Introduction: Dr. Sarbu grew up in Romania. You'll get to see some of the areas that he started to explore caves and then he got this biology, sort of a master's degree in Romania and he also joined the Romanian Cave Diving Society and started exploring caves recreationally. It's obviously really interesting biologically and I was hoping to study there but because of politics, ended up having to defect in 1987 came to the United States and joined Tom Cane at the University of Cincinnati who was a cave biologist but Sarbu actually wanted to work on something very different in studying the animals in caves. He wanted look at chemoautotrophically-based caves and proposed kind of a radical thesis idea which he's going to talk about and is the basis for his research in Movile Cave in Romania. And he got some of the inspiration from his work from work that was being done under the oceans, the deep sea [inaudible] and I'll tell you about those connections. I think you'll really enjoy hearing about it so let's welcome him.

Dr. Sarbu: The first question here is why caves? Our interest in caves is very old one. As you know, humans have inhabited caves from the very beginning and it has always been a relationship that was somewhere in between respect, fear, love so humans were drawn to caves out of curiosity. They were also drawn because there was shelter there. They were afraid of the darkness. They were afraid of the spirits living in caves and so on. I'm very often asked by people if we found any monsters in caves. I wish I could say yes but we haven't. The only monsters that live in caves are a few inches long and three of them you see here. I will get to talk more about them a little bit later.
In 1890, Sergei Nikolaevich Vinogradskii (or Winogradsky) proposed a novel life process called **chemosynthesis**.

**Chemosynthesis** is the biological conversion of one or more carbon molecules (usually CO$_2$ or CH$_4$) and nutrients into organic matter using the oxidation of inorganic molecules (e.g. H$_2$ gas, H$_2$S) or CH$_4$ as a source of energy, rather than sunlight, as in **photosynthesis**.

Chemoautotrophy is not something new. It was discovered about 120 years ago, and it is a process that makes a very nice experiment in a microbiology class. You put all kinds of stuff in a bottle. You close it and you end up with a reaction. You can see the change from one thing to the other in terms of microbial life depending on what conditions you have at various points in that bottle. In terms of chemoautotrophy being the food base for ecosystem. It took another almost a hundred years to get to that point to discover something that functions based only on chemoautotrophy.
I’m going to talk today about a cave, mainly the most part of my talk will be about a cave that is located in Romania. This country here is Romania, the cave is located right here on the shore of the Black Sea. However, at some point we will be traveling to Italy as well where I did some work in another cave that functions about the same way.
As children in Romania, we learned about this scientist Emil Racovita who was sort of a role model for us as kids. He was an explorer that worked in the Antarctic and he was a gentleman who did a lot of work in cave biology. He in fact established the first cave research institute in Romania in the 1920s. In 1907, he set the foundations for cave science as a science. Now, you have to try to put things in perspective. This is a time that's not far from the time when Darwin came up with his theory and cave biology really is able to bring a lot of evidence in support of the evolutionary theory. I'm not going to get into details on that. We can discuss that later if there is interest for that.
This is where the cave is located in Romania, and this is what I'm going to talk about. This is where Emil Racovita established the first cave research institute and I was born somewhere here. When the Romans conquered this country they came from here and they had to cross the mountains because the capital of the country was here and that’s where the gold was. In crossing the mountains they had to cross over forest. In Latin "trans" means beyond, "silva" means forest, so all these area is called Transylvania. I was born Transylvania, it was very logical for me to get into cave research.
My first work in caves was exploration, especially taking pictures, enjoying the beauty of these formations that you can see. I was privileged to work with a group of cave explorers who had access to such beautiful caves. Not all caves in the world are so beautiful. These are exceptionally beautiful caves and while doing that I learned how caves are formed. I'll go very quickly over the chemical reactions of that.
It's called carbonic acid speleogenesis. What happens is water and CO2 form carbonic acids. It's a very weak acid. However, it reacts with limestone to produce this soluble bicarbonate.
Under certain conditions the reaction goes backwards, bicarbonate dissociates form stalactites, stalagmites and columns and all kind of other wonderful things that we can admire in caves. If the conditions are proper then you end up with beautiful crystals. Some of these crystals can be several centimeters long, very nice formations that are in general in protected areas in the cave.
Now, one of the things that you may hear when you visit commercial caves, tourist caves, it's not very rare unfortunately but the visitors would ask the question is this cave completely underground. The answer is yes, caves are all underground of course.

