The Geological Society of Iowa

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THE CEDAR VALLEY FORMATION (DEVONIAN), BLACK HAWK AND BUCHANAN COUNTIES: CARBONATE FACIES AND MINERALIZATION

by

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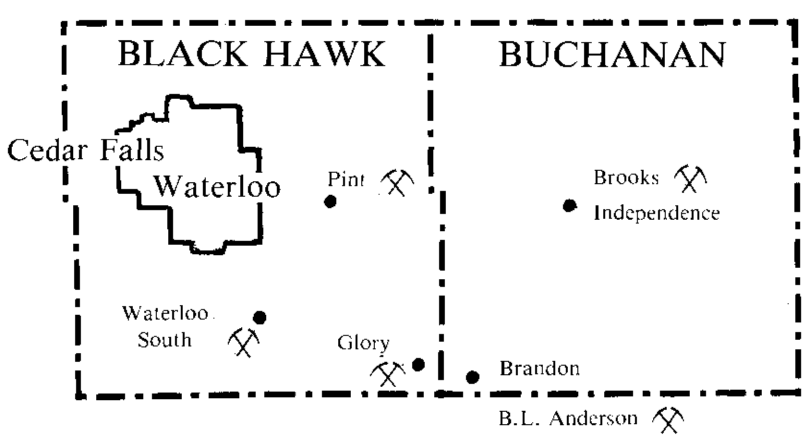


INTRODUCTION AND ACKNOWLEDGEMENTS

This guidebook is arranged in two parts. Part I, prepared by Wayne Anderson, covers the stratigraphy and environments of deposition of the Cedar Valley Formation at the five field-trip stops: 1.) Brooks Quarry; 2.) B. L. Anderson Quarry; 3.) Glory Quarry; 4.) Waterloo South Quarry; and Pint's Quarry. See figure 1 for a location of field-trip stops and figure 2 for stratigraphic position of the field stops. Part II, prepared by Paul Garvin, discusses the minerals, mineralization, and paragenesis at Waterloo South Quarry and Pint's Quarry.

We appreciate the cooperation of the following quarry owners: Bruening Rock Products; B. L. Anderson, Inc., Paul Niemann Construction Company; Basic Materials Corporation; and Weaver Construction Company. The Iowa Geological Survey provided drafting support for many of the figures contained in the guidebook.

PART I

CEDAR VALLEY FORMATION

The Cedar Valley Formation (Devonian) is the most widespread Devonian formation in the Upper Mississippi Valley. It crops out in a NW-SE trending belt from southern Minnesota, through eastern Iowa, and into western Illinois. The outcrop belt of the formation varies in width from 75 miles in the north to 20 miles in the south. The Cedar Valley Formation is well-known in Iowa's subsurface, where thicknesses may exceed 500 feet (Collinson et al., 1967).

This field trip will focus on carbonate facies, environments of deposition, and mineralization of the Cedar Valley Formation in Black Hawk and Buchanan counties. Ongoing research by geologists at the Iowa Geological Survey is providing new insights on the origin and distribution of "Cedar Valley" strata to the north of our field-trip area, and recent summaries have been prepared on the Cedar Valley Formation of the type area in Johnson County. See references by Witzke and Bunker (1984a); Witzke (1984); Witzke and Bunker (1984b); and Glenister and Heckel (1984).

No mention of the Cedar Valley Formation would be complete without reference to the work of Merrill A. Stainbrook, who published more than a dozen articles on the formation and its paleontology. Early in his career, Stainbrook (1927, p. 19) recognized the lithologic variability of the Cedar Valley Formation: "The Cedar Valley beds, considered as a whole, are exceedingly variable, both vertically and horizontally. Statements and descriptions made in one place will not apply to the same rocks seen some distance away. A section made at

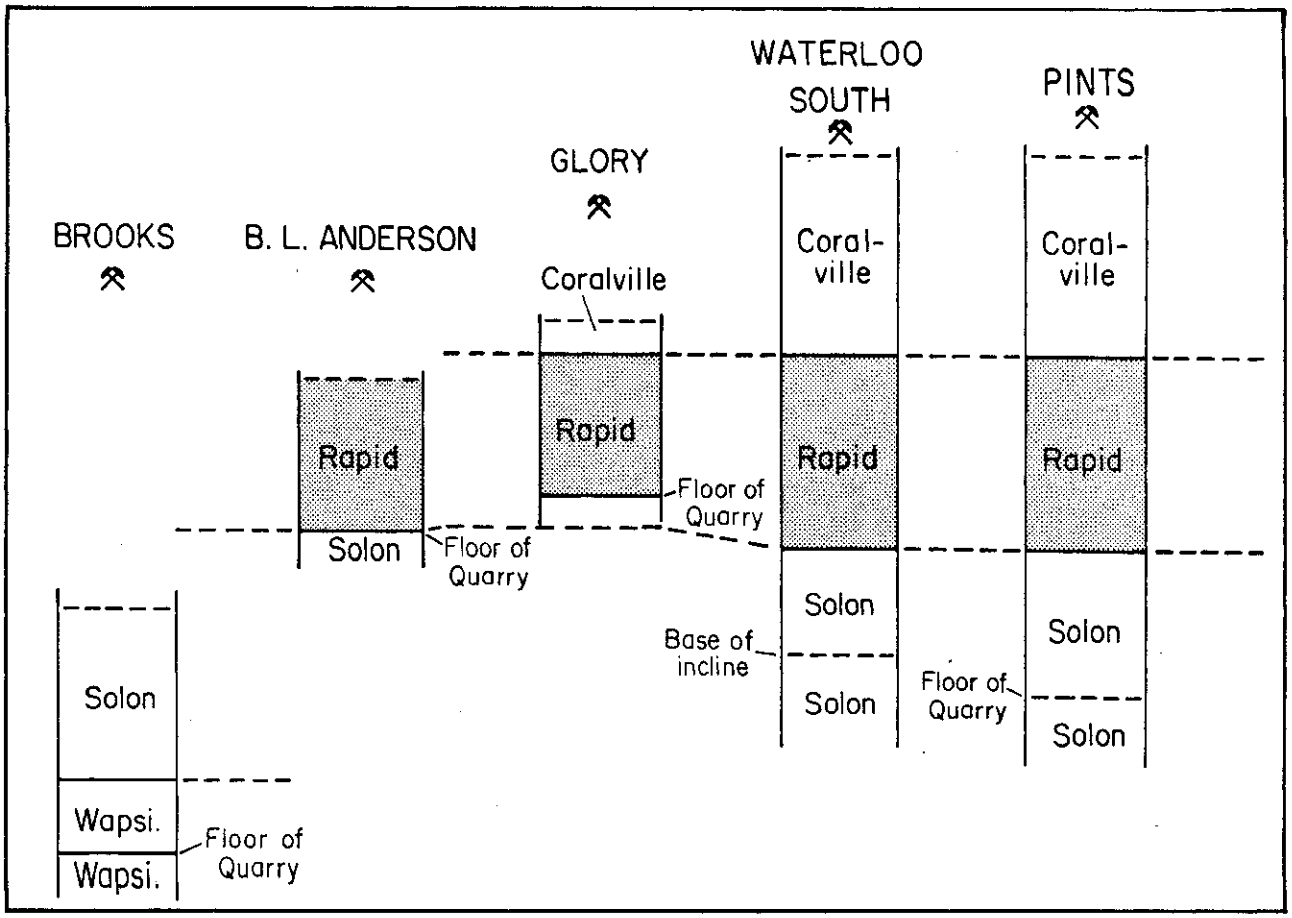


Figure 2: Diagram showing stratigraphic position of field-trip stops.

Davenport will differ radically from that at Iowa City, and likewise the latter will differ from that at Independence or Vinton. Those parts of the rocks which are in stratigraphically similar positions will be thicker or thinner, or more thinly bedded, and vice versa, and will weather differently or be more resistant to weathering from point to point."

Stainbrook came to rely on faunal zones as a means of subdividing the Cedar Valley Formation, and he proposed a number of faunal zones (based primarily on brachiopods) during his extensive studies over a 20 year period (1922-1944). Stainbrook's faunal zones for the Cedar Valley Formation are listed below for reference:

(Coralville Member)
Straparollus Zone
Idiostroma Zone
Prismatophyllum thomasi - *Stromatopora* Zone
Cranaena Zone

(Rapid Member)
"Atrypa waterlooensis" Zone
Pentamerella magna - *P. rugosa*, *Prismatophyllum cedarensis* Zone
"Atrypa bellula" Zone

(Solon Member)
"Acervularia profunda" - *Hypothyridina intermedia*-*Rensselandia* Zone
"Phillipsastrea" - *Gomphoceras* Zone

Some of these species have since been assigned to different taxonomic groups or have otherwise undergone a change in name. For example, *"Atrypa bellula"* is now recognized as a species of *Spinatrypa* and *"Atrypa waterlooensis"* has been assigned to the genus *Desquamatia*. *"Acervularia"* is more commonly referred to as *Hexagonaria* today and *"Phillipsastrea"* is assigned to the genus *Billingastrea*.

Bunker and Klapper (1984) reviewed the conodont biostratigraphy of the Cedar Valley - State Quarry interval of eastern Iowa and the Rock Island area of adjacent Illinois. Conodont zones recognized in the Cedar Valley Formation of eastern Iowa suggest a correlation with the Givetian Stage (Middle Devonian) of the standard European zonation. However, conodonts characteristic of the lowest Upper Devonian zone occur in the uppermost exposed bed of the Coralville Member at Milan, Illinois (Klapper, 1975).

Bunker and Klapper (1984) report the occurrence of conodonts from the Solon Member at Brooks Quarry (Stop 1) that are diagnostic of the *varcus* Zone of the Givetian Stage (lower Middle Devonian). They also report conodont faunas from the Coralville Member and the upper Rapid Member of Johnson County that are indicative of shallow-water biofacies.

ENVIRONMENTS OF DEPOSITION

Kettenbrink (1973) interpreted the environments of deposition of the Cedar Valley Formation as follows:

1. initial Cedar Valley transgression onto an underlying erosion surface with residual quartz and chert sands derived from several sources;
2. continued transgression with deposition of fine to medium-grained skeletal calcarenites with a diverse stenohaline fauna, near, slightly above, or slightly below effective wave base; deposition in normal marine waters of moderate depths and turbulence;
3. local development of coral and stromatoporoid biostromes or shell banks in shallower water;
4. continued transgression with deposition of argillaceous calcilutites in somewhat deeper water, below effective wave base; greater water depth and an increase in detrital muds resulted in a less diverse faunal assemblage;
5. the entire Coralville was deposited in very shallow marine water, above effective wave base. Water depths became increasingly shallower.

Kettenbrink (1972) had noted, however, that "minor transgressions" occurred during Coralville deposition, even though the overall pattern was one of regression. Witzke (1984) believes that the complex facies relationships in the Coralville sequence of the Iowa City area are better explained by multiple episodes of shallowing and deepening.

Glenister and Heckel (1984) summarized environments of deposition for the three members of the Cedar Valley Formation in Conklin Quarry, near Iowa City. The Solon Member was interpreted as a deposit under normal marine conditions, with open circulation. Faunas of the Rapid Member were interpreted as stress biotas, characterized by smaller fossil size and lower overall diversity than Solon faunas.

According to Glenister and Heckel, either of two models could explain the Rapid fauna and deposition of the Rapid beds. A shallow-water model, with water depths generally insufficient to sustain effective wave motion, is one possibility. In this case, wave energy would normally be too weak to winnow bottom muds. Sporadic occurrences of shell beds in the Rapid Member and the development of biostromes may have resulted from an increase of water depth of a few decimeters. On the other hand, the mud-dominated beds of the Rapid Member could reflect deposition in deeper water, below the reach of normal wave action. Under this interpretation, the coarser and relatively mud-free beds of the Rapid resulted from transport of fossils and coarser sediments into deeper water and the winnowing of fines by storm waves.

Glenister and Heckel see both biofacies and lithofacies trends in the Coralville Member of Johnson County as indicating a progressive upward restriction and terminal shoaling of the Cedar Valley sea. Accumulation of Coralville sediments not only resulted in a progressive shallowing of the sea, but less effective winnowing of mud and eventual "fillup" of the water column.

Witzke and Bunker (1984a) informally subdivided the Cedar Valley Formation of north-central Iowa (Mason City-Charles City area) into five members, Units A through E. Units A, B, and C display cyclic characters, and each unit apparently reflects a major transgressive-regressive sequence. Units D and E, referred to as "Upper Cedar Valley Formation" by Witzke and Bunker, do not define major depositional cycles. These units consist of a complex of interbedded fossiliferous marine carbonates and laminated, "sublithographic" and brecciated beds. The relationship of these strata to the Cedar Valley Formation of Black Hawk and Buchanan counties awaits further study.

Anderson and Wiig (1974) interpreted deposition of the Rapid Member in the Black Hawk County area as being in "shallower water than the Solon Member". They suggested shallow subtidal and intertidal environments for the Rapid Member, an entirely subtidal setting during Solon deposition, and very shallow subtidal, intertidal, and supratidal environments for deposition of the Coralville Member. Subsequently, Anderson has come to favor a deeper setting for deposition of the Rapid Member in the Black Hawk-Buchanan County area (see table below).

