A GEOPHYSICAL SEARCH FOR THE FLOOR OF A CONCEALED IMPACT CRATER IN NORTHWEST OHIO

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Abstract: We are using geophysical methods to map a sediment-filled gap in the carbonate bedrock under Sections 17, 18, 19 and 20 of Liberty Township, Seneca County, Ohio. No evidence of the 100 m thick Lockport dolomite documented in oil well logs north and south of this anomaly has been detected inside an approximately circular feature about 980 meters in diameter, concealed by about 10 m of drift. Our working hypothesis is that we are studying an impact crater. Electrical resistivity measurements used to map the crater suggest that the edge of the carbonate does not everywhere mark the edge of this hole. A well-drilling attempt outside the northwest edge encountered only a thin layer of Lockport dolomite before penetrating shale that should lie at least 80 meters deeper. Rocks of the crater lip are uplifted. A Schlumberger sounding east of the crater's center discovered 8 Ohm-m material extending from 57 m under the surface to at least 200 m. Trytten (1995) reports crater fill 600 m to the northwest in the 17 – 20 Ohm-m range. The P-wave velocity of the refractor under drift east of the crater center is about 2100 m/s, significantly less than the 2800 m/sec measured in the northwest quadrant. Cuttings from an 80 m deep borehole drilled near this seismic line in an unsuccessful search for groundwater are calcite-cemented silt, pinkish gray when dry and dark reddish gray when wet. Another well drilled into the crater encountered salt water. We speculate that brine from the oil-bearing Trenton limestone just over 400 m down migrated into the crater, forming a lake that was mostly salt water except for the northwest quadrant. We have not encountered electrical resistivity values this low, under 10 Ohm-meters, elsewhere in northwest Ohio except locations involving landfill leachate. The 2100 m/s refractor shows evidence of relief. Glaciers that swept limestone from the uplifted crater rim may have carved grooves into the lacustrine sediment's surface.

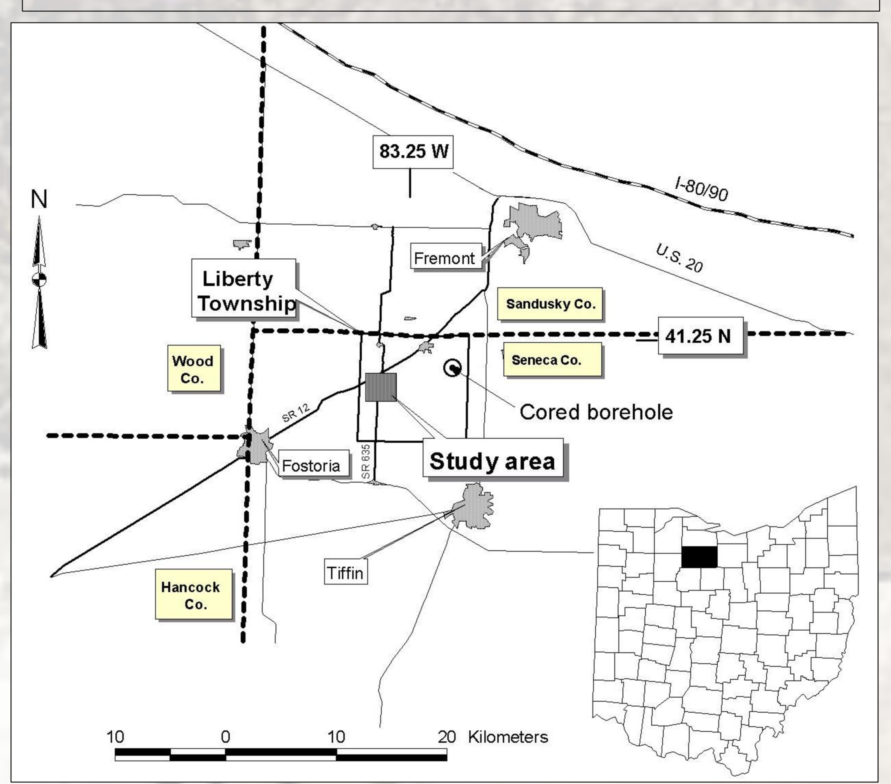


Figure 1: The study area lies in Liberty Township, Seneca County, Ohio. The cored borehole was drilled to the Precambrian by the Ohio Geological Survey (Wickstrom et. al., 1985)

Following the discovery of missing bedrock from **Well 1** (Figure 2, Table 1), seismic refraction and electrical resistivity measurements along a farm lane and fields to the east failed to detect evidence of carbonate bedrock, the regional aquifer, near the surface. Most water well logs in this area report Lockport dolomite 10 meters under the surface and most well logs report water 20 to 30 meters under the surface. Some wells are artesian. Trytten (1995) searched for a 'buried pre-glacial valley' under surrounding county and township roads but found only shallow bedrock.