And so there is no light and if there is no light there are no plants and if there are no plants then there's no food and so on. So you won't find a lot of fauna in a cave. You may find very little creatures. You may have to go crawling to have a look in little corners under rocks and so on to find something that's maybe a few millimeters long. It's not a lot of stuff there to study in terms of biology. But now try to imagine, try to think of another place on the surface of the earth where the same happens, same conditions are true. Imagine that you get on a plane, fly straight west from here for a couple of hours and then dive to the bottom of the ocean. You'll find the same conditions. Darkness, no light, no food, no plants, maybe a grumpy crab that's waiting for something to fall from the surface as food. Well, in 1977, biologists found something that changed things. So, they realized that in certain areas where the conditions are right something else can happen. You may have this type of biology.
The deep sea vents where you have hydrogen sulfide, methane, ammonia which oxidizes with oxygen gives you enough energy to support chemosynthesis, rich, very diverse ecosystems, a lot of life, a lot of new species.
Sometimes if you are lucky you find something even better, which are symbioses where microbes live inside these organisms and generate their food. I'm not going to talk more about this, let's switch back to caves.
Movile Cave was discovered in '86. My friend Cristian Lascu was the discoverer of the cave and here is a team of us while we were building a cover and a gate to protect the cave so nobody falls in it and also to limit the access to scientists doing scientific work rather than everybody going in there and changing the environment or destroying the stuff that's in there.
Well, let me show you a picture here with a detailed view of the area where the cave is located. It's right here in Mongolia. This is the Danube flowing north and then eventually into Black Sea. This is the Black Sea. All of these is limestone, 12 million years old, and the difference in altitude between the Danube and the Black Sea today is about 10 meters. That's not much. But about 5 million years ago during the Messinian Crisis when the Mediterranean was dry or almost dry, there was a big lake here called Dacian Lake and the Black Sea. The level in the Black Sea was much lower by a few hundreds of meters. The gradient, the hydrological gradient, between this lake and this lake was huge. Caves were formed. When you have limestone and water on both sides you usually have cave formation that happens and we know that at a depth of about 200 meters we have a lot of caves in this area. There's not a lot of caves in the area. This one we were lucky to find. We don't know if there are caves here in Bulgaria. This is the border between Romania and Bulgaria. We know there is limestone we don't know if there are caves or sulfuric sprint. Unfortunately, the scientists from here and from here have not really communicated a lot. They are different countries. They speak different languages, use a different alphabet and even to make things even worse, Romanians call this Southern Dobruja. Bulgarians call this Northern Dobruja. It's totally confusing.
Looking at the detailed picture of Mongolia this is the old town of Mongolia. It has been there for 2000 years. It used to be a Greek colony, initially. There are old drinking wells in the town and then there is an aqueduct that brings water from about 4 kilometers. The Greeks found sulfuric waters in their basements here and so they put an aqueduct in that would bring freshwater without hydrogen sulfide from about 4 kilometers. This, have a look at this sinkhole and then there's another one here, there's another here. When you have an alignment of sink holes like this you are almost sure that there is a geological fault that connects these. These other springs here, that's a sinkhole, that's a sinkhole, this one and this one, another alignment of sinkholes, probably another geological fault. Along these faults water comes from the deep caves 200 meters deep to the surface. Have a look at that lake, white, milky. We'll get to see another picture of it. Another milky spring here and this lake, milky water there and so on, milky water here.
Look at this lake, very strong springs that contain hydrogen sulfide on the bottom of the lake. When the water reaches the surface hydrogen sulfide gets oxidized, you end up with elemental sulfur, particles of sulfur which make the water look milky.
If you go and dig a shaft going down building a deep well, geological exploration well, you intercept water under high pressure that shoots up at about 2 atmospheres to the surface. This is thermal water, about 25 degrees Celsius, and it contains methane, hydrogen sulfide and ammonia.
Our working model is this. We have deep caves at 200 meters of that filled with water under pressure and when geological faults are present the water would shoot up along these faults and intercept the surface. We have here springs, we have sulfuric caves and if you dig or if you drill a well and intercept those caves, again, the previous slide showed you how water would shoot up under pressure.
This is the Movile sinkhole. I'll show you another picture of it. But Movile in Romanian language means little hills.
The story goes that Ceausescu who was the dictator of Romania until '89 was flying with his helicopter above this sinkhole and saw this flat area and said hey, why don't you build here a power station to produce electricity for the Black Sea Shore? If you think of building something like that, a heavy building, your first concern will be is the ground strong enough to support a heavy building. You don't want to build a big building and have it then fall into a cave which has happened before on many occasions. So geologists were sent to investigate the geology.