TABLE 1: ENVIRONMENTS OF DEPOSITION OF THE CEDAR VALLEY FORMATION IN BLACK HAWK AND BUCHANAN COUNTIES

MEMBER OR FORMATION	INTERPRETATION OF ENVIRONMENT OF DEPOSITION
CORALVILLE	deposition in quiet water for the most part, but with local agitation and turbulence sufficient at times to disrupt and abrade stromatoporoids; an overall shallowing upward sequence, complicated by episodes of minor transgressions; shallow subtidal, tidal flat, and supratidal settings are represented; development of stromatoporoid biostromes in shallow subtidal settings; low to moderate abundance of fossils; but locally fossils are abundant; overall faunal diversity is low, however.
RAPID	deposition on a muddy seafloor, generally below effective wave base; deposits include both

MEMBER OR FORMATION	INTERPRETATION OF ENVIRONMENT OF DEPOSITION
	argillaceous and carbonate muds; deposition probably reflects the deepest setting of the Cedar Valley sea; at times, storm waves winnowed bottom muds, scoured the seafloor, and transported and deposited coarser sediments and fossil debris from shallower realms; moderately abundant and diverse marine fauna, with good preservation in calcarenites and chert beds; extensive bioturbation and burrowing at times; development of coral biostromes in the lower portion of the member in a subtidal setting, generally at or above effective wave base; extensive burrowing at base of the member, and some concentration of phosphatic fish remains and glauconite.
SOLON	open-marine setting, above effective wave base; generally agitated marine environments in Johnson County area, but quieter settings in Black Hawk and Buchanan counties; abundant and diverse normal marine fauna; deposition of a basal quartz-chert arenite, possibly derived from Ordovician and Silurian strata exposed in the Ozark Dome area.
WAPSIPINICON FORMATION (DAVENPORT MEMBER)	restricted marine environment with hypersaline conditions; later solution of evaporites and collapse of overlying carbonates of the Davenport Member and lower Solon Member; followed by recementation.

Discussions and lithostratigraphic sections of the five field-trip stops follow. Our field-trip will start at the Cedar Valley Formation-Wapsipinicon Formation contact and proceed upsection. At Waterloo South and Pint's quarries, all three members of the Cedar Valley Formation are exposed.

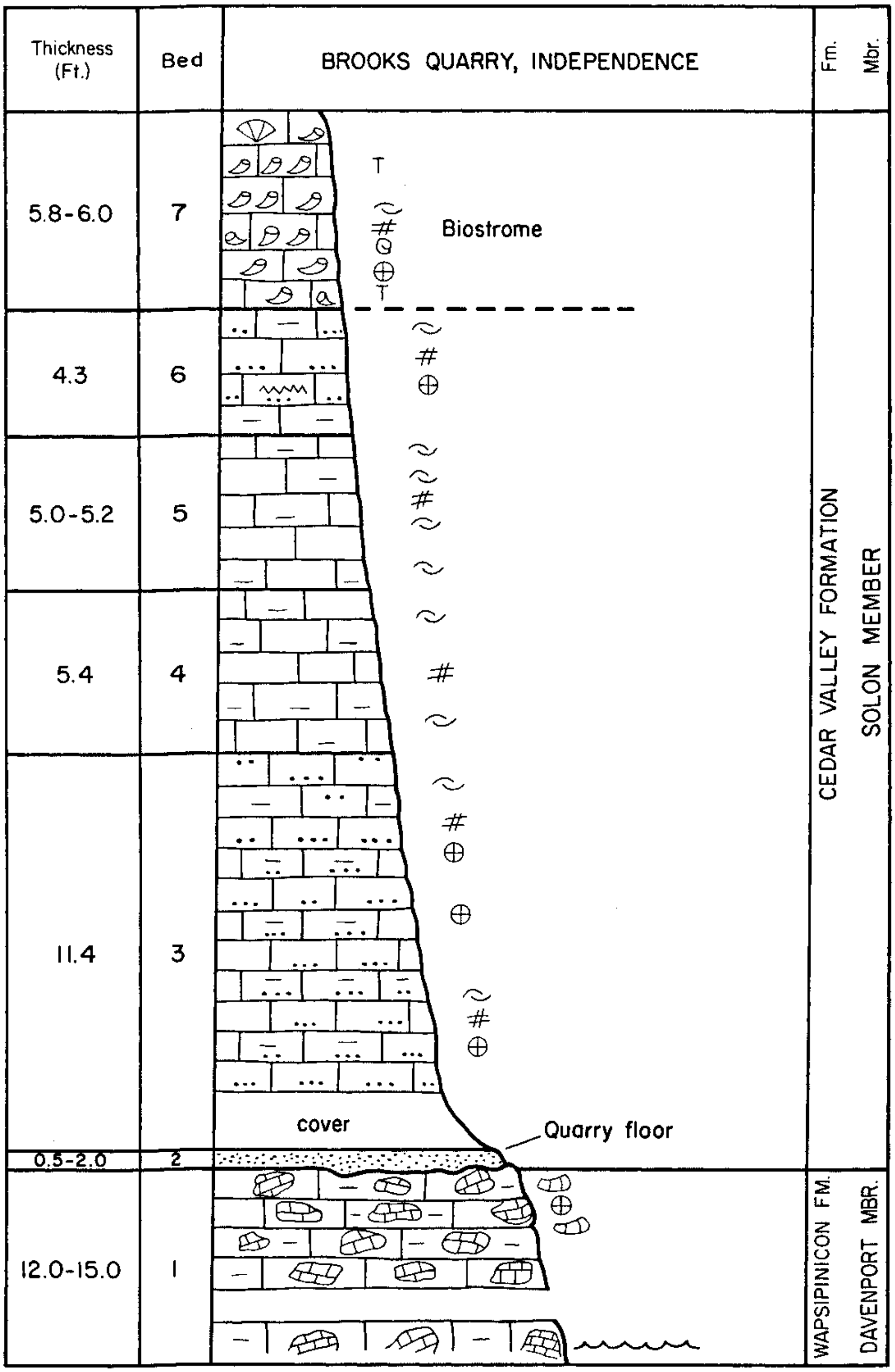


Figure 3: Stratigraphic section, Brooks Quarry, Independence.

BROOKS QUARRY, INDEPENDENCE

The stratigraphic section was measured in the northwest corner of the active quarry, approximately 1/4 mile south of old U.S. Highway 20 in Independence, NW 1/4, Sec. 2, T.88N., R.9W., Buchanan County, Iowa. The quarry is owned and operated by Bruening Rock Products, Decorah, Iowa.

Bed No.		Thickness (feet)
CEDAR VALLEY FORMATION (SOLON MEMBER)		
7.	Coral biostrome: light-yellowish gray to very-pale yellowish brown; corals in a matrix of calcilutite and fine-grained calcarenite; medium bedding; fractures, with fillings of secondary calcite; biostrome is composed primarily of rugose horn corals, including large varieties of "*Cystiphyllum*" sp.; many of the horn corals are compressed and flattened parallel to the bedding; crinoid columnals and occasional gastropods and brachiopods; favositid and other tabulate corals are present also; colonial rugose corals (including *Hexagonaria* sp.) weather from this unit in other parts of the quarry	5.8 to 6.0
6.	Limestone: (calcilutite and fine-grained calcarenite): light-yellowish gray; slightly argillaceous; medium to thick bedding; fractured; stylolites; crinoid columnals, lacy bryozoans, atrypid brachiopods	4.3
5.	Limestone (calcilutite): light-yellowish gray; slightly argillaceous; medium to thick bedding; fractured; abundant brachiopods, producing wackestone textures; atrypids, including *Atrypa independensis*, *Spinatrypa* sp., a few atrypids with purplish-red coloration; "*Platyrachella iowensis*" (a wide-winged spiriferid brachiopod) is also common; stony (trepostome) and lacy (cryptostome) bryozoans	5.0 - 5.2
4.	Limestone (calcilutite): light-yellowish gray; light-olive gray, where unoxidized; slightly argillaceous; thick bedding; fractured; similar to bed no. 3, but less fossiliferous; contains atrypid brachiopods, including *Atrypa independensis* and wide-winged spiriferids ("*Platyrachella iowensis*"); also stony bryozoans	5.4
3.	Limestone (calcilutite and very-fine grained calcarenite): light gray; slightly argillaceous; thick bedding; fractured, with fractures filled with secondary calcite; fossiliferous, with brachiopod shells, bryozoans,	

crinoid columnals, tentaculitids; ostracods 11.4
covered to quarry floor 2.0

2. Chert-quartz arenite: light gray to medium-light gray ("salt and pepper appearance"); medium to coarse grained; chert grains of various colors (including white, light gray, grayish black) slightly argillaceous; calcite cement; irregular thickness; exposed on quarry floor and in stratigraphic leak in underlying breccia . . . . approximately 0.5 to 1.0

(Total measured thickness of Solon Member = 34.3 ft.)

WAPSIPINICON FORMATION
(DAVENPORT MEMBER)

1. Limestone breccia: medium-light gray; blocks of limestone in a calcilutite and very-fine grained calcarenite matrix; argillaceous; some quartz and chert sand; both Solon Member and Davenport Member lithologies are present as clasts; Davenport lithogies include "lithographic" limestones; straight and breviconic nautiloids are present and apparently have been leaked from the Solon Member; also crinoidal calcarenites from Solon beds; exposed below main quarry floor to water level . . . . 12.0 to 15.0

Discussion: Fossils, other than groups listed in the section description, can be collected from blocks at the base of the quarry faces. The fauna here is quite diverse consisting of several species of brachiopods, corals, and bryozoans. Pelecypods, sponges ("Astraeospongia" sp.), trilobites, nautiloids, gastropods, stromatoporoids, tentaculitids, conularids, crinoid columnals, and conodonts are known. Klapper (1972) reported the presence of conodont faunas that are referable to the varcus zone of the upper part of the Middle Devonian.

Shale lies unconformably on the Solon Member on the eastern wall of the quarry. Urban (1972) recovered palynomorphs from these beds and interpreted their origin as involving deposition during Late Mississippian (Chesterian) time, with recycling of Upper Devonian fossils.

Illustrations of representative fossils from the Brooks Quarry are shown on figure 4. The taxonomy of most of the groups is badly in need of revision. Taxonomy used here is that of several previous workers. Drawings are reproduced from the Guidebook for the 36th Annual Tri-State Geological Field Conference.

The biostrome at this locality is assignable to the profunda zone of Stainbrook (1935). "Profunda" comes from the name of the colonial rugose coral Hexagonaria profunda (formerly Acervularia profunda). Two colonial rugose corals are typical of this zone: Hexagonaria (= Prismatophyllum profunda of some workers) and Billingsastrea (formerly Phillipsastrea) billingsi. Solitary rugose corals resembling Cystiphylloides or "Cystiphyllum" and Zaphrentis (?) are common, and at least one species of stromatoporoid is present. The brachiopod fauna of the profunda zone is similar to that of Stainbrook's underlying independensis zone (Kettenbrink, 1973).

Most of the brachiopod genera in the Solon Member are present in both of Stainbrook's (1935) zones, although they may be represented by different species. A wide-winged spiriferid brachiopod is particularly conspicuous. This form has been referred to Platyrachella by some workers and Spinocyrtia by others.

The lower portion of the Solon Member here is assignable to Stainbrook's independensis zone for the common brachiopod Atrypa independensis (Stainbrook, 1938). Several other species of brachiopods occur in this zone as well. Less abundant than brachiopods in the independensis zone are corals, bryozoans, stromatoporoids, gastropods, and sponges (Kettenbrink, 1973).

Exposures here represent a very fossiliferous phase of the Solon Member. Fossils are less abundant in the Solon Member at the Waterloo South and Pint localities.

The Solon at Brooks Quarry is finer grained than in the type area of Johnson County. Lithologies in the Brooks Quarry are primarily calcilutites, although some fine-grained calcarenites are present also. A few elliptical nodules of light-gray chert are present, but they are scattered and may not be present in a specific vertical section. Slickensides occur and may be related to the collapse associated with development of the "solution-collapse" breccia in the underlying Wapsipinicon Formation. Kettenbrink (1973) reported an insoluble residue content of 11 percent for the lower Solon beds at Brooks Quarry.

Kettenbrink (1973) described the Solon calciluties in this quarry as having the appearance of a "pseudo-breccia" in which fragments appear intermediate between "soft" intraclasts and "hard" breccia. He postulated an origin in weakly-consolidated sediments.

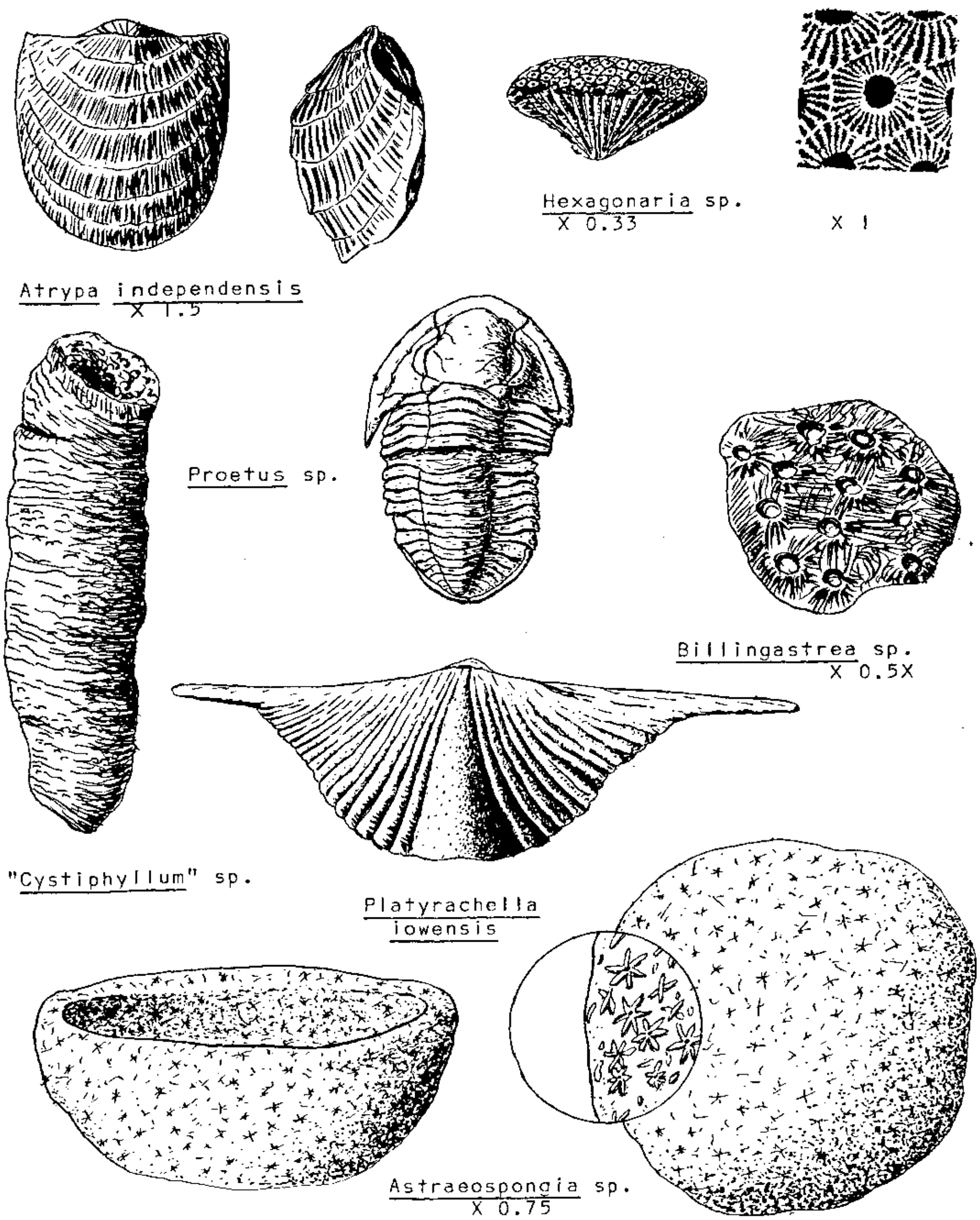


Figure 4: Representative fossils from Brooks Quarry (from Guidebook for the 36-th Annual Tri-State Geological Field Conference.

