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Environment of Deposition of the Cedar Valley Formation in the Vicinity of Black Hawk County, Iowa

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Environment of Deposition of the Cedar Valley Formation in the Vicinity of Black Hawk County, Iowa

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WAYNE I. ANDERSON and STEPHEN V. WIIG (Department of Earth Science, University of Northern Iowa, Cedar Falls, Iowa 50613). Environment of Deposition of the Cedar Valley Formation in the Vicinity of Black Hawk County, Iowa. *Proc. Iowa Acad. Sci.* 81(4): 135-142, 1974.
Nine stratigraphic sections of the Cedar Valley Formation were studied in Black Hawk, Buchanan and Benton counties in an attempt to better interpret the environment of deposition of the formation. Key environmental criteria for the interpretation of shallow water carbonate environments were recognized in the Cedar Valley Formation in the study area. The environment of deposition of the Solon Member is interpreted as entirely subtidal. The environment of deposition of the Rapid Member ranged from shallow subtidal to intertidal. The Coralville Member is interpreted as having been deposited in an environment that ranged from very shallow subtidal to intertidal and supratidal.
INDEX DESCRIPTORS: Stratigraphy, Devonian Paleogeography, Cedar Valley Formation.

The Devonian Age Cedar Valley Formation is one of Iowa's best known stratigraphic units. The formation consists mainly of fine-grained carbonate rocks and contains a fauna consisting primarily of brachiopods, corals and stromatoporoids. The formation is frequently quarried for road aggregate in eastern Iowa. Several good quarry exposures are available in the Black Hawk County area and provide gcod stratigraphic sections for the study of the stratigraphy of the Cedar Valley Formation.

The Cedar Valley Formation is divided into three members following the work of Stainbrook (1941). These three members, Solon Member (lower), Rapid Member (middle) and Coralville Member (upper), were named for localities in Johnson County, Iowa. The original division of the Cedar Valley Formation into members by Stainbrook was based primarily on the occurrence of brachiopods.

Published data on the physical stratigraphy of the Cedar Valley and interpretations of environments of deposition of the formation are limited. The principal objective of this study is to provide data on the physical stratigraphy and environment of deposition of the Cedar Valley Formation based on the study of nine stratigraphic sections in Black Hawk, Buchanan and Benton counties in Iowa. The locations of the nine sections are listed below and shown on Figure 1. Figure 2 shows the approximate stratigraphic position of each of the sections.

1. Yokum Quarry (Concrete Materials Division of Martin Marietta–Finchford Quarry), S.W.¼ Sec. 4, T. 90N., R. 14W., Black Hawk County, Iowa.
2. Burton Avenue Quarry (Concrete Materials Division of Martin Marietta), Highway 20, Waterloo, Iowa.
3. Pint Quarry (Welp and McCarten Quarry–Raymond), S.E.¼ Sec. 36, T. 89N., R. 12W., Black Hawk County, Iowa.
4. Jesup Quarry (Niemann Construction Company Quarry –Jesup), S.W.¼ Sec. 33, T. 89N., R. 10W., Buchanan County, Iowa.

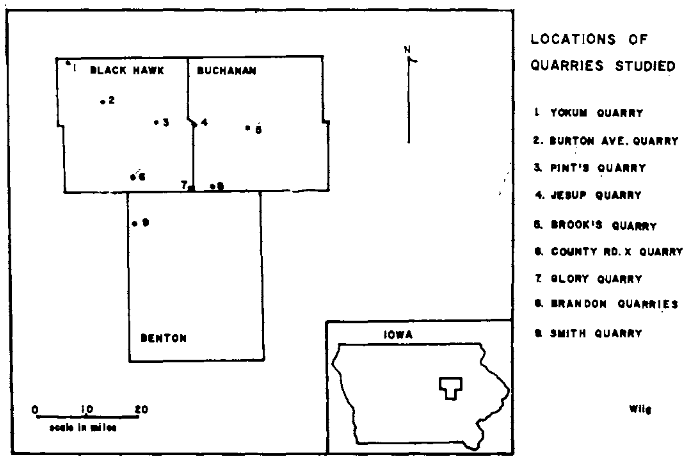

Figure 1. Location of the stratigraphic sections studied.

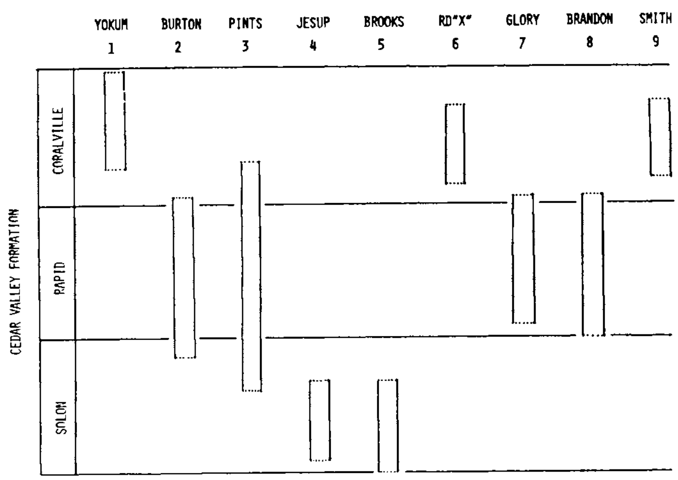

Figure 2. Approximate stratigraphic position of the nine sections included in this report.