Water Wells In and Near the Crater

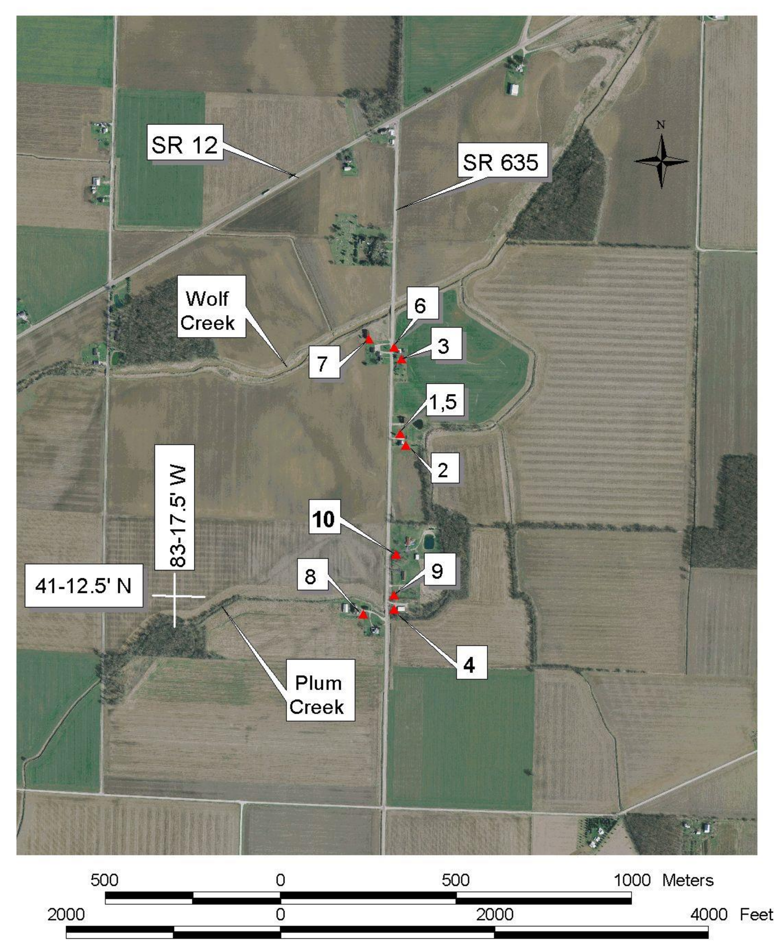


Figure 2: water wells and attempted water wells that help define the crater edge along State Route 635. Wells 7 and 8 tap the carbonate aquifer. Well 1 was the discovery well. Well 6 encountered uplifted strata characteristic of an impact crater rim. Summary information is listed in Table 1. Wells 7 and 8 are old water wells tapping the regional aquifer.

