Revised bedrock topographic map for the Oxford and College Corner quadrangles, Butler and Preble counties, Ohio

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Abstract

A collaborative bedrock/surficial deposit mapping project between Miami University and the Ohio Department of Natural Resources (ODNR), Division of Geological Survey has resulted in the generation of a revised bedrock topography map for the Oxford and College Corner 7.5-minute quadrangles, Butler and Preble counties, southwest Ohio. The study area consists of glaciated uplands dissected by filled valleys of the Indian Creek, Four-Mile Creek, and Seven-Mile Creek drainages. Late Wisconsinan-age moraine, outwash, and lacustrine deposits overlie Ordovician-Silurian sedimentary bedrock and range in thickness from 0 to >200 ft. As all subsurface geological units in the study area to some extent serve as residential, agricultural, industrial, and municipal aquifers, more accurately delineating the extent of these resources was the primary motivation of the study.

Building on mapping conducted by ODRN in the 1990s, the present study utilized water-well and borehole log data available on-line through the ODNR Division of Water Resources and the Ohio Department of Transportation. Additional Quaternary thickness and depth-to-bedrock data were derived from municipal water-supply and monitoring well logs drilled by the City of Oxford and Miami University. The study also incorporated field mapping of exposures of the Quaternary-Paleozoic contact as well as horizontal-to-vertical spectral ratio (HVSR) passive seismic analysis. HVSR data were calibrated at recording stations adjacent to wells with bedrock penetrations.

Study results generated over 950 individual elevation points of the Quaternary-Paleozoic contact, more than 3x the number used in earlier mapping efforts. The resulting higher resolution contour map of the bedrock topography indicates valley-fill deposits in some parts of the study area are narrower but deeper than previously mapped, and thus likely contain steeper basal contacts with underlying Paleozoic rocks. As valley-fill deposits serve as on the primary municipal aquifers in the study area, these findings may have important implications for the future development and utilization of local groundwater resources.

Introduction

Our revised bedrock topography map of the Oxford and College Corner quadrangles in southwestern Ohio originated from a combined undergraduate/graduate field project initiated in the fall of 2017. The primary objective of the study was to better delineate the thickness of Quaternary deposits in the area surrounding Miami University. These deposits which range in thickness from 0 to >200 ft serve as the primary municipal and private drinking water resource for northern Butler County and southern Preble counties. While previous 1:24000-scale mapping conducted in the 1990s provides a good estimation of depth-to-bedrock in the study area (Schumacher and Leow, 1997, 1999), new wells drilled over the past ~20 years, as well as borehole and monitoring-well data obtained from the Ohio Department of Transportation, the City of Oxford, and Miami University, provide a more complete catalogue of bedrock elevations. Moreover, detailed field investigations in the study area have identified previously undocumented surface exposures of the Quaternary-bedrock contact. Passive seismic data were also used to determine both the primary resonance frequency and thickness of Quaternary deposits in areas without well control. Collectively, the new data and methodologies utilized in the study provides enhanced detail of the bedrock-topographic surface in the Oxford and College Corner quadrangles compared to earlier work.

Geological Setting

The study area is situated at near the southern extent of the Miami sublobe of the Late Pleistocene Laurentide Ice Sheet. The Oxford and College Corner quadrangles are situated between the Camden and Harwell moraines (Figure 1). Quaternary surface deposits in the study area are dominated by glacial till, outwash, and lacustrine sediments representing at least four Late Pleistocene glacial advance/ablation events occurring between ~22-18 ka (Lowell, 1995).

