Revisiting the Structural Geology of Northwestern Ohio

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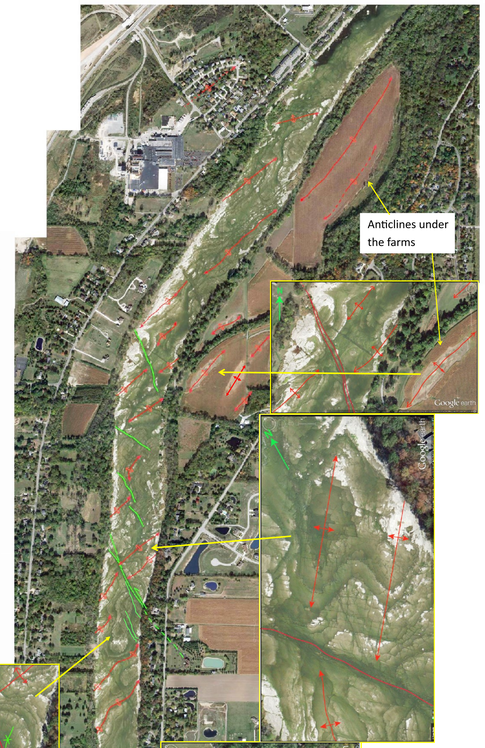
Abstract

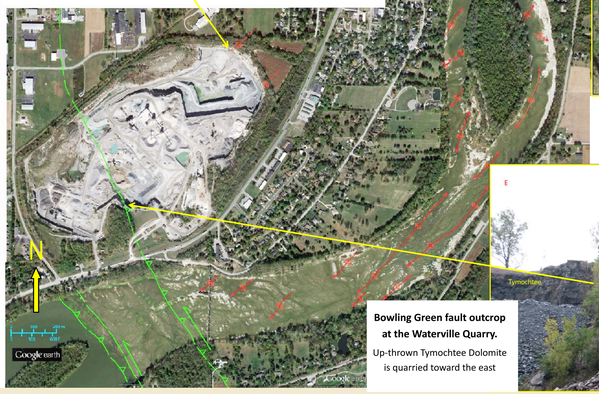
Lying at the western edge of the Appalachian Basin, Ohio is covered by low-relief Paleozoic sediments without significant folding and faulting. The Bowling Green and Outlet faults in northwestern Ohio are the only exposed and defined structural anomalies of significance in the state. Numerous studies indicate that thick glacial deposits cover the region and act as a barrier for greater certainty and a more accurate explanation of the tectono-structural geometry and history of the region. Recent geological study of northwestern Ohio, when accompanied by review of high-quality space images, reveals numerous small-scale, low-relief anticlines in the vicinity and east of the Bowling Green fault. These folds are oriented in a northeast–southwest direction, and alignment of the folds' axes indicates that they are created by northwest-directed compressive stress. Structural analysis of these anticlines shows that their detachment depth is 400–450 feet (120–140 m) below ground level at the upper Ordovician Cincinnati Group shales. The Middle Ordovician Trenton Limestone, which lies beneath the decollement zone of the anticlines, is not included in the shallow folding process.

The reduction in the length of the folded sequence requires a low-angle thrust sheet at the folds' detachment level. This thrust sheet is created by Appalachian compressive stress in the Ordovician shale that trends northwest and upslope toward the Findlay arch axis. The thrust sheet covers the area east of the Bowling Green fault and northeast of the Outlet fault, and extends eastward to the core of the basin. A thinner sedimentary sequence above the Findlay arch facilitates creation of these folds; in comparison to thicker sedimentary sequences eastward, where development of such structural features is limited. The northeast-trending axis of the anticlines indicates a northwest movement of the sedimentary sequence above the decollement zone. Thus the Outlet fault must be a sinistral strike-slip fault, while the north –south-oriented Bowling Green fault appears to be a sinistral transpression fault, as strata are uplifted east of the fault.



En-echelon anticlines & syncline

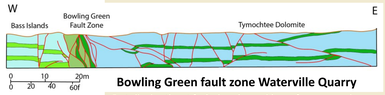
NE wall of the Waterville Quarry perpendicular to the axis of the folds displaying anticline wavelength and amplitude



Bowling Green fault outcrop at the Waterville Quarry.

