1.53	0.56	1.43
Water.....	18.84	19.96	20.46
Magnesium carbonate.....	0.39	0.57	0.34
	100.88	99.96	99.98

⁴Univ. Geol. Survey of Kans., Vol. V., pp. 146-147; 1899.

*Kansas Gypsum Earth.*¹

	Dillon.	Burns.	Longford.
Silica and insoluble material.....	12.13	2.31	10.23
Iron and alumina oxides.....	0.99	0.37	1.12
Lime sulphate.....	64.63	67.91	58.75
Lime carbonate.....	3.57	11.71	11.77
Water.....	18.75	17.72	17.10
Magnesium carbonate.....	0.88	0.52	0.94
	100.95	100.54	99.91

¹Univ. Geol. Survey of Kansas, pp. 149, 152, 154.

Oklahoma, Indian Territory, and Texas Gypsum Earth.

	Marlow, I. T. ²	Okarche, O. T. ³	Quanah, Tex. ⁴
Silica and insoluble material.....	10.67	7.98	0.91
Iron and alumina oxides.....	0.60	0.50	0.21
Lime sulphate.....	59.46	71.70	69.92
Lime carbonate.....	10.21	1.14	9.05
Magnesium carbonate.....	1.10	0.24	0.65
Water.....	16.59	18.68	18.85
	98.63	100.24	99.59

²Univ. Geol. Survey of Kansas, Vol. V., p. 149; 1899.

³Furnished by the O. K. Cement Plaster Co.

⁴Wilkinson, The Technology of Cement Plaster, p. 5; 1897.

COLORADO AND WYOMING.

	Aspen District, Colorado. ⁵	Red Buttes, Wyoming. ⁶
Silica and insoluble material.....	1.46	4.50
Iron and alumina oxides.....	.....	1.27
Lime sulphate.....	69.26	64.22
Lime carbonate.....	5.96	15.74
Water (calculated).....	21.50	14.00
Magnesium carbonate.....	1.32	.....
	99.50	99.73

⁵Calculated from U. S. Geol. Survey, Mono., XXXI, p. 240; 1898.

⁶Furnished by Prof. Wilbur C. Knight.

CALIFORNIA.

The gypsum deposits of California have been worked from time to time, but at the present time only one deposit is worked and this is near Los Angeles. The analyses are given as follows:⁷

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica and insoluble material..	2.2	1.4	4.8	14.3	13.0	6.0
Calcium sulphate and water..	88.8	88.9	83.2	72.0	87.0	72.6
Calcium carbonate.....	9.0	9.7	12.0	3.9	.....	22.0
Other materials.....	.....	.....	.....	9.8	.....	.....
	100.0	100.0	100.0	100.0	100.0	100.6

⁷Univ. of California Exp. Station, 1891-2.

No. 1, Coalinga. No. 2, Nevada Gypsum and Fertilizing Co. No. 3, Bakersfield mine. No. 4, Southern California. No. 5, San Francisco. No. 6; Los Angeles.

A comparative study of these various analyses shows that the range of gypsum (lime sulphate and water) varies from 04.53 per cent at Onondaga, N. Y., and 72 per cent in Southern California, to 99.18 on Bear Island, Florida and 99.50 in Iowa.

The gypsum of Florida, Iowa, Ohio, Kansas, will average close to 99 per cent purity. The Canada gypsum will run about 94 per cent. The California rock gypsum runs about with the gypsum earths of Wyoming, Kansas, Oklahoma, and Texas, ranging from 80 to 85 per cent.

The silica impurity is under 1 per cent in Ohio, Florida, Iowa, and Kansas; but according to the analyses given it is 4 to 6 per cent in New York, and up to 14 per cent in some of the California rock. Lime carbonate ranges around 1 per cent in most of the gypsum rock of the United States. The theoretical percentage of water is 20, and the rocks analyzed show a per cent ranging from 17.82 to 24.27.

The average per cent of lime sulphate and water, or gypsum in the analyses of the U. S. gypsum rock quoted in the preceding analyses is 92.75; or leaving out the New York and California analyses would give 97.38 per cent.

The difference in percentage of lime sulphate in favor of some deposits is often taken advantage of, for advertising purposes, but the gypsum in this country is usually of high grade of purity in the areas worked for plaster, and makes a good product. The centralization of the plaster industry in certain states is due not so much to the purity of the material, as to the extent of the deposits, nearness to railroad markets, and to the

business enterprise of the people forming the companies.

