WAPSIPINICON BRECCIAS OF IOWA

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THE WAPSIPINICON BRECCIAS OF IOWA

INTRODUCTION

It has long been known that one of the most extensive breccias of the United States is that of the lower stage of the Devonian in Iowa, the Wapsipinicon. Breccia beds involving one or more of its terranes occur along the line of strike from Muscatine county on the southeast to Fayette county on the northwest, a distance of about two hundred miles. Owing to the thickness of the strata affected and their gentle dip to the southwest, the belt of breccia is of considerable width and embraces an area which may be roughly estimated at a thousand square miles. The brecciation is therefore regional, and its causes must be equally widespread in their operation.

These beds of broken rock have been objects of observation and study since Owen in 1850 noted the brecciation of the lowest Devonian strata exposed in the valley of Cedar river, in Cedar county. McGee in 1891 devoted one or two pages of "The Pleistocene History of Northeastern Iowa" to lucid description and suggestive interpretation of the breccia as seen typically at Fayette. The writers of the reports on areal geology of the Iowa Geological Survey whose work lay in the counties in which these breccias occur have given to them more than cursory attention. Yet although these observations have continued for more than half a century the brecciation of the Iowa Devonian has remained an outstanding problem in Iowa geology for which no full and convincing solution has been given.

The processes by which rocks are broken up and reassembled into beds of breccia are many, and they do not always leave in their product clear evidence of the method of its manufacture.

In long studied areas, such as Europe and eastern North America, breccias are not uncommon, and the literature regarding them is extensive. Yet example after example might be cited of breccias which have received the most diverse of explanations and as to whose cause no unanimity of judgment has yet been reached. The solution of the Iowa problem requires the holding in mind of a genetic classification of breccias with the diagnostics of each variety, and furthermore it requires a comprehensive and minute study of the phenomena in the field. The fragments must be traced back to their sources. The strata from which they have been derived must be found, if possible, in an undisturbed condition, and assigned to their proper stratigraphic places. The matrix in which the fragments are imbedded must be scrutinized in order to find any possible traces of its origin. Nothing is too small, and nothing too large, for investigation if only it may throw light on the processes by which the strata were broken up and reassembled in these breccias.

For an exposition of the various types of breccias, the reader is referred to the author's paper on *The Classification of Breccias,* Journal of Geology, vol. XXV, pp. 160-194, 1917. The following outlines of this classification may be found convenient.

Classification by Physical Characters

Endostratic breccia: one bedded in a distinct stratum.

Crackle breccia: one showing only incipient brecciation, with little or no displacement of fragments.

Mosaic breccia: one whose fragments are largely but not wholly disjointed and displaced.

Rubble breccia: one whose fragments do not match along initial planes of rupture, and are close set.

Pudding breccia, breccia of sporadic fragments: one whose fragments are imbedded in a preponderant matrix.

Classification by Origin; Fragmentation and Assemblage

I. SUBAERIAL BRECCIAS; ASSEMBLED IN OPEN AIR.

Residual breccia: the angular debris of the waste mantle.
Talus breccia: the accumulation of waste at the foot of cliffs.
Rock glacier breccia: the material of rock glaciers, rock streams, or talus glaciers.
Landslide breccia: the material of rock falls and rock slides.
Bajada breccia: assembled in the debris slopes (*bajada*) of the rims of desert basins.
Glacial breccia: morainic deposits of glaciers.
Volcanic breccia: due to volcanic action and including
  Flow breccia: in which angular fragments are included in lava flows.
  Tuff breccia: made up of fragmental products of volcanic eruptions.

II. SUBAQUEOUS BRECCIAS; ACCUMULATED UNDER WATER

Breccias of subaerial fragmentation.
Subaqueous talus breccia.
Subaqueous landslide breccia.
Raft breccia, deposits from rafts of icebergs or icefloes, trees, or sea weed.
Desiccation breccia: fragmentation due to drying of surficial sediments of flood plains, playa lake beds and mud flats along shores.
Volcanic subaqueous breccia.
Shoal breccia: both disruption and assemblage due to the action of waves and tides on shoals.
Reef breccia: composed of the fragments of coral reefs or of other reefs of organic origin, including
  Reef-rock breccia: formed by the direct upbuilding of the reef rock.
  Island-rock breccia: composed of fragments of the reef heaped by waves into coral islands.
  Talus reef breccia: composed of fragments of the reef accumulated below wave base.

Beach breccia: composed of more or less angular material of bowlder or pebble beaches.

Glide breccia: in which brecciation is due to gravitational movement of subaqueous deposits. The precipitory causes of these glides may be *overload, earthquake shock, deformation or undercut.*

III. ENDOLITHIC BRECCIAS, FORMED WITHIN THE LITHOSPHERE.

Tectonic breccia: due to crustal movements produced by lateral or vertical pressure or by tension.

Fault breccia: fragmentation due to friction or shearing stresses along a fault plane.

Fold breccia: fragmentation due to stresses producing folds.

Crush breccia: fragmentation due to stresses without mass deformation.

Expansion breccia: caused by increase of bulk of the brecciating rock or of associated layers due to hydration or recrystallization.

Founder breccia: due to the removal by solution of inferior terranes leaving the unsupported superincumbent beds to break down into breccia. *Cavern breccia,* composed of detached masses fallen from the roofs and sides of caverns, is a variety.

HISTORY OF EARLIER INVESTIGATIONS

The position of the breccias along the line of contact of the Devonian and the Silurian indicates that it is the lower strata of the Iowa Devonian which are affected. The stratigraphic position of these lower strata, and indeed of the entire body of the Devonian in Iowa, has long been a matter of question especially in its equivalencies with other fields. A resumé of the investigations of the Iowa Devonian may thus be useful so far as they relate to the brecciated terranes.

As early as 1850 Owen correlated the Iowa Devonian with the Hamilton and the Upper Helderberg of New York.[1] He noted white, brecciated, close-textured limestone resting on the Niag-

[1]Owen, D. D., Geol. Surv. of Wisc., Iowa, and Minn. Chap. III.

aran along Sugar creek below the present site of Lime City in Cedar county and considered it an extension of the beds of the Rock Island rapids. He concluded that the Devonian rocks of the Cedar river valley consist chiefly of close-textured, white and gray limestones, in some places brecciated, or of argillaceous limestones. The former are of no great thickness, probably not exceeding seventy feet.

Hall,[2] in 1858, following the classification of Owen, recognized the Upper Helderberg at Davenport and on the road from that city to LeClaire at the level of the bottom land, referring probably to the outcrops of Otis limestone on Crow and Pigeon creeks. He states that "on Duck creek the same limestone appears in great force" and finds that at Davenport "the lowest beds are often concretionary and sometimes iron stained and brecciated."

White[3] correlated the entire Devonian terrane in Iowa with the New York Hamilton. He mentions different lithological variations such as magnesian limestone and calcareous shales, but states that "so far as has yet been ascertained none of these lithological variations characterize any particular horizon of this formation over any large portion of the area occupied by it, but the concretionary or partially brecciated bluish gray common limestone is its prevailing lithological characteristic."

In 1878 Calvin[4] announced the discovery at Independence, in a shaft sunk in search for coal, of a dark shale with a brachiopod fauna of twelve Devonian species. He suggests a tripartite division of the Iowa Devonian: in descending order, the Rockford shales, the central limestones, and the Independence shales. All of these he refers to the Hamilton epoch.

The local geologists of Davenport have recognized the individuality of the beds classified by Hall on lithologic grounds as Upper Helderberg and Hamilton. In 1877 Rev. W. H. Barris[5] distinguished the Upper Helderberg from the Hamilton by its fauna and mentions two lithologic types of the former limestone,

[2]Hall, Geol. of Iowa; Vol. I, p. 82.
[3]White, C. A., Geol. of Iowa. 1870, p. 185.
[4]Calvin, Samuel, Bull, U. S. Geol. and Geog. Surv. Terr., Vol. IV. pp. 725-730, Washington, 1878.
[5]Local Geology of Davenport and Vicinity: Proc. Dav. Acad. of Nat. Sciences, Vol. 2, p. 261.

a fossiliferous upper bed and lower concretionary unfossiliferous beds "closely approaching the character of chert." In 1879 he described new fossils from the Upper Helderberg[6].

In 1885 Mr. A. S. Tiffany[7] noted various exposures of the "Upper Helderberg" near Davenport and the brecciation of several beds. He also published a list of 246 species of fossils collected from this formation in the vicinity of Davenport!

In 1891 Calvin[8] observed that the Independence shales are not the lowest of the Iowa Devonian but are preceded by brecciated limestones exposed at Troy Mills. He classified the exposed Devonian strata of the county—so far as these have been since referred to the Wapsipinicon—as follows:

4. *Spirifer pennatus* beds.
3. *Gyroceras* beds, characterized by a large *Gyroceras* and robust forms of *Gypidula comis*.
2. The Independence shales.
1. Brecciated limestone.

As to No. 1 he states, "No fossils have been seen as yet in these beds at Independence, but at Troy Mills in Linn county they contain many brachiopods which are characteristic of the lower part of the Iowa Devonian."

In 1891 McGee[9] followed the tripartite division of Calvin and named the central calcareous terrane the Cedar Valley limestone. He described and illustrated the breccia beds at Fayette.[10] He noted the exhibition of this structure over an immense area in nine counties, and adds that "brecciation appears to be practically co-extensive with the Cedar Valley terrane." He briefly sketched a hypothesis of expansion of Paleozoic sediments by rise of isogeotherms and a consequent horizontal expansion and creep of Devonian sediments down the prevailing seaward slope. Thus the Devonian strata were "thrown into anticlinal and synclinal folds concentric with the shore, or elsewhere were crushed and broken into fragments along planes of least strength." Regarding crumpling and brecciation as coeval with deposition,

[6]Ibid, pp. 284-288.
[7]Geology of Scott County, Iowa, and Rock Island County, Illinois: Davenport, 1885.
[8]Calvin S., Additional Notes on the Devonian Rocks of Buchanan County, Iowa: Am. Geol., Vol. 8, pp. 142-145.
[9]McGee, W J, Pleistocene History of Northeastern Iowa: 11th Ann. Rept. U. S. G. S., pp. 314-323.
[10]Of McGee's excellent and typical illustrations Pl. XXV and Fig. 15 are of rubble breccia of the horizon of the Otis calcilutites, and Fig. 16 is a mosaic breccia from the thinly laminated Otis just beneath.

McGee dates both at about the close of the period of Cedar Valley deposition[11].

The writer does not find that McGee himself used the term Fayette breccia, which rather unfortunately came later into somewhat general use. McGee did not regard the breccia as a formation, but as a structure characteristic of different horizons in a formation—the Cedar Valley limestone—over a wide extent of country. His closest approach to any formal name is to speak of it as the "Devonian breccia" or the "Devonian limestone breccia."

In 1893 Norton[12] found beneath the Independence shales an extensive Devonian formation which he designated as the Otis. He discriminated four stages or zones of brecciation as follows:

4. A zone involving the *Acervularia davidsoni, Phillipsastrea billingsi* and *Spirifer pennatus* horizons.

3. A zone distinguished by the brecciation of a limestone bed called the fossiliferous Upper Helderberg at Davenport, the *Gyroceras* beds of Calvin. For this limestone the name *Upper Davenport* is suggested.

2. A zone defined by the large number of calcilutite fragments, identical with the lower unfossiliferous "Upper Helderberg" limestone at Davenport and here named the Lower Davenport.

1. A zone in which the Independence contributes largely both to matrix and to fragments.

The Davenport limestones are thus separated from the Cedar Valley. At the same time it is pointed out that they lie above the Independence, and that the Otis carries as its characteristic fossil a Hamilton and Chemung brachiopod. Hence the Davenport limestones can no longer be regarded as Upper Helderberg.

In 1895 Norton[13] described the four zones of the brecciated beds in much detail and found two magnesian terranes below the Otis and above the Anamosa beds of the Niagaran—the Coggon and the Bertram—both of which were included in the Silurian, although the inclusion of the Coggon was only provisional. He proposed the term Wapsipinicon as the designation of a stage composed of the Upper Davenport limestone and the Devonian substages underneath it. The appropriateness of this term is due to the exposure of the entire terrane along the banks of Wapsipinicon river which traverses over a large part

[11]Ibid, pp. 323, 338, 351.
[12]Norton, W. H., Notes on the Lower Strata of the Devonian Series in Iowa: Proc. Iowa Acad. Sci., Vol. I, Pt. IV, pp. 22-24.
[13]Geology of Linn County, Iowa Geol. Surv., Vol. IV.

of its course the Devonian area of outcrop east of the valley of the Cedar. Since this date, the Iowa Geological Survey, and the United States Geological Survey in its publications relating to Iowa, recognize the division of the major part of the Iowa Devonian into the two stages named after the parallel rivers which traverse the belt of outcrop of the system.

In 1897 Calvin[14] found the exposures of breccia in Johnson county to correspond with the zones of Norton and classified the *Spirifer pennatus* beds with the Wapsipinicon.

In 1897 Barris[15] withdrew the reference of the Davenport limestones to the Upper Helderberg or Corniferous. He abandoned the attempt to correlate the Iowa Devonian with the New York section and quoted with apparent approval the classification by McGee of all the limestones of the Iowa Devonian in a single terrane, the Cedar Valley. At the same time he designated the fossiliferous "Upper Helderberg" at Davenport as the "Phragmoceras beds" and listed their characteristic fossils to the number of twenty-four.

In the same year Udden[16] discriminated from the Cedar Valley limestones about Rock Island an inferior terrane which he identified as the *Gyroceras* beds of Calvin and Barris and the Upper Davenport of Norton. Number 1 of his section includes a lower fossiliferous part which "appears to be the same as Prof. W. H. Norton's Otis beds. The greater part of these beds have by the latter author been called the Lower Davenport beds." The thickness assigned to No. 1 is seventy feet, the exact thickness assigned by Owen in 1850 to the "lower close-textured white and gray limestones sometimes brecciated" of the Iowa Devonian.

In 1898 Calvin[17] published the Geology of Buchanan county. He classified the Devonian rocks of the county as belonging to the Middle Devonian, but stated with emphasis that the western Devonian can not be correlated except in a broad and very general way with the Devonian of the east. Under the Wapsipinicon stage he classified the Fayette breccia as follows:

[14]Calvin, S., Geology of Johnson County: Iowa Geol. Surv., Vol. VII, p. 59.
[15] Barris, W. H., Our Local Geology. Reprint from Proc. Dav. Acad. of Nat. Sci., Vol. VII.
[16]Udden, J. A., A Brief Description of the Section of Devonian Rocks exposed in the Vicinity of Rock Island, Illinois, Etc.: Journal of the Cincinnati Soc. of Nat. Hist., Vol. 19, pp. 93-95.
[17]Iowa Geol. Surv., Vol. VIII.

4. *Spirifer pennatus* beds, shattered.
3. Barren beds, similar in lithological characters and physical condition to the *S. pennatus* beds.
2. *Gyroceras* beds, in displaced and tumbled fragments.
1. The true brecciated beds, composed in the main of small angular fragments mostly unfossiliferous, many of the fragments fine-grained and dark drab in color.

The Independence shales are now found to lie beneath this breccia and the Otis is not exposed.

A graphic description is given[18] of the chaotic breccia of the river's bed at Independence, and consideration of the cause of this brecciation is waived by a phrase—"the general destructive process, whatever it may have been, which reduced a large number of limestone layers to the brecciated condition." Calvin distinctly states, however, that above the "*Gyroceras* beds" "the phenomena of slickensides are indicative of the tremendous crushing and shearing strains to which the rocks of this horizon have been subjected."

In 1899 Norton[19] found all the members of the Wapsipinicon present in Scott county and described the brecciation of the Davenport limestones. He defended the theory of crush under lateral pressure as the only theory tenable. He found *Phillipsastrea billingsi* in the Upper Davenport beds and again drew the upper limit of the Wapsipinicon at their summit on the ground of the faunal change at that horizon as was emphasized by Barris, but adds "If it appears that the difference in the fauna has been exaggerated the upper limit of the Wapsipinicon may well be redrawn." This remark refers to Calvin's inclusion in the Wapsipinicon of the *Spirifer pennatus* beds, which in Scott county are found in shaly limestone above the Upper Davenport.

In the same year Udden[20] in his geology of Muscatine county states: "Of the members of the Wapsipinicon stage, the Fayette breccia is alone exposed in this county and that in only a few places. There appears to be no well defined line of demarcation between it and the Cedar Valley above. This may be due to a lack of good outcrops."

[18]Ibid, pp. 224, 225, 226.
[19]Geology of Scott County: Iowa Geol. Surv., Vol. IX.
[20]Udden, J. A., Iowa Geol. Surv., Vol. IX, p. 268.

Udden's description of the partly brecciated beds of the Wapsipinicon as fine-grained, compact, very pure limestone, and especially their stratigraphic place in the section seem to indicate the exact equivalency with the Lower Davenport of the county adjoining on the north. These partly brecciated beds are overlain by the *Phillipsastrea* beds. As described by Udden, the position, the lithological character, the thickness, and the presence of the coral mentioned, along with *Acervularia davidsoni,* agree entirely with the Upper Davenport of Scott county. *Spirifer pennatus* occurs toward the summit of the *Phillipsastrea* beds, while in Scott county it is found above the Upper Davenport, taking the *Phillipsastrea* horizon as a datum plane. Calvin in a footnote to Udden's general section states that the partly brecciated limestones beneath the *Phillipsastrea* beds are the stratigraphical equivalent of the *Spirifer pennatus* beds. It will be recalled that in Buchanan county Calvin found immediately beneath the *S. pennatus* beds barren beds similar to them in lithological character and physical condition.

In 1901, in the Geology of Cedar County[21] Norton transferred the Coggon from the Silurian and made it the basal member of the Wapsipinicon, on account of the fossils found in it at Cedar Valley and at other points. The position of the *Spirifer pennatus* beds was left uncertain, whether with the Upper Davenport or with the Cedar Valley.

In 1902 Calvin[22] described the lowest Devonian strata of Howard county as resting directly upon the Maquoketa shales and stated that they belong to the Upper Davenport, "below which, before reaching the base of the Devonian in Linn and Scott counties there are the divisions of the Wapsipinicon stage which have been described as the Lower Davenport, Independence, Otis and Coggon."

In 1905 Savage[23] divided the Wapsipinicon of Benton county into the Fayette and the Coggon. The Fayette brecciated beds include the *Spirifer pennatus* beds, the *Gyroceras* beds, and probably the Lower Davenport. It is stated that "the cause and

[21]Iowa Geol. Surv., Vol. XI.
[22]Calvin, S., Geol. of Howard County: Iowa Geol. Surv., Vol. XIII, p. 50.
[23]Savage, T. E., Geology of Benton County: Iowa Geol. Surv., Vol. XV.

the process by which these brecciated beds were formed are alike somewhat obscure." After quoting Norton's theory of crumpling under lateral pressure as given in the Scott county report, Savage adds: "The facts which are revealed in most of these beds in Benton county are in harmony with such a mode of rock fracture." He also suggests that "certain phases of the Lower Davenport breccia seem difficult of explanation by assuming crushing as the mode of formation, and seem to indicate a talus origin."

In the same year Savage[24] in his table of formations divides the Wapsipinicon of Fayette county into the Upper Davenport and the Lower Davenport. The basal member of the Devonian series in the county is also stated in the text to have close resemblances to the Otis limestone. "The *Spirifer pennatus* horizon cannot be perfectly differentiated from that of the *Gyroceras* beds which precede it" and the Cedar Valley stage is held to begin with undisturbed layers a short distance below the *Acervularia profunda* and *Newberria johannis* zone.

In 1906 Norton found in Bremer county breccia of the first and second zones. The lowest fossiliferous beds contain *Spirifer pennatus* as well as *Schizophoria macfarlanei* and *Gypidula comis*.

In 1912 Ekblaw[25] found that "the Rock Island county Devonian limestones are a continuation eastward of the Wapsipinicon and Cedar Valley stages of Iowa." He also discriminated the equivalents of the Lower and Upper Davenport divisions of the Wapsipinicon stage.

In resumé, all workers in the field since the earliest reconnaissances of Owen and Hall have recognized the lithological distinctness of the Wapsipinicon from the Cedar Valley, and its prevailing brecciation has been made by some a ground for demarcation. The fauna of the Wapsipinicon has been found distinctive in the subdivisions of the Otis and the Independence. It was long held that the fauna of the Upper Davenport was sufficiently individual to warrant its reference to the Upper Helderberg, a reference now universally abandoned. While the

[24]Savage, T. E., Geology of Fayette County: Iowa Geol. Surv., Vol. XV.
[25]Ekblaw, W. E., Correlation of the Devonian System of the Rock Island Region: Trans. Ill. Acad. Sci., 1912.

Wapsipinicon has been everywhere recognized as a stage of the Iowa Devonian, there has been less unanimity in the divisions of it into substages, and there is still doubt as to whether the upper limit of it should be drawn at the summit of the *Spirifer pennatus* beds, which by Calvin were included in the Upper Davenport, or at their base. The question is wholly one of paleontology, and while the data so far gathered do not appear to have been sufficient for its complete solution, enough is known to show that the difficulty lies in the fact that species held to be diagnostic do not appear at the same horizons or with the same associates in all parts of the field.

THE DIVISIONS OF THE WAPSIPINICON STAGE

The Wapsipinicon of Iowa has been subdivided on very simple and for the most part faunal lines. The Upper Davenport, the Independence and the Otis are demarked because of their distinctive fauna. With the uppermost of these formations are associated barren beds of calcilutites[25a] and other types of limestone. They directly underlie the Upper Davenport at all points of contact where the beds are seen in place, as at Davenport and Vinton. Their affinities are with it rather than with the argillaceous Independence underneath. Yet the extension in northeastern Iowa is so wide, their lithologic characters are so distinct from those of the beds above them and below that for convenience they have been given a name, the Lower Davenport, which expresses both their individuality and their close affinity with the beds above.

Thickness—The total thickness of these terranes comprises a very considerable part of the entire thickness of the Devonian of Iowa. The amazing estimate of Tiffany[26] of 390 feet for the "Upper Helderberg" at Davenport, based on artesian well sections was corrected by Norton[27] from the same data to 115 feet and from much fuller data Norton[28] later placed the base of

[25a] *Calcilutite*, a calcareous rock of lutaceous (Lat. *lutum*, mud) structure, composed of lime particles of mudlike fineness of grain. Lithographic limestone is an example. See Grabau, Principles of Stratigraphy, p. 285. New York, 1913.

[26] Tiffany, A. S., Am. Geol., Vol. 3, p. 117, 1889.

[27] Norton, W. H., Iowa Geol. Surv., Vol. III, p. 202, 1893.

[28] Norton, W. H., Underground Water Resources of Iowa: U. S. G. S., Water Supply Paper 293, p. 494.

the Devonian at Davenport at 475 feet above sea level, giving a thickness to the Wapsipinicon at this point of about one hundred feet.

At Kenwood the thickness of the Independence is about thirty feet. The Otis at Cedar Rapids reaches a thickness of fifty feet above water level in the river and incomplete well data indicate that it is about eighty feet lower before the dolomites of the Niagaran are reached. Half of this dimension may be occupied by the Bertram beds, hitherto referred to the Silurian, but whose position is more probably with the Devonian. In Linn county the total thickness of the Wapsipinicon including the Bertram beds may easily reach 150 feet.

In the quarries and railway cut north of Vinton a section of the Wapsipinicon extending from the barren beds of the *Spirifer pennatus* beds well down in the Otis measures about sixty feet. In the artesian well at Vinton, Niagaran dolomite was reached at 135 feet, and the curb of the well is somewhat below the *Spirifer pennatus* beds.

At Waterloo the city artesians reach the Niagaran dolomite at a depth of 158 feet. In city well No. 1 no samples were saved for a depth of seventy feet. From this down to the Niagaran dolomite the drillings include a number of Wapsipinicon types of rock such as brown calcilutite, brecciated limestone, mottled buff limestone, gray sandstone and limestone arenaceous with bits of flint. The well curb is somewhat below the base of the *Acervularia profunda* beds, which occur in the Waterloo quarries[29].

To the north the Wapsipinicon abruptly thins. The Niagaran emerges in southern Bremer county, and at Waverly the city artesian reached the Niagaran dolomite at a depth of seventy feet. The well curb here is at the horizon of the *Spirifer pennatus* beds.

At Fayette the entire thickness of the Wapsipinicon measures forty-seven feet from its base resting upon the Niagaran to the summit of the *Gypidula comis—Hypothyridina cuboides* (*Hypothyris intermedia*) ledge (p. 458).

[29]Arey. M. F., Geology of Black Hawk County: Iowa Geol. Surv., Vol. XVI, p. 421.

It is now necessary to describe the physical characteristics of the different terranes of the Wapsipinicon as they are exhibited in typical exposures where they are little disturbed. We shall thus be better prepared to identify the fragments of their beds in the chaotic breccia in which they elsewhere have been commingled.

The Bertram Beds

It has been seen that the lowest beds which can be assigned to the Devonian with certitude are the Otis limestones. Between the fossiliferous beds of the Coggon phase of the Otis and the uppermost Niagaran, and showing well defined contacts with each, are unfossiliferous magnesian limestones of so peculiar a character that they have been distinguished as the Bertram beds[30]. These beds were assigned to the Silurian along with the Coggon beds of the Otis, because of their dolomitic nature. Fossils found in the Coggon afterwards proved it to be simply the magnesian basal portion of the Otis. And while the true place of the Bertram beds must be uncertain until fossils are found in it or a distinct unconformity is seen above it or below, it is related to the Wapsipinicon in texture and in brecciation, and may now be provisionally classed with that formation. These beds occur, so far as known, only in Linn county and outcrop along the zone of contact between the Silurian and the Devonian. They extend from the town of Bertram up the valley of Big creek and appear again at various points in the valley of Indian creek to the west. Sections on the former creek show a thickness of nearly or quite fifty feet.

The limestone is commonly heavily bedded. Numerous sections record layers one, two and even five and eight feet in thickness. Courses are constant although rough surfaced. The dip of the beds is low, not exceeding four or five degrees. In color the rock resembles many beds of the Wapsipinicon limestones. It is a light drab, weathering to whitish. The rock is hard and breaks with an uneven fracture. In texture it again resembles the Wapsipinicon limestones in that it is a calcilu-

[30]Norton, W. H., Geology of Linn County: Iowa Geol. Surv., Vol. IV, pp. 135-138.

tite, made of impalpable calcareo-magnesian silt, and showing no traces of granular or crystalline structure.

The rock in places is finely laminated, the harder laminæ standing in relief on weathered surfaces. The laminæ undulate, thicken to low lenses or feather out. In this feature, again, it resembles the Cedar Rapids phase of the Otis. Vesicularity is not uncommon, and minute vesicles stained yellow by oxidation indicate lines of lamination in otherwise massive layers. Weathered surfaces are usually smooth, but in some cases are pitted and rough with fantastic slender projections in low relief. In the original description of the Bertram limestone there are given several sections showing the contact with both the Otis and the Niagaran which demonstrate the individuality of this terrane.

Chemical analyses show a not unusual amount of magnesium carbonate:

ANALYSES OF BERTRAM DOLOMITES

	BIG CREEK Per Cent	SPRINGVILLE Per Cent	INDIAN CREEK Per Cent	BERTRAM Per Cent
SiO_2	1.37	00.33	00.72	00.90
Fe_2O_3	00.58	00.56	00.60	00.90
CaO	30.77	30.99	30.66	31.11
MgO	20.61	21.05	21.03	20.36
CO_2	46.84	47.50	47.22	46.72
	100.17	100.43	100.23	99.99

The Otis Limestone

This formation takes its name from the railway junction of Otis, east of Cedar Rapids, where it is very typically displayed in both its magnesian and non-magnesian phases and where it is in immediate contact with the Independence. The former facies is termed for convenience the Cedar Rapids phase and the latter the Coggon. A facies somewhat distinct from either is found at Vinton. A fourth distinct type, a basal conglomerate resting upon the Silurian, is termed the Westfield phase.

THE COGGON PHASE OF THE OTIS

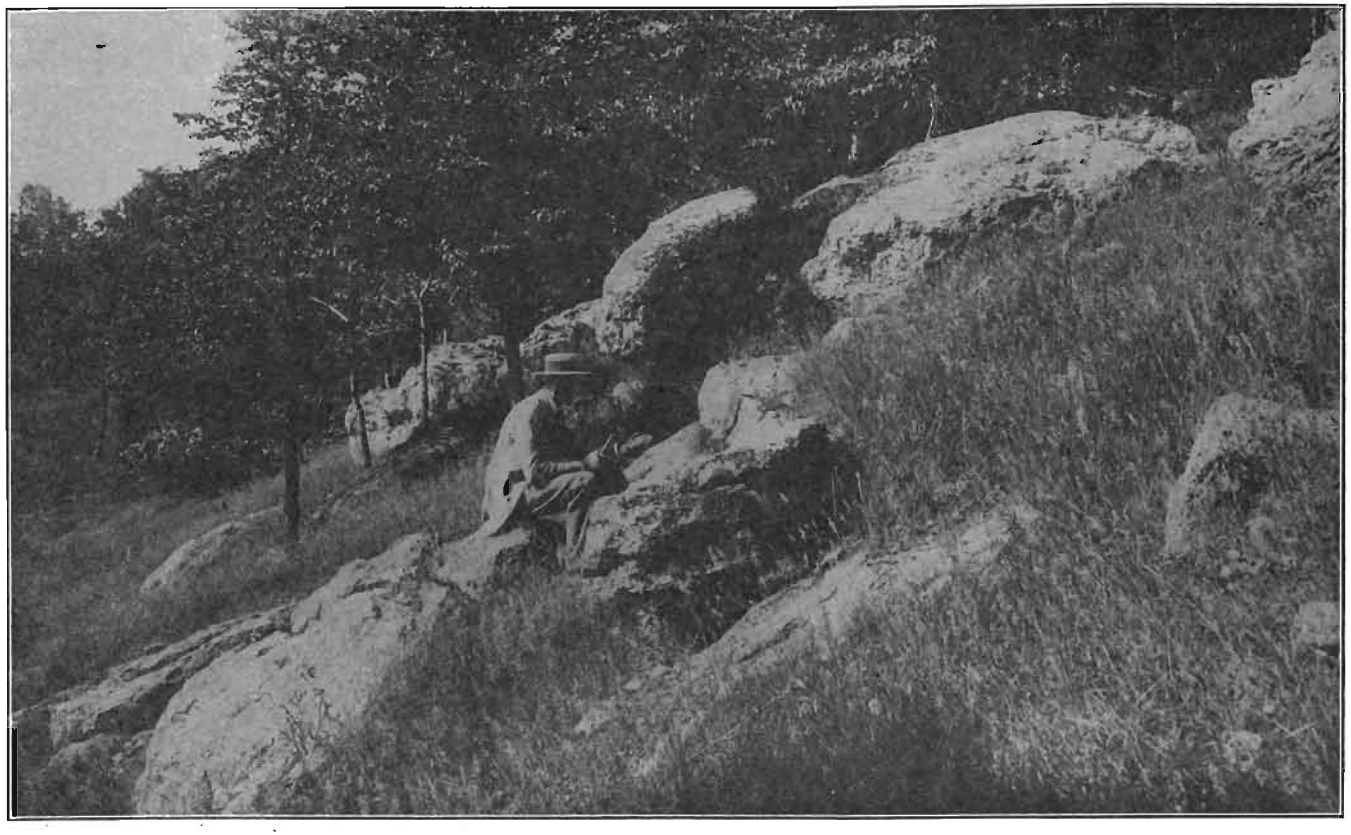
The type exposure of this bed of magnesian limestone is at Coggon, a town of northern Linn county, at the crossing of Buffalo river by the Illinois Central railway, where Ashby's quarry affords a section of it about fourteen feet thick (p. 496).

The Coggon facies is a soft magnesian limestone finely crystalline-granular, or in some places earthy, varying in color from light cream-yellow to rather dark buff. The rock is in many cases highly vesicular with dusty cavities and with moulds of fossils. In places it resembles the upper phase of the Otis in carrying dark flint nodules, which may unite to form narrow continuous bands. It is evenly and rather heavily bedded and with little or no lamination. Under the hammer it frequently emits a bituminous odor. No traces of brecciation or of shattering have been observed. The following analyses indicate the range in chemical composition:

BEALER'S QUARRY, CEDAR VALLEY		LIME CITY QUARRIES	
$CaCO_3$	58.2	$CaCO_3$	54.44
$MgCO_3$	39.5	$MgCO_3$	44.67
Fe_2O_3 and Al_2O_3	0.9	Fe, Al and Mn	00.84
SiO_2	1.2	SiO_2 and insoluble residue	00.13

The Coggon phase occurs in Scott and Cedar counties and in Linn in exposures on all the three rivers which traverse it. In Buchanan county the Devonian section does not reach its horizon and the same may be true in Benton county. In Bremer and Fayette counties this phase of the Otis is absent. In Linn county the Coggon phase rests in several interesting contacts upon the Bertram beds and in the northern part of the county upon the Hopkinton limestone of the Niagaran. In Cedar county the contact is with the Gower. Where the Coggon overlies the LeClaire beds of the Gower the contact is unconformable but no unconformity has been observed where the contact is with the Anamosa beds.

Fossils.—In Linn and Cedar counties *Spirifer subumbonus* is common and in some localities gregarious in the form of moulds and rarely of casts. At several localities the specimens are larger than those of the Cedar Rapids phase at the summit



Bowlders of weathering of Bertram limestone on Big creek, two and one-fourth miles north of Bertram, Linn county, showing massiveness of rock. All the rock is finely brecciated.

of the Otis. At the Cedar Valley quarries the Coggon phase contains *Spirifer subumbonus* in plentiful numbers. Here were collected several trilobite pygidia which were referred to Dr. John M. Clarke, who considered them to belong to "a species not far removed from *Dalmanites erina,* which occurs sparsely in the Onondaga limestone of both New York and Ohio. So far as the specimens indicate the species has little affinity to typical Silurian forms and its relation to the species cited indicates the Devonic."[31]

A cheek of a small *Proetus,* an unidentified *Conocardium* and a little spiral gastropod also were found here.

THE WESTFIELD PHASE

At Fayette, at the Westfield bridge, there rests upon the fossiliferous Niagaran about eight feet of magnesian limestone or dolomite in heavy beds distinguished by bands arenaceous with rounded grains of fine quartz sand and angular bits of white chert (p. 458). The same arenaceous bed is seen in Bremer county southeast of Waverly in similar relation to the Niagaran and fragments of it are included in breccia at Janesville of the same county (p. 472).

These beds have the essential relations of a basal conglomerate. In both Fayette and Bremer counties they are succeeded by nonmagnesian limestones of the Cedar Rapids phase of the Otis.

THE VINTON PHASE

The basal layers of the Otis exposed in the quarries north of Vinton along Cedar river probably are somewhat higher in the terrane than the Coggon phase. In all these quarries the stone is remarkably homogeneous. It is a buff finely laminated magnesian limestone lying in even and rather heavy horizontal beds.

Chemical analysis shows it to be somewhat less magnesian than the Coggon phase, and it effervesces promptly and briskly in cold dilute HCl (figure 45).

[31]Private letter to the author.

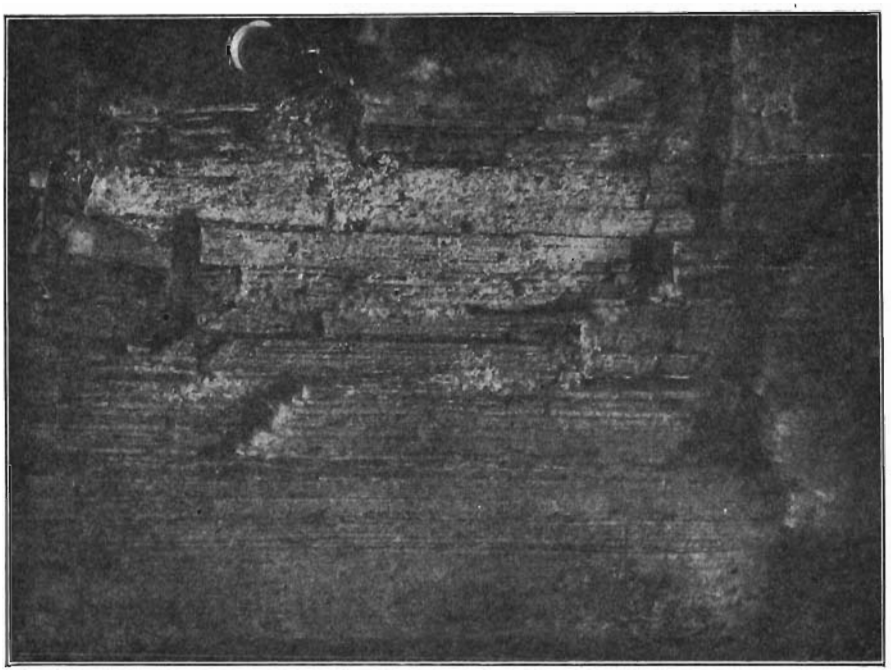


FIG. 45.—Laminated Otis magnesian beds in Kearn's quarry north of Vinton, Benton county.

ANALYSIS OF SAMPLE FROM DEGN'S QUARRY, VINTON.

Calcium carbonate	66.12
Magnesium carbonate	30.54
Silica	1.05
Iron	2.71

THE CEDAR RAPIDS PHASE

This phase includes the wide variety of lithologic types, usually but slightly magnesian, seen in the upper thirty feet of the Otis in the quarries at Cedar Rapids and at numerous other exposures at the summit of the terrane. A very common type is a hard brittle calcilutite of conchoidal irregular or splintery fracture, brown or drab in color, but weathering to lighter shades. Saccharoidal brown limestones, and some of pink and whitish color, are seen. Masses of brown crystalline rock which break with rhomboidal calcite cleavages are characteristic of this horizon.

A large part of the rock is laminated with coherent laminæ of alternating lighter and darker shades. Dark hair-line laminæ seen on vertical faces of the beds are the edges of brownish or blackish argillaceous films. In Fayette county the rock at this horizon weathers to thin ringing plates quite uniform in thickness. Here in places the brown film laminæ may be as close set as eighteen to the inch. At Cedar Rapids many of the layers thicken and thin irregularly, especially where lamination is absent. Many of the surfaces are rugose as if corroded and are covered with a blackish argillaceous and carbonaceous crust.

Flint, blackish in color, occurs in interlaminar lenticular small masses, and in mottlings which have a more or less marked vertical arrangement. Thus in a small quarry about one-half mile west of Otis black flint occurs in irregular columns and vertical leaves. Fantastic mottlings of flint and limestone also occur similar in their irregular outlines to those of the mottled brown and buff limestones also characteristic of the upper beds of the Otis of this phase.

Fossils.—In the Cedar Rapids phase *Spirifer subumbonus* is gregarious and the specimens are admirably preserved. Often the valves are found not only in unbroken condition, they are also undetached. This brachiopod ranges from Scott county through Cedar into northern Linn county along the Wapsipinicon, but to the north of this river it has not been observed.

A minute spiral foraminifer (?) is found at several localities: on Felton creek, Cedar Rapids, where it forms the entire upper layer of low dome-shaped masses immediately beneath the Independence (section B, p. 520); at Young's quarry on Indian creek, south of Marion (northwest quarter of the northwest quarter of section 12, township 83 north, range VII west); and in road cuttings in College township, Linn county, along the road leading southeast from Cedar Rapids.

CHEMICAL ANALYSES	I	II	III
$CaCO_3$	69.71	87.76	86.87
$MgCO_3$	26.16	5.66	10.02
SiO_2 and insoluble residue	0.85	.....	....
Organic matter	....	1.25	0.47
Fe, Mn and Al	1.75	....	....
Iron (Fe)	....	3.52	0.99
Silica (SiO_2)	....	2.18	1.99

I. Brown fossiliferous limestone, Otis.
II. Dark layers in Chicago & North Western Railway Quarry, Cedar Rapids.
III. Dark crystalline limestone, Ellis Park Quarry, Cedar Rapids.

LENTICULAR STRUCTURES

Especially in the uppermost beds, near or at the contact with the Independence shales, lenticular structures are characteristic of the Otis. At the Cedar Rapids outcrops these occur on a large scale, and some of them reach a horizontal diameter of nine or even twelve feet and a thickness of three to five feet. The quarrymen know this stratum as "the bowlder bed" and the lenses much resemble great elliptical bowlders of weathering both in their rounded form and in their corroded surfaces. In these quarries, which are worked only for crushed stone, the lenses are difficult to deal with. Dynamite exploded in drill holes reaching nearly to the level of the quarry floor throws down the quarry face from top to bottom, and shatters the strati-

FIG. 46.—A lens eight feet long in the upper beds of the Otis limestone, Ellis Park quarry, Cedar Rapids, Linn county.

FIG. 47.—A lens in the upper beds of the Otis limestone, split vertically. Ellis Park quarry, Cedar Rapids, Linn county.

fied rock into fragments ready for the crusher or easily broken up by "dobying," i. e. by exploding dynamite upon the surface of the rock beneath a cap of wet clay. But the bowlder-like lenses are thrown down intact and can be broken up only by the use of explosives in drilled holes.

Composition.—The lenses are generally composed in the greater part of massive brown macrocrystalline rock which may be shot through with rhombic calcite cleavages. In many cases the stone is mottled. A brown crystalline rock may be mottled especially toward the top with buff earthy limestone of fine grain. In one instance the foreign material is blackish and earthy. The mottled areas as a rule present irregularly curved and interlocking boundary surfaces, but in some instances the rock appears fragmental and the different colored areas are bounded by straight lines. In some instances the darker body rock is a drab

calcilutite, carrying *Spirifer subumbonus,* while the lighter mottlings are of an earthy gray softer limestone.

Structure.—The lenses are commonly massive, but occasionally structure lines appear. A horizontal parting may pass through the center of the lens, while convex lines appear above, and concave lines below, parallel with the surfaces of the lens.

The Overlying Beds.—In some cases these arch over the lens, but in others at the sides they feather out up the slope or overlap. In some instances they bend down steeply—in one case at 55°—to the base of the lens where they abruptly become horizontal. These layers are seamed in places with radial cracks filled with calcite and in one instance are brecciated at the base.

The Underlying Beds.—The layers immediately beneath the larger lenses bend down parallel with the under surfaces, but thin somewhat toward the center of the synclines. Again, they "underlap"; the curving surface of the lens cutting the layers farther and farther back from the base of the lens upwards. Smaller lenses in places rest on layers which are themselves thin lenticular masses and which feather out in a distance of ten feet or less. At Ellis Park quarry, Cedar Rapids, a number of the lenses rest on massive drab calcilutite whose upper surface follows their basal curves but which within a few inches merges beneath into laminated rock whose laminæ are horizontal or slightly undulating. This calcilutite, like the lens rock, carries *Spirifer subumbonus.*

The upper surface of a lens, like the surfaces of many layers of the Otis at this horizon, is rugose and covered with films or thin selvages of black unctuous clay. In one lens at the Ellis Park quarry which occurs where the rocks have apparently broken down, the upper inch or so consists of a selvage of close-set perpendicular calcite crystals. The lower surface is in places stylolitic and blackish films of clay part it from the layer underneath.

Origin.—The characteristics just mentioned disfavor various theories of origin which might be considered, such as buckling produced by lateral pressure, and local accretion by wave heap, or the growth of colonial organisms. On the other hand, a con-

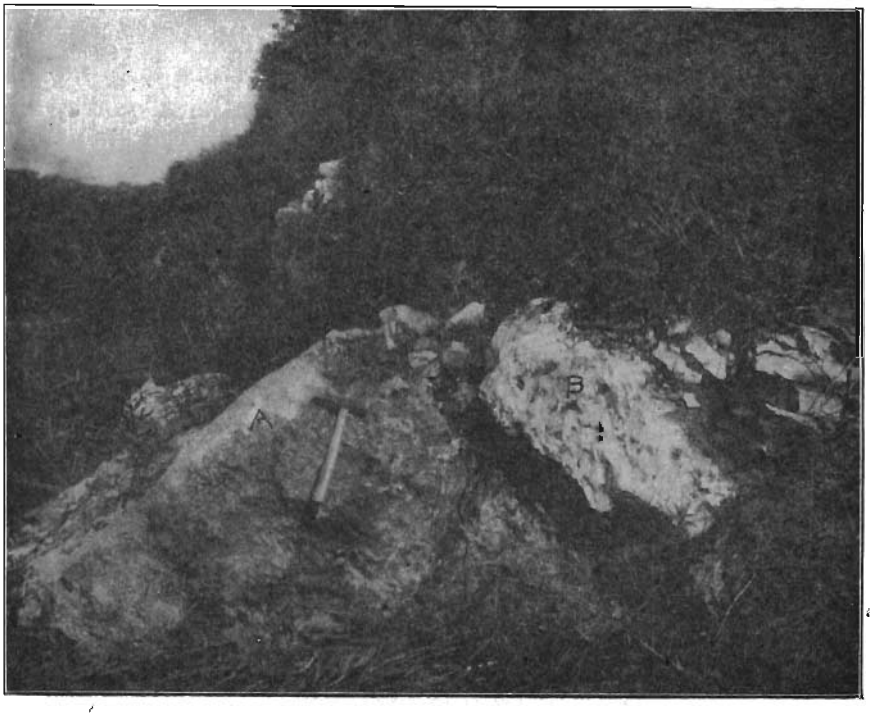


FIG. 48.—A lens in the upper layer of the Otis limestone in the quarry of the Chicago and North Western Railway Company at Cedar Rapids, Linn county. A, dark brown macrocrystalline massive limestone. B, Calcite.

cretionary origin is favored by the lenticular shape of these rock bodies, by their crystalline structure, by the dome and cup arrangement of the inclosing layers. Displacement or more probably the growth of the mass, produces underlap and overlap of the abutting layers, and the lateral thrust of the mass gives them steep slopes, and crackles and brecciates them. The entire terrane, however, has suffered slight deformation and in this way the dip of beds abutting on the unyielding lens would be accentuated. In the case of a lens in the Chicago and North Western Railway quarry at Cedar Rapids, the overarching beds seem to have buckled on one side leaving a cavity a foot in radial thickness filled now with white calcite and separated from the brown lens rock by a black clayey selvage (figures 48 and 49). Radial pressure exerted by the growing lens is seen also in the stylolitic structures mentioned.