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5. Brooks Quarry, N.W.¼ Sec. 2, T. 88N., R. 9W., Buchanan County, Iowa.
6. County Road X Quarry (Newton Quarry), S.W.¼ Sec. 7, T. 87N., R. 12W., Black Hawk County, Iowa.
7. Glory Quarry, N.W.¼ Sec. 36, T. 87N., R. 11W., Black Hawk County, Iowa.
8. Brandon Quarry, S.W.¼ Sec. 26, T. 87N., R. 10W., Buchanan County, Iowa.
9. Smith Quarry (Tama County Quarry), N.W.¼ Sec. 19, T. 86N., R. 12W., Benton County, Iowa.

Previous Investigations

The review of previous investigations will concentrate primarily on investigations that deal with the Cedar Valley Formation in the area of study (Black Hawk and adjacent counties).

Thomas (1951) published brief descriptions of the Cedar Valley Formation from localities at Finchford (Yokum Quarry), Waterloo (Burton Avenue Quarry) and Independence (Brooks Quarry) in the Guidebook for the 15th Annual Tri-State Field Conference.

Anderson (1972) published stratigraphic sections and descriptions of the Cedar Valley Formation from exposures at Finchford (Yokum Quarry), Raymond (Pint Quarry), and Independence (Brooks Quarry) for the 36th Annual Tri-State Field Conference. Kettenbrink (1972, p. 35-41) provided a detailed description of the section at Raymond (Pint Quarry) for the Guidebook for the 36th Tri-State Field Conference.

Bisque and Lemish (1959) published data on the insoluble residue content of carbonate rocks from the Cedar Valley Formation from five quarries in eastern Iowa. Included in their study were exposures of the Cedar Valley Formation at Glory Quarry, Newton Quarry (County Road X Quarry), Pint Quarry and Burton Avenue Quarry in Black Hawk County. The study by Bisque and Lemish demonstrated that carbonate rocks with a high insoluble residue content also had a high magnesium (dolomite) content.

Kettenbrink (1973) completed a doctoral dissertation entitled "Depositional and Post-Depositional History of the Cedar Valley Formation, East-Central Iowa." Although his study was concentrated in the Johnson County area, he did include several quarries in Black Hawk, Buchanan and Benton counties in his study. Pint Quarry at Raymond was used by Kettenbrink as a reference section for the Cedar Valley Formation in what was the northern extent of his study area.

To the north of Black Hawk County, the Cedar Valley Formation is highly dolomitized, making it difficult to determine environmental relationships of the formation. Kohls (1961)