§ 7. Chemistry of Michigan Gypsum.

Having passed in review the chemical nature of the various gypsum deposits in this and other countries, it now remains to examine the deposits of this state, where gypsum of marked purity can be found, and where one of the leading centers of the industry is established by the causes given in the preceding paragraph.

The chemistry of Michigan gypsum has been discussed from the beginning of the industry. Some of the old records hasten to state that the gypsum of this state is the purest in the country, a statement naturally disputed by the workers of other states. In any section it is possible to select exceptionally pure specimens of gypsum rock whose analysis approaches very closely the theoretical percentage called for by the formula. On the other hand it is possible to select portions of rock impregnated with clay and other impurities which will give an analysis showing an exceptionally poor rock. In making comparative examinations, or in giving the composition of a quarry, it is essential that careful samples be taken not from one place alone, but from different parts of the quarry. Not knowing in all cases just how the specimens were selected from which the analyses were made as given in the foregoing pages, it would not be just to draw conclusions as to the best deposits in the country, or to say where the poorest are found. Again the effect of the so-called impurities is not always known. Some of these may be beneficial. Lime carbonate in marked quantity in gypsum is usually regarded as a useless impurity in this country; but in the Paris gypsum the 12 per cent of lime carbonate is said by some authorities in that country to explain the greater strength of Paris plaster over the plaster in some other countries. The presence of alumina in amounts of two and three per cent is said to act as a retarder in the set of plaster.

Method of Sampling.

In the present work, an attempt was made to secure average samples, and this was accomplished by taking the specimens from the spouts into the buhr mills. This partially crushed rock coming from various parts of the quarry represents the rock actually ground and made into plaster. An amount of about two or three pounds weight was taken and divided. The part selected was again divided and crushed to a fine flour, and then divided and a portion ground to the finest powder in an agate mortar. One gram of the powder was taken for analysis. This method would give a lower proportion of the compounds than would be given by carefully selected pure specimens. The results may not be so valuable for advertising purposes when compared with analyses made from carefully selected samples in other districts, but should compare well with those made by the chemists of our state surveys.

The samples collected for the Kansas work were selected in a somewhat different way, but with the same object in view of determining the average quarry composition. In that state the specimens collected by the writer, were taken from various parts of the quarry, crushed and then divided two or three times and a few pounds weight were taken and sent to the laboratory where it was further divided and crushed.

Method of Analysis.

The method of analysis used on the Michigan material is based on the methods used by Prof. Bailey of the Kansas work and was as follows:

One gram of the powdered gypsum was dissolved in concentrated hydrochloric acid in an evaporating dish and evaporated to dryness on a sand bath until all odor of HCl had disappeared. The mass was then digested with dilute acid and boiled several times. A single boiling was found to leave a heavy apparently insoluble residue, which was greatly decreased on the second and third boiling. This portion of the analysis should be watched carefully so as to make sure that the lime sulphate all goes into solution. The solution is then filtered and the silica or insoluble material on the filter is washed with hot water, dried, ignited and weighed.

The filtrate is diluted to 500 c.c., and thoroughly mixed; 300 c.c. are taken for the determination of the bases, and 200 c.c. for sulphuric acid. In the first portion iron and alumina are precipitated with ammonia, and the precipitate filtered, washed with hot water, dried, ignited, and weighed. To this filtrate heated to boiling is added a hot solution of ammonium oxalate and the precipitate of oxalate of lime after standing a few hours is readily filtered, and after drying may be treated with sulphuric acid (H_2SO_4) converting the oxalate to sulphate of lime which multiplied by 7.17 will give the amount of oxide of lime (CaO). The magnesia if present in the filtrate is precipitated with sodium phosphate, which, filtered, dried, weighed, and multiplied by .756 will give the amount of (MgO), magnesium oxide.

The other portion, 200 c.c. treated with barium chloride (BaCl) will give a precipitate of barium sulphate (BaSO_4), whose weight multiplied by .3435 will give the amount of sulphuric anhydride (SO_3).

One gram of the powdered gypsum heated in an open platinum crucible to a temperature of 200°C . will give a loss in weight representing the amount of water.