MOTTLED LIMESTONES

At or near the upper surface the Otis limestone is in numerous instances fantastically mottled. At Snouffer's quarry the upper two feet of the lenticular layer shows light buff earthy areas within the dark brown saccharoidal limestone, which have a marked vertical arrangement (figure 50). The areas of differently colored rock meet on irregularly and minutely curved surfaces. In places small imbedded fragments of the buff rock are bounded by straight lines. The buff areas are at some places replaced by gray rock, but both buff and gray are like a soft argillaceous limestone or calcareous shale, and effervesce briskly in cold dilute HCl, like the brown saccharoidal rock which forms the mass of the stratum. Occasionally the gray rock is granular-crystalline.

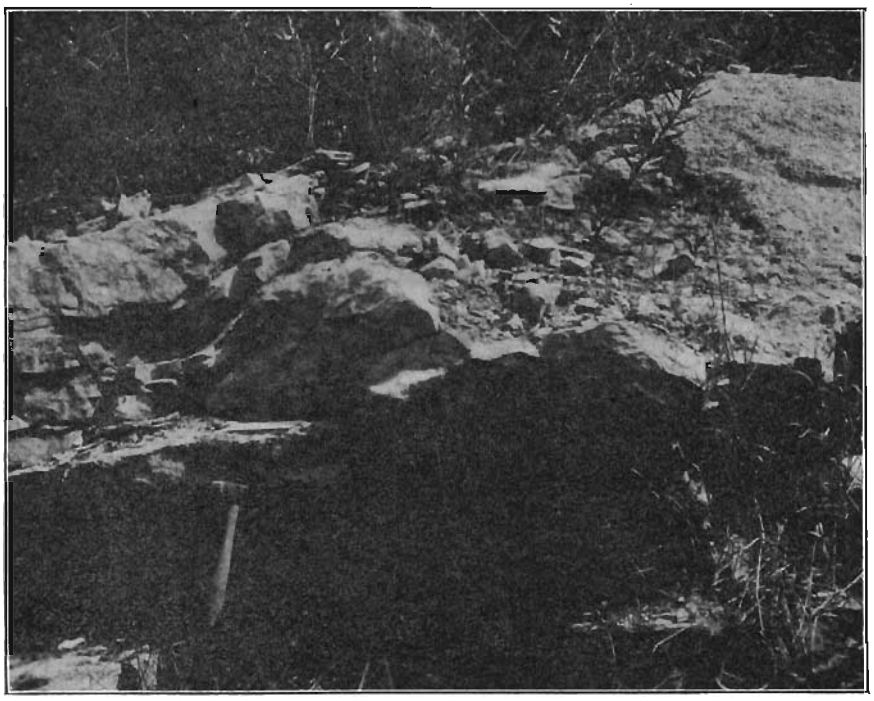


FIG. 49.—Lens in upper layers of Otis limestone in the quarry of the Chicago and North Western Railway Company at Cedar Rapids, Linn county. The layer immediately above the hammer is lenticular and feathers out to the right. The mound to the right is the lens, A, of figure 48.

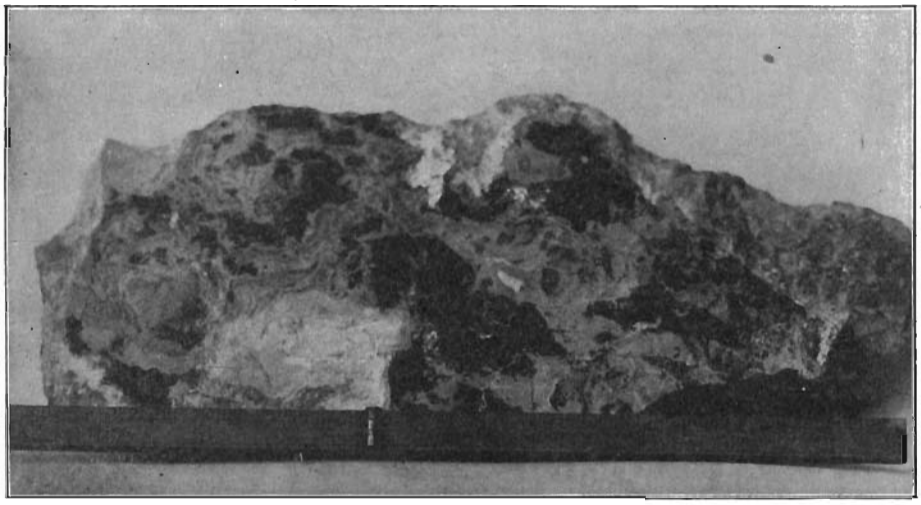


FIG. 50.—Vertically mottled limestone (polished). Upper bed of Otis limestone in Snouffer's quarry, Cedar Rapids, Linn county.

At the cut of the Chicago, Rock Island and Pacific Railway about two miles southeast of Cedar Rapids, the mottlings of the Otis at precisely the same horizon resemble buff stains on the weathered edges of the beds left by a trickling liquid. Weathering has etched out exceedingly fine lines of lamination in the earthy buff limestone. These lines are commonly concave and are crumpled slightly where they abut on the vertical edges where they meet the brown saccharoidal rock. The buff earthy rock at one point appears as an irregular band an inch and more wide inclined at an angle of 30° above a parallel parting in the lens in which it is included. The band is finely laminated and the undulating laminæ run parallel with the edges of the band. In places laminæ of the brown crystalline rock are inclosed in the laminæ of the buff earthy rock.

The same contemporaneous deposition of the two sorts of rock is seen at the quarries of the Chicago and North Western Railway where a lamina of the buff earthy type is embedded in the brown macrocrystalline rock near the top of a lens.

GEOGRAPHIC CONDITIONS OF DEPOSIT OF THE OTIS LIMESTONE

The Otis is a zone of transition in several respects. Within its limits a change was effected from heavily magnesian limestone resembling those of the Silurian to limestone almost or quite as free from carbonate of magnesia as are the limestones now in process of formation in coral seas. The even layers and homogeneous rock of the Coggon phase record quiet waters and undisturbed sedimentation, while the irregular beds of the Cedar Rapids phase present a picture of shallowing seas and shifting currents. A change also is in process ushering in the argillaceous sedimentation of the Independence. Clayey partings accumulate in the hollows of the irregular beds of limestone. Carbonaceous material also is present, contributed by decaying plants, we may assume, and in the approaching Independence conditions growing still more favorable will permit the formation of thin seams of coal. Reefs formed of minute foraminiferal (?) organisms approach the surface. Calcareous mud is thrown down in large quantities forming heavy beds. It is not improbable that considerable parts of the upper Otis limestones were precipitated as chemical deposits and that calcareous oozes on the floor of lagoons were saturated with sea water in which calcium carbonate was greatly concentrated. As a result intercrystallization went on. In massive limestones calcite crystals developed their characteristic surfaces and cleavages throughout the rock. And just as calcite crystals developing in sandstone do not extrude the sand, so here the forming calcite leaves all impurities within the crystalline mass. The sea water saturated with calcium carbonate acted also within the upper beds of the Otis as ground water similarly saturated often acts—it produced huge concretionary lenses.

The mottlings which affect the bed immediately beneath the Independence might be referred to irregular extrusion of clayey matter by growing calcite crystals but this does not seem here to be a convincing explanation. As we have seen, the more argillaceous material is in some cases deposited as laminæ imbedded in the more calcareous, and as fill in rude tubules traversing the more calcareous material vertically. As the Otis

closed clayey sediments evidently were washed in over these areas in increasing quantity and mingled with the uppermost limy oozes of the Otis. The vertical arrangement of the more clayey sediments would be explained if the limy ooze were laid about the vertical stems of aquatic vegetation. On incomplete solidification moulds of these stems would be formed and the irregular tubes left by their decay would be filled by the clayey sediments now invading the area. In settling these fillings would give the concave tabulæ-like laminæ sometimes seen. The rugose corroded surfaces of the beds common at this horizon confirm the inference of shallowing lagoons.

The Independence

Fossiliferous shale.—The discovery of the Independence is thus related by Calvin:[82] "A dark shale had been exposed in working out the layers in the bottom of one of the limestone quarries near Independence. The quarrymen penetrated the shale to a considerable depth in the hope of finding coal. The shale varies somewhat lithologically, but where it presents its most characteristic features it is argillaceous, fine-grained, and highly charged with bituminous matter."

Devonian black shale and coal were reached somewhat earlier in Linn county at the same horizon apparently, in a well sunk near the village of Lafayette. In the summer of 1877 a miner's shaft was put down through four feet of soil and eighty-one feet of rock. The coal seam when reached was found to be a quarter of an inch thick and the work was abandoned after the expenditure of several thousand dollars. The waste heap about the shaft yielded specimens of brecciated limestone and the horizon of the coal and shale—which can not possibly be that of the Carboniferous outliers found in the county—is clearly that of the Independence, although no traces of gray fossiliferous shale were found about the shaft.

The Independence was reached at some date earlier than 1893 in a well sunk west of Walker (northeast quarter of the southeast quarter of section 8, township 86 north, range VII west).

[82]On some Dark Shale Recently Discovered at Independence: Bull. U. S. Geol. Surv., Vol. 4, No. 3, p. 725, Washington, 1878.

A blue shale was pierced at a depth of about one hundred feet, and the sand pump brought up a characteristic fossil of the Independence, *Douvillina arcuata*. Crystals of pyrite were attached to the shell and it was filled with soft blue clay when submitted to the writer.

The first natural outcrop of the fossiliferous Independence to be found lies in the midst of the brecciated beds displayed in the old cut of the Chicago, Milwaukee and St. Paul Railway west of Linn, a junction station four miles north of Cedar Rapids. The shale was brought to light some years after the cut was made by a mud flow which occurred in a short steep narrow ravine leading down to the tracks in the north cut toward the upper end (Plate V). The flow consisted of gray plastic shale and carried abundant fossils (*Douvillina variabilis, Stropheodonta quadrata* and *Rhynchonella ambigua*) of the same species as those collected at the type locality of the formation—the shaft put down for coal at Independence. The shale here lies immediately beneath the drift at a height about equal to that of the summit of the breccia on either side of the ravine along the cut. The presence of the shale at this level seems due to an anticlinal structure in the breccia which brings it to the summit of the section. The weakness of the shale allows the formation of the gully which no doubt from time to time has been enlarged by similar mud flows toward the river. The slide is now overgrown with grass and brush wood.

The most important outcrops of the fossiliferous Independence are found near Brandon in Buchanan and Benton counties. They were discovered by Mr. Merrill A. Stainbrook, a student in the State University of Iowa, and reported to Professor A. O. Thomas. Exposure No. 1, the first to be discovered, was visited by Thomas and at his request later by the writer. Exposures No. 2 and 3 were studied by Thomas and Norton together and the following descriptions of them are based on the joint observation and accordant opinion of both. Thomas describes Exposure No. 1 as follows:[33]

"The shale occurs in a sharp bend or reentrant on the right bank of the creek in the northwest quarter of section 26 about a mile

[33]The Independence Shale near Brandon, Iowa: Ia. Acad. of Science, Vol. XXVI, 1919.

Mud flow of Independence shale, Linn section, Linn county. A wall built to confine it is now overflowed.

northeast of the town of Brandon. Undercutting by the stream at this point has exposed from one to six feet of the shale for a distance of fifty to sixty feet. By digging back the sod at the top of the shale it was found to extend about five feet higher up the bank, making a total thickness above the water of at least eleven feet. The immediate bank of the stream at this point is about twenty feet high, while back from this the surface rises gradually to a height of about sixty feet. The outcrop is flanked by exposures of limestones; on the downstream side the shale and limestone are separated by about three feet of weathered shale and blocks and fragments of limestone. For some twenty yards below this point the limestone is arched up into a low anticline and is considerably broken and jointed. This limestone contains Cedar Valley fossils characteristic of the lower part of that terrane. On the upstream side for a short distance the bank of the stream is low and quite sodded over. Still farther upstream the low limestone ledges are more weathered than in the anticline below and contain Cedar Valley fossils similar to those found back of the cemetery a half mile or more down stream.

The shale is dark bluish, plastic, and weathers yellow with reddish streaks. It shows no bedding, but there are small blocks which show faint lamination and in some cases smoothed and slickensided faces. Irregular blocks of harder, tougher and more calcareous shale occur and there are also small nodules of pyrite and angular blocks of hard limestone. Fossils are fairly abundant and typical; to some of them cling crystals of pyrite as is the case with the fossils collected by Calvin and Deering at Independence. In the bend of the little stream and almost in contact with the shale is a large block of Lower Davenport limestone showing the brecciation and other unmistakable features of that formation. The block is angular, is three by five feet in dimensions, and is larger than any handled by the stream in flood. No exposures of the Lower Davenport are known either up or down the valley. We must conclude that the block is intimately associated with the shale and is of the same derivation as the smaller limestone pieces incorporated in the shale."

Exposure No. 2.—This outcrop is located a few rods down valley from Exposure No. 1, on the left bank of Lime creek,

near the south line of the northwest quarter of section 26. Here the low limestone ledge which rises from the edge of the water is interrupted by a grassy bank for a distance of about four rods. At several points within this distance exposures of the shale occur near the level of the creek, but all are obscure and unimportant except one at the north end, where a short little gully is used as a cattle track to the water. This outcrop is six or seven feet high, and somewhat more in breadth, extends from water level to about the height of the limestone ledge adjacent, and both shale and limestone are overlain by drift. The shale carries the characteristic fossils of the Independence. It is a stiff gray plastic clay without stratification and is distinctly brecciated. Among the fragments is an angular block a foot in diameter of a harder, more calcareous, unfossiliferous stratified yellow shale. There are also fairly numerous included fragments of limestone, sharply angular and set at any angle, some soft, buff and argillaceous, some hard, light reddish brown, fine-grained, marked with wavy coherent laminæ of one millimeter and less in thickness and of the facies seen in the Otis beds at Cedar Rapids, and at other localities. The general appearance of this exposure is that of the shaly breccia in the quarries up valley from the railway cut north of Vinton, (page 489) but in these quarries the shale is unfossiliferous. The Vinton brecciated shale lies immediately upon the magnesian lower beds of the Otis limestone and its fragments are largely those of the Otis calcilutites which normally lie above the magnesian beds. The shale of exposure No. 2 at Brandon also carries fragments apparently derived from the upper Otis. but the shale here occurs at the horizon of the Cedar Valley limestones, which close in upon it in flat-lying beds on either side. The limestone ledge descends sharply toward the shale and the surface of the slope is covered with four to six inches of dark brown and blackish plastic clay. The shale and limestone are separated by an interval of about three feet—a cattle track, and it was not determined whether the dark brown clay just mentioned is selvage, geest, or weathered shale. The limestone wall against which the shale presumably lies trends northwest along the few feet exposed and makes an acute angle with the bank of the creek.

As in the case of exposure No. 1 the shale comes down to the water's edge and is not seen to rest on any limestone floor. But at the north end, some twelve feet in front of the main outcrop the limestone of the north wall forms the bed of the creek.

A short distance up valley from exposure No. 1, occurs a shale on the right bank north of the bridge, on the south line of section 26, similar in its lithologic facies, but destitute of fossils. Here the limestone wall of the creek is interrupted for about three rods, and at one point about seven feet above the water and at the level of the upper beds of the limestone there is exposed one or two feet of plastic gray clay. The upper contiguous layers of limestone carry the coarse-ribbed *Atrypa reticularis* of bed No. 4 of Savage's general section of the Cedar Valley while the lower layers are of rough surfaced limestone with many joints of crinoid stems. The limestone here dips from 5° to 8° south. The shale thus lies in a cavity of some sort in the limestone. The sides of the cavity incline valley-wise downward and inward, but no floor of rock in place is found to prove that the cavity is not a pipe through which the shale has been pressed upward.

An interesting outcrop showing the deformation to which the rocks of this area have been subjected is found south of the bridge above mentioned on the west bank of the creek. The spur scarped by the creek and a tributary ravine shows on the north side buff Cedar Valley limestone, with the large *Orthis impressa* and coarse-ribbed *Atrypa,* extending down creek for twenty yards. Here it gives place seventeen feet above the stream to a light drab calcilutite in large crackled blocks. The actual contact is not seen, but the Cedar Valley limestone adjacent is broken into blocks four to five feet in diameter tilted toward the contact plane. The calcilutite ledges show massive layers a foot thick and also in places thin calcareous plates. No rock appears between the calcilutite and the creek. Down stream the calcilutite gives place to the buff Cedar Valley limestone dipping south-southwest at about 10°, at bottom a coral reef with huge heads of *Favosites* and *Acervularia davidsoni.* The calcilutite appears to be the equivalent of that seen on the summit of the hill to the south. Here ledges of crackled calcilu-

tite aggregating about eight feet in thickness are exposed about thirty-five feet above the outcrop of the Independence shale, exposure No. 1, which occurs at the base of the hill and some rods to the east.

Exposure No. 3.—This outcrop, two miles south and nearly one mile west of Brandon, on the left bank of Cedar river, is in Benton county near the northwest corner of section 9, township 86 north, range X west. Here almost from the water's edge rises a perpendicular cliff of Cedar Valley limestone fifty feet high, whose various fossiliferous horizons are described in detail by Savage.[34] About four rods from its north end this cliff is cut by a shallow reëntrant at whose base occurs the outcrop of the fossiliferous Independence shale. The exposed thickness of the shale is about four feet and it lies some six feet above the river, from which it is parted by a narrow beach and talus of large limestone blocks. No rock is seen in place either beneath the shale or above it.

The entrance to the recess is about thirty feet wide. On either side the rock walls, determined by joint planes, rise almost vertical, while the strata lie horizontal and undisturbed. The recess widens within by lateral sapping. From the entrance a talus slope climbs steeply up to the summit of the cliff, where for a few feet the continuity of the strata is concealed or perhaps interrupted. A slight convexity in the shore line opposite the entrance is due evidently to a larger accumulation of talus at this point.

The basal section of the cliff is described by Savage[35] as follows: "1. Bed of light-gray limestone, somewhat shattered and brecciated, containing the following fossils, *Stropheodonta demissa, Orthis iowensis, Atrypa reticularis, A. aspera* var. *occidentalis, Spirifer pennatus,* and a species of Gomphoceras; exposed to the water's edge three feet." Savage further states that the above bed "represents the gray brecciated limestone near the upper part of the *Spirifer pennatus* beds" and notes the absence of *Gypidula comis* which is characteristic of this zone. This bed of somewhat shattered and brecciated rocks

[34]Geology of Benton County: Iowa Geol. Surv., Vol. XV, pp. 180-184.
[35]Ibid, p. 181.

rises gently—at one point rather sharply—toward the north. At the north end the cliff ends abruptly in an overhanging joint face, a slickensided normal fault of small throw. At the base the fault is bounded on the north, the upthrow side, by a mass of limestone twelve feet long along a line parallel with the fault, whose thin layers dip 60° S. 20° W. toward the fault plane. This limestone, mottled buff and drab, earthy-crystalline in structure and with some layers dark drab and macrocrystalline, is of a facies to be found both in the Otis and in the argillaceous limestones which lie above it. Upstream from this fault no cliffs occur but as far as the ravine south of Long's quarry brecciated rock masses outcrop on the hillside from water level to a height of about twenty-five feet. Some of the fragments are several feet in diameter and they are set at all angles. Some are gray crackled massive calcilutites, some are calcilutites of fine lamination, some are fossiliferous gray and buff limestones containing *Spirifer parryanus*.

Stratigraphic position and equivalency of the fossiliferous Independence Shales.—The meagre outcrops of the fossiliferous Independence shale now accessible do not make entirely certain its true place in the column of the Devonian rocks of Iowa. At none of these outcrops is the shale either covered or seen to be underlain by Devonian rock. No formation except the drift is found above it, and no section cuts below its base. Such conditions permit us to consider several hypotheses.

1. The close alliance of the fauna of the Independence with that of the Lime creek shales suggests that the two may be identical and that the exposures of the fossiliferous Independence are in reality sections of the Lime Creek shales where they fill unconformably old erosion channels cut in the earlier Devonian terranes. Thus they may be paralleled by the unconformities of the State Quarry beds and the Sweetland Creek shale. But recent more thorough studies of the faunas of the Lime Creek and the Independence show that they are not the same. It is pointed out by Thomas[36] that "The fossils of the Independence when they are critically studied are quite distinct from those of the Lime Creek." After mentioning several "striking ab-

[36]The Independence Shale near Brandon, Iowa: Iowa Acad. Sci., Vol. XXVI, 1919.

sences and differences'' Thomas concludes, ''the instances cited are sufficient to confirm the usual opinion that the Lime Creek fauna is a greatly expanded and recurrent descendant of the Independence.''

2. We may also entertain the hypothesis that the fossiliferous Independence is unconformable with the Wapsipinicon and Cedar Valley limestones but represents a formation, distinct from the Lime Creek shales, nowhere found conformably in place in the Iowa section. No special objection to this hypothesis inheres in the fact that it is found only at its unconformities, for this is true also of the Sweetland Creek and State Quarry formations. If the contacts of the fossiliferous Independence are true unconformities this hypothesis must be accepted. But if the contacts can be otherwise explained there is left no evidence in its support.

3. The contacts of the fossiliferous Independence with the Wapsipinicon and Cedar Valley limestones may be explained by deformation. On this hypothesis the horizon of the Independence is to be looked for below and not above the beds with which it is in contact. Under the stresses which have caused extensive brecciation over the area of outcrop of the Wapsipinicon the plastic fossiliferous shales have been squeezed up into the midst of higher Devonian terranes.

An interesting parallel is to be found in the breccias on Mackinac Island where the red and green shales, which in general lie somewhat below lake level, forming in places the wave-cut rock bench, are not only upwarped under anticlines of the Monroe limestone, but are also squeezed up in amorphous masses into the midst of the breccia into which that limestone has been so thoroughly broken.

It will be noted that at each of the exposures of the fossiliferous Independence shales brecciation or deformation is strongly in evidence. At the Linn Junction section (p. 388) the shale is fossiliferous and lies in the midst of a breccia in which blocks of the Upper Davenport predominate. While the outcrop shows nothing inconsistent with the theory that the shales occupy unconformably an erosion valley cut in the breccia, on the other hand it shows nothing opposed to the theory that under

the severe stresses to which the terranes have been subjected the shale has been thrust up amid the fragments of broken limestone beds which normally overlie it.

In the vicinity of Brandon Calvin noted "the unusual peculiarities" of the Devonian beds. Speaking of the ledges along Lime creek south of the town he says:[37] "The beds are folded, buckled, and displaced on a scale sufficient to produce a complex series of alternations of lithological and paleontological characters at the same level along the hillside. At one point, for example, there are beds carrying *Spirifer pennatus*. At the same level a few yards away there is a portion of the coral reef with *Acervularia, Ptychophyllum, Favosites,* and other characteristic corals. Farther on are yellow shales corresponding to No. 8 of the Littleton section and carrying the coarse ribbed *Atrypa* and other fossils which everywhere distinguish this horizon. Some of the displacement may be due to faulting on a small scale, but the residual material resulting from extensive weathering conceals the beds over most of the hillside."

The above description applies in every detail to the course of Lime creek northeast of Brandon along which are the exposures of the fossiliferous Independence. In addition the crackled calcilutite found about fifty feet above the creek at exposure No. 1 of the shale, is seen at about the level of the upper part of the shale a few rods upstream and is within a short distance replaced horizontally by the yellow beds of the Littleton section No. 8. The shale of exposure No. 1 abuts at the south upon an anticline of Cedar Valley limestone broken at the crest and with a dip of 10° and 15° upon the limbs. The shale at this point is also itself brecciated. No foreign material is found in it, but scattered everywhere through it are angular blocks and fragments of harder shale set at all angles, and the mass nowhere shows any trace of bedding planes. At this point the stream has eaten back so far into the exposure that it is quite improbable that this brecciated structure is due to slump.

At exposure No. 2 the abutting limestones lie horizontal and show no evidence of deformation. The shale, however, is here not only brecciated; it also includes sharply angular fragments

[37]Geology of Buchanan County: Iowa Geol. Surv., Vol. VIII, p. 238.

of hard limestone of Otis types. The hypothesis that the shales are a late Devonian undisturbed deposit in a channel cut by erosion in the Cedar Valley limestone is thus precluded. Nor is it easy to conceive that the brecciation of the shale is due to stresses which affected it after its deposition unconformably in its present relations.

At exposure No. 3 the walls of the recess at whose base the shale occurs show little or no trace of disturbance. Yet, as we have seen, the basal bed of limestone contiguous to the shale is brecciated and shattered to some degree, and a few yards to the north a slickensided fault occurs, beyond which the brecciated masses rise to about twenty-five feet above the river.

In these exposures where the shale is covered only by the drift or by residual soils, or lies at the bottom of a deep recess or chasm in a cliff, it may well be that the shale is largely responsible for the gully, valley, or recess in which it now occurs. A mass of plastic clay upthrust into the midst of limestone beds makes a point of weakness whenever the terrane is cut through by stream erosion. It forms a yielding foundation to the limestones which rest upon it. Thus by sapping, a gully or ravine on the hillside, or a chasm on a cliff, develops, at whose base the shale may fortunately be found, or far more probably will be covered from sight by rock-debris. In considering the position of the fossiliferous Independence shale the testimony relating to its original discovery at the type locality must carry great weight. True, the initial artificial sections are no longer accessible, but the statements of Calvin and others show with hardly a possibility of doubt that the fossiliferous shales at Independence were found by excavating through the fossiliferous limestones now seen at the base of the Independence quarries. If this is the case, the place of the shale is indisputably below the *Gyroceras* beds (Upper Davenport limestone). A shaft sunk at random through drift on a hillside might encounter a pipe filled by squeeze from below, or an erosion valley filled by deposit from above, but the limestone of a quarry floor furnishes a certain datum for an excavation made beneath it.

The first statement on this point by Calvin is as follows:[38] "A dark shale had been exposed in working out the layers in the bottom of one of the limestone quarries near Independence."

In an article on the Geology of Linn county published in the Cedar Rapids Republican under date of Feb. 21, 1880, Norton, who had visited the locality and collected fossils about the mouth of the shaft, gives the "section of the exposure in Kilduff's quarry where the shales were discovered." This section is stated to have been furnished by Mr. Kilduff.

	FEET
"Fossiliferous Hamilton limestone	20
Black fissile bituminous shale	12
Gray fossiliferous shale	4
Hard gray rock with pyrite	2"

In 1891 Calvin stated: "About a mile east of Independence the Gyroceras beds may be seen resting on the Independence shale. In the old Kilduff quarry northeast of the city, where the shales were explored for coal, the Gyroceras beds were penetrated and 'petrified snakes' attracted much attention."[39] In his report on the geology of Buchanan county Calvin[40] mentions "shafts sunk at the old Kilduff quarry, now owned by Thos. O'Toole," and again "It was in an abandoned pit a few rods west of the O'Toole quarry that the first shaft which brought to light the Independence shales of this locality was put down." It was no doubt on the basis of the facts set forth in these statements that Calvin in the report just cited placed the Independence shales below the *Gyroceras* beds and the brecciated limestones termed by Norton the Lower Davenport. The explanation of the fact that so few occurrences of fossiliferous Independence shales have been discovered lies in part in the weakness of the terrane. The shales soon become graded by the weather to slopes covered with soil and mantled with vegetation. The only natural outcrop, except those discovered near Brandon in 1917 by Thomas, is due to a mud flow in an artificial cut. But it is extremely probable that in the Independence fossiliferous tracts are rare, and that for the most part conditions were not favorable for the colonization of the sea floor or the preservation of animal and plant remains.

[38]Bull. U. S. Geol. and Geog. Surv., Vol. IV, No. 3, p. 725, 1878.
[39]Am. Geologist, Vol. 8, p. 143.
[40]Geol. Surv., Vol. VII, p. 222.

Unfossiliferous shales.—Much of the Independence consists of impure limestones, but true shales are also found widely distributed. A thin seam of black carbonaceous shale is noted in Cedar county (p. 537). In Linn county bluish or buff clayey shale, fissile or showing spheroidal weathering, occurs, especially near the base of the formation in sharp contrast with the Otis limestone. Typical sections will be found on pages 497, 513 and

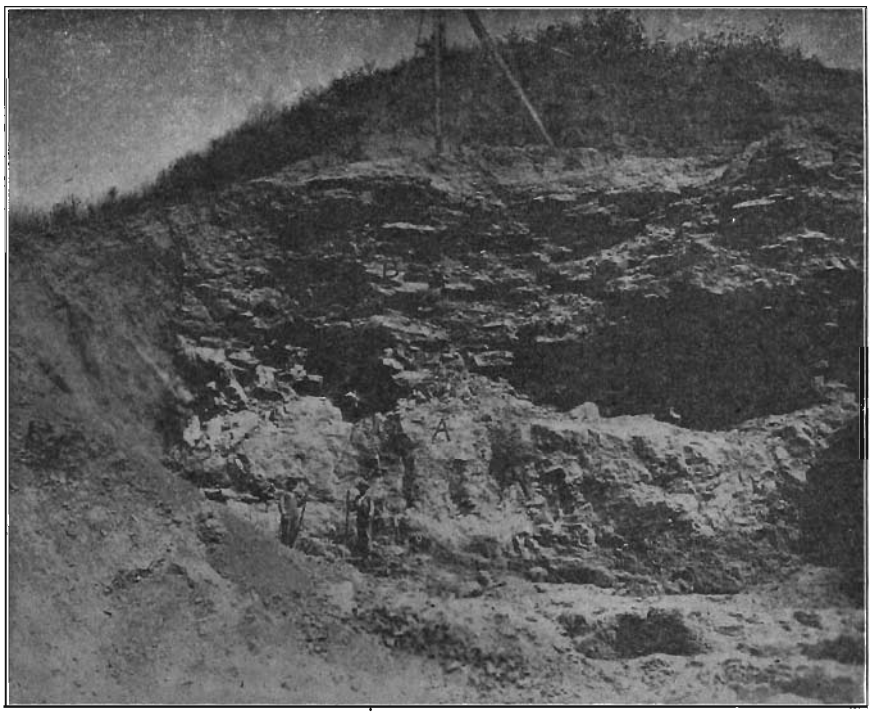


FIG. 51.—Snouffer's quarry, Cedar Rapids, Linn county. A, Otis massive upper beds. B, Independence shales. C, till. D, loess.

529. In other counties as to a large extent in Linn county the more argillaceous beds of the terrane are involved in breccia (figure 51 and Plate VI).

Impure limestones.—A large part of the formation consists of impure argillaceous buff and brownish granular or earthy limestones, weathering to clayey slopes. Occasionally a lighter rock is speckled with darker crystals, which have segregated

themselves from the more argillaceous mass. Saccharoidal limestone appears in segregated thin lenticles and layers and in beds weathering to dingy crystalline sand. Rarely occurs a layer of brittle fine-grained limestone of brown or even of whitish tint.

Inclusions.—The Independence shows not rarely thin arenaceous layers whose sand consists of rounded grains of clear quartz and minute bits of black flint or of white chert. Elliptical nodules of quartz and calcite intercrystallized are common and characteristic (figures 59 and 60). These reach a foot or more in their greatest diameter. Their weathered surfaces are rough and carious from the solution of the calcite. Occasional lenticular masses are composed chiefly of clear saccharoidal calcite with some silica and much yellow clay included in the segregation area. Very rarely intercretions are met with in the shale whose interior is fissured and whose surface also is crackled. Flint of various tints is seen also.

Distribution.—Defining the Independence as the substage of shales and clayey limestones intervening between the purer limestones of the Lower Davenport and the Otis we find exposures of it in contact with either the higher or the lower terrane widely scattered over the area of the Wapsipinicon. In Scott county (p. 543), and in Cedar county (p. 536) it is in contact with the Otis. In Linn it occurs in contact with the higher as well as with the lower terrane. In Buchanan county it is found at several points in obscure outcrops.[41] In Benton, Fayette and Bremer counties the Independence occurs only more or less brecciated and intermingled with the fragments of other terranes.

The material of the Independence is so thoroughly diagnostic that it may be recognized far from its source. Thus on finding half a dozen of the silico-calcareous nodules on the slope of a hill at Canton, Jackson county, thirty miles east of any known Devonian outcrop (figure 61) the writer identified them with the Independence, an inference confirmed by finding later at the same locality small bowlders of brecciated Devonian limestone and a clay bed with fragments of silicified Devonian fossils overlying

[41]Clavin, S., Geology of Buchanan County: Iowa Geol. Surv., Vol. VIII, p. 223.

a bed of sandstone.[42] In the basal conglomerate of the Des Moines in Muscatine county Udden[43] identified similar nodules by texture and pitting as belonging to the Wapsipinicon and silicified blocks of breccia as from the same complex of terranes.

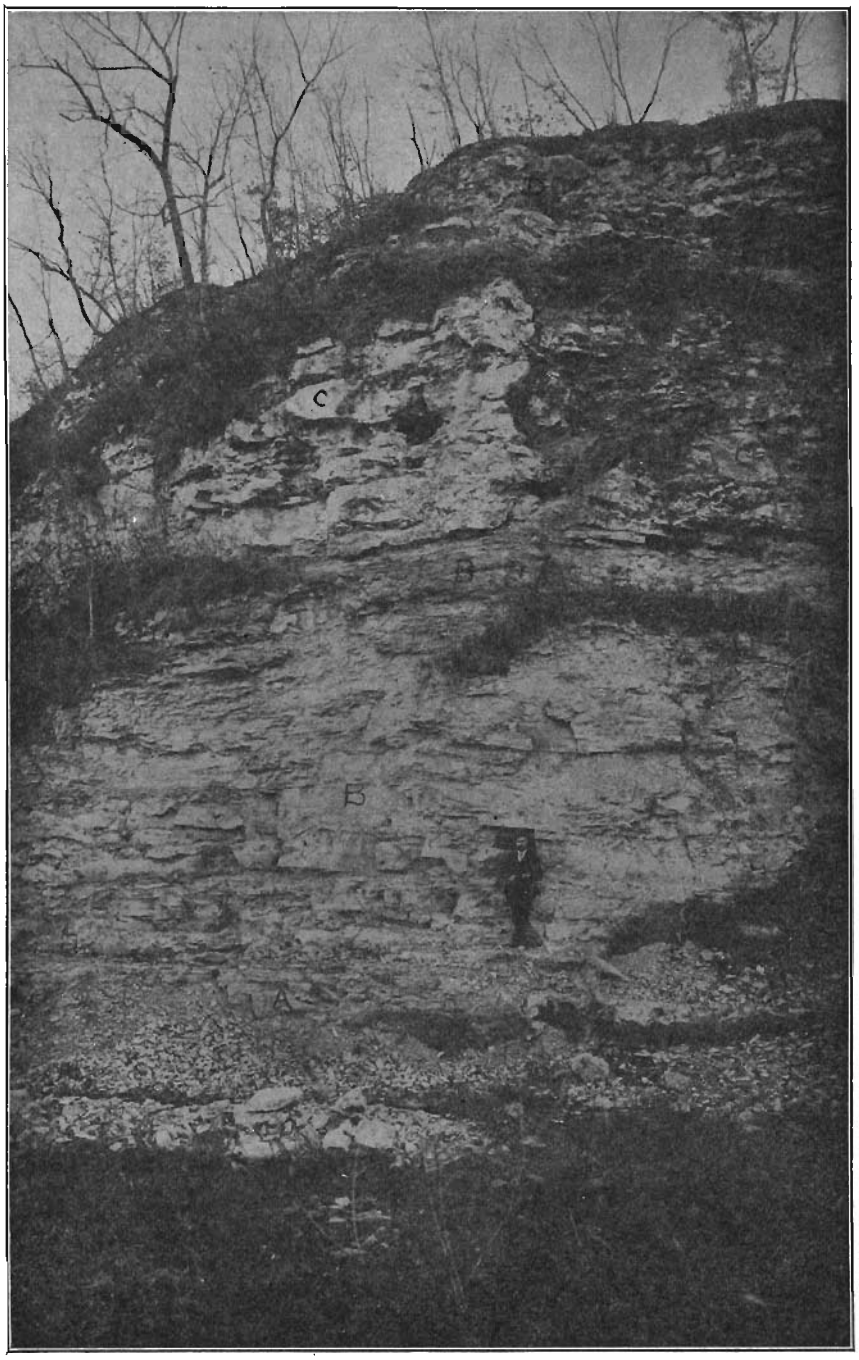
The Lower Davenport

At a number of localities[44] the earthy arenaceous and flinty limestones and the shales of the Independence are overlain by singularly pure calcilutites and crystalline limestones sufficiently in place to prove that the time of argillo-calcareous sedimentation had now given way to one characterized by the deposit of nearly pure lime carbonate.

At Davenport, and at one or two points in Cedar county and in Benton county, the fossiliferous Upper Davenport directly overlies similar calcilutites in beds but little broken up. These beds in place between the Independence and the Upper Davenport seem sufficiently well defined to constitute a distinct terrane, the Lower Davenport. Very generally they are completely brecciated. But even where brecciation has been most intense the Lower and Upper Davenport may in some places be found in contact in the same block, and zones and tracts of breccia are characterized by the prevalence of the Lower Davenport calcilutite fragments (figure 52). Where neither the Upper Davenport nor the Independence datum planes are found, outcrops may be classed with the Lower Davenport where the stratigraphy of the region compels, that is, where under normal dip of the strata the position of the outcrops is too high to be referred to the Otis, from which the Lower Davenport is lithologically indistinguishable.

The most common type of the Lower Davenport is a calcilutite, brittle, breaking with a conchoidal or splintery fracture. Massive in places, as at the West Davenport quarries and at Rochester, it is still more often found thinly laminated, as at Bettendorf and Rock Island. Massive layers graduate laterally into thin calcareous plates. The prevailing color of the rock is

[42]Iowa Geol. Surv., Vol. III, pp. 122-126.
[43]Udden, J. A., Iowa Geol. Surv., Vol. IX, p. 314
[44]As at Kenwood (p. 529), Sec. A, Felton creek, Cedar Rapids (p. 519), and the Aungst quarries, Vinton (p. 490).



Independence beds at Kenwood, Linn county. A, Otis limestone, fossiliferous. B, Independence shales. C, Independence earthy limestone. D, Lower Davenport calcilutite, partly brecciated.

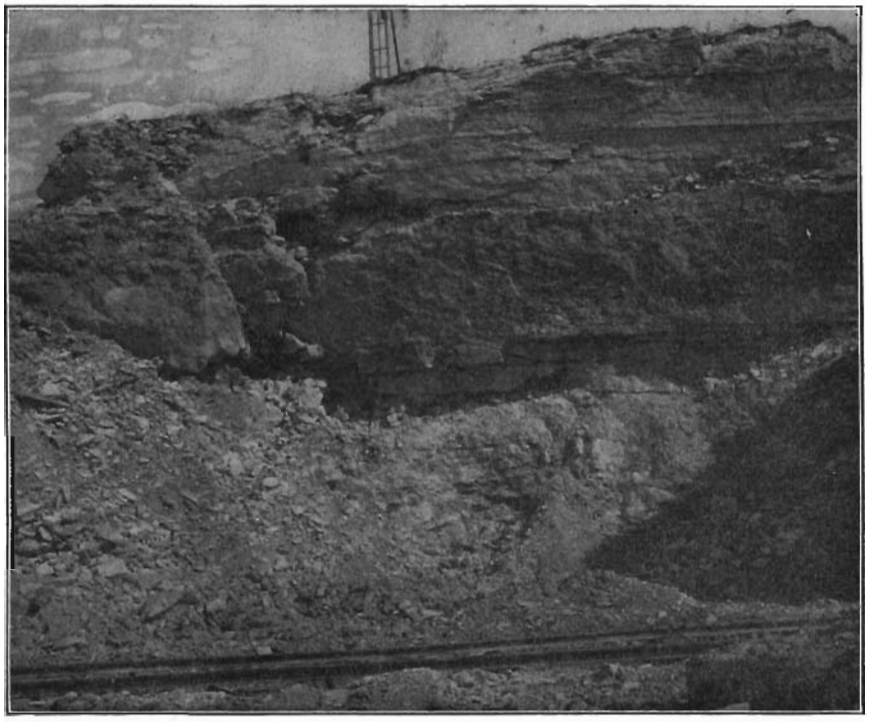


FIG. 52.—Lower Davenport limestone, Bettendorf Stone Company's quarry, Bettendorf, Scott county.

drab, or brownish drab, but like all the Wapsipinicon calcilutites it weathers to whitish gray. Crystalline limestones of whitish color are seen also and these are usually saccharoidal in texture.

Like the Otis limestone, the Lower Davenport effervesces briskly in cold dilute HCl, showing that the percentage of carbonate of magnesia is low.

The Lower Davenport is unfossiliferous. But one fossil, a cyathophylloid coral, has ever been found.[45]

[45]Udden, J. A., Journ. Cinn. Soc. Nat. Hist., Vol. XIX, p. 91.

ANALYSES OF LOWER DAVENPORT LIMESTONE

	I	II	III
$CaCO_3$	96.91	97.39	94.83
$MgCO_3$	1.93	1.54	0.25
Fe_2O_3	0.30	....	....
Fe, Mn and Al	....	0.14	2.52
SiO_2	0.86	....	....
SiO_2 and insoluble residue	....	0.28	3.22

I. Sample from ledge above Rochester on right bank of Cedar river.
II. Sample from Bettendorf.
III. Sample from Duck creek, north of Davenport.

The Upper Davenport

At their type locality in Scott county these beds form a ledge of gray granular limestone, about twelve feet thick, close textured, tough and hard, disposed in rough surfaced layers from six inches to a foot and more in thickness (figure 53). This

FIG. 53.—Upper Davenport limestone, Schmidt's quarry, Davenport, Scott county.

ledge lies between unfossiliferous calcilutites beneath and soft, highly fossiliferous shaly limestone above. These characteristics are maintained in Cedar and Linn counties. The bed in Muscatine county is described as a tough gray limestone seven feet thick in heavy ledges intercalated between unfossiliferous fine-grained limestones and fossiliferous shaly limestones as in Scott county.

In Johnson county the beds are shattered but are seen to consist of the same coarse granular stone. In Benton county about twelve feet of gray granular limestone in courses up to four feet thick represents this horizon. As in Johnson county the underlying calcilutites have been thoroughly brecciated. In Buchanan county beds lithologically similar occur at Independence and at Quasqueton in tumbled fragments and faulted ledges. At Independence they are reported to be succeeded by barren limestones. In Fayette county a bed of strong rather massive yellowish gray limestone eight to ten feet thick occupies the Upper Davenport horizon. It rests on a foot or so of fine-grained unfossiliferous limestone at Eagle Point which may represent the Lower Davenport. Beneath it lie shaly beds identified with the Independence. Thus from Muscatine county on the south to Fayette county on the north a well defined lithologic sequence generally prevails in the Wapsipinicon area as follows:

5. Shaly fossiliferous limestones.
4. Gray granular fossiliferous limestone. Upper Davenport.
3. Calcilutite. Lower Davenport.
2. Shales and impure limestone. Independence.
1. Calcilutites and magnesian limestones. Otis and Bertram.

The life zones above the Independence, which of course are far more decisive than lithologic facies, are by no means so well defined. No adequate statement is now possible, for the reason that the collection of fossils over a large portion of the field has not been sufficiently thorough and critical. The brecciation and intermingling of beds in numerous exposures has rendered the tracing of life zones extremely difficult. There appear, however, some outstanding facts from the investigations already made, which future discoveries may modify but will hardly overthrow. Tabulating the data at hand (table I) it is seen that after the Independence the Iowa Devonian area was held by five

successive faunas during the Wapsipinicon and the early Cedar Valley. The First Fauna was composed, so far as now is known, of *Hypothyridina cuboides, Gypidula comis, Schizophoria macfarlanei, S. iowensis, Pholidostrophia nacrea, Stropheodonta demissa* of normal form and especially in a small quadrate and strongly plicated variety, *Atrypa reticularis* finely ribbed, *Atrypa aspera* var. *occidentalis,* and a giant *Gyroceras.* This fauna appeared immediately at the close of the deposit of the Lower Davenport calcilutites and spread throughout the entire extent of the Iowa field from Fayette county to the northern border of Muscatine county. In Buchanan and Linn counties the first fauna survived into the succeeding life zone and mingled with the second fauna with the exception of *Hypothyridina cuboides* and the giant *Gyroceras.* In all other counties the first fauna and the second fauna, at least in part, enter simultaneously at the same lithological horizon. In southern Buchanan county the second fauna follows closely upon the first. In central Buchanan county, at Independence, the two are separated by barren beds. The second fauna is led by *Spirifer bimesialis* and by *S. pennatus.* The first named species is more definitely characteristic of the zone, since the latter lingered on to mingle with later faunas.

In Scott and Cedar counties, and probably in Muscatine county also, there enter along with the first and second faunas the corals characteristic of the third fauna—*Phillipsastrea billingsi* and *Acervularia profunda.* In the counties to the north these corals occupy a distinctly higher horizon. Either these corals made their appearance earlier in the southern counties than in the northern, or the first and second faunas delayed their entry into the southern portion of the Iowa field. Taking as a scale the sequence in Buchanan county, where the faunas enter in due succession, the first fossiliferous beds in Scott and Muscatine counties may be held as contemporaneous either with the zone of fauna one or with that of fauna three of Buchanan county. Calvin judged the latter to be true, and stated that the brecciated calcilutites of Muscatine county, which lie immediately beneath the first fossiliferous beds, are the stratigraphic equivalent of the *Spirifer pennatus* beds of Buchanan county,

i. e., the zone of the second fauna.[46] This conclusion would be better supported by the evidence if the first fauna were absent from the lowest fossiliferous beds in the southern counties. Moreover, the brecciated calcilutites, the Lower Davenport beds, form a well defined bed traceable continuously from Muscatine and Scott counties to southern Buchanan county. In Muscatine county the lowest fossiliferous bed lies twenty-nine feet below the definitely fixed horizon of the fourth fauna, the *Spirifer parryanus* beds. For these reasons it seems more probable that the first fossiliferous horizon in Scott and Muscatine counties is contemporaneous with the zone of the first fauna of Buchanan county and that the corals of the third fauna entered Iowa from the south or southeast along with the first and second faunas and did not reach the central part of the field until some time after it had been colonized by the pioneering brachiopods. In Muscatine county, it is true, none of the first fauna have been reported excepting the two Atrypas. But there is here only one exposure of the first fossiliferous beds—that of Wressley's quarries. The few fossils reported from these beds are found at the same horizon—the Upper Davenport—in Scott county, where the first fauna is well developed. Furthermore, the exposure in Muscatine county is evidently continuous with that of Cedar county just across the county line and three or four miles distant, where the *Hypothyridina* fauna is seen mingled as in Scott county with the corals of the third fauna.

