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SHORT PAPERS ON GEOLOGIC SUBJECTS

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THE MT. SIMON SANDSTONE IN NORTHERN ILLINOIS<sup>1</sup>

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Wells in northern Illinois penetrate from 1600 to 2100 feet of upper Cambrian Mt. Simon sandstone between the Eau Claire formation and pre-Cambrian crystallines. In most of the region the sandstone is pure and light colored, but in the vicinity of Boone County all but the uppermost beds are silty, argillaceous, and dark red. The light-colored sandstone long has been correlated with the Mt. Simon formation of northwestern Wisconsin, but recently the red elastics were assigned provisionally to the pre-Cambrian and correlated with the Fond du Lac formation of eastern Minnesota. The present study shows that the red elastics of northern Illinois are a local facies of the light-colored Mt. Simon sandstone. On the basis of differences in grain size, the formation is divisible into seven regionally persistent members. Evidence is presented which suggests that the Mt. Simon sandstone of Minnesota and the upper part of the Mt. Simon at the type locality belong to the Eau Claire formation.

*Previous and present studies.*—Early subsurface studies in northern Illinois referred all sandstone beneath Eau Claire dolomitic strata to the Mt. Simon, although a possible Keweenawan age for the red elastics at Dixon was suggested (Thwaites, 1923, pp. 534, 553-555). Thwaites' tentative Keweenawan correlation at Dixon was rejected by Knappen (1926, pp. 34-36). In lat-

er studies the red elastics of northern Illinois and similar strata in eastern Wisconsin were stated to be of unknown age but were not separated from the Mt. Simon formation (Thwaites, 1931, p. 742; Twenhofel, Raasch and Thwaites, 1935, p. 1693, pl. 151). Possible correlation of the arkosic basal Mt. Simon strata of southern Lee County, Illinois, with the supposedly Keweenawan Hinckley sandstone of eastern Minnesota has been suggested (Payne, 1942, p. 54). Recently the red elastics of northern Illinois were correlated tentatively with the supposedly pre-Cambrian Fond du Lac formation of eastern Minnesota (Bays and others, 1945, p. 1146; Weller and others, 1945), and the regional lithology and thickness of the "Mt. Simon-Fond du Lac (?)" sandstones were summarized (Workman and Bell, 1949, pp. 2041-2043). In the present study all available cuttings from wells in central northern Illinois which penetrated the Mt. Simon and "Fond du Lac (?)" formations were carefully examined, as well as samples from deep borings in part of northeastern Illinois.

*Name and definition.*—At the type locality the Mt. Simon formation, named from exposures on and near Mt. Simon at Eau Claire, northwestern Wisconsin (Ulrich, 1914, p. 354), consists mainly of coarse-grained, partly conglomeratic, thick-bedded sandstone 234 feet thick, which overlies pre-Cambrian granite and underlies fine-grained thin-bedded *Cedaria*-bearing Eau Claire

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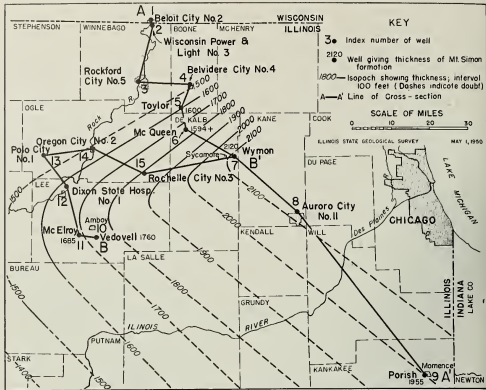


FIG. 1.—Isopach and reference map of the Mt. Simon formation in northern Illinois. (Modified from Workman and Bell, 1948, fig. 4.)

sandstone (Twenhofel, Raasch and Thwaites, 1935, pp. 1693, 1739-1740). In this report the name Mt. Simon is applied to all sandstone between pre-Cambrian crystallines and sediments which are classed as Eau Claire but probably underlie the *Cedaria* zone.

**Thickness.**—In northern Illinois only four wells (fig. 1, wells 5, 7, 10, 11) have completely penetrated the Mt. Simon sandstone, although two other wells (6, 9) are believed to have passed almost through the formation. The sandstone is thickest in a basin extending from DeKalb to Cook counties in northeastern Illinois and attains a maximum known thickness of 2120 feet in northeastern DeKalb County. From this area it thins rapidly to thicknesses of 400 feet or less in most of the states surrounding Illinois, and lenses out in

northeastern Wisconsin and southwestern Ontario (Cohee, 1945, 1948).

**Lithology.**—In northern Illinois the Mt. Simon sandstone is divisible into a light-colored facies, which constitutes the bulk of the formation in most of the region, and a red facies, which is best developed at Belvidere, Boone County. Much gradation and interfingering characterize the transition zone between the two facies, which in places is less than 6 miles wide (fig. 2, wells 4, 5). Both facies are nonfossiliferous.

**Light-colored facies.**—The light-colored Mt. Simon facies is white, yellow, or pink to light brown. The sandstone ranges from very fine to very coarse grained and locally is silty. Much of it is conglomeratic, containing quartz granules from 2 to 4 mm. in diameter and quartz peb-



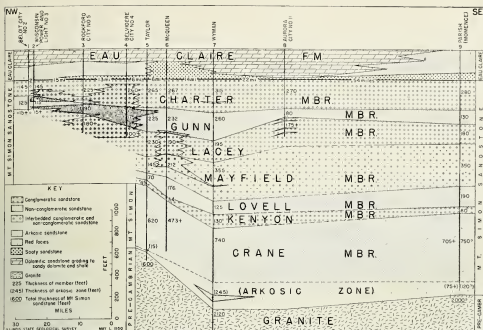


FIG. 2.—Northwest-southeast cross section of the Mt. Simon formation from Beloit, Wisconsin, to Momence, Illinois. (Line A-A', fig. 1.)

bles from 4 to 8 mm. in diameter. As a whole the sandstone is coarser grained than any other in northern Illinois. Sorting generally is poor, but some well-sorted beds are present. Although the grains range from angular to well rounded, they are chiefly subangular. The granules and pebbles are well rounded. Most of the sandstone is incoherent, but thin layers have been cemented by iron oxide or silica. A zone varying from 15 to 249 feet thick at the base of the formation is arkosic and locally contains biotite and muscovite flakes as well as granite grains and pebbles. Occasional grains of feldspar and granite and very rare gabbro and quartzite pebbles have been observed in higher beds. Thin layers of dark-red or variegated, partly micaceous shale and siltstone occur at different horizons.

**Red facies.**—Where best developed the red facies is characterized by

large amounts of disseminated dark-red hematitic clay and silt and by the presence of relatively thick interbeds of dark-red, partly micaceous, partly sandy shale and siltstone. Where weakly developed, as in southern Lee County, the facies is distinguished mainly by hematitic films on the sand grains.

