TWO FORT WAYNE WELLS IN THE SILURIAN, AND THEIR BEARING ON THE NIAGARAN OF THE MICHIGAN BASIN

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About a year ago, Professor Logan, State Geologist of Indiana, submitted to the writer complete sets of cuttings from two deep wells in the southwestern part of Fort Wayne. The samples were taken every ten feet, from surface to bottom of the wells. Accurate data as to surface elevation and location were furnished. The two wells are 2,400 feet apart. Well No. 1 is near the corner of Ardmore avenue and South street, and well No. 2 is near the corner of Taylor street and Henrietta avenue. They were drilled by the Fort Wayne Water Company. The wells are 16 inches in diameter, and the cuttings often show fragments of fair size, so that accurate determinations of the character of the rock can easily be made. These wells are, therefore, of unusual value for geologic correlations. They are 640 and 630 feet deep, and reach the bottom of the Liston Creek limestone.

Because of their importance the logs are given in great detail, with description of each ten-foot sample. Following the detailed description of the well sections, is a discussion of other well sections in the Michigan Basin region, and of the general problem of Niagaran correlations in the region. The writer has visited in the field all of the important sections of the Niagaran around the Michigan Basin, with the exception of Manitoulin Island. For that he depends on the sections given by M. Y. Williams (1919), and Walter A. Verwiebe (1927). The correlations suggested are tentative; but they are based on a wide range of field studies, and will have to be seriously considered in all future studies of the region.

Well No. 1. Surface elevation, 755.2 feet A. T.

1. 0- 10 ft. Yellow silty boulder clay.
2. 10- 20 ft. Gray silty clay with pebbles and sand.
3. 20- 30 ft. Same as 2.
4. 30- 40 ft. Gravel.
5. 40- 50 ft. Gray silty boulder clay with small pebbles.
6. 50- 60 ft. Gravel with pieces of silt.
7. 60- 70 ft. Gravel.
8. 70- 80 ft. Gravel.
9. 80- 90 ft. Two fragments of limestone. Large one brownish gray, granular, porous, with crystals of calcite. Small one light brown, fine grained, with conchoidal fracture.
10. 90-100 ft. Fragments of glacial pebbles mixed with fragments of light brown finely granular crystalline dolomite and chert.
11. 100-110 ft. Fine fragments and dust of fine grained dolomite, with some chert, and material derived from the glacial drift.

GREENFIELD DOLOMITE.

12. 110-120 ft. Almost white, pure, fine grained dolomite. No chert. Top of the

HUNTINGTON DOLOMITE.

13. 120-130 ft. Browner to gray finely granular crystalline, porous dolomite.
14. 130-140 ft. Light brown finely saccharoidal, crystalline dolomite. A few white and a few dark fragments.
15. 140-150 ft. Light gray to white or bluish, somewhat mottled, finely crystalline dolomite.
16. 150-160 ft. Very light, almost white, saccharoidal dolomite. Looks like typical Huntington.
17. 160-170 ft. Almost white, saccharoidal dolomite.
18. 170-180 ft. Same as No. 17. A few dark fragments.
19. 180-190 ft. Same as 18.
20. 190-200 ft. Same.
21. 200-210 ft. Coarser grained, white, saccharoidal dolomite. One particle of chert. One olive green piece.
22. 210-220 ft. Quite saccharoidal. More fragments of light brown and dark gray.
23. 220-230 ft. White porous saccharoidal dolomite. A few dark pieces.
24. 230-240 ft. Soft white, crumby, porous dolomite. Under the lense looks almost like sandstone.
25. 240-250 ft. Same as 24.
26. 250-260 ft. Same. Perhaps slightly darker.
27. 260-270 ft. About the same. Not quite so coarse.
28. 270-280 ft. Slightly brown. Does not effervesce quite so much as preceding samples. Probably somewhat more dolomitic. One quite large fragment quite porous.
29. 280-290 ft. Light grayish brown, finer grained, scarcely at all saccharoidal. Some white *chert*. Top of NEW CORYDON member.
30. 290-300 ft. About the same color. Slightly more granular. Very little chert.
31. 300-310 ft. Browner, but with some white pieces. Weak effervescence. *Chert* more common than in 30.
32. 310-320 ft. Gray to brown, medium fine grained, finely granular. *Chert* rare. A few splinters.
33. 320-330 ft. Darker grayish brown, finely granular. Weak effervescence. Some *chert*.
34. 330-340 ft. Browner, dense, some *chert*. Effervesces more freely.
35. 340-350 ft. Medium gray, dense, some white *chert*, and one piece of dark chert. Slight effervescence.
36. 350-360 ft. Brown, dense, very little effervescence. Specks of white *chert*.
37. 360-370 ft. Brown, with white *chert*. Weak effervescence.
38. 370-380 ft. Same as 37. Base of NEW CORYDON member.
39. 380-390 ft. A few fragments like 38, but many large flakes of bluish gray, *shaly*-looking rock.
40. 390-400 ft. Bluish gray, decidedly *shaly*. Slight effervescence. No chert and no brown dolomite.
41. 400-410 ft. Very light *almost white*, fine grained. Strong effervescence. Few gray particles.
42. 410-420 ft. White limestone.

