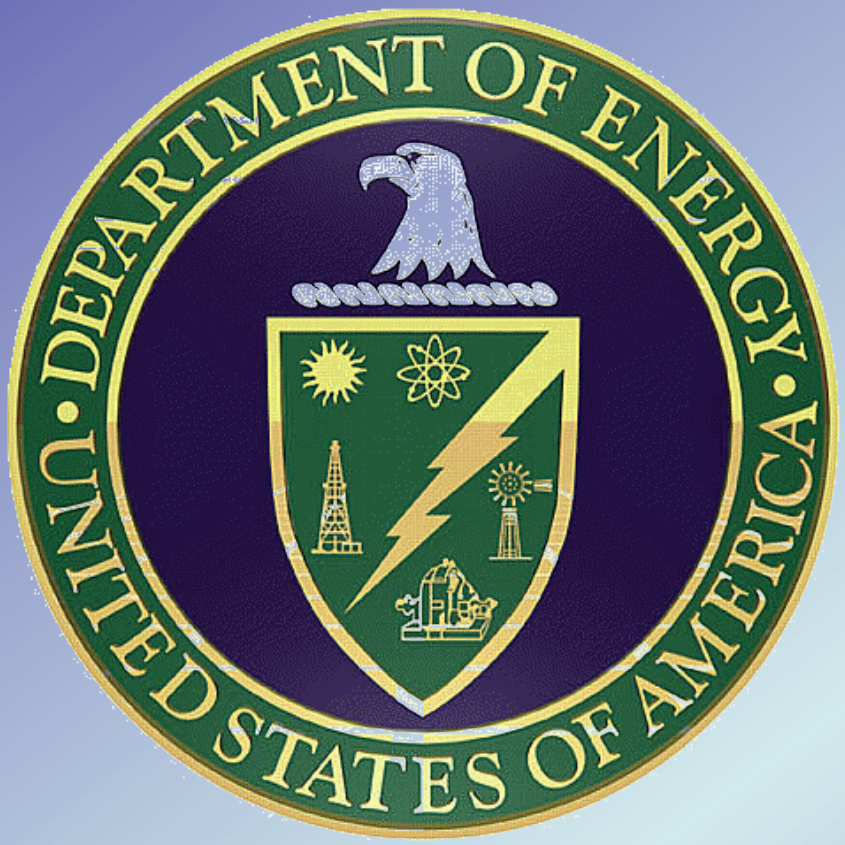
Fractures, Veins, and Faults: Characteristics of Brittle Deformation in the Utica Shale, Mohawk Valley, New York State

Alex O'Hara*, Robert Jacobi*, Nicole Fenton*

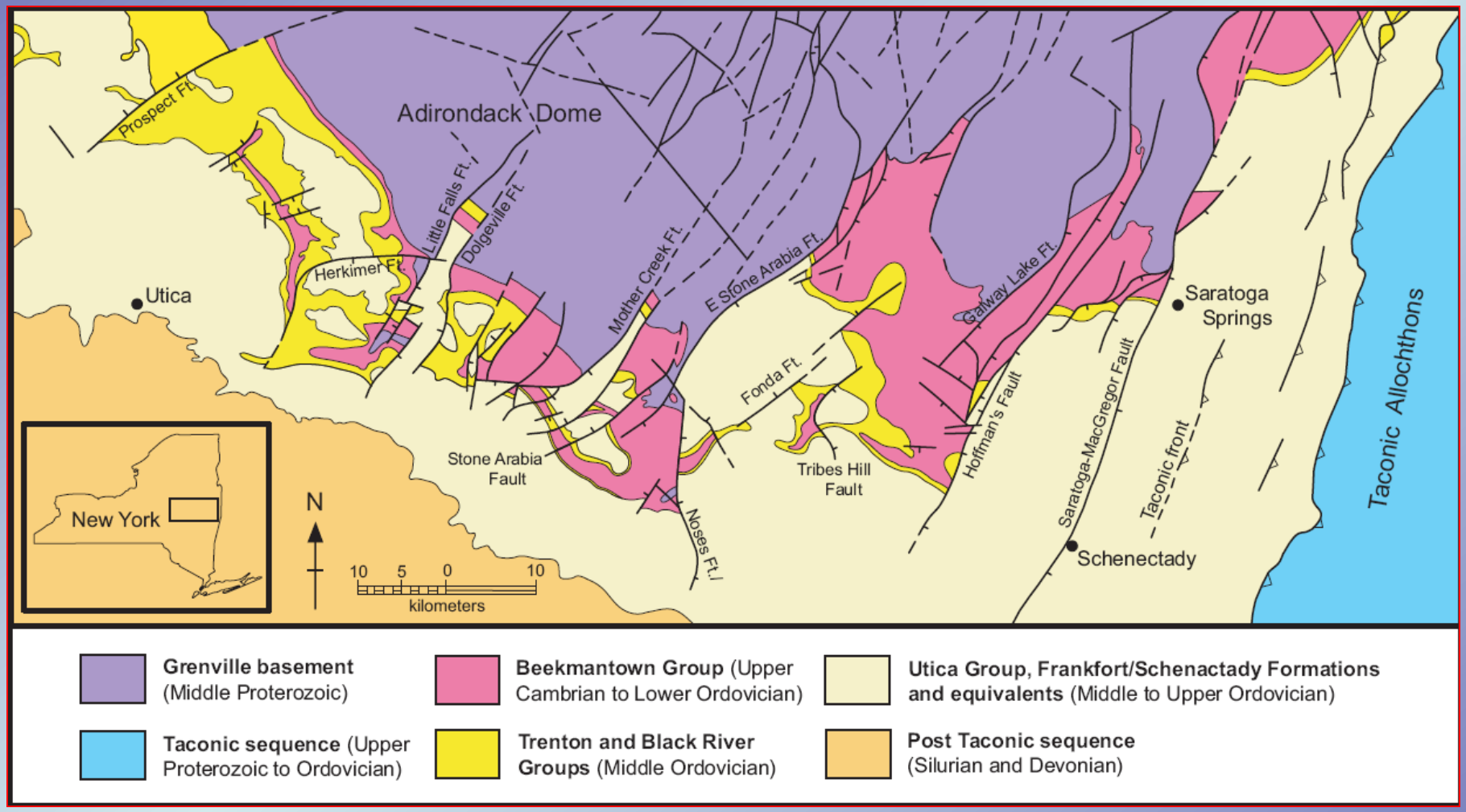
*UB Rock Fracture Group, University at Buffalo



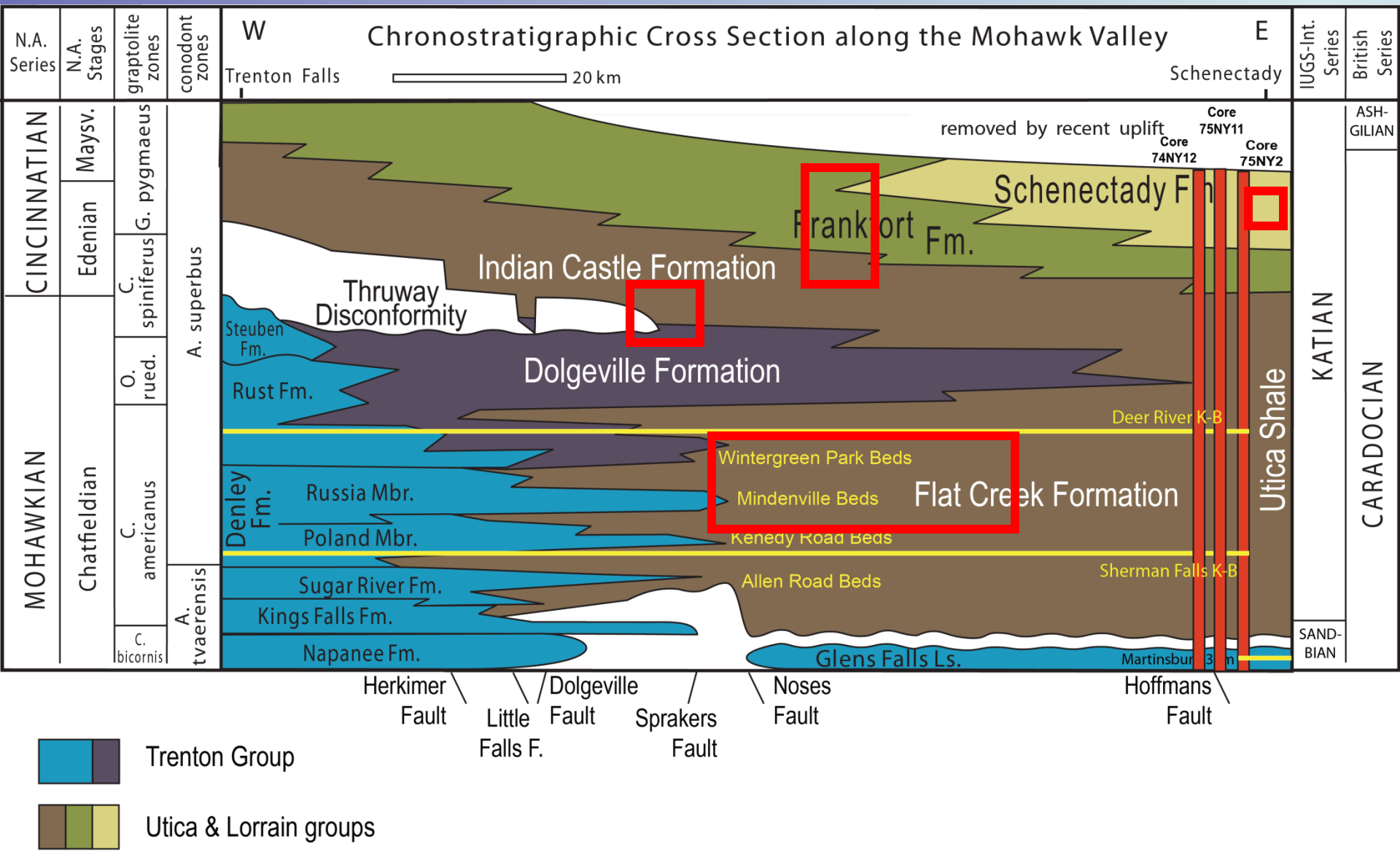
Research Supported by:
NYSERDA and DOE

Introduction

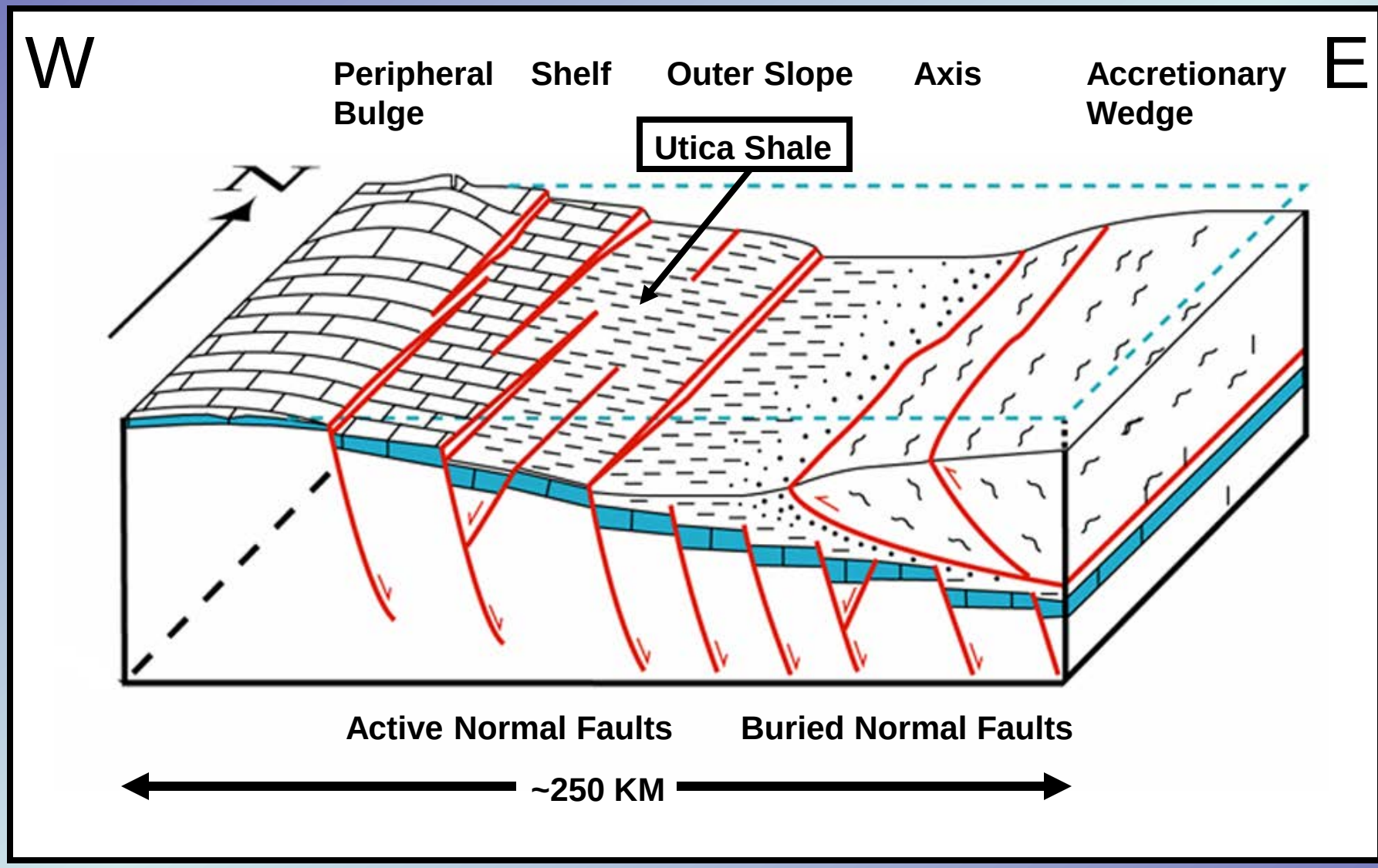

N
Adirondack Mountains
Toronto
Lake Ontario
Mohawk Valley
Study Area
Long Island Sound
200 KM
New York



From Cross (2004), after Bradley and Kidd (1991)



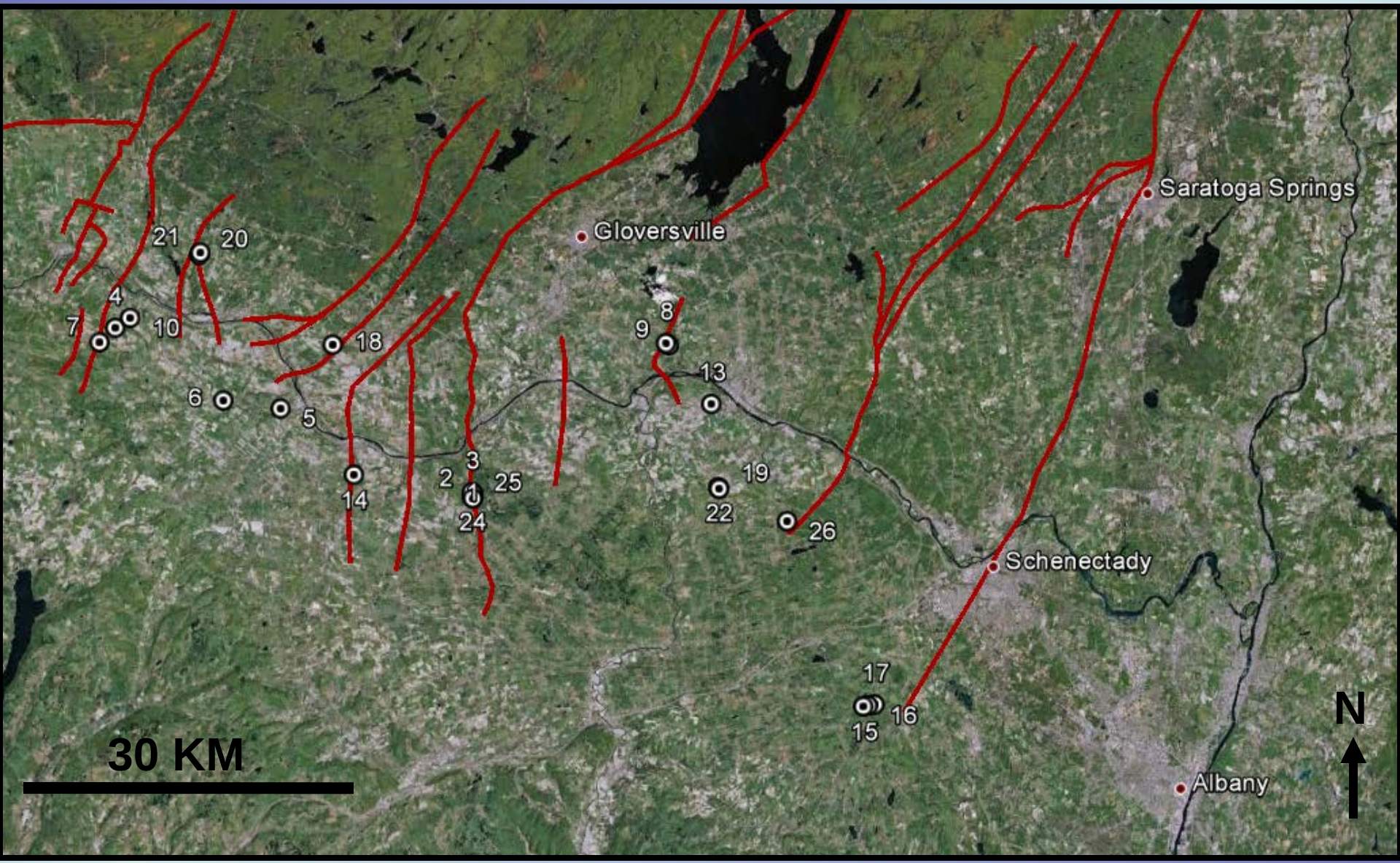
after Jacobi and Mitchell (2002)



Modified from Bradley and Kidd (1991)

