Outcrop Study of Secondary Porosity in the Mid-Ordovician Trenton Dolomite of Northern Illinois and Its Implications for Reservoir Characterization and Development*

By

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Abstract

Based on an extensive study of roadcuts, quarries, mines, caves, and springs in Northern Illinois, secondary porosity in the Trenton (Galena) dolomite can be subdivided into three types: matrix, fracture, and conduit. Secondary matrix porosity is present as small vugs and vesicles resulting from volume reduction during hydrothermal dolomitization. Fracture porosity occurs in northeast- and northwest-trending vertical fracture sets as well as in a horizontal bedding-plane fracture set. All three fracture sets are arranged in an orthogonal pattern and were emplaced as a result of orogenic compression and extension.

Vertical karst conduits are present at the junctions of the two vertical fracture sets. Horizontal karst conduits are found at the junction of the horizontal fracture set and a vertical fracture set. Study of the fracture and conduit network shows the presence of 1st, 2nd, 3rd, 4th, and 5th order fractures and conduits, ordered in a "logarithmic" base ten arrangement.

All three types of secondary porosity in the Trenton have been enhanced by karst processes, either meteoric or hydrothermal. Meteoric karstification occurred post-Trenton as well as post-Paleozoic, while hydrothermal karstification occurred during the Pennsylvanian. Vertically, maximum dissolution occurred above and below minor shale and bentonite layers in the Trenton as well as directly beneath the Maquoketa Shale cap. In the horizontal plane, maximum karstification occurred along synclinal axes as well as near major faults and fractures.

The best reservoir porosity, therefore, occurs in the top 50 to 100 feet of the Trenton, as well as in linear trends along the fault and fracture zones. This is true for the Michigan Basin and appears to be true for the Illinois Basin as well.

Outcrop Study of Secondary Porosity in the Mid-Ordovician Trenton Dolomite of Northern Illinois: Implications for Reservoir Characterization & Development

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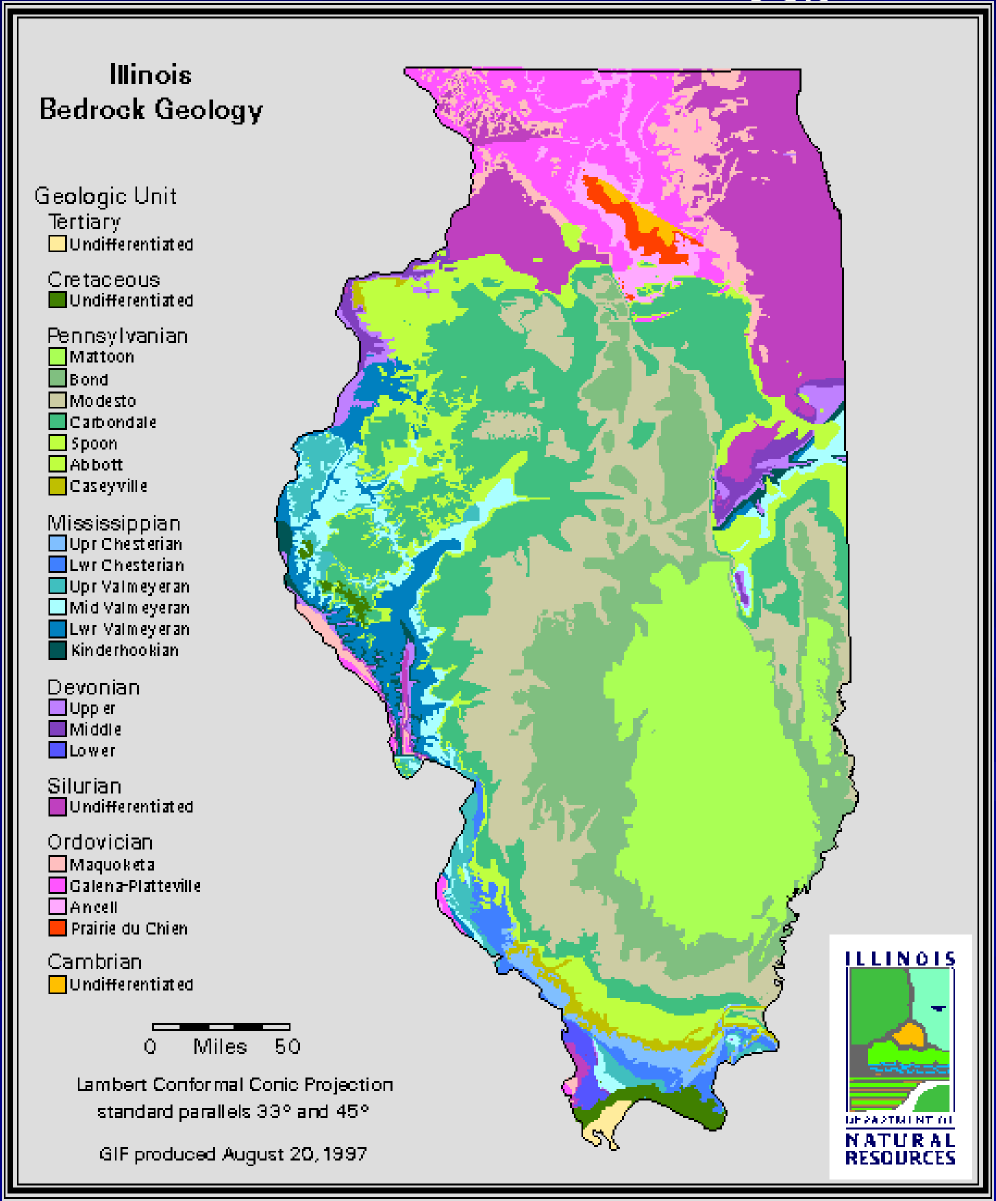
Objectives

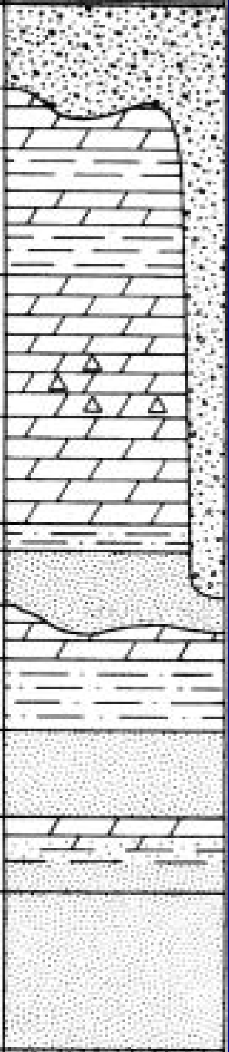
- Identify secondary porosity features in the Trenton at its outcrop area in NC IL.
- Characterize the fracture and karst conduit network
- Develop a karstification model
- Identify potential hydrocarbon source beds & traps

Illinois Bedrock Geology



Generalized Strat Column

SEQ.	SYSTEM	GROUP	FORMATION & THICKNESS	GRAPHIC COLUMN
TEJAS	QUATERNARY 0 - 0.7 m.y. B.P.		0 - 137 m (0 - 450 ft.)	
TIPPECANOE	SILUR. 405 - 440 m.y. B.P.		15 m (50 ft.)	
TIPPECANOE	ORDOVICIAN 440 - 490 m.y. B.P.	Maquoketa	46 - 61 m (150 - 200 ft.)	
TIPPECANOE	ORDOVICIAN	Galena	76 m (250 ft.)	
TIPPECANOE	ORDOVICIAN	Platteville	30 m (100 ft.)	
TIPPECANOE	ORDOVICIAN	Platteville	Glenwood 2-18 m (5-60 ft.)	
TIPPECANOE	ORDOVICIAN	Ancell	St. Peter 6-22 m (200-400 ft.)	
SAUK	CAMBRIAN 500 - 515 m.y. B.P.		Potosi 15-30 m (50-100 ft.)	
SAUK	CAMBRIAN		Franconia 15-30 m (50-100 ft.)	
SAUK	CAMBRIAN		Ironton – Galesville 23-52 m (75-170 ft.)	
SAUK	CAMBRIAN		Eau Claire 107-137 m (350-450 ft.)	
SAUK	CAMBRIAN		Mt. Simon 305-488 m (1000-1600 ft.)	
	PRECAMBRIAN			GRANITE