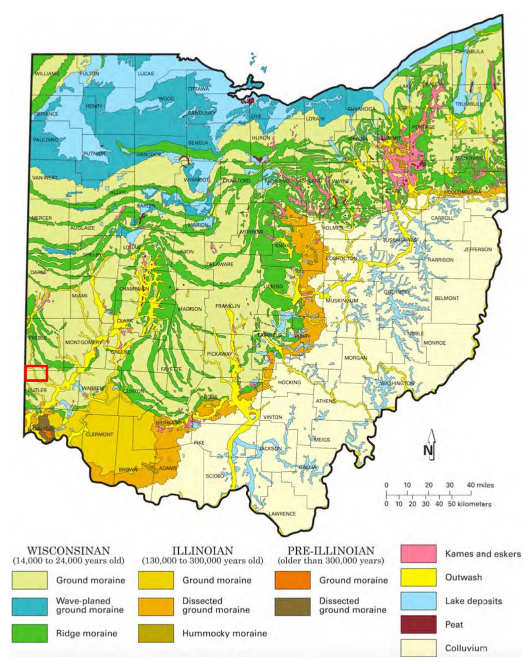


Figure 1. Glacial map of Ohio (Ohio Geological Survey, 2005). Study area in southwestern Ohio denoted by red rectangle.

Geomorphologically, upland regions of the study area are underlain primarily by deformation, lodgement and flow tills intercalated with thin interglacial loess and wetland deposits. (Figure 2). The valleys of the Four-Mile and Seven-Mile creeks also contain multiple tills, as well as fluvial outwash sand/gravel and lacustrine silt deposits (Figure 2). Relatively shallow outwash deposits in both Four-Mile and Seven-Mile creek the constitute the primary municipal water-supply aquifers in the study area, and the resource for both historical and present-day sand and gravel quarrying operations.

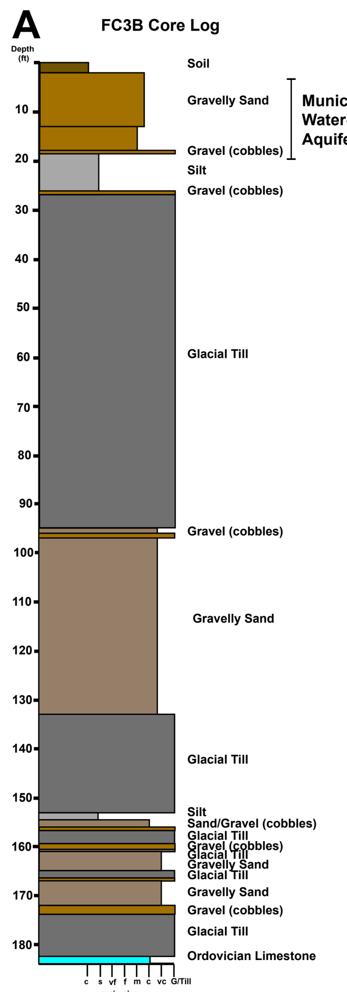
Quaternary deposits overlie Ordovician-Silurian bedrock consisting primarily of interbedded marine limestone and shale. The majority of the study area is underlain by rocks of the Upper Ordovician Cincinnati Group (Drakes through Fairview formations). Silurian rocks (Brassfield Formation) are only present in the shallow subsurface underlying the highest surface elevations (>1050 ft) in the northern part of the Oxford Quadrangle (Swinford and Schumacher, 1997, 1999).

Methods

The updated bedrock topography map of the Oxford and College Corner quadrangles relied on four primary data sets including drilling records of public/private water and groundwater-monitoring wells, information from geotechnical boreholes, field mapping of the Quaternary-Paleozoic unconformity, and Horizontal-to-Vertical Spectral Ratio (HVSR) passive-seismic analysis. Details on each of these data sources are described in more detail below.

Water-Well Database

Drilling records contained in water-well permits on file with the ODNR Division of Water Resources served as the primary data for the study. Well recordswere downloaded from the ODNR water-well web portal (https:// gis.ohiodnr.gov /MapViewer/ ?config = waterwells. Drilling records from municipal wells were obtained from the City of Oxford and Miami University. The drilling records of >900 water wells were used in the present study, 585 of which had bedrock elevations. Well location on file with ODNR were used to spatially locate each well and verified by confirming location addresses with those on file with county auditors, evaluation of satellite imagery, and field inspections. Recorded well depths and depths-to-bedrock were subtracted from DEM determined elevations for each well location to generate the top of bedrock elevation in each well.