**Subdivision into members.**—Throughout northern Illinois the Mt. Simon sandstone consists of a cyclic alternation of relatively fine-grained units and coarse-grained, granule-bearing units (figs. 2, 3). Although to the southeastward and westward granules become scarcer and smaller, and the entire formation grows more silty and finer grained, the sequence still is clearly distinguishable. Some lateral gradation or interfingering may take place along the contacts between the units. The seven major units present are herein regarded as members, and are

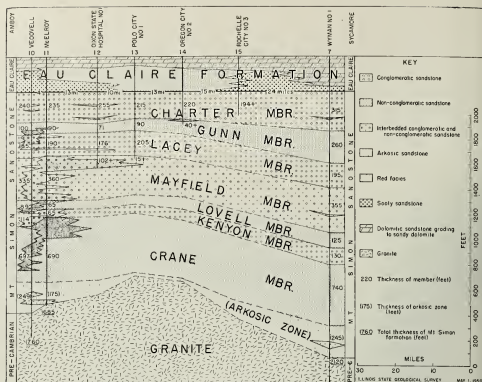


FIG. 3.—Cross section of the Mt. Simon formation from the vicinity of Amboy, Illinois, to the vicinity of Sycamore, Illinois. (Line B-B', fig. 1.)

named and described in ascending order. The members are made up of numerous subordinate units, many of which extend practically throughout the region.

The type well for the four lower members is Wyman No. 1 (well 7), a cable-tool well in the NE $\frac{1}{4}$  NE $\frac{1}{4}$  SE $\frac{1}{4}$  Sec. 35, T. 41 N., R. 5 E., DeKalb County, Illinois, sample set 1301.<sup>2</sup> The type well for the three upper members is McQueen No. 1 (well 6), a cable-tool well in the SW $\frac{1}{4}$  NE $\frac{1}{4}$  NE $\frac{1}{4}$  Sec. 27, T. 42 N., R. 3 E., DeKalb County, Illinois, sample set 1466.

*Crane member.*—For the relatively fine-grained basal member of the Mt. Simon formation the name Crane member is proposed. The name is

derived from the Crane School, NW $\frac{1}{4}$  NE $\frac{1}{4}$  NW $\frac{1}{4}$  Sec. 22, T. 40 N., R. 5 E. DeKalb County, 4 miles south of the type well. The "type section" consists of samples 387 through 491 in sample set 1301, extending from depths of 3105 to 3845 feet. The member ranges from 620 to 740 feet thick (figs. 2, 3). The grains range from very fine to very coarse, and a few granules are rarely present, but the predominant grades are fine and medium. The lower portion of the member generally is more or less shaly, silty, and arkosic.

*Kenyon member.*—For the thin conglomeratic sandstone overlying the Crane member the name Kenyon member is proposed. The name is derived from Kenyon school, NE $\frac{1}{4}$  NW $\frac{1}{4}$  NW $\frac{1}{4}$  Sec. 17, T. 40 N., R. 6 E., Kane County, 3 $\frac{1}{4}$  miles south-

<sup>2</sup>Number of sample set in subsurface files of Illinois Geological Survey. Most samples in both sets represent five- or ten-foot intervals.

east of the type well. The "type section" consists of samples 367 through 386 in sample set 1301, extending from depths of 2975 to 3105 feet. The member ranges in thickness from 34 to 130 feet. Where less than 80 feet thick, it is composed chiefly of coarse-grained sandstone containing quartz granules, but where thicker it consists of conglomeratic sandstone interbedded with nonconglomeratic layers.

*Lovell member.*—The succeeding relatively fine-grained unit is here named the Lovell member for Lovell School, SW $\frac{1}{4}$  NW $\frac{1}{4}$  NE $\frac{1}{4}$  Sec. 2, T. 40 N., R. 5 E., DeKalb County, three-quarters of a mile southward from the type well. The "type section" consists of samples 348 through 366 in sample set 1301, extending from depths of 2850 to 2975 feet. In thickness the member varies from 65 to 190 feet. Although grain sizes range from very fine to very coarse, the predominant grade is fine or medium. In the McElroy well (11) the member is partly coarse grained to conglomeratic but is clearly separable from the adjacent coarser-grained units.

*Mayfield member.*—Overlying the Lovell member is a thick sequence of interbedded conglomeratic and nonconglomeratic sandstones for which the name Mayfield member is proposed. The name is obtained from Mayfield Township, T. 41 N., R. 4 E., DeKalb County, Illinois, 5 miles west of the type well. The "type section" consists of samples 300 through 347 in sample set 1301, extending from depths of 2495 to 2850 feet. The thickness of the member ranges from 145 to 390 feet. The units composed of very coarse-grained to conglomeratic sandstone are from 5 to 125 feet thick; those

made up of finer-grained nonconglomeratic sandstone are from 10 to 90 feet thick. In the McElroy well (11) most of the sequence is conglomeratic, but in the Taylor and Parish wells (5, 9) granule beds are very subordinate.

*Lacey member.*—The fifth Mt. Simon member consists principally of conglomeratic sandstone. It is here named the Lacey member from Lacey School, NW $\frac{1}{4}$  NW $\frac{1}{4}$  NW $\frac{1}{4}$  Sec. 31, T. 42 N., R. 4 E., DeKalb County, 2 $\frac{1}{2}$  miles east of the type well. The "type section" consists of samples 257 through 278, in sample set 1466, extending from depths of 1880 to 2070 feet. The thickness of the unit ranges from 176 to 230 feet. In most wells a bed or beds of comparatively fine-grained nonconglomeratic sandstone are present in the middle of the member, and in the Parish and McElroy wells (9, 11) interbeds of fine-grained sandstone occur in the lower part of the unit. Red shale layers commonly are more abundant in the Lacey and higher members than in the underlying strata.

*Gunn member.*—The Lacey member is overlain by a relatively fine-grained unit here named the Gunn member from Gunn School, NW $\frac{1}{4}$  NW $\frac{1}{4}$  NW $\frac{1}{4}$  Sec. 16, T. 42 N., R. 3 E., DeKalb County, 2 $\frac{3}{4}$  miles northwest of the type well. The "type section" consists of samples 234 through 256 in sample set 1466, extending from depths of 1648 to 1880 feet. In thickness the member varies from 71 to 260 feet. The grain size ranges from very fine to very coarse, and a few thin beds of granule conglomerate generally are present. However, the grain size is conspicuously finer than in the adjacent members, and in several wells the dominant grade is fine.

*Charter member*—The coarse-grained to conglomeratic uppermost member of the Mt. Simon formation is here named Charter from Charter Oak School, SE $\frac{1}{4}$  SE $\frac{1}{4}$  SE $\frac{1}{4}$  Sec. 2, T. 42 N., R. 3 E., DeKalb County, 3 $\frac{1}{2}$  miles north of the type well. The "type section" consists of samples 204 through 233 in sample set 1466, extending from depths of 1381 to 1648 feet. The member ranges from 145 feet to 315 feet thick. In some wells it is composed almost entirely of very fine- to very coarse-grained sandstone which is mainly coarse grained and has one or more thin layers of granule conglomerate. In other wells conglomeratic sandstone makes up most of the member.

*Stratigraphic relations.*—The Mt. Simon sandstone rests unconformably on a pre-Cambrian basement complex. Where it has been penetrated by wells in northern Illinois, the complex consists of granite with local felsite dikes (Grogan, 1949). The Mt. Simon is overlain by the Eau Claire formation with apparent conformity in both Wisconsin and Illinois (Twenhofel, Raasch and Thwaites, 1935, pp. 1693-1696, 1714-1715).

