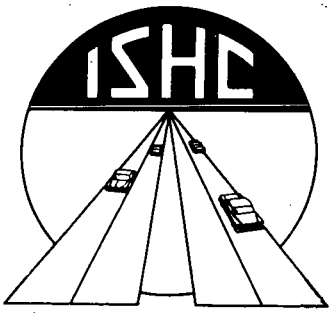
IOWA FIELD CONFERENCE ON "D"- CRACKING

NOV. 20 & 21, 1967



FOR BETTER HIGHWAYS

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IOWA STATE HIGHWAY COMMISSION
AMES, IOWA

MATERIAL SOURCE MAP
of
POSSIBLE HIGH-QUALITY AGGREGATES

Iowa State Highway Commission

1967

Newton (Coralville Member)

Otis (Otis Member)

Logan (Winterset)

71 Argentine

Menlo Argentine

Early Chapel Argentine

PORTLAND CEMENT CONCRETE SOURCES

▲ Quarry ◬ Limestone mine

● Gravel pit • potential source

● Sand pit • potential source

TYPE A ASPHALTIC CONCRETE SOURCES

▲ Quarry ◬ Limestone mine

1 - 5 (Stops with "D"-cracked pavement

Quarry names and (Argentine) geologic units

November 20, 21, 1967

IOWA FIELD CONFERENCE ON "D"-CRACKING

by

T.L. Welp, T.E. McElherne

INTRODUCTION

During the summer of 1963 the Materials Department noted the three to four year old concrete pavement on I-80 in Cass County was showing extensive surface cracking adjacent to joints and cracks. An examination of the pavement and a few cores from the cracked areas was made by the I.S.H.C. Materials Department and later by David Stark of the P.C.A.

Additional surveys were conducted on other concrete pavement made with coarse aggregate from similar rock from two different sources. Blue-line cracking was found on some primary pavement and the indications of incipient cracks were seen on I-29 in Pottawattamie County, north of Council Bluffs. A good "D"-crack pattern is now evident.

Surveys were then made of the entire Interstate concrete pavement. No other sections of Interstate were "D"-cracking, although some sections showed joint discoloration. None of these pavements, including the discolored sections, contained "D"-crack associated aggregates.

At the same time as the Interstate survey additional pavements and sources were checked. Some "D"-cracking was noticed on certain sections of primary pavement 5-10 years old, in the

vicinity of Waterloo and Cedar Rapids. The "D"-cracked pavement was from three aggregate sources, the Newton, Otis, and Burton Ave. quarries. Other pavements in this area that were older or from different coarse aggregate sources were not "D"-cracked. We believe that all the "D"-cracking is related, although dedolomitization is probably involved in the intermediate dolomite rocks.

NON "D"-CRACKED INTERSTATE I-80, I-29, I-35

Non "D"-cracked sections of these roads have now exceeded the age at which "D"-cracking was extensively developed on the Cass County section of I-80. The oldest sections have the same subgrade and pavement design as the "D"-cracked pavement. They also are laid on similar soil (Glacial Till) that is very poorly drained and there is an abundance of free water. At least seven different carbonate coarse aggregates have been used, and at least two gravels.

INTERSTATE "D"-CRACKING

Sections of "D"-cracked Interstate are confined to southwest Iowa and occur on: I-80, Cass County. Adair County line to Hwy. 71.

I-29, Pottawattamie County. Council Bluffs, north.

I-80 was paved with limestone coarse aggregate made from selected ledges in the Argentine Member. I-29 was paved with limestone coarse aggregate from selected ledges in the Winterset

Member. Both sources are Pennsylvanian in age.

GENERAL CORRELATIONS

The relationship between "D"-crack occurrences and distribution and the following variables has been investigated for all "D"-cracked pavement.

1. General soils classification and ground water conditions.
2. Cut vs fill sections.
3. Brand and approximate composition of cements.
4. Source of the fine aggregate.
5. Daily paving record, temperature, breakdowns, etc.
6. Quarry variations.
7. Aggregate variations in the pavement, pattern of failure.
8. Aggregate production record. F&T "A", Abr. Chemical composition, Mineralogy, etc.
9. Subgrade design & pavement design on main line vs ramp section.

STOP 1.

Stop 1. will include; first, a visit to the Menlo Quarry, several stops along I-80, from the Cass-Adair County line to the Jct. of U.S. 71, and a stop on U.S. 71.

Year Built, 1959 & 1960

Coarse Aggregate	Argentine Ls., Menlo Quarry
Fine Aggregate	Sand from Coon River - near Des Moines
Cement	Penn Dixie - Marquette and Ash Grove
Air Entraining Agent	Ad-Aire
Subbase	Crushed Stone or Sand & Crushed Stone
Subgrade	Glacial Till
Slab Thickness	10" Uniform, Sawed & Doweled Joints 76.5'

Subbase placed in trench, essentially slab edge to slab edge. See design sheet. (Note: New design is shoulder to shoulder.)

2 mil polyethylene film at the top of the granular subbase. Cores indicate film is still intact.

Steel Mesh	612-00/4 = 2-1/2" Nominal Depth below top. Cores indicate proper placement

Concrete placed in 2 lifts

FIELD NOTES

STOP 1.

I-80, ARGENTINE STONE (MENLO QUARRY)

GENERAL CORRELATIONS

Items 1, 2, and 3, appeared to be related to the severity of "D"-cracking at some locations. However, enough contradictions were found to indicate that as long as free water was available the "D"-crack intensity was not directly related to any one of the items. Items 4-8 have no significant correlations.

For item 9, "D"-cracking occurred on all pavements with or without granular subbase, a polyethylene film, with and without wire mesh reinforcing, and with 76 foot and 20 foot joint spacing. "D"-cracking is also occurring on other projects, built by different contractors at different times and with Argentine stone from different quarries.

ARGENTINE STONE (MENLO - EARLY CHAPEL - HWY 71 QUARRIES)

This is a brief report comparing the concrete ledges of the Argentine rock in Adair-Madison Counties with the Argentine at the quarry site south of Atlantic in Cass County. Aggregate from these quarries and the Logan quarry was used in Hwy. 34 in Mills, Montgomery, and Adams Counties.

Chemical & Mineral Composition

Adair-Madison: In Madison and Adair Counties this rock has 50% or better calcium oxide content on 100% of the seven samples taken. The magnesium oxide content is less than 1.0% on all samples. Silica and alumina together range from 4.0% to 7.0%.

The stone in this area is essentially a limestone with minor amounts of chert, quartz, and clay.

Cass Co.: The upper 1/2 of the ledge (bed 4c) in this area contains about 4% magnesium oxide. This would be about 15% dolomite content. Dolomite rhombs are easily identified in thin sections 4027-4029. The lower half of the ledge (bed 4d) is similar to the concrete ledge in Adair-Madison Counties.

Specific Gravity and Absorption

Adair-Madison: The specific gravity of the fresh stone at the Menlo quarry generally is between 2.64 and 2.66. Over a three year period 19 out of 29 tests are within this range. The absorption averages a little over one percent. Over a three year period, 11 out of 18 samples are between 0.5 and 1.5 percent absorption.

The Early Chapel quarry runs a little lower on specific gravity 2.60-2.63. Specific gravity is generally lower and absorption higher for weathered rocks.

The highest absorption recorded is 4.30 percent on a sample of extremely weathered rock.

Cass Co.: The one sample taken, so far, indicates that the specific gravity of this stone will be about 2.61 and the absorption is the 0.5-1.5 percent range, very similar to the rock in the Adair-Madison County area.

Abrasion

Over 100 tests are between 26 and 33% loss.

Freezing and Thawing Tests in Water-Alcohol Solution

Adair-Madison: Forty-four blockstone samples have been taken

from Schildberg's Menlo quarry. Of this number, three tested over 6% loss. Resamples, in the same area as the original failures, tested less than 6% loss. Average of all tests less than 6% loss is 3.5%. The high was 6.7 and the low 1.9 percent loss.

For crushed stone at Menlo, 97% passed (96 out of 99), at Early Chapel, 96% passed (92 out of 94). The average of all the tests was a little over 3.5. The high was 6.7 and the low was 1.9.

On this basis, we would expect not less than 96% of all samples of the Argentine Stone in the Adair-Madison area to meet specifications when produced from an area where 100% of the blockstone samples meet specifications.

Cass Co.: In the general area considered for quarrying, 85% (12 out of 14) samples tested less than 6%. On a bed-by bed basis, 75% (3 out of 4) were less than 6%. The average loss was 4.3%.

Petrography

Petrographically, except for the dolomite content in bed 4c at the Atlantic quarry site the Argentine rock in Cass County is very similar to the Argentine rock in Adair-Madison Counties. The rocks are similar in texture and exhibit several features in common. (see photo-micrographs).