Trenton Strat Column

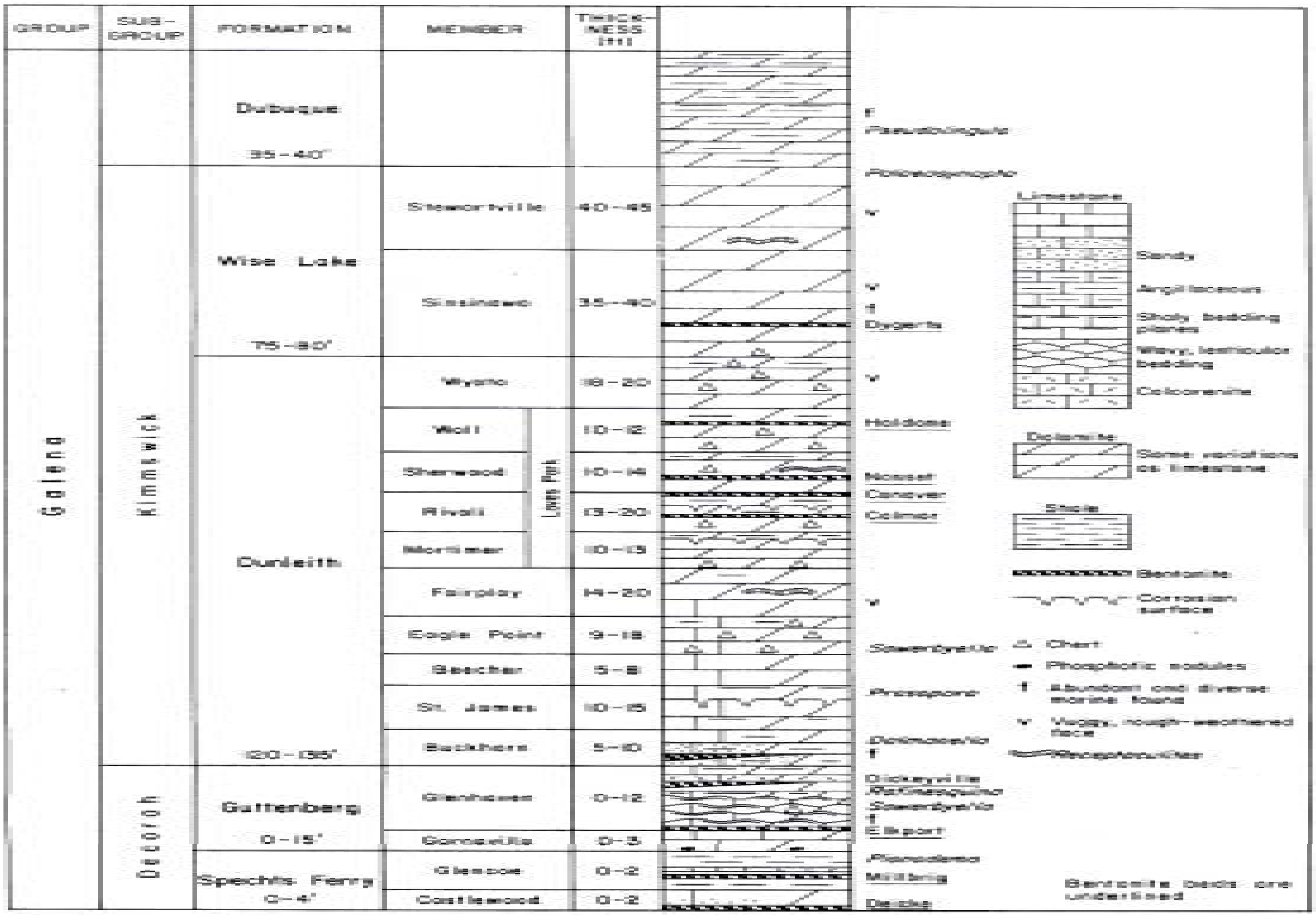
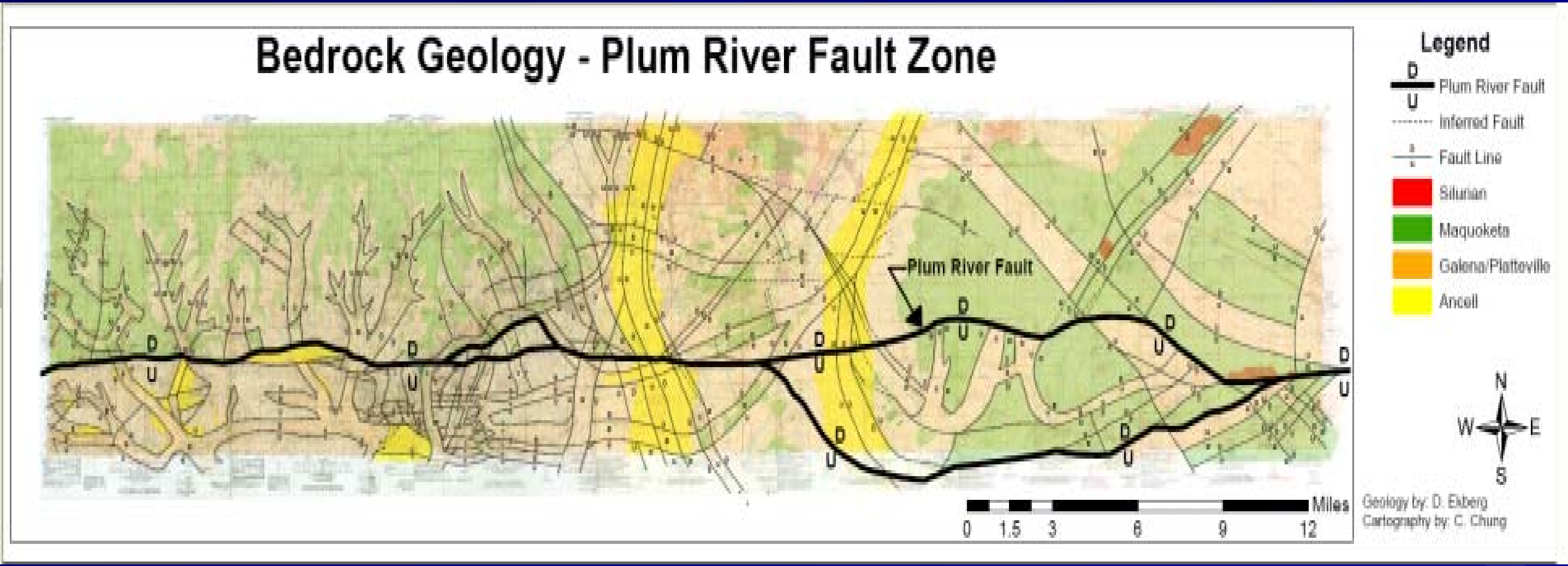


Figure 11. Columnar section of the Galena Group.

