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RESULTS OF A SPELEOTHEM U/TH DATING RECONNAISSANCE FROM THE HELDERBERG PLATEAU, NEW YORK

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The Helderberg Plateau consists of Silurian-Devonian carbonates that crop out across central New York State, supporting a well-developed, multiply glaciated karst. Stalagmites and flowstone were collected from five caves spread across a 60 km long traverse of the Plateau from Albany west-northwest to Schoharie County. Subsamples from these spleothems yielded 36 U/Th alpha count dates ranging from 3 ka to >350 ka. While the data reported here are only a reconnaissance study, they represent the most comprehensive geochronologic data base for any karst area in the northeastern United States.

Hollyhock Hollow, southern Albany County: two cave-fill samples yielded three dates of 70-56 ka and four dates of 41-35 ka; the mid-Wisconsin dates may reflect the cave's southerly position. Onesquethaw Cave, central Albany County: two stalagmites yielded 5 dates, all Holocene (<9 ka); the dates suggest that Onesquethaw Cave may be post-glacial in origin. Caboose Cave, eastern Schoharie County: five stalagmite and flowstone samples provided 13 dates, ranging from 207-56 ka, with distinct clusters at 100-56 ka and 207-172 ka; the dates support the cave being older than the last glaciation. Schoharie Caverns, 2 km west of Caboose Cave: six samples from one flowstone all dated to >350 ka; the dates indicate that the cave has survived more than one glaciation. Barrack Zourie Cave, western Schoharie County: two stalagmites yielded four dates, which cluster at 161-158 ka, with a younger overgrowth at 61 ka (two previously reported dates were 165 ka and 277 ka); the dates support the cave being older than the last glaciation.

The U/Th dates indicate that both pre- and post-glacial caves exist in New York. The dates cluster in the 100-56 ka and 207-158 ka range, and there are a surprising lack of dates from the last interglacial (130-120 ka), possibly an artifact of the sampling regime.

The Helderberg Plateau contains a sequence of Upper Silurian to Middle Devonian carbonates that crop out across central New York State (Fig. 1). The Plateau supports a well-developed karst and has undergone multiple glaciations during the Pleistocene. The Helderberg Plateau contains the longest caves in the northeastern United States (Palmer *et al.* 1991) and, as a result of being located near the New York City population center, the caves receive a significant amount of recreational visitation. The caves also form part of the regional hydrologic system, with implications for land use and water quality.

The geologic and karst setting of this region has been studied by Egemeier (1969), A. Palmer (1972), Kastning (1975), Baker (1976), M. Palmer (1976), Mylroie (1977), Palmer *et al*. (1991), and Dumont (1995), and references therein, but little geochronologic work has been done on the caves located there (Lauritzen & Mylroie 1996). The purpose of this study was to collect speleothem samples from cave locations across the Helderberg Plateau in Albany and Schoharie Counties, in order to make a reconnaissance evaluation using U/Th analyses to determine the age of the speleothems. Such a reconnaissance would provide guidance to a more in-depth geochronologic study in the future. For example, if all the speleothems turned out to be Holocene, then the likelihood of the caves carrying useful paleoclimatic information about the Pleistocene would be small, and further work would not be warranted. The reconnaissance work reported here, therefore, provides a pathway for future experimental design to determine the geochronology of karst processes in this region, and the paleoclimatology that helped drive cave genesis and development.

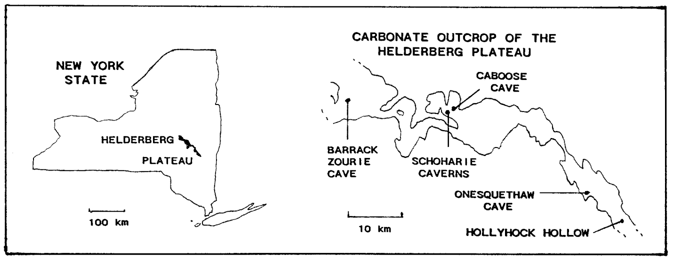

Figure 1: Location of the carbonate outcrop of the Helderberg Plateau, New York. Sampled caves locations shown. Albany County is right (east) half of the displayed outcrop, Schoharie County is left (west) half.

