DESCRIPTION OF THE GALENA AND ELIZABETH QUADRANGLES.

By Eugene Wesley Shaw and Arthur C. Trowbridge.

In their physiographic and geologic relations the quadrangles form part of the Glaciated Plains, which lie between the Appalachian chain on the southeast, the Ozark province on the southwest, and the Great Plains on the west and extend northward beyond the boundary of the United States. On the south they are separated from the Gulf Coastal Plains by a narrow strip that joins the Ozark and Appalachian provinces. (See fig. 2.) Near the middle of the Glaciated Plains there is an area of about 16,000 square miles which was not covered by ice and which therefore contains no glacial drift. At the geologic history of this driftless region is in other respects similar to that of the surrounding territory it is regarded as a part of the Glaciated Plains. The Galena and Elizabeth quadrangles lie almost wholly within the driftless region. (See fig. 3.)

A comparatively narrow belt along the western and southern sides of the province was not covered by any of the later ice sheets and is well drained, but in much of the province the streams have irregular courses and lakes and swamps are numerous. The poor drainage of this part of the province is due to its invasion by the ice, which blocked many drainages lines and caused a left of drainage to be placed along a thickness of several hundred feet and filling many of the old valleys. Where the drift is thick the drainages were wholly changed and it is only today that it appears to be a normal condition. In western Illinois there are several hill sheets, laid down in as many different ice sheets, but the well-drained belt mentioned above, which in the southern mountains lies to the west of it, was covered only by one of the earlier glaciers. In this belt the streams have become almost re-adjusted, but throughout most of the province they have irregular courses and profiles and the drainage systems show little symmetry.

The average discharge of the Mississippi at Quincy, Ill., just above its confluence with the Missouri is estimated at 72,000 second-feet. The area of the drainage basin above that point is 138,000 square miles, and the run-off per square mile is thus 0.528 second-feet. Many careful measurements show that the river carries annually past Quincy about 8,540,000 tons of sediment, in suspension, and about 14,680,000 tons of matter in solution. The surface of the basin above Quincy is thus being lowered at the rate of 1 inch in 1,100 years.

Stratigraphy—The rocks underlying the Glaciated Plains range in age from pre-Cambrian to Recent, or from the oldest known rocks to the youngest, but many of them are not represented by deposits, for the region has been at several times for long periods above sea level, so that many of the formations overlap one another. The province emerged from the sea in late Paleozoic time and has since been a land area almost if not quite continuously.

The pre-Cambrian formations are made up of igneous, sedimentary, and metamorphic rocks and exhibit a complex structure. Their top surface seems to have been long subjected to the influence of the waters of the Mississippi and Illinois, and the present river channels are merely the continuation of former channels that have been long submerged and now constitute the present course. The present course appears to be the result of the invasion of the ice, which blocked many of the early drainage lines and caused a shift of drainage to be placed along a thickness of several hundred feet and filling many of the old valleys. Where the drift is thick the drainages were wholly changed and it is only today that it appears to be a normal condition. In western Illinois there are several hill sheets, laid down in as many different ice sheets, but the well-drained belt mentioned above, which in the southern mountains lies to the west of it, was covered only by one of the earlier glaciers. In this belt the streams have become almost re-adjusted, but throughout most of the province they have irregular courses and profiles and the drainage systems show little symmetry.

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The rocks in Michigan have been divided by some writers into the Utica, Lorraine, and Richmond, and the beds in Iowa between the Glacial Plains and the Osagetonic series into the Maquoketa shales. The Maquoketa is generally regarded as of Richmond age.

The upper surface of the Ordovician rocks seems to have been considerably eroded and perhaps slightly warped before the Silurian beds were laid down, so that there is a great tectonic difference between the two systems. The silurian rocks of the province, as in the quadrangles here considered, the lowest Silurian formation is the Niagara limestone or dolomite. In Ohio and Indiana, however, there are other Silurian beds of limestones and shale which are regarded as the probable equivalent of the upper part of the Mallion of New York. The Niagara is widely distributed and was probably once present, in whole or in part, in all the province except a district near Lake Superior. Probably none of the older formations above the Cambrian is so extensive. It appears, however, that the Niagara was developed to its full thickness only in a part of the province, for in many districts certain beds found elsewhere and recognizable by their fossils are lacking. The Niagras in places reach a thickness of 300 feet or more, the eastern part of the province by other strata of more or less dolomitic limestone. The overlying beds in Ohio and Michigan are called the Menomonee group. Beds in the same position in Indiana and a part of southern Illinois, though perhaps not of exactly the same age, have been called the "Waterloo" and "Lower Heidelberg." Generally there is no conformity at the top of the Silurian, and perhaps the beds of the Silurian, Niagras and even the upper part of the Niagras itself were removed by erosion from large areas before the succeeding Devonian strata were laid down. The Niagras dolomite is the youngest rock found in the quadrangles, and the deer foot and the Cretaceous strata crop out in the basal part of the province. It consists in the study of the physiographic history of the province.

Cretaceous age in the province except those in its northwestern corner, but there probably never were extensive deposits of Glaciated Plains province.

There are now tentatively referred to the upper or Permian series, Pottsville, has been identified by means of its fossil plants at Osage, Meramec, and Chester groups.

In the States along Mississippi River the Carboniferous beds are naturally into four major divisions, known as the Kinderhook, Hand formation, Logan formation, and Maxville limestone. In Ohio, the Devonian system is best developed at places in the eastern, southern, and western parts of the province, where it attains a thickness of 700 or 900 feet, though at other places in the province it is thin. The lower part of the Devonian generally consists of more fossiliferous limestones, and the upper part of rock, carbonaceous, and nonfossiliferous shale.

