DEPOSITION OF SAUK SEQUENCE ROCKS ON THE UNDERLYING UNCONFORMABLE PROTEROZOIC COMPLEX IN THE OHIO REGION DEMONSTRATES THE EMERGENCE OF A BROAD PLATFORM DURING CAMBRIAN TIME

Mark T. Baranoski[1], Paul E. Potter[2], and Matthew S. Erenpreiss[1]
[1]Ohio Department of Natural Resources, Division of Geological Survey
[2] University of Cincinnati, Department of Geology

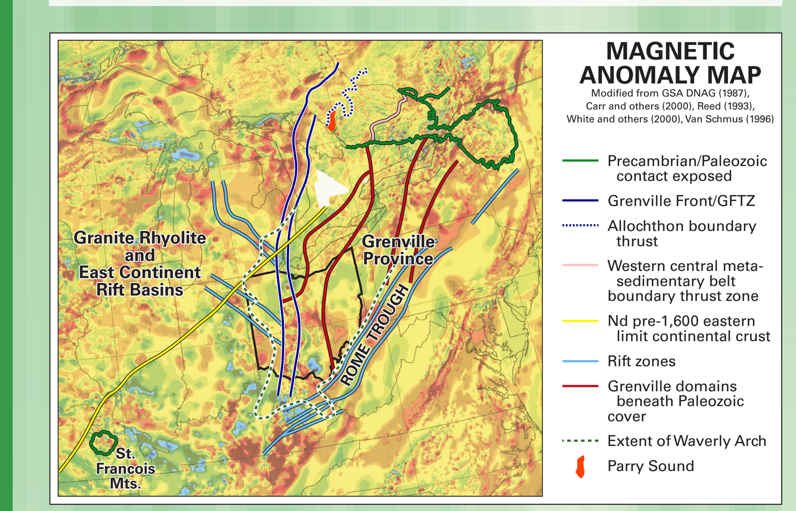
ABSTRACT

Recent subsurface correlations, using wireline and core data from deep wells, redefine Sauk sequence rocks in the Ohio region. Stratigraphic nomenclature and boundaries for the lower part of the Sauk sequence were refined and updated. Results indicate that following the Grenville Orogeny and East Continent rifting, and about a half-billion years of subsequent erosion, a broad platform developed during the Cambrian Period, marking the start of the Paleozoic Era on Laurentia. Further, essential elements of basin architecture in the Ohio region appear to be fivefold: (1) the *Waverly Arch*, redefined as a result of this research; (2) the northwestern *Rome Trough high* (a new term), a rift shoulder in southern Ohio and adjacent Kentucky and West Virginia; (3) the north–south trending Grenville front boundary zone of west central Ohio; (4) the stable cratonic Ohio Platform; and (5) adjacent structural and depositional sags (proto-Illinois-Michigan Basin, Chatham Sag, proto-Appalachian Basin, and Rome Trough). Development of the Cincinnati Arch appears to have been unaffected by either the *Waverly Arch* or Ohio Platform, as neither feature exhibits tectonic coincidence with this later-formed feature. This revised framework provides new information pertaining to saline reservoir studies for industrial-waste and brine disposal, gas storage, CO_2 sequestration, and hydrocarbon exploration.