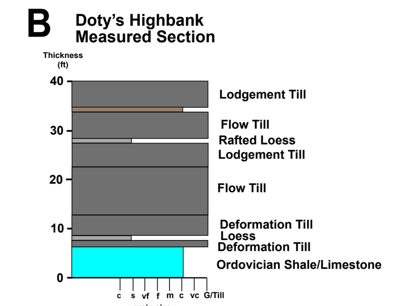


Figure 2. Measured sections of Quaternary deposits in the study area. A) Field log of rotosonic core of Well FC3B, Oxford Municipal Water Authority well field, Four-Mile Creek Valley (see Figure 6). The core was taken near the deepest part of the filled valley where the depth to bedrock is 183 ft. B) Measured section log from Doty's Highbank, Hueston Woods State Park (see Figure 6). Glacial till in the section is interpreted as the deposits of 4 separate Late Wisconsinan ice advances (Ekberg et al., 1993). This outcrop location provides a good analogue for other glaciated upland-valley margin settings in the study area.

Borehole Database

Geotechnical borehole data used in the study were derived from the ODOT online transportation database (https://gis.dot.state.oh.us/ tims/Map/Geotech) as well as records from Miami University on-campus construction projects. Bedrock and borehole subsurface elevations were determined by on-site topographic surveys. A total of 260 boreholes with 239 to bedrock elevations were used in the current mapping project.

Field Mapping

Outcrop mapping of the Quaternary-Paleozoic contact in the study area was conducted to provide better resolution of the bedrock-topographic surface, especially in areas along the margins of the Four-Mile and Seven-Mile Creek drainages. Outcrop locations were recorded with a hand-held GPS, and surface elevations determined from DEM-derived elevations for each point. A total of 132 elevations for the Quaternary-Paleozoic bedrock contact were collected as part of the project.

Horizontal-to-Vertical Spectral Ratio (HVSR) Methodology

The HVSR method takes advantage of the theory of fundamental resonance, which is the lowest natural frequency of vibration of a material. The HVSR technique records background seismic noise with a seismometer on three main orthogonal directions (North-South, East-West, and Up-Down. The HVSR method calculates the ratio between the amplitude spectra of the horizontal (H) and vertical (V) components from which the fundamental resonance frequency of surficial deposits can be discerned.

HVSR-frequency peaks are caused primarily by the shear-wave resonance of surficial deposits (Nakamura, 2000). Vertically incident shear waves traveling through a surface layer are reflected downward at the surface. These waves are again reflected upward at the base of the deposit, amplifying subsequent S waves vertically transiting the layer. This model is valid under the assumptions that Quaternary surficial deposits are soft, bedrock has a higher acoustical impedance, and the bedrock-sediment interface is horizontal.

Field Acquisition

HVSR data were acquired in the Oxford quadrangle with MoHo Tromino® 3G Digital Tomographs. Acquisition sites were selected in order to provide cross-valley transects of the Four-Mile Creek valley and an evaluation of upland versus filled-valley locations. Each record was collected by following the field procedures of Blake and Nash (2018). Examples of the HVSR-frequency plots for acquisition sites are shown in Figure 3.

