Interview with Dr. Will White discussing the Nittany Valley Karst Springs and Karst Research

June 29, 2020

Interviewed by Laura Toran and James Berglund

(Toran): So, just kind of to kick things off, one good place to start is to explain what motivated you to study these springs with your student Evan Shuster.

(White): Well, there was a considerable amount of backstory that probably goes back at least 10 years before Evan did his master's thesis work. The interest in the karst geomorphology community in the late 1950s/early 1960s was in karst denudation, and how fast new limestone landscapes evolved. And Jacques Corbel from France had published this huge monograph on the karst of Europe in which he argued that the rate of denudation was fastest in Arctic regions because the lower temperatures would increase the solubility of the limestone, and therefore tropical karst features - the gigantic cone karst for instance in China and other places - was the result of it just being extremely old. Now, I must admit at the time I thought that Corbel was out to lunch…but in order to check it out you need data. And people were going around measuring karst springs. And I had the idea of actually checking both the sinking streams AND the springs on a regular interval, of about a week or two, something like that. I don't know if you received this Laura, but I did send you a copy of a little paper written in the late 1960s with some spring data on it. We realized once we looked at those data that the springs were more interesting than the sinking streams – the sinking streams didn't do all that much - but the springs did. A second thing that happened right about that same timeframe in the early 1960s was that people were beginning to understand the geochemistry of carbonate waters. It may be hard to believe, but there was a time when we didn't understand the chemistry of carbonate waters, at least the way we do today. The guiding light behind that was Don Langmuir who was one of Robert Garrell's students, got his degree from Harvard, came to Penn State, and he was looking at the chemistry from a physical chemist's point of view, and I thought, "boy, we really could use more data," and at about the same time Evan Shuster appeared looking for a topic for his master's thesis that had something to do with caves and karst and we sort of merged the whole thing together. One of the other things that Evan had to his advantage was right about this time this concept of the saturation index as an important parameter of karst water, and to calculate carbonate dioxide partial pressure as a parameter of karst water, had just been developed primarily I think by Don Langmuir, and one of Don's students, a fellow named Roger Jacobson, had a wife who was a computer programmer, and they wrote one of the very first computer programs for calculating these derived parameters from the raw experimental data, and that was available to Evan. So a big chunk of his master's thesis consisted of pages and pages and pages copied from computer printout in which he can compute saturated indices, CO_2 pressures, hardnesses, and all the parameters that we use today all over the place. But I don't think there was any extensive use of those particular parameters prior to this.

(Toran): That's really interesting that it was kind of a combination of field, geochemistry, and modeling tools all converging at the same time that Evan was looking for a thesis.

(White): He happened to be at the right place at the right time.

(Toran): So, what did he end up doing after he finished the project, after he finished his master's degree?

(White): He went to work for the state of Pennsylvania. He was working for the office of surface mining under the department of environmental protection, and I think that was pretty much his career.

(Toran): One of the things that's fascinating about that is that sometimes your thesis research really spawns a lot of other projects and sometimes you don't know for years later, which is kind of interesting. On to another question, how did you pick the springs?

(White): Well, remember both Evan was a caver, I was a caver, so we pretty well knew the valley, particularly the valley to the northeast, up Brush Valley and Penn's Valley, because of the caves up there, we had been caving up there. So, the big obvious ones like Penn's Cave and Elk Creek Rise and Spring Bank and so on that were pretty obvious. But, we hunted around, and we just needed about a dozen or so springs, and then we knew about the springs down to the southwest in Sinking Valley and in that area so I knew about Tippery Cave so therefore I knew about Tippery Spring (or Springs, both of them) that are down there, and of course Arch Spring, and some of the other ones. Most of it was because of connections with caves – we knew were the caves were, so when looking for springs we knew where to look.

(Toran): I remember you telling me a story that you also had a driving radius because you wanted to sample - what was the time period you wanted him to complete his samples?

