A GEOLOGICAL SECTION

FROM

BESSEMER DOWN BLACK RIVER

BY

W. C. GORDON

ASSISTED BY

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State Geologist

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LETTER OF TRANSMITTAL.

OFFICE OF THE STATE GEOLOGIST,
LANSING, MICHIGAN, Nov. 13, 1906.

To the Honorable, the Board of Geological Survey of the State of Michigan:

Hon. Fred M. Warner, President.
Hon. W. J. McKone.
Hon. Patrick H. Kelley, Secretary.

Gentlemen:—I herewith transmit for publication the report of W. C. Gordon on the geology, mainly of the Keweenaw rocks, from Bessemer north to Lake Superior. This is designed to call attention to an area of copper bearing rocks which have as yet received scant attention, as well as to assist us in attacking the more difficult problems of the Porcupines. Mr. Gordon resigned to take a position with the U. S. Steel Co. I have therefore added chapters on the intrusive rocks and the pre-Keweenawan rocks and given the matter general revision in passing through the press, adding foot notes freely.

Very respectfully,
ALFRED C. LANE,
State Geologist.

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INTRODUCTION.

In June, 1904, I received instructions from A. C. Lane, State Geologist, to take a party of men, go to Bessemer, and make a complete and detailed cross-section of the Keweenawan rocks as they are exposed between that place and Lake Superior. The object in making such a section was "to correlate it, as far as possible, with the lodes of Portage Lake, and Ontonagon, and to have the assistance of the same in studying the Porcupine Mountains."

As a base for the work the party was directed "to make an accurate level and transit survey of the road from Bessemer to the mouth of Black River, locating the nearest convenient corner or quarter-post where it crossed section lines, and leaving enough well marked stations to facilitate later interpolation by pacing and barometer." "Having finished the transit and level line" we were "to contour both banks of Black River, then extend the work eastward and westward from the road, not going farther west than the middle line of R. 47 W., nor farther east than the line between Secs. 2 and 3, R. 46 W." If necessary we were to survey the road running down the middle of R. 47 W.

Having finished the transit and level lines we were advised to make "a close preliminary pacing survey, and geological examination, not by running section lines, but by following stream valleys, and lines of protuberant ridges, to determine the location of every available outcrop in the district examined." In following ridges we were advised to "look out for offsets that might indicate faults." "After having been over a goodly portion of the area in a preliminary way, and entered the material on the map," the party was directed to carry out from the main line such lines of survey and water-level as might be needful in giving accurately the more important areas.

For the cleared area near Bessemer triangulation was advised.

The party consisted of Chas. E. Smith, G. Sage Brooks, J. G. Coté, and W. C. Gordon. During September A. E. Redner was with the party, and during October A. C. Lane was in the field correcting the work done, and adding such details as seemed necessary.

Mr. Smith acted as compass-man, and in addition did some geological work. His pacing was accurate far beyond that usually done in the bush, and I cannot speak too highly of his work. The party was fortunate in having him since he had himself done much geological work, and knew well how necessary it was to be accurate. Before joining our party he had acted as geologist on the Louisiana state survey, but had been obliged to return north on account of ill health. When he had somewhat recovered he accepted a position with us as it gave him a chance for a much needed out-of-doors life in a northern climate. Mr. Brooks after helping on the transit and level lines did the mapping and all of what might be called office work, if we may speak of such in the woods. Mr. Coté accompanied the party as cook, and Mr. Redner as compass-man. W. C. Gordon acted as geologist.

All the persons of the party have my acknowledgments for the interest taken, and for the efforts put forth to help the work along. In addition to these I have to acknowledge the kindness and assistance of several others; Mr. Markstrum, Mr. Fournier, and Mr. Masse for the use of their hunting camps while we were in the field; Mr. George Rupp, County surveyor, for information and assistance; Mr. Bayless, engineer for the Oliver Iron Mining Co., for use of instruments; Hon. L. L. Wright for information and assistance; Mr. L. H. Truettner and the Wis. Cent. Ry. for the use of maps. I feel also that I must make a general acknowledgment to all the people of Bessemer with whom I had dealings for never have I been located in a place where I was more cordially used.

CHAPTER I.

GENERAL DESCRIPTION.

Before attempting a systematic report of the work done it will be well to give some general idea of the district in which the party worked.

Bessemer is a city of about four thousand population situated on the Gogebic Iron Range. Its business portion lies largely in Sec. 10, T. 49 N., R. 46 W. See Plate XXXII. The city itself covers the whole southwest quarter of the section, and also extends into Secs. 9 and 16. It lies on the north slope of an elevation known as Colby Hill, and reaches well around the west end of it. The city cannot be said to be hilly. It is entered by the C. & N. W., and Wis. Cent. Rys., and also by a spur line of the D. S. S. & A., the main line of which passes two miles to the north. D. S. S. & A. passenger trains stop at North Bessemer, a flag station on the main line, only freight trains being run over the spur line that enters the city. The spur line joins the main line one mile east of North Bessemer, at Bessemer Junction. There are no buildings at either Bessemer Junction or North Bessemer, and no residences near either, the only structures a water tank at the former and a box car, which serves as a waiting room, at the latter. A stage plies between Bessemer and North Bessemer for the accommodation of those who wish to come or go by the D. S. S. & A. Ry. Bessemer is the county seat of Gogebic County, and so the jail and court house are situated there. Ironwood is six miles west of Bessemer and is somewhat larger. The west side of Ironwood lies against the state line between Michigan and Wisconsin. All along the Gogebic Iron Range are iron mines, and around each is a small clearing. Around Bessemer there is a considerable area under cultivation, but a distance of three miles in any direction will reach beyond the cleared land, save in the direction of Ironwood, there being a belt of cleared land along the lines of the C. & N. W. and Wis. Cent. Rys., which are parallel and only a few yards apart. Around Ironwood there is more cleared land than around Bessemer, there being a well cleared and prosperous looking farming district reaching as far north as the D. S. S. & A. Ry. Most of the farms are being cleared by Finnish settlers.

The area of which the geological section was made lies between Bessemer and Lake Superior and is four miles wide and about twelve long. Outside of this area there was no work done save to trace some of the basal strata through to the state line. The section worked is traversed through practically its whole length by Black River, along the west side of which is a wagon road, sometimes just at the river bank, and sometimes as much as a half mile distant. The road was constructed by the state government, but was handed over to the township of Ironwood in which it lies. It was originally well cut out and graded, but at the time our party was in the field it was in a very poor state of repair. However it was the intention of the township to repair it, and if the intention is carried out it will, even before this report is published, be in as good a state of repair as when it was originally constructed. The road was very convenient to the party, since it enabled us to traverse easily the area that we were working.

Black River is from one hundred to one hundred and fifty feet wide but is very shallow. The whole bed is filled with pebbles and boulders, and this, along with the shallowness of the stream, makes it quite impossible for even the smallest boat to have uninterrupted passage during low water. However, during flood season the water is several feet deep. Along the whole course of the river are rapids, some of which are small, being caused by the glacial boulders that are collected in the bed, while others, being caused by rock in place, are much larger. For about the last four miles the river flows over bed rock, and there is a succession of rapids and falls which presents very picturesque scenery. The water of the river is very dark, almost black, but I am not prepared to say whether or not this is the source of the name "Black River."

Passing along the northern limits of the city of Bessemer, and extending for some miles east and west, is a ridge rising from two hundred to two hundred and fifty feet above the surrounding country. Parallel with this ridge, and lying a little more than a half mile to the north, is a similar ridge. Each is made up of a series of hills, those in the south range having a much greater tendency to develop cliffy sides, and bald tops but the tendency is not wholly wanting in the north range. Since these ridges must be often referred to in this report they will be spoken of as "The Bessemer Ridges." These ridges are often broken through by north and south gaps, varying in width from a hundred yards to over a mile. One of these gaps (Plate XXXIV) lying directly north of Bessemer, must often be spoken of and will be called "The Bessemer Gap."

North of the Bessemer Ridges is a belt of lower land running east and west, and for the most part over five miles wide. The D. S. S. & A. Ry. runs along the north side of this lower land. This belt is drift covered, and without exposure save where Black River has cut down to the country rock in Sec. 21, T. 49 N., R. 46 W. North of this drift covered country and lying on the western edge of the area worked, is a felsite hill, or, at least, a hill with a felsite top and a melaphyre base. The hill is known as "Chippewa Bluff," or, sometimes, as "Old Peak." Each of the two names is derived from mining companies that explored there, the Chippewa Mining Company about 1850, and The Old Peak Company about 1900. The name Chippewa Hill will be used in this report because it has the claim of priority. The hill slopes quite rapidly both to the north and to the south, but more gently to the west, while at the east end there is a steep bluff. The top of the hill is about three hundred feet above the surrounding country. The road spoken of winds around the eastern foot of the hill, and so closely to it that the overhanging bluff is plainly visible, especially when the leaves are off the trees. The hill just described lies almost wholly within Sec. 32, T. 49 N., R. 46 W.

Eastward from Chippewa Hill, and distant about a mile or a mile and a half, is an elevated area of more than two square miles. This area is more than two hundred feet above the surrounding land. It has not a broad flat top, but there are several elevations and depressions, but all of minor importance. There are several places on it with a level surface of several acres. The soil is thin over the whole elevation, and in several places there are rock outcrops. In this report this elevation will be called "the Black River Highlands." It includes practically all of Secs. 3 and 4, T. 48 N., and the greater part of Secs. 33 and 34, T. 49 N., R. 46 W.

Between Chippewa Hill and the Black River Highlands is a low country which is level, save for the valley of Black River, which flows across it, and for ravines caused by small streams tributary to the river.

North of the Black River Highlands the land slopes gradually to the lake. At the lake shore there is a clay bank about one hundred feet high. On the west side of the river the land is level for a distance of about two miles north of Chippewa Hill, then there is an east and west ridge rising about two or three hundred feet. Since this ridge is caused by a conglomerate formation it will be called "Conglomerate Ridge." From this ridge the land slopes to the lake which is from a mile to a mile and a half. The ridge has a rather steep slope on the north side beyond which is a series of old lake terraces. At the lake shore is a clay bank about one hundred feet high. All these things taken together make quite a change in elevation from the crest of the ridge to the surface of the lake.

Black River takes its rise about twelve miles south of Bessemer, and a few miles east. For about six miles it makes a general northwest direction, then for eight miles a northeast direction, and passes nearly three miles to the east of Bessemer. Directly east of Bessemer it is joined by another stream known as the "East Branch" of Black River. When the river is about two miles past this branch it turns directly west and flows in that direction for about five miles. It is after making two miles of this westerly direction that it enters the area worked by us during the summer of 1904. Thus, when Black River comes into our field of work it is flowing west along the north foot of the north Bessemer Ridge. When within a mile of the range line between 46 and 47 west it turns north, and then making somewhat to the east it flows across the low land between Chippewa Hill and the Black River Highlands. As it continues northward it is forced still farther east by the Conglomerate Ridge, beyond which it takes a direct route to the lake. It rises in R. 45 W., but soon enters R. 46, and after entering that range never leaves it. Before getting nearly down to Bessemer it is half way across the range, but flows back again almost to the east line. After passing Bessemer it flows almost to the west line, then takes a general easterly direction and empties into Lake Superior near the middle of the range. The area that it drains is limited on the west by the Montreal River, and on the east by the Presque Isle, so that it does not drain much more than R. 46 W., possibly between one hundred and fifty and one hundred and seventy-five square miles.

In Bessemer Gap are some prosperous looking farms, but the D. S. S. & A. Ry. is near the northern limit of cleared land, and from it to Lake Superior is nothing but forest. The area worked is covered with bush save in the neighborhood of Bessemer. Traversing it from north to south is the Black River Road.

Our only rock outcrops were found on the hills, or in the bed of Black River. Bessemer Ridges gave almost continuous outcrops. On Chippewa Hill we found outcrops of felsite with basic rocks beneath. On the Black River Highlands were found numerous exposures of melaphyre. Black River has succeeded in cutting through the drift that covers the country and has exposed much rock, and, since its course is nearly at right angles to the strike of the formation, the river bed is very useful in working out a cross-section. In the upper part of the stream the exposures are few, but they increase in number toward the mouth, and for the last five or six miles there is almost a continuous outcrop. There are no rock exposures in the district save those spoken of above. The general surface of the country is about six hundred feet above Lake Superior, and about twelve hundred above the ocean. Being drift covered it has no outcrops save where portions are elevated, or where water has removed the covering. Much of the land is dry, and some is swampy. Especially along the line between Rs. 46 and 47 W. there is a tendency to swamps and bogs. On the whole the country is easily traversed, but in many places walking is extremely difficult, because of cedar swamps or the thick underbrush that has grown up in areas where there are wind falls.

The first work done was to run the transit and level lines along the road from Bessemer to Lake Superior. The two were carried along together. To begin the transit work Polaris was observed from the quarter post between Secs. 4 and 9, T. 47 N., R. 46 W., and the correct bearing established between that station and the quarter post one mile to the north. This was easily done as there is an iron pin at each station, and a good road running down the centre of the section from one quarter post to the other. From the point of observation the line was carried forward toward the lake, but the work was necessarily slow, because the crooked road, made narrow by the overhanging bushes with thick foliage, made long sights with the instruments impossible, and greatly increased the number of set-ups required. At each station a peg was numbered, and driven into the ground, and on a tree on the road side a blaze was made and the station number placed on it. The road was carefully chained from station to station throughout its whole length, and the passing of all important places or things, such as streams, camps and so on carefully noted.

In doing the leveling an engineer's level was used. The rod was divided carefully into feet and tenths of feet. These were patterned alternately in red and black on white back-ground. Readings could be taken accurately to tenths of a foot, and the hundredths were estimated. The road was run in three parts, and each part was run and closed as a separate course, so that in case error was made it would be known which part of the road it was in. By leveling the road in sections we were able to close the work at each camp before we established another. Bench-marks were carefully established, a notch at the foot of a tree being used in most cases, a spike being put in the notch. On the side of the tree a place was peeled and the elevation of the bench-mark written with a timber scribe, and will, no doubt, be there for some time to come as healthy trees were selected. The elevations as marked on trees are above Lake Superior. To find the elevation above sea level about 602 feet should be added. In three cases the tops of iron pins were used as bench-marks, these are the pins along the road across Sec. 4, T. 47 N., R. 46 W., and in a few cases the elevations of points that it was known would soon be lost were established, but they were established merely for the convenience of the party while at work, and it was never expected nor intended that they should serve a further purpose. One such is the floor of a shack in which we stayed in Sec. 3, T. 47 N., R. 46 W., and another is a stump a half mile north of Bessemer, and still another is a point at Thomas' hunting camp.

After the transit and level lines were finished courses were paced at regular intervals from the base line to the river so as to secure an accurate map of the latter. In addition the whole course of the river was followed and paced, every bend carefully mapped, and every rapid, water-fall, and rock outcrop noted and located as accurately as was possible. While doing the river work we were obliged to wade, but that did not prove a very difficult task during the summer, as the water was seldom more than knee deep, and was warm, conditions that we did not continue to enjoy when the rains and the cold weather began in the fall.

After mapping the river the party began to work the area by sections. In as far as possible all pacing was tied to the base line, but where such was not possible the corners and quarters of the sections were used. Fully three-quarters of the corners were found. Of those not located, no doubt some were missed because of errors in pacing but others are probably destroyed. In only a few cases were all four bearing trees found, but many are still standing and in good condition. In many places the old survey lines could be found and followed by the blazes now well healed over. But in following such lines it was necessary to exercise great care because numerous other lines were blazed through the bush. In some places corners and quarters had been recently established, but these were wholly disregarded except they bore the name of a surveyor. Only those corners and quarters were accepted as true that bore the name of a surveyor or the original government marks. Bushmen have a curious and unfortunate habit of establishing lines, quarters, and corners where it seems to them that they should be because of their own pacing, and many pace very inaccurately. In one case a corner was neatly established, and four bearing trees made, while the correct corner was distant about one hundred and fifty paces, and in good preservation. Knowing the possibility of error of a corner or quarter established by any one save a surveyor, it seemed best to disregard all others beyond merely making a note of the fact.

The method of work was as follows: Each morning before leaving camp the aneroid barometer was set at the elevation of the place, which elevation had been previously determined by the line of levels. Also the inches registered was compared with the inches registered by the barograph kept in camp. We checked the instruments on returning to camp after the day's work was done. The barograph enabled us to correct our readings for change in air pressure, while the checking of the aneroid with the barograph enabled us to correct for the error caused by the slipping of the instrument, which is sometimes the cause of considerable error.

In the field we started at a section corner, and the compass-man, guiding himself by means of his compass, paced toward the corner one mile away. At each hundred paces he stopped and gave the reading of the aneroid. He also gave the reading at the tops of hills, the bottoms of ravines, or any other points of importance. When the mile was finished the error was checked and recorded as "20 paces too far north, 16 too for east." After finishing the mile another was run parallel to it and 500 paces distant, or if the section was important for any reason, lines were run at intervals of 250 paces. All the streams, and all the ridges that had outcrops were carefully followed. All the readings taken were corrected from the barograph sheets, and a map compiled by the man who remained in camp.

All notes were kept on a basis of 2,000 paces to the mile, but no person was required to pace a mile in exactly 2,000 paces, but was directed to pace the mile with the step that was natural to him, and to give the aneroid reading at every twentieth of a mile. Smith paced the mile in 1,800 paces; he therefore gave his tally at the end of 90 paces, and 100 was entered in the notes. Trying to pace with an unnatural step proved very unsatisfactory, while correction to a basis of 2,000 was easily done in the field. In this case all that was required was to add the tens figure before entering the data in the notes. Thus if a stream were crossed at 70 paces, 77 was recorded.

I shall not attempt to give the average error in pacing for the season. It would be considerable work to make the average, and would be of little use because the sections themselves have more or less error in the original surveys. It was hoped to keep the error less than two per cent, and I do not think that it exceeded that figure.

CHAPTER II.

DATA OF SURVEYS.

The transit line:—The quarter pin between Secs. 4 and 9, T. 47 N., R. 46 W., is an iron rod driven into the road. It is about two inches square, and is in the south wheel track, directly out from the fence that runs north and south across the centre of Sec. 9. It is not covered more than an inch beneath the gravel. The north quarter pin of Sec. 4 is a round iron rod about an inch in diameter, and is near the west side of the road. The centre line of the section approaches the west side of the road as it goes north. Polaris was observed from the quarter pin between Secs. 4 and 9, T. 47 N., R. 46 W., and the true bearing between this point and the quarter pin one mile north was established. The centre pin of the section which is a round iron rod driven on the west side of the wheel road but on the east of the ditch was found to lie in line with the other two. The bearing of the line is N. 00°-07′-00″ E., that is there is an error of 7′ in the line as originally established. The transit was set up at the north quarter pin of Sec. 4 and the line carried forward from that point.

It does not seem wise to reproduce here the complete survey notes as taken in the field. In many places only short sights were possible because of the dense foliage on the overhanging bushes. But sufficient is published here to enable one to draw a complete map of the road. The station numbers are not changed, but are the same here as in the original notes taken in the field. A width of one chain is allowed for the road, and where a number of successive stations fall within that width of one chain only the first and last are given. The latitude and departure of each are given and from these is worked out the bearing from one to the other. The bearing and distance from each station marked on the map is given to the next that is marked; also, the latitude and departure of each station marked on the map. The numbers along the road on the map refer to the station numbers.

DESCRIPTION OF BENCH MARKS ALONG BLACK RIVER ROAD.

Elevation.		Position.		Description.
Above lake.	Above sea.	Lat.	Dep.	
765.30	1,367.70	....	....	Near the N. E. corner S. 3 T. 47 N. R. 46 W. The floor of a shack. Not permanent.
763.00	1,365.40	−80+00	+40+00	Top of an old stump at corner 3-4-9-10 T. 47 N. R. 46 W. Not permanent.
802.30	1,404.70	−80+00	00+00	Top of an iron quarter pin 4-9 T. 47 N. R. 46 W. Pin is about 2 inches in diameter and is in the road in front of the school house. It is in the south wheel track and directly on the line down the center of Sec. 9. Buried not more than two inches.
739.80	1,342.20	−40+00	00+00	Top of center pin S. 4 T. 47 N. R. 46 W. A round iron pin about one inch in diameter on the west side of the road and on the east side of the ditch. Not covered.
684.80	1,286.20	00+00	00+00	A square iron pin about 1.5 inch in diameter on the west side of the road and not 10 feet from the fence. Covered with about two inches of soil. This B. M. is station No. 1 of the transit line.
585.32	1,187.72	+17+50	−11+00	Notch near the bottom of a birch tree, two ft. in diameter on the east side of road just south of D., S. S. & A. track.
668.27	1,270.67	+33+50	−69+50	Elm tree 30 inches in diameter about one-fourth mile from top of hill. South side of road.
698.58	1,300.98	+171+50	−118+50	Maple 20 inches in diameter at junction of main road and six mile creek road, about 3 chains north of creek.
594.79	1,197.19	+214+00	−84+00	Maple tree on east side of road, near old log road to river.
556.61	1,163.01	+311+50	−74+00	Maple tree on east side of road at the Narrows.
540.60	1,143.00	+344+50	−93+50	Maple tree, east side of road on north bank of south branch of Eight Mile creek.
568.30	1,170.70	+354+00	−101+50	Maple tree, west side of road on north bank of north branch of Eight Mile creek.
576.73	1,179.13	+441+50	−115+00	Maple tree 20 feet west of road.
609.86	1,212.26	+504+50	−95+50	West side of road just south of Old Peak Mining Camp.
574.11	1,176.51	+640+50	−78+00	Cherry tree on east edge of road, near fill in ravine. Road bends east at this point.
560.64	1,163.04	+847+50	−13+00	Top of stump at Thomas' hunting camp.
387.20	989.60	+915+50	+24+00	Hemlock on west side of road on south bank of creek.
282.42	884.82	+966+00	+48+50	Small cherry tree 10 feet on east side of road.
171.81	774.21	+1,021+00	+60+50	Maple tree 20 inches in diameter, east of main road.
146.13	748.53	1,030+50	+63+50	Hemlock tree east of road near bridge over small ravine.

Latitude and departure are reckoned from the south quarterpost Sec. 4, T. 48 N., R. 46 W.

RECORD OF SURVEY OF BLACK RIVER ROAD.

Station.		Bearing.	Distance.		Latitude.				Departure.				Remarks.
				Total.			Total.				Total.		
					+ (N)	− (S)	+ (N)	− (S)	+ (E)	− (W)	+ (E)	− (W)	
1	4	N 30° 02′ W	15+195	15+195	13+153		13+153			7+605		7+605	Sta. No. 1 is Q. P. between 4-47-46 and 33-48-46. From Sta. No. 1 a backsight was taken on Q. P. 4-9-47-46 the bearing between the two Q. P's. having been ascertained as N. 0-07 W. by observation of Polaris. Sta. No. 4 is one chain past bridge over Coxey creek.
4	5	N 58 27 W	4+236	19+431	2+217		15+370			4+177		11+215	
5	6	N 40 34 W	5+000	24+431	3+798		19+168			3+251		14+467	
6	8	N 87 10 W	13+640	38+071	0+671		19+839			13+583		28+050	
8	9	N 67 09 W	4+520	42+591	1+755		21+595			4+165		32+216	
9	10	N 85 43 W	8+000	50+591	0+595		22+190			7+978		40+193	1+12 from No. 9 is a stream 8 feet wide flowing N. 7+00 from No. 9 is Powder Mill creek flowing N. No. 10 at edge of farm on section line between 32 and 33-48-46.
10	11	S 83 55 W	7+000	57+591		0+742	21+448			6+960		47+154	
11	12	N 76 45 W	3+565	61+156	0+838		22+285			3+557		50+711	No. 12 at top of hill.
12	15	N 62 25 W	21+031	82+187	9+730		32+015			18+619		69+330	B. M. 668.27 is 1+60 south of No. 15.
15	17	N 60 23 W	20+078	102+265	9+903		41+918			17+423		86+753	
17	23	N 53 29 W	54+346	156+611	32+336		74+254			43+664		130+417	
23	24	N 00 29 E	10+923	167+534	10+923		85+177		0+092			130+325	
24	30	N 02 38 E	66+165	233+699	66+083		151+260		3+045			127+280	
30	31	N 28 46 E	11+820	245+519	10+361		161+621		5+688			121+592	No. on section line 1+12 west of corner 19-20-29-30-48-46.
31	32	N 33 05 E	2+448	247+967	2+051		163+672		1+336			120+255	
32	34	N 15 27 E	8+209	256+176	7+783		171+455		2+150			118+106	No. 34 at junction of main road and road to Black river.
34	41	N 01 03 W	3+514	259+690	3+513		174+968			0+064		118+170	

RECORD OF SURVEY OF BLACK RIVER ROAD.—*Continued.*

Station.		Bearing.	Distance.		Latitude.				Departure.				Remarks.
				Total.			Total.				Total.		
					+ (N)	− (S)	+ (N)	− (S)	+ (E)	− (W)	+ (E)	− (W)	
41	43	N 10° 19′ E	8+520	268+210	8+374	....	183+342	....	1+525	....	....	116+645	
43	44	N 31 57 E	2+882	271+092	2+451	....	185+793	....	1+524	....	....	115+121	
44	45	N 47 12 E	3+421	274+513	2+324	....	188+118	....	2+510	....	....	112+611	
45	46	N 70 31 E	3+849	278+362	1+284	....	189+402	....	3+628	....	....	108+982	
46	48	N 42 15 E	7+988	286+350	5+896	....	195+298	....	5+358	....	....	103+625	
48	55	N 46 44 E	27+942	314+292	18+710	....	214+008	....	20+698	....	....	82+926	B. M. 594.79—20 links N. of No. 55.
55	56	N 24 27 E	3+398	317+690	3+093	....	217+101	....	1+406	....	....	81+520	
56	57	N 16 34 E	8+339	326+029	7+993	....	225+094	....	2+378	....	....	79+142	
57	58	N 08 33 E	4+744	330+773	4+691	....	229+785	....	0+705	....	....	78+437	
58	60	N 03 00 E	10+325	341+098	10+311	....	240+096	....	0+540	....	....	77+896	No. 60 top of little hill.
60	61	N 12 00 E	16+750	357+848	16+384	....	256+480	....	3+482	....	....	74+414	
61	62	N 05 04 E	6+135	363+983	6+111	....	262+591	....	0+512	....	....	73+872	B. M. 579.17 is 1+10 N. of No. 62.
62	63	N 07 08 W	8+726	372+709	8+659	....	271+250	....	....	1+084	....	74+956	
63	67	N 02 35 E	33+746	406+455	33+708	....	304+958	....	1+523	....	....	73+443	
67	68	N 01 18 W	4+997	411+452	4+996	....	309+954	....	....	0+113	....	73+646	
68	69	N 18 57 W	1+514	412+966	1+433	....	311+386	....	....	0+492	....	74+038	B. M. 556.61 is 0+50 N. of No. 69. River bank 1+00 E. The Narrows.
69	73	N 44 31 W	23+637	436+603	16+847	....	328+233	....	....	16+564	....	90+601	
73	74	N 27 35 W	1+996	438+599	1+770	....	330+003	....	....	0+923	....	91+524	
74	75	N 08 16 W	2+980	441+579	2+950	....	332+953	....	....	0+428	....	91+953	
75	76	N 02 25 W	8+554	450+133	8+515	....	341+468	....	....	0+361	....	92+313	

76	77	N 27° 06′ W	3+057	453+190	2+721	....	344+189	......	....	1+393	....	93+706	No. 77 top of N. Bank of S. branch of Eight Mile creek. Bridge 1+60 from No. 76. B. M. 540.06 is 0+80 E. of No. 77.
77	79	N 45 12 W	10+607	463+797	7+469	....	351+658	......	....	7+522	....	101+228	No. 79 top of S. bank of N. branch of Eight Mile creek.
79	80	N 33 13 W	6+215	470+012	5+199	....	356+857	......	....	3+405	....	104+633	2+65 from No. 79 bridge.
80	83	N 50 15 W	8+953	478+965	5+718	....	362+575	......	....	6+876	....	111+509	B. M. 568.30 is 2+65 N. of No. 79 and 0+60 W.
83	84	N 42 16 W	6+463	485+428	4+783	....	367+358	......	....	4+347	....	115+856	
84	85	N 18 59 W	1+433	486+861	1+355	....	368+713	......	....	0+466	....	116+322	
85	86	N 03 33 W	5+987	492+848	5+975	....	374+688	......	....	0+371	....	116+693	
86	87	N 01 32 E	2+125	494+973	2+124	....	376+812	......	0+057	....	....	116+636	
87	88	N 07 04 W	1+715	496+688	1+706	....	378+518	......	....	0+211	....	116+847	
88	89	N 20 47 W	2+839	499+527	2+654	....	381+173	......	....	1+007	....	117+855	
89	90	N 02 47 E	6+150	505+677	6+143	....	387+315	......	0+299	....	....	117+556	
90	91	N 17 53 E	4+800	510+477	4+568	....	391+883	......	1+474	....	....	116+082	
91	92	N 05 55 E	1+001	511+478	0+996	....	392+879	......	0+103	....	....	115+979	
92	93	N 00 49 W	3+632	515+110	3+632	....	396+511	......	....	0+576	....	116+036	
93	95	N 01 50 E	10+258	525+368	10+249	....	406+760	......	0+328	....	....	115+709	
95	99	N 01 20 E	16+558	541+926	16+485	....	423+255	......	0+384	....	....	115+325	
99	100	N 01 16 E	18+374	560+300	18+370	....	441+625	......	0+406	....	....	114+919	
100	103	N 13 56 E	10+953	571+253	10+621	....	452+246	......	2+633	....	....	112+286	
103	104	N 07 21 E	3+834	575+087	3+802	....	456+048	......	0+490	....	....	111+796	
104	106	N 14 14 E	12+227	587+314	11+839	....	467+887	......	3+029	....	....	108+766	
106	107	N 06 25 E	1+699	589+013	1+688	....	469+575	......	0+190	....	....	108+576	
107	109	N 13 58 E	12+578	601+591	12+204	....	481+779	......	3+041	....	....	105+536	
109	115	N 23 16 E	25+258	626+839	23+189	....	504+968	......	9+974	....	....	95+562	Old Peak Mining Camp 2+00 N. of No. 115.
115	119	N 22 35 E	25+122	651+961	23+008	....	527+976	......	9+992	....	....	85+569	
119	122	N 05 18 W	10+048	662+009	9+997	....	537+973	......	....	0+927	....	86+496	
122	123	N 00 46 E	2+164	664+173	2+164	....	540+137	......	0+029	....	....	86+525	
123	125	N 12 23 E	5+424	669+597	5+288	....	545+425	......	1+139	....	....	85+385	
125	129	N 37 33 E	9+885	679+482	7+692	....	553+117	......	5+915	....	....	79+471	

RECORD OF SURVEY OF BLACK RIVER ROAD.—*Concluded.*

Station.		Bearing.	Distance.		Latitude.				Departure.				Remarks.
				Total.			Total.				Total.		
					+ (N)	− (S)	+ (N)	−(S)	+ (E)	+ (W)	+ (E)	− (W)	
129	130	N 13° 27′ E	2+237	681+719	2+176	....	555+293	.....	0+520	....	....	78+949	No. 130 top of hill.
130	134	N 10 07 E	43+977	725+696	43+286	....	598+579	.....	7+735	....	....	71+214	Spring creek 6+00 N. of No. 130.
134	135	N 02 15 E	3+880	729+576	3+877	....	602+456	.....	0+152	....	....	71+062	
135	136	N 03 30 W	10+785	740+361	10+765	....	613+221	.....	....	0+658	....	71+720	
136	140	N 20 50 W	16+108	756+469	14+902	....	628+123	.....	....	5+674	....	77+394	
140	142	N 06 31 W	10+280	766+749	10+184	....	638+307	.....	....	1+165	....	78+559	
142	143	N 08 44 E	1+890	768+639	1+870	....	640+177	.....	0+287	....	....	78+272	
143	165	N 52 11 E	93+221	861+860	57+081	....	697+258	.....	73+526	....	....	4+745	78+73 from No. 143 Thomas' hunting camp.
165	176	N 31 36 E	36+508	898+368	31+439	....	728+697	.....	19+974	....	15+229		
176	181	N 28 29 E	29+655	928+023	25+448	....	754+145	.....	14+005	....	29+234		
181	186	N 37 07 E	30+001	958+024	23+870	....	778+015	.....	18+065	....	47+993		
186	189	N 21 06 E	16+497	974+521	15+254	....	793+269	.....	5+885	....	53+184		
190	195	N 18 43 E	25+183	999+704	23+264	....	816+535	.....	7+868	....	61+052		
195	198	N 09 20 W	7+837	100+541	7+658	....	824+191	.....	....	1+258	59+794		
198	201	N 11 24 E	7+383	1,014+924	6+111	....	831+302	.....	1+233	....	61+027		
201	204	N 09 49 E	15+719	1,030+643	15+086	....	846+389	.....	2+610	....	63+637		
204	206	N 07 47 W	10+677	1,041+320	10+499	....	856+881	.....	....	1+433	62+205		
206	210	N 08 59 E	18+659	1,059+979	18+436	....	875+317	.....	2+529	....	64+733		
210	211	N 37 19 E	4+317	1,064+296	3+433	....	878+751	.....	2+617	....	67+350		
211	212	N 03 00 E	3+450	1,067+746	3+445	....	882+196	.....	0+181	....	67+531		

The Leveling.