Methods

Outcrop Distribution



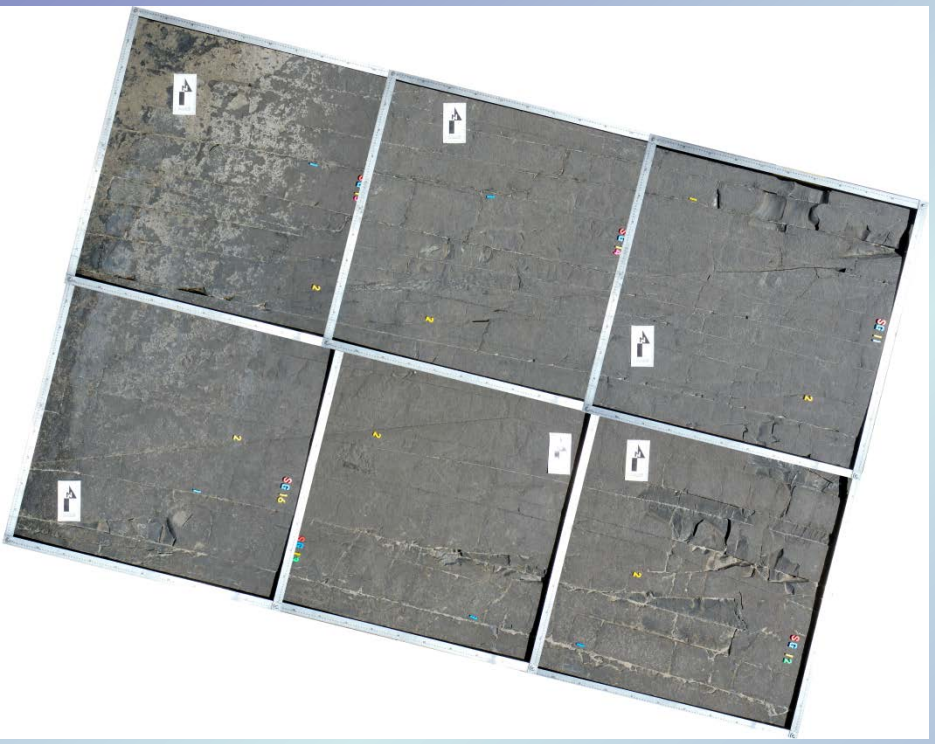
22 outcrops

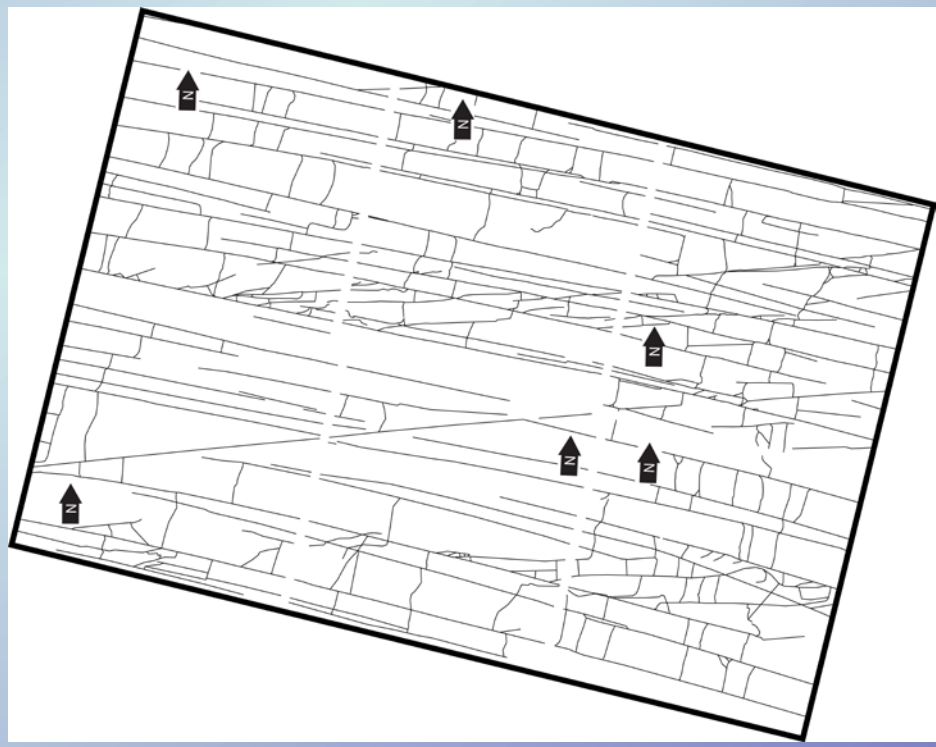
Scanline Technique

Scangrids

Orthorectification

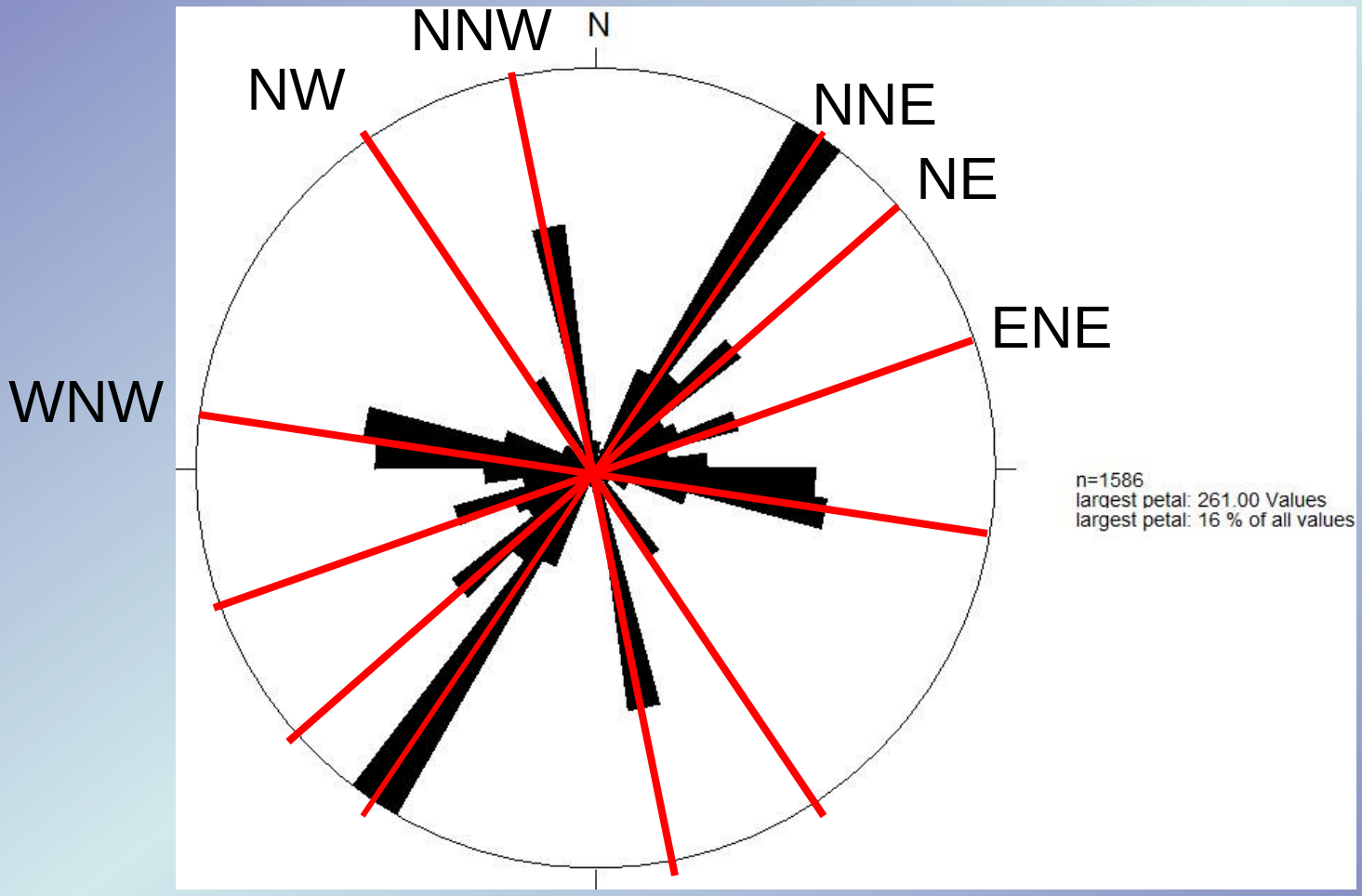
Mosaic and Interpretations

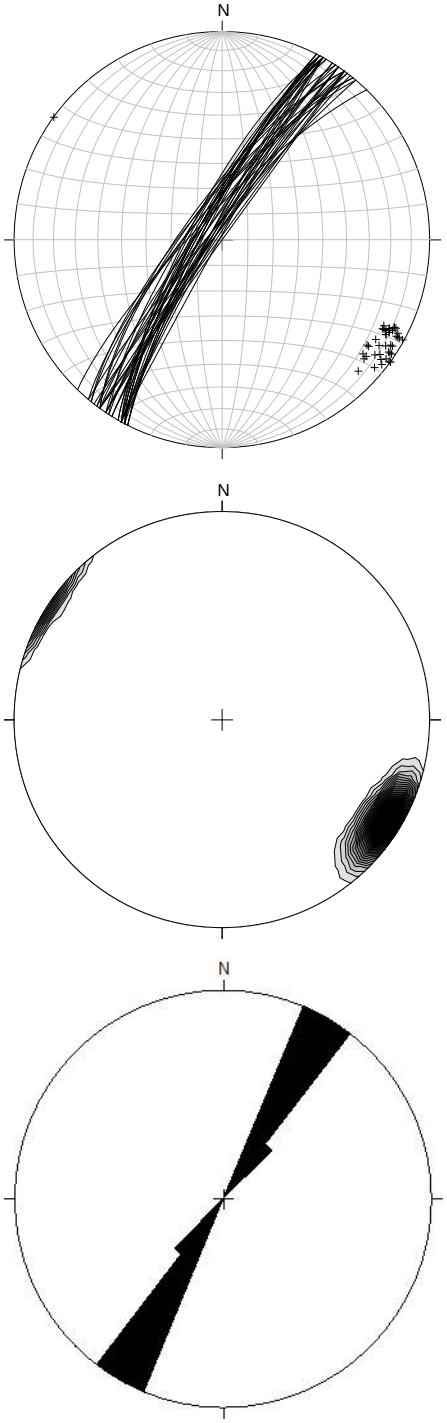


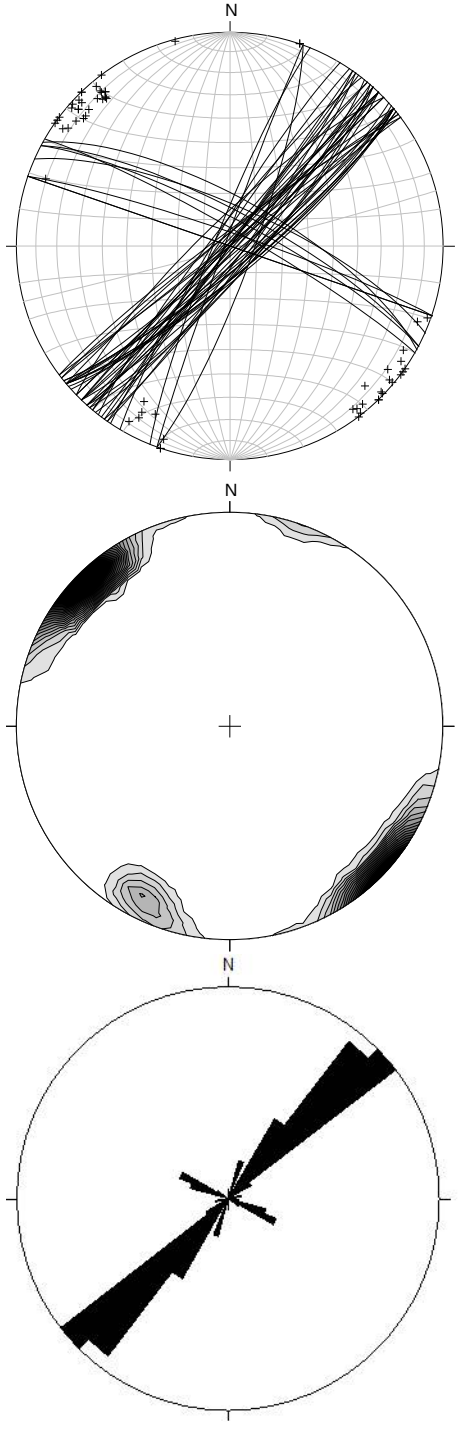


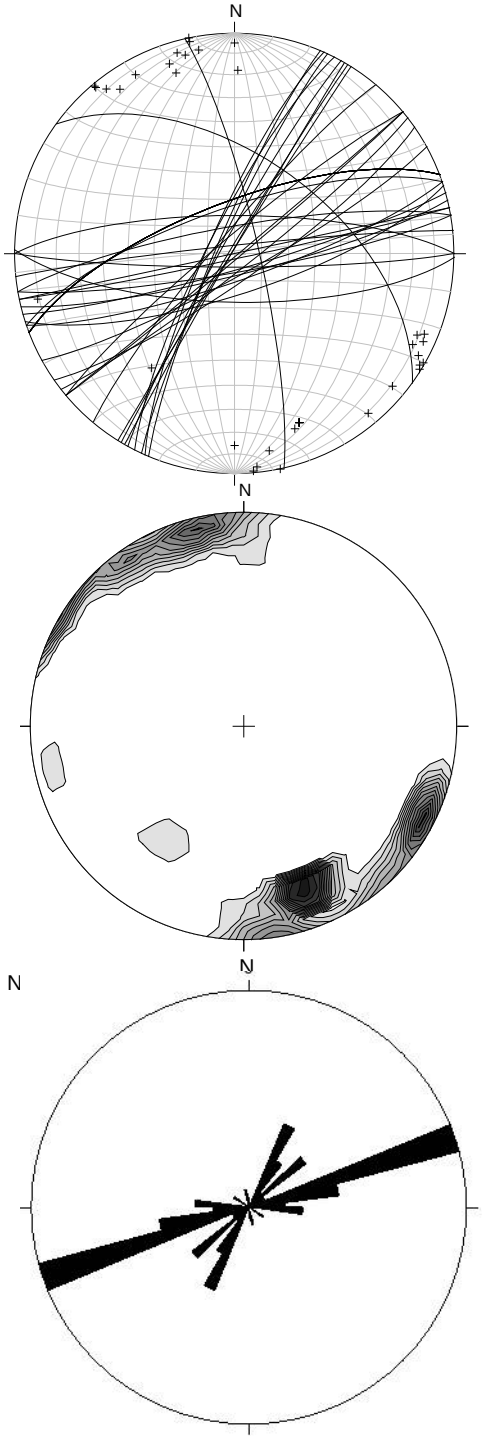
Results

Fracture Orientations

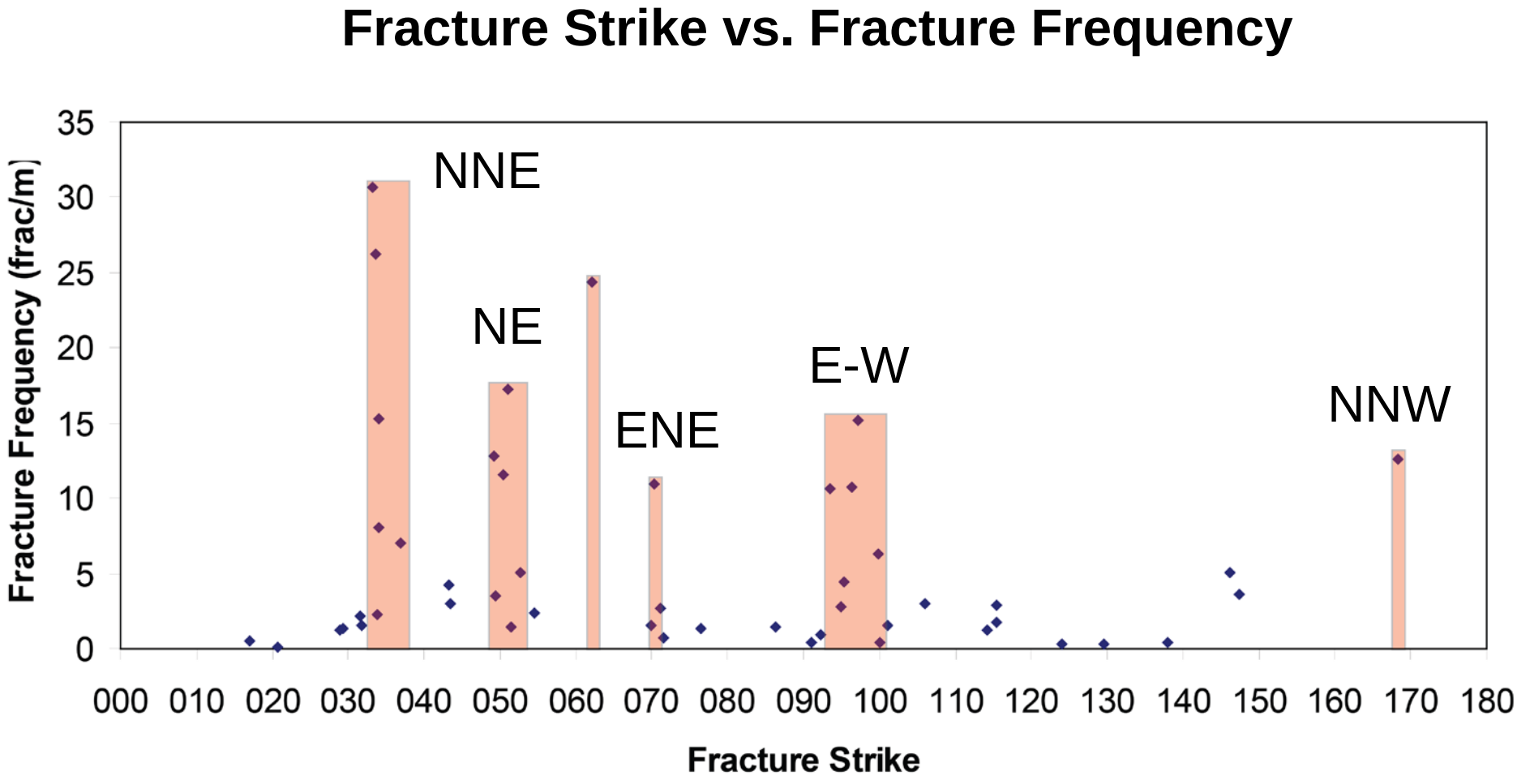



N
N
N

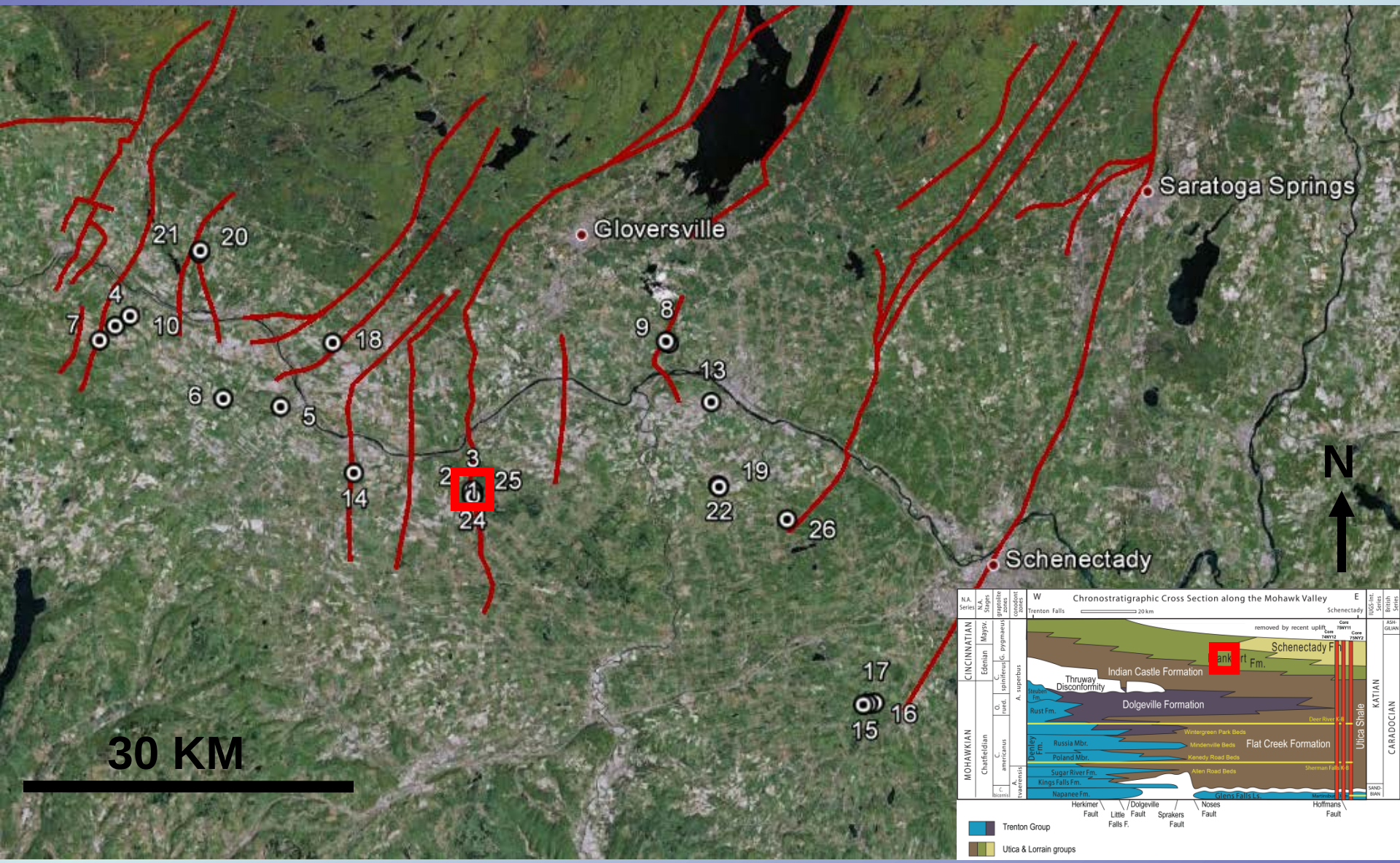

N
N
N

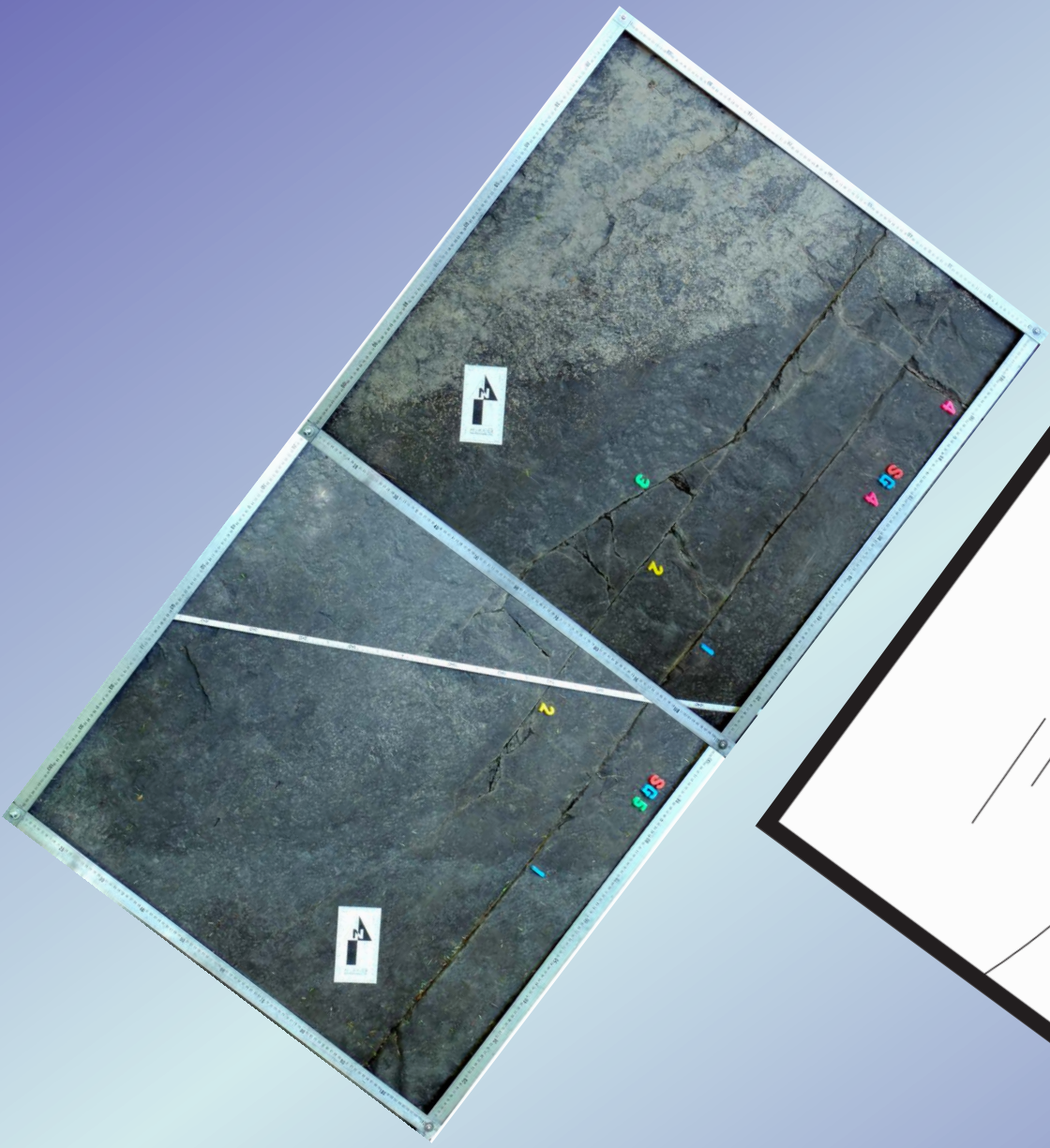