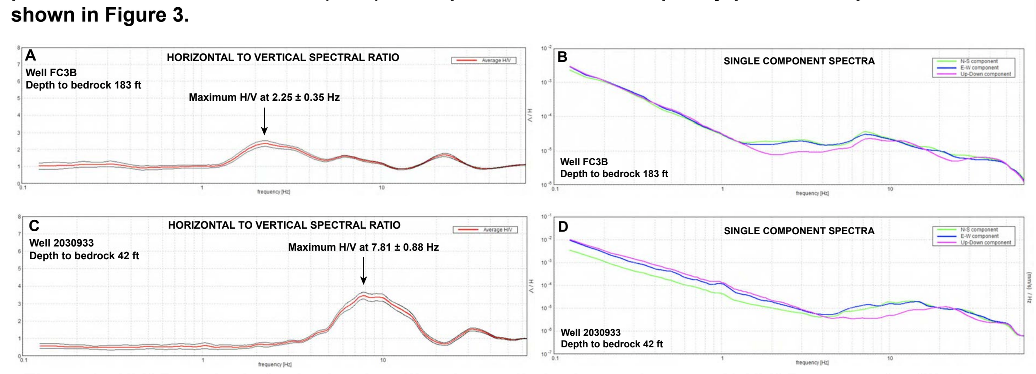


Figure 3. HVSR analysis for bedrock calibration wells in the study area. A) HVSR spectra for filled-valley station recorded near Oxford Water Authority test well FC3B. B) Individual component spectra for FC3B station (note the "fish-eye" feature corresponding to the HVSR peak). A) HVSR spectra for upland/valley-margin station recorded near private water well 20309933. D). Individual component spectra for 20309933 station. See Figure 6 for locations.

Interpretation

Data interpretation methods to determine depth to bedrock were derived from Chandler and Lively (2014). Because of compaction, shear wave velocities increase non-linearly with depth. Ibs-Von Seht and Wohlenberg (1999) demonstrated that a power-law relationship exists between peak HVSR frequency and depth using the equation $y = a(x)^b$ (Equation 1), where y = thickness of the sediment layer, and x = HVSR peak frequency of the likely bedrock-Quaternary contact. The parameters a and b are determined empirically by collecting data at control points of known depth.

Calibration Curve

Because of limited shear-wave velocity data for Quaternary deposits in the study area, a localized calibration curve was created to estimate bedrock depth. A total of 11 water wells were selected in the Oxford quadrangle for analysis. The depth-to-bedrock in these well ranged from 12 to 198 ft. HVSR measurements taken in close proximity to the wells (Figure 4) were used to generate a local calibration curve for the study area. The curve shows peak frequency plotted against the bedrock depth using Equation 1, above.

Initial results were analyzed to establish an estimated error relationship between the best-fitting power-law equation and actual well depth. Only one relatively shallow well had a calculate depth error of >±50%. Omitting this well from the calibrated dataset returned best-fit power law curve with the equation $y = 382.2\ (x)^{-1.076}$ ($R^2 = 0.9571$; Figure 4).Calculated depths for the 10 wells used in the final calibration fell within ±25% of actual well depth, with 70% within ±15% of actual depth (Figure 5).

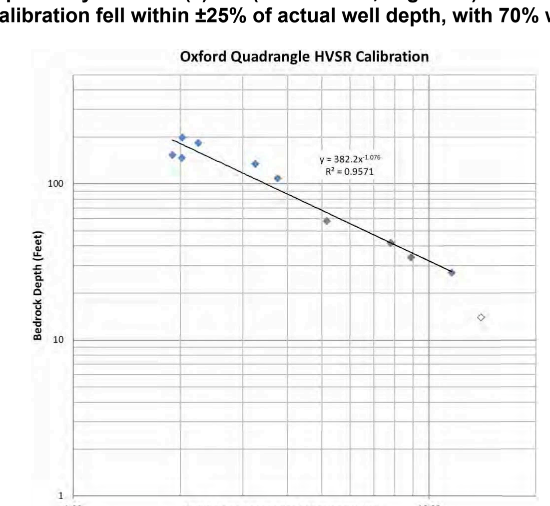


Figure 4. Local calibration curve for wells in the Oxford quadrangle. The curve was created using the HVSR data in a power regression function ($y = ax^b$) . The a value = 382.2, b = –1.076, and the R^2 = 0.9571. Open symbol denotes well excluded from final calibration.