The road was leveled in three parts, and each part closed as a separate survey. The first extends from the quarter pin at the south end of the transit line, and extends to just north of Six Mile Creek, where there is a road going east from the main road to the river. The bench mark on which we closed this course is at the junction of the two roads. The second part of the leveling extends from the same bench mark to the north side of the north branch of Eight Mile Creek. The third part extends to the lake. As several bench marks were read on, both in going and coming, any error made was known to be within very small limits. Another line was run with the water level from the north quarter pin Sec. 4, T. 47 N., R. 46 W. south one mile along the road across the centre of Sec. 4, then east one-half mile between Secs. 4 and 9, then S. W. across Sec. 3 to the S. W. corner of the section where one of our camps was located. This line was not closed.

An initial bench mark was taken near Six Mile Creek, at our first camp, and an elevation above Lake Superior assumed for it. The elevation of the lake on the day that we reached it with the line of levels was ascertained from the government office at Houghton, so that all the elevations taken during the summer were easily reduced to sea level.

The bench marks have their elevations recorded above Lake Superior, but the contour lines on the map are above sea level.

All the bench marks were originally numbered, but in this report the bench marks are known simply by their elevation above Lake Superior.

The elevation of the lake on the day that we reached it was 602.40 feet above sea level.[1]

The total closing error of the leveling of the whole road was 0.47 feet.

Above (p. 414) is given a record of the bench marks established.

Below are printed some facts that may prove of interest to those living in Bessemer and vicinity, or they may prove, not only of interest, but of value to those who have work to do in the district.

From the Court House to North Bessemer is 2.40 miles, to the top of the hill beyond the D. S. S. & A. Ry. is 2.80 miles, to where the road changes from a westerly direction to north 4.00 miles, to Six Mile Creek 5.25 miles, to the Narrows 7.40 miles, to the south branch of Eight Mile Creek 7.75 miles, to the north branch 8.00 miles, to Old Peak mining camp 10.00 miles, to Thomas' hunting camp 12.70 miles, and to the mouth of Black River 15.50 miles. When the road passes North Bessemer it turns well west. At the end of this westerly part of the road one is 2.13 miles west of Bessemer and 2.55 miles north. There is no other point in the road so far west as this point. Old Peak mining camp is 1.75 miles farther west than the Court House. Thomas' hunting camp is about a mile farther east than Old Peak mining camp, and about 0.75 farther west than the Court House. The mouth of Black River is almost due north of the Chicago and Northwestern depot in Bessemer, and 12.75 miles from it in a straight line.

The "lake hill," (Fig. 21) the top of the terrace near the lake, is just 100 feet above Lake Superior. The hill south of the D. S. S. & A. Ry. at

[1] Portage Lake gauge.

North Bessemer is 99.5 feet and that on the other side 97 feet. The iron pin in front of the little schoolhouse one mile from Bessemer is 802 feet above the lake, and the same little schoolhouse is farther above the top of North Bessemer hill than the top of the hill is above the rail-

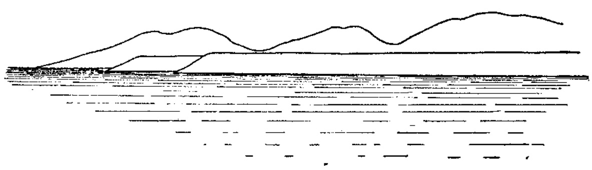
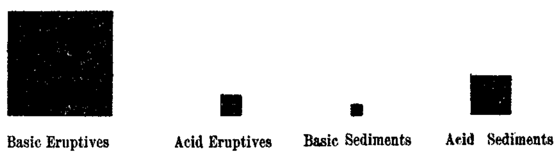


Fig. 21.—The Porcupine Mountains from the mouth of Black River. The "lake hill," or terrace 702 A. T. is well shown. There is also a suggestion of the pene-plain, though the highest parts of the Porcupine Mountains rise as "monadnocks" slightly above it.

road track by about fifteen feet. The highest point on the bare hills west of Bessemer is 1,720 feet above the lake, and the highest point on the hills to the east 1,800 feet.[1] Chippewa Hill is 1,520, and the Conglomerate Ridge to the north 1,460, while the one to the east across the river is 1,480 feet.

Fig. 22.



Relative proportion of the kinds of rock exposed in the Black River cross section of the Keweenawan Series.

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[1] In Upper Michigan there are a large number of accordant hill tops at an elevation of just a little less than 1,800 feet, which may therefore be a pene-plain. L.

CHAPTER III.

STRATIGRAPHY AND GEOLOGIC COLUMN.

The Keweenawan rocks, as displayed in Black River, are made up of Irving's two divisions, the Upper and the Lower. The contact is seen in the N. E. ¼ of the N. E. ¼, Sec. 21, T. 49 N., R. 46 W.

The Upper Keweenawan is made up wholly of sedimentary rocks, as, indeed, would be necessary from Irving's basis of division because he makes the base of the horizon that point, "which is above any known occurence of eruptive matter." In the Black River section it is made up of two formations, the Nonesuch formation (II) and the Outer Conglomerate (III), the "main body of sandstone" (I) not appearing on Black River. The Nonesuch is basic and the Conglomerate acid. The former is about 500 feet thick, and the latter about 5,000, making a total thickness of about 5,500 feet for the Upper Keweenawan on Black River.

The Lower Keweenawan is made up of mixed sedimentaries and eruptives, the latter predominating and always increasing in proportion to the whole as the base is approached. For the sake of convenience the Lower Keweenawan is in this report divided as follows:

IV	Lake Shore Trap	500	feet
V	Conglomerate	350	
VI	Mixed eruptives and sedimentaries	5,500	
VII	Felsite	450	
VIII	Eruptives with very few sedimentaries	26,000	
IX	Mixed eruptives among which are conspicuous labradorite porphyrites	4,800	
X	Gabbro	200	
XI	Melaphyres and labradorite porphyrites that are not conspicuous	4,500	
XII	Basal sandstone	300	
	Total Lower Keweenawan	42,500	feet
	Upper Keweenawan	5,500	feet
	Lower Keweenawan	42,500	
	Total Keweenawan	48,000	feet

The stratigraphy will be considered in this report under the headings briefly outlined above.

Division I. Sandstone.

(1.) Sandstone:—The geologically highest rock noted in the work of the season was a sandstone. This sandstone does not outcrop in the Black River section proper, but is exposed on the shore of Lake Superior about five miles west. It is what Irving spoke of as "the main body of sandstone." There was practically no work done on it, so no extensive report concerning it can be made here. The chief reason for trying to locate it was so that the upper contact of the underlying Nonesuch would be known. The outcrop of this sandstone on the lake shore is just about where the line between Secs. 14 and 15, T. 49 N., R. 47 W., comes down to the shore. The outcrop was located by pacing from the line between Rs. 46 and 47 W., and so required the pacing of a distance of two miles along a gravel beach where the walking was not easy, hence there may be some error in placing the outcrop on the map. But if we allow for a very large east or west error, which would be the error of pacing, there can be no very great error either north or south in the placing of the contact between the sandstone and the underlying Nonesuch, because the direction of the shore is nearly the same as the strike of the formation, which is about N. 80° E. However, near the sandstone the strike becomes N. 70° E., and by following westward after the sandstone is reached it is seen that the formation turns inland toward the west. At the same time the dip increases, which is to be expected, since Irving has reported that at the Montreal River, which is about thirteen miles west, the sandstone stands nearly vertical.

Just where the sandstone appears on the east side of Black River, or whether it appears at all, cannot be said, as there are clay banks for some distance along the shore, and no outcrops of any kind.

Sp. 20130: From the shore of Lake Superior where the line between Secs. 14 and 15, T. 47 N., R. 47 W. reaches the shore.

Sandstone:

Macroscopic: The specimen has a brownish gray color, and a uniform texture. It is made up of water worn particles, mostly well rounded, but some are quite angular. The particles are of all diameters up to 1mm. The most abundant constituent is quartz, although others, such as felsite, and fragments of feldspar, are also present in considerable quantity. There are also black particles whose nature cannot be told with the aid of the hand lens only. The matrix is composed of calcite, which is present in such quantity as to give a tinge of gray to the rock. When the rock is broken across calcite faces as much as an inch in diameter are seen, and in this secondary "poikilitic" calcite the sedimentary particles are imbedded. The specimen effervesces freely with acid. The coloring caused by the iron oxide makes it difficult to tell the nature of the particles.

The hand specimen shows no sedimentary planes, and no tendency to cleave, but the rock as a mass shows the sedimentary planes distinctly. There are layers of red shale in the rock varying from a trace up to an inch. It cannot be said that this shale does not become even more important, because no extensive work was done to discover whether it does or not.

Microscopic: The particles are well rounded, and none will exceed 1 mm. in diameter. The most abundant is quartz, many grains of which are quite angular. There are also some felsite particles. Striated feldspar is abundant, far beyond what would be expected from an examination of the hand specimen. There is an occasional fragment of microcline. Ophite fragments are quite common, but in no case is the augite so well preserved that it could be identified in the thin section, but the lath shaped feldspars imbedded in the decomposed ground mass leave no doubt as to the origin. The whole is heavily charged with iron oxide, so that the thin section appears a marked red even to the unaided eye. Calcite is not nearly so abundant in the thin section as would be expected from an examination of the hand specimen, while the basic material is much more abundant.

Division II. The Nonesuch Formation.

(2.) Nonesuch:—Lying beneath the sandstone just described is the Nonesuch formation. It is the one formation that we are able to positively identify in an isolated cross-section, although there are others that may be named with only a small probability of error. With the identification of the Nonesuch we are able to correlate the cross-section with a greater degree of certainty than we otherwise could. There can be no doubt about this formation being the Nonesuch.

The formation is exposed at the mouth of Black River, and also several places westward along the shore. Near the mouth of the river it is exposed on the south side, at the point where the traverse line reaches the water. In fact, the traverse line ends at the point of contact between the Nonesuch and the underlying sandstone. There is a little spring creek which empties into Black River about two hundred yards from the lake shore, and at the mouth of this creek is where the survey line was ended. On the right side of the creek is a sandstone while on the left is a wall of shale about ten feet high.[1] The shale does not appear east of this point on the south side of the river, but is continuous westward nearly to the lake shore, which is distant about two hundred yards. The shale appears on the north side of the river also for a short distance in a low outcrop almost covered by the water. The outcrops on either side of the river disappear before the lake shore is reached because of the beach material gathered at the mouth of the river. Westward from the mouth of the river there is a red clay bank for a short distance along the shore, beyond which is a wooded bank. All along the foot of this bank is a beach. Near the west side of Sec. 9, T. 49 N., R. 46 W., are some low reefs of Nonesuch shale about one hundred yards from the shore. Just west of the line, between Secs. 8 and 9, there is an outcrop of shale on the shore, but it does not continue far because the formation is cut completely through, and the underlying sandstone is exposed across the front of nearly the whole of Secs. 8 and 7, the Nonesuch appearing again just before Maple Creek is reached, which is at the line between Rs. 46 and 47 W. About 100 paces up Maple Creek the lower contact of the formation is exposed. Beyond Maple Creek the Nonesuch forms the shore line for a distance of about two miles, beyond which is "the main body of sandstone." It would scarcely be expected that the formation would appear on the lake shore west of this point as it seems to turn well inland leaving the lake to the north.

All the outcrops along the shore, whether sandstone or shale, are low, scarcely reaching above the gravel of the beach, or the surface of the water. The sandstone is more prominent than the shale, but all are so low as to be washed completely over by the waves. Reefs of Nonesuch are quite common all along the shore, and generally lie out in the water from 50 to 100 paces, and just come to the surface of the water. It is surprising how a rock so easily cleaved can resist the ice action of the lake, but it is, no doubt, due largely to the fact that the rocks dip lakeward at a low angle, thus giving the inward pressing ice an easy plane to slide over. The outward pressure can never be great so near the shore.

East of the mouth of Black River there are no outcrops because of the clay banks along the shore, and, at any rate, the strike and width of the formation are such that the rock would scarcely be at the lake shore, but would fall south of it, except, possibly, for a short distance at the mouth of the river.

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[1] Specimens at this point show a little copper carbonate.

The lower contact of the Nonesuch is well exposed near the mouth of Black River, on the lake shore just west of the west line of Sec. 9, T. 49 N., R. 46 W., and also about 100 paces up from the mouth of Maple creek. The upper contact is not exposed at the mouth of Black River, nor is any rock above the Nonesuch exposed there. The only exposure of the upper contact is, as stated before, about two miles west of the line between Rs. 46 and 47 W. There may be some error in locating this contact, but, at any rate, it is certain that the Nonesuch is not thick in the Black River section.

There is an exposed surface width of 1,300 feet. The strike is N. 73° E., and the dip 25° N. There is no evidence that any allowance in width is to be made because of faulting, although indications are that the whole district is a much faulted one. Whatever faults there may be are not shown by this stratum. A surface width of 1,300 feet. and a dip of 25° gives a thickness of 550 feet for the Nonesuch in the Black River cross-section.

There are in this formation two kinds of rock, to be known as the Nonesuch shale and the Nonesuch sandstone. They are both rather dark colored, owing to the fact that they are made up largely of basic material. There does not seem to be any regularity of occurrence of either the shale or the sandstone in the formation, the whole being made up of an indiscriminate mixture of both, although the shale is present in greater quantity than the sandstone. Sometimes the sandstone phase becomes a conglomerate, having pebbles as much as two inches in diameter.

Stains of copper carbonate may sometimes be noticed.

The following descriptions of specimens will serve to give an idea of the nature of the rocks exposed.

Sp. 20119. From the bed of Maple Creek, about 100 paces from the mouth, near the lower contact of the Nonesuch.

Nonesuch Shale.

Macroscopic: Dark gray color; fine grained, and massive in the hand specimen, although the rock mass cleaves readily along the sedimentary planes. Except for this cleavage the rock breaks with a conchoidal fracture. The specimen is soft, being easily scratched with a knife. There is no signs of a development of a slaty cleavage. On the broken surface are small shining particles that look like mica, and this is common to all of the specimens of Nonesuch shale that were examined. The specimen is too fine grained to allow of any of the particles of which it is composed being identified under the hand lens. The rock does not effervesce with acid.

Microscopic: The rock is fragmental but is fine grained; the largest fragments will not exceed 0.1 mm. and these make up only a small portion of the whole, the mass being much finer. Striated feldspar can be easily distinguished. Calcite is developed in small quantity. The fragments are angular and closely packed together.

Sp. 20120. From the bed of Maple Creek.

Sandstone:

Macroscopic: The specimen has a dark gray color. It is somewhat coarser grained than 20119, and represents a phase between the Nonesuch shale and the Nonesuch sandstone. It cleaves readily along the sedimentary planes. It is made up of rounded grains. The cleavage faces of feldspar, and some quartz can be seen. Secondary calcite is developed, and the rock effervesces freely with acid.

Sp. 20026. From the north end of the traverse line, near the mouth of Black River.

Nonesuch shale:

Macroscopic: Dark gray color; very fine grained; easily scratched with a knife; cleaves readily.

Sp. 20110. From near the mouth of Black River.

Nonesuch shale:

Macroscopic: Red color; very fine grained; cleaves readily along the sedimentary planes; mineral constituents cannot be told under the hand lens. This specimen differs from the other specimens of Nonesuch shale in that it has a red color.

Sp. 20113. From near the mouth of Black River.

Nonesuch sandstone:

Macroscopic: This specimen represents typically the Nonesuch sandstone. It has a dark gray color with a tinge of green. It is made up of rounded fragments about one-half mm. in diameter. Feldspar and quartz are readily distinguished; while quartz is uniformly scattered through the whole it is not one of the important minerals. There are also many dark colored grains whose nature cannot be told under the hand lens, but they seem to be basic. Calcite is developed more strongly than in any of the other specimens from this formation save Sp. 20120. No doubt, the marked development of calcite in this specimen is due to its porous nature.

One of the important things to be noticed in the Nonesuch formation is the amount of basic material, although acid material is by no means wanting. In no other sedimentary rocks of the Black River cross section does the basic become so prominent, and in most cases it is unimportant as compared with the great amount of acid material.

Division III. The Outer Conglomerate.

(3.) Sandstone and conglomerate:—Underlying the Nonesuch is a conglomerate, or, at least, a sedimentary formation whose top is a sandstone, and whose base is a conglomerate. It is that which Irving spoke of as the "Outer Conglomerate."

This formation is exposed along the shore of Lake Superior nearly all the way across Secs. 7 and 8, T. 49 N., R. 46 W., where the Nonesuch is cut through as described above. The exposures at this point are red sandstone. There are also exposures in the bed of Maple Creek, and the change from sandstone to conglomerate may be traced. About 100 paces up from the mouth of the creek is the upper contact. In the S. W. ¼, Sec. 18, T. 49 N., R. 46 W., Maple Creek has a low overhanging cliff of conglomerate and in the same quarter section there are falls over conglomerate. The chief exposures, however, are in Black River, where there is practically a continuous outcrop all across the formation from the lower to the upper contact. Near the mouth of the river the upper contact is exposed. At that point the river flows nearly west. Following up stream for about an eighth of a mile there is a bend in the river, and above this bend the water flows across the formation nearly at right angles. The exposures are almost continuous to where the base of the formation is seen in the N. E. ¼ of the N. E. ¼, Sec. 21, T. 49 N., R. 46 W. Besides the exposures spoken of above there are various others in Secs. 16, 17 and 18 of the same town and range, on Conglomerate Ridge, and some in the bed of a small creek that flows parallel with Black River, and about a quarter of a mile west in Secs. 10 and 15, but none of these last exposures add any information beyond what is already known from the other exposures.

The upper contact is exposed in the bed of Maple Creek, along the lake shore, and also at the mouth of Black River. The lower contact is exposed in the N. E. ¼ of the N. E. ¼, Sec. 21, T. 49 N., R. 46 W., but in no other place in the area worked. The dip at the upper contact is about 25° N., and that at the base 30° N. If we allow an average dip of 27° the 11,000 feet of surface that we have gives a thickness of 5,000 feet for the Outer Conglomerate.

This formation is not a conglomerate throughout, for in its upper measures it is mainly sandstone, while at the base it is a conglomerate, yet there is a great deal more conglomerate than there is sandstone so the name is a suitable one.

Descending through the formation we get in succession sandstone, sandstone with conglomerate phases, mixed sandstone and conglomerate, conglomerate with sandstone phases, and pure conglomerate. The change from sandstone above to coarse conglomerate below is a gradual one, and there is no sharp dividing line, but in a general way, it may be said that the upper one quarter is sandstone, and the remaining three-quarters is conglomerate.

The sandstone is exposed along the shore of the lake, in Maple Creek, and in Black River from the first falls (center of Sec. 10, T. 49 N., R. 46 W.) to the mouth. It is generally brick red in color, but there are places where it is reddish brown, and even brown. Throughout are bands of white varying in thickness from a quarter of an inch to a quarter of a foot. Besides these bands there are numerous spots of white varying in size from those not larger than a pin head up to those several feet in diameter. The coloring matter of the rock is iron oxide, but whether the white strata were always white is hard to say. It is possible, and even probable, that they were originally red and lost their coloring matter because of water action. There can be no doubt about the white spots spoken of being due to water action. On a plane surface the spots are round, but when the rock is broken in various directions they are seen to be spherical. The shape suggests weathering from a central point. Where the white is seen to be certainly the result of water action is at the lake shore where the waves have washed over the rocks and the water has found its way back through the cracks and crevices. In such cases the coloring matter is leached out back from the cracks for several inches. In some cases it seems that the leaching goes on fairly rapidly.

Below the falls the river has succeeded in cutting down into the sandstone so that, except for some rapids near the foot of the falls, the last three-quarters of a mile of river is at lake level. From the falls near the center of section 10, to where the river turns west, which is a distance of nearly a half mile, the rock stands in more or less perpendicular walls along the edge of the river. The sandstone in these walls cleaves readily, and in many places splits into layers not more than a quarter of an inch thick. In fact, it cleaves so readily that it looks like red shale when viewed from a short distance. The sandstone along the lake shore also shows a tendency to cleave but not equal to that shown by the sandstone in the river. However, all the sandstone of this formation exposed in the area worked shows so great a tendency to cleave that it is wholly unfit for building purposes.

The following descriptions of specimens will give some idea of the nature of the sandstone that makes up the upper part of the formation:

Sp. 20111. Forty paces S. W. from the north end of the traverse line, Sec. 3, T. 49 N., R. 46 W. Sandstone:
Macroscopic: Much more compact than the typical sandstone of this formation. The particles are mostly quartz of a glassy appearance and well rounded; an occasional cleavage face of feldspar can be distinguished; there is some basic material, but the amount is small. The specimen is hard, and not easily scratched with a knife. It is not at all porous. Some secondary calcite is developed causing rather free action with acid, indeed, far more than would be expected from an examination of the hand specimen. It has a fairly high specific gravity for a specimen from this formation. It must be said that the weight, and the compact texture of this specimen are not typical.

Sp. 20116. On the line between Secs. 3 and 10, T. 49 N., R. 46 W. Sandstone:
Macroscopic: Brick red in color; porosity about that of an average sandstone; particles from one-fourth to one-half mm. in diameter and are almost wholly of quartz. There is no action with acid. The rock absorbs water quite freely, much more so than the specimen described above.

Sp. 20117. Taken from near the last specimen described. Sandstone.
Macroscopic: Grayish white color; porous texture, absorbing water freely. It has a little coarser grain than either of the two specimens described above. The particles are nearly all quartz, and are all well rounded. Although the rock specimen is very light colored, a close examination under the hand lens shows many grains of red color, some green, and some black, but in no case is the coloring intense. This specimen is from one of the white layers so common in the red rock and was taken as a typical specimen of such.

Sp. 20118. From the lake shore, Sec. 8, T. 49 N., R. 46 W.

Sandstone:
Macroscopic: This specimen was taken because it shows well the white spots that are developed in the sandstone. It is of a reddish brown color and has a compact texture. The particles, which are well rounded, are almost wholly quartz. The coloring matter makes it hard to tell the nature of the grains, but where the coloring is wanting, as in the white spots, their nature is easily distinguished.

Gradually the sandstone phase of the formation gives way to the conglomerate phase, not by becoming coarser and coarser, but by an increasing prevalence and width of conglomerate bands. However, within that portion of the formation that is a true conglomerate the material becomes coarser and coarser, increasing from pebbles which will in no case exceed three inches, such as those at the first falls, up to boulders more than a foot in diameter at the base of the formation.

The geologically highest band of conglomerate lies beneath the Nonesuch formation not more than fifty feet and is not more than ten feet thick. It is persistent in the Black River section, being exposed at the mouth of the river and at the mouth of Maple Creek. The pebbles in it are not large, for only exceptionally do they exceed two inches. They are of all kinds, like the pebbles of the other conglomerate phases of the formation, but there is in addition a larger number of iron ore and jaspilite pebbles of the Huronian than elsewhere.

Lying between this narrow band of conglomerate and the main portion of the conglomerate which will now be described, is the sandstone which has just been described. All are of one formation and it is merely for convenience of description that it is considered here under the heads of "sandstone" and "conglomerate."

In the conglomerate portion is every phase of material, from pebbles only a fraction of an inch up to boulders more than a foot in diameter. Thin bands of sandstone occur indiscriminately throughout the conglomerate. It was impossible to trace the bands any great distance for there was no extent of exposure along the strike of the formation. Scarcely any of these layers of sandstone would exceed twenty feet in thickness, all sizes from this down to only a few inches being present. The smaller ones generally end quickly, thinning out in both directions somewhat like a lens, and it is highly probable that the larger ones did the same, and, in fact, it is pretty well proven that they did, for in some cases that portion exposed was the end, and the same manner of thinning out and ending was seen. It seems certain that even the thickest bands of sandstone in the conglomerate phase do not continue far. Such sandstone bands are less frequent in the lower measures of the conglomerate than in the higher.

All the pebbles are water-worn and rounded. Angular fragments are difficult to find. One cannot look at the formation and doubt that the material has been subjected to water action. In some places in the river, during low water, the bed, viewed from a short distance, looks as though strewn with boulders brought down by the present river, but on approaching closer it is readily seen that the boulders are all closely cemented together, forming one solid mass. (Plate XXXV.)

There is a very great variety of pebbles such as melaphyre, ophite, jasper, labradorite porphyrite, granite, syenite, amygdaloid, trap, chert, graywacke, and quartzite, but all these are few in number compared with the great mass of felsite pebbles. The total of all the others forms only a small per cent compared with the quantity of felsite.

The conglomerate may be well described as a felsite conglomerate in which other pebbles are present, and to merely say that they are present is putting the statement strongly enough.

Below is given a description of some of the pebbles found in the conglomerate.

1. Felsite: Reddish chocolate brown color. Very fine grained ground mass with phenocrysts of glassy quartz and orthoclase, the former being the more numerous. Some of the phenocrysts are nearly two and a half millimeters, but the majority will not exceed one millimeter. The pebble is fresh in appearance showing little or no weathering. It is water worn.

This felsite pebble resembles to a small extent the felsite of Chippewa Hill.

2. Felsite: A well rounded pebble with a dull chocolate brown color. It has a fine grained ground mass in which are numerous crystals of quartz about 1 mm. in diameter, and of nearly a uniform size. The rock shows flow structure quite distinctly. There is considerable weathering, resulting in calcite being developed in the rock, as is shown by the effervescence with acid, chiefly along the flow lines.

3. Felsite: Chocolate brown color. The rock has a fine grained ground mass thickly filled with phenocrysts of orthoclase and quartz, the former being more plentiful than the latter. The crystals of feldspar vary in size from 2 to 4 mm., and those of quartz from 1 to 2 mm. There is some calcite developed but nevertheless, the specimen has a rather fresh and unweathered appearance. In some places calcite is as distinctly bounded as the phenocrysts.

This felsite does not resemble any felsite found in place, the chief difference being the numerous phenocrysts in the pebble.

4. Felsite: Reddish brown color. The pebble has a fine grained ground mass in which there are numerous crystals of orthoclase feldspar from 1 to 2 mm., and few crystals of quartz. The ground mass has an acid appearance, but not so distinctly so as some of the other pebbles.

5. Felsite: A fine grained rock with a chocolate colored ground mass containing a number of phenocrysts of feldspar and a smaller number of quartz. The feldspar is without striæ. The rock breaks with an angular fracture.

This pebble strongly resembles the felsite of Chippewa Hill Sec. 32, T. 49 N., R. 46 W.

The felsites described above are all different in character, although the difference is only slight. Still others might be described but it seems useless to add them. Some have feldspar crystals and none of quartz, others have quartz and no feldspar, while some have both. Some have numerous crystals and some have almost none. In some of the pebbles the ground mass is distinctly acid in appearance, while in some it is more basic. But these differences are nothing more than is to be expected by one who has studied the acid flows lower down in the Keweenawan series, both because the flows differ one from another, and even within the same flow specimens can easily be obtained which differ much among themselves.

6. Felsite Porphyrite: A chocolate colored rock with a fine grained ground mass containing phenocrysts of striated feldspar. The phenocrysts are from 2 to 3 mm. The rock has a slightly more basic look than the felsites described above, but there can be no doubt about it being strongly acid.

7. Felsite Porphyrite: A reddish brown rock with a porphyritic texture.) It has crystals of striated feldspar from 2 to 3 mm. long, in a fine grained ground mass. The pebble shows some weathering and effervesces in some places with acid.

Other felsite porphyrites varying somewhat from those described are readily found but it seems to serve no purpose to add a long list of descriptions here. None of these could be identified as belonging positively to any of the lower eruptive strata of the Keweenawan but at the same time it must be remembered that there are strata of felsite porphyrite from which it is possible that they could have been derived.

8. Amygdaloid: This pebble has numerous amygdules of calcite and chlorite. It is typical of Keweenawan amygdaloids, and there cannot be the least doubt of its origin. It is certainly from near the top of a basic melaphyre flow.

9. Amygdaloid: This pebble is not so amygdaloidal as number eight but its origin is no more doubtful. It is evidently from not so near the top of the flow. There are amygdules of quartz, epidote and calcite. The ground mass is rather brown in color and contains hairlike crystals of feldspar.

10. Melaphyre: This pebble is like the two described immediately above except that it represents the massive centre of a flow rather than the amygdaloidal top. It is somewhat weathered, chlorite being developed. The whole is fine grained and none of the individual minerals and crystals can be told with the naked eye.

11. Melaphyre: Like the one described above it is a specimen of trap rock, and comes from the centre of a flow.

The above four specimens which could be readily duplicated show that the basic pebbles are at least present in the conglomerate, both the amygdaloidal tops and the massive centres being represented. To be sure they are a very small factor in building up the great mass of conglomerate, but they are present and may always be found by a little searching.

12. Labradorite porphyrite: A porphyritic rock of brownish color. There are phenocrysts of plagicolase feldspar 5 to 10 mm. long. The ground mass contains also smaller phenocrysts 1 to 2 mm.

13. Labradorite porphyrite: Dark grayish brown rock with a porphyritic texture. There is a fine grained ground mass in which are crystals of plagioclase feldspar 5 to 8 mm. long. and also some smaller hair like crystals.

14. Labradorite porphyrite: A brown colored rock with a fine grained ground mass in which there are some small hairlike crystals and some larger crystals of plagioclase. The larger crystals are from 5 to 8 mm. long and about 1 mm. across. The other surface of the crystals just described is disk shaped, or nearly so, the real shape of the phenocryst being nearly a disk 8 mm. across and about 1 mm. thick. These crystals are nearly all oriented in the same way and are collected together in starlike aggregations. The specimen shows one pipe amygdule the filling of which is calcite and agate.

The source of this specimen cannot be positively stated yet when one has seen it and also seen some of the labradorite porphyrite flows near the base of the Keweenawan there can be little if indeed, any, doubt of its origin.

15. Labradorite porphyrite: A reddish brown colored specimen with disk shaped crystals like the pebble described immediately above. The disks are as much as 20 mm. across and 2 thick. The crystals are not in star shaped aggregations. Besides these larger ones there are also smaller ones, evidently of another generation. The specimen is somewhat weathered and chlorite is developed.

Several labradorite porphyrite pebbles have been described, not because of the quantitative importance of this variety of rock in the conglomerate, but to show that there is a variety in this kind of pebbles just as there is a variety in kinds of labradorite porphyrite flows that appear near the base of the series. The quantity of these pebbles is not at all important in the conglomerate, for they are found only with difficulty.

16. Graywacke.
17. A light colored chert.
18. Jasper: Red colored, hard, and faintly banded.
19. Quartzite: Brownish colored and vitreous.
20. Augite syenite: Reddish colored, holocrystalline. Crystals 2½ to 3 mm. in diameter. The chief mineral is orthoclase, and the only remaining one easily identified is augite.
21. Augite Syenite: Much like the one described immediately above, but has much finer grain.
22. Granite: Composed of orthoclase feldspar, augite and quartz. Crystals are from 2 to 3 mm.

The kinds of pebbles present in the conglomerate make it certain that material was received from the basement complex, from the Iron Formation, and also from the older parts of the Keweenawan itself. The great mass of material is felsite, and the only known source from which this could come is from the Keweenawan, which has in it several acid flows.

The formation just described can scarcely be any other than the "Outer Conglomerate" of Irving. Above it is the Nonesuch, and below it a series of amygdaloidal flows which correspond well with the "Lake Shore Trap." Above the base of this conglomerate there is only sedimentary material, while immediately below begin the interstratified eruptives and sedimentaries. Here, then, is the base of the Upper Keweenawan, which is made up (remembering, of course, that the "main body of sandstone" does not appear in the Black River cross-section) of Nonesuch 550, and Outer Conglomerate 5,000 feet, making a total of 5,500 feet. This thickness of rock, because of its low dip, represents 12,000 feet of surface width.

Division IV. The Lake Shore Trap.

The Lake Shore Trap:—Lying beneath the Outer Conglomerate, and in conformable contact with it is a formation made up of a series of flows of eruptive rocks. These mark the highest eruptive matter in the Keweenawan series, and there seems to be no doubt but that the formation is Irving's "Lake Shore Trap" and as such it is considered here. There are no exposures of this series of flows save in the bed of Black River near the east side of Sec. 21, T. 49 N., R. 46 W. The northern exposures of the series are in the river bottom and are covered with water save in the dry season. The river bed is nearly 150 feet wide and is almost a level floor of rock, but some places are lower than others, and such low places are covered with water and sand moved down by the river. Toward the south end of the exposures of this series of flows the river goes through a gorge on either side of which are rock walls from thirty to forty feet high. The water coming over the falls caused by the conglomerate beneath the trap enters this gorge immediately. The gorge is from 100 feet to 200 feet long.

The Lake Shore Trap as exposed in Black River has a surface width of about 800 feet. The dip is about 30° N., so that the thickness of rock is about 400 feet. Both the upper and the lower contacts are well exposed in the river bed. Above the trap is the Outer Conglomerate while below it is another very similar in appearance.