Schlumberger soundings and dipole-dipole profiles

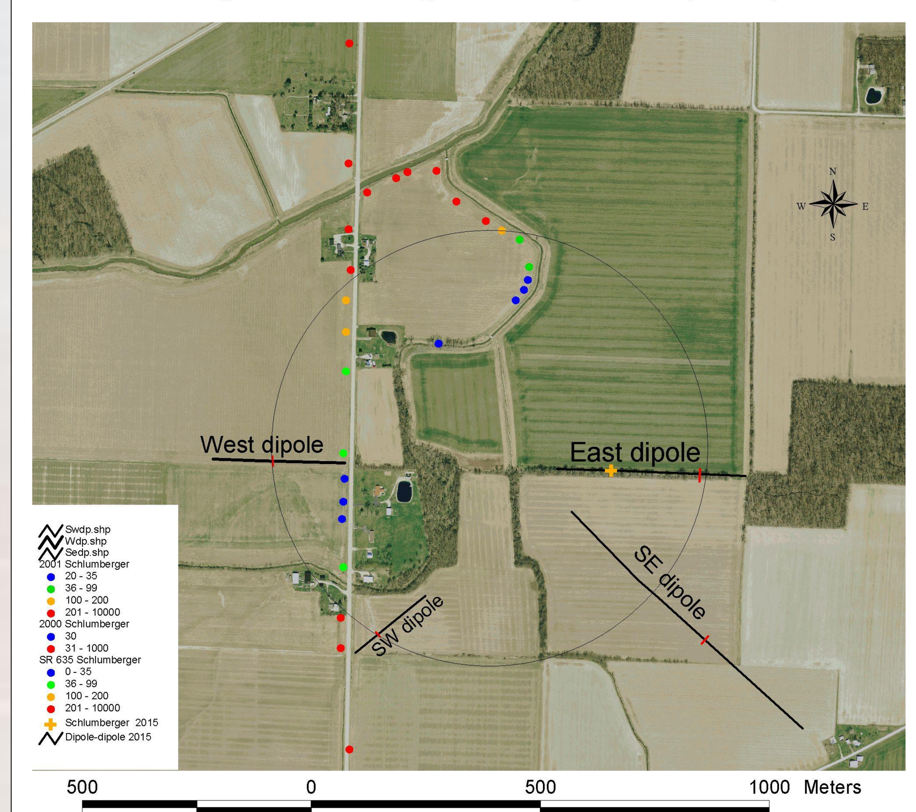


Figure 4: locations of Schlumberger soundings (dots, cross) and dipole-dipole profiles used to map variations in what lies under about 10 m of till. Dot colors show range of electrical resistivities of rock or sediments under the till. Sounding curve for the 2015 sounding and the interpretation are shown in Figure 5 and dipole-dipole resistivity models are shown in Figure 6. Red line segments crossing dipole-dipole profile lines show edge of bedrock/edge of crater fill. Reference circle crosses 3 of these markers and separates good wells from crater wells.

I.D.	State_id	Date_compl	Utm_e	Utm_n	Elevation		Depth		Water_table		Top_of_bedrock		Comments
		yearmody	Meters	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	
1	710376	19900508	308508	4564668	732	223	260	79	no water		not detected		discovery well
2	664239	19870815	308524	4564636	733	223	140	43	not listed		not detected		no bedrock
3	386155	19681015	308513	4564882	723	220	44	13	5	2	not detected		gray shale & gravel 30 to 44 feet
4	386153	19681010	308497	4564324	724	221	77	23	15	5	38	12	rock at 38', 1 gpm
5	704346	19900815	308508	4564668	732	223	44	13	14	4	not detected		not a bedrock well
6	no log	19990901	308491	4564914	726	221	130	40	no water		25	8	Carla's well, cuttings on file
7	no log	old	308419	4564937	733	223	no log		not measured		no log		Good well (artesian)
8	no log	old	308403	4564155	725	221	no log		2	1	no log		Good well (artesian)
9	784797	19940423	308490	4564210	723	220	203	62	23	7	52	16	limestone at 52 ', red clay at 190'
10	272053	19620223	308490	4564168	723	220	140	43	16	5	32	10	shale, red rock, grey shale
													hit salt water at 140'
Logs are posted on-line at			http://ohiodnr.com/water/maptechs/wellogs/appNew/Default.aspx										
UTM datum is NAD27													

Table 1: Summary information from well logs, direct observations and interviews with property owners. Salt water encountered in Well 10 is documented on the original well log but was not transcribed when the water well digital database was developed.

The property owner collected a handful of cuttings when Well 1 was drilled in 1990. Cuttings fizz vigorously when tested with a geologist's standard 1% HCl solution. HCl was used to disaggregate several samples. Dry weight of the disaggregated, rinsed samples was about 15% less than the dry original, calcite-cemented samples. Cuttings from that well are pinkish gray when dry (Munsell 5YR 6/2) and dark reddish gray (Munsell 5YR 4/2) when wet. The sediment is **poorly sorted**, about half silt and half clay. Results of size analysis are displayed in Figure 3.

