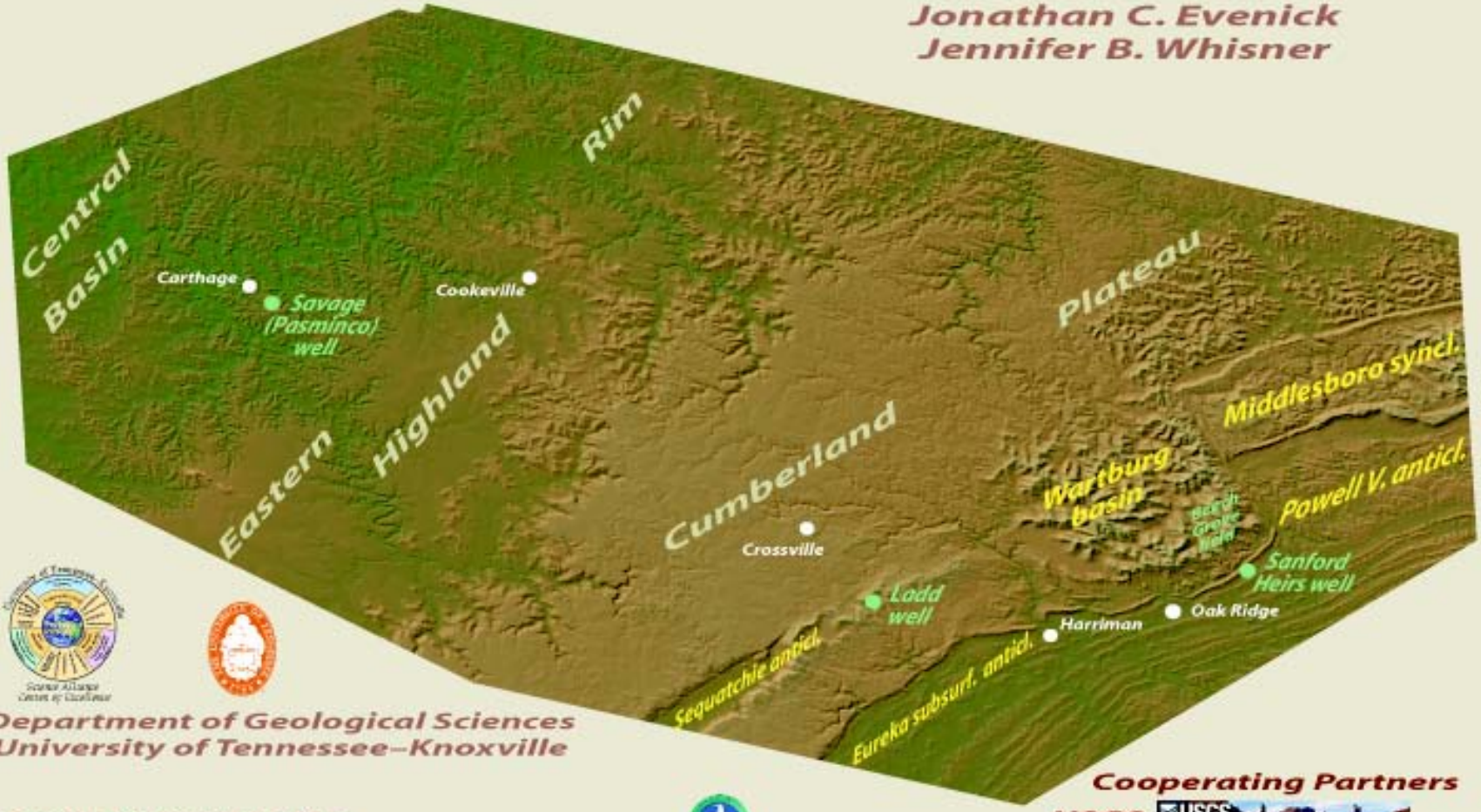
Resolving Stratigraphy in the Middle-Upper Ordovician Beneath the Cumberland Plateau in Tennessee and Southern Kentucky: Key to Understanding Structure and Hydrocarbon Accumulations

Robert D. Hatcher, Jr.
Jonathan C. Evenick
Jennifer B. Whisner



Department of Geological Sciences
University of Tennessee–Knoxville

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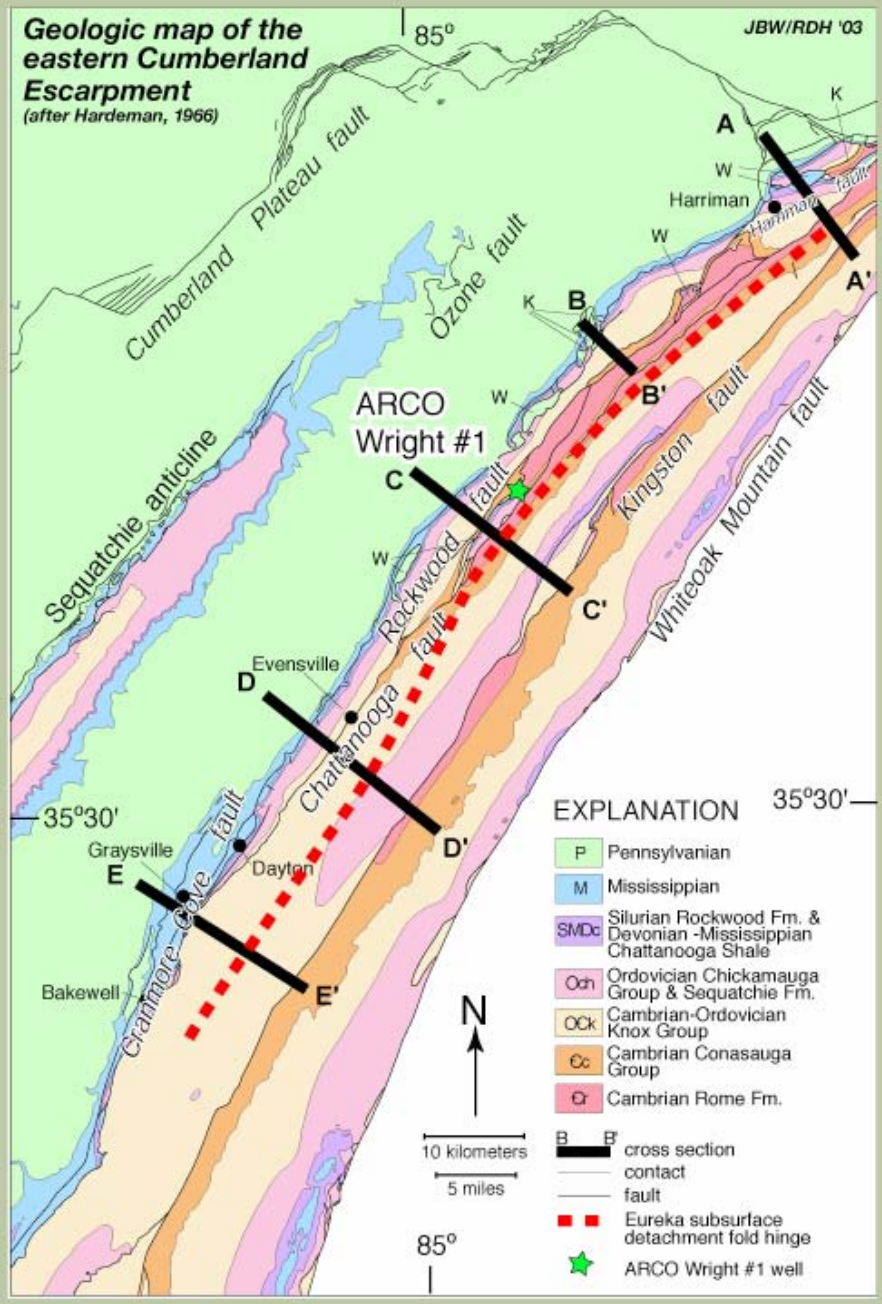
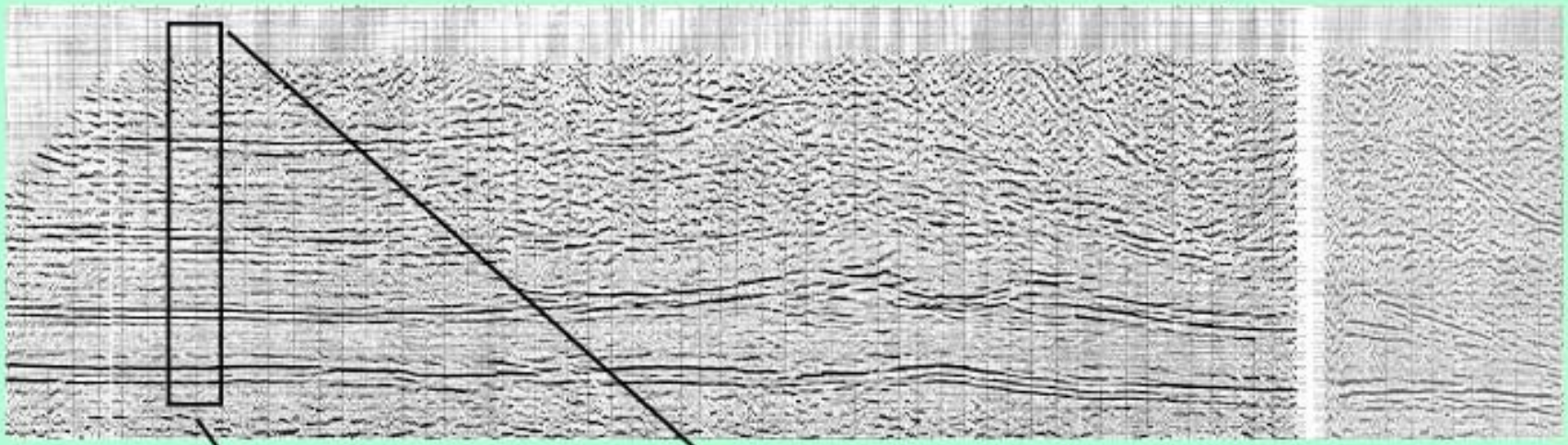
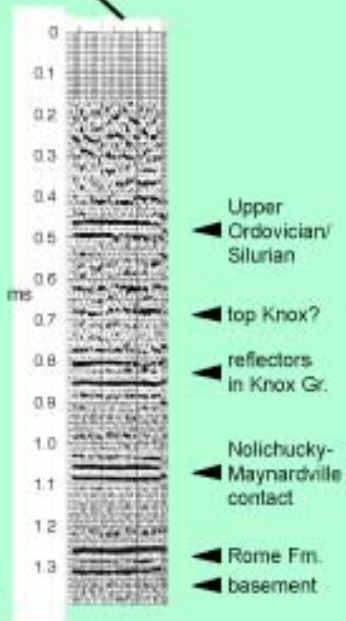

Geologic map of the eastern Cumberland Escarpment
(after Hardeman, 1966)
JBW/RDH '03
85°
35°30'
Cumberland Plateau fault
Ozone fault
Sequatchie anticline
Rockwood fault
Chattanooga fault
Kingston fault
Whiteoak Mountain fault
Cranmore Cove fault
Harriman fault
Harriman
Evensville
Dayton
Graysville
Bakewell
ARCO Wright #1
A
A'
B
B'
C
C'
D
D'
E
E'
W
K
EXPLANATION
P Pennsylvanian
M Mississippian
SMDc Silurian Rockwood Fm. & Devonian -Mississippian Chattanooga Shale
Och Ordovician Chickamauga Group & Sequatchie Fm.
OCk Cambrian-Ordovician Knox Group
Ꞓc Cambrian Conasauga Group
Ꞓr Cambrian Rome Fm.
B B' cross section
contact
fault
Eureka subsurface detachment fold hinge
ARCO Wright #1 well
N
10 kilometers
5 miles