N
N
N
N

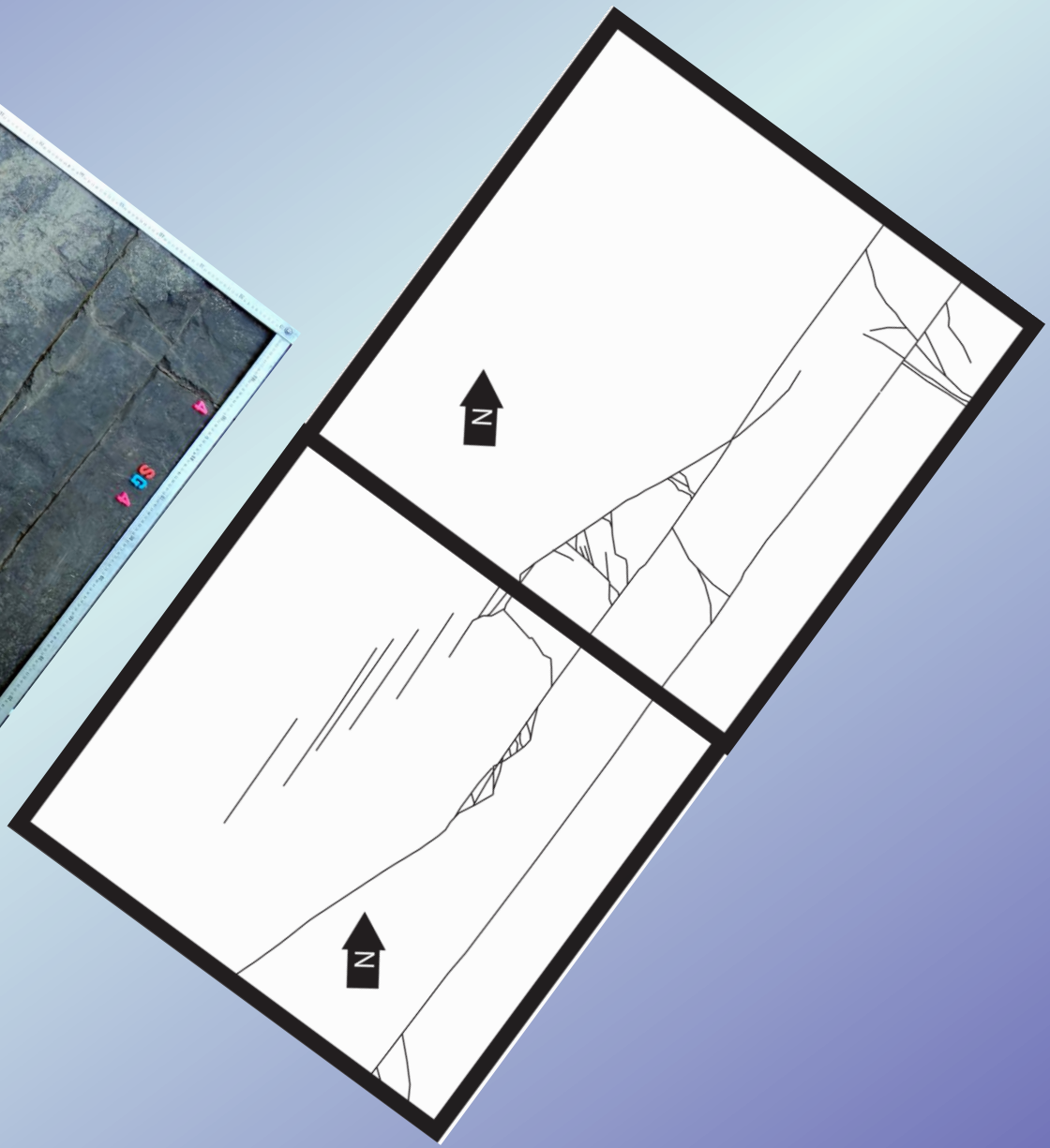
Fracture Frequency

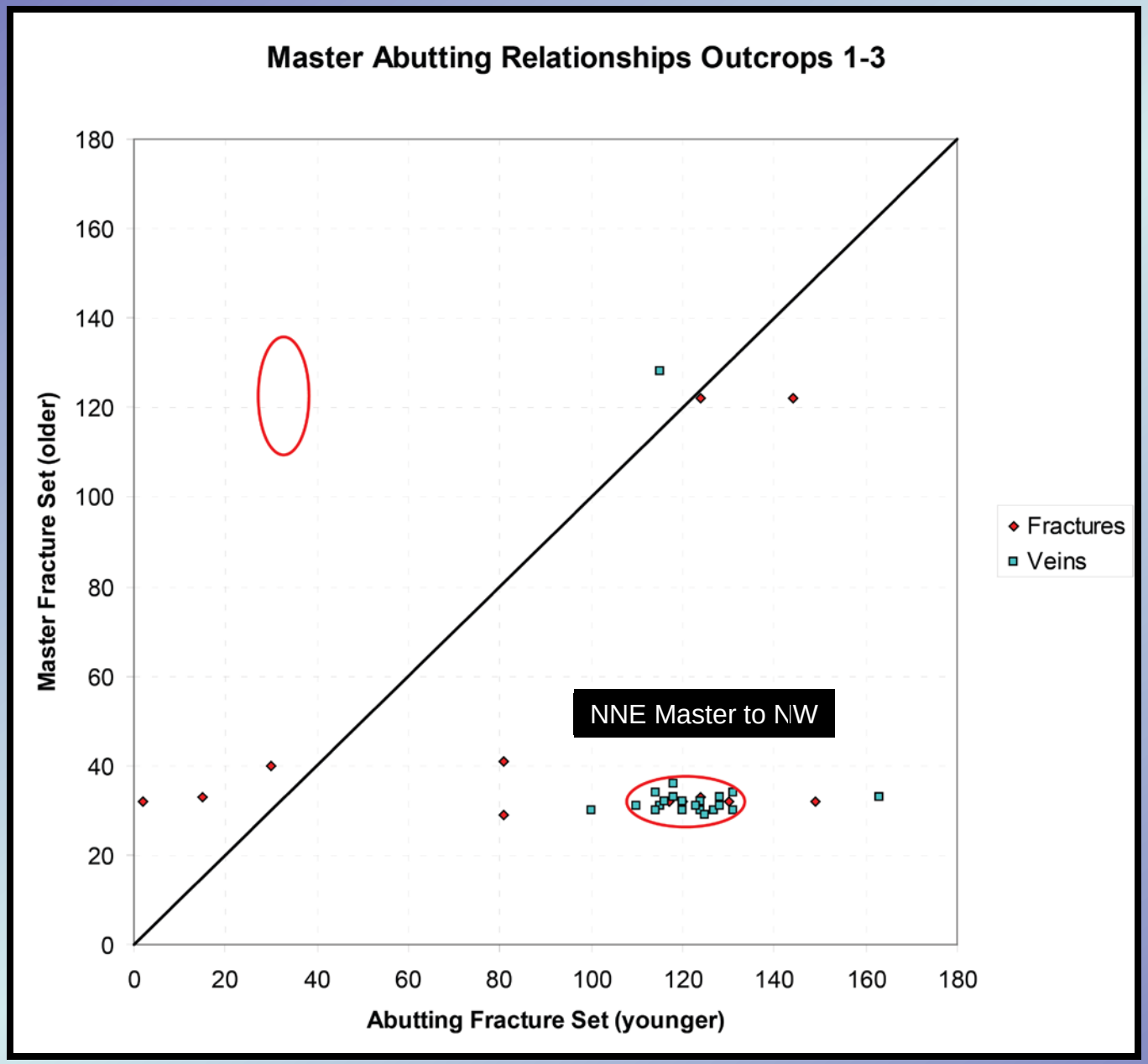


Abutting Relationships

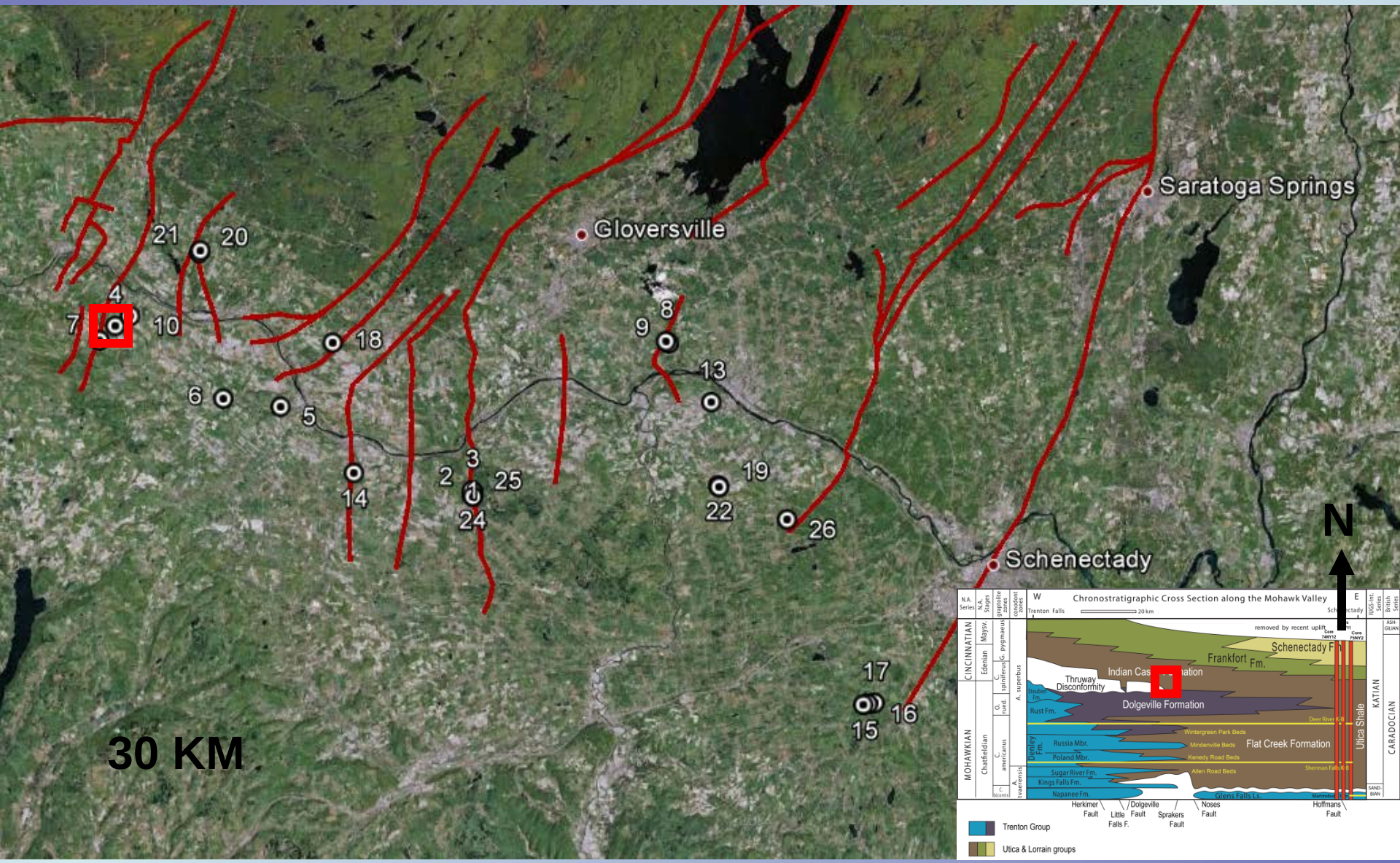


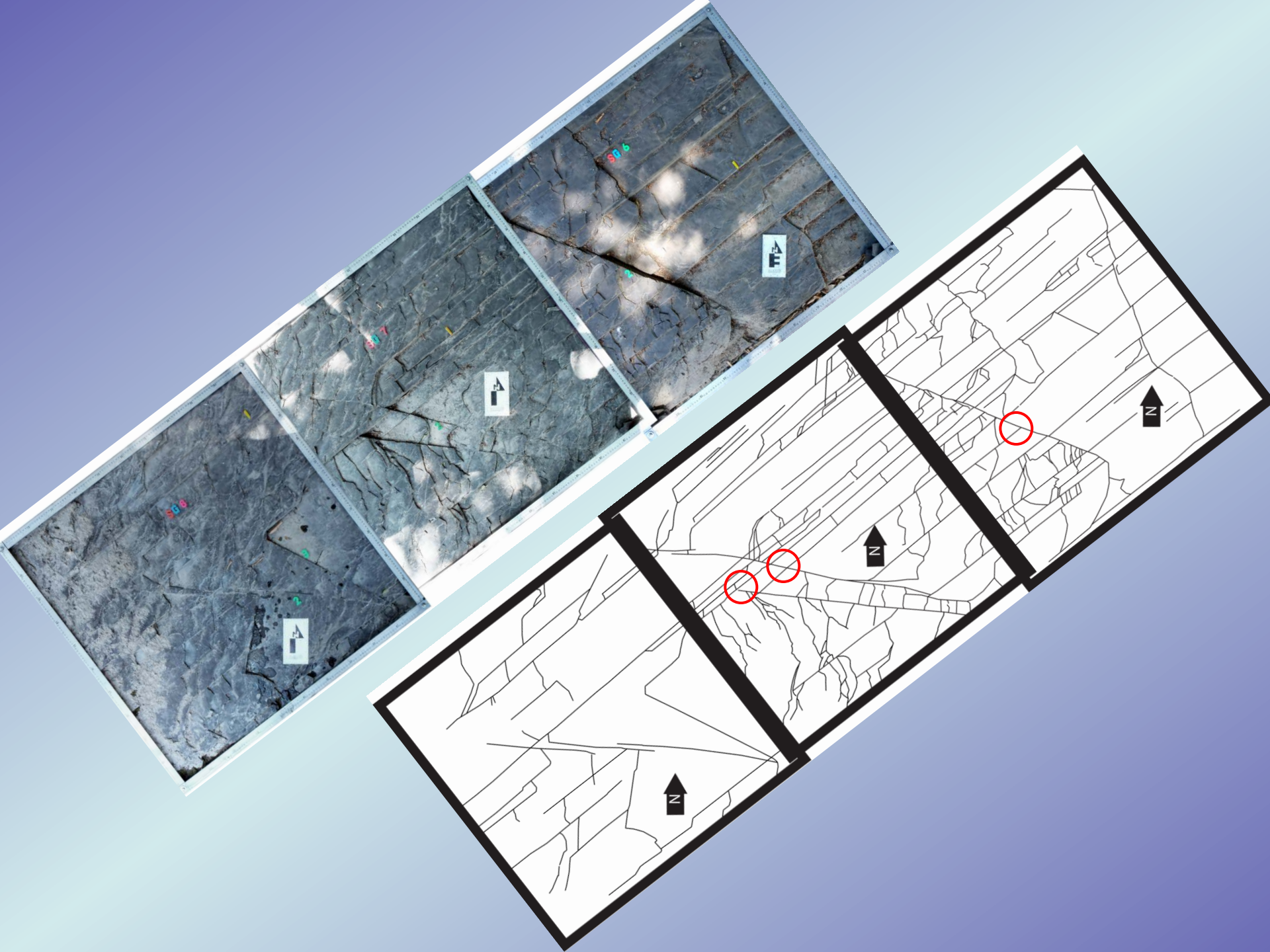

SB 4
3
2
1
SB 5
2
1

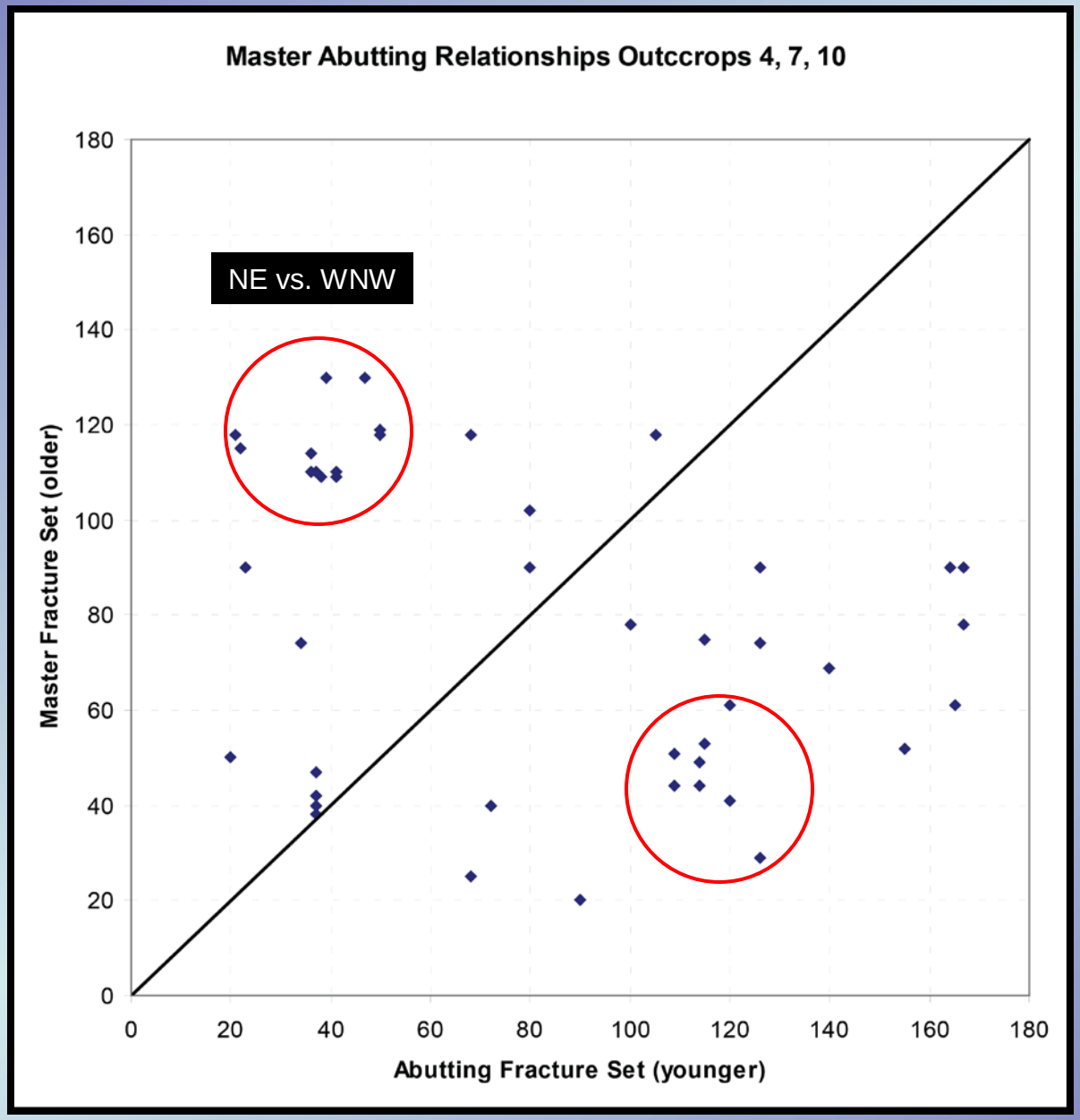

N
N


Master Abutting Relationships Outcrops 1-3
Master Fracture Set (older)
Abutting Fracture Set (younger)
0
20
40
60
80
100
120
140
160
180
NNE Master to NW
Fractures
Veins

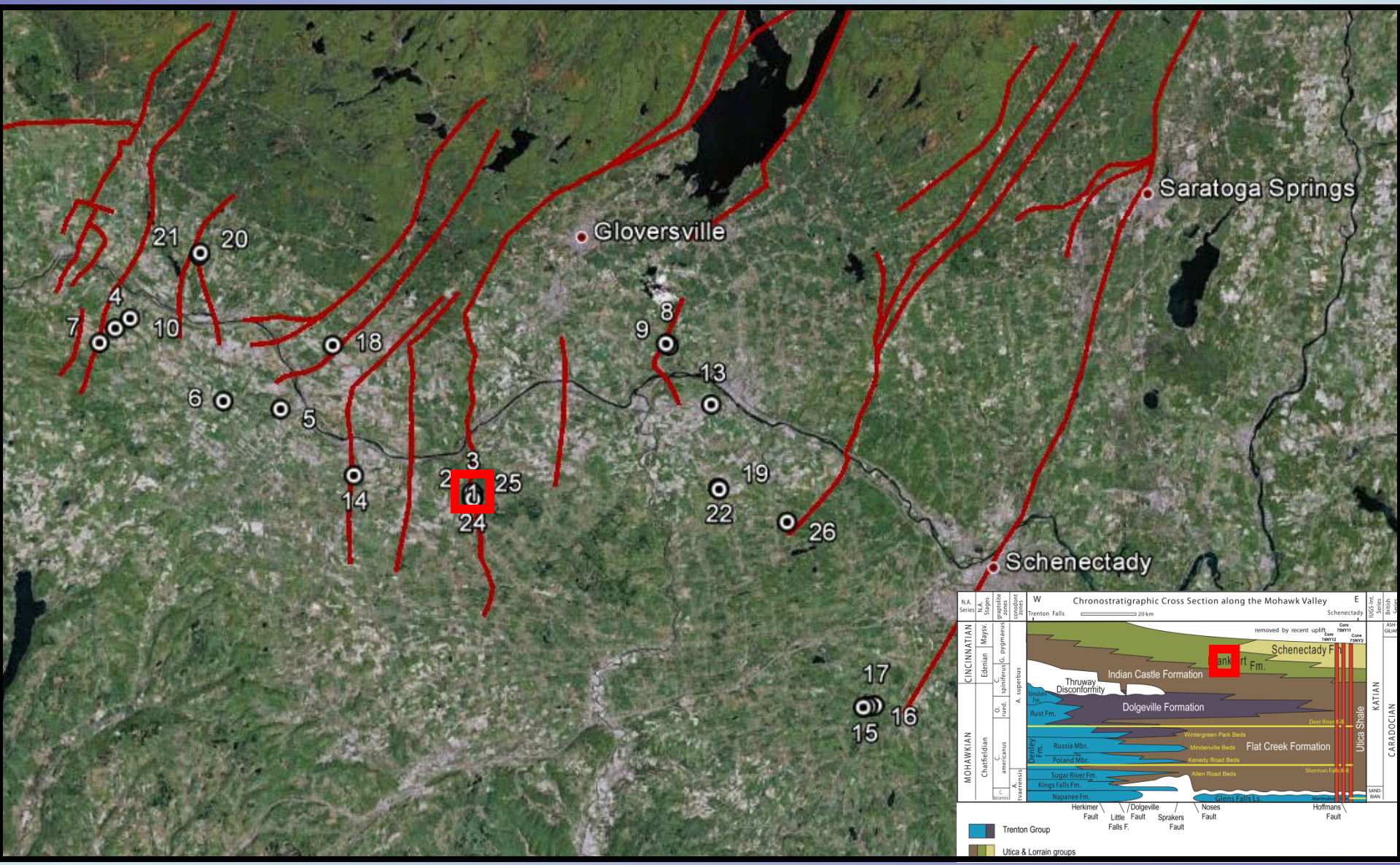
Abutting Relationships






