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The Contributions of J.A. Udden to an Understanding of Iowa Geology[1]

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Johan August Udden served on the faculty of Augustana College from 1888 until 1911. His research during that time was directed toward an understanding of the geology of areas close at hand, the region around Rock Island and nearby areas in Iowa and Illinois. Udden's most significant contributions to Iowa geology were in his treatment of 1) Paleozoic, Cretaceous, and Quaternary stratigraphy; 2) subsurface geology, including information on bedrock elevations and topography; 3) characteristics and origin of the loess. Most of this information was included in the Annual Reports of the Iowa Geological Survey published between 1899 and 1903. He made important contributions to the study of the Devonian of eastern Iowa. He was the first to recognize cyclic sedimentation in Pennsylvanian strata. He compiled subsurface information on the thickness of Pennsylvanian rocks in Jefferson County and was probably among the first to present such information on a map. He prepared what may be the earliest maps of bedrock topography, in Muscatine and Louisa counties. He was an unwavering proponent of the eolian hypothesis for the origin of loess. He noted that modern wind deposits have the same particle-size distribution as does the loess, and in the process of making these analyses he devised a widely used size-grade scale.

Udden's work was characterized by careful observation and attention to detail. Whenever possible, he expressed his observations quantitatively. His work was notably innovative and original. His experiences in Iowa, and in Illinois, set the stage for his significant contributions to the wealth of the state of Texas and its university through discoveries of quicksilver, potash, and especially, oil.

INDEX DESCRIPTORS: Udden, Iowa, geology.

Johan August Udden served on the faculty of Augustana College from 1888 until 1911. His research during that time was directed toward an understanding of the geology of areas close at hand, the region around Rock Island and nearby areas in Iowa and Illinois. Later he spent his summers working for the Texas Bureau of Economic Geology and Technology, and in 1911 he left Augustana to begin full-time work with that bureau. In 1915 he was appointed State Geologist of Texas, a position he held until his death 5 January 1932.

Udden was born 19 March 1859 in Uddabo, Lekasa Parish, Vastergotland, Sweden, but was brought to the United States by his parents in 1861. The family settled in Carver County, Minnesota, about 30 miles southwest of Minneapolis. Johan attended both St. Ansgar Academy in Minnesota and Augustana Academy in Rock Island. He graduated from Augustana College in 1881, having pursued a classical curriculum rich in language, history and theology. In addition, Udden took courses in physics, zoology, botany, physiology, and chemistry from Josua Lindahl, the first *bona fide* scientist at Augustana College. Lindahl had completed his Ph.D. at the university at Lund, Sweden, in 1874 and joined the Augustana faculty in 1878. Udden began his teaching career at Bethany College, Lindsborg, Kansas in the fall of 1881. He returned to Augustana in 1888 when Lindahl left to become State Geologist of Illinois (Udden 1913a; Norton 1932; Baker 1933; Sebelius 1949; Hansen 1985; Heiman 1963; Anderson 1992; Underwood 1992).

STUDIES OF IOWA GEOLOGY

Udden's work on Iowa geology is in the form of five county reports published in the Annual Reports of the Iowa Geological Survey between 1899 and 1903, more than a dozen papers in scientific journals, and two numbers in the Augustana Library Publications series. The counties for which he wrote reports are concentrated either in the southeast part of the state (Muscatine, Louisa, and Jefferson) or in the southwest (Pottawattamie, Mills, and Fremont) (Fig. 1). Most of the papers published in scientific journals are based on this field work. In addition, his son, Jon Andreas Udden, reported on the geology of Clinton County (Udden, Jon, 1905). The county reports followed a standard format in which the physiography, stratigraphy, geologic structure, and economic products were described.

In general, Udden's most significant contributions were in his treatment of: 1) Paleozoic, Cretaceous, and Quaternary stratigraphy; 2) subsurface geology, including information on bedrock elevations and topography; and 3) characteristics and origin of the loess.

Paleozoic Stratigraphy

In his report on Muscatine County, Udden included 18 measured and described sections of middle Devonian exposures and 8 similar descriptions of upper Devonian Sweetland Creek beds (Udden 1899c). He then summarized the Sweetland Creek beds in a composite section (Fig. 2). An earlier version of this composite section was published in 1897, and the Sweetland Creek beds were also described in 1899 (Udden 1897a, 1899d). Lists of fossil invertebrates accompanied these descriptions of middle and upper Devonian beds. Udden also recovered fish teeth from these beds (Udden 1899b), one of which was named after him (Eastman 1900).