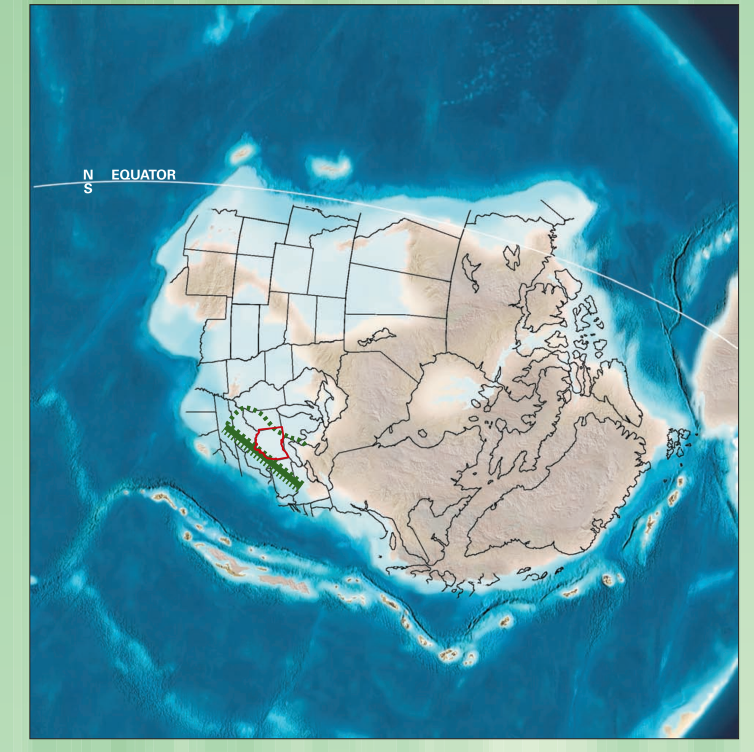
Updated maps of the Proterozoic complex (Granite Rhyolite and Grenville Provinces and the East Continent Rift Basin) unconformity surface in the Ohio region are essential when selecting potential sites for injection into saline Cambrian reservoirs. The *Waverly Arch* is considered a Late Mesoproterozoic to Neoproterozoic extension of the Ontario, Canada, Laurentian (Algonquin) Arch, which controlled depositional facies and basin architecture of the proto-Illinois-Michigan and proto-Appalachian basins and Rome Trough. Thickness and extent of potential Cambrian reservoirs have been redefined on an emergent platform for the Ohio region. The Mt. Simon Sandstone was deposited in an area limited to western Ohio and the adjacent proto-Michigan-Illinois basin. The eastern limit of the Mt. Simon is redefined astride a broad, reduced *Waverly Arch* of the exposed Laurentian craton. The Mt. Simon subcrops to a feather edge along the reduced *Waverly Arch* and along an ENE-trending shoulder of the Rome Trough, which formed paleotopographic barriers to deposition. Between these positive areas, the Mt. Simon graded laterally with mixed clastic-carbonate Conasauga Group facies. Following Mt. Simon deposition, the stable Ohio Platform developed, dominated by cyclical, mixed clastic-carbonate sediments of Eau Claire Formation and Conasauga Group. The new term *Sandusky formation* has been proposed to clarify confusing nomenclature where the Eau Claire and Conasauga intertongue. The redefined sub-Knox units of the Ohio region illustrate that the Mt. Simon is not the regional basal "blanket sandstone," deposited on a Precambrian peneplain, as traditionally mapped.

STOP 1—Major tectonic elements affecting Cambrian deposition.

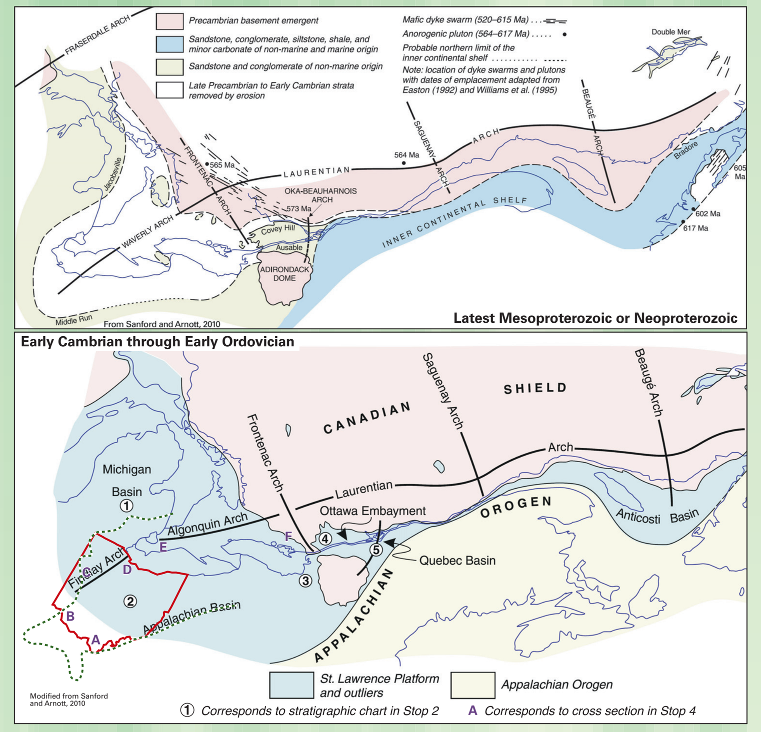
- Precambrian Provinces: Eastern Granite Rhyolite, East Continent Rift Basin, Grenville.
- Waverly Arch, Ohio Platform, and Rome Trough.
- Proto-Illinois/Michigan and proto-Appalachian Basins.



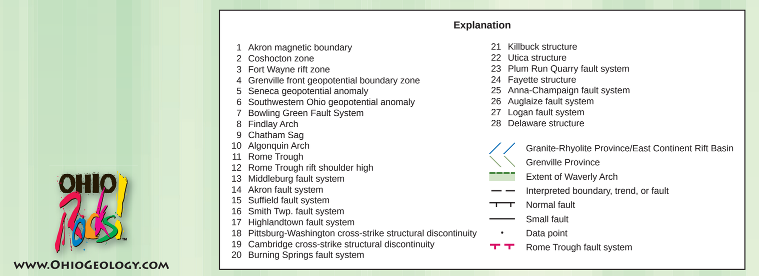
Magnetic anomaly map showing changes in relative magnetic intensity along tectonic boundaries and structural trends (GSA, 1987).