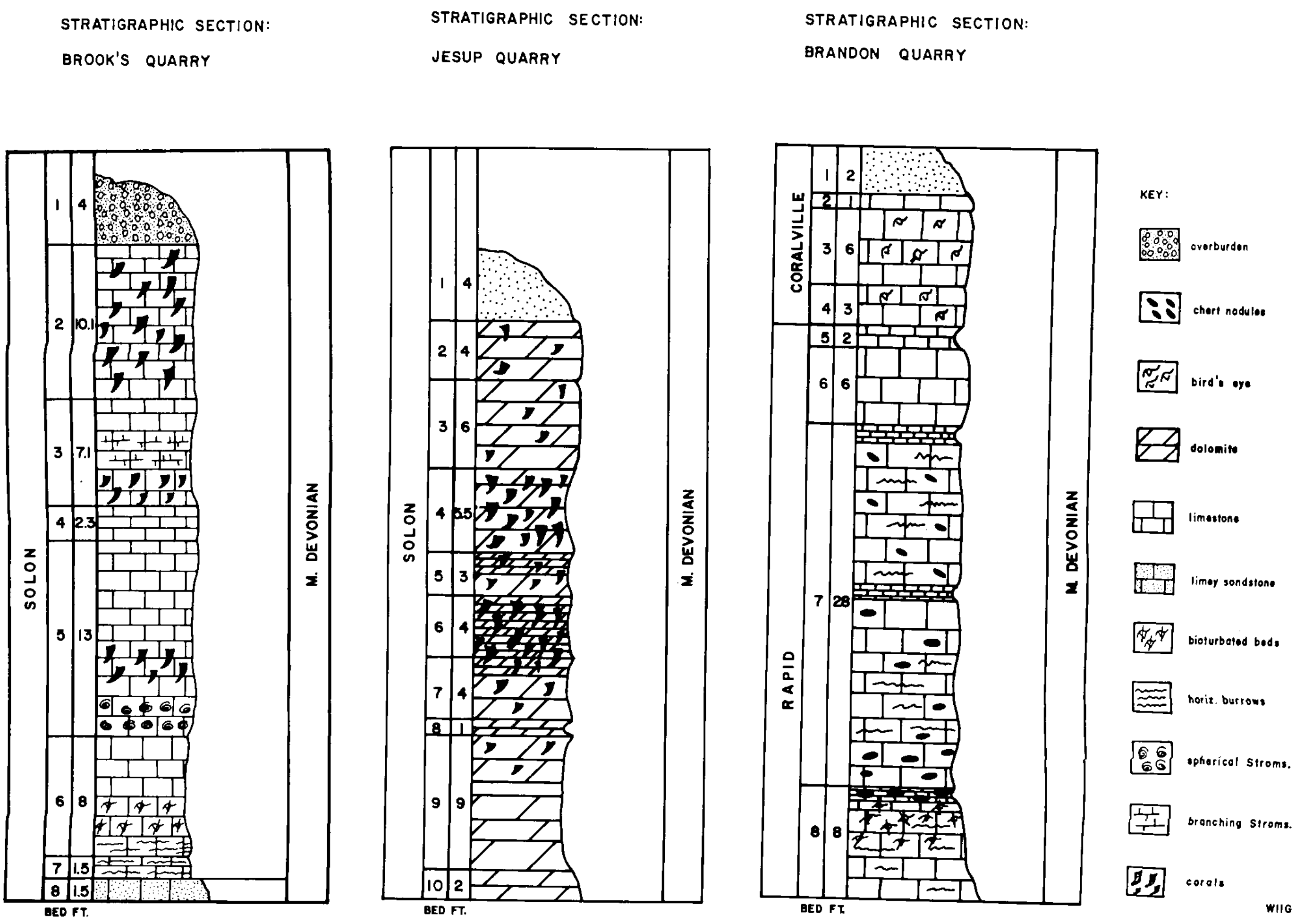

Figure 3. Stratigraphic sections at Brooks, Jesup and Brandon quarries.

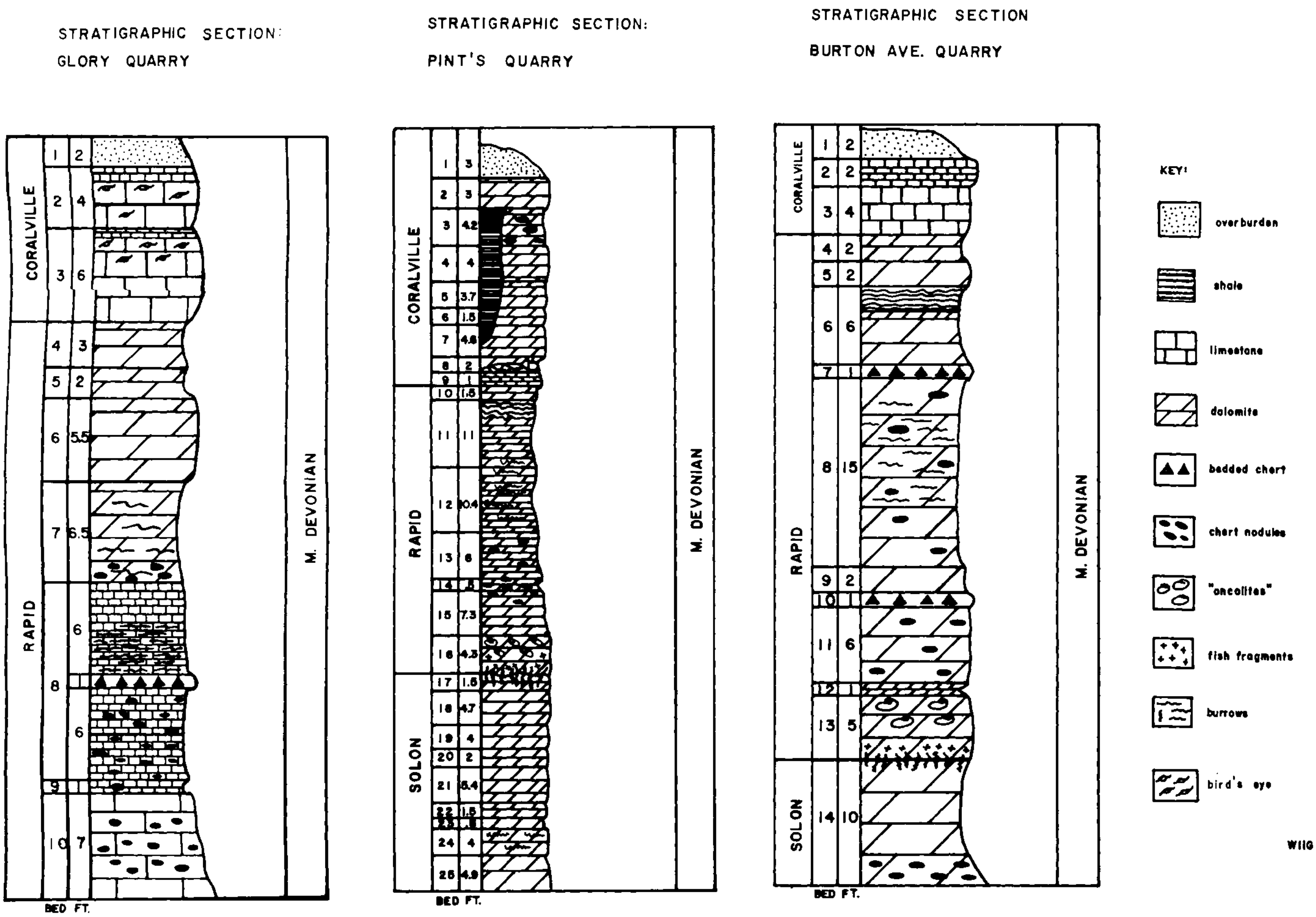

Figure 4. Stratigraphic sections at Glory, Pint and Burton Avenue quarries. Pint Quarry section from Kettenbrink (1972, p. 36).

studied the Cedar Valley Formation in northern Iowa and southern Minnesota for his doctoral dissertation at the University of Minnesota. Dorheim and Koch (1966) published several stratigraphic sections illustrating the dolomitized nature of the Cedar Valley Formation in Iowa's northern counties.

Collinson and others (1967) summarized data on the Devonian System of the north-central United States. Included in this report is a summary of the regional setting and distribution of the Cedar Valley Formation.