The fourth fauna is led by *Spirifer euryteines* (*parryanus*) and forms a very definite horizon. Few members of the earlier faunas survive. Among them are such long lived forms as *Atrypa reticularis, Schizophoria iowensis* and *Stropheodonta demissa. Spirifer subvaricosus, S. pennatus, S. asper* and *Pentamerella dubia* linger on. Associated with *Spirifer euryteines* (*parryanus*) in parts of the field are *Newberria johannis, Curtina unbonata* and *Athyris fultonensis.*

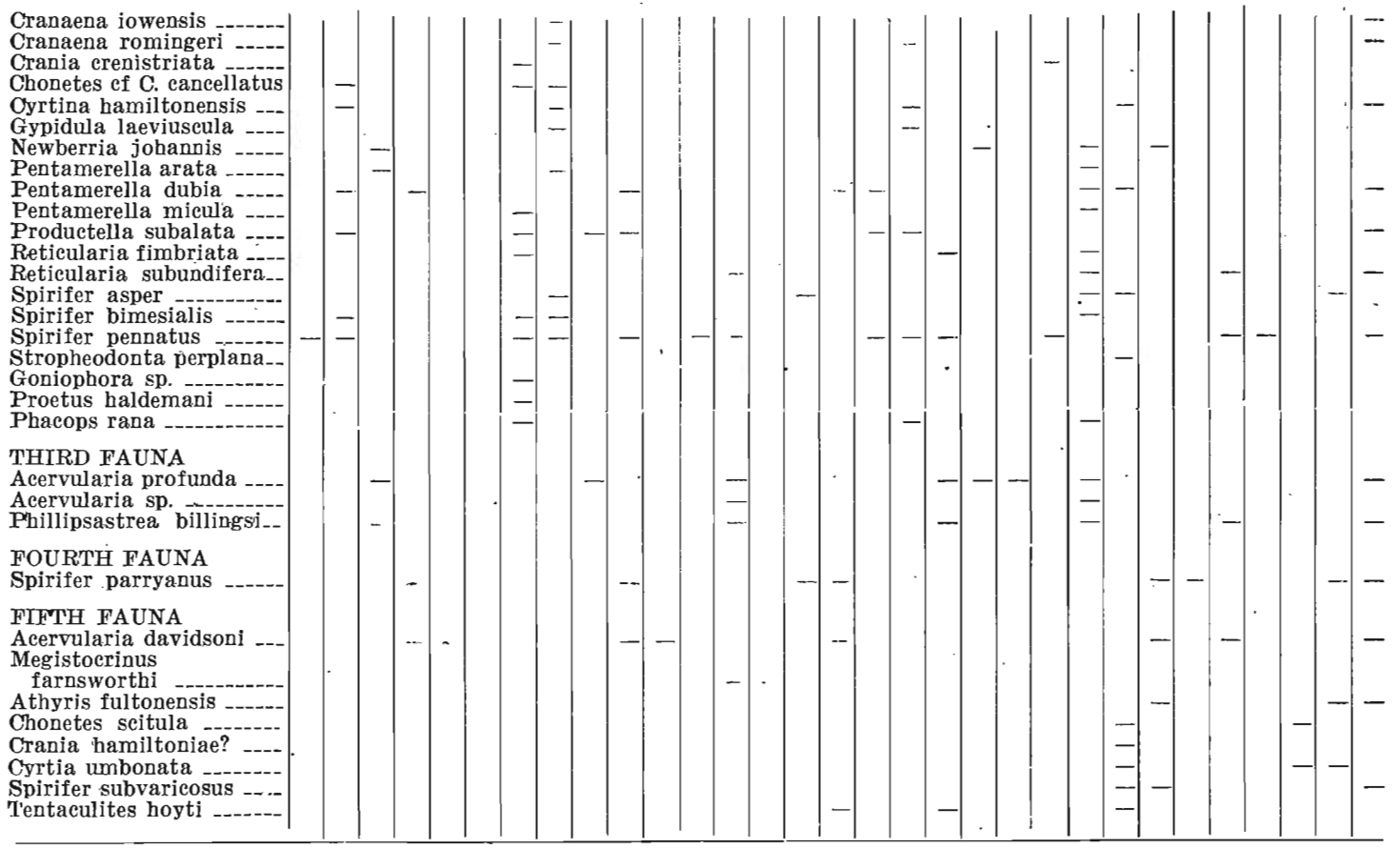
The fifth zone, the coral reef of *Acervularia davidsoni* and other corals, is well defined in the north, but in Muscatine county no Acervularias are reported after the entrance of the fourth fauna, while in Scott county *Acervularia davidsoni* occurs along with *Spirifer parryanus.*

[46]Iowa Geol. Surv., Vol. IX, Pl. 6, footnote.

TABLE I

PROVISIONAL LIST OF FOSSILS OF THE UPPER DAVENPORT AND CEDAR VALLEY LIMESTONES AS FAR UPWARDS AS THE ACERVULARIA DAVIDSONI REEF, WITH THE HORIZONS AT WHICH THEY HAVE BEEN OBSERVED. COMPILED CHIEFLY FROM COUNTY REPORTS OF THE IOWA GEOLOGICAL SURVEY.

	Buchanan County					Linn Co.		Benton County			Johnson County				Fayette County					Cedar Co.	Scott County			Muscatine County			R.I. Co Ill.*
	Hypothyridina beds	Spirifer pennatus beds	Phillipsastrea billingsi beds	Spirifer parryanus beds	Acervularia davidsoni beds	Hypothyridina beds	Spirifer bimesialis beds	Hypothyridina and Spirifer pennatus beds	Acervularia profunda beds	Spirifer parryanus beds	Acervularia davidsoni beds	Hypothyridina and Spirifer pennatus beds	Phillipsastrea beds	Acervularia profunda beds	Spirifer parryanus beds	Acervularia davidsoni beds	Hypothyridina beds	Spirifer pennatus beds	Phillipsastrea billingsi beds	Newberria johannis beds	Coral beds	Hypothyridina beds	Hypothyridina and Phillipsastrea beds	Spirifer pennatus and Orthis vanuxemi beds	Spirifer parryanus and Acervularia davidsoni beds	Athyris fultonensis beds	Phillipsastrea beds	Othis vanuxemi beds	Chonetes scitula beds	Spirifer parryanus and Coral beds	Phillipsastrea beds
FIRST FAUNA																														
Hypothyridina cuboides	—																													
Gypidula comis	—	—				—	—																							
Schizophoria macfarlanei	—	—				—	—																							
Schizophoria iowensis var.		—				—	—	—	—			—																		
Pholidostrophia nacrea		—				—	—	—	—			—																		
Stropheodonta demissa				—		—	—	—	—	—		—	—																	
Stropheodonta demissa var. plicata		—				—	—		—																					
Atrypa reticularis (fine ribbed)	—	—				—	—	—																						
Atrypa aspera var. occidentalis	•	—				—	—																							
Gyroceras sp.	—					—	—	—																						
Gomphoceras sp.								—																						
SECOND FAUNA																														
Favosites alpenensis					—			—				—					—													
Favosites placenta																														—



*From Correlation of the Devonian System of the Rock Island Region (E, b and E, c), W. E. Ekblaw, Trans. Ill. Acad. Sci., 1912.

THE BRECCIATED ZONES

The descriptions already given of the beds of the Wapsipinicon are based upon outcrops where they are but slightly if at all disturbed. But in very numerous sections over the entire area of outcrop of the Wapsipinicon its terranes are more or less completely broken up and intermingled. Almost every outcrop of the Wapsipinicon from Fayette and Bremer counties on the north to Scott and Muscatine counties on the south shows brecciation either incomplete or thoroughgoing. Roadside sections, small quarries and shallow railway cuts may exhibit certain general characteristics found over the entire field, but it is the larger outcrops which supply the key to their interpretation. The chief exposures are the deep railway cuts north of Vinton, west of Linn and at Fayette, the long cliffs along the Volga in Westfield township of Fayette county, the river bed and banks at Independence, Quasqueton, and Troy Mills, and several outcrops adjacent to Cedar Rapids.

At any one of these sections the first casual impression of the breccia is that of a chaotic hodge-podge of debris. A closer attention shows that the breccia is by no means uniformly heterogeneous. There are zones and tracts characterized by preponderating material and the remains of nearly obliterated structures. And one familiar with the lithologic characteristics of the different Wapsipinicon terranes can identify their contributions to the hodge-podge and recognize the different zones in each of which the material of some one terrane is preponderant or even exclusive. The breccia as a whole or any exposure of it is therefore best described by subdividing it into zones according to the terranes which make it up.

Characteristics Due to the Major Brecciation

The main characters of the breccia are referable to a single cause, as will be seen later, and these characters may be grouped as the effects of what we may designate as the *Major Brecciation*. But enigmatic features also are found which indicate a complexity of causes and show that the breccia is not the result of a single process, but embraces the results of a long succession

of processes of different sorts. These features will be treated under *Minor Brecciations.*

As we proceed to describe the characteristics of the major brecciation under zones it must not be supposed that these zones retain either the horizontality or the sharply definite boundaries of their parent formations. Boundary lines are in many places vague and usually oblique. Zones arch, thicken and thin, are dislocated and interrupted. Nor in any zone are the materials of other than the parent terrane necessarily excluded. Thus the Independence zone, predominantly of clayey detritus from the Independence, may contain fragments of the brittle Otis and Lower Davenport calcilutites, blocks of the Upper Davenport, and even somewhat of the fossiliferous *Spirifer pennatus* beds. A very generalized section may assist in making these statements plain (figure 54).

BERTRAM BRECCIA

The Bertram beds experienced the same powerful stresses which brecciated the superior terranes, but in no case are its

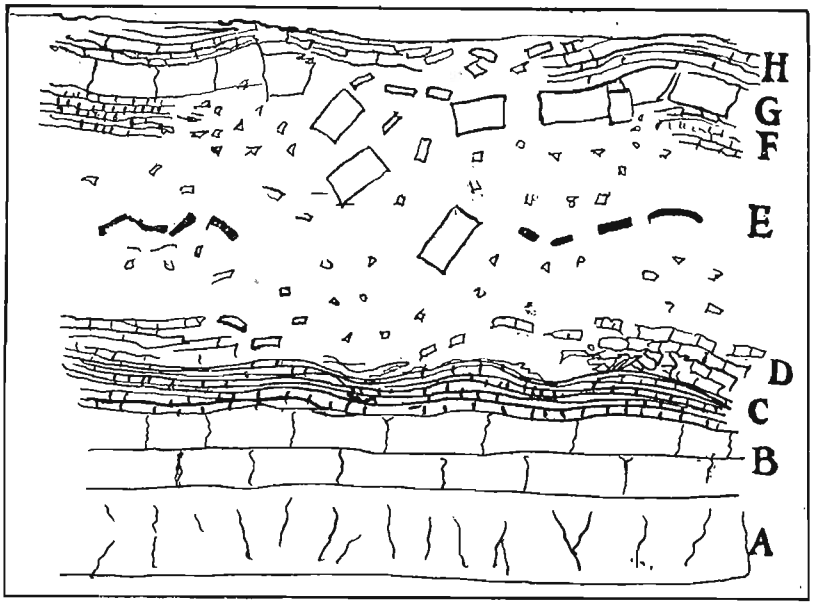


FIG. 54.—Generalized section of Wapsipinicon brecciated beds. A, Bertram. B, Otis, Coggan phase. C, Otis, Vinton phase. D, Otis, Cedar Rapids phase. E, Independence. F, Lower Davenport. G, Upper Davenport. H, *Spirifer pennatus* beds.

fragments intermingled with theirs. The entire body of the rock is shattered to a greater or less degree. Universally the ruptures have been filled with calcite and not with partly detrital material; hence when the stresses occurred, the rock was not accessible to the sediments of the sea floor. Thick beds are found shattered with rupture planes spaced to less than an inch apart. Upper weathered surfaces are covered with a network of incised lines whose rhombic meshes vary from a fraction of an inch to a few inches in width. These fissures vary from a hair line in width to nearly one-half inch. The surface of a fresh vertical fracture may show horizontal veins of calcite intercalated between the laminæ, as closely set, exceptionally, as ten to the inch. These veins occasionally branch and break across the laminæ. In places where they are not completely filled with interlocking calcite crystals the fissures between the blocks into which the rock has been shattered are lined with drusy calcite.

The stresses which so intimately shattered the Bertram beds did not convert them into rubble. The fragments are not dislocated, very few blocks are rotated and the major bedding planes are little disturbed. This may imply a considerable weight of superincumbent rock whose weight tended to keep the beds in place, while they yielded by crackling to the sudden stress. But the strength of this heavily bedded dolomite undoubtedly helped it to resist strains which would have completely broken up a weaker rock.

OTIS BRECCIA

As far to the north as Vinton the Otis limestones do not appear to have been involved in the major brecciation, to the extent of a commingling of their fragments with those of higher terranes. The beds on Crow and Pigeon creeks of Scott county are crackled. Those northeast of Rochester in Cedar county are fissured, with the planes of rupture filled with calcite, and those of Linn county are thrown into low gentle undulations and the more brittle beds are meshed with close-set calcite seams —all the result, it is assumed, of the major brecciation. Even these evidences of strain are confined to the upper beds of the

Otis, the Cedar Rapids phase. The basal beds, the Coggon phase, escaped brecciation so far as is known.

The lower magnesian beds which are exposed at Vinton show no effects of the major brecciation (figure 55) except local archings of the strata which may reach an exceptional dip of limb of 15°. The calcilutites which in places in the Vinton quarries immediately underlie the zone of the Independence, however, are shattered to crackle breccia or disrupted to a mosaic breccia of fragments which in many cases match along seams filled with calcite or with fine chinkstone[46a] of the same nature as the large fragments (figure 56). In places the calcilutites of the Otis have been broken into close-set rubble with which a few fragments and a scant matrix of the Independence and fossiliferous

FIG. 55.—Otis limestone overlain by Independence breccia, Aungst quarries, Vinton, Benton county. A, closely laminated magnesian Otis limestone. B, massive upper layer of the same with sporadic fragments. C, breccia of Independence with calcilutite fragments also and fossiliferous blocks of Upper Davenport.

[46a]Chinkstone. Small fragments of stone which fill the chinks, or interstices, between larger fragments.

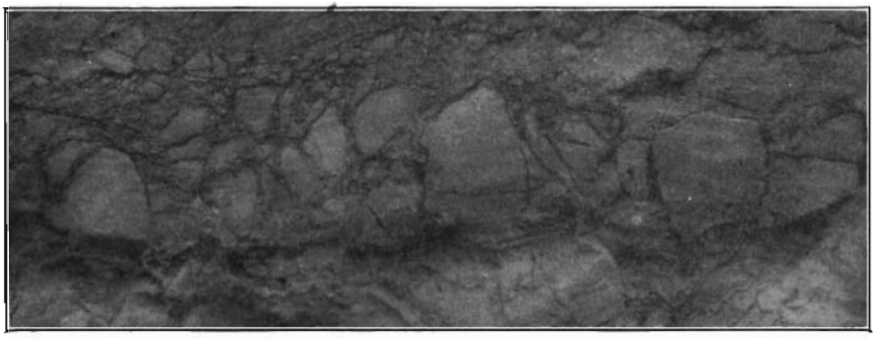


FIG. 56.—Otis calcilutite showing a disrupted layer at the base of the railway cut north of Vinton, Benton county. Scale, ¼.

fragments from higher beds are commingled. At one point (p. 493) this rubble forms a bed twelve feet thick which thins to six feet at an angle of 45° and rests immediately upon the buff magnesian layers of the Otis. Elsewhere amid the breccia of the Independence zone one finds fragments which may be referred to the horizon of the Otis calcilutites, such as fragments with hair-line blackish laminæ.

In Fayette county the basal beds in contact with the Silurian —the Westfield phase—were massive enough to resist completely the strains of the major brecciation. It is quite different with the thin-bedded, fine-grained limestones which rest upon them. These beds were bent into a series of low arches whose width is nine to twelve feet and whose height is less than two feet, while the laminæ have been fractured by a meshwork of close-set narrow vertical seams now filled with calcite (figure 57.) At Eagle Point the upper layers of this bed have been brecciated to a rubble of angular blocks some of which are two feet in diameter (figure 85.)

The Otis calcilutites of Fayette county seen at West Union and Fayette were less elastic and resistant and received greater strains than the beds beneath, perhaps because of their nearness to the yielding Independence. They were intimately shattered to a crackle or mosaic breccia to be recemented by calcite deposited by ground water, the original planes of bedding being largely retained. Or, yielding more fully to the stresses, they were crushed to rubble of small fragments to whose inter-

stices more or less of the shaly detritus of the Independence found access. Large blocks were plucked away and left amid the Independence debris and thus in places the entire body of the rock was broken up and its bedding destroyed beyond possibility of recognition. This is the breccia described and figured by McGee as typical of the Devonian limestone breccia of Iowa. It will be noted particularly that this breccia bed belongs to the zone of the upper Otis calcilutites and that it has small admixture of the Independence and no commingling of higher fossiliferous beds. At Eagle Point the Independence is more intimately intermingled (p. 464), but no fragments of fossiliferous higher terranes appear.

THE INDEPENDENCE BRECCIA

This zone comprises the areas in which buff or rarely bluish argillo-calcareous detritus is conspicuous or predominant. It can be traced continuously from Fayette to Scott county and is

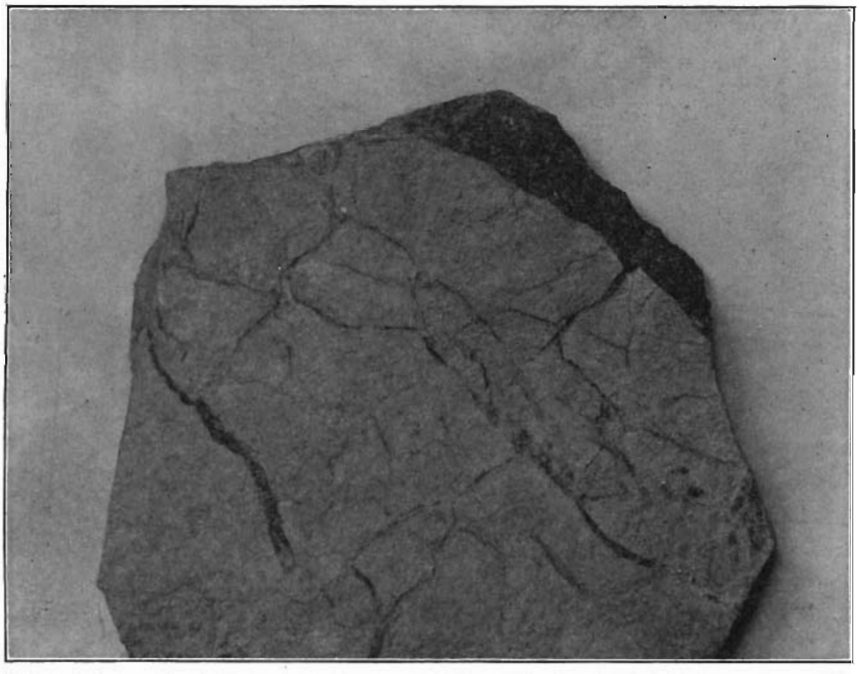


FIG. 57.—Crackled surface of detached lamina of Otis limestone near the base of the railway cut at Fayette, Fayette county.

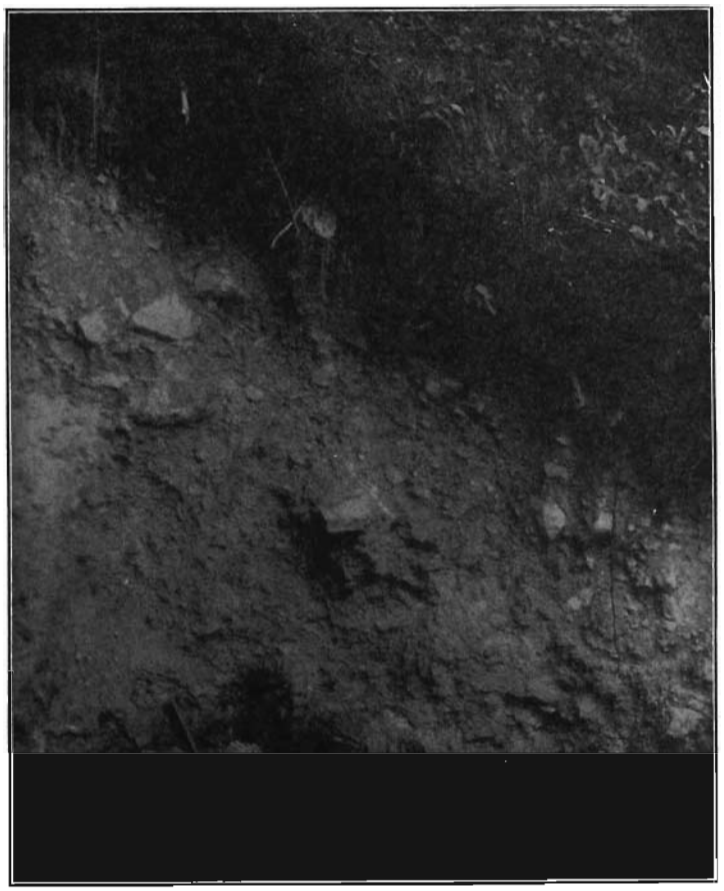


FIG. 58.—Unindurated breccia composed chiefly of Independence detritus. Kearn's quarry north of Vinton, Benton county. At the base are seen the magnesian beds of the Otis. Above the hammer may be seen layers of Independence shale arched and broken but not crushed.

everywhere found in the same position, immediately beneath the zone of the Davenport limestones. On account of the large amount of argillaceous material and poor cementation, the areas of the Independence are weak and weather back to slopes while adjacent tracts of the limestone breccias stand in strong cliffs or ledges. The breccia of this zone in some places is scarcely more indurated than glacial till, and fragments of limestone can be picked from it quite as easily as can pebbles from glacial stony clays. The two formations, so diverse in origin, have a strong superficial resemblance because of their common lack

of bedding, their clayey base and the stones of all sizes promiscuously intermingled (figure 58).

The material in this zone which may be referred to the Independence comprises first the buff argillo-calcareous and in many cases sandy matrix. This is not laminated or bedded and shows no trace of sedimentary deposit in its present relations. Sporadic fragments show no signs of having been droppd on the sea floor in the midst of accumulating layers of argillo-calcareous sediments. Stratification would be easily detected, for the matrix is in places somewhat arenaceous with rounded grains of quartz and angular bits of flint, which soon are left in conspicuous relief on weathered surfaces. Such grains are without linear arrangement, and like the larger fragments are sporadic. The nearest approach to stratification is found in certain small areas of lumpy structure where the rock weathers to flattened irregular lenslike bodies two inches and more in diameter. Since this structure occurs also in the Independence where that is unbrecciated, it may be supposed that in these areas masses of the Independence have been preserved nearly or quite intact.

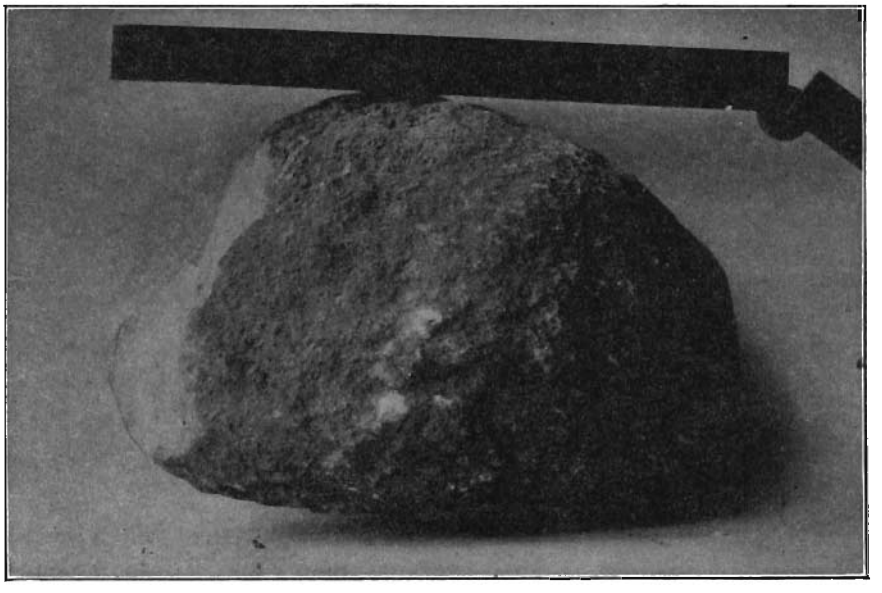


FIG. 59.—Silliceo-calcareous nodule, Independence beds.

There are also many fragments of various sizes of dingy buff limestone which may be difficult to detect from the matrix rock. Areas which seem at first sight to be composed entirely of the buff matrix may be found to be largely made up of fragments of the same texture, color, and apparent composition.

Siliceous material derived from the Independence beds embraces the rounded grains of crystalline quartz and the angular bits of black and white cryptocrystalline silica already noted.

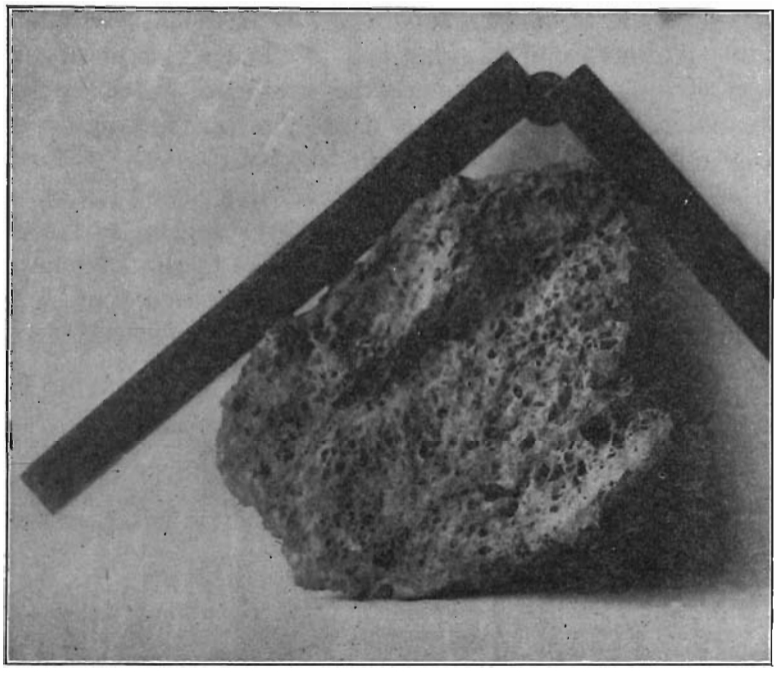


FIG. 60.—Fragment of a siliceo-calcareous nodule from which the calcite has been removed by solution. Independence horizon, Canton, Jackson county.

There are also sharp-edged fragments of flint of some size. Large nodules of intercrystallized quartz and calcite are as characteristic of this zone as they are of the Independence beds where those are undisturbed, and in the breccia these nodules are set at any angle (figures 59 and 60).

Ledges of massive limestone of Independence facies a foot and more thick occur—buff, impure, speckled, and in some cases minutely fragmental. These are in every instance tilted and

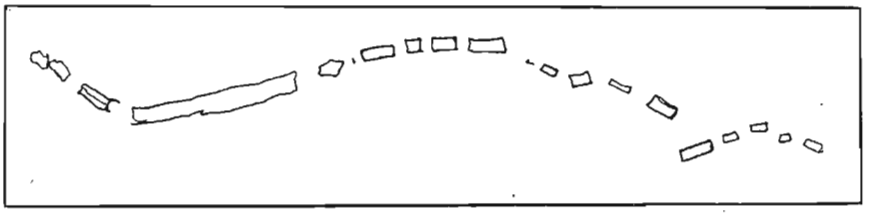


FIG. 61.—String of blocks of dingy brownish Independence limestone representing a flexed and broken layer. From the railway cut north of Vinton, Benton county. Scale, one inch equals ten feet.

discontinuous or broken into blocks which are surrounded on all sides with rubble breccia (figure 61). Beneath them one occasionally may find laminated shales up to a foot or so in thickness. That shales and limestone were not deposited upon the breccia beds beneath is clear from the fact that the underlying breccia contains (Vinton, p. 488, Linn, p. 506) fossiliferous fragments of Upper Davenport limestone. The shales and limestone were deposited in orderly succession during Independence time. Later, the stresses of the major brecciation, which crushed so much of the Independence to fine detritus, here left a ledge of limestone tilted with some of the underlying shale protected by it, and thrust underneath them a rubble of breccia with fragments from higher formations.

Small areas of similarly protected shales are sometimes found with their laminæ strongly arched (Linn railway cut, figure 62). These areas also represent parts of the Independence which have not been crushed out of all semblance to their initial structures.

FIG. 62.—Obscure flexures in shale of Independence zone, Linn section, Linn county. A, Strong breccia of limestone fragments. B, Buff laminated shale with a few sporadic limestone fragments, bent and fractured. C, Weak breccia with abundant buff Independence matrix.

At one or two stations the position of layers of some length or of strings of dislocated blocks of calcilutite strongly suggest that these beds are native to the Independence. It is true that where the Independence may be seen intact fine-grained limestones of the type of these calcilutites are almost unknown. The only instances observed are at Eagle Point (p. 464) and in a thin bed of fine-grained whitish limestone at the cut of the Chicago, Rock Island and Pacific Railway two miles southeast of Cedar Rapids and a layer of brown limestone in the quarries of the Chicago and North Western Railway at that city. Neither of the beds at Cedar Rapids adequately resembles the calcilutites of the breccia of the Independence zone. It is true that an immediate source for calcilutite fragments in the Wapsipinicon breccia beds is found in the calcilutites of the Lower Davenport and of the Otis and that their commingling with the Independence detritus is unquestionable. There is no need, however, to avoid the conclusion wherever evidence leads to it, that calcilutites indistinguishable from those of the Otis and Lower Davenport were laid to a limited extent in Independence time. We define the Independence lithologically as the period of the deposit of shales and impure granular limestones. This definition does not imply that colonies of lime-secreting organisms may not locally have produced thin beds of calcilutite in the midst of prevailing shales. The Independence breccia contains a large amount of foreign material. In the northern counties where the Otis has been broken up, it contributes ledges of limestone under which the Independence shaly breccia has been thrust. Where the fragmentation of the Otis is more complete an Otis rubble breccia may be seen to graduate into an Independence area with Otis sporadic fragments. In Linn and Johnson counties the Lower Davenport furnishes abundant small drab calcilutite fragments from its shattered laminæ. And throughout the area except in the extreme south the Upper Davenport and even the *Spirifer pennatus* beds supply their characteristic fossiliferous fragments which are often found far down in the breccia-zone of the Independence (figure 63).

Structure lines due to deformation are naturally not so obvious in the Independence zone as in the limestone breccia where

brecciation has been less complete. The boundaries of the zone, however, indicate deformation even where brecciation has been most intense. In the Fayette railway cut the Independence zone displays low archings 140 feet in diameter, thin at the summit, thickening to the bases of the limbs. In the Linn section the areas of the Independence breccia alternate laterally with those of limestone breccia and their boundaries dip steeply outwards as if the Independence breccia here formed the axes of strong anticlines. At intervals of about fifty feet in places the limestone breccia stands in almost vertical towers while the weak intervening shaly breccia weathers back to slopes. Within the Independence zone are commonly seen, as in the Vinton railway cut, tilted ledges of the stronger Independence limestone in places continuous for several feet, and strings of blocks of some thicker limestone stratum each completely surrounded by brec-

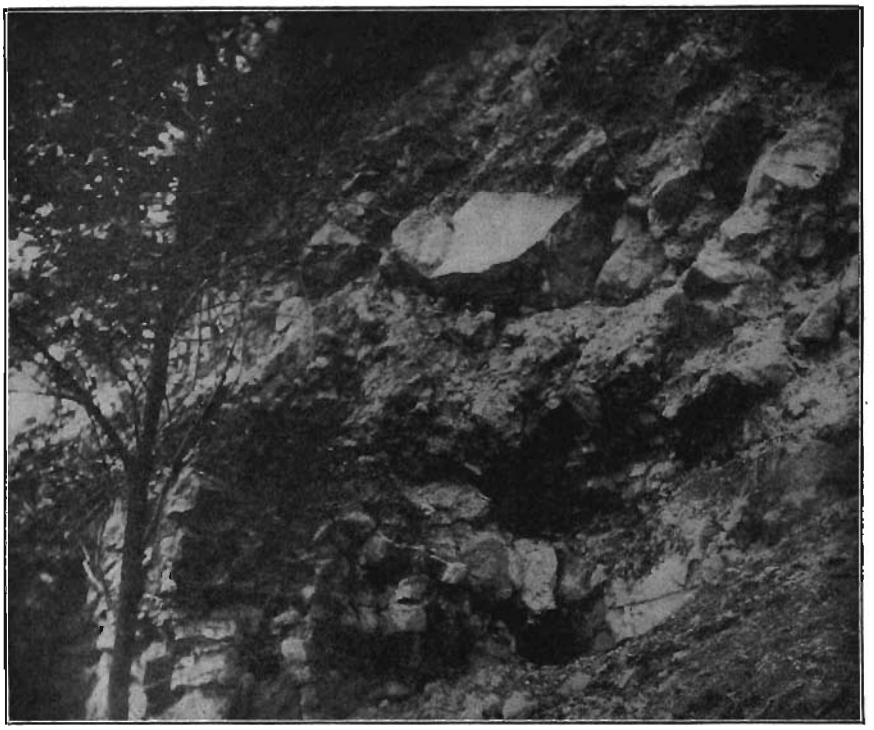


FIG. 63.—Otis beds overlain with breccia of the Independence zone. Aungst quarries, north of Vinton, Benton county.

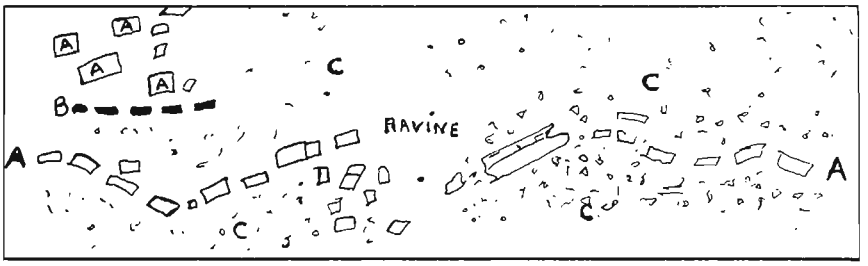


FIG. 64.—Structure lines in Independence zone. Railway cut north of Vinton, Benton county. AA, Blocks of whitish calcilutite in a sinuous broken line dipping 30° to the right of the ravine. A, Blocks of white calcilutite. B, string of fragments of buff impure limestone. C, Breccia of predominant Independence shaly fragments.

cia of shaly matrix. These blocks, parted and many of them somewhat rotated, still trace by their alignment irregular, in some cases faulted, folds and steep monoclines which may be traced with interruptions for as much as three or four rods in places (figure 64).

THE LOWER DAVENPORT BRECCIA

In the Lower Davenport zone all gradations may be traced from areas where the layers are closely crackled (figures 66, 67, 68, 69) and slightly bent, to those where the same layers are ruptured to mosaic breccia and on to where they have been more or less completely broken up into rubble (figure 70). At Quasqueton, at Kenwood, near Rochester in Cedar county, and about Davenport and Rock Island such gradations may be observed. The matrix in the crackle and mosaic breccias and in some rubble is of chinkstone and indurated powder of the broken rock together with calcite deposited at some later time by ground water. Rubble breccia, however, shows usually some buff interstitial matrix of the Independence detritus and may graduate into a pudding breccia where the Independence matrix is abundant and the sparse Lower Davenport fragments are sporadically distributed throughout it.

In all types the fragments are small as a rule, up to two or three inches in diameter, and many have the form which would naturally result from the breaking up of a thinly laminated limestone. In rubble they are set at all angles. Their edges retain their initial angularity and no trace can be seen of

bedding or sorting after their fragmentation. In mosaic breccia some of the laminæ are slightly bent and may be seen to have broken where the fold was sharpest. But the brittleness of these calcilutites, like their fracture, approaches that of flint, and they rupture under very little strain.

The rubble breccia of this horizon is perhaps the most common of all the Wapsipinicon breccias exposed. This is due not so much to its extent and thickness as to the strength of its well cemented masses. It stands in ledges and buttresses where the

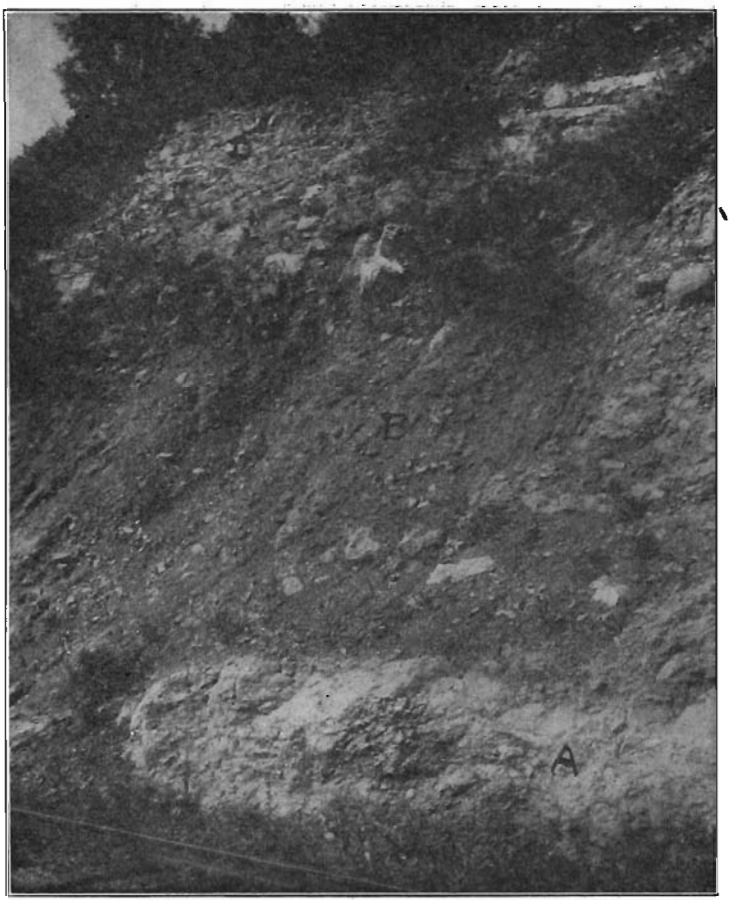


FIG. 65.—General relations of the Independence zone of brecciation. Railway cut north of Vinton, Benton county. A, Ledge of Otis calcilutite, brecciated. B, Independence zone. C, Upper Davenport beds, brecciated. D, Barren beds, arched, in places brecciated.

abutting clayey breccia of the Independence weathers down to slopes. More than any other terrane the Lower Davenport limestone is apt at any point to be completely involved in the brecciation and to leave no evidence of itself except a rubble breccia more or less intermingled or interfingering with the Independence.

North of Independence the Lower Davenport is very thin and its presence is questionable. On the contrary in Scott and Muscatine counties it reaches a thickness of over forty feet. In

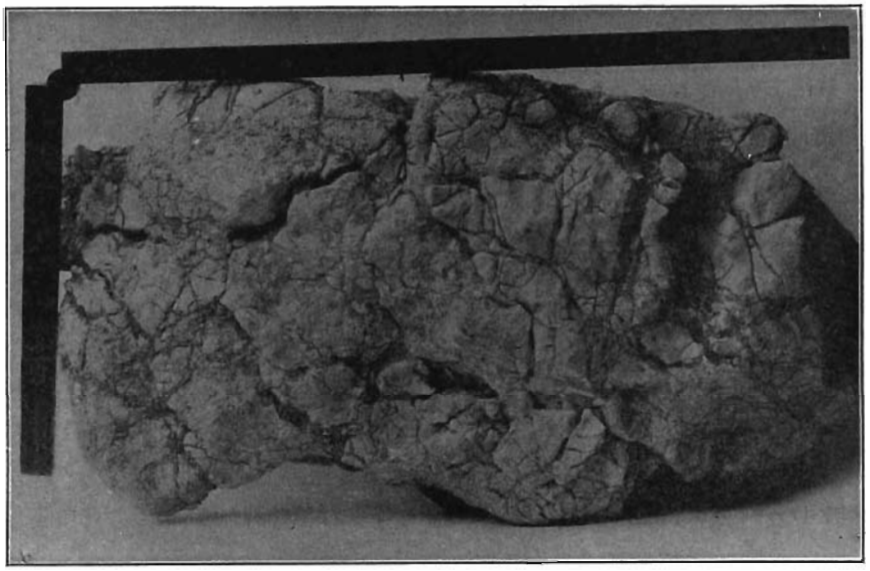
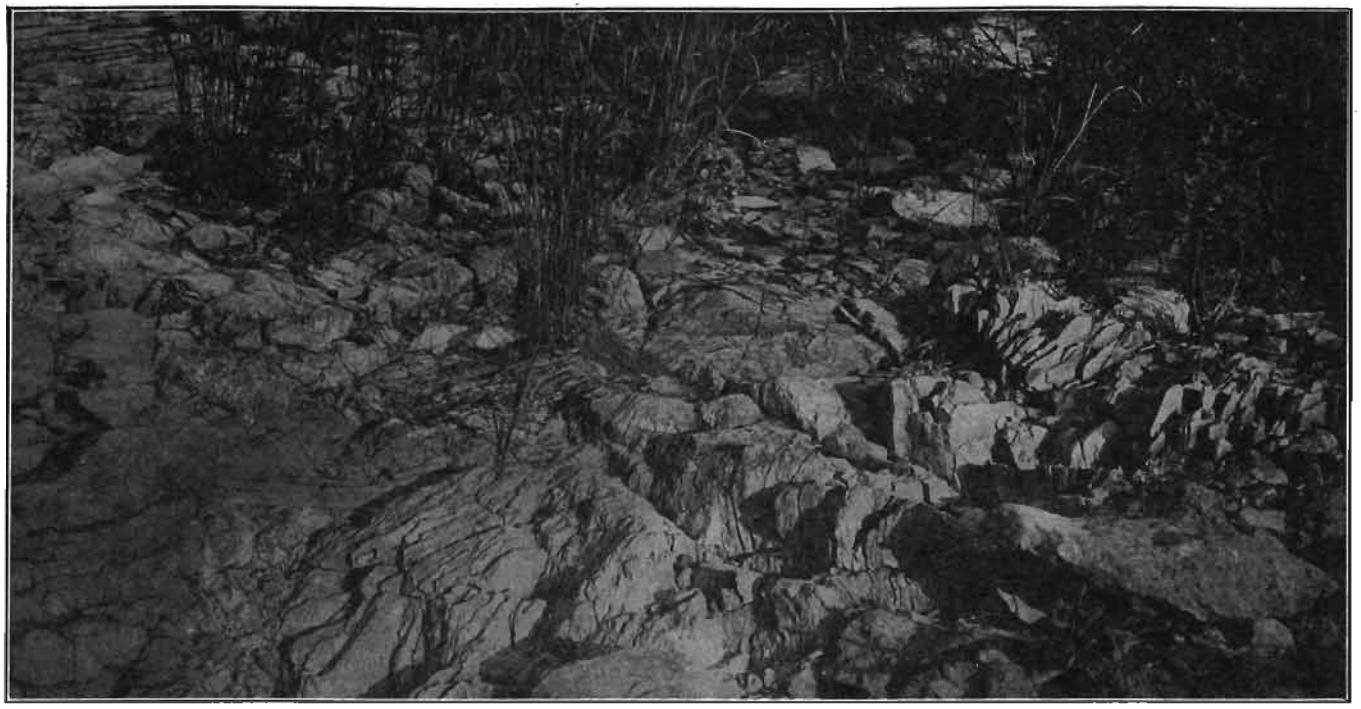


FIG. 66.—Crackle breccia. Upper surface of layer of Lower Davenport limestone. Section E, Felton creek, Cedar Rapids, Linn county.

and about Davenport these beds lie in low arches up to 100 feet in diameter the centers of whose synclines are in some cases broken into breccia. On Rock Island areas of mosaic and rubble breccia seldom exceed a rod or so in length (Plate VII).

Besides thinly laminated and more massive calcilutites the Lower Davenport also contains saccharoidal limestones finely displayed in the quarry of the Bettendorf Stone Company, Davenport (figure 52 center), and in exposures about Cedar Rapids. These also are involved in the brecciation at several points as



Area of brecciated laminated Lower Davenport limestone, Rock Island, Illinois.

FIG. 67.—Block of massive Lower Davenport limestone, in part crackled, in part crushed to rubble. Felton creek, Cedar Rapids, Linn county.

at the Linn section and in Section E, Felton creek, Cedar Rapids, where they appear in dislocated ledges and large blocks.

THE UPPER DAVENPORT BRECCIA

The ledges of tough granular heavily bedded Upper Davenport limestone yielded to brecciation by breaking into blocks which reach large sizes. There may be but slight movement of the blocks in the gently undulating stratum, a movement indicated by slickensides, or, with more strongly marked archings of the bed, the blocks may be rotated and disparted. Thus at the railway cut west of Linn and in the cut north of Vinton the Upper Davenport zone is marked in places near the summit of the section by undulating lines of tumbled blocks which in some places have a diameter of three to five feet and in a few cases are eleven feet in diameter. The fracture planes commonly are

smoothed and grooved and the slickensides break across bedding planes and cut sections in the thick shells of *Gypidula comis* and other brachiopods (Plate VIII).

Where, as along the Volga cliffs west of Fayette, the Upper Davenport remains for rods practically horizontal it is yet sharply flexed upward in places or broken down for a few feet in a tumble of big blocks imbedded in the Independence. Where the stresses have been evidently greater, as in the Vinton and Linn sections, the Upper Davenport is found in places deep down in the breccia in masses of rotated blocks, accompanied by fragments of the superior fossiliferous or barren limestones (figure 71). The river sections at Independence, Quasqueton and Troy Mills exhibit the zone of the Upper Davenport mingled with both *Spirifer pennatus* beds from above and the Lower Davenport and Independence from below. At Quasqueton the ledge of Upper Davenport north of the dam is largely in place but displays at one point a conspicuous thrust.