STOP 2.

I-29 - Council Bluffs north to Missouri Valley

Year Built, 1958

Coarse Aggregate	Winterset Ls., Logan Quarries
Fine Aggregate	Platte River, Nebraska Sand
Cement	Ash Grove
Air Entraining Agent	Ad-Aire
Subbase	Crushed Stone and Fine Sand
Subgrade	Loess and Sand Fill

2 mil Polyethylene film at top of subbase

Subbase and Pavement design - same as I-80

FIELD NOTES

STOP 2.

I-29 AND WINTERSET STONE

GENERAL CORRELATION

"D"-cracking became apparent on this section of highway about two years later than on I-80, althouth it is a little older than I-80. We do not have any direct explanation for this. However, I-29, in general, has a loess subgrade and the quality of the rock may be more resistant to failure.

With the exceptions of time of occurrence and degree of severity, all conclusions for general correlations under I-80 apply to I-29.

WINTERSET STONE (LOGAN QUARRY)

Aggregate referred to as Logan stone is produced from selected ledges in the Winterset limestone at two quarries near Logan, Iowa. A typical tabulation sheet is attached.

Chemical and Mineral Composition

The rock has a 51% or better calcium oxide content on several samples from each bed and will generally average about 52+%. Silica, alumina, and MgO, generally total less than 5 percent.

The rock is a calcite limestone with minor amounts of chert, quartz, and clay.

Specific Gravity and Absorption

The average specific gravity of over 50 samples for the two quarries is generally between 2.625 and 2.650. Over a two year period 54 out of 58 were within this range. Occasionally it has

dropped to 2.61 and has risen as high as 2.66. Twenty-eight of the 54 tests were 2.63.

The absorption averages about 1.3. Over a two year period 38 out of 40 tests were between 1.0 and 1.5% with a high of 1.9 and a low of 0.95.

Freezing and Thawing Tests (16 Cycle Water-Alcohol)

Over 40 blockstone samples have been taken from the ledges used for concrete since 1956. 100% of these samples were less than 6% loss. The average of these tests is about 2.7% loss. The high was 5.9 and the low 0.9 percent loss.

For tests on the finished product over a four year period, 299 tests of 301 tested less than 6 percent loss. Over 250 of these tests had less than 2.5% loss. The highest test value was 8.2 and the lowest test value 0.5.

On these bases we expect 100% of the ledges to meet requirements and at least 99% of the routine samples to comply.

Abrasion

An average of 30 with most tests between 28-32.

Petrography

The rock is very similar to the Argentine, is 50 to 80 percent microcrystalline calcite with minor amounts of coarse grained calcite islands and stringers. (See photo-micrographs).

"D"-CRACKING WITH INTERMEDIATE DOLOMITES

The second part of this field conference is to show additional "D"-cracking that we believe is related to that which we have encountered on our Interstate, even though the Interstate was made with significantly different carbonates.

"D"-cracking of these pavements has been associated with intermediate or variable dolomite content rocks from the Devonian and Mississippian age formations.

In the late 1930's and early 1940's "D"-cracked and disintegrating pavement was associated with stone produced from the Maynes Creek Member of the Hampton Formation at the town of Le Grand.

In the late 1950's concrete made with the Otis Member of the Wapsipinicon Formation began to show a "D"-crack pattern and associated blow ups.

In 1964 "D"-cracking was noticed on pavement made with an aggregate from the Coralville Member of the Cedar Valley Formation from quarries near Waterloo. This stone had been used in the early 1940's. Pavements made during that period with this aggregate were not, and still are not, showing any significant "D"-cracking.

These aggregates all met modern specifications and did not appear to be significantly different in any property parameter except one from all other acceptable aggregates with satisfactory service records. The major difference between these aggregates and the satisfactory service rocks appeared to be in the mineral composition of the rock. These were rocks that were dolomitic limestones or calcitic dolomites.

A review of the sources with more than 20 years of service showed that almost all the satisfactory service had been obtained with rocks with less than 5% or more than 16% MgO contents. Satisfactory service was also obtained with aggregates that were a mixture of limestone and dolomite that occurred in the working face as separate and distinct rock types.

Service records with a wide variety of intermediate dolomites are limited. Only a few were used before the late 1950's and with the exception of the Waterloo area stone the pavements all developed "D"-cracks when the concrete was between 5 and 15 years old.

AVAILABLE INFORMATION

A detailed report on Iowa's experience with carbonate aggregates and the intermediate dolomite problem is presented in Highway Research Record Number 45, 1964. Additional references that present the majority of the published data on the Iowa problem are in the appendix.

STOP 3.

U.S. 218 in the Town of Washburn and Pints Quarry or Newton Quarry, if time permits.

Year Built, 1953

Coarse Aggregate	Coralville Ls., Newton Quarry
Fine Aggregate	Cedar River Sand, Waterloo
Cement	Dewey
No Subbase	
Contraction Joints	16-1/3' dowelled - Mastic
Subgrade	Glacial Till or laid on old concrete
Slab Thickness	10" - Somewhat less on overlay

FIELD NOTES

STOP 4.

U.S. #20 - West of Jesup in Black Hawk County

Year Built, 1957

Coarse Aggregate	Coralville (Pint's) 36-89-12W, Black Hawk Co.
Fine Aggregate	Conc. Mat'ls 16-89-13, Black Hawk Co.
Cement	Lehigh and Penn-Dixie
Air Entraining Agent	Presstite
Pavement	24' wide, 10" thick
Center Joint	1-1/2" Sawed
Contraction Joints	1-1/2" Sawed on 20' spacing

STOPS 3 & 4.

U.S. 20 & 218, NEWTON STONE (CORALVILLE MEMBER, CEDAR VALLEY FORMATION, WATERLOO AREA)

Problems with the Le Grand and Otis stones and the related research has been reported previously. This is the first report of "D"-cracking associated with the Newton stone.

Very small diagonal interior corner cracks were first observed in 1964 on seven year old concrete. Subsequent surveys on all known pavement with this aggregate gave the following information.

1. A 13 year old pavement with this aggregate was extensively "D"-cracked in some sections and less severely "D"-cracked in others. The degree of "D"-cracking was related to the pavement design. Most severe cracking was in sections where the new concrete was placed on top of older sound concrete less severe cracking occurred were pavement was in contact with the dirt subgrade.
2. Pavements built in the 1940's were still in very good condition with no "D"-cracking in evidence. Cores taken on a study of these pavements showed that the aggregate was fractured in the "D"-cracked pavement but not in the non "D"-cracked pavement.
3. The aggregate in the projects came from exactly the same stratigraphic horizon in the Coralville Member from two quarries, ten miles, or so, apart.
4. Pavement made with aggregate from the Solon Member of the Cedar Valley looked like it too was beginning to "D"-Crack. However, this has not been investigated

as yet.

The Newton stone is a 40 to 60 percent dolomite rock with very uniform properties. The specific gravity is about 2.65 to 2.68, absorption of about 1.5, and an average freeze-thaw loss of about 2.5%.

STOP 5.

U.S. #150 - West of Marion

Year Built, 1958

Coarse Aggregate	Otis Stone, 1-83-7, Linn Co.
Fine Aggregate	Hennessey Bros., 11-83-7, Linn Co.
Cement	Penn-Dixie, Lehigh & Marquette
Air Entraining Agent	Protex
Pavement	24' wide, 10" thick
Center Joint	Parting Strip; 1/2" x 36" tie dowels on 30" spacing
Contraction Joints	1-1/2" Sawed

STOP 5.

U.S. 150, OTIS STONE (OTIS MEMBER, CEDAR VALLEY FORMATION)

This stop will be made only if time permits. The Otis is a Calcite Dolomite, 60-80% Dolomite.

GENERAL RESEARCH

Research studies have been conducted on both the rock and the concrete rock system by the Iowa State Highway Commission and by research contracts sponsored by the Commission.

This research has been conducted on over 50 carbonate aggregate sources. About 40 of these are completely satisfactory for service lives of up to 45 years.

The test data have not been completely summarized and analysed and are far too extensive to list in this report. However, it is appropriate to list the properties that have been extensively investigated for both the good and bad aggregates.

When the same properties are determined for a wide variety of different carbonate rocks the parameters of the good overlap the parameters of the bad.