Willman & Kolata, 1978

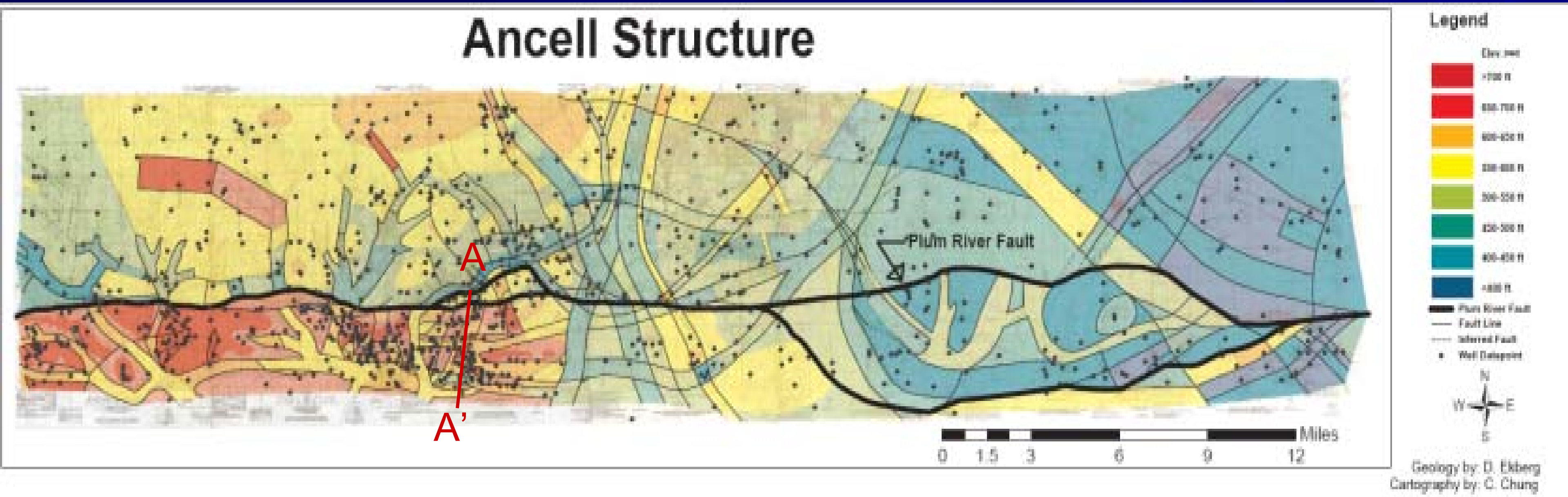
Bedrock Geology

North Central Illinois



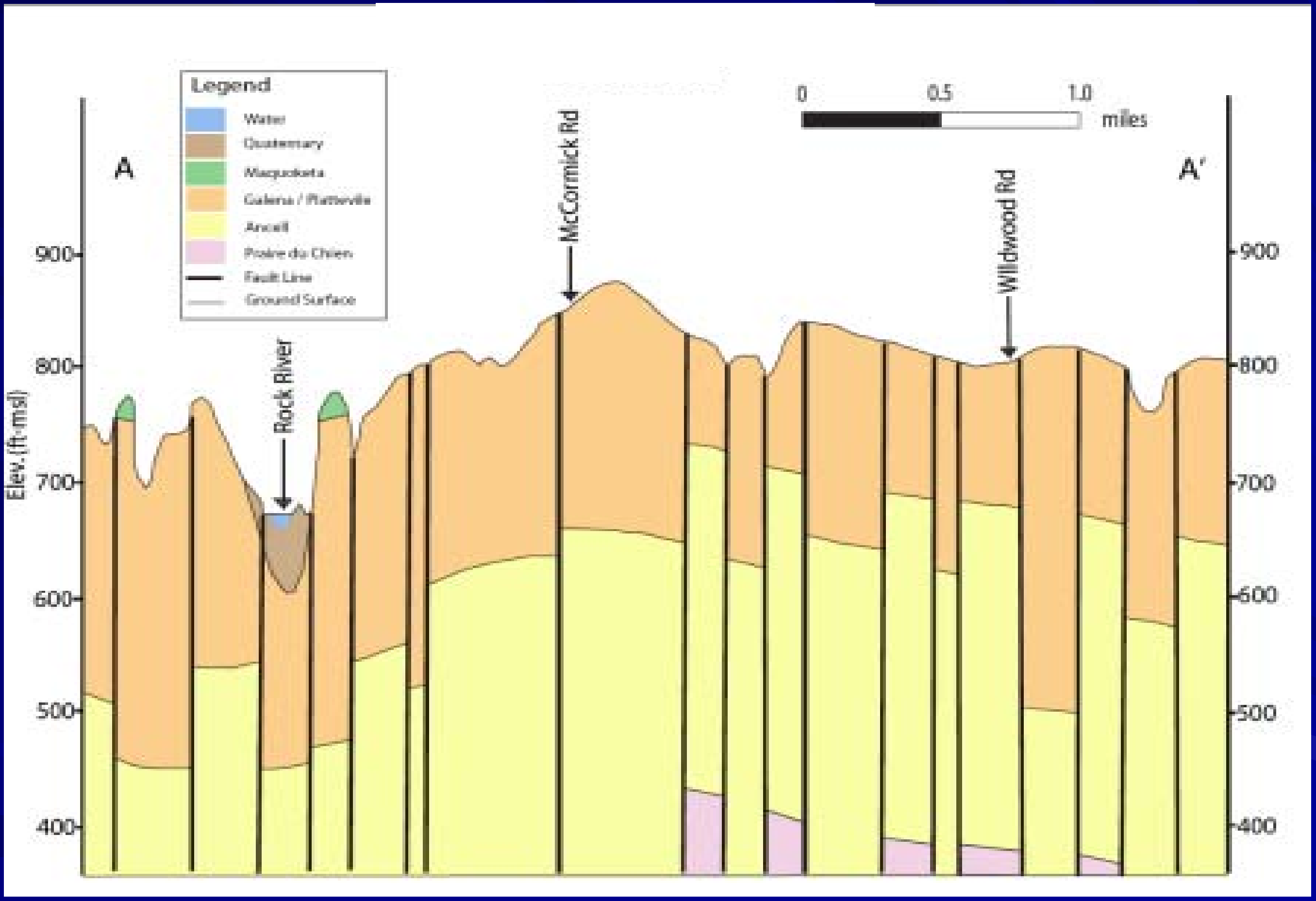
Ancell Structure

North Central Illinois

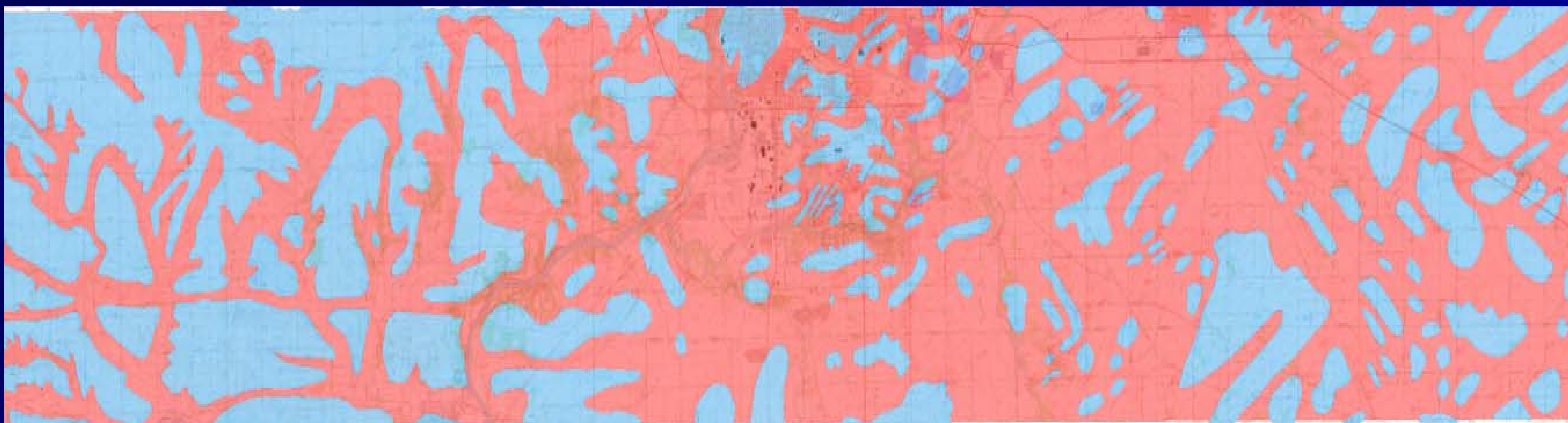


Plum River Fault Zone

X-Section A-A’



Specific Capacity - NC IL



< 1.0 gpm/ft dwdn

≥ 1.0 gpm/ft dwdn

Secondary Porosity Types

Trenton Dolomite

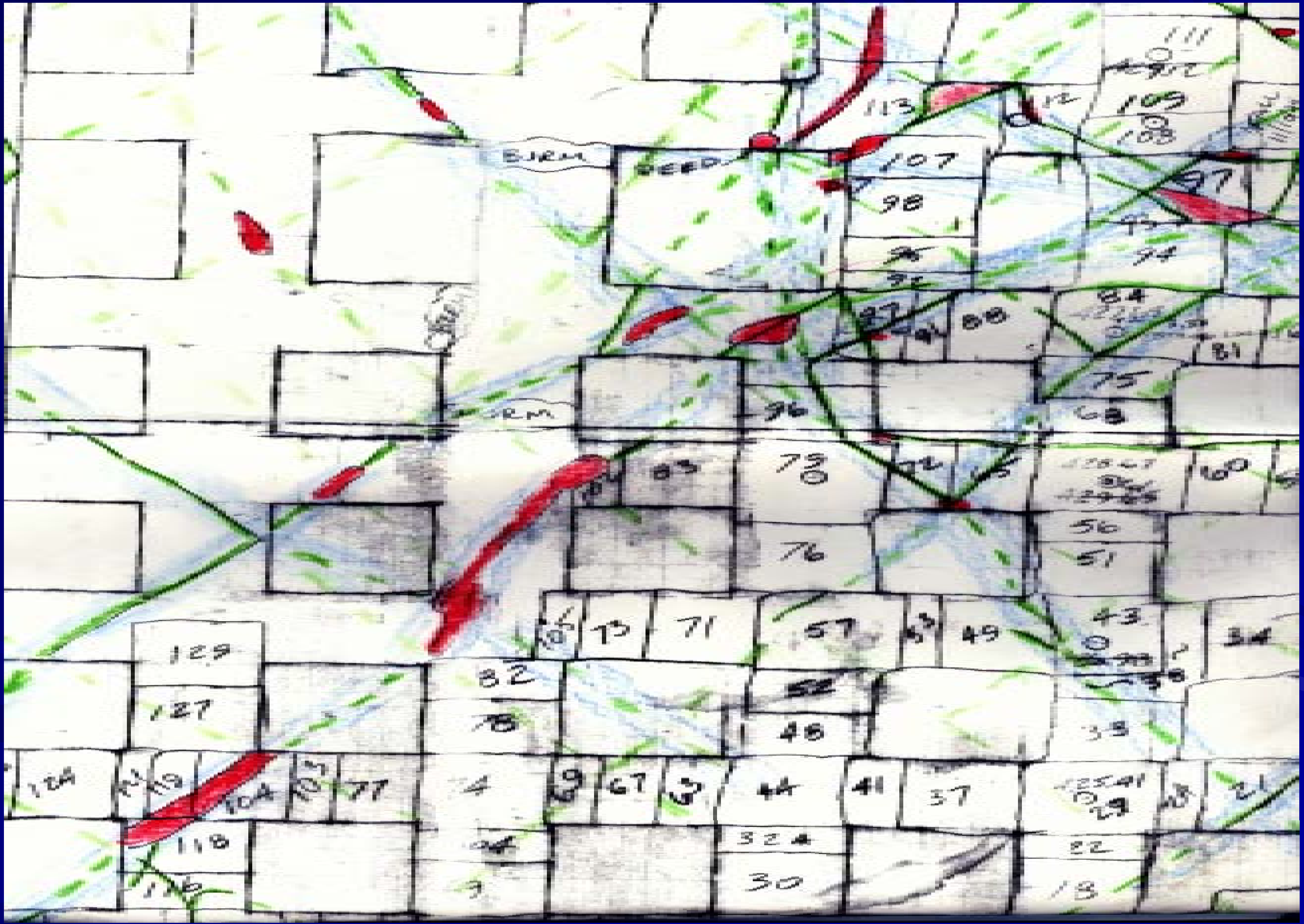
- **Matrix:** Increased porosity due to reduction in volume resulting from dolomitization
- **Fracture:** Northwest and Northeast vertical fractures and horizontal bedding plane fractures
- **Conduit:** Vertical and horizontal karst pipes forming at the junction of the vertical fractures and the junction of the vertical and horizontal fractures