The Devonian series is divided into three series, the upper and the lower containing little or no coal and the middle containing much valuable coal. In the eastern part of the province the lower, the Mississippian series, consists of shale and sandstone, and even the upper part of the Niagras itself were removed by erosion from large areas before the succeeding Devonian strata were laid down. The rocks at the top of the Silurian, and perhaps the beds of the Silurian, and even the upper part of the Niagras themselves were removed by erosion from large areas. The Devonian strata consist of four major divisions, known as the Kinderhook, Hand formation, Logan formation, and Maxville limestone.

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DESCRIPTIVE GEOLOGY.

The exposed rocks of the Galena and Elizabeth quadrangles are wholly of sedimentary origin and consist in part of limestones, in part of sandstones, and in part of conglomerates.

The limestones of the area are all of Paleozoic age and are of several distinct formations that are informally known as the Dekalb, Platteville, and Decorah Shales.

The Dekalb Shale is the most abundant formation in the area and consists of a succession of limestones, dolomites, and shales that are interbedded in a nearly horizontal manner.

The Platteville Limestone is a thickly bedded limestone formation that is well exposed in the area and is characterized by its high calcium content.

The Decorah Shale is a black, fossiliferous shale that is well exposed in the area and is characterized by its high carbon content.

The area is also characterized by its well-developed drainage system, which includes several major rivers such as the Mississippi, the Apple River, and the Tete de Mort River.

The climate of the area is classified as humid continental, with cold winters and hot summers.

The area is also characterized by its rich agricultural land, which is well suited for the cultivation of crops such as corn, soybeans, and wheat.

The area is also well known for its rich mineral resources, including lead, zinc, and silver.

The area is also home to several major cities, including Galena and Elizabeth, which are located along the Mississippi River.

The area is also home to several major railroads, including the Chicago & Northwestern and the Illinois Central.

The area is also home to several major industries, including lead mining and agriculture.

The area is also home to several major tourist attractions, including the Galena River, the Tete de Mort River, and the Apple River.
possibly the Maquoketa shale. The following species are common and are characteristic of the formation: Thalas spongia (Conrad), Lepidostrobus planus, Ambonyx ovalis, and Batrachoceras ovoides. Though the last named is not found in the Maquoketa formation, it is very abundant in the platteville, the other strata not being found below the platteville in this area but extend up into the Maquoketa and into smaller masses in the upper part of the Galena. The platteville is regarded as equivalent to the lowville limestone, a formation whose fossils are found in large numbers in one of the large pools in the Mississippi basin.

**Decorah Shale**

**Definition and occurrence.** The Decorah shale consists largely of grayish clay shale interbedded with limestones, which generally occur in thin beds and which greatly resembles the basal limestone layers of the Galena dolomite above. Hence it is difficult to draw the boundary between the two formations on purely lithologic criteria. With the oil rock, however, which is gray and abundant, the beds above and below the contact may commonly be distinguished. A long-beded variety of Ordovician (Dolomia) subaqueous, which is broadened in a large form above the middle of the formation, is very abundant in the Decorah and appears to be confined to it. *Stictoporella frondifera* and *E. capitata* are also found in almost every outcrop of the Decorah but not in formations above or below it.

The Decorah shale is named from the town of Decorah, in Winneshiek County, northeastern Iowa, where the formation is well developed and much thicker than it is in the quadrangle immediately south of Decorah, where it is known as the *Stictoporella* zone of the Decorah shale. This shale is widely distributed in Iowa and Minnesota, where it is known as the *Stictoporella* zone of the Decorah shale.

The Decorah presumably underlies the entire area of the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district.

**Chemical composition.** The main glass rock ranges in thickness from 18 inches to 4 feet. The material commonly called oil rock in the stratigraphic column is shown in Plate III. 1.868

**Section of Galena dolomite exposed near Galena.**

**Definition and distribution.** The Galena dolomite was named from its typical exposures at Galena. It immediately underlies the surface throughout most of the northern half of the quadrangles and crops out extensively in the southern half. It is not only the most common of the formations that is fully exposed in the area, but it completely fills in the gaps formed by the oldest Marine of the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district. In fact, nearly the whole of the ore-bearing rocks in the district.

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When the shale is heated with ether it yields a thick, heavy gum, which is doubtless the most abundant element in the oil. The major part of these singular bodies is not known, though it is generally believed that they are of organic origin. They are regarded by David White as probably either plant spores richly protuberant with crystals of later formation, their appearance suggesting fistulous growth beneath the snow surface. The nature of these singular bodies is not known, though it is generally believed that they are of organic origin. They are regarded by David White as probably either plant spores richly protuberant with crystals of later formation, their appearance suggesting fistulous growth beneath the snow surface.

The oil rock derived its volatile hydrocarbons from these fossil plant materials, which in a few years are quite rich in the material and in the tannin phlobaphic.
The shale diatomites rapidly and is therefore largely concealed by products of decay and by vegetation. Continuous vertical sections of any considerable thickness are found only along small streams that are vigorously scouring their beds or undercutting their banks, or in gullies that have been cut deeply into the shale.

Peaks and valleys. — Throughout the upper Mississippi basin its is in general notably fossiliferous. The shale at its base, measuring generally 2 to 5 feet, contains rather abundant fossils, but those near the surface of the rest of the rock have weathered away. Among them are the following species, all small and most of them preserved as the interior of the specimens: a species of Onychopora, a species of Planolites, a species of Pseudofibularia, a species of Pseudolimnoria, a species of Pterostichella, and a species of Pterolimnoria.

The fossils of the Maquoketa formation prove that its age is approximately that of the Richland group of Ohio and Indiana and of the lower part of the Medina group (Quarternary series) of New York and Ontario.