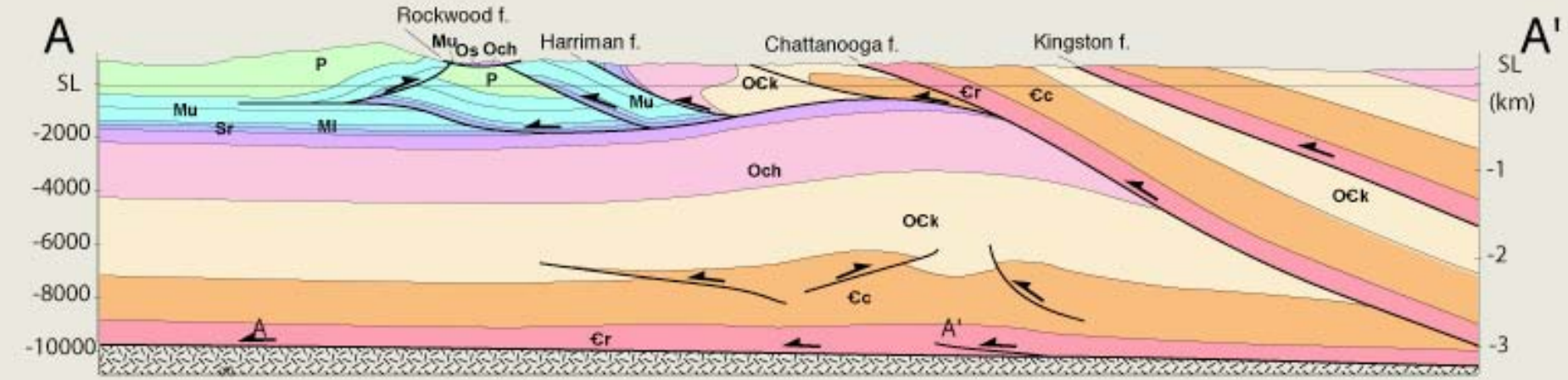
Sample seismic reflection data

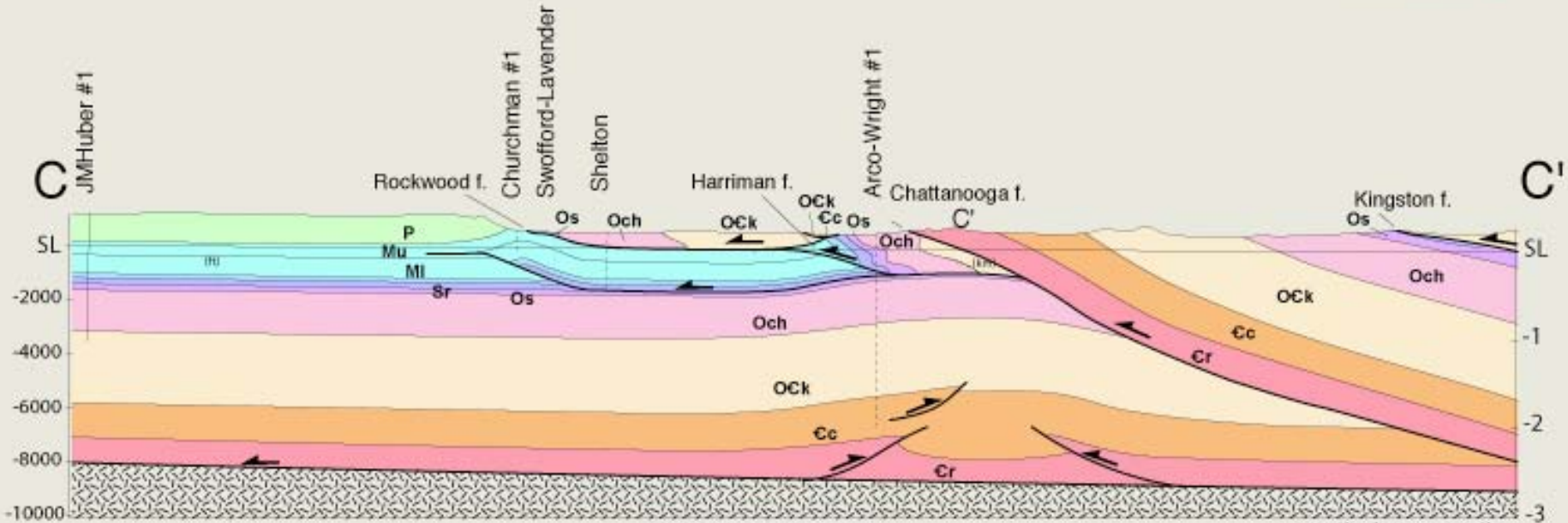
Eureka detachment fold anticline
(0.05-0.15 ms structural relief)





JBW/RDH '03

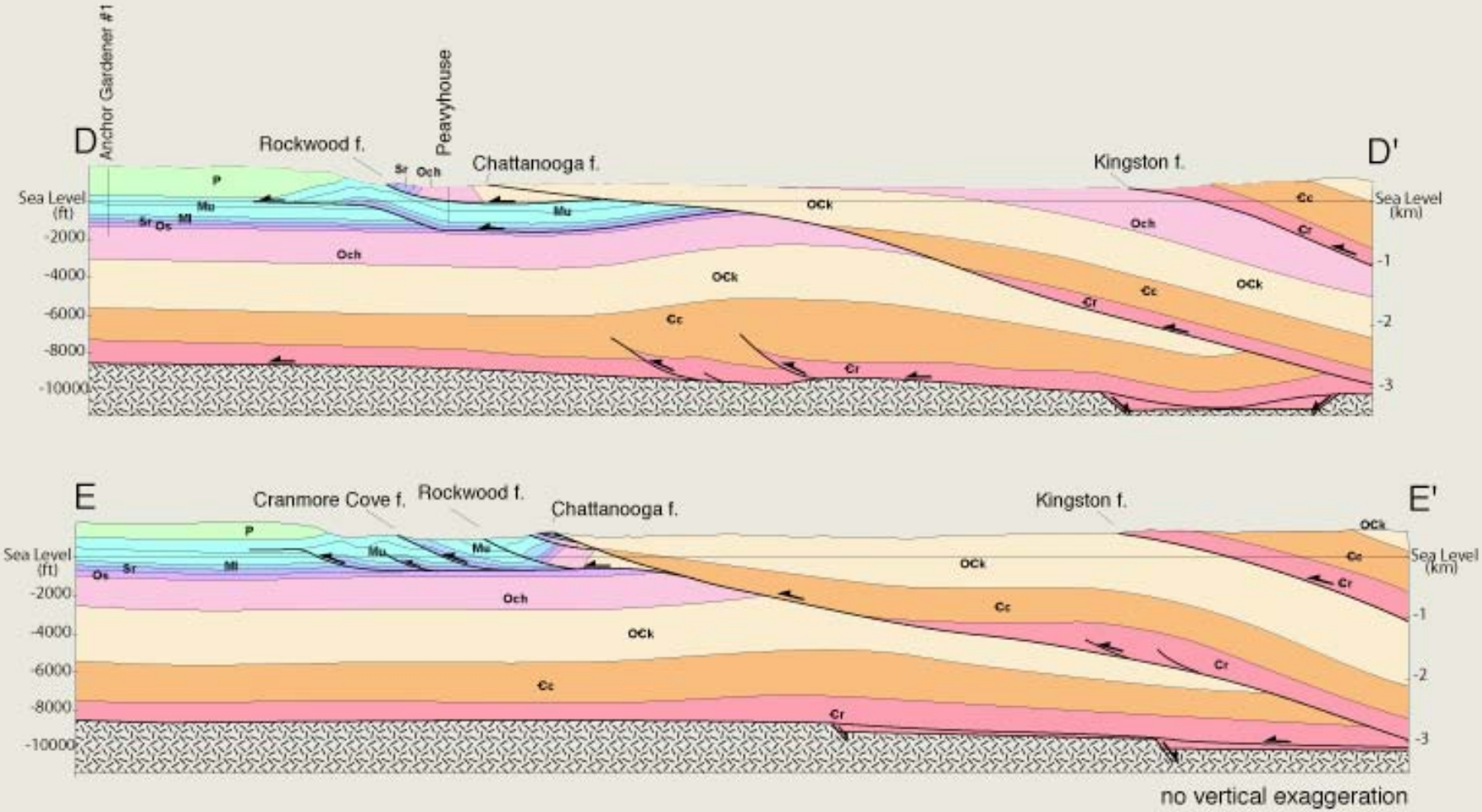




no vertical exaggeration

EXPLANATION

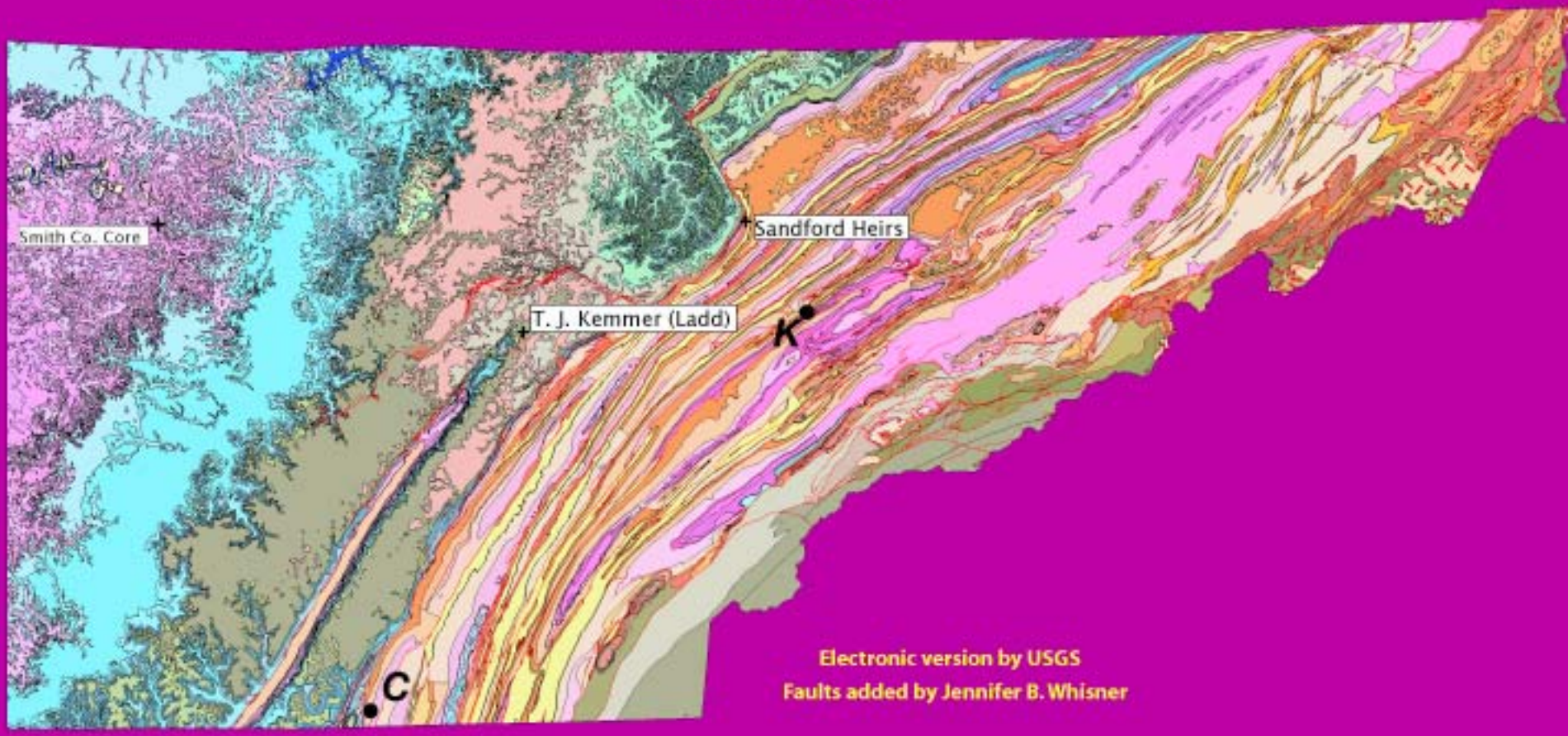
- P — Pennsylvanian
- Mu — Upper Mississippian
- Ml — Lower Mississippian
- S — Silurian Rockwood Fm. & Mississippian-Devonian Chattanooga Shale
- Os — Ordovician Sequatchie Fm.
- Och — Ordovician Chickamauga Group
- OCk — Cambrian-Ordovician Knox Group
- Cc — Cambrian Conasauga Group
- Cr — Cambrian Rome Fm.
- Precambrian crystalline basement


D
D'
Anchor Gardener #1
Peavyhouse
Rockwood f.
Chattanooga f.
Kingston f.
Sea Level (ft)
Sea Level (km)
-2000
-4000
-6000
-8000
-10000
-1
-2
-3
P
Mu
Ml
Sr
Os
Och
OCk
Cc
Cr
E
E'
Cranmore Cove f.
Rockwood f.
Chattanooga f.
Kingston f.
no vertical exaggeration

JBW/RDH '03

Geologic Map of Tennessee (East half)

(Hardeman, 1966)



Electronic version by USGS

Faults added by Jennifer B. Whisner

Knox, Stones River, and Nashville Groups

Nashville Group ("Trenton")

Catheys + Leipers ~350 ft thick
- Shaley, fossiliferous limestone

Cannon Limestone ~150 ft thick
- Clean limestone "Sunnybrook"
- Petroliferous odor, oil-filled vugs
- Flat gamma ray signature

Hermitage Formation ~80 ft thick
- Shaley and sandy limestone
- Shaley gamma ray signature
- Curdsville Member cleaner limestone near base
- T–5 above Curdsville in silty-nodular member

Stones River Group ("Black River")

Carters Limestone 80–150 ft thick
- Upper Carters thin-bedded, lower massive limestone
- 40-ft thick shale (toward SW VA)
- Mostly flat gamma ray signature
- T–4 (Millbrig, Mud Cave) near or at top
- T–3 (Deike, Pencil Cave) ~20 ft below T–4
- Gamma ray spikes
- Low density

Lebanon Limestone 80–120 ft thick
- Thin-bedded, minor shaley limestone
- Irregular/ shaley gamma ray signature

Ridley Limestone ~275 ft thick
- Massive limestone, like lower Carters, shale ;ayers near base
- Mostly flat gamma ray signature, except lower shales

Pierce Limestone 20–30 ft thick
- Thin-bedded to shaley limestone
- Massive limestone in middle

Murfreesboro Limestone 145–545 ft thick
- Mixed massive limestone and shaley limestone
- Irregular/ shaley gamma ray signature

Wells Creek/Pond Spring (Dot) Formation
Blackford Formation
Douglas Lake Member
0–250 ft thick
- Mixed dolomite, limestone, and shaley limestone
- Reworked Knox erosion surface debris
- Red or maroon shaley cherty limestone and dolomite
- Irregular/ shaley gamma ray signature