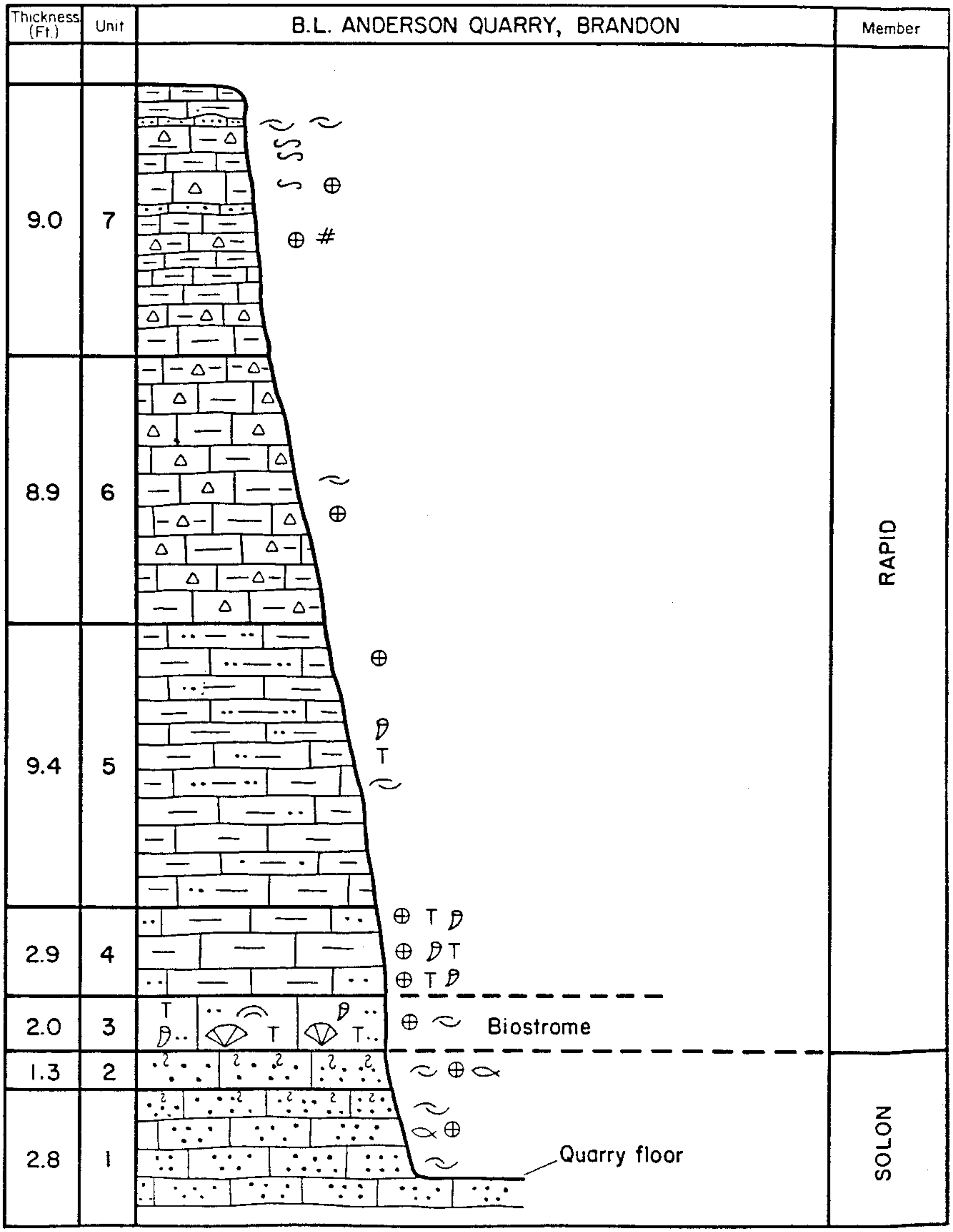


Figure 5: Stratigraphic section, B. L. Anderson Quarry, Brandon.

B. L. ANDERSON QUARRY, BRANDON

Stratigraphic section measured on south face of quarry, NW 1/4, Sec. 34, T.87N., R.10W., Buchanan County. Quarry owned by B. L. Anderson, Inc., Cedar Rapids, Iowa.

Bed No.		Thickness (feet)
CEDAR VALLEY FORMATION (RAPID MEMBER)		
7.	Argillaceous limestone (calcilutite): pale orange to pale-yellowish brown; thick bedding with platy beds in upper 4.0 feet; cherty, with nodules and nodular beds; horizontal burrows (approximately 5 mm. in diameter) in upper part; interbedded with skeletal calcarenites in 1-2 inch thick lenticular beds; calcarenites contain brachiopods (atrypids, spiriferids, rhynchonellids, terebratulids), trepostome bryozoa, crinoid columnals; some of the fossils and calcarenite beds have been replaced by chert; very fossiliferous at and just below top of quarry, where brachiopods make a "pavement surface".	9.0
6.	Argillaceous limestone (calcilutite): very-pale yellowish brown; thick bedded; cherty, containing white to light gray chert in nodules and thin beds; brachiopods and crinoid columnals	8.9
5.	Argillaceous limestone (calcilutite and fine-grained calcarenite): light gray, weathers to pale-yellowish brown; thick bedded; highly fractured; fractures with fillings of secondary calcite; a few vugs, with calcite crystals; fossiliferous, containing brachiopods (spiriferids and atrypids), rugose horn corals, favositid tabulate corals, large crinoid columnals in upper 2.0 feet; stylolites	9.4
4.	Argillaceous limestone (calcilutite and fine-grained calcarenite): light-olive gray to light-medium gray; medium to thick bedding; fossiliferous, with numerous crinoid columnals and corals (rugose horn corals and large favositid tabulates)	2.9
3.	Biostrome (corals in a matrix of calcilutite and fine-grained calcarenite): light-olive gray to light-medium gray; massive; contains colonial rugose corals, including *Hexagonaria* sp., rugose horn corals, favositid tabulate corals, laminar stromatoporoids; some corals have been "rotated" from growth position; also contains brachiopods and crinoid columnals; fractured; secondary calcite	2.0

(Total measured thickness of Rapid Member = 32.2 ft.)

(SOLON MEMBER)

2. Limestone (fine to medium-grained calcarenite): light to medium-light gray; glauconitic; thick bedded; burrowed, with vertical burrows (approx. 4 to 5 mm. in diameter); fossiliferous, with abundant fish fragments; also, brachiopods and crinoid columnals 1.3

1. Limestone (fine to medium-grained calcarenite): light to medium-light gray; thick bedded; fossiliferous, with fish fragments, crinoid columnals, brachiopods; burrowed; forms quarry floor 2.8

(Total measured thickness of Solon Member = 4.1 ft.)

Notes: Large atrypids present in loose blocks, probably *Atrypa waterlooensis*.

Discussion: This quarry exposes 32.2 feet of the Rapid Member, including a basal coral biostrome (2.0 feet thick). The biostrome contains abundant colonial and solitary rugose corals, favositid tabulate corals, and minor stromatoporoids. Coral-bearing calcilutites immediately overlie the biostrome in the quarry. Elsewhere, this interval also illustrates biostromal development.

Zawistowski (1971) studied the Rapid Member in nearby exposures along Lime Creek in Brandon, a locality that he considered to be one of the the "best nattural exposures of Rapid biostromes". There, he recognized "two discrete coral-stromatoporoid biostromes", 1.5 to 3.0 feet thick. According to Zawistowski, these biostromes occur in a position stratigraphically lower than those of Johnson County, although they are lithologically and paleontologically similar.

Witzke and Bunker (1984a) tentatively correlate the Rapid biostromes of Johnson County to a regressive (shallowing) carbonate interval in central and northern Iowa (Mason City area). Overturned coral heads in the Rapid biostromes are interpreted as evidence of a shallow setting, above effective wave base.

Although the biostromal beds of the Rapid Member in Buchanan and Black Hawk counties lie stratigraphically lower than similar beds in Johnson County, they also show indications of wave agitation. Overturned corals are present in the Rapid biostrome near Brandon and possible oncolites occur in basal Rapid biostromes at Pint's (Raymond) and Burton Avenue (Waterloo) quarries.

The contact of the Solon Member with the Rapid Member is distinct in this quarry, being marked by a bioturbated interval with glauconite and a concentration of fish remains. According to Zawistowski, the Rapid-Solon contact in east-central Iowa is gradational, but recognizable by: 1) a color change from pale brown Solon to the gray Rapid; 2) a change in texture from predominantly calcarenitic beds of the Solon to argillaceous-calcilutite or fine calcarenites of the Rapid; 3) a bioturbated diastem with associated fish remains; 4) reference to the faunal zones of Stainbrook; or 5) a combination of the above.

The argillaceous calcilutites, above the Rapid biostrome and coral-bearing beds here, are assignable to the "waterlooensis" zone of Stainbrook. As interpreted by Witzke and Bunker (1984), the "waterlooensis" zone probably correlates to a transgressive open marine carbonate interval in northern and central Iowa that occurs between intervals of shallower-water restricted carbonates.

Fossiliferous calcarenites in this section, such as beds near the top of rock unit No. 7, probably represent storm deposits. The argillaceous calcilutites are interpreted as deposits in quiet water, generally below effective wave base.

Merrill A. Stainbrook: Man From Brandon

Merrill Addison Stainbrook was born at Brandon, Iowa on February 27, 1897. His grandfather had moved from Pennsylvania to Iowa and was one of the founders of the town of Brandon.

Merrill grew up on the family farm in northern Benton County, just two miles south of Brandon. At the age of five, young Stainbrook lost the sight in his left eye as a result of an accident while playing with his brothers. They found a dynamite cap and hit it with a hammer; the resulting explosion cost Merrill the vision in one eye. The accident did not limit Merrill's participation in outdoor activities. In particular, he enjoyed rock collecting and fishing.

After attending country school and junior high school at Brandon and senior high school at LaPorte City, Merrill enrolled at the University of Iowa in 1916. He received a B. A. degree in geology in 1921 and the M. S. degree in 1922. His Ph.D. was earned from The University of Iowa in 1927, where he majored in geology with a speciality in paleontology. Stainbrook pursued his graduate research on Devonian faunas, an interest that was initially sparked by collections during his boyhood wanderings near Brandon. Stainbrook's major professor at the University was Professor A. O. Thomas, also a Devonian-fossil enthusiast. From 1927 to 1948, Stainbrook taught at Texas Technological University (then, Texas Technological College), Lubbock, Texas. He progressed in rank from assistant professor to associate professor (1934) and full professor (1940). During most of the years spent in Texas, Merrill returned to Iowa for the summers to rest or work as he pleased. For a number of summers, he served as a consulting geologist on Devonian formations for the Iowa Geological Survey. Under this arrangement, Stainbrook worked almost entirely according to his own wishes, either in the IGS office in Iowa City or working in the field out of the family home near Brandon. He also traveled to neighboring states to study Devonian formations.

Merrill Stainbrook is best known for his work on the paleontology of the Cedar Valley Limestone and the Independence Shale of Iowa and the correlation of those formations with Devonian strata elsewhere. A dozen papers were published on fossils from the Cedar Valley Formation and four on the fauna of the Independence Shale. Stainbrook believed that the Upper Devonian Independence shale fossils came from beds stratigraphically below the Cedar Valley Formation and, therefore, that the Cedar Valley Formation must also belong in the Upper Devonian. Others, however, concluded that the Independence Shale was equivalent in age to the Lime Creek Formation, and that it was considerably younger than the Cedar Valley Formation. These workers explained the position of the Independence Shale, within and below the Cedar Valley Formation, by subsidence into caverns and fractures.

Under this line of thinking, the Cedar Valley Formation might well be Middle Devonian, rather than Upper Devonian.

Through an immense amount of field work and study of drill cuttings, Stainbrook found many places where he was convinced that the Independence Shale was in place beneath the Cedar Valley Formation and vigorously supported this contention to the time of his death.

One of Stainbrook's chief opponents in the Independence Shale controversy was Dr. G. Arthur Cooper of the Smithsonian Institution, Washington, D.C. Even though Stainbrook and Cooper disagreed, they were on friendly terms. Cooper offered this tribute to Stainbrook: .