(White): Well, this two week sampling interval which shows up in Shuster's data, is an accident of the logistics. After all he was taking courses, he had other things to do, so he found he could drive up Penn's and Brush Valleys, sample about thirteen or fourteen springs, get the water samples, make the *in situ* measurements and pH and conductivity and temperature, come back in sometime the next day or two, analyze the samples, tabulate the data, and that would sort of line up the week, and in the following week he would go the other way – go to the southwest, down to Sinking Valley and do the same thing. So this got to be a cycling sample run – just go one way and then go the other way. And I've seen a lot of people copying that two-weeks sampling interval, saying "Well, according to Shuster and White, we used a two week interval…" – and that two week interval is nothing more than an accident, you know, how long it would take to drive up the valley, get samples, drive back, and analyze them.

(Toran): Wow, that's really interesting. One of the questions that Jim and I had is whether Birmingham Cave and that highway next to it was as busy back then as it is now, because that one is hard to get to!

(White): I found that cave entrance just because I spotted it out the car window. If you look at the geology up in that end of the thing it gets very complicated because of the Birmingham Thrust Fault, and so the structural geology is very complex there, and that little spring is actually in the Gatesburg Dolomite. But, go on up around the corner up past Birmingham to where the Hundred Springs are, and then continue up the road past Hundred Springs where it goes up the ridge, you would come to my uncle's farm which is where I tried to teach myself geology, a long long time ago. And so I knew about the Hundred Springs, and knew about this, spotted this little cave along the outcrop driving up there, and so came back one time and crawled in as far as I could go up the Birmingham crawl-way, not very far. But, yeah that's a main highway and it's been a main highway as long as I've been going up there.

(Toran): It was a good find because its character is a little different. So what were some of the similarities and differences that you observed in these springs?

(White): Well, we found out -- the most frequently mentioned thing -- is that there are some springs in which there are parameters, like say hardness and even temperature, varies all over the place with pronounced seasonal cycles, superimposed on a shorter-term period related to storms. With storms, we didn't have all that figured out at the time, but it looked like the springs that showed a lot of variability were draining out of cave systems, draining conduits, whereas the other springs, particularly the Big Spring at Bellefonte, which is really the type example of this kind of thing, where essentially any parameter you care to measure is absolutely constant, it doesn't pay any attention to the seasons, it doesn't pay any attention to the frequency of storms or anything else, and we thought well maybe that's because the variable ones are draining from caves and open conduits and the others are draining out of deep fracture systems and some kind where there is a long residence time. And other people have attempted to correlate the coefficient of variation, which is the parameter we were using, to describe this, with the amount of allogenic recharge and flow rates. So, anyway, just by dumb luck in the location in which we happened to be living where there was this pronounced variability – it doesn't occur everywhere – John Thrailkill looked at some of the same kinds of springs in the Inner Bluegrass Kentucky, and didn't find this variability, because they don't have mountain runoff in the Inner Bluegrass. We have a location here dominated by surface runoff from clastic rock mountains. If we had had a different location we might never have seen the effects.

(Toran): That's interesting. Can you comment more on how the landscape in this setting impacted the different types of recharge and discharge?

(White): What we have here in central Pennsylvania is what's called the "folded Appalachians," and so we have mountain ridges underlain by clastic rocks, and we have intermediate valley floors mostly underlain by carbonate rock. The mountains around here are synclinal and the valleys are anticlinal, and so carbonate rocks and folded sets of the upper Ordovician carbonates (Black River and others) are against the flank of the mountains, and the base of the mountains, and the core of the valley…are either Ordovician or Cambrian dolomite. And dolomite tends to dissolve more slowly than limestone. Karst features tend to be less prominently developed in dolomite, and so when we get recharge in the center of the valley, and then drain from there to one of these dolomite springs, the water has a very long residence time, and has plenty of time to come into both chemical and thermal equilibrium with the wall rock. Whereas the water draining off the mountains mostly drain into sinkholes which are lined up right along the limestone contact at the base of the mountain, and then tend to make a right angle turn, from effectively coming down dip along the mountain, to moving along strike along the edge of the valley flowing through the cave systems that tend to be master conduits.