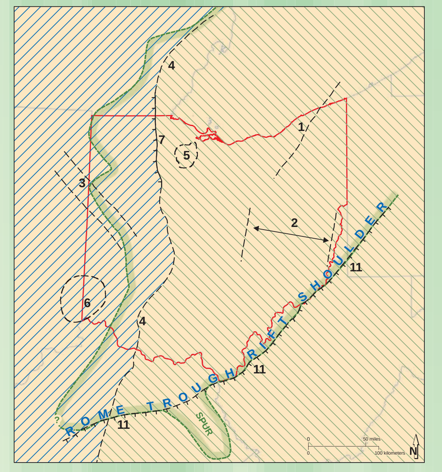


Paleogeography and proposed extension of the Waverly Arch during late Middle Cambrian Rome Trough time. Modified from Blakey, 2006.

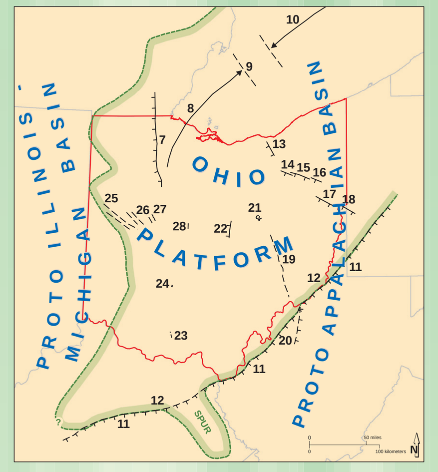


Regional maps showing major tectonic features and deep-well and outcrop locations for this poster and generalized paleogeography during Cambrian time and revised Waverly Arch.

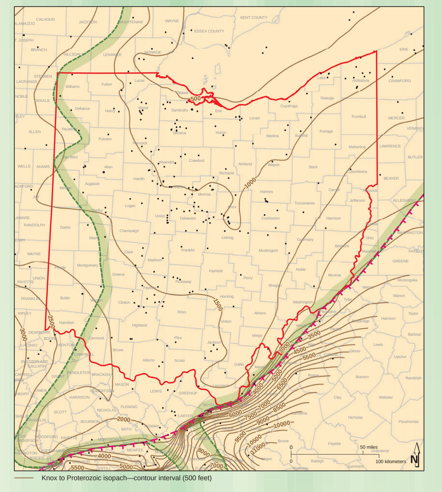




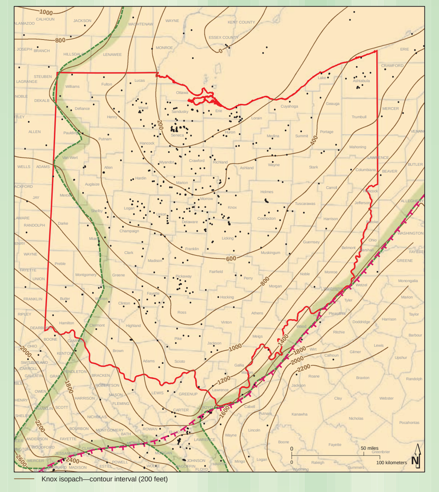
Proposed extension of the Late Mesoproterozoic to Neoproterozoic Waverly Arch and major structural features.



Emergent Ohio Platform, proto-basins, and major structural features.



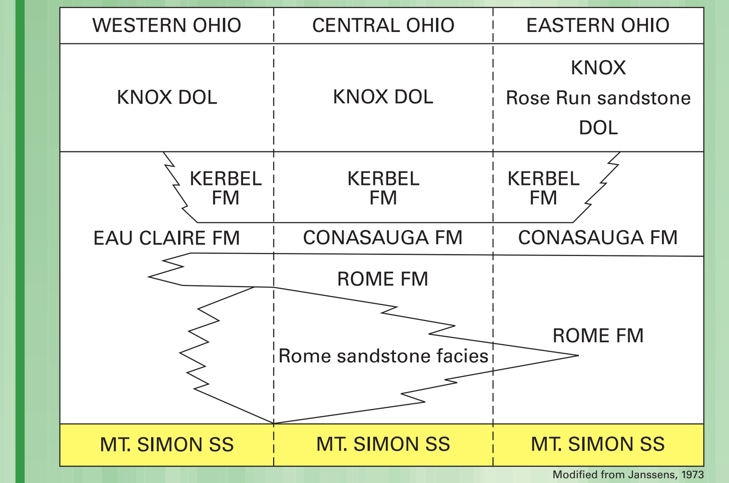
Isopach of Sauk sequence shows Cambrian/Early Ordovician extent of the emergent Ohio Platform.