The Lake Shore Trap is made up of five flows here named in order from the top downward.

a. (4). 35 feet.
b. (5). 35 feet.
c. (6). 115 feet.
d. (7). 85 feet.
e. (8). 130 feet.
Total 400 feet.

i. (4). This is the youngest flow of the Lake Shore Trap, and is the highest exposure of eruptive rock in the Black River section, and, in fact, in the whole Keweenawan series. It is exposed in the N. E. ¼ of Sec. 21, T. 49 N., R. 46 W., in the bed of the river, and in no other place so far as seen in the work of the season. These outcrops are covered with water save in the dry season, and even then much is seen under a thin sheet of running water.

The upper contact of the flow may be seen, a conglomerate lying above. The lower is also exposed. The surface width is not great, only 70 feet, and since there is a dip of about 30° N., the thickness is about 35 feet.

It is a melaphyre flow with a marked amygdaloidal top of about 12 feet, below which is a more massive portion, but in one or two places there are thin bands of amygdaloid below the surface amygdaloid. The amygdules are of calcite, chlorite, and laumontite.

Sp's. 20015, 20014, 20017 and 20016 are taken in geologically descending order from the flow in the order in which they are named. All the specimens need not be described in detail, but some points in connection with the four considered together should be noted. Descending there is an increase in the size of the grain and a decrease in the amygdules, both in the size and in the number, but more particularly in the number. Calcite is present in quantity, being the main filling in all the amygdules, while laumontite is more plentiful in the more vesicular specimens than in the less vesicular, and chlorite is more abundant in the latter than in the former.

S. 20014. N. E. ¼, Sec. 21, T. 49 N., R. 46 W. Bed of Black River. Top flow Lake Shore Trap.

Melaphyre:

Macroscopic: Dark brownish gray; strongly amygdaloidal; so fine grained that the component minerals cannot be told by means of the hand lens; its weight and general appearance leave no doubt about it being strongly basic. The amygdules are of average size except for a few larger ones. They are of fairly regular shape but some have changed because of weathering. The fillings are nearly all pure white calcite, the only other mineral noted being chlorite of which there is a little on the cavity walls. One side of the specimen was exposed to the action of the weather and the river water with the result that the fillings are removed completely from the cavities.

S. 20017. N. E. ¼ Sec. 21, T. 49 N., R. 46 W. Bed of Black River. Top flow of the Lake Shore Trap, but a little lower down than the specimen described immediately above.

Melaphyre:

Macroscopic: Grayish brown; very fine grained but hairlike crystals of plagioclase feldspar can be distinguished in the ground mass. It is apparently more amygdaloidal than the specimen described above, but a close examination shows that the appearance is the result of an increase in the size of the cavities as a result of weathering. Some of them have weathered so much that they quite lack any regular shape. The main cavity filling is white calcite, but there is also some chlorite which almost invariably surrounds the calcite.

Microscopic: Amygdaloidal, with amygdule fillings of calcite and chlorite surrounding it. The finer grained amygdule wall is in most cases weathered through, but there is a portion left here and there. Calcite is developed in the ground mass of the rock, and as in the cavities is surrounded by chlorite. The slide is highly feldspathic, small crystals of plagioclase being packed together. As they are much weathered it is difficult to tell the variety but the extinction though only vaguely determined is such as to leave no doubt that the feldspar is basic. Olivine was originally present in quantity, but is now weathered to serpentine which in this section is a deep reddish brown and almost opaque owing to the large amount of iron oxide present. These show the same color in reflected light. There is also some magnetite present. Whatever may have been originally there is nothing now that could be called augite.

S. 20016. N. E. ¼ Sec. 21, T. 49 N., R. 46 W. Bed of Black River. Top flow Lake Shore Trap from near the bottom of the amygdaloidal portion.

Melaphyre:

Macroscopic: Brownish gray color; coarser grained than the specimens described above from the same flow; amygdaloidal and pseudoamygdaloidal cavities, but all are small; calcite is strongly developed both in the cavities and in the ground mass; chlorite is relatively more important than in the other specimens of the same flow. The only mineral that can be distinguished are small crystals of feldspar. The specimen has a tinge of color that shows that iron oxide is developed.

ii. (5). This is the second flow from the top of the Lake Shore Trap. It is 35 feet thick and has an amygdaloidal top of 12 feet. It is possible that this flow and the one described above are parts of one larger flow 70 feet thick. As there was a covering of flowing water it was difficult to decide. If there is only one flow then what is taken as an amygdaloidal top would be an amygdaloidal centre of a larger flow. No pipe amygdules and no well marked contact were observed. However pipe amygdules are often wanting at the bottom of a flow, therefore much cannot be argued from their absence. The reason for supposing that there are two flows instead of one is that there is a marked amygdaloidal zone.

No specimens were taken from this flow, but it is quite like the flow described above with amygdules of calcite, chlorite, and laumontite.

iii. (6). This flow has a surface width of 230 feet and since its dip is 30° N., a thickness of 115 feet.

This is also a melaphyre flow with an amygdaloidal top and a massive centre. It is not continuously exposed like the other flows of this formation, but is low and water covered except at the very bottom, where the river begins to form a gorge. Where this flow is thus exposed there is seen to be a strong jointing in two directions, the first series of planes being N. 80° E., and dipping 55° S., while the second is N. 10° W., and dips 85° E., so that the two systems are not far from at right angles.

iv. (7). This is the fourth flow from the top, and is exposed in the bed of Black River, not in low water covered outcrops, as is the previous bed, but forms the walls of a gorge through which the river flows. The flow has a surface width of 170 feet, and a thickness of 85 feet. The same system of jointing shows as at the base of the flow above.

S. 20019. N. E. ¼ Sec. 21, T. 49 N., R. 46 W. Bed Black River. Lake Shore Trap, Fourth flow from the top.
Macroscopic: Reddish brown color; massive; cleavage faces of feldspar can be easily seen; uniform texture; grain ½ mm.; no phenocrysts; this specimen much resembles 20021 described below, except that the latter has phenocrysts of feldspar.

v. (8). This fifth is the thickest flow of the Lake Shore Trap. It is the lowest, and hence the oldest.[1] Below it is a conglomerate, and above it a flow very similar to itself. This lowest flow has an amygdaloidal top, and also an amygdaloid of ten feet at its base. The thickness of the flow is 130 feet. The cavity fillings are calcite, laumontite, and chlorite.

S. 20021. N. E. ¼ Sec. 21, T. 49 N., R. 46 W. Bed Black River. Lowest flow Lake Shore Trap.
Macroscopic: Reddish brown color; grain ½ mm.; crystals of feldspar can be readily distinguished in the ground mass; phenocrysts of striated feldspar 2 to 3 mm. are present.
Microscopic: Idiomorphic augite, in very small crystals, is quite abundant and is scattered through the whole rock quite evenly. The feldspar crystals are of two generations. Those in the ground mass are ½ to ¾ mm., and make up a large portion of the rock. The extinction of these crystals is 30°-30° to 33°-34°. The large phenocrysts are also labradorite. They are brotocrystals.[2] One is so rounded as to have lost every vestige of its original shape. It is surrounded by a ring of secondary feldspar that has an extinction angle slightly greater than the original feldspar in the crystal. In the centre of this same brotocrystal is a piece of augite that extinguishes with the augite outside the crystal. The phenocrysts of feldspar are from 2 to 3 mm. There seems to have been little original olivine, and none remains now as such. Chlorite and magnetite are not developed, but there is some iron oxide. The rock is an augite porphyrite of the Minong type.

Division V. Conglomerate.

(9). Exposed in the bed of Black River, in the S. E. ¼ of the N. E. ¼, Sec. 21, T. 49 N., R. 46 W.

This conglomerate lies beneath the Lake Shore Trap and is in conformable contact with it. In it there are no important sandstone phases, indeed, nothing save sandstone spots, without important length or thickness. Like the conglomerate above the Lake Shore Trap, it is made up of a variety of pebbles, but the great mass is felsite, and the formation is distinctly acid. By searching one can find melaphyre, labradorite porphyrite, jasper, granite and so on as in the Outer Conglomerate, but they are uncommon and not important in building up the rock mass. The finer material between the pebbles is also acid. The largest boulders are less than a foot in diameter, and all sizes from this down may be found. They are all water worn and well rounded.

Calcite is developed between the pebbles and shows strongly in spots and patches rather than scattered uniformly throughout the whole.

The surface width is about 660 feet, and the dip 30° N., or possibly a degree or so more. The thickness of the formation cannot exceed 340 feet. The surface width cannot possibly be much greater than that given above for the unexposed thickness beneath cannot exceed 50 feet, and there is no unexposed width above. The outcrop below is a massive melaphyre, and at least enough of the fifty feet must be given to that flow to add an amygdaloidal top.

Over the north edge of the conglomerate is a waterfall. But the water does not bound over a ledge. It flows down the north side of the conglomerate with the dip. The water has succeeded in cutting a gorge through the melaphyre lying on the river below the conglomerate,

[1] The number of flows in the Lake Shore Trap group is not very different from the number around Calumet.
[2] A term suggested by me which Gordon has found it convenient to use to apply to crystals, corroded and evidently not formed during the last process of consolidation.

but the conglomerate has proved itself able to resist water action that the melaphyre could not resist. (Plate XXXV.)

No pebbles from this formation are described here, because all the descriptions of the Outer Conglomerate and boulders apply equally well here. In fact, one might think of the deposition of conglomerate as going on when nature was disturbed by the eruptive flows which make up the Lake Shore Trap, and after that period of eruption was over nature resumed its original manner of laying down conglomerate, receiving its material from the same sources.

Division VI. Amygdaloidal Melaphyres with interbanded acid sedimentaries.

Beneath the conglomerate just described is a series of basic flows, more or less interbanded with sedimentaries in the form of sandstones and conglomerates. This series will be taken as Group VI in the Black River section of the Keweenawan, and will be represented geologically under one color. Probably there is no very important reason why this division should be made, and yet it seems to be the most satisfactory for the present report.[1] It extends geologically from Conglomerate V down to the Chippewa felsite. It is exposed only in the bed of Black River, and the exposures are not continuous, in fact far from it. The highest exposure is in the S. E. ¼, of the N. E. ¼, Sec. 21, T. 49 N., R. 46 W., and the bottom of the group in Black River is near the centre of the N. E. ¼ Sec. 32 of the same town and range, but there is no outcrop at this point. Topographically the group lies between two lines drawn N. 80° E. through these two points. It is made up of a thickness of 5,500 feet of rock, which corresponds to 8,500 feet of surface width. Of this thickness nearly 3,000 feet must be passed over as unknown because of want of exposures.

The top flows of this group are seen only under running water, and are worn down level with the conglomerate in front of them. In fact, the conglomerate seems to establish a base level below which the action of the river cannot wear these rocks. Back a short distance from the conglomerate the rocks rise above the surface of the stream because they are not yet worn down to this base level. On the whole the action resembles that at the mouth of a river where the receiving body of water is at an established base level.

i. (10). Melaphyre:—Only the massive portion of this flow is exposed, but there is an unexposed width of about 60 feet below the conglomerate, a portion of which must represent the amygdaloidal top of this flow. The thickness of the flow must be at least 60 feet. The rock is so covered with water that nothing definite could be learned of it.

(11). Melaphyre:—This flow much resembles (10), and like it is much covered with water. Its thickness is 90 feet, and the amygdaloidal portion 25 feet.

(12). Melaphyre:—Surface width 320 feet, thickness 180 feet, amygdaloidal top 35 feet. Amygdules of calcite, chlorite, and laumontite. Like the two flows above it is covered with water.

(13). Melaphyre:—Thickness 90 feet, amygdaloidal top 20 feet.

[1] A similar group, characterized by the frequent alternation from sediment to lava is found all along Keweenaw Point.

Amygdules of calcite, chlorite and laumontite. The bottom of the flow begins to rise above the surface of the river water, and to form rapids. S's. 20006, 20007, 20008, 20009. The descriptions of two of these will cover all the characteristics.

S. 20006. Bed of Black River, S. E. ¼ Sec. 21, T. 49 N., R. 46 W.
Macroscopic: Dark gray color; massive; fine grained; the hand specimen does not seem to be much decomposed, but chlorite and iron oxide are developed in spots. The grain of the rock is too fine to admit of mineralogical identification macroscopically, but the rock is plainly basic.
Microscopic: Porphyrite; Oligoclase feldspar with crystals of two generations, those of the one being very small, and making up the great mass of the rock, while those of the other are larger but will not exceed 1½ mm. and are few in number. Secondary quartz, calcite, and chlorite are developed between the crystals. Augite and olivine are not present and there is but little to suggest that they ever were. The whole is much decomposed.
S. 20007. Black River. S. E ¼ Sec. 21, T. 49 N., R. 46 W.
Macroscopic: Dark red with a tinge of gray. The rock is mottled red and green because of a development of chlorite and hematite. Decomposition is well advanced. The specimen is fine grained and massive. It has a basic appearance.
Microscopic: Decomposed porphyrite. Like 20006, being from the same flow, but it gives the additional positive information of some original olivine. There is much secondary quartz, some of which is in the form of spherulites. There is more decomposition in this slide than in the one described above.

iii. (14). Melaphyre:—Exposed in the bed of Black River only. It has a thickness of 140 feet. It has suffered much decomposition and has a great amount of pseudo-amygdaloid. There are cavity fillings of laumontite, calcite and chlorite. In one much decomposed band of the flow laumontite is very prominent.

Sp. 20005.
Macroscopic: This specimen has amygdules of chlorite with a small amount of calcite in the centre. It is fine grained, and much weathered. Its appearance suggests that much secondary quartz is developed in the ground mass. The specimen has a basic appearance.
Sp. 20002.
Macroscopic: Reddish brown color; medium fine grained but yet small lath feldspars can be readily seen; some amygdules of calcite, chlorite and laumontite. The specimen is evidently from near the base of the amygdaloidal zone.
Microscopic: Melaphyre; oligoclase feldspar; only a very small amount of augite; olivine which was originally important is now completely decomposed. The substance left by the decomposition of the olivine is by far the most interesting in the slide, in fact, is one of the most interesting things in the whole series of specimens. It is colored nearly like biotite, and greatly resembles it, but yet it is not biotite. It has a very marked cleavage in one direction and extinguishes when the cross-hairs are parallel with this cleavage. There is some pleochroism but it is not nearly so strong as in biotite. The outer edge of every segregation of it is opaque, probably because of a difference of chemical composition, that difference being a greater amount of iron oxide. In some cases this mineral gives an image in convergent light that seems to be uniaxial, but a good picture could not be obtained.[1] The best description of it seems to be that it is a substance on the road of change from olivine to biotite, and this supposition is given strength in that there are in the slides taken as a whole almost every step in the change. The coloring matter is, no doubt, largely hematite as is shown in reflected light. In connection with this mineral see Vol. VI, Mich. Geol. Survey, page 154, under the head of "Olivine."

Sp. 20001. This specimen is quite like 20002 both macroscopically, and microscopically.

vi. (15). Melaphyre:—Only the amygdaloidal top of this flow is exposed. It is quite like the flows described.

vii. (16). Unexposed:—Beneath the flows described above is a thickness of 1,200 feet without exposure in the Black River section. Since the flows beneath this unexposed area are so like the flows above it is grouped here as if it were made up of such flows but there is no certainty about how it is made up.

viii. (17). Conglomerate:—Only the base of this conglomerate is exposed, and hence, its thickness is not known. This stratum was discovered by Dr. Lane. He was in the river bed by some very fine grained rock on the left bank, at a point where the river runs nearly east and west. Knowing from the grain of the rock that he must be near a contact, he climbed up on the little ledge and found that there was a conglomerate above the melaphyre.

[1] It is iddingsite.

ix. (18). This flow is a melaphyre. The massive part is exposed in the river about 1,750 paces N. and 300 W., Sec. 29, T. 49 N., R. 46 W. The thickness is 40 feet.

x. (19). Melaphyre:—Exposed in the river in the N. E. ¼ of the N. E. ¼, Sec. 29, T. 49 N., R. 46 W. The thickness is 40 feet of which 10 feet at the top is amygdaloidal.

Sp. 20032. From near the base of the flow.
Macroscopic: Brown color from iron oxide; massive; the minerals cannot be identified macroscopically, but the specimen has a basic appearance; uniform texture with no phenocrysts; chlorite is developed in the ground mass.

xi. (20). Ophite:—Exposed in the bed of Black River in the N. E. ¼ of the N. E. ¼, Sec. 29, T. 49 N., R. 46 W., the outcrop extending along the river into N. W. ¼ of the N. E. ¼, Sec. 28. It has a thickness of 75 feet, 15 of which is amygdaloidal. The amygdules are very conspicuous, having been increased in size by weathering. Laumontite is very abundant, as is also chlorite and calcite. S's 20033, 20034, and 20035.

Sp. 20033.
Macroscopic: This specimen is from the amygdaloidal part of the flow. The ground mass, which is very fine grained, is colored with iron oxide. The cavity fillings give the predominant color to the specimen because of the size of the cavities, and the vivid color of laumontite which is the main filling. Calcite and chlorite are also present. The calcite is invariably pure white, and is surrounded by the laumontite.
Microscopic: The slide shows flow structure. The rock is very fine grained and is amygdaloidal. The amygdule fillings are laumontite and calcite, the former being next to the cavity wall. Oligoclase feldspar is abundant. Originally olivine was abundant but it is all decomposed. There is no augite in the slide, but this is probably because the specimen is from the top of the flow. The specimens taken from lower down have augite.
Sp. 20034.
Macroscopic: Brownish color; massive; lath shaped feldspars can be distinguished. The rock has a basic appearance.
Microscopic: Oligoclase feldspar is abundant; olivine is also abundant, but none is fresh, being weathered to serpentine stained with iron; there is a small amount of augite, and it shows an ophitic texture; in some places olivine is completely surrounded by augite; calcite, chlorite, serpentine, and quartz are developed.
Sp. 20035. Ophite:—This specimen is from the same flow as 20034, and is quite like it macroscopically, and microscopically, and adds no information.

The flow just described is the highest in which ophitic texture was apparent. It is not at all marked as compared with some of the flows that we shall meet further down.

xi. (21). Ophite:—This is an ophite with an amygdaloidal top. The surface width is 100 feet, and the thickness of the flow 70 feet. It is exposed in the river in the N. E. ¼ of the N. E. ¼, Sec. 29, T. 49 N., R. 46 W., and also in the N. W. ¼ of the N. W. ¼, Sec. 28. The river at this point flows nearly along the strike of the formation.

Sp. 20037. This specimen is so nearly like 20034 and 20035 that it is difficult to distinguish them. The thin section is cut in a coating mostly spherulitic quartz, caused by rock slipping.

Sp. 20030.
Macroscopic: Brownish color; amygdaloidal; amygdules of chlorite and laumontite, the former being the more plentiful; the specimen has a basic appearance.
Microscopic: Oligoclase feldspar is very plentiful; there is much olivine but all is altered; there is some augite enclosed in which are feldspars. This specimen resembles in every respect the specimens from the flow above 20034 and 20035.

This flow shows evidences of faulting, the planes being N. 5° W., and dipping 65° E. The evidences here are not of extensive faulting, but since other evidences are found near, the fact can scarcely be passed over without notice. There are numerous faces that show rock slipping, e. g, Sp. 20037.

xii. (22). This is a basic flow quite like those immediately above. The surface width is 125 feet and the thickness 80 feet. It has an amygdaloidal top. At the base it is in some places so decomposed that it is little more than a mass of laumontite and calcite which crumbles down very easily, while in other places it is not at all decomposed.

Sp. 20040.
Macroscopic: Amygdaloidal with amygdules of chlorite calcite, and a small amount of laumontite.
Microscopic: The slide is much altered; the rock is fine grained; acid feldspar is abundant, as is also altered olivine; there is no augite visible, but this is probably because it is from the amygdaloidal zone as was the case in a flow above.

xiii. (23). Sandstone:—This is a typical sandstone with a yellowish brown color, and in it there is no tendency to conglomeritic phases. The thickness is 30 feet, the strike N. 78° E., and the dip 42° N. It lies in the bed of the river which here flows along the strike of the formation, and follows this stratum for nearly 200 paces, and at most seasons of the year completely covers it.

This bed, and also the one above it is cut off on the west by a fault which runs through here. Of course it is certain that other beds are cut off also but the break in these two is exposed in the river bed. There is a fault breccia whose strike is N. 10° W., and dip 65° E. This breccia stands out like a dike, and is about four feet across. It can be traced for nearly 200 paces across a bend of the river, and into the bush, but there is not much information to be gained concerning the amount and direction of the throw. In addition to this large fault there is a small one showing about 100 feet east. The strike of the fault plane is N. 12 E., and the throw is 28 feet. Certainly this throw is only small but its importance comes in connection with other evidences of faulting. Since there is so much disturbance it seems possible that an important fault might be near here.

xiv. (24). Ophite:—This flow has not so prominent an amygdaloidal top as the other flows that we have met. S. 20048 is from that zone and has not a great number of cavities.

Sp. 20041. Ophite.
Macroscopic: Dark gray color; massive; there are a few phenocrysts of plagioclase 2 to 3 mm. in an aphanitic ground mass; chlorite is the only secondary development that can be identified.
Microscopic: Ophitic texture, but there is only a small amount of augite; abundant oligoclase in very small crystals but there are a few phenocrysts 2 to 3 mm. long; considerable spherulitic quartz is developed in the ground mass, as is also chlorite; olivine was a very important original mineral but it is now decomposed.

xv. (25). Conglomerate:—This is an acid conglomerate 20 feet thick. The pebbles will scarcely exceed three inches in diameter. It is exposed in Black River in the S. E. ¼ of the N. E. ¼, Sec. 29, T. 49 N., R. 46 W.

xvi. (26). This is a basic flow. Its thickness is 25 feet, and it has an amygdaloidal top of 10 feet. The flow shows strong jointing in planes N. 80° E., dipping 35° S.

xvii. (27). Basic flow with a surface width of 40 feet and a thickness of 25 feet. The amygdaloid is not pronounced here the band being only 4 feet.

xviii. (28). Basic flow with a thickness of 25 feet, and a very pronounced amygdaloidal top of 15 feet.

xix. (29). A basic flow with a surface of 60 feet, a thickness of 40 feet, of which 10 feet is amygdaloidal.

xx. (30). Basic flow 20 feet thick, of which the top five feet is amygdaloidal.

xxi. (31). This is a basic flow whose thickness is 40 feet, the top half being amygdaloidal.

S. 20054. This specimen has a grayish brown color. It is so fine grained that the minerals cannot be identified except a few fine feldspars. It is amygdaloidal, the cavity fillings being calcite and chlorite.

xxii. (32). Basic flow; thickness 20 feet; amygdaloid 8 feet.

xxiii. (33). Sandstone:—This is a typical sandstone with no tendency to conglomerate. It is reddish colored. It has a uniform grain. The sedimentary planes are well marked, the rock cleaving quite readily along them. Strike N. 72° E., dip 44° N., thickness 25 feet.

This sandstone ends abruptly at the east end, and has every appearance of being faulted. There is no indication as to the amount or direction of throw. Even the direction and dip of the fault plane cannot be taken because of the rapid running water in the river where the rock is faulted. However there can be no doubt about the sandstone being faulted because an eruptive rock appears on the opposite side of the river along the strike of the sandstone. The faulting is not far from the line of the fault breccia a short distance down the river, which breccia was mentioned in connection with sandstone 23. Though there is a considerable distance of river between the two places where faulting is shown, yet they are not more than 125 paces apart in a straight line because the river is very crooked here. If the first mentioned fault be continued in the direction that it has it will pass only a few yards from the second. It is probable that both belong to the same fault, or at least are the result of the same strain which resulted in step faulting.

xxiv. (34). Lying beneath the sandstone, and in contact with it is a melaphyre having a thickness of 30 feet, 10 feet of which is amygdaloid.

xxv. (35). This flow resembles 34. Its thickness is 70 feet.

xxvi. (36). Melaphyre:—This flow is thicker than the others that we have met. Its thickness is 140 feet, 40 feet of which forms an amygdaloidal zone.

Sp. 20058. This specimen is rather coarser grained than any eruptive specimen yet examined. It has plagioclase feldspar, the cleavage faces of which can be readily seen in the hand specimen. Augite also is present. There are numerous very small spots of red, evidently iron oxide; these suggest altered olivine, since, in numerous other specimens where they occur, the thin section showed abundant olivine, and always weathered to a red substance which is serpentine stained with hematite.

xxvii. (37). Only the amygdaloidal top of this flow is exposed. The flow is basic.

xxviii. (38). Unexposed:—This represents a rock thickness of 900 feet.

xxix. (39). This flow has a surface width of 140 feet and a thickness of 90 feet. The upper contact is not exposed but the fine grain of S. 20059 makes it certain that it is not far from the top. If so there can be no important amygdaloidal zone.

Sp. 20059. This specimen is fine grained and massive. There are a few very small phenocrysts of feldspar. While the specimen is basic its appearance leaves no doubt about it running higher in silica than the average basic Keweenawan flow. It breaks with a fracture that approaches conchoidal. The fine grain of the specimen helps to make it certain that it is from near the top of the flow and hence that the amygdaloid cannot be important.

xxx. (40). This flow has a surface of 140 feet, and a thickness of 90 feet. It is exposed in the bed of Black River in the S. W. corner of the N. E. 1/4 of the S. E. 1/4, Sec. 29, T. 49 N., R. 46 W. There is no important amygdaloidal top. The flow is somewhat different from the various flows that have been described above in that it is somewhat more acid. There seems to be little doubt but that the correct place to classify it is among Irving's quartzless porphyries, and as such it will be considered here.

Sp. 20060. Quartzless Porphyry: The specimen has a reddish brown color, and a general appearance that somewhat suggests felsite, yet it has a more basic appearance than felsite. It is very fine grained. There are a few phenocrysts of feldspar that do not seem to be striated. The specimen is faintly banded suggesting flow structure. It breaks with a conchoidal fracture. This specimen approaches felsite in appearance more nearly than any previously examined. There are no phenocrysts of quartz. Some calcite, and some chlorite are developed, but only a small amount of each.

xxxi. (41). This flow is exactly like the one above, and a description given for the one will do for the other. The thickness is 90 feet.

xxxii. (42). Lying beneath these quartzless porphyries is a thin stratum of sandstone whose thickness cannot exceed 30 feet.

This sandstone shows faulting by terminating abruptly at the west. There is no evidence of the direction or amount of throw. If the fault plane spoken of above in connection with sandstones 23 and 33 were continued it would pass near this place, and this fault would come in the same series of step faulting as do those.

xxxiii. (43). Melaphyre:—There is exposed a thickness of 45 feet of rock belonging to the top of the flow, the lower part being covered.

xxxiv. (44). Unexposed:—170 feet.

xxxv. (45). Sandstone:—20 feet.

xxxvi. (46). Melaphyre:—70 feet.

xxxvii. (47). Conglomerate:—The pebbles in this conglomerate are small none exceeding three or four inches in diameter. They are predominatingly acid, and the descriptions of pebbles from the higher conglomerates might be repeated here. The lower contact is not exposed. The exposed thickness is 100 feet.

xxxviii. (48). Unexposed:—Beneath the conglomerate is a thickness of rock of 1,300 feet that is not exposed. The rock above the gap is conglomerate, and that below is Chippewa Felsite. There is no evidence to decide how much of this space is underlain by either kind of rock, at least there is no evidence in the Black River section. The unexposed area is taken here as if it belonged to Group VI.

There are some reasons that make the division of the rocks classified under Group VI a convenient one for this report. It is best to draw a line above it at the base of Conglomerate V, for it is possible that it corresponds with Irving's Great Conglomerate. Below it the Chippewa felsite is an important stratum that should be classified by itself. Within these two lines of division this group that we have just been considering is left. Also it is from top to bottom pretty regularly interbanded with sedimentaries in the form of sandstone and conglomerates. Such bands occur below the Chippewa felsite, but not so frequently. Another point is that all through this group so far as is known ophites do not become important. There are ophites in the group but their nature is revealed only under the microscope, the augite being present only in small amount. The rocks below the Chippewa Felsite are predominatingly ophite, and have such pronounced characteristics as to reveal themselves immediately to the unaided eye. It may possibly be said too, that olivine is somewhat more conspicuous in this group than elsewhere in the Black River section.

Division VII. Chippewa Felsite.

i. 49. This felsite is the most acid rock in the Black River section. It is exposed in the river in the S. W. ¼ of the N. E. ¼, Sec. 32, T. 49 N., R. 46 W., but it is only when the water is very low that the rock can be seen here. The most important exposures are on Chippewa Hill in the same section. The east end of the hill is a bluff of felsite at the foot of which is a large talus slope. The outcrop extends a considerable distance around toward the north side of the hill, and also so far around the south side that Bessemer and Ironwood can be seen from the edge of the cliff. The cliff apparently extended farther in both directions than it does at present as there is considerable old talus slope now completely covered with soil and vegetation. There are also exposures of felsite on the top of the hill near the east and west centre line of the section. The same line runs almost directly over the centre of the cliff. There are outcrops of rock on the south side of the hill a little way down from the top that are not felsite, since the hill is composed of basic rocks capped by a felsite top, and it is probable that it is the enduring power of the felsite cap that has successfully resisted the degrading influences of nature. The hill is almost wholly in Sec. 32, only a small part reaching into Sec. 31, and in this latter section there is an outcrop about 150 paces west of the east quarter-post. There are in the Black River section no outcrops of the Chippewa felsite save those mentioned above. West of the hill the land is level and inclined to be swampy and is wholly without outcrop of any kind. Between Chippewa Hill and Black River there are no outcrops. East of the river, where the felsite should outcrop, the land is flat and deeply covered with till.

The lower contact is exposed in the river, and it can be located within thirty feet on the hill. The upper contact cannot be so definitely located. The most northerly exposure on Chippewa Hill is felsite, and lying north of this exposure is a space of nearly three miles without outcrop, beyond which is the conglomerate of Conglomerate Ridge. Above the felsite, in the river, is a space of 1,300 feet without exposure, beyond which is conglomerate 47. The exposed surface of the felsite is 660 feet giving a thickness of 460 feet. The greatest possible surface that it could have is about 2,000 feet, and the greatest thickness 1,400 feet, and to have this surface and thickness all the unknown space above would have to be underlain by it.

In Monograph V, U. S. G. S., Irving says "The 'trap rock' of the old Chippewa location S. W. ¼ Sec. 22, evidently belongs to the main mass underlying the porphyry." The exploration work on this location was done almost at the contact of the porphyry and the basic rock, so the felsite is exposed on the location. But it is not on Sec. 22, it is on Sec. 32. As Irving was not in the particular locality, but got his information from others he was probably misinformed. His map is drawn with the porphyry passing through Sec. 22 instead of 32, which places it two miles farther north than it should be.

The felsite of the Chippewa location shows the flow structure well in places, as at the east end of the cliff on the east end of the hill. The flow structure is brought out more prominently where the rock is weathered.[1] The rock breaks into angular fragments so that it is difficult to obtain typical specimens. In many places on Chippewa Hill it crumbles beneath the hammer, breaking into pieces from one-half to one inch in diameter. This is evidently due to being exposed to the action of the atmosphere. In the Black River where the disintegrated surface is worn away by the action of the water, and the material that it carries, the surface of the rock is as smooth as glass, much smoother than that of any other rock that we met. In such places the rock does not crumble down when struck with the hammer. The crumbling does not seem to be due to chemical decomposition of the rock, because the rock is not decomposed; it seems to be due to little joints that seem to be present everywhere and to form lines of weakness when the rock is exposed. Where the rock is fresh it breaks with a conchoidal fracture giving pieces with knife like edges.

The ground mass is very fine grained. The most conspicuous phenocrysts are of orthoclase feldspar. In some places they are very plentiful while in others they are almost wanting. They range in size from those very small up to those about one-eighth of an inch in diameter. They are generally nearly red in color, but where they have been exposed to the action of the atmosphere they are more nearly white. Quartz phenocrysts are not so plentiful as those of feldspar, and in some places they do not seem to be present at all.

It is quite easy to select specimens from the Chippewa felsite that vary much in appearance. In fact, to place some of the specimens by others one would scarcely think that all were from the same flow, and perhaps from only a few feet apart. This fact may do much to explain the variety of pebbles in the conglomerates described above. It is not intended to give the impression that all the pebbles might have been derived from one flow, but it is intended to point out that it is not necessary to have as many acid flows as there are kinds of acid pebbles in the conglomerate. The variety of pebbles seems to me to be due not only to the variety of parent acid flows, but also to the variety within the same flow.

Sp. 20061. Bed of Black River, Sec. 32, T. 49 N., R. 46 W.
Felsite:
Macroscopic: Deep chocolate brown color; fine grained and very compact; conchoidal fracture; no phenocrysts of quartz, but there is so much secondary quartz that it is visible to the naked eye; this secondary quartz tends to make the rock a lighter color; there are only a few phenocrysts of orthoclase feldspar, the largest of which are about 2 mm.

Sp. 20062. Black River, Sec. 32, T. 49 N., R. 46 W.
Felsite:
Macroscopic: This specimen though from near 20062 is much lighter in color, being almost a red. Much secondary quartz is developed and is so arranged as to give the specimen an appearance of parallel

[1] At the steep bluff close to the road the flow lines ran dip. 59° to N. 15° W. and the joints were: dip 80° to E. 50° S., dip 30° to E. 30° S. and 90° to W. 25° S. On the hill they were 90° to E. 30° S., and banding nearly parallel to the bottom contact dip 60° to N. 5° W.

banding. The rock breaks with a conchoidal fracture and knife like edges. There are quite a few phenocrysts of quartz a fraction of an inch in diameter. There are also crystals of feldspar but they are not plentiful. Both this specimen and the one described immediately above have very smooth surfaces as a result of the wearing by the river. No rock in all the series seems capable of being worn so smooth as does this Chippewa felsite.