(Berglund): One second, if I could interrupt quickly, I think we're getting a little bit of a sound coming back through the recording.

(White): Does it sound like a typewriter?

(Toran): Yes, that could be it.

(White): Yeah, my good wife is over there typing an envelope.

(Berglund): Yeah, that sound is coming through. I thought it was just feedback, but now that you mention it it does sound like a typewriter.

(White): There still are such things!

(Berglund): Yep, your microphone is picking up the typewriter ticks.

(White): Okay, well, we just delete that part and go back?

(Berglund): It was only a minute or two of explanation, mostly the part where you were explaining the general geology of the valley – if you could quickly just re-explain that – how the valley bottoms were the anticlines and the ridges were the synclines, and generally what the water does as it recharges into the valleys and takes the right turns, and how the dolomite is less developed.

(White): I might have to try and tell the same story twice. I'm not good at that! Well we could go back and see how this goes.

We're talking about central Pennsylvania, which is part of the Valley and Ridge Province of the Appalachians. And so our topography consists of long parallel relatively flat skyline mountains underlain by Silurian primarily shales, sandstones, particularly the Tuscarora Quartzite, which is the main ridge former. And the intermediate valleys are underlain by carbonate rocks, and these range from the upper Ordovician all the way through the Cambrian, and the valleys tend to be anticlinal, which means that the youngest rocks – the upper Ordovician carbonates, which are the best cave formers and have the most extensively developed karst surfaces – are along the basal flanks of the mountains, and out in the centers of the valley is the crest of the anticline exposing the older, mostly dolomitic rocks. So, if we have diffuse infiltration out on the valley floor through relatively thick soils, we have a groundwater system draining to the big springs, like the Big Spring in Bellefonte, through primarily fracture systems, and there is a long residence time, and plenty of time for water to come into both chemical and thermal equilibrium with the wall rock. Whereas along the edge of the valleys the streams flowing down off the mountains, down the mountain slopes, reach the limestone, go in through sinkholes (swallow holes) and there the flow path makes a right angle turn to something coming down the slope of the mountain to water which is running through a large open conduit parallel to the mountain along the geologic strike, and these eventually open into big springs, like the Rock Spring at the head of Spruce Creek or Heart Spring in Sinking Valley or the Elk Creek Rise in Brush Valley and so on.

(Berglund): Great, thank you, that pretty much covered that section.

(Toran): One of the things I wanted to follow up on that question: is it one of the things that was a bit surprising in the study that the type of outlet at the spring – like whether it was a big cave or more modest size fracture – did not predict the chemistry, like you couldn't tell from the visual appearance of the cave what that background network looked like – am I correct in that that was a bit of a surprise?

(White): No, I don't know if it was a surprise, because a lot of caves have no entrances. And some places where the spring is coming out of a big rubble pile – if you got in there with a backhoe, you might very well clean the rubble away and discover yourselves looking in a cave passage with a nice little stream running along the bottom. But if you tried digging into the fracture system you'd dig your way down to the bedrock and what you'd find was solutionally-widened fractures with water coming out of them. But the surface has been disturbed enough by collapses at the heads of gullies where a lot of these springs are located, or something, so the physical appearance of the spring tells you absolutely nothing about the flow system that's feeding water to it.

(Toran): So as a caver you weren't as surprised maybe as somebody else might have been. Was there something else that did surprise you when the study finished?

(White): Actually, well we already knew we were going to see variability because I had done this study almost ten years before, back in the early 1960s, where we definitely found considerable variability at three of the big springs that we looked at – Penns Cave, Spring Bank, and Elk Creek Rise. So I wasn't surprised to see variability, but what I was a little surprised to see was the contrast between what we were calling fracture springs and what we were later calling conduit springs. There was more of a contrast than what we had expected to see.

(Toran): Yeah, interesting, so what you're saying is more of a contrast in the geochemistry than what you would have expected.

(White): Variability of the geochemistry.

(Toran): Why do you think the paper has endured so long as a paper that people cite?