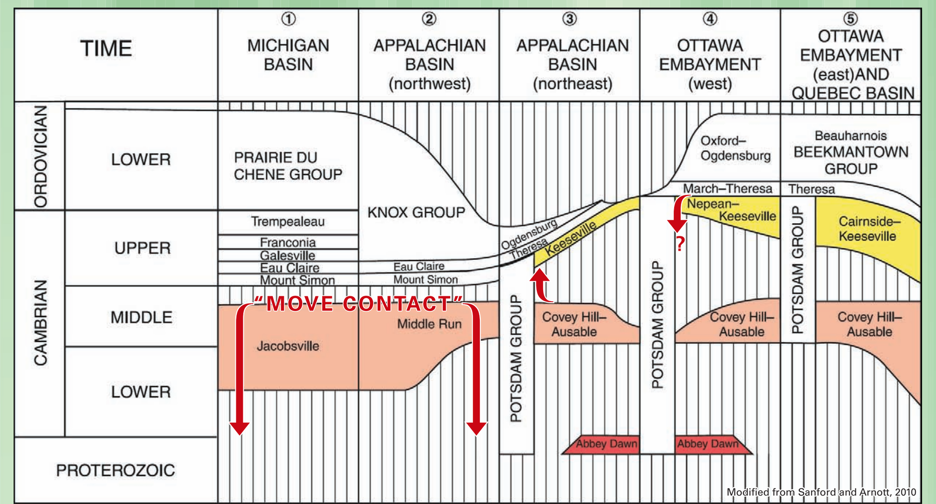


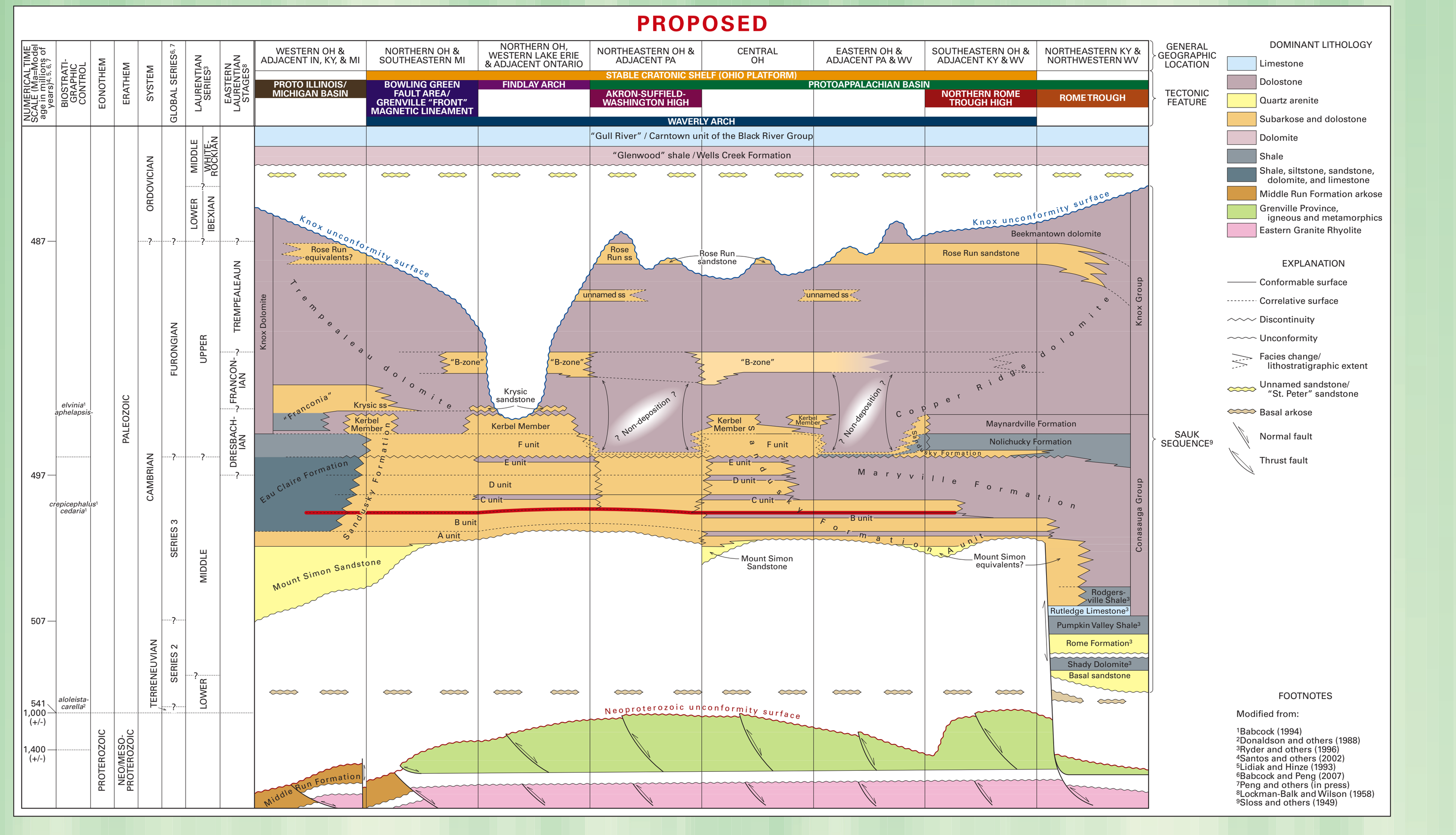
Isopach of upper Sauk sequence shows Cambrian/Early Ordovician extent of the emergent Ohio Platform.