PROCEDURE

Stratigraphic sections representing various exposures of the Cedar Valley Formation were measured and described from nine localities in Black Hawk, Buchanan and Benton counties (Figures 1 and 2). The stratigraphic sections (Figures 3-5) were measured and plotted by Wiig as part of an undergraduate research project at the University of Northern Iowa. Both authors visited all nine sections and made field observations for the presence of various lithologic, paleontologic and primary structural criteria that have been found useful in identifying tidal flat and shallow subtidal carbonate environments.

The reader is referred to articles by Walker and Laporte (1970, p. 930-933) and Heckel (1972, p. 226-286) for a more detailed discussion concerning the origin and significance of features characteristic of shallow subtidal carbonate environments. Table 1 lists the environmental criteria that were utilized in this study. A brief discussion of each of the criteria follows.

DISCUSSION OF ENVIRONMENTAL INDICATORS

Birdseye

Shinn (1968) recognized birdseye structure (both planar isolated vugs and isolated bubble-like vugs) from recent and ancient limestones. The term "birdseye" refers to the glassy glint of these structures as seen on a freshly fractured rock surface. Planar birdseye structure was described as consisting of vugs 1 to 3 mm high by several millimeters in width. The bubble-like vugs are generally 1 to 3 mm in diameter.

Shinn's studies of recent carbonate sediments demonstrated that birdseye structure was preserved in supratidal sediments

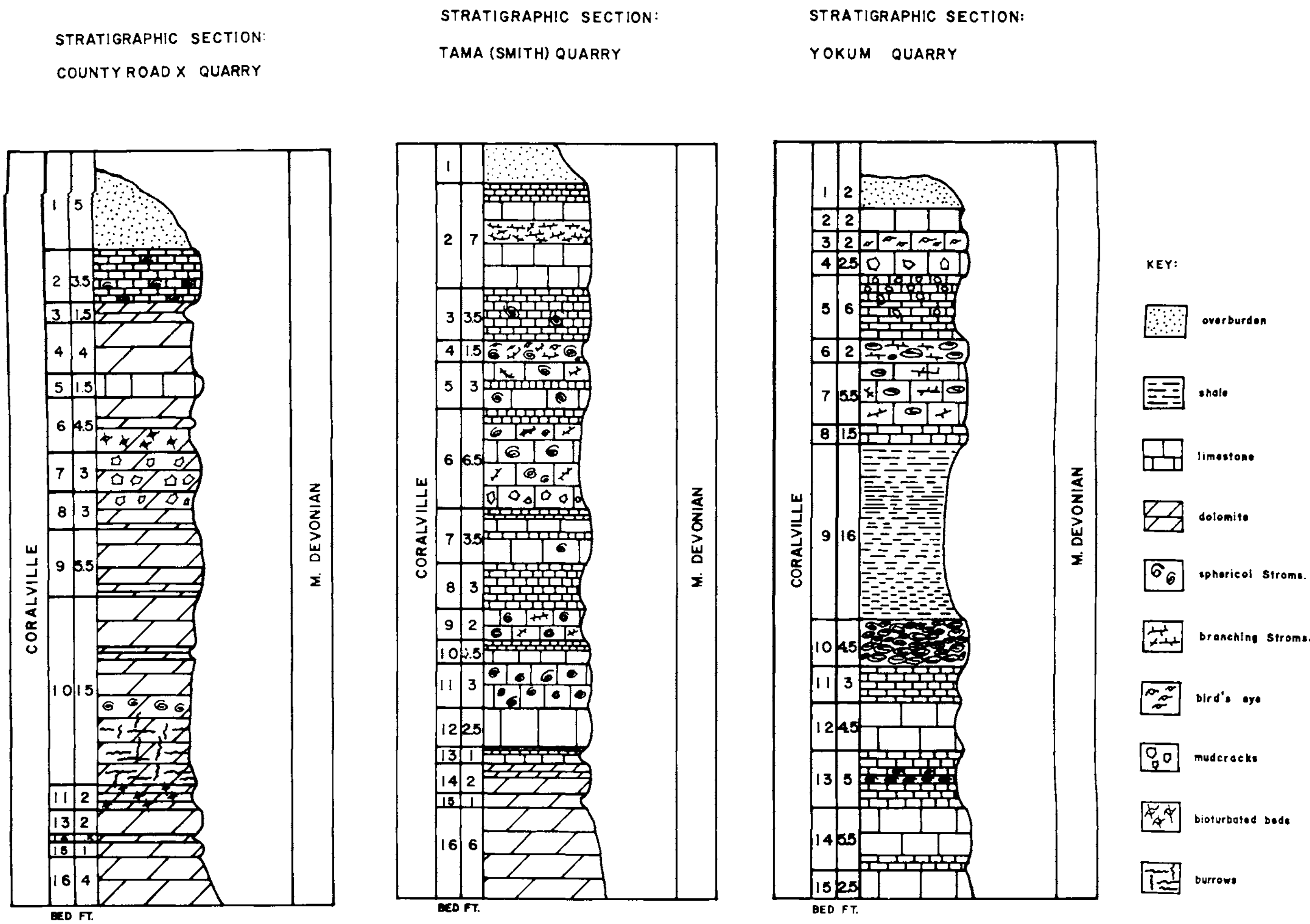

Figure 5. Stratigraphic sections at County Road X, Smith and Yokum quarries.