Knox Erosion Surface
- 0 (in PA)–1,800 ft (OH) of erosional relief
- 100–250 ft of relief in TN, southern KY

Knox Group

Mascot Dolomite 300–600 ft thick
- Massive cherty dolomite, minor limestone, dolomite-cemented sandstones, chert-cemented ("chert-matrix") sandstone at base
- Flat gamma ray signature
- Oil residues in vugs Gas production

Kingsport Formation ~400 ft thick
- Massive dolomite and limestone (lower 1/3 mostly limestone)

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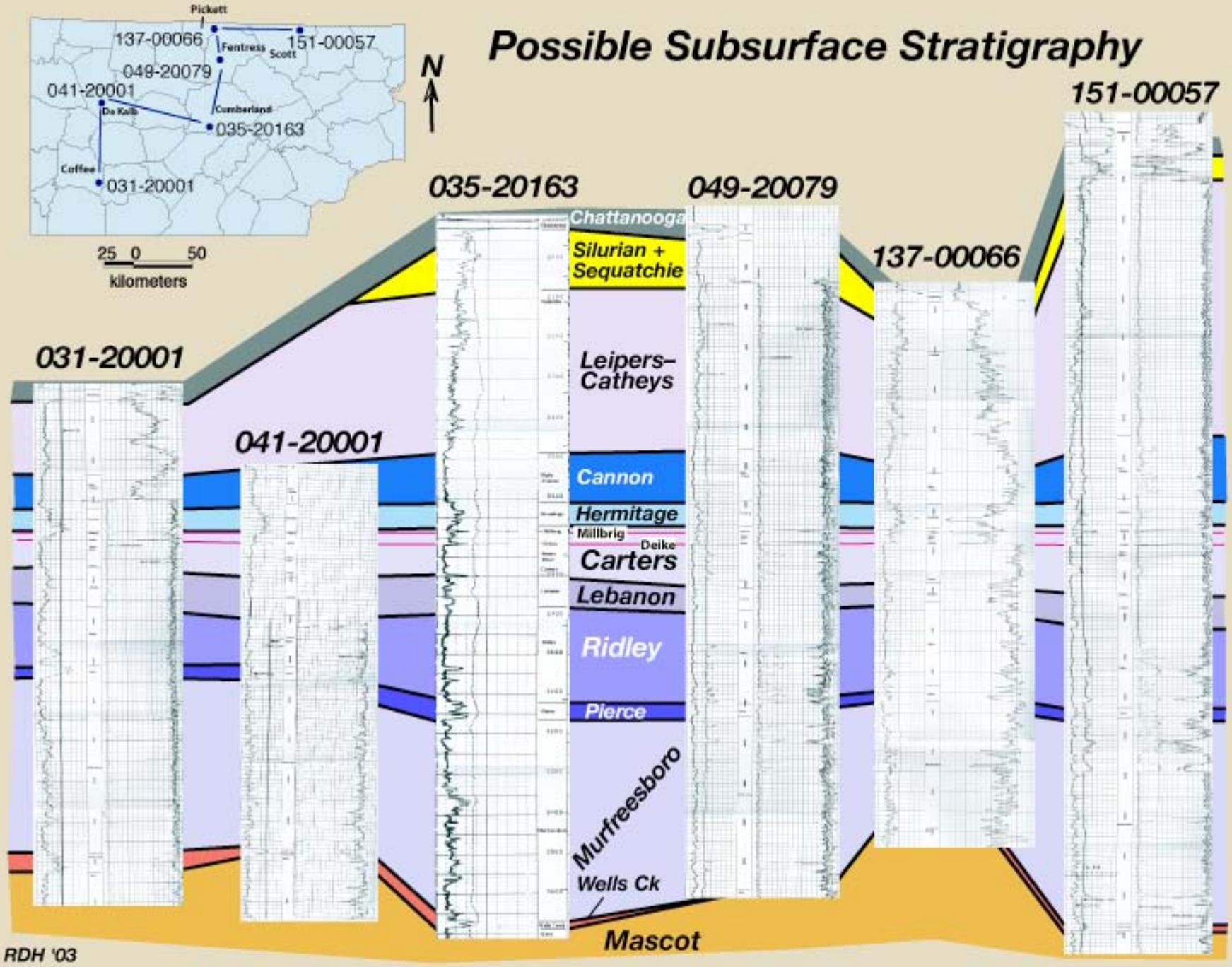
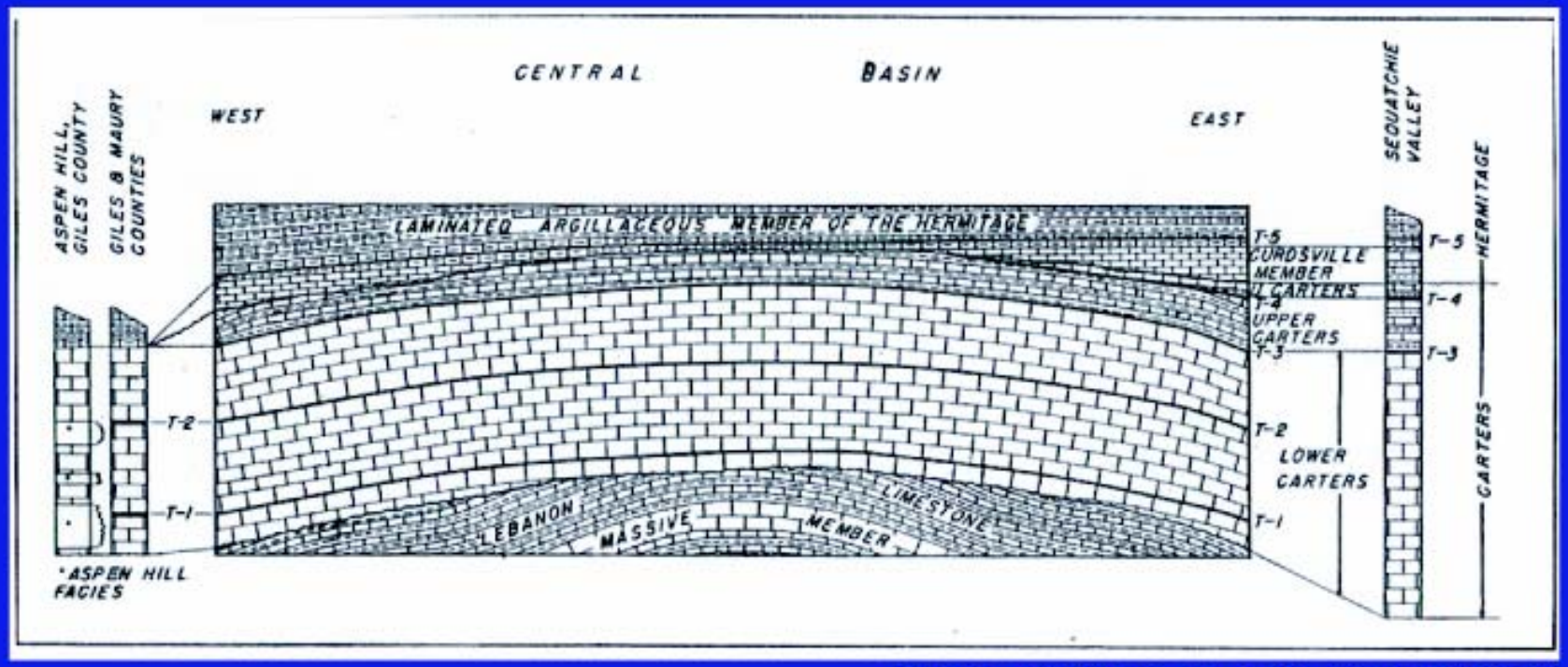
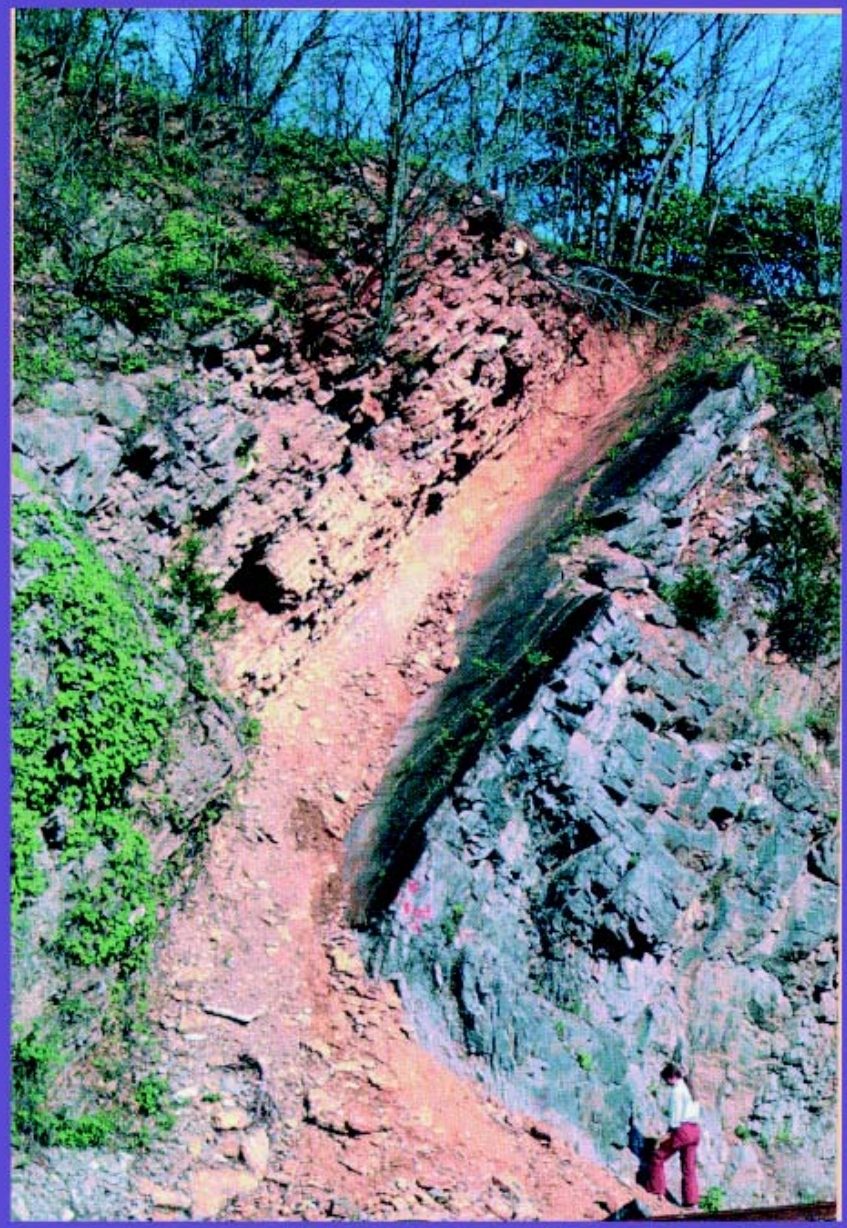

Possible Subsurface Stratigraphy
Pickett
137-00066
Fentress
Scott
151-00057
049-20079
041-20001
De Kalb
Cumberland
035-20163
Coffee
031-20001
25 0 50
kilometers
N
031-20001
041-20001
035-20163
049-20079
137-00066
151-00057
Chattanooga
Silurian +
Sequatchie
Leipers–
Catheys
Cannon
Hermitage
Millbrig
Deike
Carters
Lebanon
Ridley
Pierce
Murfreesboro
Wells Ck
Mascot
RDH '03

Lebanon–Carters–Hermitage Facies, Central Tennessee



from C. W. Wilson, Jr., 1949, TDG Bulletin 56

TN 109 (Gallatin) Exit off I–40 E



T–4 (Deike, Pencil Cave) Lee Co., VA

Photo by Stig Bergstrom

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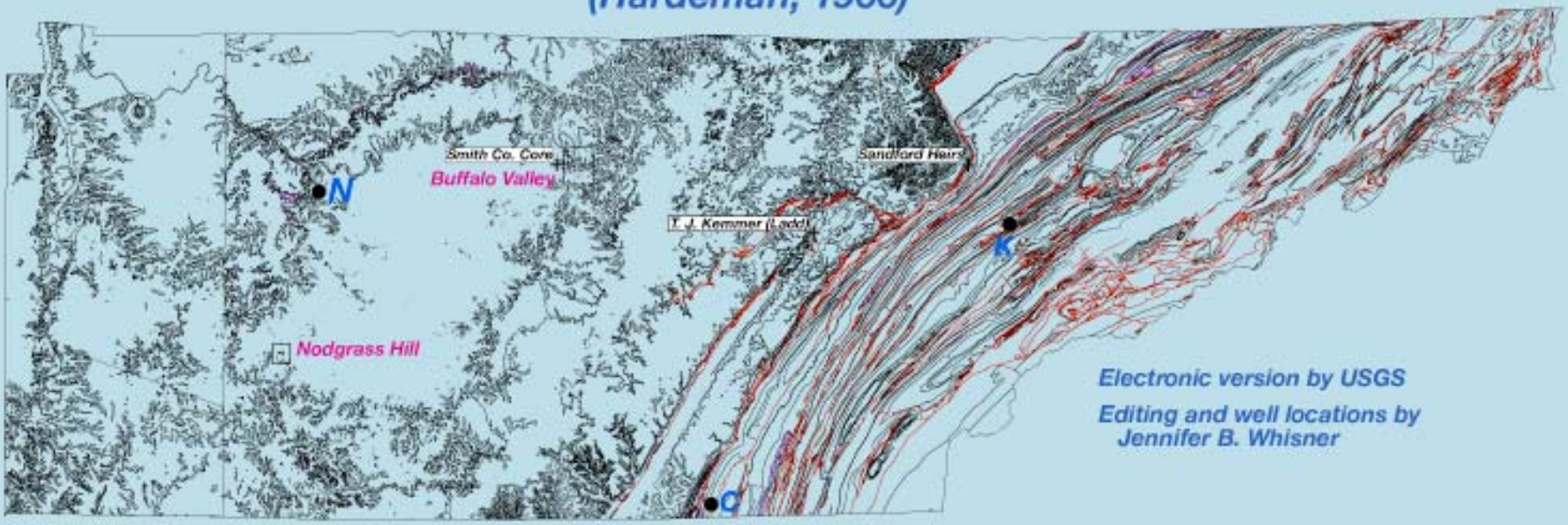
Leipers-Chattanooga Contact