Udden accorded similar treatment to the Mississippian rocks in Louisa County, where in 30 measured sections he described strata extending from what he considered the Kinderhook group up into the St. Louis breccias, exposed just north of the county line. These he referred to as the Mississippian Series of the Carboniferous System. Udden recognized that these beds were significantly thinner than

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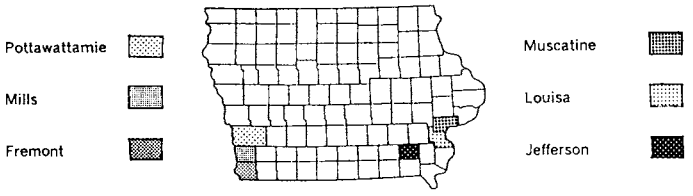

Fig. 1. Map of Iowa showing the counties for which Udden furnished reports published in the Annual Reports of the Iowa Geological Survey.

Combining all the exposures at this point the following succession of separate layers is evident:

		FEET.
11.	Dark gray bituminous shale, with one or two thin, green bands about 4 feet below the highest exposure. Occasionally small, flat concretions of pyrites are seen. Next the green layer the shale is dark, filled with a maze of fine green filamentous lines. Drift overlies	8
10.	Dark shale, containing lingulas, *Spathiocaris emersoni*, Rhynchodus, and a fossil resembling *Solenocaris striata*. This number is continuous with No. 11	1½
9.	Greenish clay, with flat concretions of iron pyrites, frequently having white, stony lamellar extensions from the margin	3
8.	Dark shale	½
7.	Greenish, stony shale, with a conchoidal concretionary fracture	½
6.	Hard, light grayish-green shale, with white, flattened, cylindrical fucoid concretions of a concentric structure in horizontal positions	½–¾
5.	Greenish, argillaceous or arenaceous, fine grained dolomite, in ledges from 4 to 10 inches in thickness, with occasional lingulas and a fragment of a cast of a gasteropod near the base, frequently exhibiting small, cylindrical, concretionary impregnations of a deeper green, and occasionally impressions of plant-like fibrous structure covered with a thin layer of bituminous material	3
4.	Greenish shale	1½
3.	A stony seam filled with finely granular pyrites, and occasionally showing larger lumps of the same mineral, in one instance associated with plant like fibrous impressions, frequently containing rounded, worn fragments of fish teeth	½–¾
2.	Green, hard shale	½
1.	Greenish stony layer, with frequent, mostly rounded fragments of teeth of *Ptyctodus calceolus*	½

Fig. 2. Composite section for the middle Devonian of Muscatine County (Udden 1899c, p. 292).

they were to the south in Keokuk County, and he attributed this thinning to the supposition that the shore of the Mississippian sea lay less than 50 miles to the north (Udden 1901a, p. 92). He also noted that the St. Louis lay uncomfortably on the lower beds, an observation confirmed by later work (Witzke, et al. 1990, p. 23).

Udden recognized the Sweetland Creek beds at the base of the Kinderhook in Louisa County . As in the Muscatine County report, he included a list of fossils, identified by Stuart Weller of the University of Chicago. He also reported finding microfossils (rhizopods) in the shaly Pella beds (Udden 1902c). In his report on Jefferson County Udden described 27 exposed sections of Mississippian rocks and referred them all to the St. Louis Stage, Lower Carboniferous Series, Carboniferous System, rocks which had previously been described in detail in Washington County (Bain 1896). Recent study shows, however, that these strata are not strictly correlative with the type St. Louis (Witzke et al. 1990).

Polk 20	Black Hawk 15	Penn 30	Walnut 10
Locust Grove 80	Fairfield 75	Buchanan 20	Lockridge 40
Des Moines 50	Liberty 50	Cedar 20	Round Prairie 20

Fig. 3. Plat of estimated average thickness of the Des Moines in several townships of Jefferson County (in feet) (Udden 1902a, p. 414).

Udden's contributions to the understanding of Iowa's Pennsylvanian stratigraphy are also found primarily in his county reports, which include measured and described sections of Pennsylvanian strata as follows: Jefferson County (21 sections), Mills and Fremont counties (26 sections), Muscatine County (7 sections), and Pottawattamie County (8 sections) (Udden 1899c, 1901a, 1901b, 1902a, 1903b). In Muscatine, Louisa, and Jefferson Counties Pennsylvanian strata were referred to as the Des Moines Stage, Upper Carboniferous Series, Carboniferous System. These rocks lie uncomfortably upon Devonian or Mississippian limestones. In Louisa County Udden recognized paleokarst at the top of the Mississippian where "the Burlington often has cavernous tunnels and crevices filled by the deposits of the next succeeding period" (Udden 1901a, p. 93). Udden did not offer an opinion as to the age of this karst fill, but he noted that farther north, presumably in Muscatine County, the lowest parts of these deposits "are found frequently to contain Subcarboniferous chert." He continued,

> It is quite evident that the erosion preceding the next submergence cut this limestone almost to its present condition. Accompanying this erosion there was a tilting of the land to the south. Following the erosion and tilting of the land it was again submerged and the Coal Measures were laid down in the marginal waters of a sea advancing an unknown distance to the north (Udden 1901a, p. 93).