(White): Well, I often wondered about that! Let's see, what was it…a couple of things happened. One of them was it was one of the first times when this sort of new and revised and improved approach to carbonate geochemistry was used for a groundwater type of study. The editors in the Journal of Hydrology were in fact very pleased with this thing and they were willing to publish what you probably know as an exceptionally long paper for a journal article. Secondly, there were quite a number of people that were poking around in the same kind of thing – some in Great Britain, others in the United States – we sort of got there first, by not all that big a margin. And so there was a lot of interest in the paper so it got on a lot of peoples' radar and got passed down through generations of graduate students and followers and so-on. And I think finally just because it was kind of a big paper that lays it all out, so makes a useful reference to use as a starting point for people who are writing up more recent work.

(Toran): I think that's a very good description. I have a couple more general questions but I want to pause and see if Jim has any follow-up questions, especially since he worked on the springs for so long himself.

(Berglund): Sure, just…in my mind I'm imagining part of the video is sort of visiting the different sites –, did you have a favorite spring or were there springs you really enjoyed visiting or were there some springs you didn't get a chance to study and really wanted to?

(White): Actually, no, you see, looking back in the old days of the 1960s, and farmers were a lot more friendly because they hadn't been trampled over by so many people, and so getting permission to sample the springs was no problem. I don't remember any place where we had to negotiate with the land owner in order to get access to the spring. And some of the springs as you well know are a lot easier to get to than others. But we probably had a certain partiality to springs that we could get to quickly because we had to drive there every other week, and what we had at that time was a big bulky pH meter – I'm not sure if anyone remembers any of these things, but we had an original Beckman pH meter was about a cubic foot of solid mass of electronics and weighed, I don't know, maybe 15 or 20 pounds, and dragging this thing down over the bank and down to a spring site and fiddling around with the electrodes and so-on was kind of a tedious business, especially doing it over and over again. So, none of the springs that we had, and we picked all the ones that we wanted, there wasn't any that we rejected, particularly. We did not include Hundred Springs in the sampling in part because that was a water supply and an active pumping station – we didn't even try to chase down permission to go up there and sample those. But all the rest of them pretty much we sampled everything we wanted.

(Berglund): Were there any particular springs that you enjoyed the most visiting?

(White): Nah. You know, springs, like caves, like my children, I don't pick favorites.

(Toran): I love that answer, I don't think I've ever visited a spring that I didn't want to go, "Oh that's so beautiful!" I love watching groundwater discharge.

(Berglund): Do you know if those structures at Hundred Springs, like the pool, or kind of the outlet construction at Birmingham Cave, were those there when your study was conducted in the 60s or were those fairly recent structures?

(White): No, I have no idea who might have built the stone wall across the Birmingham Spring – that one was used as a water supply – it was kind of a place where people would pull up and get a jug out of the car and fill it up at the spring, and that part is kind of disintegrated, but the whole idea of putting that wall across with a pipe through it was so that people could fill up water jugs. The pumping station there at Hundred Springs was in full operation – it was the water for a big paper mill in Tyrone, and back in the days when we were doing this the paper mill was running full bore, which meant there were no fish in pond right there, but anyway...so that was not as easy a place to access as it is now.

(Toran): We felt that pretty lucky that we got access, but we did lose a logger there – there was a big structure, a box that they built, and we had to crawl into it to put our logger in, and when Jim went to pull that one in they had cemented the top across and our logger was inside.

(Berglund): Yeah, they had, I think they put a steel riveted structure on top. That logger in that box had been tampered with once or twice before. I think a lot of people tended to walk back on that trail, and the land owners at one point caught onto it and they didn't like people hopping into that culvert even though – it was about up to my chin when I'm inside of it - so I would hop in and hop out, but I don't think they liked people going in there. Eventually, we just went out there and it was riveted shut and so we couldn't even get our logger out, which was too bad.

(Toran): That's a paper that we haven't worked on yet, because the temperature responses in those springs was quite variable despite their proximity to each other, so there's a story there, but we haven't sorted it out yet.