Pasminco core hole near Carthage, TN

Chattanooga-Maury-Ft. Payne Contacts

Pasminco core hole near Carthage, TN

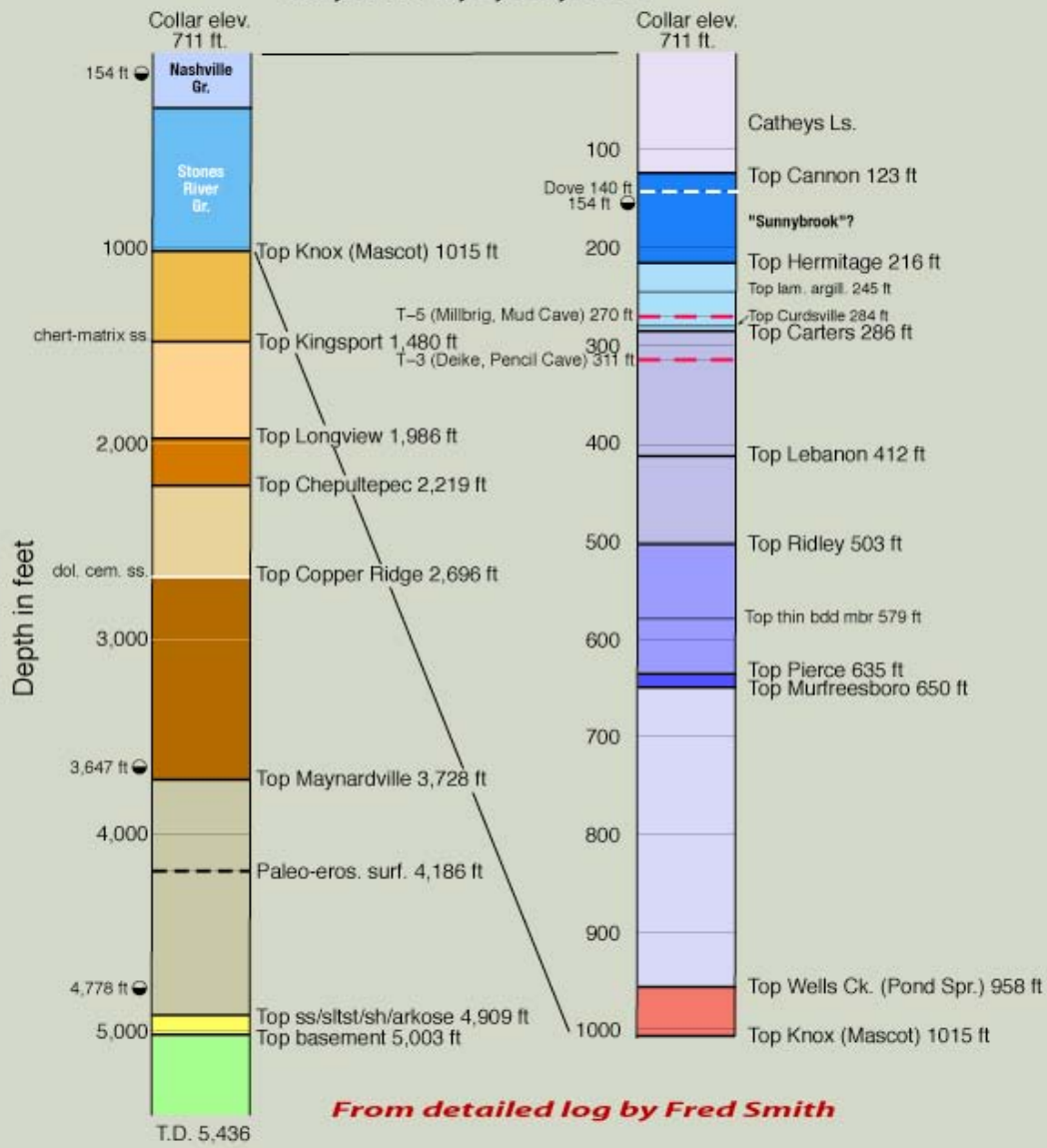
Mostly Silurian Rocks, Geologic Map of Tennessee
(Hardeman, 1966)



Electronic version by USGS

Editing and well locations by
Jennifer B. Whisner

Savage (Pasminco) Mining Co.
Basement Core Hole
Smith County, TN
657,511.8 N; 2,029,465 E

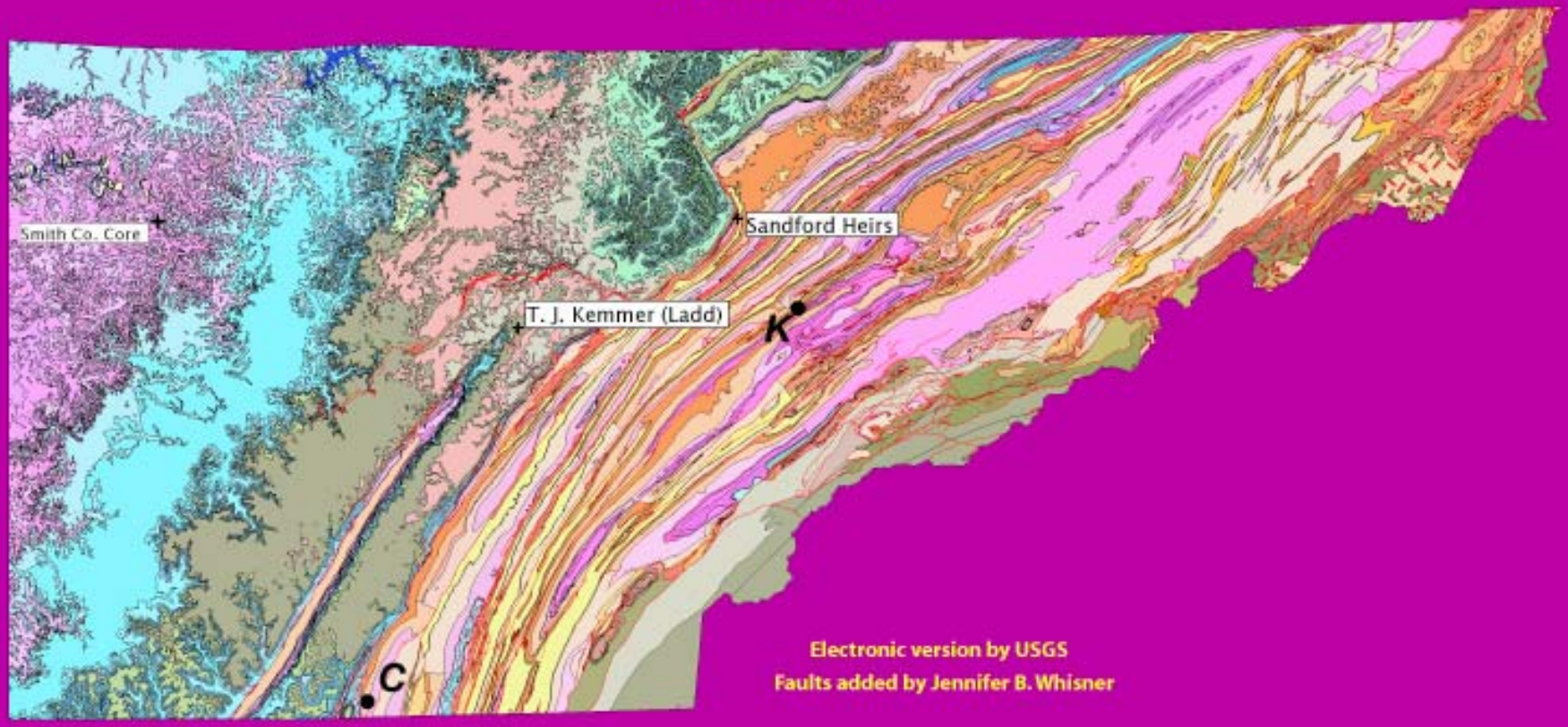


From detailed log by Fred Smith

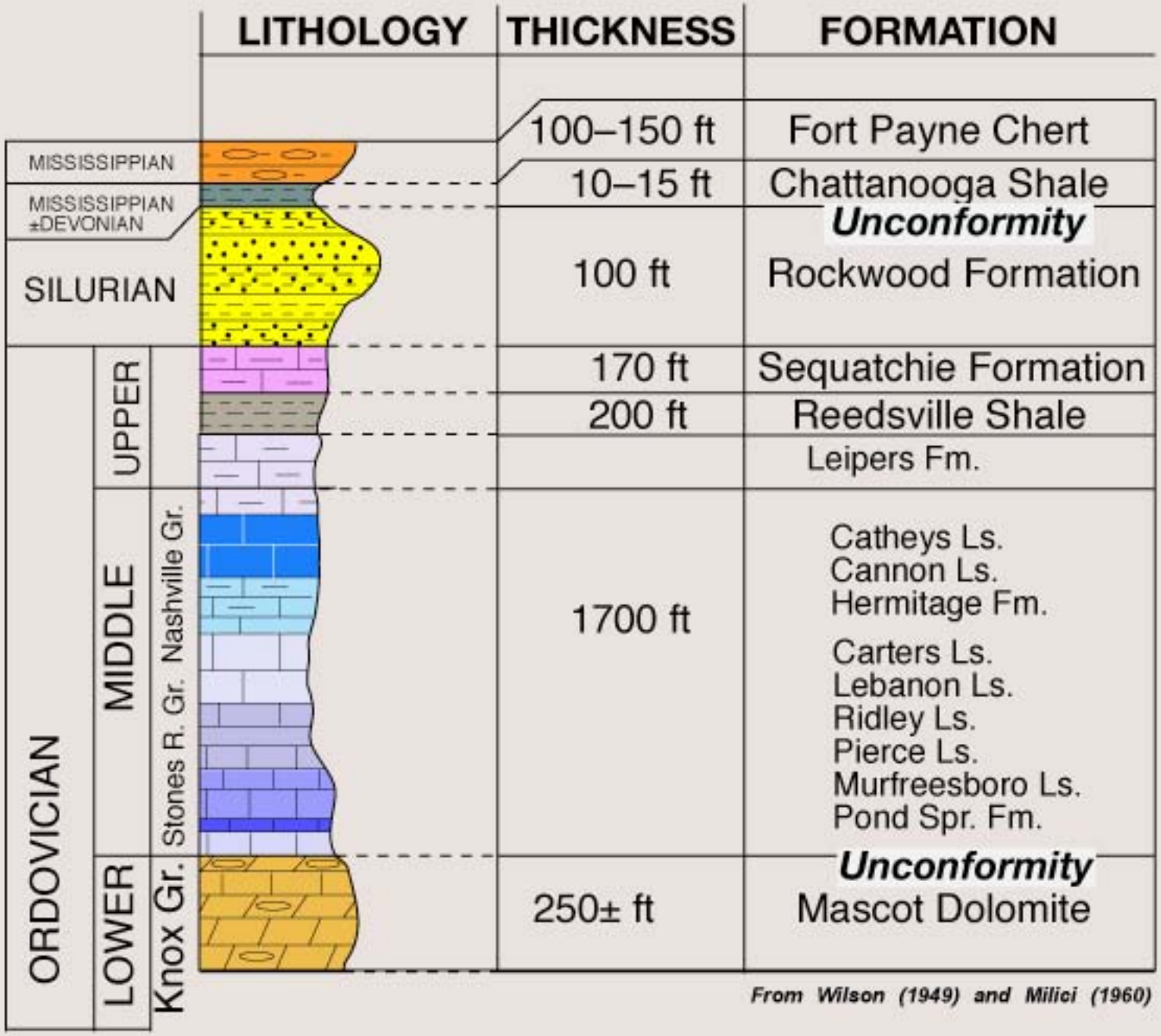
RDH 6/3/03

Geologic Map of Tennessee (East half)