It is not clear whether Udden considered the karst-fill to be Pennsylvanian or pre-Pennsylvanian in age. He reported that green shales overlie the St. Louis and were overlain by unequivocal Coal Measures in places in Jefferson County. He suggested that these green shales may be Chester equivalents (upper Mississippian) (Udden 1902a, p. 418). Furthermore, he recognized that in Louisa County "Only a small part of these deposits [Des Moines] are left . . . and they occur as small isolated outliers." In Jefferson County he compiled information on the thickness of the Pennsylvanian drawn from well records and outcrops, computed average thickness by township, and presented this information on a map of the county. The result is one of the earliest attempts to produce what today we call an isopach map (Fig. 3). Udden concluded:

> It should be remembered that the figures given are estimates and that since both the upper and lower limits of the formation conform to ancient erosion contours there are apt to be great local variations in its development. It is believed that the maximum development of the formation will not exceed three times the figures given, while at the same time it is known excepting Fairfield and Locust Grove Townships, the minimum limit is zero; that is, the Coal Measures have been entirely removed at some point in nearly all the townships (Udden 1902a p. 414).

Udden was a pioneer in the use of the data from wells to compile information on subsurface geology, a technique that he applied very profitably later as Director of the Texas Bureau of Economic Geology and Technology (Baker 1933; Heiman 1963). As a result of his study of the records of wells in the Rock Island area (Udden 1896a, 1898b), the subsurface geology in this area was understood as well as any comparable area in the United States (Norton 1899, p. 505; 1932, p. 25; Baker 1933, p. 403).

For Jefferson County, Udden included a list of fossils from the Des Moines (Middle Pennsylvanian), tabulated by locality. A similar list of Missourian (Upper Pennsylvanian) fossils was presented in the report on Mills and Fremont counties. He reported finding a bone of *Pleuroptyx clavatus* Cope, an amphibian, in a black Coal Measures shale in Jefferson County (Udden 1902d).

In the southwestern counties, Pottawattamie, Mills, and Fremont, Udden refers to the Pennsylvanian as Missourian Stage, Upper Carboniferous Series, Carboniferous System. In the report on Mills and Fremont counties he included a plate of geologic sections with the beds keyed to the numbered units in his verbal descriptions (Udden 1903b, Plate vi). The graphic sections were not arranged in the form of a correlation chart, but he did indicate correlations in the text. The fossils and lithologies led him to conclude that these strata (Upper Pennsylvanian) were deposited under conditions of fluctuating sea level but generally in a more off-shore environment than that of the Des Moines rocks (Middle Pennsylvanian) in Muscatine and Jefferson counties.

Udden washed and sieved samples of Missourian sediments from Mills and Fremont counties, discovering a microfauna consisting of fusulinid foraminifera and "chitinous denticles and plates of brown color, some resembling in form the jaws of Nereidavus, described from the Devonian, and other forms, more frequent, resembling fragments of the radulae of gasteropods" (Udden 1903a). This suggested that not even tiny microfossils, some perhaps conodonts and scolecodonts, escaped Udden's attention.

Mesozoic Stratigraphy

Udden recognized Cretaceous sediments in the southwestern counties, but aside from a generalized section of these rocks along the west bluff of the Nishnabotna River in Fremont County he presented no detailed stratigraphic descriptions. He did, however, study the clast lithology of the sandstones and conglomerates, noting that the clasts consist of several varieties of chert from the Coal Measures, and quartz. He tabulated these by grain size and demonstrated that the ratio of chert to quartz varies inversely with particle size (Udden 1903b, p. 163). He also measured the sizes of a sample of 55 spheroidal concretions from these sediments, separated them into 10 size classes ranging from 5 to 50 mm, and then tabulated the results, (number of concretions per size class). He made mechanical analyses of three samples of the sandstone, from the base, the middle, and the top, finding that most of the sand is between ¼ and ⅛ mm in diameter and that 95.8 percent of the middle sample lies in that grade. These beds constituted what was known at the time as the Nishnabotna Stage, Dakota Series, Cretaceous System. Udden interpreted them as littoral deposits in the advancing Cretaceous sea.