Master Abutting Relationships Outccrops 4, 7, 10
NE vs. WNW
Master Fracture Set (older)
Abutting Fracture Set (younger)
0
20
40
60
80
100
120
140
160
180

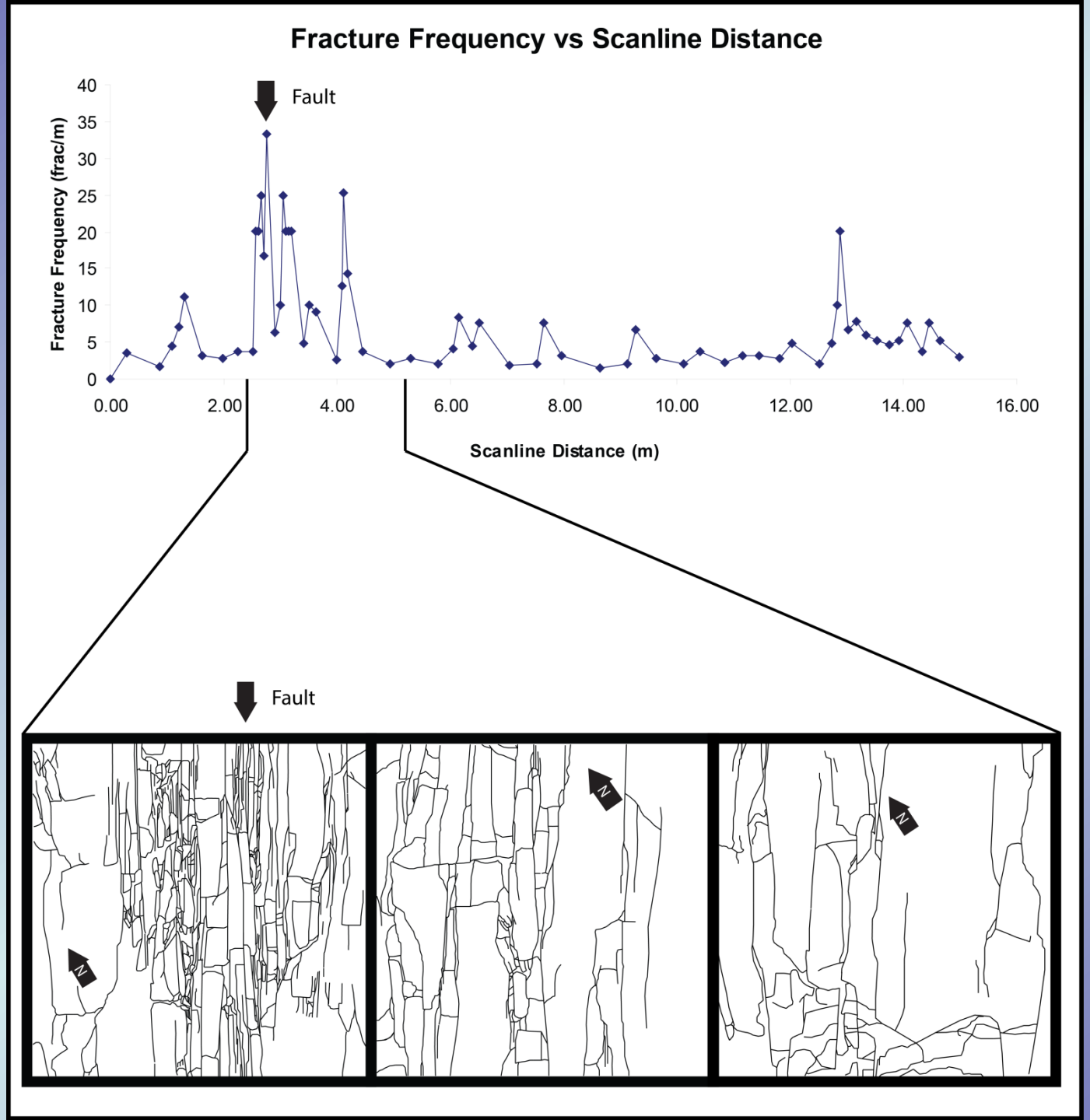
Fault, Fracture and Vein Relationships

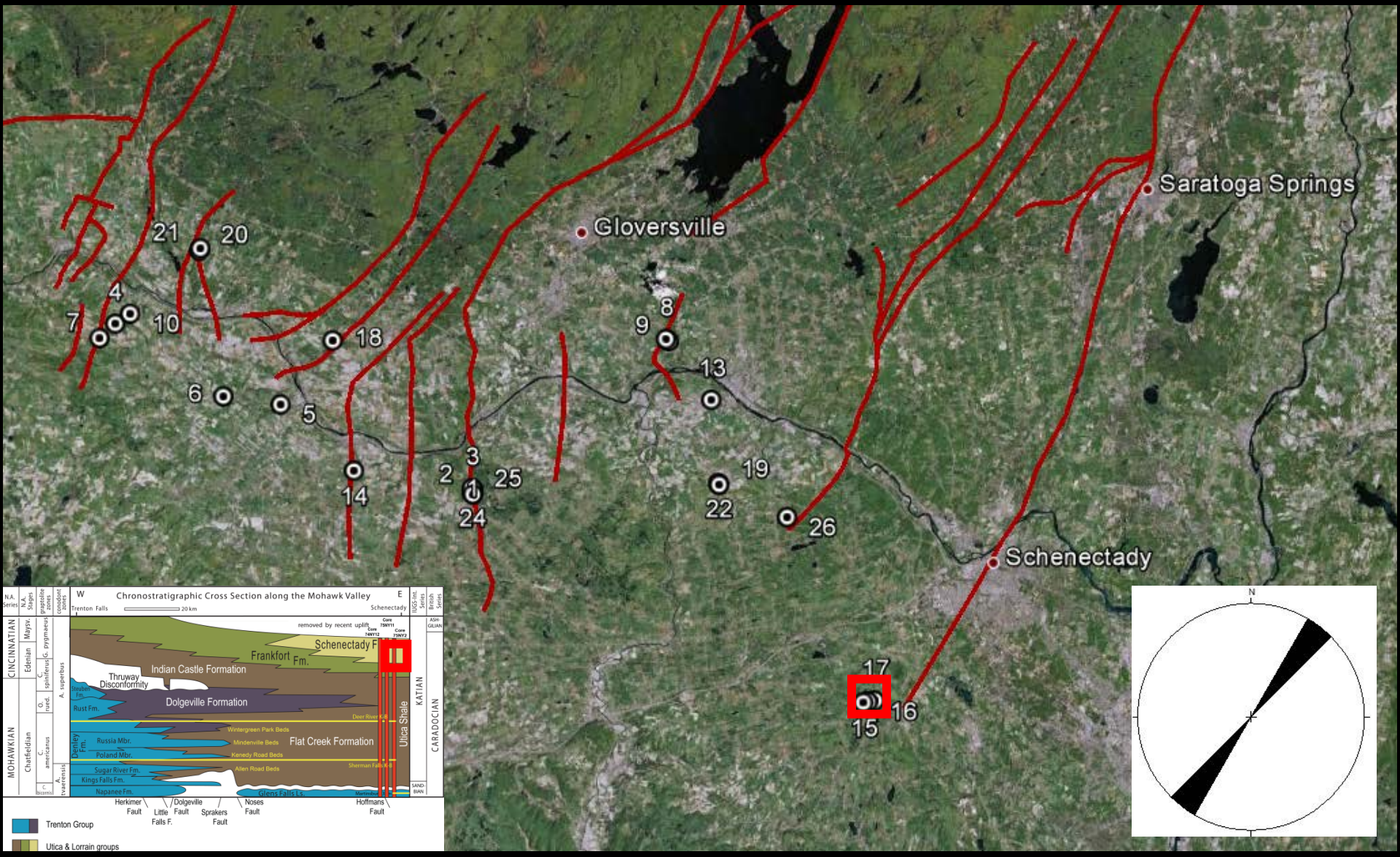



U
D
120cm

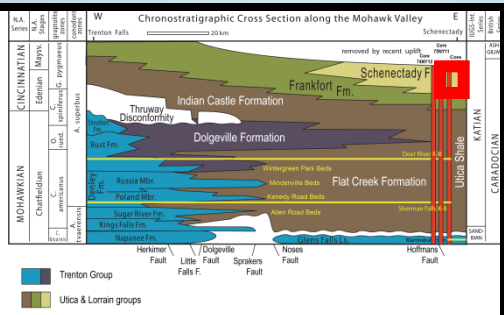
W

E


Fracture Frequency vs Scanline Distance
Fault
Fracture Frequency (frac/m)
40
35
30
25
20
15
10
5
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Scanline Distance (m)
Fault
N
N
N