The Helderberg Plateau region offers useful potential information regarding the nature of ice cover during the late Pleistocene in this region of the United States. The karst area is located within a few hundred kilometers of the southern margin of the maximum ice sheet extent during the Pleistocene. Such a location is more sensitive to subtle variations in ice margin location than would be karst areas farther to the north and, therefore, farther from the ultimate ice margin, such as those in Canada (Ford 1977). The relatively low elevation of the Plateau (<500 m) removes alpine effects from consideration. Many studies of glaciation and karst (e.g. Ford 1977) in North America have focussed on alpine examples, where tectonism, high hydraulic gradients, and small glacier size create conditions unlike those found in lowland continental glaciation situations. Geochronological analyses have been done in glaciated midwestern caves in the United States (e.g. Milske *et al.* 1983), but not in the northeast.

The first approximation of continental ice-cover effects on speleothem deposition is that speleothem growth terminates when ice advances over a cave and vadose groundwater flow commonly stops. This cessation of vadose flow can be the result of permafrost development (White 1988 and references therein), or as a result of entombment of the regional hydrology creating stagnant phreatic conditions in the caves (Ford & Williams 1989, and references therein). A hiatus in speleothem growth is assumed to represent ice cover conditions, and continuous growth is thought to represent the absence of ice and free circulation of vadose groundwater (Ford & Williams 1989, and references therein). However, a growth hiatus can represent other factors, such as change in vadose water input location, or other climatic effects, such as aridity.

The initial goal of a reconnaissance speleothem geochronological survey is to identify the episodes of growth and non-growth. With sufficient speleothem samples, patterns may develop that correlate with ice-cover and ice-free conditions. More detailed analyses of speleothem growth bands, carbon and oxygen isotopes, and intercalated sediments may lead to a more sophisticated interpretation of paleoclimatology of a given region (e.g. Lauritzen 1996). The study reported here lays the foundation for more detailed work.

GEOLOGIC SETTING

As noted earlier, the geologic and karst setting of this region has been studied by A. Palmer (1972), Kastning (1975), Baker (1976), M. Palmer (1976), Mylroie (1977), Palmer *et al.* 1991, and Dumont (1995), and references therein, and that body of description is condensed and presented here. The outcrop pattern of the Helderberg Plateau carbonates in central New York (Fig. 1) begins as a narrow band of folded rocks parallel to the Hudson River in southern Albany County. This outcrop swings west and broadens as it leaves Albany County and enters Schoharie County. The degree of deformation declines significantly, with major faults and folds absent in western Albany County and Schoharie County (Gregg 1974; Mylroie 1977). Cave development occurred in two major parts of the carbonate stratigraphy. The majority of cave development occurred in the Helderberg Group limestones and dolomites, which cross from late Silurian to early Devonian. A major clastic section, the Ulster Group, overlies the Helderberg Group carbonates, and in turn is overlain by the Onondaga Group limestones of Middle Devonian age. Cave development in the Onondaga Group is significant in central and eastern Albany County, but declines in importance westward into Schoharie County.

The glacial history of the area has been studied by LaFleuer (1969), Dineen and Hanson (1985) and Dineen (1987) and references therein. Ice advanced into the area from the north, but was diverted by the Helderberg Escarpment into a more westerly direction in Schoharie and western Albany Counties, and in a southerly direction in eastern Albany County. During the Wisconsin glaciation, Schoharie Creek was ponded by stagnant ice on a number of occasions, creating glacial lakes that extended from Schoharie County into western Albany County. Glaciolacustrine clays are found at a variety of elevations in this area. Analogues to these clays occur in many caves in the area (Mylroie 1977, 1984; Dumont 1995). The entire area contains abundant evidence of glaciation, including drumlins, polished rock surfaces, and till sequences of variable thickness. Cave systems commonly have small, active passages that are in concordance with the glacially-deranged landscape, while larger upper level passages are concordant with the original landscape as determined by gravity and seismic data (M. Palmer, 1976; Mylroie, 1977; Dumont, 1995; Milunich & Palmer, 1996). These latter passages are, therefore, interpreted to have existed at least prior to the last glaciation.