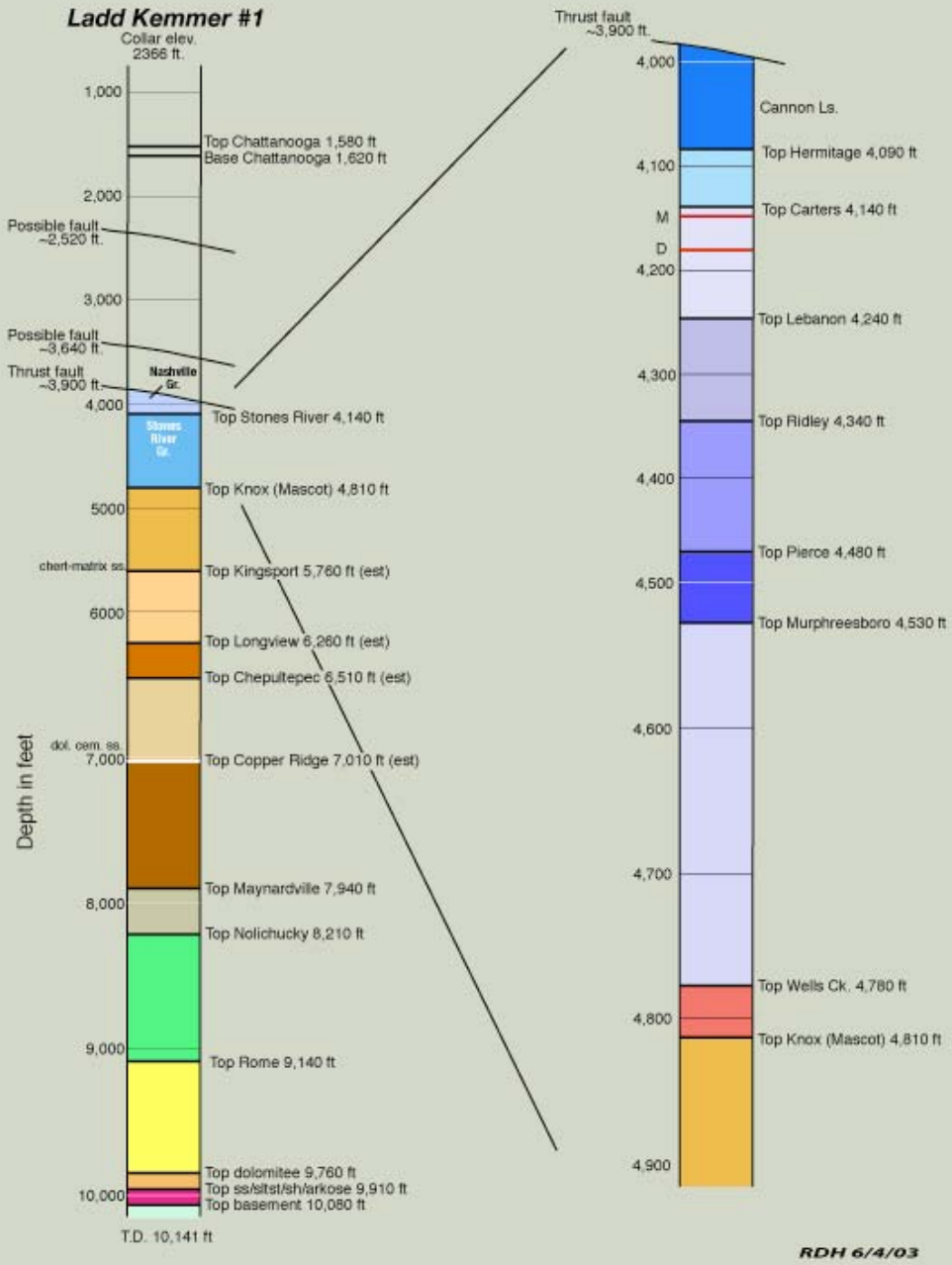
(Hardeman, 1966)



Ordovician–Silurian Stratigraphy in Sequatchie Valley

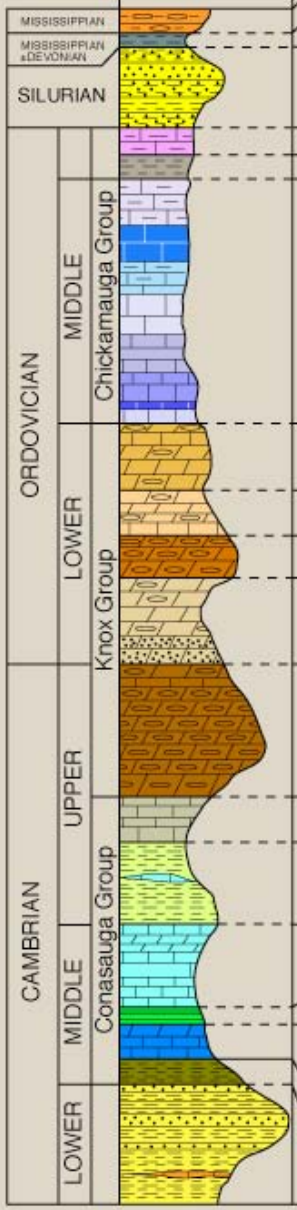


From Wilson (1949) and Milici (1960)


Ladd Kemmer #1
Collar elev. 2366 ft.
1,000
2,000
3,000
4,000
5000
6000
7,000
8,000
9,000
10,000
Depth in feet
Top Chattanooga 1,580 ft
Base Chattanooga 1,620 ft
Possible fault ~2,520 ft.
Possible fault ~3,640 ft.
Thrust fault ~3,900 ft.
Nashville Gr.
Stones River Gr.
Top Stones River 4,140 ft
Top Knox (Mascot) 4,810 ft
chert-matrix ss.
Top Kingsport 5,760 ft (est)
Top Longview 6,260 ft (est)
Top Chepultepec 6,510 ft (est)
dol. cem. ss.
Top Copper Ridge 7,010 ft (est)
Top Maynardville 7,940 ft
Top Nolichucky 8,210 ft
Top Rome 9,140 ft
Top dolomitee 9,760 ft
Top ss/sltst/sh/arkose 9,910 ft
Top basement 10,080 ft
T.D. 10,141 ft
Thrust fault ~3,900 ft.
4,000
4,100
4,200
4,300
4,400
4,500
4,600
4,700
4,800
4,900
Cannon Ls.
Top Hermitage 4,090 ft
M
D
Top Carters 4,140 ft
Top Lebanon 4,240 ft
Top Ridley 4,340 ft
Top Pierce 4,480 ft
Top Murphreesboro 4,530 ft
Top Wells Ck. 4,780 ft
Top Knox (Mascot) 4,810 ft
RDH 6/4/03

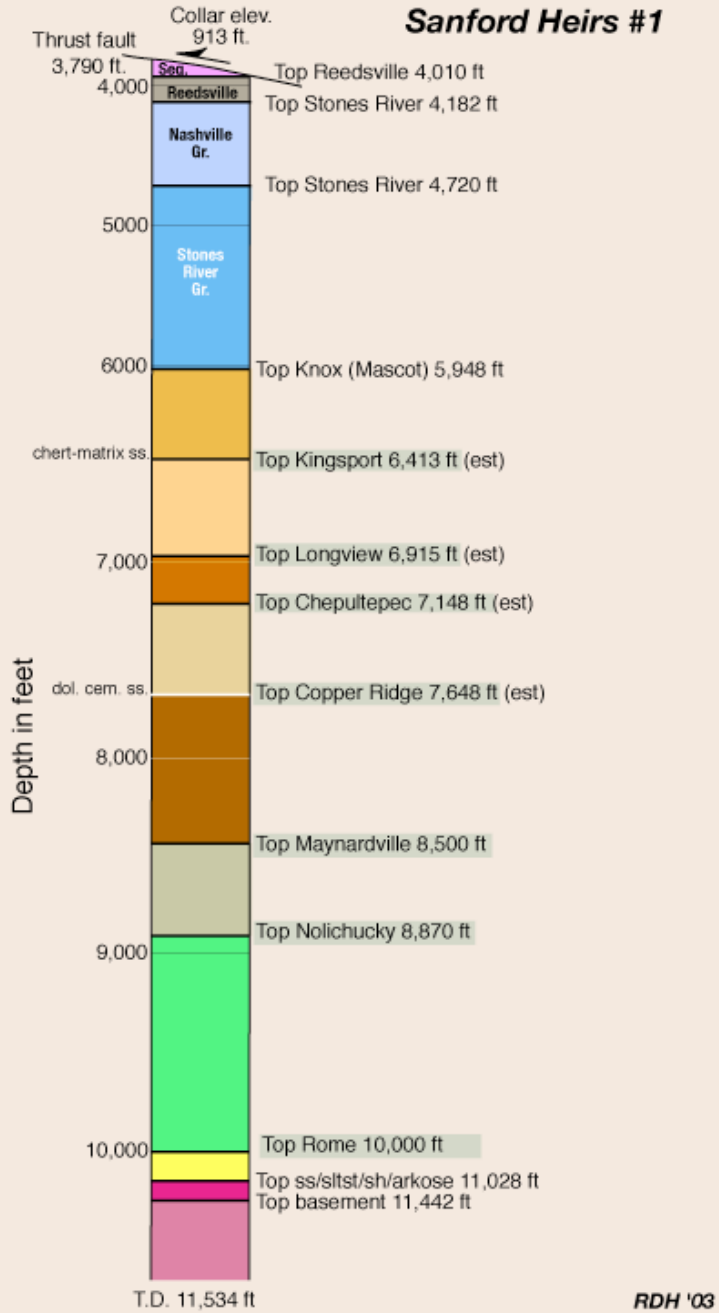
Stratigraphy of the Oak Ridge Area

OAK RIDGE VALLEY
EAST FORK RIDGE±PILOT KNOB
PINE RIDGE
BEAR CREEK VALLEY
CHESTNUT RIDGE

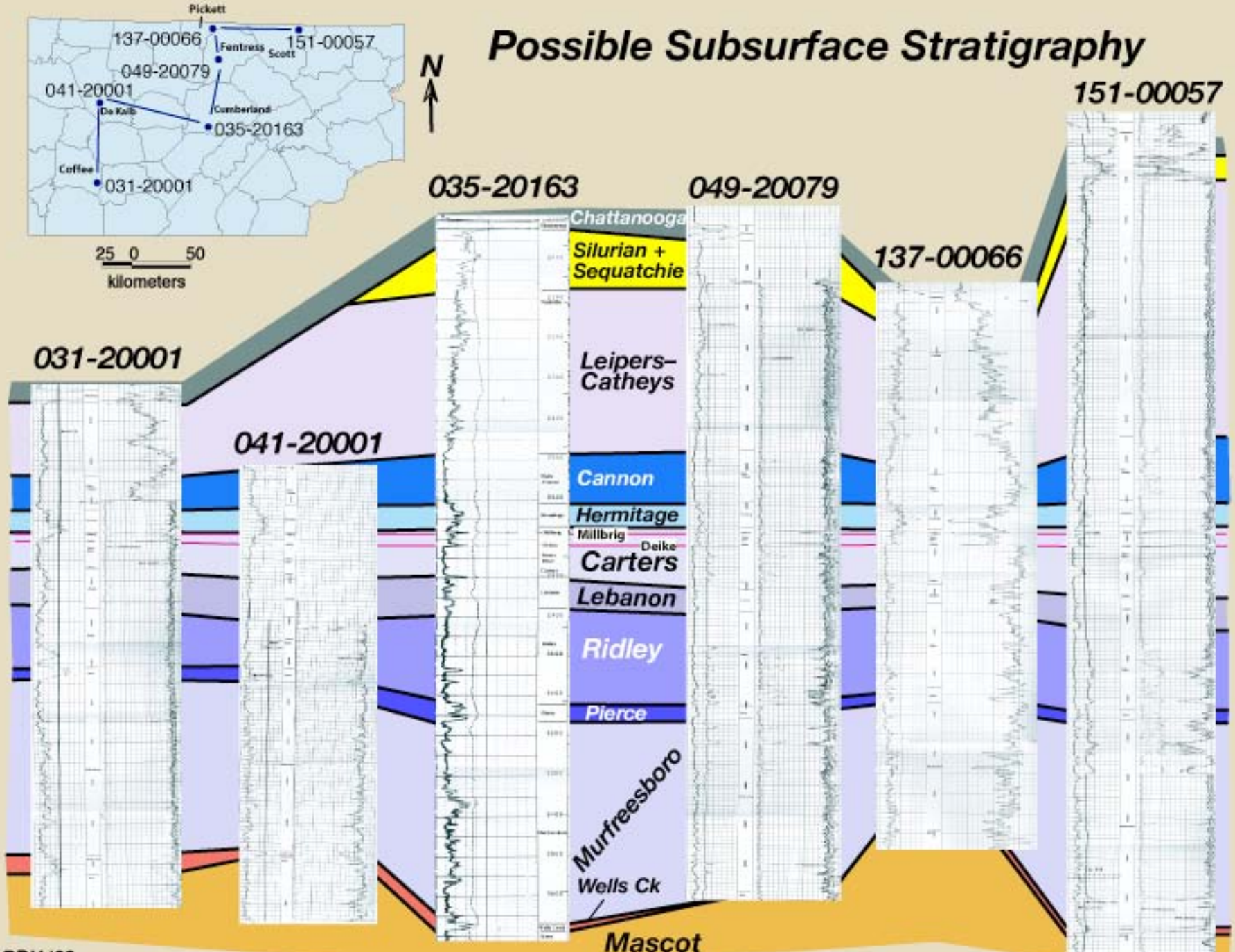


			LITHOLOGY	THICKNESS	FORMATION
MISSISSIPPIAN				100±150 ft	Fort Payne Chert
MISSISSIPPIAN				20±30 ft	Chattanooga Shale
MISSISSIPPIAN ±DEVONIAN					***Unconformity***
SILURIAN				400 ft	Rockwood Formation
ORDOVICIAN	MIDDLE	Chickamauga Group		200 ft	Sequatchie Formation
				200 ft	Reedsville Shale
				1700 ft	Leipers Fm. Nashville Group: Catheys Ls., Cannon Ls., Hermitage Fm. Stones River Group: Carters Ls., Lebanon Ls., Ridley Ls., Pierce Ls., Murfreesboro Ls.
	LOWER	Knox Group			***Unconformity***
				250±400 ft	Mascot Dolomite
				300±500 ft	Kingsport Formation
				130±200 ft	Longview Dolomite
				500±700 ft	Chepultepec Dolomite
CAMBRIAN	UPPER			800±1100 ft	Copper Ridge Dolomite
		Conasauga Group		340 ft	Maynardville Limestone
				490±590 ft	Nolichucky Shale
	MIDDLE			320±410 ft	Dismal Gap Formation (shale/limestone formerly Maryville Ls.)
				80±110 ft	Rogersville Shale
				100±120 ft	Friendship Formation (limestone/shale formerly Rutledge Ls.)
	LOWER			185±225 ft	Pumpkin Valley Shale
				1000+ ft	Rome Formation