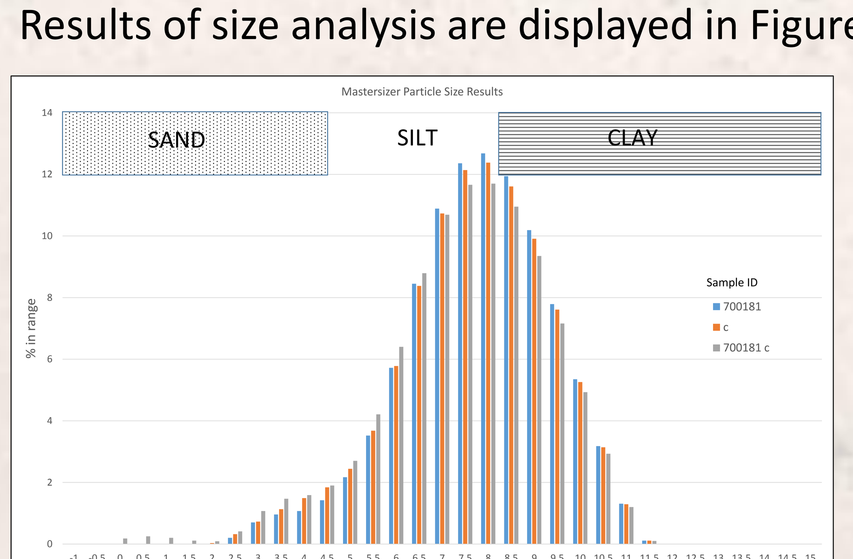
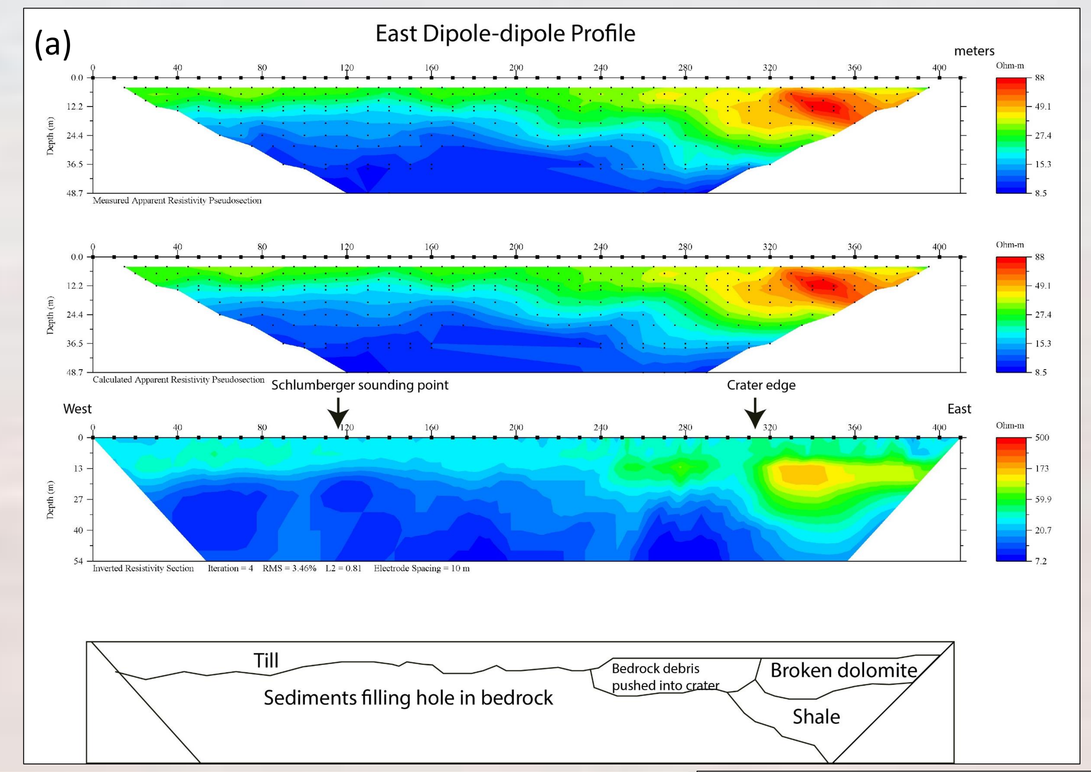


Figure 3: Mastersizer analysis (Department of Environmental Sciences Glacial Lakes and Sediment Studies Lab) of disaggregated sediment from Well 1 cuttings.