(sediments deposited above normal high tide level) and sometimes in intertidal sediments (sediments deposited between normal high and normal low tide). Shinn found birdseye structure to be particularly abundant in supratidal sediments and to be completely absent in subtidal sediments (sediments deposited below tidal fluctuations). According to Shinn, a combination of laboratory experiments and field observations suggests that the bubble-like vugs are produced by gas bubbles and that the planar vugs are produced by shrinkage associated with desiccation of exposed sediments.

Mudcracks

According to Walker and Laporte (1970), polygonal desiccation cracks are often well developed in carbonate sediments that are exposed to the air. A discussion of mudcracks in recent carbonate sediments of Florida can be found in Ginsburg (1957).

Intraclasts

Walker and Laporte (1970) summarized the development of intraclasts in shallow carbonate environments. According to them, carbonate sediments exposed to the air (such as in an intertidal environment) will quickly dry out and become hard. Further drying results in desiccation and produces fragments of the hardened carbonate sediment. These fragments or intraclasts are often re-distributed by later tidal flooding and may eventually come to rest as intraclasts within the supratidal or intertidal zones. Ginsburg (1957) described the formation of carbonate-pebble conglomerates by such a process from recent environments in Florida.

Massive Laminated Bedding

Irregularly to regularly laminated sediments that occur in massive beds are typical of tidal flat carbonate environments, according to Walker and Laporte (1970). The laminations are often caused by the sediment-trapping and -binding action of algal mats which grow on the sediment surfaces in these environments. Similar laminations can be produced in subtidal environments, but they are generally not preserved because the burrowing activity of organisms in the subtidal environment destroys or disturbs the laminations (see Logan and others, 1964; Gebelein, 1969).

Massive Lumpy Bedding

Primary bedding structures are generally lacking in subtidal environments because the sediments are constantly being re-worked by organisms, according to Walker and Laporte (1970), or see also Imbrie and Buchanan (1965). This reworking by organisms results in a disrupted, mottled fabric and the massive lumpy bedding that is characteristic of subtidal carbonate deposits.

Thin-Medium Bedding and Scour-and-Fill

Walker and Laporte (1970) noted that carbonate tidal flat environments are subject to frequent variations in water depth, water turbulence, texture of sediment and degree of sediment induration. This can result in a sequence of sediments characterized by thin to medium bedding, alternating carbonate mudstones with scour-and-fill surfaces, pebble-conglomerates and skeletal lag deposits.

Algal Laminae and Oncolites

Logan and others (1964) reported on the environmental significance of algal structures. They noted that blue-green and green filamentous algae function as sediment "binders" in shallow, low subtidal and intermittently moistened intertidal and supratidal zones. Successive algal mats will form structures consisting of alternating laminations of algae-rich layers and trapped sediment. It is common for the algae-rich layers to decompose and form space which is later filled with secondarily formed carbonate minerals. It is not the algae that are preserved, but the so-called organo-sedimentary structures that they form. According to Walker and Laporte (1970), "in general, regular to irregular continuous laminae are typical of the higher part of the tidal flat environment, hemispherical heads attached to the substrate are typical of the middle portion and free-lying unattached, algally laminated grains ('oncolites') are typical of the lower part."

Burrows

Rhoads (1967) has studied the environmental significance of burrow shape for modern marine burrowers. In general, burrowers in subtidal environments produce predominantly horizontal burrows as they burrow shallowly just below the sediment-water interface. Burrowers in intertidal zones are forced to burrow more deeply in the sediment to avoid the ecologic stresses associated with intermittent exposure to the air, and so produce predominantly vertical burrows.

Fossil Abundance and Diversity

Marine organisms increase in diversity and abundance as one goes offshore from the tidal to the subtidal realm. Populations may be large in tidal flat environments even though diversity may be minimal. This is because food resources may be large enough to support a large population within the tidal flat regions (see Walker and Laporte, 1970; Laporte, 1968).

Stromatoporoid Biostromes

Stromatoporoids are extinct representatives of the phylum Coelenterata. They are common constituents of Paleozoic subtidal communities. Stromatoporoids are often associated with shallow subtidal zones and were apparently often involved with building wave-resistant structures (Heckel, 1972).

OBSERVATIONS

The nine measured stratigraphic sections are shown in Figures 3-5. Symbols are used to depict lithology, fossil content and key environmental features. Table 1 records the occurrence of key environmental features in each of the three members of the Cedar Valley Formation. Some of the more important environmental features associated with the Cedar Valley Formation are discussed below.

TABLE 1. ENVIRONMENTAL INDICATORS FOR IDENTIFYING TIDAL FLAT AND SHALLOW SUBTIDAL CARBONATE ENVIRONMENTS

X = Features are common and typical
O = Features are present
C = Coralville
R = Rapid
S = Solon

Indicator	*Supratidal*	*High Intertidal*	*Low Intertidal*	*Subtidal*	*Occurrence in Cedar Valley Formation*
Birdseye	X				C
Mudcracks	X	X	O		C
Intraclasts	O	X	X		C,R
Massive Laminated Bedding	X				C
Massive Lumpy Bedding				X	S
Thin-Medium Bedding, Scour-and-Fill		X	X		R (?)
Algal Laminae	X	X	O		
Algal Oncolites			O	X	R (?)
Vertical Burrows	O	X	O		C
Horizontal Burrows			O	X	C,R,S
Fossils Rare	X				C,R
Few Taxa, Many Individuals		X	X		C
Many Taxa, Many Individuals				X	R,S
Stromatoporoid Biostromes				X	C

Adapted in part from Walker and Laporte, 1970, p. 931.