METHODOLOGY

SAMPLE COLLECTION

Stalagmites and flowstone were collected from five caves across a 60 km traverse, WNW to ESE, along the limestone outcrop of the Helderberg Plateau in Albany and Schoharie Counties (Fig. 1). Collection was done from both *in situ* deposits, and from loose clasts on the cave floor. The *in situ* samples were carefully collected from areas in the caves where sample removal would not detract from the esthetics of the cave. Loose samples were taken from stream deposits and cave floors to further avoid damage to the caves' natural beauty. Pristine samples were avoided, but a casual effort was made to collect speleothems that had an appearance of significant age. The samples were logged and transported to Norway for analyses. A total of 12 samples was collected over a time frame from 1982 to 1996. All but the Hollyhock Hollow samples were analyzed in 1995; those latter samples were analyzed in 1996.

URANIUM-SERIES DATING

Uranium-series disequilibrium dating can be performed on speleothems provided sufficient uranium is present (>0.02 ppm) and that the system was initially free from non-authigenic ^{230}Th, as monitored with the $^{230}Th/^{232}Th$ index (Latham & Schwarcz 1992). The 12 samples collected were then cut to produce 36 subsamples (10 - 15 mm thick, 10 - 60 g) at regular stratigraphic levels for U-series dating. All contained sufficient uranium for dating. Given that alpha counts were being performed, and that this was a reconnaissance study, smaller sample analyses, which would give greater resolution, were not performed.

The samples were digested in excess nitric acid, spiked ($^{228}Th/^{232}U$) and equilibrated by H_2O_2 oxidation and boiling for several hours. Uranium and thorium were pre-concentrated by scavenger precipitation on ferric hydroxide. Iron was then removed by ether extraction in 9M hydrochloric acid, and uranium and thorium separated by ion exchange chromatography on Dowex 1 resin. The purified, carrier-free fractions of uranium and thorium were then electroplated onto stainless steel disks and counted for alpha particle activity in vacuo on an Ortec Octéte unit with silicon surface barrier detectors for 2-4 days. Each spectrum was corrected for background and delay since chemical separation and processed by tailored software (Lauritzen 1993). Samples with Th index ($^{230}Th/^{232}Th$) less than or equal to 20 were corrected for initial ^{230}Th by using equation 8 in Schwarcz (1980), assuming an initial $^{230}Th/^{232}Th$ ratio of 1.5. All samples can be corrected, but for $^{230}Th/^{232}Th$ greater than 20 the correction does not move the corrected age outside of the 1σ error of the original date. In other words, the effect of the correction is not significant and it is therefore not done. It will, however, give a significant ($>1\sigma$) shift if the index is less than about 20. All dates were performed at the Uranium-Series Geochronology Laboratory at the Department of Geology, University of Bergen, Bergen, Norway.

RESULTS

Summaries of the results obtained are presented in Table 1. Analytical results and ages are reported with 1 σ error. Some samples yielded "finite" ages between 300 and 400 ka, but the associated errors (up to +300 ka) render these numbers useless. It is safer to assume them as greater than or equal to 350 ka at the 1σ level. A description of each of the sample locations follows (also see Fig. 1).

Two stalagmite pieces were collected from rubble in a surface cave dig at Hollyhock Hollow at the southernmost portion of the study area in southern Albany County in 1996. Sample HH1 yielded U/Th dates of 70-56 ka and sample HH2 dates of 41-35 ka. The site is developed in the Helderberg Group limestones.

Two stalagmites were collected *in situ* from Onesquethaw Cave in central Albany County in 1982. Sample O-1 was collected near the terminal sump at the downstream end of the cave; sample O-2 was collected from a breakdown block upstream from the Barnyard, a point in the middle of the cave. These stalagmites yielded five dates, all Holocene, less than 9 ka. See Palmer (1972) for a map and detailed description of the cave. The cave is developed in the Onondaga Group limestones.