A few examples of the parameter ranges are listed below:

Specific Gravity	2.55 to 2.7	Some as low as 2.5 but no long record
Absorption	0.5 to 9+%	Correlation Coef. with $NaSO_4$ .266
Freeze-thaw loss	0.5 to 5.5%	
Sodium Sulfate	2.0 to 56	Correlation Coef. with F&T "A" .08
Alkali Expansion	0.0 to -.21%	Nearly all samples shrink
De-dolomitization		Nearly all dolomites de-dolomitize
Porosity	1.0 to 29.4%	
Permeability	1.0 to 170 MD	
Specific Surface	0.1 to 5.+ square meters per gram	
Chemical and Mineral		Usually pure ls. or dol. Less than 5.% insol.
Petrography	.5 to 95%	Microcrystalline matrix

Concrete Properties

Compressive Str., PSI	28 days, 4500 to 6000+; 1 year, 5000 to 7000 3 years, 6000 to 8000 No significant correlation to source or 5 to 7% air content
Durability Factor	7 to 99 90 day moist cure before testing Correlation Coef. with str. 28 days .66 1 year = .41; 3 year = .44

Two element statistical analyses do not give sufficiently good correlation coefficients for any of the variables to account for, or predict, any of the properties of the concrete or the durability, except for the durability factor determined after a 90 day moist cure. So far, most of the poor aggregates have a low durability factor. However, about 30 percent of the good aggregates have low durability factors but perform satisfactorily.

CONCRETE AGING STUDIES

For a number of years, Dr. John Lemish, Iowa State University, has been studying the concrete systems that are acquiring progressive age. At the present time these studies seem to offer some significant progress toward understanding the changes taking place in both good and poor concrete. This information should be useful in predicting service life when pavements are still very young.

APPENDIX

1. List of References
2. Pavement Design Sheet
3. Menlo Quarry Column
4. Photomicrographs of Argentine Stone
5. Geologic Column of Logan Quarry
6. Tabulation of Test Results, Logan Quarry
7. Photomicrographs, Logan - Newton
8. Geologic Column, Pint's Quarry

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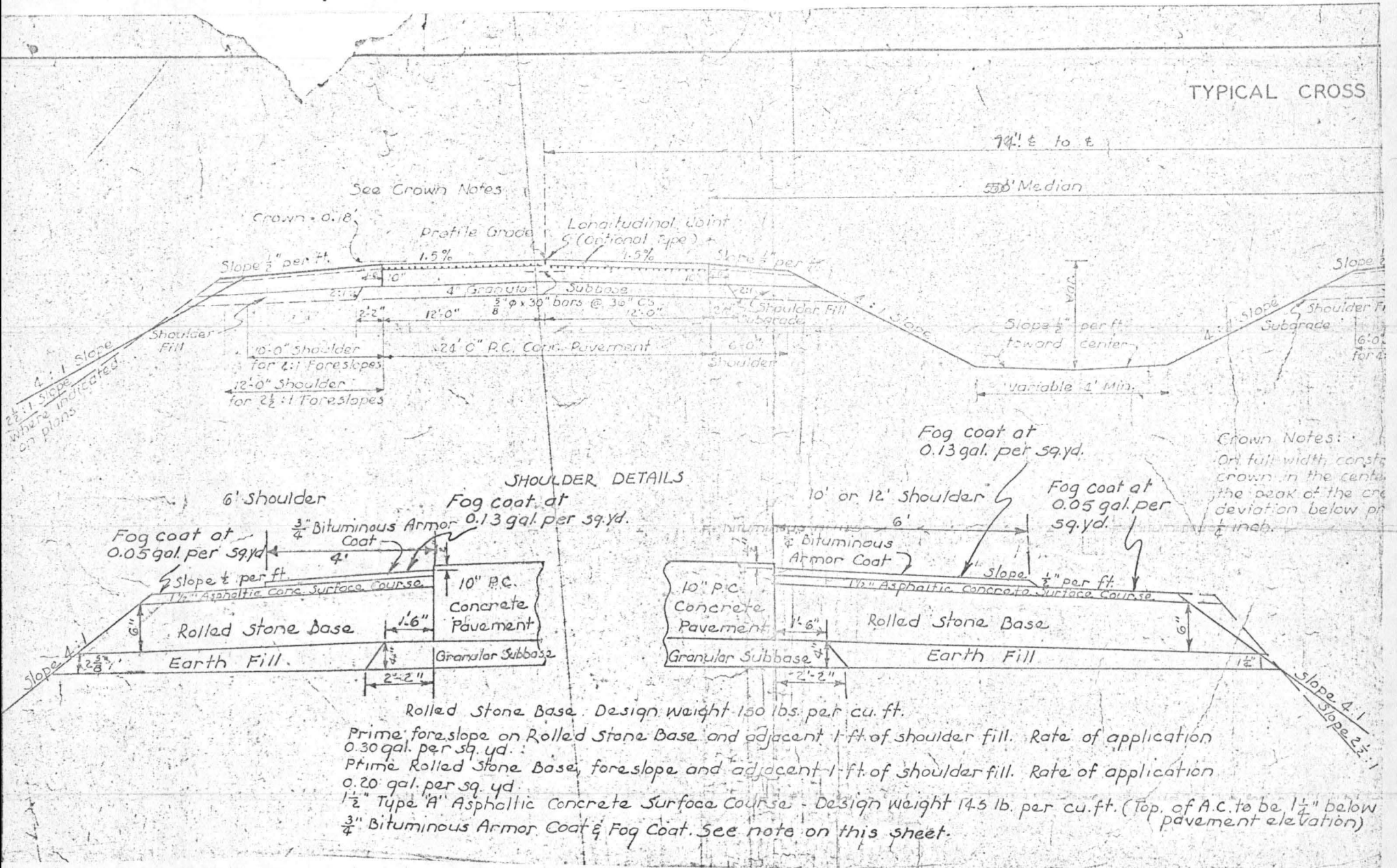
TYPICAL CROSS



SHOULDER DETAILS

6' Shoulder

Fog coat at 0.05 gal. per sq.yd.

¾" Bituminous Armor Coat

Fog coat at 0.13 gal. per sq.yd.

4'

Slope ¼" per ft.

1½" Asphaltic Conc. Surface Course

10" P.C. Concrete Pavement

6"

Rolled Stone Base

1'-6"

Granular Subbase

Earth Fill

2'-2"

Slope 4:1

Slope 2⅝:1

Crown Notes:

On full width constr
crown in the cente
the peak of the cr
deviation below pr
¼ inch.

Rolled Stone Base. Design weight 150 lbs. per cu. ft.

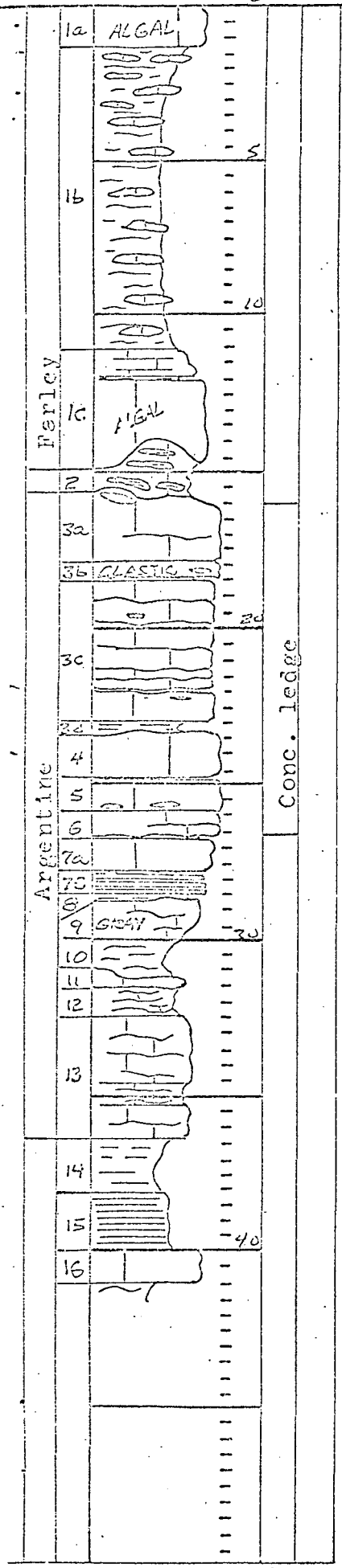
Prime foreslope on Rolled Stone Base and adjacent 1 ft. of shoulder fill. Rate of application 0.30 gal. per sq. yd.:

Prime Rolled Stone Base, foreslope and adjacent 1 ft. of shoulder fill. Rate of application 0.20 gal. per sq. yd.

1½" Type "A" Asphaltic Concrete Surface Course - Design weight 145 lb. per cu. ft. (Top. of A.C. to be 1¼" below pavement elevation)

¾" Bituminous Armor Coat & Fog Coat. See note on this sheet.