Sp. 20077. Sec. 32, T. 49 N., R. 46 W., 850 N. 1800 W. From Chippewa Hill.
Felsite:

Macroscopic: The specimen is a deep chocolate brown; the most conspicuous characteristics are the flow structure and the numerous phenocrysts of orthoclase feldspar. Along the flow lines are partings that cause the rock to break readily, but not like along sedimentary planes, for the fracture crosses from one flow plane to another very readily. While the flow banding taken as a whole is parallel it is not so at every point. The phenocrysts of orthoclase show in rhomb shaped faces from 2 to 3 mm. Where weathered they are nearly white in color but where they are not weathered they are nearly red.

The orthoclase crystals are numerous but there are none of quartz. There is no secondary quartz. This specimen is quite unlike either 20061 or 20062 yet it is from the same flow.

Sp. 20078. Sec. 32, T. 49 N., R. 46 W., 1600 N. 1500 W. From Chippewa Hill.
Felsite:

Macroscopic: This specimen resembles 20077 very much but there are not so many phenocrysts of feldspar, and there is an absolute lack of flow structure.

Microscopic: In ordinary light the slide has a red color. There are no phenocrysts of quartz, but there are some of orthoclase about 1 mm. Quartz is abundant in the ground mass. The slide shows no flow structure.

Sp. 20097. Sec. 32, T. 49 N., R. 46 W. Black River. This specimen comes from a point only a few feet from the base of the Chippewa Felsite.

Macroscopic: Reddish brown color; there is a mottled appearance which a close examination shows to be from the development of secondary quartz in spots. In a few places there are cavities in which are quartz crystals. There are no phenocrysts of quartz, but those of orthoclase are quite numerous though not conspicuous.

Sp. 20059. From Chippewa Hill.

This specimen has a chocolate brown color but there is a tinge of violet. There is but a trace of flow structure. No phenocrysts of quartz and only a few of orthoclase. Aphanitic ground mass.

Other specimens from this felsite could be described differing from these but there are sufficient here to prove that there is a very great variety of appearance in the same flow.

Division VIII. The Ophites.

Beneath the Chippewa Felsite is a series of ophites with a few interbedded sedimentaries. The ophitic texture is much more pronounced in this division than in VI, or than in any other division of the series. The exposures are in the bed of Black River, on the Black River Highlands, and on the south side of Chippewa Hill. The division extends from the base of the Chippewa Felsite to the lowest exposures in Sec. 21, T. 48 N., R. 46 W., beneath which is a wide gap whose underlying rocks are not exposed, and hence, not determined. The flows of this division are not so well determined as those of other divisions as they are not so well exposed. So far as the outcrops are in the bed of Black River, where they are cut across at nearly right angles to the formation, they are well determined, but the exposures on the Black River Highlands, to the east, are not continuous, and it becomes impossible to give the number and thickness of the flows. The information about these is rather general. It is certain, however, that the flows are thicker than elsewhere, because of the coarser mottling of the ophites. It does not seem advisable to even attempt to give here the various flows of this part which is exposed only on the highland. The chances of error are so great that any column prepared would be little better than a guess, and would be so misleading that it would be worse than useless. That portion of the area will be passed over as one known to be made up of a series of flows predominatingly basic, but whose number cannot be determined.

The few sedimentary strata that occur in this division are acid but have more basic material than the strata that occur above them except the Nonesuch, which is strongly basic. The sedimentary strata are insignificant in quantity as compared with the amount of eruptive material. There are some flows which are pretty well toward the acid end of the line, but, like the sedimentaries, their quantity is not at all important.

i. (50). Sandstone:—This sandstone lies beneath the Chippewa felsite and in contact with it. The very bottom of the felsite itself seems to have considerable sedimentary matter in it, probably material that it has picked up as it flowed. There is in the sandstone a considerable amount of material that looks like volcanic ash fragments.

The surface width of the sandstone is 40 feet, and the thickness 25 feet.

Sp. 20092 is a typical sandstone of acid variety.

Sp. 20093. Sec. 32, T. 49 N., R. 46 W., 1250 N., 600 W.

Sandstone:—

Macroscopic:—Greenish gray color; there is a large amount of fragmental matter in which quartz is prominent; no sedimentary planes; many angular fragments that seem to be of volcanic origin. The whole specimen is so altered and charged with secondary matter that it cannot be well described from the hand specimen.

Microscopic:—Sedimentary; fragments of quartz, plagioclase and ophite; some are rounded but for the most part they are angular; secondary quartz and epiodote are prominent.

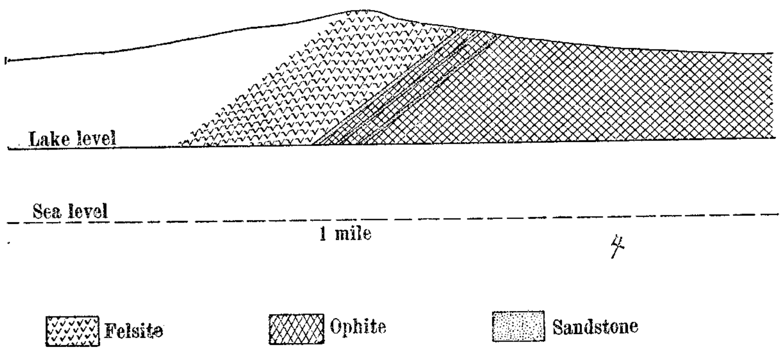

Fig. 23.—Section of Chippewa Bluff.

ii. (51). Ophite:—This ophite is exposed on the south side of Chippewa Hill in a test pit made by the Old Peak Mining Co. Besides this there are three other exploratory openings about the hill. This particular pit is well up the side of the hill, and is only a few feet from an exposure of felsite. No great amount of work was done as the hole is not more than about thirty feet deep. The old windlass, the old bucket and other things still remain where they were when the location was abandoned. The amygdaloid thrown out on the surface shows fillings of calcite, chlorite, epidote and quartz. There is only the smallest trace of copper, certainly nothing to cause any person to hold out hope.

Farther east, in the river, the same flow is exposed and the ophite grain is seen to be about 1 mm.

The surface width of the flow is 60 feet, and the thickness 40 feet; about 15 feet at the top is amygdaloidal.

iii. (52). Ophite:—This flow is about the same thickness as the flow above it, 40 feet. The Chippewa Mining Co. also tested this flow at the foot of the bluff at the east end of the hill, but with no success. The dip of the felsite is such as to bring that rock directly above the tunnel that runs into the base of the cliff.

iv. (53). Sandstone:—A thin stratum of acid sandstone exposed in Black River. Thickness is 10 feet.

v. (54). Ophite:—There are exposures in the bed of Black River and also on the south side of Chippewa Hill. In addition to these places the rock may be seen in a tunnel at the foot of the cliff, about 150 feet from the tunnel spoken of above. This seems to be the largest opening made by the company, for judging from the dump pile, it must reach into the side of the hill as much as 100 feet. There are trees as much as six or eight inches in diameter now grown on the old dump pile. The rock thrown out is only slightly amygdaloidal and it looks as if the work were done near the base of the amygdaloidal portion of the flow. The rock is a coarser ophite with augite mottles 2 to 2½ mm.[1] There is some amygdaloid and pseudoamygdaloid at the base as is shown by a test-pit made by the Old Peak Mining Co. in the sandstone below, which test-pit exposes a portion of the base of this ophite.

The surface width of the ophite is 160 feet and the thickness 100 feet.

Sp. 20076. Sec. 32, T. 49 N., R. 46 W., 750 N., 1700 W.
Ophite:
Macroscopic: Dark gray color; pronounced ophitic texture; augite crystals 2 to 2½ mm.

vi. (55). Sandstone:—The Chippewa Mining Co. also tested this stratum, but apparently with no success. The test-pit is probably about 50 feet deep. It is on the south side of the hill and is the only place where this sandstone may be seen. The material thrown out shows that the stratum is partly sandstone of acid type and partly conglomerate, which is also acid, but basic material is quite common. There are some pebbles nearly an inch in diameter at the base. Much of the material is angular. Although this is below the Chippewa felsite there are many felsite pebbles in the stratum. The whole is heavily charged with calcite. No traces of copper were seen in any of the material dumped from the test-pit.

The strike is N. 80° E., and the dip 45° N., and the thickness 15 feet.

S's. 20099, 20100, 20101, 10102 and 20103 are all from the stratum but they are merely acid sandstones much like others that we have met and their lengthy description here would add nothing of value.

vii. (56). Ophite:—Exposed in Black River. Surface 80 feet, thickness 50 feet.

viii. (57). Ophite:—Exposed in the river. Surface 50 feet, thickness 40 feet.

ix. (58). Ophite:—Only the top 25 feet of this flow is exposed.

x. (59). Unexposed:—The unexposed width here represents a rock thickness of 140 feet.

xi. (60). Ophite:—This flow is exposed on the south of Chippewa Hill. Neither the upper nor the lower contact is exposed, but specimens were taken from the flow below, so the lower contact can be

[1] About 190 feet below the felsite at right angles to the dip I found mottles as much as 5 mm. across, about 830 paces N., 1650 W., Sec. 32.

fairly accurately located. The grain of the specimen in hand shows that it comes from at least 25 or 30 feet from the contact and the thickness of the flow may be a great deal more.

Sp. 20065. Sec. 32, T. 49 N., R. 46 W. 500 N., 1933 W.

Ophite:—

Macroscopic: Typical ophite with mottling from 1 to 2 mm. There are phenocrysts as large as 5 mm., but they are not numerous.

xii. (61). Ophite:—This is a typical ophite, and is exposed on the south side of Chippewa Hill. The flow is 50 feet thick.

Sp. 20066. Sec. 32, T. 49 N., R. 46 W., 500 N., 1865 W.

Ophite:—

Macroscopic: Typical ophite with pseudoamygdules whose fillings are quartz.

Microscopic: Feldspathic ophite; pseudoamygdules, mostly of spherulitic quartz, but some chlorite; abundant chlorite and some serpentine are developed in the ground mass; augite, labradorite feldspar, olivine and magnetite are primary minerals; feldspar is the most abundant of all and is of labradorite variety; augite is not so abundant as in most ophites; there never was much olivine and none of it is unaltered; magnetite skeleton crystals are very abundant and there seems to be no doubt about their primary origin; the magnetite appears to be older than either the augite or the plagioclase.

Sp. 20069. South side of Chippewa Hill.

Ophite:—

Macroscopic: This specimen is a typical dark colored ophite.

Microscopic: Augite 1 to 1½ mm.; olivine altered to serpentine; labradorite feldspar; much chlorite is developed, and in places seems to be mixed with serpentine; olivine must never have been important as can be seen from the small amount of mineral that has resulted from its decomposition. There are rarely phenocrysts of feldspar.

At the base of ophite 62 there is a small amount of sedimentary matter some of which is more or less mixed with the base of the flow.

xiii. (62). Unexposed:—Surface width 150 feet representing a rock thickness of about 100 feet.

xiv. (63). Melaphyre:—Exposures of this rock occur only in the bed of Black River, Sec. 32, T. 49 N., R. 46 W. This and the two flows immediately beneath it are quite alike and are quite different from the other flows of the section. They are more acid in appearance than the other melaphyres, and are probably more like Ash bed rocks than any other that we have met. The cavity fillings are largely agate, a filling that is not met elsewhere save in the flows near the base of the Keweenawan series. The rock is of porphyritic type having phenocrysts up to ⅛ inches long. Epidote is developed more plentifully than in any of the rocks previously noted.

This flow and the two immediately below it have so successfully resisted the wearing action of the river as to cause rapids which are larger than those over any other basic rocks on the river, but not so large as some of those caused by conglomerate.

Sp. 20074. Sec. 32, T. 49 N., R. 46 W. Black River.

Melaphyre:—

Macroscopic: The specimen has a brownish color; it breaks with a rough somewhat pitted surface; it is somewhat more harsh to the touch than other melaphyres; plagioclase is important; some phenocrysts of lath-shaped feldspar; epidote is present; iron oxide is developed.

Microscopic: Feldspathic ophite. There is a large amount of oligoclase feldspar, but it is somewhat altered. The amount of augite is small; what is present surrounds the feldspar crystals giving an ophitic texture. Apparently there was abundant olivine present, mostly in grains, but all of it is now altered, leaving conspicuous iron oxide. Epidote and calcite are developed between the crystals.

xv. (64). Melaphyre:—Exposed in Black River immediately below

63. Thickness 100 feet. The descriptions given for 63 apply almost equally well to this stratum.

xvi. (65). Melaphyre:—This flow may be seen in the river in contact beneath 64, which it is much like. The bottom is covered but there is an exposed thickness of 80 feet.

From Lake Superior to the stratum just described we were able to follow the succession of strata fairly accurately because of the work that had been done by the river in removing the drift covering from the rock. There were some places that the rock was still covered, but on the whole the column is fairly complete. The work of the river gave another great advantage in that the water flowed nearly north and south, thus giving a chance of our working across the formation nearly at right angles to the strike. From stratum 66 it cannot be followed so well. Beyond this there are practically no outcrops in the river, the only ones being in Sec.'s. 8 and 21, and even here the rock is not so well exposed as to enable one to determine the successive flows.

The exposures next to be considered are on the Black River Highlands. With the exposures scattered here and there over a rather large area it is impossible to compile any accurate geological column. In view of this fact I shall not attempt to denote the separate flows. The best that can be done is to describe in geologically descending order the various specimens taken, and to give a general description of the whole.

There is to be considered under this head a thickness of about 8,000 feet of rock. So far as seen all the exposures are basic eruptives, but it must be remembered that there is every chance for both acid eruptives and sedimentaries to be present and not be exposed. Yet it is evident that this part of the column is made up mainly of basic flows with amygdaloidal tops and massive centres. The flows are not thick, as is evident from the grain of the rocks, but from the same evidence it is certain that they are thicker than the flows that we have met above or, indeed, any below except some ophites that are exposed in Sec. 21, T. 48 N., which are the thickest eruptive beds in the series.

The minerals which make up the rocks and the properties of the rocks will be brought out in the descriptions of the specimens.

This part of the column though pretty uniform in quality is itself divided because of places that are without exposure. While it is highly probable that these unknown places are underlain by the same rock as the other parts yet they are here made divisions by themselves and denoted as unknown.

xvii. (66). This part is exposed on the Black River Highlands, in Sec's. 33 and 34, T. 49 N. It is made up of several flows which cannot be separated in this report. It is certain that it is nearly all melaphyre.

Continuing the strike that the rocks have there would be no gap at all between this part of the column and the lowest part of the column exposed in the lowest flow seen in Sec. 32, that is strata 63, 64 and 65. But it is probable that there is a fault passing between the exposures in the river and those on the hill to the east. There is very great evidence to show that there is a fault here if we remember what was seen in the lower part of the river. It is certain that no fault, at least none of importance, can pass between Chippewa Hill and the river, as the strike and dip of the felsite on the hill are such that the formation would go through just where it is found on the river. If the faulting planes seen in Sec. 29, T. 49 N., R. 46 W. were continued they would lie east of the river in Sec 32, that is, would pass between Black River Highlands and Black River. In such a case, and it is just the probable case, the column compiled here would be inaccurate, but there is no certain evidence as to the amount or direction of the throw, and the best that can be done is to compile the data as if there were no fault, but with the knowledge that ultimately some change must be made.

It is difficult to say how many flows are in this part which is being considered under 66, in fact more than difficult, it is impossible. From the exposures seen it is known that there are at least six amygdaloids shown and one outcrop that is so near a contact that the grain is very fine. It is practically certain then that the least number of flows that there can be is eight.

The surface width of this group is 2,300 feet, the strike N. 80° E., and the dip 45° to 50° N. There is a rock thickness of about 1,700 feet. With this thickness which is made up of at least eight flows the average thickness of the flows cannot exceed 200 feet. Some of the flows may not be as thick as the average, and some may be much thicker. It seems certain from the grain of some of the specimens that the flows from which they are taken must be as thick as 200 feet:

20081. Sec. 34, T. 49 N., R. 46 W., 1,000 N., 1,640 W [1].
Macroscopic: A fine grained basic rock.
Microscopic: A fine grained augite porphyrite of the Minong type.
Sp. 20073. Sec. 33, T. 49 N., R. 46 W., 800 N., 600 W.
This specimen is a typical amygdaloidal melaphyre.
Sp. 20084. Sec. 34, T. 49 N., R. 46 W., 75 N., 300 W.
Macroscopic: A melaphyre in which augite and plagioclase can be readily distinguished. The most interesting mineral in the specimen is a bronze colored mineral probably iddingsite. It looks much like biotite mica but a close examination shows it to have a more bronzy appearance, and, in addition, instead of cleaving like mica it crumbles beneath the point of the knife. When scratched it shows a red color which suggests a very high per cent of hematite. When one has considered the alteration of olivine, and followed it through the numerous stages of changes that is shown in this suite of specimens, and seen it in every stage of change from olivine to biotite one must conclude that this micaceous looking mineral in this specimen is but an example of that which was originally olivine but now far on the road of alteration, and well toward the biotite end of the line.
Microscopic: Augite not abundant; abundant labradorite feldspar; olivine altered as usual to that mineral which so resembles mica; some epidote developing; chloritic last interstices.
Sp. 20082. Sec. 34, T. 49 N., R. 46 W., 950 N., 550 W.
This specimen is a typical fine grained melaphyre.
Sp. 20083. Sec. 34, T. 49 N., R. 46 W., 950 N., 30 W.
Macroscopic: A typical melaphyre.
Sp. 20088. Sec. 34, T. 49 N., R. 46 W., 775 N., 490 W. This specimen comes from the same test pit as 20087 described below.
Macroscopic: It is not quite so acid in appearance as 20087. The ground mass has not the same reddish brown color and is not so dense. There are phenocrysts of unstriated feldspar not much weathered and other phenocrysts of feldspar, probably plagioclase, now altered almost to epidote.
Sp. 20087. Sec. 34, T. 49 N., R. 46 W., 775 N., 490 W. From a small test pit.
This is the most acid rock of this group of melaphyres. It is fine grained and has a reddish brown colored ground mass. There are phenocrysts of orthoclase feldspar as much as 4 mm. long. It is amygdaloidal with amygdules of chlorite and epidote. On the whole the specimen is probably among the basic rocks but at the acid end and may be called a porphyrite.
Sp. 20085. Sec. 34, T. 49 N., R. 46 W., 750 N., 500 W. From a test pit.
This specimen is amygdaloidal with cavity fillings of epidote, chlorite and quartz. There are phenocrysts of feldspar 3 to 4 mm. All the minerals are much altered.
Sp. 20086. Sec. 34 T. 49 N., R. 46 W., 750 N., 500 W. from a test pit.
The specimen is highly altered and shows both macroscopically and microscopically, only quartz and epidote. There is not a trace of any of the original minerals left. Its appearance suggests that it is from the amygdaloidal top of a flow.
Sp. 20071. Sec. 33, T. 49 N., R. 46 W., 925 N., 95 W.
Macroscopic: A medium fine grained rock with a dark purplish color. It breaks with a pitted surface. Its appearance is such as to show that it is basic, but its minerals cannot be distinguished macroscopically.
Microscopically: A much altered ophite with andesine feldspar. Olivine is present in grains. Chlorite, calcite and quartz are present.

[1] The locations of specimens as given in text are those on the labels originally assigned to them, and do not agree exactly with the location of outcrops on the map, Plate XXXII, which have been corrected.

Sp. 20064. Sec. 34 T. 49 N., R. 46 W. 500 N., 900 W. This rock is much like 20063, but is finer grained; it is a melaphyre in which chlorite is prominently developed. There is also some epidote and some calcite.

Sp. 20063. Sec. 33, T. 49 N., R. 46 W. 00 N., 1600 W.

Macroscopic: A uniform grained rock without phenocrysts; augite and plagioclase feldspar are both present; some of the feldspar crystals are more than 1 mm.; there are numerous spots of red whose color is evidently due to hematite, and there seems to be no doubt about these spots being the result of the weathering of the olivine, and are probably iddingsite; chlorite is strongly developed. The rock is melaphyre.

Sp. 20070. Sec. 33, T. 49 N., R. 46 W., 425 N., 1000 W.

Macroscopic: This specimen is much altered, iron oxide, chlorite and epidote being present as secondaries. There are some phenocrysts of feldspar.

Microscopic: The minerals are much altered, none being unchanged. The oligoclase feldspar is pretty well decomposed; olivine was originally abundant, but is weathered as usual. Apparently augite was never so abundant as in the average ophite and there is but little left of what originally was present. Much chlorite and secondary quartz are present, and there is also some epidote developing.

Sp. 20072. Sec. 34, T. 49 N., R. 46 W., 250 N., 1900 W. This specimen was taken from a test pit about four feet deep.

Macroscopic: This is the coarsest grained eruptive specimen yet met. Both augite and striated feldspar can be distinguished under the hand lens; some of the feldspar crystals are as much as 1 mm. The grain of the rock is very uniform. Hematite is developed in spots as if from the weathering of some individual mineral. There in also considerable magnetite. Occasionally a mineral can be found that appears much like biotite, but it does not cleave into flexible laminae, but rather crumbles beneath the point of the knife. The abundant feldspar gives the rock a rather light color.

Microscopic: A very feldspathic ophite; labradorite feldspar 1 to 2 mm.; augite not so abundant as in some ophites; crystals 3 to 4 mm.; some of the augite is yellow under crossed nicols which is the usual color in this suite of specimens, but some of it has rather brilliant colors as blue, violet and violet-red; olivine was originally abundant but it is now completely altered yielding serpentine, hematite and magnetite; a mineral resembling mica is developed; it is not biotite but is tending that way; it has not the bird's eye maple appearance, nor the pleochroism; this mineral is generally surrounded by a heavy opaque band of iron oxide; except the olivine the minerals are well preserved there being very few secondaries, only a small amount of quartz and chlorite being developed.

xviii. (67.) There is an unexposed surface width of about 1,900 feet or a rock thickness of 1,400 feet. It is probable that this width is underlain by melaphyres.

xix. (68.) The only exposures of 68 occur on the Black River highlands in Secs. 3 and 4, T. 48 N. The rocks that are considered under 68 are much like those under 66. They are melaphyres, and are present in flows that are probably a little thicker than the average flow exposed in this section of the Keweenawan rocks.

This group will bear the same relation to the column that 66 does so far as being misplaced by a fault is concerned. It is in all probability correctly placed with regard to 66, because there are no fault indications that would suggest a movement of either of these two relative to the other, so if 66 is thrown back or thrown ahead then so is 68.

There is a surface width of 2,600 feet, and a rock thickness of 2,000 feet. There are seen at least eleven amygdaloids in this thickness and it is probable that there are more. It is probable that there are some rather thin flows here, and it is certain from the grain of the rock that there are some rather thick ones.

This belt of rocks is interesting in that it shows copper in a few places, yet there was seen nothing of obvious economic value. The most conspicuous showing was 500 paces south of the quarter post between Secs. 3 and 4, T. 48 N. The amygdaloid in which this copper shows is very much altered, and is almost a mass of epidote. The particles of copper are very small. Besides the small amount of copper there was some copper oxide, and some copper carbonate. The strongest statement that could be safely made is to say that if one were prospecting in the district it might prove interesting to look at this showing, and about this section.

In the flows that come under this head epidote is prominently developed. Not only is it in the cavities but it shows all through the rock mass. The amygdaloids above the Chippewa Felsite were found to be almost wholly without epidote. Besides the epidote quartz is prominent.

This part of the column considered under 68 must be considered as was 66, that is a description of specimens given in descending order. It is quite impossible to separate the flows with anything like accuracy of either number or thickness.

Sp. 20165. Sec. 3, T. 48 N., R. 46 W., 170 N., 540 W.
Macroscopic: Basic rock highly charged with chlorite; the primary members are augite and plagioclase feldspar. There is considerable epidote and iron oxide in the specimen.
Microscopic: Primary minerals are labradorite feldspar, abundant olivine and augite. Secondary are chlorite, epidote, serpentine and magnetite. The specimen has ophitic texture. The weathering of the olivine is quite different from common, being altered into green serpentine surrounded generally by a ring of dark iron oxide.
Sp. 20166. Sec. 4, T. 48 N., R. 46 W., 1000 N., 300 W.
Macroscopic: The specimen is a typical melaphyre highly altered; chlorite is prominently developed; traces of lath shaped feldspar can be seen.
Microscopic: Coarse doleritic melaphyre with marked olivine. The feldspar is much altered, as is also the augite of which there was originally only a small amount. The olivine is completely altered.
Sp. 20167. Sec. 4, T. 48 N., R. 46 W., 1000 N., 200 W.
This specimen very strongly resembles 20166.
Sp. 20168. Sec. 3, T. 48 N., R. 46 W., 1000 N., 1960 W.
Macroscopic: This is a more acid looking rock than the typical melaphyre. The specimen is strewn with small white spots, evidently altered phenocrysts of feldspar.
Microscopic: Augite porphyrite of the Minong type.
Sp. 20171. Sec. 3, T. 48 N., R. 46 W., 1210 N., 356 W.
Macroscopic: Massive melaphyre showing augite, feldspar, chlorite, magnetite and hematite.
Microscopic: Ophite; augite 4 mm.; labradorite feldspar; olivine all altered; magnetite and chlorite.
Sp. 20174. Sec. 3, T. 48 N., R. 46 W., 750 N., 1040 W.
Macroscopic: Melaphyre; augite, feldspar, chlorite, iddingsite, and hematite.
Microscopic: Ophite, augite 3 mm.; labradorite feldspar; olivine completely altered; magnetite, hematite and serpentine.
Sp. 20172. Sec. 3, T. 48 N., R. 46 W., 570 N., 200 W.
This specimen is much like 20174 and is probably from the same flow.
Sp. 20170. Sec. 3, T. 48 N., R. 46 W., 1,000 N., 700 W.
This specimen is a typical melaphyre, much altered and charged with epidote and chlorite.
Sp. 20173. Sec. 3, T. 48 N., R. 46 W., 500 N., 2.000.
This specimen was taken because of the copper content. The specimen is a highly altered amygdaloid heavily charged with epidote. In the specimen may be seen some native copper, some malachite, and some copper oxide. There is nothing of economic importance. The exposure of this amygdaloid is on the very top of a high peak 500 paces south of the quarter post between Secs. 3 and 4.

xx (69). Unexposed:—The next 800 feet of rock is without exposure.

xxi. (70.) The next group is exposed in Black River, Sec. 8, T. 48 N., R. 46 W. Like the two groups above, this group is composed of melaphyre flows. It would be easier to gain a knowledge of the number and thickness of the flows in this group than in the other two, yet it is felt that any attempt must give inaccurate results and it seems best to consider them as a whole.

The fault which was spoken of above as possible, and, indeed, probable, setting 66 and 68 up or down the column from what they should be, cannot displace this part of the geological column because the fault would pass to the east of these exposures the same as to the east of the exposures in the south part of Sec. 32, T. 49 N., R. 46 W. It is practically certain that this part of the column is correctly placed relatively to the exposures in Sec. 32, or in other words if we added anything to the thickness of the rock, or took anything from it by crossing the fault we have done the opposite by recrossing it and the total thickness represented should be correct.

There are only a few specimens described below as it seems useless to give lengthy descriptions since the exposures are so much like 66 and 68.

Sp. 20161. Sec. 8, T. 48 N., R. 46 W.
Macroscopic: A typical fine grained melaphyre.
Sp. 20162. Sec. 8, T. 48 N., R. 46 W.

A much altered melaphyre.

Sp. 20163. Sec. 8, T. 48 N., R. 46 W.
Macroscopic: The specimen is basic, but it has an appearance that suggests that it is more acid than the average melaphyre. It is amygdaloidal. It has a reddish color.
Microscopic: An altered oligoclase melaphyre.

Sp. 20164. Sec. 8, T. 48 N., R. 46 W.
Macroscopic: A typical melaphyre with secondary developments of calcite and chlorite.
Microscopic: The thin section shows much alteration. The augite, if ever present, is not to be recognized now. The feldspars are changed, but are probably labradorite. The olivine is altered as usual into that micaceous looking mineral. The whole is well charged with calcite. The rock is a much altered melaphyre.

xxii. (71). Unexposed:—Beneath the rocks that show in the river in Sec. 8, there is a thickness of 4,000 feet without exposure. The rock above and that below this gap is ophite. The boulders in the river, some of which are very angular, and surely not far from place, are also ophite. While there is no means to enable one to say positively what the rock is, all the evidence that can be gained seems to indicate that it is ophite. There is no high land anywhere in the area underlain by this belt of rock, as it would just skirt along the north edge of the Black River Highlands and far to the south of Chippewa Hill on the west side of the river.

xxiii. (72). The exposure of this stratum and the next two or three below it occur in the west part of Sec. 15, T. 48 N., which is far east of the Black River. Also the exposures are on the east side of the Black River fault, and hence are thrown up or down the geological column according to the direction and amount of the throw of the fault. This flow is a melaphyre. The top is not exposed and neither is the bottom.

Sp. 20230. Sec. 15, T. 48 N., R. 46 W., 1000 N., 500 W.
Microscopic: The rock is an altered melaphyre in which is developed calcite, chlorite, epidote and magnetite. The feldspars are too much altered to determine further than that they are plagioclase. The augite is also altered.

xxiv. (73). Sandstone:—This sandstone outcrops in the bed of a creek in Sec. 15, T. 48 N., just below the melaphyre described immediately above. It is on the west side of the Black River fault and seems to give some argument that the throw is not great, since Dr. Lane found a sandstone in the river which seemed to be in place, and is not far off the line of strike of this stratum. Too much weight should not be put on this point, however, as the sandstone in the river may not be in place, and even if it is it may be another stratum. It was because of the outcropping of this sandstone in the creek bed that the stream is called Sandstone Creek in this report.

The sandstone is at least 100 feet and it cannot exceed this thickness very much as it is limited both above and below by melaphyres.

Sp. 20227. Sec. 15, T. 48 N., R. 46 W., 1000 N., 500 W. From the bed of Sandstone Creek.
Macroscopic: A very ordinary rather fine grained reddish brown sandstone.
Microscopic: A sandstone with a large amount of quartz grains. There is also considerable plagioclase, and some augite fragments. Calcite and epidote show between the particles. There is a larger amount of basic material than is common in the sandstones of this cross section save in the Nonesuch[1].

xxv. (74). Melaphyre:—Exposed in Sandstone Creek immediately below the sandstone. It has an amygdaloidal top. The thickness of the stratum is 100 feet.

Sp. 20232. This specimen is from Sandstone Creek. It is a very ordinary typical amygdaloidal melaphyre with amygdules of chlorite and laumontite.

[1] This is not unlike the Wolverine sandstone, Marvine's Cg. 9. L.

xxvi. (75). A melaphyre like 74. Only the top of this flow is exposed but there is enough to show that it is at least 40 feet thick.

xxvii. (76). Unexposed:—There is represented here a rock thickness of 1,400 feet. It is very probable that it is mostly underlain by basic rocks. At the bottom of this unexposed distance are boulders which are certainly very near to place, for they are very angular, so it becomes quite certain that the bottom at least is ophite.

xxviii. (77). Ophite:—Only bottom exposed.

xxix. (78). This is a more acid flow than is typical of the series. It is a feldspar porphyry.

Sp. 20234. Sec. 21, T. 48 N., R. 46 W. From the mouth of Sandstone creek.
Macroscopic: Reddish brown rock with a somewhat acid appearance. It has phenocrysts of coarsely striated feldspar 3 to 4 mm., as well as some which show no striae. A close search reveals an occasional small crystal of quartz, probably primary. This rock would if silica content alone were considered fall within Irving's quartzless porphyry.
Microscopic: The slide shows the rock to be a feldspar porphyry with poikilitic quartz. The phenocrysts of feldspar are mostly oligoclase. There are no quartz crystals showing in the slide.

xxx. (79). Unexposed:—The only indications as to what this 800 feet of rock is, are that both above (except 78) and below are ophites, and the whole river bed is filled with angular ophite boulders.

xxxi. (80). This ophite is exposed in the river in Sec. 21, T. 48 N., R. 46 W. These exposures show the largest augite crystals of any rock in the series. Some of the mottles are a full inch across, and we may infer a thickness of at least 500 feet.

xxxii. (81). This flow is quite like the one above, a very coarse lustre mottled melaphyre.

The contact of these two ophites is exposed in the river but the top of the top flow, and the bottom of the bottom flow are both covered. It is safe to say that each flow is more than 500 feet thick, a fact that is shown by the very coarse mottling, such as is seen on S. 20241.

There are several specimens from these flows but the description of one will be sufficient.

Sp. 20185. Sec. 21, T. 48 N., R. 46 W. From Black River.
Macroscopic: A coarse grained ophite with mottling a full inch across. The specimen is very fresh showing no weathering.
Microscopic: Augite crystals 20 mm., enclosing labradorite feldspar. Augite is more plentiful in this rock than in any previously met. There is no olivine, and the only suggestion that there might have been some originally, is the presence of a few magnetite particles; in any case olivine never could have been abundant.