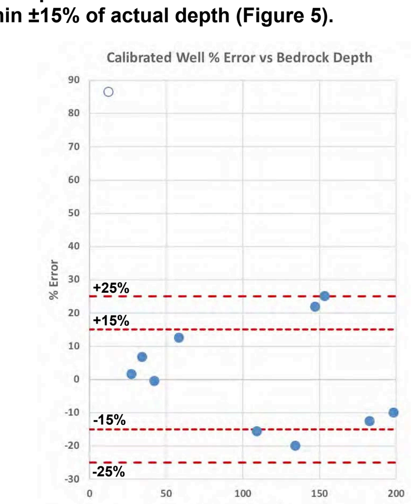


Figure 5. Percent-error plot of power-curve calibrated wells. Open symbol denotes well excluded from final calibration. Open symbol denotes well excluded from final calibration.

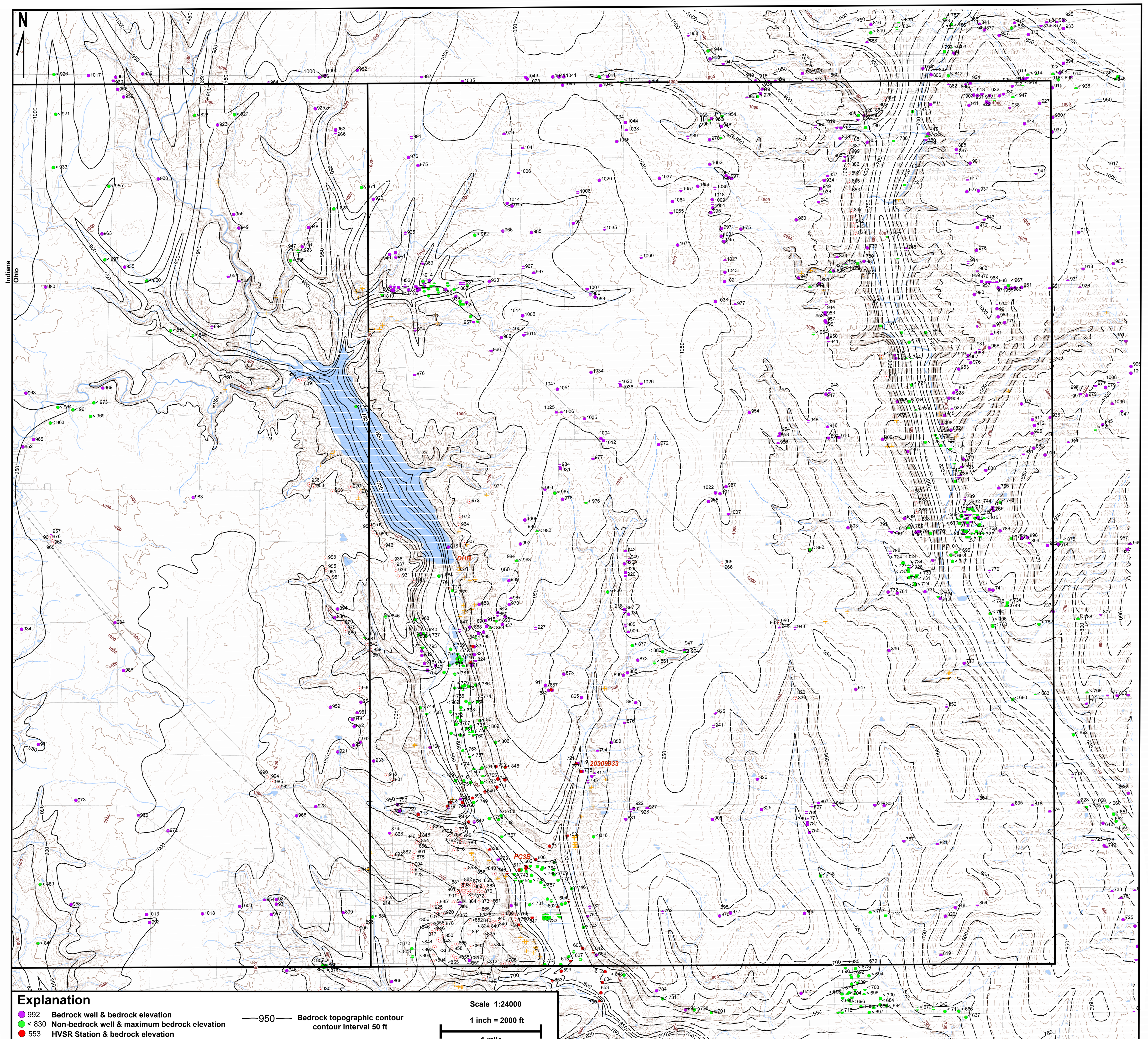


Figure 6. Revised bedrock topographic map of the Oxford and College Corner quadrangles.