Iowa State Highway Commission



Location: SE¼ Sec. 17 T. 77N R. 31W Co. Adair
Schildberg Rock Prods. Menlo Quarry
Remarks: Additions to Welp's 6/15/61 Sec. (bed nos. the same)
Measured by: Dirks Date: 2/28/66

Bed:	Description	Thk.
00:	Overburden-Sand-Loess-Till	
1a.	Ls., tan to greenish, algal clastic	0-1.3'
1b.	Shale, greenish-gray, contains numerous tan, fine grained limestone nodules.	0-9.7'
1c.	Ls., gray-tan, algal clastic, Massive top 1.0' may grade to greenish, very argillaceous limestone.	1.5-4.1
	Island Creek?	
2.	Ls., rubble, contains abundant green shale.	0.4-3.9'
	Argentine 18-20'	
3a.	Ls., tannish-gray, sublithographic to medium crystalline, massive to bedded, contains some dark chert, grades from Bed 2.	2.0-2.4'
3b.	Ls., tan to brown, algal clastic, may contain chert, a distinctive marker in quarry.	0.3-0.6'
3c.	Ls., tannish-gray to red-brown; sub-lithographic to medium crystalline, thin wavy beds, contains some dark chert, distinctively leached and oxidized in zones, may have shale band 1.0 to 1.7' above base.	3.5-5.0'
3d.	Shale, green, soft. (Beds 4 through 6 generally occur as one unit 40" thick).	0.1-0.4'
4.	Ls., tan to brownish-gray, sublitho-graphic to medium crystalline, has shale parting at base.	1.0-1.3'
5.	Ls., similar to Bed 4, as one bed	0.9-1.3'
6.	Ls., similar to Bed 4, massive to thin bedded, has distinctive shale band at base	1.0
7a.	Ls., tannish-gray, fine grained, generally as one bed.	0.8-1.1'
7b&c.	Ls., tan to gray, fine grained, as two or three beds with argillaceous zones on bedding planes.	0.4-0.6'
8.	Shale, olive to dark gray, calcareous.	0.1-0.3'

Iowa State Highway Commission

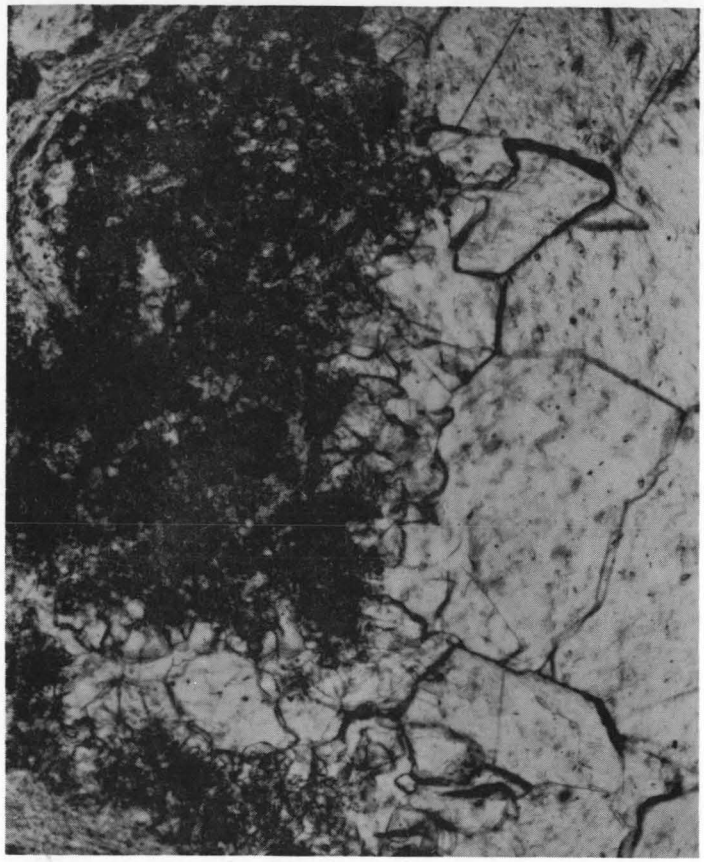
Location: _____ Sec. ____ T. ____ R. ____ Co. _____