Quaternary Stratigraphy

In his county reports, Udden described the glacial tills using the terminology that was current at the time. The oldest drift, presumably derived from the north or northwest, was termed the Albertan. This was overlain by Aftonian sand and gravel, which in turn was overlain by Kansan till. In places Buchanan gravels overlay the Kansan till and in other places the Yarmouth Soil was developed at the top of the Kansan. Relationships of these materials in Louisa County were illustrated by field sketches (Udden 1901a). He noted the rare presence of pebbles of Cretaceous shale and crystals of staurolite in the Kansan of eastern Iowa and considered that this indicated a source to the north in Minnesota (Udden 1899a). He sampled literally thousands of pebbles from the tills of Iowa, not only to determine the sources of the tills, but also to document the effect of weathering on till-pebble lithology (Udden 1913b). He recognized Illinoian till in Muscatine and Louisa Counties. He described it as discontinuous in Muscatine County, whereas in southern Louisa County it was more than 50 feet thick and formed a morainic ridge along its western margin, even a double ridge, rising as much as 50 feet above the surrounding upland (Udden 1901a, p. 107).

Udden described the tills in the southwestern counties much less completely than he did those in southeast Iowa, probably because exposures were limited in this area of thick loess and because no detailed undersranding of these deposits had developed. To a large extent, the latter is still the case. Udden presumes that both Albertan and Kansan tills were present, but he found no way to differentiate them. He saw no paleosols, although reddish horizons reported by drillers suggest that they were present. Pebble counts from the base and top of the till showed no significant differences. He noted that the till in Pottawattamie County averaged about 140 feet in thickness but became thinner both to the north and south and toward the Missouri River.

In 1894, Udden, on the basis of direct observation and theoretical calculation, concluded that "the wind-theory would appear to furnish an adequate explanation of the occurrence of the loess in the Mississippi Valley" (Udden 1894). He compiled newspaper accounts of "dust and sandstorms in the west," and from these he concluded that because of their frequency, severity, and widespread distribution, these storms were capable of producing the loess deposits he observed in Iowa and adjacent areas (Udden 1896b). He admitted that newspaper accounts were a crude and inexact means of analysis; nevertheless, he considered them to be of some value as a first approximation. Perhaps because of these reservations, he elected to publish this study in *Popular Science Monthly* rather than in a more respected scientific journal, a strategy he may have used on another occasion, as well (Hansen 1985, p. 209). In Louisa County Udden noted that the loess is thickest along the bluffs of the Mississippi River and recognized its relationship to nearby valleys:

> Frequently there is a perceptible thickening along the edge of the bluffs adjoining larger valleys. This is most common where the bluffs face west. Sometimes this feature is pronounced and the edge of the upland consists of a bordering ridge which may be composed of fine sand . . . Shallow ponds may lie back of these ridges, which are evidently blown up by the wind (Udden 1901a, p.111).

In Pottawattamie County, Udden collected samples of loess and made 11 mechanical analyses, noting that the size of 60 percent of the material lay between $1/16$ and $1/32$ mm in diameter and that less than 2 percent was greater than ⅛ mm or less than $1/128$ mm in diameter. At Loveland he saw a dark zone with bits of charcoal that divides the loess into two roughly equally thick units. This is the Loveland Soil, which is now considered Sangamonian in age.