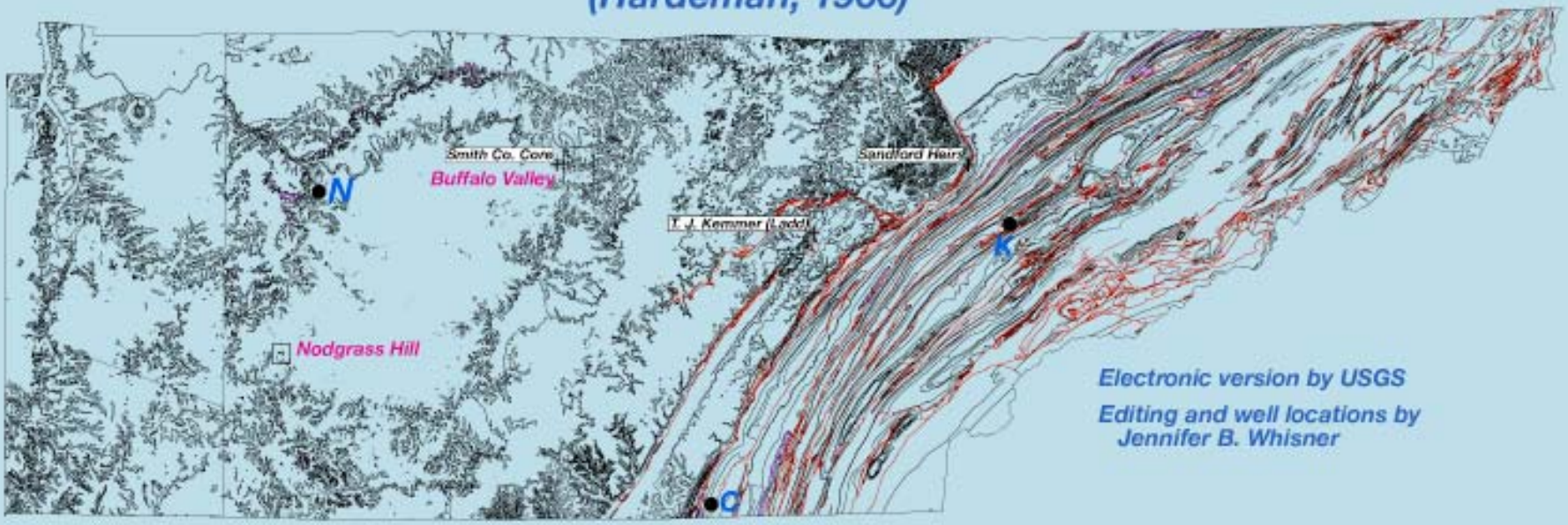
Hatcher 6/3/03


Sanford Heirs #1
Collar elev.
913 ft.
Thrust fault
3,790 ft.
Seq.
Reedsville
Nashville Gr.
Stones River Gr.
Top Reedsville 4,010 ft
Top Stones River 4,182 ft
Top Stones River 4,720 ft
Top Knox (Mascot) 5,948 ft
chert-matrix ss.
Top Kingsport 6,413 ft (est)
Top Longview 6,915 ft (est)
Top Chepultepec 7,148 ft (est)
dol. cem. ss.
Top Copper Ridge 7,648 ft (est)
Top Maynardville 8,500 ft
Top Nolichucky 8,870 ft
Top Rome 10,000 ft
Top ss/sltst/sh/arkose 11,028 ft
Top basement 11,442 ft
Depth in feet
4,000
5000
6000
7,000
8,000
9,000
10,000
T.D. 11,534 ft
RDH '03

Possible Subsurface Stratigraphy

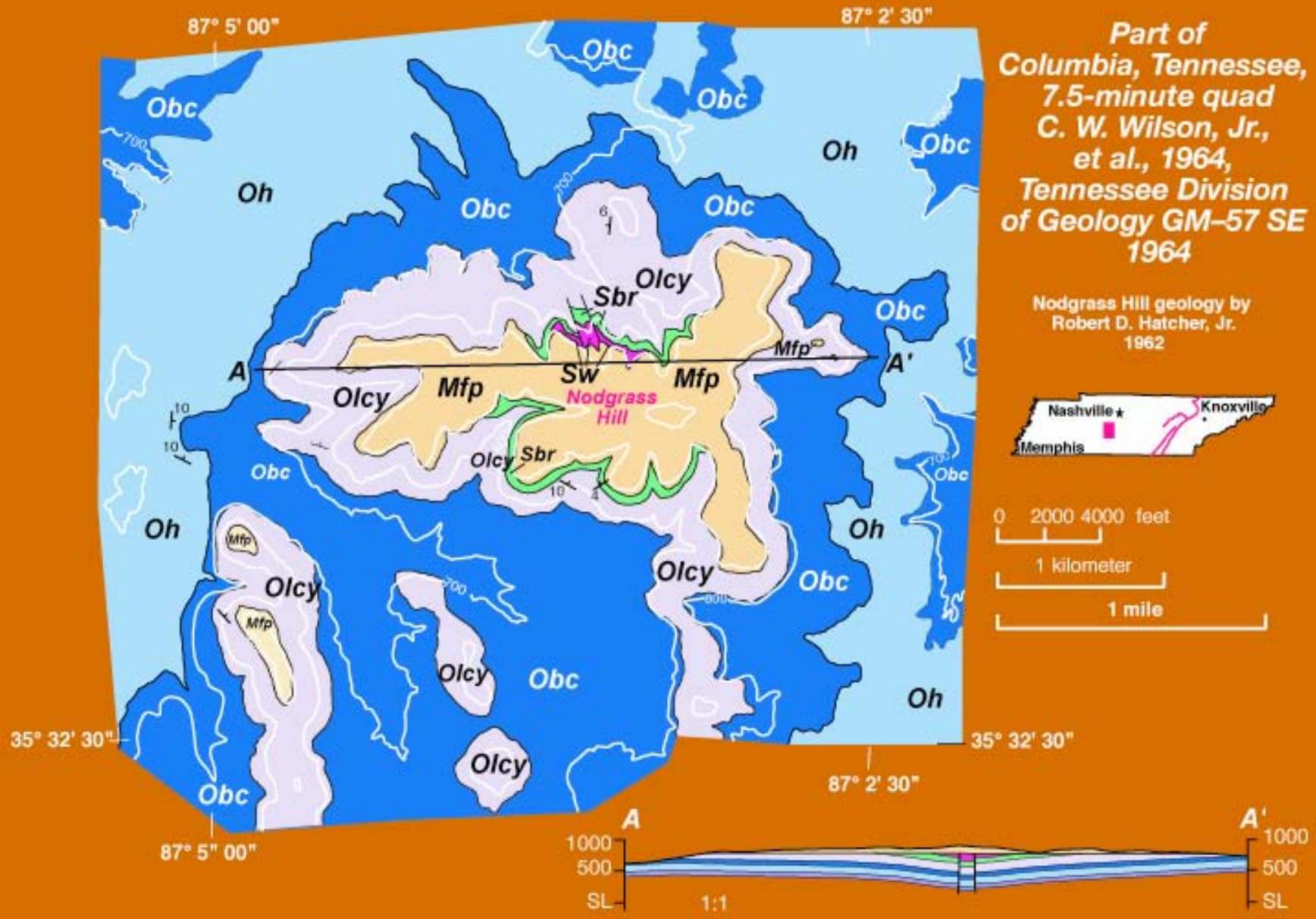


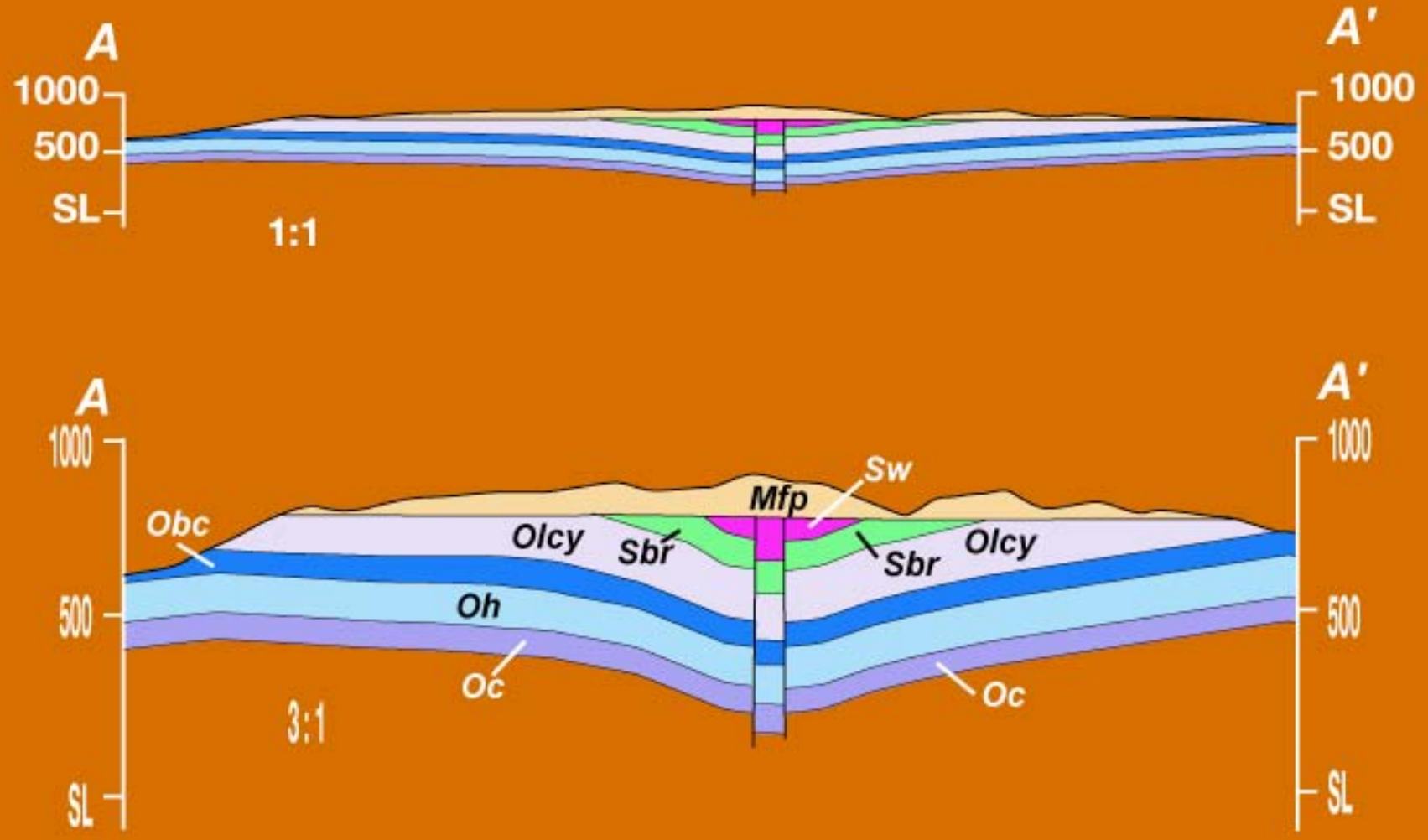
Mostly Silurian Rocks, Geologic Map of Tennessee
(Hardeman, 1966)