Dolostone, calcium, with very few shells, near Sherrill Mound, northwest of Dubuque, Iowa, contains a few of the marine species, all small and most of them preserved as the interior of the specimens: a species of Onychopora, a species of Planolites, a species of Pseudofibularia, a species of Pterostichella, and a species of Pterolimnoria.

The following generalizations show the character of the formation in several districts.

Section of Niagara dolomite exposed near Dolton.

Dolostone, light brown to gray, best light gray on weathered surface, massive.

Dolostone, light brown, light gray, containing considerable chert.

Dolostone, light gray, massive, with fresh but weathering quickly to a dark gray, with considerable chert. Detrital, light brown to gray, best light gray on weathered surface, massive, with a few specimens of Pentamerus oblongus, Calymene niagarensis, and other fossils.

In place where the Maquoketa shale is thinnest the lower part of the Dolostone shows a distinctive appearance, differing both from other parts of the Niagaran and from the Maquoketa. It is fine grained, earthy, and ranges from white and crystalline to yellowish and angleclastic. It contains very few fossils, though two or three species of Eurytoma sp., Orthis eleganula, and Oligoneura niagarensis have been found in it, and it weathered readily to a smooth surface. At the base there is usually a thin layer of limestones, which looks like laminated sandstone but that in reality is composed of dolomite containing some grains of calcite. The character of this thick layer suggests that the fossils in the Niagaran surface had been eroded and filled before any deposits were made on the surface of the Maquoketa formation. There is some indication that these thick layers were subjected to erosion during a part of the time when the horizons were being filled. In fact, as stated below, these basal beds may represent sediments of Medina age.
the bedding planes have been broken off, tilted, or greatly displaced by the undermining and weathering of the softer \textit{Mesohippus} shale.

In its general features the Niagra resembles the Galena, but it may be distinguished from that formation not only by its stratigraphic position and its fossils, but also by the following criteria: (1) The stratigraphic character of the strata composing the Niagra is not so persistent nor so homogeneous as that of the strata forming the Galena, for beds of the Niagra that seem to lie at the same stratigraphic horizon differ more or less at different locations; (2) the color of the Niagra includes a trid in the gravelly clays, in addition to the usual gray, which is prevailingly gray; (3) The Niagra strata are more thinly laminated and their weathered surfaces are not in general so curvate or pitted as those of the Galena; (4) the clear in the Niagra is more abundant, occurs in larger masses, and is more highly waterworn than that in the Galena; it is also harder, of a finer grain, and at most places is of a lighter color; (5) dark-red clay and abundant charcoal are characteristic products of the disintegration of the Niagra, whereas the Galena weather to yellowish clay and manganous sand.

Topographic relations in connection with the softer underlying shale the resistant dolomite and chert beds of the Niagra give to the region its dominant topographic features—

- the main valley of the Mississippi and in at least one place on the valley-side, where the gravel is waterworn, and a few are striated; all show deeply the effects of weathering and erosion. The stones in the drift are so different from any that are encountered in the valley at some places, as near Hanover and near Galena, as to permit its definite interpretation, but its topographic expression is prevailingly gray; (3) The Niagra strata are more thinly laminated and their weathered surfaces are not in general so curvate or pitted as those of the Galena; (4) the clear in the Niagra is more abundant, occurs in larger masses, and is more highly waterworn than that in the Galena; it is also harder, of a finer grain, and at most places is of a lighter color; (5) dark-red clay and abundant charcoal are characteristic products of the disintegration of the Niagra, whereas the Galena weather to yellowish clay and manganous sand.

- the uppermost unconsolidated material in a considerable part of the loess. Such dunes are common along both the valley-side wind deposit but may be a stream deposit laid down in slack water at the lower end of a tributary valley at the time that certain gravel deposits were being laid down at about the same altitude on the west side of the river.

\textbf{Unconsolidated Drift.}

The principal terraces of the area are of late Pleistocene age and are confined to the Mississippi proper and the lower parts of a few of the valley-side streams. Many of them are only fragments of terraces, their missing parts having been cut away completely by recent erosion. The terrace in the valley of tributary streams are horizontal and as a rule stand about 60 feet above the flood plain in contrast to the uppermost drift, which is more inclined and generally well-rounded pebbles of quartz as well as gravelly or pitted as those of the Galena; (4) the clear in the Niagra is more abundant, occurs in larger masses, and is more highly waterworn than that in the Galena; it is also harder, of a finer grain, and at most places is of a lighter color; (5) dark-red clay and abundant charcoal are characteristic products of the disintegration of the Niagra, whereas the Galena weather to yellowish clay and manganous sand.

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\textbf{Unconsolidated Drift.}

The principal terraces of the area are of late Pleistocene age and are confined to the Mississippi proper and the lower parts of a few of the valley-side streams. Many of them are only fragments of terraces, their missing parts having been cut away completely by recent erosion. The terrace in the valley of tributary streams are horizontal and as a rule stand about 60 feet above the flood plain in contrast to the uppermost drift, which is more inclined and generally well-rounded pebbles of quartz as well as gravelly or pitted as those of the Galena; (4) the clear in the Niagra is more abundant, occurs in larger masses, and is more highly waterworn than that in the Galena; it is also harder, of a finer grain, and at most places is of a lighter color; (5) dark-red clay and abundant charcoal are characteristic products of the disintegration of the Niagra, whereas the Galena weather to yellowish clay and manganous sand.