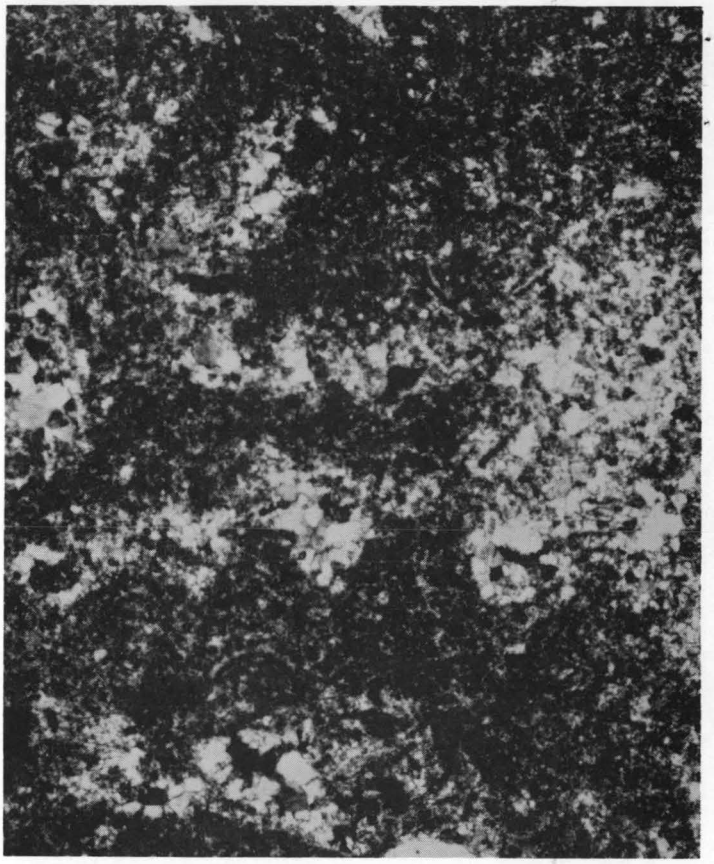
Remarks: _____

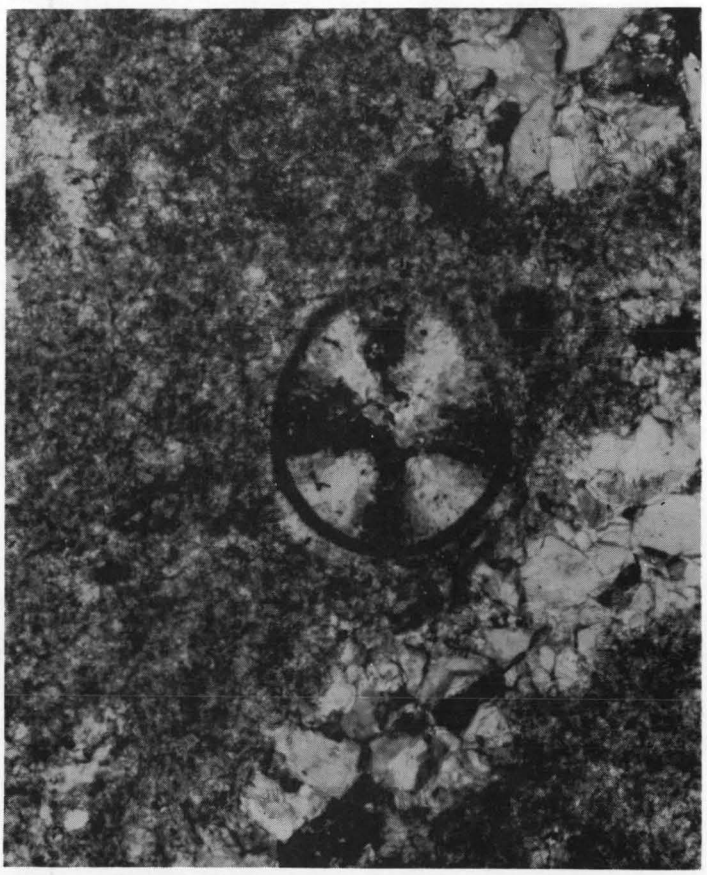
Measured by: _____ Date: _____

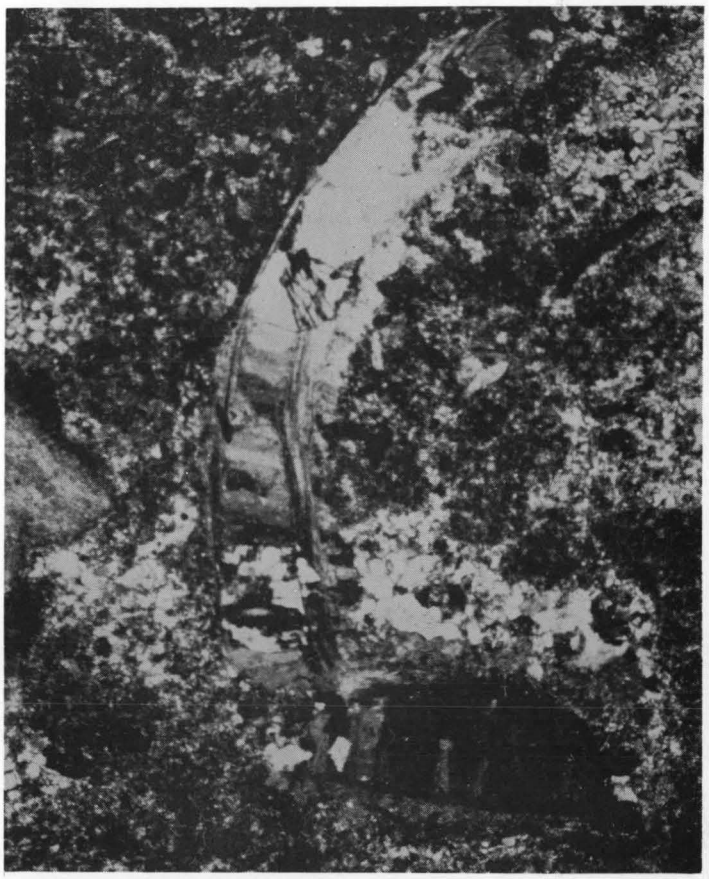
Bed:	Description	Thk.
	Page 2	
9.	Ls., gray, fine grained, argillaceous	1.0-1.7
10.	Shale, greenish to dark gray	0.8-1.5
11.	Ls., blue-gray, fine grained	0-0.5'
12.	Shale, gray, calcareous	0.8-1.2'
13.	Ls., gray, fine grained, very argillaceous	2.6-4.0
	Quindaro	
14.	Shale, gray to dark gray	
15.	Shale, black, fissile	1.7'
	Frisbie	
16.	Ls., blue-gray, fine grained	0.7-1.0'