These two flows where they show in the river in Sec. 21 show faulting. Almost no indication is given of the amount or direction of throw, but the rocks are so fractured and crumbled and broken as to strongly suggest rock movement. The indications are that the fault plane runs a little west of north which would connect it with the faulting in the river in Sec. 29, T. 49 N., and, indeed, it is probable that all these indications are of the same fault. The dip of the fault plane in all the cases is toward the east at a high angle.

xxxiii. (82). Unexposed:—This is the widest unexposed area in the whole cross section. It represents at a dip of 64° a rock thickness of about 8,500 feet. It is possible that there is a strike fault in this gap representing the continuation of the great fault that bounds the south side of the Keweenawan on Keweenaw Point, and, if so, this calculated thickness of 8,500 feet would be incorrect. The rocks above the space are basic, as are also the rocks below, and it is probable that the underlying rocks are also basic.

Division IX. The Porphyrites.

This division is a rather mixed division, because in it are melaphyres, both ophitic and non-ophitic, felsites, porphyrites which closely approach Irving's quartzless porphyries, and labradorite porphyrites, but of all these the last are the most conspicuous. This division might be called one in which are conspicuous labradorite porphyrites. There are labradorite porphyrites outside this division but they are not such that their nature is revealed at a glance like these. Besides the fact that in this part these rocks are conspicuous the division is also marked by the gabbro at its base. This division shows the greatest variety in the kind of rocks that build it up of all the divisions of the column.

It covers practically the north of the two Bessemer Ridges. All of the outcrops are shown in the hills which are so characteristic of the base of the Keweenawan about here. The most northerly exposures of the division are seen in Powder Mill Creek.

i. (83). This is a blue colored trap rock of which only the base is exposed.

ii. (84). Melaphyre 80 feet.

iii. (85). Blue trap 170 feet. This trap does not show any coarse grain, but is uniform in texture through the thickness of the whole flow. The exposures of it on Powder Mill Creek were not continuous and it is possible that the thickness taken here is made up of more than one flow. The possibility of overlooking a contact is greater since these dense blue rocks do not have important amygdaloidal zones, and sometimes none at all.

iv. (86). Labradorite porphyrite. Only the top of this flow is exposed. There is no amygdaloidal zone. The ground mass of this is like that of the two blue trap flows above and it is highly probable that these two flows would be found to be labradorite porphyrites if they were well examined, since in places in such flows the crystals are often not conspicuous. The phenocrysts of this flow which are red colored plagioclase feldspars will not exceed 2mm.

v. (87). Unexposed 150 feet.

vi. (88). A drab colored amygdaloid with amygdules of chlorite. Thickness 50 feet.

vii. (89). A blue colored labradorite porphyrite with a uniform grained ground mass through which is scattered a few crystals of feldspar which will not exceed 1mm. in length. In this flow are large secondary cavities as much as three inches across. These cavities are filled with laumontite. Thickness of flow 80 feet.

vii. (90). A gray fine grained trap that has no amygdaloidal zone. Thickness 80 feet.

ix. (91). This is another labradorite porphyrite. It is exposed in Powder Mill Creek, and also in a rock cut on the D. S. S. & A. Ry., Sec. 32, T. 48 N., R. 46 W., 350 N., and 650 W. In the creek there are a large number of plagioclase phenocrysts in a dense blue ground mass. These phenocrysts are tabular shaped and sometimes are as much as 20mm. across, but the majority are smaller. There is a tendency of these crystals to collect together. In the railroad cut the crystals are not nearly so numerous and hence not so conspicuous. The showing of numerous phenocrysts in one part of a labradorite porphyrite flow and not in another was seen to be true of other strata also. It does much to cause a change in the appearance of the flow, and hence a failure to recognize two separate outcrops as belonging to the same strata. In the railroad cut there are secondary cavities as much as eight or ten inches across filled with laumontite, most of which is in long crystals radiating from the centre of the cavity. Thickness 140 feet.

x. (92). Porphyrite:—This porphyrite has such characteristic properties that it can be readily traced and recognized. It has a reddish brown ground mass in which are numerous red tabular striated crystals of feldspar, which are more or less collected together in star like aggregations. These crystals are generally 6 to 8 mm. long although some are much larger. The flow does not show any amygdaloidal zone at all.

This rock is most conspicuously exposed in the bed of Powder Mill Creek, just north of the line between Ts. 47 and 48 N., where the stream has made a deep cut through the rock below the falls which are a few paces south of the line. There are also other outcrops of the rock lying toward the west and not far from the line since it is thrown back because of faulting. On the east side of the creek it is exposed north of the south corner of Secs. 32 and 33, T. 48 N. The stratum is exposed west of the area worked and the exposures were located as far west as the state line. It is exposed on the west side of the road at the foot of a hill, Sec. 9, T. 47 N., R. 47 W., 2,000 paces N., 1,200 paces west, and also 1,740 N., 2,000 west in the same section. This outcrop is also near the roadside. It also outcrops on the bank of the Montreal River at the Michigan-Wisconsin state line, in Sec. 9, T. 47 N., R. 47 W. The rock is exposed on both sides of the river.

The surface width of this rock is well exposed in Powder Mill Creek and is at least 250 feet, so there is a thickness of about 220 feet.

The rock appears at first glance like a labradorite porphyrite, but microscopic determinations show its feldspar of acid plagioclase variety.

Sp. 20208. From Powder Mill Creek just north of the township line.

Macroscopic: Porphyrite: This rock has very pronounced characteristics. The ground mass is a reddish brown color, and in it are numerous red phenocrysts of red plagioclase which are tabular shaped, and average from 6 to 8 mm. in diameter, but some of the largest are as much as 15 mm. Besides these crystals small crystals of lath shaped feldspar can be distinctly seen in the ground mass. The plagioclase crystals are largely collected together in star-like aggregations. The rock has a rather acid appearance and probably is more acid than the labradorite porphyrites.

Microscopic: Porphyrite; phenocrysts of plagioclase feldspar of oligoclase variety; the ground mass is made up of oligoclase crystals and a small amount of idiomorphic augite; a little quartz and a little chlorite are developed in the ground mass.

xi. (93). This red colored porphyrite has very characteristic properties that can be quite easily recognized. It outcrops quite often. It is exposed in the N. W. corner of the N. E. ¼ Sec. 3, T. 47 N. at the north foot of a high hill. It is also well exposed on Powder Mill Creek where the town line crosses, which is just below the falls. There are also numerous other exposures west of the creek, along with stratum 92. The two can be followed across T. 47 N. to the Michigan-Wisconsin state line. This stratum is a little more than 100 feet thick. It has no amygdaloidal top. It is a reddish colored rock thickly filled with small lath shaped crystals of striated feldspar about 2 mm. long. The rock is evidently more acid[1] than the average basic flow and yet it is much less acid than the felsites. In acidity it would probably compare well with the stratum immediately below it.

xii. (94). This is a very common looking gray trap rock without amygdaloidal top. It is exposed in several places but the best exposure is in Powder Mill Creek. The flow is 60 feet thick.

xiii. (95). Felsite:—Excepting the Chippewa felsite this is the most acid rock in the Black River section of the Keweenawan series.

It is exposed in Sec. 3 T. 47. N., R. 46 W., at the north foot of the rock hill in the north part of the section. It is also exposed on both sides of the road that runs north from the north ¼ post of Sec. 4 and can be easily traced for several paces on the east side of the road. Other exposures are 80 paces north of the south corner of Sec's. 32 and 33, T. 48 N., in Powder Mill Creek just north of the town line, and extensively in Sec. 6, T. 47 N., 2,000 paces north and from 1,500 paces west to near the west corner. This felsite shows flow structure in several places, the most conspicuous being along the north line of Sec. 6. The rock has a very acid appearance but in no place is that appearance so pronounced as in the Chippewa felsite. The specimens vary in color from a chocolate brown to a deep reddish brown. In no place does it break with the clear fracture and knife like edges that the Chippewa felsite in the river breaks with. It seems to crumble in the same manner as the Chippewa felsite where it is weathered, and also seems to be affected chemically.

There are a few very small phenocrysts of quartz, but they are so few and so small that they are found only by searching carefully. In some of the specimens quartz cannot be seen at all. Phenocrysts of orthoclase 2 to 3 mm. are very plentiful, and there are some as large as 5 mm. There are also some crystals of plagioclase.

A peculiar thing about this felsite is that it has an amygdaloidal top. The amygdaloidal zone is not thick, but in it there are numerous cavities all of which are small, none exceeding 4 mm. They are nearly all filled with crystalline quartz and agate but there is some epidote and some chlorite. These cavities differ from those in the basic rocks in that these are elongated and lens shaped, while those in the basic rocks are generally nearly spherical, except, of course, the pipe amygdules at the base of the flows.

The thickness of this rock is about 165 feet. The dip was taken as 65° N.

As this felsite flow and the two porphyrites below it are traced along their strike they show very conclusively several faults in which the east side is thrown south. These faults are considered under the chapter on faulting.

S. 20244. Sec. 10, T. 47 N., R. 46 W. From the north foot of the hill in the north part of the section.

Macroscopic: This specimen comes from the amygdaloidal zone of the felsite. The cavities are numerous, but are much smaller than those in the basic rocks. They are for the most part lens shaped. The fillings are mostly quartz and agate, but there are also some of chlorite and some epidote. There are a great many orthoclase phenocrysts from 2 to 4 mm. long. The ground mass is fine grained and dense, and has a chocolate brown color. The rock is distinctly acid in appearance.

Microscopic: The ground mass is a deep reddish brown so intensely colored as to be almost opaque. There are crystals of orthoclase feldspar from 2 to 3 mm. long. There is also some magnetite which is probably primary. There are numerous amygdules, all elongated in the same direction; these amygdules are filled with quartz, epidote and chlorite. The rock is a felsite.

[1] "Salic" or feldspathic; this felsitic horizon indicated by flows 85 to 95 may connect with the one indicated by Irving in Plate XXII of his Monograph V. U. S. Geol. Survey, as crossing the Gogogashugun on the north line of Sec. 8, T. 46 N., R. 2 E. of the Wisconsin meridian.

Sp. 20133. Sec. 5, T. 47 N., R. 46 W., 2000 paces N., 100 W.
Macroscopic: An acid looking rock with a chocolate brown color. There is a fine grained ground mass in which there are numerous phenocrysts of orthoclase and a few of striated feldspar. There is a slight appearance of banding but it is only slight.
Microscopic: A spongy ground mass of poikilitic quartz in which is scattered numerous crystals of orthoclase. Besides these small crystals of feldspar there are a few phenocrysts the majority of which are oligoclase. There are some of orthoclase. The relative proportion of oligoclase and orthoclase as shown in the thin section is misleading as the hand specimen shows that the orthoclase phenocrysts are the more important.

Other specimens from this felsite which are much different from those described above might be described. The same fact is brought out as was seen in studying the Chippewa felsite, namely, that pebbles in the Keweenawan Conglomerates that differ much in appearance may come from the same acid flow.

Where this felsite shows along the north line of Sec. 6, T. 47 N. there is an ophite not far above, in fact almost in contact. On Powder Mill Creek there are several exposures above and no showing of any ophite. This may be indication of a fault, and is considered in the chapter where the faults of the district are discussed.

Some of the basal members of the Keweenawan were traced as far west as the state line. The flows just above this felsite were readily traced to the line but the felsite itself and a few flows below could not be located, and it seemed almost certain that they were pinched out. The whole thing considered together seemed to indicate a strike fault.

xiv. (96). This labradorite porphyrite is seen in contact with the felsite which lies above it about 100 paces N. E. from the south ¼ post of Sec. 32, T. 48 N. It is also exposed below the felsite along the north line of Sec. 6, T. 47 N., and may be traced for some distance. The flow is 60 feet thick. It is not so rich in phenocrysts as some of the labradorite porphyrites. The ground mass is of a drab color and is very fine grained and dense. The phenocrysts are 8 to 10 mm. long. There are only a few amygdaloidal cavities at the top, the flow being almost without an amygdaloidal zone.

xv. (97). A fine grained basic rock with a very thin amygdaloidal zone at the surface.

Sp. 20131. 2,000 p. N., 650 p. W., Sec. 4, T. 47 N., R. 46 W.

Macroscopic: The hand specimen is very fine grained gray colored rock with a very uniform texture and appearance. It has an occasional amygdule of quartz.
Microscopic: A fine grained augite porphyrite of the Minong type, with oligoclase feldspar of two generations.

xvi. (98). This is the most conspicuous labradorite porphyrite of the whole Black River section. It has numerous phenocrysts of plagioclase feldspar, many of which are as much as 30 mm. long. It can be traced for several miles without any danger of error because of its marked characteristics.

It is conspicuously exposed in a bare hill in the N. W. ¼ of the N. E. ¼ Sec. 3 T. 47 N., R. 46 W. It is again exposed in the S. W. ¼ of the S. E. ¼ Sec. 33, T. 48 N., and can be traced for more than a hundred paces. Other exposures occur along the town line about 200 paces west of the north ¼ post Sec. 4, T. 47 N. Again there are exposures on Powder Mill Creek a few paces south of the town line, and still others about 200 to 300 paces east. It is again exposed 250 paces south and 250 paces east of the N. W. corner Sec. 5, T. 47 N., and also a few paces south of the N. W. corner of the township. Boulders were found west but the ground where it should occur is low and not favorable for outcrops. Near the state line it does not outcrop and it seems to be pinched out suggesting the probability of a fault.

All of these exposures show a strike of N. 80° E. or thereabout, hence there must be considerable faulting in order that the exposures may occur where they do. In every case the east side is thrown south.

The flow has an amygdaloidal top but it is not conspicuous.

The thickness of the stratum is 250 feet.

Sp. 20145. Sec. 5, T. 47 N., R. 46 W., 1500 N., 2000 W.

Macroscopic: The rock is a labradorite porphyrite. The ground mass is a reddish gray color. In it can be seen numerous lath-shaped crystals of feldspar. Besides these small crystals there are phenocrysts of striated feldspar 20 to 30 mm. long.

Microscopic: The ground mass is largely made up of crystals of labradorite feldspar only a fraction of a millimeter long. There is also some augite in the ground mass but there is nothing of ophitic texture. The amount of serpentine and magnetite that is present suggests that there was probably a very considerable amount of olivine. The olivine is not weathered to iddingsite which was the common weathering in the ophites above. Some of the magnetite is probably original. The most conspicuous thing in the section is a number of large labradorite phenocrysts.

xvii. (99). Below this coarse labradorite porphyrite is a gray amygdaloidal melaphyre 120 feet thick.

xviii. (100). A blue trap much like the other blue traps described. Exposures of this rock are seen in the cleared field about 200 paces S. 60° W. from the N. ¼ post Sec. 4, T. 47 N. Thickness 200 feet.

xix. (101). The next flow is a porphyrite and so far as silica content is concerned it must be very near to Irving's quartzless porphyry. It is not so acid as the Chippewa felsite, nor even stratum 95. No very great error would be made if this rock were called a felsite. It has a dense aphanitic appearance. There is an occasional small phenocryst of feldspar but so small as to scarce be seen by the unaided eye. The flow has no amygdaloidal top. There is no flow structure, the closest approach being a marked tendency to cleave parallel to the strike of the formation and also to weather in such a manner as to suggest banding.

The rock is exposed in Powder Mill Creek a few hundred paces above the town line but the most conspicuous exposures are in Sewer Creek in Sec. 10, T. 47 N., along the D. S. S. & A. Ry. spur line that runs into Bessemer.

Sp. 20248. Sec. 10, T. 47 N., R. 46 W. From the bed of Sewer Creek.

Macroscopic: The specimen is very fine grained and has a very uniform texture. There is an occasional exceedingly small crystal of feldspar. There are numerous dark green patches elongated in a similar direction faintly suggesting banding. These patches probably receive their color from chlorite that has developed and are elongated because the structure of the rock allows weathering more readily in one direction than in another. This may be a faint trace of flowage. The rock has an acid appearance.

Microscopic: A fine grained ground mass made up of quartz and very small crystals of feldspar. The thin section is very heavily stained with iron oxide. Chlorite is developed in spots, and it is probably this chlorite that causes the green color in the hand specimen.

The thickness of this flow is 140 feet.

xx. (102). This flow is exactly like the one above it and any descriptions of the one are almost equally applicable to the other.

The thickness of this flow is 230 feet.

Strata 101 and 102 are exposed both in Powder Mill Creek and in Sewer Creek. It is known from the other strata that there is a fault running nearly north and south in Bessemer Gap lying north of Bessemer. These last two strata show that the fault must lie east of Sewer Creek, and, hence, very close to the rock hill that lies in the east part of Sec. 10.

xxi. (103). An amygdaloidal melaphyre exposed in Sewer Creek along the D. S. S. & A. Ry. spur line. Thickness 80 feet.

xxii. (104). An amygdaloidal melaphyre exposed in Sewer Creek along the spur line of the D. S. S. & A. Ry. Thickness 70 feet.

xxiii. (105). An amygdaloidal melaphyre exposed in Sewer Creek. Thickness 50 feet.

xxiv. (106). Next to these melaphyres is a porphyrite exactly like 102 and 103. Its thickness is 90 feet.

xxv. (107). Amygdaloidal melaphyre.

xxvi. (108). Unexposed 500 feet.

xxvii. (109). This bed is a volcanic agglomerate. It is exposed in the bare rock hills on the County Farm. It is 80 feet thick.

xxviii. (110). Ophite:—Only 20 feet of the thickness of this flow is exposed, both the top and the bottom being covered.

xxix. (111). Amygdaloidal melaphyre. Thickness 100 feet.

xxx. (112). Amygdaloidal melaphyre 50 feet.

xxxi. (113). Amygdaloidal melaphyre 100 feet.

xxxii. (114). A basic flow with a clinkery volcanic agglomerate top. The thickness of the flow is 30 feet and the agglomerate portion 10 feet.

xxxiii. (115). The next 240 feet shows only one small outcrop and that is ophite.

xxxiv. (116). Amygdaloidal melaphyre having a thickness of 120 feet.

xxxv. (117). Amygdaloidal melaphyre 60 feet.

xxxvi. (118). Amygdaloidal melaphyre with a clinkery top 100 feet.

xxxvii. (119). Amygdaloidal melaphyre 30 feet.

xxxviii. (120). Amygdaloidal melaphyre 30 feet.

xxxix. (121). Amygdaloidal melaphyre 90 feet.

xl. (122). Amygdaloidal melaphyre 140 feet.

xli. (123). Unexposed 170 feet.

xlii. (124). Augite porphyrite:—Only the base of this flow is exposed where it is seen in contact with the gabbro (stratum 125) that lies immediately below it. Exposures are seen in Sec. 4, T. 47 N. 890 N., and 1,500 W. and Sec. 5, 700 N., 400 W., and Sec. 6, 400 N., 1,550 W.

Division X. The Gabbro.

The only rock in this division is a gabbro. It is, I think, the only horizon of the Bad River Gabbro seen in Michigan, and to Dr. Lane belongs the credit of its discovery.

Outcrops are seen in Sec. 4, T. 47 N., 840 N., 1,550 W., Sec. 5, 700 N., 100 W., also 650 N., 400 W., Sec. 6, 300 N., 1,550 W., and in Sec. 2, T. 47 N., R. 47 W. The outcrop in Sec. 4, T. 47 N., which is about 125 paces long, is in a cleared field. It lies at the south foot of a hill and since it weathers so much more nearly white than the other rocks it can be seen for some distance, being plainly visible from the north and south road that runs along the centre line of Sec. 4, although it is a quarter of a mile distant. The more easterly outcrop in Sec. 5 is also in a cleared field. The other outcrop in the same section is on the east bank of Powder Mill Creek and can be readily found by any person who wishes to look for it. The outcrop in Sec. 6 forms a low hill but is not conspicuous. This outcrop is about 50 paces long east and west. The outcrop in Sec. 2, T. 47 N., R. 47 W. is just behind a farm house. Boulders were found nearly a mile west of this last outcrop so plentifully that there can be no doubt about their being close to place. The gabbro was searched for very carefully from this point west to the state line, but not the least indication of it could be found anywhere. Yet the places where it would have occurred, if it retained its strike, were all low, and not favorable for outcrops. It was traced in all about five miles along the strike of the formation. There is a space about three miles between the most westerly outcrop and the state line. It was not found at all east of Bessemer gap nor were there any boulders in any place to suggest that it might be near.

The lower contact is not exposed in any place, but there is a rock occurring below it a short distance on the east bank of Powder Mill Creek limiting the distance that it may extend downward. The upper contact is seen in every exposure, except one, in the area worked by us. There is above the gabbro an augite porphyrite.

The greatest exposed width of gabbro is about 125 feet, and the exposures on the east bank of Powder Mill Creek show that the thickness of the stratum cannot exceed 200 feet.

Sp. 20192. Sec. 4, T. 47 N., R. 46 W., 840 N., 1500 W.
Macroscopic: Gabbro. There is a very large amount of striated feldspar, some of the crystals of which are as much as 20 mm. long. Between the feldspar crystals there is augite. There is some magnetite.
Microscopic: A very large proportion of labradorite feldspar; some augite; a comparatively large amount of magnetite apparently partly primary and partly secondary. Chlorite is strongly developed.
Sp. 20200. Sec. 4, T. 47 N., R. 46. W.
Macroscopic: Gabbro.
Microscopic: A much altered gabbro with labradorite feldspar. There is micropegmatite in the interstices.
Sp. 20196.
Microscopic: Gabbro; marked olivine; enstatite; diallage; labradorite; and micropegmatite.

The gabbro appears with eruptive flows above and below. Considering its coarse grain and position it seems almost certain that it is a sill, for although intrusive it appears in this area to be at a constant horizon.[1]

Division XI. The Lowest Keweenawan Effusives.

Below the gabbro just described is a series of melaphyres among which are some labradorite porphyrites. The melaphyres are amygdaloidal with fillings largely of crystallized quartz and agate, but there is a very considerable amount of chlorite also. The labradorite porphyrites, save one flow, are not conspicuous as they were in Division IX, and in many cases it requires a close macroscopic examination to see that there are phenocrysts of feldspar.

The thickness of this division is about 3,000 feet. The strike is the same as shown through the whole Black River area, N. 80° E., and the dip is greater than that of any of the rocks north being nearly 75° N.

The exposures of the lower part of the division are numerous, being largely in the bare hills that form the south Bessemer Ridge. The north part of the division lies somewhat between the two ridges and is not so well exposed. But even with these numerous exposures it is difficult and, in fact quite impossible to tell the number of flows because of the number of false tops and bottoms that are to be seen.

[1] See also Chapter VIII L.

i. (126). This melaphyre shows below the gabbro Sec. 5, T. 47 N., R. 46 W., 600 N., 400 W., on the east bank of Powder Mill Creek. Neither the top nor the bottom of the flow is exposed. The contact with the gabbro is not seen but this flow places a downward limit to the possible extent of the gabbro.

ii. (127). Unexposed 300 feet.

iii. (128). Melaphyre with neither top nor bottom exposed.

iv. (129). Unexposed 200 feet.

v. (130). Melaphyre with only bottom exposed.

vi. (131). Amygdaloidal melaphyre with only top exposed.

vii. (132). Unexposed 80 feet.

viii. (133). Melaphyre, bottom only.

ix. (134). Melaphyre, top only.

x. (135). Unexposed 500 feet.

xi. (136). Melaphyre, bottom only.

xii. (137). Amygdaloidal melaphyre 60 feet.

xiii. (138). Amygdaloidal melaphyre 40 feet.

xiv. (139). Amygdaloidal melaphyre 100 feet.

xv. (140). Amygdaloidal melaphyre 120 feet.

xvi. (141). Amygdaloidal melaphyre with only the top exposed.

xvii. (142). Unexposed 160 feet.

xviii. (143). Amygdaloidal melaphyre exposed for 80 feet at the bottom.

xix. (144). Amygdaloidal melaphyre 40 feet.

xx. (145). Amygdaloidal melaphyre top only exposed.

xxi. (146). Unexposed 150 feet.

xxii. (147). Amygdaloidal melaphyre 70 feet.

xxiii. (148). Amygdaloidal melaphyre 40 feet.

xxiv. (149). Amygdaloidal melaphyre 30 feet.

xxv. (150). Amygdaloidal melaphyre 20 feet.

xxvi. (151). Amygdaloidal melaphyre 20 feet.

xxvii. (152). Amygdaloidal melaphyre 40 feet of top.

xxviii. (153). Unexposed 500 feet.

xxix. (154). Melaphyre, bottom 80 feet exposed.

xxx. (155). Amygdaloidal melaphyre 60 feet.

xxxi. (156). Amygdaloidal melaphyre 40 feet.

xxxii. (157). Amygdaloidal melaphyre 40 feet.

xxxiii. (158). Amygdaloidal melaphyre 80 feet.

xxxiv. (159). Amygdaloidal melaphyre 40 feet.

The melaphyre flows from 126 to 159, inclusive, are practically all alike. They are composed of plagioclase feldspar, augite, olivine and nearly all seem to have some magnetite as a primary mineral. The feldspars are for the most part oligoclase although there are some that have feldspar more basic. The augite is not strikingly abundant, and while it encloses feldspar crystals to some extent the texture is not nearly so pronounced as in the flows in some of the higher divisions, nor, indeed, is it so pronounced as to attract attention. It can scarcely ever be noticed in the hand specimen, in the rocks of this division. As usual the augite is weathered with the resultant development of chlorite. The flows seem to be more acid than the average melaphyre flow resulting in a marked development of secondary quartz both in the ground mass of the rock and as cavity fillings. The flows all have amygdaloidal tops, with amygdule fillings of chlorite and quartz, much of which is in the form of agate. The pipe amygdules at the base represent quite a noticeable feature, although they are not always present, nor is their presence or absence divided according to flows for they are present in some parts of a flow and absent in other parts of the same flow.

xxxiv. (160). Labradorite porphyrite 40 feet. The phenocrysts in this flow are not conspicuous but they can be readily seen when the rock is closely examined.

xxxv. (161). Labradorite porphyrite 30 feet. This labradorite porphyrite is very conspicuous, and its phenocrysts, some of which are 20 mm., will attract attention at a glance. It is the most pronounced labradorite porphyrite of the whole Black River series except stratum 98. In some parts the phenocrysts are thickly crowded together, but in others they are not so plentiful. As one follows along the number of phenocrysts is seen to decrease and increase. The flow is well exposed along the line 1,700 paces north between Secs. 8 and 9, T. 47 N., R. 46 W., and can be traced a short distance both east and west. It is also exposed on the bare rock hills in Sec. 10, but on the top of the hill it may be passed over unnoticed because the feldspar phenocrysts are not plentiful there. Near the edge of the bluff the number of crystals is greatly increased and the flow will be quickly recognized as that which is exposed on the hill to the west of Bessemer Gap.

xxxvi. (162). Labradorite porphyrite 40 feet. The feldspar phenocrysts are plentiful but not large.

xxxvii. (163). Amygdaloidal melaphyre 100 feet.
xxxviii. (164). Amygdaloidal melaphyre 60 feet.
xxxix. (165). Amygdaloidal melaphyre 50 feet.
xl. (166). Amygdaloidal melaphyre 60 feet.

The cavity filling of the above four melaphyres is mostly quartz.

xli. (167). Labradorite porphyrite 100 feet.
xlii. (168). Labradorite porphyrite 40 feet.
xliii. (169). Labradorite porphyrite 30 feet.
xliv. (170). Labradorite porphyrite 30 feet.
xlv. (171). Labradorite porphyrite 50 feet.
xlvi. (172). Labradorite porphyrite 70 feet.
xlvii. (173). Labradorite porphyrite 50 feet.
xlviii. (174). Labradorite porphyrite 50 feet.
xlix. (175). Labradorite porphyrite 50 feet.
l. (176). Labradorite porphyrite 50 feet.

The above labradorite porphyrites total a thickness of about 500 feet. The porphyritic nature of the rock is not so conspicuous as to be noticed at a glance as were the labradorite flows in Division IX. However, many of the phenocrysts are as much as 8 mm. Most of the phenocrysts are smaller and often it requires rather close macroscopic examination to see that the rock is a labradorite porphyrite.

The flows described above are exposed in the south Bessemer Ridge on both sides of Bessemer Gap.

li. (177). Amygdaloidal melaphyre 100 feet.
lii. (178). Amygdaloidal melaphyre 30 feet.
liii. (179). Amygdaloidal melaphyre 80 feet.

liv. (180). Amygdaloidal melaphyre 30 feet.
lv. (181). Amygdaloidal melaphyre 50 feet.
lvi. (182). Amygdaloidal melaphyre 30 feet.
lvii. (183). Amygdaloidal melaphyre 80 feet.
lviii. (184). Amygdaloidal melaphyre 30 feet.
lix. (185). Amygdaloidal melaphyre 30 feet.
lx. (186). Amygdaloidal melaphyre 30 feet.
lxi. (187). Amygdaloidal melaphyre 70 feet.

These last eleven flows are quite alike. They have marked amygdaloidal tops, and generally an amygdaloidal zone at the base in which pipe amygdules are very plentiful. The chief cavity filling is silica but there is also much chlorite. The primary minerals are feldspar, olivine and augite, and apparently some magnetite. The olivine is weathered, but it does not tend to develop that biotite-like substance that was seen in the higher divisions. The feldspar is, generally speaking, oligoclase. The augite is not abundant as compared with the amount of feldspar. While it always encloses some of the feldspar crystals the ophitic texture is not at all important. These flows contain quite a quantity of clasolitic matter which is practically all quartz.

These are the lowest flows of the Keweenawan series and lie upon the basal sandstone. They are exposed across the area worked and, no doubt, could be traced east and west for the hills along the base of the series are quite bare.

Division XII. The Basal Sandstone.

This Basal Sandstone is the lowest stratum of the Keweenawan series. It represents a time between the laying down of the iron rocks and the beginning of Keweenawan eruptive activity.

It is made up of well assorted and well rounded material. It is composed almost wholly of quartz grains which are only a small fraction of a millimeter in diameter. There is no tendency anywhere to become conglomeritic. The grains are more closely cemented together than those of the other sandstones of the Keweenawan series, and in this respect it is more nearly a quartzite; but it is not a quartzite; it will probably be expressing it well to say that it is on the road from a sandstone to a quartzite.

The exposed thickness of the sandstone will not exceed 200 feet. There is a distance of about 2,500 feet from the lowest exposure of sandstone to the highest exposure of graywacke beneath, but it is not known how this intervening space is underlain. The strike of the rock is N. 80° E., and the dip 75° to 80° N.

It is exposed along the south foot of Bessemer Ridge in Sections 8 and 9, T. 47 N., R. 46 W., and also near the west side of Sec. 7. There are no exposures that we could find on the east side of Bessemer Gap, although there is some loose sandstone at the foot of the bluff which appears to be near to place. It is also exposed north of Ironwood in R. 47 W.

Near Bessemer it has been quarried to a small extent, and at Ironwood, about a half mile north of the fair-ground. Some men were quarrying it in 1905, but no great amount had been taken out. There seems to be no reason why it might not be a fair building stone.

General Remarks.

The Keweenawan rocks lie above, and are younger than the rocks of the Penokee-Gogebic iron series. Whether there is an unconformity between these two series or not cannot be said from any evidence that was obtained from the Black River work.[1] There is a space of nearly a half mile between the lowest exposures of the Keweenawan, and the highest exposures (graywackes) of the Penokee-Gogebic. The strike of the two formations is about the same N. 80° E. The dip of the base of the Keweenawan is a little greater than that of the graywackes which is about 55° N. But the closest exposures of the Keweenawan to the graywackes where the dip was taken seem to have a less dip than those rocks a little further north in the same series, which seems to suggest that the dip might have been affected by something that acted on both series alike. And, indeed, it is probable that the Bessemer fault which passes close to these outcrops has affected both series. A very complete discussion of possible conformity and unconformity is given by Irving and Van Hise in their Penokee-Gogebic monograph[1] and reference is made to that for a full discussion of the question.

Keweenawan Time seems to have been inaugurated by a period of quiet as is indicated by its basal sandstone with its well assorted material and ripple-marks. Succeeding that comparative short period of quiet came a period of eruptive activity. This period seems to have broken in suddenly and to have been violent as is indicated by the unmixed column of eruptive material. It seems to have died out gradually as is indicated by the ever increasing proportion of sediment as we go up in the series. When the Lake Shore Trap was thrown out the period of eruptive activity was at an end. After this there is a great column of sedimentary material beginning with a coarse conglomerate and changing gradually to finer material and finally becoming a sandstone.

The flows are for the most part thin, but few exceeding 100 feet in thickness, although there are at least two ophites and one felsite that will reach 500 feet. They represent every degree of acidity from the very basic melaphyres up to the very acid felsites. If one were to take a specimen from every flow in the series and arrange them in order of acidity there would be a very complete set and a very gradual gradation. With this steady grading from basic melaphyre complicated by every phase of texture, naming often becomes a very difficult task.

The basic flows have for the most part amygdaloidal tops and massive centres. However, some basic flows have no amygdaloidal tops and others almost none. Generally there is at the base a thin amygdaloidal zone, prominent in which are pipe amygdules. But these pipe amygdules are not always present. Often one can trace along the base of a flow and see conspicuous pipe amygdules, but in only a short distance the same flow shows no amygdaloid of any kind at the base, but is completely massive. The acid flows are, generally speaking, without amygdaloidal tops but yet stratum 95 which is one of the most acid of the whole column has a marked amygdaloidal top. Generally the labradorite porphyrites are not so amygdaloidal as the other basic flows.