STOP 2—Revised sub-Knox nomenclature.

Charts show: current (Janssens, 1973; Sanford and Arnott, 2010) and revised nomenclature and proposed lithostratigraphic model for the Sauk sequence units in Ohio and the surrounding region. Logging of Ontario deep core verifies the proposed lithostratigraphic model for the Waverly Arch and emergent platform. Nepean Fm and Covey Hill outcrops in eastern Ontario are lithostratigraphically similar to the Conasauga/Sandusky and Mt. Simon, respectively. Sanford and Arnott's (2010) Jacobsville and Middle Run should be placed in the Proterozoic.



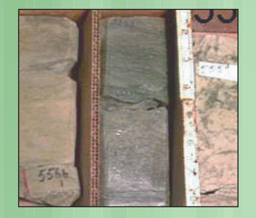




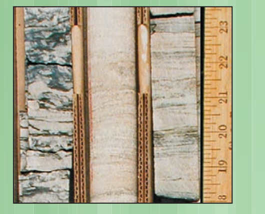
REFERENCES CITED

STOP 3—Revised sub-Knox nomenclature.

The diamond core recovered from deep wells shown on the cross section at Stop 4 are the foundation for the proposed lithostratigraphic model for the Waverly Arch and emergent platform. The Sandusky is notably bioturbated and heterolithic compared to the underlying Mt. Simon. Nepean Fm and Covey Hill outcrops in eastern Ontario are lithostratigraphically similar to the subsurface Conasauga/Sandusky and Mt. Simon, respectively.

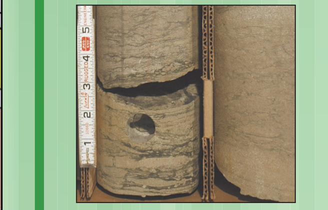


A. 3414502212 Sandusky fm, ~5,560 feet.

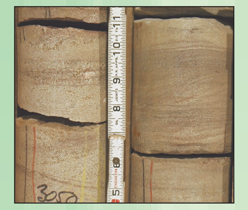


B-1. 3416560005 Sandusky fm, ~3,130 feet.

B-2. 3416560005 Mt. Simon Ss, ~3,300 feet.



C-1. 3400363691 Sandusky fm, ~2,850 feet.

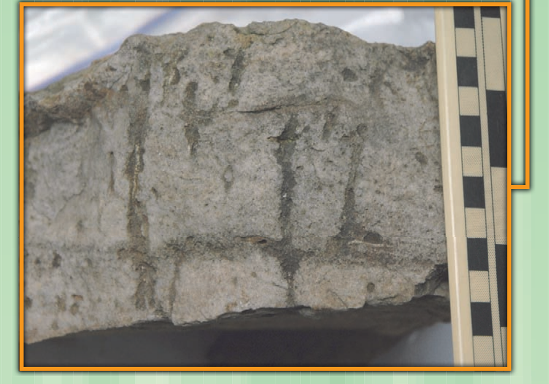


C-2. 3400363691 Mt. Simon Ss, ~3,050 feet.

D. 3414760840 Sandusky fm, ~2,700 feet.

E. Kent Co., Ontario: Eau Claire Fm (Sandusky fm), ~3,620 feet.

F. Harts Gravel Rd., Phillipsville Escarpment, northeast of Kingston, Ontario: Nepean Fm (Dalyrmple, unpub.data).



Quartz arenite: very fine grained, bioturbated, cross bedded, trace to minor carbonate cement. Arrows and boxes point to approximate locations.