"I regarded Merrill Stainbrook very highly as a person and as a stratigrapher and paleontologist. Our disagreements were indeed of a very friendly nature, even though we were widely apart in our opinions. I regard his paleontological work very highly. His generic work in the brachiopods is very good. It was most unfortunate that his Cedar Valley work could not have appeared as a monograph because it is a very important and very good piece of work." Perhaps the most remarkable work that Merrill Stainbrook did was on the Independence Shale. His discovery of the numerous localities which are so obscure was a great contribution. The position of the Independence in the Devonian column is a matter that is still debated and it will probably be some years before agreement on it is finally reached.

Stainbrook was a remarkable man and a good and devoted man to geology. I think Merrill Stainbrook was one of the outstanding collectors in this country. I collected with him extensively in the Devonian in Michigan and Iowa, and believe that his one eye was quicker at seeing fossils than the two eyes of our best collectors."

In 1948, Merrill resigned from Texas Tech and moved back to Brandon. The return required a semi-trailer truck just to transport his sizeable personal library and fossil collection. After Merrill's death, these materials were donated to the Department of Geology at the University of Iowa as a memorial.

During the last eight years of his life (1948-1956), Merrill engaged in a number of activities that he previously had not had time to pursue. He became a 32nd Degree Mason in near record time. He also joined the Odd Fellows and Rebeccas. He dabbled in art and wrote poetry. Merrill constructed a printing press and printed his poems, but he never distributed them. He also played cards intensely with family members. Games often ended in shouting matches! (C. A. Stainbrook, 1974).

Early in July, 1956, Merrill started alone on a trip to Washington, D. C., where he planned to confer with Dr. G. Arthur Cooper. After meeting with Cooper, Merrill had planned to make a geological field trip to the outer end of the Gaspe Peninsula.

Stainbrook never reached Washington, D.C., however. On the morning of July 11, he was found dead in his hotel room at Frederick, Maryland, about 40 miles from Washington. A post-mortem indicated a coronary occlusion as the cause of death (C. A. Stainbrook, 1974).

Stainbrook is buried near the Devonian rocks that he loved. His grave, in the cemetery at the northeast edge of Brandon, is only a stone's throw from Cedar Valley exposures in a nearby rock quarry and along Lime Creek.

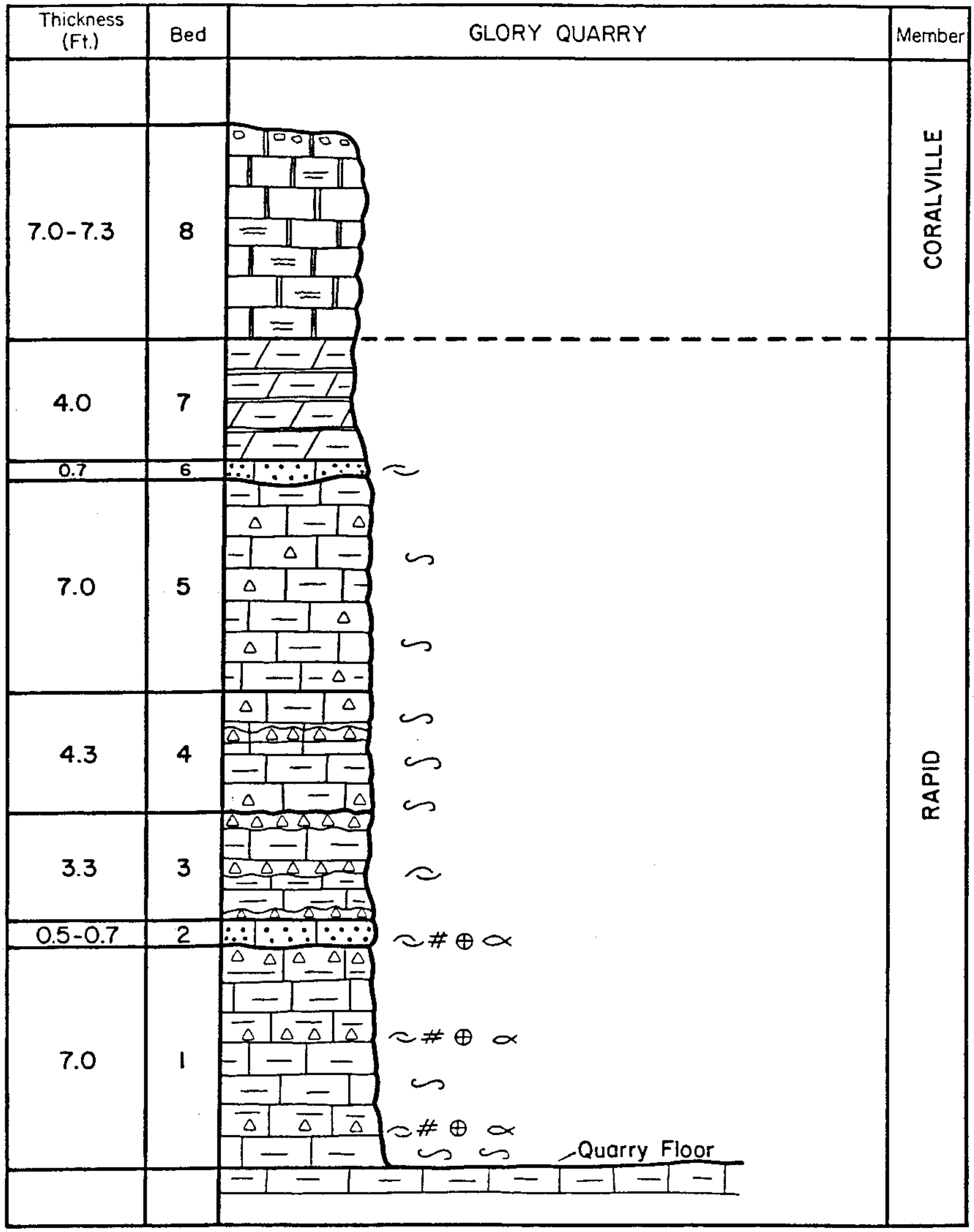


Figure 6: Stratigraphic section, Glory Quarry, S.E. Black Hawk County.

GLORY QUARRY

Stratigraphic section measured in the northwest end of the quarry, NW 1/4, Sec. 36, T.87N., R.11W., Black Hawk County, Iowa. Quarry operated by Paul Niemann Construction Company, Sumner, Iowa.

Bed No.	Thickness (feet)

CEDAR VALLEY FORMATION
(CORALVILLE MEMBER)

8. Limestone (calcilutite): very-pale yellowish brown; medium to thick bedding; "sublithographic"; color laminations; intraclasts at the top . . . . 7.0 to 7.3

(Total measure thickness of Coralville Member = 7.3 ft.)

(RAPID MEMBER)

7. Argillaceous dolomite: yellowish brown; medium bedding with shaly partings; fine grained 4.0

6. Limestone (fine-grained calcarenite): yellowish gray to light-olive gray; medium bedding; sparry calcite cement; a few brachiopod shells; lenticular 0.7

5. Argillaceous limestone (calcilutite): yellowish gray on weathered surface; light to medium gray; medium to thick bedding, with laminations; bedding disrupted by bioturbation; contains very-light gray to yellowish-gray chert in nodules and stringers; less cherty than units No. 4 and No. 3 . . . . 7.0

4. Argillaceous limestone (calcilutite): light to medium gray; medium to thick bedding, with laminations; horizontal to sub-horizontal burrows, 3-5 mm. in diameter by 100 mm. or greater in length, generally unbranched, but some "Y"-shaped forms; chert nodules and stringers 4.3

3. Argillaceous limestone (calcilutite): light to medium gray; medium to thick bedding; very cherty, with nodular chert horizons 2.0 ft. and 3.3 ft. above base of unit; patches of white and clear secondary calcite; minor pyrite; very-light gray chert preserves brachiopod shells and other fossil fragments; best preservation where calcarenite lenses have been silicified 3.3

2. Limestone (skeletal calcarenite): medium gray; coarse grained; medium bedding; poorly washed, with stringers of lime mud; grades upward into calcilutite; fossiliferous with skeletal debris of brachiopods, bryozoans, and crinoids; a few fish fragments; lenticular . . . 0.5 to 0.7

1. Argillaceous limestone (calcilutite): light-olive gray to light gray; medium to thick bedding, with laminations; chert nodules and stringers; chert (very-light gray to white) preserves brachiopod shells, trepostome bryozoans, crinoid columnals; unit also contains horizontal burrows, fish fragments, silicified spiriferid brachiopods, and a few lacy bryozoans 7.0

(Total measured thickness of Rapid Member = 27.0 ft.)

Notes: Fossils identified from cherts and calcarenites on quarry floor: brachiopods (spiriferids, atrypids, terebratulids, rhynchonellids); bryozoans (trepostomes); fish parts, crinoid stems. Large atrypid observed on talus block: probably Atrypa waterlooensis (= Desquamatia waterlooensis). A 1953 core log from the Iowa Geological Survey indicates that the Solon-Rapid contact is about 4.0 feet below the quarry floor.

Discussion: The contact between the Coralville and Rapid Members is exposed in Glory Quarry, along with 7.3 feet of Coralville and 27.0 feet of Rapid beds. Whereas the Rapid-Coralville contact in the Johnson County area is marked by a distinct burrowed discontinuity, the contact in the Black Hawk County area is one of lithologic change from argillaceous calcilutites of the Rapid Member to "lithographic" or "sublithographic" calcilutites of the Coralville Member.

Horizontal to sub-horizontal burrows are a conspicuous feature of the laminated argillaceous calcilutites (units 1, 3, 4, and 5) of the Rapid Member at this site. These features can best be viewed on large blocks on the quarry floor and along the access road to the quarry.

A 6-feet interval of distinctive burrowed beds in the Rapid Member was considered to be a "Key bed" by Zawistowski (1971, p. 37). According to Zawistowski this interval is characterized by:
1) pyrite-filled burrows that weather to form mottled surfaces;
2) extreme bioturbation;
3) distinct conchoidal fracture; and
4) sparse faunal content.

Zawistowski recognized this interval in a number of localities in east-central Iowa. We will also see extensively-burrowed zones in the Rapid Member at Waterloo South Quarry and Pint's Quarry.

The argillaceous calcilutites of the Rapid Member contain scour-like features, suggesting that wave action affected the sea floor at times. For the most part, however, the Rapid beds were probably deposited in quiet water, below effective wave base.

Skeletal calcarenites (units No. 2 and 6) occur as lenticular deposits within the argillaceous calcilutites and probably represent storm episodes, when coarser sediments were transported into deeper water. Some of the fossiliferous cherts in this section formed by silicification of skeletal calcarenites. Fossils are more numerous in the cherts and calcarenites than in the argillaceous calcilutites

The argillaceous calcilutites of the Rapid Member here are part of Stainbrook's "waterlooensis" zone. Articulated crinoids are preserved in beds of the "waterlooensis" zone in the Iowa City area and are significant in understanding the depositional processes of this interval (Witzke, 1984). Crinoids readily disarticulate and the preservation of delicate articulated forms, generally requires rapid burial. Crinoid occurrences such as these may be storm-related deposits.

GLORY QUARRY: WHAT'S THE STORY?

Go east from Barnes Ferry and on past Purdy's Crossing. Before you reach McChane's Crossing, you'll be at a place called Buzzard's Glory. Old timers say that turkey buzzards used to roost in trees in this area, where a crossing on the Cedar River had long been called "Glory": Hence, the name Buzzard's Glory. Buzzard's Glory was a regular stop on the WCF & N Railroad. In its heyday, Buzzard's Glory was also the site of a major quarrying operation that employed almost 130 persons, working in shifts around the clock. Much of the stone quarried at Glory was used for the WCF & N interurban roadbed (Waterloo, Cedar Falls, & Northern Railroad). Apparently, some of the quarried rock was also used for concrete pavement in the original U.S. Highway 218. Glory Quarry opened about 1915 and had its most productive years from 1924 to 1927 (Griffiths, 1975).

Some quarry workers stayed in boxcars scattered along the hills above the quarry; others lived with their families in makeshift tar-paper shanties; and the interurban brought workers daily from Waterloo. Long-time residents of the area remember the quarry workers as "rough type of men, who were less than well-liked" by the predominantly Wesleyan Methodist farming community. Because the area came to be known as Buzzard's Glory, the local country church (Emmanuel Wesleyan Church) was commonly spoken of as "The Buzzard Church", much to the dismay of the local congregation (Griffiths, 1975).

The remnants of a "six-silo crushing building" can still be seen near the old railroad bed. Railroad cars pulled under the silos and were loaded by chutes. Various sizes of crushed rock were stored in different silos.

The lower levels of the quarry are now filled with water and are inaccessible. Paul Niemann Construction Company has purchased part of the old Glory Quarry site and currently produces crushed aggregate from the Rapid and Coralville members of the Cedar Valley Formation. The old WCF & N railroad bed and right of way are now part of the Cedar Valley Nature Trail.