*Correlation.*—In Kane County, northeastern Illinois, the basal two-fifths of the Eau Claire formation is composed mainly of sandy dolomite and shale which contains obovoid brachiopods in the lower half (fig. 2). Westward these beds grade laterally into gray, very fine- to coarse-grained sandstone which is given a sooty aspect by encrusting particles of black pyrite (Workman and Bell, 1949, pp. 2043-2049). The sooty sandstone extends into western Illinois and northward to Winnebago County. However, before reaching Beloit, Wisconsin, it passes laterally into light yellow sandstone

which is distinguished from the underlying Mt. Simon sandstone by its finer grain-size and the absence of granules. Both the sooty and the yellow sandstone locally contain obovoid brachiopod fragments.

At the type section in Wisconsin the Mt. Simon sandstone shows the following sequence from the base upward: (1) granule-bearing, 3 feet, (2) without granules, 28 feet, (3) granule-bearing, 108 feet, and (4) without granules and containing obovoid brachiopod fragments, 95 feet (Twenhofel, Raasch and Thwaites, 1935, pp. 1739-1740). It is thought most likely that units 1 through 3 correspond, respectively, to the Lacey, Gunn, and Charter members and that unit 4 is equivalent to the basal Eau Claire sandstone of northern Illinois. Definite correlations must await detailed surface and subsurface tracing between Beloit and Eau Claire, Wisconsin. However, if this interpretation is correct, it would appear desirable to include unit 4 of the Mt. Simon type section in the Eau Claire formation because this unit (1) can be distinguished lithologically by the lack of granules, (2) is said to contain marine fossils, in contrast to the barren, presumably fresh-water beds beneath, and (3) grades eastward into dolomite which is entirely similar to the dolomite facies of the Eau Claire formation.

The sandstone termed "Mt. Simon" in eastern Minnesota directly underlies the Eau Claire *Cedaria* zone and in places contains much glauconite and glauconitic shale and siltstone (Atwater and Clement, 1935, pp. 1674-1676), which in Illinois is entirely confined to the Eau Claire formation. Most of this sandstone probably corresponds to the basal Eau Claire sandstone of north-

TABLE 1. TYPICAL HEAVY MINERAL ANALYSES IN PERCENTAGES

	Anatase	Apatite	Epidote	Garnet	Ilmenite	Leucoxene	Magnetite	Rutile	Titanite	Tourmaline	Zircon	Opacques	Unknown
Eau Claire sooty sandstone; base <sup>1</sup> . . . . .	6					4			31	59			
Mt. Simon light-colored facies; top <sup>2</sup> . . . . .	1				1	3			27	68			
Mt. Simon light-colored facies; lower <sup>3</sup> . . . . .	1		Tr.			9			28	62			
Mt. Simon light-colored facies; base <sup>4</sup> . . . . .				9 <sup>a</sup>		11			11	69			
Mt. Simon light-colored facies; base <sup>5</sup> . . . . .				20 <sup>b</sup>		Tr.	40		20	20 <sup>b</sup>			
Mt. Simon red facies; upper <sup>6</sup> . . . . .					5	1			19	76			
Hinckley sandstone at Sandstone <sup>7</sup> . . . . .	2	3 <sup>c</sup>				18	Tr. <sup>d</sup>	2	12	63			Tr.
Hinckley sandstone at Net River <sup>8</sup> . . . . .	1	1 <sup>e</sup>				12	44 <sup>d</sup>	1	13	27			Tr.
Fond du Lac sandstone <sup>9</sup> . . . . .	50		7			A			23	13	4		2
Granite, Taylor No. 1 <sup>10</sup> . . . . .	15					P	5	65		15 <sup>e</sup>			
Granite, McElroy No. 1 <sup>11</sup> . . . . .	C	R			C	P	P	P		C			

<sup>1</sup>Well 7, 1710'-1720' (Herbert, 1944);  
<sup>2</sup>Charter member, Well 7, 1730'-1750'  
(Herbert, 1944); <sup>3</sup>Crane member, Well 7,  
3790'-3805' (Herbert, 1944); <sup>4</sup>Crane member,  
Well 7, 3835'-3840' (Herbert, 1944);  
<sup>5</sup>Crane member, Well 5, 2900'-2905'  
(Marsden, 1933); <sup>6</sup>Gunn member, Well  
5, 1645'-1650' (Herbert, 1944); <sup>7</sup>Tyler  
and others, 1940, p. 1512, sample P438B;  
<sup>8</sup>Tyler and others, 1940, p. 1512, sample  
P423B; <sup>9</sup>Tyler and others, 1940, p. 1508,  
sample P405; <sup>10</sup>Well 5, 2955'-2960'  
(Marsden, 1933); <sup>11</sup>Well 11, 3760'-3772'  
(Winchell, 1932; Grogan, 1949, pp.  
98-99); a: angular; b: unzoned; c: includes  
zoisite; d: includes ilmenite; e: zoned;  
A = abundant but not included in anal-  
ysis; C = common; P = present; R =  
rare; Tr = trace.

ern Illinois, although true Mt. Simon  
strata locally may be included.

Except that it is indurated, the  
type Hinckley sandstone is exceed-  
ingly similar to the light-colored Mt.  
Simon sandstone of northern Illinois  
(Atwater and Clement, 1935, pp.  
1669-1672, 1680; Stauffer and Thiel,  
1941, pp. 15-23). The heavy mineral  
suites are fairly similar (table 1),  
although the Hinckley generally has  
higher proportions of magnetite, il-  
menite and leucoxene and lower pro-  
portions of tourmaline and zircon.  
Feldspar is rare in the Hinckley,  
rare in the Mt. Simon of Illinois, ex-

cept in the basal arkosic zone, and  
present only in very low percentages  
in the Mt. Simon of the type area  
(Stauffer and Thiel, 1941, p. 18,  
table 1).

The contact between the Hinckley  
and the underlying red Fond du Lac  
formation is gradational (Stauffer  
and Thiel, 1941, p. 17). The chief  
differences between the two sand-  
stones are (1) the higher iron-oxide,  
shale, and feldspar content of the  
Fond du Lac, and (2) the presence  
of apatite and garnet and a higher  
percentage of leucoxene in the Fond  
du Lac heavy mineral suite. It  
seems most likely that the Fond du  
Lac is an arkosic, impure, basal  
facies of the Hinckley formation, the  
heavy minerals of which were de-  
rived from sources that later became  
buried. An analogous situation oc-  
curs in northern Illinois where the  
heavy mineral suite of basal Mt.  
Simon strata locally differs from  
that of the higher beds (table 1).

Raasch (1950) has presented evi-  
dence for the Cambrian age of the  
Hinckley and Fond du Lac forma-  
tions. The writer tentatively corre-  
lates the entire Hinckley-Fond du

Lac sequence with the Mt. Simon sandstone of northern Illinois. Further study is needed to determine whether it has the same succession of conglomeratic and finer-grained members. Since no lithologic or physical evidence has been found for a formational break in the northern Illinois sequence, the name Mt. Simon is applied throughout.

The Mt. Simon sandstone of northern Illinois also is considered equivalent to the Bayfield and Jacobsville sandstones of the south shore of Lake Superior (Raasch, 1950) and to the Lamotte sandstone of eastern Missouri (Workman and Bell, 1948, pp. 2041-2043, figs. 2, 3).

#### HISTORICAL INTERPRETATIONS

In Wisconsin the pre-Cambrian surface appears to have been a peneplain interrupted by monadnocks. The sparse data provided by wells in northern Illinois also suggest that the basement surface had slight relief.