Northwest Fractures

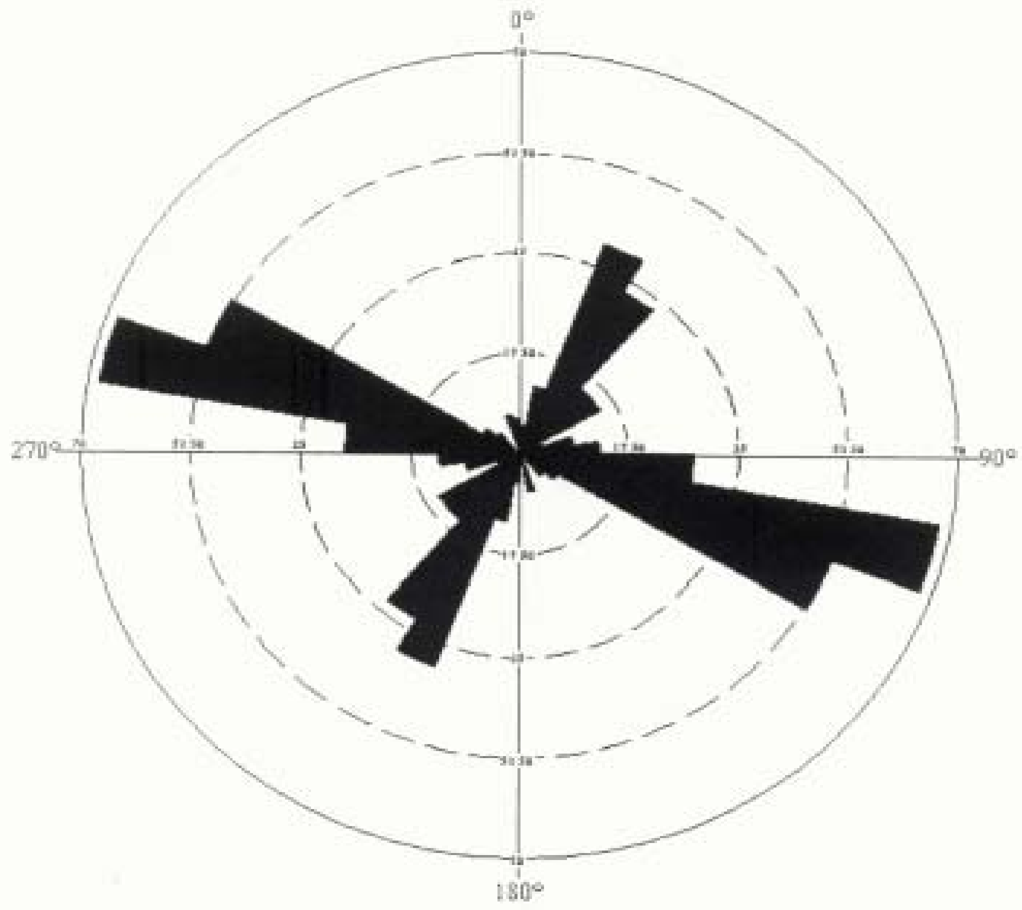
Winquist Quarry

Karst and Fractures

North Aurora Mine

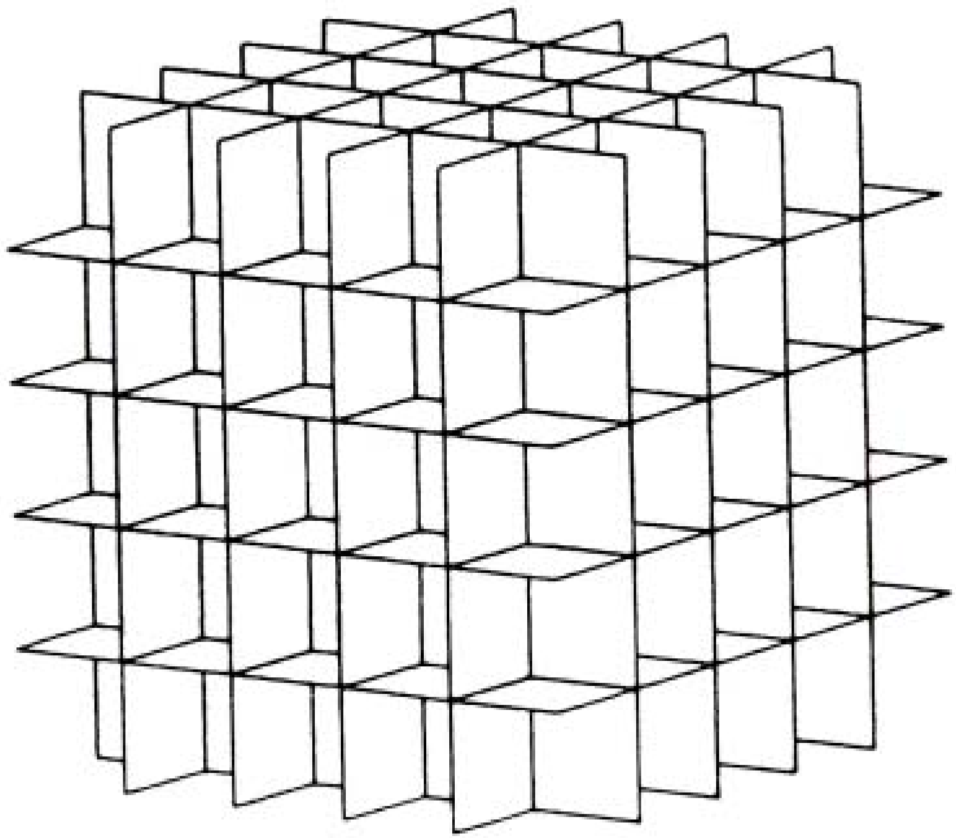


Fracture Rose Diagram



McGarry, 2000

Orthogonal Fracture Model



Dershowitz & Einstein, 1983

Vertical Fracture Characteristics - Trenton

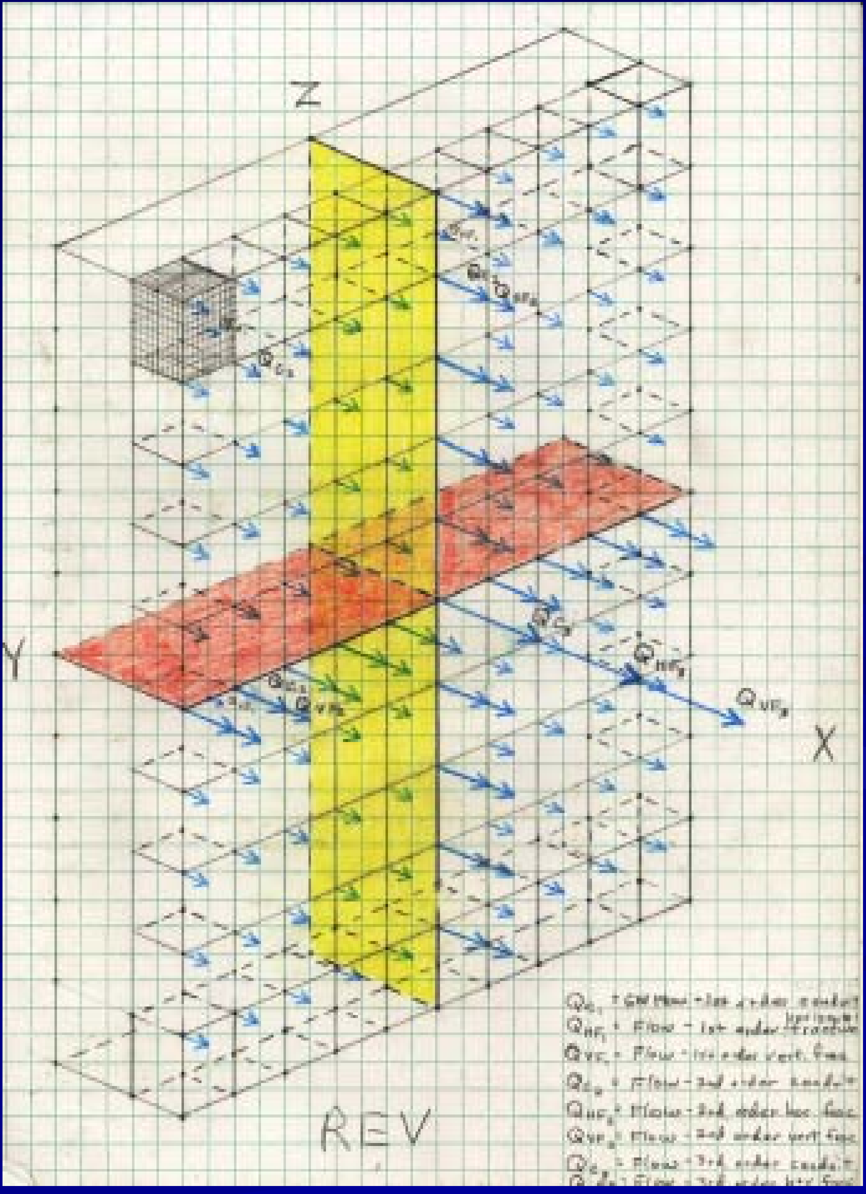
(North-Central Illinois)

		Orientation		Spacing			Aperture		
		NW	NE	NW	NE	Average	NW	NE	Average
Winquist Quarry	Major	N 62 W	N 30 E	40'	220'	130'	0.82"	0.43"	0.63"
	Minor	N 62 W	N 30 E	3.1'	3.2'	3.15'	0.147"	0.139"	0.14"
I-39 Road Cut	Major	N 68 W	N 26 E	123'	100'	114'	0.86"	0.38"	0.63"