Solon Member

The Solon Member is a very fossiliferous limestone, as seen in exposures at Brooks Quarry (Figure 3). Many taxa and many individuals compose the fauna of the Solon at this locality. Brachiopods, colonial rugose corals and horn corals are particularly abundant. The colonial corals. *Hexagonaria profunda* and *Billingsastrea billingsi* of Stainbrook's (1936) *profunda* zone, are found in the upper part of the Solon at this exposure. The brachiopods, *Atrypa independensis* and *Platyrachella iowensis*, are common at the Brooks Quarry locality. Stromatoporoids, nautiloids, gastropods, bivalves, sponges, bryozoa, crinoid stem fragments and conodonts are also present in the Solon Member at Brooks Quarry.

Solon exposures at the Jesup Quarry are also very fossiliferous. Brachiopods and corals are common at the Jesup Quarry.

The lower beds at Brooks Quarry contain horizontal burrows, and some of the beds appear bioturbated. The bioturbated structures are thought to have been produced by burrowing organisms. These beds have a swirled appearance. Horizontal burrows also occur in the Solon Member at Pint Quarry.

The bedding in the Solon Member is typically massive and lumpy. Some disturbances have occurred in the bedding

Proceedings of the Iowa Academy of Science, Vol. 81 [1974], No. 4, Art. 3

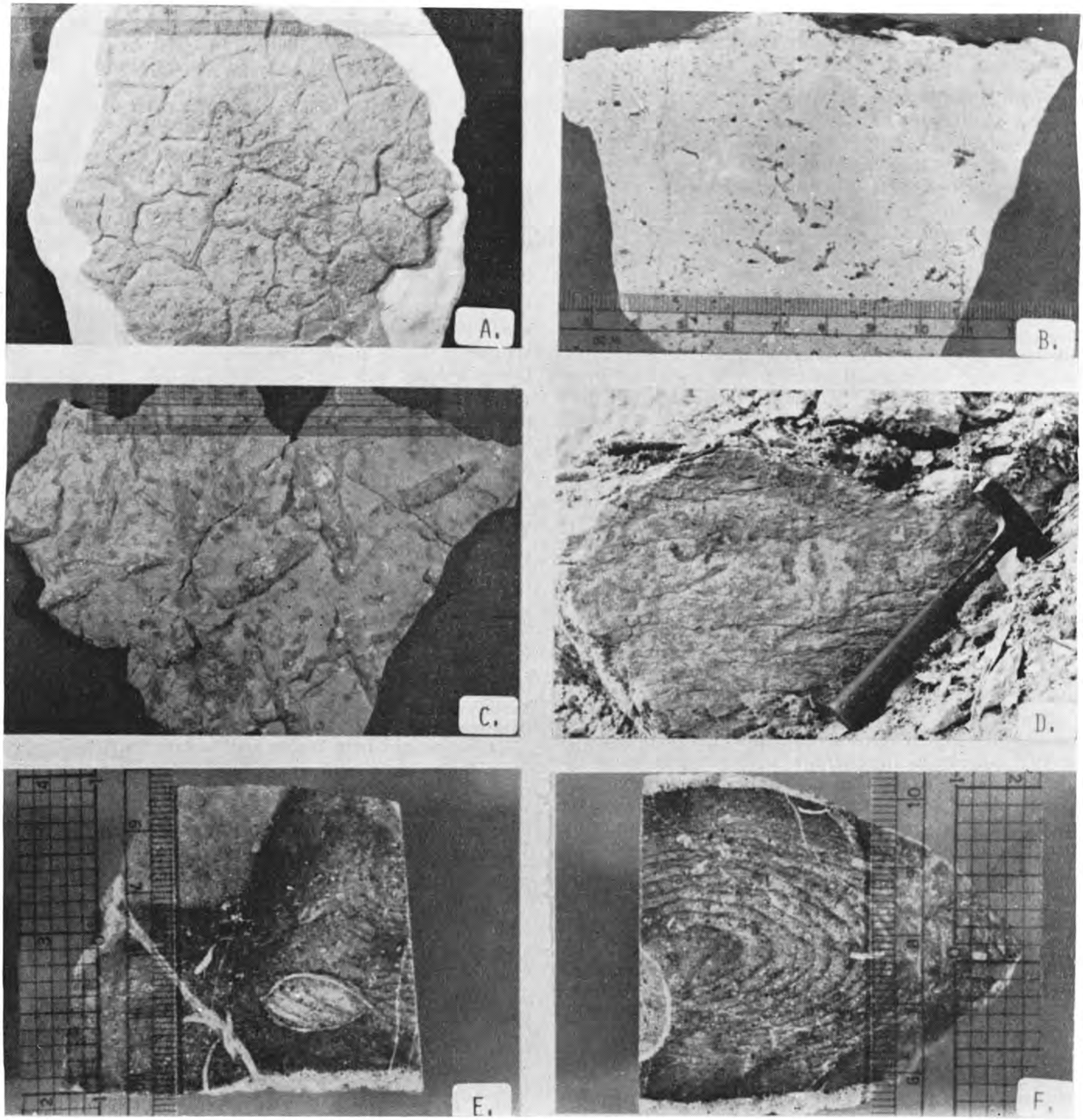

Figure 6. A plastic scale is shown in the figures to provide scale. The plastic scale is marked in millimeter and 1/10th of an inch divisions.