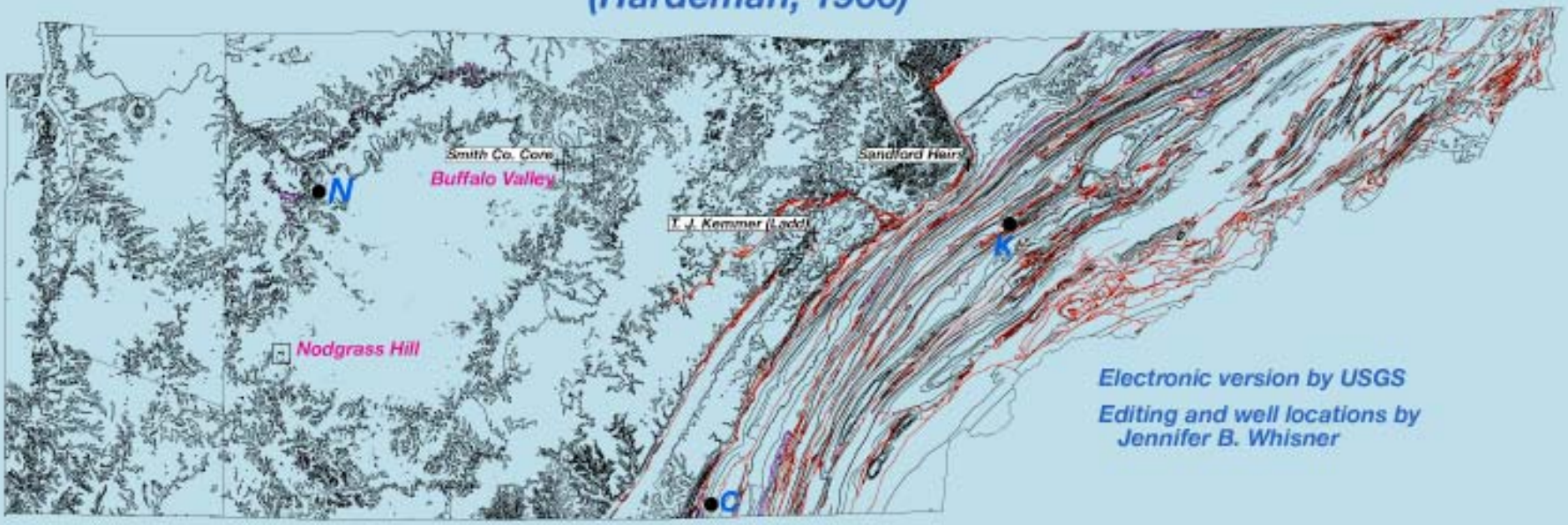
Electronic version by USGS

Editing and well locations by
Jennifer B. Whisner


Part of
Columbia, Tennessee,
7.5-minute quad
C. W. Wilson, Jr.,
et al., 1964,
Tennessee Division
of Geology GM–57 SE
1964
Nodgrass Hill geology by
Robert D. Hatcher, Jr.
1962
87° 5' 00"
87° 2' 30"
35° 32' 30"
Obc
Oh
Olcy
Sbr
Mfp
Sw
Nodgrass Hill
A
A'
Nashville
Knoxville
Memphis
0 2000 4000 feet
1 kilometer
1 mile
1000
500
SL
1:1


A
A'
1000
500
SL
1:1
A
A'
1000
500
SL
Sw
Mfp
Obc
Olcy
Sbr
Sbr
Olcy
Oh
Oc
Oc
3:1
RDH '03

Mostly Silurian Rocks, Geologic Map of Tennessee
(Hardeman, 1966)



Electronic version by USGS

Editing and well locations by
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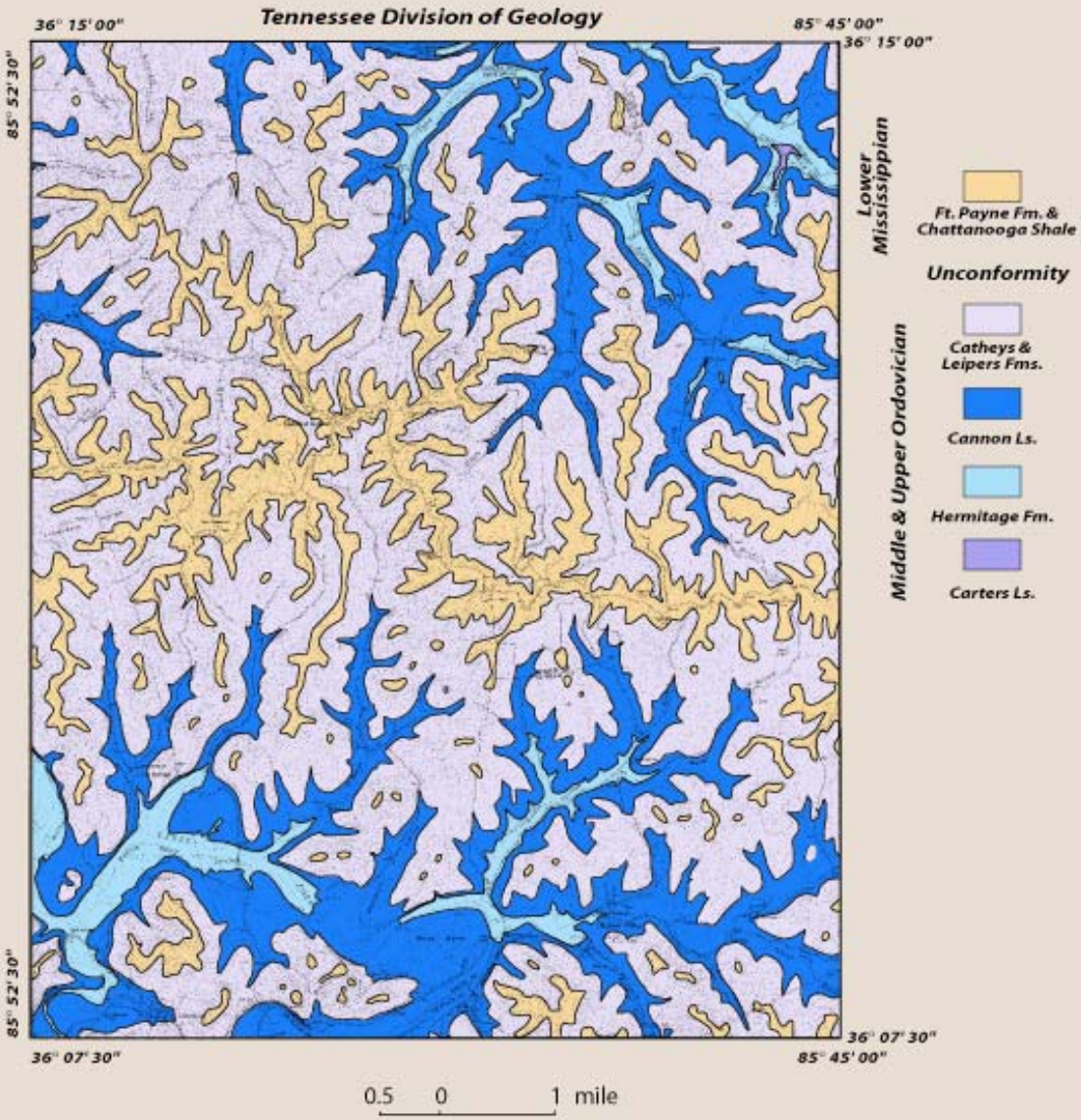
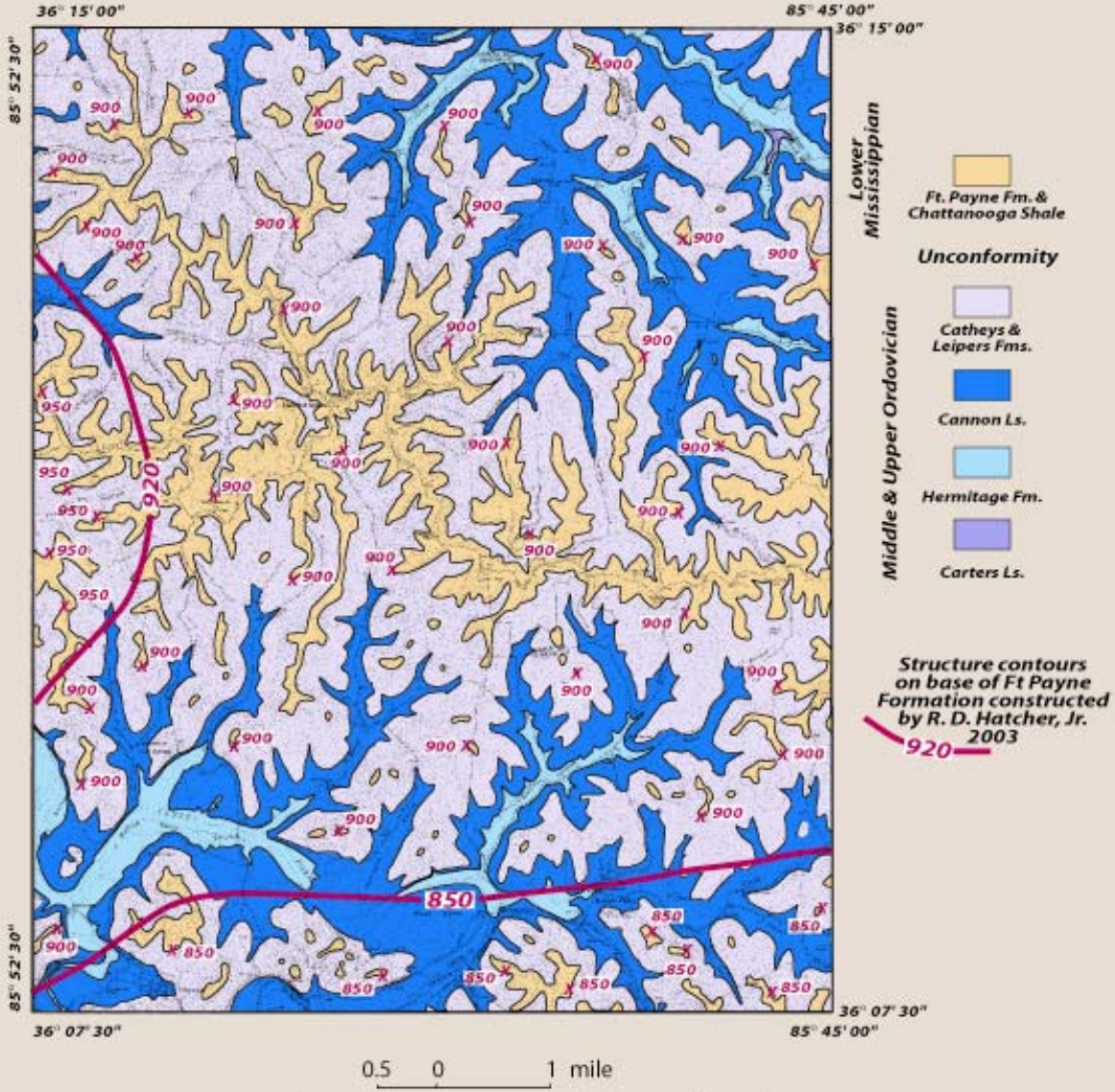


Geologic Map of the Buffalo Valley Quadrangle, Tennessee

Charles W. Wilson, Jr.

GM 322–NE

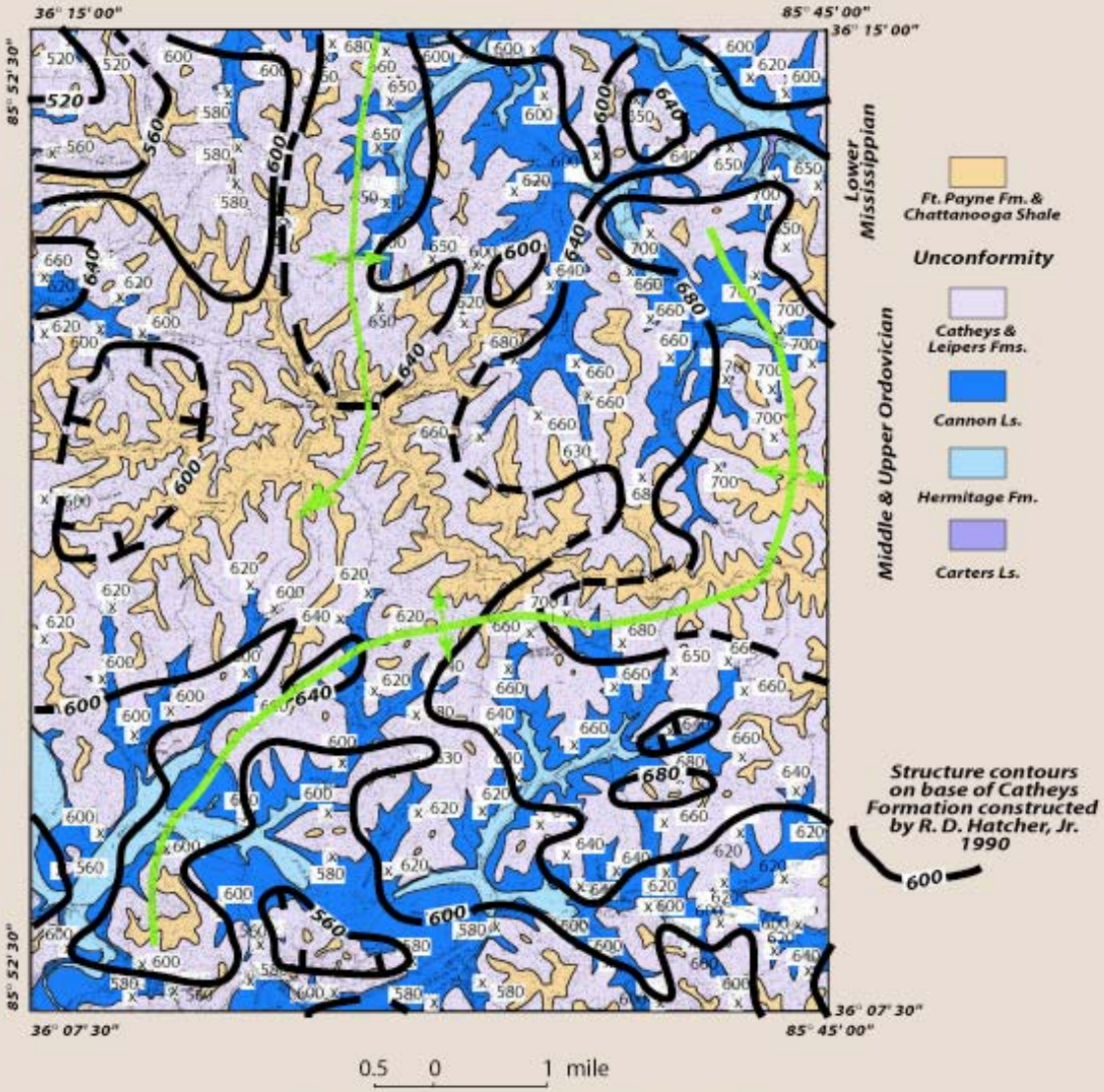
1971



Structure contour map based on the Geologic Map of the Buffalo Valley Quadrangle, Tennessee

Charles W. Wilson, Jr.
GM 322–NE
Tennessee Division of Geology

1971



Structure Contours based on the Geologic Map of the Buffalo Valley Quadrangle, Tennessee

Charles W. Wilson, Jr.