- the uppermost unconsolidated material in a considerable part of the loess. Such dunes are common along both the valley-side wind deposit but may be a stream deposit laid down in slack water at the lower end of a tributary valley at the time that certain gravel deposits were being laid down at about the same altitude on the west side of the river.
A residual clay overlies the bedrock throughout a large part of the area—perhaps more than half of it. Generally of a light-buff color, but where it is overlain by drift or loess it is commonly streaked with reddish buff. It is formed by the decomposition in place of the underlying rocks, chiefly the Galena and Niagara formations, which have a greater lateral extent beneath the surface deposits than any others in the area. These two formations consist chiefly of dolomite—the double carbonate of magnesium and calcium—with which are mingled certain other substances, chiefly feldspar, feld, muscovite (and perhaps iron carbonate), and clay. The carbonates are dissolved and carried away by water, but most of the oxides and silicates remain. The unlined and chemical composition of the residual clay thus differs materially from that of the rock. The residual clay contains much silica, which was worn away not only from the bedrock but also from the clay itself. The Galena dolomite contains nearly 56 per cent of soluble matter (calcium and magnesium carbonates), practically all of which is carried away by weathering, and only 4 per cent of other substances, most of which remain in the clay after the carbonates have been removed. The samples analyzed contained no nodules of chert, which are abundant in some parts of the dolomite, and no noticeable clayey lenses; the average rock of the formation probably contains much more silica and alumina than the analysis indicates.

An extensive study of the residual clay of the Driftless Area was made by Chamberlin and Salisbury,1 who found that the average thickness of the deposit, as determined by 1,800 measurements, is 7.0 feet. It is thicker on the hillsides and in the valley bottoms and thinner on the plains, and it is entirely absent from some places—such as the bare rocky ledges along the sides of some of the valleys. Its maximum thickness appears to be about 70 feet. About 1,500 measurements on broad uplands gave an average thickness of 3.55 feet. If the chemical composition of the original rock is compared with that of the residual clay and the thickness of the clay is considered it is evident that the amount of silica in any locality represents a great thickness of rock—just how great it is impossible to say without analysis, but the data on hand afford ground for a general estimate. The calcium and magnesium carbonates have practically disappeared from the clay, yet it has not made up its place by the bare rock ledge along the area by weathering. It should also be borne in mind that the residual clay still remaining is likely to be but a fraction of the amount formed during the long period of weathering, for ordinarily erosion nearly keeps pace with weathering on an area of uneven surface free from those of quadrangles.

Map of the area over which the bedrock is exposed shows several important features. The strata in northwestern Illinois lie nearly level but slope gently southeasterly at the rate of about 20 feet to the mile. The slope is not regular but is interrupted here and there by domes of residual clay, synclines, and minor irregularities. Along the permanent streams, and even along many of the other streams in the area, as indicated by the line showing the former position of the top of the Galena dolomite. The reliability of the structure contours depends on three factors: (1) the accuracy of the altitudes obtained directly; (2) the difference between the actual and the assumed interval to the key rock; (3) the number and distribution of the observations. In the Galena and Niagara quadrangles the altitudes of many outcrops were obtained by hand. Enough marks were sometimes made on most of the area and the determinations therefore involved only short horizontal distances and small possible errors. The second factor is more likely to be at fault, because the axes are not quite parallel. The most striking lack of parallelism is seen in the irregularity in the interval between the top of the Galena dolomite and the base of the Niagara dolomite. The intervals between most of the other strata in this area do not differ more than 20 feet. Another deviation from regularity is seen in an apparent abrupt thickening of the Galena dolomite in the vicinity of Pilot Knob, south of Galena. A comparison of the structure contours in figure 5 with those on the areo-geology map will make the abruptness of this thickening evident. Interpretations elsewhere in the third factor are thought to be small, for throughout both quadrangles the determined altitude of reference surface agrees within 

(4) actual mechanical denudation of the rocks by lateral pressure may have and undoubtedly has taken place, especially in some of the more marked and deeper folds. It is probable that some of these causes alone has produced all the basins, but that two or more have worked together, for while the lower beds of the Galena were being deposited small basins were already in existence, and in them the thicker deposits of oil rock were made. The shape of the basins themselves and the lateral compression and shuffling of the oil rock would seem to be due to this as well as due to the lateral compression to which the beds were subjected.

**PRE-CAMBRIAN TIME.**

All the hard-rock formations in the district except the Mesopotamian shales show distinct systems of joints, which are especially well developed in the massive beds of the Galena dolomite and have played an important part in the denudation of the area. The principal joints are practically vertical but trend in several directions. Among the miners those trending nearly north and south are spoken of as "north and south," those trending northwest-southeast are called "ten o'clocks," and joints parallel to the rim of the basin. Much of this material was doubtless a product of the disintegration of older sandstones. The St. Peter sand seems to have been above sea level and to have been subjected, it seems quite possible and rather probable that the deposits were formed in the district in Carboniferous time and were afterward eroded away. The present Carboniferous strata consist of shales and sandstones and thin beds of coal, all presumably laid down in extensive marshes that lay not far from sea level.

**MISSISSIPPIAN ERA.**

No record of Triassic or Jurassic time is preserved in the quadrangles or in any area that is near enough to afford information as to the events of those periods. The district probably lay a little above sea level and the surrounding region was probably nearly high, so that there was neither extensive erosion nor extensive deposition.

During the Cretaceous period the sea advanced from the west and in its sedimentation now forms sandstone, shales, and limestone which were deposited in eastern Iowa and Minnesota, but there is no evidence that the Cretaceous sea covered northern Illinois. So far as is known, no Cretaceous strata are recorded in this area either in deposits or in surface features. All land forms developed during the period seem to have been destroyed by erosion. The general low line of the Cretaceous rocks to the west and south indicates that the region lay at a low altitude and was nearly level.