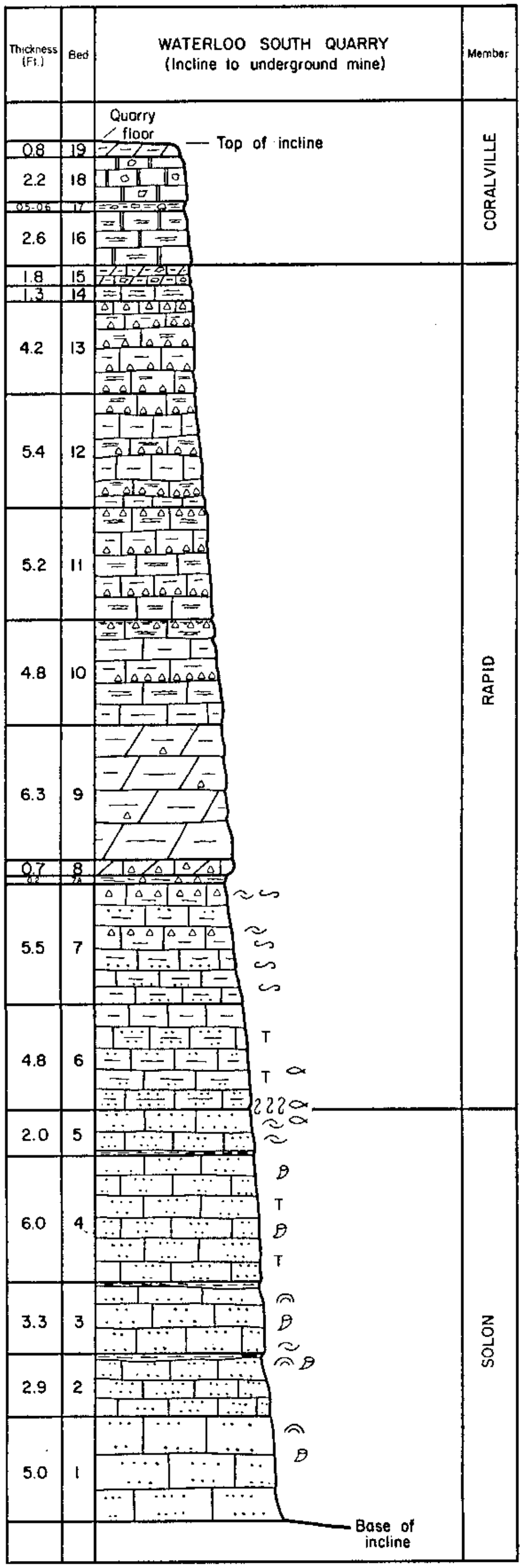


Figure 7: Stratigraphic section, Waterloo South Quarry (incline to underground mine), Black Hawk County.

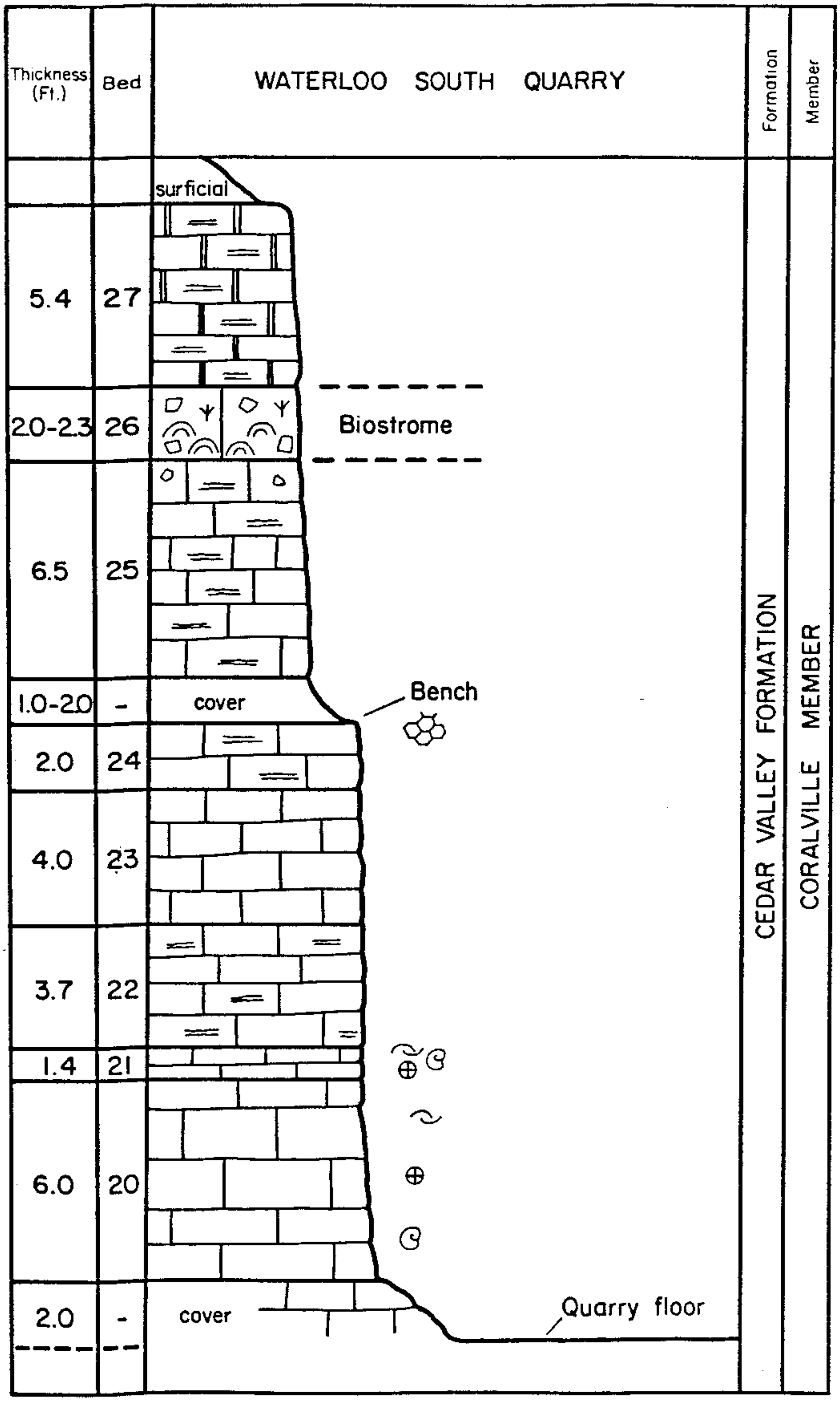


Figure 8: Stratigraphic section, Waterloo South Quarry, Black Hawk County.

WATERLOO SOUTH QUARRY

Stratigraphic section measured along west side of incline to underground mine for units 1-19, and on south quarry face, directly south of underground entrance, for units 20-27. Quarry operated by Basic Materials Corporation, Brooklyn, Iowa. Location: NW 1/4, Sec. 18, T.87N., R.12W., Black Hawk County, Iowa.

Bed No.		Thickness (feet)
	CEDAR VALLEY FORMATION (CORALVILLE MEMBER)	
27.	Limestone (calcilutite): yellowish gray to very-pale yellowish brown; "sublithographic"; thick bedding; finely laminated, with small scour structures terminating some laminations	5.4
26.	Limestone breccia and biostrome: pale-yellowish brown to moderate-yellowish brown; branching (*Amphipora* - like) and subspherical stromatoporoids and angular calcilutite fragments in a calcilutite matrix; one massive bed; stroms up to 1 foot in diameter, many "rotated" from growth positions	2.0 to 2.3
25.	Limestone (calcilutite): very-pale yellowish brown; laminated; thick bedding; a few intraclasts; patches of secondary calcite; base covered	6.5
24.	Limestone (calcilutite): very-pale orange to very-pale yellowish brown; laminated; thick bedding; a few crystals of secondary pyrite; forms top of quarry bench . . .	2.0
23.	Limestone (calcilutite): pale-yellowish brown; thick bedding; small vugs, lined with secondary calcite, possibly localized around burrows	4.0
22.	Limestone (calcilutite): grayish orange to pale-yellowish brown; massive bedding; irregular laminations; vugs, with calcite and pyrite; platy weathering at top	3.7
21.	Limestone (calcilutite): very-pale yellowish brown; medium to thick bedding; fossiliferous, containing brachiopod shells (including atrypids), crinoid columnals, and gastropods; fossils composed of clear sparry calcite	1.4

20. Limestone (calcilutite): very-pale yellowish brown; massive; with one medium-bedded bed at top; vugs with calcite; a few brachiopods, gastropods, and crinoid columnals; fossils composed of clear sparry calcite; "blotchy" appearance, with patches of yellowish-brown calcite, possibly from burrow fillings; approximately 2 feet of cover to floor of quarry 6.0

Notes: Possible salt (halite) casts observed on laminated calcilutites (in stratigraphic position of unit 24) on upper quarry bench in southwest part of quarry. "Casts" are now composed of calcite, but many are cubic or "near cubic" in form. Desiccation cracks observed in this unit also.

(Waterloo South Quarry, Stratigraphic Section measured along west side of incline to underground mine)

19. Dolomite; argillaceous: light gray to light-olive gray; fine grained; medium bedding; caps face by road to underground operation; forms floor of main quarry 0.8

18. Limestone (calcilutite) and limestone breccia: light olive gray; "lithographic"; thick bedded; fractured, with fractures filled with calcite 2.2

17. Shale and limestone breccia: light to medium-light gray; medium bedding . . . . 0.5 to 0.6

16. Limestone (calcilutite): yellowish brown; "lithographic"; laminated; thick bedding with shaly interval at top; secondary calcite and pyrite 2.6

(Total measured thickness of Coralville Member = 37.5 ft.)

(RAPID MEMBER)

15. Limestone (calcarenite) and argillaceous-dolomite breccia: light olive gray and light gray; distinct contact with laminated beds below 1.8

14. Argillaceous limestone (calcilutite): light to medium-light gray; thick bedded; black pyritiferous laminations 1.3

13. Argillaceous limestone (calcilutite)and chert: light-olive gray; interbedded with medium-light gray chert beds and nodular chert; 5 distinct chert beds; less laminated and argillaceous than bed No. 12; thick bedding 4.2

12. Argillaceous limestone (calcilutite): cherty, 3 medium-light gray chert beds, laminated; irregular bedding in places 5.4

11. Argillaceous limestone (calcilutite): medium-light gray; cherty, 3 medium-light gray chert beds; nodular chert, also; thick bedding, with dark pyritiferous laminations; vugs with calcite 5.2

10. Argillaceous limestone (calcilutite): medium-light gray; cherty, 2 medium-light gray chert beds; nodular chert, also; thick bedding with dark pyritiferous laminations; possible scour features; vugs lined with calcite and fluorite (rare); dark clay seam at top 4.8

9. Argillaceous dolomite: light gray to light-olive gray; fine grained; massive; minor chert; calcite vugs; mottled; limonite-stained bedding plane at top; fractured 6.3

8. Dolomitic limestone and chert: light gray to light-olive gray; fine grained; irregular chert nodules throughout 0.7

7A. Shale seam with chert nodules: medium to light gray; some nodules display concentric banding and preserve crinoid columnals and shell fragments; limonitic stains 0.2

7. Argillaceous limestone (calcilutite and fine-grained calcarenite): light-olive gray to medium light gray; cherty; thick bedding; mottled; bedding highly bioturbated; vugs, with calcite; brachiopods preserved in chert 5.5

6. Argillaceous limestone (calcilutite and fine-grained calcarenite): light-olive gray to medium-light gray; glauconitic; mottled; highly burrowed at base; abundant fish fragments; favositid corals; abundant vugs and secondary calcite, some localized around corals 4.8

(Total measured thickness of Rapid Member = 40.2 ft.)

(SOLON MEMBER)

5. Limestone (fine-grained calcarenite): light olive gray to medium gray; massive; spiriferid brachiopods; fish fragments near the top; dark shaly parting at base 2.0

4. Limestone (fine-grained calcarenite): light olive gray to medium gray; thick bedding; rugose horn corals and favositid corals; calcite-lined vugs, some of which developed around corals 6.0

3. Limestone (fine-grained calcarenite): very-pale yellowish brown; thick bedded; irregular (carbonaceous) shaly seam at top; calcite-lined vugs; laminar stromatoporoids, horn corals, and brachiopods 3.3

2. Limestone (fine-grained calcarenite): light-olive gray to medium gray; massive bedding; carbonaceous streaks; shaly seam near top; laminar stromatoporoids and horn corals near the top 2.9

1. Limestone (fine-grained calcarenite): light-olive gray; massive bedding; dark carbonaceous stringers; vugs with calcite; a few stromatoporoids and horn corals; fractured 5.0

(Total measured thickness of Solon Member = 19.2 ft.)

(Section started at base of road to underground mine, opposite pump.)

Discussion: The stratigraphic section for Waterloo South Quarry shows 37.5 feet of Coralville, 40.2 feet of Rapid, and 19.2 feet of Solon. Additional beds of the Solon Member can be seen in the underground operation and additional units of the Coralville Member are exposed in the southwest face of the quarry.

The Solon-Rapid contact here is marked by a burrowed zone and abundant fish remains. Although corals occur in the basal Rapid beds here they do not form biostromes as seen elsewhere. The argillaceous calcilutites of the Rapid Member here are laminated and burrowed, as seen elsewhere in the area (Pint's Quarry, Glory Quarry and B.L. Anderson Quarry at Brandon). Chert is prevalent in the Rapid Member here.

The Coralville-Rapid contact here, as elsewhere in the Black Hawk County area, is marked by the appearance of "dense", "lithographic" or "sublithographic" calcilutites of the Coralville Member. The upper unit of the Rapid Member at this locality consists of a brecciated interval of limestone and argillaceous dolomite.

A submarine discontinuity surface, commonly burrowed, marks the upper Rapid surface in the Johnston County area. According to Witzke (1984), the discontinuity surface developed coincident with a widespread shallowing of the Cedar Valley seas.

Although this discontinuity surface is not represented in the Buchanan-Black Hawk County Area, the contact between the Rapid and Coralville members is easily recognized on the basis of lithology. Lithologic changes across the Rapid-Coralville boundary in our field-trip area can also be explained by a shallowing of the Cedar Valley sea.

Bisque and Lemish (1959) documented chemical distinctions of the three members of the Cedar Valley Formation. The Rapid Member is characterized by an insoluble residue content greater than 10 percent and a $MgCO_3$ content of 15 percent. The Coralville Member of Black Hawk and Johnson counties was found to contain a 5 percent $MgCO_3$ content and low amounts of insoluble residue.

Mineral-lined vugs occur in the Rapid and Solon members at Waterloo South Quarry and some of the same minerals are found here, as at Pint's Quarry. Paul Garvin discusses the mineralization at Waterloo South and Pint's quarries in another section of the guidebook.