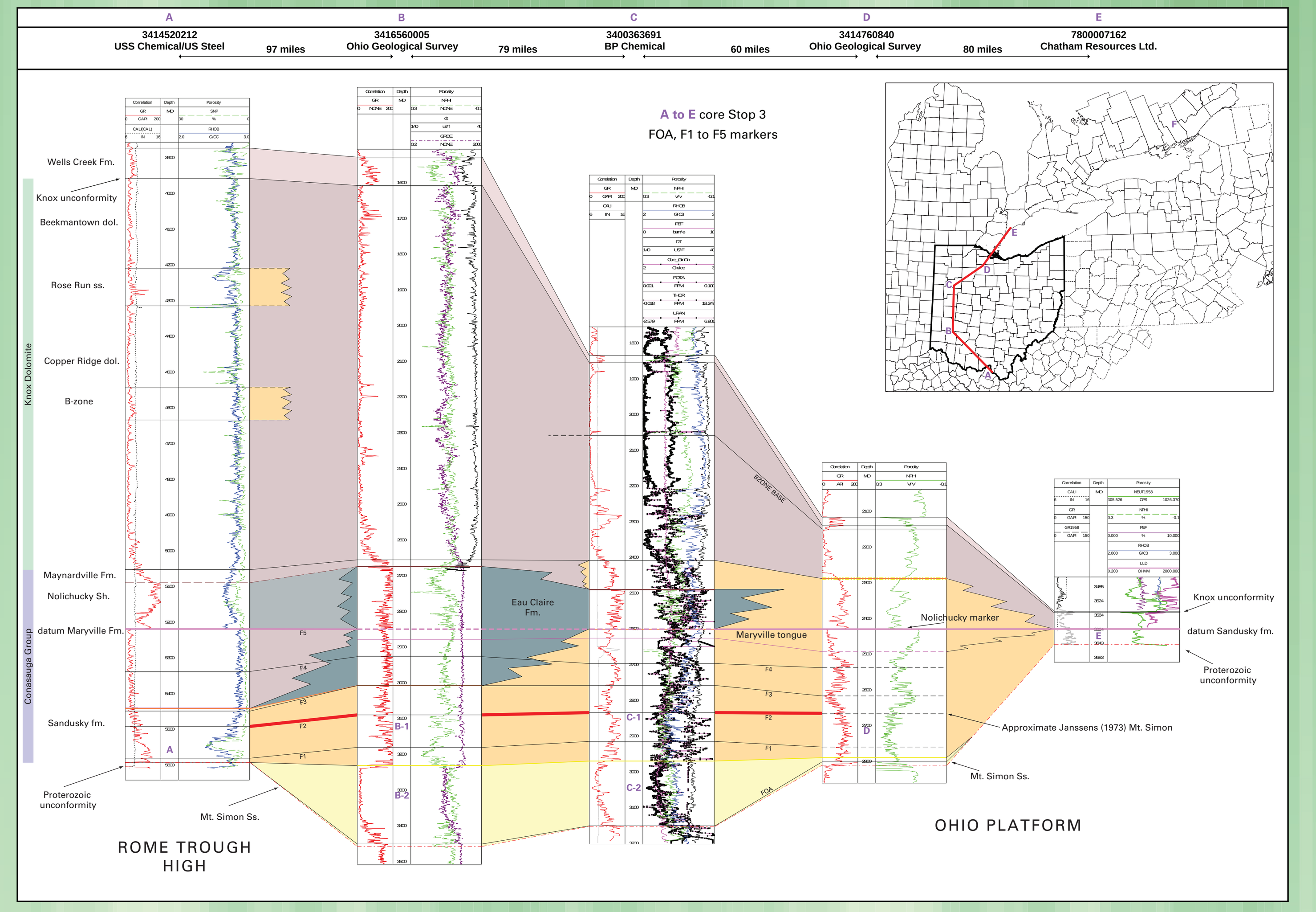
F. Sloan quarry, northeast of Kingston, Ontario: Nepean Fm above angular contact with Covey Hill Fm.

Quartz arenite: very fine grained, laminated, hematitic, cross bedded of Covey Hill Fm.

Sloan quarry, trace fossil Anthropod trackways on steeply dipping, eolian, cross-bedded quartz arenite of Covey Hill Fm.

STOP 4—Regional cross section showing redefined Mt. Simon thickness decreasing onto the Ohio Platform and Rome Trough high.