Up-thrown Tymochtee Dolomite is quarried toward the East

Eroded axes and core of anticline exposed under water at the Maumee River bed

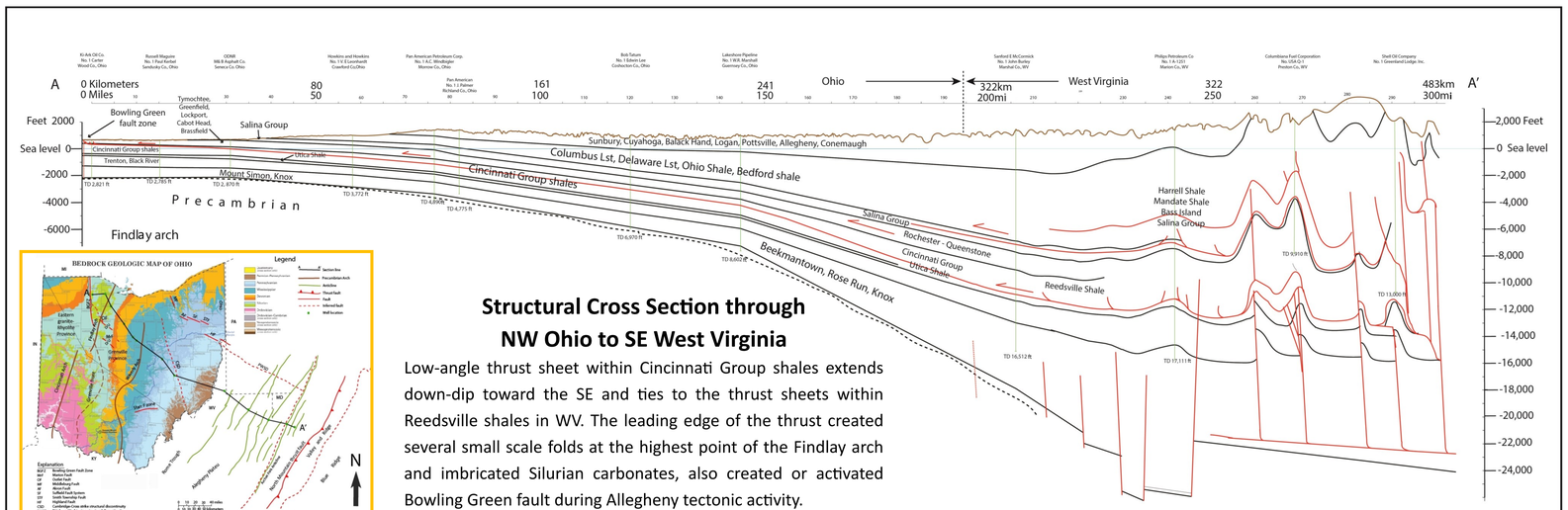


Bowling Green fault zone Waterville Quarry

East-dipping thrust faults is a clear evidence for compressive stress from east. Modified from Onasch & Kahle, 1991.

General Stratigraphy of Northwestern Ohio

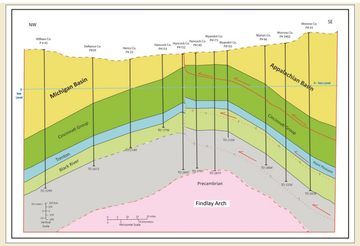
System/ Period		Rock Unit
Silurian		Bass Island Dol
	Salina Group	Tymochtee Dol
		Greenfield Dol
		Lockport Dol
		Sub-Lockport undiff.
Ordovician		Cincinnati Group shales, Utica
		Trenton Lst
		Black River Group
Cambrian		Knox Dol
		Eau Clair
		Mount Simon ss
Pre-Cambrian		Granite, Rhyolite



Structural Cross Section through NW Ohio to SE West Virginia

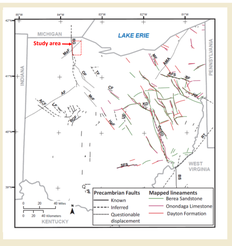
Low-angle thrust sheet within Cincinnati Group shales extends down-dip toward the SE and ties to the thrust sheets within Reedsville shales in WV. The leading edge of the thrust created several small scale folds at the highest point of the Findlay arch and imbricated Silurian carbonates, also created or activated Bowling Green fault during Allegheny tectonic activity.