43. 420-430 ft. Same. A little white chert. Fair effervescence.
44. 430-440 ft. White limestone. Effervesces rather strongly. Many large flakes of dark gray shale.
45. 440-450 ft. Dense, fine grained, very light gray dolomite. Weak effervescence. A few blue flakes.
46. 450-460 ft. Dense, fine grained flaky limestone. Light gray. Fair effervescence.
47. 460-470 ft. Almost white, saccharoidal dolomite.
48. 470-480 ft. Decidedly saccharoidal, white, granular dolomite.
49. 480-490 ft. Same as 48.
50. 490-500 ft. White, coarse, crystalline dolomite.
51. 500-510 ft. White saccharoidal dolomite, mottled with streaks and spots of blue.
52. 510-520 ft. Same as 51.
53. 520-530 ft. Same as 51.
54. 530-540 ft. Same as 51. Very crystalline.
55. 540-550 ft. Coarse, white, saccharoidal dolomite. Mottled. Very porous Slight effervescence.
56. 550-560 ft. Light gray, crystalline, coarse, mottled dolomite.
57. 560-570 ft. Dense, fine grained, light gray, in very small chips with sharp edges. Fair effervescence. Top of LISTON CREEK LIMESTONE.
58. 570-580 ft. Very *cherty*, light gray, dense, flaky limestone. Large, sharp-edged flakes. Effervesces strongly.
59. 580-590 ft. Dense, medium gray, flaky limestone. Good effervescence.
60. 590-600 ft. Slightly darker gray, dense, flaky, sharp-edged, limestone fragments. Some *chert*. Slightly porous. Has the look of typical Liston Creek limestone.
61. 600-610 ft. Finely pulverized, slightly argillaceous, gray, flaky, mottled limestone.
62. 610-620 ft. Mottled, medium gray, flaky limestone. Sharp-edged fragments. Good effervescence.
63. 620-630 ft. Medium gray, dense, sharp-edged fragments. Somewhat mottled. A little *chert*.
64. 630-640 ft. Light gray, dense, almost lithographic limestone. Flaky. Like typical Liston Creek limestone. Fragment of *Orthothetes*? About the base of the LISTON CREEK LIMESTONE.

Well No. 2. Surface elevation, 754.52 feet A. T.

1. 0- 5 ft. Yellow silty clay.
2. 5- 10 ft. Gray pebbly clay.
3. 10- 15 ft. Same as 2.
4. 15- 20 ft. Very pebbly clay.
5. 20- 25 ft. Hard gray silty clay.
6. 25- 30 ft. Gray pebbly clay.
7. 30- 35 ft. Hard gray silty clay.
8. 35- 40 ft. Same as 7.
9. 40- 50 ft. Gravel.
10. 50- 55 ft. Silty clay and pebbles.
11. 55- 63 ft. Gravel and sand.
12. 63- 70 ft. Fine angular sand.

13. 70- 80 ft. Light brown, fine grained, granular, drusy dolomite. Some particles light blue, lithographic. GREENFIELD DOLOMITE.
14. 80- 90 ft. Half and half brown and light blue, fine grained dolomite. The blue chips indicate a finely laminated rock.
15. 90-100 ft. Some fragments dark gray to brown, and a very few fine grained light gray. A few large fragments of very light gray, saccharoidal dolomite.
16. 100-110 ft. Mostly gray granular dolomite. A few fragments of fine grained, buff, splintery dolomite; and some fragments of sandy-looking dark greenish gray that might be glauconite. Base of GREENFIELD DOLOMITE.
17. 110-120 ft. *White*, fine grained to finely crystalline and saccharoidal dolomite. Fragment of a coral (*Favosites*?). Top of HUNTINGTON DOLOMITE.
18. 120-130 ft. Several flat chips of fine grained medium gray dolomite. Look as though slickensided.
19. 130-140 ft. Like 18. Finely crystalline.
20. 140-150 ft. Very small pieces, angular, light brown, dense, sharp-edged. Dolomite.
21. 150-160 ft. Dense, fine grained, hard, medium gray dolomite. Slight effervescence. A few lighter colored particles.
22. 160-170 ft. Same as 21.
23. 170-180 ft. Same; but with fragments of sandstone with calcareous cement.
24. 180-190 ft. Some like 23; but with much white crystalline dolomite. One large fragment very coarse, granular and porous.
25. 190-200 ft. Like 21 and 22.
26. 200-210 ft. Same.
27. 210-220 ft. Same; but drusy, with calcite and stylolites. Fragments of *Halysites*, *Favosites* and crinoids.
28. 220-230 ft. Small pieces. Mostly lighter colored. Stylolites.
29. 230-240 ft. Almost *white*, slightly buff, porous, finely granular dolomite. Numbers *18 to 28 are interpreted as reef rock.*
30. 240-250 ft. White, mottled with gray, crystalline. Some pieces very porous. Mostly flaky-crystalline.
31. 250-260 ft. White, rather fine grained.
32. 260-270 ft. White to light gray, flaky, coarsely crystalline. Slight effervescence. Crinoid fragment.
33. 275-280 ft. White, flaky-crystalline. Good fragment of crinoid stem.
34. 280-290 ft. White or very light gray. Flaky crystalline.
35. 290-300 ft. Three large pieces of drusy, porous, finely granular, crystalline, light brownish gray dolomite. Fair effervescence.
36. 300-310 ft. Almost *white saccharoidal* dolomite.
37. 310-320 ft. Mostly large sharp-edged flakes of dense, light gray dolomite. Some white porous dolomite. Fair effervescence.
38. 320-330 ft. Light gray to almost white, flaky, crystalline dolomite.
39. 330-340 ft. Mostly very light gray saccharoidal dolomite. One piece of finely granular brown dolomite.
40. 340-350 ft. Very light gray to white, flaky, coarse dolomite. Porous. Fairly good effervescence.