Photomicrographs of Argentine Stone

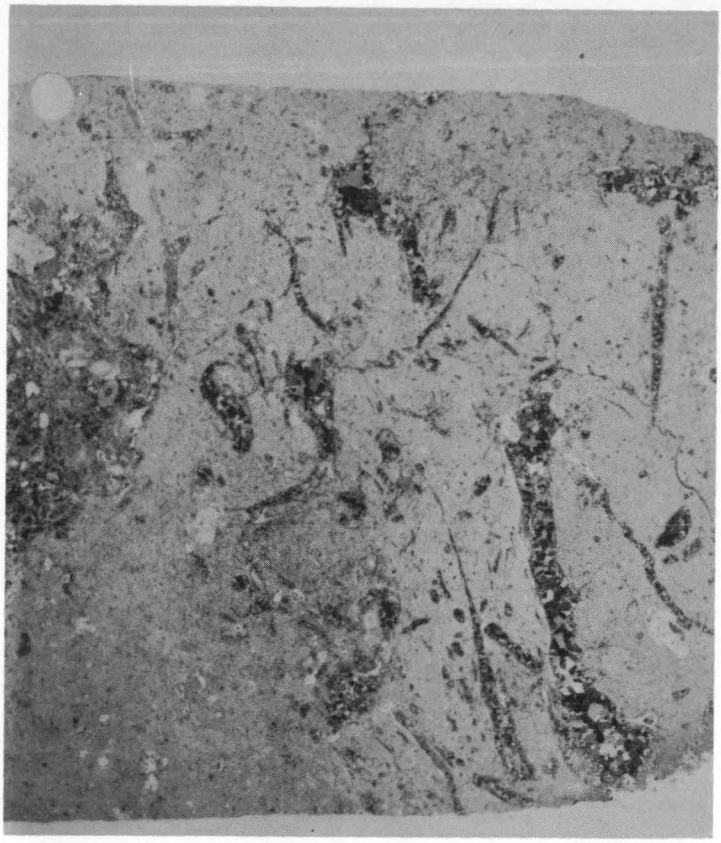


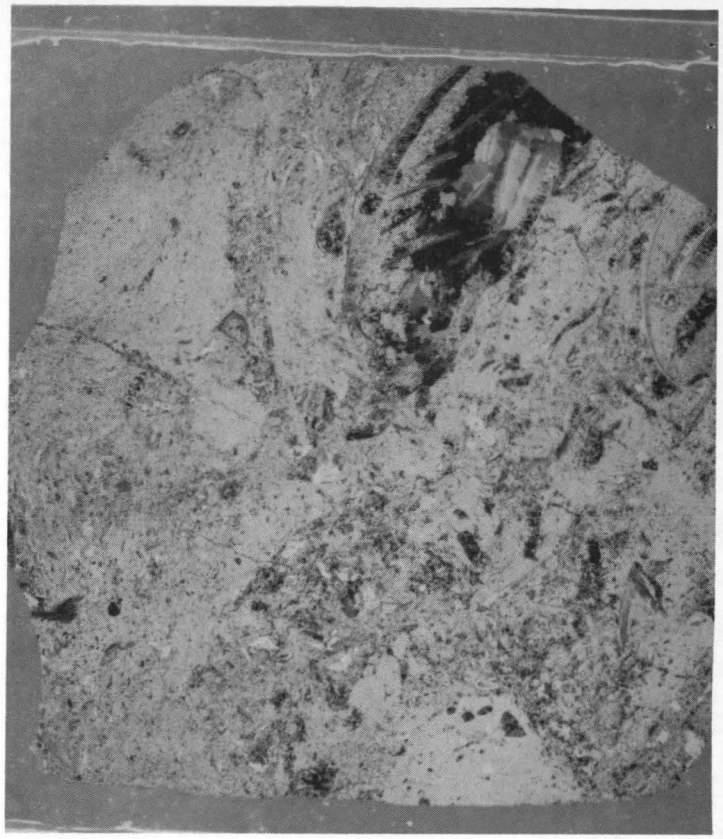


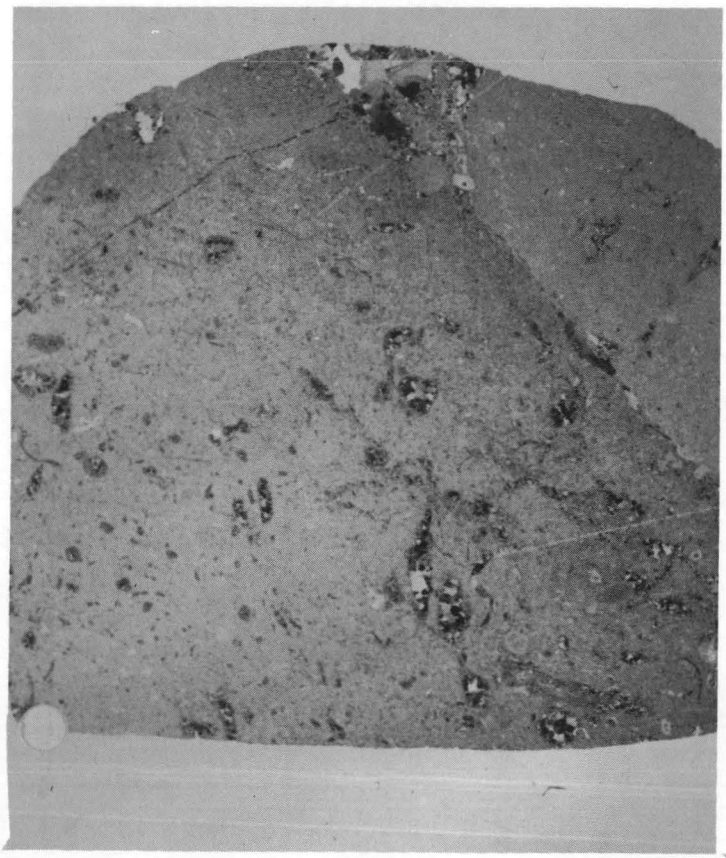


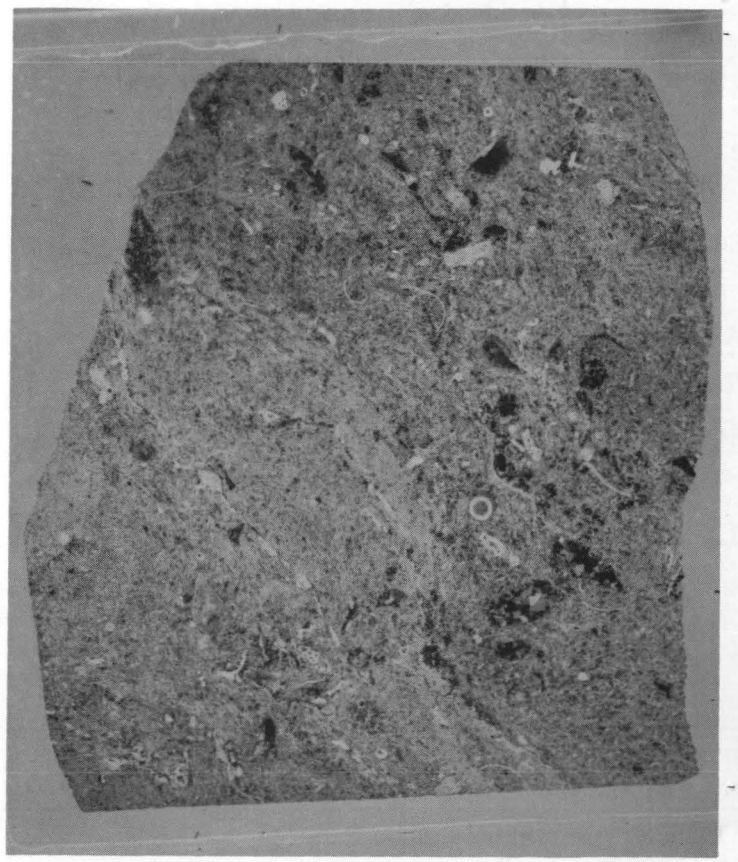


Photomicrographs of Argentine Stone





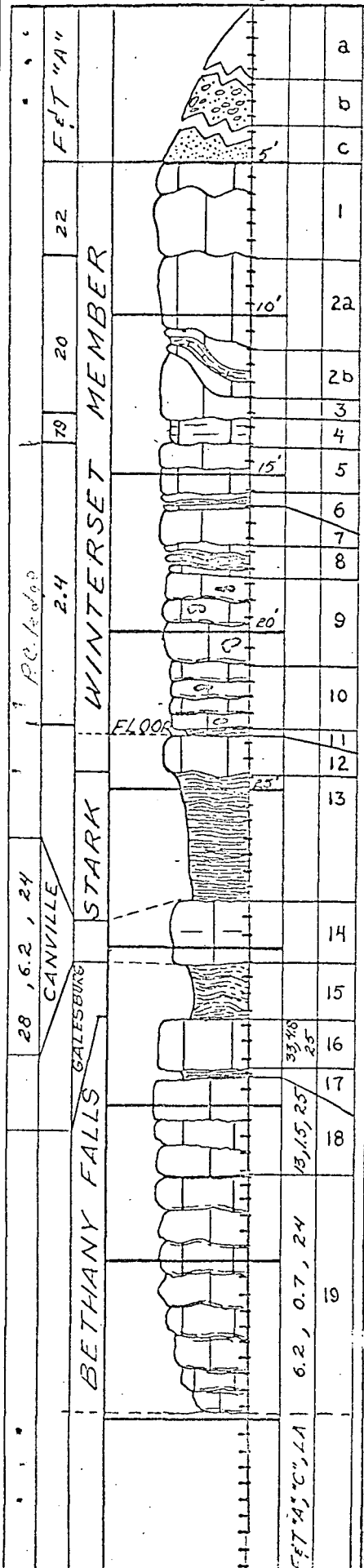




GENERAL GEOLOGIC SECTION TO BE USED IN THE FOLLOWING 3 ARTICLES
(1) CLARK'S "SOUTH" QUARRY (2) CLARK'S NEW NORTH QUARRY NE¼ 17-79-42
(3) SCHEMMER'S "UPPER" QUARRY SE¼ 18-79-42 KLD. 5/22/64

Iowa State Highway Commission

P. G. Kratzke
Producer
Field Book



Location: SE 1/4 NE 1/4 Sec. 19 T. 79 R. 42 Co. Harrison
Clarks new Logan Quarry South of highway
Remarks:
Measured by: Michael, Dirks, Jones Date: 9/10/57

Bed:	Description	Feet : Thk.
00:	Overburden: +70'	
	a. Loess	+50'
	b. Gravel	±15'
	c. Fine gray sand	±7'
	Winterset Limestone Member 14'-21'	
1.	Ls.; buff to brown; weathered on top; hard; wavy bedding with sh. partings; bottom very irregular.	1.5-3.0'
2.	Ls.; g ray: ±4.0	
2a.	Ls.; gray; hard; as one massive bed; pominent in quarry	1.5-3.0'
2b.	Ls.; dark gray; argillaceous; as two beds with calcareous sh. parting; unit may pinch out to just a parting or may thicken out and be undistquishable from No. 2a.	.4-1.5'
3.	Ls.; prominenet cream colored; hard; as one massive bed.	1.-2.2'
4.	Ls.; gray; very argillaceous; soft; forms reentrant on face; as one massive bed.	.8-0.9'
5.	Ls.; dark gray; fine grained; hard; as two even beds.	1.5'
6.	Ls., sh., ls., dark gray argillaceous ls. between two black calcareous shales.	.1-0.4'
7.	Ls.; gray; fine grained; hard; as one massive bed.	1.-1.3
8.	Ls.& Sh.; dark gray; thin bedded ls. beds separated by gray sh.; a discontinuos chert band occurs near middle of unit; bottom very irregular.	.6-1.0
9.	Ls.; dark gray; hard; as three even beds with shale separations; black fragmental chert.	2.7'
10.	Ls.; dark gray similar to bed No. 9; beds average 0.5' thick; some black chert.	2.0'
11.	Sh.; gray, calcareous.	0.1'
12.	Ls.; dark blue gray; medium grained; one massive bed; easily recognized; hard; very fossiliferous, blue brachiopods. Top of bed is quary floor.	1.0'
	Stark Shale Member	
13.	Sh.; gray; soft.	± 4.0'

Bed No. 12 correlates with Bed No. 11 of 6/12/56 Geologic section of Schemmer's quarry.

Dy. Geology
P. G. Kratzke
Field Book

Iowa State Highway Commission

Location: SE¼ NE¼ Sec. 19 T. 79 R. 42 Co. Harrison
Clark's New Logan Quarry
Remarks: Addition to 9/10/57 Geol. Sec.
Measured by: D. Jones Date: 11/17/57

Bed:	Description	Feet : Thk.
	Canville limestone member: 2.0'	2.0
14.	Ls; gray; soft; almost a shale; massive.	
	Galesburg shale formation: 1.7'	1.7
15.	Sh; greenish gray; fissile; wavy undulating bedding.	
	Swope formation:	
	Bethany Falls limestone member:	
16.	Ls; light brown; hard; algal; massive; good index bed.	1.5
17.	Sh; greenish gray; soft.	0.2
18.	Ls; light gray to buff; hard; 3 main beds.	± 3.0
19.	Ls; similar to bed No. 18; massive with random shale partings; becomes softer and more shaley toward bottom.	± 7.5

12-19

IOWA STATE HIGHWAY COMMISSION
MATERIALS DEPARTMENT

Summary of Crushed Limestone Tests

PRODUCER 1965

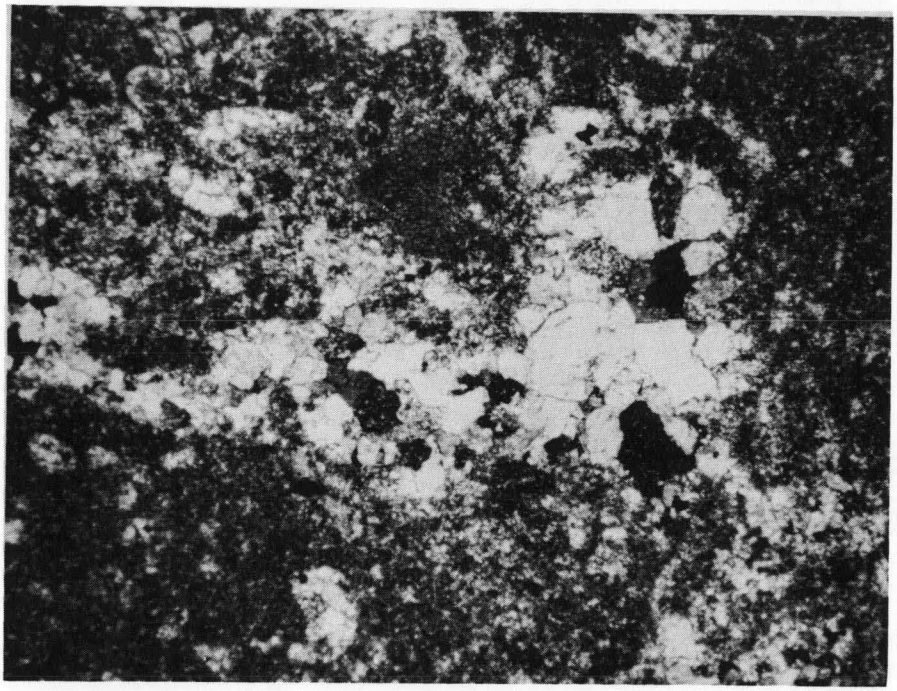
QUARRY NAME Clark's Logan Quarry

LOCATION NW¼ SEC 17 TWP 79 R 42 CO. Harrison Co.