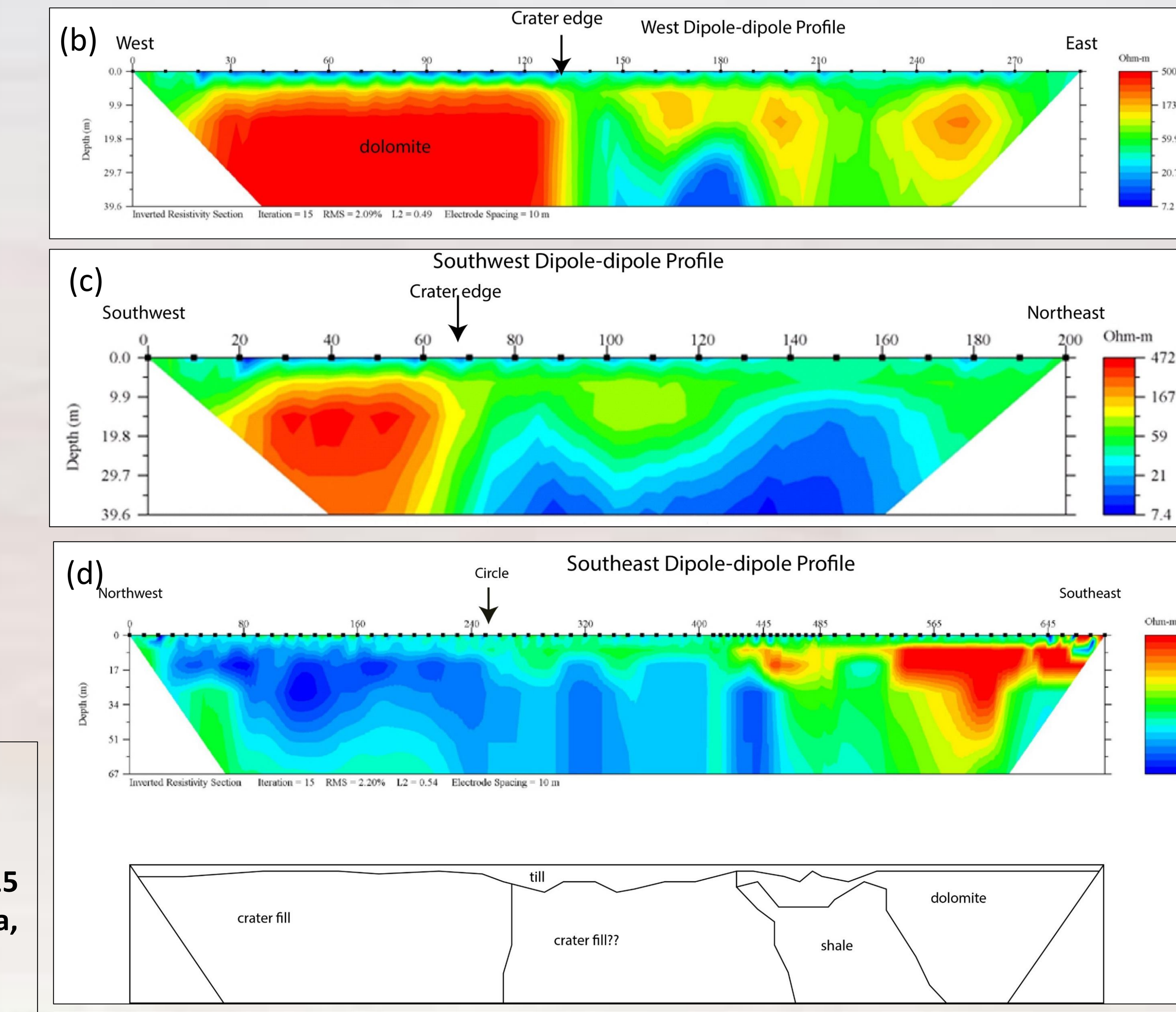
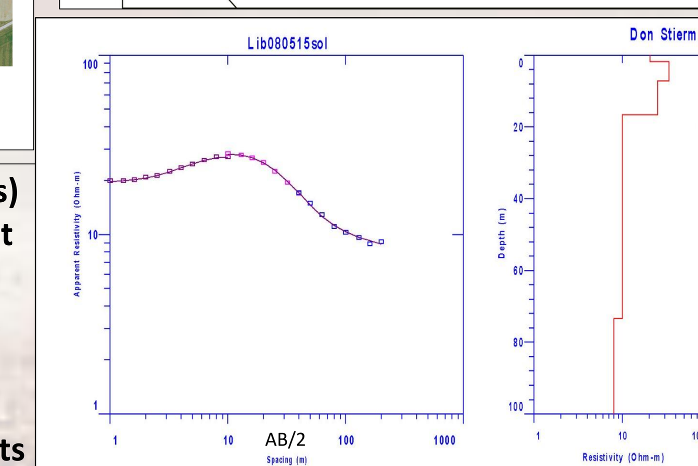