41. 350-360 ft. Light gray to white, coarse flaky dolomite.
42. 360-370 ft. Very light gray, coarsely crystalline, flaky.
43. 370-380 ft. Mostly white, saccharoidal dolomite. Good effervescence.
44. 380-390 ft. Same as 43.
45. 390-400 ft. Same.
46. 400-410 ft. Slightly darker and more flaky. Stylolites.
47. 410-420 ft. Very light gray to white, splintery, porous.
48. 420-430 ft. Very light brown granular, saccharoidal dolomite. Fair effervescence.
49. 430-440 ft. Light brownish gray, saccharoidal. Good effervescence.
50. 440-550 ft. Dense, finely granular, light brownish gray. Angular fragments.
51. 450-460 ft. *White*, saccharoidal, fair effervescence. Looks like typical Huntington dolomite.
52. 460-470 ft. Pure white dolomite.
53. 475-485 ft. White dolomite, mottled with gray to blue.
54. 485-495 ft. Buffish white, very finely pulverized, soft dolomite.
55. 495-505 ft. White, saccharoidal dolomite.
56. 505-515 ft. White dolomite.
57. 515-520 ft. Light gray, dense, porous, flaky, dolomite. Very slight effervescence.
58. 520-525 ft. White to gray, mottled, saccharoidal dolomite. Crinoid fragment.
59. 525-535 ft. White to gray, very saccharoidal dolomite.
60. 535-545 ft. Coarsely saccharoidal, white, porous. Finely pulverized. Evidently very soft.
61. 545-555 ft. Slightly grayer, very saccharoidal dolomite.
62. 555-565 ft. Light bluish gray, dense, *very cherty*, hard splintery limestone. Light blue to white chert very abundant. Top of LISTON CREEK LIMESTONE.
63. 565-575 ft. Very *cherty* light gray limestone, with white, strongly effervescent particles. Chert light gray.
64. 575-585 ft. Dark gray, splintery, prous dolomitic limestone. Much light gray *chert*.
65. 585-595 ft. Same, but with less *chert*.
66. 595-605 ft. Medium gray, spintery, *cherty* limestone.
67. 605-615 ft. Medium gray, *very cherty*, dense, splintery limestone.
68. 620-630 ft. Dark gray, porous, dense limestone. Very muddy sample. Three pieces of blue soft shale. Probably top of MISSISSINEWA SHALE. This last screw evidently just touched the top of the shale.

These detailed well sections may be summarized as follows:

Well No. 1 reaches a thin remnant of *Greenfield* dolomite somewhere between 100 and 110 feet. At 110 feet it enters pure, almost white, granular, fine grained dolomite of typical Huntington or Guelph character. This white dolomite, often very saccharoidal, persists with a few slight alternations of browner or gray dolomite, to a depth of 280 feet, where a grayish brown to brown somewhat cherty dolomite set in and continues to 380 feet. This 100 foot bed has the lithology of the *New Corydon* formation of Cumings and Shrock (1928). From 380 to 400 feet the samples show considerable blue, shaly rock. This evidently represents an expansion of the shaly streak sometimes seen on the outcrop at the base of the New Corydon. Below this level, down to 560 feet, the rock is coarsely saccharoidal, granular, very white and typical of the *Huntington* as seen in the outcrops of eastern Indiana. At 560 feet the drill enters a fine grained, light gray, very dense, cherty, splintery rock of typical *Liston Creek* lithology. This persists to the bottom of the well at 640 feet.

0′		Well cap at 755 ft. A. T.
	110′	Glacial drift.
		Thin remnant of Greenfield dolomite.
110′		Top of Huntington dolomite.
	170′	
280′		Top of New Corydon dolomite.
	100′	New Corydon dolomite.
380′		Base of New Corydon dolomite.
	180′	
560′		Base of Huntington dolomite.
	80′	Liston Creek limestone.
640′		Bottom of well.

Thickness of Huntington dolomite (and New Corydon member) 450 feet. Thickness of Liston Creek limestone 80 feet. Thickness of Niagaran 530 feet.

Well No. 2 reaches a light brown, fine grained dolomite at about 70 feet, and penetrates the same rock to 110 feet. This 40 feet of brown dolomite has the characteristics of the *Greenfield* dolomite of Ohio, and is so correlated. At 110 feet the well enters a very white, fine grained to finely crystalline, saccharoidal dolomite, which is evidently the top of the *Huntington* formation. A fragment of coral, probably *Favosites*, occurs in sample No. 17. Below this level for 110 feet, the samples are of an unusual character, usually light gray to light brown, dense, flaky, sharp-edged, and sometimes slickensided. Stylolites are common, and fragments of corals and crinoids appear in the samples, notably No. 27. These cuttings are quite different from those at the corresponding levels in well No. 1, and can only be interpreted as reef-core rock. From the known abundance of reefs in the Huntington formation in Indiana and Ohio, such an interpretation is perfectly admissable; and the lithology of samples 18 to 28 clearly supports it. At 230 feet the well enters almost white saccharoidal dolomite, and this persists with some alternations of gray and denser rock to 450 feet, below which to 555 feet the cuttins show white, coarsely granular typical Huntington rock. Some of the samples in this interval suggest the New Corydon member; but the New Corydon lithology does not persist as it does in well No. 1. Evidently actual reef conditions or proximity to a r eef are influencing the rock in this well down through practically the entire Huntington interval. At 555 feet the drill penetrates very cherty, dense flaky rock of typical *Liston Creek* character, and this persists to the bottom of the well. The last sample, No. 68, is very muddy, with several fair sized chips of shale, and evidently the drill just touched the top of the *Mississinewa* shale.

0′		Well cap at 754.5 ft. A. T.
	70′	Glacial drift.
70′		Top of brown Greenfield dolomite.
	40′	Greenfield dolomite.
110′		Base of Greenfield. Top of Huntington.
	120′	Reef rock, except upper 10 feet.
230′		Base of reef-core rock.
	325′	Huntington rock, with suggestions of the New Corydon member.
555′		Base of Huntington dolomite. Top of Liston Creek limestone.
	75′	Liston Creek limestone.
630′		Bottom of well. Base of Liston Creek limestone. Top of Mississinewa shale.

Thickness of Greenfield 40 feet. Thickness of Huntington (including New Corydon member) 445 feet. Thickness of Liston Creek limestone 75 feet. Thickness of Niagaran 520 feet.

Two wells at Fort Wayne, recorded by Logan (1926, p. 25), give 30 and 34 feet of Waterlime (Greenfield) and 570 and 571 feet of Niagaran limestone and shale. These penetrate the Mississinewa shale, for they go on down to the Trenton, which is reached at 693 and 650 feet below sea level. How much of the Mississinewa shale is included in the so-called Hudson shales of these well sections it is impossible to determine. If Logan's determination of the top of the "Hudson" is correct, there would be only 40 or 50 feet of Mississinewa. This is probably the shale so commonly reported as "Rochester" and "Clinton" in the Michigan and Ohio wells.