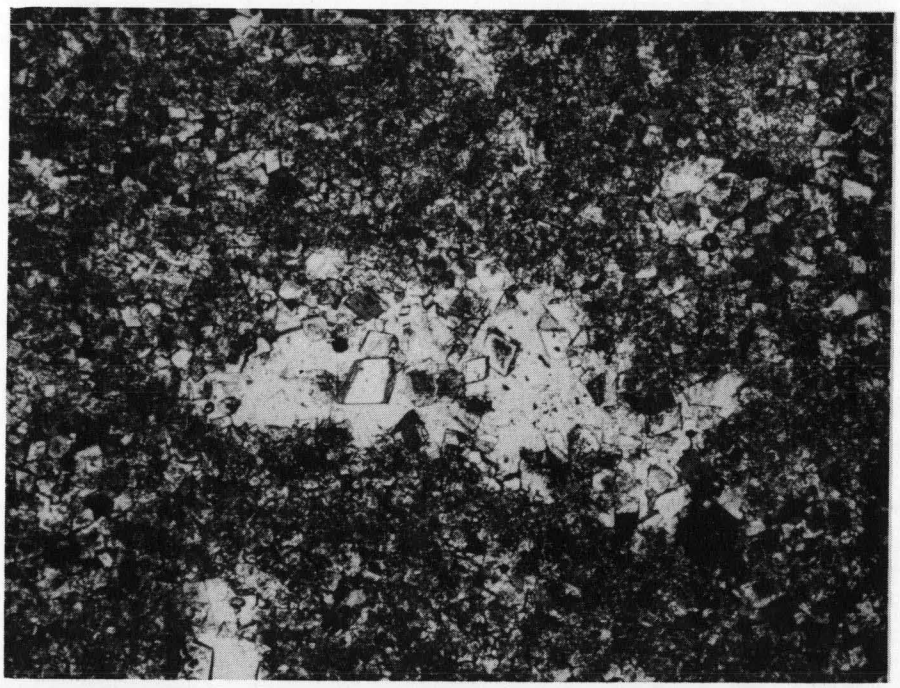
GEOLOGIC SECTION BED NO.

BEDS 1965 remarks	DATE	lab. no. AAR5-	abrasion	fat A	fat C	sp. gr.	absorption	proc. den.	p. i.	% solids
Winterset Ledge	11/15-16/65	429	B 31		3.8					
1-4 2 days run 2000 T.		AAC5-								
Winterset Ledge 1" 2 days run		22	B 31	1.8		2.632	1.60			
5-10 Same Geo.Sec. 100% pass										
1500 T.	4/20-21									
Winterset Ledge 3000 T.	5/24-27	87	A 33	1.7		2.649	1.33			
5-10 Same Sec. 2 days run										
" " " " "	5/28-30	88	A 28	2.5		2.635	1.70			
3 days run-4000 T. rest the same										
as above	6/7-9/65	97	A 32	2.2		2.625	1.60			
Winterset Ledge 4000 T.	5/31-6/3	99	A 30	2.0		2.625	1.30			
5-10 Same Geo Sec 3 days run										
2 days run 3000 T. 100% psg.1"										
rest the same as above	6/19,21/65	124	B 30	1.1						
" " " " "	6/10-14	125	A 30	1.6		2.639	1.23			
Stock at jobsite	6/24/65	144	A 30	2.2						
Winterset Ledge 3000 T.	6/16&23	154	A 32	1.7		2.618	1.83			
5-10 Same Geo Sec. 2 days run										
" " " " "										
	6/24-25/65	156	A 31	2.0		2.646	1.50			
2000 T. rest the same as above										
	6/29-7/1/65	167	B 30	2.2		2.628	1.35			
3000 T. rest the same as above										
	7/7-8/65	169	A 31	2.0		2.611	1.75			
" 2 days run "	7/1-2/65	171	A 30	1.9		2.626	1.48			
2000 T. the rest is the same as										
those above	7/6-7/65	173	B 31	2.1		2.630	1.38			
" " "	"7/9-10/65	179	A 31			2.611	1.93			
" " "	"7/9-10/65	180	B 31	2.9		2632	1.75			
2500 T. the same as above	7/15-16	194	B 30	1.8		2.639	1.35			
3000T. the rest as above	7/15-	195	A 30	2.9		2.626	1.53			
Winterset ledge 2500 T.	7/13-14	196	B 31	2.2		2.639	1.30			
5-10 Same Geo Sec. 2 days run										
Tri-Center Ready Mix	7/20/65	200	B 29	1.7						
Stockpile	7/20/65	201	B 32	2.1						
Ready Mix-Harlan, Ia.	7/29/65	203	B 28	1.9						
On jobsite	7/21/65	204	A 43	1.8						
Winterset Ledge 3500 T.	7/17&21/65	216	A 31	0.9						
5-10 Same Geo Sec. 2 days run										
Winterset Ledge 3000 T.	7/20-21/65	217	B 30	2.3		2.637	1.40			
5-10 Same Geo Sec 2 days run										
2 days run-3000 T. & the	7/22-23/65	218	A 30	1.6		2.618	1.50			
rest is the same as above										
Stock-Clark Ready Mix-Tri-Center	7/25/65	226	B 28	1.7						
CK Tri-Center Ready Mix	20/65	229	B 32	1.3						

Photomicrographs



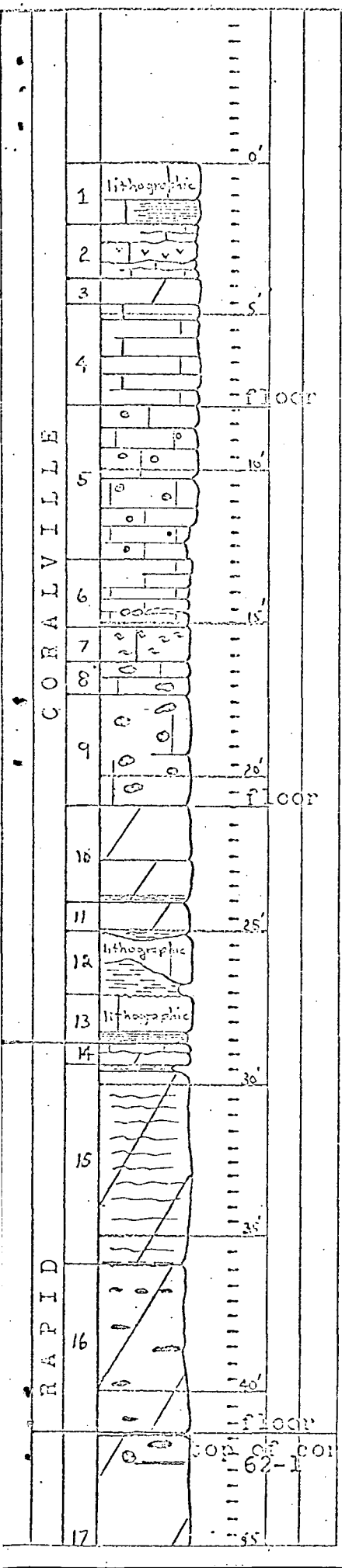
Logan



Newton

Myers' 10/11/66 Revision
Described thru Bed # 24.
in the quarry.