The Coralville Member at Waterloo South Quarry consists primarily of laminated calcilutite. Units 20 and 21 contain brachiopods, gastropods, and crinoid columnals. These beds were probably deposited in a shallow subtidal setting in quiet water. Unit 26 is composed of a stromatoporoid biostrome and limestone breccia. This unit contains overturned stromatoporoids and other indicators of wave agitation. Desiccation cracks and possible salt casts in unit 24 are suggestive of intervals of immergence on tidal flats. Elsewhere in Black Hawk County (Yokum Quarry at Finchford), both mud cracks and birdseye structure has been reported from Coralville beds (Anderson and Wiig, 1972).

PINT'S QUARRY

Pint's Quarry, operated by Weaver Construction Company, exposes all three members of the Cedar Valley Formation. The quarry is located on the east edge of Raymond, Iowa in the SW1/4, Sec. 36, T. 89 N., R. 12 W., Black Hawk County, Iowa.

Discussion: Approximately 102 feet of the Cedar Valley Formation are exposed here, and the Solon Member is exposed further in an underground mine. Quarry exposures include all of the Rapid Member (41 feet), a portion of the Solon Member (28 feet), and part of the Coralville Member (33 feet). The upper part of the Coralville has been removed by erosion and is overlain by Pleistocene till. Core information from the Iowa State Highway Commission indicates that another 42 feet of Solon is present below the quarry floor, so the total thickness here is approximately 70 feet.

The following information is summarized primarily from Kettenbrink (1972). A stratigraphic section prepared by Kettenbrink for the 36th Annual Tri-State Geological Field Conference is reproduced as figure 9 of this guidebook.

Diagenesis is a striking feature of the rocks at Pint's Quarry. Recrystallization of calcite and dolomitization are extensive. Few beds in the quarry have escaped extensive dolomitization. Silicification, although less abundant, is pervasive. Vugs, ranging from 1/2 inch to 6 inches in diameter and lined with calcite crystals, are conspicuous features throughout the formation. Additional mineralization of these vugs with pyrite, marcasite, sphalerite, barite, flourite, and other minor minerals have made this quarry a favorite with mineral collectors. Fluorite is perhaps the most unusual and noteworthy for the size of individual crystals (up to 1 inch in diameter). A study of the various minerals and their crystal forms has been published by Lin (1978). Paul Garvin discusses the mineralization at Pint's Quarry in another section of this guidebook.

Solon Member-- The Solon rocks are dark brown, with bedding thick to massive. Irregularly spaced, discontinuous bituminous partings are common. Concentration of more closely spaced partings (forming "shaly" seams up to 1 inch thick) mark the top of most beds in the Solon Member. Horizontal, unbranched, sinuous burrows are particularly common in the lower part of the quarry exposure. The burrows, averaging 3/8 to 1/2 inch in diameter, have been traced up to 12 inches, and are particularly well displayed on bituminous partings. In cross-section, these burrows appear as an ellipse with the major axis parallel to bedding and with a slightly different texture and color than the surrounding matrix. The most distinct feature of the burrow cross-sections is their peculiar "swirled" texture.

The Solon Member contains 10 to 25 percent recognizable fossils and is not as fossiliferous at Pint's Quarry as at some other Solon sections in the area. Rugose corals are the most abundant fossils in the Solon at this locality. Favositid corals are also common. Stromatoporoids, brachiopods, bryozoans, and crinoid fragments are also found, but are definitely scarcer at Pint's Quarry than at most Solon localities. A notable exception to the general scarcity of fossils at Pint's Quarry is the abundant fish fauna.

Of the many crystal-lined vugs in the Solon, most give no indication as to their origin. However, when silicification was included in the mineralization of these structures, the origin is apparent. Silicification around the outer margin of these vugs has preserved the skeletal structure of various corals. Silicification of the outer part of these corals was followed by solution of the remaining carbonate skeletons of the corals, leaving voids. Following calcite emplacement in the voids, selective mineralization of individual vugs produced the mineral suites now found.

Rapid Member-- The Solon-Rapid contact can be placed at a prominent burrowed discontinuity. This contact is several feet below the lowest bench in the quarry. A lag concentration of phosphatic fossils (fish remains) and glauconite pellets occurs on this contact and it is accompanied by a slight, but distinct change in lithology between members. A distinct color change from medium yellowish brown in the Solon Member to medium greenish gray in the Rapid Member exists at this contact. The basal several feet of the Rapid Member are more dolomitic than the underlying Solon. The basal Rapid is also coarser grained and more fossiliferous than the rest of the overlying Rapid, and it represents a transitional lithology between the two members. This basal transitional lithology of the Rapid has one of the largest concentrations of mineralized vugs of any bed in the quarry. Large silicified corals are also abundant in this transitional lithology. Of particular interest, is the occurrence of possible silicified oncolites. These "oncolites" range from 1/2 inch to 7 inches in diameter. Larger specimens are due to the coalescence of smaller "oncolites", forming larger compound structures. The strongest evidence of an algal origin of the "oncolites" is the overlapping festoon laminae that most of the specimens exhibit. In thin section, there is a definite textural and mineralogical difference between these festoon laminae and surrounding portions of the "oncolites". Some laminae show possible borings or burrows. The "oncolites" may or may not show a distinct nucleus. The orientation of skeletal material within the "oncolite" structures is a problem. One would expect to see more of a tangential alignment of elongated fragments in true oncolites that have rolled on the sea floor than is seen in the fossil remains within them. The loss of much structural detail due to the combined effects of recrystallization, dolomitization, and silicification present serious problems in the interpretation of these structures.

Contorted and deformed bedding of laminated dololutites occur within the top few feet of the Rapid Member. In areas of less pronounced deformation, the bedding superficially resembles current ripples in both plan and cross section views. The wavelengths of "ripples" vary from 1/2 to 12 inches, with the majority of the wavelengths measuring approximately 2 inches. Preservation of equally spaced pyrite laminations and lack of cross bedding preclude a ripple (primary) origin for these structures. The "ripples" are interpreted as being caused by the deformation of soft sediment, possible due to intrastratal folding of weakly-consolidated carbonate mud. These contorted and deformed beds were cut by still later micronormal faults with displacements up to 1 cm. This deformation may have resulted from gravitational slippage of mud layers.

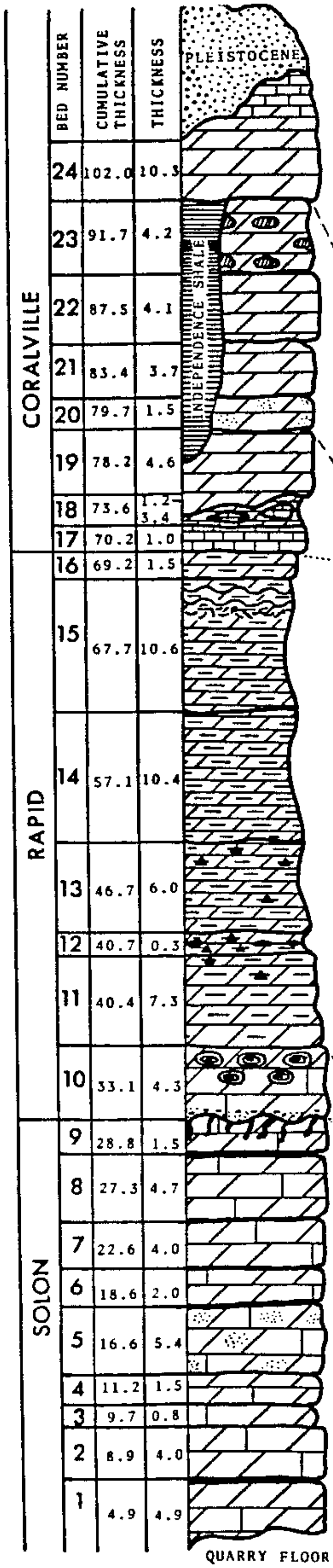
Fossils in the Rapid Member are sometimes black in color, probably because they have been impregnated with fine-grained pyrite. At Pint's Quarry, dolomite constitutes 90 to 100 percent of the Rapid Member, whereas typically the dolomite content of the Rapid ranges from 15 to 30 percent. The appearance in hand specimens of dololutites and calcilutites with high dolomite content is the same as that of relatively undolomitized portions of the Rapid Member (Kettenbrink, 1973). For example, the field appearance of the laminated and argillaceous dololutites of the Rapid Member at Pint's Quarry is nearly identical to that of the argillaceous calcilutites of the Rapid Member at Brandon, Glory, and Waterloo South localities.

At Pint's Quarry, both horizontal and vertical burrows are found in the Rapid Member. Bioturbation is more prevalent in the lower half of the member and and diminishes upward. Primary "cut and fill" structures, "scour markings", and other less well-defined erosional features are present in the finely-laminated dololutites of the Rapid Member at Pint's Quarry.

<u>Coralville Member</u>-- The bulk of the Coralville Member consists of thick-bedded to massive, light to dark brown dololutites, with varying amounts of sparry calcite as recrystallized fossils, void filling, and cement. Again recrystallization and dolomitization has been intense, destroying much original fabric. Ghost fossils, mainly favositid corals almost completely obliterated by diagenesis, produce a "blotchy" mottling pattern similar to that found in the upper Solon beds.

Very soft to "earthy" dark brown dololutite, mottled with large single crystals of dark brown calcite occurs in the upper third of the Coralville. Single crystals of calcite, up to several inches in diameter, occur in the dololutite beds. The large calcite crystals break along cleavages, and are very prominent because of their reflection of sunlight. It appears that the crystals started as void filling and proceeded to replace the dololutite as indicated by a transition zone along the margin of crystals.

Several beds contain numerous irregular spar-filled fissures which may represent desiccation cracks. Unequivocal desiccation polygons have been found at about the same stratigraphic position



dololutite/calcilutite, lower part similar to bed 23, but without calcite, abrupt change in middle to thinly laminated dololutite, top few feet which is poorly exposed is a laminated/thin-bedded calcilutite with scattered intraclasts and fossils.

dololutite, dark brown, soft to "earthy" with cavities up to several inches filled with single crystals of dark brown calcite. Top of bed forms third prominent bench.

dololutite, similar to beds 20 and 21, but darker and with more iron staining, possible dessication (?) features near top.

dololutite, similar to bed 20, but with fewer recognizable fossils.

dololutite, similar to bed 19, recrystallized corals produce "blotchy" mottling, concentration of recrystallized brachiopods and crinoid fragments near middle of bed.

dololutite, buff, massive, no bedding features, calcite lined vugs present, this ledge forms the second prominent bench in quarry.

dololutite, argillaceous with intraclasts of underlying bed, calcite void filling, much variation in composition, texture.

calcilutite, laminated/thin bedded, light color, hard, dense, composed of 90% micritic pellets, no dolomite present.

dololutite, argillaceous, calcitic, light brown, weathered, undeformed.

dololutite, argillaceous, similar to bed 14, but finer laminations and more pyrite upper 3 feet contain deformed bedding, some of which closely resemble ripplemarks.

dololutite, argillaceous, thinly laminated, scattered horizontal and vertical burrows, small "cut and fill" structures, prominent iron stained zone at top.

dololutite, argillaceous, similar to bed 11, no distinct laminations, discontinous layer of chert nodules near top in a prominent iron stained horizon.

dololutite, very argillaceous, less resistant unit, contains flat calcite nodules and chert.

dololutite, argillaceous, fine pyrite laminations-but not very distinct, more crystal lined vugs in lower half of bed, a few scattered chert nodules near top.

dololutite, calcitic, light gray, transitional Rapid lithology, coarser grained than overlying dololutites, lag concentration of phosphatic (fish) fossils and glauconite pellets on disconformity, abundant silicified corals, crystal lined vugs, and silicified "oncolites", top of bed is lowest bench in quarry.

dololutite, calcitic, light brown, fewer vugs and fossils, top of bed is burrowed disconformity with 6 to 8 inches relief and marks the Solon-Rapid contact, distinct color change at contact.

dololutite, calcitic, similar to units 5, 6 & 7, but with fewer crystal lined vugs, shaley parting at top of bed.

dololutite, calcitic, similar to beds 5 and 6, but with fewer crystal lined vugs, shaley partings at top of bed.

dololutite, calcitic, similar to bed 5, fluorite in vugs first noted here.

dololutite, calcitic, similar to beds below, abundant scattered vugs in lower part, more abundant solitary corals in upper part, recrystallized corals produce "blotchy" mottling.

dololutite, calcitic, similar to beds 2 and 3, but lighter in color.

dololutite, calcitic, similar to bed 2.

dololutite, calcitic, similar to unit 1, but with fewer bituminous partings, and more vugs, abundant horizontal burrows.

dololutite, calcitic, thick-bedded to massive, dark brown, numerous discontinous bituminous partings particularly near the top, abundant crystal lined vugs, a few discontinous calcite veins parallel to bedding, a few scattered fossil fragments and solitary corals.

Figure 9: Stratigraphic section, Pint's Quarry, Raymond. The Independence Shale is no longer exposed (from Kettenbrink, 1972).

at other localities in the area. In the top six feet of the section there is an abrupt change from thick-bedded dololutites, to laminated/thin-bedded calcilutites. These limestones are very fine-grained and contain scattered intraclasts and a very few fossil fragments (Kettenbrink, 1972).