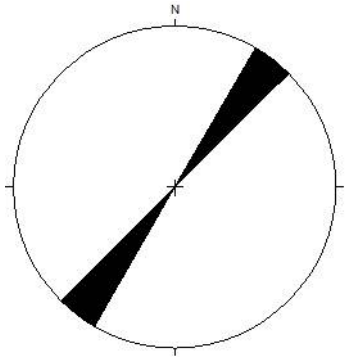

Saratoga Springs
Gloversville
Schenectady
21
20
4
7
10
18
6
5
8
9
13
3
2
1
25
14
24
19
22
26
17
16
15
N
W
Chronostratigraphic Cross Section along the Mohawk Valley
E
Trenton Falls
20 km
Schenectady
removed by recent uplift
Core 75NY11
Core 74NY12
Core 75NY2
Schenectady Fm.
Frankfort Fm.
Indian Castle Formation
Thruway Disconformity
Dolgeville Formation
Steuben Fm.
Rust Fm.
Deer River Mbr.
Wintergreen Park Beds
Mindenville Beds
Kenedy Road Beds
Allen Road Beds
Sherman Falls Mbr.
Flat Creek Formation
Denley Fm.
Russia Mbr.
Poland Mbr.
Sugar River Fm.
Kings Falls Fm.
Napanee Fm.
Glens Falls Ls.
Utica Shale
Herkimer Fault
Little Falls F.
Dolgeville Fault
Sprakers Fault
Noses Fault
Hoffmans Fault
Trenton Group
Utica & Lorrain groups
CINCINNATIAN
MOHAWKIAN
Edenian
Maysv.
Chatfieldian
KATIAN
CARADOCIAN
ASH-GILLIAN
SANDBIAN

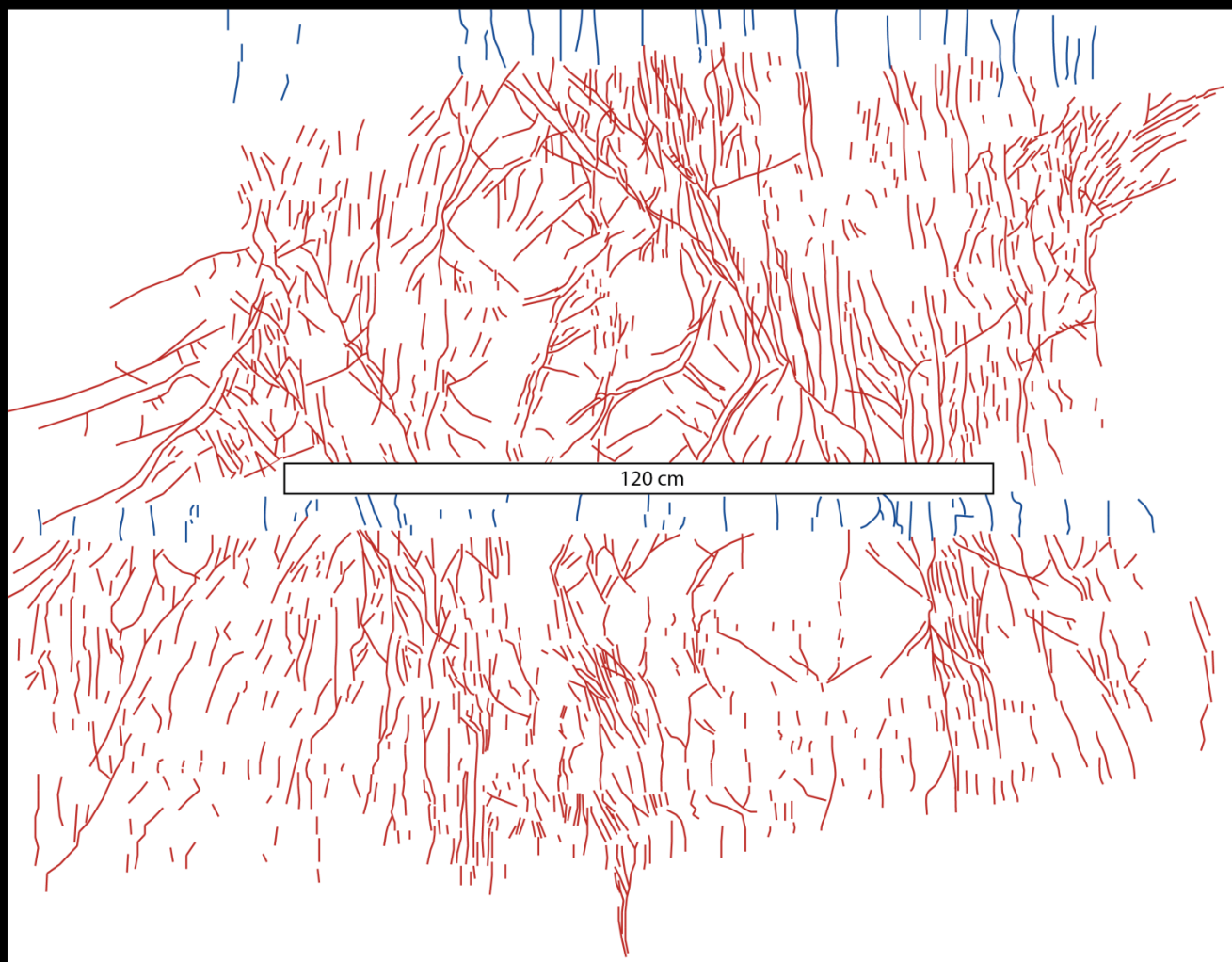

120 cm

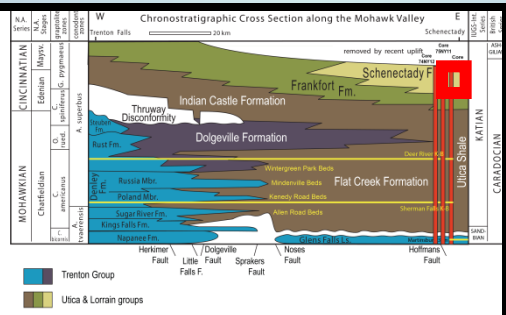


Legend

- Shale/Slitstone Fractures
- Sandstone Fractures



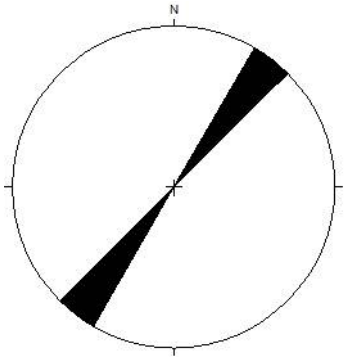


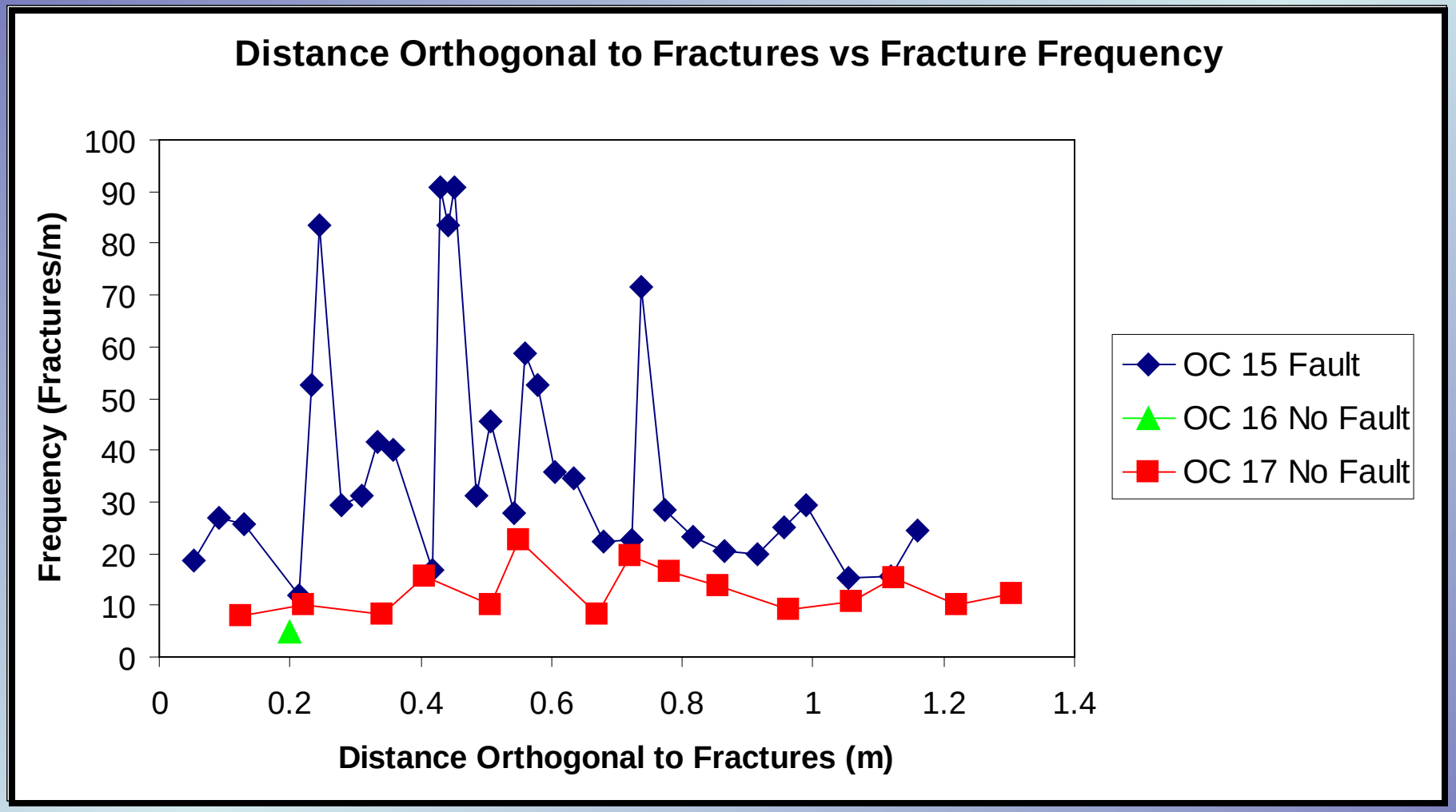


Legend

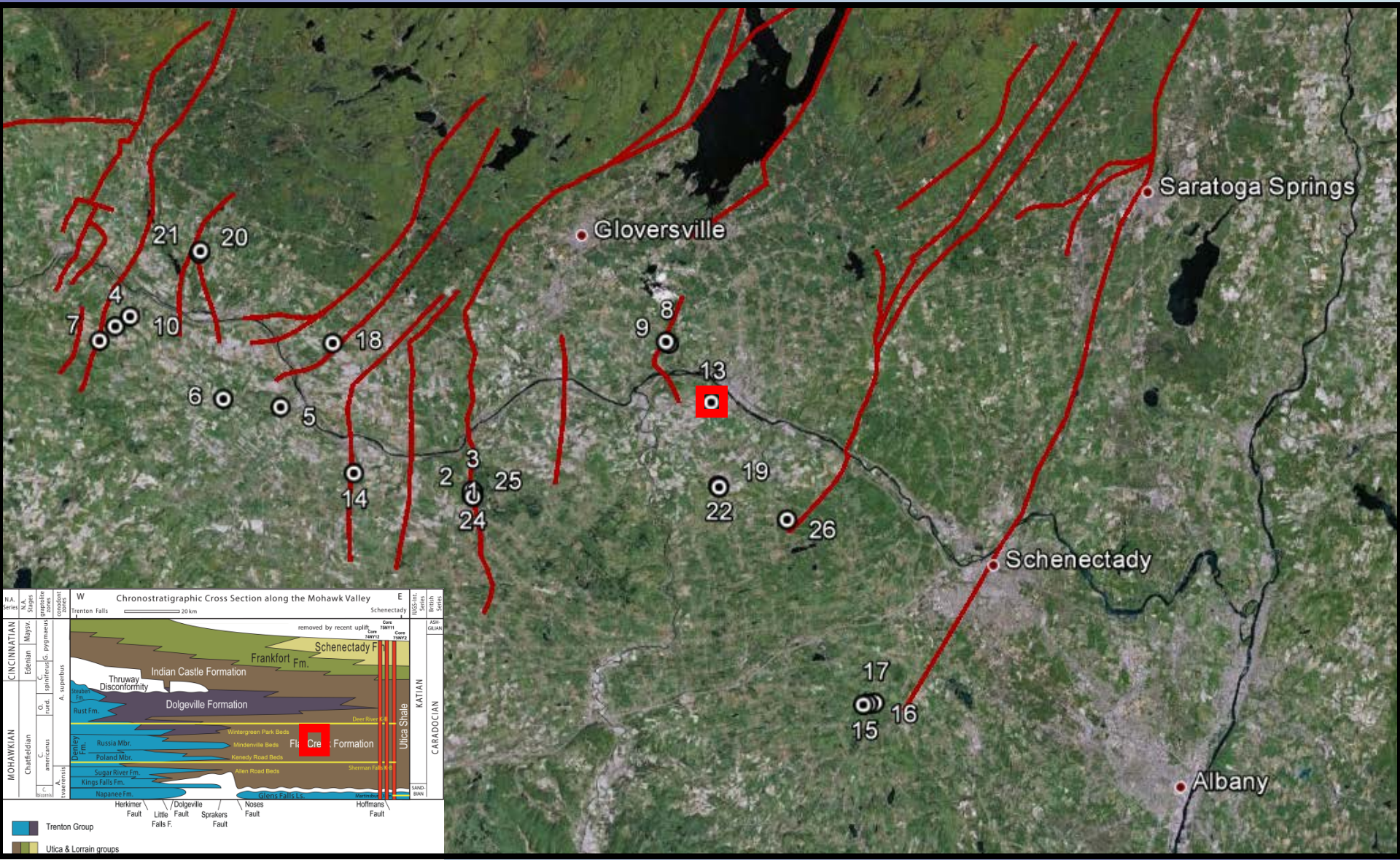
Shale/Slitstone Fractures

Sandstone Fractures

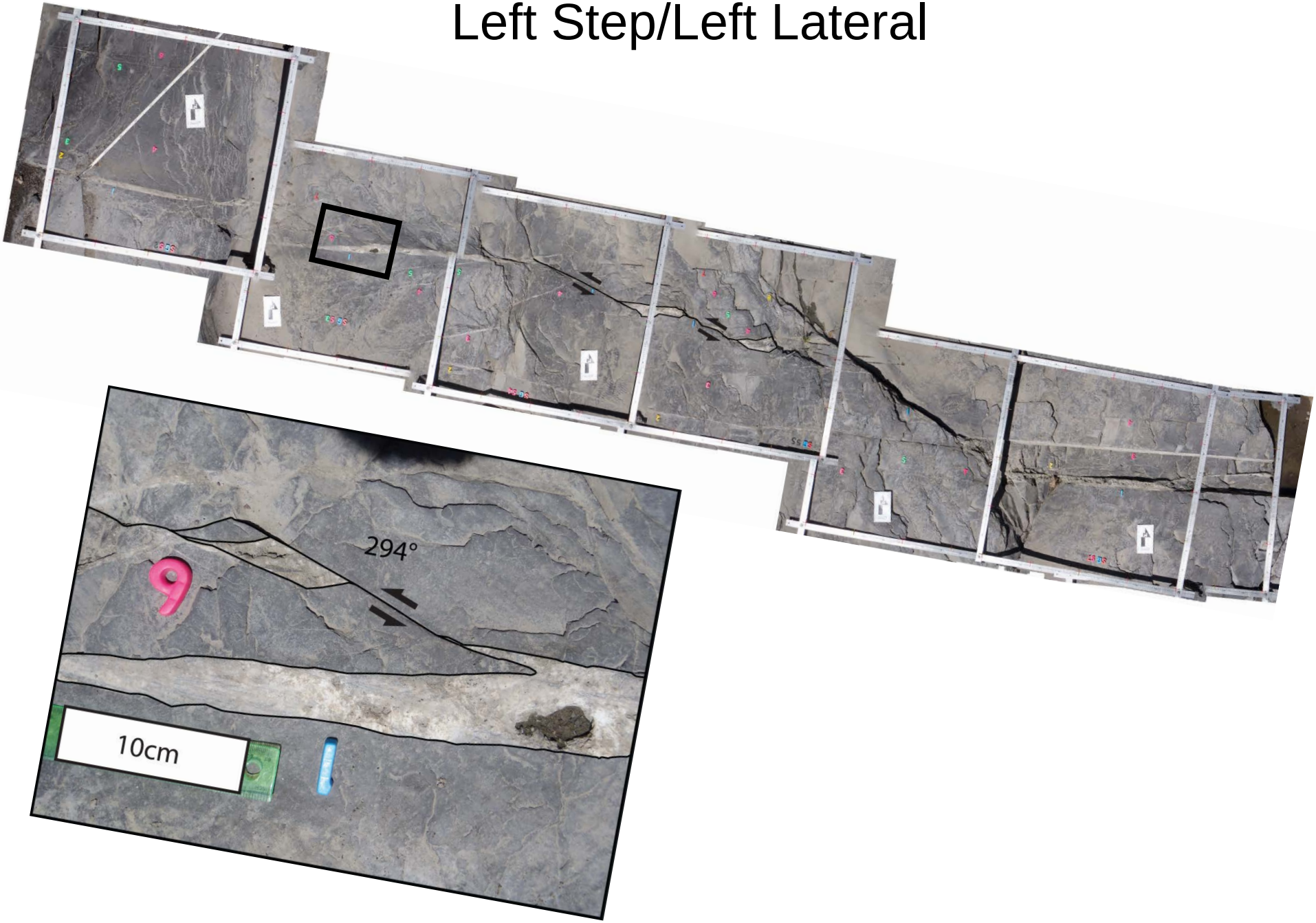



Distance Orthogonal to Fractures vs Fracture Frequency
Frequency (Fractures/m)
100
90
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Distance Orthogonal to Fractures (m)
OC 15 Fault
OC 16 No Fault
OC 17 No Fault