It has been suggested that the Mt. Simon sandstone was rapidly deposited in a shallow, fresh- or brackish-water inland sea (Twenhofel, Raasch and Thwaites, 1935, pp. 1714-1715). The fact that the sandstone seems to be thickest in northern Illinois instead of thickening southward like most other Paleozoic formations supports this concept. Rapid sinking of the basement must have accompanied deposition to produce by far the thickest formation in Illinois. Periodic uplifts of the surrounding borderlands sent influxes of pebbly sand into the sea. Nonconglomeratic sand was laid down during intervals of crustal quiescence.

Probably the Mt. Simon quartz sand was derived mainly from weathered granites and gneisses to the

north and was transported to the sea by streams. The general lack of rounding, frosting, and sorting indicates that the sand was not greatly reworked before deposition. The differences between the heavy mineral suites of the Mt. Simon and the underlying granite in northern Illinois (table 1) and the partial rounding of most Mt. Simon heavy minerals show that the bulk of the basal sand was not derived from the granite of that region. However, erosion of the granite contributed angular feldspar fragments to the initial sediments. The arkosic zone probably is thickest in the areas of greatest basement relief, as adjacent to monadnocks. That a minor part of the basement in northern Illinois or nearby areas consisted of schist is demonstrated by the presence of angular garnets in the heavy mineral suite of basal Mt. Simon strata in the Taylor and Wyman wells (5, 7) and by the occurrence of small schist fragments in the Mt. Simon of the Parish well (9).

In an area northward from Illinois a red clayey mantle probably developed on granitic rocks under conditions of low relief and a warm, humid climate, such as prevail at present in the southern Appalachian piedmont. It is believed that the Mt. Simon red facies was deposited off the mouth of a river which drained this area and discharged into the sea north of Belvidere, Boone County. The similarities in the heavy minerals of the red and light-colored facies suggest that both were derived from the same granitic terrane. Enlargement of the sea just prior to the marine invasion of Eau Claire time (Twenhofel, Raasch, and Thwaites, 1935, pp. 1714-1715) is reflected in abrupt overlap of the red sediments by a

relatively small thickness of white sandstone. Persistence of a drainage system which furnished red clastics is suggested by the recurrence of a similar red facies in the Franconia and uppermost Eau Claire strata of Boone County.

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PETROLOGY OF THE BASAL HIGH-PURITY BED  
OF THE BURLINGTON LIMESTONE\*

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*State Geological Survey, Urbana*

A high-purity, virtually chert-free limestone occurring near the base of the Burlington limestone in western Illinois is being mined or quarried at Quincy, Gladstone, and Pearl. This article presents the results of an initial study of the petrology of this 10 to 25-foot unit. Twenty thin sections, perpendicular to the bedding, were prepared from specimens collected at the localities mentioned, especially the Quincy area.

The specimens are mixtures, in varying proportions, of five principal components: (1) large fragments of crinoid plates and stem segments, which are inclusion-rich, unit-extinguishing sheets of calcite; (2) secondary white calcite, deposited in optical continuity upon the detrital fragments; (3) moderate to fine-grained fossil detritus, including fragments of bryozoa, pelecypods, brachiopods, and smaller bits of crinoid plates and stem segments; (4) very fine-grained dark gray interstitial calcite; and (5) small unit-extinguishing rhombs of dolomite. Coarsely crystalline specimens of the limestone consist chiefly of the secondarily enlarged pieces of crinoidal calcite. Finely crystalline varieties show pronounced banding in thin section, with different bands varying both in components and in particle size. The banding, in general, parallels the bedding planes of the rock, but in detail it may be contorted or lenticular at some places.

Dolomite rhombs occur mostly in the fine-grained interstitial carbonate component, and are thus commonest in fine-grained varieties of the rock.

## HISTORY OF EVENTS

The history suggested by the thin-section study is indicated in table I. In the first stage crinoid fragments were deposited with a mud containing abundant fossil fragments. The interstitial material between the crinoid fragments contains far too much debris and is too fine grained to have crystallized

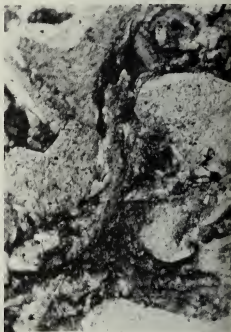


FIG. 1.—Subparallel alignment of smaller detrital fragments. Parallel nicols, 20 X.

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from circulating water. A streakiness in the fine-grained portion of the interstitial material arises in part from the presence of elongate, laminated pieces of pelecypod shells, and, almost certainly, in part from the original deposition of elongate pieces of fossil detritus in planes essentially parallel with the ocean floor. However, a "streamline" effect seen in some places (fig. 1), in which sub-parallel particles diverge to go around larger particles, suggests local flowage during compaction which accentuated the other two features.

Secondary white calcite, free of inclusions, was deposited in optical

that are coarsely crystalline aggregates (fig. 3). The deposition of secondary white calcite has been so extensive in some places as to cut across and isolate areas of streaked interstitial material. In these areas rearrangement of particles by flowage would have been unlikely without some disruption of the secondary calcite, which has not been seen;

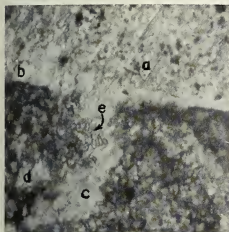


FIG. 2.—Portion of crinoid stem segment (a), secondary calcite rim (b), vein-like extension of rim (c), "island" (d), and fine-grained aggregate interpreted as result of late partial destruction of vein-like extension (e). Parallel nicols, 135 X.

continuity upon the large, inclusion-rich, unit-extinguishing sheets of calcite in crinoid plates. Less commonly (fig. 2) it forms vein-like extensions into fine-grained interstitial calcite. Secondary calcite from two or more nearby fragments commonly meets along a curving contact, giving rise to local areas in the rock

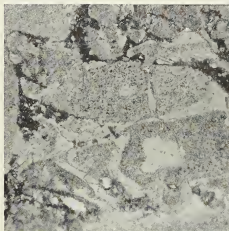


FIG. 3.—Secondary calcite rims on adjacent grains grown together to form a coarse-grained rock, with small remnant areas of dark fine-grained interstitial calcite. Parallel nicols, 20 X.

hence deposition of secondary calcite is placed after compaction and flowage.

The margins of many of the secondarily enlarged calcite sheets in contact with interstitial carbonate are ragged, and the question arises as to which calcite is replacing the other. The fact that there are outlying islands of secondary white calcite in optical continuity with larger areas (fig. 2) suggests that the fine-grained interstitial calcite is the active replacing agent, but the "islands" may actually be continuous in the third dimension with the main mass. Further evidence is furnished by a few fine-grained aggregates of

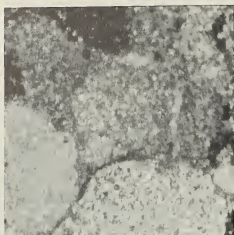


FIG. 4.—“Ghost” composed of small grains in center of picture; two unit-extinguishing sheets of inclusion-rich crinoid calcite below. Crossed nicols, 65 X.

clear white calcite adjoining the secondary calcite projections, which are best explained as partially resorbed marginal portions of the projections.

“Ghosts” in the interstitial calcite show outlines of larger calcite particles that are now represented by an aggregate of small grains (fig. 4). Although the “ghosts” were not necessarily formed at the same time as the partial solution of the secondary carbonate rims, their presence does indicate that coarsely crystalline calcite has at one time during the history of the rock undergone alteration to a fine-grained aggregate. Both these solution effects can be placed, with considerable assurance, later than deposition of secondary calcite because cores of organic calcite lying within the secondary calcite rims are smooth and uncorroded.