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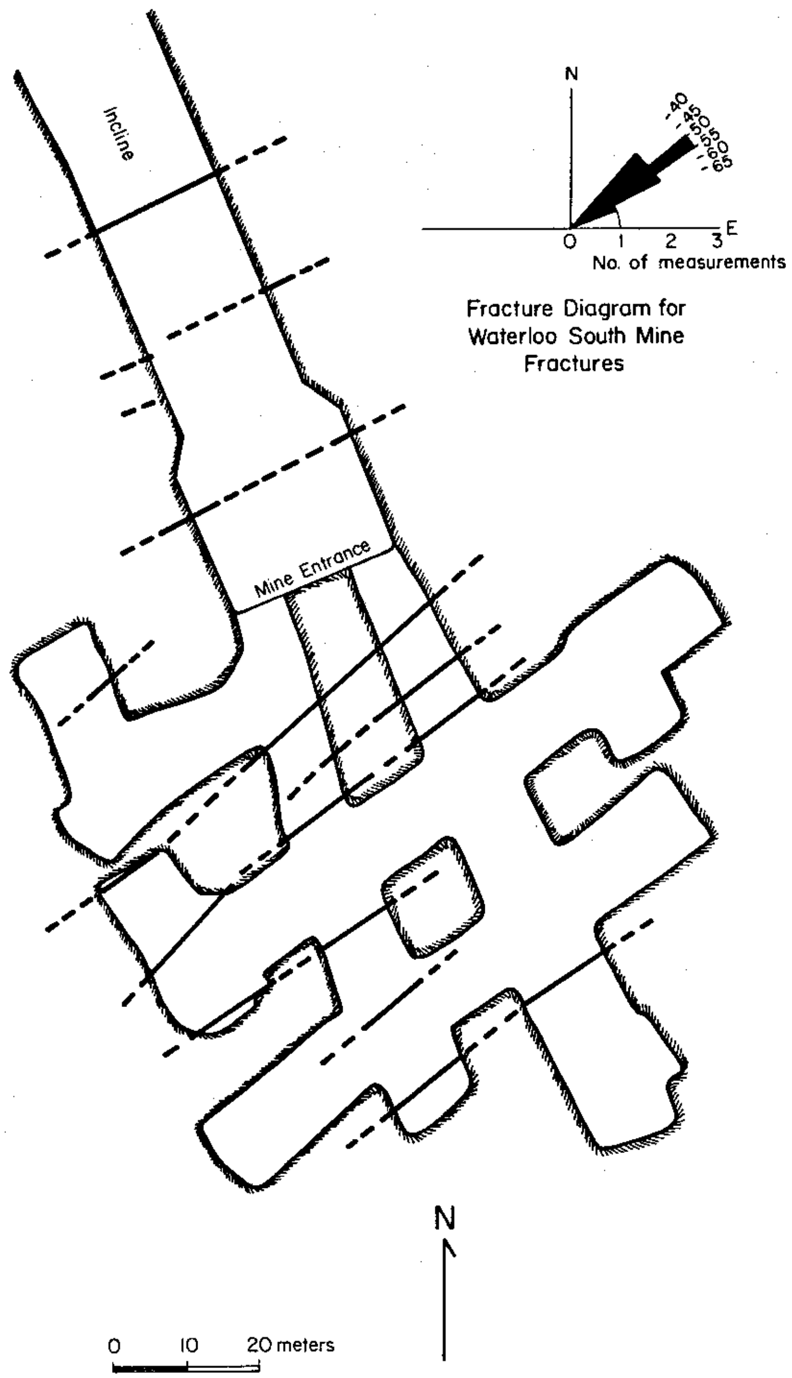

Figure 10: Map showing distribution of joints at Waterloo South Mine, Black Hawk County (mapped by Martin-Marietta Corporation, 1980).

PART II

WATERLOO SOUTH QUARRY

The Waterloo South Quarry, developed and formerly worked by the Martin-Marietta Corporation, and presently operated by Basic Materials Company, is located in the NW1/4, Sec. 18, T87N, R12W, in Black Hawk County (figure 1). The quarry exposes all members of the Cedar Valley Formation, the Coralville and Rapid members in surface workings, and the Solon Member in an underground mine. A stratigraphic section for the Waterloo South Quarry (figures 7 and 8) and discussions of the stratigraphy and environment of deposition at this site are found elsewhere in the guidebook.

A unique feature of the quarry geology is the presence of solution-enlarged joints. These joints (called mud seams by the miners because of contained clay fillings) are most numerous in the area of the underground workings, and die out to the north and south. They are readily visible in the incline and in the mine back. The strike of the joints ranges from N42° - 63°E, with near vertical dips (figure 10).

Mineralization at the Waterloo South Quarry is localized along joint and bedding plane fractures, in subspherical to irregular-shaped vugs, and in areas of brecciation. Vug mineralization appears to be the dominant type. Vugs are more concentrated in certain stratigraphic horizons, suggesting that distribution is controlled by bed permeability. Distribution is not predominantly controlled by fossils, as at Pint's Quarry; at least, fossil remains are rare. Mineralization occurs in all members of the Cedar Valley Formation, but is most varied and abundant in the Solon Member.

Mineralogy

Minerals occuring at the quarry are: pyrite, marcasite, chalcopyrite, fluorite, calcite, barite, and quartz. Pyrite occurs as crusts on fracture

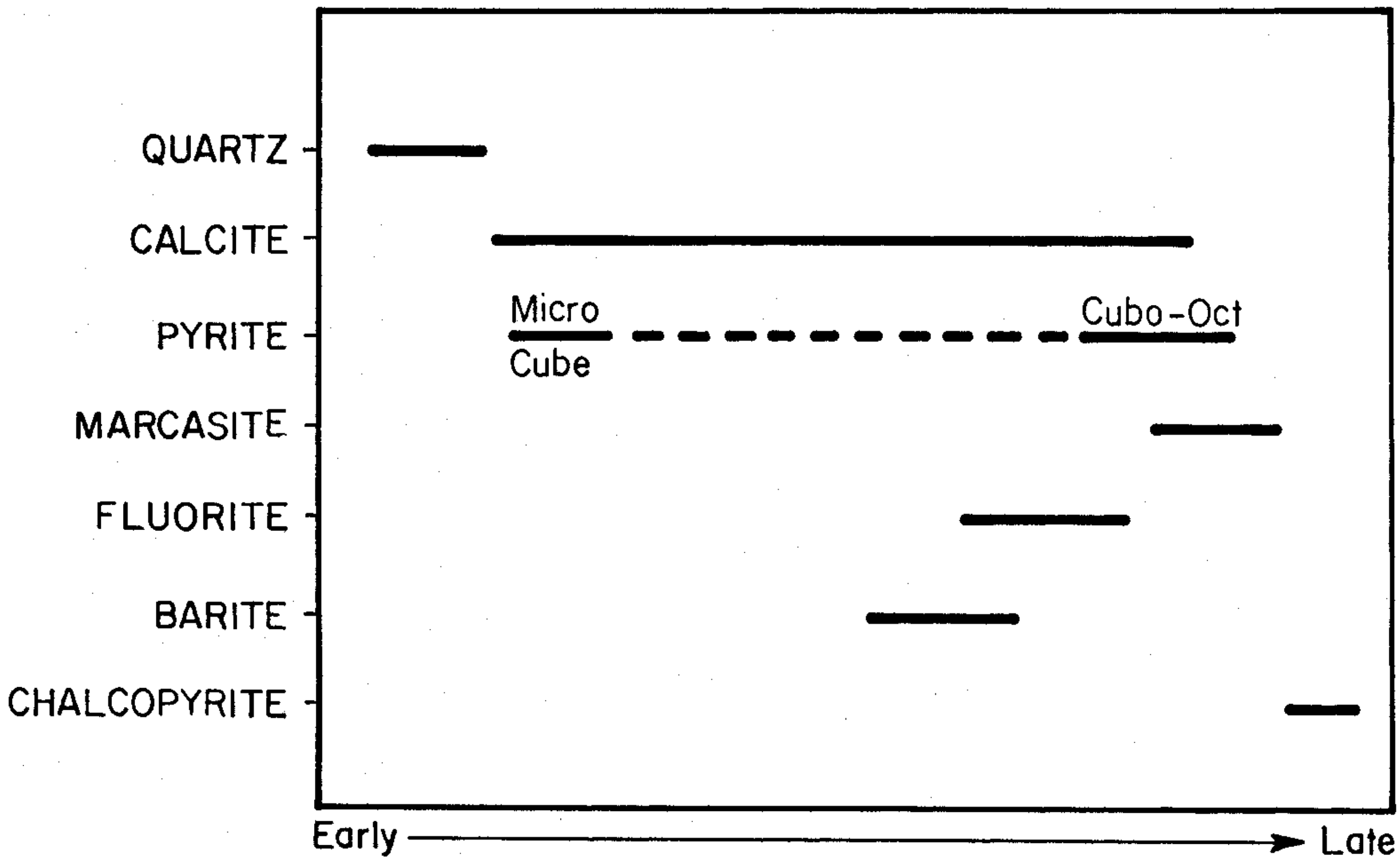

Figure 11: Paragenetic sequence of mineralization at Waterloo South Quarry.

walls and breccia clasts, and as inclusions in calcite crystals. Crystals are typically combinations of octahedron, cube, and pyritohedron. They are generally not more than a few millimeters across. Marcasite occurs as thin blades and capillary crystals. It is commonly perched on pyrite crystals, suggesting a genetic relationship between the two minerals. A single specimen of chalcopyrite is known from the quarry. It occurs as tiny pseudotetrahedral crystals on calcite. Fluorite is quite common. It is very similar in appearance to the fluorite from Pint's Quarry. It ranges in color from pale transparent yellow to rootbeer brown. Locally, it is a nearly opaque tan. The tan variety appears to have undergone some kind of alteration, however, its X-ray diffraction pattern is identical with that of "fresh" fluorite. In long wave ultraviolet light (356 nm), the tan variety is intense yellowish white, whereas the translucent rootbeer variety fluoresces yellowish gray. Crystals are simple cubes, commonly with slightly curved or parketted faces. Individual crystals may reach 2 cm across. Calcite is by far the most abundant epigenetic mineral at the quarry. It is prominent in vugs and accentuates bedding plane and cross fractures. It ranges in color from brownish yellow (always early) to white or colorless. The early calcite fluoresces creamy white in long wave ultraviolet light, while the later calcite is non-fluorescent or fluoresces dull pink. Prism and scalenohedron are the dominant crystal forms. These are generally truncated by positive and negative rhombohedra and a second scalenohedron. Some late calcite is sparry. Crystal lengths may reach several centimeters. Barite is uncommon at the Waterloo South Quarry. Where present, it occurs as white, almost opaque blades, which are often in radial clusters. Blades are generally less than 2 cm in length. Quartz is rare. In the single specimen I collected, it occurs as a fine druse in association with fluorite. Quartz crystals are transparent and doubly terminated, and appear to replace a tabulate coral.

Paragenesis

The paragenetic sequence at Waterloo south is quite similar to that at Pint's. Minerals common to both quarries appear in approximately the same relative positions in the sequence (see figure 11).

PINT'S QUARRY

Pint's Quarry, operated by Weaver Construction Company, boasts the largest variety of minerals in any reported locality in Iowa. The quarry is located in the SW1/4, Sec. 36, T89N, R12W, in Black Hawk County. The quarry exposes all three members of the Cedar Valley Formation. The Solon is further exposed in an underground mine. A stratigraphic section for Pint's Quarry (figure 9) and discussions of the stratigraphy and environment of deposition at this site are found elsewhere in the guidebook.

Mineralization at Pint's occurs in all units exposed in the quarry, but is most varied and abundant in the Solon Member. The minerals are confined essentially to vugs. These are especially abundant near the top of the Solon. Vug distribution appears to be controlled by bedding plane fractures and partly silicified coral fossils. Dissolution of unsilicified portions of these fossils created many of the openings. Vug minerals are commonly perched directly upon silicified coral. Although jointing is quite prominent in the host rock, joints are not significantly mineralized. They are, however, ironstained.

Mineralogy

Minerals reported from the quarry are: pyrite, marcasite, sphalerite, galena, fluorite, calcite, barite, gypsum, and quartz. Pyrite occurs as bright to irridescent-tarnished single and intergrown crystal groups. Microcrystals are common as inclusions in calcite. Nodular masses are observed locally. Cube and octahedron are the dominant forms. Pyritohedron is subordinate and is observed only in combination with the other two forms. Crystal size ranges from less than a millimeter to more than a centimeter across. Marcasite is less common than pyrite in the Solon, but more common in the Coralville. It is most often bladed, with blades ranging from a millimeter to more than a centimeter in length. Largest blades occur in the Coralville. Single and polysynthetic twins and capillary forms (sometimes mistakenly called millerite), occur locally. Frequently observed oriented growths of marcasite on pyrite suggest a genetic relationship. Sphalerite is rare at Pint's Quarry. It occurs as small (less than 1 cm) dark brown, generally poorly developed, tetrahedra. Galena is extremely rare. Menzel and Pratt (1968) report a single occurrence. A specimen of galena showing cubic crystals is in the geology museum at the University of Northern Iowa. I have collected a single specimen in which massive galena thinly coats a fracture. Fluorite is relatively common at Pint's Quarry. It is most abundant in the Solon. Colors range from very pale yellow to dark brown. Rarely, purple fluorite druse is found in small vugs in the Rapid. Crystals are cubic and are scattered singly or are in complex intergrowths. Crystal size ranges from a few millimeters to three centimeters or more. All fluorite (including the purple variety) fluoresces creamy white to whitish yellow in long-wave (356 nm) ultraviolet light. Locally, fluorite crystals appear to have undergone some kind of alteration, which caused them to become almost opaque and somewhat crumbly. This same phenomenon has been observed in fluorite from Waterloo South Quarry. Like Waterloo South, this altered fluorite gives an x-ray diffraction pattern identical with that for "fresh" fluorite. Calcite is by far the most abundant mineral at the quarry. It is generally colorless or white. A darkbrown, almost irridescent, film present on the surfaces of some crystals is probably organic matter. Some sparry calcite is pale amber color, the color likely due to organic or iron-bearing impurities.