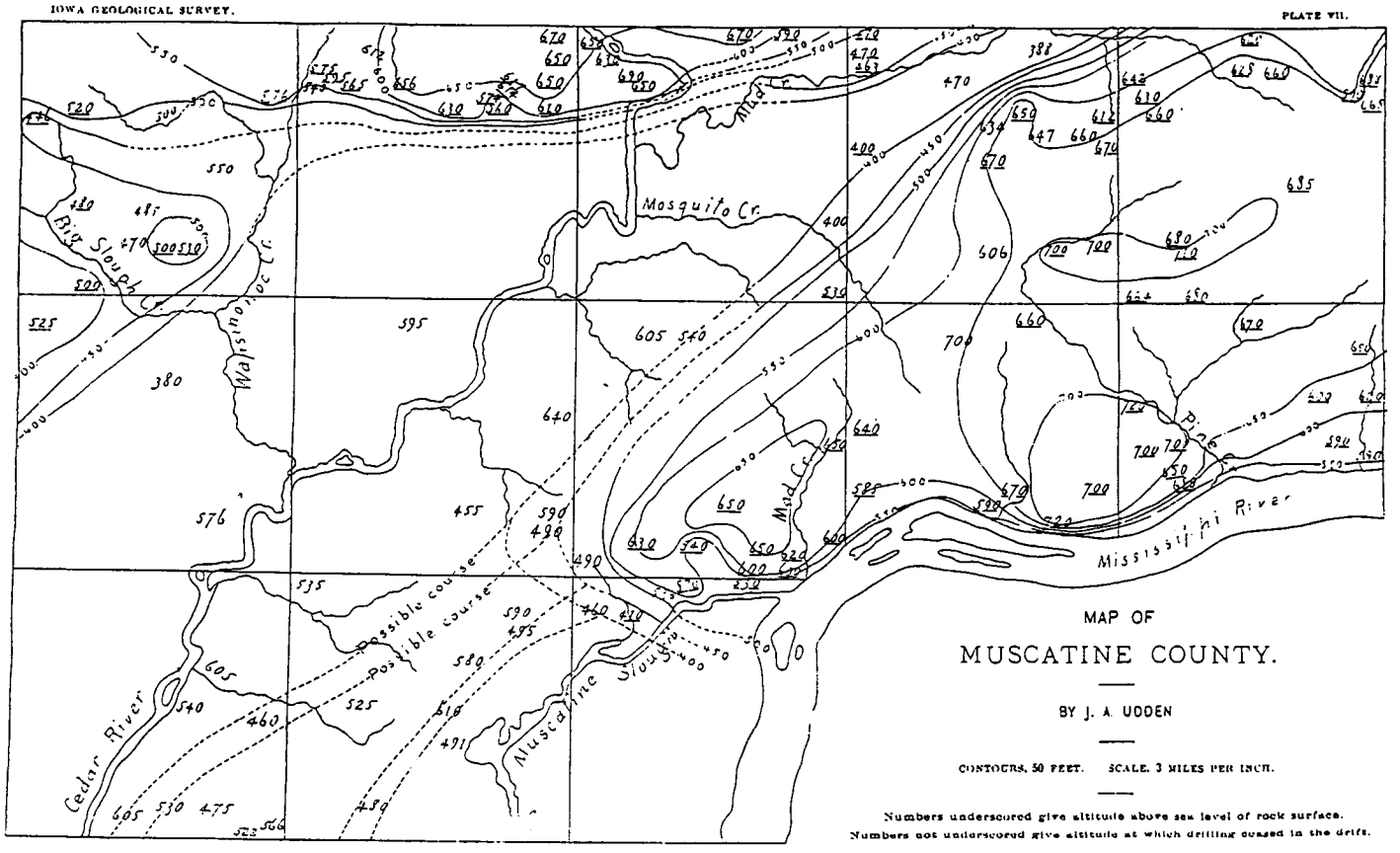

Fig. 4. Map of the bedrock topography of Muscatine County (Udden 1899c).

Udden collected snails from the loess in each county he surveyed except in Jefferson County where he found no snails because the loess was thin and completely leached. The collections from the southwestern counties were submitted to Bohumil Shimek for identification and interpretation. Study of Udden's snail samples and those he collected himself led Shimek to conclude that the loess was "not subaqueous" in origin (Shimek 1896, 1898). Rather, it was deposited under conditions similar to those that exist today, when wind storms blow dust in sufficient quantities to have formed the loess. In his county reports Udden did not comment directly on the origin of the loess, except in Louisa County where he described it as a "deposit of terrestrial dust." That he favored an eolian origin is obvious (Udden 1894, 1897b), but in his seminal report on "The Mechanical Composition of Wind Deposits" he suggested that:

> Though the eolian hypothesis has been more or less considered by all geologist [sic] who have had occasion to study the loess, it seems that the nature of the work performed by the atmosphere is too imperfectly known to admit, as yet, of any thorough discussion of the efficiency of the wind as a loess-maker in America. A study of this work should precede a final verdict on the origin of this formation, and this thought has been the stimulus while pursuing the studies whose results are here recorded (Udden 1898a, p. 69; Fig. 5).

Perhaps because he did not look at the mineral composition of the loess, Udden did not make the connection between the loess and glacial flour, the silt fraction of the till. Instead, following Shimek, probably the most out-spoken advocate of the eolian hypothesis (Shimek 1896, 1898), Udden considered that the loess was deposited under conditions similar to those that exist today (Udden 1897b). Although Udden may have influenced Chamberlin in accepting an eolian origin (Hansen 1985), it was Chamberlin who ultimately recognized the glacial derivation of the loess (Chamberlin 1897).

In Pottawattamie County, Udden (1902b) noted some enigmatic horizontal shear planes at the base of the loess, where it overlay the "gumbo", a material ranging from red clay to a pebbly, loess-like sediment that "when moistened absorbs the liquid and swells up visibly" (Udden 1901b, p.258). He thought these shear planes might result from mass-movement or even glacial motion, but he was not satisfied with either of these explanations.

Udden was instrumental in compiling information on the occurrence of the mastodon and mammoth remains in Illinois and Iowa (Anderson 1905). He then summarized this information in terms of the age and type of sediment in which these fossils occur, the species represented, and the types of associated fossils. Finally, he evaluated evidence linking man with proboscidians (Udden 1905).

