Cave-Hosted Glaciolacustrine Facies as Indicators of the Footprint of Glacial Lake Schoharie, Helderberg Plateau, Central New York

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Introduction

As glaciers advanced and retreated across northeastern USA during the Late Pleistocene, sediment and exposed bedrock was stripped from the cave-rich Helderberg Plateau in central New York State (Fig. 1), and then subsequently covered by allochthonous glacial sediment. The sediment was deposited in two places: a) on the surface of the plateau and, b) in caves within the plateau. The glacial sediment deposited within the caves has been sheltered from surficial elements, (i.e. weathering and erosion), perhaps allowing for a more accurate record of information to be preserved. Specific horizons of sediment found within the caves in the area are thought to be associated with the existence of a glacial event (Mylroie, 1984; Palmer et al., 1991; Palmer et al., 2003). The work presented here re-interprets those earlier studies, and classifies the unique cave sediments as being the result of a glacial lake in position above the caves. This lake, referred to as Glacial Lake Schoharie, is believed to have existed during the Late Wisconsinan glacial period approximately 23 - 12 kya in the current day Schoharie Valley in central New York (e.g. Dineen, 1986).

In order to determine the nature of the surficial environment in the Schoharie Valley during the Late Wisconsinan glacial period, multiple research trips were taken to select caves located in the Helderberg Plateau. From west to east the caves in this study include: Barrack Zourie Cave, McFail's Cave, Howe Caverns, the Secret-Benson Cave system, Gage Caverns, Westfall Spring Cave, Schoharie Caverns, Caboose Cave, and Knox Cave (Figs. 1 and 2). As documented by Lauritzen and Mylroie (2000), age determinations by U/Th dating of stalagmites demonstrate the caves of the Schoharie Valley exceed the onset of the most recent glaciation, and in some cases, several glaciations reaching back 350 kya.

The purpose of this study was to reconstruct the paleo-environment of a proglacial lake, Glacial Lake Schoharie, located primarily within Schoharie County, New York State. The glacial lake is thought to have endured at least four readvances of the Mohawk and Hudson glacial lobes during the Woodfordian Substage of the Late Wisconsinan glaciation (see Dineen (1986) for more detail on the nature of the readvances). The multiple readvances caused the shoreline of the lake, and hence its footprint, to be modified multiple times throughout its existence. The caves selected for investigation were chosen because of the known or suspected existence of what had been presumed to be glacially deposited clastics, (i.e. a characteristic white or tan clay, which in some instances displayed varved sequencing) (e.g. Mylroie, 1984; Dumont, 1995) (Figs. 3 and 4). It was also the purpose of this study to determine the composition of the 'white' clay horizon as well as the composition of other associated sediment stratigraphic horizons (Fig 4).

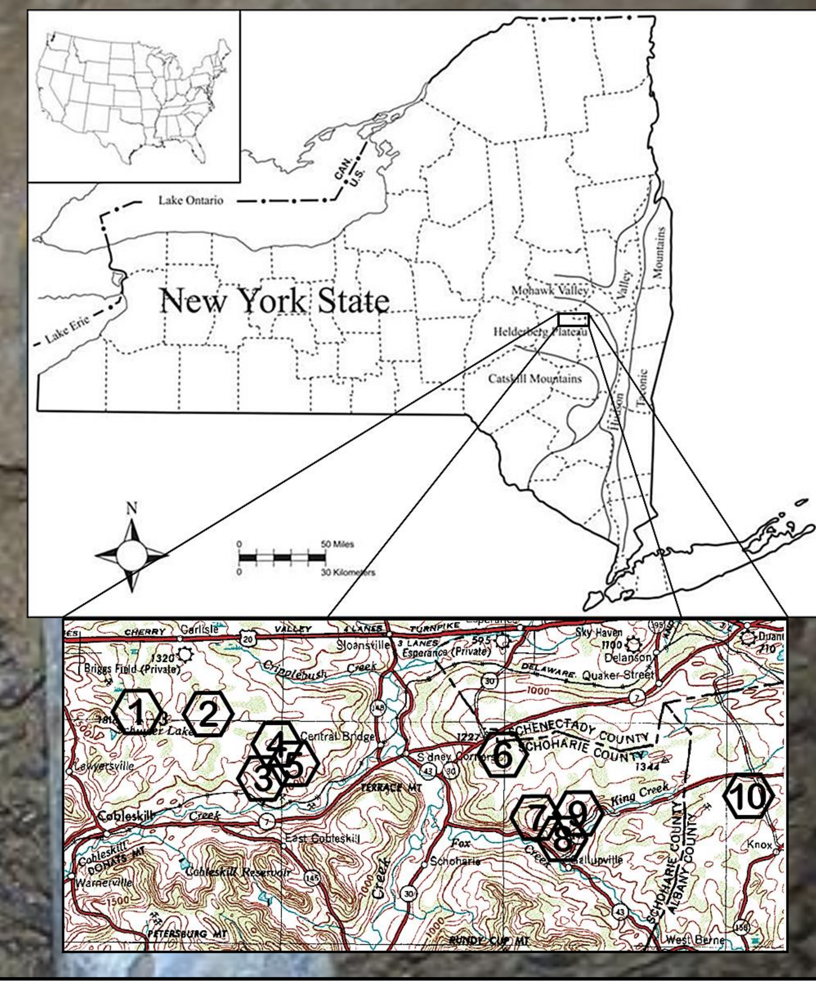

Figure 1: Map showing the general location of the Helderberg Plateau in east-central New York State as well as the locations of the caves included in this study. 1 =Barrack Zourie Cave, 2 = McFail's Cave, 3 = Howe Caverns, 4 = Secret Caverns, 5 = Benson's Cave, 6 = Gage Caverns, 7 = Westfall Spring Cave, 8 = Schoharie Caverns, 9 = Caboose Cave, 10 = Knox Cave. Re-drawn and modified from Dineen (1986). The topographic map is a USGS Digital Raster Graphic of the Binghamton Quadrangle (1:250,000 scale).