The dolomite rhombs have been identified by Debye powder X-ray diagrams; in the absence of evidence to the contrary, they are assumed to be of a single age and of essentially

constant composition. They are later than the postulated compaction, for they cut across “streamline” textures. They are earlier than at least part of the period of replacement of coarsely crystalline calcite, for many thin sections contain rhombs that have been partially dissolved (fig. 5). The prominence of this solution varies considerably within limited stratigraphic thicknesses. The age of the rhombs with regard to the deposition of secondary calcite is uncertain. A few rhombs project into the secondary calcite, but it is not yet known whether the rhombs have replaced the coarsely crystalline material, or the latter has replaced the material around the rhombs but left them untouched.

#### MINOR COMPONENTS

Uncommon small irregular areas of low birefringence, moderate index, and non-uniform extinction are found within large unit-extinguishing crinoid plates (fig. 6). They are not potash feldspar, since a sodium cobaltinitrite staining test gave neg-

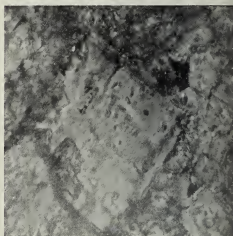


FIG. 5.—Dolomite rhomb partially dissolved along left-hand margin. Parallel nicols, 280 X.

Table I. History of Events

<p>1. Deposition of detritus from crinoids; interstices between larger crinoid fragments filled with mixture of lime mud, glauconite granules, and fossil detritus.</p>		
<p>2. Compaction locally accentuates parallelism of elongate particles in interstitial material.</p>		<p>Formation of dolomite rhombs.</p>
<p>3. Deposition of secondary calcite in optical continuity upon crinoid fragments</p>		
<p>Some crinoid fragments in interstices reduced to fine-grained aggregates.</p>	<p>4. Secondary calcite partially replaced by fine-grained aggregate, perhaps contemporaneously with solution of dolomite rhombs and with replacement of small detrital fragments.</p>	<p>Partial solution of dolomite rhombs.</p>

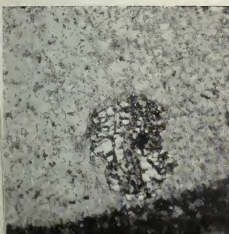


FIG. 6.—Aggregate of grains which may be secondary silica, lower center near margin of crinoid stem segment. Crossed nicols, 65 X.

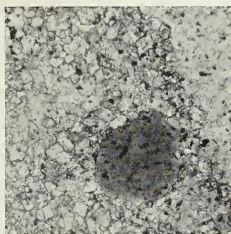


FIG. 7.—Glauconite grain in dolomite-rich Burlington limestone. Parallel nicols, 65 X.

ative results, but they may be secondary silica.

Rounded areas of a greenish material (fig. 7) give an X-ray pattern and a differential thermal curve which correspond in general with those expectable for glauconite, but this identification will not be meaningful until glauconite and related layer-lattice minerals have undergone much more study as mineral types. A basal spacing of 10 Ångström units was noted, but other

critical X-ray reflections were obscured by lines of quartz, which occurred even in the 1-micron fraction of the "glauconite." These rounded greenish areas do not cut across other structures, and are most likely detrital in origin. Many dolomite crystals end abruptly against the "glauconite," without completing the rhomb shape. In some cases they penetrate into cracks, but no actual replacement of "glauconite" by either calcite or dolomite has been noted.

## PREGLACIAL GRAVELS IN HENRY COUNTY, ILLINOIS

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Preglacial deposits of iron-stained chert gravels underlie the glacial drift at a number of localities in the Mississippi Valley region (fig. 1). These gravels, which generally have been referred to the late Tertiary Lafayette formation, are significant in recording geologic events during closing stages of the lost interval between Pennsylvanian bedrock deposition and Pleistocene glaciation. It is the purpose of the present

Kewanee, Henry County, Illinois (400 feet N. of S. W. cor. sec. 3, T. 15 N., R. 4 E.), in the section described below.

The Tertiary gravels differ from all known glacial deposits in the area in their degree of surface alteration, polish, and uniform siliceous composition. Their lithology, based on a count of 120 pebbles, is 79% chert, 18% vein quartz, and 3% quartzite. Crystalline rocks and local bedrock

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Wisconsin drift				
Peorian loess				
Soil, gray .....	0	6	0	6
Loess, tan, mottled gray, non-calcareous.....	3	0	3	6
Loess, tan to gray, calcareous, concretions .....	2	0	5	6
Farmdale loess				
Silt, carbonaceous, peaty, gray with black humus streaks, abundant gastropods in pockets, non-calcareous.....	0	4	5	10
Loess, maroon-brown, compact, non-calcareous, gastropods .....	2	0	7	10
Illinoian drift				
Gumbotil, gray-brown, siliceous residuals, non-calcareous except for some secondary enrichment at top.....	2	6	10	4
Till, yellow-brown, abundant chert mixed with other rock types, non-calcareous .....	1	0	11	4
Sand, brown, in local channel .....	1	0	12	4
Tertiary gravel				
Gravel, 80% fossiliferous chert, iron oxide patination, rounded to angular, average 1 to 2 inches, irregular basal contact .....	3	0	15	4
Pennsylvanian (Canton) shale				
Shale, yellow-buff, micaceous, clayey, broken down by weathering .....	3	6	18	10
Shale, buff-gray, stratified .....	5	0	23	10

paper to describe gravels from a new locality in western Illinois and to indicate their bearing on late Tertiary geomorphic events.

### DESCRIPTION

The gravels are exposed in a highway cut (fig. 2) 7 miles northwest of

appear to be completely absent. Nearly all the cherts have a yellow-brown iron oxide patina 1-3 mm. thick which is as hard and dense as the interior of the pebbles. A few cherts have a whitish surface alteration and the quartz and quartzite pebbles show surficial iron-staining.

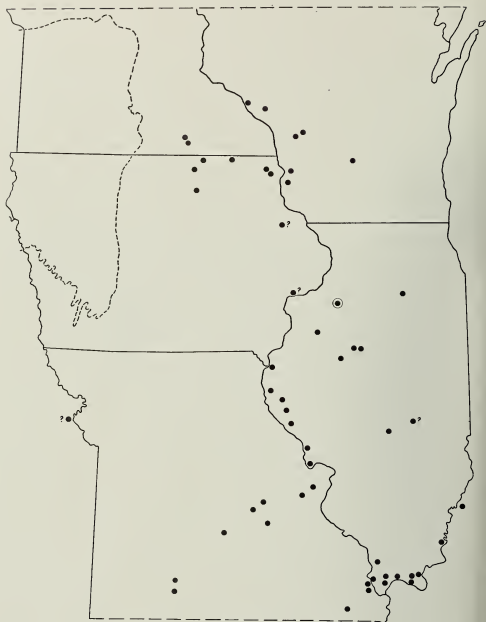


FIG. 1.—Occurrences of preglacial Lafayette-type gravels in the Mississippi Valley region. The Henry County locality is circled. The eastern boundary of Cretaceous deposits in Iowa and Minnesota is shown by a dashed line. Based on references cited and field notes on south-central Missouri by J. H. Bretz.