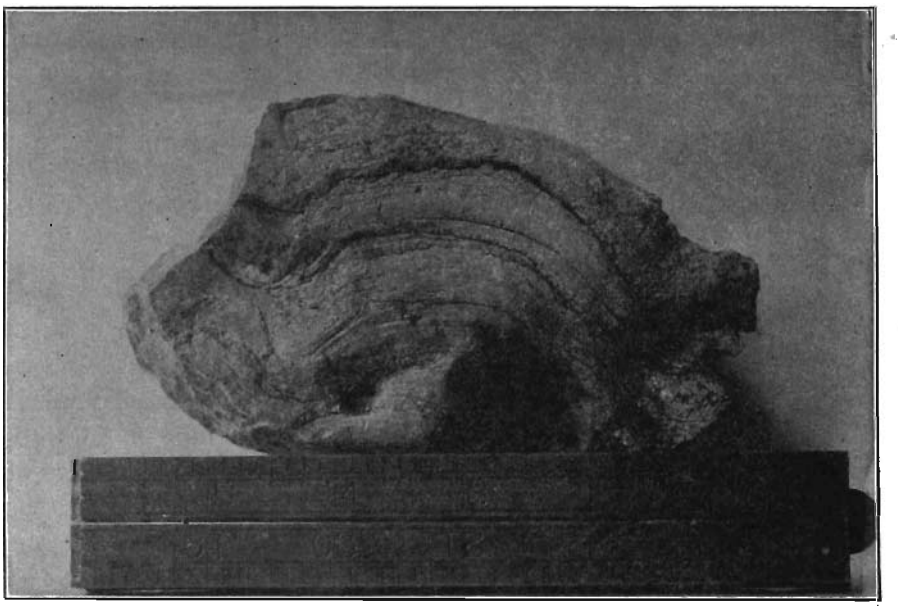
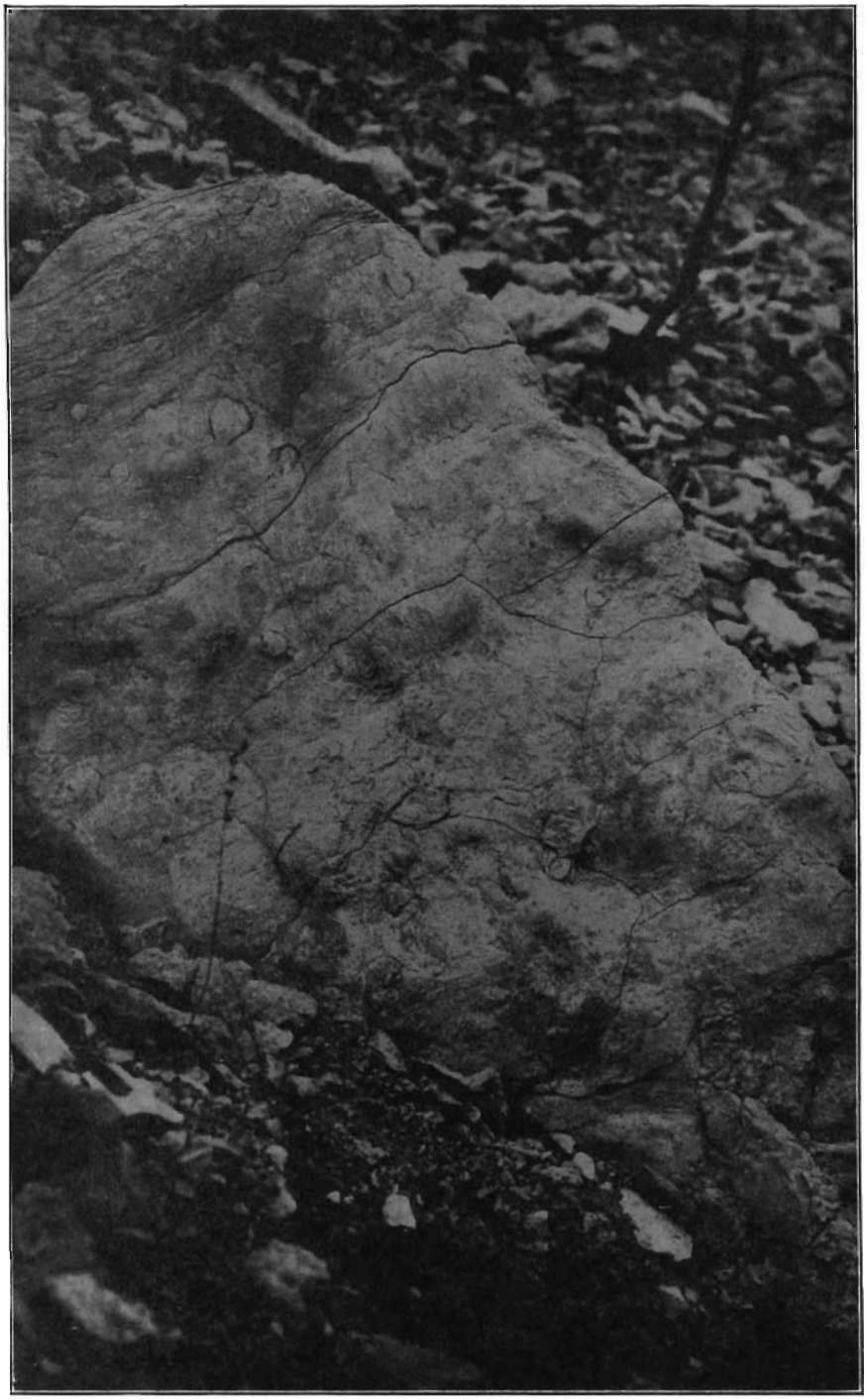


FIG. 68.—Flexed laminæ of Lower Davenport limestone. Duck creek, Scott county.



Slickensides on block of Upper Davenport limestone, Linn section, Linn county.

BRECCIATION OF THE SPIRIFER PENNATUS BEDS

The limestones above the Upper Davenport are usually but slightly involved in the Wapsipinicon brecciation. But at several points, as at Linn and at Troy Mills, their fossiliferous fragments are found deep down in the breccia commingled with those of inferior terranes. In very many cases they are affected by

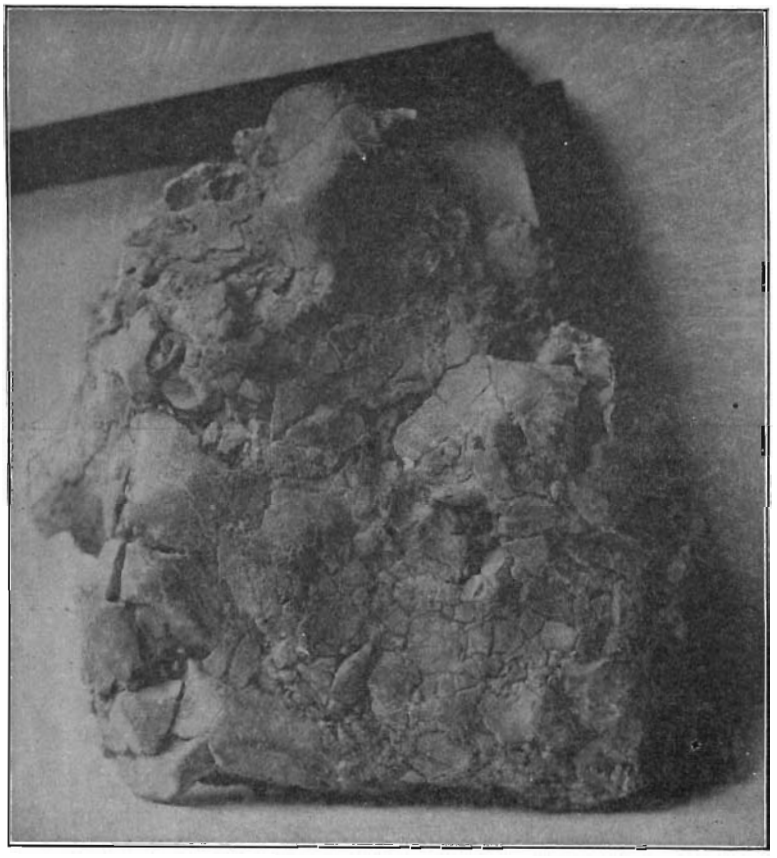


FIG. 69.—Mosaic breccia of Lower Davenport limestone. Rock Island, Illinois.

folding and lie in long gentle undulations whose dips seldom exceed fifteen degrees. Shattering is also a common phenomenon at this horizon. Thus in Sumner township, Buchanan county, there lies above the *Gyroceras* beds a body of limestone "not distinctly bedded but very much shattered and cut by joints

FIG. 70.—Ledge of Lower Davenport laminated calcilutite largely crushed to rubble. Section E, east end, Felton creek, Cedar Rapids, Linn county.

that intersecting at every possible angle, divide the bed into a great number of shapeless fragments which still retain their relative position unchanged."[47]

While the shattering effects of frost on superficial beds of limestone are well known, the phenomena of slickensides very extensively developed on the joint walls led Calvin to infer the "tremendous crushing, and shearing strains to which these rocks have been subjected."[48]

THE SIGNIFICANCE OF FOSSILS IN BRECCIAS

The question whether the zones of breccia just described are fossiliferous or unfossiliferous is one of moment. A fossiliferous matrix such as that of the glacial breccia uplifted from the sea floor to form the Chaix Hills, Alaska, has obvious

[47]Calvin, Geol. of Buchanan County: Iowa Geol. Surv., Vol. VIII, p. 225.
[48]Ibid, p. 226.

implications. Fossiliferous fragments admit of several explanations. It was early stated by McGee[49] of the breccia at Fayette that "both fragments and matrix are sometimes fossiliferous and their fossils are identical." The fragments of the breccia are abundantly fossiliferous when the *Spirifer pennatus* beds or the Upper Davenport are involved. No fossils have yet been found in fragments from the Otis. This terrane is not involved in the major brecciations to the south where it is fossiliferous, and so far as is known it is unfossiliferous north of Linn county in the area where it contributes to the breccia. The Independence certainly has its highly fossiliferous tracts, but these appear to be so few that no fossils have been found in the Independence breccia zone except in the one little-disturbed fossiliferous tract of the Linn section (p. 388). The characteristic

FIG. 71.—Large blocks of Upper Davenport limestone along the top and at the right. Railway cut north of Vinton, Benton county.

[49]McGee, W J, Pleistocene History of Northeastern Iowa: 11th Ann. Rept. U. S. Geol. Survey, Pt. 1, p. 319, Washington, 1891.

fossils of the shale are fragile, it is true, but if they had been contributed in any large numbers to the breccia, they surely would have been recognized.

The matrices of all zones are entirely unfossiliferous, so far as is known. This statement is hardly necessary for the limestone and calcite matrices of the crackle and mosiac breccias and the close-set rubbles of the Otis and Lower Davenport zones. Where the Independence detritus constitutes the matrix some caution is needed in observation. The fossils of the *Spirifer pennatus* beds are very readily detached and may be picked up free of inclosing lime rock on any weathering outcrop. It is therefore to be expected that where the *Spirifer pennatus* beds contributed to an Independence matrix breccia not only fossiliferous rock fragments but also an occasional detached fossil may be found. In three instances detached shells of an *Atrypa* or an *Orthis* have been observed in the Independence matrix. In each case the *Spirifer pennatus* beds contributed to the breccia of the zone in which the fossils were found. In no case did the appearance of the shells or their filling warrant the assumption that they originally belonged to marine sediments which now supply a matrix to fragments which had been deposited among them. The filling of these shells was hard limestone of the *Spirifer pennatus* beds facies, and not soft earthy Independence matrix. In no case has a fossil been found in the Independence matrix where the upper fossiliferous beds have not contributed fossiliferous fragments to it.

Cause and Conditions of the Major Brecciation

The extent of the Wapsipinicon breccia at once removes it from the class of merely local breccias such as those due to landslide or composed of talus. The universal angularity of the fragments as well as a number of other considerations forbid its classification as a residual or as a bajada breccia. The close association of crackle, mosaic and rubble breccia proves that it cannot be a shoal, a reef, or a beach, subaqueous breccia, or a raft breccia of any variety.

Subaqueous glide as the cause of the major brecciation cannot be so summarily dismissed from consideration. The glide upon

the sea floor of partly indurated sediments may be supposed to produce sharply angular fragments in the hardened beds and a gradation from crackle to rubble and even to a breccia of sporadic fragments. A zonal arrangement of material is to be expected where the gliding mass includes a sequence of different beds. Weak beds such as shales will supply matrix out of their detritus. More stable tracts may remain unaffected in the midst of a widespread creep. Moreover, subaqueous glide breccias are normally associated with foldings of the strata. In all these particulars the Wapsipinicon breccia tallies closely with those caused by subaqueous glide.

An effective objection to this hypothesis hardly lies in the wide extent of the Wapsipinicon breccia of Iowa. True, all breccias recently referred to glide, so far as the writer is aware, are quite local. But our knowledge of the phenomena of the slump of sediments of continental deltas which are overloaded—or shaken by severe earthquakes—or of sediments laid on slopes accentuated by deformation, is too limited to prescribe the extent possible in such movements.

In glides, however, a certain plasticity of the sediments is necessary—the plasticity of sediments but partly indurated. The summit beds of the gliding mass are the muds and oozes of the sea floor, and these will mix as matrix with fragments of lower beds which have become hard enough to break. In a brecciation so nearly contemporaneous with even the deeper strata involved, beds may be found some distance beneath the surface which will remain so poorly cemented as to flow plastically. But nothing is clearer than that the summit beds of the Wapsipinicon breccia, the *Spirifer pennatus* beds, were thoroughly indurated at the time of brecciation. They were bent but slightly before they were shattered into angular fragments. In no instance do they intermingle as matrix with fragments of deeper beds. From summit to base of the terranes involved, all limestones show only the slightest capacity for yielding plastically to strain, while shales are crushed instead of flowing plastically as mud.

The overlying beds of a subaqueous glide are undeformed. The glide does not die out above, but ends sharply at a horizon

above which the beds are undisturbed. The contact is accordant when the glide has been reworked and leveled by the waves. In this case the overlying beds contain at bottom fragments of the strata of the glide, either rounded and forming a basal conglomerate, or partly angular, forming a breccia-conglomerate with the same significance. If the slidden mass is reassembled below wave base, the superincumbent beds are free from fragments, but the contact is discordant. As we have seen, the Wapsipinicon breccia has no such upper limit. It is covered neither by a basal conglomerate nor by a discordant stratum. The deformations which accompany it have no defined upper limit. They die out gradually.

The base plane of a slidden mass should be accounted for by the composition of the sediments involved. The plane of shear in a glide would hardly traverse well indurated limestones. Shale with superincumbent limestone furnishes an ideal base for a creep down slope of oceanic sediments or for a more vigorous debacle, just as it conditions many subaerial landslides. It is true that the Independence shale is involved in the Devonian breccia of Iowa, but it is not its base. In the northern counties the chief brecciated beds are underlying limestones, thoroughly indurated at the time, as seen by their intimate shattering. Everywhere the strains which gave rise to the brecciating process extended far below the level of the base of the Independence.

Excluding the hypothesis of subaqueous glide for the reasons just given, we reach by elimination the class of endolithic breccias. Of these we may dismiss expansion breccias as far too local, and founder breccias for want of evidence either of foundering or of conditions leading to it. There remains the species of endolithic breccia due to deformation, known as tectonic breccia. Three varieties of tectonic breccia are discriminated, fault breccia, fold breccia, and crush breccia, according to the manner in which deformation is accomplished. It is believed that a satisfactory explanation of the major brecciation of the Iowa Devonian is to be found in deformation by folding accompanied with some faulting parallel or nearly parallel with the bedding planes.

The association of brecciation with folding of the strata in the Iowa Devonian is of the closest (figures 72 and 73). The degree of brecciation is in proportion to the degree of folding and the brittleness of the rock. From a central zone where both folding, faulting and brecciation are most intense, all three effects decrease vertically in both directions, and finally die away. Where deformation is comparatively slight, brecciation is limited to areas, such as the bottoms of anticlines, where the change in direction of the fold is greatest and the

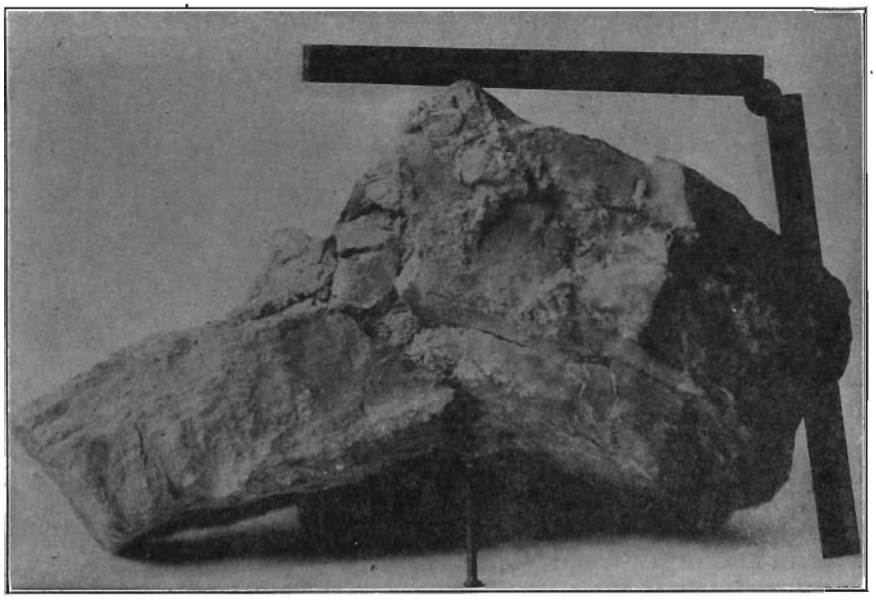


FIG. 72.—Faulted fold in a fragment of Lower Davenport limestone, Linn section, Linn county.

strain most severe. Every gradation may be traced from ruptured and shattered beds to rubble breccia in which fragments of other and different beds are intermingled, so that there can be no doubt that the disruption of the rock into both crackle and rubble breccia are due to the same internal strains.

The degree of disruption varies also inversely with the competency of the stratum. Thick beds of tough granular Upper Davenport limestone break into large blocks which grind upon each other and are more or less rotated and displaced accord-

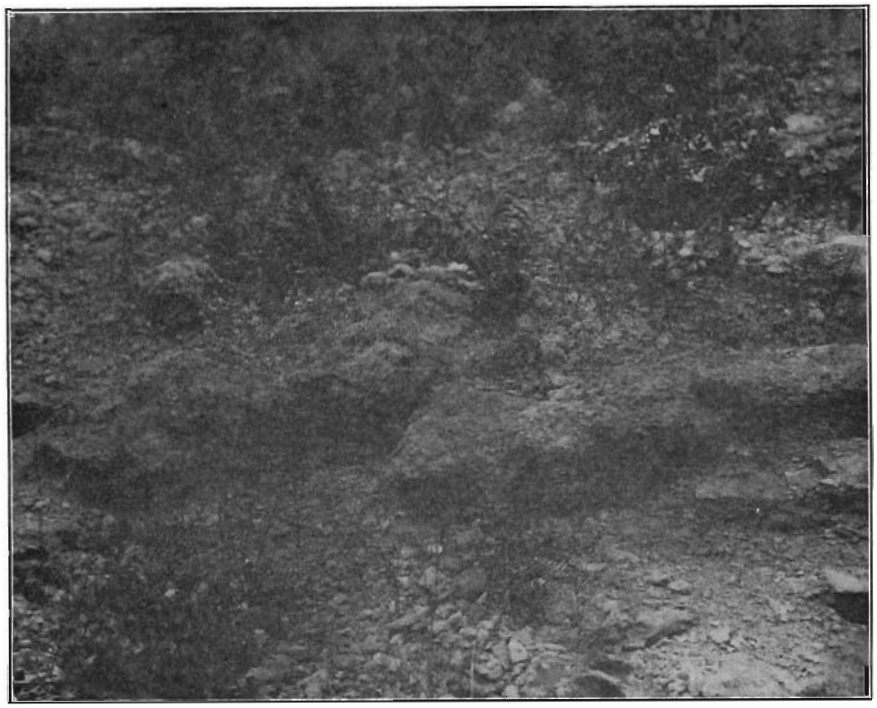


FIG. 73.—Faulted massive bed of Lower Davenport fragmental limestone. Base of Section E, Felton creek, Cedar Rapids, Linn county.

ing to the intensity of the stresses and the movement of the underlying beds.

The terrane of special weakness in the Wapsipinicon complex is clearly the Independence. At this horizon brecciation is most intense. This body of shales and impure limestones is locally crushed to fine detritus which serves as a matrix to the fragments of the inclosing limestones and of its own more resistant beds. Because of the yielding of these shales the limestones either immediately above it or below, or both above it and below, receive the maximum strains and are broken up more completely than those more distant. The horizon of the Independence is therefore the horizon of the major brecciation. The Lower Davenport is brecciated readily and in many places completely both because of its nearness to the Independence and also because of the brittleness of its thinly laminated limestones. It seems in places to have broken to pieces under strains hardly

more severe than those necessary to brecciate beds of chert of equal thickness. Indeed, there are exposures, e. g., near Cedar Rapids and along the Mississippi north of Davenport, where the Lower Davenport is partly brecciated, while the more elastic Independence seems to have very largely escaped. The Otis shows compressive strains in its low undulations which are generally sufficient to shatter its calcilutites, but leave its basal granular magnesian limestones little affected, while the still deeper brittle Bertram beds are only intimately crackled.

The sharp angularity of the fragments of the breccia in all its zones also points to a tectonic origin (figure 74). Wear by ocean waves and streams after fragmentation is entirely precluded. The angularity of the fragments even offers some difficulty to the theory of fold and crush. The intimate commingling of beds suggests considerable horizontal movement in drag folds and along planes of shear under which more wear by mutual attrition might be expected than is actually to be observed.

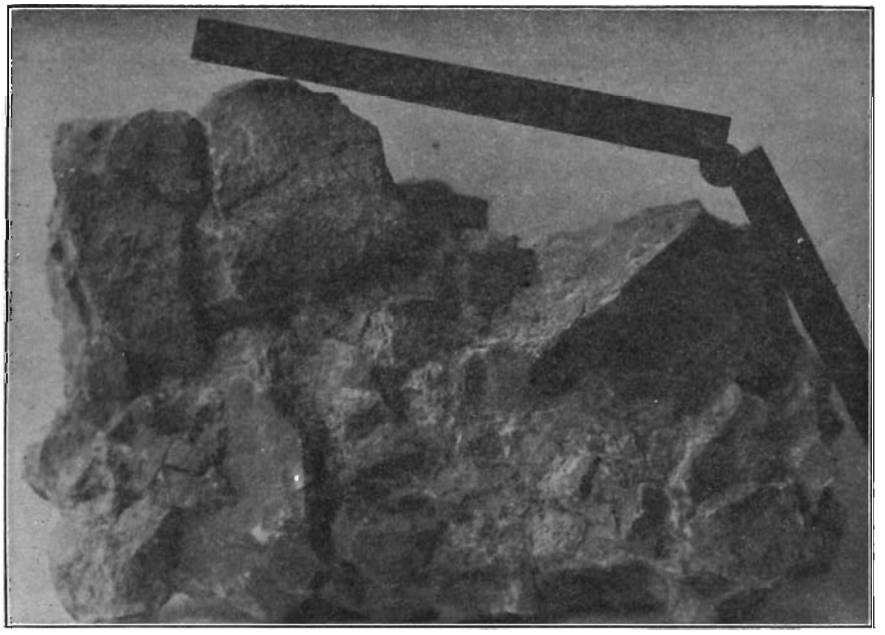


FIG. 74.—Breccia of Lower Davenport limestone fragments. Schmidt's quarry, Davenport, Scott county.

The date of a tectonic deformation is fixed as not earlier than the latest strata involved. As we have seen the strains of the major brecciation die out in the Cedar Valley limestone. Here and there, as at Osage, local folding accompanied by brecciation occurs well up in the Cedar Valley limestone, but these occurrences are so limited in the thickness of the rocks affected that they may perhaps be best explained by subaqueous glide. We may therefore conclude that at some time later than the deposition of the limestones of the lower life zones of the Cedar Valley, the Devonian terranes suffered deformation under lateral pressure. The Wapsipinicon complex was thrown into low troughs and arches. The Independence and the laminated calcilutites immediately adjacent to it formed a zone of special weakness and these terranes were crushed and brecciated and their fragments intermingled. The Upper Davenport and the *Spirifer pennatus* beds also were involved in the brecciation largely because of the incompetency of the supporting strata. It remains to be stated that the foldings of the various beds of the Wapsipinicon are accordant. This is best seen where the folding is least intense as at the Cedar Rapids quarries where a single set of low undulations involves both Otis and Independence, and along the cliffs of the Volga west of Fayette where the same accordance is seen between the Independence and the Davenport and Cedar Valley limestones. Where the stresses were more severe the Independence naturally yielded in more numerous and sharper folds than affect the more competent beds.

From the accordance just stated we may infer that the major brecciation was due to a single diastrophic movement dating not earlier than the Cedar Valley, rather than to a succession of deformations.

The Minor Brecciations

The theory of a single tectonic deformation occurring not earlier than the Cedar Valley stage accounts, as we have seen, for the larger phenomena of the Wapsipincon breccias. But there remain certain outstanding facts still unexplained.

Davenport brecciations.—We may mention first a number of lines of evidence converging in proof of a minor brecciation of the Lower Davenport at a time about its close. Blocks of this limestone are found not infrequently which themselves are brecciated (figure 75). Such a block is composed of detached laminæ imbedded in a paste identical in texture and nearly of the same color as the fragments. The block itself, along with other blocks and fragments of the Lower Davenport, the Upper Davenport, and some of the stronger rocks of the Independence, is

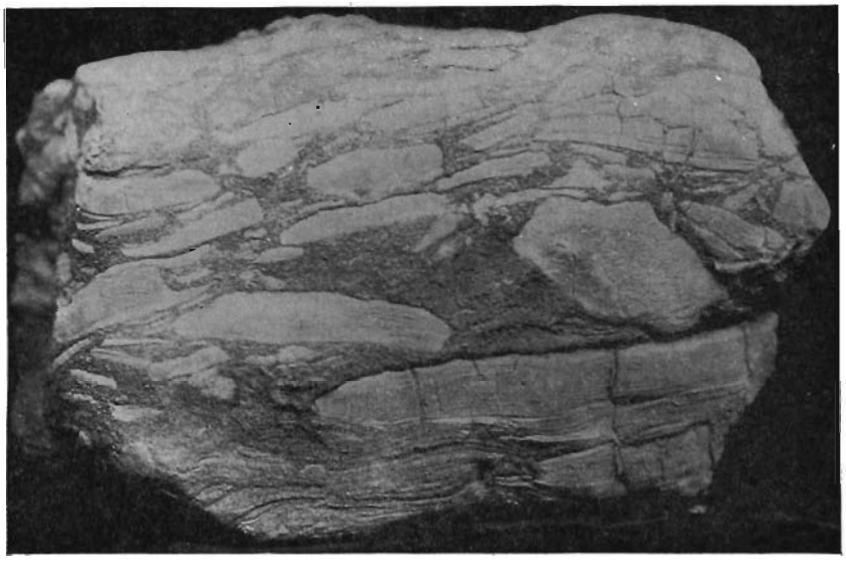


FIG. 75.—Complex brecciation, with parallelism of detached laminæ in fragment. Linn section, Linn county.

mingled with the Independence buff and earthy detritus. The major brecciation fully accounts for the breaking up of ledges of thoroughly hardened Lower Davenport and the incorporation of the blocks in the chaotic mass of debris. But the structure of the block can no more thus be explained than the intimate structure of a bowlder imbedded in till can be explained by glacial plucking. The brecciated structure of the block shows clearly that while the calcareous oozes of the Lower Davenport sea floor were still unset, laminæ already indurated were somehow broken

up and mingled with the oozes to form new layers. In many cases the fragments of the laminæ retain much of their parallelism and their attitude suggests incorporation by mass movement rather than by ordinary sedimentary deposition of the fragments by wave and current. A few blocks show distinctly the effect of movement under pressure. In figure 76, from the Linn section, a mass of minute fragments of thin plates shows distinctly convergent and divergent lines on either side of a narrow gate between the ends of a broken thicker layer. The attitude of the laminæ strongly suggests movement under pressure through the gate.

The same radiation of lines of unequiaxed fragments of broken laminæ at a parting in a thicker layer was observed in fragments at Troy Mills.

Contemporaneous brecciation is seen also in fragmental saccharoidal limestones, which are found at a number of exposures of the Lower Davenport. Thus at Bettendorf the Lower Davenport limestone includes toward the base of the quarry section white saccharoidal limestone which contains sparse fragments of drab calcilutite whose fragmentation must have antedated the formation of the layer in which they are imbedded. Here the major brecciation left the strata undisturbed. The same phenomenon occurs in No. 7, Section A, Felton creek, Cedar Rapids (p. 520). At Section E on the same creek the lower zone exposed exhibits faulted and tumbled blocks of heavily bedded fragmental limestones whose fragments include several different lithologic types (p. 522). The breaking up of the original beds and the assemblage of the fragments in the heavily bedded limestones must have long preceded the major brecciation which faulted the ledges and left their tumbled blocks at the base of a breccia hodge-podge which includes fragments of the Upper Davenport.

In a number of blocks contacts are seen between the Upper and the Lower Davenport, which indicate a brecciation of the lower bed so nearly contemporaneous that the upper had not had time to become indurated at time of brecciation. Blocks indeed are sometimes found which show the lower surface of the Upper Davenport resting upon the parallel unbroken laminæ of the Lower Davenport. Here there is entire conformity.

But in other cases the upper layers of the calcilutite, the only ones present in the block, have been crackled, or more completely shattered and the paste of the Upper Davenport fills the fissures to some depth, as in figure 77. It will be noted in this

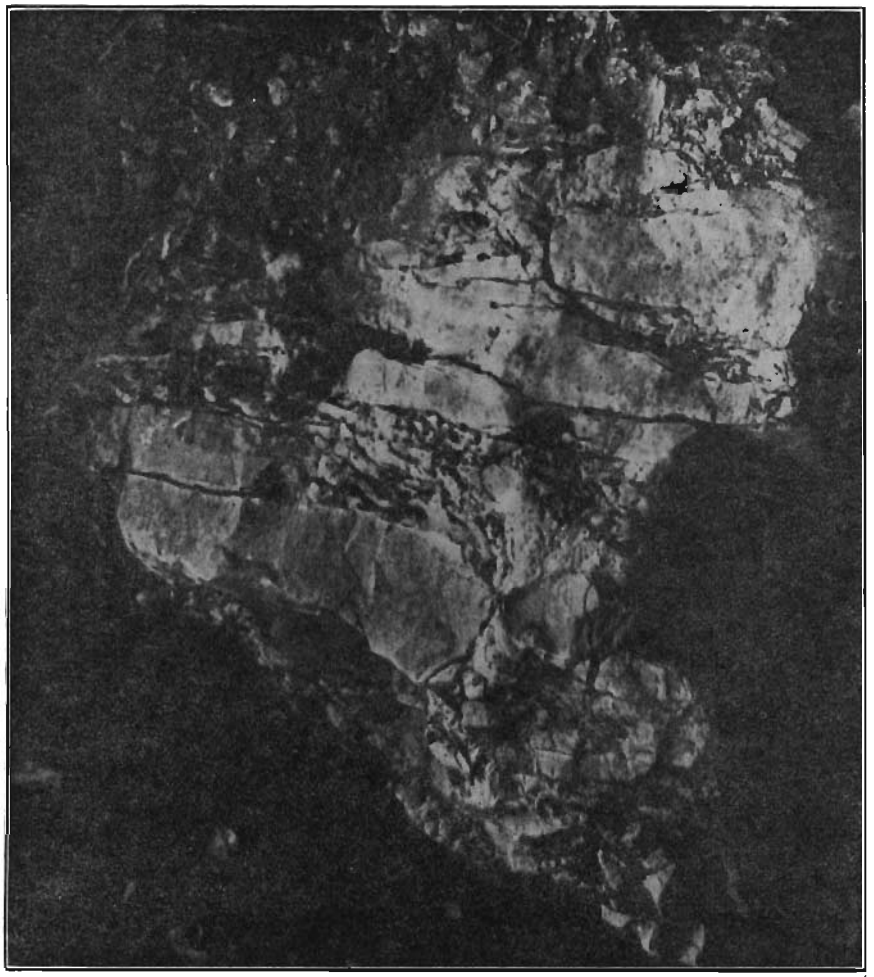


FIG. 76.—Fragment showing complex brecciation. Linn section, Linn county.

figure that the whitish calcilutite beneath is a mosaic breccia. The fragments largely match along their apposed surfaces and for the most part retain their original horizontality. Their position is not that of a bed of fragments assembled on the

Fig. 77.—Block of breccia. Section E, Felton creek, Cedar Rapids, Linn county. Light rock, Lower Davenport. Dark rock, Upper Davenport.

ocean floor by waves to be covered later by the gray limestone of the Upper Davenport. The brecciation of the calcilutite evidently did not precede the deposit of the darker limestone upon it. It occurred after the deposit of the basal layer of the Upper Davenport, but while the latter was still so pasty that it could be pressed in plastically among the fragments into which the brittle calcilutite underneath it had been broken.

From Davenport to Independence the basal layers of the Upper Davenport limestone or the blocks into which it has been broken contain sparse, small angular fragments of calcilutite of the Lower Davenport facies (figure 78). They do not form a sedimentary layer and they show no signs of water wear. They are distributed sporadically and set at all angles but blocks are seen on whose surfaces the fragments seem to have been impressed, leaving the surface of the block and that of the fragments flush.

These fragments are to be distinguished by their shape and attitude, if not microscopically by their structure, from the thin horizontally lying lenses of organic origin which have been already mentioned as occasionally found in the Upper Davenport.

Angular fragments of a stratum of limestone incorporated sporadically in the stratum immediately above are so rare among sedimentary rocks that some cause outside the ordinary course of sedimentation is to be inferred. A reef of calcilutite might perhaps be plucked by waves and its fragments mingled with a coquina depositing in deeper waters. But all of the phenomena just mentioned which prove an early fragmentation of the Lower Davenport limestone are associated together, and a common cause is to be found for all if possible. The incorporation of fragments is to be explained by the same cause as that invoked to explain complex brecciation. That this common

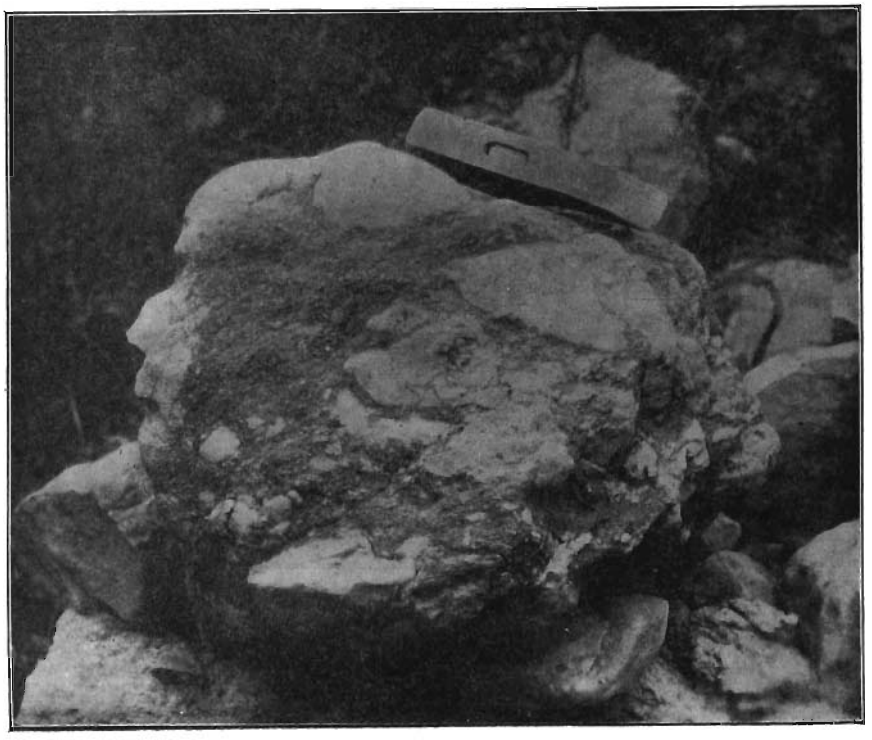


FIG. 78.—Block of dark granular Upper Davenport limestone with included fragments of Lower Davenport calcilutite. Aungst quarries, north of Vinton, Benton county.

cause is to be found in brecciation under internal strain is confirmed by an example of Schmidt's quarry, Davenport (figure 79). At one point in this quarry fragments of Lower Davenport calcilutite are more conspicuously intermingled with the Upper Davenport coquina than at any other locality known, and they range from the bottom of the beds to include the coralline layer near the top. At this particular point the beds are strongly deformed. A bed of Lower Davenport rubble breccia (A), two feet in thickness is pressed up at an angle of 40° against a mound of blocks of Upper Davenport with which fragments of the same calcilutite are intimately commingled both within and between the blocks. Evidently the incorporation of fragments

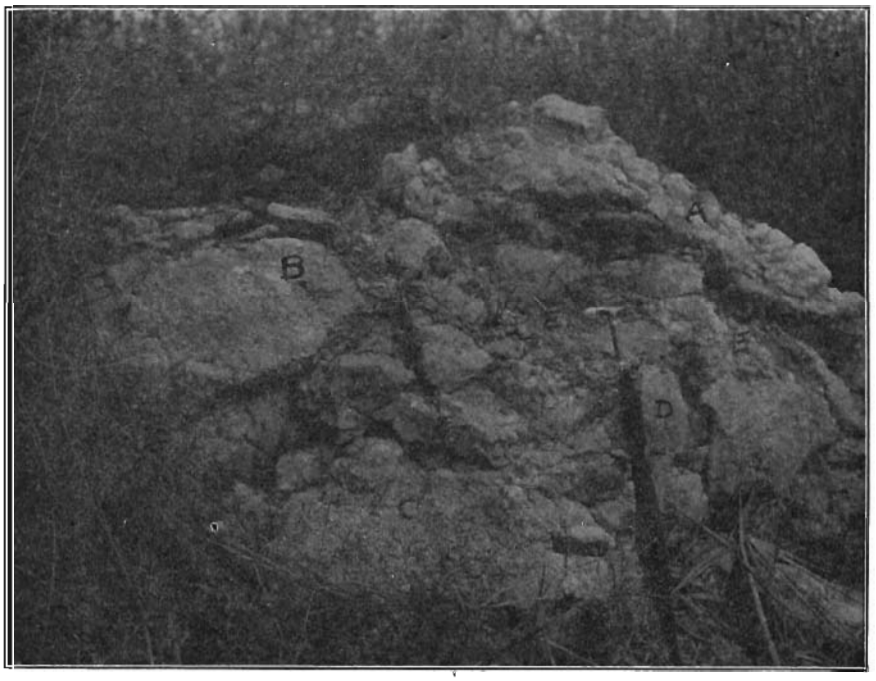


FIG. 79—Mound of Upper Davenport limestone, with small fragments of Lower Davenport calcilutite commingled. Schmidt's quarry, Davenport.

A. Rubble of small close-set fragments of Lower Davenport calcilutite in tilted bed two feet thick, matrix of chinkstone and like fragments.
B. Block of Upper Davenport limestone with a central horizontal zone in which small calcilutite fragments are sporadic. Corals are imbedded both above and below this zone.
C. Block in which Lower Davenport fragments are thickly inset in Upper Davenport matrix.
D. Blocks in which Lower Davenport fragments are very few.
E. Rubble breccia similar to A.
F. Rubble breccia of Lower Davenport fragments in a sparse buff matrix.

in the Upper Davenport and the deformation are due to a common cause and both took place while the Upper Davenport coquina was still plastic and the Lower Davenport calcilutite was firmly set.

An alternative hypothesis is that while the Lower Davenport fragments were incorporated in the Upper Davenport while the latter sediments were still unindurated, the deformation, the formation of the tilted bed of Lower Davenport breccia (figure 79-A) and of the breccia of the same type imbedded between the Upper Davenport blocks (E) occurred later, presumably at the time of the major deformation. Against this hypothesis stands the close similarity in size and facies of the fragments of the rubble breccia and the sporadic fragments within the blocks or deeply impressed upon their sides. The number of the imbedded fragments here in the Upper Davenport is entirely exceptional. Hence the improbability that precisely at the point where the Upper Davenport sediments had somehow become commingled to such an extraordinary degree with fragments of the Lower Davenport a later local deformation should have again crushed the Lower Davenport beds to breccia. While all the phenomena appear to be caused by a single deformation, it is possible that this deformation was that producing the major brecciation, *provided that the major deformation took place while the Upper Davenport sediments were still unindurated.* This is impossible if the Upper Davenport beds are to be dated by the First Fauna which they contain, that is, if they are contemporaneous with the *Gyroceras* beds of Linn and Buchanan counties. For the major brecciation certainly occurred in these counties after the arrival of the Fifth Fauna and the deposit of heavy beds of limestone upon the Upper Davenport. The hypothesis may be entertained if the Upper Davenport beds of Scott county were contemporary with the arrival in the north of the highest fauna which they include. To what extent the higher Devonian limestones of Scott county share the deformation of the Upper Davenport has not been ascertained. The Upper Davenport itself is largely in place. Contacts with higher beds are found only at a single locality—Schmidt's old quarry, where exposures of the higher beds are few and small and obscure. Against this hypothesis lies the fact that the inclusions of fragments of Lower Davenport calcilutite in the Upper Davenport beds is common throughout the Wapsipinicon area as far north as Independence, and it is probable that the inclusion took place under the same conditions and at the same time. In the northern counties this inclusion could not be due to the major deformation, since that took place long after the deposit of the Upper Davenport and its induration. The phenomena in question seen in figure 79 are therefore referred to the minor brecciation which occurred soon after the close of Lower Davenport time.

The entire group of phenomena seem best explained by a succession of subaqueous glides producing local mass movements of the sediments. Beds of more or less indurated rock would thus be broken up. Their fragments would be mingled with unconsolidated sediments and thus in moving on to form new beds

would retain their angularity far more than if handled only by wave and undertow. Thus fragments of Lower Davenport calcilutite were imbedded in a paste of the same nature, and saccharoidal and other limestone fragments were completely commingled. Still later indurated beds of Lower Davenport were shattered and their fragments were taken up in glides of the Upper Davenport sediments which then formed the sea floor.

The crackle breccias into whose seams the Upper Davenport paste is injected, and the accompanying deformations, as at Davenport, suggest as an adequate cause of these glides a slight ridging of the strata under lateral pressure with perhaps a shattering by accompanying earthquakes.

Independence brecciations.—The evidence for contemporaneous Independence brecciations is somewhat different from that of the superior terranes. This evidence consists of fragmental limestones and local beds of breccia where the formation as a whole has been little disturbed. In the Chicago and North Western Railway quarries at Cedar Rapids, for example, the Independence contains a bed of fragmental limestone, a rubble breccia of small fragments with an hummocky upper surface (No. 8 of section, p. 518). The bed is formed in situ by the breaking up of a layer of laminated limestone, for in places there exists a complete lateral gradation into crackle breccia. So far, this might all be due to the strains of the major brecciation. But in places the fragmental layer graduates upward into soft buff earthy Independence limestone in which its fragments are sporadic. Fragmentation here took place before the deposit of the beds of the Independence which rest upon the fragmental layer. In places in the Independence zone of breccia fragmental limestones occur in blocks which are of characteristic Independence facies. Matrix and minute, in some cases sporadic, fragments are commonly much alike, although fragments of a different lithologic type may also be present. The matrix is not of chinkstone and calcite—the typical matrix of a bed of rocks crushed after complete lithification but not intermingled with other fragments. Even a calcite matrix in a fragment of breccia which itself is brecciated demands explanation. But in these cases the matrix appears to be of contemporaneous sedi-

ments and thus is proof of contemporaneous brecciation. Nor is it to be expected that the same stresses which crush a rock to minute bits will break the recemented layer into blocks and imbed them in very heterogeneous breccia.

Where the Independence is very little disturbed there are limited tracts which show complete brecciation. Such could be accounted for by the yielding of certain weak beds to the lateral pressure of the major brecciation while the stronger beds which inclose them took up the thrust without deformation. For example, at Cedar Rapids (No. 3, Section C, Felton creek, p. 521) we have a rubble breccia six feet thick intercalated in impure limestones which remain about horizontal. The beds have suffered lateral pressure, for the lower two and one-half feet of the thickly bedded limestone immediately above the breccia is bent to low undulations. The pressure was sufficient to brecciate thin-layered limestones and shales at this horizon, for the thick-layered limestone above the breccia is broken into large blocks at the axis of a syncline. So far there is nothing which cannot be explained by deformation at the time of the major brecciation. But the breccia contains a large variety of lithologic types. It seems improbable that six feet of the Independence or some commensurate larger vertical dimension, should contain so many types. Certainly no such variety is anywhere in evidence in Independence outcrops within equal limits. On the other hand a subaqueous glide collecting its material from different depths and spreading it in varying thicknesses could readily assemble all the debris of the breccia bed and upon it would be deposited the horizontal limestones of the section. Later, under the strain of the major brecciation, the limestone in immediate contact with the breccia was slightly bent and at one point broken.

To what extent the intermingling of different beds of the Independence and those of the Otis limestone seen in the Independence zone of breccia is due to contemporaneous subaqueous glides in Independence time is impossible to determine. The major brecciation wherever complete effaced evidences of former brecciations except that of brecciated fragments. The fragmental limestones of the Independence where of depositional

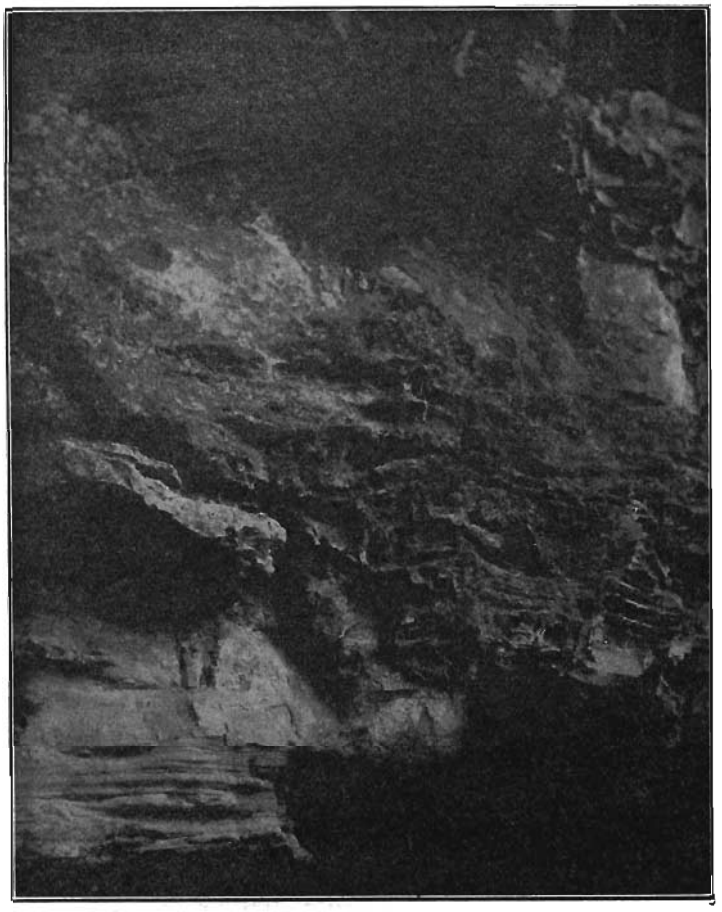


FIG. 80.—Portion of cliff, "Cedar Bluffs," on Wapsipinicon river about three miles southeast of Troy Mills, Linn county.

origin, either found now in continuous beds or in detached blocks imply no great disturbance at the time of their formation. They may be due to very local glides extremely limited in depth, or to the action of waves and tides on shoals. Fragmental layers of similar origin are to be found both in the Otis and in the Bertram limestones, but they require no further description than that already given in the sections of the outcrops of these formations.