They drilled and dug some shafts all around the sinkhole and we were very lucky because one of them that went 21 meters deep, about 20 meters deep, intercepted a natural cave that ended up being the cave that we studied in 4 years. This was in December of 1986.
Narrow passages first.
Then you get to larger passages, see their shape which is oval here indicates corrosion by this atmosphere very rich in carbon dioxide. We have up to 3 percent carbon dioxide in the scale.
You get down to the lower level of the cave. The walls are covered by gypsum crystals. This is, here the temperature of the water about 21 degrees.
And if you get right to the water surface you see how corroded like Swiss cheese, how these walls look. There are no gypsum crystals because the water level can go up for about a meter and it would dissolve the gypsum. Gypsum is soluble. I’m here with the turkey baster in my hand trying to collect little creatures that live in the water.
Here is the map of the cave, the shaft is here. We crawl through here, get to the lake, and one of the very important things in the lake and I was lucky to be a cave diver when we found the cave because I ended up exploring the underwater passages and we realized that the cave goes under water for about 40 meters or so, not very long. But then you end up with some air bells. And this is where most of the interesting biology happens, there and there. The amount of oxygen in these air bells is lower, microbes can develop. They form microbial mats which I'll be showing you in a minute or so.
Again, collecting fauna in the water, you spend hours there looking for very small creatures trying to catch them and then send them to taxonomists so they can tell you if they are a known species or a new species.
It just so happened that pretty much every single species we found at this cave, 33 of them at this point, are all endemic, are all new for science. They only live in this little cave.
That was a millipede, a pill bug or wood lice, how they are called.
This is another pill bug. This about 2 centimeters long, it's huge and there's a lot of them. They are very active, they move all over the place, very unusual for cave biology. You don't see that happen in most caves. There's no food. All the animals move very slowly. They don't want to waste energy. These guys have enough of it. They can afford moving fast and you can see a lot of them, some of them end up being in densities of up to 200 specimens per square meter. That's huge per cave biology.
This is a centipede, about 5 centimeters long.
Centipedes are very unusual cave creature. That one there is a leech. It's the only cave adaptive leech in the world. You think well, what's that cave adaptive leech? Well, first of all, it doesn't have any pigment in its body and it doesn't have eyes.
What you see here, this brown color, it's the hemoglobin of the leech itself that you can see through the transparent skin of the animal. Since leeches are like us, they do have hemoglobin in their blood.
Another interesting one is this water scorpion. It's an insect that would sit under water, breathe through that snorkel and wait for some prey to just come right in front of it, usually amphipods, isopods, little crustaceans that live in the water. It's the only cave adaptive Hemiptera in the water.
So it makes very interesting and if you look at the portrait of a surface water scorpion, look how big the eyes are and look here, this is the head of a cave-adapted water scorpion, no eyes whatsoever.
This picture I got this morning and I just couldn't resist. I had to include it in the talk. It's an ostracod which is a very small crustacean. This would be about 0.1 millimeter so we talk about the very small creature and it's a new species again. A friend of mine who's studying this took this picture on confocal microscopy and I got it this morning and I thought wow, this has to go in the presentation. Still not described, she's working on it right now.
Now, when you see something like Movile Cave you find a cave like this and you start telling people wow, this is interesting. This is a very interesting ecosystem biologically, really nice. We are all excited about it. So, people would say well, how do you know that there's no food coming from the surface, how do you know that this is not next to a sewage pipe that brings water from some houses in the neighborhood and dumps it into the underground. Well, we were challenged by these questions and it was not easy to find answers to them.

Well first of all there's no sewage pretty much in the area to begin with. But in '92, one of our friends was measuring the environmental radiation in the area. Romania is not far from where Chernobyl happened in '86. And Cesium 137 is not something that occurs naturally. It is an artificial isotope. It was generated by A-bombs or Chernobyl type of accidents. So at the surface he found quite a bit of it. There was nothing in the sediments of the cave. There was nothing in the springs in the area. So that was encouraging.
Well, looks like not much comes from the surface. We installed these little frames made out of these PVC pipe. Each one of these is 10 centimeters so this gives us a surface of about 100 square centimeters. This is microbial mat that grows on the surface of the water. There is bubbles of CO2 and methane that keep it afloat and we are trying to harvest every month the microbial mat in that square and then measure it and do some work on it, try to investigate, see what's in there and how does it work. What does it do?