The brown chert pebbles, which make up 70% of the deposit, contain fossil corals, crinoids, and brachiopods of Lower and Middle Silurian age (Heinz Lowenstam, personal communication, 1950).

The pebbles range in diameter from a fraction of an inch to 7 inches, the average being between 1 and 2 inches. The brown chert pebbles are larger than the other types and there is a distinct variation in average size from one part of the exposure to another. All the cherts are angular. Many pebbles are broken rounds, some are chipped, and a few have percussion markings. The gravels are unconsolidated, and the matrix, if it was ever present, has been removed by weathering.

The basal contact of the gravel is irregular and slopes to the south and west. Since the low ridge crest on which the gravels occur slopes northeast, it is clear that the gravels were laid down on a land surface unrelated to the present topography.

The upper part of the Canton shale underlying the gravels is oxidized and mechanically weathered to a depth of about 3 feet. Under the microscope the weathered shale is seen to differ from the unaltered shale in its lack of stratification, disaggregation into silt and clay-size particles, oxidation, and content of limonitic aggregates.

The gravels occur at an elevation of 730 feet near the northern margin of a buried bedrock upland, which locally has an average elevation of about 750 feet and lies 450 feet above the buried bedrock valley of the ancient Mississippi river some 15 miles to the north. The upland surface has been correlated with the Lancaster peneplain of the Driftless Area (fig. 1) (Horberg, 1946, pp.

186-188.) Farther south in western and southern Illinois nearly all occurrences of preglacial gravel are on this surface or equivalent surfaces correlated with the Ozark and Calhoun peneplains.

#### CORRELATION AND AGE

Although it is probable that similar deposits of different ages are represented and that some gravels are reworked, the deposits in the Mississippi Valley region can be correlated in a general way by lithology and physiographic position. On this basis the gravels in Henry County appear to be equivalent with the Windrow formation of Wisconsin, Iowa, and Minnesota (Thwaites and Twenhofel, 1921); the "Tertiary" gravels of LaSalle County (Willman, 1942, pp. 140-141), Peoria County (Udden, 1912, p. 50) and other counties in western Illinois (Worthen, 1866, p. 330; 1870, p. 37; Bannister, 1870, p. 179; Salisbury, 1891, pp. 252-253); the Grover gravel of the St. Louis region (Salisbury, 1892, pp. 183-186; Rubey, 1931); and the Lafayette gravel of southern Illinois and southeastern Missouri (Lamar and Sutton, 1930, pp. 857-859). Correlation with the Rockville conglomerate at Dyersville, Iowa (McGee, 1891, p. 304) and the Pine Creek conglomerate near Muscatine, Iowa (Udden, 1899) is questionable because of the high proportion of crystalline rocks in these deposits. Also it is uncertain whether the two occurrences at lower elevations within the area of the Central Illinois peneplain (fig. 1) are primary or reworked.

A Tertiary age for the gravels farther south is evidenced by their presence on truncated Eocene formations at the head of the Gulf em-



FIG. 2.—Highway cut 7 miles northwest of Kewanee, Illinois. Wp—Peorian loess; Wf—Farmdale loess; It—Illinoian gumbotil and till; Tg—Tertiary gravel; Pc—Pennsylvanian (Canton) shale.

bayment and by the occurrence of Tertiary wood in the gravels near Grover, St. Louis County, Missouri (Rubey, 1931). Because the Eocene formations were beveled by the Ozark peneplain before deposition of the gravels, a late Tertiary age is indicated. A similar age for the gravels in western Illinois is evidenced by their occurrence on a buried bedrock surface which appears to be the northward continuation of the Ozark peneplain (Horberg, 1946, pp. 186-188).

#### INTERPRETATION

The gravels in Henry County probably were derived largely from residual accumulations on Silurian formations, which occur less than 20 miles to the north, and were deposited, along with pre-Cambrian materials from farther north, by a south-flowing stream. This is evidenced by the composition of the gravels and their angularity and poor sorting. The absence of locally-derived Pennsylvanian rocks in the gravels

further suggests that they represent a widespread aggradational deposit rather than a channel fill and also that they are primary rather than locally re-worked from older gravels.

The physiographic position and character of the gravel in Henry County are in full accord with other occurrences in the Mississippi Valley region and suggest that the following major geomorphic events were contemporaneous over a wide area:

1. Development of the Lancaster-Calhoun-Ozark peneplain in middle to late Tertiary time. Weathering of the Canton shale in Henry County.

2. Uplift of gravel-source areas to the north and initiation of a new cycle marked by gravel deposition. Removal of the upper part of the weathered zone on the Canton shale and deposition of gravel in the local area by a south-flowing stream.

3. Development of the Central Illinois peneplain and Havana strath in central Illinois (Horberg, 1946). Weathering of gravels and



probably some subsequent erosion and redeposition in western Illinois.

4. Erosion of deep bedrock valleys and removal of gravels except for patches on remnants of the Lancaster surface.

5. Pleistocene glaciation result-

ing in further stripping of gravels and their final burial. Henry County probably was glaciated during the Nebraskan and Kansan stages, as well as the Illinoian, although the record at the gravel locality is incomplete.

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THE NEDA FORMATION IN NORTHEASTERN ILLINOIS<sup>1</sup>L. E. WORKMAN<sup>2</sup>*Illinois State Geological Survey, Urbana*

In the vicinity of Mayville, Wisconsin, an "oolitic hematite" called "seed ore," "flaxseed ore," or "shot ore," was originally designated by Chamberlin<sup>3</sup> as the "Clinton iron ore deposit." He described the grains of iron ore as "little lens-shaped concretions" composed of hydrated hematite averaging 1/25 inch (1 mm.) in diameter, but varying from 1/10 inch (2.5 mm.) to those that are very minute. Cross sections indicated that the ore occurs between the Cincinnati shale and the "Niagara limestone." He stated that, although a few fossils of Cincinnati age were reported to have been found in ore enclosed in a mass of glacial drift, an obvious unconformity at its base in outcrop and a less apparent break at the top indicate the deposit to be Silurian. He suggested that it was made in detached shallow basins over which the succeeding Silurian sea spread more widely. Figure 1 is a photograph of ore recently obtained at Mayville.

Thwaites<sup>4</sup> further described the deposits of "Clinton" ore as occurring in eastern Wisconsin in broad lenses varying in thickness up to a known maximum of 55 feet. He pointed out that at many places where the iron ore is not present there are nevertheless beds of red rock at the same horizon, and pre-

sented a map (fig. 2) showing the known occurrences of iron ore and red rock. He reported also that in the Green Bay region the ore is interbedded with shale, and in an area

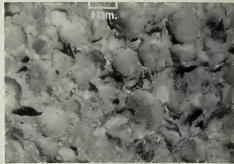


FIG. 1.—Neda Iron Ore from Mayville, Wisconsin (X6).

about 15 miles southeast of Mayville it appears from well cuttings to be broken up and mixed, or perhaps interstratified, with limestone.

Savage and Ross<sup>5</sup> pointed out that the relations of the iron ore to formations both above and below are unconformable, but that fossils collected from the ore in place indicate it to be of Maquoketa (Cincinnati) age. They described the deposit as containing pebbles of shale, iron ore, and iron-oxide-replaced fossil fragments and suggested that the deposit is a formation laid down in local basins that, because of the presence of marine fossils, probably were connected and remained after the main portion of the normal marine Maquoketa sea had withdrawn from the greater part of the region

<sup>1</sup>Published by permission of the Chief, Illinois State Geological Survey. (Presented at the 1949 meeting of the Academy.)