Five stalagmite and flowstone samples collected in 1982 from Caboose Cave in eastern Schoharie County provided 13 dates ranging from 207-56 ka, with a distinct clustering from 100-56 ka and 207-172 ka. Some of the samples (C-1, C-3, C-5) were flowstone clasts in coarse sediment, so their growth position cannot be determined. Sample C-1 came from the north rift in the Maximum Formation Room. Sample C-3 was a clast in an eroding bank of sediment in The Streamway. Sample C-5 was found loose outside the cave entrance. Sample C-2 was a flowstone crust located *in situ* in the Drownstream Siphon area. Sample C-4 was collected *in situ* in the upstream end of the Loxodrome area. For a full description of Caboose Cave, see Mylroie (1977). Caboose Cave is developed in the Helderberg Group limestones.

Schoharie Caverns is located a few kilometers west of Caboose Cave in Schoharie County. One flowstone sample, S-1, was collected *in situ* from this cave in 1982, part of a large mass directly against the cave wall ~120 m upstream of the cave entrance. Six sub-samples from this flowstone all dated to in excess of 350 ka. See Kastning (1975) and Mylroie (1977) for a cave description. Sub-sample S-1F was re-run after the initial results gave an age out of stratigraphic order (226 ka); the second run produced an age of >350 ka, in agreement with the rest of the sample, and an error in sub-sample processing is assumed for the first run of S-1F. Schoharie Caverns is developed in the Helderberg Group limestones.

Barrack Zourie Cave is located at the northwestern end of the traverse, in western Schoharie County. Two stalagmites (BZ95-04 and BZ95-05) were collected *in situ* from large passages in 1995, and they yielded four dates. The dates cluster at about 161-158 ka, except for one, an obvious younger overgrowth that had a 61 ka date. BZ95-04 was collected from the Virginia passage midway through the cave, and BZ95-05 was collected from Rocky Road in the last third of the cave. A complete description of the cave can be found in Dumont (1995). Barrack Zourie Cave is developed in the Helderberg Group limestones.

DISCUSSION

It is important to emphasize that the dates reported from this reconnaissance study reflect a limited number of samples collected in a manner designed to be unobtrusive as opposed to thorough. As a result, interpretation of these data needs be considered somewhat speculative. Nonetheless, possible interpretations are presented here to help guide the design of future work of a more detailed nature.

CAVE INTERPRETATIONS

Hollyhock Hollow: Some dates here are the youngest collected from Pleistocene-aged samples, and may reflect the southern position of the cave. In other words, ice could have

Table 1. Uranium- series disequilibrium dates of speleothems from New York State.