(White): The story there of Hundred Springs may be pretty hard because you're sitting on two quite complicated structures, and the pathway the water gets to the spring at point A might be quite than pathway going to point B which is only 30 or 40 yards up the valley.

(Toran): Yep, that's exactly what the temperature tells us.

(Berglund): Kind of along those lines, something we were eventually going to talk to you about, but with the two Tippery Springs – Tippery and Near Tippery, with that sink that drains into the sinkhole up the road, was that something you knew of when you did the 1960s study and just were focusing more on the springs, or was this connection not known yet?

(White): I knew that a sinking stream was up on the mountain because it was on the topo map, but I never actually hiked up there, and the first time I saw it was when I went up the valley with you guys a few years ago, but I knew about Tippery Cave and I had gone in – some of us had gone in - and made a map of Tippery Cave, you know the big sinkhole up on the bluff right above the spring, so we knew about the springs, and we said, you know there's another spring because we knew there was a pool in the cave, which the people at that farmhouse, at least at that time, were using it for a water supply, a pipe came through the roof of the cave and you could see the pump right there in the pool. But, that's how we found the Tippery Caves, and the chemistry quickly told us that they were two independent springs and weren't two outlets of the same water body.

(Toran): That's interesting because you knew that Hull had done the dye trace. I'm trying to remember when he did that, was it in the 80s?

(White): Yeah, Hull was a little bit later, he was in the early 80s.

(Berglund): Yeah I think that thesis was 1980. That's what pops into my head, so it must have been a year or two before that.

(White): Hull was one of Don Langmuir's students, I was on his doctoral committee, and I thought he had done a really nice piece of work.

(Toran): Were you involved in any dye traces in the valley or just Don's students?

(White): That was the only one at Tippery, I never did any dye tracing. One of my students did dye tracing at Kooken Cave which is around the corner from Tippery. In fact, one of my hypotheses was that the lake at the downstream end of Kooken Cave…the stream comes off the mountain, runs through the lake and Kooken Cave, about half to three-quarters of a mile, and empties into a pool which has no visible outlet at the very end of the cave. And I was looking and realized this thing was the end of a cave that was just sort of cut off and almost on the Yellow Springs Fault. And I had the bright idea that maybe the water from the East Lake is then draining along the fault like a fracture and coming up in the Tippery Spring. Well, some more accurate altimeter measurement says the spring is higher than the lake so that didn't seem too probable, and I had a student who poured dye in there and also dyed in Tytoona Cave, trying to find proof that Tytoona and Arch were connected, which doesn't come as any big surprise. But, there's a story there actually the student (this was an undergraduate senior thesis type project) she poured a whole pile of rhodamine WT into Tytoona Cave and went home, with the idea that she would come back and pick up here dye packets the next day. Well, the travel time through the cave is only a few hours, so she managed to turn Arch and Sinking Run BRIGHT RED! Running right down through the Amish farm country. That caused a certain amount of local consternation.

(Toran): That's a kind of common dye trace story isn't it, "It kind of got away from us."

(White): Yeah, well, we misjudged, or she misjudged, but not much doubt about the Tytoona Cave connecting to the Arch.

(Toran): Yeah, I don't know if I think I told you when we did a dye trace at Tippery Sink, we left our fluorometers in place and we also put notes up on all the farm houses along the little stream, and we did get a phone call from somebody who said the stream had turned green. But when we went back to get the fluorometer data, the concentration wasn't high enough to be visibly green, and either the guy was seeing things or there was another outlet and it turned the stream green. We think it's the latter because I don't know why somebody would say "hey, the stream is green."

(White): No, I think that this is very likely the case.

(Toran): Yeah.

(White): If there is anything we've learned in flow paths is that they are complicated things most of the time.

(Toran): Yes. And we did not as expected get 100% of the dye out at Tippery so – what was it Jim?

(Berglund): We got about 60 to 65% that showed up at Tippery, so we lost 30-40% somewhere else.

(White): Okay.

(Berglund): And it didn't show up at Near Tippery, we got none, which was kind of interesting. The fluorometer was pretty sensitive, and no dye ever showed up at Near Tippery from going into that sink.