Consistent thickness of the overlying Cambrian units emphasizes the stability and uniform subsidence of the Ohio Platform and additional saline reservoirs. The F2 marker beds correlate in part with previously defined Mt. Simon. See regional map at Stop 1 for approximate well and outcrop locations. Stop 3 shows representative diamond core examples. Previous Mt. Simon workers (e.g. Janssens, 1973) apparently were caught in the "peneplain trap" for regional correlations. All sandstones deposited on the Precambrian unconformity surface in the Ohio region are NOT categorically mappable as the Mt. Simon.

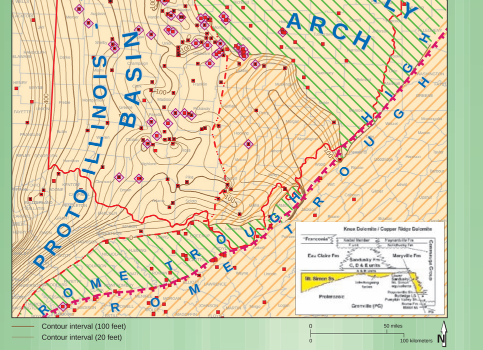


STOP 5—Chart showing distinguishing characteristics of the Sauk sequence units in Ohio.

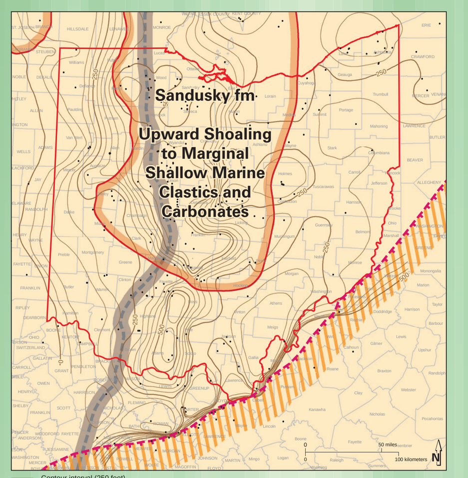
Previous workers (e.g. Janssens, 1973) have inconsistently carried Upper Mississippi Valley and southern Central Appalachian Basin surface nomenclature into the Ohio subsurface using deep test wells. The Sandusky fm is introduced to eliminate and clarify correlation problems with the sub-Knox. Previous Mt. Simon correlations across the Ohio Platform region included the Sandusky F2 (B-unit on revised nomenclature chart) marker on the cross section in Stop 4. Note the similarity of lithology and geophysical log response of the Sandusky fm and Eau Claire Fm, which contrasts with the underlying Mt. Simon Ss.

Unit name	Generalized lithology and bedding	gamma ray units = API relative natural radiation	density units = calculated grams/cc relative to fresh water	photoelectric units = barns
Knox Dolomite	dolostone—light to medium to dark gray; massive to medium bedded; locally, vuggy, glauconitic, arenaceous, shaley, wispy to laminated, nodular, rip up clasts	low	high	medium
Conasauga Group, Maynardville Formation	dolostone and limestone—light to medium gray; thin to medium and wispy bedded; locally, glauconitic, arenaceous, nodular, rip up clasts	low to medium	medium to high	medium
Conasauga Group, Nolichucky Formation	shale and dolostone—medium to dark gray to black; laminated to interbedded, to thin to medium and wispy bedded; locally, fossilferous, glauconitic, arenaceous	high	low medium	low to
Conasauga Group, Maryville Formation	dolostone—light to medium gray; thin to medium to massive bedded; locally, bioturbation, glauconitic, arenaceous, nodular, anhydrite, rip up clasts	low	high	medium
Sandusky formation (proposed new name)	quartz arenite to subarkose to siltstone to dolostone—variable color: light to medium gray to pinkish gray to dark gray to light brown to reddish brown to white; interbedded to thin to medium to massive to wispy to cross bedded; cyclical; bioturbation; feldspathic, arenaceous to dolomitic; locally pelloidal; glauconitic, paleosols, shaley, anhydrite, rip up clasts	medium to high (cyclical response)	low to medium (cyclical response)	medium (cyclical response)
Eau Claire Formation	quartz arenite to subarkose, shale, siltstone, dolostone and limestone—variable color: light to medium gray to pinkish gray to dark gray to light brown to reddish brown to white; interbedded to thin to medium to massive to wispy to cross bedded; cyclical; bioturbation; glauconitic, rip up clasts	medium to high (cyclical response) 40 to 190 API units (mean 140) BP	low to high (cyclical response) 2.25 to 2.75 units (mean 2.55) BP	medium (cyclical) response) 4.0 to 4.9 units (mean 3.5) BP
Mount Simon Sandstone upper	quartz arenite—white to light gray to red to purple; medium to massive to cross bedded; bioturbation, rip up clasts	low to medium 20 to 100 API unit (mean 50) BP	low to medium 2.45 to 2.60 units (mean 2.5) BP	low 1.8 to 2.2 units (mean 2.0) BP
Mount Simon Sandstone lower	quartz arenite to arkose to shale, siltstone—white to light gray to red; interbedded to thin to medium to massive to wispy to cross bedded; locally conglomeratic, cyclical, bioturbation, rip up clasts	medium (cyclical response) 40 to 140 API units (mean 90) BP	low to medium (cyclical response) 2.45 to 2.60 units (mean 2.5) BP	low to medium (cyclical response) 2.0 to 3.0 units (mean 2.5) BP
basal arkose	quartz arenite to arkose to shale, siltstone—white to light gray to red; interbedded to thin to medium to massive to wispy to cross bedded; locally conglomeratic, cyclical, bioturbation, rip up clasts	high	low to high	na
Precambrian	highly variable—quartz, arenite, granite, rhyolite, gabbro, schist, mnarble, diorite, amphibolite, granodorite, anorthosite	variable	variable	variable