<sup>2</sup>Geologist and Head, Subsurface Geology Division.

<sup>3</sup>Chamberlin, T. C., *Geology of Wisconsin*, Wisconsin Geol. Sur., vol. 3, 1878, pp. 327-335.

<sup>4</sup>Thwaites, F. T., Recent discoveries of "Clinton" iron ore in eastern Wisconsin, U.S.G.S. Bull. 540, 1914, pp. 338-342.

<sup>5</sup>Savage, T. E., and Ross, C. S., The age of the iron ore in eastern Wisconsin, *Am. Jour. Sci.*, Fourth Series, vol. 41, 1916, pp. 187-193.

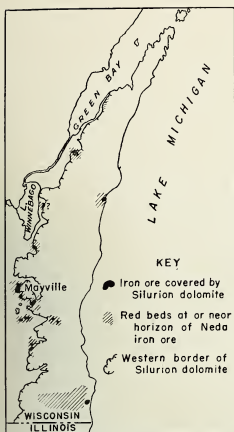


FIG. 2.—Locations of Neda Iron Ore in Wisconsin (after Thwaites).

farther south in the Mississippi valley. They named it the "Neda Iron Ore" formation.

Hawley and Beavan<sup>6</sup> made a detailed analysis of the minerals of the Neda Iron Ore formation. They determined that nuclei observed in the oolites consist of: (a) fragments of reworked ore, (b) fossil fragments, (c) mineral or rock fragments, and (d) cross-shaped objects. They emphasized, however, that most of the oolites show no central nuclei. They showed that the spheroids are composed of at least 26 varieties of minerals, chief of which are goethite

( $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ), calcite, and halloysite ( $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot n\text{H}_2\text{O}$ ). Halloysite is a clay that was found to compose most of the insoluble residue after treatment with acid and that looked under the binocular microscope like finely granular unglazed porcelain, making up the fragile spheroidal shells of the spheroids. There are ten varieties of phosphates, and 50% of all phosphorus is contained in the outer shells of the spheroids. The non-oolitic portion of the ore is largely pore space. Crystalline hematite has grown from the spheroids into part of the space, and there are a number of sedimentary minerals such as quartz and materials from the weathering of igneous rock. The most abundant transported material consists of angular grains of scoriaeous lava largely altered to iron oxide. There are rounded fragments of reworked ore and nodules of calcite and dolomite. The authors state that the source of the predominant ore minerals is a baffling problem.

The Neda iron-bearing formation is reported in the same stratigraphic position in eastern Iowa<sup>7</sup>, eastern Kansas<sup>8</sup>, and northwestern Missouri<sup>9</sup>.

Athy<sup>10</sup> very fully described the Neda deposit in Illinois but called it the Noix Oolite of basal Alexandrian (Silurian) age. The outcrops which he described, situated in sections 26, 27, and 35, T.32 N., R.10 E., Kankakee County, are the only ones known in Illinois. He reports the iron ore spheroids as occurring in a

<sup>7</sup> Howell, J. V., An outlier of the so-called Clinton formation in Dubuque County, Iowa, Proc. Iowa Acad. Sci., Vol. XXIII, 1916, pp. 121-124.

<sup>8</sup> Lee, Wallace, The stratigraphy and structural development of the Forest City Basin in Kansas, Geol. Sur. Kan., Bull. 51, 1943, p. 42.

<sup>9</sup> Crane, G. W., The iron ores of Missouri, Missouri Bur. Geol. and Mines, 2nd Series, Vol. X, 1912, pp. 148-149.

<sup>10</sup> Athy, L. F., Geology and mineral resources of the Hersher quadrangle, Ill. Geol. Sur. Bull. 55, 1928, pp. 33-38.

<sup>6</sup> Hawley, J. E., and Beavan, A. P., Mineralogy and genesis of the Mayville iron ore of Wisconsin, Amer. Mineralogist, vol. 19, 1934, pp. 493-514.

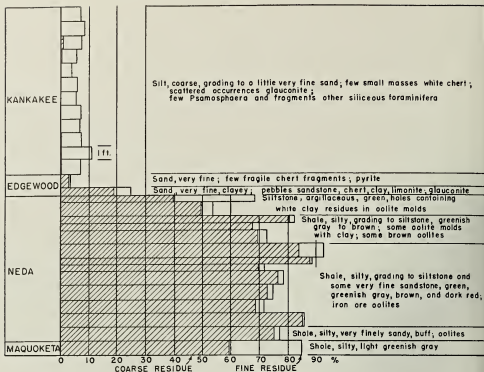


FIG. 3.—Graph of insoluble residues from Neda formation and associated strata in outcrop above spring in NW.  $\frac{1}{4}$  SE.  $\frac{1}{4}$  NE.  $\frac{1}{4}$  sec. 27, T. 32 N., R. 10 E., Kankakee County, Illinois.

matrix of reddish brown, purplish, and green ferruginous shales and shaly dolomite reaching a thickness of 8 feet, 2 inches, and resting unconformably on olive-green Richmond (Maquoketa) shale. The spheroids are generally the size of fine to coarse sand averaging .5 mm. across. The shale was reported to contain much silt and fine quartz sand (up to .25 mm. diam.) and some medium sand (.25 to .50 mm.).

The writer obtained insoluble residues from samples, taken at one-foot intervals or less from several of the outcrops along Kankakee River, by treating the rock samples with weak hydrochloric acid. The graph of the most complete section (fig. 3), taken at the locality figured by Athy on page 32 and described on page 33 (see footnote 10), shows

10½ feet of Neda ore-bearing material on top of the Maquoketa shale and under the Edgewood formation. The insoluble material of the Neda deposit consists of: (a) silty shales to siltstones variously colored brown, yellow, greenish, and purplish by iron oxide cement; (b) some very fine sand that grades in the middle of the deposit to very fine sandstone; (c) iron-ore spheroids scattered in variable proportions but nowhere composing most of the deposit as in Wisconsin. The total residue varies from 54 to 93 percent. These proportions are not essentially different from the proportions in the Maquoketa shale below, which in the single sample taken amounted to 85 percent. Neither is the silty shale to siltstone matrix greatly different, except for some sand content, from the

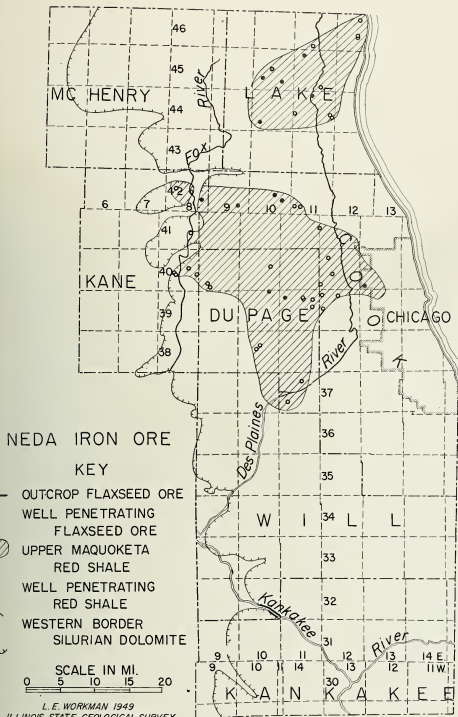


FIG. 4.