A well drilled in Perry township, Allen county, Indiana, gives, according to Logan (*loc. cit.*) 749 feet of limestone, underlain by 430 feet of "white shale," and the latter by 240 feet of black shale, down to the Trenton. Part of the stated thickness of limestone is undoubtedly Greenfield. The "white shale" might be in part Mississinewa, which in wells in the Wabash valley region is sometimes reported by the drillers in this way. This well is about 14 miles north of the two detailed above. The Trenton is reached at 856 feet below sea level.

A well in Maumee township, Allen county, 18 miles northeast of the Fort Wayne wells gives: drift 48 feet, limestone with a little shale and "red rock" 554 feet, shale 715 feet, to the Trenton. The base of the Mississinewa cannot be fixed in any of these wells.

The thickness of the Huntington dolomite, which correlates with the Racine and Guelph (Port Byron) of Illinois and Wisconsin, and with the Springfield and Cedarville (Durbin) and "Guelph" of Ohio, is accurately determined as 450 feet in the Fort Wayne wells. Thie thickness of the Liston Creek is 75 to 80 feet, if the shale shown in the last sample (No. 68) of well No. 2 is the top of the Mississinewa. These wells were drilled for water and evidently stop at the top of the impervious Mississinewa formation, after penetrating the porous dolomites. The thickness of the Mississinewa cannot be determined in any of the northeastern Indiana wells. Probably part of this formation is confused in the various well logs with the underlying Cincinnatian shales. Within the Huntington dolomite, the cherty New Corydon dolomite forms a bed about 100 feet thick.

At Huntington, Indiana, the base of the Liston Creek limestone is 680 feet above sea level, at the Erie quarry east of the city. At Fort Wayne it is 125

Fig. 1—Key map of the Michigan Basin region.

feet above sea level. The Niagaran therefore descends 555 feet between Huntington and Fort Wayne, or about 25 feet per mile. In this same distance the Trenton descends about 440 feet. This is a rather unexpected result, and probably indicates thinning of the Mississinewa formation to the northeast. In the wells in Huntington county, and elsewhere in the Wabash valley region, the Mississinewa is commonly reported as limestone. For example, in the many logs listed by Logan (1926) from near Warren in southeastern Huntington county most of the 400 feet or more of "limestone" is below the top of the Mississinewa, since that formation outcrops along the Salamonie river to within a short distance of Warren. The more detailed logs given on page 269 of Logan's report indicate from 240 to 280 feet of limestone beneath the 20 feet or so of drift, and underneath this "white shale" or "white mud" for as much as 160 feet. In other logs this is all included as "limestone." What this "white mud" is geologically it would be difficult to say. If it is Cincinnatian, that division would be given a thickness of over 700 feet in Huntington county wells, which is comparable with its reported thickness in the Fort Wayne wells, and more in keeping with what would be expected. On this supposition, the eastward thinning of the interval between the base of the Liston Creek and the Trenton is due to the reduction of the Mississinewa formation.

Bownocker (1903) has summarized the well data of Ohio in his report on oil and gas in Ohio. A well at Findlay (*op. cit.*, p. 69) gives 275 feet of Niagara and "Clinton" limestone and shale, 47 feet of red "Medina" shale, and 762 feet of Cincinnatian. Greenfield dolomite outcrops at Findlay, so that this figure represents the entire thickness of the Niagaran of that locality. "Lower Helderberg" (Greenfield), Niagara and "Clinton" limestones are 330 feet thick at Lima. Forty feet of "Clinton shale" is reported below the limestone and above so-called red Medina shale. A well at Beaverdam, near Lima, reports 105 feet of "Clinton shale." These wells report over 800 feet of Cincinnatian shales. A well at Celina gives 135 feet of Niagara limestone and 15 feet of Niagara shales, underlain by 43 feet of "Clinton" limestone and 20 feet of "Medina shales." This "Clinton" may be the Bassfield limestone, and the "Medina" the Elkhorn formation of the Richmond. The upper 85 feet of the Niagara is described as yellow and white, and is undoubtedly Huntington, which outcrops a few miles west of Celina. The lower 50 feet of the Niagara is described as drab and of various shades. This might be the Liston Creek limestone. The writer has reexamined the quarry at Lewisburg, Ohio, 50 miles south of Celina, and is convinced that Prosser's (1916) "Osgood" and "Laurel" are not correlates of these well-known southern Indiana formation; but feather edges of the Mississinewa and Liston Creek formations of the northern Indiana area. The two have a combined thickness of only 13 feet at Lewisburg, whereas in the Wabash valley their combined thickness is some 300 feet. If the above interpretation of the Celina well is correct, their combined thickness there is 65 feet. The evidence of the wells is thus entirely consistent with the southeastward thinning of the lower Niagaran described by Cumings and Shrock (1928, 1928a).

Wells in northwestern Ohio also report Niagara and "Clinton" shales below Niagara limestone. At Bowling Green in Wood county, Bownocker (p. 59) reports 108 feet of Niagara and "Clinton" limestones and shales, below 167 feet of limestone. At Rollersville, in Sandusky county, 30 miles west of Sandusky, he reports (p. 74) gray and white limestone 300 feet (Huntington), blue limestone 20 feet (Liston Creek), white slate 2 feet, brown limestone 21 feet and light slate

20 feet. This lower 43 feet may be Mississinewa. Below this he has 100 feet of "Clinton" and 80 feet of "Medina." Interpreting this "Medina" shale as Queenston, this well contains 760 feet of Cincinnatian. A well at VanWert Van Wert county, (p. 98) has 185 feet of Niagara limestone and 15 feet of Niagara shales.