Figure 6: Resistivity models (EarthImager by Advanced Geosciences, Inc) of the 4 dipole-dipole profiles shown in Figure 4. (a) shows the complete output (observed, calculated, resistivity model) plus my interpretation. Space limits precludes showing the entire output for all profiles.



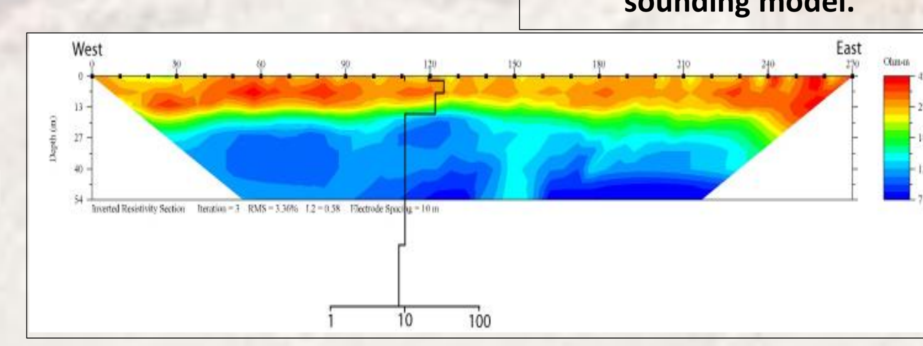


Figure 5 (left): curve and layered inversion model (Interpex IX1D) for Schlumberger sounding 2015 (Figure 4). Points show data, curve is consistent with resistivity-depth model. When the west end of East profile uses a narrow resistivity range (below), it shows the same detail as the sounding model.

Electrical resistivity of basin fill is much less in the east and southeast than it is to the west and northwest. I speculate that impact broke through shale and released brine from the oil-bearing Trenton limestone. This is consistent with excavation of a hemisphere about 500 m in radius. Depth to the Trenton is less than 500 m (= 1640 feet - see Figures 10b and 10c). I have not encountered such low electrical resistivities in NW Ohio that was not associated with landfill leachate.