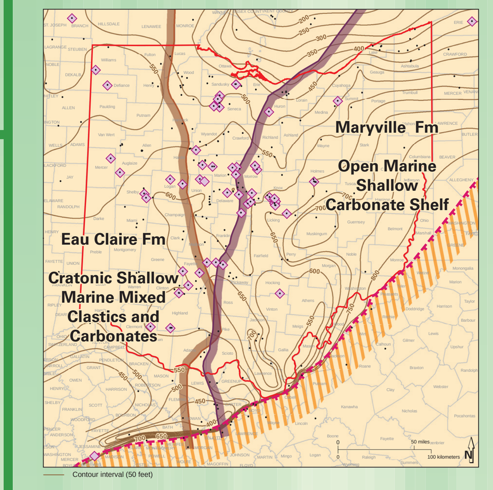
STOP 6—Isopach maps showing complex structural and stratigraphic relationships of the Mt. Simon and overlying Eau Claire, Conasauga, and Sandusky.



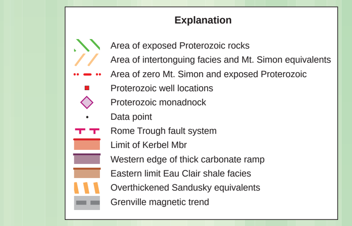
Isopach of Mt. Simon showing reduced Waverly Arch, basin development, and the emergence of the Ohio Platform.



Isopach of Sandusky showing thick contoured area astride the Grenville magnetic trend, extent of Kerbel facies, and reduced Waverly Arch on the emergent Ohio Platform.



Isopach of Eau Claire/Conasauga/Sandusky showing extent of facies, reduced Waverly Arch, basin development, and the emergence of the Ohio Platform.



STOP 7—Conclusions.

- A deeply eroded, tectonically complex Proterozoic surface controlled development of the Waverly Arch, Rome Trough, proto-Illinois/Michigan & proto-Appalachian Basin architecture, and deposition of the Sauk Sequence in Ohio and surrounding region. Although the basement complex is assumed to be an "impermeable" sealing interval, the injection potential of the basement complex is poorly understood and requires updating and modernizing of available rock and geophysical data.
- The Mt. Simon is not a regional "blanket sandstone" extending across Ohio into the Appalachian Basin, as traditionally mapped. Updated mapping demonstrates the presence of the Waverly Arch and development of the emergent Ohio Platform.
- Subsidence of proto-Illinois/Michigan Basin during Mt. Simon deposition was in part contemporaneous with Rome Trough subsidence and part of Conasauga Gp deposition. The Rome Trough high and reduced Waverly Arch acted as barriers, effectively controlling Mt. Simon and Conasauga deposition.
- Following Mt. Simon deposition, Eau Claire Fm, the upper portion of Conasauga Gp, and equivalents formed the stable, very-low relief Ohio Platform, which was dominated by cyclical, mixed clastic-carbonate sediments throughout central Ohio and primarily carbonates eastward.
- Proterozoic monadnocks are completely buried during Sandusky E unit deposition, marking a previously unknown regional hiatus.
- The Sandusky fm is proposed to eliminate and clarify current sub-Knox correlation problems.
- Nepean Fm and Covey Hill outcrops in eastern Ontario are lithostratigraphically similar to the Conasauga/Sandusky and Mt. Simon respectively.
- Updated mapping of the extent and quality of Cambrian reservoirs has implications for hydrocarbon exploration, gas storage, CO_2 sequestration, and industrial and oil field waste injection.