	Minor	N 68 W	N 26 E	18.9'	11.5'	15.5'	0.16"	0.1"	0.13"
Myers Quarry	Major	N 75 W	N 5 E	26'	42'	34'	1.67"	1.28"	1.39"
	Minor	N 75 W	N 5 E	5.3'	6.6'	6.1'	0.2"	0.1"	0.13"
Conco Mine	Major	N 50 W	N 45 E	81.8'	98.3'	88.9'	1.5"	1.5"	1.5"
	Minor	N 50 W	N 45 E	10'	10'	10'	0.125"	0.125"	0.125"
Combined Average	Major	N 64 W	N 27 E	68'	112'	90'	1.21"	0.90"	1.04"
	Minor	N 64 W	N 27 E	9.3'	7.8'	8.7'	0.16"	0.12"	0.13"

Fracture and Conduit Network

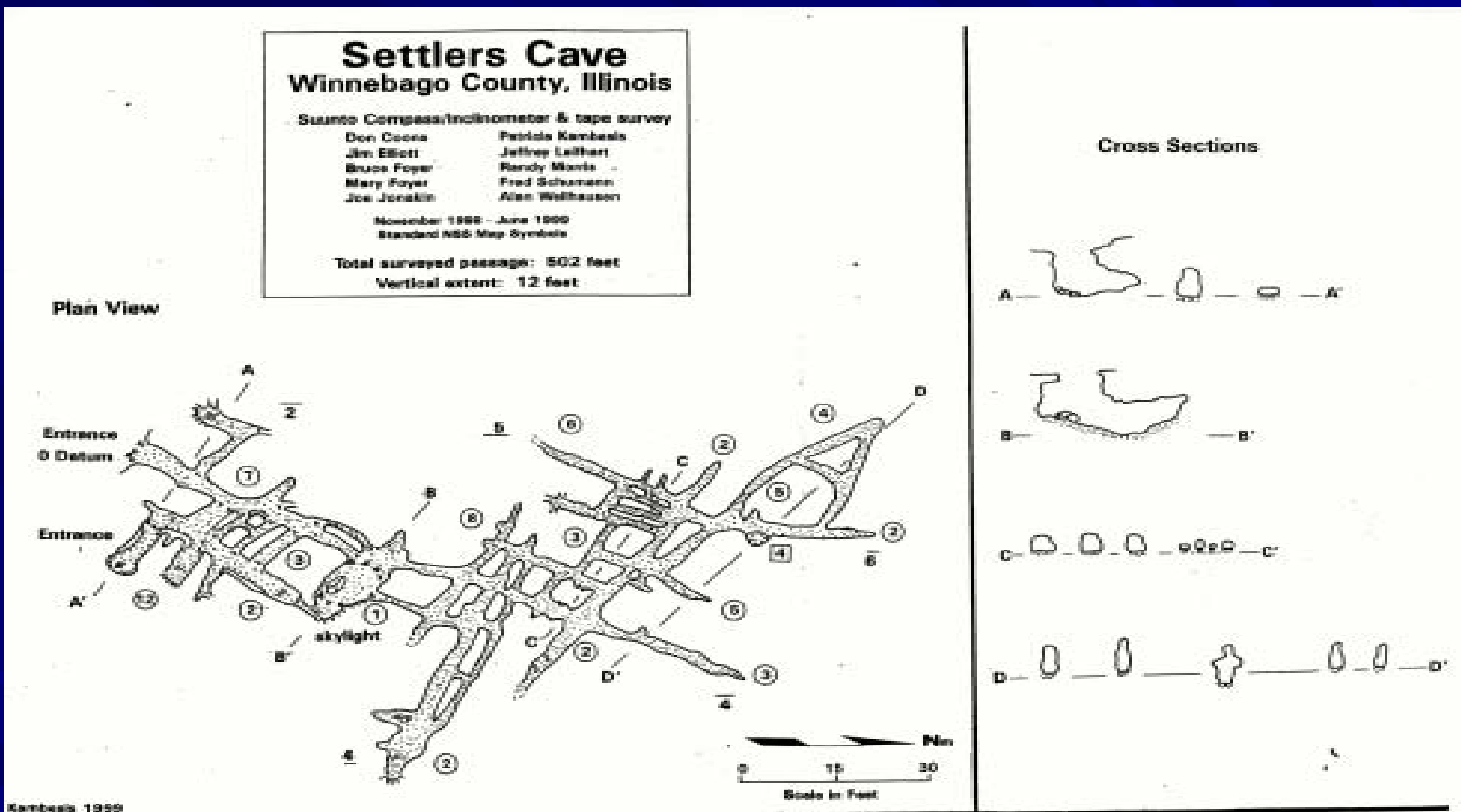
Conduit and Fracture Spacing	Fracture b	Conduit d	Conduit and Fracture Order
10,000'	10.0'	100'	4th
1,000'	1.0'	10'	3rd
100'	0.1'	1.0'	2nd
10'	0.01'	0.1'	1st
1'	0.001'	0.01'	Zero