These amygdaloidal zones are liable to appear at any portion of a

[1] U. S. Geological Survey, Monograph XIX.

flow which may have been a surface for any period of time, and the pipes may appear at any part of a flow that represents a base of a moving lava which includes a part of a flow moving upon another part of the same flow. Very often there are what may be described as false tops and false bottoms. There is no reason why a tongue of a flow could not reach out ahead of the main flow and then be overtaken possibly because of an extra gush from the opening from which the lava issues. In such a case the top of the tongue would be amygdaloidal and the base of the portion overflowing it would be very liable to have pipe amygdules. Such seems to be exactly what has occurred in many places, examples of which can be seen on the bare trap hills northwest of Bessemer. These hills have been burned over so that the rocks are pretty well uncovered. There are places that seem to show a flow 5, 10, 15, or 20 feet thick, but when these apparent flows are traced in either direction they are seen to narrow down at both ends which would be the case with a tongue cut at right angles to the line of motion, or to narrow down at one end and the contact cease abruptly at the other which would be the case with a tongue cut in the direction of the line of motion. Such tongues were found, from those very small, up to those that were readily mistaken for flows. Some very large ones were traced and there can be no reasonable doubt but that many larger ones would be seen if the soil covering could be completely removed. This one difficulty alone is enough to cause great error in compiling a cross-section in which the flows are denoted, and the difficulty is even more applicable to drill sections than to surface exposures. The cross-section taken from the hills on the east side of Bessemer fault does not agree with the section taken on the west side and this is one of the sources of error. It is highly probable that some of the flows 10 feet thick given in the geological column in this report are merely tongues of other flows and, indeed, some of the much thicker flows could easily be the same. This difficulty becomes of some importance when the flow under consideration appears in the geological column along with many others lithologically like it, which is exactly the case at the base of the Keweenawan. Among other strata such as the labradorite porphyrites the flows can be separated quite readily because each has such distinct characteristics that it is readily recognized.

Another difficulty that might be mentioned, though only a small one, is the change in character of some of the labradorite porphyrites because of the change of the number of phenocrysts visible. Stratum No. 161 near the base shows numerous phenocrysts in some places and is the most conspicuous labradorite porphyrite of the whole series save No. 98. Such is the case where it is exposed on the hill to the northwest of Bessemer. But trace that same stratum 100 paces in either direction and there is such a decrease in the number of phenocrysts that it would not be recognized as the same flow. All along the flow there is a very marked decrease and increase in the number of feldspar crystals. Another similar example is the labradorite porphyrite flow exposed in the D. S. S. & A. Ry. cut in the S. W. 1/4 of the S. W. 1/4 of Sec. 33, T. 48 N., R. 46 W. At this point there are comparatively few phenocrysts, but the same rock is exposed in Powder Mill Creek and is rich in crystals. The adjacent flows leave no doubt about it being the same flow.

Apparently these flows were laid down under water. The evidence for this is the large amount of interbanded sedimentary material. Besides that noted in the column as compiled there are numerous thin seams from a quarter of an inch up to two or three inches, or even more. Where there is a pocket that was formed in the top of a lava flow it is filled with sedimentary material.

The vast amount of material in the Keweenawan series is basic but there is a very considerable amount of acid material also. On the other hand the great amount of the sedimentary material is acid but there is basic. (See Fig. 22). Since this sedimentary material was apparently derived from the Keweenawan itself things seem to have gone aside a little from what would naturally have been expected. The Nonesuch is the only basic sedimentary formation. The appearance of this basic sandstone and shale suggests that there is a more or less important break at the beginning of its formation that the basic eruptive members of the Keweenawan were being tilted and exposed to the degrading influences of nature, and the basic material thus derived was carried down and deposited. There is a thin conglomerate band in the sandstone about ten feet below the Nonesuch which is richer in jasper pebbles than any other part of the Outer Conglomerate is, and it may be that this also is an indication of the time break.

The highest strata exposed on Black River show a northward dip of about 20°, while the base of the Keweenawan is tilted to about 75° to 78°. The change of dip is gradual and there is no evidence of time break in the series except the one mentioned above as possible at the base of the Nonesuch. There is almost certainly no time break at all between the Upper and the Lower Keweenawan. It is difficult to say when the tilting took place. There is a small amount of basic material in the Outer Conglomerate which might suggest that the basal members were exposed during the latter part of Keweenawan time. But the amount of basic material is so small that it could be readily derived without the strata being tilted, and, indeed, it seems that, if the whole base had been tilted and exposed, there would have been a very large amount of basic material in the sedimentary portions, much larger than really does appear. True the basic material would not stand the wear and weather action that the acid material does, but the material between the pebbles is not basic, nor is the cementing material that which would be derived from decomposing basic rocks. It is possible that the dipping is caused by a great strike fault at the base, but this is only a suggestion, a possibility, because no proof of such fault was seen.

One of the most noticeable features is that the amount of acid sedimentaries is greater than the amount of acid material in place. Possibly there were large acid knobs caused by the viscosity of the material and these knobs wearing down gave the material for the acid sedimentaries. Certain it is that the acid strata in sight could not yield sufficient material to build up the sedimentary rocks that have been built up.

CHAPTER IV.

FAULTS.

In the Keweenawan.

There can be no doubt but that the Keweenawan rocks in the vicinity of Bessemer are much faulted. Some of the faults are quite important while others are small. There are several dip faults and it is probable that there are several strike faults also.[1] The dip faulting seems to be a series of step faults.

The Bessemer Ridges are broken through by a series of north and south gaps which vary in width from those very narrow to those nearly a mile across. These gaps are prominent near Bessemer in our area and are distinctly seen both east and west of where we worked. It is known that these gaps near Bessemer are caused by faulting of the strata and it is probable that those both east and west are from the same cause.

Bessemer Gap, Pl. XXXIV, directly north of the city of Bessemer is about three-quarters of a mile wide. There are some very characteristic strata, such as labradorite porphyrites and a felsite, showing on either side of the gap. These strata show that there is a horizontal throw of about 1,500 feet, the east side being thrown toward the south. While the throw is 1,500 or 1,600 feet on the north side of Bessemer Ridge it is not more than 1,000 or 1,100 on the south side of the same ridge which means that the throw decreases as we go toward the iron series, which underlies the copper rocks. It is difficult to say how far north the fault extends. There is evidence that there is a fault almost in line with it running almost north and south generally following the direction of Black River, and showing in the stream bed in Sec. 29, T. 49 N., R. 46 W. While it is possible that these are the same fault it seems best here to consider them otherwise and to end this Bessemer fault at the north side of Bessemer Ridge. The reason for separating them will be given when the fault showing in the river bed is discussed.

The Bessemer fault has caused a dragging of the strata on the west edge of the bluff in Sec. 10, T. 47 N., so that it strikes more nearly east and west than elsewhere. This is evidence that the fault plane lies near the bluff, which may be taken as a fault scarp. In addition to this evidence strata continue east outcropping in Sewer Creek in the N. W. ¼, Sec. 3, T. 47 N., leaving only a small distance within which the fault plane must lie. It seems certain that the fault plane lies close to the north and south centre line of Sec. 3. It trends a little west of north.[2]

For convenience of reference I shall call the fault just described the "Bessemer Fault."

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1 Sudden variations in the amount of throw of the other class of faults suggest this.
2 There are a prominent set of tension joints in this direction. L.

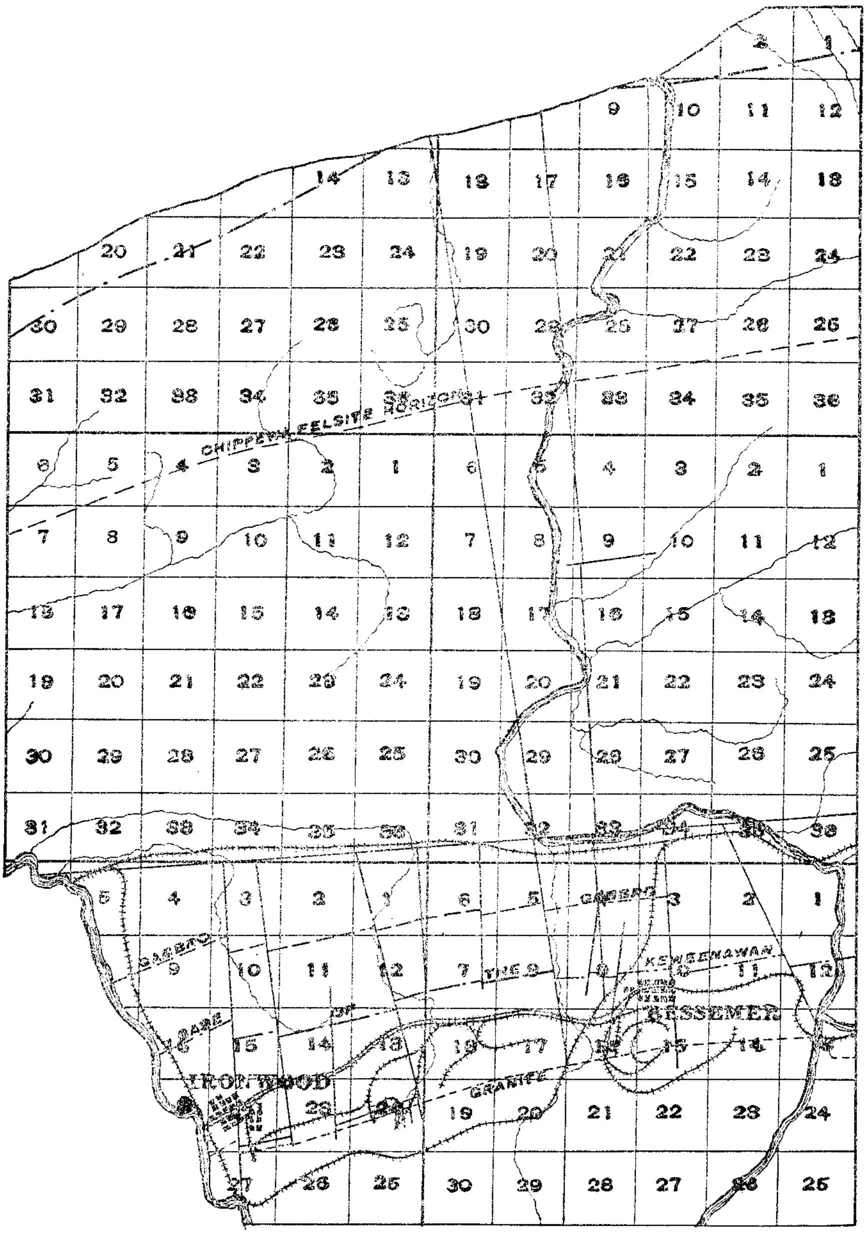


Fig. 24. Sketch of possible faulting system, Bessemer to Ironwood. L.

Along the centre line of Sec. 9, T. 47 N., R. 46 W., about 800 paces south of the quarter pin between Secs. 4 and 9, there is some faulting at the west end of the hill. At this point the basal sandstone is seen in contact with the overlying eruptives. The amount of throw, which is 80 feet, is easily seen because of the sandstone. The east side is thrown south. There is a thin seam of sandstone between two flows which also shows the same throw. Two hundred paces west there is another fault, this time in the opposite direction for the sandstone is thrown back to its original position and fifty feet more. The direction of the first of these two small faults is N. 30 W.,[1] and that of the second nearly north and south.

Another fault runs nearly north and south along the bed of Powder Mill Creek and might be called the Powder Mill Creek Fault. There can be no doubt of its existence because the strata along the creek give the evidence too plainly. The fault cannot be seen in the creek below the line between Townships 47 and 48 because at this point the stream makes a sudden jog to the east and leaves the line of weakness made by the fault. South of the town line there is every evidence of a fault and since it shows along the stream so far as there are rock outcrops it is apparent that the stream has followed the line of weakness made by the fault.

The first stratum to give unmistakable evidence is the coarse grained labradorite porphyrite No. 98. It is well exposed on one side of the creek while there is directly along the line of strike, and not more than 50 feet away, a melaphyre on the opposite side. The labradorite porphyrite shows on the west side of the stream down about 350 feet which is proof that there is a fault with that amount of throw. Farther up stream the gabbro comes to the east bank of the stream but where it should appear on the west side there is a melaphyre. Down stream there are numerous gabbro boulders, evidently very near place, but no outcrop. The basal sandstone also shows unmistakably a throw of about 350 feet the east side being thrown south. This fault has the same direction of throw as the Bessemer fault and has about one-quarter the amount of throw.

There is another fault running nearly north and south across the Bessemer Ridges, the evidence of which shows in Secs. 6 and 7. The fault is about a quarter of a mile west of the line which marks the east side of the two sections. The proof of faulting is given chiefly by the strata that are exposed near the town line in Powder Mill Creek and west toward the range line, strata Nos. 91 to 100. Besides this evidence there is the suggestive fact of a gap running north and south through the ridges.

The felsite band lies just north of the town line 240 paces west of the north corner of Secs. 5 and 6, T. 47 N. If it were to continue the strike that it has at this point it would be considerably south of the line when it had reached three-quarters of the way across the section, but instead it is still found nearly on the line. The labradorite porphyrite shows in the same way and it seems certain that there is a fault with a throw of about 350 feet. As was the case in the other faults the east side is

[1] About 1,300 N., 600 W., in the same section is a gap in the range parallel to this fault, where I k there is also a fault. The evidence is not coercive. See Fig. 24. L.

thrown south. It begins now to be seen that the Bessemer Ridges are broken across by step faulting.

This fault just considered seems to be like the Bessemer fault in that it decreases toward the iron bearing rocks, a fact that is shown in that the basal sandstones shows no preceptible throw. However, the sandstone outcrops are much farther apart than the other outcrops that gave evidence and there is therefore a greater possibility of error.

There is no reason to suppose that there is another fault across these ridges within our area, but the topography suggests that both east and west there are similar faults to those just described.

All along Black River there are fault indications strongly suggesting faults running nearly north and south across the strata. In the conglomerates the pebbles are often seen to be broken across and faulted with a throw very small as if the rock were gently easing itself to some external strain.

About the centre of the S. W. ¼ Sec. 15, T. 49 N., R. 46 W., there are fault indications in the conglomerate. There are numerous small fault planes running east of north and dipping east. None of them have a throw beyond a few inches but they suggest that probably there is a larger fault near by. Near the same place is a cave caused by faulting. It is in the conglomerate at the edge of the river. It extends back about forty or fifty feet and is as much as thirty feet high. It can readily be seen to be caused by a fault running about N. 40° E., and dipping 70° E. The cave is quite interesting as it shows well the lines of weakness along a fault and how the water is able to circulate. It illustrates well how the underground waters would circulate in a fault and how they would assist ore deposition. There is nothing to show the amount or direction of throw of this fault.

In Sec. 29, T. 49 N., R. 46 W., there is also evidence of faulting. On the section line about 350 paces south of the northeast corner of the section it can be plainly seen that there is rock slipping, but the slickensided surfaces are small. About the centre of the N. E. ¼ of the section there is a fault breccia that has a strike N. 10° W., and dips 65° E. This breccia is about four feet thick and can be traced for about 100 paces across a bend of the river and up into the woods, where it stands up like a wall about fifteen feet above the soil. The breccia gives no indication of the direction of throw but in a small fault to the east of it the east side is thrown south.

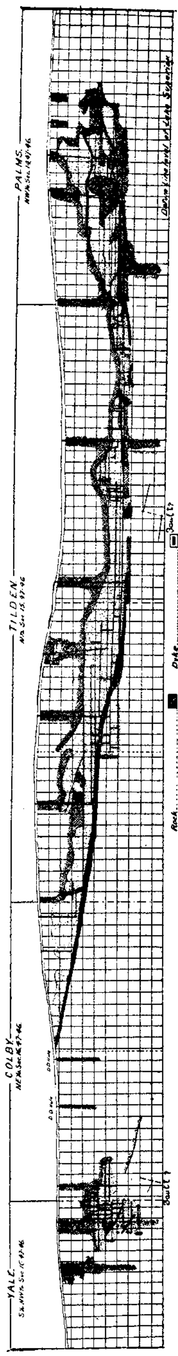


Fig. 25. General sketch of dikes of mines. A. H. Meuche, after notes of Mine managers.

In the S. E. ¼ of the N. E. ¼ of the same section there is a sandstone, stratum No. 33, showing on the west side of the river, and over to the centre but not on the east side. The fault just mentioned above must pass very close to this point, and while it may not be exactly the same fault plane in both cases yet the two are very close together, and parallel and certainly belong to the same system of faulting.

Near the centre of the S. E. ¼ of Sec. 29 there is another sandstone stratum, No. 42, which is suddenly terminated on the west end. Like the one mentioned above it was hard to get satisfactory evidence concerning it because it is pretty well covered with flowing water.

In Sec. 21, T. 48 N., R. 46 W., in the river bed, the much crumbled and broken ophites show signs of having been faulted. The strike of the fault plane seems to be a little west of north and the dip seems to be at a high angle toward the east.

The fault indications seen in Sec. 29, T. 49 N., compare well with those in Sec. 21, T. 48 N., both lying in one plane striking a little east of north and dipping east at a high angle. It is highly significant that the indications in these two sections are both of one fault. North of Sec. 29 it would lie west of the river; in the section it is practically along the river bed; it is then on the east side of the river for about four miles but parallel with it and never more than half a mile from it; in Sec. 21 it is again in the river after which it is again on the east side.

Whether this fault reaches south and connects with one of the faults that cross Bessemer Ridges or not is very hard to say. There is some indication of a fault going east and west along the gap that lies at the north side of the Bessemer Ridges, so it seems wise here to terminate all the north and south faults at an east and west fault running along the north side of the ridge. However in taking this position it is plainly recognized that there is a very large possibility of error, and all that can be said in defence of the position is that it seems the best interpretation of the scanty evidence at hand.

Whether the Black River fault reaches north to Lake Superior or not is not known. Certainly the Nonesuch formation does not show faulting, but at the same time the shales are much more capable of adjusting themselves to the strain than any other rock of the Keweenawan series.

There is no evidence of the amount of throw given to the strata by the Black River fault, and very little indication of the direction of throw, in fact almost too little to argue from.

It is possible that Maple Creek follows a line of weakness made by a fault, and, indeed, where it cuts through the Outer Conglomerate it looks like it. But there is nothing to prove that there is a fault, and if there is one the Nonesuch does not show it at all.

Besides the dip faults mentioned above there are possibly some strike faults.

In Powder Mill Creek there are several flows showing that do not show farther west. The coarse grained labradorite porphyrite and the felsite, strata Nos. 92 and 95, are exposed near the northwest corner of Sec. 6, T. 47 N., R. 46 W. Immediately north of the corner is a coarse ophite. No such ophite is similarly exposed in Powder Mill Creek, but instead there is quite a column of labradorite porphyrites, porphyrites,

VIEW OF THE BESSEMER GAP.

blue traps, and gray traps. It seems that a strike fault has cut these strata out near the corner of Sec. 6. Much more satisfactory evidence might have been obtained if the outcrops had continued farther north of the corner than they do.

On the line between Rs. 46 and 47 the basal sandstone and the coarse labradorite porphyrites, strata 92 and 188 are exposed 9,000 feet apart. They are exposed in Powder Mill Creek 7,500 feet apart. One way that this fact may be explained is that there is a strike fault. The gabbro appears in such outcrops as to prove that if there is such a fault it must lie south of the gabbro. The distance between strata 92 and 188 along the east line of the area worked agrees with the distance along Powder Mill Creek. However it does not follow that there must be a strike fault because these strata are not always the same distance apart because it might be the result of some other cause. In fact, it could be explained from the varying throw of the most westerly of the dip faults as crossing the Bessemer Ridges, for it was seen that the throw of the fault increased as we went north and since the west side is thrown north it would increase the distance between the strata on the west side of the fault.

The pre-Keweenawan Faulting. L.

Mr. Gordon has given above a description of the well marked and clearly proven faults affecting the Keweenawan rocks.

In my judgment there is more or less faulting along others of these northerly joints, and they are the determining features of the numerous gaps in the range.

But anyone can sketch these in for himself and it seemed hardly worth while to alter the map as Gordon left it when the amount of throw of such faults would be purely hypothetical, though I am inclined to look with much faith on topographic indications of faults or veins. I have given, therefore, a sketch diagram (Fig. 24) which does not pretend to be accurate but rather to show the system as I conceive it. Gordon has remarked that the amount of throw seems to diminish toward the granite. It was interesting to find on Section 15, T. 47 N., R. 46 W., about 200 feet north and west of the E. quarter post nearly vertical joints striking N. 25° W. with the east side thrown south a few millimeters. These joints were often filled with a fine silicious matter not like the crushed quartz of ordinary veins but like jaspilite or chert, as though due to the working down into the granite of similar circulating waters to those that guided the iron ore enrichment. Another N. 10° W. joint has a slight displacement of the east side to the north. This is like the faulting on Section 9.

The line of granite contact goes across the line of the Bessemer gap on Section 15 with no throw that can be detected. It seems therefore that the granite has been subject to the same stress but has yielded less. Other joints at the exposures just mentioned were dip near 90° to W. 30° S.; dip 45° to N. 10° W.; dip 80° to E. 5° N. There were also veins dip 40° to S. 40° E.

When we come to the iron bearing rocks there is hardly enough exposure to warrant any statements, and it is noticeable that Irving and Van Hise traversing this district with their eyes set on iron ore at first made no mention of faults here. By studying Figure 25 and the development of the mines it appears that the big Colby dike breaks up when it reaches a point where the Besssemer fault might be expected to go through and instead of continuing down fragments are found rising, which is the kind of effect that the Bessemer fault throwing the east side of a south dipping dike might produce. Moreover, Thompson[1] has found a little west "cross faulting running north and south of about 25-35 feet throw, nearly vertical, and the east side of the fault is in each case thrown north." These correspond to the relatively rarer set of faults around Bessemer. There is another "strike W. 28° N.," "gains to the S. W. 10 feet for every 100 feet of depth," "the southwest side apparently elevated about 25 feet relative to the northeast," which is more nearly like the Bessemer fault.

"With one exception the faults are all of small movement, and with this exception I would characterize the range as one much broken by many faults of small throw."

This has the strike of the formation,—a steeper dip, perhaps 75°-80°, with the north side moved east 400 feet, and a parallel fault with a similar throw of 30 feet. Mr. Thompson believes this continues east to the Colby. It may be the determining feature of the valley which lies north of the iron range.

As between the north faults throwing the east side north and the northwest faults throwing the east side south the latter seem to be dominant for the strikes of the range are pretty persistently somewhat more north of east than its trend.

Unfortunately we do not know as much of the relative ages of the joints and faults as might be desired. It would seem as though one might account for the system of jointing and faulting by supposing the granite relatively rigid, the strata above cumulatively compressible and a collapse of bottom of Lake Superior to have taken place during Keweenawan time compensated to some extent to the west by an eastward and upward shove to the upper layers from an intrusion (the Bad River gabbro?) to the west. That is what I have assumed in Figure 25.

1 Quoted by Van Hise 21st Annual Report U. S. G. S., 1901, Part 3, page 345.

CHAPTER V.

SURFACE CHARACTER.

The area worked during the season of 1904 consists of about fifty-one square miles, embracing the westerly four tiers of sections in that part of R. 46 W. which lies north of the city of Bessemer. The sections in T. 49 N. which lie next to the lake do not contain a square mile each, but have an acreage as follows, according to the old government surveys, Sec. 3-199.20, Sec. 4-11.00, Sec. 9-601.80, Sec. 8-374.20, Sec. 7-182.60.

Running practically north and south through the area is Black River, but the course of the river, and the various hills and ridges have been described on a different page, and will not be repeated here.

In order to give as definite an idea as possible of the area the sections will be described separately.

T. 47 N., R. 46 W.

Secs. 15 and 16 appear on the map, but were not worked by the party. Maps furnished by the Wisconsin Central Railway Company give the contours of the large hill lying in these sections. It is 1,128 feet above Lake Superior, or about 1,730 above the sea. This hill is known as "Colby Hill." About it are situated iron mines. The hill rises nearly three hundred feet above the city of Bessemer, which lies at its northern foot.

Sec. 10—The S. E. quarter is level and fit for agricultural purposes. The S. W. quarter is covered by the city of Bessemer. The N. E. quarter has in it a vertical rocky cliff about 200 feet high, and at the foot of the cliff is a talus slope. At least 60 acres is rendered useless because of the cliff. Along the southern end of the hill is a strip of land that is cleared and under cultivation. The N. W. quarter of Sec. 10 slopes from the foot of the hill westward toward Sewer Creek, which flows along the western side. The greater part of this quarter section is fit for cultivation. The city cemetery lies in it.

Sec. 9—the S. E. quarter contains a part of the city of Bessemer. This quarter section is level, and fit for farming purposes. It is for the most part cleared. The S. W. quarter is much like the S. E., but is uncleared. The N. W. and N. E. quarters each contain high rocky hills with bald tops and steep rocky sides. Around the foot of these hills there is a small amount of good soil which is generally cleared, and under cultivation.

Sec. 8—Generally speaking the south half of this section is fairly level, and will, when cleared, be fit for farming purposes. In some parts, however, there is a tendency to swamp. The north half is hilly, and is useless for farming purposes save in small isolated patches. Powder Mill Creek, which flows through the eastern half of the section, has a small amount of level land along it, but the amount is really insignificant. The creek is fifteen to twenty feet wide in this section, and has sufficient fall to render it of some value as a water-power. The timber on the section is hemlock and maple chiefly.

Sec. 7.—This section contains numerous high, bald, and cliffy hills. Rock outcrops over a large portion of the section. In small isolated patches there is sufficient soil for cultivation. Along the south part of the section there is a marsh which is filled with water even in the dry season of the year. The timber is hemlock and maple, with cedar in the lower areas. The timber of this section is being rapidly removed, chiefly for fuel.

Sec. 3.—The eastern half of this section is very high, in some places 1,700 feet above the sea. There are many rock outcrops, cliffs, and steep slopes, all of which tend to make the section useless for farming purposes. On the top of the high hill there is a small area which could easily be put under cultivation. The western half of the section is more level. Through it flows Sewer Creek which carries the sewage of Bessemer city. The west half of the section is good farming land. The hilly part of the section is covered with maple and hemlock which is being rapidly removed for fuel. The remainder of the area is covered with small poplars.

A spur line of the D. S. S. & A. Ry. runs across this section along the bed of Sewer Creek.

Sec. 4.—This section is level save for hills which lie on the western edge. Practically the whole section is cleared and under cultivation. The farms here are, so far as soil is concerned, first rate. The farm buildings on these farms are in good condition, and, on the whole, this section is so improved as to show that farming in the vicinity of Bessemer is a possibility. Many of the farmers here have been on their farms for several years, and are getting on quite as well as many of the farmers in Southern Michigan. The county farm lies in this section.

Secs. 5 and 6—These sections are covered with hills, and in many places the rock outcrops. For the most part the land slopes rapidly, and in many places there are cliffs. Where there is soil it is of good quality, but it lies so much in isolated patches, and on such slopes that it is of little value for agricultural purposes.

That part of T. 47 N., R. 46 W. which was worked by the party is generally hilly and broken, but in some places it is level, such as in Bessemer Gap. In general it is not adapted for agricultural purposes, but what soil there is is first class. The timber, which is, for the most part, maple and hemlock, is being rapidly removed because of the close proximity to Bessemer and the iron mines, which causes a demand for fuel and mining timber. In the more swampy places there is some cedar.

T. 48 N., R. 46 W.

Secs. 32, 33, and 34—These three sections resemble each other very much and may well be described together. Black River flows nearly west across these sections, but turns more to the north in Sec. 32. On the south side of the river the area is hilly, it being the north slope of Bessemer Ridge. But even here there are not many outcrops, indeed very few for the north slope of a hill. On the north side of Black River the land is quite level save for the river hill. It is generally elevated 1,200 to 1,250 feet above sea level. The part of these sections that lie north of Black River may be considered good farming land. When the river turns more nearly north in Sec. 32 it moves away from Bessemer Ridge and leaves an area of level land on the south side of the river. The soil in these three sections is of a high class, and there is no reason why the land should not be regarded as excellent for farming purposes.

Sec. 31—Except at the extreme south edge this section is level, and largely swampy. There is some hemlock and also some cedar. In the north part of the section the timber is all small, and will not average more than four inches in diameter, and is quite useless for any purpose. This section will make good farm land when drained.

The main line of the D. S. S. & A. Ry. goes through the north part of Secs. 31, 32, 33, and 34. The station of North Bessemer is situated in the S. W. quarter of Sec. 33.

Secs. 27 and 28—These two sections are level, drift-covered and without outcrop. They are elevated from 1,200 to 1,240 feet above sea level. The timber is mostly maple and is all small, and without value. The soil is thickly filled with pebbles and boulders.

Sec. 29—This is better than either Sec. 27 or 28 both as to soil and timber, but there is considerable cedar swamp, especially along Black River, which runs along the west line. In the N. E. quarter is a marsh from which is taken some marsh hay each year. The area of the marsh is about 20 acres, part of which is wet only in wet season, and part always. The remainder of the quarter section and the whole of the N. W. quarter is covered with small poplars which will not exceed an average of three inches in diameter, and which are wholly useless. The surface is somewhat stony, but very level.

Sec. 30—Lies on the west side of Black River. There is no timber of value in the whole section. The east half is covered with small poplars averaging not more than three inches in diameter, and the west half with small spruce and tamarack of about the same size. The whole section is level. The east half could be easily cleared and put under cultivation, and the west half has some good soil which will be of value when drained, but at present it is largely swampy. Along the east and west centre line, near the west side of the section is a peat bog, but its area will not exceed five acres. It is hardly possible that this peat will some day be of value when we consider that there are other peat bogs in the district.

Secs. 15, 16, 21 and 22 are all good farm lands, except in a few places they may prove to be somewhat stony. The land is level. There is a large quantity of hard wood and some hemlock. There are low lying places which are swampy, but these could be drained. A stream from fifteen to twenty feet wide flows across the south part of Secs. 15 and 16, but the fall is not so great as that of some of the streams of the district, and it is not so valuable as a water power. Black River flows along the west side of section 21, and is quite rapid having cut down to the country rock.

Sec. 20—This section has first rate farm soil with a rolling surface.

Sec. 19—It is also good farm soil. The timber is maple and hemlock but there is some nice pine in the S. E. quarter. There is also in the S. E. quarter a field of marsh hay through which flows Six Mile Creek.

Sec. 17—Black River flows through this section and is quite rapid. The N. E. quarter is decreased in value for farming purposes because of hills caused by the river, but the rest of the section, which has good soil, is level.

Sec. 18—This section is covered largely by a peat bog, the surface of which is covered with black spruce and tamarack, which have an average diameter not exceeding five inches. The only portions of the section not covered by the bog are a small part in the north of the N. E. quarter, and the southern part of the S. E. and S. W. quarters. The total area of the section according to the government survey is 599 acres. Of this about 350 acres is peat bog. That portion of the bog lying in Sec. 18 is all of value and also the portion extending northward into Sec. 7, but this latter is of much less importance. A stick was pushed down into the peat and the following depths found, 40 inches, 61 inches, 88 inches, 64 inches, 82 inches, 66 inches, which give an average depth of 66 inches, or 1.83 yards. The total bog area in Sec. 18 is 352 acres or 1,703,680 square yards. Thus there are over 300,000,000 cubic yards of peat as it lies in the bog, and it is certain that this area will be much increased by what lies in Sec. 7, and in Sec. 13, T. 48 N., R. 47 W.

Sec. 10—This section is level and good for agricultural purposes. There is a stream running through it along either side of which is cedar swamp, but all this would, no doubt, prove to be arable land if drained. The timber, except along the stream, is almost wholly maple.

Sec. 9—This is a level section, covered for the most part with hemlock and maple. The soil is first rate.

Sec. 8—This section has some good arable land, but it is cut across by Black River, which causes some hills, and by Eight Mile Creek, which causes some swamp land.

Sec. 7—This is largely swampy, but much of the land could be made arable by draining. The land seems to be in ridges covered by hemlock and maple with swamps between.

Sec. 3—The south half of this section is a steep east and west slope rising about 200 feet. It is the south end of the Black River Highlands. The soil is thin, and second rate. The north half of the section is on the top of the hill and is fairly level. A large part of this half of the section could be cultivated, but the soil is mostly thin.

Sec. 4—The S. E. quarter is hilly and useless for argicultural purposes. The rock outcrops freely through the thin covering of soil. The remaining part of the section has not such numerous outcrops but the value is decreased because of its rapid slope, the west side of the Black River Highlands being here.

Sec. 5—This section is cut by the river, and is made somewhat hilly, but the soil is first rate. Along the river there is considerable cedar swamp.

Sec. 6—This is good farm land except that some portions of it are low. The timber is chiefly hemlock.

T. 49 N., R. 46 W.

Sec. 34—The north side of Black River Highlands lies in this section, thus it slopes rapidly southward and is hilly. The soil on this slope is thin. There is a level area at the foot of the hill, but it is largely swampy. The whole section is of little value for agricultural purposes.

Sec. 33—The north slope of Black River Highlands makes the S. E. and a part of the S. W. quarter of this section almost useless agriculturally. The remainder of the section has good soil. Along the foot of the hill are several small peat bogs.