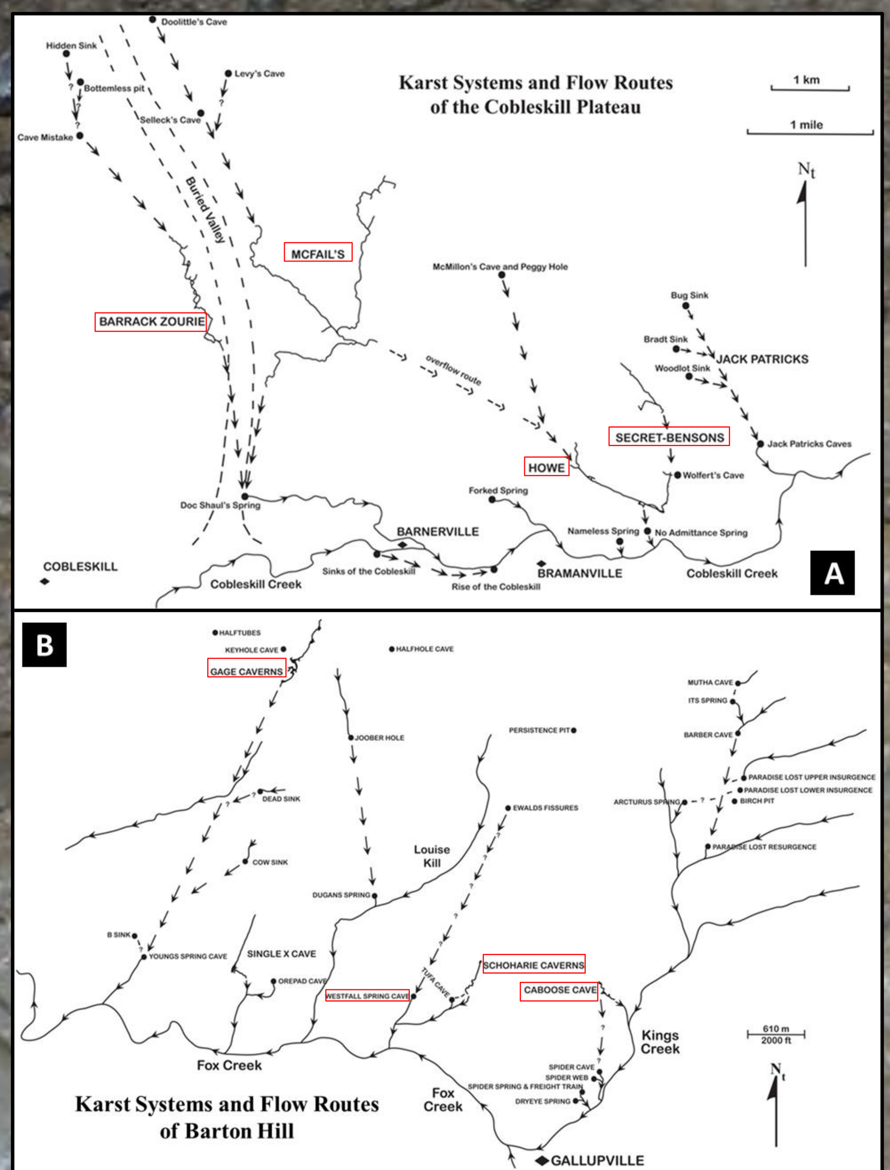

Figure 2: A: Map of the karst systems and flow routes of the Cobleskill Plateau. The buried valley is located between Barrack Zourie Cave and McFail's Cave (re-drawn from Dumont, 1995). **B:** Map of the karst systems and flow routes of Barton Hill (re-drawn from Mylroie, 1977). Red boxes denote caves investigated by this study.