Detail Flow Model



Settler’s Cave

Settler’s Cave Map



Settler’s Cave

Left Passage

Indian Cave #2

Irene Quarry Spring

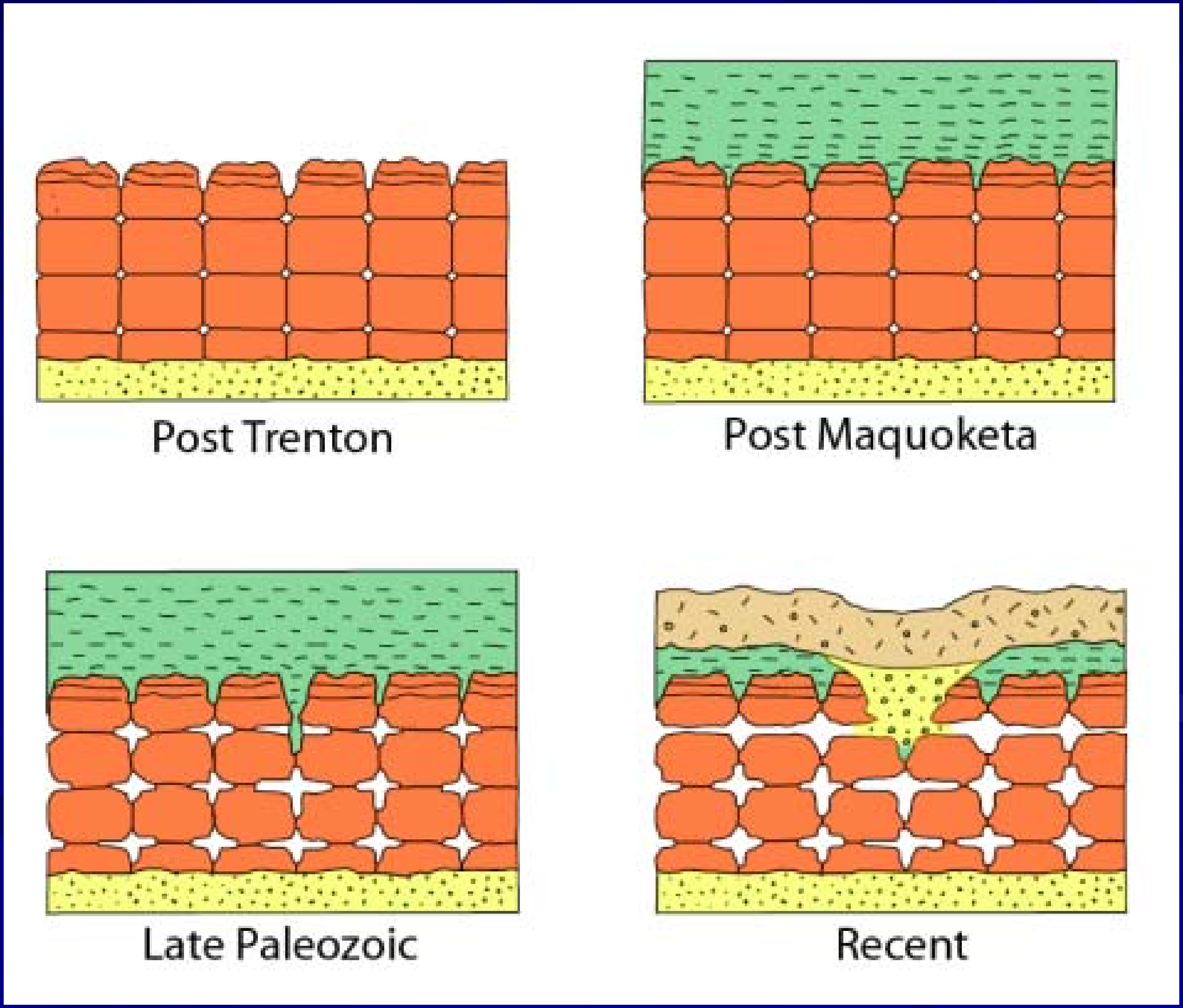
Top of Dygert's Bentonite

Karstification History (Trenton)

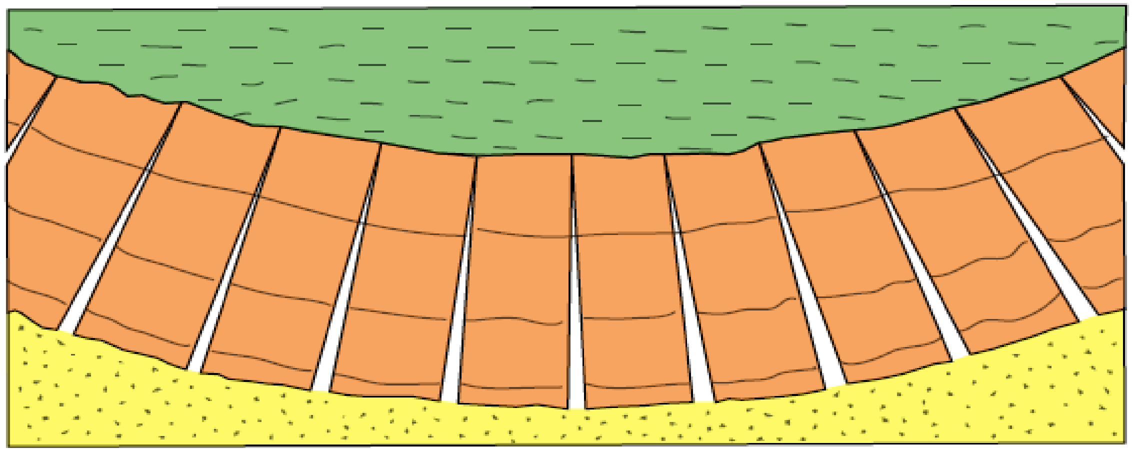
- Galena deposition (mid-Ord)
- Uplift and meteoric karstification (mid-Ord)
- Maquoketa through Pennsylvanian deposition (mid-Ord thru Penn)
- Hydrothermal karstification (late Paleozoic)
- Uplift, erosion, and further meteoric karstification (late Paleozoic thru present)