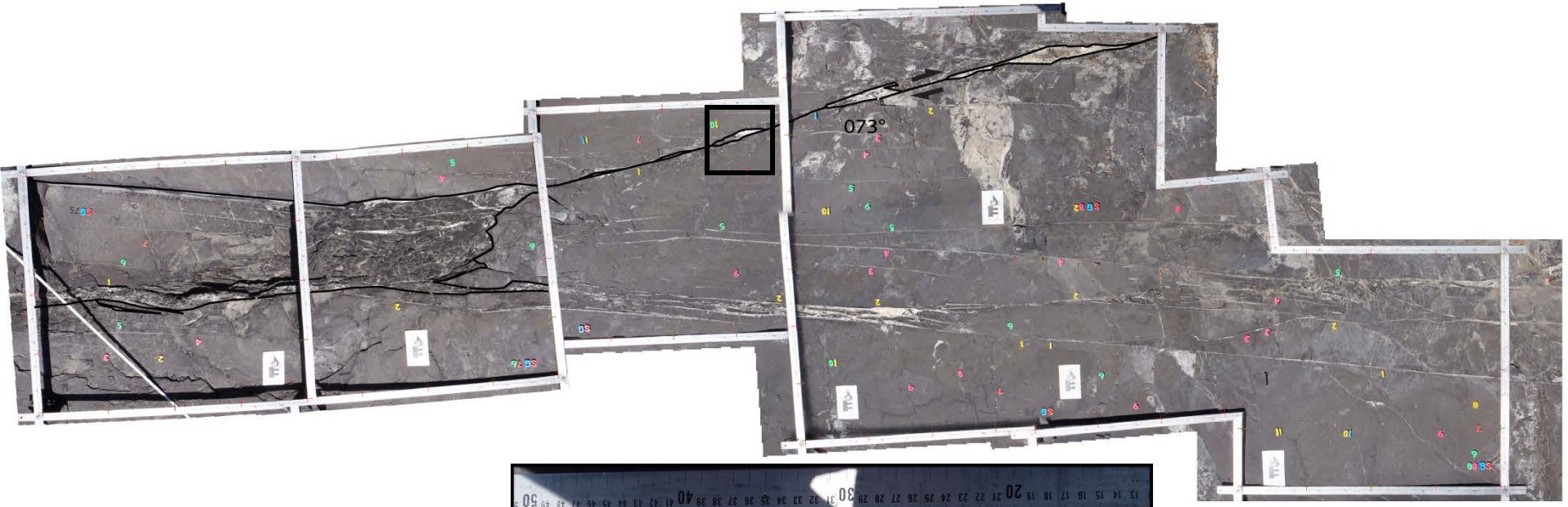
Inferred Shear: Veins

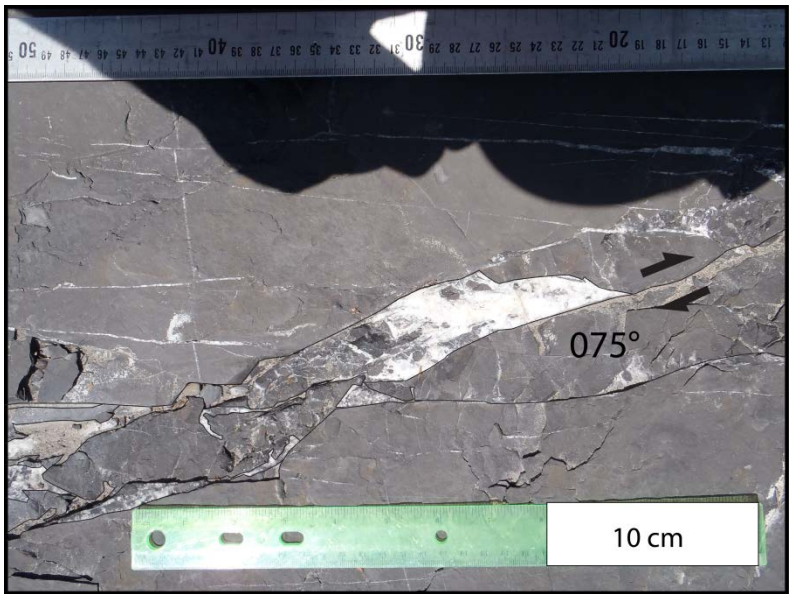


Left Step/Left Lateral

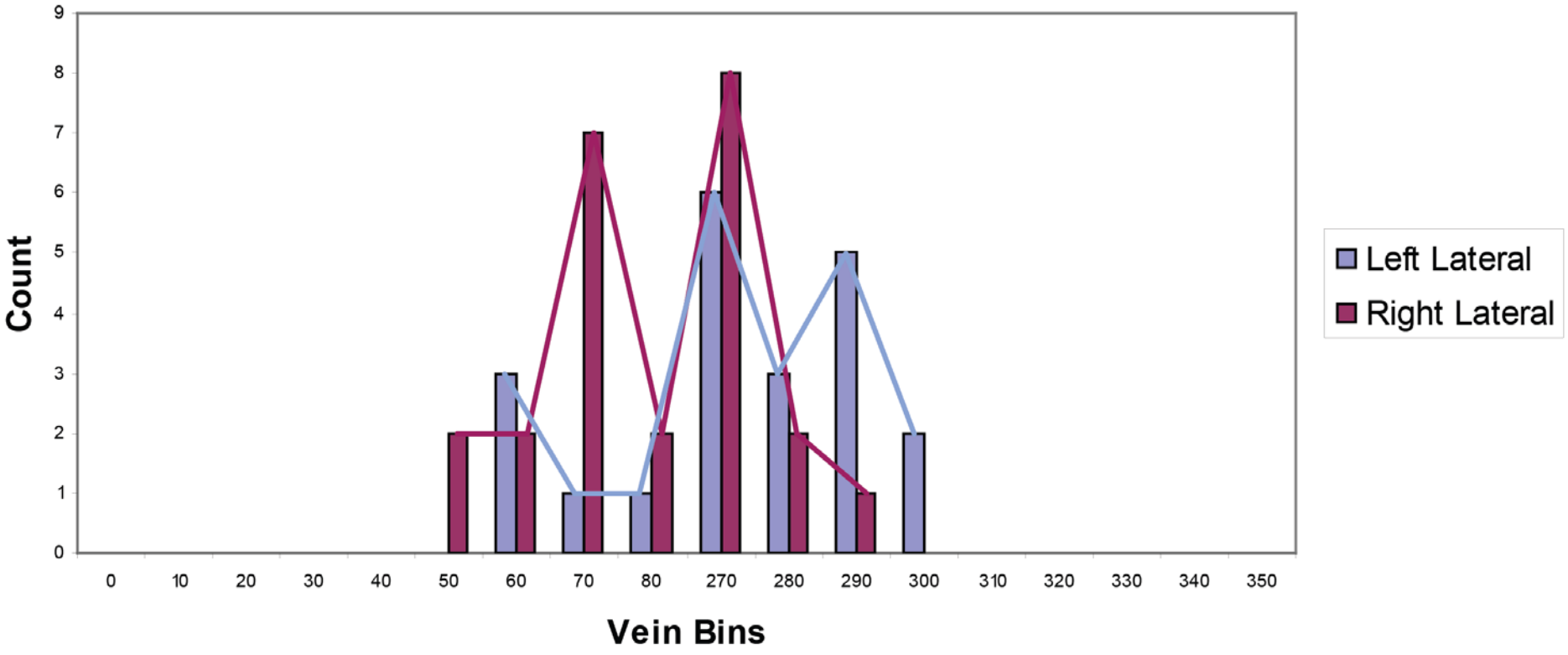


Right Step/Right Lateral



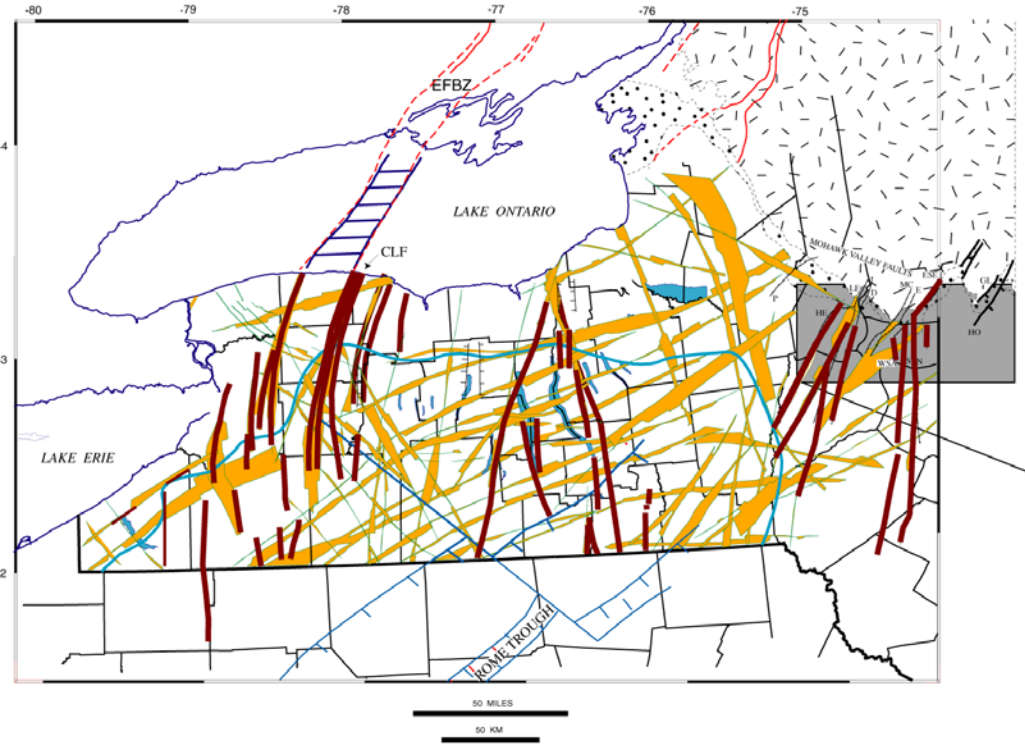


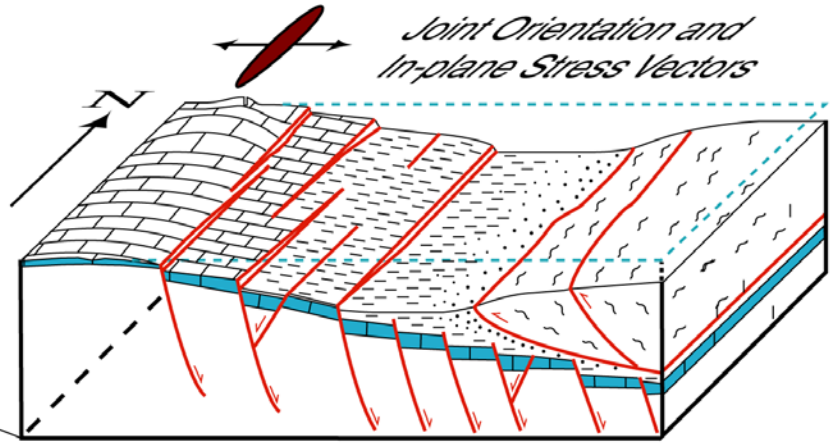
Outcrop 13: Transcurrent Motion of Veins