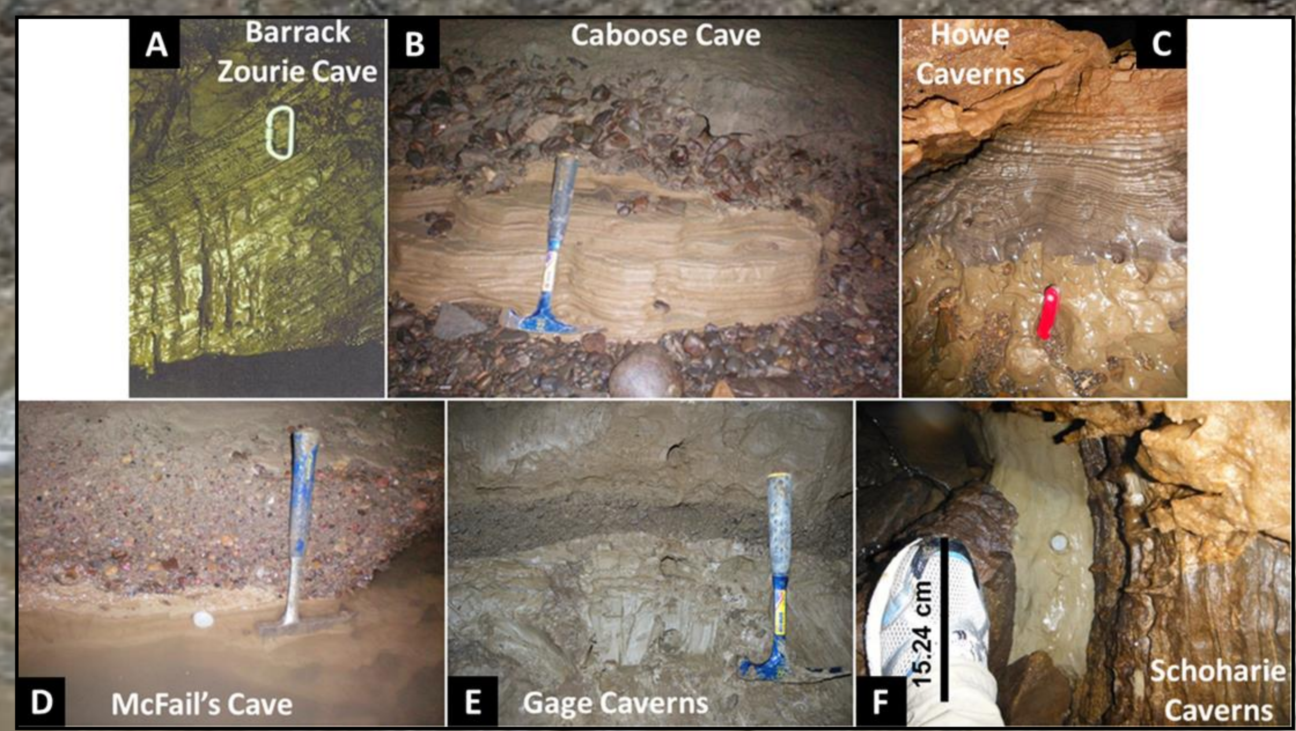

Figure 3: Distinct 'white' clay was found to exist in multiple caves selected for this study. Note in B, D and E the abrupt transition from the finally laminated light colored material at the bottom of the section to the very coarse gravelly layer above. Note the darker colored fine-grained deposit that commonly caps the sequence, best seen in B. Earlier studies found that the 'white' clay was rich in fine-grained $CaCO_3$.

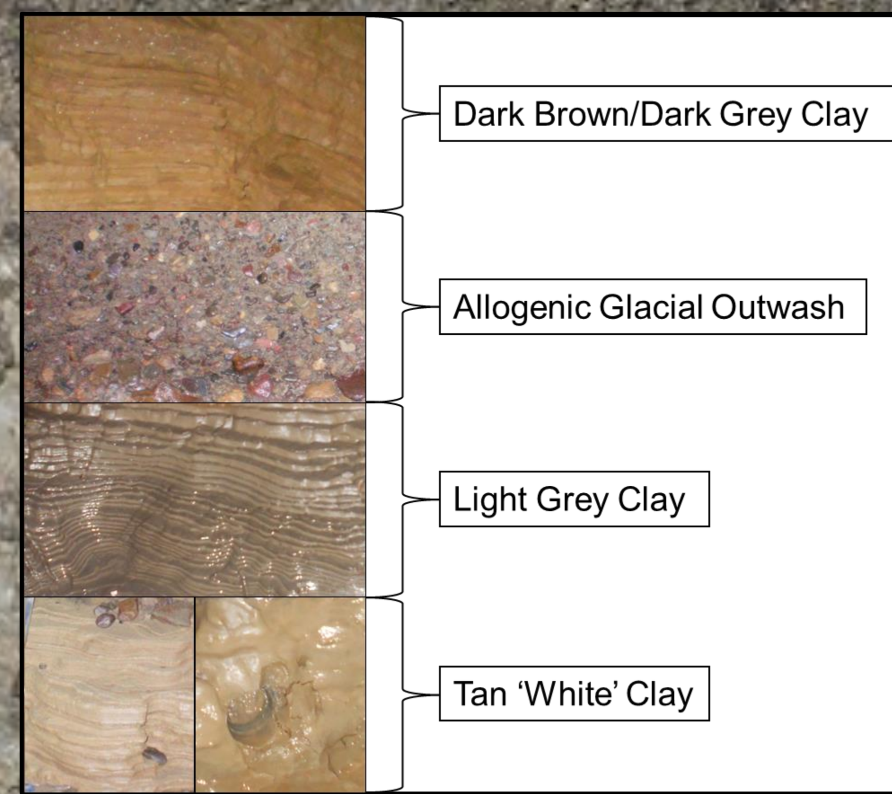

Figure 4: Sediment stratigraphic column depicting the different units encountered within the caves.

Previous Interpretations

The initial interpretation of Mylroie (1984), was that the sediments found in the caves were considered caused by stagnant sub-ice conditions during the last glacial maximum. Under these conditions, Mylroie (1984) thought that the stagnant water would soon saturate with $CaCO_3$, and any further fine-grained particulate $CaCO_3$ introduced to the caves would not dissolve, and could collect as a sediment deposit. There was no disagreement in the literature to this interpretation (e.g. Palmer et al. 2003), but it was recognized that caves in other areas of the state lacked these glacial sediments. The question became what was unique about the caves in the Schoharie Valley? The presence of a glacial lake could create the same stagnant water conditions in the underlying caves, as proposed by Mylroie (1984), but the lake's footprint would explain the unique cluster of caves containing the glacial sediment.

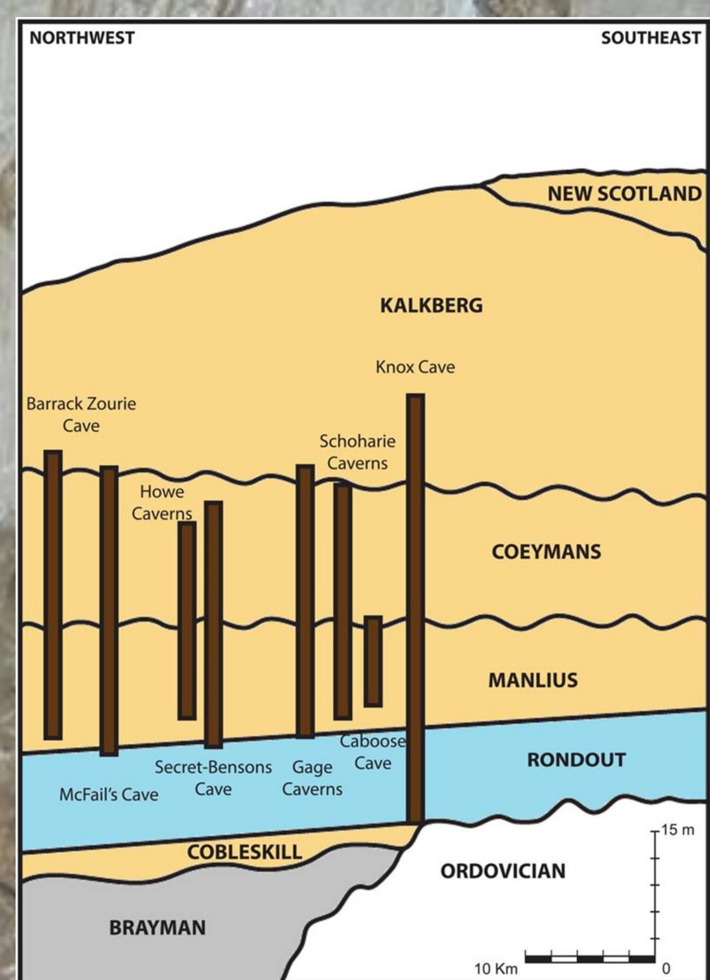

Figure 5: Generalized diagram depicting the units in which the caves of this study formed. The grey units represent shale, blue units represent dolomite, and the tan units represent limestone.