Such an analysis of a specimen of gypsum will give the simple compounds which can be united to show the probable composition of the rock. The sulphate of lime will equal the amount of sulphuric anhydride plus the amount of lime oxide equal to the sulphuric anhydride multiplied by .7, and the remaining portion of the lime oxide is probably combined with carbon dioxide (CO_2) whose amount may be determined by multiplying it by 11.14.

ANALYSES.

Western Michigan.

The analysis of the Alabastine quarry rock selected by the method given shows the following percentages:

	Per cent.
Silica and insoluble material.....	1.28
Iron and alumina oxides.....	1.825
Lime oxide.....	32.94
Sulphuric acid (SO ₃).....	44.697
Water	19.00
Magnesium oxide.....	trace
	99.742

By calculation of this analysis the probable composition of the rock would be:

	Per cent.
Silica and insoluble material.....	1.28
Iron and alumina oxides.....	1.825
Lime sulphate.....	75.984
Lime carbonate.....	1.951
Water	19.00
Magnesium carbonate.....	trace
	100.04

The lower course of rock in this quarry, red in color, was formerly rejected as being too impure for finished plaster and was only suitable for rough uses as land plaster, but at the present time this rock is used with the rest of the quarry rock. Its analysis shows that the red color is not a badge of impurity.

	Per cent.
Silica and insoluble material.....	0.505
Iron and alumina oxides.....	trace
Lime oxide.....	32.90
Sulphuric anhydride (SO ₃).....	45.114
Water	20.57
	99.08

The analysis would give a probable rock composition of:

	Per cent.
Silica and insoluble material.....	0.505
Iron and alumina oxides.....	trace
Lime sulphate.....	76.74
Lime carbonate.....	2.39
Water	20.57
	100.205

Across the Grand river from the Alabastine quarry in the English shaft mine, the gypsum rock has practically the same composition.

	Per cent.
Silica and insoluble material.....	1.18
Iron and alumina oxides.....	1.87
Lime oxide.....	32.74
Sulphuric anhydride.....	44.72
Water	19.00
	99.51

Calculating the probable composition of the rock gives:

	Per cent.
Silica and insoluble material.....	1.18
Iron and alumina oxides.....	1.87
Lime sulphate.....	76.02
Lime carbonate.....	2.57
Water	19.00
	100.64

In the same neighborhood a short distance east is the cave mine of the Grand Rapids Plaster Co., mill No. 2, where the rock has the following composition:

	Per cent.
Silica and insoluble material.....	1.245
Iron and alumina oxides.....	0.495
Lime oxide.....	33.115
Sulphuric anhydride.....	45.40
Water	19.03
	99.285

Calculating this analysis, gives the probable composition of this rock as:

	Per cent.
Silica and insoluble material.....	1.245
Iron and alumina oxides.....	0.495
Lime sulphate.....	77.186
Lime carbonate.....	2.380
Water	19.03
	100.336

Passing to the southwest five miles at Grandville, the Durr quarry rock has a composition as indicated in the analysis below:

	Per cent.
Silica and insoluble material.....	1.06
Iron and alumina oxides.....	0.325
Lime oxide.....	33.095
Sulphuric anhydride.....	44.13
Water	19.72
	98.33

The probable composition is then:

	Per cent.
Silica and insoluble material.....	1.065
Iron and alumina oxides.....	0.325
Lime sulphate.....	75.017
Lime carbonate.....	3.936
Water	19.72
	100.063

The bright selenite plates found in this quarry do not show much purer composition than the compact rock.

	Per cent.
Silica and insoluble material.....	0.35
Iron and alumina oxides.....	.....
Lime oxide	32.78
Sulphuric anhydride.....	45.61
Water	20.59
	99.33

Calculated:

	Per cent.
Silica and insoluble material.....	0.35
Iron and alumina oxides.....	.....
Lime sulphate.....	77.537
Lime carbonate.....	2.085
Water	20.59
	100.562