Richard A. Smith (1914) reports on the deep wells in Michigan, including also several in Ontario peninsula. A well at LaSalle in Monroe county, Michigan, (*op. cit.*, p. 76) has "Niagara (Guelph and Lockport)" 490 feet, described as "white lime"; and "Rochester shale and Clinton" 165 feet, described as "blue shale and shells." From a well at Strasburg, near LaSalle, he reports (p. 77) "Guelph and Lockport" 410 feet. Judging from his detailed description, based on the examination of a set of samples by Dr. A. C. Lane, this mass is very much like the 450 feet of Huntington in the Fort Wayne wells, and even includes 80 feet of " 'very hard,' brown, sandy looking" dolomite which may be interpreted as New Corydon. Below this he reports 70 feet of "Rochester shale?" and 130 feet of "Clinton," described as "ferruginous dolomite and limestone." There is nothing in this well that can be interpreted as Liston Creek. From the Carman well at Petrolia, Ontario, southeast of Port Huron, he reports 275 feet of "Guelph and Niagara lime" (p. 54), 60 feet of "Rochester (Niagara) shale," described as "red and dark," 90 feet of "Clinton" and 275 feet of "Red Medina." The top of the Guelph is 1,438 feet below sea level. Williams' well sections (1919, fig. 4) give only a little over 100 feet of Medina at Tilbury, just east of Lake St. Clair, and Beachville, near Woodstock, Ontario. This "red Medina," therefore, must be largely Queenston shale, of which Williams indicates several hundred feet in the sections mentioned. Williams' Tilbury section indicates about 300 feet of Lockport and Guelph, and 50 feet of Rochester shale, as scaled from his graph. Sections along the north shore of Lake Erie, at Port Burwell, Port Ryerse, Walpole, Dunnville and Bertie, also show Rochester shale up to 40 feet or so in thickness. From Hamilton, Ontario, northwest, however, the Rochester shale and Clinton completely disappear. Whether the "Clinton" reported by Smith and Williams is Clinton or Brassfield (Cataract) cannot be determined. Clinton has not been certainly identified in the Michigan Basin region, while Medinan (Brassfield, Cataract, Mayville, etc.) is known to occur widely.

In southwestern Michigan Smith (p. 177) reports on a deep well at Dowagiac, Cass county, which reached nearly to the Trenton. At 1,100 feet the drill entered light gray dolomitic limestone, somewhat cherty. The next 580 feet are referred to the Lockport and Guelph. The lower 70 feet contains considerable silica and clay, and is described as "white to gray fine grained limestone" and "creamy white marly limestone." Overlying this is 70 feet of "grayish white to gray fine grained limestone" containing "flint" (chert). This is probably the Liston Creek (Waukesha) limestone. The lower 70 feet may represent the Joliet limestone. Forty feet of "Rochester" is reported below the Niagara limestones. This may belong to the Cincinnatian.

Well No. 2 at St. Ignace in the Upper Peninsula (Smith, p. 243) penetrates 656 feet of "Niagaran," without reaching the bottom of this division. The upper 60 feet is described as light dolomite, and the next 15 feet as "white sandy dolomite." Below this is 7 feet of "hard mixed cherty dolomite." This probably represents the top of the Coral Beds or Manistique. The upper 75 feet may be referred to the Engadine (Racine). The lower 450 feet or more should be in the Burnt Bluff (Byron) formation of Ehlers (1921).

In Wisconsin the Racine-Guelph dolomite is underlain by the Waukesha cherty limestone in the southeastern part of the State, and by the cherty Coral Beds in the Door Peninsula region. The Waukesha and the Coral Beds are thin bedded, cherty, slabby, dense, gray limestones, like the Liston Creek limestone of Indiana, and contain the same Louisville coral fauna, characterised by species of *Alveolites, Favosites, Halysites, Thecia, Strombodes, Syringopora, Cladopora, Eridophyllum, Lyellia, Heliolites, Plasmopora* and *Zaphrentis.* These cherty coral beds are also present throughout the Upper Peninsula of Michigan, and were extensively collected from by Rominger, especially at Point Detour, Chippewa county, and on Drummond Island. Ehlers (1921) has redefined the term Manistique, which was proposed by R. A. Smith (1916) for the great mass of dolomites below the Engadine dolomite, and made it apply to these coral beds. The coral beds are also known on Manitoulin Island, where, as at Coral Hill, they contain the corals in extraordinary abundance. M. Y. Williams (1919) mentions corals in the lower part of the Lockport at Cabot Head and Owen Sound in Bruce Peninsula, Ontario. The writer visited the principal sections in Ontario, during the past Summer, and found the coral beds in typical development at Isthmus bay, just north of Lion Head, and at Dyer bay. At Isthmus bay 35 feet of thin layers abounding in corals, and containing a little chert, are overlain by the massive Lockport dolomite. In the lower part of these coral beds *Pentamerus oblongus* is very abundant. At Dyer bay 64 feet of thin coral beds rest on a dense very evenly jointed, brownish gray dolomite, much like the Byron of Wisconsin. The coral beds are capped by massive Lockport dolomite. No well developed coral beds were seen south of Isthmus bay and Lion Head; though at Owen Sound there are some corals and the lower part of the Lockport is thinner bedded than the main mass, and contains *Pentamerus oblongus* abundantly. This brachiopod also occurs in abundance at the base of the coral beds in Michigan and Wisconsin. The coral beds with their characteristic Louisville corals do not occur in New York and the Niagara peninsula.

The last statement raises the question whether any of the typical Lockport of New York is an old as the coral beds. Williams (1919) regards the Lockport as an invasion from the north, and intimates that the lower portion of the more northwestern secions may be older than the New York Lockport. The Lower Shelby or first Guelph fauna of Clarke and Ruedemann (1903) occurs well down in the Lockport. With the exception of a few stray Guelph species in the Liston Creek reef at Markle, Indiana, and in the reefs of the Lower Coral Beds of Wisconsin, the Guelph fauna first appears in the Racine of Wisconsin and Illinois and in the lower Huntington of Indiana and Ohio. This would correlate the New York Lockport with the Racine, in accordance with the arrangement indicated by Ulrich (1911, pl. 28) and Savage (1926, p. 533); though in the text, Ulrich (p. 561) places the Racine "in the hiatus between the Rochester and the Lockport." From Ulrich's correlation of the Louisville *above* the Guelph there must be complete dissent, as also from Schuchert's statement (1910, p. 534) that the corals of the Siluric have little stratigraphic value. Schuchert places the Racine above the Lockport.