The Independence in some places presents angular cavities due to the removal of fragments under weathering. Where the

fragments were close set there results a reticulated surface as the matrix is left standing in narrow partition walls in high relief. Such surfaces are common on stacks and cliffs of the Monroe breccia of Mackinac Island, Michigan, and the adjoining shores of the mainland. In the Independence breccia they are seen along the Wapsipinicon river outcrops and are specially noteworthy at "Cedar Bluffs" three miles southeast of Troy Mills (figures 80 and 81).

SECTIONS OF THE WAPSIPINICON

Fayette County

In all the sections of the Wapsipinicon in Fayette county the breccias are very much alike, and with the exception of some minor phenomena all are referred to the major brecciation.

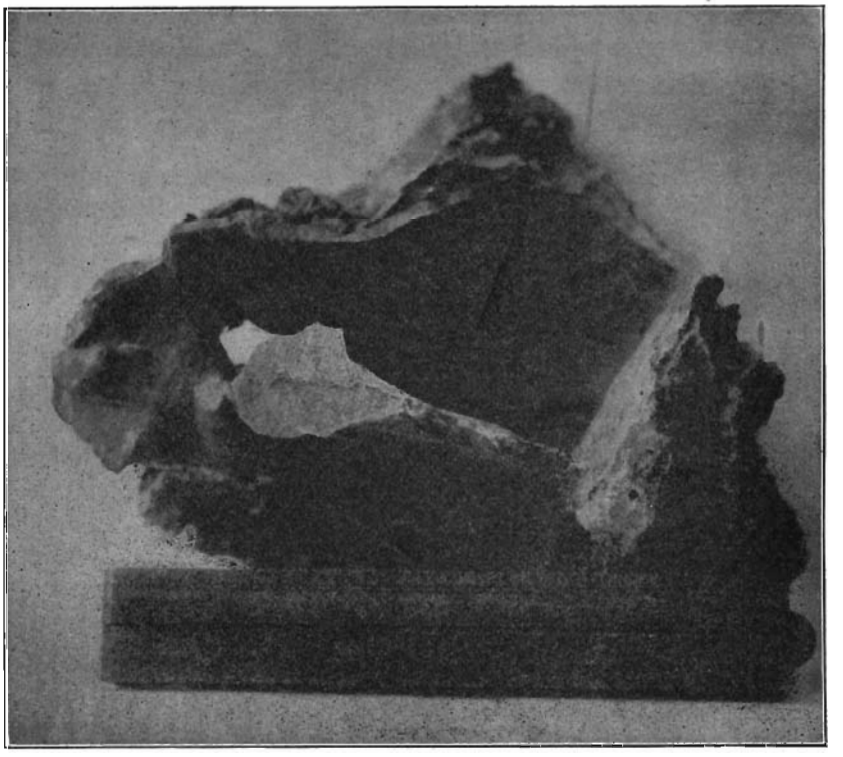


FIG. 81—Matrix from which fragments have been removed by weathering. Independence beds, on Wapsipinicon river at Cedar Bluffs, about three miles southeast of Troy Mills, Linn county.

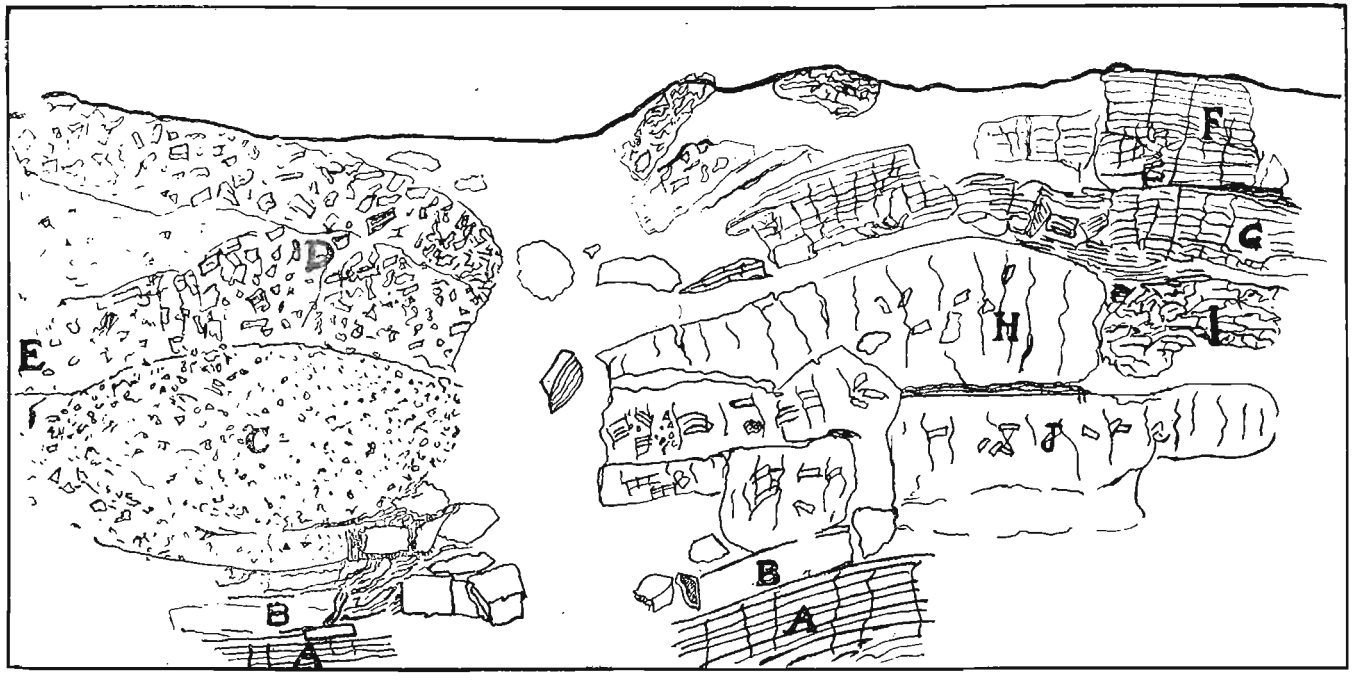
Under the horizontal pressure of this brecciation the strata adjacent to the weak zone of the Independence were all folded together. The shaly portions of the Independence were crushed to minute fragments and thick limestone beds were broken and displaced. The Davenport limestones generally were only gently arched but in places they were abruptly bent or were broken down into the zone of the Independence. The Otis calcilutites immediately beneath the Independence in many instances remained in place. Here they were crackled and in some cases broken to endostratic mosaic breccia passing into rubble. In places they were completely removed and broken up. The thinly laminated Otis beds beneath were in places heavily dragged along their upper margin where the Otis calcilutite ledge also was torn away, as at Eagle Point. Everywhere they were bent to low folds and crackled. They were also brecciated along joint planes and the axes of synclinal folds. The massive basal dolomites of the Otis, the Westfield phase, supported by the Niagaran strata, were strong enough to endure the strain without visible signs of deformation.

Fragmental limestones of the Independence seem to imply disturbed sedimentation during that period. Further brecciation during Independence time may be responsible for some of the sporadic breccia of this zone, but of this there is no clear proof.

Northern Sections.—The most northern exposure of the Wapsipinicon lies in the northwestern township of Fayette county on Crane creek, where a cliff of Devonian limestone thirty-five feet high embraces beds which range from the *Acervularia profunda* beds at the top to brecciated calcilutite beds at the bottom.[50] About a mile and one-half to the east of this section there is exposed on the bank of a small stream a succession of beds of which the two lowest are described as follows by Savage.[51]

	FEET
2. Bed of yellowish gray limestone in rather indistinct layers which are checked with numerous joints; containing *Productella subalata, Pentameralla dubia, Gypidula comis, Spirifer pennatus, Atrypa reticularis, A. aspera* var. *occidentalis*	8

[50]Savage, T. E., Geol. of Fayette County: Iowa Geol. Surv., Vol. XV, p. 511.
[51]Ibid, p. 509.



Section in City quarry, West Union, Fayette county. Outlines drawn from a photograph. A, Laminated Otis limestone, No. 2 of quarry section. B, Otis limestone, No. 3. C, Lens of broken Otis calcilutite continuation of H—J. D. Rubble of Otis breccia, many fragments of which are three to four inches in diameter. E, Rubble breccia of large Independence matrix with Otis fragments. F, Crackled laminated Otis calcilutite, in places a mosaic breccia. G as F, but somewhat more brecciated, faulted, and laminæ bent in places and rotated. H, Massive, finely crackled and some fragments displaced. I, Mosaic breccia. J, Ruptures chiefly vertical, mosaic-crackle breccia.

1. Bed composed largely of light colored shale in which a few irregular fragments of limestone are imbedded. Such fragments become more abundant in the lower part; talus-covered to bed of stream..... 7

Although this and the preceding outcrops were not visited by the writer, we may easily identify No. 1 with the Independence zone of breccia since No. 2 is the horizon of the Upper Davenport.

West Union.—A quarry opened within the corporate limits of the city of West Union on the left bank of a small creek exhibits the laminated Otis limestone, somewhat folded and crackled; and resting upon it brecciated Otis calcilutites, and in places breccia of the Independence type.

1. The lowest beds now visible in the quarry are apparently the same as the more massive magnesian limestone seen at the bottom of the railway cut at Fayette and situated near the base of the Devonian.
2. Upon these lies thinly laminated nonmagnesian limestone about four feet thick. As at Fayette this member has been thrown into gentle undulations about six feet from crest to crest. The laminæ also show slight crenulations two or three inches in width, and are everywhere crackled. The mesh work is as fine as an inch in diameter and the ruptures are filled with calcite. Under the weather this bed breaks into thin ringing plates (Plate IX, A).
3. Number 2 is capped in entire conformity by a nonlaminated layer of pinkish calcilutite about six inches thick. The faces of the layer are smooth, but the layer is finely fragmental, especially toward the top, and is made of fragments two or three millimeters in diameter. It is thicker in places and thinner in others, and the upper surface is irregular (Plate IX, B).
4. At the north end of the quarry No. 3 is succeeded by Otis calcilutites about seven feet thick. These layers, like those below, are bent into low arches, but either because of stronger stress or of less ability to withstand it, they are partly brecciated. The layers retain for the most part their continuity. In part they are shattered to a mosiac breccia with close set vertical calcite seams and most of the small intercepted fragments still in place. A few, however, are rotated from their original position and here and there the laminæ are bent and faulted (Plate IX. F, G, H, J). At one point is seen a lens (Plate IX, C) two feet thick made of cemented fragments some of which reach an inch in diameter, although most of them are minute. At the left this lens and the layers above it break down into a rubble breccia, and the same is true of the entire thickness of the Otis calcilutite bed a few yards to the right. Here the Otis is completely broken up and mingled with buff Independence debris; and the latter is predominant in the center of the east side of the quarry (figure 82).

Here for a distance of a few feet the Independence rests directly upon the minutely fragmental layer which tops the thinly laminated Otis beds. Immediately to the right of the view ledges of Otis calcilutite again appear arching upward on the limb of an anticline which includes the entire vertical sequence of the quarry beds. The same removal of the Otis calcilutite ledges—or their lack of deposition—over extremely limited areas, and their re-

placement by a breccia of predominant Independence debris with some shaly beds remaining uncrushed is seen at Eagle Point near Fayette and in the quarries north of Vinton.

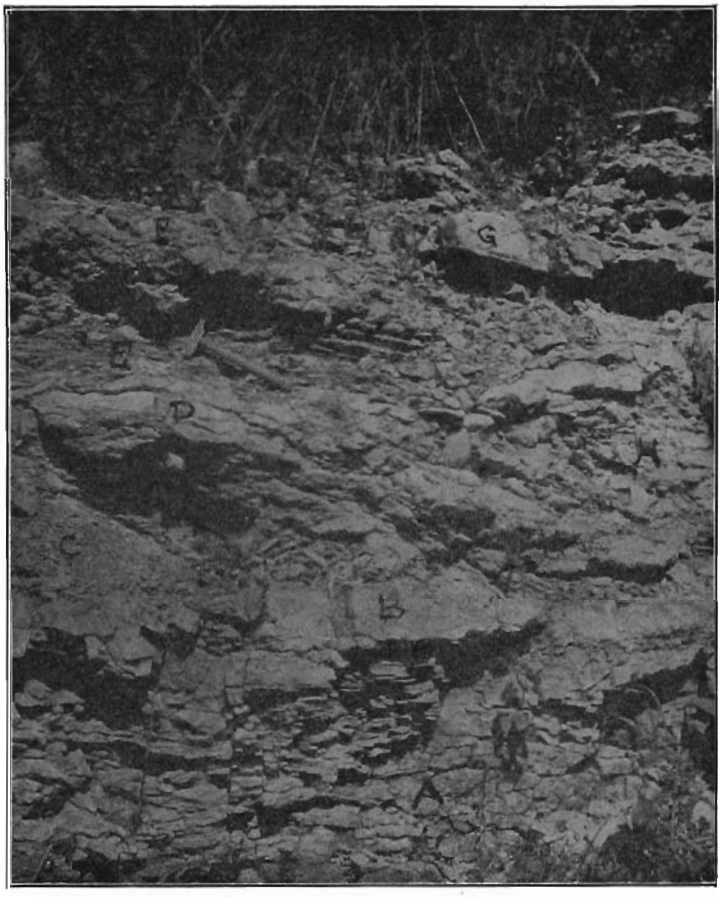


FIG. 82—H. Layer of calcilutite four inches thick underlain by a few inches of buff thinly laminated shale.

G. Breccia of Otis calcilutite fragments well cemented passing to the right into strata of Otis in place.

F. Breccia of Independence zone; much soft buff detritus, fragments mostly under three inches in diameter.

E. Shale, buff, thinly laminated. At right of hammer is an inch layer of minute fragments of calcilutite in a yellow matrix intercalated in shale.

D. Earthy buff limestone of Independence type, in part fragmental, over which the shale of E arches.

C. Breccia, Independence buff shale preponderating in fragments, with sporadic fragments of calcilutite which is more numerous to the left until in a few feet C graduates into a rubble breccia of Otis calcilutite.

B. Otis limestone, minutely fragmental upper layer.

A. Otis, thinly laminated beds, limestone plates bent and crackled.

Westfield Bridge Section, Fayette.—The upper part of this section is given by Savage as follows:

		FEET
13.	"Decayed zone composed of thin fragments, which in places are crowded with valves of *Newberria johannis*. Weathered individuals of *Acervularia profunda*, *Cystiphyllum americanum*, *Cladopora iowensis*, and Favosites sp. occur in the upper part	1
12.	"Bed consisting of fine-grained, yellow impure limestone in layers two to eight inches thick. The layers are somewhat broken, and contain the fossils *Atrypa reticularis* and *A. aspera* var. *occidentalis*. Small cavities lined with crystals of calcite are not rare	5½
11.	"Bed of yellow colored impure limestone in three layers. * * * besides the fossils in No. 12, *Pentamerella dubia* and *Spirifer pennatus* occur in the lower layer	7
10.	"Bed of rather massive yellowish gray limestone, less magnesian than the layers of No. 11 above, somewhat broken, but the large fragments lie in the general plane of the original layers; containing in the upper portion Favosites sp., *Pentamerella dubia*, *Gypidula comis*, *Spirifer pennatus*, *Atrypa reticularis*, *A. aspera* var. *occidentalis* and *Hypothyridina cuboides*.[62]	8"

The lower part of the section is supplied by the writer:

9.	Limestone, Independence, buff, unfossiliferous, in irregular layers, in part fragmental, fragments of buff limestone like matrix usually lighter in color, some of two or three inches diameter, but mostly minute. In places the layers are broken into fragments, some of two feet diameter, set at all angles. Some layers are arenaceous with white chert sand. Nodules of whitish crystalline silica occur. Considerable calcite is seen in interstitial seams. Upper surface somewhat irregular with depressions two inches in depth with a horizonal diameter of six inches, filled with the limestone of No. 10. In places upper surface is crossed by close unhealed fissures whose general direction is NNE. Bed graduates beneath into clayey shale	7
8.	Breccia, Otis calcilutite, Cedar Rapids phase, in highly irregular courses, in places massive, endostratic, fragments and matrix of light brown calcilutite weathering to gray. In places occur layers of laminated calcilutite, undulating but not brecciated	10
7.	Limestone, Otis, gray, fine-grained, weathering to thin plates, which on dislodgment fall with a submetallic tinkle	11
6.	Limestone, buff, effervescence rapid in cold dilute HCl; laminated, with some brownish partings. Upper surface irregular, graduating in places laterally into the thin plates of No. 7. In two layers	3
5.	Limestone, blue-gray where unweathered; in two irregular layers, the upper 1½ feet thick, for the most part massive, but in places laminated to one-half inch; effervescence slow. Distinguished by angular fragments of white chert of which few exceed three or four mm. in diameter, giving to certain bands the appearance of	

[62]Savage, T. E., Iowa Geol. Surv., Vol. XV, p. 502, Des Moines, 1905.

a chert sandstone. With argillaceous partings from beds above and below..... 2

4. Dolomite, gray, highly arenaceous with minute angular bits of cryptocrystalline silica and rounded grains of fine quartz sand..... 3
3. Dolomite, yellow-gray, upper 1½ feet massive, lower foot in layers from ½ to 3 inches. Thin shaly partings in places between the two members. Highly arenaceous with coarse angular chert sand..... 2½
2. Clay, greenish yellow, plastic, gritty..... ....1-12 to 2-3
1. Dolomite, Niagaran, yellowish, upper surface irregularly curved; chert nodules abundant; small cavities numerous; layers up to five feet in thickness. Fossils identified by Savage as *Lyellia americana, Favosites favosus, Halysites catenulatus, Leptaena rhomboidalis.* To level of Volga river 15½

The basal bed of this section, No. 1, was recognized as Silurian by McGee[53] and was proved by Savage to belong to the Delaware stage of the Niagaran.[54]

The beds of arenaceous dolomite which rest upon No. 1 resemble it somewhat in general facies, but with some marked distinctions. They are separated from it by shaly partings along an irregular surface which simulates or constitutes a parallel unconformity. They are unfossiliferous. The chert which they contain is in the form of layers of sand and gravel instead of in nodular concretionary masses. They thus represent a wholly different type of sedimentation from that of the quiet waters and coral dotted sea floor of the Niagaran as preserved in the fossiliferous dolomite of No. 1. The cherty nodules of the Niagaran had now been broken up by long weathering during an erosion interval or by the attrition of waves upon the shore. The minute fragments to which the cherts had been reduced were swept by comparatively powerful currents and mingled with limy oozes to form Nos. 3, 4 and 5 of the Westfield section. These beds are regarded by Savage as belonging to the Niagaran. But although they resemble the Niagaran in their dolomitization, they are here assigned to the Devonian because of their arenaceous content which gives them the characteristics of a basal conglomerate, which derived its material from the obdurate constituents of the subjacent stratum. Similar beds occur at the same horizon in Bremer county (p. 470). The contact between the Silurian and the Devonian is thus held to occur at the summit of No. 1.

[53]McGee, W J, Pleistocene History of Northeastern Iowa: 11th Ann. Rept. U. S. G. S., p. 315, Washington, 1891.
[54]Savage, T. E., op. cit., p. 502.

Number 7 is unquestionably Devonian and No. 6 belongs with it structurally and because of its small magnesian content. Number 8 is the zone of brecciated Otis calcilutites, and No. 9 is the Independence.

A section a short distance east of the center of section 5, Westfield township, shows the same contact relations.[55]

		FEET
7.	"Bed composed of fragments of drab-colored fine-grained limestone, imbedded in a matrix of calcareous material which also is fine-grained in texture, but lighter in color, without fossils. The layers show slight undulations....	12
6.	"Bed composed of fine-grained yellowish colored limestone which is very finely laminated; upon weathering the material splits along the lamination planes into thin fissile fragments; without fossils.....	9
5.	"Irregular band of yellow colored dolomite, coarse-grained in texture, in places appearing somewhat arenaceous; nonfossiliferous	1½
4.	"Bed of yellow impure dolomite in layers four to eight inches thick bearing some chert and containing *Favosites favosus* and *Halysites catenulatus*.....	3"

Number 4 is stated to rest on beds of fossiliferous Niagaran limestone containing chert concretions and aggregating about eight feet in thickness. Number 7 of this section is identical with No. 8 of the Westfield Bridge section and both belong to the Otis calcilutite zone. Number 6 of this section is the same as the bed of calcareous plates of the Westfield Bridge section, No. 7, which also is referred to the Otis. Number 5, which Savage includes in the Niagaran, is placed by the writer in the Devonian for the reasons stated regarding Nos. 3, 4, and 5 of the Westfield section.

Cut of the Chicago, Milwaukee and Saint Paul Railway, Fayette.— This rock cut, 600 feet long and 50 feet deep, presents a section quite similar to that of the Westfield bridge. Owing to the nearly vertical walls it is less accessible for close study and it does not reach to the Niagaran horizon. The description of the three upper beds is abridged from Savage.[56]

		FEET
7.	Limestone, fine-grained, yellow, impure, in somewhat shattered layers three to nine inches in thickness, containing *Atrypa reticularis* and *A. aspera* var. *occidentalis*.....	11½
6.	Limestone, yellow, magnesian, similar to No. 7, in imperfect layers one and one-half to three feet in thickness, containing *Gypidula comis*, *Spirifer pennatus*, and the Atrypas	8½

[55]Savage, T. E., op. cit., p. 497.
[56]Savage, T. E., Iowa Geol. Surv., Vol. XV, pp. 506, 507.

5. Limestone, gray, somewhat fractured, yet not so thoroughly brecciated but that the original layers can be recognized. The large fragments contain *Favosites placenta, Strophеodonta demissa, Pholidostrophia nacrea, Productella subalata, Orthis iowensis, Gypidula comis, Spirifer pennatus, Atrypa reticularis, A. aspera* var. *occidentalis, Athyris fultonensis,* and tritors of *Ptyctodus calceolus*..10

The lower layers are as follows, as studied by the writer:

4. Breccia, the Independence zone, No. 9 of the Westfield Bridge section, weak, retreating under weathering beneath the cornice of No. 5. Predominant material: soft, yellow calcareous shale or argillaceous limestone, and bluish shale, the former in broken and tumbled blocks set at all angles or in certain tracts largely still in place. Many of these limestone blocks are minutely fragmental with fragments of the same texture and composition as the matrix. Spheroidal weathering gives the appearance of coarsely conglomeratic structure in places. Characteristic siliceous nodules are found here and there. Structure lines are marked by low arches a few feet wide which consist of dislocated blocks, by a tilted stratum, or by a string of blocks which in places lie at angles as high as 35°. The zone itself is disposed in broad arches which reach 140 feet in diameter. The upper surface is fairly even, but in a few places rotated blocks of the Davenport limestones are seen to be broken down into the Independence zone in masses four or five feet thick. With this exception the Davenport limestones do not mingle with the breccia beds beneath and the breccia is, therefore, unfossiliferous. The lower surface is extremely irregular, giving large variation in thickness of the zone. The broad arches above mentioned thin at top to two or three feet and thicken to ten feet and more at base of the limbs. The zone also thickens where the breccia beneath it drops abruptly to the west by a fault-like offset. The Independence may interrupt and displace the breccia beneath and rest for a short distance, as at the limb of an arch, directly upon No. 2. Blocks of Otis calcilutites are intermingled in many places along the base of the Independence zone and where the Otis ledges are most completely shattered small fragments of the Otis are set in an Independence matrix.
3. Breccia, Otis calcilutite zone, No. 8, Westfield Bridge section. Where brecciation is most complete this bed forms a rubble of well cemented small quadrangular fragments whose colors vary from whitish to light drab, purplish and brown. Some fragments are laminated, others not, but all are of fine grain and some of lithographic texture and marked conchoidal fracture; matrix fine, of buff and bluish Independence detritus, and of gray Otis chinkstone. Fragments are left in relief on weathering.

   Where brecciation is somewhat less complete there obtains a rubble breccia of fragments as before with a sparse chinkstone and calcite matrix. Where the strata have not been completely broken up and their fragments intermingled, they are shattered to a crackle or mosaic endostratic breccia with a calcite matrix. Tracts are numerous, especially at the base of the zone, where

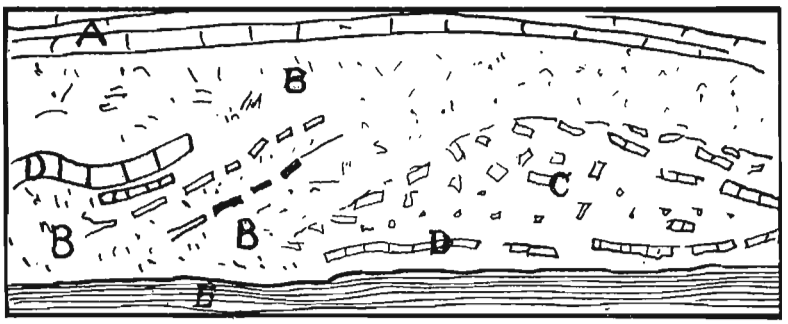


FIG. 83.—Section in the railway cut at Fayette, Fayette county, on the south side west of the bridge. A, Davenport limestone. B, Independence zone of buff shales and limestone, brecciated. C, Breccia of Otis calcilutite. D, Detached and broken layers of Otis calcilutite. E, Otis thinly laminated limestone.

the layers remain largely in place. At the west end of the cut the basal stratum can be traced with some interruptions for seventy feet.

In the midst of the rubble breccia of this zone and reaching into the Independence zone may be seen layers of calcilutite a foot thick and continuous for as much as ten feet, tilted or flexed but only a little broken. These layers and similar strings of dislocated blocks mark parallel structure lines in the breccia accordant with its broad arching and also smaller flexures of as little as two or three feet radius (figure 83).

The lower limit of the zone is fairly even and regular, resting on the unbroken but gently undulating surface of No. 2. But in places the breccia of this zone invades No. 2 in angular depressions a foot or so in depth, beneath which No. 2 is apt to be brecciated itself along a narrow inclined zone. At two points thirty feet apart, No. 2, here undisturbed, is sharply cut off at troughs of synclines to a depth of about two feet (figure 84). Above one of these offsets the Independence zone itself is offset about eight feet.

The upper limit of the zone is highly irregular from intermingling with the Independence and from broad accumulations in convex masses eighty feet and more in diameter, where the Otis attains its maximum thickness and over which the Independence arches and thins as mentioned above.

The breccia is well cemented and by differential weathering projects beyond the inclosing beds. Over No. 2 it forms a cornice which in places overhangs as much as three or four feet.

2. Limestone, Otis, light yellow-gray, rapid effervescence in cold dilute HCl, finely laminated, weathering to thin plates. Laminæ often close and delicate. In places they include very thin brown partings as many as eighteen to the inch, which are due to clayey admixture. Strata gently flexed. Some of the most marked synclines measured have a depth of a foot or a foot and a half with a width of nine or twelve feet measured from the crest of the including anticlines. Joints run N. 60°E. and

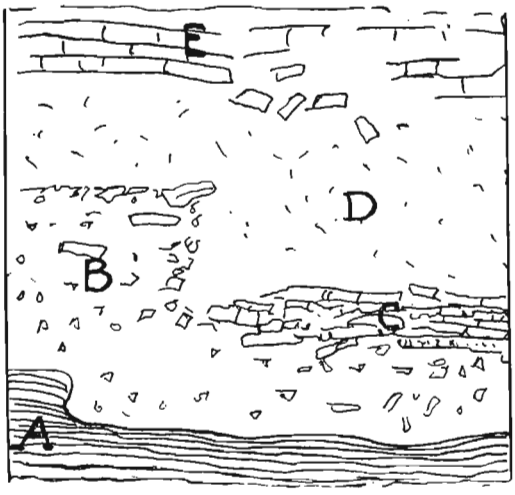


FIG. 84.—Offsets in the railway cut at Fayette, Fayette county. Scale, one inch equals twelve feet. A, Otis thinly laminated beds. B, Rubble breccia of Otis calcilutite, small close set fragments. C, Ledge of Otis calcilutite. D, Independence buff breccia. E, Davenport beds.

E. 15° S. Laminæ traversed with numerous narrow close-set vertical fractures healed with calcite; some of the larger fractures noted trend about north and south (figure 57). In limited areas mostly at axes of synclines the laminæ have been broken into a mosaic breccia whose apposed fragments are tilted at all angles. Small thrust faults with a throw of a foot or so occur.

The upper layer of No. 2, differs from those below as at Vinton and West Union. At the west end of the cut it is seen to be six inches thick and fragmental with minute sporadic fragments of the same nature as the matrix rock. It is overlain in places with a shaly breccia from one to three inches thick upon which rests the calcilutite breccia of No. 3.

The upper surface of No. 2 exhibits irregular breaks a foot or two in depth filled with breccia composed of laminated fragments of No. 3 set in a sparse interstitial, rather hard, buff matrix. There are other angular depressions filled with breccia largely but not wholly composed of fragments of No. 2.....10

1. At east end of cut. Limestone, Otis, light buff, granular, effervescence slow in cold dilute HCl, irregularly bedded in courses a foot and a half in thickness, sparingly vesicular, some ellipsoidal cavities reaching a diameter of 8 mm.; in places contains minute brown spots. In a few small areas contains sparse small rectangular fragments of laminated limestone of same general facies as the matrix rock. Lenticles occur of white intercrystallized quartz and calcite interleaved at edges with laminæ of buff limestone. At one place at base of cut on the north side this stratum graduates into a soft bluish argillaceous rock and at one point becomes fragmental with numerous small chert fragments and fragments of blue calcareous shale and buff limestone set in matrix of the

buff limestone. This stratum graduates into No. 2, by lenses of the massive rock up to six feet in diameter which appear along the base of the laminated limestone.. 3

No. 1 is referred to the Niagaran by both McGee and Savage, doubtless because of its magnesian content. But in general facies, in the character of its vescicles and siliceous inclusions and in its graduation into stratum No. 2, it appears to the writer to be clearly Wapsipinicon. The Niagaran, as is seen in the Westfield Bridge section, lies some distance below the base of the rock cut.

Eagle Point Section.—The most accessible exposures of the brecciated beds of the Devonian at or near Fayette are to be found one and one-half miles west of the town at Eagle Point and the long line of cliffs on the opposite bank of Volga river in the northern half of section 31, Westfield township. These cliffs measure sixty or seventy feet in height according to Savage, and by far the larger part of this height belongs to the Cedar Valley and the Upper Davenport stages. The zone of brecciation as seen at the base of the cliffs comprises about twenty feet of Otis and Independence beds. The section of the south face of Eagle Point is as follows:

FEET

5. Limestone, Cedar Valley and Upper Davenport. (F. figure 85.) 40
4. Limestone, unfossiliferous, fine-grained, resting directly and apparently conformably on vertically shattered rocks of No. 3. Upper foot light brown, massive, with obscure lamination, lower six inches gray, with undulating narrow brownish bands..... 1½
3. Breccia, Independence zone (C, figure 85), soft, argillaceous, buff with blue-gray cores. Courses arched but otherwise little disturbed at top. In central part the layers are broken into blocks which still preserve something of their parallelism and horizontality. The lower part of this member is pretty thoroughly brecciated. The layers in places form endostratic breccia composed of minute angular fragments of soft buff limestone similar to matrix. Sporadic small quadrangular fragments of brown and gray calcilutite occur in restricted areas. Some quartz and some pyrite nodules of one or two inches diameter are found. Blocks of calcilutite, one foot in diameter, occur sporadically and set at all angles. Midway in this breccia, on the west face of the cliff, a bed one foot wide of brown finely laminated calcilutite extends for eight feet horizontally and is continued by two dislocated and somewhat rotated blocks. This bed is entirely similar to the brown calcilutites of the subjacent member. It ends abruptly with vertical fracture

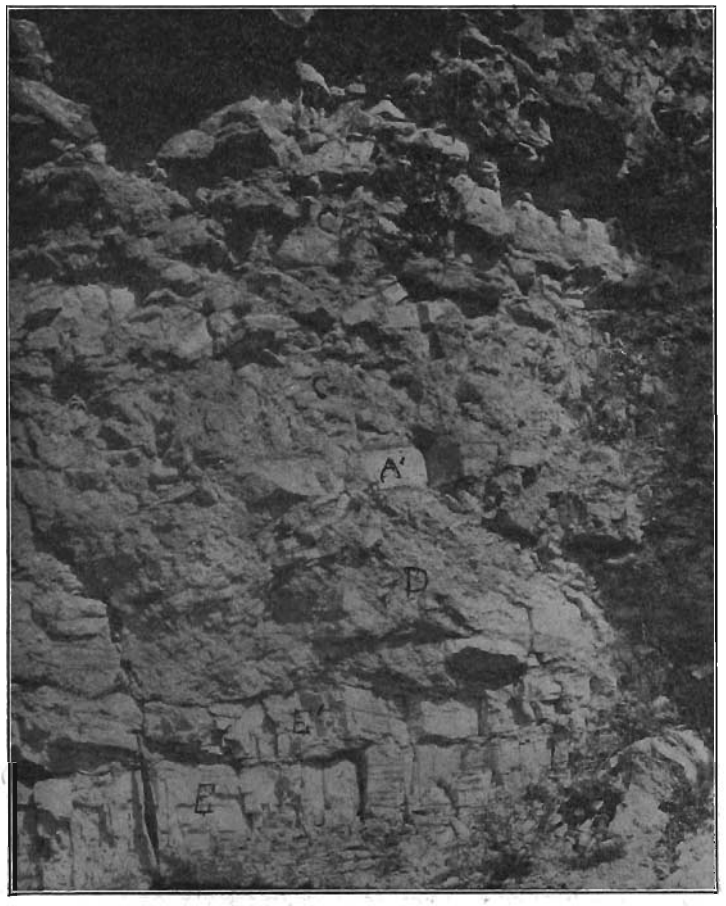


FIG. 85.—Portion of the south face of Eagle Point near Fayette, Fayette county, as high as the base of the Upper Davenport limestone.

planes abutting on the soft buff limestone of No. 3, and not with the thinning edges of a lens deposited in place.

The juncture of this member with the arching cornice of the more resistant No. 4 is fairly even. At its base it breaks down deeply at several points along narrow vertical planes of fracture into the zone beneath..... 9

2. Breccia, Otis calcilutite zone (D, figure 85), fragments predominately of calcilutite, the fragments of a layer often preserving some of their initial attitude. The upper limit of this member is marked by an undulating line of blocks about one foot thick evidently belonging to a single layer, the general dip of the line being about 8° W (A, figure 85). On the west side of the cliff this layer forms a gentle syncline brecciated at the axis but elsewhere well-nigh continuous. The rock

of this layer is a light gray calcilutite with close and coherent laminæ. In places the laminæ show sharp flexures with narrow downfolds and upfolds four inches wide. Here the laminæ are broken and independently flexed within the limits of the layer. This layer in places contains many spheroidal cavities one or two millimeters in diameter filled with soft white calcium carbonate, probably the moulds of foraminifera. On some surfaces these are so close as to become confluent.

For three or four feet below the layer just described the breccia is mostly a rubble (D, figure 85), but many of the larger fragments, which reach a length of half a foot, preserve traces of flexures antecedent to their dislocation. The matrix of this breccia is of chinkstone, and also of buff soft granular rock with sand of white chert. Some fragments are, like the matrix, composed of buff cherty limestone. Beneath this breccia are calcilutite layers which have been flexed and broken and whose dislocated blocks still retain something of the gently bent planes of bedding. The uppermost of these layers (H, figure 86), about six inches thick, is traceable for eighteen feet along the south face of the cliff. At top this layer is a light brownish gray calcilutite, in places finely fragmental with matrix of the same rock as the

FIG. 86.—The base of the south face of the bluff at Eagle Point near Fayette, Fayette county, showing the folding and disruption of the upper part of the thinly laminated limestone (E).

minute fragments. At bottom it is a drab or buff laminated rock sandy with much angular chert and well rounded grains of clear quartz. The two facies represent continuous deposition, but under stress the upper part of the layer has been shattered and recemented. The basal portion of No. 2 is a breccia of small fragments of broken calcilutite laminæ in a clayey and sandy matrix, in thickness ranging from one to twelve inches. Where thinnest it becomes a yellow shale... 5 to 6

1. Limestone in thin calcareous plates, enquivalent to No. 2 of the railway cut and to No. 7 of the Westfield Bridge section. It consists of the following members:

d. At top folded, faulted, broken into angular blocks up to two feet in diameter, tilted at all angles, lower surface of this zone of brecciation in undulations with a length of four feet and a height of three inches. At east end this bed is only slightly disrupted. E, figures 85 and 86) 1 2-3

c. An undulating, lenticular layer of buff limestone associated with clay..... ¼

b. A layer obscurely laminated, finely fragmental, made of bits of broken laminæ a fraction of an inch in diameter in matrix of same..... ½

a. Layers slightly undulating but unshattered..... 5

At the long line of high cliffs on the south side of Volga river a few rods upstream from Eagle Point the Independence and the Otis calcilutites together with the superjacent limestones are all gently arched together. The thinly laminated beds of the Otis, No. 2 of the Fayette railway cut section, appear only in places for a foot or two at the base of the section.

The Otis calcilutites are for long stretches little disturbed. Their thick layers may be shattered to a mosaic breccia but each bed retains its continuity unbroken. The upper bed, here traceable for long distances, consists of remarkably pure calcilutite a foot or a foot and a half thick. Close set laminæ are disposed within the layer in a peculiar way—in sharp narrow synclines and broader flatter anticlines. This layer is especially characterized also by spherical cavities a millimeter or so in diameter taken to be of foraminiferal origin. This layer is capped in places by three or four inches of minutely fragmental calcilutite. The thickness of the Otis calcilutite zone is about five feet, corresponding thus in thickness as in character and brecciation with the same beds at West Union, Fayette, and Vinton.

The Independence zone of breccia reaches a thickness of about fifteen feet, but in many places is much thinner. Its contact with the Otis is very irregular where the latter is displaced and broken up. Thus one may see where the upper layer of the Otis with

its spheroidal cavities, tilted, and in part crushed to rubble, abuts on buff Independence breccia, and where the Independence breccia thrusts tongues of buff detritus three feet long diagonally into the Otis calcilutite rubble, the boundaries of these intrusions being parallel with the arches or overthrusts of the breccia. But where the Otis is not displaced the line of contact with the Independence breccia is even.

Where the Otis is undisturbed there is a notable absence of strings of blocks of calcilutite in the Independence. On the other hand, where the Otis calcilutites are disrupted and displaced large blocks of calcilutite characterize the Independence zone. The inference is obvious that the presence of these blocks in the Independence zone is due to thrust and shear which has intermingled the disrupted ledges of Otis calcilutite with the buff shaly detritus of the Independence.

As at Vinton and at the Linn section, large blocks of limestone in the Independence are in some instances accompanied by blue fissile shale a few inches thick, alongside the edges of a block, with the laminæ inclined at high angles—70° in one instance—parallel with the side of the block.

Where the Otis is least disturbed, the Independence above it consists of massive buff shaly detritus. Sufficient is left in place to display spheroidal weathering and the rounded cores might on casual inspection be mistaken for rounded included breccia fragments. In blue shale, however, the rounded masses are always blue, while all buff masses are sharply angular. In buff shale there occur rounded buff masses identical with the rock, while angular fragments of like and unlike rocks also are found. In comparison with other sections the amount of shale present and its continuity is very marked. But even where apparently it is little disturbed it contains sporadic fragments of soft buff and bluish limestone and of fine-grained hard limestone, all sharply angular. These included fragments may be sparse or thick enough to form rubble breccia. Much of the matrix rock is made of minute broken particles rather than of sedimentary granules. Sporadic fragments are noticeable not only where the shale is massive, but also where it has a lumpy structure approaching a thin irregularly lenticular lamination. Siliceous

nodules are here rather numerous, but commonly are less than an inch in diameter. The breccia is sufficiently well cemented that fragments can not easily be detached without a hammer. Here the general facies is that to be expected from a local subaqueous glide.

The upper part of the Independence zone shows buff soft limestone in irregular but unbroken courses above which appears the even cornice of the Davenport limestones.

Bremer County

A low dome which brings the Niagaran limestone to the surface as an inlier, far within the Devonian area of outcrop, lifts also the Wapsipinicon to view in several outcrops along Cedar river and its affluent creeks southeast of Waverly. These are the most northern exposures of the Wapsipinicon noted in the reports of the Iowa Geological Survey in the valley of the Cedar. To the south, in Black Hawk county, the Wapsipinicon sinks below the surface again to emerge as the country rock in Benton county north of Vinton.

In Bremer, as in Fayette county, the thickness of these beds is much abridged from that in the counties to the south and southeast. The first incursions of the Devonian sea transgressing upon the Niagaran old land are recorded, as in Fayette county, by a basal conglomerate whose arenaceous content includes well rounded grains of clear quartz sand whose source may be referred to the waste of Ordovician and Cambrian sandstones outcropping to the north, and also angular bits of flint which could be supplied by the chert nodules of the Niagaran.

As in Fayette county, the uppermost stage of the Niagaran, the Gower limestone, is wanting and the basal conglomerate rests directly upon the Hopkinton. The gap between the Silurian and the Devonian is further widened by the absence on the Devonian side of the Bertram limestone and the basal magnesian beds of the Otis—the Coggon phase. Immediately on the basal conglomerate rest the Otis calcilutites. These reach a thickness of fifty feet in places. The few incomplete outcrops show characteristic structures in both massive and laminated fine-grained limestones, which in places are mottled and fragmental. Some

disturbances of sedimentation, or stresses experienced while the layers were yet plastic are thus recorded. But, as a whole, the Otis remains much as it was laid during a normal course of sedimentary deposit.

The Independence probably is thin, as in Fayette county. Only two unsatisfactory outcrops occur. Both show thorough brecciation, and the included fragments suggest, but do not prove, that the brecciation is of that which we have designated as the major brecciation and was of the tectonic type, commingling fragments of the Upper Davenport with the calcareo-argillaceous material of the Independence.

The Lower Davenport in two small exposures shows a mosaic-rubble breccia with which the Independence and higher fossiliferous beds are not commingled. Parallelism of detached laminæ imbedded in a limestone paste of the same nature as the fragments indicates contemporary brecciation.

The massive beds of the Upper Davenport with the *Gyroceras* fauna do not appear. The *Spirifer pennatus* fauna holds the basal fossiliferous beds of the Devonian. It has been seen in excavations near the mill dam at Waverly and in the bottom layers of the quarries north of town. The species collected here are *Spirifer pennatus, S. bimesialis, Atrypa reticularis* (large), *A. aspera* var. *occidentalis* (coarse ribbed), *Schizophoria iowensis, S. macfarlanei, Cyrtina hamiltonensis,* and *Productella subalata.*

QUARTER SECTION RUN SECTION

(Southeast quarter of the southwest quarter of section 20, township 91, range XIII west).

		FEET
5.	Limestone, upper part in one massive layer four feet thick, lower part in layers about eight inches thick; mottled, light brownish drab weathering to lighter gray, slightly vesicular, surface in places scoriaceous, in places smooth, fracture uneven	6
4.	Concealed	15
3.	Limestone, of facies of No. 5, but in separable laminæ	1
2.	Cherty sandstone, in layers from four to six inches thick. Chert fragments angular, small, those of an inch and one-half being rare. Sand, fine, of moderately well rounded grains of clear quartz, cement calcareous. Not seen in place but scattered in slabs over a slope of	5
1.	Niagaran limestone, exposed a few rods down stream, greenish yellow, subcrystalline, argillaceous, weathering to irregular rough-surfaced layers from one to four inches	

thick. Dip south at varying angles reaching as high as 13°. Among the fossils collected are *Leptaena rhomboidalis, Encrinurus nereus* and *Halysites catenulatus*.. 8

A few rods farther to the west the same series outcrops on the left bank of the run in the following section.

		FEET
5.	Slope of hillside strewn with gray bowlders of weathering, massive, of facies of No. 5 of preceding section, but generally smooth-surfaced	38
4.	Concealed	10
3.	Slope strewn with fragments of cherty sandstone, as No. 2 of preceding section	5
2.	Niagaran limestone, No. 1 of preceding section, layers horizontal	6
1.	Concealed to water's edge	2

It will be noted that in the last section the thickness of the Otis reaches about fifty feet. Up valley from the mouth of Quarter Section run the following general section may be taken:

GENERAL SECTION, CEDAR RIVER, LEFT BANK

(*Southwest quarter of the southeast quarter of section 18, township 91, range XII west*).

3. Breccia, in places of mosaic type, fragments close set, small, of drab thin layered calcilutite; matrix sparse and drab in color, like fragments. Exposed at twenty-five feet above water level in river.
2. Breccia, of pudding type, matrix buff, containing sporadic sharp-edged fragments of finely crystalline gray limestone, exposed some rods to the north of No. 3, eight feet above the river.
1. Limestone, light brownish drab, nonmagnesian, in irregular, rough-surfaced layers eight to twelve inches thick, composed of coherent laminæ, some hard and dense alternating with others of lighter color, and weathered in places to a scoriaceous surface; laminæ irregular, undulating, and in places broken, giving here to weathered rock a finely fragmental appearance; outcropping between Nos. 2 and 3, at water's edge in a ledge five feet thick.

Here No. 1, which closely resembles No. 5 of the Quarter Section run section, is assigned to the Otis. Number 2 is of the Independence type of brecciation, so that No. 3 may safely be referred to the Lower Davenport.