Section modified from Ryder and others, 2009.



Structural Section through Findlay arch & Bowling Green fault

Thrust faults indicate that Bowling Green fault is created by NW directed compressive stress resulted from Alleghenian orogeny. The highest point of the Findlay arch was the thinnest and weakest point to break and create Bowling Green fault. Section is adopted from Wickstrom & others, 1992.



Structural Trends of Northeastern Ohio

Solis, pers. comm. 2015.

Decollement within Salina Formation salt layers and westward movement of the upper beds

Length of three upper beds in black shows 3, 9, and 2 meters increase in comparison to the lowest flat bed. The lowermost and uppermost layers are flat and follow the geometry of underlying and overlaying non-salt formations.

Observations and Conclusions

More than 50 small-scale, doubly plunging anticlines are exposed along the Maumee River southwest of Toledo, Ohio; where glacial deposits have been removed by the river exposing Silurian age Tymochtee and Bass Islands carbonates are exposed. The trend and abundance of these folds in the lowland area around the river indicates that hundreds of similar folds exist toward the east and southeast under the glacial deposits.

The exposed anticlines are aligned in 22 parallel rows in NE–SW direction. Their wavelengths vary from 200 to 500 feet (60–150 m) and their lengths are around 300–1,500 feet (90–450 m). A few of these anticlines are exposed at the walls of Waterville quarry at the south end of these exposures, providing opportunity to observe wavelength and amplitude of the anticlines.

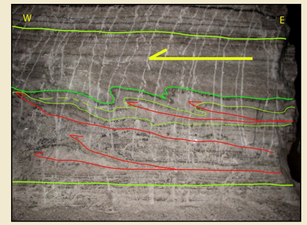
Detachment depth calculation (DD=S/A-B) for these anticlines show that they are detached from lower horizons of the stratigraphic sequence at the depth of 400–450 feet (120–150 m) below ground level within Ordovician-age Cincinnati Group shales. Detailed study of the anticlines and synclines shows that they were created by northwest directed compressive forces similar to Valley and Ridge structures of the Appalachian Basin in West Virginia and Pennsylvania during the Allegheny orogeny.

Accommodation of the combined amount of shortening of the folded layers reveals that the competent sedimentary sequence above the Ordovician shales has moved toward the northwest. This movement is facilitated by a low-angle thrust sheet within Cincinnati Group. This thrust sheet /decollement extends southeast to the center of the Appalachian Basin and ties to the thrust sheet within the Reedsville Shale in West Virginia. The northwest edge of the thrust sheet imbricates the thinner overburden at the highest point of the Findlay arch and creates or activates Bowling Green high-angle reverse fault. The Northwest-directed Outlet fault zone and most of the faults mapped at the northeastern Ohio, as well as structural trends, are in accordance with movement of this thrust sheet. These faults have a NW–SE direction, and northeast of the faults are uplifted indicating sinistral motion along the faults.

A similar thrust sheet is present and observable in an underground salt mine within the upper Salina Group in northeast Ohio. Decollements within salt layers and westward movement of the overlaying formations shows that there is another thrust sheet at this horizon.

Numerous geologists have studied the Bowling Green fault and presented it as a high-angle thrust to vertical fault which was activated from early Paleozoic. Results of this study are only applicable for shallow thrust sheet within Cincinnati Group shales and their equivalents; this study does not consider deeper displacements of the region.

Conclusions: The Northeastern Ohio sedimentary blanket located east of the Bowling Green fault and northeast of the Outlet fault zone has experienced a northwestward compressive stress during the Allegheny orogeny. Cincinnati Group shales hosted and facilitated creation of a thrust sheet/decollement. Formations above this decollement are thrusted toward the northwest. Sinistral Outlet fault and other sinistral northwest-directed faults are created. Finally, Waterville anticlines were developed, and excessive stress activated or created (?) the Bowling Green fault.



Decollement within salt layers of Salina Formation and westward creeping of the upper layers

References

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