J.No	Sample	Cave	U(ppm)	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	Age (ka)	Corrected Age
0931	BZ95-05 Rocky Road	Barrack Zourie	0.17±0.003	1.974±0.039	0.8077±0.0195	34	146.7±6.7	
0935	S-1 A	Schoharie	0.51±0.01	1.639±0.047	1.0688±0.0413	61	>350	
0936	S-1B	Schoharie	0.75±0.01	1.432±0.028	1.0624±0.0256	599	>350	
0937	S-1 C	Schoharie	0.86±0.02	1.351±0.027	1.0309±0.0259	182	>350	
0938	S-1 D	Schoharie	0.93±0.02	1.321±0.020	1.0209±0.0352	89	>350	
0939	S-1 E	Schoharie	0.74±0.01	1.373±0.022	1.0546±0.0242	>1000	>350	
0940	S-1 F base	Schoharie	0.48±0.01	1.444±0.033	0.9443±0.0272	133	226.1±20.0	
0941	C-5 A 170-180 mm from base	Caboose	2.75±0.04	2.434±0.025	0.4318±0.0104	>1000	57.8±1.8	
0942	C-5 B 135-140 mm from base	Caboose	2.5±0.03	2.313±0.015	0.4231±0.0049	>1000	56.4±0.82	
0943	C-5 C 120-130 mm from base	Caboose	0.88±0.01	2.163±0.026	0.5461±0.0088	172	79.0±1.75	
0944	C-5 D 95-87 mm above base	Caboose	0.71±0.01	2.138±0.031	0.5802±0.0110	55	86.0±2.3	
0945	C-5 E 85-80 mm above base	Caboose	0.68±0.01	2.095±0.026	0.6006±0.0097	67	90.5±2.1	
0954	C-1A NY	Caboose	0.20±0.004	1.608±0.037	0.8852±0.0233	28	184.6±11.0	
0955	C-1B	Caboose	0.20±0.004	1.614±0.032	0.8835±0.0197	379	183.6±9.0	
0956	C-1C	Caboose	0.75±0.015	2.411±0.048	0.6573±0.0202	24	102.2±4.7	
0957	S-1 Base repeat S-1 F	Schoharie	0.48±0.006	1.370±0.014	1.0197±0.0149	>1000	>350	
0962	BZ 95-O4A	Barrack Zourie	1.96±0.03	2.015±0.023	0.4457±0.0088	>1000	60.7±1.53	
0963	BZ 95-O4B	Barrack Zourie	0.17±0.004	1.643±0.037	0.8503±0.0215	17.4	168±8.8	161.49±9.5
0964	BZ 95-O4C	Barrack Zourie	0.20±0.004	1.565±0.033	0.8537±0.0204	9.25	171.7±8.7	158.49±9.6
0965	BZ 95-O4D	Barrack Zourie	0.16±0.005	1.652±0.060	0.8347±0.0298	28	161.7±12.0	
0966	O-1A	Onesquethaw	0.11±0.003	1.502±0.050	0.1097±0.0108	3.59	12.5±1.31	7.49±1.8
0967	C-2A	Caboose	0.41±0.015	2.002±0.083	0.6398±0.0309	32.9	99.7±7.45	
0979	O-1B	Onesquethaw	0.10±0.003	1.390±0.060	0.1105±0.0136	4.94	12.6±1.65	8.96±2.1
0980	O-2A	Onesquethaw	0.81±0.012	1.013±0.013	0.0279±0.0034	2.5	3.1±0.38	1.24±0.6
0981	O-2B	Onesquethaw	0.74±0.013	0.956±0.017	0.0281±0.003	19.2	3.1±0.34	2.86±0.4
0982	O-2D	Onesquethaw	0.71±0.014	1.159±0.026	0.0614±0.0063	3.21	6.9±0.73	3.71±1.0
0983	C-4A	Caboose	0.16±0.003	1.577±0.031	0.9244±0.0219	53.1	206.0±12.0	
0984	C-4B	Caboose	0.13±0.003	1.559±0.032	0.9126±0.0240	4.80	200.3±13.0	172.11±15.1

J.No	Sample	Cave	U(ppm)	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	Age (ka)	Corrected Age
0985	C-3A	Caboose	0.23±0.006	1.820±0.049	0.8889±0.0247	20.4	180.4±11.0	
0986	C-3B	Caboose	0.36±0.006	1.997±0.034	0.9531±0.0188	62.1	206.9±9.8	
1655	NY-96-HH1-1	Hollyhock Hollow	0.09±0.003	1.497±0.071	0.5195±0.0400	4.44	75.8±8.3	56.32±10.2
1656	HH1-2	Hollyhock Hollow	0.13±0.003	1.466±0.040	0.5117±0.0191	11.3	74.4±3.8	67.28±4.2
1657	HH1-3	Hollyhock Hollow	0.14±0.003	1.534±0.045	0.4909±0.0216	19.7	70.0±4.20	66.16±4.4
1658	HH2-1	Hollyhock Hollow	0.15±0.005	1.607±0.057	0.3259±0.0197	>1000	41.7±3.0	
1659	HH2-2	Hollyhock Hollow	0.14±0.004	1.510±0.050	0.3191±0.0182	30	40.8±2.8	
1660	HH2-3	Hollyhock Hollow	0.14±0.004	1.467±0.044	0.3159±0.0175	28	40.3±2.6	
1661	HH2-4	Hollyhock Hollow	0.12±0.004	1.451±0.054	0.2986±0.0200	15.8	37.8±3.0	34.74±3.2

retreated earliest from this locality during the mid-Wisconsin interstadial (oxygen isotope stage 3) without having had ice yet retreat from caves farther north and west (and therefore no speleothem growth occurred in those caves at these times). Ice re-advance would have reached this southern locality later than caves to the north. The samples were part of fill material removed from a rock-walled sinkhole, so the actual provenance of the samples is suspect, but the field setting indicates a collapsed cave passage. This collapse might be related to the late Wisconsin ice advance (oxygen isotope stage 2) in the area.