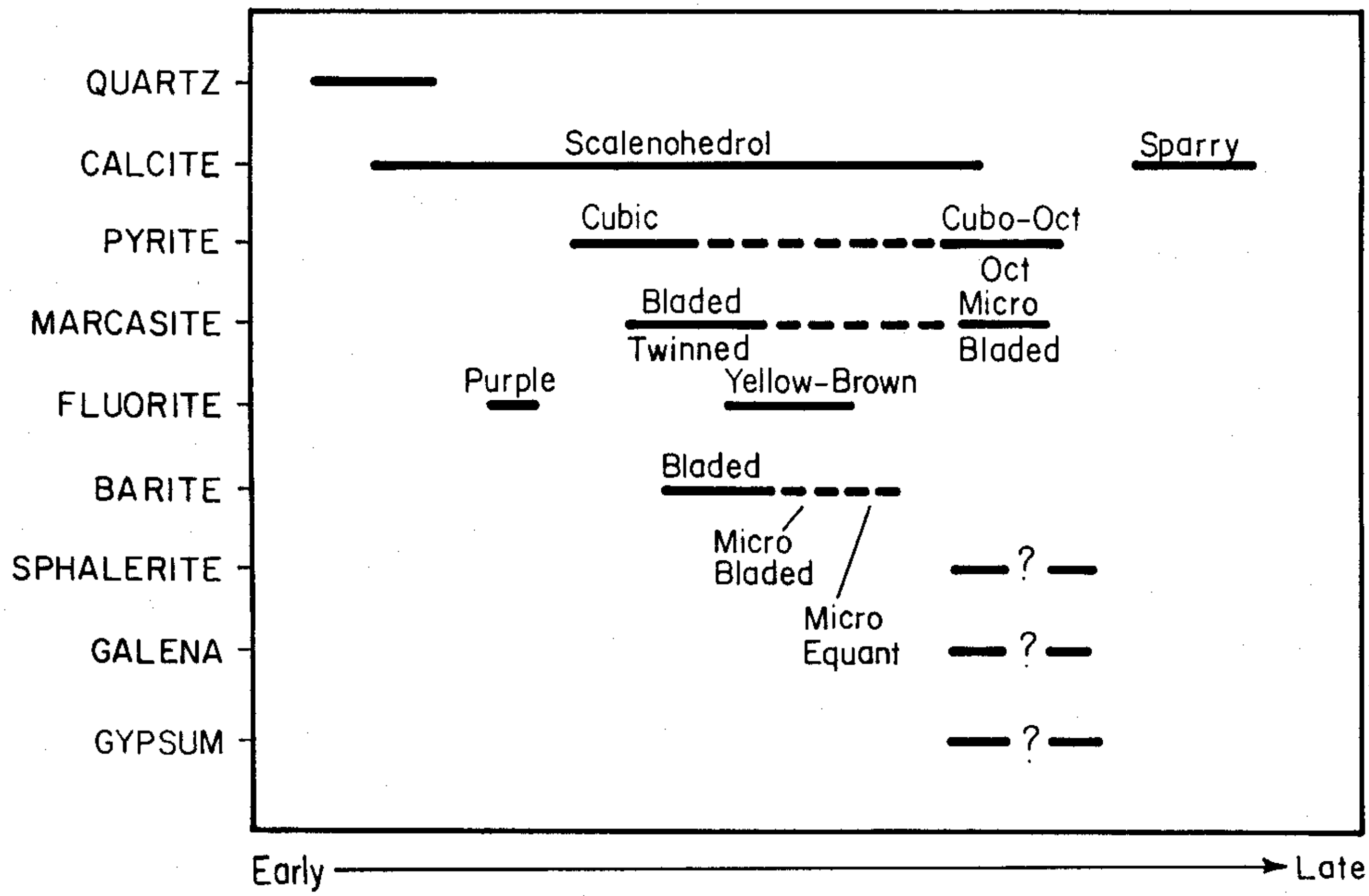

Figure 12: Paragenetic sequence of mineralization at Pint's Quarry.

Locally, pale pink calcite has been observed in association with sparry white calcite. All sparry calcite is late. Calcite crystals range in length from less than a centimeter to at least 10 cm. In the Solon and Rapid members, scalenohedron is the dominant form, modified by one or more rhombohedra and prism. High pitched, almost acicular rhombohedra are observed locally. Locally, barrel-shaped calcite crystals occur, consisting of scalenohedron and basal pinacoid, upon which have grown a later generation of oriented scalenohedra. The barrel, including the pinacoidal terminations, are coated with an organic or oxide film, while the later scalenohedral growth is not coated. Calcite from the Coralville Member is characteristically rhombohedral in habit, with individual crystals up to 3 cm across. Barite occurs as colorless to white, tabular to bladed crystals which characteristically appear in radiating clusters. Individual crystals reach several centimeters in length. Commonly, a second generation of much smaller barite blades encrusts the earlier, larger crystals. Locally, water-clear equant microcrystals of barite are perched on calcite. Barite blades are commonly stained with iron oxide. Gypsum is reported from a single locality. It is massive and intimately intergrown with calcite, suggesting a replacement relationship. Quartz is most often observed as pseudomorphic replacements of corals (*Hexagonaria* and *Favosites*) in the Solon. Locally, it occurs as clusters of well-terminated crystals up to a centimeter in length. Additional descriptive information on Pint's Quarry minerals can be found in Menzel and Pratt (1968), and Lin (1978).

Paragenesis

The euhedral nature of most of the vug materials, and the lack of replacement by a given mineral of its predecessor in the paragenetic sequence make the determination of paragenesis at Pint's Quarry a straightforward task which can be accomplished quite easily with a hand lens and a binocular microscope.

Nevertheless, the paragenetic relations are quite complex because some of the minerals appear in more than one generation. The different generations of each mineral are distinguished by color and crystal habit and by relationship to the minerals on the sequence. Early pyrite is cubic, late pyrite is cubo-octahedral or octahedral. The general isolation of sphalerite, galena, and gypsum from the remaining minerals and from each other make it impossible to place them in the sequence with any degree of precision. Paragenetic relations are summarized in figure 12.

COMMENTS ABOUT THE ORIGIN OF THE MINERALIZATION AT PINT'S AND WATERLOO SOUTH QUARRIES

Minor sulfide mineralization occurs in several localities in eastern Iowa in host rocks ranging in age from Ordovician to Devonian (Heyl, et al, 1959; Heyl and West, 1982; Brown, 1967; Garvin, 1983, 1984a,b). Some, like the Mineral Creek deposit (Allamakee County) and the Martin-Marietta deposit (Linn County), on the basis of structure, mineralogy, paragenesis, and temperature of formation, strongly resemble upper Mississippi Valley (UMV) zinc-lead deposits (Heyl, et al, 1959; Garvin, 1983, 1984b). Mineralization at Pint's and Waterloo South resembles UMV mineralization in that all minerals found in these two quarries have also been reported from the UMV district (Heyl, et al, 1959). There are, however, two important differences: 1) Form of the deposits, and 2) mineral paragenesis. UMV deposits are fracture controlled. The pitch-flat deposits, vertical gash veins, and breccia fillings are examples. At Pint's and Waterloo South, although vertical and bedding plane fractures were important in controlling fluid migration, most mineralization is contained in vugs. Regarding paragenesis, UMV deposits are characterized by early iron sulfide and late calcite; whereas at Pint's and Waterloo South, calcite is early and most sulfides are late. (Recently, Heyl (written communication) has discovered rare early calcite in the main district.)

Temperature data for Pint's and Waterloo South mineralization are lacking. Homogenization temperatures for fluid inclusions from the Conklin Quarry (Johnson County), with which Pint's and Waterloo South deposits are quite similar, range from 74 to 118° C (Garvin, 1984a). Temperatures of mineralization in minor sulfide-bearing mineral occurrences in the general midcontinent area range from 56 to 144°C (Coveney and Goebel, 1983).

The greater abundance of mineralization in the Solon Member, compared to the Rapid and Coralville members, is in part due to the greater abundance of vugs in the Solon, which in turn is due (at least at Pint's) to dissolution of fossils. The higher concentration of sulfides in the Solon at Pint's may be related to the high organic content of the Solon limestone, evidenced by the general brown color and the presence of black bituminous partings. Pyrite and marcasite from all three members were analyzed for Ni, Cu, and Co using atomic absorption spectrophotometry (Garvin, unpublished data). The results are summarized in Table 1. Note that there is definite enrichment of these metals in iron sulfides in the Solon. The common association of these metals with carbonaceous material (Tourtelot, 1970) suggests that they and perhaps the iron and sulfur in pyrite and marcasite were derived locally from Solon beds by circulating hydrothermal fluids. It is also possible that chemical reduction of these fluids by carbonaceous material caused precipitation and concentration of sulfides in the Solon (Krauskopf, 1979, pp. 253-256.)

Mineralized vertical fractures (especially prominent at Waterloo South), and mineralization in all units exposed in both quarries evidences fluid migration along a vertical plumbing system. Evidence for vertical fluid movement elsewhere in the UMV district is discussed in Ludvigson, et al, (1983).

Table 1. Ni, Cu, and Co Contents of Pyrite and Marcasite From Pint's Quarry, Black Hawk County Iowa. Values in parts per million)

Rock Unit	No. of Analyses	Ni Ave	Ni (Range)	Cu Ave	Cu (Range)	Co Ave	Co (Range)
Solon	20	202	(23-830)	21	(8-66)	28	(8-56)
Rapid	2	90	(40-141)	9	(9-10)	21	(18-25)
Coralville	10	26	(14-41)	19	(13-44)	12	(6-27)

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KEY

TO QUARRY STRATIGRAPHIC SECTIONS

Major Lithologies

- calcilutite
- calcarenite
- "sublithographic" limestone
- coral or stromatoporoid-rich limestone (biostrome)
- laminated calcilutite
- fractured, brecciated, or intraclastic
- argillaceous shale partings
- sandstone
- mudstone
- shale

Other lithologic and fossil symbols

- stylolites
- oncolites
- chert
- sandy
- mudcracks
- digitate stromatoporoids
- hemispherical or laminar stromatoporoids
- colonial tabulate corals (mostly favositids)
- nautiloid cephalopods
- colonial rugose corals (mostly *Hexagonaria*)
- solitary rugose corals
- brachiopods
- bryozoans
- gastropods
- crinoid debris
- fish teeth, plates
- burrows (horizontal)
- burrows (vertical)

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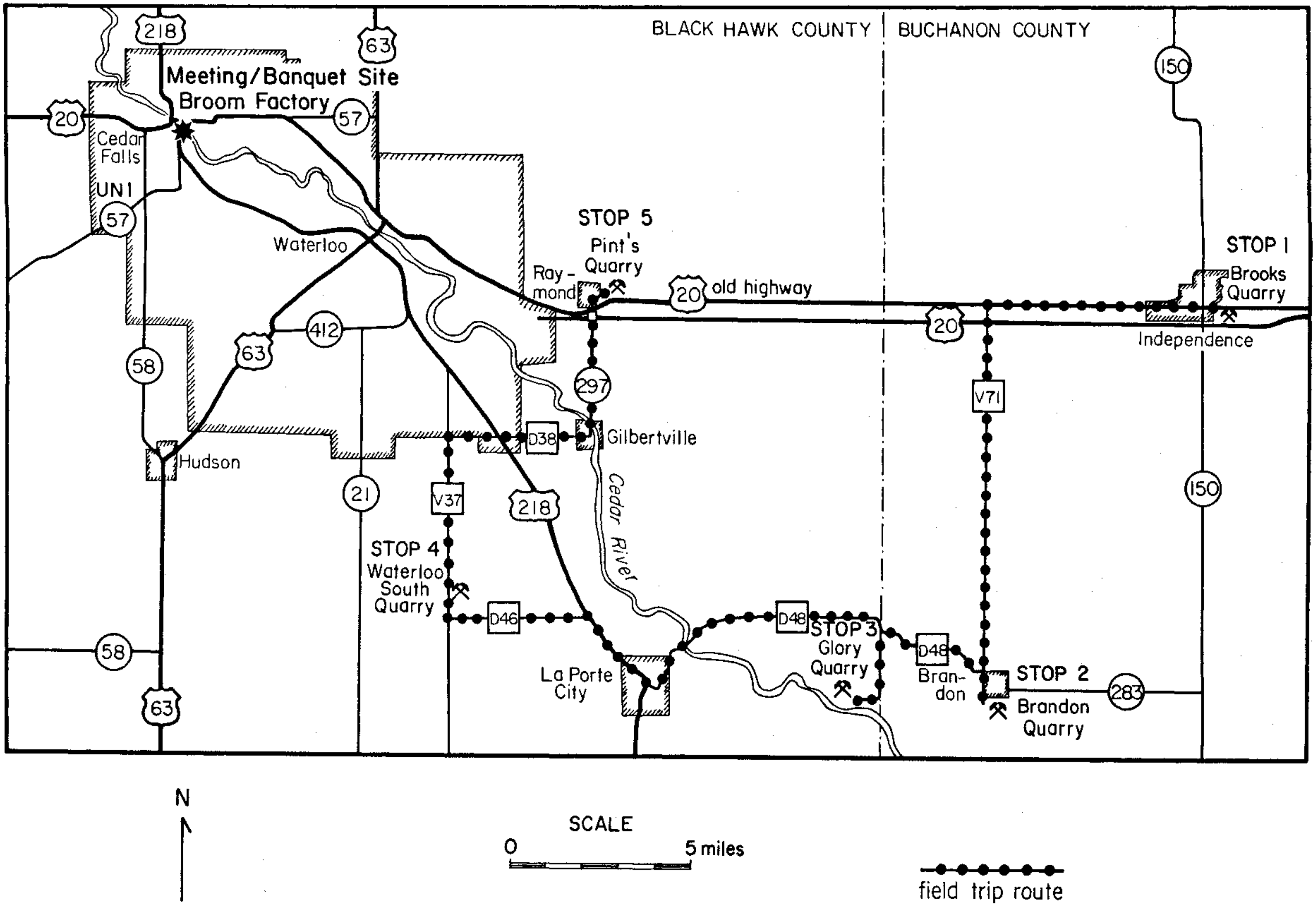

Figure 1: Location Map for field-trip stops.