Iowa State Highway Commission

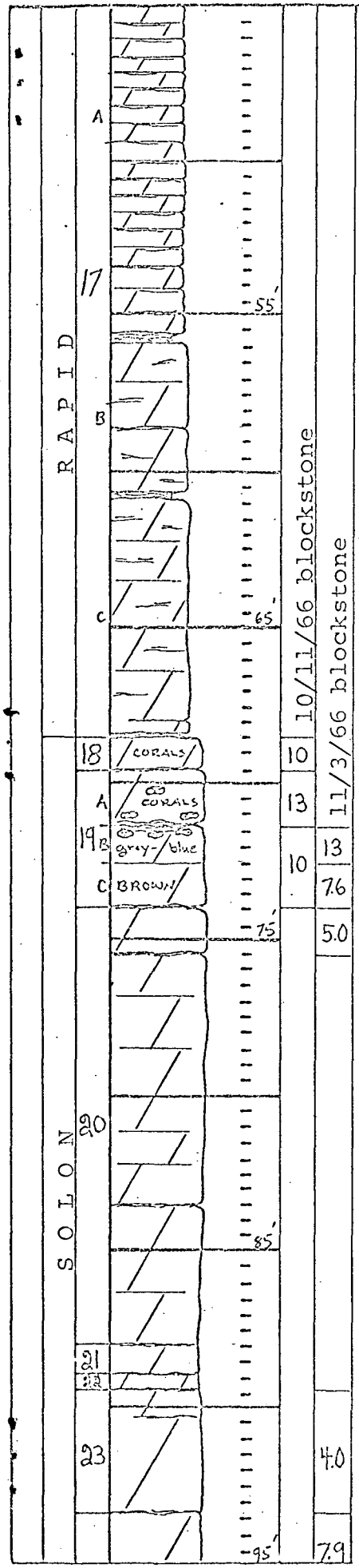


Location: SW¼ Sec. 36 T. 89 R. 12 Co. Black Hawk
Pint's quarry and cove - Lowe & Eschman Const. Co.
Remarks: Measured to floor where core was drilled in bed #7
Measured by: Myers Date: 5-28-62

Bed:	Description Revised 5/16/66	Th
Formation:	CEDAR VALLEY	
Member:	Coralville	
1.	Limestone; brown, pinkish; lithographic; two beds - top 1.3' massive, bottom 0.7' laminated; hard.	2.0
2.	Limestone; brown; fine to medium grained; thin irregular beds top and bottom with a ±0.6 vesicular zone in middle; hard.	1.7
3.	Dolomite; cream colored; fine grained; one bed; hard.	0.7
4.	Limestone; brown-gray; fine to medium grained; thin irregular beds; hard.	3.4
5.	Limestone; brown; fine to medium grained; spotted with darker brown recrystallized areas; hard.	5.0
6.	Limestone; brown-gray; fine to medium grained; 4 to 5 beds; calcite-lined vug layer ±0.5 from bottom; hard.	2.4
7.	Limestone; brown-gray; fine to medium grained; numerous brachiopod fossils; hard.	1.1
8.	Limestone; brown-gray; fine to medium-grained; calcite lined vugs; 2 beds; hard.	1.0
9.	Limestone; brown; fine grained; numerous calcite lined vugs; 2 massive beds; hard.	3.5
10.	Dolomite; brown; fine saccharoidal texture; 2 massive beds; bottom ±0.3' laminated; hard.	3.4
11.	Dolomite; buff to blue-gray; fine-grained; thin to heavy shale seam at base; hard.	1.0
12.	Limestone and shale; pinkish lithographic limestone with shale on bottom; individual thicknesses vary but 2.0' total thickness fairly constant.	2.0
13.	Limestone; pinkish tan; lithographic; bottom ±0.2 laminated; hard.	1.
Member:	Rapid	
14.	Dolomite; gray; fine to medium grained; one bed; top ±0.3 laminated limestone; hard.	0.

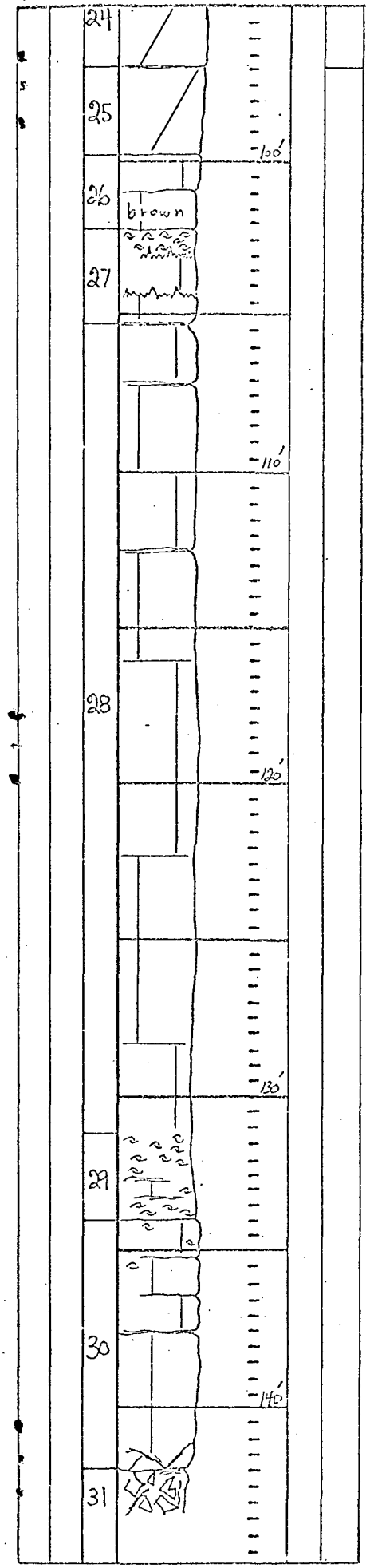
Iowa State Highway Commission

Location: SW¼ Sec. 36 T. 89 R. 12 Co. Black Hawk
Pint's Quarry and core - Lowe & Eschman Const. Co.
Remarks: Measured to floor where core was drilled in Bed 17.
Measured by: Myers Date: 5/28/62



Bed:	Description	Thk
	Page 2:	
15.	Dolomite; blue-gray; fine to medium grained; color banded; no chert; 0-0.3' shale seam at top; moderately hard.	6.4
16.	Dolomite, like Bed #15 but color banding less prominent and contains soft, earthy, chert nodules, moderately hard, 5.5' to floor where core was drilled.	5.5
17A.	Dolomite; gray-blue; medium grained; argillaceous; thin (±0.5') regular beds; soft to moderately hard.	14.3'
B.	Dolomite; grey-blue; medium grained; has a 0.3' shaly zone with chert nodules at the top and a 0.2' shale seam at the bottom; two massive beds; soft to moderately hard.	5.3'
C.	Dolomite; grey-blue; medium grained; argillaceous; massive with a thin shale parting 0.5' from bottom; has a 0.1'-0.2' thick shale seam at bottom; soft to moderately hard.	7.6'
18.	Dolomite; fine to medium grained; grey-blue; shale seam at bottom; one bed; hard.	0.8'
19 A.	Dolomite; same as Bed #18 with a zonal contact with 19B consisting of several thin shale partings; there are many crystal-lined cavities both above and below this shaly zone.	1.8'
19 B.	Dolomite; same as 19B with a regular but thin parting at contact with 19C; 19B & 19C may appear as one massive bed.	1.3'
19 C.	Dolomite; brown; medium grained; some of the blue-grey color of Beds 19A & B is present just below the contact with Bed #19B; has a good shale seam at base; very hard, tough.	1.6'
20.	Dolomite; dark brown; medium grained; small coral masses; has a 1.5' thick massive bed at top; massive with some irregular, black shale partings; very hard; tough.	13.5'

Iowa State Highway Commission



Location: SW¼ Sec. 36 T. 89 R. 12 Co. Black Hawk
Pint's Quarry and core - Lowe & Eschman Const. Co.
Remarks: Measured to floor where core was drilled in Bed 17.
Measured by: Myers Date: 5/28/62

Bed:	Description	Thk
	Page 3:	
21.	Dolomite; same as Bed #20 but distinguished by 2 thin black, persistent shale partings, at the top and bottom of the bed.	1.3'
22.	Dolomite; same as Bed #21, also marked by thin black, shale partings.	0.5'
23.	Dolomite; same as beds above but slightly earthier in texture; massive but has a ±0.9' bed which may split off the top.	4.0'
24.	Dolomite; calcareous; dark brown; earthy texture; softer.	3.6
25.	Dolomite; calcareous; dark brown; dull; earthy texture; moderately hard.	2.8
26.	Limestone; fine grained; blue-grey on top; brown on bottom.	2.4
27.	Limestone; fine grained; grey-blue; numerous brachiopods in top±1.0'; argillaceous; moderately hard; shale seam at base.	3.1
28.	Limestone; fine grained to lithographic; green-blue; massive; very argillaceous but has very few shale seams or partings; gradational into Bed # 29 below; hard; moderately brittle.	25.5
29.	Limestone; same as Bed # 28 except it contains numerous brachiopods and shale partings.	2.7
30.	Limestone; grey; fine grained; shale partings and brachiopods at top becoming more massive; dense; unfossiliferous toward bottom; some shale partings at base; hard.	7.8
31.	Breccia; blue; fine grained limestone fragments in a very shaly limestone matrix; soft.	1.5