Onesquethaw Cave: The U/Th dates reported here are Holocene, and may support the argument that Onesquethaw Cave might be post-glacial in origin (A. Palmer 1972), as its passages are small, active, and in accordance with the glacially re-arranged topography. Secondary calcite is notably sparse in this cave, which may reflect the cave's youth, or may indicate that stalagmite formation is not prolific enough to provide an adequate record. The cave floods many times a year, and older speleothems may have been removed by flood water dissolution (even though modern speleothems are growing today). The cave may well be older than the last glaciation.

Caboose Cave: The samples came from large high level passages underdrained by small, youthful passages. These youthful passages are in agreement with current surface geomorphology. The older nature of the upper level passages is supported by the U/Th dates determined from samples collected in those passages. As only two samples were *in situ* (and one other sample was actually found outside the cave), the data here are not rigidly controlled. This cave has been reported to contain sediments considered to be glacial rock flour (Mylroie 1984), and the U/Th dates support the cave's existence prior to the last glaciation (oxygen isotope stage 6).

Schoharie Caverns: The entrance to this cave was created by excavating a large amount of glacial till from a buried cliff line in the limestone. The cave contains an abundance of flowstone material, including very large chunks in the streambed. The relationship of the glacial till to the cave indicates the cave was in existence at least prior to the last ice advance of the Wisconsin glaciation. The U/Th dates support the field evidence of the cave being at least older than one glaciation, and suggests that the cave has been in existence at least prior to the glaciation associated with oxygen isotope stage 10 (350 ka).

Barrack Zourie Cave: In addition to the sample dates reported here, Dumont (1995) reported two previous dates, from a stalagmite in the upstream end of the system, as 165 ka and 277 ka. The data reported here extend from that 165 ka date (161-158 ka) to more recent time (61 ka). The cave drains a glacially blocked valley, indicating it existed at least prior to the last glaciation. Barrack Zourie Cave also contains glacial rock flour (Dumont 1995), as was reported for Caboose Cave, another indication of origin prior to at least one glaciation. The U/Th data from the study reported here support this interpretation and the earlier work of Dumont (1995) suggests that the cave was in existence prior to the glaciation associated with oxygen isotope stage 8; i.e. the cave has survived multiple glaciations.

REGIONAL INTERPRETATIONS

Regional interpretations are limited by the same conditions of low sample number and non-systematic sample collection that limited interpretations of individual caves. While detailed, solid interpretations cannot be made, it is clear caves in the northeastern United States survived continental glaciation. Further interpretations are more speculative, but are presented again to help guide future work.

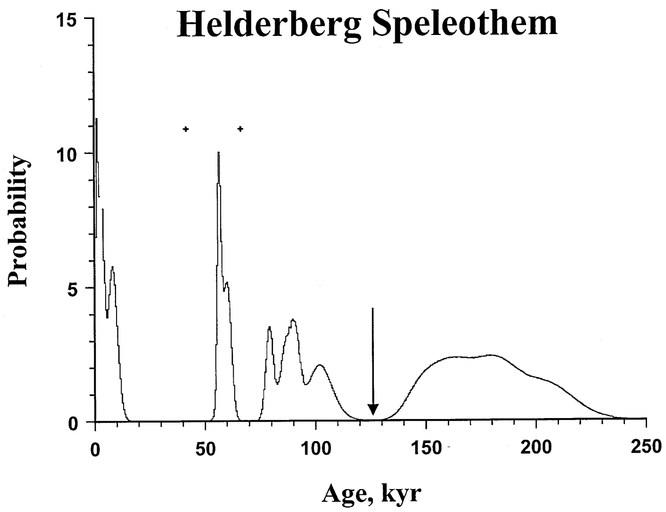

Figure 2: Graph displaying the date distribution of 29 U/Th samples. Crosses mark the approximate center of the two Hollyhock Hollow date clusters. Arrow emphasizes the lack of dates from the last interglacial (oxygen isotope substage 5e).