Udden's interest in the topography of the bedrock surface beneath the drift was manifest by tables listing the location of wells, their curb elevation, and the thickness of materials overlying the Paleozoic bedrock: 92 wells in Muscatine County, 85 in Louisa, 64 in Pottawattamie, and 27 in Jefferson. This provided sufficient control in Muscatine and Louisa counties to construct maps of the bedrock topography, surely among the earliest such maps ever produced (Fig 4.). These maps revealed deep valleys that Udden considered preglacial in age: the southwestward continuation of the Cleona Channel in Muscatine County and the *"Udden Channel" in Lousia County*, which coincides quite closely with the present course of the Iowa

River (Hansen 1973). For Pottawattamie County he plotted bedrock elevations on a map, but did not contour them, presumably because there were not enough data points (Udden 1901b, Plate VI). In all of his county reports Udden considered the relief on this bedrock surface to be a result of Tertiary erosion. He described no evidence of pre-glacial weathering on this surface except for a single locality in Lousia County. He did, however, describe the Pine Creek Conglomerate in Muscatine County, which he considered "post-Carboniferous and preglacial" (Udden 1898c; 1899c). The fact that it contained some northern lithologies led Udden to suggest that it might actually represent an early glaciation.

Structure

In each of the counties he studied, Udden attempted to determine the direction and degree of the dip by noting the differences in elevation of correlative beds at different locations. In addition, he made scores of measurements of the strike of joints in the hopes that they might shed light on the dip of these almost flat-lying beds. Although the results were inconclusive in some areas, in general, he found dips to the south and west (Udden 1899c, 1901a, 1901b, 1902a). Small faults and flexures in the upper part of the St. Louis limestone in Jefferson County were attributed to collapse of underlying cavernous limestone.

Udden used newspaper accounts to assess the effects of the May 26, 1909, earthquake that was centered in northern Illinois and affected areas from northwestern Indiana to eastern Iowa and southern Wisconsin. From this information he constructed an isoseismal map based on the Rossi-Forel scale of intensities (Udden 1901b). The most affected area in Iowa extended from Davenport to Dubuque. In a more popular account, Udden goes somewhat afield and described human reaction to the earthquake, noting among other things that "its intensity was near that limit, which is strong enough to scare women but not men. This limit must approximate seven in the Rossi-Forel scale, and the unsentimental seismologist may hence add another criterion for correctly locating the seventh isoseismal" (Udden 1910a).

Economic Geology

Unlike his later work in Texas, which was largely devoted to finding and developing natural resources, Udden's work in Iowa was directed more toward basic rather than toward applied geology. To be sure, one of the most important objectives of the county reports of the Iowa Geological Survey was to assess natural resources, and Udden's reports satisfied this objective. He evaluated the present utilization of a variety of natural resources and commented on their potential for future development, but his treatment of this subject lacked the depth and thoroughness he devoted to purely geological topics. Building stone, clay, coal, natural gas, gravel and sand, soils, and water supply were the principal natural resources he considered.

DISTINCTIVE CHARACTERISTICS OF UDDEN'S WORK

Udden's work in Iowa was characterized by careful observation and attention to detail. His county reports included dozens of measured and described sections, often summarized as composite sections. Whenever possible, he expressed his observations quantitatively. He tabulated the location and elevations of wells; he published lists of fossils and the localities where they were found; he made pebble counts of Cretaceous conglomerates and Quaternary tills; he made mechanical analysis of Cretaceous sandstones, "gumbo," and loess. Although he offered explanations for these observations, he was not inclined toward extended discussion and interpretation. Regarding his position on the origin of the loess, for example, he was unwavering in his support of the eolian hypothesis, but his support was in the form of analysis of: 1) the effectiveness of the wind as a geological agent (Udden 1894), 2) the similarity in mechanical composition between the loess and modern wind-blown sediments (Udden 1898a; Fig. 5), and 3) the topographic position of the loess (Udden 1901a). He collected data, offered his interpretation, and by implication, at least, allowed the reader to draw her or his own conclusions.