In the writer's view the coral beds (Louisville, Liston Creek, Waukesha, Manistique as restricted, etc.) constitute the most reliable and easily traceable horizon in the entire Niagaran. In the Michigan Basin region they constantly occur immediately beneath a very massive, saccharoidal, light gray, pure dolomite, variously known as Racine, Engadine, Lockport and Huntington (lower).

These coral beds extend as far east as northwestern Ohio and Lion Head in Bruce Peninsula; but no farther. The massive overlying dolomite extends much farther east and south, namely nearly to Hamilton, Ontario, and beyond Cedarville, Ohio. To the westward and northward it is coextensive with the coral beds.

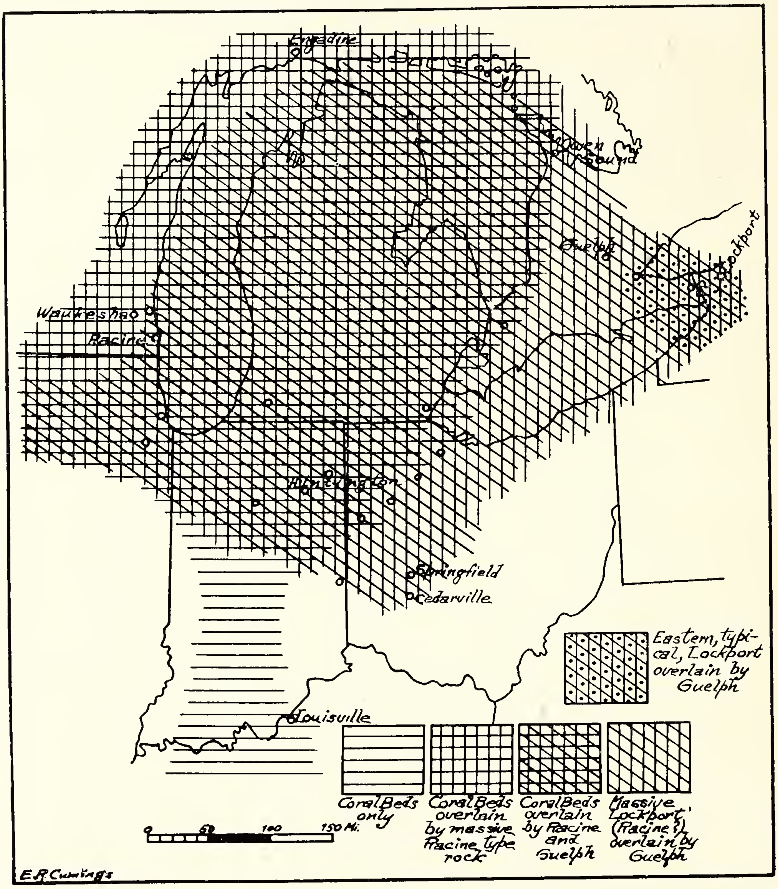

Fig. 2—Map of the Michigan Basin region, showing general distribution of the coral beds, Racine and Guelph formations. Boundaries extended somewhat beyond present area of outcrop.

The exceedingly massive, light gray mottled saccharoidal dolomite of Bruce Peninsula, overlying the coral beds, resembles the Engadine dolomite of the Upper Peninsula of Michigan to an astonishing degree, and weathers in the same way into enormous boulders, which thickly besprinkle the landscape, as any one who has ever driven the road to Tobermory will agree. This massive gray dolomite persists southeastward to about Nelson, a few miles north of Hamilton, Ontario; abounding in coral reefs, as at Milton and Rockwood, and often becoming a mass of crinoid fragments. East of Hamilton, the only thing that at all resembles this great dolomite lithologically is the Gasport dolomite (or limestone) at the base of the Lockport. The chert beds and "Barton beds" of Dundas have nothing corresponding to them farther north—so far as lithology goes. Evidently the muddy waters of Hamilton were too much for the corals and crinoids that provided the material of the massive dolomites from Nelson to Tobermory.

In the laying down of this massive gray dolomite, after the time of the cherty coral beds, the teeming life of the Niagaran sea assumes complete mastery of the sedimentation and builds a formation, the Racine-Guelph, entirely derived from its own exuviae. The Racine is the foundation of the great mass of which the Guelph is the superstructure. They are both comprised within the Huntington of Indiana, 450 feet in thickness; and this name might appropriately be used in this sense throughout the Michigan Basin region. "It is a single, well-defined episode, ushered in by an increasing spread of the coral seas at the close of Liston Creek time............" (Cumings and Shrock, 1928a).

The well sections discussed above, and the field studies of the past few years around the rim of the Michigan Basin, suggest some interesting conclusions in regard to the formations *below* the coral beds.

In Indiana the coral beds (Liston Creek) are underlain by an argillaceous limestone, the Mississinewa shale, containing 50 per cent or more of non-calcareous matter (Cumings and Shrock, 1927, 1928, 1928a). Its exposed thickness is 75 feet; but wells in the Wabash valley indicate at least 100 and probably 200 feet or more of this formation. The interval between the base of the Liston Creek limestone and the top of the Cincinnatian shales is at least 250 feet. In the well logs this is often reported as limestone—sometimes as white shale. In the outcrop, more resistant limy layers are sometimes seen, as at Jalapa on the Mississinewa river. It is not unlikely that the formation as a whole is composite, consisting of limestone and shale members. Some of the more detailed well sections suggest this. Toward the northwest the formation becomes more calcareous.