About two miles north of these outcrops (northwest quarter of the northeast quarter, section 12, township 91, range XIV west), a ledge five feet thick outcrops three feet above water level. This ledge is of breccia of small fragments of drab calcilutite weathering to lighter gray, of lithographic fineness of

grain, set in a gray calcareous matrix. In part, long, detached laminæ retain their parallelism. Flexed fragments are also to be seen. The position of this outcrop below the Cedar Valley limestone of the quarry of the Cedar River Stone Company, as well as its structure, place it with the Lower Davenport.

A most interesting section is afforded on Baskin run, two miles and three-quarters southeast of the last outcrop mentioned.

LIMEKILN QUARRY SECTION

(*Southwest quarter of the southeast quarter, section 17, township 91, range XIII west*).

		FEET
3.	Breccia, fragments sharp, angular, of drab calcilutite, laminated, the laminæ in places flexed and broken, but retaining an approximate parallelism; matrix gray, interstitial	1
2.	Sandstone, filled with small angular fragments of white chert, in two or three layers, resting with apparent conformity on No. 1	½
1.	Dolomite, light buff, crystalline, vesicular, in heavy, rough-surfaced horizontal beds; fossiliferous, with numerous *Halysites catenulatus*, base about thirty feet above level of Baskin run	13

In this section No. 1 is Hopkinton dolomite and No. 2 the basal conglomerate of the Wapsipinicon. Number 3 has the facies of No. 3 of the preceding section and is accordingly assigned to the Upper Davenport.

JANESVILLE SECTION

	FEET
Left bank of Cedar river at the milldam. Breccia: matrix soft yellow earthy limestone, in which the fragments are set without apposition or arrangement; fragments sharp edged, showing no signs of wear, usually small, those exceeding an inch in diameter being rare, many from one to three millimeters in diameter; fragments mostly of drab, laminated calcilutite, many surfaces crackled. Some fragments of buff earthy limestone similar to the matrix. Some of these are so arenaceous with sharp sand of chert and rounded grains of clear quartz as to deserve the name of sandstone. In places the breccia has weathered to a yellow calcareous clay with residual masses of dingy limestone, highly vesicular from the removal by solution of the calcilutite fragments. Total exposure to water's edge	14

Some rods up the river are exposed the fossiliferous beds at the level of the water in the mill pond. Apparently the breccia, whose matrix is of the Independence type, and whose calcilutite fragments are supplied from the Lower Davenport, lies immediately beneath these fossiliferous beds.

Buchanan County

In this county no section of the Wapsipinicon reaches the base of the Independence. The Lower Davenport limestone is found in force affected both by the major brecciation which has broken it, usually to rubble of small fragments, and by earlier brecciations whose evidences appear in blocks of brecciated limestones in which fragments of calcilutite are imbedded either in a similar Lower Davenport paste or in an Upper Davenport coquina. The Upper Davenport is much more broken up and its blocks are more intermingled with the fragments of inferior beds than is the case in Fayette county.

Independence Sections.—The quarries at Independence lie above the horizon of the Independence shales and therefore also above the main zone of brecciation. But evidences of the stresses which crushed the terranes subjacent are to be seen in the more competent beds of the Cedar Valley limestones. Thus, Calvin[57] has noted that in a quarry in the eastern edge of the town the *Spirifer pennatus* beds are "interrupted by a great number of joints" and that "the phenomenon of slickensides is developed on the joint faces on an extensive scale." He observed also in the quarry about one mile south of town the great shattering of a body of soft gray limestone which overlies the *Gyroceras* or Upper Davenport beds.[58] The natural section exposed along the river in the town at water level below the wagon bridge exhibits the most thoroughgoing brecciation. A more graphic description could hardly be penned than that of Calvin in describing these beds.[59] "The breccia is here composed of angular fragments of limestone varying in character, evidently the product of many distinct layers, and all cemented together by a calcareous matrix. The fragments range from small pieces with dimensions of a fraction of an inch up to masses a yard or more in length and width and a foot in thickness. There are fine-grained dark drab fragments which break with conchoidal fracture and there are finely laminated fragments of the same color. There are pieces of fine-grained light colored lithographic limestone, and coarser dingy yellowish colored beds were also in-

[57]Calvin, S., Iowa Geol. Surv., Vol. VIII, p. 229, Des Moines, 1898.
[58]Ibid, p. 225.
[59]Ibid, pp. 224, 225.

volved in the general destructive process, whatever it may have been, which reduced a large number of limestone layers to the brecciated condition. The fragments large and small, of different color and of different texture are promiscuously tumbled and heaped together, some on edge and others at all possible angles with the original position." The general horizon of the breccia at the Independence bridge is that of the Upper Davenport, but along with its broken blocks are commingled fragments of Lower Davenport calcilutites and of the buff argillaceous limestone of the Independence shales, while small areas show also the sandy and clayey matrix of the Independence. One area on the left bank shows a surface twenty-one feet long and six feet wide predominately of blocks of the fossiliferous granular Upper Davenport. Of these blocks five are of large size. In these blocks of the Upper Davenport coquina are seen embedded fragments of calcilutite from one to three inches in diameter. There are also blocks of calcilutite some of which show complex brecciation of another type. One of these blocks, on edge, one foot and eight inches long, consists of finely laminated brown calcilutite weathering to whitish gray. Along one of the bedding surfaces the laminæ are bent, broken and dissevered and at the middle a soft yellow matrix appears. This block, itself a fragment of a brecciated bed, now forms part of a wide brecciated zone. A rod away another block of brown laminated calcilutite nine feet long exhibits the same phenomena. What may be considered the lower part, some eight inches thick, is in thin plates, while the upper part, four inches thick, is composed of small fragments, some of which are three or four inches in diameter. Both matrix and fragments are of the same rock.

On the right bank immediately beneath the bridge a ledge of breccia extends within two feet of water level. Most conspicuous is a block of gray, granular Upper Davenport, on edge, five feet long and five and a half feet high. The lower foot and a half is crowded in places with valves and entire shells of *Gypidula comis*. *Schizophoria macfarlanei* also is common. This part of the block includes sparse quadrangular fragments of calcilutite one or two inches in diameter. A foot above this zone and at one point coming within two inches of it is a zone of

rather plentiful *Spirifer pennatus,* with large *Atrypa reticularis,* and rare *Orthis* (one imperfect specimen). The rock of both zones is the same. Adjoining and even with the top of this interesting block is dark buff Independence limestone with sparse small fragments of calcilutite, small fragments of light yellow earthy limestone, and cavities of the shape which would be produced by the solution of calcilutite fragments. Blocks of the same soft buff limestone, one foot in diameter and set at all angles, occur higher up the bank. In one of the uppermost of these blocks the buff limestone is covered with brownish gray calcilutite of the Lower Davenport type, crackled with calcite seams and brecciated into a mosaic of closely apposed matching fragments. The calcilutite fills a conspicuous depression in what is taken as the upper surface of the buff earthy limestone.

Adjoining the block just described is a block of fossiliferous Upper Davenport limestone with a Lower Davenport base of laminated calcilutite, in part in place, and in part broken into angular fragments and involved in the gray granular Upper Davenport. The block also contains four or five lenses of calcilutite parallel with the bedding.

The ledge is composed chiefly of large blocks of the Upper Davenport limestone. Thus touching the *Spirifer pennatus* block described is one of the same type of limestone which is five feet through and is nearly horizontal. On this block rest two more on edge, which are from the same bed. The horizon is clearly that of the large tilted blocks of Upper Davenport limestone.

About a mile south of Independence on the south bank of Wapsipinicon river the Independence zone of brecciation is exposed at water level. Here a soft yellow clay weathering from shaly beds contains sparse small fragments of buff soft limestone and of drab calcilutite. The Upper Davenport appears along the bank in blocks containing a large *Gyroceras,* plentiful *Gypidula comis,* and an occasional *Orthis.*

Quasqueton Sections.—The Wapsipinicon beds are finely displayed on both sides of Wapsipinicon river. On the left bank there are continuous ledges north of the bridge both above and below the site of the old mill dam. On the bank below the dam there is exposed at low water a wide rock floor swept clean of

waste by floods. The vertical sections of about fifteen feet exposed on the left bank are thus supplemented by this extensive horizontal section of brecciated rock.

On the right bank below the dam the Independence occurs at the base of the ledges in tracts of lumpy buff soft argillaceous massive limestone with small sporadic fragments of calcilutite. The upper surface of one of these tracts, about twenty feet in length, slopes notably to the south, the general direction of structure lines in the breccia at this point. Above and between these tracts of brecciated Independence occurs a rubble and mosaic breccia which is composed of fragments of calcilutite. Blocks several feet long appear in place, but show the stresses to which they have been subjected. One block three feet long, of wavy laminated calcilutite, light brown weathering whitish, is heavily crackled and is surmounted by a four-inch layer of non-laminated fragmental limestone composed of close-set minute fragments of the same limestone as that of the crackled limestone underneath, with a matrix of angular limestone sand and some interstitial calcite. This upper minutely fragmental layer is seen on other blocks also in the same ledges. The same structure appears immediately beneath the Upper Davenport above the dam. In another block three feet long and eight inches thick and resting on a nearly horizontal plane, the layers of brown calcilutite of which it is composed are largely in place but are partly brecciated, the interspaces between the fragments being composed of minute chinkstone like the larger fragments and of calcite.

In other areas mosaic and crackle breccia gives way to rubble in which all traces of initial bedding have been destroyed. Here the breccia is composed of close set fragments of various strata. Gray granular blocks of Upper Davenport are seen within a foot of the base of the ledge while near the top of the ledge occur fragments of brownish Lower Davenport calcilutite. Highest at this outcrop is a light buff fossiliferous limestone carrying *Spirifer pennatus.*

Above the dam the fossiliferous beds are better exposed on account of the greater height of the section. Here from weathered surfaces the following fossils were collected: *Atrypa reticularis,*

Chonetes cf. *C. cancellatus, Cyrtina hamiltonensis, Pentamerella dubia, Pholidostrophia nacrea, Spirifer bimesialis, Spirifer pennatus, Stropheodonta demissa* var. *plicata.*

At a little lower horizon large blocks of Upper Davenport limestone, more or less tilted, lie approximately in the same plane. Mingled with them in places are light yellow fossiliferous blocks from a higher horizon. At one point the Upper Davenport beds are continuous for thirty feet and dip to the southeast. At the extreme north end the angle of dip is 14°, at the center 10°, while at the south end the bed is bent down abruptly at 18° to a thrust fault beyond which the bed dips 5° north.

Several large blocks show that the deposition of the granular Upper Davenport fossiliferous beds followed directly on that of laminated calcilutite. One block four feet long and nearly two feet thick, gently flexed, is made of Upper Davenport above, while the lower portion consists of unshattered laminæ of calcilutite, parallel with the flexed surface of the Upper Davenport above. Another block shows at top one and one-half feet of fossiliferous Upper Davenport limestone, with elliptical horizontally set lenses of light brown calcilutite similar to that of the layer underneath imbedded near the base. A middle layer consists of brownish calcilutite, three inches thick, whose laminæ are flexed, broken and detached, but retain their parallelism for the most part. Some fragments are lenticular. The paste in which they are imbedded is the same as the fragments. At base is a four inch layer of brown crystalline limestone.

In these ledges occur small irregular areas of buff matrix rock highly arenaceous with angular white chert and well rounded grains of clear quartz and containing sparse small sporadic fragments of drab calcilutite.

On the west side of the river the breccia of the horizontal section is largely made up of calcilutite mingled with large masses of the Upper Davenport. There are small areas of pudding breccia in which the buff arenaceous Independence is conspicuous. Here blocks may be seen which include adjoining layers of the Upper and Lower Davenport, and exhibit their relations as originally deposited. Along the line of junction the Upper Davenport comes down into crevices and surrounds detached laminæ

of the calcilutite. The Upper Davenport paste was clearly intruded into the Lower Davenport calcilutite during or after its shattering, and at the time the Upper Davenport must have been in highly plastic state. In certain blocks the parting between the Upper Davenport and the Lower Davenport is extremely intricate, with interlocking areas. In these blocks the laminæ of the Lower Davenport are greatly broken up. In places the blocks of the Upper Davenport are shattered, and show wedge-shaped fissures up to three inches in width, filled with calcite, much as in the railway cut at Vinton. There are also blocks of Lower Davenport limestone in which the laminæ are bent and detached, but retain more or less of their parallelism and are imbedded in a matrix of calcilutite indistinguishable from that of the fragments except by a somewhat lighter color.

The outcrops at Quasqueton include the horizon of the Upper Davenport tilted blocks, but include also the underlying zone of the Lower Davenport, with some involvement of the Independence.

Benton County

The chief exposures of the Wapsipinicon beds in Benton county are located four and five miles northwest of Vinton along the right bank of Cedar river. As noted by Savage[60] a long and narrow ridge here faces the flood plain of the river, rising to the height of eighty feet above it. For the distance of a mile and a quarter along this bluff numerous excavations have been made, and near the southern limit of these quarries the ridge is trenched by the deep rock cut of the Chicago, Rock Island and Pacific Railway. The northernmost of the quarries, located near the center of the east side of section 36, Cedar township, is that of Mr. Niels Degn. About half a mile farther south is Kearn's quarry and a few rods beyond the numerous excavations of the Aungst quarries begin, extending into the southern half of section 6 of Taylor township.

The beds exposed in the railway cut and quarries are:

Barren beds
Upper Davenport beds
Lower Davenport beds

[60]Savage, T. E., Iowa Geol. Surv., Vol. XV, p. 158. Des Moines, 1905.

Independence limestone and shale
Otis calcilutite beds
Otis buff lime quarry beds

The barren beds have been extensively shattered. The Upper Davenport beds have been broken into huge blocks, in part in place and in part commingled with the fragments of lower terranes. The Lower Davenport beds are seldom found in place, but to this horizon are referred many calcilutite fragments mingled with the Independence shale in a common brecciation, which includes also fragments of the Otis. The Otis calcilutites are seen in an endostratic rubble of minute fragments and in crackle and mosaic breccias. The Otis buff beds also furnish at top a thin endostratic rubble or pudding breccia, but with this exception the beds are little disturbed.

Otis Buff Limestone.—This stone is singularly uniform from top to bottom and from end to end of the quarries it is everywhere a buff, heavily and evenly bedded laminated limestone, soft and crystalline-granular. The sparkle of the calcareous crystalline grains is even suggestive of an arenaceous content, but quartz sand is entirely absent from the rock, so far as the writer has observed. Along joint planes the etching of the weaker layers by the weather brings the laminated structure into conspicuous relief (figure 45). The laminæ vary in thickness from a quarter of an inch to layers so fine that eleven or twelve may be counted to the inch. The usual alternation is between rather soft buff laminæ and those of a light brownish tint, harder and more compact. Hair-line dark laminæ in the midst of wider bands of lighter color may be seen. In some of the lower beds lamination is somewhat obscure, but is nowhere wanting. In places the stone is minutely vesicular especially toward the top of the bed. The lines of lamination run parallel with the major bedding planes and with each other. In evenness of lamination the stone approaches the Anamosa phase of the Gower limestone of the Silurian. In this respect it differs from the Otis beds in the Cedar Rapids quarries, with which it is entirely akin in closeness of lamination and in hair-line brown partings. More quiet conditions of deposition and perhaps deeper water are indicated than obtained in central Linn county. The laminæ are coherent and while under prolonged weathering the rock

splits into layers from one to three inches thick the quarries exhibit undivided beds up to six feet in thickness.

Joints at Degn's and Kearn's quarries run in two sets, southeast-northwest, and northeast-southwest, and are from three to ten feet apart. The rock lies in gentle undulations which in some cases scarcely depart from horizontality, or in places attain dips of 3° to 7°. In one instance an exceptional dip of 15° is reached. These are referred to the stresses of the major brecciation. The thickness of the beds exposed at any one place is about fifteen feet, but the base is not reached by the excavations, some of which extend below flood plain level. A few rods north of the railway bridge the summit of the beds appears twenty-four feet above low water in the river.

No fossils have been found to certify the place of this terrane in the Wapsipinicon but its lithology and general relations refer it with little doubt to the Otis. In close lamination and in freedom from high magnesian content it differs from the bottom beds of the Otis, the Coggon phase, which probably here lies still deeper.

The uppermost layer of the Otis buff beds shows disturbed sedimentation. This layer has an irregular hummocky upper surface, and is more or less fragmental in structure. For a depth ranging from a few inches to two feet from the surface the rock contains sparse angular fragments. These are of the same lithologic nature as the matrix rock or differ from it in kind as the laminæ differ from one another. In places the laminæ of rock are bent or shattered into bits. The fragments are minute—a diameter of one-half inch is exceptionally large. The continuity of this fragmental layer is not interrupted by fractures. It will be recalled that a similar fragmental layer caps the laminated Otis beds in the Fayette county outcrops and that lenticles affect the same horizon at Cedar Rapids.

Otis Calcilutite.—In places, but not continuously, there rests upon the Otis buff beds a ledge of brownish calcilutite weathering to gray. Under the stresses of the major brecciation it is shattered in places to crackle breccia, in places it is further disrupted to a mosaic breccia of fragments which in some cases match along seams, which are filled with calcite or with fine chink-

stone of the same nature as the larger fragments. There has been little or no intermingling of material from other horizons. In places the Otis calcilutite bed is absent either because of lack of conditions favorable to deposition or because it has been torn up and commingled with the breccia hodge-podge to which the Independence and the Upper and Lower Davenport beds also contribute.

The Independence Breccia Zone.—At the railway cut and at all the quarries the Otis is succeeded by a rubble breccia to which an abundance of soft shaly material is contributed by the Independence. While the Otis mosaic breccia layer just described forms a solid bed of firmly cemented fragments with little or no admixture of foreign rock, the zone of the brecciated Independence is scarcely more indurated than till. The Independence contributes also tabular fragments of a dingy buff earthy limestone. The Otis contributes fragments of buff granular crystalline rock indistinguishable from the buff basal beds of this locality and drab calcilutites with characteristic hair-line laminæ. From this source also come fragments with minute dark scattered linear crystals of celestite. Other fragments of calcilutite are contributed probably by the Lower Davenport beds, while the Upper Davenport furnishes blocks of all sizes up to five feet in diameter which come down within a foot or so of the base of the breccia. Masses of even the whitish limestone of the uppermost barren beds also are to be found well down within this zone, whose width is about fifteen feet. The usual siliceous nodules and sand of clear quartz and chert are present.

The relation of the Independence breccia zone with the lower beds is significant. In places the shaly Independence, little disturbed, rests directly and conformably upon the buff Otis beds. At Kearn's quarry one may see six inches or a foot of blue-gray or buff calcareous shale composed of laminæ a millimeter or less in thickness and continuous for several feet lying upon the undisturbed laminæ of the buff Otis. Here sedimentation apparently was continuous during the deposition of the two formations. At one point the basal four inches of shale passes laterally into limestone. At Degn's quarry in places the upper part of the laminated undisturbed buff Otis has its thin calcareous plates

interleaved with greenish yellow argillaceous sediments. But for the most part the Independence shale, brecciated and thoroughly mixed with foreign limestone fragments, rests directly upon either the Otis calcilutite breccia, the undisturbed buff Otis or its minutely fragmental uppermost layer.

Structure lines in the breccia of the Independence zone may be picked out by occasional strings of fragments of once continuous layers of limestone which trace synclines and anticlines of moderate dip, and by much steeper boundary lines of areas of weak shaly breccia and of strong breccia of predominant limestone fragments.

Immediately beneath this bent and broken stratum in the railway cut there lies, for an extent of twenty-eight feet, a blue-gray fissile shale. This shale reaches a thickness in places of eighteen inches, is broken by joints which are one to three inches apart and is very thinly laminated, the leaves being only a fraction of a millimeter in thickness. It is calcareous and slightly gritty. It conforms to the slant of the stratum of limestone above it and to its irregular lower surface. The shale rests on Independence breccia four or five feet thick, which parts it and the broken stratum above it from the basal ledge of brecciated Otis calcilutite. This breccia of the Independence zone is unindurated, buff or bluish in color, with numerous small fragments of various types, including black and white flint and calcilutites with blackish hair-line laminæ. The lumpy argillaceous matrix is sandy in places with black and white grains of flint. The most important characteristic of this breccia is the presence in it of fossiliferous fragments—a block two feet long carrying *Chonetes* cf. *C. cancellatus*, and an angular fragment with an imbedded valve of *Orthis*. That the shale was not deposited subsequent to brecciation by inwash in an irregular cavity left beneath the ledge of strong rock either in the process of brecciation or afterward by the settlement of the breccia beneath the ledge is seen in the fact that the lamination of the shale is not horizontal, but follows the dip of the blocks above. All the relations of shale and limestone point to continuous sedimentation in their deposit. Consideration must be accorded the hypothesis that they were deposited upon the

underlying breccia, and that later crustal movements involving the whole terrane folded and dislocated the limestone stratum with the protected shale beneath. In this case the breccia beneath the stratum must have been produced in Independence time. This hypothesis explains most satisfactorily the relations of shale and overlying limestone. Moreover, local contemporaneous brecciation is known to have occurred during the Independence as shown by the Cedar Rapids outcrops (p. 451). But the breccia beneath the shale is not made up wholly of fragments of the Independence and subjacent beds. It contains fossiliferous fragments belonging at least as high as the Upper Davenport. If the shale and limestone were laid upon a breccia so constituted they must be younger than the fossiliferous beds whose fragments are included in the breccia. The implications of this hypothesis are that all the types of rocks represented in the breccia of the Independence zone were deposited during Independence time or earlier. The heterogeneity of the zone of breccia is due to the heterogeneity of a single formation. During Independence time there were laid on the sea floor, not only shales and argillaceous limestones, but also fossiliferous limestones of different types identical lithologically and in their fossils with the limestones of known higher terranes. Such various deposits were laid contemporaneously over different tracts of the sea floor and on individual tracts in different succession. Such a theory would fully explain the variety of fragments in the Independence zone of brecciation. Conclusive evidence in its support would consist of beds of Upper Davenport or Cedar Valley facies and fossils interbedded with those of Independence facies in areas where strata are undisturbed, or so slightly disturbed that their initial positions can be traced. But in such areas the Cedar Valley horizon invariably overlies the Upper Davenport while still further down the stratigraphic column come the argillaceous beds denominated the Independence. Even the brecciated areas do not yield the evidence necessary to support the theory. The Upper Davenport limestones, whether seen in place or in broken blocks above the Independence, are massive and tough. Under brecciation which crushes soft weak rock to powder and shatters brittle rock to a

rubble of small fragments, the Upper Davenport is commonly left in broken rotated blocks which largely preserve the bent surface to which the plane of deposition was deformed before rupture. Certainly if such layers had existed interbedded with shales and argillaceous limestones, they would now be found in the Independence zone in strings of fossiliferous blocks, similar to the strings of the stronger Independence limestones occasionally seen. Strings of Upper Davenport blocks are seen indeed, but always as a distinctly higher horizon than the rubble breccia with shaly matrix that marks the Independence zone. Where the Upper Davenport limestone occurs within the Independence zone of brecciation it occurs in single blocks or smaller fragments entirely unrelated to one another in position, or if in numbers in any tract, wholly chaotic in their lack of arrangement and without the slightest trace of an initial deformed plane of deposition. We are therefore compelled to abandon this hypothesis and to revert to the theory of the successive formations of the Wapsipinicon and Cedar Valley Devonian in the order adopted by the Iowa Survey. In the specific instance noted in the railway cut, we are compelled to believe that the fossiliferous fragments in the breccia beneath the shale and limestone layer are younger than the shale and limestone which now overlie them. The breccia of which they form a part is also younger and can not belong to Independence time but is of later date than the youngest fossiliferous fragment in it, and is to be referred to the major brecciation.

The Lower Davenport.—The Lower Davenport calcilutites are not found in force in these outcrops. In the most northern of the Aungst quarries they form a ledge of gray calcilutite five feet thick in layers from four to six inches thick which are greatly shattered and healed with calcite. The bed here dips 10° to 25° south. In other quarries large blocks of crackle breccia mark this horizon. Complex brecciation is seen also in blocks broken into fragments poorly cemented with a scant gray matrix or parted by fissures in some cases open or inclosing minute fragments. In one instance a fragment thus inclosed consists of a portion of the valve of an *Orthis,* imbedded in minute cemented chinkstone of calcilutite. The fossil, derived from the

Upper Davenport horizon, clearly indicates the zone of juncture of the two formations. The Lower Davenport also occurs in subangular fragments more or less rounded on corners and edges and imbedded in Upper Davenport blocks and ledges. This fact also shows that the deposition of calcilutite immediately preceded the deposition of the Upper Davenport coquina.

The Upper Davenport.—This limestone is heavily bedded at all outcrops and is largely broken into slickensided blocks. They form gently arched but disrupted beds at the summit of the breccia of the Independence zone, with which the Lower Davenport is usually commingled, or descend far into the zone in detached fragments up to five feet in diameter.

Some of the blocks of Upper Davenport carry lenticular masses conspicuous because of contrast in color and texture. These lenses are half an inch or more in vertical diameter and two to three inches in their longer horizontal axis. Fresh fracture shows a brownish calcilutite or a subcrystalline structure of finest grain. Exposed surfaces have weathered to whitish gray. They lie parallel with the bedding planes. Thus forming horizontal rows of narrowly spaced whitish lenses in the midst of the gray limestone, they are conspicuous even at a distance of several rods. Their shape, their spacing and attitude, the fact that they are not assembled like beach shingle or like the sporadic fragments of a breccia suggest their formation *in situ* by colonial organisms, such as stromatopora or sponges. In one instance this is demonstrated by the structure remaining on the upper surface of the lenticle.

Associated with the blocks of gray granular limestone characteristic of the Upper Davenport are large blocks, also similarly slickensided, of a blue-gray earthy limestone which weathers to yellow. A large *Chonetes* akin to *C. cancellatus* is specially common and characteristic of this bed, which also contains *Stropheodonta demissa.*

The following fossils collected at the railway cut and identified by Savage[61] are probably all from the Upper Davenport horizon.

[61]Savage, T. E., Iowa Geol. Surv., Vol. XV, p. 184.

Fistulipora constricta Hall
Stropheodonta demissa Conrad
Pholidostrophia nacrea Hall
Orthotetes chemungensis Conrad
Chonetes cf. *C. cancellatus* Calvin
Productella subalata Hall
Schizophoria iowensis Hall
Pentamerella arata Conrad
Gypidula laeviuscula Hall
Gypidula comis Owen
Atrypa reticularis Linn. Independence type
Atrypa aspera var. *occidentalis* Hall
Spirifer pennatus Owen
Spirifer asper Hall
Paracyclas elliptica Hall
Gyroceras sp.
Phacops rana Green

Barren Beds.—These beds are best seen in the railway cut where on the west side near the north end they form a ledge of light gray limestone about ten feet thick. The layers run in undulating courses parallel with the synclines and anticlines of the Upper Davenport massive bed beneath. The rock is shattered and in one area at the north end it is completely broken up.

Cut of the Chicago, Rock Island and Pacific Railway north of Vinton.—This section, of about thirty-five feet, has its base about twenty-five feet above the river and embraces all the zones of the Wapsipinicon as far down as the buff Otis lime rock, which lies slightly below its level.

FEET

4. Limestone, light buff, weathering to whitish gray, unfossiliferous, in undulating courses, in places shattered and completely broken up; estimated thickness.....10

3. Upper Davenport limestone, gray, granular, in heavy courses up to four feet thick, broken and faulted into large slickensided blocks which in places follow undulating courses parallel with those of No. 4. In places the interstices between the blocks are filled with dark gray, nonlaminated clay, or with chinkstone of the same rock, or with both intermingled. In these interstices several fossils of the Atrypas are found as parts of rock fragments. In one instance a large finely ribbed *Atrypa reticularis* was found in an interstice completely detached and imbedded in the clayey matrix, but this is regarded, like the others, as a fragment instead of as a constituent part of the matrix. In places the rocks are shattered and healed with calcite. Rarely in these rocks occur lenticles of calcilutite with their long axes parallel with the bedding..... 4-10

2. Zone of the Independence. This zone is well demarked from those above and below. On account of lack of cementation, and because of the abundant shaly material, it generally forms a steep slope, while the stronger rocks which inclose it stand in nearly vertical ledges. Exceptional areas of better cementation and less shale form outstanding crags. The color, a dingy buff or bluish gray, indicates the high argillaceous content and is in contrast with the whitish tints of the inclosing ledges. It is marked also by its heterogeneity and by the generally small size of the included fragments.

The constituents of this breccia which may be referred to the Independence limestone and shales as their source are, first, the argillo-calcareous buff or bluish matrix. This is perhaps as well described by its negative as by its positive characteristics. It is not laminated or bedded and shows no trace of sedimentary deposit in its present relations. In places it is more than interstitial, and forms small areas in which small foreign limestone fragments are sporadic. But there is no evidence that these fragments were dropped into a sea-clay in process of deposition. The lumpy or amorphous nature of the matrix indicates rather that it, like the fragments, is the product of crush—it of weaker argillaceous beds, they of harder, stronger calcareous strata. Angular bits of black and of white flint in places speckle the matrix rock. Sand grains of clear quartz also are present. There are also fragments, small and large, of a buff argillaceous limestone some of which are themselves finely fragmental. These occur in strings, to be described more fully, and are taken to be native to the Independence. There are also strings of fragments of calcilutite beds which perhaps were deposited in the midst of the normal sediments of the Independence.

The foreign constituents of the Independence zone of brecciation are first, the blocks of the upper beds of the Wapsipinicon. At one point on the east side of the cut is an area of large fragments of the upper beds which comes down within four feet of the ledge of Otis calcilutite mosaic breccia at the base of the section. This area crosses the tracks diagonally with a northeast-southwest strike and appears on the opposite side. On the east side at the base of the area, is a block of Upper Davenport fossiliferous limestone five feet through. Above this block is a mass of whitish or light yellow limestone blocks, apparently the same as the barren beds at the summit of the section. A fragment of a large trilobite, however, was found in these. The matrix filling the interspaces of this mass is chiefly of calcite, seams as much as three inches wide being completely filled with white, brown, and clear crystals of this mineral. Chinkstone matrix of the same material as the blocks also occurs. One large block, five feet in length, is broken in two in the middle and the wedge-shaped fissure is calcite filled. Blocks of fossiliferous Upper Davenport limestone are found apposed to this mass and to a small extent intermingled with it. On both sides the area of large blocks touches tracts of shaly breccia with small fragments. It would appear that in brecciation the shales of the Independence here failed to penetrate to any extent the interstices of the large blocks of the area and these were left to form an easy way for ground water, which at some later time deposited calcite therein. There may be seen a few blocks of the bluish fossiliferous limestone, weathering buff, with the large *Chonetes* resembling *C. cancellatus* which occurs plentifully in the Aungst quarries.

The Lower Davenport calcilutites apparently were thin in this area and none are now left in place at the railway cut. The calcilutite fragments in the Independence zone are probably in part derived from the Lower Daven-

port, but no attempt is made to discriminate them from calcilutites from other horizons.

Calcilutite fragments in the Independence zone are in part derived also from the upper horizon of the Otis. Fragments with blackish hair-line laminæ and the rare ones showing minute celestite crystals may be referred to the Otis as their source.

The most pronounced structure lines in the Independence zone are those afforded by strings of fragments of once unbroken layers. Blocks evidently belonging to a single stratum, once continuous and horizontal, are now found more or less rotated, separated from one another by the same shaly breccia which forms the main body of breccia of the Independence zone. They are now aligned in irregular, in some instances faulted, folds or in steep monoclines, which with interruptions may be traced for lengths of three or four rods. Thus about six feet from the base on the west side of the cut, blocks of whitish calcilutite one foot to two feet in diameter are ranged along a sinuous line a rod and more in length in the midst of the shaly breccia (AA. figure 64, page 424).

Near the south end of the cut, on the west side, begins the outcrop of a broken stratum, about one foot thick, of light brownish granular rock with darker spots, weathering to buff. The lower part of the layer is gray, is speckled with black, and contains some small sporadic fragments like the mass of the rock. A sketch of a part of this outcrop shows graphically the degree to which this stratum has been folded, faulted and broken into detached fragments (figure 61, page 421).

1. Zone of Otis calcilutite. This member is best exposed and reaches its maximum height of five feet at the north end of the cut. Declining to the south it passes below the level of the rails in about 120 feet. It reappears toward the south end of the cut but its structure here is less typical. Where the bed of Otis calcilutite passes below the level of the rails at the north end of the cut it is about twenty-five feet above low water in the river, or about the same height at which the summit of the Otis buff lime rock is found a few rods up river in the Aungst quarries. The rock is a finely laminated calcilutite brownish or drab in color but weathering to light gray. The close set laminæ are etched on weathered surfaces. A marked type is a light gray rock with rather distant dark hair-line laminæ. In places exceedingly minute dark short acicular crystals of celestite speckle an area of a square inch or two. At the north the calcilutite is found in a bed brecciated to a mosaic but without admixture with fragments of other strata. Many of the fragments are apposed along the fractures and retain something of the original plane of deposition, but in places they are rotated to all angles and form a rubble. The matrix consists of interstitial calcite filling the seams of the crackle and mosaic breccia, and chinkstone of the same rock as the fragments in the larger interspaces. The sandy buff granular shaly matrix of the Independence zone is not seen in this bed.

   At or near the upper surface of this bed there occur in places one or more layers a few inches thick which are composed of minutely fragmental calcilutite in angular bits from the size of sand to a diameter of a quarter

of an inch with a very slight and interstitial matrix of granular rock of the same color. These layers, which weather to fretted surfaces, are thus contrasted with the evenly laminated layers which bound them.

DEGN'S QUARRY SECTION

FEET

3. Breccia, Independence zone, gray, shaly, uncemented, with the general appearance of a clayey till. Fragments in rubble, small, sharply angular, of various lithologic types—thin, brittle, cracked calcareous plates, drab and brown calcilutite, finely laminated brown calcilutite, fossiliferous Upper Davenport limestone, blocks of shattered and recemented brown laminated calcilutite whose fragments generally are matching and apposed and whose fissures are filled with chinkstone or are open at the surface. Areas of breccia which are drab in color and more clayey with smaller fragments may be distinguished from other areas which are more yellow in color with larger fragments, but no structure lines are visible. Matrix supplied by Independence shale, which also furnishes some lumpy fragments; estimated thickness 12
2. Limestone, Otis, in plates from a fraction of an inch to two inches thick; in lamination, texture and color like beds beneath, in part fragmental; in places thin leaves of greenish yellow clay part the thicker laminæ of limestone. The latter are irregularly surfaced and slightly flexuous and the impression is given of continuous deposition rather than of the intercalation of the clay after the deposit of the limestone. Contact with No. 3 fairly even 2
1. Limestone, buff and brownish gray, fine crystalline-granular to earthy, of rapid effervescence in cold dilute HCl, in even parallel beds from two and four inches beneath to five feet nine inches above, laminated with rather obscure slightly wavy laminæ marked by slight differences in color, in places vesicular with minute spheroidal cavities, joints southeast-northwest and southwest-northeast, from three to ten feet apart..... 9

KEARN'S QUARRY SECTION

5. Limestone, Upper Davenport, with sparse inclosed calcilutite fragments, in ledges on hillside.
4. Breccia, Independence zone, a rubble, shaly, light blue-gray or yellow; fragments of shale of several inches diameter observed which retain initial lamination; many limestone fragments of different lithologic types, some of buff Otis, some of brown calcilutite, some slickensided blocks of Upper Davenport limestone, one of large size noted within three feet of base of breccia; a fragmental *Orthis macfarlanei* found five feet above base, fragments easily detached; estimated thickness..... 10
3. a. Shale, calcareous, buff, fissile, laminæ a millimeter and less in thickness, continuous for five feet horizontally, in places bent and broken but with no included foreign fragments, at base passes laterally for four inches into argillaceous buff laminated limestone..... ½-1

b. Or, breccia, buff argillo-calcareous lumpy matrix, numerous small fragments of limestone of buff Otis..... 3

2. Limestone, Otis lime rock, light brownish drab, laminæ alternating buff and light, brownish gray, even and regular; some layers vesicular, vesicles filled with calcite; in layers up to six inches thick; gently undulating with the limbs of the low folds dipping from 5° to 7°; upper foot contains a few minute sporadic fragments of rock of same facies..... 6

1. Limestone, buff, granular-earthy, obscurely laminated with lighter and darker bands and with distinct brown hair-line laminæ graduating into browner rock beneath; undulations as in No. 2; the master joints of both run southeast-northwest and northeast-southwest..... 8

AUNGST QUARRIES

These quarries, opened by the Aungst Bros. for lime rock, extend for more than one-half mile along the bluffs bounding Cedar river and include representatives of all the members of the Wapsipinicon. With the exception of the Upper Davenport beds which were used many years ago in the construction of the buildings of the State College for the Blind at Vinton, the only stone quarried has been that of unbrecciated buff beds of the Otis which are used for lime. On account of the heavy cover of rock which overlies this basal bed, tunnels ten and fifteen feet high have been driven as far as one hundred feet under the hill and several feet below the level of the flood plain of the river. Large chambers attest the amount of rock which has been removed. The rock is identical with that of the buff Otis beds in the Kearn and Degn quarries, so that the description of these beds will not be repeated. While these beds lie approximately horizontal for the most part, the strongest anticlinal fold seen in the Vinton outcrops occurs in a quarry up river from the bridge where a dip of limb of 15° was observed.

The upper layer of the buff Otis beds differs from those beneath in its irregular upper surface and its fragmental nature. The following section at the roof of the tunnel of one of the southern excavations shows the relations of this bed:

FEET

3. Breccia, plentiful fragments of brown calcilutite and other lithologic types two and three inches in diameter, matrix soft, clayey.

2. Limestone, Otis, brownish, vesicular, in places minutely fragmental, some fragments soft, angular, buff, some

harder, brown; upper surface irregular, the breccia of No. 3 filling the depressions 1 2-3
1. Otis limestone, buff, finely and evenly laminated, forming roof of tunnel 1

The width of this upper bed of the buff Otis varies from a few inches to two feet. All the fragments are of the same type as the matrix rock or differ from it only in the kind and degree that the brown and buff laminæ of these beds differ from each other. The fragments are minute—one-half an inch in diameter would be exceptionally large—and many of them show by their quadrangular form that they are bits of broken up laminæ. The bed is massive, the fragments being scattered through the matrix rock or the whole forming rubble breccia of minute fragments.

Upon the fragmental massive upper bed of the Otis rests either the clayey matrix breccia of the Independence zone of brecciation, as at the northernmost quarry, or a ledge of calcilutite breccia.

At one exposure forty rods southeast of the railway bridge, the lime rock is overlain by a nearly horizontal ledge of calcilutite five to seven feet thick. The rock is of the usual type, light brown and finely laminated. It is irregularly bedded in courses about one foot in thickness. The rock is seamed and in part is fragmental. At base it changes to subcrystalline dark gray limestone. The entire ledge in places forms a rubble breccia of native fragments firmly cemented with chinkstone matrix and finer material of the same nature as the fragments. Many of the fragments are several inches in diameter. This ledge gives place laterally to a breccia of shaly matrix. In places the ledges of calcilutite have been shattered to rubble. As example there may be cited an exposure a few rods up river from the railway bridge. Here the summit of the buff beds is twenty-four feet above low water level, and at approximately the level of the rails in the railway cut. At this quarry a vertical wall of close-set rubble breccia twelve feet thick thinning to six feet at an angle of 45° rests directly on the buff Otis lime rock. The fragments are chiefly brown calcilutite. They are mostly small but areas occur where fragments from six inches to two feet in diameter predominate. Some of these larger fragments are themselves

seamed, dislocated and healed with calcite. Most of these fragments can well be attributed to the breaking up of beds of Otis calcilutite, such as that seen at about this level at the bottom of the railway cut and that just described in the quarry forty rods south of the bridge. But the clayey matrix, the soft yellow limestone fragments and the lumpy fossiliferous fragments which form a minor part of the same breccia bed show that other and higher terranes also have contributed to it.

In all the Aungst quarries the horizon of the Independence is represented by a rubble breccia in which the shales and dingy buff impure limestones of the formation have been broken up and mingled with fragments of the limestone beds beneath them and above. The shales are easily crushed and contribute a matrix which is soft, lumpy and in places arenaceous.

Small areas of shale little disturbed or intermixed with other constituents occur where they have been protected by limestone blocks or ledges. Thus in the quarry forty rods south of the bridge dark gray shale is seen amid the tilted blocks toward the base of the zone of broken massive limestone beds which succeeds the Independence breccia zone along these outcrops. Underlying a broken arch of blocks is a mass of shale from two to six inches in thickness and a foot or so in length which remains largely intact although tilted with the adjacent surfaces of the limestone blocks to slopes of 35°, 45° and more than 50°. Siliceous nodules and chips of flint occur at this horizon, though not so numerously as in the Linn county outcrops.

Structure lines are seen in beds of strong rock which either remain unbroken for some distance, or if broken permit their courses to be traced by strings of fragments. The alignments of dissevered blocks are seldom if ever horizontal, nor are they continuous for any considerable distance. Within the limits of the face of the quarry they come to an end and give place to structureless rubble breccia. For example, in the quarry forty rods south of the railway bridge structureless rubble breccia rests upon the ledge of Otis calcilutite already described. A few feet up the slope it is interrupted by a string of blocks of brown calcilutite from one to two feet thick tilted at a moderate angle to the south. Higher up the quarry face there appears a short

ledge of buff granular dingy limestone of the Independence type which is tilted more strongly in the same direction. A little to the east a syncline of dislocated blocks of brown calcilutite, some of them four feet long, appears high up in the Independence zone. In the quarry a few rods above the bridge, where twelve feet of rubble breccia with close-set calcilutite fragments overlies the Otis lime rock, this breccia is bounded above by an undulating bed of light brown calcilutite three feet thick in irregular massive beds about one foot in thickness. Weathering shows that the rock is minutely fragmental in structure. In places the ledge is broken and faulted. Immediately upon this rests for a short distance a soft buff limestone and a foot or so higher up is a string of large and small fragments of soft speckled buff limestone. A tract of weak breccia with shaly matrix separates these ledges from the zone of big blocks which lie above the Independence. At one of the most southern of the quarries, where a weak breccia with fragments from two inches to two feet in diameter, imbedded in soft clayey matrix, rests upon the buff Otis lime rock, a string of brown laminated calcilutite blocks appears above this breccia. The string has a distinct dip to the southeast, and a number of blocks of whitish calcilutite a few feet above show the same trend.

The Lower Davenport beds are seen in place only at the Aungst quarry adjacent to Kearn's quarry where they appear in the form of a cornice of drab and gray calcilutite five feet thick, dipping from 10° to 25° and greatly shattered, the seams being filled with calcite. Angular or somewhat rounded fragments of calcilutite are occasionally seen included in the Upper Davenport.

The Upper Davenport appears in massive ledges as in the railway cut. In large part they retain their initial position relative to the weaker lower beds. But great slickensided tilted blocks are found far within the brecciated Independence zone and smaller but characteristic fossiliferous fragments are found nearly to its base. Thus at a quarry up river from the bridge a twelve-inch fragment of the Upper Davenport occurs within one foot of the undisturbed buff Otis lime rock and a large

block of the Upper Davenport may be seen within three and one-half feet of the same datum plane.

Linn County

The three trunk streams which trench the Wapsipinicon terrane in their courses across the county afford excellent sections of the beds involved in the major brecciation. These streams are Cedar river from Covington to Otis, Buffalo creek at Coggon and the Wapsipinicon from Troy Mills to Central City. The shattered Bertram beds are exposed along Indian and Big creeks, tributaries of the Cedar. The Coggon phase of the Otis is seen practically undisturbed at Otis, at Coggon and at Springville. The Cedar Rapids phase has suffered only a slight deformation marked by low undulations of the strata and crackling of the more brittle beds. The Independence is slightly folded but only partly brecciated at Kenwood, Otis and in the quarries about Cedar Rapids; but at the old cut of the Chicago, Milwaukee and Saint Paul Railway west of Linn it is intermingled with the higher terranes. The Lower Davenport is generally thoroughly brecciated, but at Kenwood beds only partly brecciated immediately overlie the Independence. The Upper Davenport appears west of Linn and along Felton creek, Cedar Rapids, in characteristic broken ledges carrying the First Fauna. The Linn section shows the soft buff limestones which hold the Second Fauna, shattered and intermingled with lower terranes. It is in the sections of Linn county that the sequence of the terranes of the Wapsipinicon is most clearly displayed and the effects of the major brecciation are most readily distinguished from those of the minor brecciations which preceded it.

SILURO-DEVONIAN CONTACTS

SECTION EAST OF CENTRAL CITY

(Northwest quarter of the southwest quarter of section 1, township 85 north, range VI west)

		FEET
5.	Otis limestone, Cedar Rapids phase, with much black flint..	6
4.	Slope, no rocks exposed.....	10
3.	Otis limestone, Coggon phase, abundantly fossiliferous, resting directly and apparently conformably on bed below..	16¼

2. Limestone, magnesian, compact, gray, crystalline-granular, made up of two layers in even courses four and five inches thick and a basal irregular layer about one foot thick which rests directly upon bed below..... 1¾
1. Dolomite, Hopkinton stage of Niagaran, with casts of corals and *Bronteus* cf. *B. laphami*..... 4

SECTION SOUTH OF PARALTA ON BIG CREEK

(Northeast quarter of the southwest quarter of section 7, township 83 north, range V west)

FEET

5. Slope covered with imbedded fragments and blocks of Bertram limestone; near the base a ledge of same six feet thick; actual contact with No. 4 not observed although they are but a foot or so apart.....28
4. Dolomite, or magnesian limestone, saccharoidal, light gray, weathering yellow, hard, compact, in obscure courses resembling rough masonry which become thinner and more distinct below.....19½
3. Dolomite, or magnesian limestone, dark gray, similar to No. 4 but evenly and distinctly stratified in layers one-half inch to three inches thick; weathering to quadrangular chipstone 3
2. Unexposed 1½
1. Limestone, Anamosa phase of Gower stage of Niagaran, finely granular, buff, finely laminated, with abundant casts of *Leperditia*.....12

COGGON SECTIONS

At Coggon, five miles due north of Central City, Buffalo creek cuts nearly to the base of the Wapsipinicon beds, and the Niagaran appears a mile east of the village at Nugent's quarry. Exposures in and about the town afford a general section reaching as high as the basal shaly beds of the Independence.