Sec. 32—This section is cut in a north and south direction by Black River. There is a small amount of land lying on the east side of the river. On the west side of the river is Chippewa Hill, whose east end is a felsite cliff. Around this hill is some rather level land fit for agricultural purposes. The timber of the section is almost wholly hemlock save on Chippewa Hill where it is maple.

The Chippewa Mining Co. did some work about Chippewa Hill about a half century ago, and within a decade the Old Peak Mining Co. explored on the same hill.

Sec. 31—The west end of Chippewa Hill extends into the east end of this section and decreases the value of that portion. In the west part of the section there is some cedar swamp, but on the whole the section is such that it could be made of value as farm lands. There is very little timber save hemlock on the section.

Sec. 27—This is good farm land.

Sec. 28—The soil of this section is first rate but there are so many ravines that it cannot be of the greatest value for cultivation.

Sec. 29—Black River flows along the east side of this section. Away from the river the section is good for agricultural purposes.

Sec. 30—This section is largely cedar swamp and cedar thicket. On the map which accompanies this report it is marked almost wholly cedar swamp, but it is more correctly a series of ridges and swamp with cedar covering both. The growth is so dense that it is almost impossible to get through. There is no timber on the whole section save cedar. The soil might be drained and made of value.

Sec. 22—This is a level section covered with hemlock and maple. The soil is first rate.

Sec. 21—Black River flows through this section. On the east side of the river there is a small amount of arable land. Along the river there is a considerable amount of cedar swamp. Some of the land on the west side of the river could also be put under cultivation. The N. W. corner of the section is hilly.

Sec. 20—On the whole this section is level and of value for agricultural purposes.

Sec. 19—This section is largely swampy, and covered with cedar. The growth is extremely thick. There is a small amount of arable land along the east side of the section.

Sec. 15—This section slopes north quite rapidly, but yet it is nearly enough level to be arable land. The soil is good. The timber is largely hemlock. The amount of level land in the west part of the section is greatly decreased by Black River flowing through it. The river cuts through the country rock, and has worn a deep channel for itself so that there are steep vertical cliffs of conglomerate about fifty feet high on either side. There are numerous falls and rapids in this part of the river.

Sec. 16—This may be considered good agricultural land. The timber is chiefly hemlock.

Sec. 17—This section lies on the north side of Conglomerate Ridge. The crest of the hill lies just within the northern limit of the section, and is about 1,460 feet above sea level. The north side of the section is about 760 feet, so that there is a decline of 700 feet in less than a mile. The soil is thin, and, on the whole, the section is of little value for farming. The timber on the ridge is chiefly maple. Along the northern side of the ridge the trees have been thrown over by the wind, so that at the present time there is a very dense growth of almost impenetrable underbrush.

Sec. 18—Like Sec. 19 this section slopes rapidly northward. The soil is thin. It is also in the area of windfalls. In this section Maple Creek becomes rapid having in one place a fall of 25 feet. It has cut down into the country rock and worn a channel for itself. This creek would yield some power in this section.

Sec. 10—This section is covered largely with hemlock. The land would be level were it not cut by Black River, and by numerous small ravines. The river hill is high, and the conglomerate causes them to be steep. There are numerous falls and rapids. Some of the land of this section could be put under cultivation.

Sec. 9—This section is fairly level, and has good soil. It fronts the lake. Its chief drawback is the number of steep and deep ravines. Most of these ravines have streams in them in the wet season but not in the dry season. Some of them have spring streams in them which flow the year around. The lake bank is from 90 to 100 feet high, and is steep. There is a narrow gravel beach at the foot of the bank.

Sec. 8—The government survey notes give the area of this section as 374 acres. Like Sec. 9 it is cut by numerous ravines which render the section of less value for agriculture than it otherwise would be.

Sec. 7—What has been said of Sec. 8 applies equally well of Sec. 7. The area is 182 acres.

Sec. 3—The area is 199 acres. It lies almost wholly on the east side of the river. It is somewhat inclined to be wet, but it could be easily drained. The soil is good. The timber which was cedar, hemlock and some pine has been largely removed.

Sec. 4—There is only a small corner of this section.

In the few preceding pages has been given a description of the surface, section by section, chiefly to convey an idea of the land for agricultural purposes. Of the fifty square miles covered by the party it is quite safe to say that forty can be put under cultivation. Of this probably ten miles will have its value decreased by being cut by ravines, from the work of Black River, and from the presence of swamps. Also it is certain that some of the land will be in small isolated areas. There are many such areas containing two, three or four acres which would make excellent building and garden lots for a person who was located in the country and who did not live by farming. Perhaps the country will so develop that these small areas may be so used. There are many places which are at present quite damp, but the soil is good, and draining will be an easy task so such land can be easily recovered for farming purposes.

The areas that cannot be put under cultivation lie chiefly in the Bessemer Ridges, on the Black River Highlands, and on Conglomerate Ridge. There are in these places numerous rock outcrops and many places where the soil is only a few inches deep. Only a small amount of land is rendered valueless because of Chippewa Hill. Practically all of T. 48 N., R. 46 W. is good farm land, but some of it is so stony as to be reduced in value.

It is often argued that there is no land along the south shore of Lake Superior that is of value for agricultural purposes, but there can be no doubt but that such an idea is an erroneous one. It is urged that the climate is such that crops cannot be grown. With snow on the ground from November to April it is certain that the summer is short and the winter long, but even with this short summer there are crops that can be grown with profit. It must be remembered that Dakota and Montana lie further north and are considered good agricultural countries. Certainly the great wheat belt of the Canadian Northwest is much further north and also colder. Manitoba has a longer and a colder winter, yet the worth of Manitoba wheat is well established.

In many of the old government reports the soil is marked second or third rate when it is really first rate. For instance when T. 47 N., R. 46 W. was surveyed the land where Bessemer lies was marked second rate sandy soil. Now that it is cleared up it looks quite different, and might be called good soil. Where the land is cleared and under cultivation there are many prosperous looking properties. Near Ironwood there are more farms than near Bessemer, and some of them are fine looking properties. Farming has already been proven a possibility.

Close to the area worked by the party of 1904 is the Penokee-Gogebic Iron Range. This would give a market for a great deal of what could be raised. During the time of clearing the mines would require timber, and the people about the mines would require fuel. These things would give cash enough to keep a poor man while the land is being cleared. There are, however some areas such as Secs. 29 and 30, T. 48 N., that have no timber fit for market, not even for fuel.

CHAPTER VI.

THE BLACK RIVER RUNOFF.

The chief agent of drainage of the area is Black River. Running parallel with the river, and practically along the west line of the range, Maple Creek flows for a little over three miles. Where it empties into Lake Superior it is fifteen to twenty feet wide and eight to ten inches deep in low water season. The source of the stream is in Sec. 30, T. 49 N., R. 46 W. This section with a large part of 19 is inclined to be swampy. On the east side of Black River, and running parallel with it, and about a quarter of a mile distant is a stream about four feet wide.

All along the lake shore are steep narrow ravines. A few have spring creeks in them which flow the year around. These little streams are generally rapid. Besides these ravines are numerous others along the lake shore which have no water in them during the summer. These ravines are all young, narrow and steep, so that the area along the shore presents new topography.

On the west side of Black River, Sewer Creek, or City Creek, takes its rise at the iron mines south of Bessemer in Sec. 15, T. 47 N. It flows into Sec. 10, and cuts across the northeast corner of the city. Just where it leaves the city limits it receives the city sewage. After flowing across Sec. 3 it empties into Black River, in the S. W. ¼ Sec. 34, T. 48 N., R. 46 W.

The creek has its source at the iron mines, and receives the water pumped from them. It is thus extremely red from iron ore, but the color is somewhat reduced before it reaches the river. The burden of hematite and the sewage from Bessemer city makes this an undesirable creek.

Coxey Creek rises in the S. E. ¼, Sec. 4, T. 47 N. It is a beautiful spring creek and is a valuable addition to the farms through which it flows, since it has no ravine. The stream turns west as it flows into Sec. 33, T. 48 N. It crosses the road twice and empties into Powder Mill Creek near the mouth.

Powder Mill Creek is the largest branch of Black River in our area. It takes its rise S. W. of Bessemer and flowing about a mile to the west of it, goes across Secs. 16, 8 and 5, T. 47 N., flowing almost north, after which it enters Sec. 32, T. 48 N. and turns east almost immediately, after which it turns again north and empties into Black River almost on the line between Secs. 32 and 33, at about 650 paces north. The water of this stream is quite as dark as that of Black River. For the most part it is rapid, especially where it cuts through the Bessemer Ridges. Where it enters Black River it is about twenty-five feet wide, and from a foot to a foot and a half deep. This stream would be useful as a water power.

For some distance after leaving Powder Mill Creek there is no stream entering Black River from the west side. Six Mile Creek empties into Black River in the S. W. corner of Sec. 20, T. 48 N., after flowing across Sec. 19. The stream is not large, not rapid, and the water is dark and impure. It receives its name because it is about six miles from Bessemer, the correct distance from the court house being five and a quarter miles.

Eight Mile Creek receives its name from the fact that it is about eight miles from Bessemer on the Black River road, and this distance is nearly correct. There are two branches which come from the west and join just after crossing the road. From the point of junction the stream flows a little east of north and empties into Black River in the S. W. corner of the S. E. ¼ of Sec. 5, T. 48 N. The stream is about ten feet wide at its mouth. It drains the swamp area in Secs. 7 and 18. It is neither large nor rapid. The water is very dark. The south branch is sometimes known as "Pine Creek." Both Six Mile and Eight Mile creeks are in the level area lying between Bessemer Ridge and Chippewa Hill.

There is a stream rising in the S. W. corner of Sec. 27, T. 48 N., R. 46 W. After flowing across Sec. 28 it turns north, at about the west line of the section, and reaches the river about a half mile after the turn. It is joined by a stream from the east which flows across the north of Secs. 27 and 28. Both branches of this are slow in movement, and neither is of any value as a water power. The water is dark and impure.

Another stream flows southwest across Sec. 15, then more nearly west across Sec. 22, and empties into Black River in the N. E. corner of Sec. 20. This is the largest tributary on the east side of Black River in the part of the country where the party worked, and only Powder Mill Creek on the west side exceeds it in size. The stream had no name so far as the party could learn, so for convenience of reference it will be spoken of here as "Sandstone Creek," a name suggested by Dr. Lane from the fact that it exposes a stratum of sandstone in Sec. 15. When it enters our area it is about fifteen feet wide, and quite rapid since just there it is flowing over bed rock. It would yield some power, especially in the west part of Sec. 16, T. 48 N. Farther down it is not so rapid. The water of this stream also is dark.

Flowing around the south foot of Black River Highlands is another stream of some size. Like the others it is not rapid and can be of little value as a water power.

A stream flows around the north side of the Black River Highlands but it is smaller than that which flows around the south side.

Flowing across the north part of Sec. 27, T. 49 N. is another stream, which empties into Black River almost at the line between Secs. 21 and 28, and about 800 paces west. The stream is very clear since it carries spring water. It is joined near the mouth by a stream carrying the united waters of several small spring streams. Sec. 28 is very much cut up by the ravines of these streams.

There are no other streams of importance entering Black River in this area. But there is a great amount of water in circulation beneath the ground, as is shown by the numerous springs of the district. These springs were found everywhere from Bessemer to the lake. They seem to follow the rock in some places and finally come to the surface, while in others, chiefly along the river banks, there can be no doubt but that clay is the impervious layer. One spring of importance is Coxey spring, in the S. E. ¼ Sec. 4, T. 47 N., from which flows Coxey Creek. Springs are numerous along the Bessemer Ridges. At the Narrows about fifty yards from the road there is a nice spring flowing out of the river bank. The water of this spring is about twenty feet below the surface. The spring is very near the road and is much used by people traveling back and forth. From Chippewa Hill to the lake there are numerous springs along the river on either side. Fully as many springs are along the lake bank as are along the river. The clay banks are in many places so saturated with water that they are continually slipping, forming a mire at the foot of the bluffs facing the flood plain.

There is no doubt but that very considerable power could be developed from Black River south of Bessemer, and it is certain that a great deal of power could be developed from that part lying between Bessemer and Lake Superior. The elevation of Black River where it flows along the north foot of Bessemer Ridge is about 1,175 feet above sea level, or about 575 feet above the lake. The river is from 150 to 200 feet wide, generally speaking. In flood season the water would be at least six or eight feet deep, but during low water it is scarcely a foot. From where the river enters the area worked by the party of 1904 for a distance of about five miles it is not extremely rapid, although it always has a rapid current. In the east part of Sec. 21, T. 48 N., R. 46 W. the river becomes very rapid for nearly a mile, after which it is less rapid until the Narrows is passed in the N. W. ¼ of the N. E. ¼ Sec. 17. From this point across Sec. 8 the river is very rapid. Again in Sec. 5 it is less rapid. In Sec. 32, T. 49 N. are some large rapids. The river then makes a large loop and is not rapid in Sec. 28. Through Sec. 29 it is rapid. In Secs. 28 and 21 it is quite rapid but not so rapid as some of the other parts. In crossing the above distance which has been briefly reviewed the river has flowed along its bed about twelve or thirteen miles, and has reached a point about eight miles nearer the lake. In that distance it has descended about 200 feet, which leaves it still about 375 above the lake. To the centre line of Sec. 21, T. 49 N., R. 46 W. there have been no falls at all in the river in our area, although there are some south of it. Below that point there is an increase in the number and size of the rapids and an introduction of falls. The falls are as follows:

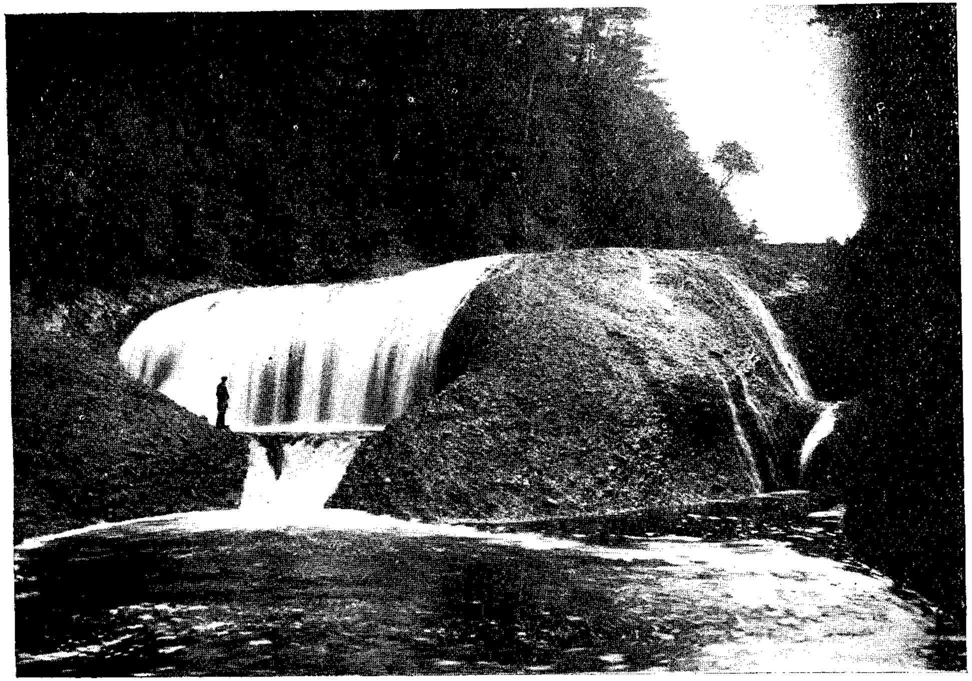
S. E. ¼ of the N. E. ¼ Sec. 21, T. 49 N., R. 46 W., 25 feet over conglomerate.

S. W. ¼ of the S. W. ¼ Sec. 15, T. 49 N., R. 46 W., 32 feet over conglomerate.

S. W. ¼ of the S. W. ¼ Sec. 15, T. 49 N., R. 46 W., 40 feet over conglomerate.

S. W. ¼ of the N. W. ¼ Sec. 15, T. 49 N., R. 46 W., 8 feet over conglomerate.

N. E. ¼ of the N. W. ¼ Sec. 15, T. 49 N., R. 46 W., 22 feet over conglomerate.



VIEW OF FALLS OVER CONGLOMERATE.

S. E. ¼ of the S. W. ¼ Sec. 10, T. 49 N., R. 46 W., 8 feet over conglomerate.

S. E. ¼ of the S. W. ¼ Sec. 10, T. 49 N., R. 46 W., 20 feet over conglomerate.

N. E. ¼ of the N. W. ¼ Sec. 10, T. 49 N., R. 46 W., 10 feet over conglomerate.

On the centre line of Sec. 10, T. 49 N., R. 46 W., and 1,200 paces west falls 40 feet over conglomerate.

The above named falls have a total height according to the aneroid of 205 feet. The remaining 170 feet of decline that the river has in this last part is chiefly in rapids about equally distributed from a point about a quarter of a mile south of the first falls named to a point about a quarter of a mile below the falls nearest the lake. The last quarter of a mile of the river is practically at lake level.

A gage[1] was set on Sec. 17, T. 48 N., R. 46 W., at the Narrows as shown. The gage was braced against an overhanging cedar in which a notch was cut and a nail driven at 4.5 of the gage, which is about the level of the flood plain.

The gage readings were taken twice a day usually about 7 in the morning and 5 in the evening, but not with strict regularity. Observer generally J. G. Coté. Observations in parenthesis A. C. Lane, in brackets J. W. Vogtlin. Low water is not much below .85 I think, judging from the vegetation.

The results are as follows:

Date. 1904.	Gage readings. A. M.	Gage readings. P. M.	Iron River.[1]	Menominee River.[1]
Sept. 26	.86	.9	86.45	3.95
Sept. 27	.85	.85	86.40	4.15
Sept. 28	.85	.85	86.40	4.00
Sept. 29	1.2	1.3	86.35	3.50
Sept. 30	1.5	1.5	86.35	3.37
Oct. 1	1.4	1.4 (1.38)	86.35	3.05
Oct. 2	1.3	1.3	86.35	2.75
Oct. 3	1.25	1.2	86.35	2.65
Oct. 4	1.15	1.1	86.35	2.45
Oct. 5	1.1	1.1	86.40	2.75
Oct. 6	1.15	1.15	86.35	2.85
Oct. 7	1.15	1.15	86.35	2.55
Oct. 8	1.15	1.2	86.50	2.90
Oct. 9	1.3	....	86.60	3.80
Oct. 10	2.1	2.22	87.45	6.70
Oct. 11	2.3	....	87.20	7.60
Oct. 17	....	(1.5) at 2.30	86.55	5.55
Oct. 24	[2.8]	....	86.70	5.15
Oct. 29	[3.4]	....	86.55	4.35
Oct. 30	[3.3]	....	86.50	4.30

[1] From U. S. G. S. Water Supply paper No. 129, pp. 21 and 24, and annual report for 1904. The rest of the report is by A. C. Lane.

Sections across the stream were also taken at the gage and 25 feet above as follows, beginning at a point opposite gage. (The water level on gage being at .86.)

At gage. Feet.	Depth.		25 feet above gage. Depth.
32	0	water's edge	0
37	.40		.30
42	.65		.67
47	.66		1.01
52	.70		.98
57	1.00		1.11
62	1.20		.91
67	1.37		.92
72	1.44		.82
77	1.60		1.00
82	1.96		1.07
87	1.82		1.05
92	1.86		1.16
97	1.74		1.55
102	1.58		1.79
107	1.59		2.32
112	1.70		2.68
117	1.39		2.33
122	1.33		1.90
127	1.28		1.32
132	.89		.62
134	.85		bank.
135	.00		bank.

"Bank" is cut vertically about 5 feet high into heavily wooded flood plain.

The cross-sections at this point seem to be in the one case 130.46 square feet and upstream 124.07 or say 128 square feet as an average for a gage height of .86. Observations of maximum velocity with floats check remarkably well in discharge curves, considering how rough they are.

The rating curve is almost straight.

At 0.86 gage the max. vel. was 25 ft. in 23 seconds, 1.1 ft. per sec.

At 1.38 gage the max. vel. was 25 ft. in 13 seconds, 1.9 ft. per sec.

At 2.2 gage the max. vel. was 25 ft. in 7 or 8 seconds, 3.1 ft. per sec.

For every foot increase in gage height I estimate the increased area by a formula [103+12.5 (a—.86)](a—.86) where *a* is the gage reading. The minimum discharge for gage height .8 is not far from 110 cubic feet per second. Using Chas. Cumming's estimate of the area above the gaging station in the Michigan Engineer for 1904, and subtracting 30 for the part of the basin below the station from 250 square miles gives 220 square miles area and a low water run-off of .50 cubic feet per second per square mile. Comparing this with the records in Water Supply Paper No. 83, pp. 246-262 of Upper Peninsula streams, we note that October is a month of low water, and that the run off per square mile is comparable with the Dead River near the Hoist and the Carp.

Comparing with records of Water Supply Paper No. 129 for the same dates, we see that 1.1 on this gage about corresponds to 86.4 on the Iron River gage and to 2.6 at Iron Mountain,—the Menominee River. On Black River 1.1 gage would mean a run off of about 180 cubic feet per second, or .84 cubic feet per second per square mile of area. For the Menominee River 2.6 gage means 1.942 second feet run off or for the area of 2,415 square miles .805 cubic feet per second. This is a very good agreement to be obtained from such rough observations of surface float velocities and indicates that probably observations on the Menominee River may be used in estimating this stream by assuming that the run off of the two streams is proportional to their drainage basins.

CHAPTER VII.

CORRELATIONS.

In looking over the column and section, which Gordon has constructed with such great care, the great thickness of the Keweenawan shown impresses one at once. It must be remembered also that there is an indefinite amount of sandstone above the Black River section to which Irving assigns a thickness of 12,000 feet not far away on the Montreal River[1]. Leaving this out of account we have 48,000 feet of beds. Adding it would make 60,000 feet. At the very base of the series the beds are not remarkably metamorphosed, the augite is not changed to hornblende, nor any of the metamorphic changes which are so often found in deeply buried strata or those which have been invaded by eruptive rocks. It is also interesting to note that no intrusives have yet been found north of North Bessemer. This agrees with Irving's observations that none have been observed more than one-third the way above the base of the series. Now if the lower strata were ever buried beneath the upper by anything like 60,000 feet, then even if the rate of increase of temperature going down in the earth were no greater in those early times than at present[2], still the rocks would have been buried so as to pass into the zone of folding, not fracture, and be heated, one would think, more than enough to produce some metamorphism, even supposing all their initial heat escaped as they were formed. It would be rather more natural to suppose that a good part of the initial heat was buried with them and that the rate of increase of temperature in the earth's crust was greater in early times.

This difficulty might be escaped in two ways. First we might suppose that the thickness is only apparent, and that there is really a great deal of reduplication by faulting. While Irving found thicknesses comparable to those we have found, that very able geologist Lawson, was inclined to think in studying the North Shore of Lake Superior that Irving's estimates were much exaggerated, owing to repetition of the beds by a series of faults. Therefore we have as carefully as possible looked for any indication of such faults, just as I did in the Isle Royale report.[3]

While we found numerous faults, (See figure 24) no strike faults paralleling the formation were noticed though they probably exist. But no repetitions of similar successions of corresponding beds such as would be produced if the series were repeated by faulting were found. We may, I think, go so far as to say that no such faults with very large throw can exist, except possibly in places where the beds

[1] Copper bearing rocks, U. S. Geological Survey, Monograph V, p. 153.
[2] See Chamberlin's suggestions, Geology, 1904, pp. 533-542.
[3] Geological Survey, Mich., Part I, Volume VI, p. 97-104.

are covered and in particular the gap just north of the D. S. S. & A. R. R. This will appear in a detailed way, only by study of the column, but we may point out a few glaring facts.

The Nonesuch shales appear but once. The heavy conglomerates of the upper part of the column appear but once. The group of beds VI in which almost every trap flow is separated from the next by a bed of sandstone or conglomerate has no counterpart lower down.

The Chippewa felsite appears at but one horizon. The felsites lower down are distinguishable and are associated with labradorite porphyrites and other entirely different beds.

The extremely coarse ophites occur only at one horizon. Intrusive dikes seem to be confined to the region south of the D. S. S. & A. R. R. The lower beds leaning to porphyrites with conspicuous crystals of labradorite appear nowhere north of the D. S. S. & A. R. R. None of the divisions which Gordon made are then repeated.

The result is that the only place where there is any reasonable probability of a great repetition by faulting is north of North Bessemer, where some of the eight thousand feet of unexposed strata just north of North Bessemer may be but repetitions of the lower beds, and the Keweenawan fault may go through here. Yet we have no direct proof of this, and while it seems to me likely that there is such a fault it is hardly probable that it includes all the eight thousand feet in the repetition caused, and there may be very much less. To take off 10,000 feet from the geological column for fault repetitions would be in my judgment extreme.

If then, there is no great repetition by faulting, we can still escape the difficulty of supposing that this let us say sixty thousand feet of strata were superimposed by supposing that the lower strata were lifted and tilted before the upper were laid down. There are a variety of reasons for believing this to be true.

In the first place the upper sediments contain a very large amount of material which appears to be derived from the lower part of the formation. The Nonesuch shale is composed of basic debris, and the conglomerates contain fragments of melaphyres, porphyrites, and felsites, and even of agates which look like the agates which form the amygdules in many of the flows, especially Division XI.

In the second place the lower beds are much more tilted than the upper, and even than the iron bearing rocks underlying them, and though it is of course natural to expect the beds nearer the center of a synclinal to have flatter dips, still the difference of dip is disproportionate for a synclinal as broad as Lake Superior.

This, however, may be due to initial difference of slope. Chamberlin has treated this problem quite elaborately in Volume II of his Geology recently published.[1] He calls attention to the fact that if beds are built out from a continental shelf like the beds of a delta, there might be inferred from the dips an immense thickness having no connection with the thickness of the basin in which the beds were formed, and not present in any one place. The dip would be merely that of cross bedding on a gigantic scale.

The steeper dip of the basal Keweenawan beds as compared with the underlying iron bearing formation may be largely initial dip. This

[1] Chamberlin and Salisbury, Vol. II, pp. 192 and 265.

explanation he directly applies to our Keweenaw problem, yet explicitly states that it does not account for all the dip.

Chamberlin's explanation is certainly a help. Yet the fact, in addition to the others, that we find identical horizons and lava flows on Keweenaw Point and on Isle Royale points to a certain amount of real synclinal folding or collapse of the central part of Lake Superior since these beds were formed.

I have speculated on the possibility that the Isle Royale beds, which though thick are thinner than on Keweenaw point might have flowed across the lake from a center on the south side. Their flatter dips would fit in nicely with this hypothesis, for then the original dip of deposition northward would be subtracted from the dip southward. But in view of the intrusions and dikes around Port Arthur and along the Minnesota coast, it seems hardly necessary to look for a source to the south side, though that may have been the source for particular beds like the "Greenstone."

According to Dana the slope of lava beds can be even up to 20 or more degrees, though such streams are likely to be hollow.

We can thus readily assign 10° or more of the dips to the initial dip of deposition. But even assuming an initial dip of 20° would only reduce our aggregate[1] thickness to about 33,000 feet—more than half of the present estimate and an average slope of 20° seems again extreme. We shall still have to revert to the assumption of intra-formational uplift.

Some light on the probable thickness of the Keweenaw formation may perhaps be found from the following consideration:

Lake Superior is a great trough which is underlain by the Keweenawan formation, which occurs all around it and not far from it. Now recent observations have indicated that the continents float as it were above the general level of the crust, like ice in water because they and the rocks under them are lighter, while the rocks beneath sea bottoms are unusually heavy. Suppose this to be applicable to Lake Superior, which is a great actual concavity in the earth's crust, and has been so apparently from the beginning. There is this to commend such a supposition, that the Keweenawan traps are heavier than the surrounding granites. We do not know the mean density of the Keweenawan rocks as we shall when Pres. McNair gets through with his detailed work. But suppose the Keweenawan traps average a density of about 2.85, that is, weigh about 2,850 ounces to the cubic foot. Then they will weigh about 200 ounces to the cubic foot more than granites, which run about 2.65 in specific gravity. Now the granitic areas around Lake Superior seem to be remnants of a dissected peneplain about 1,800 feet above sea level. Now as Lake Superior is 1,000 feet deep in its deepest part and over a large area is over 600 feet deep, and its elevation is about 600 A. T. we have some 2,200 feet of rock in the Huron Mountains (5,820,000 ounces per square foot) over against 1,000 feet of water (1,000,000 ounces per square foot) as an extreme, or in a general way 1,600 feet of rock as against 600 feet of water (4,230,000 ounces as against 600,000 ounces).

Now if this is due to extra weight of Keweenawan traps under Lake

[1]The 48,000 feet column of Gordon is about 12 miles in width. This corresponds to an average dip of 50°. Making its dip 30° for the same breadth would give us 33,000 feet.

Superior, which makes an equilibrium, there would have to be, under[1] the suppositions 24,100 to 18,250 feet of them.

It is easy to see that this argument indicates a thickness of Keweenawan traps under Lake Superior, of the same general order of magnitude as indicated otherwise, and that the balance, known as the isostatic balance, may easily be supposed complete.

For closer figures one would have to have fair contour maps both of the Lake bottom and the Huron Mountains, and also closer figures as to density.

It seems probable therefore that a geological column and thickness of Keweenawan, if not as thick as that obtained by summation, sixty thousand feet, yet at least large fraction thereof, does really exist in the center of the basin, but that around the margin of the basin, owing to erosion, denudation and uplift, the bottom beds were never buried by any such thickness. It seems as if Lake Superior marked a place where a block of the earth's crust had foundered.

A notable thing is the persistence of the groups of beds. The main sandstone we find all the way along the shore to the Portage Lake Canal. The Nonesuch shale belt is supposed to appear in Swede Town Creek west of Hancock.

The Lake Shore Trap belts are well defined on Sec. 3 and 16, T. 56 N., R. 33 W., near Calumet. The Great Conglomerate is also well marked, 2,100 feet thick there to 350 here. Quite possibly some of the group below is also coeval with the greater thickness at Calumet. It is not to be expected that the last flows marking a waning of the volcanic activity should be so widespread as those of the culmination.

The next group of eruptives with sedimentaries (VI) some 5,500 feet, characterized by the frequency of sedimentary belts, and the absence of lavas dominantly either of the ophite or the Tobin porphyrite types seems to be recognizable also. At Eagle River there are about 1,159 feet down to Marvines bed 35 and perhaps more[2] which seem to correspond. At Calumet there seems to be 1,900 feet or so, down to 195 feet in Tamarack No. 5 shaft. On Isle Royale the section is apparently much thinner (567 ft.)

The next and very well marked horizon, the Chippewa felsite (an orthophyre?) we do not find in Houghton County, but we do find a similar bed in Ontonagon County nearly to the county line, north of working mines. From Irving's notes we know it on the Presque Isle and Potato rivers. It also occurs close to the D. S. S. & A. R. R. in Wisconsin and I think it goes in a continuous band past the Porcupine Mountains. The main mass of the felsite there is a very different appearing rock,—the feldspar and quartz crystals are large and conspicuous.

From its associations at its northward extension we know that it has affiliations with the feldspathic ash bed group, and occurs at the same horizon. It therefore marks a persistent horizon.

Underneath it in the Black River come some beds which seem to represent to some extent the ash bed group.

The next group (VIII) is the one which is most difficult and most interesting to divide, for I suspect that most of the mines are working in

[1] (5,820,000—1,000,000) ÷ 200, respectively (4,230,000—600,000) ÷ 200.
[2] Vol. I of our reports, Part II, p. 124.

this horizon. A great abundance of trap, comparatively little sediment, a marked predominence of ophites with mottles often observable by the naked eye,—these are characteristics that remind one at once of the series from the Greenstone down to the Mount Houghton felsite, the Praysville porphyry. But whereas that group on Keweenaw point is only 6,000 to 10,000 feet thick, this appears to be 26,000. However there is about 10,000 feet covered which may perhaps be deducted. Then the whole column being thicker we should expect the groups to be so—some of them at least.

It can hardly be accident that everywhere (Isle Royale, Keweenaw Point, Mamainse, Black River), beneath a series including some of the heaviest and coarsest flows, comes a felsite flow and tuff, and that beneath this horizon intrusions are not uncommon.

Gordon's group (IX) mixed eruptives among which are some conspicuous labradorite porphyrites has a well marked felsite and felsite tuff at its summit. Close beneath come some beds which have very large and conspicuous Labradorite crystals, brotocrysts.

These are however rather irregularly distributed in the same flow,—when absent the trap is a peculiarly hard blue trap.

Now these rocks occur all along the South Trap Range,—just north of Sunday Lake, and past the south end of Lake Gogebic.

Irving also seems to refer to them, on page 229, along the Gogogagashugun. The foot trap of the Kearsarge Lode is of the same type, and might be a thinner representative, but I do not think we come to any such *group* until we get down to the rocks of the Little Montreal River sections described by Hubbard.[1] It seems to me probable therefore that the North Bessemer felsite is at or not far from the horizon of the Mount Houghton felsite. And as there so here, up to about this horizon intrusives have invaded the series. To be sure in the Bare Hills district there are intrusive felsites which we have not recognized here, and in the Bessemer district there are diabase dikes, which are not known, I believe, on Keweenaw Point. Then the intrusive gabbro of Bessemer is very different in appearance from the Mount Bohemia Gabbro. So we cannot lay too much stress on the resemblance. To the description of these intrusives we next address ourselves.