**CENOZOIC ERA.**

The record of the Tertiary period is almost as scanty as that of late Paleozoic and Mesozoic times, but it appears to show that near the beginning of the period the region was uplifted and tilted southward. In the following cycle of erosion much material was removed from the area and a new surface, approximately a plain—a peneplain—was formed. Remarks of this plain are believed to still be present in the area, for the tops of many of the highest hills stand at concordant altitudes and the better preserved of these hills are flat-topped and bear about 200 feet of the Niagara dolomite. The remnants of this old surface seen to increase in altitude from heights of 900 to 1,000 feet above sea level in the southern part of the area to a height of 1,200 feet in the northern part. In southern Wisconsin isolated hills rising heights of 5,000 to 6,000 feet above sea level seem to have been capped by the same rocks that are the highest hills 10 or 20 miles to the south, whose tops are 500 feet lower. It also cuts across formations. For example, it has been traced across formations from the Niagara dolomite to the Platteville limestone between Dubuque and Church, Iowa. It is believed to be the same plain that is marked by high-level gravels at Winona, Iowa, and Devils Lake, Wis. The age of the plain indicated by these hilltops is not known and can be estimated only by comparing the area, or regarding its features and the amount of erosion, with districts whose history is similar and with districts in which the amount of post-Tertiary erosion is known. Estimates so made, though uncertain, indicate that the plain marked by the hills capped with Niagaran dolomites is in existence in Tertiary time, though perhaps its dissection began as early as the middle of the period. This plain, whose formation no doubt occupied a long time, was probably not the product of long erosion and was probably not constructive, yet it is inconceivable that during Mesozoic and early Tertiary time there was practically no erosion and no deposit of sediments. If it was a plain and if deposition it must represent the surface of deposits laid down in middle Paleozoic time—in other words, the plain is flat-topped and is products of the Devonian age—which remained almost unmodified until late Cretaceous time, and this is extremely improbable. A later and lower plain covers much of the northern part of the area and so much territory in southern Wisconsin. This surface may date from late Tertiary time, when a similar plain was formed in other parts of the Mississippi basin. It could not be called smooth, and it was probably so rough that it could hardly be called a plain, for it was broken in places by remnants of the older plains, or monadnocks, which, though now somewhat reduced in size, still stand as the hills—commonly called mounds—eroded by the Niagaran dolomites.
However, the surface was so nearly a plain that even after
later uplift and erosion it is still recognizable.

Probably near the end of the Tertiary period the region
was again uplifted to form a new plain in which narrow valleys
several hundred feet deep were cut. The rock bottoms of the
Mississippi gorge is about 500 feet below the near-by upland,
and some geologists believe that it was cut to that depth
before the end of the Tertiary period, for certain material from
the bottom of it seems to be a product of late Quaternary age,
and the bottoms of the valleys of tributaries of the Mississippi
are somewhat concordant in position with the bottoms of the
gorges. Others, including the writer, suspect that in late
Tertiary time a divide, from which small streams flowed north­
ward and northwest, lay just north of the area, and that the
deep, partly filled Mississippi gorge and other deep, narrow
valleys in the region were formed largely in the earliest part of
Quaternary time. That the plain into which the valleys are
cut was in existence in early Pleistocene time is indicated by
the fact that in Iowa it bears a cover of till which may be
Nehmkan.

QUATERNARY PERIOD.

PLEISTOCENE Epoch.

The events of the Pleistocene epoch, which profoundly and
widely affected much of North America, affected only indi-
rectly most of the Galena and Elizabeth quadrangles, where
the Pleistocene neared is short and incomplete. Of pre-
Illinoian time the only record is found in the remnants of
till in the southwest corner of the area and in part of the
northeastern corner. Both the pre-Kansan or Nebraskaan and
the Kamsan ice sheet approached at least within 15 miles of the
area. Possibly the thin edges of both sheets covered the part
of the land that is now Illinois. It is possible that some glaciers
soon to have crossed the river and advanced to the vicinity of
Hinckley.

A long interglacial stage (the Yarmouth) succeeded the Kans­
an stage and was followed by the Illinoian ice invasion.
The surface between the two stages is near the level of the
modern river. In its upper reaches the ice sheet lay upon the
alluvium in the stream bottoms, and the clearing out by the
Illinoian as well as by its tributaries, at their lower ends,
was due to the late Pleistocene streams. In their middle and
upper parts most of the tributaries are now, an entrenched
stream, deeply cut and bordered by terraces.

The recent events of the Recent epoch consist of the furth­
er development of the mantle of partly decayed rock that
covers the surface of the area, and the cutting down and
erosion of the alluvium in the stream bottoms, and the clearing
out by the Illinoian as well as by its tributaries, at their lower
ends, of part of the late Pleistocene ice sheet.

The great events that have affected the area were the
formation of the Mississippi valley, the valley fill, and the
progress of the glacial gorge.

RECENT Epoch.

The way the area has been finally settled and developed
has long been known to the producer of lead and zinc ore.
Small amounts of the ore have been found in all the Paleo­

The geologic resources of the Galena and Elizabeth quadran­
gles include ore of lead and zinc, sulphur, building stone, clay,
cement materials, lime, sand, sand materials, water, and coal.

LEAD AND ZINC DEPOSITS.

O ccurrence.

The quadrangles lie within the area which has been called
the Upper Mississippi Valley lead and zinc district and which
has long been known as the producer of lead and zinc ore.
Small amounts of the ore have been found in all the Paleo­

The ore consists of several minerals containing lead or zinc,
which are associated with other minerals that must be separated
from those in the concentrations of the ores.