GM 322–NE

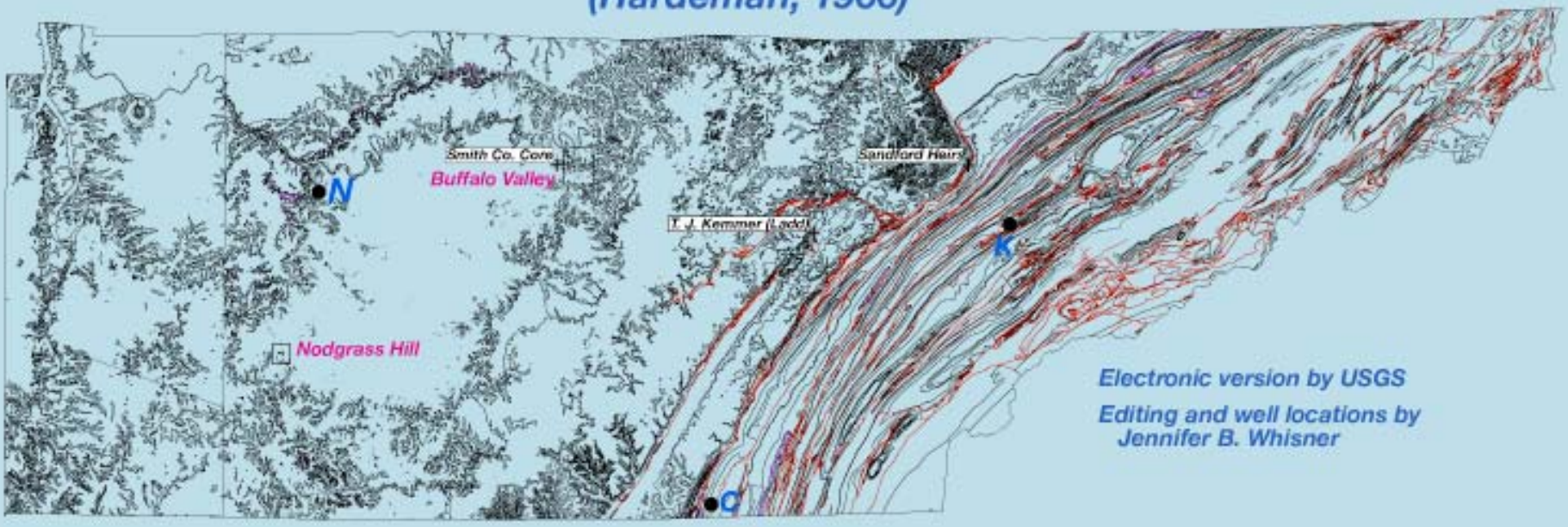
Tennessee Division of Geology

1971

RDH '03

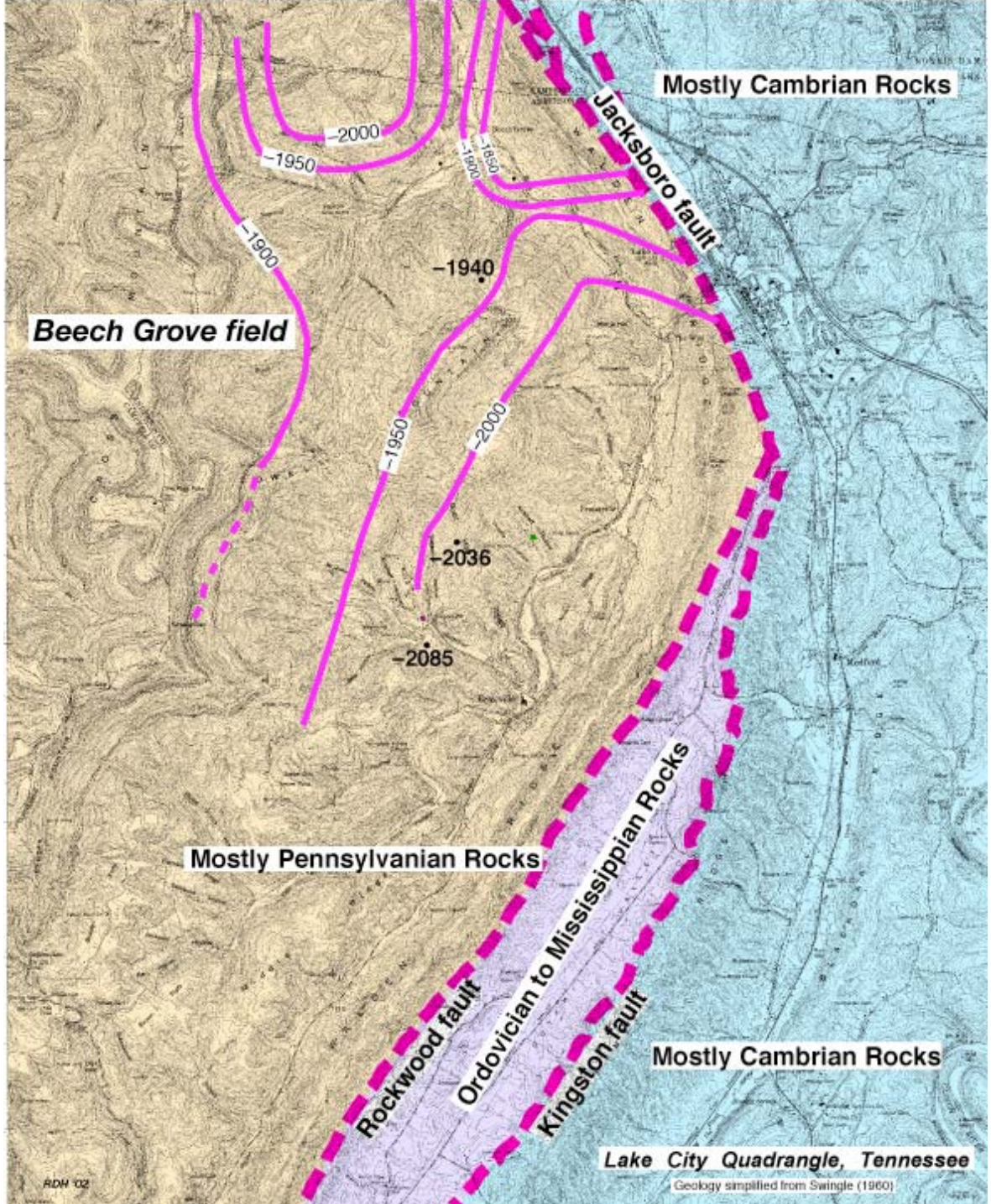
640
600
640
600
640
680
640
640
920
600
640
680
850
600
560
600
Structure contours on base of Ft Payne Formation
920
Structure contours on base of Catheys Formation
600

Mostly Silurian Rocks, Geologic Map of Tennessee
(Hardeman, 1966)



Electronic version by USGS

Editing and well locations by
Jennifer B. Whisner


Mostly Cambrian Rocks
Jacksboro fault
-2000
-1950
-1850
-1900
-1900
-1940
Beech Grove field
-1950
-2000
-2036
-2085
Mostly Pennsylvanian Rocks
Ordovician to Mississippian Rocks
Rockwood fault
Kingston fault
Mostly Cambrian Rocks
Lake City Quadrangle, Tennessee
Geology simplified from Swingle (1960)
RDH '02

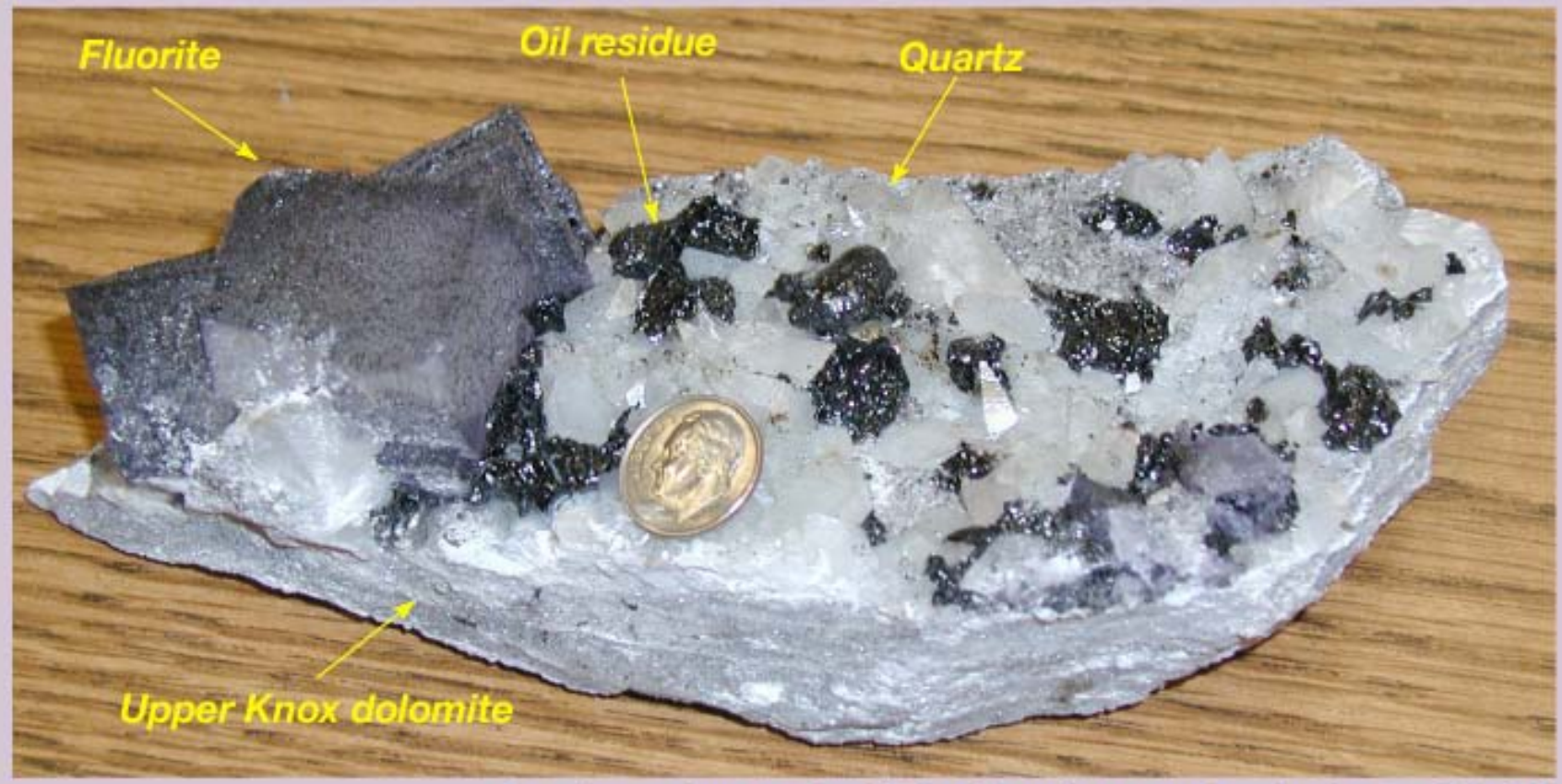
Reports of Oil in Pre-Chattanooga Rocks

- Oil-filled vugs in quarries in Cannon Limestone around Nashville.
- Oil shows in Knox and mid-Ordovician Gordonsville area cores (TN & S. KY).
- Problems in crusher at Gordonsville.
- Oil residues in core and in vugs.
- Oil in well water at Concord and Thorn Hill.
- Dead oil in the Copper Ridge Dolomite.
- Rose Hill & Swan Creek fields.
- USGS analyses indicate algal source of oil.

Upper Knox breccia, Gordonsville, TN

Oil Residues in Vug in Knox Dolomite

Pasminco Elmwood Mine near Carthage, TN



Specimen donated to UT by Pasminco and geologist Fred Smith

Conclusions

- Potential major field in 50-mile long subsurface anticline in W. V & R.
- Abundant evidence of hydrocarbons in pre-Chattanooga rocks likely sourced by Cambrian and Ordovician carbonates.
- Exposed structures in Middle Tennessee truncated by the pre-Chattanooga unconformity may serve as a model for structure and oil accumulations beneath the Plateau in Tennessee and S. Kentucky.