Discussion

Current Model

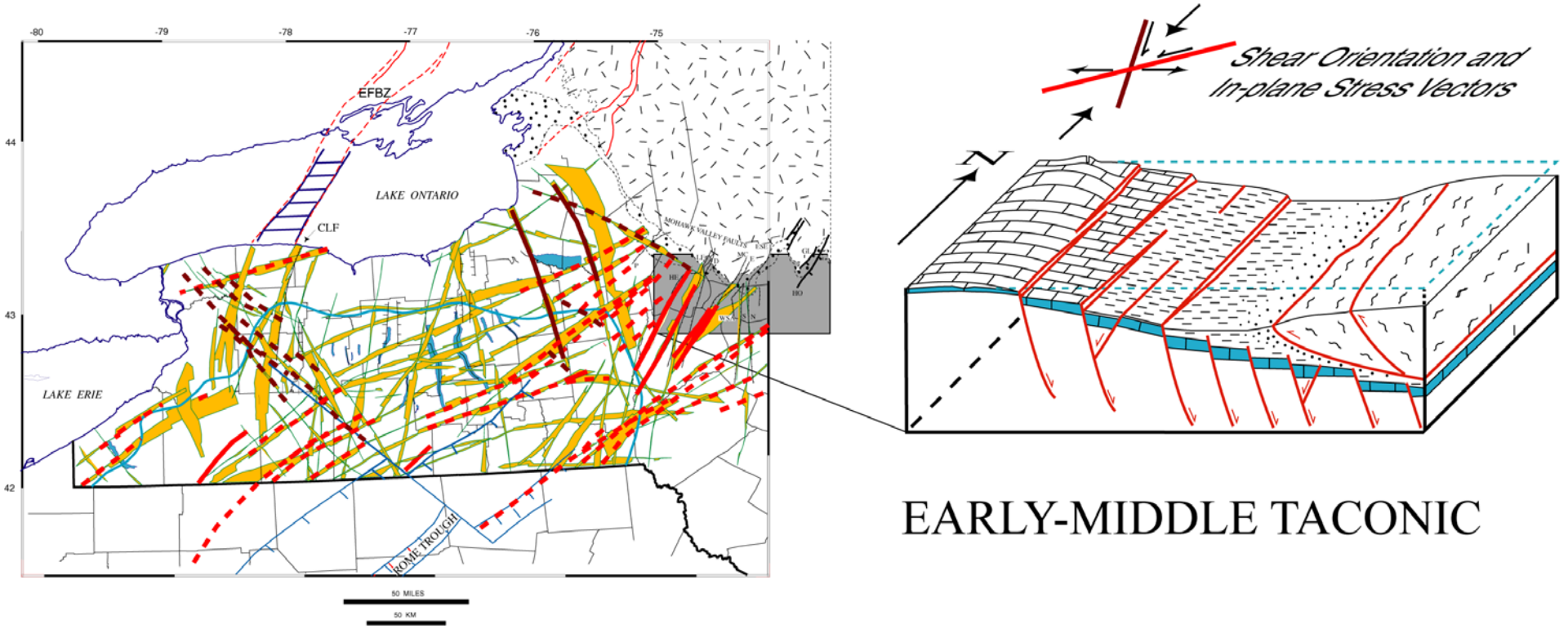




EARLY-MIDDLE TACONIC
OPEN MODE I JOINTS

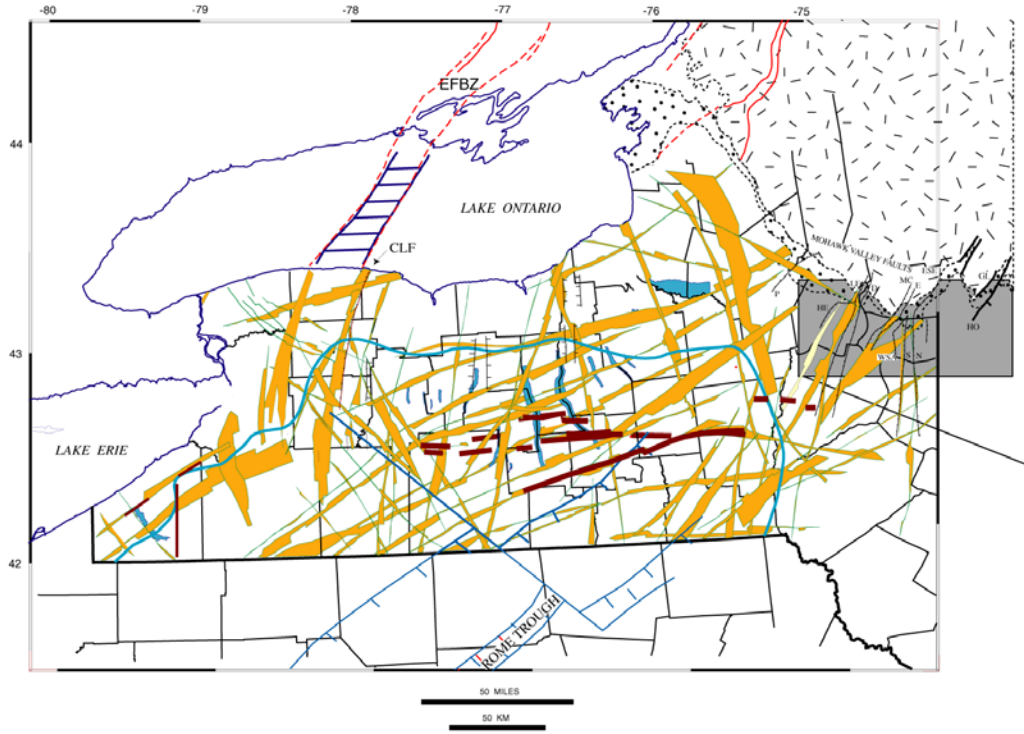
Jacobi et al., 2003

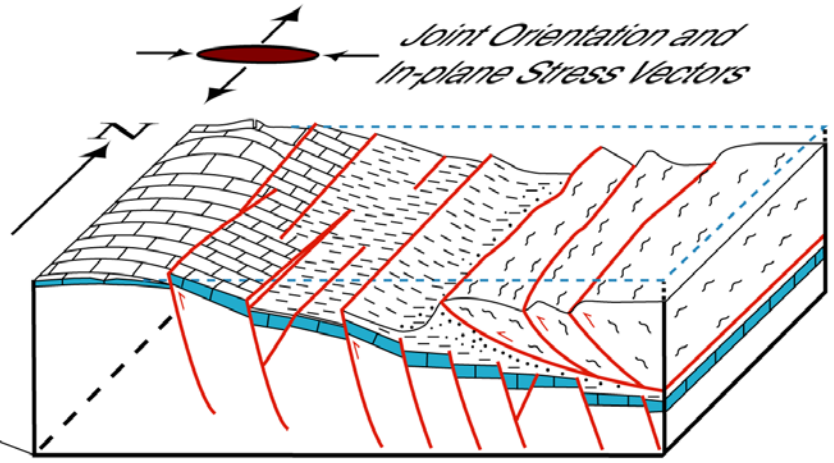
Current Model



Jacobi et al., 2003

Current Model

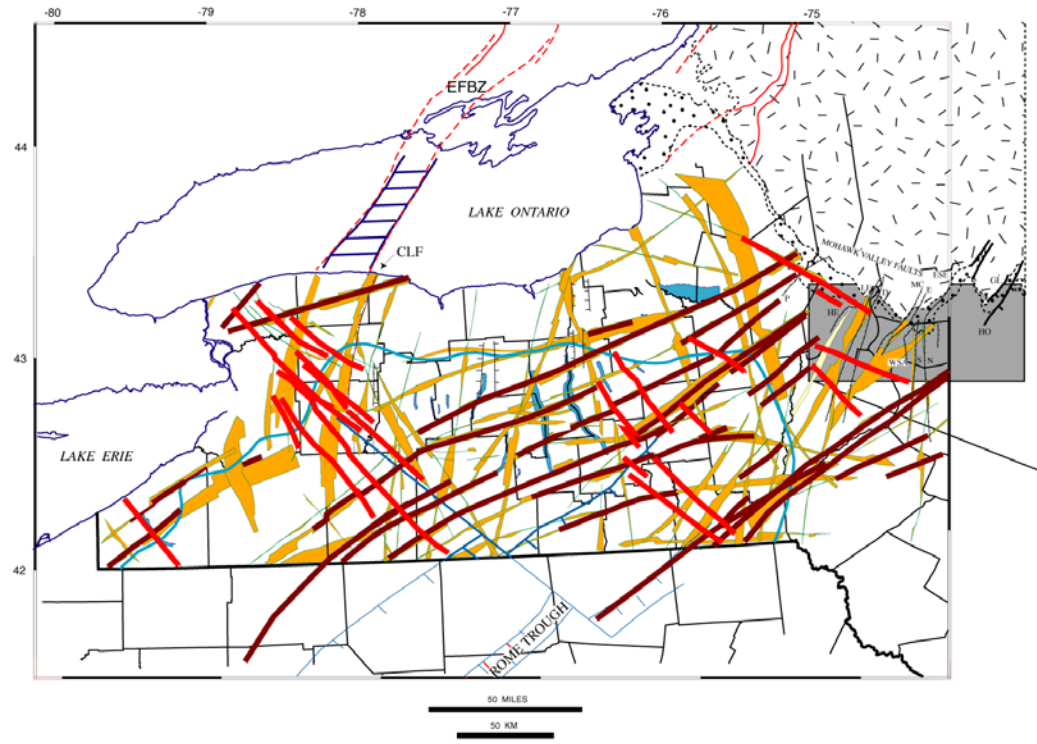


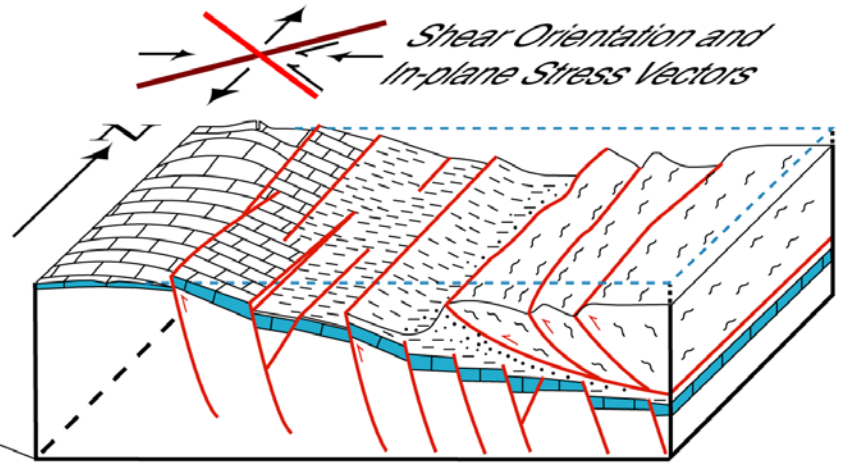


LATE TACONIC
OPEN MODE I FRACTURES

Jacobi et al., 2003

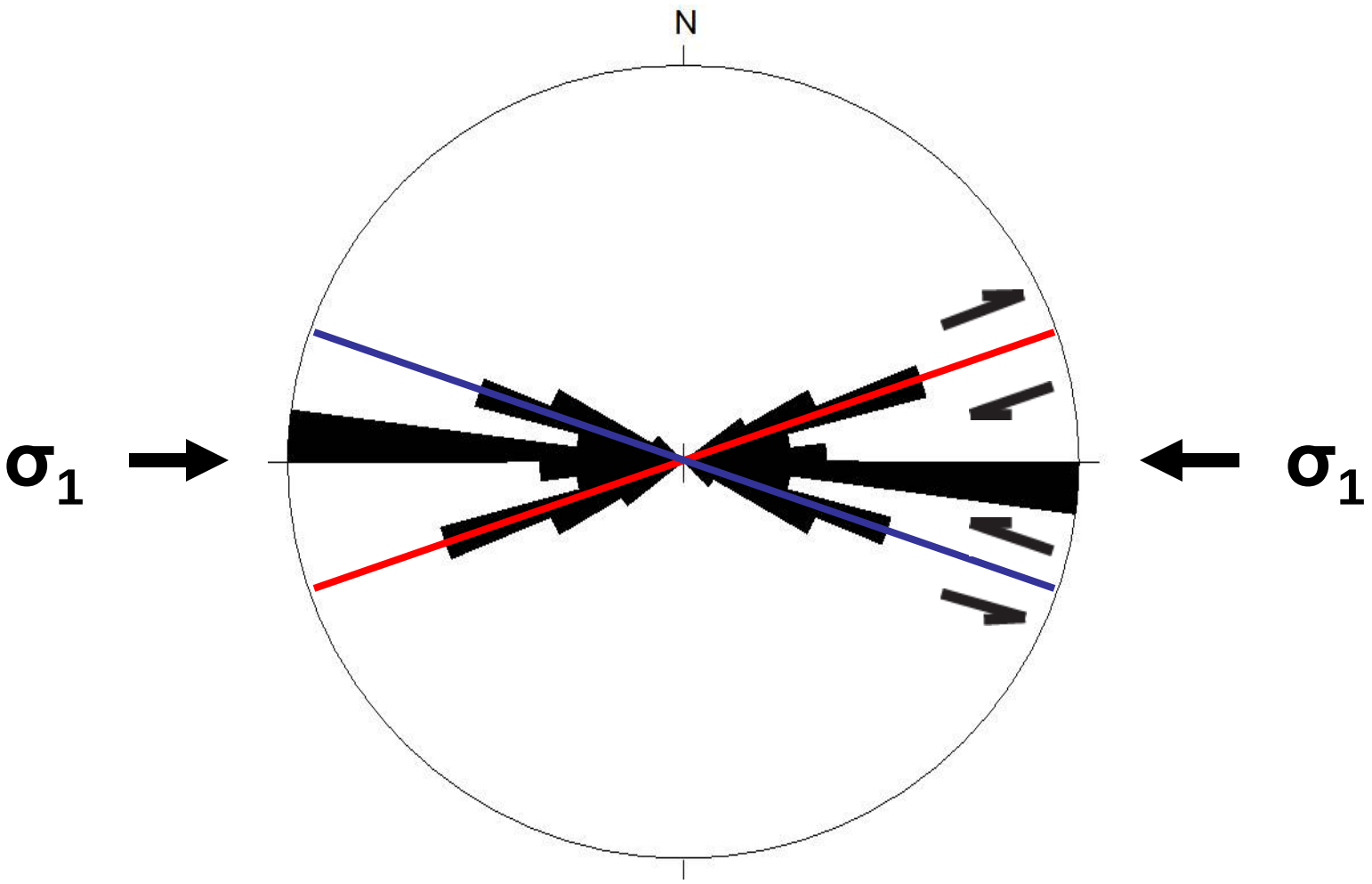
Current Model



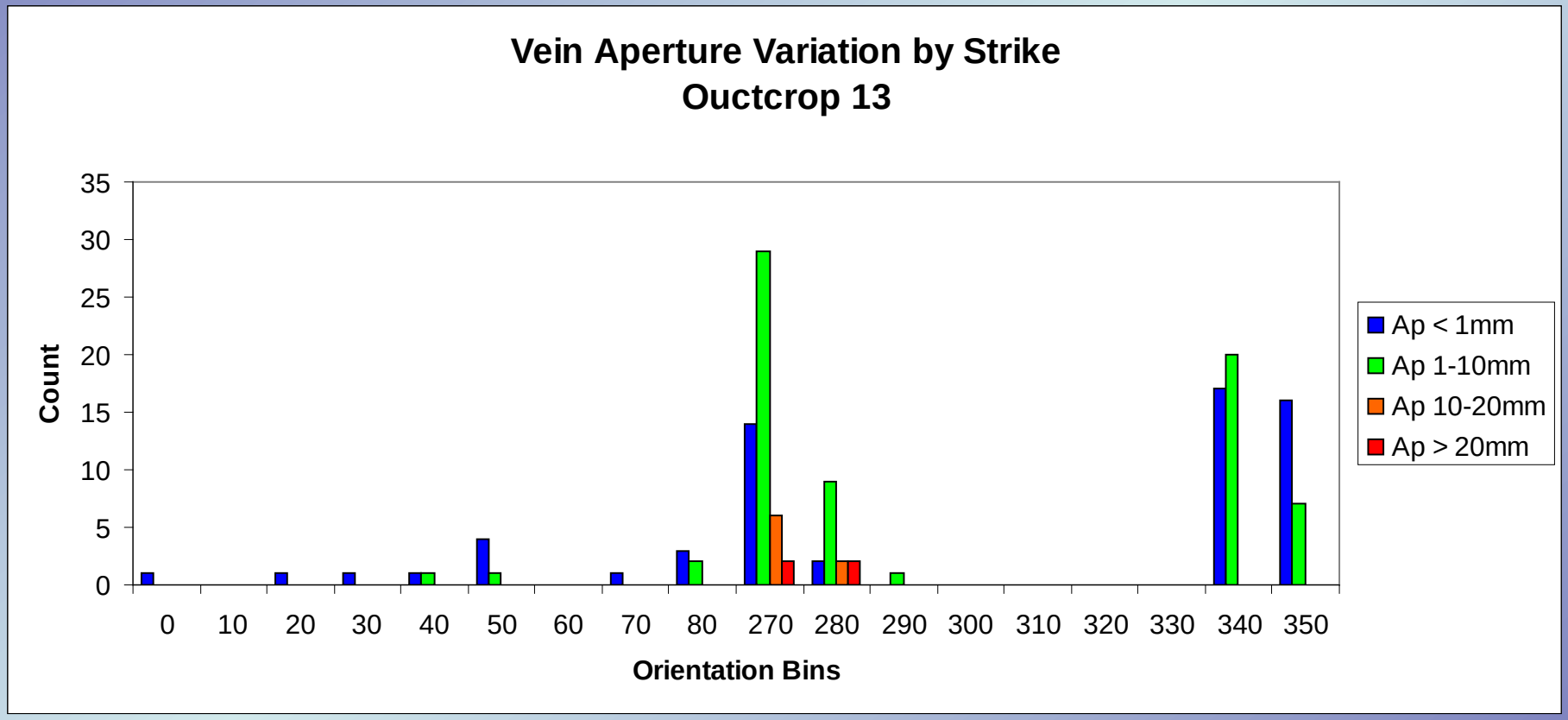


Jacobi et al., 2003

Conjugate Shear, E-W Compression and Formation of Thrust Faults

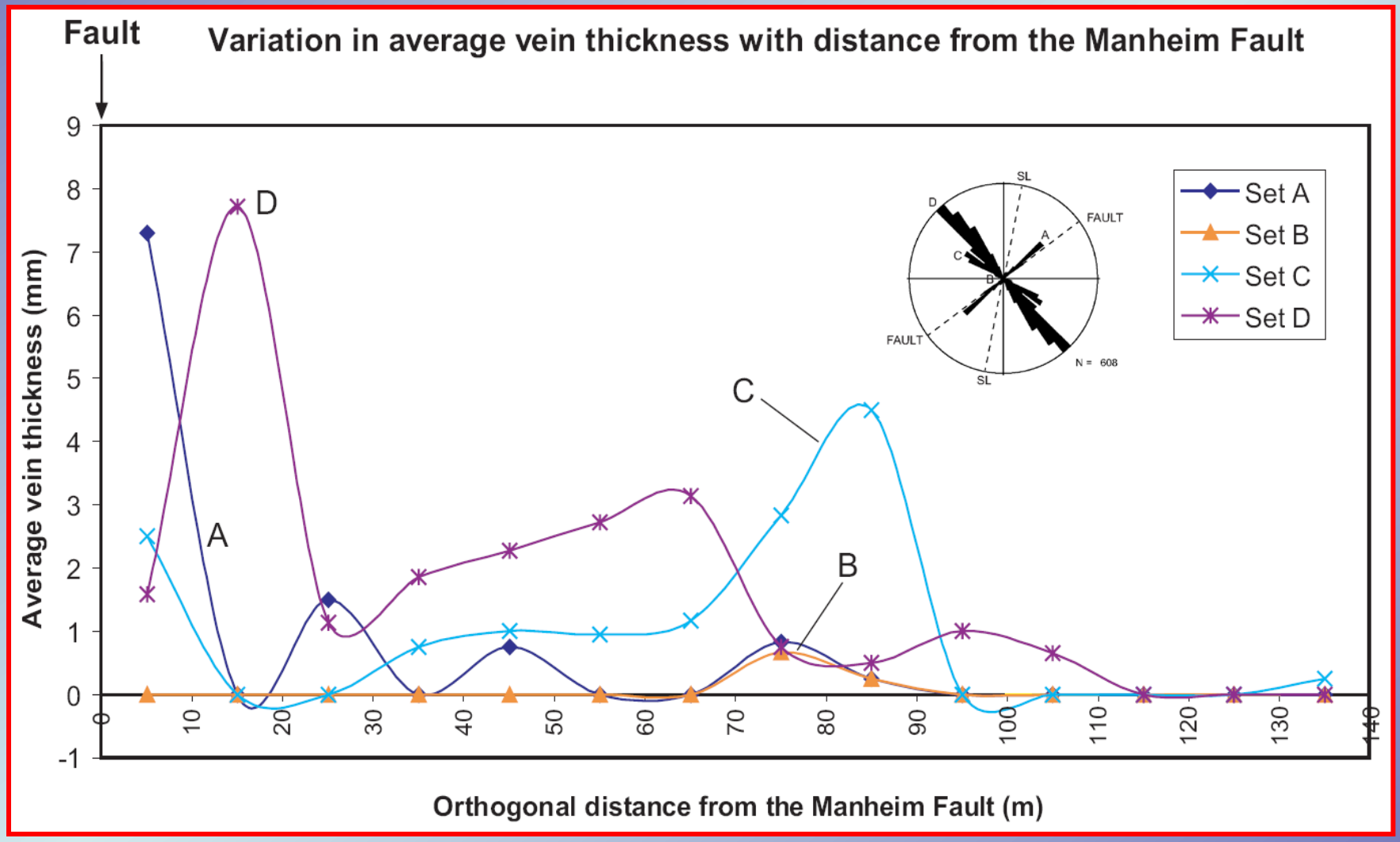


Maximum Vein Aperture



North/South Striking Thrust

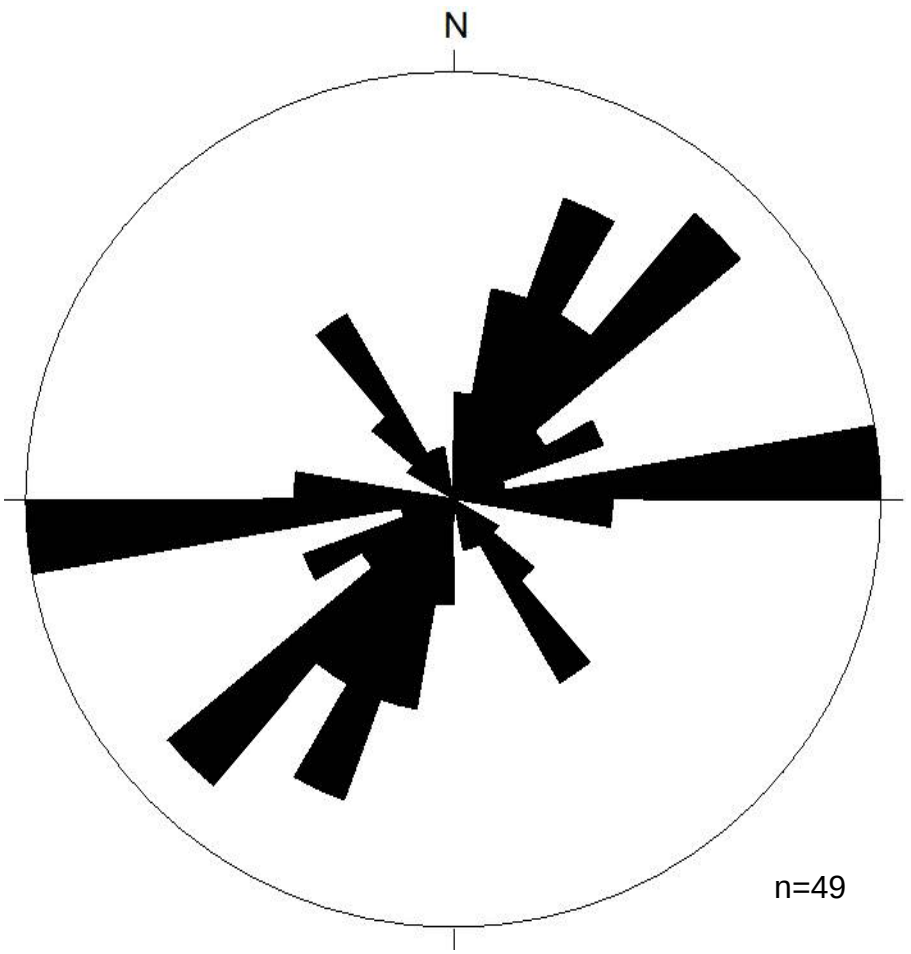
WNW Compression Based on Increasing Vein Aperture Width