Galena or lead sulphide (PbS; lead, 86.06 per cent; sulphur,
13.94 per cent; sp. gr., 5.8 to 6.0), is one of the commonest
minerals in the district, and is the only ore mineral of the
district. It is found in the ores of all the ores of the district,
and is the only ore mineral of the district. As it usually lies
below the level of ground water it was not discovered in the early
explorations of the district and was not utilized for many years
after its discovery. It is also found in smaller quantities in the
early lead mining in the district it was not neglected, and in the early
period of zinc mining it was about the only one of zinc mining.
Sphalerite or zinc sulphide (ZnS; zinc, 67.15 per cent;
sulphur, 32.85 per cent; sp. gr., 3.9 to 4.1) is known also as zinc
blende and by the miners as "black jack," or simply as "jack,"
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ole spar or simply as spar, and the miners usually call it "nug." It is the most common mineral in the district, and is almost everywhere associated with the lead and zinc ores. At many places it lies in the interior of the deposit after the metallic sulphides already mentioned. It occurs also in veins or in any kind of cavity in the dolomite and carbonates of the quadrangles, especially in the Galena and Platteville formations.

Dolomite (CaMg(CO₃)₂); carbon dioxide 47.9 per cent; lime, 39.4 per cent; magnesia, 21.7 per cent; sp. gr., 2.6 to 2.9), though the principal constituent of most of the Galena formations, rarely occurs in large crystals and does not seem to have been deposited in the crevices.

Selenite or hydrous calcium sulphate (CaSO₄·2H₂O); sulphur trioxide, 46.1 per cent; lime, 25.5 per cent; water, 29.0 per cent; sp. gr., 2.2), occurs in small crystals, but is not very common. It undoubtedly owes its origin to certain chemical reactions that take place between the solution of the rock and the sulphatic acid produced by the break down of the crystals of the ore minerals.

Baryte or barium sulphate (BaSO₄); sulphur trioxide, 34.3 per cent; baryta, 65.7 per cent; sp. gr., 4.3 to 4.6), commonly known as heavy spar, is found at some places near the oil rock, and also in veins that occur in small cavities, although it is undeniably produced by the decomposition of the iron sulphates, marluret and pyrite. It is nowhere found in sufficient quantity to be economically important.

Quartz (SiO₂); oxygen, 55.3 per cent; silicon, 44.7 per cent; sp. gr., 2.65 to 2.70), occurs chiefly in the form of sand, which is abundant in parts of the Galena dolomite. Notwithstanding the large amount of silica in the ore-bearing rocks it is rarely found in crystalline form.

ORDER OF DEPOSITS.

Classification.—The lead and zinc ores are at many places associated, and both occur in the same kinds of formations and at the same horizons. The deposits may be grouped into two divisions based upon their form, those that occur in crevices or cavities in the rocks, including both vertical cavities and the flat and pitch areas described below, and those that are disseminated in small particles throughout the rock.

Creviced deposits.—The deposits in crevices or fissures and along joint planes, many of which have been enlarged by solution, before the ore was deposited, were formed in open cavities, and not by replacement.

Most of the crevices trend from east to west or from a little north of west to south of east and are essentially vertical. They are crossed by many other cavities, the main series of which range a little east of north and west of south, about at right angles to the major set. The first series of crevices the miners apply the term "east and west," the second, "north and south." In addition there are smaller features, called centers, which cut across the main. Some of these today are 10' to 20' apart, others 30' to 50'. Most of the ore mined has come from the east-west crevices, but particularly rich deposits occur at the junction of these two sets of cavities.

The general term "range" is applied by the miners of the Upper Mississippi Valley district to an ore-bearing crevice or to a series of such crevices that lie parallel and close together. Some of the ranges can be traced for several hundred feet, and more, apparently, for a few miles.

The ore deposits in the crevices at some places impinge adjacent beds laterally for short distances, where solution of the dolomite has occurred. Irregular cavities that are more or less filled with ore have thus been formed, and to these cavities the term "openings" has been applied. Most of the openings are less than 10' apart, although the outermost part of the deposit a few feet from the edges of the deposit are connected with horizontal openings that run along the bedding, which also contain ore. It is these peculiar forms of deposits that the miners call flats and pitches and which extend horizontally or perpendicularly to the vertical cavities just described.

Many of the flats and pitches are connected with vertical crevices or fissures. The crevices as a rule do not extend below the horizon of the oil rock, although some of the Galena-Elizabeth region contain numerous fissures filled with ore. A series of flats and pitches may be 100 feet to 200 feet across, and in a flat that runs back from a pit to the heel wall there may be a considerable mass of laminated rock, which extends from one pitch to the other, and which can be mined out. In general the pitches in any one mine are approximately parallel with one another and also parallel with a vertical crevice, but at some places there are secondary pitches that cross the main crevice at an angle very different from that of the main system of pitches.

An analogy of the crevice deposits to other to which the name "honeycomb" deposits has been applied, but these are not generally diffused from the ordinary crevice deposits. They occur in large cavities that are open at the mouths of the crevice and where the rock has been brecciated, semifelicitized, or stratified, and where it has therefore been more subject to solution. In the solution that has been described along the edges of the crevice, ore has been deposited. Deposits of this kind, which grade directly into the crevice deposits, occur at many places.

As before stated, many of the vertical cavities that are filled with ore are not connected with flats or pitches. Flats also occur just below the horizontal plane of the oil rock. At these points there is another thin bed of ore. The ore in some of these flats has been deposited in open cavities made by solution, but that in others is the result of the replacement of the sand, and thus to grade directly into the next class, called disseminated deposits.

Disseminated deposits.—At certain horizons the rock has been more or less permeated or impregnated by ore-bearing solutions and in such places crystals of sphalerite and of Galena occur in abundance. The disseminated deposits can not be sharply separated from the flats that occur in connection with the oil rock, just mentioned. Most of them are found in thin beds of feldspar that contain a large number of these crystals, which grade directly into the crevice deposits, occur at many places.