CUT OF ILLINOIS CENTRAL RAILWAY, ABOUT ONE-HALF MILE NORTH OF COGGON

FEET

9. Limestone, dark reddish 3
8. Limestone, buff or purplish, in layers from one inch to eight inches thick, containing nodules of quartz and calcite, and arenaceous with quartz sand and angular bits of chert 4
7. Shale, highly argillaceous, blue, thinly laminated; unfossiliferous 5
   The section is continued downward in the adjacent *Mains Quarry*.
6. Shale, greenish, and limestone, thin-layered, with imbedded limestone fragments 1½
5. Limestone, like No. 4 in the next section, but less variable 8

SECTION ADJOINING THE RAILWAY TRACK NORTH OF THE STATION

5. Limestone, light yellow-gray calcilutite, in thin layers.... 2
4. Limestone, variable and lenticular, mottled, earthy-crystalline, in places composed of minute angular fragments of hard limestone with buff matrix. Siliceous, especially above, with black flint, in places becoming vesicular like pumice, probably from the removal of interstitial calcite 8
   With an interval of a few feet the section is continued in *Ashby's Quarry at the railway station.*
3. Limestone, gray, hard, compact subcrystalline magnesian layers from one inch to four inches thick, weathering into block chipstone 2
2. Limestone, massive, pale buff, magnesian, moderately hard, granular, subcrystalline, porous and vesicular, with a few irregular cavities about an inch in diameter, in layers from eighteen to twenty-four inches thick, moulds of *Spirifer subumbonus* plentiful; lower two feet variable, in places brownish buff, semiearthy-semicrystalline 8
1. Slope to water in river, elsewhere seen to be occupied by massive limestone similar to the above..... 6

In the above combined sections Nos. 6 and 7 are the Independence, and 1 to 5 inclusive belong to the Otis. Number 2 with No. 3 is the magnesian basal phase of the Otis designated as the Coggon beds by the writer before the identification of the prevalent fossil, *Spirifer subumbonus,* of both the magnesian lower and the nonmagnesian upper beds proved the identity of the Coggon with the Otis. While minor disturbances of sedimentation are to be noted, as in No. 4 and No. 6, no general brecciation is here displayed. The zone of the major brecciation, here as farther to the south, at Cedar Rapids, and west, as at Troy Mills, or north, at Quasqueton, no doubt lies above the basal Independence.

TROY MILLS SECTION

At Troy Mills, on the right bank of Wapsipinicon river below the dam, several square rods of the breccia of the major brecciation are exposed slightly above water level. The surface of this floor is hummocky, due to the relative resistances of different areas of breccia according to amount of matrix and degree of cementation.

The geological horizon is that of the Upper Davenport, and blocks of this hard, tough granular fossiliferous limestone, a foot and more in diameter are numerous. Some of these blocks show slickensides. The yellow fossiliferous fine-grained limestone immediately overlying the Upper Davenport beds also is

involved and may be seen in undisturbed strata, in large fragments tilted and mingled with those of lower beds, and, under the bridge, in a ledge three or four yards long composed chiefly of shattered and partly brecciated rock of this horizon abutting at the west on a breccia of blocks of Upper Davenport.

An exceptional number of blocks show the juncture of the Lower Davenport calcilutite and the Upper Davenport coquina. Along the zone of juncture the laminæ of the former are flexed, broken, detached and imbedded in the paste of the latter rock. The brecciated beds from which such blocks were broken evidently were formed before the Upper Davenport was lithified. These blocks range from one foot to two and one-half feet in diameter, thus showing the firmness of their cementation and their ability to withstand without crush the stresses of the major brecciation which broke the bed into blocks and mingled them with fragments of other strata. Blocks are noted in which the contact is even and the calcilutite laminæ are undisturbed. But here a few small angular bits of the calcilutite occur sporadic in the Upper Davenport portion of the block. A block of two and a half feet diameter shows calcilutite laminæ mostly in place but partly bent and detached and imbedded in the granular fossiliferous paste. This block is also traversed by a half inch seam filled with the same paste and some calcite.

In one area of a yard square blocks chiefly of Upper Davenport are cemented with calcite which fills seams in places an inch and a half wide.

There are also areas of rubble breccia of calcilutite fragments set in interstitial yellow matrix of which but little is here arenaceous. The fragments when detached show no wear upon their edges, which remain as sharp as when first broken and show no corrosion upon their sides.

Two miles southeast of Troy Mills (southwest quarter of section 10, township 86 north, range 7 west) there is a noteworthy outcrop on the left bank of a small creek flowing into the river from the south and affording the following section:

	FEET
3. Independence shale, buff and blue, weathering to clay, with some harder layers of crystalline-earthy limestone one or two inches thick, and dark brown earthy-granular limestone three to four inches thick, with some large siliceous	

nodules. Slightly undulating in swells eight inches high and five feet long 13

2. Limestone, hard, brown and buff..... 2-3
1. Otis limestone, massive, crackled, seams healed with calcite, fossiliferous with *Spirifer subumbonus;* thickness to water level at east end..... 2¾

To the west a vertical fault, with a throw of about three feet, drops No. 1 just below water level.

On the hill overlooking this creek from the east the road gullies disclose about twenty-five feet of the Independence shale, overlain by five to ten feet of a breccia of small fragments of drab calcilutite—the Lower Davenport horizon.

Still farther down river on the right bank the following section is poorly exposed at the "Wolf's Den" (southeast quarter of the southeast quarter section 14, township 86 north, range VII west).

5. Upper Davenport horizon, seen in blocks of fossiliferous limestone on sloping hillside.
4. Lower Davenport horizon marked by a few poor outcrops of drab calcilutite breccia.
3. Lower Davenport breccia, in strongly cemented ledge, fragments of drab calcilutite up to one foot in diameter, set at all angles, matrix sparse..... 4
2. Limestone, rather hard, brown; mottled with masses of soft, light buff limestone whose upper surface is highly irregular and which is absent in places; maximum thickness 2½
1. Limestone, buff, earthy, fine-grained, evenly laminated, in beds up to five feet thick, to water's edge about..... 15

About one mile down stream in the south half of section 24 a steep hillside fronting the Wapsipinicon on the right bank gives the following section:

FEET

8. Upper Davenport horizon, seen in blocks of fossiliferous limestone nine inches thick apparently in place eight feet above summit of No. 7.
7. Lower Davenport limestone, brown and gray calcilutite, in uneven, finely fragmental layers of two or three inches thickness 2
6. Independence limestone, in cliff, buff, soft, earthy, evenly laminated, beds undulating, in places brecciated, fragments and matrix alike but matrix more resistant. The removal of the angular and commonly quadrangular blocks by solution and other processes of weathering gives the surface of the brecciated beds where exposed in the cliff a peculiar reticulated appearance. The interstitial matrix is left in high relief as a network of thin limestone walls somewhat resembling those of septaria (figures 80 and 85). These matrix walls occa- matrix walls occasionally are marked by close-set, low parallel linear ridges, giving them a finely laminated

appearance. The ridges, however, are not harder laminæ left in relief but are casts of the etched edges of the weaker laminæ of the formerly inclosed fragment. Hence a time sufficient for the etching of the sides of fragments elapsed after fragmentation before the completion of the filling with the matrix 18

5. Talus slope 18
4. Independence shale, argillo-calcareous, buff with blue cores, showing spheroidal weathering 2
3. Talus slope 3
2. Otis limestone, mottled brown and buff, in low gentle undulations, in places consists of drab calcilutite carrying *Spirifer subumbonus* and overlain with three inches of brown saccharoidal limestone ..... ¾
1. Otis limestone, gray and browish gray, crystalline, in uneven layers about one inch thick; to level of the river... 2½

Number 6 of this section is apparently identical with No. 1 of the section at The Wolf's Den, and both strongly resemble the magnesian layers of Aungst's quarry of Vinton, which are referred to the lower beds of the Otis. But the presence of typical basal Independence in No. 4 of this section, thus closely paralleling the Kenwood section, and still more the presence of Otis limestone in No. 2, with the characteristic Otis fossil, *Spirifer subumbonus*—its most northerly known occurrence in Iowa—concur in identifying No. 6 with the Independence.

Down valley, as Wapsipinicon river cuts more and more deeply into the beds which bear its name, it reaches the base of the Otis limestone and enters the Niagaran dolomite at or near Central City. Two miles northwest of this village, at Granger's old quarry (southwest quarter of the southeast quarter of section 28, township 86 north, range 6 west), the Niagaran is still below water level, but the basal magnesian beds of the Otis are, in force with characteristic fossils.[62]

CEDAR RIVER SECTIONS

THE LINN SECTION. ABANDONED CUT OF CHICAGO, MILWAUKEE AND SAINT PAUL RAILWAY. WEST OF LINN.

This cut, which scarps the bluffs on the left bank of Cedar river for the length of about three-quarters of a mile and offers a vertical section of about sixty feet, is one of the most extensive Wapsipinicon exposures in the state. The brecciated zone here involves all terranes of the Wapsipinicon except the Otis, whose

[62]Norton, W. H., Geology of Linn County: Iowa Geol. Surv., Vol. IV, pp. 149, 150.

calcilutites appear two miles to the southeast in old quarries along the Chicago, Rock Island and Pacific railway, but here have dipped beneath the level of the base of the outcrop. No exposure in the state shows more thoroughgoing and complete brecciation. Furthermore, this section is of exceptional importance in that it and the Brandon exposures recently discovered by Thomas offer the only outcrops of the fossiliferous Independence shales which are open to observation.

It is quite impossible to give any general vertical section of the chaotic brecciation displayed which will be applicable to it at all points. Here the breccia is composed largely of detritus of the buff Independence and there of Lower Davenport calcilutites. At one point fossiliferous limestones of the *Spirifer pennatus* beds are found commingled with blocks of the Upper Davenport and Lower Davenport at the bottom of the cut and at another the shaly Independence predominates to the summit.

The railway grade descends from fifty-nine feet above the river at the north end of the cut to twenty feet above it at the south end. The diagonal belt thus scarped has a total height of about sixty feet, but as the terrane dips southward the stratigraphic thickness of the section probably is considerably less.

It is possible to make out traces of a zonal arrangement of the material from the beds which have contributed to the breccia. Thus at the north end of the cut the highest beds are from a coral reef containing *Phillipsastrea billingsi, Acervularia,* numerous cyathophylloids and *Favosites.* In places along the top of the cut, but at a lower level than that of the coralline zone, the *Spirifer pennatus* beds are well-nigh continuous. Somewhat lower, the horizon of the Upper Davenport is marked in places by lines of huge blocks in which *Gypidula comis* is the common fossil. The Lower Davenport calcilutites are nowhere in place, but large areas of breccia are composed chiefly of the quadrangular fragments of these brittle, thinly laminated beds. The Independence is most conspicuous in tracts of exceptionally abundant buff, soft matrix.

Toward the south a wide, open valley tributary to the Cedar interrupts the section, dividing it into a south and a north cut, the latter being much the longer.

In the south cut, as in the north, the dip of ledges and the boundaries of areas of weak breccia trace obscure anticlines (figure 87). At the center of one of these upfolds, and four feet above the railway grade, occurs an interrupted ledge of massive soft saccharoidal limestone four feet thick, mottled white and brownish with some periphyral calcite crystals (A). Resting on this bed is a tract of buff sandy matrix of Independence facies with sporadic pebbles of white crystalline rock and of soft fine-grained buff limestone (B). Above this is a tract of rubble breccia of drab calcilutite fragments (C). It is surmounted by seven inches of buff soft limestone in part minutely

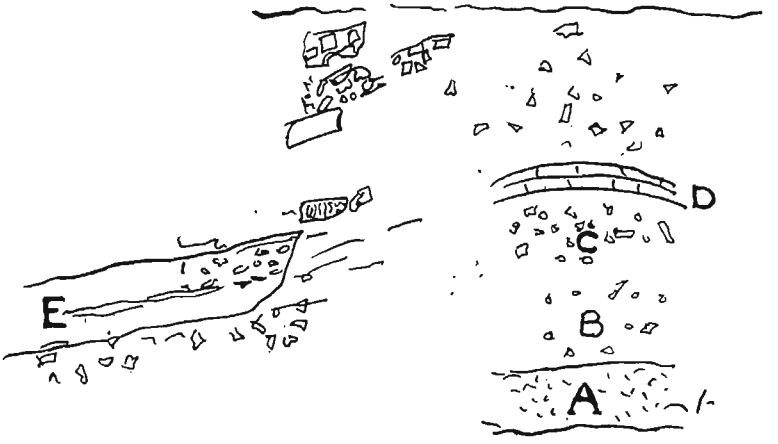


FIG. 87.—Section in the south part of the old railway cut west of Linn, Linn county.

fragmental, bent to an arch with a diameter of eight feet and a height of one foot (D). At the summit of this obscure anticline the breccia is somewhat fossiliferous (two specimens of *Atrypa reticularis* were observed), denoting a slight commingling of fossiliferous beds. The lowest ledge recalls the ledges of somewhat similar limestone seen at the base of the breccia of section E of Felton creek, Cedar Rapids.

A similar ledge occurs near the base of the northern limb of the arch. Here a ledge of limestone three feet thick is tilted northward at an angle of 10° (E). It consists of a layer two feet thick resting on a somewhat lenticular mass of brownish crystalline rock. The two-foot layer is composed above of whitish

saccharoidal limestone inclosing small sparse fragments of a pinkish buff fine-grained limestone, with a few small calcilutite fragments. Within the same layer this whitish limestone passes downward into a four inch bed of pinkish buff rock identical with the fragments included in the whitish limestone. To the north the pinkish buff rock is little disturbed, except that calcite seams in relief show considerable crackling of the rock, but to the south it is much broken up and its fragments are imbedded in the matrix of the whitish rock above. At this end of the ledge the whitish rock also shows larger and more numerous fragments. The ledge thus records continuous but disturbed sedimentation. It rests upon a breccia of preponderant buff Independence matrix carrying near the top an elliptical six inch siliceous nodule. The ledge also abuts laterally on breccia of the same type. In juxtaposition at the south end are two large fragments each showing complex brecciation and parallelism of detached laminæ of calcilutite. The place of these whitish saccharoidal limestones seems to be the same as that of those seen in section A of the Felton creek exposures, that is at the base of the Lower Davenport.

A few rods from the lower end of the north cut and also at the northern base of a rude anticlinal structure there is seen a horizontal bed of breccia two feet thick whose unequiaxed fragments are set at all angles. These fragments range up to three inches in diameter and consist mostly of drab calcilutite with some small chips of light buff fine-grained limestone. The matrix is light buff and is little more than interstitial. In places it is slightly sandy. Upon this bed rests another layer of breccia one foot thick, whose close-set calcilutite fragments are smaller than those of the bed beneath. A little chert sand is visible but very little of the buff matrix rock is to be seen. There is considerable gray granular rock either as matrix, as fragments or as both.

The bedding of the layers indicates sedimentary deposition. In this case the high angles at which the unequiaxed fragments stand would point to flow en masse rather than to deposition of fragment after fragment by a slightly overloaded current. The fragments of the beds are similar to the fragments throughout

these breccias in their angular unworn condition. The position of this ledge as well as its structure suggests comparison with the basal ledges in the south cut, and the fragmental structure of both seems to be due to minor brecciations during Lower Davenport time while the breaking up of the ledges is referred to the major brecciation.

Independence Areas of Breccia.—These are not areas in which the Independence has been preserved intact. They are areas of breccia characterized by the abundance of material which is referable to that formation. The large admixture of Independence detritus renders the breccia argillaceous and soft, so that these areas weather back to slopes. In comparison with the fragments of other and harder beds the soft buff Independence detritus appears as matrix. It is not a sediment in which the foreign fragments of hard rock have been imbedded; no lamination lines are seen within it as a rule; it is the fine detritus to which weak rock has been crushed in a brecciation involving harder beds. Other outcrops, however, show that sedimentary breccias were formed in Independence time, and a few probable relicts of such breccia are to be found in this section.

The larger of the Independence areas rise in the centers of rude and obscure upfolds with steeply outward-dipping areas of strong breccia on either hand, but smaller areas occur at several places in the section. Where it is most abundant, the material referred to the Independence weathers to flattened irregular lumps two inches and more in horizontal diameter, a structure similar to that seen in No. 7 of the Chicago, Rock Island and Pacific Railway cut at Cedar Rapids, where the shales are practically undisturbed. Much of the material is sparingly arenaceous, with disseminated bits of chert easily recognizable on weathered surfaces. These grains are not assembled into laminæ in the matrix rock but are sporadic like the larger fragments. They are not gathered around the base of larger fragments as if swept and lodged there by currents of water. Siliceous nodules of intercrystallized quartz and calcite, elliptical or ovate in shape and as much as a foot in longest diameter, occur sparingly. Some of these are set at high angles in the breccia.

FIG. 88.—An area of predominant Independence shale strongly bent and much broken with some included fragments. Strong Davenport breccia at left. Summit of arch, Linn section, Linn county.

Certain fragments of impure limestone in the breccia which probably belong to the Independence are a dingy buff color. Some of these are themselves sporadically fragmental, and in this case a disturbance of sedimentation in Independence time is inferred. At a few points some of the beds seem to have been preserved. At the lower end of the north cut a buttress of strong well-cemented limestone breccia rises abruptly from the tracks and forms natural ledges on the valley sides. Immediately beyond, an area of Independence, forty-five feet wide, gives rise to talus which rises within twelve feet of the summit of the cut. At three points the Independence breaks through to the top of the section in chimneys of weak shaly breccia and talus parted by towers of breccia of the upper limestones. At the north of this area of Independence, blocks of the higher formations descend steeply

to the railway grade in well-nigh vertical cliffs. Along the summit of this Independence area one may find in places a fine gritless calcareous shale closely laminated and bent to strong convex curves to conform to the curves of the lower surface of the limestone breccia above or at either side. It is clearly impossible that the laminæ were deposited in their present attitude, and their deformation is attributed to the major brecciation (figure 88).

Some rods north of this area there appears midway the section a ledge of massive bluish limestone two feet thick, weathering to buff, soft, fine-grained, earthy, of Independence facies, dipping 20° to the north (figure 89, B). The bed contains very rare minute sporadic fragments of drab and buff limestone and some quartz nodules. It graduates above along an undulating line into light grayish buff clayey rock of about the same thickness, which weathers into minute chipstone and irregular lenticular lumps (C). This bed contains areas of finely laminated calcareous shale and weathers back beyond both the ledge below and a cornice above. The bed contains fragments of drab limestones more numerous than those of the ledge on which it rests but still small and sparse. The cornice which overhangs it is of breccia (D) whose fragments are larger and more numerous and better cemented than those of the beds beneath. The aspect of these beds is that of continuous deposition and recalls the bed of breccia intercalated in the little disturbed layers of the Independence in Section C of Felton creek, Cedar Rapids.

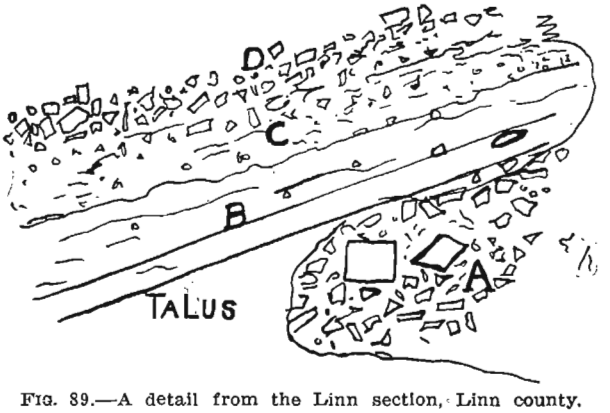


FIG. 89.—A detail from the Linn section, Linn county.

For ten feet this ledge of Independence facies overlies a tract of well-cemented rubble breccia (A) of Upper Davenport with an occasional fossiliferous fragment and Lower Davenport calcilutite fragments with sparse matrix, just as in the Vinton Railway cut a similar ledge, the lower part of which is laminated shale in place, rests upon a breccia carrying fossils of higher beds. For the reasons mentioned in the discussion of the Vinton section the ledge is referred to the Independence, and its fragmentation is referred to an Independence brecciation. The fossiliferous breccia underneath it is assumed to have been underthrust from the south, thus tilting it to a moderately high angle.

The Lower Davenport Zone of Brecciation.—The tracts to which calcilutites referable to the Lower Davenport have contributed the mass of the fragments do not offer any features different from those seen in other sections. The fragments are well cemented by a sparse calcareous matrix in some places gray and in others buff and slightly arenaceous. Here the stresses were sufficient to intermix fragments of the higher fossiliferous beds, and more than sufficient to destroy any ledges of mosaic breccia such as those seen at Quasqueton. But a few fragments, themselves of crackle or mosaic breccia, lead to the inference of a brecciation during Lower Davenport time or at its close, when such ledges were produced.

The Upper Davenport Zone of Brecciation.—The tough, hard beds of fossiliferous gray limestone (the *Gyroceras* beds of Calvin) are here more broken and displaced than in several other sections (Plate X). Yet in places they appear in interrupted ledges, the blocks tilted but retaining something of their initial attitude (Plate XI). The large size of a few of the blocks is noteworthy. One measures eleven feet in length with a thickness of two and one-half feet. The fracture planes are commonly smoothed and grooved with slickensides on a few of which calcite crusts have formed. These surfaces cut across bedding planes and transect the thick shells of *Gypidula* and other fossils. Besides these ledges near the summit of the section, large blocks and irregular masses of breccia of this type occur down to the level of the railway grade. Thus at the lower end of the north cut, blocks two to three feet in diameter are common and one

In Upper Davenport zone of brecciation, Linn section, Linn county.

block five feet long is seen. In this strong breccia blocks of Upper Davenport, Lower Davenport, and the *Spirifer pennatus* beds are mingled pell-mell without the slightest zonal arrangement except near the top where the *Spirifer pennatus* beds prevail. The matrix here is scant and of the sandy buff Independence material.

The stresses which broke the Upper Davenport into blocks seem to have been sufficient as a rule to detach from it the Lower Davenport laminæ. In one case only were the two lithologic types found conjoined in a single block. In this case the contact phenomena showed that there had been undisturbed continuous deposition without fracturing of the laminæ of the lower rock. Several blocks appear, however, which show calcilutite fragments imbedded in the Upper Davenport. Thus one seen near the base of the section at the lower end of the north cut contains twenty-two small angular sporadic calcilutite fragments in an area six inches square. All these were under one inch in diameter except a fragment three inches in size which itself was brecciated. Such crowding is quite exceptional. No lenticles of calcilutite arranged in lines parallel to the bedding have been observed.

Zone of the Spirifer pennatus beds.—A soft, yellow shaly highly fossiliferous limestone lies along the summit of the north cut. The beds are shattered and in places blocks are set on edge. Of these beds distinctive fragments also have been mingled with the rubble breccia beneath to the bottom of the cut.

An interesting block at the base of the north cut near the upper end consists of a large mass of *Diphyphyllum* coral between whose slender branches hundreds of the young of various species of brachiopods had found a sheltering home.

ELLIS PARK QUARRY, CEDAR RAPIDS

Figures 46 and 47, pages 380 and 381

This quarry, operated by the city for crushed stone, is situated at the northeastern edge of the park on the side of a bluff facing Cedar river. Beneath a shallow and here negligible cover of drift, the Independence appears as a buff calcareous shale.

The juncture of the shale with the Otis limestone beneath is particularly well marked. The upper zone of the limestone is characterized by the development of gigantic lenses. Beneath these the main body of the Otis consists of brown limestone, laminated in places, which passes downward into brown magnesian limestone vesicular at the base. The Otis has been thrown into low undulations and the beds are traversed with narrow vertical and oblique seams filled with calcite. The base of the section is nine feet above water level in the Cedar. Many of the layers are irregularly bedded, with brownish or black films covering rugose surfaces.

INDEPENDENCE.

		FEET
17.	Shale, buff, calcareous, weathering to clay, stratification shows in horizonal lines of cores of weathering and in harder thin beds. Easily cut down anywhere with spade. Small elliptical nodules of black flint occur and larger masses of intercrystallized quartz and calcite.....	8

OTIS.

16.	Limestone, lenticular or massive mottled buff and dark brown, or light gray and dark drab, fragmental in structure. Lenses up to nine feet in diameter and from three to five feet thick form the base of the stratum. These are overlain by massive limestone of the same structure or in places by thin overwrapping layers of hard drab limestone, whose laminæ are flexed and in places broken.	7
15.	Limestone, hard, brown, fine-grained with disseminated crystalline particles, some layers saccharoidal, in layers from three to eight inches thick, laminated conspicuously with narrow bands of alternating lighter and darker stone which may be as numerous as ten to the inch, and in places are slightly undulating. Overhanging layers show a mesh-work of projecting fissure casts. Some layers show narrow stylolitic surfaces. Closely filled nests of calcite, a few inches in diameter, occur. The stratum is flexed beneath lenses of No. 16.....	6
14.	Limestone, brown, finely crystalline, subconchoidal fracture, compact, rapid effervescence, crackled.....	2-3
13.	Limestone, brown, in irregular courses from one-half foot to two feet thick, parted by blackish films along rugose surfaces. Some layers affected throughout with lustrous cleavages of calcite. Some layers of calcilutite. One or two feet at base is massive, light brown crystalline or granular limestone with disseminated subangular or rounded darker masses a fraction of an inch in diameter. In the finely granular matrix rock these masses are of coarse saccharoidal limestone; in the more crystalline matrix they are in part or wholly of black flint.....	4
12.	Limestone, calcilutite, light gray, moderately brisk effervescence, crackled with vertical and oblique calcite-filled seams, the fine hair-line seams grouped half a dozen to the inch, the larger three to four inches apart.....	1

Large blocks of Upper Davenport limestone in alignment, Linn section, Linn county.

11. Limestone, brown, massive, rapid effervescence, in places traversed by calcite cleavages, in places mottled or minutely fragmental as is No. 13, but not so conspicuously, surface hummocky and minutely rough, parted from No. 12 by brownish crust 2
10. Limestone, light gray calcilutite similar to No. 12, small calcite nests with diameters of one to three inches; massive, and parted from No. 9 along irregular surface..... 1 1-6
9. Limestone, brown, crystalline, lenticular, slow effervescence, rather obscurely laminated with undulating lines and bands of more earthy and lighter colored rock, with elliptical calcite nests up to one foot in diameter.. 3½
8. Limestone, crystalline, slow effervescence, buff and coarsely and highly vesicular above, brown, coarsely saccharoidal and more compact below..... 1 1-6
7. Limestone, brown or black, macrocrystalline, rapid effervescence, passing into soft impure ochreous limestone with stretches of elongate cavities filled with calcite crystals mingled with ochreous-calcareous clay, upper surface parted from No. 8 by black crust..... 1-3
6. Limestone, brown, hard, cryptocrystalline, crackled, slow effervescence, laminated, overwrapping in three layers the lenticular surface of No. 5..... 1 1-3
5. Limestone, rough, buff, vesicular, lenticular, with elliptical calcite nests up to a foot in horizontal diameter; rather slow effervescence 1
4. Limestone, hard, brown, cryptocrystalline, obscurely laminated, with lines of minute cavities resembling molds of short flexuous rods of less than a millimeter in diameter; effervescence varying from slow to moderately rapid 5
3. Limestone, brown, laminated ..... ½
2. Limestone, brownish buff, massive, cryptocrystalline, vesicular, slow effervescence, upper surface irregular and stained reddish ..... ¾
1. Concealed to level of river 9

SNOUFFER'S QUARRY, CEDAR RAPIDS

Right Bank of Cedar River, Near Chicago, Rock Island and Pacific Railway Bridge (figure 51, page 400).

PLEISTOCENE.

FEET

19. Loess, brown, weathered 5
18. Sand, light yellow, in horizontal layers, graduating by interbanding into loess above 10
17. Till, reddish 6

INDEPENDENCE.

16. Shale, calcareous, soft, buff, weathering to detached laminæ a fraction of an inch thick and to brittle flakes a millimeter in thickness. Harder layers of buff argillaceous limestone an inch or more thick are seen, also thin lenticles, which coalesce into layers an inch or so thick. These lenticles consist of saccharoidal calcite and some silica with interlaminated areas of soft impure buff

limestone. Lenses of silica up to three inches in thickness occur 6

15. Shale, calcareous, blue, weathering to buff 6
14. Shale, blue, thin-layered, fissile in flakes a fraction of an inch thick, unctuous on wet surfaces, spheroidal, weathering to lenticular surfaces 4
13. Shale, calcareous, blue, with close flexuous dark lines of lamination which knot into nodules in places. Layers up to five inches in thickness 2 1-3
12. Shale, calcareous, buff, with narrow blue cores, in layers from two to eight inches in thickness, wavy laminæ, lenticular partings 2
11. Limestone, blue, argillaceous, obscurely laminated, with small nests of dog-tooth spar horizontally arranged. Laminæ in places marked by close-set wavy lines. In two layers both of which thicken down the sides of the lenses of No. 9..... 2

OTIS.

10. Limestone, brown, weathering light gray, a calcilutite below becoming more or less crystalline-granular in texture above. Upper three inches laminated. Upper surface rugose and covered with thin clayey parting, and with hollows filled with calcite. This layer partly evens the depressions in the lenticular layer beneath and thus differs in thickness within a horizontal distance of four feet from four inches at the crown of the lens to one foot eight inches in the hollows..... 1 2-3
9. Limestone, massive, lenticular, brown, saccharoidal, mottled buff or gray. Upper surface hummocky and rugose, parted from No. 10 by a thin selvage of brownish clay. Lower surface irregular with a clayey selvage and purplish decayed fragmental limestone four inches or less in thickness. Containing *Spirifer subumbonus.*

    Fantastic mottlings (figure 50) affect particularly the upper two feet of this layer. A vertical arrangement in the mottling is marked, the buff earthy areas having the appearance of narrow irregular and discontinuous pipes in the mass of brown crystalline rock. The areas of differently colored rock meet on irregularly and minutely curved surfaces. In places small imbedded fragments of the buff rock are bounded by straight lines. The buff areas in places are replaced by gray rock. Both buff and gray areas are composed of soft argillaceous limestone or calcareous shale which is earthy but effervesces briskly in cold dilute HCl. Occasionally the gray is found to be somewhat granular-crystalline. The brown saccharoidal rock is in places shot through with calcite cleavages and a number of small rhombs of clear calcite occur. Small nodules of black flint with buff smooth surfaces are rarely found. At one point an area of one or two square feet contains numerous sporadic quadrangular fragments of whitish fine-grained laminated limestone less than one-half inch in size.....3 to 5
8. Limestone, massive, gray or light brown, parted from No. 9 by clayey selvage, conforms to lower surface of No. 9, rising between its lenses. Upper surfaces rugose with protuberances an inch and less in height and three inches wide but with a few three or four times as large.

The upper one to three inches fragmental with numerous small rounded fragments of soft light yellow limestone. The lower surface bends downward beneath the lenses of No. 9, but with a diminished curve 1

7. Limestone, light brown, weathering light gray, closely laminated with laminæ of different shades, somewhat wavy, but generally parallel and even. Small cavities with linear horizontal arrangement common. In places a little disturbed sedimentation is seen in broken inset laminæ. Some thin horizontal calcite seams..... 4
6. Limestone, calcilutite, light brown weathering to gray, massive, with some irregular half-inch cavities with horizontal arrangement. In parts of the quarry the stone is subcrystalline 2
5. Limestone, light brown, crystalline, laminæ gently undulated, of lighter and darker shades. At the west end of the quarry the lower two feet of this layer is massive and the basal part of this massive layer is broken and the fractures are filled with brown calcite. Some parts are mottled with black flint in sporadic irregular areas a fraction of an inch in diameter or with gray chert.... 3
4. Limestone, calcilutite, light yellow-gray, massive. The basal portion between the lenses of No. 3 is darker and minutely crystalline. Upper surface horizontal, lower surface conforming to curved surfaces of lenses of No. 3 2
3. Limestone, brown, crystalline, brisk effervescence; in places laminated with close set slightly wavy laminæ; nests of white calcite. This layer in places is lenticular and macrocrystalline with brown calcite crystals; its hummocky rugose upper surface is covered with a brownish or blackish crust of clay. Horizontal seams, one five feet long, of brown calcite crystals .....1 to 2
2. Limestone, calcilutite, light gray, laminated above, massive below 2 2-3
1. Limestone, brown, crystalline 1¼

The bedding of the quarry is fairly even and horizontal except where affected by the lenticular structures noted. The Independence, however, shows slight undulations of the strata. The beds of the Otis are quite generally traversed by vertical and oblique narrow cracks healed with calcite. These are more marked in the massive and brittle calcilutites.

CUT OF CHICAGO, ROCK ISLAND & PACIFIC RAILWAY.

Two and a quarter miles southeast of First Avenue, Cedar Rapids

This cut exhibits twenty feet of the Independence resting at the southeast end on ledges of the Otis. The entire body of the Independence is argillaceous and much of it is a fissile shale. Some more calcareous layers standing in relief on the weathered slope show a slight dip to the northwest. All layers are slightly

undulating, and shaly beds show strong folds within narrow horizontal and vertical limits.

		FEET
10.	Shale, buff, calcareous, with large siliceous nodules	4
9.	Limestone, argillaceous, brown, coarsely saccharoidal, weathering to dingy crystalline sand	2
8.	Limestone, whitish, fine-grained, brittle	1-3
7.	Shale, calcareous, with lumpy structure due to flattish irregular cakes which are traceable on vertical surfaces. Weathering to clay	5
6.	Limestone, argillaceous, brown, weathered parts crumbling under the fingers into sand	½
5.	Shale, blue, fissile, weathering to brittle flakes. In the midst of this bed there may be traced for ten feet a layer of slate colored earthy limestone from four to six inches thick made of lumpy fragments. At one point it forms a tiny lens whose interior is fissured like septaria and whose surface also is crackled	6
4.	Limestone, argillaceous, buff, with blue cores, with wavy laminæ, in layers up to nine inches thick	1½
3.	Shale	2
2.	Limestone, fine-grained, compact, blue weathering to grayish buff, earthy, fine-grained, in three layers, the lower crystalline, finely laminated, upper layer inconspicuously arenaceous with sporadic sand much of which consists of grains of black flint. These layers are wrapped evenly over the gently arching lenticular surfaces of No. 1, and in places thicken down the lens and thus even up the surface	1½
1.	Limestone, brown, saccharoidal, lenticular, with curved structure lines which have been opened by weathering directed outward and downward; mottled with buff or gray areas having a vertical arrangement. On the weathered edges of the beds these elongate splotches resemble buff stains left by a liquid trickling down the side of the brown rock. The buff areas are of a fine-grained earthy limestone on which weathering has etched out exceedingly fine lines of lamination. These lines are commonly concave and abut on the vertical sides of the area, where they are somewhat crumpled. In some a fragmental structure is indicated. As in other outcrops the boundaries of these mottlings are irregular, and some of them are rather intricately curved. The bluish gray mottlings are entirely similar to the buff except in color. At one point the buff finely laminated rock appears in an irregular band more than an inch wide and inclined at an angle of 30° above a parallel structure line in the lens. The band is finely laminated and the undulating laminæ are parallel with the edges of the band. In places laminæ of the brown crystalline rock are inclosed in the laminæ of the buff earthy rock. We have here contemporaneous deposition of the two while the dip of the band and the flexing of the laminæ indicate some distortion before the sediments became hard. The rock carries *Spirifer subumbonus*	5

CHICAGO AND NORTH WESTERN RAILWAY QUARRY, CEDAR RAPIDS.

This large quarry has been opened along the left bank of Cedar river southeast of the city. The section reaches from near the summit of the Independence to the lower magnesian beds of the Otis.

THE INDEPENDENCE

About thirty-five feet of the Independence have been preserved at the north end of the quarry, but over the larger part of the area most of the formation had been removed by erosion, and Pleistocene deposits rest upon the Otis limestone. A section near the north end along a north-south face is as follows (figure 90).

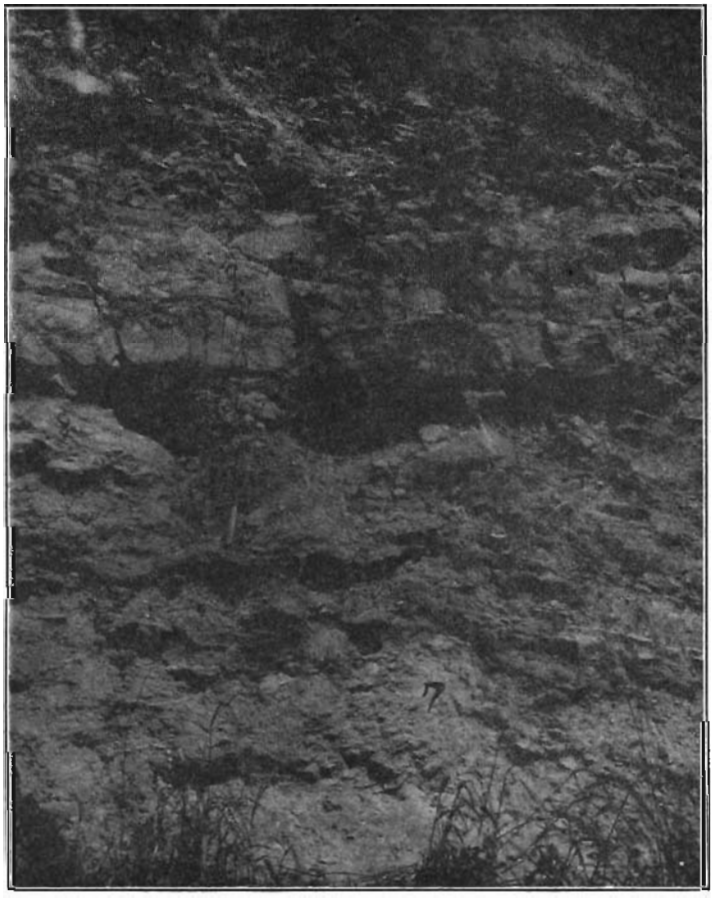


FIG. 90.—Independence limestone and shale. Quarry of the Chicago and North Western Railway Company, Cedar Rapids, Linn county.

FEET

9. Limestone, buff, earthy, weathering in places to thin plates, in even layers up to one foot thick, upper portion split to thin beds, slightly undulating and much shattered. In places the rock is speckled with disseminated darker crystals set in lighter granular rock. Commonly laminated with close-set wavy narrow lighter bands and darker more crystalline lines. In places the laminæ are bent to gentle folds less than a foot in width.....12

8. Limestone, fragmental, a rubble breccia, fragments small, usually a fraction of an inch in size, but some three and four inches long, angular, brown, finely crystalline, laminated, weathering to dark drab, finely granular surfaces. Matrix interstitial or somewhat larger in amount, soft, buff, in places weathers back leaving fragments in high relief. One larger fragment is seen to be shattered into quadrangular matching pieces. Upper surface hummocky. In places depressions are filled by the basal layer of No. 9, in places No. 8 graduates into No. 9 as its sporadic fragments are fewer and fewer upward within the limits of the same bed. Stratum continuous over most of outcrop, but in places gives way for two or three feet to masses of broken fragments of buff granular limestone similar to that of No. 9, half a foot or a foot in diameter. At one point the stratum graduates laterally into buff limestone with few sporadic fragments which graduates beneath into buff calcareous shale.

   This layer may be seen along a road leading into the quarry from the east and here it is less disturbed and is made up of clearly defined layers about two inches thick. These layers are themselves laminated, and the laminæ are more or less shattered and recemented within the limits of the layer. Some of the laminæ are merely broken without displacement and all degrees of rotation and displacement may be observed from this shatter-breccia to the condition where the entire bed is converted into a rubble breccia..... 1

7. Shale, buff, calcareous, with some limestone, largely brecciated, fragments easily detached; in places flexed to narrow anticlines and synclines. At top is a bed in places two feet thick in which siliceous nodules, for the most part broken to a rubble of sharp-edged fragments, are specially conspicuous. There are also many buff fragments and some fragments of brown finely crystalline limestone with diameters as much as three inches. The matrix is abundant and clayey, and fragments are easily detached. The rock in places is minutely fragmental and here fragments and matrix are nearly alike. At one point a bed of fragmental limestone, strongly cemented, is arched, one limb descending three feet within a horizontal distance of five feet.

   On the section along the road leading into the quarry from the east there may be seen undulating strings of quadrangular pieces of flint, parallel with the undulating surface of the layer in which they lie. The brittle flint deposited in a continuous thin bed was broken into bits while the still plastic limy muds with which it was intercalated yielded to the stress by bending. In places the flint chips are so sporadically scattered

in the midst of well defined layers that a contemporaneous breaking and deposition is implied.

Below these beds characterized by the abundance of siliceous fragments the breccia is softer, with the buff detritus as matrix or fragments more abundant, Siliceous nodules and fragments are found here. In places the matrix is highly arenaceous with angular grains of black and white flint and rounded grains of clear quartz sand. The lower part of these beds weathers to clay with cores of disintegration and fragments of shattered limestone layers largely in place. Much of lower part concealed by talus. Total thickness of No. 7.....15

6. Limestone, buff, argillaceous, irregularly bedded, passing above into buff thin layers and arenaceous shales..... 3
5. Shale, buff, calcareous, weathering to clay..... 2
4. Limestone, blue, argillaceous, weathering to buff for an inch or so from bedding planes and joints, arenaceous in certain thin layers with sand of angular black and gray flint and rounded grains of crystalline quartz..... 2

OTIS

3. Limestone, light gray, horizontally bedded, in thin irregular layers, fine of grain, fracture subconchoidal, seamed, contains some sporadic fragments of same rock..... 1
2. Limestone, brown, weathering gray, fine of grain, in uneven layers from a fraction of an inch to one foot thick, wrapping about lenticular masses of No. 1 with steep dips on the sides of the lenses and broken in places into breccia at their bases. In places sporadically fragmental with fragments the same as the matrix rock. Rock closely crackled, and seams passing through fragments as well as matrix. Sparingly fossiliferous with *Spirifer subumbonus*. Lenses of macrocrystalline brown limestone and of other types up to three feet in vertical diameter..... 4
1. Limestone of same general character as in Ellis Park and Snouffer's quarry 20

SECTIONS ALONG FELTON CREEK, CEDAR RAPIDS

SECTION A

A steep-sided narrow ravine takes its rise a few rods east of the Catholic cemetery, Cedar Rapids, and, continuing eastward a short distance, falls into Felton creek. This ravine gives the following section on the left bank near its mouth.

FEET

9. Breccia, fragments small, some six inches in diameter, dark drab weathering light gray, fine-grained, conchoidal fracture, some laminated, laminæ coherent and undulating, matrix buff, slight in amount. Along a path five feet below top of outcrop *Atrypa reticularis* and fragments of *Orthis* and *Spirifer* were found weathered out. Exposed in scattered bowlderets over slope of hillside in vertical distance of..... 8

8. Breccia, matrix buff, abundant, fragments of calcilutite sparse, some with wavy laminæ some of which are two millemeters thick..... 4
7. Small outcrops of white saccharoidal limestone in places containing sporadic drab fragments, in places mottled white and buff..... 3
6. Limestone, buff, soft, vesicular, in layers about one foot thick. Obscure undulating lamination..... 7
5. Limestone, reddish buff, weathering to thin layers, closely laminated, laminæ etched out on weathered surfaces; darker, more vesicular buff laminæ alternating with lighter colored and more compact..... 8
4. Limestone in thicker layers and lighter color than above with thin, brownish irregular laminæ..... 3
3. Limestone, brown, in thin layers..... 2
2. Limestone, buff, soft, earthy, fine-grained, massive, containing sparse small quadrangular fragments of hard dark drab limestone, edges mostly angular but not splintery, in places numerous but not in apposition, also fragments of thin laminæ of soft dark limestone; rare small nodules of dark gray flint 3
1. Limestone, buff, weathering to marl, with ledges of buff argillaceous rock with blue earthy-crystalline cores, speckled, the darker crystalline grains being set in a lighter earthy matrix, the crystalline grains left in relief on weathered surfaces. Sporadic fragments of dark bluish drab and of brownish crystalline limestone. The most characteristic feature is the abundant angular siliceous fragments and elliptical nodules some of which are as large as four inches in diameter. Small nodules of dark gray flint appear in places in the blue cores. In places the buff rock is thickly set with small quadrangular fragments of white chert as from broken laminæ a fraction of an inch thick, but for the most part the siliceous inclusions are crystalline.....10

The base of this section lies about twelve feet above the level of the creek. About fifteen rods up the valley of the creek the summit of the Otis appears. In the above section Nos. 1 to 6 inclusive are referred to the Independence, while the higher beds are of the Lower Davenport, for the most part brecciated and including fragments from the fossiliferous horizons which overlie it.

SECTION B

This outcrop is that of the Otis limestone referred to in the preceding paragraph. The outcrop occurs in the bed of the creek in low domes of drab calcilutite. The one fully exposed measures twelve feet in diameter and exposes a foot and a half of its upper layers. Two other domes of about the same dimensions are partly exposed on the left bank where they are covered by the buff Independence. The limestone lies in convex layers

from one-half inch to one foot thick, which are in part composed of tests of a minute spiral foraminifer (?). The surfaces are crackled with a close mesh as small as one-half inch in diameter.

SECTION C

A few rods north of this exposure of the summit of the Otis the creek bends to the east and extends about parallel with the Mount Vernon Road which lies on the divide to the north. Along the steeply rising creek floor there are exposed a number of sections from the base of the Independence to the fossiliferous beds of the Upper Davenport. A short distance above the turn to the east the bed and the banks of the creek offer the different members of section C, all of which belong to the Independence.

		FEET
5.	Limestone, buff and gray, compact, finely laminated, approximately horizontal, in weathered spalls from a small fraction of an inch to 2-3 inch thick	5½
4.	Limestone, dark buff, of same texture as above but less finely laminated, in three layers. Undulating in swells eighteen feet in length and one or two feet high. At the bottom of a syncline these layers are broken into a mass of blocks, some a foot and more in length, forming a coarse breccia	2½
3.	Breccia, buff or blue in color, soft, so that fragments stand in relief on weathered surfaces and can be easily detached with the fingers. Matrix abundant, buff, soft, argillaceous, or in places blue, harder, more calcareous; in places irregular masses of a clay shale dark brown or blackish. Fragments less in bulk than matrix, not in apposition, angular and unrolled, set at all angles, mostly small, commonly less than two inches in diameter, rarely as large as four inches, of lithologically various types, including: A soft buff rock like matrix except that it is thinly laminated and laminæ have dark argillaceous surfaces like No. 4 of section A. Shale in small fissile blocks. Limestone, dark drab, compact, hard, subcrystalline. Limestone, brown, hard, fine-grained, conchoidal fracture, with small disseminated crystals of calcite. Limestone, hard, blue, obscurely laminated, subcrystalline. Limestone, hard, buff, compact, laminated, contains black flint in discontinuous laminæ. Limestone, blue, gray, saccharoidal. Nodules and fragments of crystalline silica. Sand, siliceous, in matrix consisting of angular siliceous grains, blackish white and gray, and well rounded grains of clear quartz the largest of which are one-half millimeter in diameter. All of these types are found in the Independence, and some occur also in the Otis. Total thickness of this bed	6

2. Limestone, gray weathering buff, soft, upper surface smooth, unscored, overlain in places with an inch or two of drab or blackish shale slightly undulating..... ½
1. Limestone, blue weathering buff, argillaceous, saccharoidal and earthy, in irregularly bedded rough surfaced layers six and eight inches in thickness, lower two feet more massive and containing elliptical siliceous nodules..... 3

SECTION D

About thirty-five rods up valley there is exposed on the left bank five feet of brown crystalline limestone weathering light gray, in irregularly bedded layers with a maximum thickness of six inches. The strata run approximately horizontal but with slight noticeable undulations. The lower layers are laminated and resemble the upper layers of the preceding section.