A. Mudcracks, Coralville Member, Smith Quarry.

B. Birdseye structure, Coralville Member, Yokum Quarry, Finchford, Iowa.

C. Horizontal burrows, Rapid Member, Glory Quarry.

D. Rapid-Solon contact, Brandon, Iowa. Contact is irregular and has been burrowed by bottom-dwelling organisms. The upper (darker) Rapid lithology projects down into the lighter Solon lithology. Rock hammer shown for scale.

E. "Oncolite," lower Rapid Member, Pint Quarry. Cut section of a so-called "oncolite." Note lines that continue inside the margin of the brachiopod shell.

F. "Oncolite," lower Rapid Member, Pint Quarry.

at Brooks Quarry, producing slickensides and collapse breccias.

The basal beds of the Solon Member at Brooks Quarry lie on or near the contact with the underlying Davenport Member of the Wapsipinicon Formation. A "salt and pepper" sandstone, consisting of chert and quartz grains, is present in the basal Solon at this locality.

The exposures of the Solon Member at Pint Quarry and Burton Avenue Quarry are primarily exposures of dolomite, and these beds are only sparsely fossiliferous. Crystal-lined vugs occur in the Solon at these localities, and some of the vugs appear to have formed by the diagenesis and recrystallization of corals.

The Solon-Rapid contact at the Pint and Burton Avenue quarries is represented by a burrowed discontinuity. The mineral glauconite and phosphatic fossil remains occur on the discontinuity surface. Lithologies of the Rapid Member extend down into the Solon as burrow-fillings. Figure 6D illustrates the irregular, burrowed zone that is characteristic of the Solon-Rapid contact in the Black Hawk County area. The photograph shown in Figure 6D is of the Solon-Rapid contact at the B. L. Anderson Quarry, Brandon, Iowa (N.W.¼ Sec. 34, T. 87N., R. 10W., Buchanan County). The Solon-Rapid contact at the Burton Avenue and Pint quarries is similar to the contact illustrated in Figure 6D.

Rapid Member

In the study area the Rapid Member is represented primarily by fine-grained, argillaceous carbonate rocks. The Rapid Member is composed of argillaceous limestones at the Brandon and Glory quarries. Argillaceous dolomite is the predominant lithology of the Rapid at the Pint and Burton Avenue quarries.

The Rapid Member is much less fossiliferous than the Solon Member. A few brachiopods, bryozoa and crinoid stem fragments occur in the Rapid at the Pint and Burton Avenue quarries. These fossil remains are often found in thin cherty zones in these quarries. Similar fossils are present in the Rapid Member at the Brandon Quarry and fossils are more abundant at the Brandon locality.

The basal bed of the Rapid Member is a coral biostrome. The top of the biostrome lies at the level of the floor in the Brandon Quarry and is not shown on the columnar section (Figure 3). The biostrome is well exposed in a nearby quarry, the B. L. Anderson Quarry just south of Brandon.

At Pint and Burton Avenue quarries, the basal Rapid biostrome is well exposed and contains corals and silicified structures resembling algal "oncolites." These structures are rounded and elliptical in shape and display a concentric banding. Fossil remains such as brachiopod shells and crinoid stem fragments occur within the oncolite-like bodies. The bodies have been silicified to such an extent that their exact origin cannot be determined. Figures 6E and 6F show cut views on the oncolite-like bodies. Note that the concentric bands are not true growth lines, but secondary features, as they cut through the brachiopod shell and are, therefore, younger than the brachiopod. The banding is apparently a secondary feature associated with the silicification of the bodies.

Numerous horizontal burrows occur in the Rapid Member at the Brandon, Glory, Pint and Burton Avenue exposures. Horizontal burrows are particularly well represented at the Glory Quarry locality (Figure 6C).

The exposures of the Rapid Member at the Pint and Burton Avenue quarries display fine to medium layering with numerous small-scale "cut-and-fill" structures. An interesting bed occurs near the top of the Rapid Member at the Burton Avenue and Pint quarries. The bed appears to contain well-preserved current ripple marks, but upon closer examination the structures are better interpreted as deformed beds. The beds were probably deformed before they were completely lithified.

The contact between the Rapid and Coralville members is placed on the basis of lithologic differences between the two members. The Rapid Member is more argillaceous than the Coralville Member. Fine-grained limestones (lithographic limestones or micrites) are typical Coralville lithologies, and the contact is drawn at the base of the lowest occurrence of such fine-grained limestones in the sections at Brandon, Glory, Pint and Burton Avenue quarries.

Coralville Member

The Coralville Member is more lithologically diverse than the Solon and Rapid members. The Coralville is characterized by a high percentage of dense, fine-grained carbonate beds. Very fine-grained limestones (micrites) are common in the Coralville Member at the Brandon, Glory, Smith, Yokum and Burton Avenue quarries. Fine-grained dolomites occur in the Coralville Member at County Road X and Pint quarries. Locally, at Yokum Quarry near Finchford, the Coralville contains a fairly thick bed of shale (Figure 5).

Massive laminated bedding is present in the fine-grained carbonates of the Coralville Member at exposures in Smith and Yokum quarries. Both horizontal and vertical burrows are common in the Coralville at the County Road X Quarry.

Fossils are rare in the Coralville Member in the study area. A few recrystallized brachiopods and crinoid stem fragments occur within the fine-grained carbonates at most localities. Spherical and branching forms of stromatoporoids are the most common fossils in the Coralville. Stromatoporoids are present in the Coralville at the County Road X and Smith quarries. Two well-developed stromatoporoid biostromes occur in the Coralville Member at the Yokum Quarry. Brachiopods and gastropods are present in the lower biostrome at the Yokum Quarry.