Sulphur (S); sp. gr., 2.2), though not abundant, occurs here and there in the region in a pelletiform or minutely crystalline form in crevices or small cavities, and is undeniably produced by the decomposition of the iron sulphates, marluret and pyrite. It is nowhere found in sufficient quantity to be economically important.

ORDER OF THE ORE DEPOSITS.

Origin of the ores.—As has already been stated, the ore in the crevices was deposited in the open fissure. The usual order of deposition of the minerals, from the wall to the floor of the crevice, is: (1) galena, (2) sphalerite, (3) calcite, in some places containing galena, (4) dolomite, (5) hematite, (6) barite. Each of these minerals appears in a characteristic position in the crevice deposits, and in a flat where the rock has been brecciated, semifelicitized, or stratified, and where it has therefore been more subject to solution. In the solution that has been described along the edges of the crevice, ore has been deposited. Deposits of this kind, which grade directly into the crevice deposits, occur at many places.

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In the Galena and Elizabeth quadrangles the level of ground water ranges from 10 feet to 200 feet below the surface in the valleys to 100 feet below the surface on the broad interfluve areas. Although each of the three zones is characterized by its own peculiar mineralogy, galenas extend from the first zone down to the second zone, which contains principally semihematite, and some galenas is found also in the zone of sphalerite, especially near its top. At many places in the lower zone crystals of galena have been deposited on flakes in the open crevices of the rock, when the surface of the deposit was a little below the top of the zone of sphalerite, but just below the top of this zone these crystals of galena are much less numerous, and in the lower part galenas it is intimately mingled with sphalerite.

The eminences of the district is a product of the alteration of the original sphalerite, an alteration which has taken place everywhere in the zone above the level of ground water, and which at some places extends a few feet below that level. The lower part of the second zone contains large specimens showing all stages of alteration from sphalerite to smithsonite.

Relation of ore deposits to structure.—Attention has already been called to the fact that the crevice deposits occur in joints, and more commonly in joints that have been enlarged by solution. These joints bear a more or less close relation to the stripping that the rocks in the district have undergone, and the principal joints running nearly parallel to the main axes of extension.

Recent detailed work in the Upper Mississippi lead and zinc district has shown that many of the lead and zinc deposits of the region lie in or near the domes of synclinal basins, especially the disseminated deposits, the flats associated with the main oil rock, and the thin beds of oil rock that lie just below the plates of the rock of the Potosi district. Many and perhaps many of the flats of the fills and pitch also lie in synclinal basins, though it must be noted that no data are hand to show positively that all of them occur in such basins.

The general character and the origin of the synclinal basins have been discussed in the description of the structural geology, under the heading "Folds" (pp. 8-9).

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have acted as channels for water that descended to the imper­
vious floors and then flowed down the pitching synclines form­
ning the basins. The disseminated deposits and those in the
lowest part of the flats and pitches suggest that the organic
matter in the oil rock may reasonably be supposed to have aided
materially in precipitating the ore in crevices higher up in the
formation.

There is evidence that the ore minerals are continually
migrating downstream along the crevices to become arranged in
the horizontal zones already described. Sphalerite, which is
readily altered to smithsonite, is dissolved and carried down­
ward to be precipitated close to the water level as smithsonite,
or carried still further down and precipitated as sphalerite.
Galena is not so easily dissolved and does not travel downward
so rapidly. A large part of the galena lies close to the surface
and travels downward about as fast as the surface is lowered by
erosion. The lead ore that is dissolved and carried downward is
commonly reprecipitated near the level of ground water, and
precipitation gives rise to the large crevices of galena that
line the veins in the upper part of the lower ore zone in many
places.

MINERALS AND PRODUCTION

The most productive mines are grouped in certain rather
small districts, known as the Galena, the Sand Prairie, and
the Elizabeth districts. The principal mines near Galena are
Drapers, White, Darth, and Living Wood, Flax River Valley, Oldenburg, Northwestern, and Stacy; those
in the Sand Prairie district are the California, the Pittsburg, and the Peru or Black Jack; those around Elizabeth are the Weldon, Apple River, Skena, and Queen. Two shafts
have been sunk near Sauls Mound (the Vinton Granite and the
Gazette prospect), and several smaller prospects have been
opened at other places.

The Elizabeth district is sharply defined, being separated from other producing areas by a wide belt of barren territory.
Many of the mines in the district were a few years ago abandoned but have since been re-opened.
Most of the mines are 100 to 300 feet deep, but the extreme
depth in one is 1000 to 300 feet. The production of lead con­
centrate in 1914 was 846 short tons, valued at $28,178, and
that of zinc concentrate was 16,725 tons, valued at $350,012.
The maximum production of lead was reached between 1890
and 1895 and that of zinc between 1900 and 1910.

The ranges and the districts that in early days produced lead
and zinc are in large quantities close to the surface on, other
things being equal, which gives a distinct advantage for pros­
pecting.

The ranges are those which have produced considerable
quantities of rich ore in the upper part will bear large quan­
tities in the lower part, the main difference being that below
the level of ground water there will be less lead, practically
no sphalerite, and probably more pyrrhotite. In prospecting,
however, only those areas can be selected in which there
is below the level of ground water a considerable thick­
ness of the Galena dolomite—that is, a considerable thickness
of rock that may be mined—for the deposits are in most cases
limited by the base of the Galena and in practically all places
are limited by the oil rock. It should be added that a range or
a series of ranges or a district then at a certain level on the
ground is a more favorable place for prospecting than one not so situated.

SULPHURET ORE

The metallic sulphides—galena, sphalerite, and marcasite—are
sources of sulphur. Sphalerite, a ore of low grade that are
burned for zinc oxide are first roasted, and the resulting sulphur is used for making sulphuric acid. In a few of the
mines marcasite is so abundant that it is possible to sell it to
manufacturers of sulphuric acid.