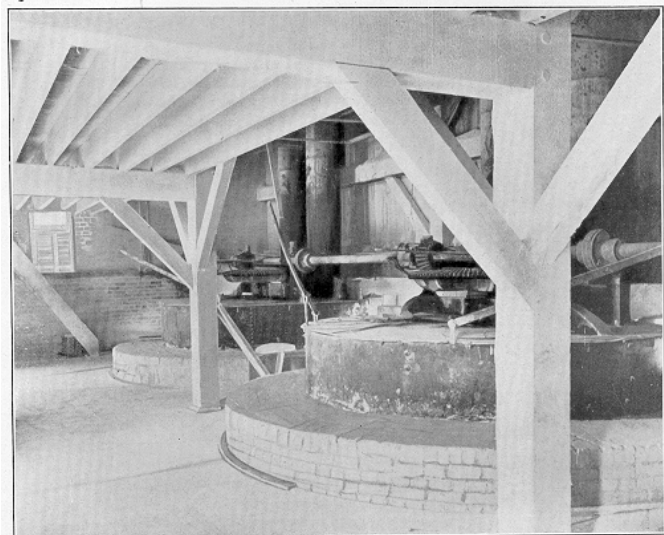
Winchell in the 1860 report,¹ (pp. 163 and 164) gives the following analyses of the Michigan gypsum:

Silicic acid.....	trace	.....	
Alumina and iron oxide.....	.5354	3.89	loss
Lime oxide.....	32.0385	32.67	
Sulphuric acid (SO ₃).....	46.2257	44.44	
Potassia	.2115	.....	
Soda	.0140	.....	
Chlorine	.0078	.....	
Water	20.8445	19.00	
	99.8774	100.00	

¹The one by L. R. Fisk, the second by S. P. Duffield.

Geological Survey of Michigan.

Vol. IX Part II Plate XIX.



TOP OF GYPSUM KETTLES, MILL OF GRAND RAPIDS PLASTER CO.

[XIX. Top of Gypsum Kettles in Mill of Grand Rapids Plaster Co., at Grand Rapids]

Alabaster.

In the Alabaster quarry, probably the largest gypsum quarry in the United States, the average analysis shows the following composition:

	Per cent.
Silica and insoluble material.....	0.555
Iron and alumina oxides.....	trace
Lime oxide.....	33.155
Sulphuric anhydride.....	45.745
Water	20.28
	99.735

Calculated:

	Per cent.
Silica and insoluble material.....	0.555
Iron and alumina oxides.....	trace
Lime sulphate.....	77.766
Lime carbonate.....	1.86
Water	20.28
	100.461

Selected material from this quarry shows great purity, as given in the following analysis by Geo. H. Ellis, who states it is the finest gypsum he has ever analyzed. It would be possible to select a large quantity of such rock from this quarry.

	Per cent.
Lime sulphate.....	78.67
Water	20.98
	99.65

St. Ignace.

The deposits of St. Ignace in northern Michigan were analyzed, though only a small amount of material was available for the examination.

	Per cent.
Silica and insoluble material.....	0.195
Iron and alumina oxides.....	.....
Lime oxide.....	32.795
Sulphuric anhydride.....	45.845
Water	20.32
	99.155

Calculating the probable composition of this rock gives:

	Per cent.
Silica and insoluble material.....	0.195
Iron and alumina oxides.....	.....
Lime sulphate.....	77.936
Lime carbonate.....	1.257
Water	20.32
	99.708

At Grayling in the deep well, gypsum was found with a thickness reported as 132 feet, at a depth of 408 feet. This was analyzed as follows:

	Per cent.
Silica and insoluble material.....	19.08
Iron and alumina oxides.....	0.31
Lime oxide.....	29.755
Sulphuric anhydride.....	31.297
Water	14.10
	94.542

This gypsum is evidently a gypsum rock mixed with lime stone, and calculated gives:

	Per cent.
Silica and insoluble material.....	19.08
Iron and alumina oxides.....	0.31
Lime sulphate.....	53.20
Lime carbonate.....	13.92
Water	14.10
	100.61

The Michigan gypsum rock is seen from these analyses to range from 94.73 to 98.26 per cent of sulphate of lime and water, or in selected samples 99.65 per cent, with

an average of over 97 per cent. This is slightly below the average in Ohio, Iowa, and Kansas. The real explanation of the difference is to be found in the excess of lime carbonate over the localities in Ohio, Iowa, and Kansas.

The silica impurity is but little over 1 per cent, and it is often less than this amount.

In calculating the probable percentages of the rock, the analyses usually run over the 100 per cent. This is explained in the Kansas gypsum by Bailey as due to a combination of some of the lime with the silica, which is decomposed in the process of getting the mineral into solution. It being impossible to tell how much of the lime to add to the silica, it was all computed as united with carbon dioxide (CO₂) in the form of carbonate of lime; and this gives a slight excess in the total of the compounds.

Anhydrite Analyses. L.