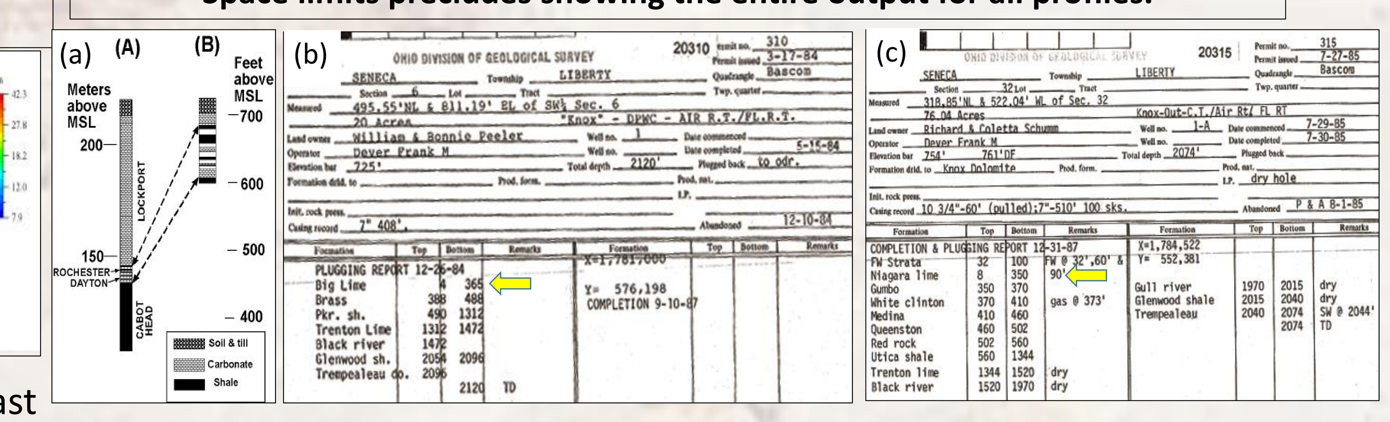


Figure 10: (a) comparison of projected stratigraphy from a continuous cored hole about 7.2 km to the ENE (Wickstrom et al., 1985) (column A) with rocks collected while Well 6 (Table 1, Figure 2) was drilled (column B). Oil well logs from boreholes about 2 km north (b) and about 2 km south (c) of Well 6 are consistent with column A – more than 340 feet of carbonate. Rocks collected from Well 6 lie 70 – 80 m above their expected elevation. Comparison of Well 6 cuttings with the core at the H.R. Collins Lab and Core Repository led to my identifying the cuttings collected as shown for column B. I interpret this as evidence for an uplifted rim of an impact crater.

Seismic Refraction Spreads

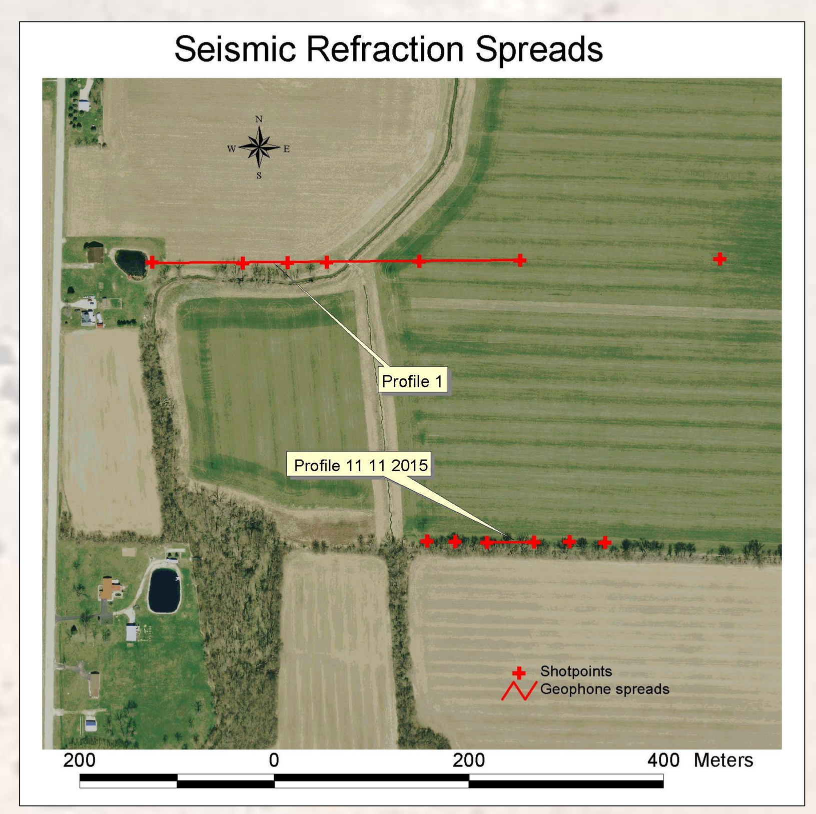


Figure 7: seismic refraction profiles (seismic spreads and shots)

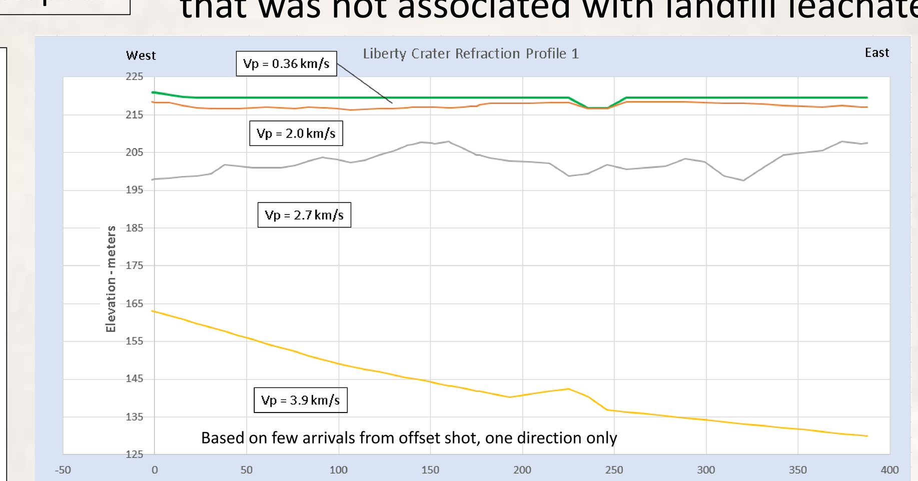


Figure 8: Interpretation of Profile 1: results from Rimrock's SIPT2 software.