Maquoketa silty shale. On the other hand, the residue proportions are quite different from the 25 percent residue of the overlying Edgewood and there is an abrupt change from the silty sandy shale below to a sandy conglomeratic dolomite above. The pebbles of the conglomerate consist of grains of underlying shale and a few weathered iron ore spheroids. Were it not for the pebbles the proportion of insoluble residue of the lowest sample of Edgewood would be similar to that of the next sample above, that is, less than 10 percent.

In the subsurface of the Chicago region (fig. 4) the spheroids of iron ore are found in a variety of sediments. Like those along Kankakee River, they occur in silty shales having various iron-oxide colors. As in the Wisconsin outcrops, they occur as spheroids loosely cemented with crystalline hematite, though the beds are so thin that only a relatively small part of a 5-foot well sample consists of such material. They are commonly associated with red to green weak silty clay that contains small pebbles and grains of weathered Maquoketa dolomite. In some samples they appear to occur in a yellowish brown silty clay which has a starch-like fracture and contains brown flakes, suggesting a soil zone. In one sample the spheroids occur in a very fine sandstone containing grains of dolomite, hematite, and a hematite-replaced spicule. All occurrences are in the midst of more extensive areas where the top of the Maquoketa is represented by red clay shale containing weathered dolomite fragments. Such red shale areas are present only where the Maquoketa reaches its maximum thickness of 190 to 250 feet, as may be noted by comparison with Du-

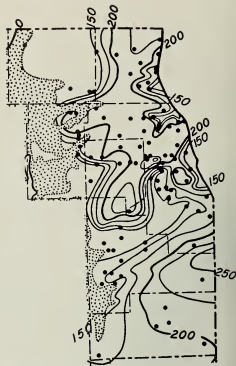


FIG. 5.—Thickness of Maquoketa formation in the Chicago region; isopach interval 25 feet (after DuBois).

Bois'<sup>11</sup> isopach map of the Maquoketa (fig. 5).

Elsewhere in Illinois Neda spheroids have been noted in two wells in eastern Whiteside County and in another in eastern Peoria County where the Maquoketa thickness is near a maximum for the region of a little more than 200 feet. All these conditions are interpreted as indicating that the Neda was deposited on a relatively flat surface of the Maquoketa and was eroded widely along with the Maquoketa formation in an interval previous to Edgewood deposition.

The iron-oxide spheroids in the matrix of silty shale of the Neda de-

<sup>11</sup> DuBois, E. P., Subsurface relations of the Maquoketa and "Trenton" formations in Illinois, Illinois Geol. Survey Rept. Inv. 103, fig. 1, p. 8, 1945.

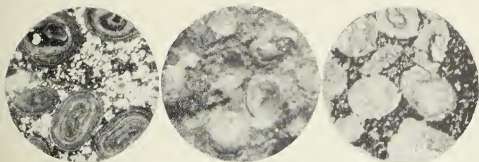


FIG. 6.—(Left) Thin section of Neda iron oxide spheroids in matrix of silty shale from Illinois (X18).

FIG. 7.—(Middle) Broken surface of Neda silty shale showing spheroids altered to clay (X18).

FIG. 8.—(Right) Thin section of Neda deposit showing spheroids replaced by calcite (X18).

posit in Illinois are generally smaller than those in Wisconsin, ranging up to 1 mm. in larger diameters, only a few reaching 1.25 mm. diameter, and averaging .75 mm. or less. They are similar in appearance to those in Wisconsin, being generally spheroidal and having smooth surfaces not only on the outsides of grains but on secondary surfaces made by breaking off the oolitic shells. Many of the spheroids in thin section show no nuclei, but the most common nuclei observed are fragments of other spheroids, especially fragments of the outer shells (fig. 6). A few were observed that were fragments of the matrix of silty shale, and a very few contained single silt grains or other material at the center. Most of them show a slightly darker brown outer hull.

Some observations of interest in considering the composition and geologic history of the oolites are as follows:

1. In the upper portions of outcropping Neda beds, varying in observed thickness from a few inches to as much as eight feet, the former oolites which were subjected to weathering previous to Edgewood

deposition lost their iron-oxide content, leaving a residuum of clay (fig. 7). This clay has been identified by Grim<sup>12</sup> as illite. Usually its texture is dense and porcelaneous, showing only faintly or not at all the former concentric rings of the oolites. The dull olive-green color disappears on treatment of the sample with acid, leaving the clay almost white. These clay masses appear slightly smaller than the average iron-ore spheroid, and the shapes of the cavities in which they occur, though roughly spheroidal, are somewhat distorted, indicating that the sediments have been somewhat compacted to fill partly or entirely the former oolite spaces. However, it becomes evident that, because of the large amount of residual clay, some original spheroids were not highly iron-bearing. Some clay masses are soft and porous, and occupy proportionately less space than the dense variety in the cavity left by solution of the iron oxide. Some consist only of flat round blebs of green clay in sizes typical of the oolites. Evidently these last formerly contained high

<sup>12</sup> Grim, Ralph E., personal communication.

proportions of iron oxide before the iron was dissolved and the sediments collapsed.

2. Some of the former oolites contain partial replacements of gray crystalline calcite (fig. 8). The cleavage faces of the calcite are so oriented as to indicate that each oolite replacement developed as a single crystal. Surrounding the crystal mass is the residual clay. Some of the calcite masses occupy practically all the former oolites except the outer hulls, whereas others are smaller and the residual clay masses seem to be larger accordingly. It is suggested that calcite formation took place only after the cavities had been left by iron-oxide solution and that the sizes of the crystals were governed by the available space. Thus it would appear that the calcite deposited after the beginning of Edgewood time, possibly long after that time.

3. Some of the residual material enclosing the calcite grains has the appearance of perfect fragments of outer hulls of iron-ore spheroids except that they are dark brown to black, suggesting the presence of organic material. Kosanke<sup>13</sup> examined some of these and reported that they show no cellular structure but appear rather to be composed of amorphous material. Upon being heated in a test tube the black color disappears, leaving light-brown amorphous clay suggestive of that described by Hawley and Beavan as halloysite in the hulls of oolites in Wisconsin and of a somewhat different chemical character

than the materials making up the remainder of the colite.

The considerable variety of sedimentary materials in which the iron-ore spheroids are found, the occurrence of the spheroids in north-eastern Illinois and elsewhere only where the Maquoketa is thickest, and recognition of the same type of iron-ore spheroids at about the same geologic horizon in widely separated areas from Kansas to Wisconsin and Illinois, suggest that the Neda formation was a widespread deposit of variable character lying upon known Maquoketa (Cincinnati) shale, and was to a great extent eroded away during pre-Edgewood (pre-Lower Alexandrian) uplift. It appears significant for considerations of correlation that the Neda type of oolite occurs elsewhere in the eastern half of the United States in Silurian strata only, that is, the Red Mountain formation of Upper Alexandrian and Lower Niagaran ages in the Birmingham District, and the Clinton group of Lower Niagaran age in New York.

There is no difficulty in assuming that conditions of deposition favorable to the formation of Neda oolite recurred at intervals from late Cincinnati to early Niagaran times, but in order to be sure that these conditions prevailed across the Ordovician-Silurian boundary the possibility should be examined that the Maquoketa fossils found in the Neda in both Wisconsin and Iowa may have attained their position by being reworked by an early Silurian sea.

<sup>13</sup> Kosanke, R. M., personal communication.