Caves of the Helderberg Plateau

The caves located in the Helderberg Plateau formed in the Upper Silurian and Lower Devonian limestones of the Helderberg Group. The major caves and cave systems within the plateau, including the caves mentioned in this study, primarily formed within the thick-bedded Coeymans Limestone and the thinly-bedded Manlius Limestone (Fig. 5). There has also been cavern development within the Rondout Dolomite (e.g. Knox Cave and Baryte's Cave (Mylroie, 1977; Palmer, 2009)); although cavern development within this particular unit is usually limited to conduits with small cross-sectional areas.

Westfall Spring Cave was included in the study as its geologic context suggested it was post-glacial in origin, and therefore should not have a glacial sediment signature. Knox Cave was included as it is outside the footprint of Glacial Lake Schoharie. These two caves acted as controls for the sediment study.

REFERENCES:

Dineen, R.J., 1986, Deglaciation of the Hudson Valley Between Hyde Park and Albany, New York, in D.H. Cadwell, ed., The Wisconsinan Stage of the First Geological District, Eastern New York p. 89-108.

Dineen, R.J., Hanson, E.L., 1985, Deglaciation of the Middle Mohawk and Sacandaga Valleys, or a tale of two tongues, in R.H. Lindemann, ed., Field Trip Guidebook of the New York State Geological Association 57th Annual Meeting, Saratoga Springs, New York, p. 250-256.

Dumont, K.A., 1995, Karst Hydrology and Geomorphology of the Barrack Zourie Cave System, Schoharie County, New York [M.S. thesis]: Mississippi State, M.S., Mississippi State University, reprinted as New York Cave Survey, Bulletin 5.

Lauritzen, S-E., Mylroie, J.E., 2000, Results of a Speleothem U/Th Dating Reconnaissance from the Helderberg Plateau, New York: Journal of Cave and Karst Studies, v. 62, p. 20-26.

LaFleur, R.G., 1969, Glacial Geology of the Schoharie Valley, in 61st Annual Meeting of the New England Intercollegiate Geological Conference Guidebook for Field Trips in New York, Massachusetts, and Vermont, p. (5-1)-(5-20).

LaFleur, R.G., 1976, Glacial Lake Albany, in Rittner, Donald ed., The Pine Bush Albany's Last Frontier: Albany, N.Y., Pine Bush Historic Preservation Project, p. 1-10.

Mylroie, J.E., 1977, Speleogenesis and Karst Geomorphology of the Helderberg Plateau, Schoharie County, New York [Ph.D. dissertation]: Troy, N.Y., Rensselaer Polytechnic Institute, reprinted as New York Cave Survey, Bulletin 2.

Mylroie, J.E., 1984, Pleistocene Climatic Variation and Cave Development: Norsk Geogr. Tidsskr, v. 38, p. 151-156.

Palmer, A.N., 2009, Cave Exploration as a Guide to Geologic Research in the Appalachians: Journal of Cave and Karst Studies, v. 71, no. 3, p. 180-192.

Palmer, A.N., Rubin, P.A., Palmer, M.V., 1991, Interaction between karst and glaciation in the Helderberg Plateau, Schoharie and Albany Counties, New York, in New York State Geological Association Field Trip Guidebook 63rd Annual Meeting, p. 161-190.

Palmer, A.N., Rubin, P.A., Palmer, M.V., Engel, T.D., Morgan, B., 2003, Karst of the Schoharie Valley and land use analysis, Schoharie County, New York State, in New York State Geological Association Field Trip Guidebook 75th Annual Meeting, p. 141-165.

Ridge, J.C., 2004, The Quaternary glaciation of western New England with correlations to surrounding areas: Developments in Quaternary Sciences, v. 2, p. 169-199.

Weremeichik, J.M., 2013, Paleoenvironmental Reconstruction by Identification of Glacial Cave Deposits, Helderberg Plateau, Schoharie County, New York [M.S. thesis]: Mississippi State, M.S., Mississippi State University.

Glacial Lake Schoharie

The instability of glacial ice caused Glacial Lake Schoharie to have a number of shorelines at varying elevations throughout the Late Wisconsinan glaciation. The Woodstock ice margin was established by the halt of retreating stagnant ice (between 18.2-17.4 kya based on Ridge, 2004). Following the establishment of the ice margin, glacial meltwater began to flood the Schoharie Valley. As the stagnated glacial ice continued to melt and retreat toward the northeast, water levels continued to rise until a glacial lake was established with a shoreline at an elevation of 213 m (700 feet) above sea level (Dineen, 1986) (Fig. 6). The establishment of Glacial Lake Schoharie shall be regarded as stage one of three known stages of the glacial lake's development.

With the onset of the Middleburg readvancement (~17.4 kya, based on Ridge, 2004) active glacial ice re-entered the Schoharie Valley and the greater Helderberg area until the ice reached the Catskill Front (Catskill Mountains). Upon reaching the Catskill Front the glacier stagnated and once again began to retreat northward. While retreating, the glacier produced a vast amount of meltwater resulting in the enlargement of several proglacial lakes (Dineen, 1986). In Glacial Lake Schoharie's case the lake enlarged considerably and established a shoreline between 354-366 m (1,160-1,200 feet) above sea level (Fig. 7), reaching stage two.

With the establishment of the Delmar ice margin (~16.2 kya, based on Ridge, 2004), water from Glacial Lake Schoharie drained to the northeast, through what is known as the Delanson spillway (LaFleur, 1969). The spillway fed the Delanson River which eventually emptied into Glacial Lake Albany (LaFleur, 1976). The stage three shoreline of Glacial Lake Schoharie was established at 256-213 m (840-700 feet) above sea level (LaFleur, 1969; Dineen and Hanson, 1985) (Fig. 8).