(White): Well it looks like the Tippery Springs are two upstream branches of a flow path which at one time probably connected somewhere not far from where the present spring locations are to flow out on into that stream that goes down through the gap and on down to join Frankstown Branch. And so the cave has been eroded away upstream to what essentially would have been a fork in the passage at some time in the distance past, is the way I read the thing. So you got the one flow line coming down the valley from up toward the quarry, and you got another flow path coming off the mountain up by the big swallow hole. So, I don't find it that mysterious, actually…

(Berglund): Yeah, I think I remember when we were there – when we went there with the karst field trip back in 2018 they were testing a lot of their field loggers, or field measurement probes, and I remember that that was a good spot to test temperature and pH and I think they even did an alkalinity test, and a lot of the students couldn't believe that they would go over to Tippery and measure it and walk over to Near Tippery and get very obviously different results even though they're walking distance to each other, you could see groups of people at both springs from the same spot, and I think that was interesting for them to see how you could get so much variation in just a short distance.

(Toran): Let's go on to a couple more questions of a general nature. In your time studying karst, how has changing technology altered the way we study and think about karst? You know the drone footage is one example, and modeling advances are another example – what sort of changes in the thought process have come about as technology has changed?

(White): Well, one of the things that's changed is our ability to put loggers into the springs or in the cave springs or whatever, has changed the whole perspective of the time-scale and I'm not sure whether the realization of the necessary time scale instigated the use of the loggers or the loggers allowed the change in thinking, because a lot of folks looking at groundwater still talk about doing quarterly sampling of a well, as if that's going to tell you a lot about the time dependence of the chemistry, and we learned with these studies back in the old Shuster days that the time scale for karst processes is a lot shorter than the timescale for most groundwater movement, and so we were there looking at a time scale of days and weeks (and that is still was much to go on), as it turns out some of the measurements once we could put a continuous data logger of some sort in the spring we realized that we got stuff where the time scale is 15 minutes or half an hour between the storm flow coming by and so on the rising level hydrograph or whatever. But that's basically made possible by new technology. If you look at this work that Jack Hess did in the Mammoth Cave area in the mid-70s he and an electrical engineer friend actually built their logger for conductivity, temperature, and so on, and it had, in addition to the probes, it was actually a miniature stripchart-recorder which is sitting there in a box run by a battery pack so he could get about, oh I suppose, a couple of weeks' worth of data before he had to get in there and physically change the strip chart, and so on. Well now you got something like a HOBO to measure temperature, you stick this tiny little gizmo in the stream under a rock some place and go away and come back when you feel like it and take the thing out. But continuous logging has made a big difference in the quality and timescale of the data that you can now see. The dye tracing has gone from looking to see if the screen turned green all the way up to building up complete breakthrough curves and quantitative dye recovery and a whole lot down to the part per trillion sensitivity level, a whole lot of stuff that was unthinkable back in the 60s and 70s or thereabouts. Remote sensing tools of various sorts – microgravity, ground penetrating radar, infrared sensors and using infrared instruments – now the most recent thing I've seen in the cave and conduit business is using LiDAR to actually make a quantitative image of a cave passage, so if you want sort of a more exact geomorphic data, it doesn't get much more exact than that. So, it's like everywhere else in science, there's a kind of hand-in-hand, a new gadget allows you to do something you couldn't do before, you discover something which inspires the invention of still another new gadget, and you kind of sort of hop-frog back and forth between a scientific advance and a technological advance.

(Toran): Do you think the modeling is doing the same thing? Do you think karst modeling is keeping up with the questions that we are trying to ask?

(White): Well let's see, I'm going to say that it's certainly been greatly improved; however, whether it's answered all the questions is something I'm not so sure of. But, some of the more recent modeling has been really impressive.

(Toran): Why do you think field – and this is sort of an easy question – why do you think fieldwork is an important component of karst research?