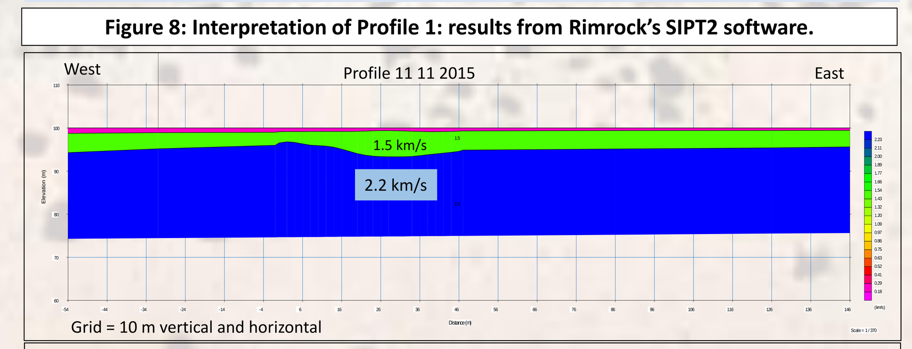


Figure 9: Interpretation of Profile 11 11 2015. Depth to top of the 2.2 km/s calculated under each geophone and each shot.

Refraction Profile 1 (Figures 7 and 8) consists of 2 overlapping geophone spreads extending east of the base of topographic high into which Well 1 (Figure 2, Table 1) was drilled. This was our initial search for shallow bedrock in which the home owner hoped to tap the carbonate aquifer. The deepest layer is based on only a few arrivals in one direction only so there is no way to discriminate between true velocity and contact dip. P-waves propagate with little amplitude loss along the 2.7 km/s refractor. We have not encountered similar behavior (2.7 km/s, efficient propagation) elsewhere. The short geophone spread (closely spaced geophones) for profile **11 11 2015** was used in an unsuccessful attempt to detect reflections from the crater bottom. Although reflections were not observed, first breaks served as input for Geometrics' **SeisImager2D** software. The basin fill refractor is significantly slower than Profile 1.

Discussion: Geophysical profiles have mapped an approximately circular hole about 980 m in diameter in the Lockport Dolomite. There are geophysical hints of uplifted strata at the crater edge under some profiles, but drilling near the crater edge for a water well (unsuccessful) encountered shale and other rocks elevated 70 – 80 m above the depth predicted based on nearby borehole logs and the gentle regional dip, proof of uplift. Sinkholes do not have uplifted rims. An isolated circular basin with uplifted strata on the rim, hundreds of kilometers from the nearest post-Proterozoic orogenic belt or mantle plume, is probably ***not*** volcanic in origin. It is probably an impact crater. Crater fill in the northwestern quadrant exhibits a higher seismic velocity and higher electrical resistivity than fill along the radius east of center. I speculate that hard water from the carbonate aquifer precipitated calcite cement that indurated silty clay in the NW quadrant, while brine from the Trenton limestone, exposed when the meteorite exploded, lowers the electrical resistivity in the eastern half. Brine may have prevented hard water from the 'Big Lime' aquifer from precipitating calcite, resulting in a lower P-wave velocity in the east. A Schlumberger sounding that should detect any change less than 200 m under the surface failed to reveal evidence of a crater floor. Even if this feature is not an impact crater, a deep bedrock hole filled with low-energy sediment might hold a continuous record of hundreds to thousands of years of climate change.

Acknowledgements: I am grateful to property owners for permission to work on their land, to numerous students who have assisted in many field expeditions, and The Department of Environmental Sciences for use of the department's F-150, computer resources and geophysical instruments.

References Cited

Oil well logs accessed via https://gis.ohiodnr.gov/MapViewer/?config=oilgaswells

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