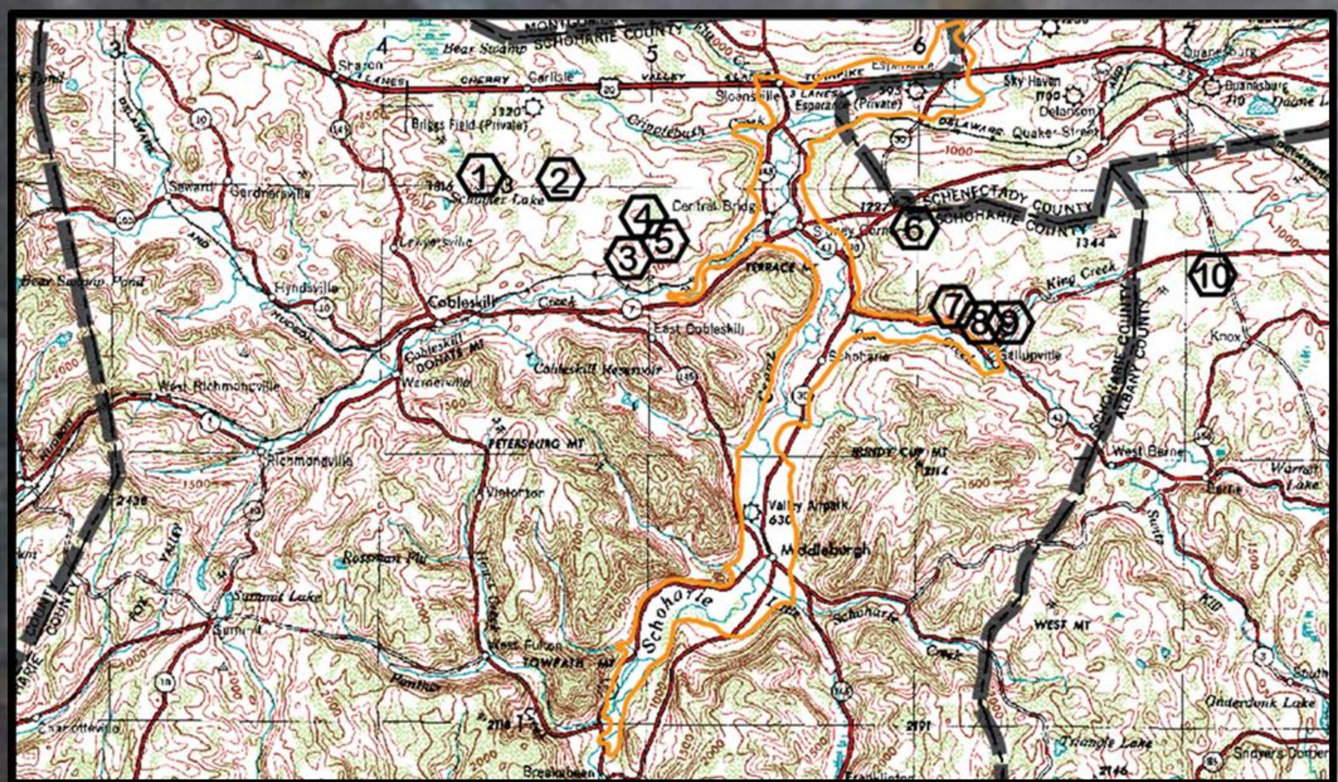

Figure 6: Topographic map showing the location of the caves in relation to the 213 m (700 foot or stage one) shoreline of Glacial Lake Schoharie outlined in orange (created using information provided by Dineen, 1986). Refer to Figure 1 for identification of caves.