Results

The final calibration equation was used to determine the estimated bedrock depth for 27 station locations in the study area. Calculated depths for HVSR peak frequencies of 1.88 to 13.59 Hz ranged from 194 to 34 ft, respectively. Depth to bedrock along and within the Four-Mile Creek drainage are consistent with interpreted geomorphic setting (filled valley/tributary vs. glaciated upland setting), and both down- and cross-valley gradients determined by outcrop, well and borehole data (Figure 6).

Study results generated over 950 individual elevation points of the Quaternary-Paleozoic contact, more than 3x the number used in earlier mapping efforts. Contouring of all bedrock elevation data resulted in a bedrock topographic map with higher resolution compared to previous maps (Figure 7). The greatest difference between the original and revised maps is the ~25-50 ft deepening of the filled valleys in both the Four-Mile and Seven Mile Creek Drainages and observed steepening of valley margins (Figure 7; Figure 8). Additionally, mapping revealed an increased down-valley slope in the upper reaches of the Four-Mile Creek buried valley.

Conclusions

The resulting higher resolution contour map of the bedrock topography indicates valley-fill deposits in some parts of the study area are narrower and deeper than previously mapped, and contain steeper cross and down-valley contacts with underlying Paleozoic rocks. As valley-fill deposits serve as on the primary municipal aquifers in the study area, these findings may have important implications for the future development and utilization of local groundwater resources.

Acknowledgements

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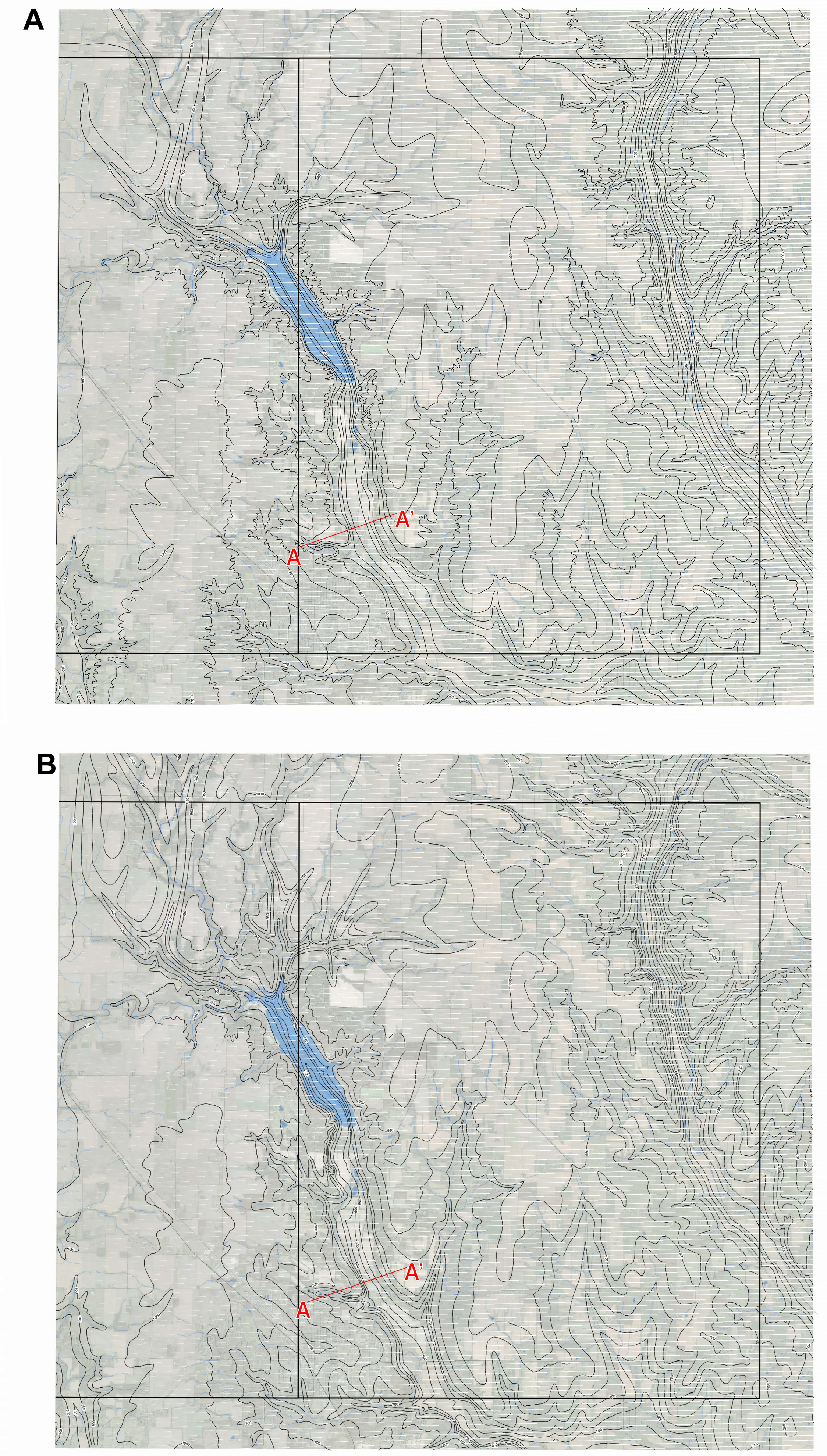