(White): Well, karst research has always been a field activity, going back to the oldest cave investigations, cave mapping, the old eastern European karst geomorphologists who wandered around through Serbia and Croatia and Slovenia looking at these incredible landforms trying to figure out what they meant and how they got there. Actually, I'm hard-put to think of an aspect of karst science where the theory lead the field observations. It's always been a case of piling up more field data than you knew how to interpret, and you had to sit down and think real hard about what it all meant.

(Toran): That's an interesting perspective. Nonetheless, fieldwork can be pretty challenging from the access issues to the equipment issues both then and now. Would you have any advice to new investigators to encourage them to pursue fieldwork?

(White): Well I think fieldwork is changing perspective as the planet becomes more heavily populated and we spread blacktop over a larger and larger area. What is going to be very important in the future, I think, are these cave preserves. You can think of the Tytoona Cave preserve, for instance, which is a really nice river cave, which is available for use – you don't have to worry about getting kicked out halfway through your thesis, which was always a concern actually in the old days. You know, if somebody is going on to somebody's property looking at something and coming back over and over again making measurements and collecting chemical data on the water, or whatever, and then some hunter manages to T-off the farmer and he says "alright, all you guys get out of here" and that was always a threat hanging over the head of any of the field studies that started. So you have something like Tytoona or something like Butler Cave Conservation Society down in Virginia that will give you access to Butler Cave and the Chestnut Ridge cave system and you have more cave than you could possibly get your arms around, which is open to you, and you could set up long-term logging equipment or do whatever you want and don't have to worry about wearing out your welcome. So, I think that preserves or parks or national parks or some kind of more formal arrangement with whoever happens to be the property owner are going to become more and more important.

(Toran): That's a great point. It is hard to find those access points, especially in the built-up areas, but we probably do need to be studying urban karst as well.

(White): Yeah, well. The advantage – well, I hate to call it an advantage – but for the urban karst there's almost, no matter where you go, there is some authority in charge, if you could figure out what the authority is and convince them what you are doing is worth doing, you may be okay.

(Berglund): If I could to ask one more question I would say, just from my own experience it seems like a lot of karst research is very, it's a little multi-disciplinary where you use multiple different techniques at the same time. Do you think it's important that karst researchers are themselves multi-disciplinary, knowing how to do modeling, understanding geochemistry, being sort of a physical hydrologist along with being a geochemist in a way, or do you think it's better to focus on one aspect at a time?

(White): You know what has happened over the last 20-30 years is that cave and karst science is very nicely integrated into the rest of the geological sciences, and you can judge this at the GSA meetings, and the kinds of papers dealing with caves and karst. But the two main parts of it are either the paleoclimate aspect using speleothems and cave sediments and that kind of thing, and of course the hydrology and hydrochemistry, and so on. But in a sense all science is now become multidisciplinary. The days of speleology as a unique science in caves all sort of all off by itself doesn't exist anymore. You can't take any branch of science and stovepipe it and say "look this is what I do and to heck with the other guys" - you know everything is connected to everything.

(Toran): That's a great point.

(Berglund): You had mentioned the issue of changing climate, do you think that karst regions in particular are more susceptible or more sensitive and should be monitored over longer periods of time, I know a lot of studies for an area of groundwater might go into a study and consider that good for a while, but is that applicable for karst?

(White): Well I think using caves as a way of climate modeling I think is a very useful thing to do. One thing that might have been interesting to do is find a nice spot in a nice accessible cave, accessible physically and accessible legally, and just monitor the long-term – you know a typical of groundwater type study your timescales may be a year, two years - I mean, how long can you ask a graduate student to stay at it? But at some place set up in such a way that you can monitor over decades. And I think some of the folks at the Karst Institute at in Posojna, Slovenia, I think are doing this kind of thing over longer view – well, long view on a human scale, although very short view on a geologic scale, but I think this is very worthwhile stuff.

(Berglund): Thank you.

(Toran): Yeah that was great. I think we're going to have a really good video to put together here, and like I said I hope we're going to inspire some other people to make videos of their karst areas, whether they use a drone or just some ground shots, we'll see what comes of it.