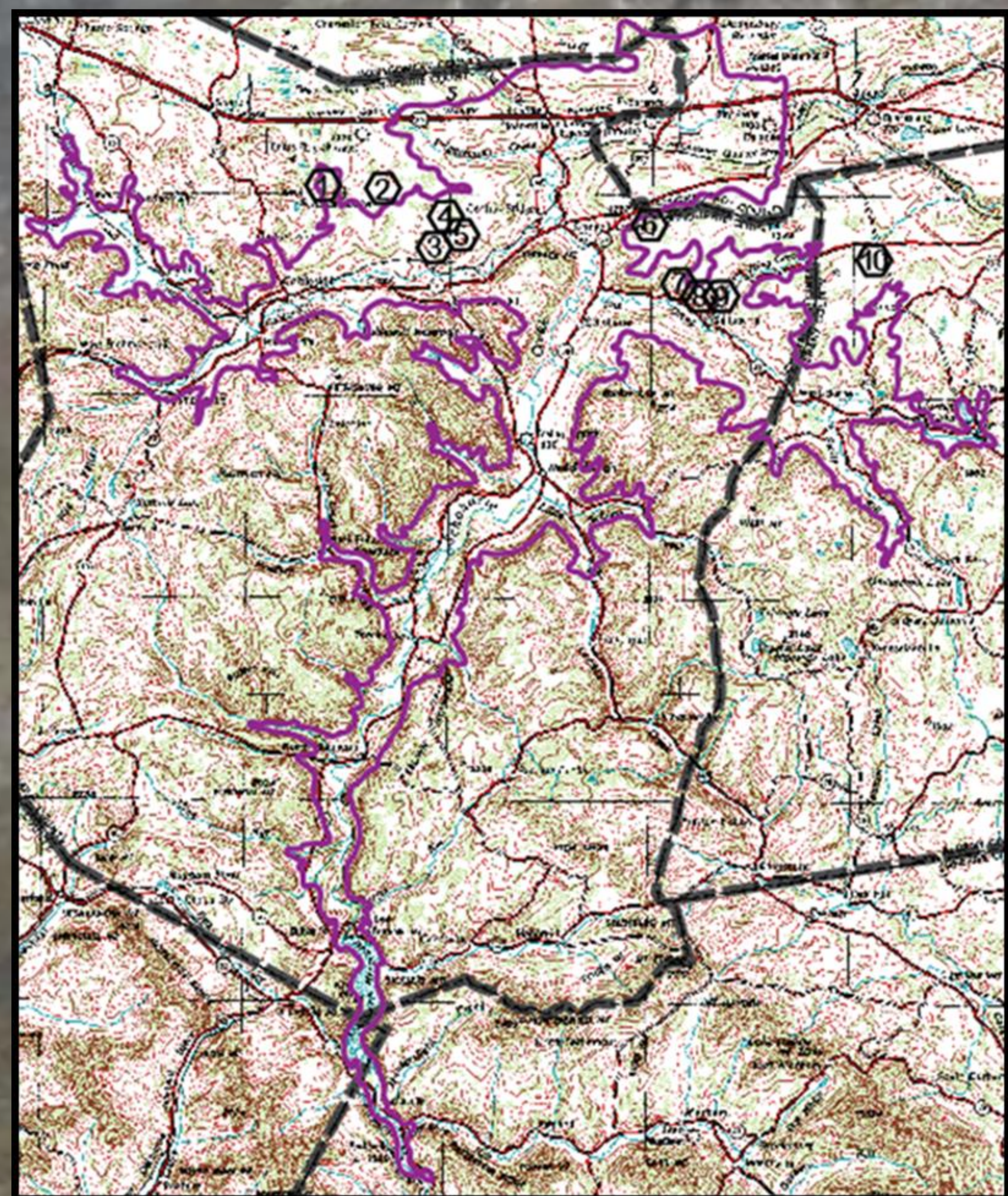

Figure 7: Glacial Lake Schoharie with an established shoreline at 354-366 m (1,160-1,200 feet or stage two) above sea level. The area inside the purple line indicates the size and location of the glacial lake. Note the expansion of scale to portray a much larger lake, and the lake's extension eastward into Schenectady and Albany Counties. Refer to Figure 1 for identification of caves.

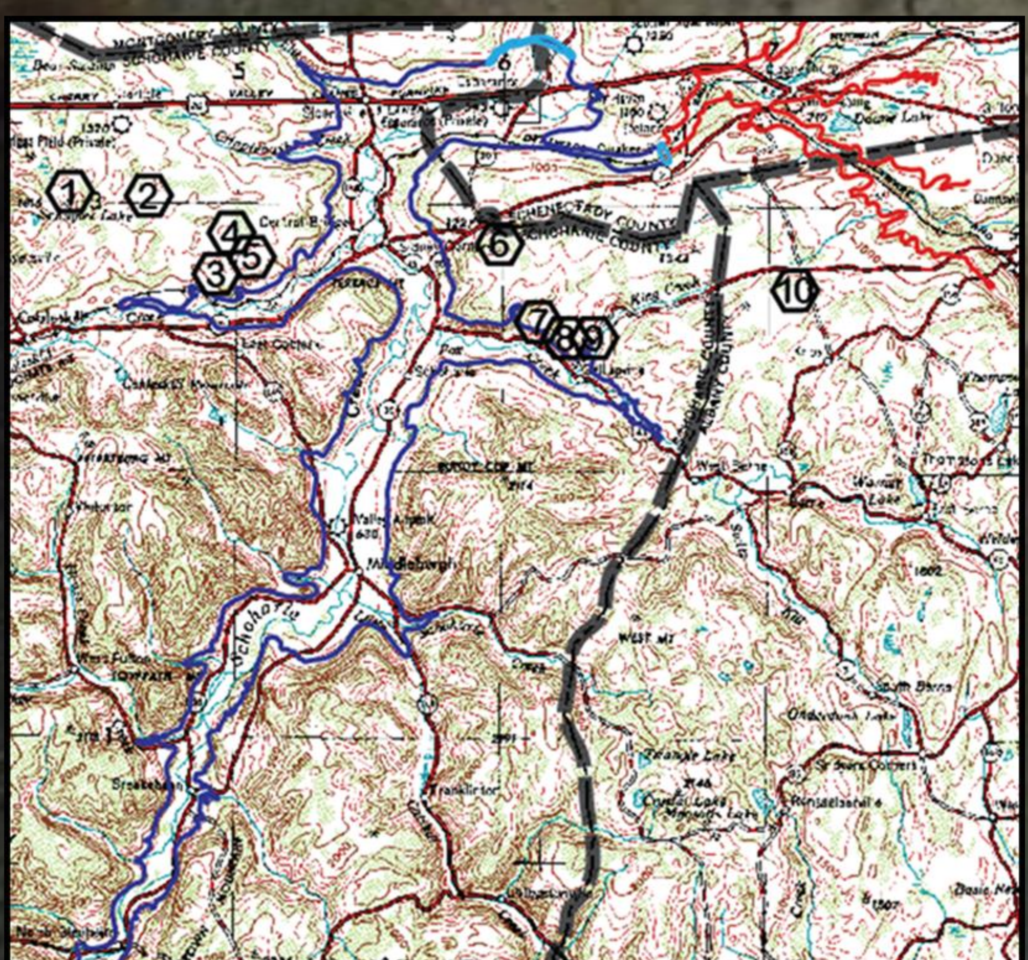

Figure 8: Glacial Lake Schoharie (outlined blue) with a shore line at 256 m (840 feet or stage three) above sea level (created using information provided by LaFleur, 1969 and Dineen and Hanson, 1985). Area between red lines indicate a spillway and light blue lines indicate boundary between glacial lake water and active glacial ice. Refer to Figure 1 for identification of caves.

Results

Laboratory analysis of samples to determine the mass of water in each sample, the mass of carbonates, and the mass of organics with the purpose of discerning a pattern amongst individual clastic units recovered from the ten caves in this study was conducted; but was inconclusive in terms of a recognizable pattern. The methods and resulting analyses can be seen in Weremeichik (2013).