[1] Geological Survey, Mich., Vol. VI, Part II.

CHAPTER VIII.

INTRUSIVE.

§ 1. *The Bad River Gabbro:*

I think there can be no doubt that the intrusive sill, described by Gordon as Division X of his column is the extreme end of a tongue of the Bad River Gabbro described by Irving in the Wisconsin Reports and his Monograph of the Copper Bearing Rocks, though as Gordon says we could not trace it to the Wisconsin line. However a tongue is mapped crossing the Gogogashugum River in Sec. 9, T. 47, Range 2 E. (Wisconsin) which is heading directly for it.

It is of interest, not merely from its economic value, though I think it would make a good building and monumental stone of the order of the "Duluth Granite," but because it supplies an instance of a plutonic or deep seated rock, a kind represented otherwise only by the granite south of Bessemer and rarely found in the Keweenawan. Moreover its intrusive relations are especially clear, and geologically very interesting.

Gordon has already described it, as composed mainly of labradorite, with subordinate amounts of augite (at times diallagic) magnetite, serpentine (after olivine?), and interstices filled with micropegmatite, (an intergrowth of quartz and orthoclase) to some extent from margin to center. This brings it in Irving's class of orthoclase gabbros.

The observations on grain are tabulated below. The increase of grain of the micropegmatite toward the center may be explained, either as the direct result of slower cooling near the center of the sill or as due to the fact that it occupies larger interstices near the center, which interstices are due to the slower cooling and coarser crystallization of earlier minerals. According to this view the micropegmatite interstices would be considered as microscopic little pegmatitic or aplitic igneous veins.[1]

The size of the interstices seems to follow the grain of the augite pretty closely, being about one-fourth the size. The diameter of the coarser of the little rods of quartz and feldspar which make up the micropegmatite texture is about one-tenth the diameter of the pores as a rough average.

As Gordon has said, the contact with the overlying rock,—one of the usual porphyrites of that part of the series,—is exposed at many points and is different from the contact of the diabase dikes, in that it is close welded, so that it is not hard to break off pieces showing both sides. Little tongues may occasionally be found penetrating the country rock, so that we have a typical intrusive contact. A marked feature is a band of much finer grain from four to eight inches wide just inside the line of intrusive contact. Sometimes the part with very

[1] It is worth noting that granitic and syenitic rocks are associated with, and cut the main mass of the gabbro farther west. Monograph V, 232 to 233.

coarse feldspar is quite distinct from it. In other cases the coarse feldspar seems to occur as phenocrysts in it. The coarse feldspar in or next to this fine band is fully as coarse, or a little coarser than at the center, while the augite and magnetite are not so plain as farther in.

The grain of the augite in the uniform central part seems to be about the same as that of the magnetite and the micropegmatite patches. Calling it 4.5 mm. we see that it is about 4 times that of the Marquette diabase dike. Moreover the width of that dike is about 56 feet, and the width of the gabbro sheet is 200 feet according to Gordon. The rocks are composed of the same minerals and probably the conductivity is about the same, as well as the crystallizing power of the augite, and the temperature at which it formed. If all these things are true and the grain at the center proportional to the width of the dike, which appears to be in a rough way true, then we may infer that the temperature of the country rock was the same relative to that of the augite formation.[1]

Or since the temperature of augite formation was probably somewhere about 1100°C., and it is not likely that the general country rock would differ much in the two cases relative to it, we may assuming this ask the thickness of the whole zone affected, including the thickness of the gabbro belt and of the rocks appreciably heated by it. It comes out 252 feet. As the gabbro seems to be somewhat less than 200 feet thick there would be implied a contact zone of some 26 feet, somewhat more in proportion than that of the Marquette dike. But we have made so many assumptions that we could lay no stress on it did it not happen to fit in with other indications that the gabbro was hotter, more plutonic, and would be expected to have a broader contact zone.

Near the margin the augite varies in grain (see table), but while very close to the margin the grain appears to be .2 to .44, but sharply crystalline and earlier than the feldspar, in the coarser part of Sp. 20196 it attains a grain of .6 to .14 mm., and within 9 feet it appears to be as coarse as the feldspar. Accordingly the rate of increase of the normal augite at the margin can hardly be less than .003 and may be more. From this we may estimate that the temperature of consolidation of the augite was .57 of that of the gabbro intrusion, that of the country rock being taken as 0°.[2] Or if we assume that the augite crystallized about 1050° above the temperature of the country rock, the initial temperature was 1850°,(—not far from that which I found for the Medford intrusion).

The titaniferous magnetite will lead to similar results. It is about 4 mm. at the center, and in 10 feet is three or four times as coarse as in 8 inches, and even there is about 1 mm. across, whence also we may infer a high initial temperature for the gabbro. The feldspar, at the

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[1] From the equations on p. 224, Annual for 1903. $E = kc / a \pi \sqrt{v}$. Let the subscript $_1$ refer to the Bessemer Gabbro, and $_2$ to the Lighthouse Point dike at Marquette. $E_1 = 4.5 = 4$ ($E_2 = 1.1$) $E_1 = k_1 c_1 / a_1 \| \sqrt{v_1}$. But the rocks are so similar in mineraological composition that we assume $k_1 = k_2 - a_1 = a_2$ and v^1 = the difference between the country rock temperature and that of the augite crystalization $= v_2 s$ then $E_1 : E_2$ should $= C_1 : C_2 = 4.5 : 1 = 77{,}000$ mm. : 19,000 mm. $C_1 =$ 252 feet, which would leave 26 feet plus for contact zone on either side, a somewhat greater contact zone than at the Marquette dike, but all things considered not unreasonable.

[2] $E/C^1 c = 4.5 / (.003) \times 77{,}000 = .02$ ∴ by Fig.6, p. 219, Annual for 1903. $v/u_0 = .57 = (1100° - 50°) / 1850°$. Magnetite would apparently give a lower value for $E / C^1 c$, hence a higher for u_0 since v for magnetite is apparently higher than for augite, — it is generally so given and it crystallizes earlier.

center, is some 8 mm. long or rather more than four times the length of that of the Lighthouse Point dike. The general appearance of the rock is five or six times coarser than that at the center of the Lighthouse Point dike, which is in general proportion to its greater thickness. It may therefore be inferred that the conditions of consolidation of the center of the gabbro need not have been radically different from that of the dike except as to the size of the sheet and central zone. It must be remembered that in a zone of uniform grain at the center, which there is in both cases, the initial temperature of the molten rock when it was intruded plays no part in fixing the coarseness.

In comparison with the Medford dike which is somewhat thicker where studied (120,000 to 77,000 m m) the augite at the center is about twice as coarse, and so is the feldspar.[1] In both cases within a very short distance from the margin it is as coarse or coarser than at the center. This latter factor points to a high initial temperature in both cases.

When we come to apply any exact mathematical analysis to the grain of the feldspar, or the augite for that matter, near the margin, we obtain no results at present satisfactory. There is near the margin the usual tendency to a porphyritic texture in the feldspar.

Along the upper contact there is a band of relatively finer grain of from 4 to 8 inches. The transition to the coarse feldspathic type is sharp often within a fraction of an inch, though just at the contact line (Sp. 20196) we find the feldspar and augite of the fine grained zone penetrating the interstices of the coarse crystals, and at some points (Sp. 20192) the large feldspar crystals are disseminated porphyritically through it.

In this narrow zone the grain is relatively uniform, though apparently somewhat coarser at its center. Iron oxide is much more conspicuous than in the normal gabbro and disseminated through it in fine crystals, with very sharp forms, either octahedra, or plates.

I have considered the possibility that this might be an earlier path making intrusion, under which the main intrusion came, but this is ruled out by the way the finer intrudes the coarser zone. I have also considered the possibility that it might be a later aplitic intrusion, which is more possible. But it is much coarser than so narrow a dike would normally be. It must therefore have followed close after the main intrusion, before it had cooled off.

Another way of explaining this zone is to suppose that it was one of fusion and interaction between the gabbro and the overlying rock. This might be chemically settled, if the two were not so alike in chemical composition. There is a certain faint trace of a pre-existing texture, like a palimpsest, and a sharpness to the iron oxide grains, and a granulitic character to the augite (like that around fused enclosures) in this marginal zone, all of which suggest this origin for it.

As this zone encloses the large crystals of the main mass of the gabbro, we must suppose that the main mass must have had the feldspar of the margin crystallized at least before the loss of its heat and gas sufficed to fuse the immediate contact.

The most serious objection to this supposition, which would be like that made by Daly for the Moyie Sill, is that the grain of the margin

[1] 1–7: 4.5 for augite, 5 + : 8 to 15 for feldspar.

zone seems to be a little finer, as appears from the table of observations on grain near the coarse gabbro than at its center. The only way that I can see to account for this would be to suppose that some mineralizer, promoting fluidity and coarse crystallization was derived from the country rock, and decreased away from the margin of the gabbro, just as the heat and gas pressure must have diminished the other way. It is not inconceivable that the iron oxide which seems much more abundant in the narrow zone may have had such an effect. It is even possible that it was an oxidizing action on the iron in the gabbro. The gabbro appears to have less than a normal amount of iron.[1] See table p. 492.

§ 2. *The Diabase Dikes.*

The dikes belonging to the Keweenawan cut not only the lower parts of the Keweenawan up to the Duluth and South Shore Railroad, but also the formations beneath. They usually form one side of the trough, Fig. 26, in which the iron ore was laid down, as has been fully described by Van Hise.[2] In this case they are generally largely altered to kaolin the so-called "soaprock,"[3] In such case of course very little can be said definitely as to the origin, composition and texture, although even when practically all kaolin like the dike under the Colby and Aurora one can still see a finer grained zone at the margin, and in the center form of the original feldspar grains is often visible. No analyses of these rocks have been made, but three analyses made for Van Hise from a dike of the region, Sec. 13, T. 47 N., R. 46 W., are given below, (Monograph XIX-page 357), and also the computations by Washington (Professional paper U. S. G. S., page 331).

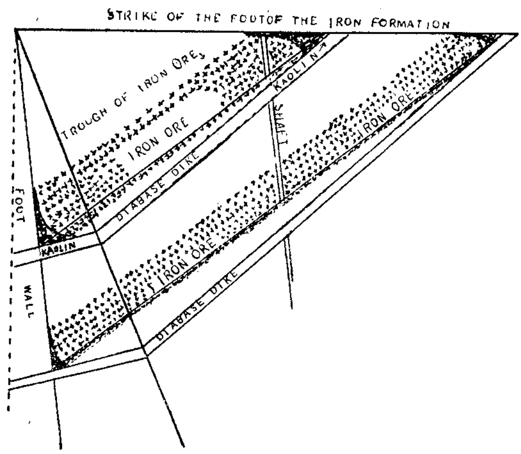

Fig. 26. Diabase dikes and their relation to ore.

[1] Less than the eutectic ratio, I have had no analysis made as yet to see just what the composition of this gabbro here is, but it is notable in looking over the analyses given in the literature of the gabbros of this region that they have less iron than the diabase dikes. In general gabbros have less iron and more of it ferrous than the superficial rocks, and the experiments of Vucnic (Central Blatt, 1904, p. 299.) show that up to at least 16%, magnetite lowers the melting point of anorthite, and we appear to have less and less iron the farther from the contact we get.

[2] Monograph XIX, U. S. G. S., pp. 355-359.

[3] Loc. Rep., also annual for 1892, p. 185.

Table of Dimensions of Gabbro Grain in mm.

	Distances from margin.	Iron oxides.	Augite.	Feldspar. Av. An.	Micro-pegmatite.	Miscellaneous and remarks.
20193	Just outside.	.04 to .16 (Secondary smaller).	.16 + Granulitic.	1.06 x .2 to .46 x .2.	None.	
20194	Just inside.	.2 ?		.5.		Like finer part of 20196.
20197	Corner inside.	.3 to .4	.2 to .44 idiom.	.6 ±.	Patch .1, rod .007.	At one end a little like 20193.
20195	5 inches 127 mm.	.5 (eye) .3 — .6	1.00.	1.2 to .8 x 2.	Patch .26, rod .02.	Micropegmatite abundant, general effect coarser than 20193; largest grains not different, except more Fe.
20196	8 inches 203 mm.	.18 octab. .27 x .09 plates. .8 to 1.1 irr.	.26 to .4 and .55 to 1.4.	7 +, large. .5, small.	Patch .43, rod .04.	Resembles 20192 to the eye. Apatite .11 x .04 to .07.
	9 feet 2740 mm.	3 oct.				
20198	10 feet 3062 mm.	3 to 5.	6 ?	15 x 3.		
20199	20 feet. 6	3 to 5.	5 ?	7.5.		
	30 feet.	3 to 5.		20 to 8.		
	40 feet.	3 to 5.		15.		
20200	75 feet.	3.6. 4 ±.	4 to 5. 3 to 6.	15 long. 10 x 8. 8.5 x 8.	Patch 1.1 to 2 .3, rod 1.1 to 17.	Apatite, .7 x .13.
	95 feet.					
20201	125 feet.					
	135 feet.					
20192		1 —.		16 or 8–13.		

	1.		*2.*	*3.*
H_2O at 105°	.15		3.12	.29
H_2O at red heat	2.34		8.25	13.54
Co_2	.38		1.89	.38
*SO_3	.03		.06	.....
P_2O_5	.13	.001	.16	.14
SiO_2	47.90	.798	46.85	41.60
TiO_2	.82	.010	1.12	3.79
†Al_2O_3	15.60	.153	22.62	37.20
Fe_2O_3	3.65	.023	.12	3.21
Cr_2O_3	trace	.....	.....	.....
FeO	8.41	.117	1.58	.30
NiO (CoO)	.10	.....	.08	.....
MnO	.17	.002	2.54	.08
BaO	.05	.....	.10	trace
CaO	9.99	.178	1.25	.23
MgO	8.11	.203	2.01	.02
K_2O	.23	.002	2.66	.....
Na_2O	2.05	.033	.80	.07
	100.15		100.21	100.85

* SO_3 calculated from BaO found, as this latter probably exists as Ba SO 4.
† Al_2O_3 is probably a little high owing to alkali retained by titanic acid.

Washington reckons its norm to be:

		mode from norm.
Quartz	0.3	micropegmatite.
Orthoclase	1.1	
Albite	17.3	labradorite Ab_2 An_3
Anorthite	32.8	
	50.1	
Diopside	13.5	augite
Hypersthene	24.8	
	38.3	
Magnetite	5.3	titaniferous magnetite and ilmenite.
Ilmenite	1.5	
	6.8	

This agrees quite closely with the appearance of these rocks.

To two things about the molecular proportions in this analysis, special attention may be called. In the first place the ratio of all the bases to silica is 722:798, not far from 1.1 as in the pyroxenes generally. In the second place after subtracting all the (CaO, MgO 2 SiO_2) possible (.381), this being the common dominant augite molecule, in the remainder the ratio of the alkalies to the silica is almost exactly 1:12 (.035×12=.42 instead of .417 which is the ratio that I have supposed might be that of an eutectic line from micropegmatite down. I am therefore not surprised that there seems to be little or no tendency for any constituent to crystallize out early and porphyritically because of being in excess.

The Keweenawan Dikes.

From the gabbro we have just described these dikes are not very different in origin. Both are later than the beginning of the Keweenawan but there is good reason to believe from their composition, which is quite like that of the flows, and their attitude, that they were intruded during Keweenawan time. These dikes generally strike northeasterly, and dip southeasterly.[1] This prevalent dip to the south is an indication that the formation has been tilted to the north since they were intruded, since there is no apparent reason otherwise why they should dip against the formation. A slight dip to the south could indeed be explained if there were only a slight dip of the formation by supposing they followed slightly tilted joint planes. But in the case before us the Lower Keweenawan beds are tilted so much that now the most direct course for a dike from beneath would in many cases be the bedding planes. But these are used practically only by the gabbro.

If we restore these dikes to their original horizontality it is a simple problem of spherical right triangles to estimate how much of the present tilting of the beds occurred since the intrusion of the dikes by estimating how much of a tilt to the south would be needful to make the dikes fairly vertical. Van Hise already came to the correct conclusion that in the iron bearing rocks the tilting of the formation was 60° to 70° and the original strike southwest to northeast. A good many of them thus seem to come from the region of the Porcupine Mountains, which seem to have been a volcanic focus in Keweenawan time.

Exceptions, as on Cora's Peak, sometimes certainly are, and may always be stringers or offshoots of a main set of dikes.

The dikes differ from gabbro then:—

First, in that they were nearly vertical, instead of an intruded sill;

Secondly, almost without exception their contacts are fine grained beyond recognition of the grain;

Thirdly, their contacts are not closely welded. While with the gabbro it is not hard to get a piece showing both wall rock and gabbro it is next to impossible with the diabase dikes.

This may be ascribed either, (1) to intrusion of dikes into wet rocks, of the gabbro into hotter and dry rocks, making a good joint, or (2) to the gabbro having included gas which could not escape, and by mutual reaction along the edges promoted a close joint.

With one exception, not noticed in the field, so far as observed these dikes resemble very strongly the quartz diabases, the type of which is the Lighthouse Point Dike, Marquette, which I have fully described elsewhere. I had in 1906 a good chance to make observations of another dike of this family near Marquette, just opposite the little station of West Yards, of the L. S. & I. R. R., Sec. 3, T. 48 N., R. 25 W., for comparison.

In general it may be said that the center of these dikes shows labradorite laths, visible to the naked eye, and in the thicker dikes up to 1

[1] See Irving and Van Hise, Monograph XIX, p. 272.

to 2 mm. long. These feldspar laths make up about half of the rock and are the first formed of the principal components, next follows opaque matter, mainly magnetite (with ilmenite and graphite?).

Augite takes most of the room next to the feldspar, and follows next in order. The last interstices are filled with an intergrowth of quartz and feldspar (orthoclase), called micropegmatite. These interstices are often the centers of decomposition, but there may also appear reaction rims of the original components near them, hornblende being built from the augite, liotite from the iron oxides.

Remnants of olivine are generally entirely changed to serpentine, iddingsite or talc, etc. Apatite occurs in minute needles especially near the acid interstices. The only sign of these that can be seen without a microscopic thin section is occasionally a minute red speck.

The grain in the larger dikes is uniformly coarse for a belt at the center but at the margins it grows finer, but the feldspar at the margin is of a great variety of size,[1] whereas the augite is more uniform.

Details regarding some of the dikes follow.

The dike farthest north so far as known is 52 steps south of the cut on the D. S. S. & A. track, just west of North Bessemer, and thence S. 50° W. It might be traced 250 feet or more (1,700 paces W., 230 N., Section 33, T. 48 N., R. 46 W.). It may easily be 60 feet or so wide.

The joints run: dip 75° to S. 20° E., dip 80° to S. 45° E., dip 35° to S. Although no section was cut, specimen 20271 looks like a normal diabase and is in grain apparently like that of the West Yards diabase at 131 inches from its margin. As the width of the two dikes is similar the presumption is that other conditions, except possibly the initial temperature, were similar, and as regards that my general impression of the relative proportion of the width of the dike to the selvages of the finer grain is that they are similar.

On Cora's Peak on the south side near the sandstone quarry is a dike 7 to 8 feet wide. Probably as an offshoot of this there is a trap dike on the east side of the hill dipping 56° to S. 50° E., jumping from one layer to another by following joints. It sends off a 1 or 2 inch stringer which runs clear up to the knob to the northwest. It has well marked fine grained selvages and it is nearly a foot thick as one goes up the hill. (See map.) Where this was about 8 inches thick a piece was taken from margin to center, and a section showing nearly the whole made by Axel Anderson. There are also five sections, numbers 20190.1 to 20190.5 giving 92 mm. The large section made by Anderson shows beautifully the finer, and at the same time the more irregular grain toward the margin and the greater abundance of iron oxide, especially along the little cracks which may be primary. At the very margin, the feldspar has an appreciable size of 0.21 mm. x 0.02 mm., sometimes larger, and the iron oxide grains are 0.2 to 0.3 mm., but the augite cannot be noticed. At the center the large feldspars are hardly longer, though the average feldspar is distinctly coarser, but they are 2 or 3 times stouter, the common size being 0.21 mm. x 0.03 mm. The iron oxides are twice as coarse—0.08 mm., and the augite is very close to .06 mm. Intermediate observations show that the augite increases clear to the center, there being no belt of uniform grain, for in-

[1] "Seriate" Journal of Geology, Dec., 1906.

stance at 46 mm. from the margin the average grain of the augite is .037; at 50 mm. it is .048.

The rate of increase of augite clear to the center is .0006 to .0008, substantially the same as that at the margin of the West Yards and Lighthouse Point dikes. The inference may be drawn that this dike probably consolidated clear through under similar conditions to the margins of those dikes of similar distance from a contact, and at an early stage of cooling, so that the grain follows the law of the increase of grain in the margins of those dikes. Consequently in all probability the initial temperature of this little dike was not much above that of consolidation. In harmony with this is the increase of the grain of augite clear to the center. If we compute the ratio of initial temperature to that of consolidation of augite, $v \div u_0$, it will come out .96 to .99.

On the other side of the Bessemer gap there are also a number of dikes. Specimens 20184 and 20185, 182 paces S., 650 paces W. of the N. E. corner of Section 10, T. 47 N., R. 46 W., come from the small 8-inch dikes dipping 75° to S. 55° W. A couple of hundred paces north,—Section 3, T. 48, R. 46—is another dike about 16 inches wide dipping again 65° to S. 17° E. Another dike shows in the side of the hill which runs nearly north from the south quarter post of 3 a very similar strike (N. 32° E.). It is 8 to 12 feet wide. We also have a number of similar dikes probably in the iron bearing formation. One directly under the Colby mine Van Hise says is about 90 (?) feet thick, with a similar strike and dip to those already mentioned, then below this at the 4th and 5th levels of the Yale mine there is a four to five foot dike in a general way parallel to the Colby. Then to the northwest of Cora's Knob, a little north of the corner between Sections 4 and 5 is another dike, dipping as usual to the S. E. and a few feet wide. I have no doubt careful examination would find others.

One dike which occurs directly in Bessemer just west of the sidewalk in the Creek Valley 830 paces north and 1,500 west, Section 10, T. 47 N., R. 46 W., appears to be somewhat different, judging from sections 20176 and 20177. It is not over 45 feet thick. The strike is somewhat similar to the others, N. 68° E., but it dips apparently 60° N. It may be that the different appearance is due to absorption and modification of the surrounding graywacke. Specimen 20177 is from the margin and very fine grained with feathery minute feldspars (trichitic arborescent) and a *mottled* appearance with white dots freer from iron oxide surrounded by a rim of black oxide, or possibly graphitic matter. The remainder of the ground is brown.

Beside the minute feldspar fibers (.07 mm. to .14 mm. long), there are large porphyritic crystals generally forked at the ends (from .2 to .5 mm. long, in one case 1 mm.) evidently crystals formed in transit —rhyocrystals. There are also minute equidimensional granules .03 mm. across. Specimen 20176 20 inches (508 mm.) shows iron oxide in much coarser development. The individual granules are only .03 mm., say, across, but they are gathered into arborescent or dendritic growths and lines often parallel from 2 or 3 mm., and at times as much as 1.4 mm. long but only .03 mm. wide. Feldspar is very abundant up to .7 mm. long in forked rhyocrysts. Opaque matter occurs in feathery sheaves and appears to be graphitic. The augite is also in long prisms arranged in sheaves (1.0 mm. x .2). In comparison with the Lighthouse Point dike the feldspar are longer and slenderer. It is obviously a more andesitic rock,—an augite porphyrite, and not a melaphyre in composition and may correspond to some of the labradorite porphyritic flows, but it is worthy of further study.

CHAPTER IX.

THE PRE-KEWEENAWAN ROCKS.

Introductory.

The main study by Gordon was naturally given to the Copper-bearing or Keweenawan Rocks, in accordance with his instructions.

But the map also includes in one corner older rocks and for completeness it may be well to describe them. The rocks of this region were the subject of the Monograph of Irving and Van Hise (XIX of the U. S. Geol. Survey) on the Penokee-Gogebic Range. A later description is given by him in his general article on the iron ores of Lake Superior. Even since then studies, largely elsewhere, have made some change in the general view regarding these rocks.[1]

According to our present views there occur beneath the Keweenawan the following groups or series of rocks, each having its own peculiar character and generally separated from others by some disturbance, often involving its elevation and erosion.

It is true, as Gordon has said, that in the area covered by this map there is no evidence of unconformity between the Keweenawan and the next older rocks, the neo-Huronian or Animikie. Yet by going only four miles east to Sunday Lake on the south side of Sec. 9, T. 47 N., R. 45 W., a marked labradorite porphyrite like those at Bessemer are found directly lying on the Bijiki iron bearing part of the Animikie, and it is clear that there is at least that kind of unconformity which Grabau has called a disconformity (described also in Monograph XIX, p. 470), by which varying beds of one series are brought in contact with different beds of the other without any marked unconformity of strike and dip, as if all that had happened to the older formation (the Animikie), before the later (the Keweenawan) was uplift and erosion.

There does not appear to be any jointing, igneous metamorphism or other disturbing action affecting the Animikie that does not also affect the Keweenawan just here. This statement is not true of the Marquette Range for instance. But the break between Animikie or neo-Huronian and Keweenawan seems unusually little on the Gogebic range, which may indicate that the lower beds of the Keweenawan and highest of the Animikie meet here.

Animikie, neo-Huronian.

This formation may be divided into the following parts:[2]

(a) Michigamme slate (Tyler).

This is dominantly made up of black graphitic slates, varying to

[1] See Annual Report Michigan Survey for 1904. pp. 132 to 153. Also Vol. 5, Monograph XIX, U. S. G. S.: also 21st Annual Report Pl. XLIX. p. 338 and following.

[2] We use the geographic names of the Marquette Monograph rather than those applied by Van Hise in the 21st Annual Report, as we believe the correlations are safe and it hardly seems worth while to multiply names. However we give the others in parentheses.

graywackes (sandy slates). It lies close to the surface under the town of Bessemer, has been exposed in numerous cellars, and occurs at the surface about 300 steps up hill from the south corner between Sections 9 and 10, also in the valley of Sewer Creek in the north part of the town, 800 paces N., 1,400 paces W., Sec. 10, T. 47 N., R. 46 W., and elsewhere. With the black slate, pyrite, calcite and chert seams occur. It appears to dip about 75° to N. 20° W. The thickness allowing about 800′ for the underlying iron bearing (Bijiki or Ironwood) formation, below and 300′ or so for the overlying Keweenawan sandstone, but making no allowance for faulting or thickening accompanying the slaty cleavage is .... 4,000 feet.

(b) Bijiki (Ironwood) iron bearing formation.

Beneath the slates are about 800 feet of iron bearing rocks proper,—ferruginous cherts, cherty carbonates and siliceous beds, with a distinct quartzite at the base, between which and the cherty iron series there is apparently a little unconformity.

They are exposed at all the mines to some extent though there is no complete section. The basal member and contact is well seen along the tracks which run a litle north of east from 50 steps north of the east quarter post of Section 15. About 600 paces north of this quarter post and 50 paces west is some basic tufaceous slate, not certainly in place, however, which certainly belongs somewhere in the Huronian, and may, like the Clarksburg formation, represent volcanic activity extending into the neo-Huronian. These rocks are often massive, thick-bedded, yellow and brown and granular like limestone, and the iron enrichment can be seen working in on joints and cracks as well as along bedding planes. Again the rock is better bedded and more slaty, and often the whole rock is so replaced that only a powdery mass of soft ore remains.

In this series especially, Irving and Van Hise developed the theory of the formation of iron ore bodies by concentration of water working down along troughs made by some underlying impervious bed and some dike or fault cutting across the formation. In Huronian and earlier time there were in this region great outcroppings of basic lavas, containing much iron. The iron has found its way, either immediately as iron chlorides and sulphates to the ocean (as in the Rio Tinto) or slowly as these lavas and ashes decayed, were eroded and leached. In many cases they were precipitated in the ocean as cherty iron carbonate, or as greenalite or glauconite, but when these rocks were elevated above the surface of the sea again and tilted, downward working waters once more began their assorting work. This is of two kinds, collecting the iron from elsewhere and concentrating it in the ore body, or secondly removing other materials so as to leave the iron ore as a residuum.

Careful examination makes it clear that in the ore bodies both actions have taken place. Iron has been introduced along the cracks and on the other hand silica has been leached out. Pebbles of the iron ore in the conglomerates near the mouth of the Black River make it clear that the action had gone far before the close of Keweenawan time.

The deeper mines from Hurley to Sunday Lake are encountering waters rich in calcium chloride. The study of the distribution of such waters may show something regarding the underground currents. The

Colby pit seems to lie between the foot wall dipping 67° to N. 16° W. and a dike dipping 50° to S. 40° E.

The thickness of the Bijiki (Ironwood) we assume as .... 800 feet.
The line between it and the overlying slates is not apparent here. On the Marquette range the formation is not over 200-300 feet thick.

(c) The Goodrich (Palms) formation.

This is a series of green and red banded slates (like the slates of Rome, Georgia says Hayes), with a marked conglomerate base. There appears to be fine grained green tufaceous material, which reminds one of the Clarksburg and other marked volcanic centers that were in activity at about this time. The marked conglomerate base is well marked just south of the road and extending to about 100 north and over 328 west of the east quarter post of Section 15, 47 N., R. 46 W. This exposure is described and figured by Irving and Van Hise, p. 147. Here it laps directly upon the granite, and contains boulders of granite with pebbles of schistose dikes, jaspilite and dolomite, which bear witness to the earlier Huronian formations here absent.

Van Hise describes many thin sections. There is a notable amount of chlorite. The thickness of this formation can be more accurately measured than the others. The present tendency is to sink the main working shafts down in it so that the ore may be completely mined out without disturbing the shaft. This is exposing it much better. The breadth of the exposure seems to increase slightly to the east and there appears to be a little discordance between the strikes of these slates at their contact with the granite, and of that of the iron ore bodies, N. 82° E., the latter bearing a little more north of east.[1]

Thickness .... 350 to 400 feet.

Missing formations.

The *mio-Huronian* is the main iron formation of Ishpeming and Negaunee. It has been divided into three members:

(a) Siamo slate.

(b) Negaunee iron formation.

(c) Ajibik quartzite.

It is entirely absent here except perhaps in pebbles in this conglomerate.

The Mesnard or eo-Huronian series, has been divided into three formations in the Marquette range as follows:

(a) Wewe or Goose Lake slates.

(b) Kona dolomite (Bad limestone).

(c) Mesnard quartzite.

Of all this series the sole representatives if any are a few directly above the granite of alternate laminae of cherty layers with an arkose (a sandstone of granitic debris) which may represent the knife edge remnant. The Kona dolomite and Mesnard quartzite do, however, appear finely developed a little east on the S. E. quarter of Sec. 18, T. 47 N., R. 44 W.

[1] Strikes from N. 80° E. to N. 85° W. were noted, the latter on the Goodrich slates near the east quarter post of section 15, which may locally be affected by the Bessemer gap fault.

The Laurentian.

The Animikie is then underlain by an older formation from which it is separated by a great unconformity.

This formation is mainly granite, cut by a lot of old schistose dark dikes which do not cut the Animikie. The rocks into which the granite intrudes are not found just at Bessemer, but are well exposed to the east at Sunday lake and to the west at Ironwood (the Keewatin or Greenstone schist series).

The granite is sometimes faintly gneissoid parallel to the course of the iron range.

About 50 paces S. 250 or 300 east of the west quarter post of Section 15, just south of Tilden No. 7 shaft an outcrop of medium grained granite, which shows a parallel structure dipping 47° to N. 40° W., partly indicated in the feldspar tablets which are 2 to 4 mm. across, partly by aplitic seams and joints. There are also joints parallel to the Bessemer gap faulting N. 10° 30° W. and nearly vertical, but dipping a little to the east. In another exposure back of the Tilden Mine there are also strings of basic enclosures parallel to N. 60° E. and nearly vertical veins of quartz either coarse or fine grained silica running 5° to 25° W., also another set dipping 56° to N. 50° E. From the Colby hill near the W. quarter post of Sec. 15, outcrops of granitic appearance may be seen off the south in many directions as far as the eye can see, though east and west of the hill are low gaps where there are no outcrops of granite or anything else so that there is room for some faulting in continuation of that affecting the copper-bearing rocks. The general strike of the northern limit of the granite from the Tilden to the Palms mine is N. 80° E. Crossing the gap to the hill near the Palms mine, we found a little north of the quarter post and some 400 paces west of the east line of Section 15, exposures of granite beginning again. The joints are as follows, just northwest of the quarter post:

Parallel to the Bessemer fault N. 25° W. with displacements of the east side, to the south a few mm.:

N. 30° W., dip almost vertical to W.

N. 10° W. curved with the east side thrown north.

Dip 60° to S. 40° E., parallel to many of the Keweenawan dikes.

Dip 45° to N. 10° W., parallel to the contact with the Goodrich conglomerate nearly. On this in one place, however, I found the dip to be 50° to N. 10° E., parallel to the dike in the granite.

There are a number of old dikes in the granite, schistose, and dipping 50° to 60° to N. 10° E. or west, which evidently record an epoch of intrusive activity older than the Animikie. The granite here is a little coarser than back of the Tilden, say 4-5 mm.

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