Birdseye structures and mudcracks are present in the Coralville Member (see Figures 6A and 6B). These features are particularly common in the upper beds of the Coralville, such as the beds exposed at the Smith and Yokum quarries.

DISCUSSION AND CONCLUSIONS

The environment of deposition of the Solon Member in the study area is interpreted as entirely subtidal. The presence of an abundant invertebrate fauna consisting of coelenterates, brachiopods, cephalopods, gastropods, bivalves, bryozoa and crinoids tends to support this conclusion. The presence of beds with horizontal burrows and massive lumpy bedding characteristics is also in line with this interpretation.

The Rapid Member was probably deposited in shallower water than the Solon Member. The fossil content and bedding characteristics of the Rapid are consistent with a shallow subtidal to intertidal environment of deposition for the member.

The Coralville Member contains certain characteristics of very shallow subtidal to intertidal and supratidal environments. The presence of mudcracks and birdseye structures in the Coralville can be explained by the deposition of lime mud in very shallow water and later exposure to subaerial (supratidal) conditions.

The stromatoporoid biostromes of the Coralville would have been developed in a subtidal environment, although it is likely that this was a very shallow subtidal environment. The environmental indicators preserved in the Coralville are consistent with an environment of deposition that ranged from very shallow subtidal to tidal and supratidal zones.

Although the environments of deposition during Cedar Valley time in the Black Hawk County area were probably marked by several fluctuations, the over-all pattern was of progressively shallower deposition throughout Cedar Valley time. The Solon Member was deposited entirely under subtidal conditions. Some of the upper beds of the Coralville show the influences of a supratidal environment.

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LITERATURE CITED

ANDERSON, W. I. 1972. General geology in the vicinity of northern Iowa. *Guidebook for the 36th Annual Tri-State Geological Field Conference.* 80 p.

BISQUE, R. E., and J. LEMISH. 1959. Insoluble residue-magnesium content relationship of carbonate rocks from the Devonian Cedar Valley Formation. *Jour. Sed. Petrology* 29:73-76.

COLLINSON, C., D. H. SWANN, G. W. JAMES, L. E. BECKER, M. P. CARLSON, F. H. DORHEIM, and J. W. KOENIG. 1967. The north-central region, United States. *International Symposium on the Devonian,* p. 933-971.

DORHEIM, F. H., and D. L. KOCH. 1966. Devonian of northern Iowa. *Guidebook for the 30th Annual Tri-State Geological Field Conference.* 45 p.

GEBELEIN, C. D. 1969. Distribution, morphology and accretion rate of recent subtidal algal stromatolites, Bermuda. *Jour. Sed. Petrology* 39:49-69.

GINSBURG, R. N. 1957. Early diagenesis and lithification of shallow-water carbonate sediments in South Florida. *Regional Aspects of Carbonate Deposition,* p. 80-99. Soc. Econ. Paleontol. and Mineral. Spec. Pub. 3. Tulsa, Oklahoma.

HECKEL, P. H. 1972. Ancient shallow marine environments. *Recognition of Ancient Sedimentary Environments,* p. 226-286. Soc. Econ. Paleon. and Mineral. Spec. Pub. 16. W. K. Hamblin, editor.

IMBRIE, J., and H. BUCHANAN. 1965. Sedimentary structures in modern carbonate sands of the Bahamas. *Primary Sedimentary Structures and Their Hydrodynamic Interpretation,* p. 149-172. Soc. Econ. Paleontol. and Mineral. Spec. Pub. 12. Tulsa, Oklahoma.

KETTENBRINK, E. C., JR. 1972. The Cedar Valley Formation at Pint Quarry. *Guidebook for the 36th Annual Tri-State Geological Field Conference,* p. 35-41.

———. 1972. Depositional and Post-Depositional History of the Devonian Cedar Valley Formation, East-Central Iowa. Unpub. Ph.D. thesis, The University of Iowa.

KOHLS, D. W. 1961. Lithostratigraphy of the Cedar Valley Formation in Minnesota and northern Iowa. Unpub. Ph.D. Thesis, University of Minnesota.

LAPORTE, L. F. 1968. Recent carbonate environments and their paleoecologic implications. *Evolution and Environment,* p. 229-258. E. T. Drake, editor. Yale University Press, New Haven, Conn.

LOGAN, B., R. REZAK and R. N. GINSBERG. 1964. Classification and environmental significance of algal stromatolites. *Jour. Geol.* 72:68-83.

RHOADS, D. C. 1967. Biogenic reworking of intertidal and subtidal sediments in Barnstable Harbor and Buzzards Bay, Mass. *Jour. Geol.* 72:461-475.

SHINN, E. A. 1968. Practical significance of birdseye structure in carbonate rocks. *Jour. Sed. Petrology* 38:215-223.

STAINBROOK, M. A. 1935. Stratigraphy of the Devonian of the Upper Mississippi Valley. *Kansas Geol. Soc. Guidebook, 9th Annual Field Conf.,* p. 248-260.

———. 1941. Biotic analysis of Owen's Cedar Valley limestones. *Pan-Amer. Geologist.* 75:321-327.

THOMAS, L. A. 1951. Devonian of north-central Iowa. *Guidebook for the 15th Annual Tri-State Geological Field Conference.* 21 p.

WALKER, K. R., and L. F. LAPORTE. 1970. Congruent fossil communities from Ordovician and Devonian carbonates of New York. *Jour. Paleontol.* 44:928-944.