Although the laboratory results were inconclusive, X-ray diffraction yielded more conclusive information. Table 1 shows the mineralogical content found to exist in each sample, Figure 4 provides the vertical sequence of the sediment units as found in the caves and presented in Table 1. The XRD data were not used to determine actual amounts of materials in a given sample; it was an assay of presence or absence. For example, the dark grey/dark brown clay unit had calcite in 62% of the samples, and the allogenic outwash unit had calcite in 40% of the samples. Together, these post-glacial lake sediments had 56% calcite occurrence. The light grey clay unit had calcite in 100% of the samples, and the tan "white" clay unit had calcite in 75% of the samples. Together, the supposed glacial lake sediments had calcite in 81% of the samples. The Knox Cave and Westfall Cave sediments, as controls, had calcite in only 32% of the samples. Brushite shows a different trend, being more common in the post-glacial sediments.

Mineral	Post Glacial Sediment			Glacial Lake Sediment			
	Dark Brown Clay	Allogenic Glacial Outwash	Total	Light Grey Clay	Tan 'White' Clay	Total	Control Samples
Calcite	62%	40%	56%	100%	75%	81%	33%
Dolomite ?	4%	0%	3%	0%	0%	0%	0%
Quartz	100%	100%	100%	100%	100%	100%	100%
Muscovite	73%	80%	75%	60%	69%	67%	83%
Phlogopite	31%	40%	33%	40%	19%	24%	67%
Chlorite	0%	0%	0%	0%	0%	0%	0%
Montmorillonite	0%	0%	0%	0%	0%	0%	0%
Albite (low temp)	58%	50%	56%	20%	44%	38%	67%
Enstatite ?	0%	0%	0%	0%	6%	5%	0%
Brushite	65%	40%	58%	40%	31%	33%	83%
Nacrite	15%	0%	11%	20%	0%	5%	17%
Carbon	8%	30%	14%	0%	25%	19%	67%

Table 1: X-ray diffraction results.

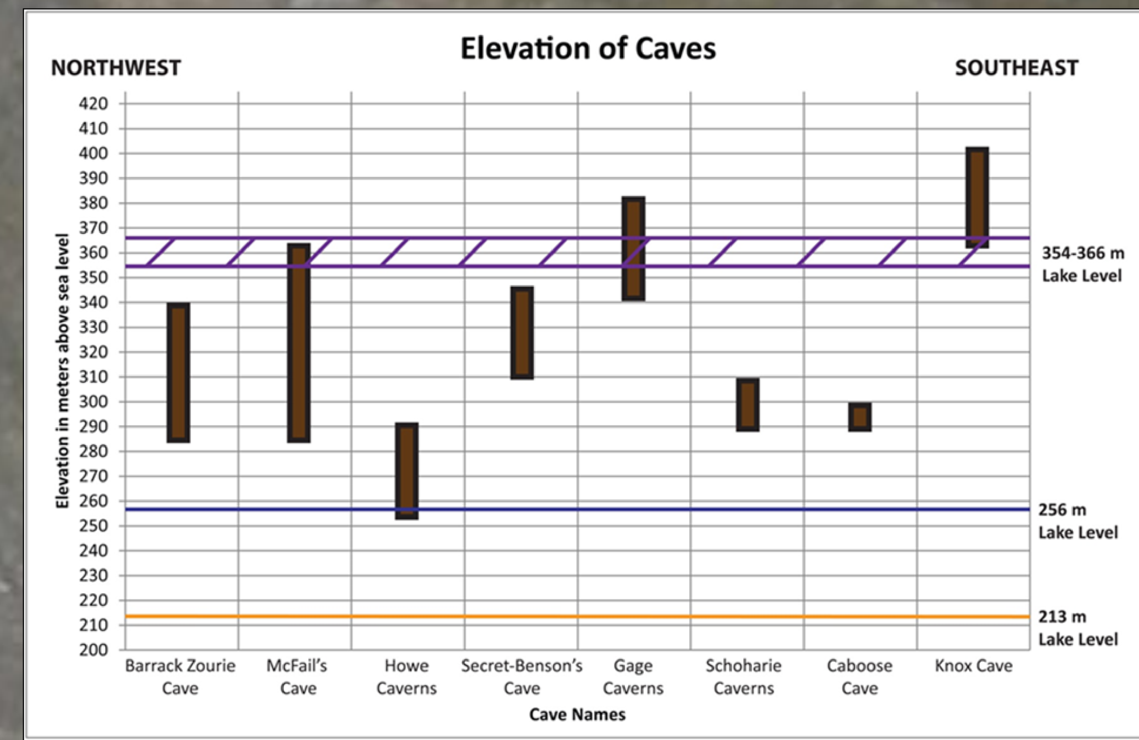

Figure 9: The elevations occupied by each cave in the order by which they are encountered from Northwest to Southeast is shown above as well as the proposed shore line elevations of Glacial Lake Schoharie.