Table XXXIV. **Mechanical Composition of Shower Dust fallen at Rock Island, Ill., January, 1895.**

Length of diameter in mm.	147 From the ice of the Mississippi, near bank.	148 From the ice of the Mississippi, near bank.	149 From a crack in ice of the Mississippi, in channel.	150 From the ice of the Mississippi, centre of the channel.	151 From the ice of the Mississippi, near the bank.	Average.
16—8	.....	.....	.....	.....	.....	.....
8—4	.....	.....	.....	.....	.....	.....
4—2	.....	.....	.....	.....	.....	.....
2—1	.....	.....	.....	.....	.....	.....
1—½	.....	.....	.....	.....	.....	.....
½—¼	tr.	1.2	.5	.....	tr.	.3
¼—⅛	2.0	10.9	1.4	.7	.2	3.1
⅛—1/16	18.0	13.8	15.2	9.0	11.2	13.0
1/16—1/32	32.0	41.5	44.6	36.3	30.0	36.9
1/32—1/64	37.0	29.8	34.0	36.3	49.0	37.2
1/64—1/128	9.0	3.9	4.7	15.1	7.0	7.9
1/128—1/256	7.0	.....	.3	1.8	1.1	.8

Fig. 5. Histograms showing the mechanical composition of dust collected directly from the atmosphere (Udden 1898c, p. 53).

His work was notably innovative and original. He proposed the grade scale that is in widespread use today (Udden 1898a; Krumbein 1932; Blatt et al. 1980, p. 89). He was among the first to make extensive use of subsurface data. He was the first to recognize the cyclic nature of Pennsylvanian sediments (Weller 1930; Langenheim and Nelson 1993). Although this was not apparent in his Iowa reports, undoubtedly his experience with the Pennsylvanian of Iowa played a role in revealing cycles in the better exposed Pennsylvanian of the Peoria Quadrangle, Illinois (Udden 1912). His experience in Iowa, and in Illinois, set the stage for his significant contributions to the wealth of the state of Texas and its university through discoveries of quicksilver, potash, and especially, oil (Baker 1933; Heiman 1963).

SIGNIFICANCE OF UDDEN'S WORK IN IOWA

J.A. Udden was part of a remarkable, turn-of-the-century undertaking by the State of Iowa: to survey the geology of the state and to publish the results on a county by county basis. As they were completed, these surveys were published in the annual reports of the Survey, beginning in 1893. In all, 91 county geological reports were published, most of them during the two decades spanning the turn of the century. Twenty-four authors contributed to the project. Udden reported on six counties, a number exceeded only by T. H. MacBride, Samuel Calvin, H.F. Bain, and M. F. Arny. This effort produced not only an essential inventory of the natural resources of the state, but also laid a solid foundation for all subsequent geological investigation. Udden's reports, by their attention to detail and their emphasis on basic science, contributed greatly to the overall success of this project.

LITERATURE CITED

ANDERSON, N. C. 1905. A preliminary list of fossil mastodon and mammoth remains in Illinois and Iowa. Augustana College Library Publication No.5. Rock Island, Illinois.

ANDERSON, R. C. 1992. The first 75 years of geology at Augustana College. Pages 7–24. *In* Earth Interpreters: F. M. Fryxell, Geology, and Augustana: Schroeder, D. A., and Anderson, R. C., eds. Augustana College Library Publications No. 36, Rock Island, Illinois.

BAIN, H. F. 1896. The Geology of Washington County. Iowa Geological Survey Annual Report for 1895 5:113–174.

BAKER, C. L. 1933. Memorial of Johan August Udden. Geological Society of America Bulletin 44:402–413.

BLATT, H., G. MIDDLETON and R. MURRAY. 1980. Origin of sedimentary rocks. Prentice-Hall, Englewood Cliffs, New Jersey.

CHAMBERLIN, T. C. 1897. Supplementary hypothesis respecting the origin of the loess of the Mississippi Valley. Journal of Geology 5:795–802.

EASTMAN, C. R. 1900. Dentition of some Devonian fishes. Journal of Geology 8:32–41.

HANSEN, R. E. 1973. Bedrock topography of southeast Iowa. U.S. Geological Survey, Miscellaneous Geological Investigations Map I-808.

HANSEN, W. B. 1985. Dust in the wind. J. A. Udden's turn-of-the-century research at Augustana. Pages 203–214. *In* Geologists and Ideas: A History of North American Geology E. T. Drake and W. M. Jordan, eds. Geological Society of America Centennial Special Volume 1.

HEIMAN, M. 1963. A pioneer geologist: biography of Johan August Udden. Braswell Printing, Kerrville, Texas.

KRUMBEIN, W. C. 1932. A history of the principles and methods of mechanical analysis. Journal of Sedimentary Petrology 2:89–124.

LANGENHEIM, R. L. and W. J. NELSON. 1992. The cyclothemic concept in the Illinois Basin: a review. Pages 55–71. *In* Eustasy: the historical ups and downs of a major geological concept R. H. Dott, Jr., ed. Geological Society of America Memoir 180.

NORTON, W. N. 1899. Geology of Scott County. Iowa Geological Survey Annual Report for 1898 9:389–520.

NORTON, W. H. 1932. Johan Augusr Udden. Proceedings of the Iowa Academy of Science 39:24–26.