BEDDING AND STRIKE

The thinner beds of the Galena dolomite, especially those in
the upper member of the formation, furnish good building
stones, and at Dubuque, Iowa, stones from some of the massive
beds lower down in the formation have been used in construct­
ing large buildings and in bridge and railway work. West of
Dubuque the lower part of the Niagra dolomites includes about
20 feet of good building stone, which has been quarried at some places for use near by.

The district contains plenty of building stone for all local uses, and even for supply shipments to outside points, but it probably will not be shipped in large quantities, for
much of the surrounding country is almost equally well supplied.

CLAY

The clays of these quadrangles, though widespread and of
excellent quality, have not yet been extensively utilized. Most
of those that have been used were derived from three sources—
(1) loam and alluvium, (2) residual clay, and (3) clays in the
Magoapo shale, all being suitable for making ordinary bricks.
Alluvial and sandy loam taken at low levels are used at
Dubuque for making common building bricks, and such clays
are also manufactured in small-size kilns at the Galena and
Elizabeth quadrangles. The demand for brick and other clay
products, however, is slight, for an abundant supply of ordi­
nary building stone is everywhere available.

The Magoapo formation contains, near its base, much
sand and clay that can probably be used for making clay
molds, including pressed brick and tiles. None of this material
is now used in the area. An analysis of shale from Kidder,
Iowa, near Lattimer, just west of the Galena quadrangle, is
given below:

<table>
<thead>
<tr>
<th>Analyses of Magoapo shale from Kidder, Iowa.</th>
</tr>
</thead>
</table>

| Clayaceous shale (MgO) | 1.40 |
| Clayey (SiO2) | 1.80 |
| Limestones (CaO) | 0.20 |
| Magnesium carbonate (MgCO3) | 0.40 |
| Potassium carbonate (K2CO3) | 0.10 |
| Sodium carbonate (Na2CO3) | 0.10 |

Transporation for the plastic clays of the Magoapo can be
had at some places along the Chicago Great Western Rail­
road, and as the shale lies rather high above the railroad track
the material could be loaded on the cars by gravity.

LIME

The ruins of kilns that once furnished local supplies of lime
are a source of certain illuminating gases particularly of
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The quality of the water is shown below:

<table>
<thead>
<tr>
<th>Analyses of water from deep wells in the Galena and Elizabeth quadrangles.</th>
</tr>
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<tbody>
<tr>
<td>(Water per gallon)</td>
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The deep wells in the quadrangles derive their supplies from
two water-bearing formations—the Cambrian strata and the
St. Peter sandstone—one or both of which lie beneath the
whole area. The sandstone in the upper part of the Priarie
du Chien group is also commonly water-bearing, though it
carries no water in places where it is not separated from the
St. Peter by beds of limestone. At Dubuque, where it lies
about 435 feet below the level of the Mississippi, it yields on
armour flow.
Wells sunk to the St. Peter sandstone furnish abundant
supplies of water that is softer than that derived from the
dolomites. At Stockton two wells about 1,500 feet deep have
been drilled and the water in them stands about 125 feet below
the surface.

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STREAMS AND WATER POWER.
The annual rainfall in the district is about 35 inches, and the streams are numerous, and irrigation is not necessary. The smaller streams have rather steep gradients, at some places as much as 60 feet to the mile, but the average fall of the large streams in their lower parts does not exceed 10 feet to the mile. Many of the streams that have a fall of 10 to 40 feet to the mile are large enough to furnish power for small gristmills. Abandoned mills and millraces testify to the use of these water powers before the large mills in the Northwest were built. The Mississippi is the only navigable stream in the area.

SOIL.
The fertility of a soil depends on many factors, among which are geologic processes, for the texture and the physical and chemical composition of a soil are determined in part by the character of the rock or rocks from which it has been derived. That part of the soil of these quadrangles that was derived from the formations which outcrop at the surface shows at any locality a character corresponding to that of the underlying rock or deposit, though it may be modified somewhat by surface wash.

The soil on the Galena and Niagaran dolomites is generally fine grained, compact, and dark gray, but at some places, particularly on the Niagara platform, it is reddish or even bright red, and at other places, especially where it is old and contains some calcareous wash, it is very black. The dolomite generally weathered first to a more or less clayey material having a remarkable sandy texture.

The soil that lies upon the Maquoketa shale is generally very fine grained and uniform, though the Maquoketa contains so much dolomite that the soil derived from it does not differ greatly from the soil on the Galena and Niagaran dolomites except that it is nearly either reddish or deep black.

The loess soil varies with the character of the underlying loess, being most porous along the river bluffs and most fine grained and impervious at places farthest from the river. Both the physical and the chemical nature of the loess soil tends to make it very fertile. It is composed of a great variety of more or less decomposed minerals and a goodly supply of organic matter. Its consistency is that of a soil made of dust particles somewhat modified by weathering. It is comparatively open and porous and consists of very fine sand or silt with which more or less clay is mixed. The soil developed by the weathering of glacial till differs from the soils described above principally in being somewhat gravelly. It is more compact than the soil in the loess areas, and more heterogeneous in composition than the soil on the hard rocks. It covers only small areas on the eastern and western sides of the area.

The alluvial soil contains much sand and gravel derived from the chalk in the dolomites and is deep black, porous, and fertile. Along the borders of the alluvial tracts are irregular boulders of colluvial soil consisting of material that has been washed from the adjacent slopes. It is somewhat similar to the alluvial soil but is generally deeper and blacker and less washed.

On the whole, the soils contain less deep, black alluvial material than is found in the soils of the surrounding glaciated area, yet they yield abundant and diversified crops, including corn, oats, and hay.

December, 1914.