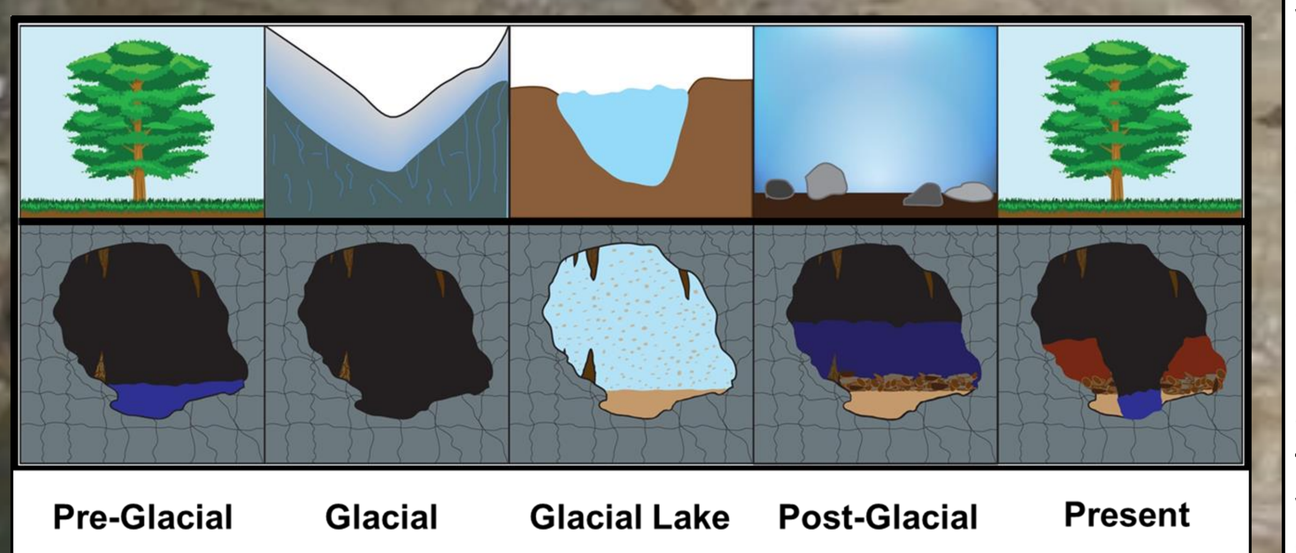

Figure 10: Model depicting the caves' history during a glacial cycle showing the progression of time from left to right.

Discussion

During stage one of Glacial Lake Schoharie's development, there would not have been any outlet for the water to escape from the Schoharie Valley. However, it would have been possible for the water in Glacial Lake Schoharie to drain north towards what would be known today as the Mohawk Valley. Though there is a problem with this idea, as during the Late Wisconsinan the Mohawk Valley was occupied by the active Mohawk glacial lobe. The Mohawk glacial lobe, also referred to locally as the Mohawk Ice Block, filled the area between neighboring Cobleskill and Barton Hill plateaus and acted as a plug trapping glacial meltwater in the Schoharie Valley (LaFleur, 1969). Nearing the close of the Wisconsinan glaciation, greater than or equal to 50% of Glacial Lake Schoharie would have been covered by active glacial ice belonging to the Schoharie glacial sub-lobe (Dineen, 1986). By observing Figure 6 and 9 one could see that there would have been an insufficient amount of water in Glacial Lake Schoharie to even partially inundate the caves of the Cobleskill Plateau and Barton Hill included in this study.

Through the observation of Figures 7 and 9 it can be seen that nearly all of the caves in the Cobleskill Plateau and Barton Hill are completely inundated by water from Glacial lake Schoharie. Note that although the entrances to both McFail's Cave and Gage Caverns are not inundated, the majority of the master cave passages are over 30 m below the surface and would have been inundated based on their elevation relative to sea level. This would include inundation of locations within the caves where samples were collected for the study. It is also important to note that the upper passages where samples were collected in Knox Cave would not have been inundated by glacial lake water due to their elevation above sea level (Fig. 9), even had the lake extended that far east, and so these samples acted as a control. Westfall Spring Cave, being post-glacial in origin, is not shown relative to Glacial Lake Schoharie positions in Fig 9.

The Howe Caverns sediment section is especially instructive. It is the thickest of all such sequences. While most caves have less than or equal to 1 m of the light grey and tan 'white' clay, Howe Caverns has over 2 m of section. This greater thickness is the result of Howe Caverns' main stream passage being the lowest in elevation of all the cave passages studied, by a significant amount (approximately 30 meters, Fig. 9). Therefore, while lake surface elevations shifted vertically, Howe Caverns spent more time under Glacial Lake Schoharie than any other cave in the study. In addition, Figure 3 shows an interesting transition from a very amorphous white clay deposit at the base (next to the knife), to a progressively better layered light grey clay in which the individual layers get thicker upwards to the contact with more traditional cave sediments. This transition can be interpreted to indicate initial clay deposition under the 354-366 m lake elevation stage, when the Howe Caverns stream passage would have been ~100 m below the lake surface. Sediment transport by laminar flow into the cave would have been slow, and quite isolated from seasonal changes, indicated by the lack of rhythmical layering in the 'white' clay deposit. As lake level lowered to the 256 m level, the Howe Caverns main stream passage would have been merely meters below the lake surface, and more likely to record the seasonal changes in water and sediment addition to the lake, as demonstrated by the light grey clay. The upward thickening may record the final transition of Howe Caverns out of the lake footprint as the lake drained away. The sequence of events that produced the sediment column of Fig 4 is presented in Fig 10.

Conclusions

The caves suspected to have been inundated by glacial lake water and to have thereby collected fine-grained lake sediment do not show any statistical correlation between samples collected (see Weremeichik, 2013), but as seen in Figure 3, it is apparent that physical similarities between the samples collected exist. These physical similarities can be identified in the mineral color, and grain size. It was originally hypothesized in the infancy of the study that the sediment in the caves may have been deposited during a retreat phase of glaciation resulting from stagnant lake ice cover conditions (e.g. Mylroie, 1984). This hypothesis was thought to be true because it explained how the fine-grained sediment was deposited in the caves. This could not be accomplished if there was turbid or even transitional laminar flow through the caves. Ice cover was thought to have created the necessary stagnant conditions. The glacial lake hypothesis presented here also would create stagnant conditions, but in an environment where the associated fine-grained sediment could more easily enter the cave. Glacial Lake Schoharie endured multiple retreats and readvances of glacial ice in part by being insulated and protected by a layer of stagnated glacial ice. During retreat phases of glacial activity new glacial meltwater carrying glacial-derived sediment must have been delivered to the lake, which subsequently filtered into the caves below.

The analyses of the sediments themselves are consistent with the glacial lake hypothesis. They are extremely fine-grained, very low in organics, and with a measurable soluble content of $CaCO_3$. They are visually striking when observed in the field, and are easily recognized. They are, to date, known only from the footprint of Glacial Lake Schoharie. This final aspect is important, as the deposits were originally considered by other earlier workers (e.g. Mylroie, 1984) to be sub-ice deposits. The failure to find such deposits elsewhere in the Helderberg Plateau, or in other glaciated karst regions, was very problematic. Everyone who saw the deposits *in situ* agreed with the glacial rock flour hypothesis (e.g. Palmer et al., 2003). The use of the Glacial Lake Schoharie footprint to explain these deposits as not sub-ice, but sub-glacial lake deposits, answers the final question about the failure to find such deposits in other glaciated karst locales in the region.

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