SEBELIUS, S. J. 1949. Master builders of Augustana. Rock Island, Illinois, Augustana Book Concern.

SHIMEK, B. 1896. A theory of the loess. Proceedings of the Iowa Academy of Science 3:82–89.

SHIMEK, B. 1898. Is the loess of aqueous origin? Proceedings of the Iowa Academy of Science 5:32–45.

UDDEN, J. A. 1894. Erosion, transportation, and sedimentation performed by the atmosphere. Journal of Geology 2: 318–331.

UDDEN, J. A. 1896a. An account of the Paleozoic rocks explored by deep borings at Rock Island, Illinois, and vicinity. Pages 829–849. U.S. Geological Survey 17rh Annual Report, Part 2.

UDDEN, J. A. 1896b. Dust and sandstorms in the west. Popular Science Monthly, September 1896, pp. 655–663.

UDDEN, J. A. 1897a. A brief description of Devonian rocks exposed in the vicinity of Rock Island, Illinois, with a statement of the nature of its fish remains. Journal of the Cincinnati Society of Natural History 20: 93–95.

UDDEN, J. A. 1897b. Loess as a land deposit. Geological Society of America Bulletin 9:7–9.

UDDEN, J. A. 1898a. The mechanical composition of wind deposits. Augustana Library Publications No. 1.

UDDEN, J. A. 1898b. A new well at Rock Island, Illinois. American Geologist 21:199–200.

UDDEN, J. A. 1898c. The Pine Creek Conglomerate. Proceedings of the Iowa Academy of Science 6:54–56.

UDDEN, J. A. 1899a. Some Cretaceous drift pebbles in northern Iowa. American Geologist 24:389–390.

UDDEN, J. A. 1899b. *Dipterus* in the American middle Devonian. Journal of Geology 7:494–495.

UDDEN, J. A. 1899c. Geology of Muscatine County. Iowa Geological Survey Annual Report for 1898 9:247–388.

UDDEN, J. A. 1899d. The Sweerland Creek beds. Joutnal of Geology 7: 65–78.

UDDEN, J. A. 1901a. The geology of Louisa County. Iowa Geological Survey Annual Report for 1900 11:55–126.

UDDEN, J. A. 1901b. The geology of Pottawattamie County. Iowa Geological Survey Annual Report for 1900 11:199–278.

UDDEN, J. A. 1902a. The geology of Jefferson County. Iowa Geological Survey Annual Report for 1901 12:355–438.

UDDEN, J. A. 1902b. Loess with horizontal shear planes. Journal of Geology 10:245–251.

UDDEN, J. A. 1902c. On the occurrence of rhizopods in the Pella beds of Iowa. Proceedings of the Iowa Academy of Science 9:120.

UDDEN, J. A. 1902d. *Pleuroptyx* in the Iowa Coal Measures. Proceedings of the Iowa Academy of Science 9:121.

UDDEN, J. A. 1903a. Foraminiferal ooze from the coalmeasures of Iowa. Journal of Geology 11:283–284.

UDDEN, J. A. 1903b. The geology of Mills and Fremont counties. Iowa Geological Survey Annual Report for 1902 13:123–184.

UDDEN, J. A. 1905. On the proboscidian fossils of the Pleistocene deposits in Illinois and Iowa. Augustana Library Publications 5:45–57.

UDDEN, J. A. 1910a. Observations on the earthquake on May 26, 1909. Popular Science Monthly, August 1910, pp. 154–162.

UDDEN, J. A. 1910b. Observations on the earthquake in the uppet Mississippi Valley, May 26, 1909. Transactions of the Illinois Academy of Science 3:132–143.

UDDEN, J. A. 1912. Geology and mineral resources of the Peoria Quadrangle, Illinois United States Geological Survey Bulletin 506.

UDDEN, J. A. 1913a. Autobiographical notes. Unpublished, Augustana College Library Special Collections.

UDDEN, J. A. 1913b. The effect of leaching on drift pebbles. Journal of Geology 21:564–567.

UDDEN, Jon A. 1905. The geology of Clinton County. Iowa Geological Survey Annual Report for 1904 15:69–432.

UNDERWOOD, J. R., Jr. 1992. The life of Johan August Udden, geologist, teacher, inventor: through the Kansas years. Transactions of the Kansas Academy of Science 95:177–191.

WELLER, J. M. 1930. Cyclical sedimentation of the Pennsylvanian Period and its significance. Journal of Geology 38:97–135.

WITZKE, B. J., R. M. MCKAY, B. J. BUNKER and F. J. WOODSON. 1990. Stratigraphy and paleoenvironments of Mississippian strata in Keokuk and Wahington Counties, southeast Iowa. Iowa Geological Survey Guidebook Series No. 10.