In the Chicago area, an even bedded, light colored, impure limestone, the Joliet, underlies the coral beds (Waukesha). Some 80 feet of this formation is exposed in the quarry at Joliet. It has been described and named by Savage (1926). It is correlated by Cumings and Shrock with the Mississinewa shale of Indiana. Its fauna is not especially diagnostic; but the fine graptolite fauna of the Mississinewa, and a large list of species recently collected by the writer from a reef in the Mississinewa, are sufficient to correlate at least the upper part of that formation with the Rochester shale of New York. (See Shrock, 1928). The Joliet is underlain by the Kankakee (Brassfield) formation of Medinan age.

In Wisconsin the Byron formation, an even bedded, perfectly jointed, light colored, often rather thin bedded dolomite, with some lithographic bands, and occasional argillaceous beds, underlies the coral beds (Waukesha, Coral Beds). Underneath this formation is the Mayville vesicular, rough, massive dolomite. These two formations give rise to the conspicuous cuesta east of Lake Winnebago and Green Bay. They have been traced into the Upper Peninsula of Michigan by Ehlers (1921), Verwiebe (1927) and the writer; where the Byron has been renamed the Burnt Bluff formation by Ehlers. The Byron of Upper Michigan is exactly like the Byron of Wisconsin. The Mayville has been identified on Drummond Island by Verwiebe. In the Seaman quarry at Drummond village, much of the Byron is somewhat argillaceous, and the weathered material on the dump looks like Mississinewa shale.

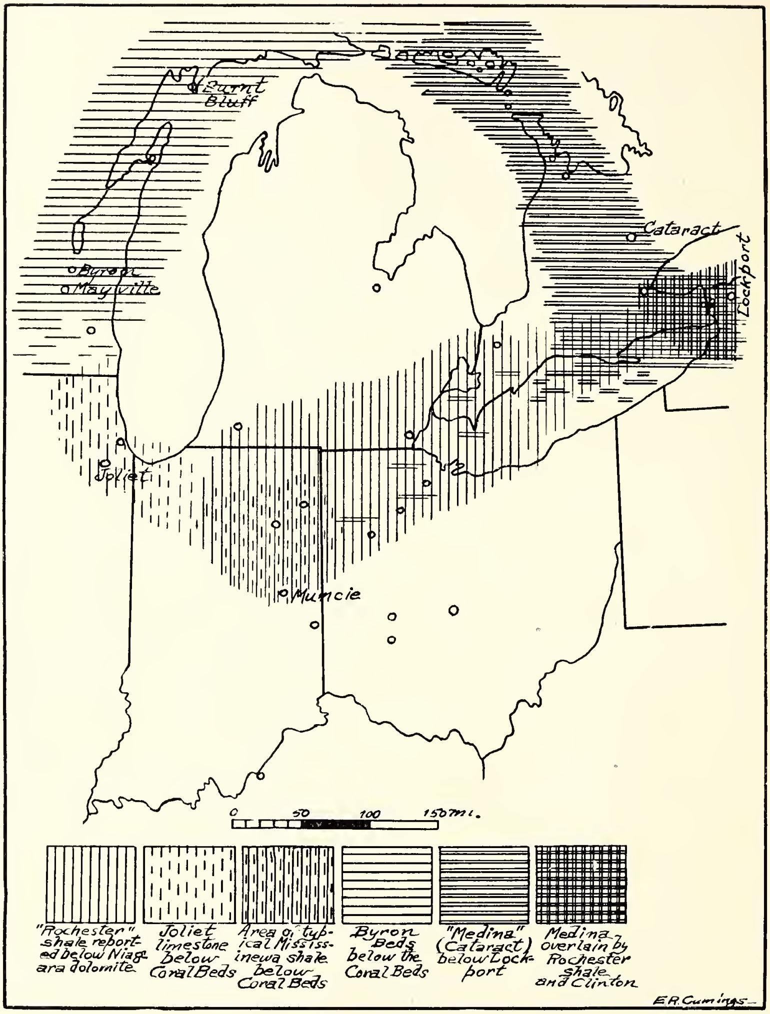

Fig. 3—Map of the Michigan Basin region showing general areas of the Mississinewa, Joliet, Byron and Mayville and Cataract (Medina) formations. Boundaries extended somewhat beyond present area of outcrop.

The Rochester shale of New York disappears at Dundas, Ontario, and north of there the Lockport rests first on the Clinton limestone, and then, beyond Milton, on the Medina (Cataract) shales. The Medina formation (Cataract) has been traced across Ontario Peninsula by Williams and others, into Manitoulin Island, becoming first more shaly, and finally more calcareous, till on the Island there are several heavy beds of dolomite, of which the Manitoulin dolomite is the most important.

Wells along the north shore of Lake Erie and in the region of Lake St. Clair indicate that the Rochester shale persists to the westward. It is reported from wells in southeastern Michigan and northwestern Ohio. The "Medina shale" beneath it is referred to the Cabot Head shale by Williams.

The facts stated in the preceding summary are expressed graphically on the accompanying map, (fig. 3). They are mostly facts of common knowledge among