It will be noticed that I have stated that most of the calcium sulphate constituents at a considerable depth in wells, such as those of Alma, Mt. Pleasant, and Midland, and the series of the deeper wells in the Saline along the Detroit river, St. Clair river and the shore of Lake Michigan, is anhydrite. This is mainly based upon microscopic determinations. However, Mr. H. R. Browne of the Michigan Alkali Works at Wyandotte, made some tests of samples of their well (Ford No. 23) showing that the so-called gypsum is at least largely anhydrite. As the samples come up wet, a certain admixture of gypsum may come very easily from the water. We have also the results of an analysis of a sample from Mt. Pleasant as follows:

Analysis by M. A. Cobb, Oct. 26, 1903, of sample taken at 1,225 to 1,270 feet depth.

	Per cent.
Fe ₂ O ₃ }	1.4
Al ₂ O ₃ }	
CaCO ₃	2.83
MgO	.2
CaSO ₄	87.15
Difference, SiO ₂ , CO ₂ }	8.42
and Moisture }	
	100 00

The Michigan gypsum rocks are of high grade of purity and the plasters made from these rocks are standard products in the market.

§ 8. Chemistry of the Finished Plasters.

ANALYSES.

*Plaster of Paris in France.*¹

	Silica.	Iron and Alumina.	Lime Sulphate.	Lime Carb.	Mag. Carb.	Water.
Vintry (Seine), ordinary...	4.9	2.5	70.9	10.2	5.05	6.45
" " fine.....	3.7	2.7	72.6	12.0	5.45	3.55
Villejuif (Seine).....	4.8	0.6	77.95	8.5	1.9	6.25
Bondy (Seine), ordinary...	1.4	1.5	79.05	9.9	2.3	5.85
" " fine.....	2.4	1.0	83.4	6.9	2.3	4.0
Romainville (Seine).....	0.6	0.8	87.7	2.4	2.7	5.8
Bois le Comte (Seine).....	1.2	0.35	85.75	4.3	....	8.4
Lamarche.....	1.6	....	88.45	3.75	....	6.2
Bussiere.....	1.05	0.45	84.0	7.15	0.4	6.95
Roquevaire (Bouches du Rhone).....	11.2	3.1	70.55	6.7	5.65	2.8
Bassin de la Couze (Dordogne).....	4.0	1.4	71.60	14.1	5.05	3.85
Herepain (Herault).....	4.2	1.0	81.6	....	....	13.2
Partel (Aude).....	0.7	0.4	86.85	5.3	....	6.75
Malancene (Vaucluse).....	0.6	....	92.0	0.35	....	6.15
Poligny (Jura).....	0.8	....	93.5	3.4	....	3.3
Grasse (Alpes-Maritimes)...	0.1	0.2	95.65	....	....	4.05

¹Quoted from M. Durand Claye, Catalogue de Expos, de 1876, in Thorpe's Dictionary, Vol. 1. p. 470 474.

*Ohio Calcined Plaster.*¹

	No. 1.	No. 2.
Silica and insoluble material.....	0.68	0.46
Alumina.....	0.16	0.29
Lime sulphate.....	77.45	78.54
Lime carbonate.....	1.11	0.75
Water.....	20.14	20.00
Magnesia.....	0.56	0.03
	100.10	100.07

These analyses though given for calcined plaster were probably of uncalcined gypsum as indicated by the water percentage.

¹Calculated from analyses in Mineral Resources, U. S. Geol. Survey, p. 600; 1887.

Wyoming Plaster.

The cement plaster made at Laramie, Wyoming, according to Slosson and Moudy has the following composition:²

	Per cent.
Silica and insoluble material.....	5.50
Alumina oxide.....	0.59
Lime sulphate.....	73.73
Lime carbonate.....	7.86
Water.....	6.93
Magnesium carbonate.....	3.04
Lime oxide.....	2.35
	100.00

²Tenth Annual Report Agricultural College of Wyoming, p. 8; 1900.

Kansas Cement Plasters.

The gypsum plasters in Kansas are made from the rock and from the gypsum earth. These have been analyzed by Prof. Bailey with the following results:³

	Blue rapids Rock.	Springvale Earth.
Silica and insoluble material.....	1.20	4.27
Iron and alumina oxides.....	0.20	0.47
Lime sulphate.....	89.42	83.55
Lime carbonate.....	1.68	3.07
Water	6.82	6.67
Magnesium carbonate.....	1.18	1.47
	100.50	99.50

³University Geol. Survey of Kansas, Vol. V, p. 160; 1899.