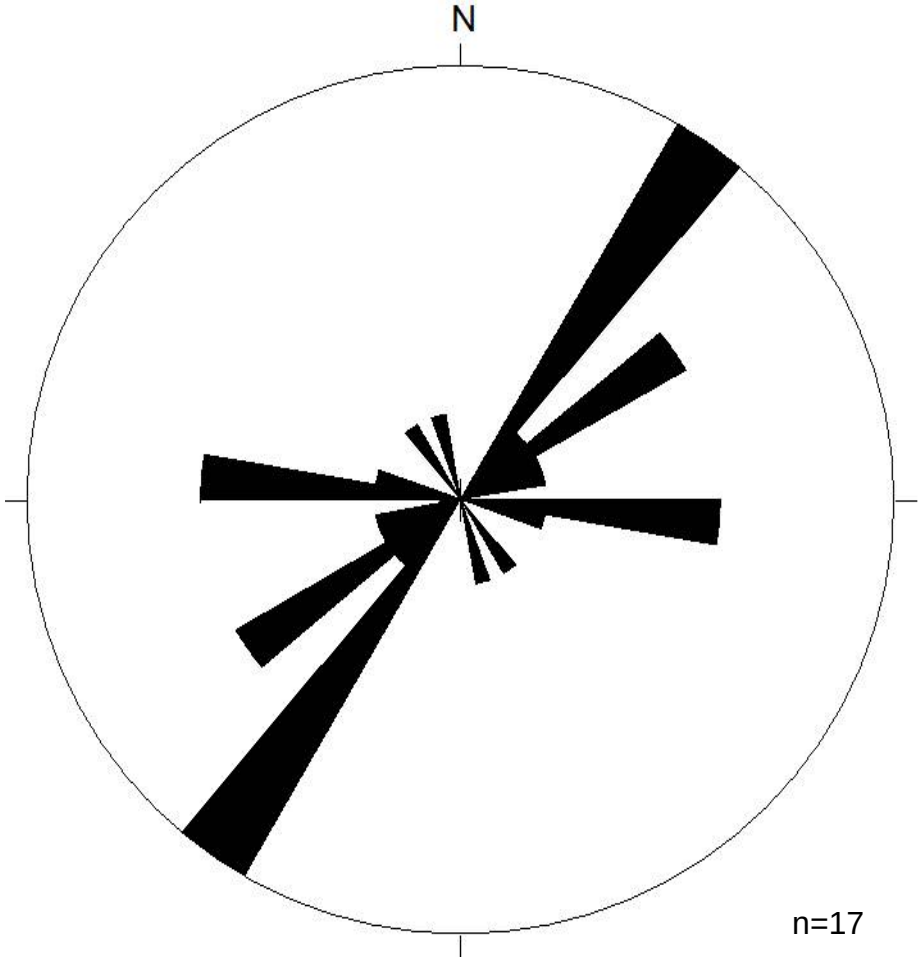
Cross, 2004

Fault Induced Fracture Intensification Domains

Faults

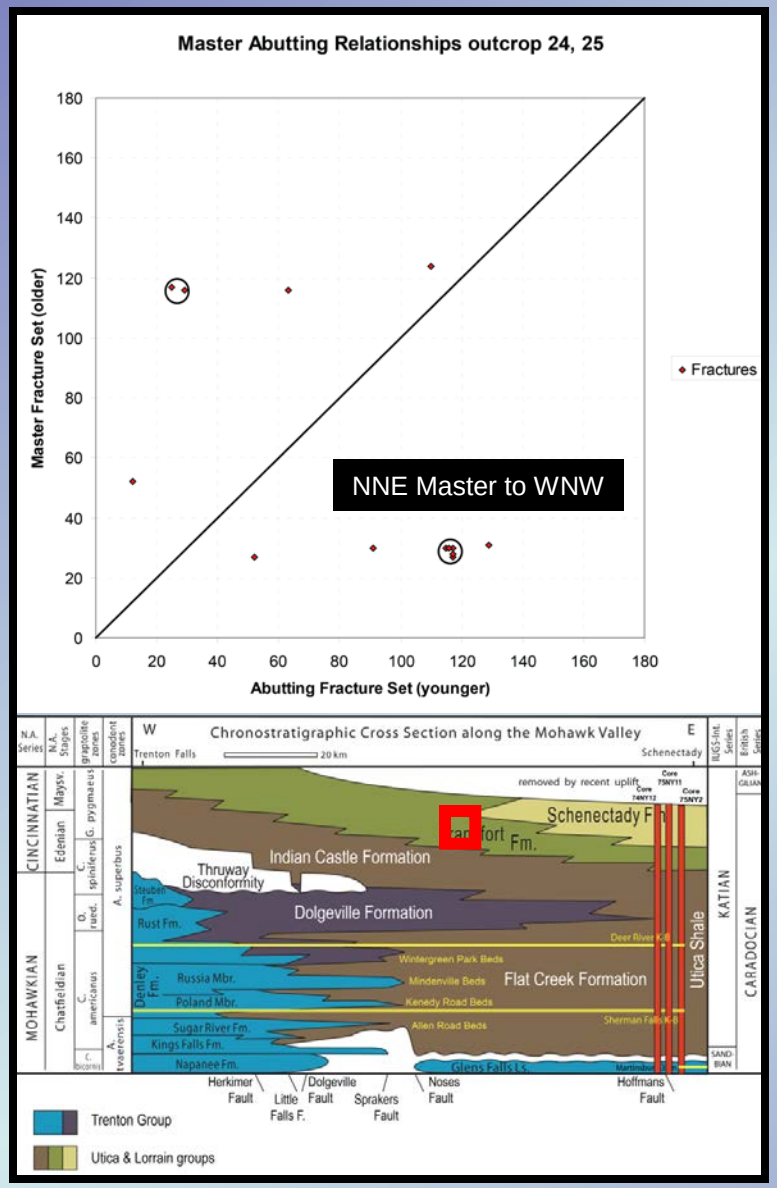


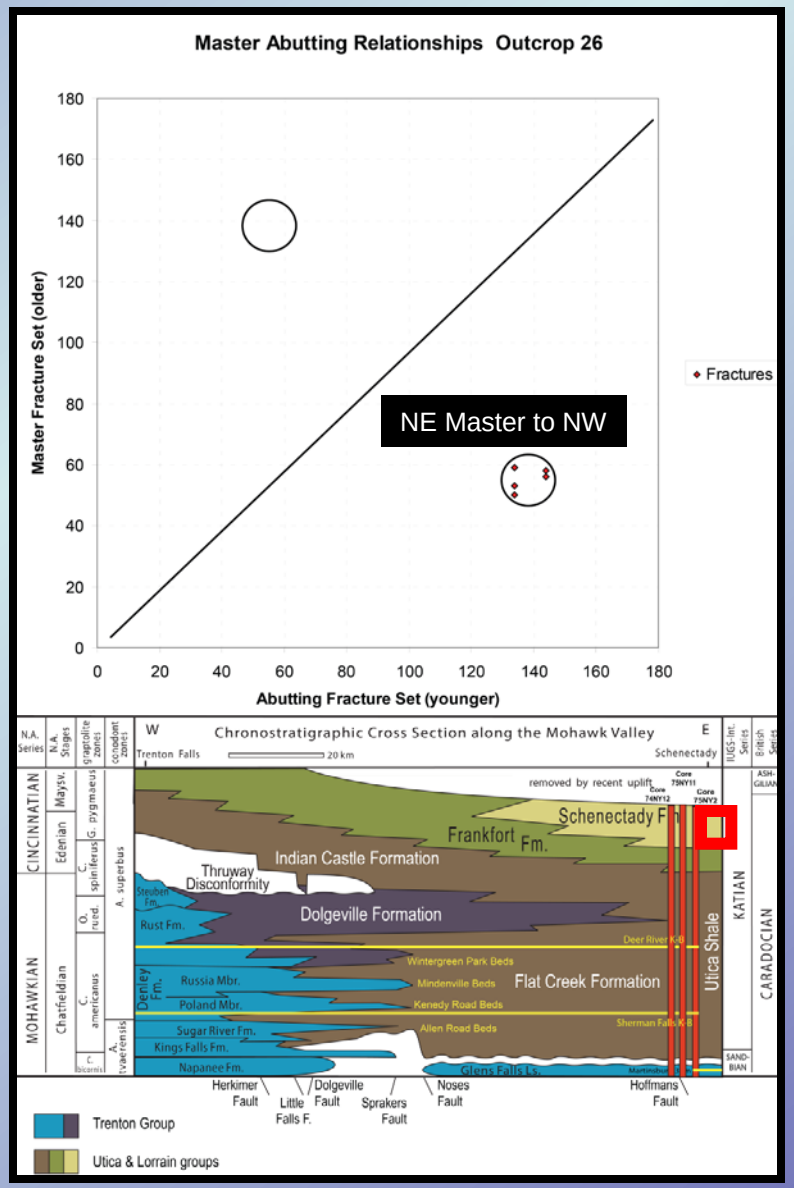
Fracture Intensification Domains



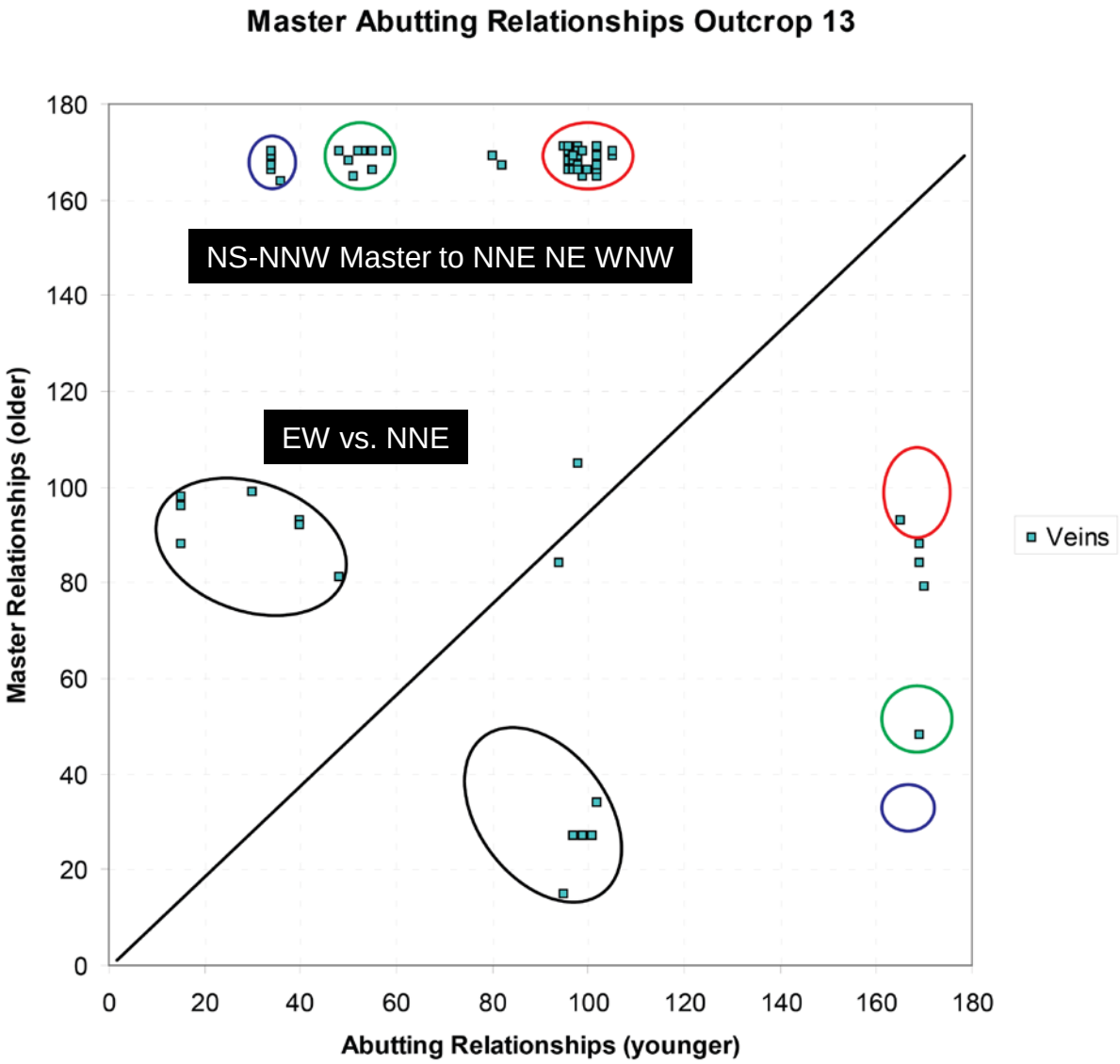
Cross, 2004; measured from Fisher (1980)

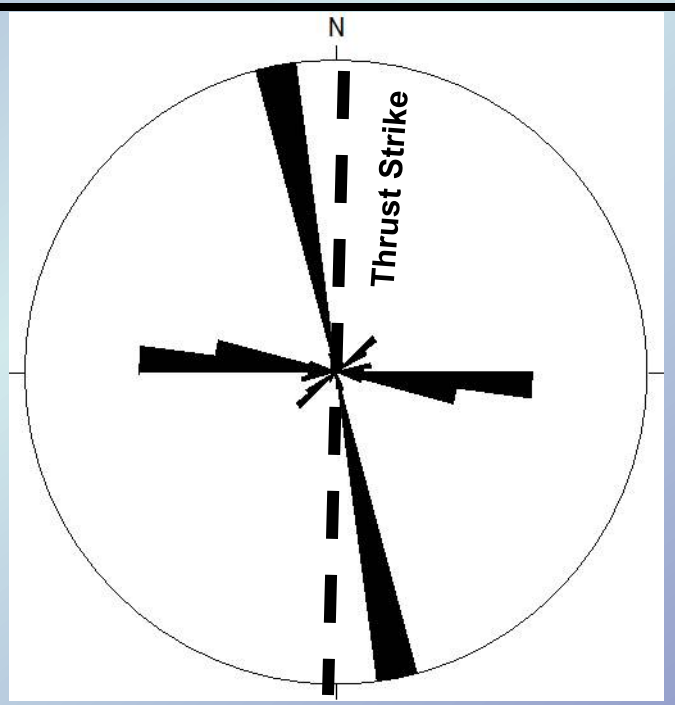
Fracture Relative Timing

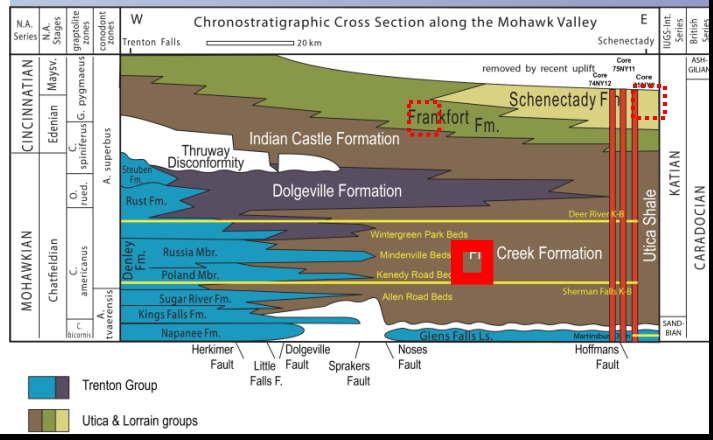




Vein Relative Timing







Conclusions

- Fault-parallel fracture frequencies increase toward a fault
- Fault parallel fracture sets exhibit the highest fracture background frequencies across the field area whereas orthogonal sets exhibit the lowest frequencies
- Master and abutting relationships vary in complexity across the Taconic basin with respect to stratigraphic position. NNE and NE sets are master in the upper stratigraphic formations (upper Indian Castle and Schenectady) with relationships becoming more complex as one moves down section
- The fault parallel sets formed contemporaneously with the flexural extension of the plate and the resultant normal faulting
- The E-W and WNW sets in the lower basin formed under the maximum compressive stress of the Taconic Orogeny and may have reactivated faults as thrusts within the basin
- Faulting in the uppermost Taconic basin units is consistent with reactivation of Taconic faults during later orogenies (Acadian, Alleghanian)
- Crosscutting relationships of veins within the basin are consistent with the current model of Taconic stress rotation and fault formation in the Mohawk Valley as is the case in present day Australia convergence (e.g. Muller et al., 2012)