SECTION E

Figure 91, page 523

A few rods north and across the valley an old quarry gives a section of about twenty feet whose base is not far from the top of section D.

Zonal arrangement.—While the strata of the exposure are brecciated from top to bottom, it is possible to make out zones characterized by the predominance of certain types of rock referable to different terranes. Thus an upper zone, particularly at the west, is characterized by prevalence of blocks of the gray fossiliferous rock of the Upper Davenport. In a middle zone crackled blocks and mosaic and rubble breccia of the Lower Davenport gray calcilutites prevail. A basal zone presents large blocks of crystalline fragmental limestone. There are also areas affecting the centers of the archings to be mentioned which are characterized by a large amount of a soft buff argillo-calcareous material. These areas are found also intercepting the blocks of the basal zone and in some cases immediately above it.

The boundaries of these zones are by no means well defined. Fragments of the fossiliferous Upper Davenport may be found sporadically intermingled with fine rubble breccia near the base of the middle zone. Fragments of the characteristic limestones of the basal zone and of the Lower Davenport calcilutite occur in places at the summit of the section and the detritus of the soft buff earthy beds ranges from top to bottom.

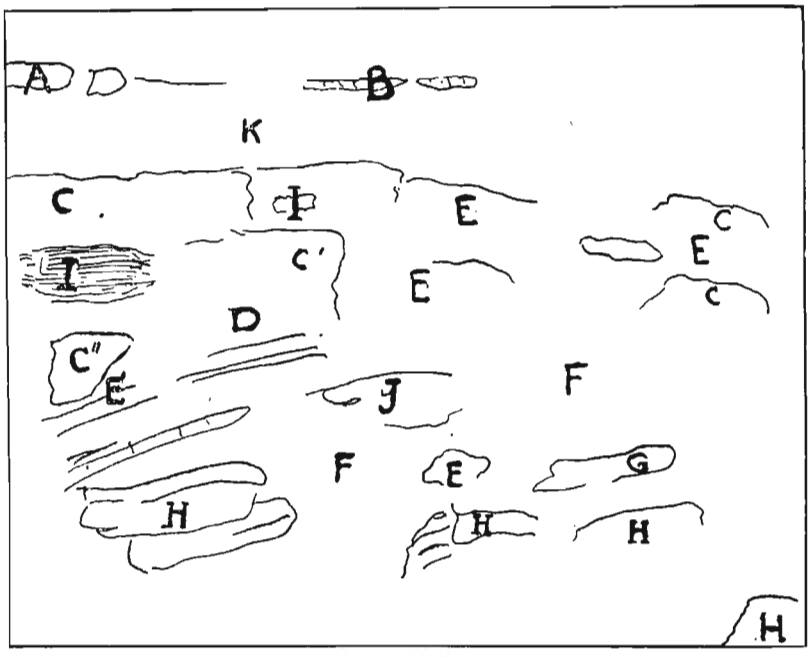


FIG. 91.—Outline sketch of the eastern end of section E, Felton creek, Cedar Rapids, Linn county. A, Upper Davenport with inclosed sporadic fragments of calcilutite. B, Crackled layers of Lower Davenport calcilutite. C, Mosaic breccia of Lower Davenport fragments. (C" crackled block of Lower Davenport). D, Rubble breccia of Lower Davenport fragments. E, Large buff Independence detritus with much Lower Davenport rubble. F, Predominant buff detritus. G, Limestone, buff, Independence facies. H, Crystalline limestone. Basal Lower Davenport type. Commonly with sporadic fragments. I, Mass of buff limestone with a few sporadic gray crystalline fragments. J, Mass of buff crystalline limestone with sporadic white fragments. K, Slope with fossiliferous fragments among others.

Structure Lines.—In the midst of the general chaos accordantly dipping blocks and ledges of the same rock and the boundaries between different belts of breccia trace ill-defined lines of structure. Thus near the east end of the quarry certain ledges have a dip of 13° and 16° W., while ledges of crackle and rubble breccia of the Lower Davenport zone have a still sharper descent (figure 91). Here too in the center of the anticline whose western limb is traced by the ledges mentioned the areas of buff shaly rock rise to near the summit. Structure lines are to be seen in certain archings in the basal zone, where a stratum eleven feet long and more than a foot thick has been bent upward and broken into three faulted blocks.

Zone of the Upper Davenport.—Along the summit from the center of the outcrop toward the west and especially at the west end down the sides of an ill-defined syncline are found numerous blocks of the Upper Davenport limestone. Weathered outcrops along the summit yield the following fossils: *Gypidula comis, Schizophoria macfarlanei, S. iowensis, Atrypa reticularis, A. aspera* var. *occidentalis, Pholidostrophia nacrea, Spirifer bimesialis* and *S. pennatus;* but under the conditions of strong brecciation prevailing here, it can not be certain that none of these are weathered from fragments of higher beds.

The size of the blocks is not so large as in some other sections of this horizon although blocks a foot or so in diameter are common. An unusual number of blocks include both Lower Davenport calcilutite and the Upper Davenport limestones. In some of these the Lower Davenport is shattered or brecciated and the Upper Davenport paste descends into the interstices of the calcilutite fragments or these fragments are found sporadic in the paste (figure 72). Still more common are blocks of Upper Davenport with small quadrangular fragments of calcilutite imbedded, in some cases rather thickly. At the summit of the section on the east end are rather large thin slabs of greatly crackled calcilutite whose interstices are filled with a granular gray paste which apparently is Upper Davenport, although it is not fossiliferous (figure 66, figure 91).

Lower Davenport Zone.—(Figure 91 C, C′, C″, D; figure 70). This is characterized by the prevalence of the calcilutites referred to the Lower Davenport. The rock weathers to a light blue-gray, and the interiors of fragments are yellowish or light brownish in color. It is of lithographic fineness of grain, brittle, and breaks with conchoidal fracture. Much of it is finely laminated. Fragments occur with pustulose surfaces. In certain ledges the rock is a crackle breccia and the narrow ruptures are filled with calcite. This graduates into mosaic and close-set rubble breccia with fragments of various sizes down to finest chinkstone and all of the same rock and set at all angles. Farther on in the ledge fragments of other types intermingle. Blocks of Upper Davenport are found at the bottom as well as at the top of the zone, and a similar range obtains for the fragments of

the well marked limestones from the ledges of the lower zone.

In small irregular areas the rubble breccia is composed of fragments of all kinds commingled, and a fraction of an inch in size, but these areas do not resemble in outline layers deposited by water, as no bedding planes are seen within them, nor are the fragments waterworn. In places fragments of buff soft limestone and its detritus prevail and here the breccia is weak and weathers back under cornices of the stronger breccia of the prevailing Lower Davenport calcilutite.

The Lower Zone (figure 91, H).—This zone, which extends upward for seven or eight feet from the base of the section, is characterized by heavily or irregularly bedded crystalline fragmental limestones in large blocks which are arched, faulted, and widely interrupted. In some cases these are of hard brown crystalline granular rock, weathering to drab, with nests of calcite, and very sparse small fragments and with lenticular structure more or less developed. In other cases the rock is conspicuously fragmental and is composed of fragments of whitish fine saccharoidal limestone, and fine-grained light buff limestone which is very sparingly arenaceous with small angular grains of white chert. In all the basal blocks of either type, a few small rectangular fragments of drab laminated calcilutite occur. While these beds are fragmental there can be no doubt of their deposition under water. Thus the faulted stratum of figure 73 shows in the upper three or four inches distinct lines of lamination which are parallel with the surface of the block though they are somewhat broken and displaced. Strings of dislocated laminæ still retain their parallelism with the bedding planes of the block.

Especially in the cores of the anticlines we have buff, finely granular earthy limestone (figure 91, E. F). It occurs in strongly inclined beds a foot thick which are continuous for a yard or so and thence merge into a rubble derived from its own fragmentation and from that of similar beds. It is found in fragments, some of which are of considerable size, which are mingled with the fragments of the calcilutite rubble breccia, and apparently it is its finer detritus that forms so much of the interstitial matrix of this rubble. In places the rock has a pronounced lumpy lenticular structure as if it were composed of small

flattish irregular lenses. Angular sand of flint and rounded grains of quartz are in places noticeable while in others they are nearly or entirely absent. This buff earthy and somewhat arenaceous constituent of the breccia is referred to the Independence. Its horizon seems to lie beneath that of the crystalline limestones of the basal zone, which then may be assigned to the Lower Davenport, although it is a question not easily determined and one of no special importance on which side of the division line between the two terranes these limestones should be placed.

SECTION F

A few rods up valley from section E a small quarry shows at top about four feet of the Upper Davenport in ledges little disturbed and in slickensided blocks. Weathered chipstone on the surface of the ledges yielded the following numbers of different fossils, which probably is some indication of their relative proportions in the rock.

Atrypa reticularis	39
A. aspera var. occidentalis	16
Gypidula comis	11
Schizophoria iowensis (?)[63]	8
Stropheodonta plicata	7
Pholidostrophia nacrea	6
Schizophoria macfarlanei	3
Stropheodonta demissa	1
Gyroceras sp.	3

The Upper Davenport exhibits small angular imbedded fragments of calcilutite as is the case at other outcrops.

At a lower level the stripping of the quarry shows the whitish Lower Davenport calcilutite in crackled shattered masses which appear to be largely in place, but which graduate into areas of rubble breccia of the same material but mingled with fragments of other horizons, such as slickensided blocks of the Upper Davenport. The lower part of the quarry face shows rubble breccia which is blue at bottom and buff above, the line of oxidation passing through imbedded fragments.

KENWOOD SECTION

At Kenwood, on the right bank of Indian creek, a cliff about fifty feet in height displays at top the Lower Davenport lime-

[63]Some fragments included are not distinguishable from *S. macfarlanei.*

Cliff at Kenwood, Linn county.

stone in part but little disturbed and in part thoroughly brecciated with the Upper Davenport. The full thickness of the Independence is shown in the center of the section, while at the base appear the upper beds of the Otis calcilutites carrying *Spirifer subumbonus*.

FEET

6. Breccia (Plate XII, E), rubble of well cemented small fragments of Lower Davenport drab calcilutite, weathering whitish, many of them crackled, with some included blocks of gray granular fossiliferous Upper Davenport limestone, some of which are a foot in diameter. Some of these blocks include sporadic fragments of drab calcilutite, a fraction of an inch in diameter. Matrix small in amount, interstitial, yellowish. This mass of breccia occupies the center of a low syncline. It thins to the left and apparently is here less well cemented, since it weathers back. Fossiliferous fragments carrying the First Fauna are found to the base of the mass.....11

5. Limestone, Lower Davenport (D, Plate XII); at east end (left of Plate XII) is a light pinkish gray limestone weathering whitish, bedding irregular or obscure, in places distinct and even, partly brecciated. Laminated areas are seen where the laminæ are bent in short flexures and in some instances are brecciated at the axes of the synclines. In places masses of thin calcareous plates four inches thick, are set on edge. A brecciated bed six inches thick is seen to be covered by a layer four inches thick which is closely laminated and crackled, with vertical and oblique seams which are filled with calcite. This crackled layer graduates upward into a brecciated bed to the base of which it furnishes fragments which lie approximately parallel to the bedding. Matrix similar to fragments but of yellowish tinge. No buff sandy Independence matrix observed. At base of No. 5 lies a layer of crystalline lenticular rock one foot four inches thick whose laminæ are coherent. Number 5 descends gently to the west forming a cornice above the weaker rock of No. 4..... 7

FIG. 92.—Passage of massive vesicular buff Independence limestone (A) into laminated limestone (B); thickness of bed about one foot, Kenwood, Linn county.

4. Limestones, Independence, brownish and buff, dingy, earthy, in places massive, in places graduating laterally or passing abruptly into thin reddish calcareous plates (figure 92). Along the eastern part of the outcrop (left of Plate XII) undulating laminated shaly beds predominate for some eight feet vertically beneath the

cornice of No. 5. Here occur small lenticles of massive rock. To the west of the mass of breccia of No. 6 (E, Plate XII) these shaly beds merge into massive dingy limestone which forms the apparent downfold on the right of the area shown in Plate XII. This lenticular mass at base passes to the right into calcareous plates which dip 20° E. parallel with the lower surface of the lens. These calcareous plates are themselves brecciated in places and the massive limestone of the lens also shows in places included angular blocks which are now standing on edge and which consist of the same dingy limestone as the rest of the lens. Siliceous angular fragments and broken elliptical siliceous nodules are common at this horizon.....15

3. Shales. (B, Plate XII) blue weathering buff, calcareous, weathering to slopes of marly clay. Toward the top they contain siliceous nodules and fragments of flint. Some beds show spheroidal weathering. In places fissile 15
2. Shaly parting, fissile, greenish ..... ½
1. Limestone, Otis (A, Plate XII) drab, dense, in layers four or five inches thick carrying *Spirifer subumbonus*. Smoothly bedded, layers parallel, in long gentle undulations, in places slightly fragmental; fragments a fraction of an inch in diameter and of same texture as the matrix rock, but slightly darker..... 8¼

Johnson County

The Devonian-Silurian frontier passes diagonally across the northeastern township of Johnson county, parallel with the course of Cedar river. The only exposures of the Silurian are found in the cliffs sixty feet high along the river bluffs. These show the LeClaire phase of the Gower stage of the Niagaran. A belt several miles in width intervenes in which no outcrops occur. Near Elmira and Solon the Devonian appears in a breccia whose place is near the summit of the brecciated zone of the Wapsipinicon. As Calvin[64] states on the evidence of deep wells over the belt of drift, "This region, or at least a part of it, seems therefore to be occupied by a preglacial valley over which the limestones and shales were cut away." The strata thus removed include the Bertram and Otis limestones and the Independence.

SOLON SECTION

About forty rods north of Solon the road cuts through ledges of breccia in some of which the Independence predominates, although for the most part the breccia is made up of "angular

[64]Calvin, S., Iowa Geol. Surv., Vol. 7, p. 58, Des Moines, 1897.

fragments of very fine-grained gray or drab limestone lying in all possible positions in a softer lighter colored gray matrix.''[65] At the northern edge of Solon an exposure shows small areas of the dingy buff argillaceous Independence underneath the rubble of Lower Davenport. Elsewhere in the northern part of the town the breccia beds involve the fossiliferous beds and fragments contain *Atrypa reticularis, A. aspera* var. *occidentalis, Schizophoria iowensis* and *Gypidula comis.*

On the western edge of the town occur partly brecciated beds belonging to the Upper Davenport. The brachiopod fauna as given by Calvin includes *Gypidula comis, Schizophoria macfarlanei, Hypothyridina cuboides, Spirifer pennatus,* and the Atrypas. ''The strata at this point are very much shattered, the bedding planes are obliterated, oblique joints intersect the beds and divide the mass into numberless shapeless pieces from a few inches to a foot or more in diameter,[66] the texture is coarse and granular.''

ELMIRA SECTION

A mile north of Elmira Calvin found an exposure of fossiliferous limestone, in some of whose beds, he states, ''the brecciation is more complete than any seen at the corresponding horizon at Solon.''[67] As in other counties, brecciation is associated with low foldings of the strata. Thus down the valley of Rapid creek from the outcrop noted, the rocks lie in a series of low arches, and at some points the axes of the anticlines are found brecciated. An example given by Calvin is in Graham township (southeast quarter of the northeast quarter of section 20). ''Here the fold is quite sharp, the strata dipping from the axis on either side at an angle of fifteen degrees.'' The axis of the fold shows the following section:

		FEET
3.	*Megistocrinus* beds evenly bedded	6
2.	*Phillipsastrea billingsi* beds, not shattered or brecciated	8
1.	Limestone, imperfectly bedded, very much shattered and divided into small angular pieces by oblique joints; fauna contains *Schizophoria iowensis, Atrypa reticularis, A. aspera* var. *occidentalis* and *Gypidula comis*	12

[65]Calvin, ibid, p. 58.
[66]Calvin, ibid, p. 59.
[67]Ibid, p. 60.

The line separating the Wapsipinicon and the Cedar Valley is drawn by Calvin between Nos. 1 and 2.

Cedar County

Cedar county exhibits some of the clearest contacts between the Devonian and the Silurian to be found within the state. Owing to the large quarries at Cedar Valley and at Lime City the basal magnesian beds of the Otis, which here lie above the quarry rock of the Niagaran, are exceptionally well displayed. The Otis calcilutites are seen in typical facies and relations, but in only a few outcrops and in no great force. Sections of Independence are very rare. A deep railway cut, such as that of the Chicago, Milwaukee and St. Paul at Fayette or west of Linn, or that of the Chicago, Rock Island and Pacific north of Vinton would be very welcome to the geologist in any township of Cedar county where it would trench the Independence and its inclosing strong terranes. For lack of good natural or artificial sections of the Independence it is difficult to refer certain ledges of calcitutite definitely to either the Otis or the Lower Davenport. Where the Lower Davenport horizon is defined by the presence of the Upper Davenport the lower formation is found to be brecciated. In the absence of any deep or extensive sections of the upper terranes of the Wapsipinicon it is difficult also to speak with certainty as to the intensity of brecciation. It seems safe to say that brecciation is less pronounced than in Linn county to the northwest and more pronounced than in Scott county to the southeast.

The Otis exhibits in force the lower magnesian, or Coggon phase, which embraces here not only soft vesicular and fossiliferous earthy limestone but also saccharoidal limestones weathering to crystalline sand. The upper horizons also embrace a variety of lithologic types—the lenticular masses and reefs of calcilutite carrying *Spirifer subumbonus*, and the brown limestone shot through with cleavage planes of calcite, all characteristic of the horizon immediately beneath the Independence.

The Independence shows a typical dingy impure buff limestone which in places is speckled. A seam of black shale underlain with thin brown sandstone outcrops at one point in a road

section. There also occur saccharoidal limestones of various colors, some of which are mottled with argillaceous material. These are probably of chemical deposition—an inference confirmed in one instance by the inclusion of minute perfect hexagonal crystals of clear quartz. No outcrops of blue calcareous shale, or of fossiliferous shale have come under observation. Nodules of silica intercrystallized with calcite are characteristic. As they decay these nodules leave curiously carious surfaces.

The Lower Davenport shows massive ledges of calcilutite, which at places graduate laterally into thin plates and the usual breccia of drab calcilutite fragments. The Upper Davenport follows the Scott county and Linn county type of a tough granular fossiliferous limestone with *Gypidula comis* as its most common fossil.

Zones of brecciation of the Wapsipinicon terranes are visible only in road cuttings and a few other very imperfect sections. Little can be expected from such data except scraps of evidence confirming or casting doubt on conclusions reached by the study of more complete sections in other counties.

The Lower Davenport exhibits the usual intense brecciation which formed a rubble of angular calcilutite fragments, but in places crackle and mosaic breccia bring us nearer to the initial condition of the beds. Complex brecciation obtains in fragments which show broken and detached laminæ imbedded in a paste and with their parallelism in part preserved, indicating that the first brecciation was contemporaneous with the deposit of the beds. The Independence also shows in places local and contemporaneous brecciation. Sporadic fragments in some beds of the Otis also show disturbed sedimentation. The basal magnesian beds of the Otis show no evidences of stress or of interruptions to the normal course of sedimentary deposit. It is probably owing in part to lack of good sections that archings and flexures of the strata are so seldom seen. The best example noted is that described in the section given on page 538 (southeast quarter of section 8, township 79, range II west), where the beds below the Lower Davenport breccia have been thrown into a series of low arches.

SILURO-DEVONIAN CONTACTS

In Cedar county the Devonian rests on the Gower limestone, which is quite free from siliceous inclusions, instead of on the cherty Hopkinton as in the northern counties of the Devonian area. The basal conglomerate, or rather the beach breccia, of cherty angular fragments, which is present in the lowest Otis in Fayette and Bremer counties, is here absent. Where the Otis rests upon the hard crystalline LeClaire lime rock of the Gower the latter was able in at least one instance to supply limestone fragments to the lower two feet of the Otis to form a beach breccia which has the characteristics of a basal conglomerate. But where the Otis was laid upon the soft Anamosa rock of the Gower its basal layers are free from inclusions of the older stone. In places the magnesian beds of the Otis are absent and the nonmagnesian saccharoidal limestone rests upon the Niagaran.

ROCK CREEK SECTION

(Section 25, Township 80 North, Range III West)

		FEET
3.	Limestone, soft, buff, vesicular, in layers about eighteen inches thick of Coggon facies and fossils, exposed at two horizons within a vertical distance of.....	8
2.	Limestone, buff, horizontally bedded, finely granular, in layers from one-half inch to six inches thick. The horizontal face exposed in the bed of the draw shows interlacing seams along which weathering has taken place and *imbedded angular bowlders of the underlying LeClaire, some of which are two feet in diameter, also small imbedded fragments of the same rock*.....	2
1.	Limestone, hard, gray, crystalline, of typical LeClaire facies, fossiliferous, in heavy beds dipping as high as 30°, in recurring ledges to water in creek.....	20

At the head of the ravines which here descend to Rock creek there outcrops at the height of about fifty feet above the creek, a dark brown macrocrystalline nonmagnesian limestone characteristic of the higher beds of the Otis as these may be seen at the station of the same name and at Cedar Rapids. This well marked horizon, considered in connection with the summit of the LeClaire below would indicate a thickness for the Otis of not far from thirty feet.

SECTION AT BEALER'S QUARRY, CEDAR VALLEY

OTIS LIMESTONE, COGGON PHASE

		FEET
6.	Limestone, hard, dense, yellow-gray, breaking into large rhombic chipstone by diagonal cracks about six inches apart	1
5.	Limestone, laminated of similar texture as No. 6, in spalls one to four inches thick	1
4.	Limestone, soft, granular, laminated, with minute moulds of brachiopods	1
3.	Limestone, soft, light buff, with occasional lenses of dark flint, fossiliferous with minute moulds, in layers up to one foot in thickness	2½
2.	Limestone, in massive layers about three feet thick, soft, earthy, buff, with some flint nodules, and with many characteristic specimens of Coggon fossils, *Spirifer sub-umbonus*, and trilobite pygidia	7

NIAGARAN LIMESTONE, ANAMOSA PHASE

1.	Limestone, horizontally bedded, with apparently conformable contact with No. 2, light buff, granular, even-bedded, quarried for building stone	100

The Otis is seen to rest on the tilted layers of the LeClaire phase of the Gower or on its equally characteristic calcareous massifs at the lime quarries at Cedar Valley and at Lime City. Another contact between the LeClaire and Coggon may be seen on Rock creek, in the northeast quarter of section four of township 80, range 3 west.[68]

The Coggon magnesian phase of the Otis is not everywhere present. Thus at the crossing of Rock creek on the Tipton-Rochester road, southeast quarter of the southwest quarter of section 23, township 80 N., range II W., the following section may be observed below the bridge:

		FEET
4.	Limestone, briskly effervescent in cold dilute HCl, irregularly bedded, in part massive, in bed five feet thick, without trace of stratification, but with imbedded sporadic fragments of fine-grained yellow magnesian limestone. Abutting on this in places is drab dense limestone weathering to layers an inch thick. Elsewhere the rock appears in courses two feet thick, highly crystalline, pink and yellowish green, with lines of lamination indicated by different tints. Upper layers brownish, macrocrystalline	11
3.	Limestone, reddish, crystalline, saccharoidal, approximately horizontal, briskly effervescent, in two layers	2
2.	Contact of Nos. 3 and 1 not observed.	
1.	Dolomite, Gower, dipping 30° SSE	20

Above the bridge the macrocrystalline nonmagnesian limestone of the Wapsipinicon comes again within four feet of the Gower dolomite, which here dips at angles exceeding 45°.

[68]Norton, W. H., Iowa Geol. Surv., Vol. XI, p. 329. Des Moines, 1901.

THE OTIS, INDEPENDENCE AND LOWER DAVENPORT

In Cedar county as in Linn the Otis exhibits quite a variety of lithologic types. The following section shows a larger amount of crystalline limestones than is common. All these layers of the Otis from No. 2 up, are magnesian, are useless for building stone, and because of their crystalline-granular texture are called "sand rock" by the workmen. All are practically horizontal.

BUILDING STONE QUARRY, LIME CITY

OTIS

		FEET
7.	Limestone, saccharoidal, slightly pinkish, laminæ up to four inches thick	1
6.	Limestone, white, saccharoidal, with close coherent laminæ	2
5.	Limestone, yellow-gray, soft, earthy luster, weathering to layers two to four inches thick	2½
4.	Limestone, saccharoidal, pink and yellowish gray, decaying into crystalline limestone sand. This layer changes both laterally and vertically into brittle, gray, dense fine-grained rock in layers one to four inches thick which breaks into rhombic chipstone of dull earthy luster	6
3.	Limestone, light buff, saccharoidal, in heavy laminated courses, weathering to fine crystalline sand	5
2.	Limestone, massive, highly vesicular, with moulds of fossils of Coggon phase	3¾

GOWER

1.	Dolomite, hard, crystalline	22

The only locality where the Otis calcilutite upper beds are found to be fossiliferous is that of the following section, which shows also the Coggon magnesian phase beneath and the Independence above. The presence of black shale in the Independence suggests the coal found in the formation in Linn county. The streak of sandstone is exceptional.

SUGAR CREEK SECTION

On Sugar creek and in the road to the west at the bridge between section 3, township 79, and section 34, township 80, is exposed the following section:

INDEPENDENCE

		FEET
12.	Limestone, buff, argillaceous, weathering to calcareous clay with some harder layers of buff dense dark speckled limestone, some finely laminated, all briskly effervescent in cold dilute HCl., with lenticular nodules of silica having carious surfaces from the solution of intercrystallized calcite	18

11.	Limestone, buff, earthy, breaking into rhombic chipstone, at base a layer of green clay one-half inch thick	2½
10.	Limestone, buff, soft, more or less crackled	2
9.	Shale, black, argillaceous	1-6
8.	Sandstone, brown	½
7.	Limestone, buff, earthy, crossed with parallel cracks about three inches apart, dipping about 10° N. Briskly effervescent	5
6.	Limestone, soft, buff, dark-speckled, earthy, dipping as above	1

OTIS

5.	Limestone, brown, crystalline, nonmagnesian, in thin plates; with *Spirifer subumbonus*	¾.
4.	Limestone, gray, earthy, dipping 10° N.	½
3.	Concealed	4
2.	Limestone, Coggon facies	1½
1.	Concealed, to water in creek	8

An interesting contact between the Otis calcilutite and the Independence is opened to view by the narrow trench of a small run entering Rock creek from the east north of Rochester (northwest quarter section 6, township 79 north, range II west). The bottom of the trench, which is about twelve feet deep, is floored a few rods upstream from the road bridge with extremely irregular ledges of calcilutite in lenses up to ten feet in length quite similar to those which form the summit of the Otis along Felton creek in the eastern edge of Cedar Rapids (p. 520). About three feet of this layer is exposed to view. It is fissured to a crackle breccia, and the seams are filled with calcite. A layer of bluish clay three to six inches thick, with some white saccharoidal limestone intermixed, immediately overlies the calcilutite. Arching over these lenticular masses, and forming the main body of rock exposed in the section is a soft dingy brown speckled argillaceous limestone of Independence facies. In places it is formed of laminæ which are an inch and less in thickness and are more or less flexed. In places the rock forms a pudding breccia with small sporadic fragments generally of brownish rock of the same texture as the matrix limestone. But near the ledges of calcilutite there occur also fragments of drab laminated calcilutite set at all angles. One noted was one foot long and five inches broad.

At the top of the section lies a pinkish saccharoidal limestone forming a lenticular mass twelve feet long and five feet thick

and extending half a rod upstream in a layer one foot thick. A thin selvage of bluish plastic clay parts this lens from the impure limestone underneath.

The brecciation of the Independence here is taken to be contemporaneous. The brown fragments, like the matrix, are supplied by the laminæ in process of deposition and the calcilutites are derived from the adjacent reefs. The crackling of the Otis calcilutite may be due to later stresses, since the fissures and seams thus opened were inaccessible to the sediments of the Independence. Later than the deposition and brecciation of the shaly limestone came the deposition of the pink crystalline limestone, probably by evaporation of calcium-saturated water in a shallow depression on the shoal.

CROOKED CREEK SECTION

At the crossing of Crooked creek (southeast quarter of section 8, township 79 north, range II west) and on a hill a few rods west there is exposed in the road a section showing the following succession:

		FEET
3.	Limestone, calcilutite, closely laminated, gray, more or less brecciated. Some layers, especially those toward the base, are massive and finely fragmental, the fragments remaining in juxtaposition and being disclosed only on weathered surfaces. There is also considerable rubble breccia with sparse interstitial lighter gray matrix. In certain layers the closely set coherent laminæ are sharply flexed within the limits of a hand specimen. Here and there are large fragments set at all angles. There is seen also the type of fragment where the laminæ are separated but retain within the matrix considerable of their initial parallelism. Lenticles of silica occur. At base a foot or so of light colored saccharoidal limestone is seen	25
2.	Unexposed	10
1.	Limestone, white, saccharoidal at top, brownish buff and earthy at base. Considerable difference in appearance of strata, but all briskly effervescent. Among types noted are light gray earthy limestone, dark drab cryptocrystalline limestone, and a saccharoidal white limestone mottled with irregular greenish yellow argillaceous laminæ, the white portions containing considerable clear quartz in minute detached perfect crystals. Siliceous nodules with carious surfaces are present	8

The upper stratum is assigned to the Lower Davenport zone of brecciation. A part of Number 1 of the section is probably Independence.

ROCHESTER SECTION

A mile northwest of Rochester on the right bank of the Cedar a little above the mouth of Rock creek (southeast quarter of the northwest quarter of section 3, township 79 north, range III west) a ledge of calcilutite, probably referable to the Lower Davenport, overlooks the river:

		FEET
3.	Limestone, drab weathering to lighter tints, calcilutite, in places crackled and fragmental, in massive layers two feet thick and more, which here and there graduate laterally into thin plates a fraction of an inch thick	10
2.	Limestone, nonmagnesian, gray, semicrystalline, weak, retreating under No. 3	2
1.	Unexposed to flood plain of Cedar river	25

Directly across the river from Rochester the same ledge appears at nearly the same height. A miner's shaft which was sunk here some years ago, shows to a certain extent the nature of the underlying strata.

		FEET
8.	Upper portion of shaft not observed	7
7.	Limestone, rough, brown, crystalline	2
6.	Limestone, brown, soft, earthy luster, ferruginous and argillaceous, briskly effervescent in cold dilute HCl	6
5.	Limestone, buff, earthy, speckled with darker spots, thin layered	1
4.	Limestone, bluish, nonmagnesian, in part crystalline, in part earthy	4
3.	Limestone, pale buff, argillaceous, weathering to chipstone	3
2.	Limestone, buff, dull earthy luster, laminated, in even layers two to six inches in thickness	1
1.	Limestone, white, saccharoidal	½

Lithologically these layers may be referred to the Independence, with the exception of No. 1, which resembles the saccharoidal Otis, and thus the calcilutite ledge of the preceding sections falls in with the Lower Davenport. This inference is to a degree corroborated by the appearance of the Lower Davenport three miles south of Rochester in association with the Upper Davenport at the level of the higher river terraces (p. 540), the position to which a normal moderate dip would carry the strata.

UPPER DAVENPORT OUTCROPS

The highest bed of the Wapsipinicon within the limits of the county may be seen in going down the Cedar about three miles

south of Rochester where it appears at the level of the upper terraces of the river. The following section, taken in an abandoned road in the southwest quarter of the southeast quarter of section 23, township 79 north, range III west, is wholly characteristic of the Upper Davenport and its relations over several counties. Unfortunately so slight is the exposed thickness of this bed that its brecciation is not well made out.

UPPER DAVENPORT.

		FEET.
3.	Limestone, hard, tough, gray, a coquina of minute fragments of shells, valves of *Gypidula comis* very abundant, ten individuals being counted on a surface six inches square	½

LOWER DAVENPORT.

2.	Breccia, fragments large, nonfossiliferous, of Lower Davenport type, some of them nearly three feet long. Some fragments crackled. In places matrix abundant and fragments small	6
1.	Breccia, fragments dark drab calcilutite, mostly small, matrix abundant, light yellowish in color, of coarser grain than fragments	2½

One mile south of this exposure an old quarry in the southwest quarter of the southeast quarter of township 79 north, range III west shows ten feet of tough, hard, gray, irregularly bedded limestone, in part a coquina. The following brachiopods were collected here: *Gypidula comis, Stropheodonta demissa* var. *plicata. Atrypa reticularis* winged, *A. aspera* var. *occidentalis, Hypothyridina cuboides* (*?*) immature, *Spirifer pennatus.* At the base of the hill the Lower Davenport appears in three feet of finely laminated calcilutite with many of the laminæ curved.

Scott County

Scott county contains the type exposures of the Upper and the Lower Davenport beds of the Wapsipinicon, which occur in contact in the quarries of the city from which they take their name. At Bettendorf and along Duck creek northeast of the city the Lower Davenport beds display a thickness not elsewhere attained within the state. Farther to the northeast along Crow and Pigeon creeks, the Independence shale and the upper Cedar Rapids phase of the Otis limestone outcrop in contact.

The Upper Davenport, as exposed in the quarries of West Davenport, is a tough hard gray crystalline-granular limestone, lying in irregular and rough surfaced layers varying in thickness up to two feet. Under the sledge it breaks unevenly. The rock is highly fossiliferous as a rule, and certain layers form a coquina, but so firmly are the shell fragments cemented, and so tough and hard is the rock, and so resistant to decay, that fossils are disengaged with difficulty and perfect forms are rarely obtained. The entire thickness of the beds is probably compassed within fifteen feet. Stylolites are common and many joints show slickensides. Small angular imbedded fragments of the Lower Davenport calcilutite are sometimes seen.

It is fortunate that the fossils of these beds were collected with great pains for many years by members of the Davenport Academy of Natural Sciences. In the publications of this Academy are recorded lists of fossils and descriptions of new species for which science is indebted chiefly to the indefatigable labors of Barris. Mr. A. S. Tiffany also collected largely from these beds, and after his death the writer secured for the museum of Cornell College a number of rare specimens labelled in Mr. Tiffany's handwriting as coming from the "Corniferous" of Davenport. The rock texture of these specimens corroborates the reference and shows that if they are from Davenport they could have come only from the Upper Davenport beds, called by the Davenport geologists "the Corniferous." The following list comprises the fauna of the Upper Davenport beds of the county so far as these have been specifically identified.

Acervularia profunda
Phillipsastrea billingsi
Stromatopora expansa
Favosites placenta
Calceocrinus barrisi
Megistocrinus nodosus
Stereocrinus triangulatus
Atrypa reticularis
Gypidula comis
Newberria johannis
Hypothyridina cuboides
Pentamerella arata
Pentamerella dubia
Pentameralla micula
Productella spinulicosta
Reticularia fimbriata
Reticularia subundifera
Schizophoria iowensis
Schizophoria macfarlanei
Spirifer bimesialis
Spirifer asper
Actinoptera decussata
Conocardium cuneus
Paracyclas elliptica
Capulus echinatum
Capulus erectum
Platystoma lineatum
Straparollus lativolvis
Gyroceras pratti
Piragmoceras walshi
Proetus clarus
Proetus crassimarginatus
Proetus prouti
Proetus rowei
Phacops rana
Ptyctodus calceolus

The following additional species are reported by Ekblaw[60] from the same beds in Rock Island county, Illinois. *Astreospongia hamiltonensis, Alveolites goldfussi, Acervularia davidsoni, Cladopora palmata, Craspedophyllum archiaci, Cystiphyllum americanum, Favosites hamiltonensis, Favosites alpinensis, Heliophyllum halli, Streptelasma simplex, Hemitrypa tenera, Orbignyella monticula, Athyris fultonensis, Atrypa hystrix, Cranaena romingeri, Cranaena iowensis, Nucleospira ventricosa, Productella subalata, Pholidostrophia iowensis, Spirifer subvaricosus, Spirifer euryteines, Bellerophon pelops, Pleurotomaria lucina, Gomphoceros.*

The Lower Davenport beds as seen in the Davenport quarries and along Duck creek immediately underlie the Upper Davenport limestone and are composed largely of a calcilutite of finest grain and conchoidal and even splintery fracture. The rock is light brownish gray or medium dark drab color weathering to whitish, in irregular layers few of which reach a thickness of more than nine inches. In the quarries about Bettendorf, much of the calcilutite is evenly bedded and is composed of laminæ an eighth of an inch to an inch in thickness. The laminæ weather to separable plates. Gray mottled and finely saccharoidal limestones also occur. Siliceous elliptical nodules with curiously carious surfaces and with diameters as large as six inches are rarely seen.

The upper surface of the Lower Davenport in some places is uneven, and a thin band of greenish clay, not exceeding two inches in thickness, intervenes between it and the Upper Davenport. In the Schmidt quarry the Lower Davenport rises at the east end and pinches the Upper Davenport beds to a thickness of about five feet.

Deformation is seen both in the low archings in which the strata are commonly disposed, and in local brecciation more or less complete. The ledges about Rock Island show low synclinal and anticlinal flexures. On the Iowa side along the river

[60]Ekblaw, W. E., Correlation of the Devonian System of the Rock Island region: Trans. Ill. Acad. of Sci., 1912.

the strata show low arches from twenty to one hundred feet in length. Brecciation, while locally intense enough to shatter the laminated rocks and leave the fragments set at all angles, has left the larger part of the strata unaffected. On Rock Island few of the brecciated areas are more than a rod or so in width. Ledges along the river on the Iowa side opposite the Island show local brecciation in the hollows of the synclines. In places in the quarries of West Davenport brecciation is complete. In such areas we have a mosaic and rubble breccia of small fragments which retain their sharpest flint-like edges intact. The matrix is interstitial and consists of limestone of the same general nature as the fragments, of calcite and in a few places of clay. The thinly laminated upper beds along Duck creek show extensive crackle breccias; in places the vertical calcite-filled seams are an inch and less apart. Here some of the laminæ are arched in little folds of three or four inches diameter, which may pass into breccia at the axes of the synclines or throughout. Crackle breccia passes into rubble, and while a shattered layer retains its bedding planes, its upper surface becomes irregular. At one point there was observed a layer of minute rubble which was included between two layers of crackled rock. Contemporary brecciation is inferred also from the small angular fragments of Lower Davenport calcilutite which are sporadically scattered through the lowest layer of Upper Davenport in places along Duck creek.

The Independence beds are found at two outcrops on Crow creek, resting directly on the fossiliferous calcilutites of the Otis. Their contact with the overlying Lower Davenport has not been observed. Lithologically the formation at these outcrops is a rough brown earthy and ferruginous limestone in layers from two to four inches thick containing lenticular nodules of silica and weathering to a stiff clay. The total thickness observed is seven feet.

The Otis beds outcrop along Crow and Pigeon creeks in several ledges, one of which is twelve feet high. The total thickness of these exposures may aggregate twenty feet. The limestone is identical lithologically with the same horizon in Linn

county, that is, a drab calcilutite in beds for the most part about one foot thick and somewhat lenticular. In places they are crackled and fragmental and thus present surfaces and fractures which are highly irregular. At one point the beds are thin and here also they are more or less fragmental. These outcrops of the Otis, like those along Cedar and Wapsipinicon rivers in Linn county, are indentified by the presence of *Spirifer subumbonus*.

The magnesian lower beds of the Otis which have been designated as the Coggon phase have not been identified with certainty in Scott county. Vesicular magnesian limestones found in conjunction with the Otis calcilutite, in a road cutting in Pleasant Valley township (northwest quarter of the southeast quarter of section 13) and in Hanna's and Dodd's quarries (southwest quarter of the southeast quarter of section 12 of the same township) probably belong to this formation, but in the absence of fossils they can not be assigned to either the Devonian, or the Gower stage of the Silurian.

WAPSIPINICON SECTIONS IN SCOTT COUNTY

MEUMANN QUARRY, FIRST WARD, DAVENPORT

		FEET
2.	Limestone, Upper Davenport, gray, granular, crystalline, close textured, tough, hard, in rough-surfaced irregular layers varying in thickness from fourteen inches to four inches. Many blocks show slickensides. Rarely there may be seen a small angular imbedded fragment of Lower Davenport calcilutite. Most abundant fossils are *Phillipsastrea billingsi* and *Gypidula comis*	6
1.	Limestone, Lower Davenport, calcilutite, brownish drab, in irregular layers nine inches and less in thickness, unfossiliferous, now under water.....	5

SCHMIDT QUARRY, FIRST WARD, DAVENPORT

3.	Shale, Cedar Valley, calcareous, yellow, highly fossiliferous	1¼
2.	Limestone, Upper Davenport, of color and texture as described in the above section, layers six to ten inches thick, joints oblique. A coquina of *Newberria* and other shells two feet thick forms the upper surface in places. *Acervularia* six inches from top of bed.....	12
1.	Limestone, Lower Davenport, calcilutite, light brownish gray or medium dark drab, in obscure, irregular, undulating layers, in places three feet thick, elsewhere thinner, more or less brecciated into a mosaic-rubble breccia of small angular fragments of sharpest edges, matrix slight, partly of calcite, partly of limestone of same general nature as fragments but slightly more earthy and of a lighter color, in places of clay.....	8

The quarries of the First Ward (West Davenport) have been abandoned for some years and their floors are deeply covered with water. Their side walls, of which only a few feet emerge, are largely concealed beneath the dumps of city and factory waste. Only the Upper Davenport is now to be seen except at the eastern end of the Schmidt quarry.

In both the Meumann and the Schmidt quarries the surface of the Upper Davenport ledge shows a coquina of brachiopods, in which valves of *Newberria johannis* are conspicuous. Beneath this layer is a coral reef, about two feet thick, in which *Phillipsastrea billingsi* occurs in fine heads usually set in the position of growth, associated with numerous other corals. *Phillipsastrea billingsi* extends down beneath this coral layer to a distance of six feet from the surface of the bed. *Acervularia profunda* occurs in the same zone.

The only contact now to be seen between the Upper and the Lower Davenport limestones is at the east end of the Schmidt quarry where the Lower Davenport rises from the water in a pure whitish massive calcilutite. The rock is intimately crackled and the upper inch or so is shattered to a mosaic or rubble breccia. The upper surface is hummocky. The Upper Davenport arches over these hummocks in irregular courses and a space of about an inch is now left between the two formations, a parting probably filled with clay when the quarry was opened. Here the Upper Davenport limestone does not fill the cracks in the Lower Davenport nor do fragments of the Lower Davenport calcilutite occur in the upper rock.

Immediately above the Upper Davenport limestone the fossiliferous shale may still be seen and the following fossils were collected: *Cyrtina umbonata, Cyrtina hamiltonensis, Strophеodonta perplana, Spirifer pennatus.*

QUARRY OF THE BETTENDORF STONE COMPANY, BETTENDORF

This extensive quarry offers one of the deepest sections of the Lower Davenport to be found within the state.

FEET

5. Limestone, calcilutite, whitish, in thin plates, gently arched accordantly with the arches of the underlying beds 6
4. Limestone, light brownish gray, finely mottled, upper four feet massive, but traversed by irregular planes of stylolites at vertical intervals of six inches to one foot; upper surface somewhat hummocky and rugose, with deep stylolites. Lower two and one-half feet in rather even layers one foot and less in thickness..... 6½
3. Limestone, lithographic calcilutite, light brownish gray, massive 1¾
2. Limestone, finely saccharoidal, light gray and whitish, in irregularly bedded layers two to six inches thick. In places contains sparse small angular drab fragments. In places are conspicuous partings of plastic blue clay an inch thick 3
1. Limestone, granular, earthy, light brownish buff..... 1

"DEVIL'S DEN," DUCK CREEK

Pleasant Valley Township, Section 27, Northwest Quarter

12. Limestone, gray, granular, highly fossiliferous, Upper Davenport 1
11. Limestone, Lower Davenport, whitish calcilutite, laminated, crackled, laminæ minutely folded in places and in places brecciated to mosaic and rubble 8
10. Limestone, crystalline, purplish brown, irregularly bedded, containing a few angular fragments of whitish calcilutite 1
9. Limestone, light gray, hard, compact, fine-grained, in layers three to four inches thick, composed of laminæ two to six millimeters thick, with distinct alternations of shades of color 4½
8. Limestone, as above, laminæ in places flexed, broken and brecciated within the layer 1 2-3
7. Limestone, as No. 9..... 1-3
6. Shale, reddish brown, highly calcareous, brittle, finely laminated ..... ½
5. Limestone, dove-gray, hard, finely laminated..... 1-3
4. Limestone, light gray, calcilutite..... 1 1-3
3. Limestone, coarse-grained, laminated, laminæ coherent.. . 4 1-3
2. Limestone, drab weathering to white, compact, semi-crystalline, in two layers, breaking in places into small irregular chipstone 5¼
1. Limestone, finely crystalline, white or light gray, weathering to thin plates, passing downward, and in places laterally, into mottled vesicular darker gray limestone, which merges into a basal massive light yellow-gray finely crystalline rock which is briskly effervescent in cold dilute HCl 8

Muscatine County

The exposures of the Wapsipinicon in this county are very limited. The lowest beds outcropping, according to Udden[75], are on the west bank of Cedar river south of the county line. Here there are exposed twenty-five feet of a very pure grayish or white compact unfossiliferous limestone much of which is brecciated. In their stratigraphic position and in their facies these beds appear to correspond with the beds of the Lower Davenport in the counties to the north and northeast. This inference is confirmed by Udden's observation of overlying beds of tough gray limestone carrying *Phillipsastrea billingsi* and other fossils found in the Upper Davenport of Scott county.

[75]Udden, J. A., Geology of Muscatine County, Ia. Geol. Surv., Vol. IX, pp. 269 et seq.