Texas and Oklahoma Territory.¹

	Okarche, O. T.	Quanah, Tex.
Silica and insoluble material.....	13.29	2.53
Iron and alumina oxides.....	0.71	0.45
Lime sulphate.....	73.67	78.81
Lime carbonate.....	4.77	11.22
Water	5.78	5.70
Magnesium carbonate.....	1.91	0.74
	100.13	99.45

Heat of the proper degree applied to the gypsum rock changes it to plaster of Paris, through the loss of approximately three-fourths of the water. The formula of the calcined plaster (CaSO_4)₂, H₂O, calls for 6.2 per cent of water and 93.8 per cent of calcium sulphate as has been explained in the early part of this chapter.

Many of the Paris plasters approximate very closely the theoretical percentage of water, but are usually low in the percentage of sulphuric anhydride as are all commercial plasters through the included impurities in the gypsum rock. The lime carbonate present in the rock is in all probability not altered in the change as the temperature is not sufficient to drive off the carbon dioxide (CO₂).

The Ohio analyses though given for calcined plasters were incorrectly labelled or the title represents a mistake in the proof. The Wyoming plaster and those of Kansas, Texas, and Oklahoma, show nearly correct amount of water for properly calcined plasters as determined by the theoretical percentages.

In some mills a few years ago and occasionally at the present time the plaster was drawn after the first settling. This method would enable the manufacturer to make plaster in a shorter period of time and so increase the capacity and lower the cost of fuel and labor. Such plasters have not been received with satisfaction by the trade.

In a specimen of the Michigan plaster obtained from one of the mills, the water percentage after the first settling was 6.67 and at the close of the second settling was 5.70 per cent. This analysis would not condemn the plaster in the first sample. It is similar to the amount in the Blue Rapids plaster of Kansas which is a standard grade of plaster. The second percentage agrees with

the analyses given above of the Okarche, O. T., and of the Quanah, Texas, plasters. The physical tests of these materials and their relations to the chemical analyses are discussed under that chapter.

Prof. Bailey² has made an interesting series of analyses of the plaster in Kansas in different stages of the manufacture, which are given below as taken from the Kansas report:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica and insoluble material.....	9.78	10.84	12.02	10.81	25.83	11.63
Iron and alumina oxides.....	0.30	0.50	0.44	0.42	1.52	0.67
Lime sulphate.....	64.91	69.06	68.36	59.84	39.18	69.60
Lime carbonate.....	6.12	9.37	14.39	10.50	24.15	11.74
Water	17.37	9.02	4.88	16.35	4.18	4.78
Magnesium carbonate.....	0.70	1.10	0.93	0.82	2.00	0.93
	99.18	99.89	101.12	98.77	96.76	99.35

No. 1. Crude material.
No. 2. Sample taken after two hours of boiling.
No. 3. The finished material.
No. 4. A sample that has been set.
No. 5. The screenings or tailings.
No. 6. A sample that has been treated with a retarder.

These analyses show that one-half the water is expelled in the first two hours, and about one-fourth in the last hour. The plaster as set (No. 4) shows about the original percentage of water as found in the uncalcined rock. The tailings or screenings (No. 5) are high in silica, the oxides of iron, alumina and magnesia, and low in lime sulphate with a water percentage about normal for the finished product. An analysis of the retarded plaster (No. 6) shows practically no chemical difference from the non-retarded plaster. The amount of retarder added is so small that it is not detected by analysis of the plaster.

¹Technology of Cement Plaster by Wilkinson, p. 5; 1897.

²University Geol. Survey of Kansas, Vol. V, p. 166; 1899.

Michigan Finished Plasters.

The following analyses were made for the writer by Dr. F. B. Dains of Washburn College, except those of the Powers' Mill and the plaster of Paris made at the Alabastine Mill, which analyses were made in the chemical laboratory of the University of Kansas under the direction of Prof. E. H. S. Bailey.

Alabaster Plaster.

	Per cent.
Silica and insoluble material.....	0.80
Lime oxide (CaO).....	38.95
Sulphuric anhydride (SO ₃).....	54.67
Water	5.24
	99.66

This analysis would give a probable composition by calculation of:

	Per cent.
Silica	0.80
Lime sulphate.....	92.95
Lime carbonate.....	1.26
Water	5.24
	100.25