Trenton Karstification History

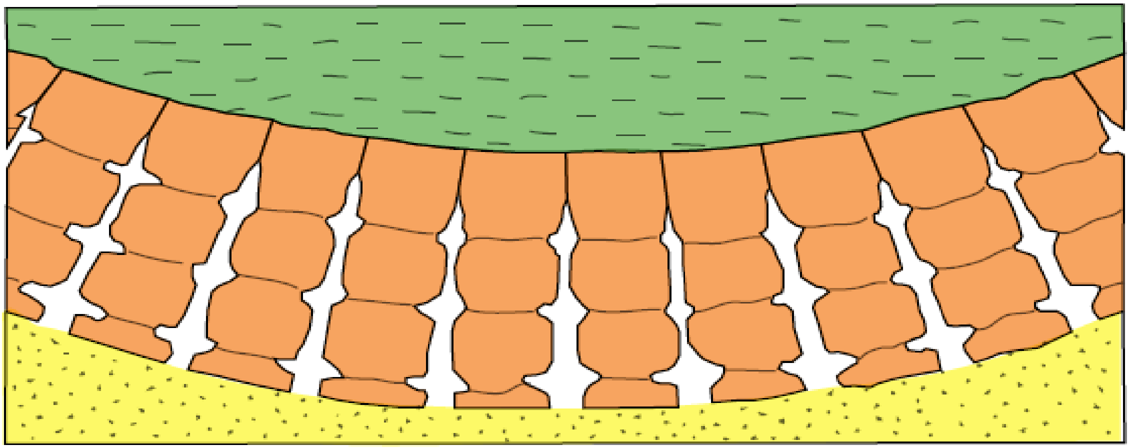
Northern Illinois



Synclinal Karstification



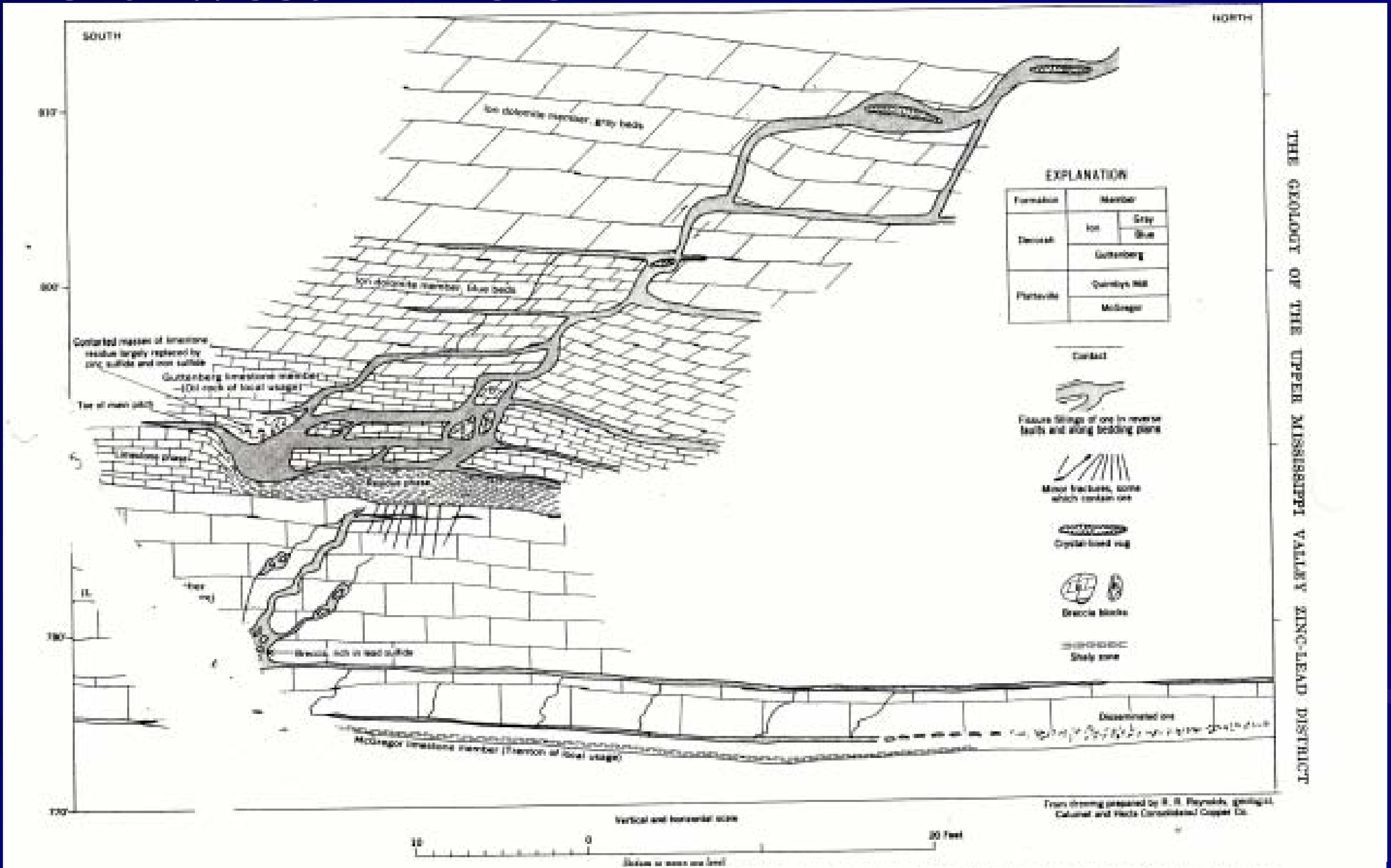
Pre-Hydrothermal



Post-Hydrothermal

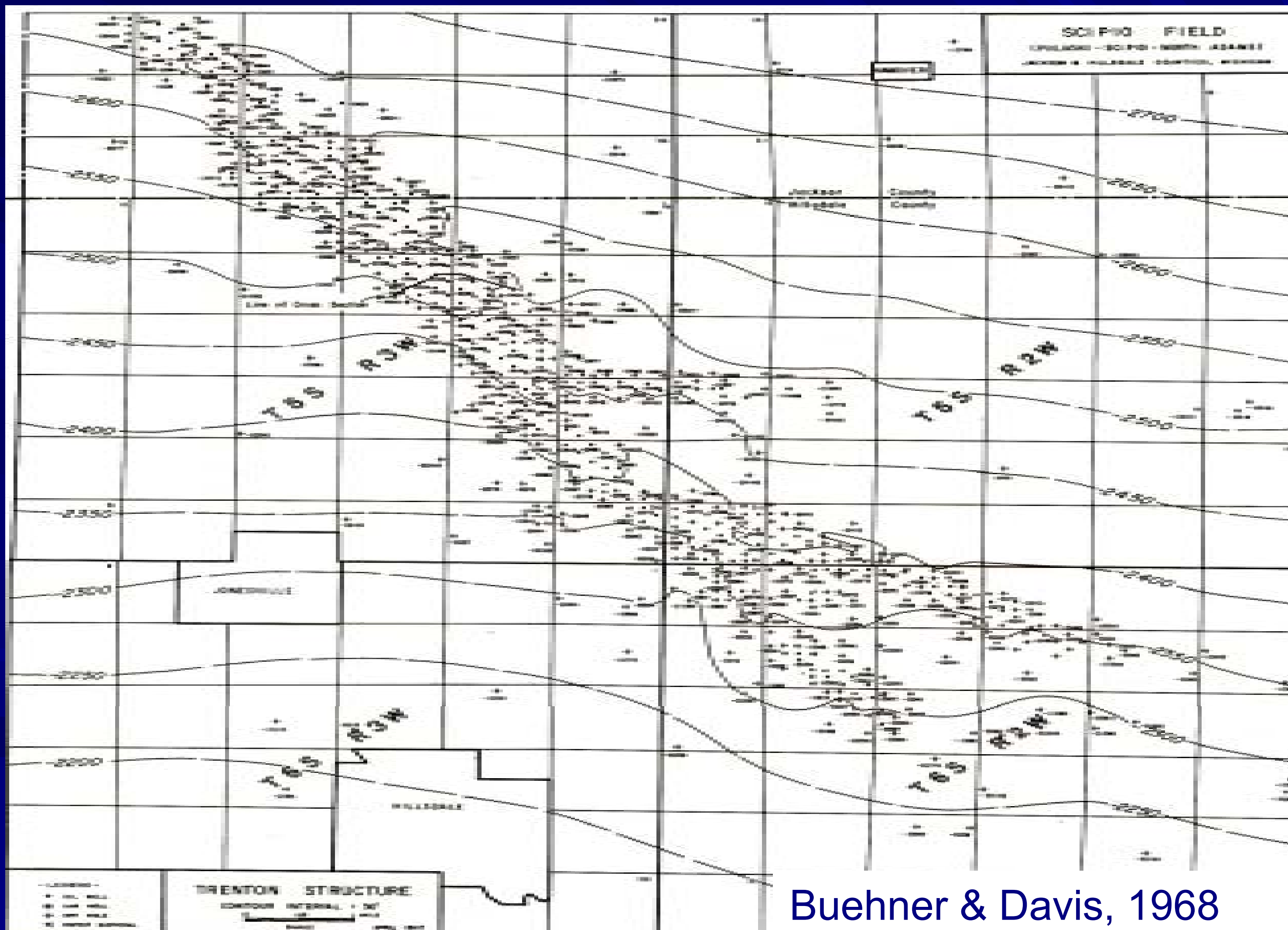
MVT Fracture Mineralization

Northwest Illinois



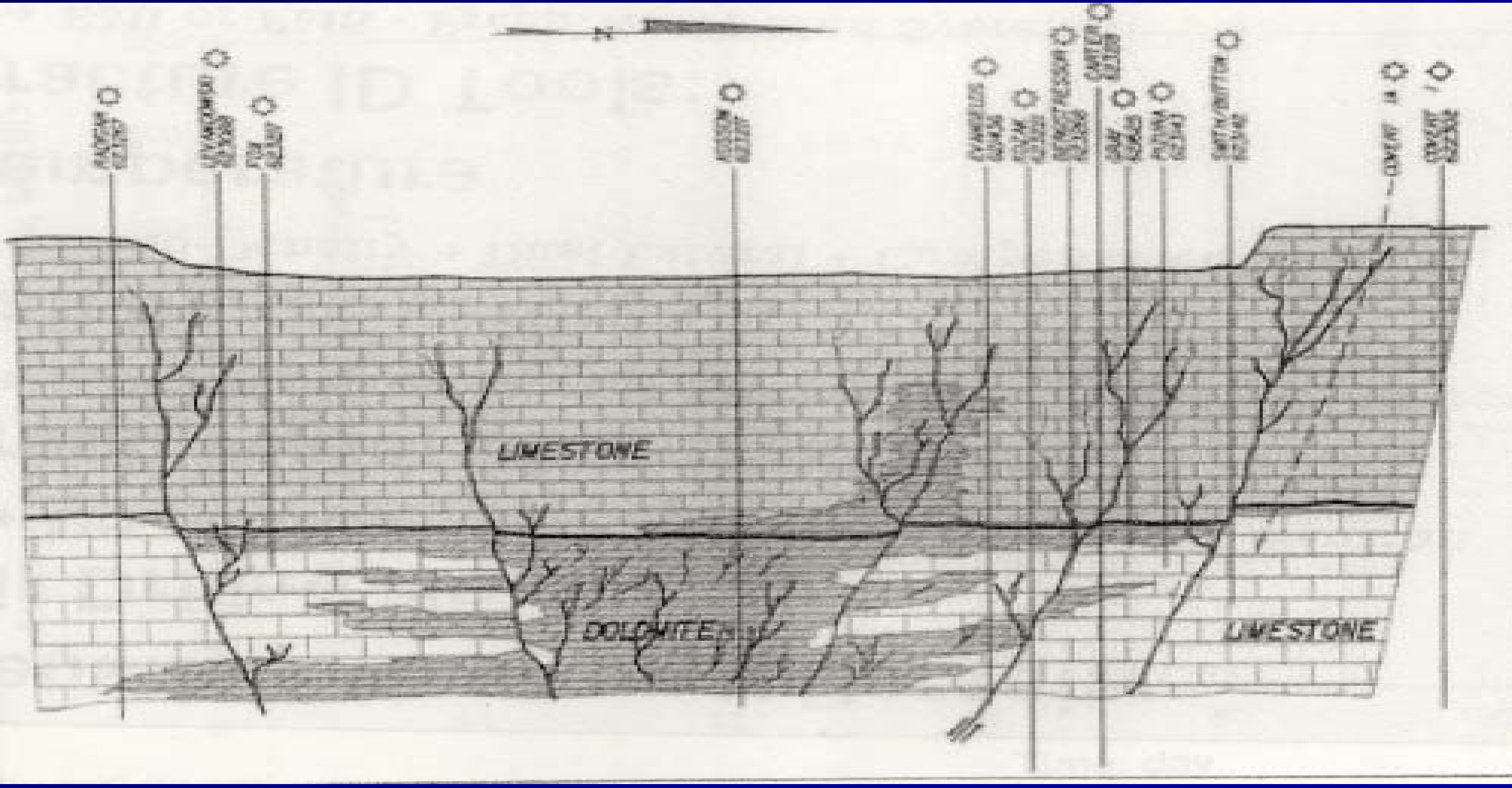
Heyl et al, 1959

Trenton Structure
Scipio Field



Buehner & Davis, 1968

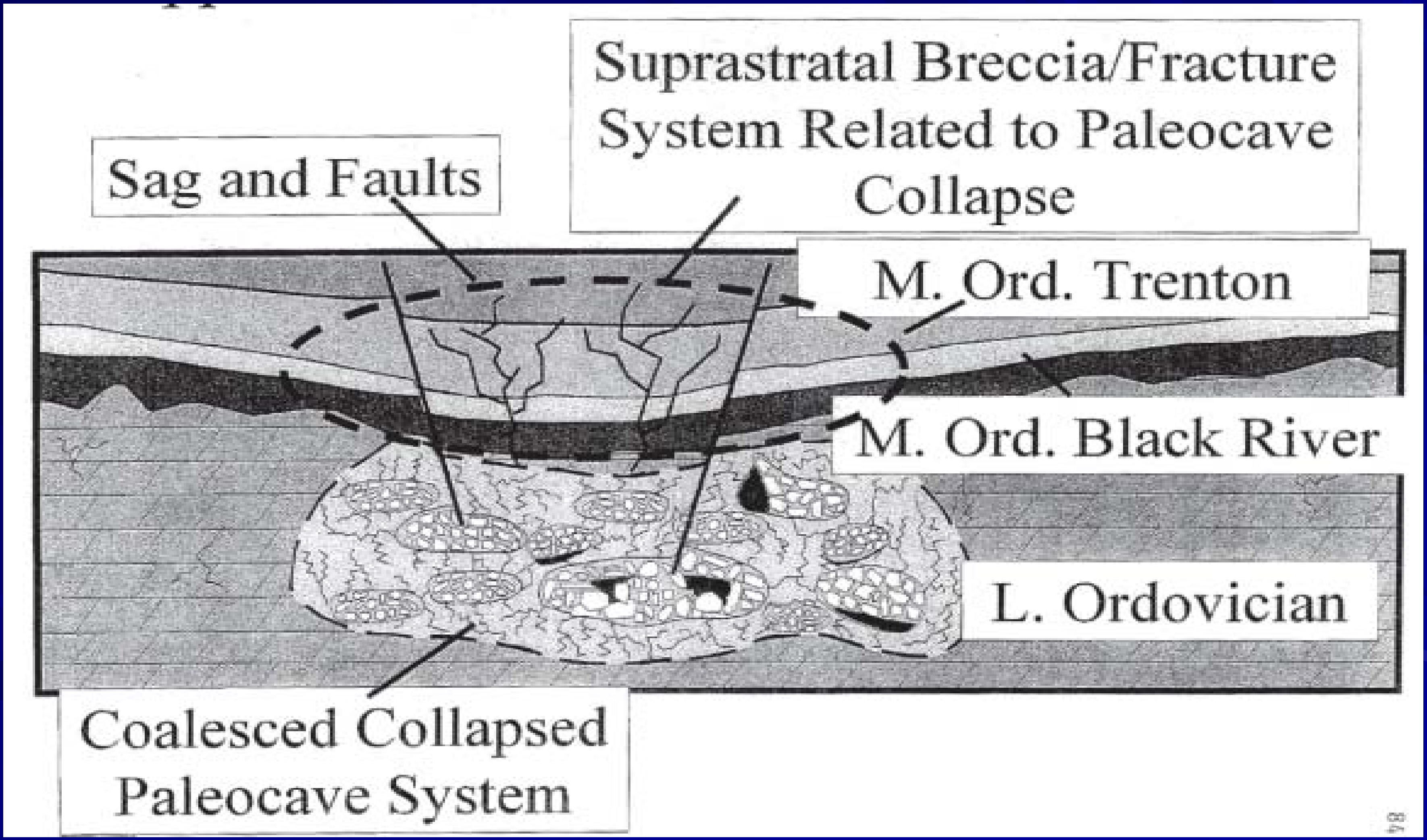
Trenton Dolomitization
Michigan Basin



USGS, 1995

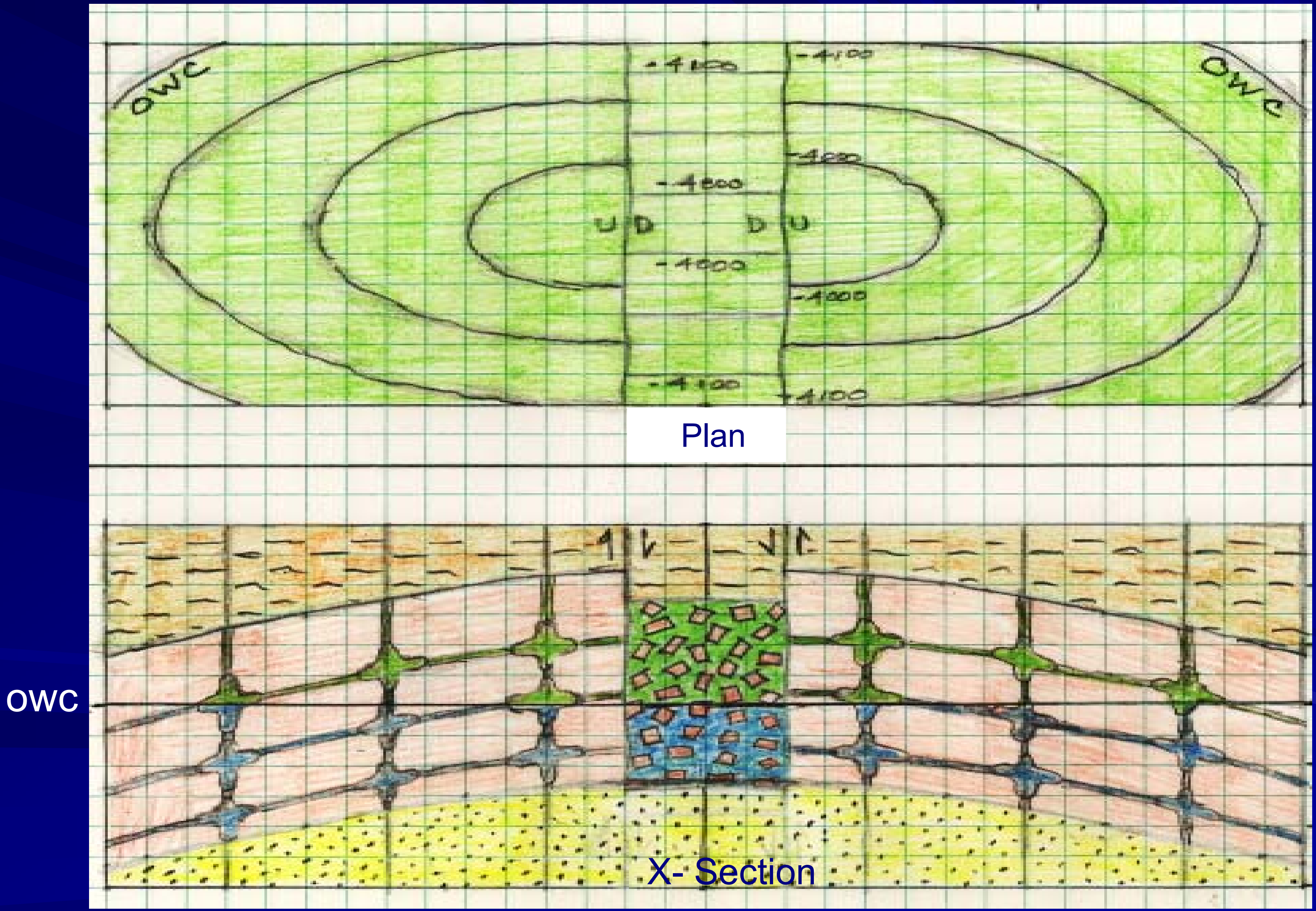
Karst Collapse Breccia

Trenton-Michigan Basin



Faulted Karst Dome

Hydrocarbon Trap



Conclusions

- Secondary porosity in the Trenton occurs as conduits, fractures, and matrix vugs
- Fractures and conduits are arranged in an orthogonal pattern with conduits forming at the fracture junctions
- Karstification process:

  1. Meteoric karstification in post-Trenton
  2. Hydrothermal karstification in Late Paleozoic
  3. Post-Paleozoic meteoric karstification
- Source beds for the Trenton are the Maquoketa shale and the Guttenberg (Decorah) shale
- Hydrocarbons can be stratigraphically trapped in faulted karst domes and faulted & karst synclines