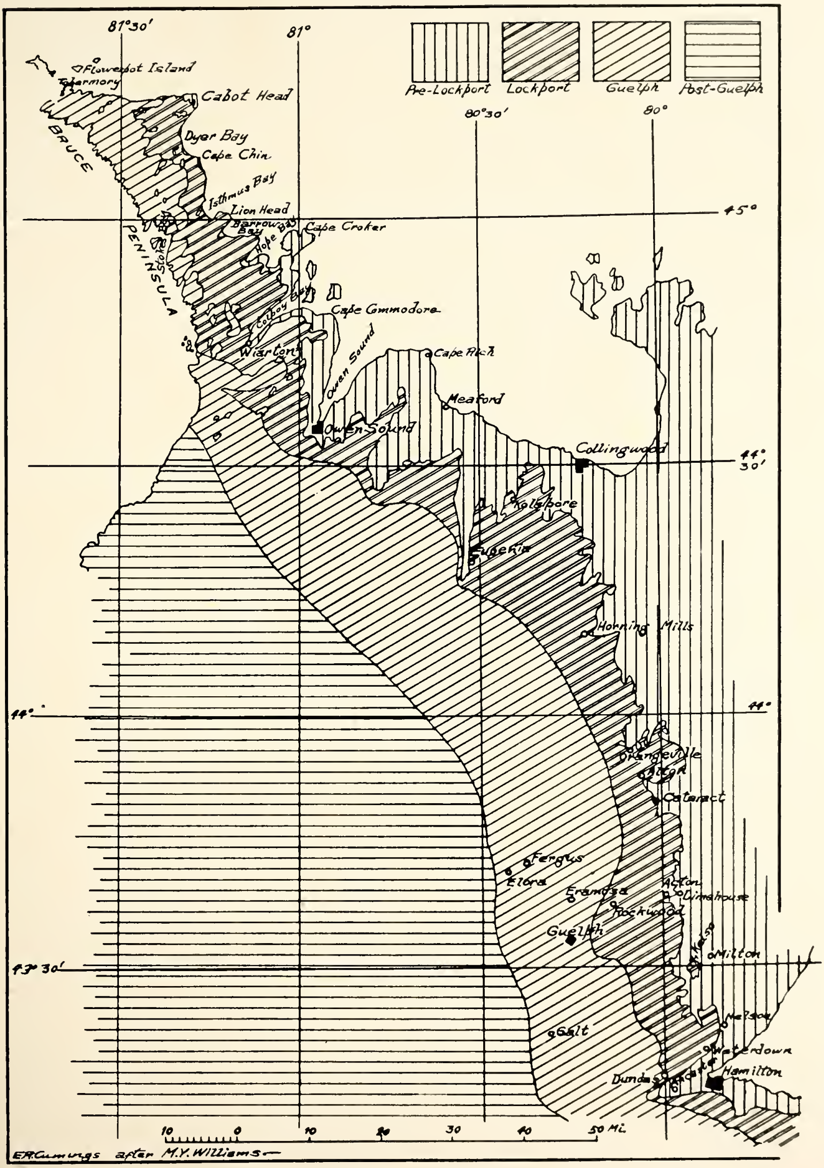

Fig. 4—Map of a portion of Ontario, including Bruce Peninsula, showing distribution of the Lockport and Guelph.

geologists familiar with the region. It is in their interpretation that opinions vary. For example, the Mississinewa formation, so far as recognized at all heretofore, has been placed in the Lockport division (so, Kindle and others). The Joliet is placed at the base of the Lockport by Savage (1926). The Mayville is correlated with the Clinton by Ulrich (1923) and others, and with the Lockport by Ulrich (1911); and with the Edgewood by Savage (1926). The Byron is placed in the Lockport by most geologists; but it is correlated with the Brassfield by Savage (1926). Verwiebe's chart (1927, p. 313) is difficult to interpret, but appears to indicate that the lower part of the Byron is to be correlated as pre-Lockport. He correlates the Mayville with the Manitoulin dolomite (p. 319). Paleontologic evidence of the age of the Byron is singularly meager.

All of these formations are older than the coral beds, which are regarded by the writer as very early Lockport, and indeed older than the typical Lockport of New York. None of them, therefore, is Lockport. The pre-coral beds to the south (Illinois, Indiana, Ohio) are probably Rochester. They are underlain by Medinan. The Mayville and the Byron are believed to be western calcareous equivalents of the entire Cataract formation of Ontario and Manitoulin Island, and may rise even into Clinton and Rochester horizons.

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SILURIAN REEFS NEAR TIFFIN, CAREY AND MARSEILLES, OHIO

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In the paper by Cumings and Shrock (1928, p. 614) on Niagaran coral reefs of Indiana and adjacent States, reefs are indicated, on the authority of Winchell (1873), near Tiffin and Carey, Ohio. Recently the writer visited the localities mentioned by Winchell, and confirmed the surmise of 1828 that these structures are reefs.

In his report on Seneca county, Winchell described (p. 615) abnormal dips along the Sandusky river, between Tiffin and Fort Seneca. On page 614 he says, "Throughout the most of this distance the dip of the formation (Niagara) is from five to ten degrees toward the southwest, but with various flexures and undulations in all directions." On page 615 these flexures are described in detail. Winchell did not suspect that these are reef structures. He mentions reversed dips as high as 10 degrees.

This locality was visited by the writer on Oct. 10th, 1929, and studied rather carefully, with the following results.

A few small outcrops may be seen within the city of Tiffin along the edge of the river, below the concrete retaining wall; but nothing of consequence. At the first dam north of Tiffin the dip is slight and the layers of rock not very massive. One-fourth mile north, massive beds of light brown somewhat banded dolomite (Greenfield) are exposed in the east bank of the river, underlain by Niagara (Guelph) to river level. The contact is exposed, and is clean-cut.

At the second dam, and concrete bridge, one mile north of Tiffin, the upper layers, at the east end of the bridge, are thin, even, saccharoidal dolomite, of light gray color. They dip 5 to 6 degrees upstream (south). North of the bridge the dip changes to north (down stream). Under the bridge very massive ledges of ash-colored, saccharoidal, sandy dolomite are exposed in the bed of the river. These ledges are very rough looking, and are probably reef rock. Just north of the west end of the bridge, massive unstratified, very rough, ragged, much brecciated dolomite, full of stromatoporoids, is exposed in the bed and bank of the river. *Favosites* is also common. This is typical reef-core rock. The overlying layers here dip to the southeast. The reef is apparently a ridge running in a northwest-southeast direction across the river.

Four-tenths of a mile north of this bridge the layers rise again, on the south side of the river opposite the power house, to a dip of 4 degrees south; but within a few rods reverse to a north dip. The rock under the center of this arch is irregular, but not very massive, and is probably just above the core of a reef.