Figure 7. Comparison of the previous (A) and revised (B) bedrock topographic maps of the Oxford and College Corner quadrangles. Comparative cross section A–A´ is shown in Figure 8. Previous bedrock topographic map from Schumacher and Leow (1997, 1999)

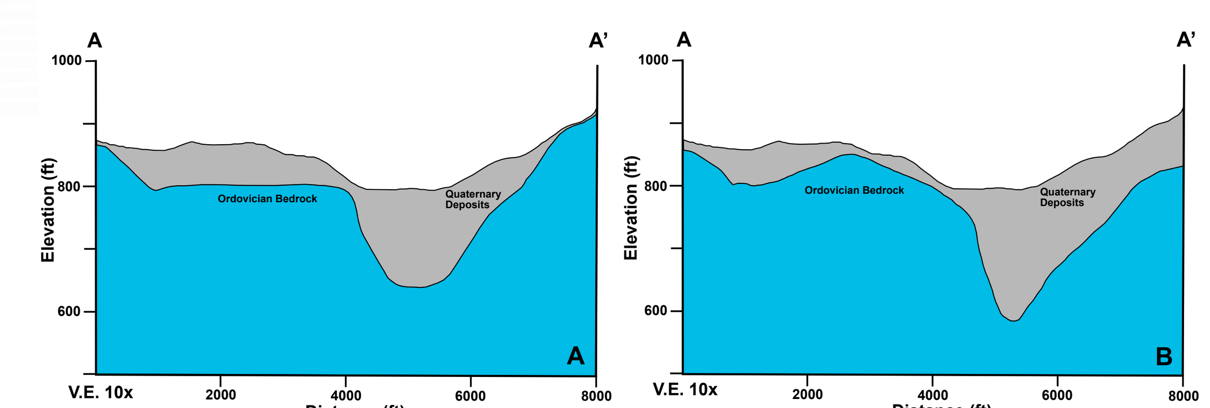

Figure 8. Cross sections of the Four-Mile Creek Valley north of Oxford, Ohio comparing the existing (A) and revised (B) bedrock-topographic surface. Location of cross section A-A" shown in Figure 7.

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