A total of 36 valid U/Th alpha count dates was obtained. While the number of samples is low, some preliminary observations are possible. The first and most obvious conclusion is that four of the five of the caves sampled must be older than at least the last glaciation, and Schoharie Caverns has evidence that it has persisted through perhaps three full glaciations. Caboose Cave and Schoharie Caverns, as well as other caves in the county, such as Howe Caverns and McFails Cave, were interpreted by Mylroie (1977) to have been in existence at least prior to the Wisconsin glaciation. That conclusion was based on field evidence such as glacial rock flour deposits in caves, entombment of caves in glacial drift, upper level passages not in concordance with current topography, and extrusion of glacial drift into cave passages. The geochronological observations support this interpretation for Schoharie Caverns and Caboose Cave (Barrack Zourie Cave was not discovered until 1992 and was therefore not part of the 1977 study).

Figure 2 is a standard probability distribution plot (PDF) of the data (Gordon *et al.* 1989) from Table 1. The broadening of the peaks with increasing age is an indication of the increase in error and, therefore, uncertainty. The data clearly show that speleothem growth was active in the Holocene, about 60 ka, in a band from 105-75 ka, and a broader band from 235-135 ka. The Holocene data is entirely from one cave, Onesquethaw, in central Albany County. This is perhaps an artifact of the sampling procedure, in that we sought to avoid active, pristine stalagmites, and also were preferentially searching for older looking speleothems to get a Pleistocene record. As noted earlier, Onesquethaw has only sparse stalagmite development, and collection options were limited.

One of the most surprising results of the reconnaissance, given that 36 analyses were made from 12 samples, is the lack of any speleothem growth during the last interglacial (oxygen isotope substage 5e, *ca.* 125 ka), as shown by the arrow in figure 2. One possible explanation is that the data are real, and represent unfavorable conditions for speleothem growth during the last interglacial. Such a growth deficit would be most easily explained by aridity that limited the vadose groundwater flux into the existing caves. Another possible explanation is that such speleothem growth was simply missed by the rather scanty collection regime. Holocene speleothem growth (i.e. active growth) is obvious to the casual visitor in all of the caves, yet few samples from this study showed Holocene dates, indicating that major growth episodes can be missed by a selective and limited sampling regime.

Figure 2 does not show the Hollyhock Hollow data as part of the curve, as these samples were in debris from a collapse sinkhole and not truly inside a cave. These data are displayed as the two crosses on the figure. These crosses fall into gaps on the curve, but given that Hollyhock Hollow is the most southerly of the sites, speleothem growth there may have begun earlier, and lasted later, than that of more northerly samples displayed by the curve as centered on 58 ka. Such an interpretation is extremely speculative given the low sample frequency.

The dates are all alpha counts, which agrees with the overall reconnaissance purpose of the study. The data collected here suggest some further work be done to refine the broad outline revealed by the study. The initial collection regime was careful to sample in a manner so as not to destroy the esthetics of the caves. The result was a dependence on loose samples from sediment banks, digs, and cave streams. Future work should carefully select a long stalagmite that would be amenable to TIMS U/Th dating [Thermal Ionization Mass Spectrometer], which yields higher precision from smaller samples than alpha count dating. Stable isotope analyses (^{18}O and ^{13}C) could be done on the same sample in conjunction with the TIMS dates. Such stable isotope analyses have been done from the midwest and west, but not from the northeastern United States. Such studies, if done in the Helderberg Plateau, could assist in unraveling the timing and magnitude of ice advance and retreat in the northeastern part of the country.

CONCLUSIONS

The dates collected so far are insufficient in number to allow making detailed paleoclimatic interpretations. The dates do indicate that both pre- and post-glacial (last glaciation) caves exist in New York. The clustering of dates in the 100-56 ka and 207-160 ka range is a bit surprising, as is the lack of dates during the last interglacial time period (130-120 ka) which is possibly an artifact of the sample quantity. The existence of dates beyond equilibrium (>350 ka) indicate that New York caves, as has been shown elsewhere, can survive multiple glaciations.

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