We installed these inverted fish tanks on the surface of the water in the cave lake and we're trying to monitor the growth of the microbial mat under these bells. Some of them had more holes in their bottom here or in their top, I should say, and some had less. This way we could monitor if more or less oxygen would make a difference in terms of how much growth of mats happens in these bells. The striking fact was that in the cave lake here there's no floating mat whatsoever. But in this part of the cave we have more oxygen than in the air bells. Apparently, the less oxygen you have the better the mats grow.
Here is a picture that we took and that's again a picture of the microbes but of course you look at them, all of the microbes look like little spheres or like little egg-shaped structures or spiral shaped and that's about all you can say. Most of them don't want to grow on Petri dishes, we learned that the hard way and back then, this is 20 years ago, molecular microbiology was not really there. We tried to do some DNA sequencing, we didn't get too far. It was very expensive. You had to use P32. Do your own gels. Incubate them and find out about a week or 10 days later that it didn't work. By now P32 is old enough, it didn't work, you have to order more and so on. So this is ancient science. Nowadays, things are completely different and so there's a whole group of people that are investigating the microbiology, the molecular microbiology of Movile Cave as we speak.
We tried to do incubations with C-14 labeled bicarbonate or CO2 hoping that the microbes being autotrophic will incorporate the radio-labeled CO2 and produce radioactive organic matter. At that point in time the TSA wasn't doing a great job. In fact it was an old TSA so you could fly with a bottle of radioactive bicarbonate from Cincinnati to Romania, do your experiments, come back with the samples all radioactive and read them in their counter at the University of Cincinnati. Nowadays of course you could not do that.

The results were not very encouraging, hard to convince an editor of a good journal to publish an article with those results. We showed some inquiries but it wasn't convincing. Eventually, I managed to steal, so to speak, got inspired by the people doing work on the deep sea vents and steal their idea of using stable isotopes in cave biology and ecosystems studies.
And in the next couple of minutes I'll give you just a quick presentation, a short presentation on the use of stable isotopes here. What are stable isotopes? Well, they sit in the same box in the periodic table and the reason for being different is just the fact that the number of neutrons is different in these atoms. So we have C-12, 99 percent of carbon out there is C-12 and then C-13, there's about 1 percent. When we measure stable isotopes values we, in fact what we do, we send them to the lab and we get these delta values back. What does that mean? It's an easier way of expressing the amount of C-13 versus C-12 in your sample. It makes it easier to work with when you have it expressed as delta rather than the raw numbers that you measure. Now what is isotopic fractionation? Think about it. If you were an enzyme and had to push the whole day, C atoms from one place to the other, get CO2, combine them and make glucose the whole day. You'd learn very fast to select for the lighter ones and so work more with the C-12 rather than C-13. You'd leave the C-13 aside. So what ends up happening is when you start with CO2 that has a stable isotope value, a delta value of minus 7, RuBisCO would select, go down about 20, 21 percent as you see here from 7 to minus 27 minus 28 somewhere there. So you end up with light organic matter. Right. We started with heavy, we go to light.
Now, basically, the rule is that we are what we eat plus 1.5 per ml. So if this was grass minus 27, the deer eats the grass and end up being minus 25. Why is this difference because the deer during their respiration eliminated the light CO2. Again, there is enzyme. There are enzymes there that prefer to take the light carbon, send it out as CO2 and what's left, the deer is minus 25.5. You go to the wolf that eats the deer, another 1.5, the fleas on the wolf, the mites on the fleas and so on, right. So it makes it very easy to look at food webs using this method. Well, sometimes it's not that easy but in an ideal world this is what you do. Now, let me ask you a question here. If I found a deer that has a minus 45 delta C-13 minus 45, would that be deer, would that deer be able to be one that ate this grass? No way. That deer is much lighter, would be somewhere on that wall next to the periodic table. It would have to have a different food that was lighter than the deer.
So now when in Movile Cave we found our samples to be somewhere here at minus 42, minus 45 and so on, and the surface samples are somewhere here at minus 22, minus 27 and so on. And then in hand-dug wells you find a combination because there is some of this food available but there's also stuff falling from the surface. This is perfect nice proof that this fauna does not eat that food. This type of data was accepted by the editors of science and we published a paper that described the food web in Movile Cave as being based on something else than photoautotrophy. The data points are so nicely clustered that we were thinking that we don't need any statistics when you analyze this. And we were thinking the statistic was invented to cover up when you don't do very good science. So eventually we had to do some statistics because the editor required it and we couldn't publish without it but we just ran a test and that was fine.
Now why is the organic matter that light isotopically, because along the faults there's methane coming up thus C-13 for methane is minus 60. When microorganisms would oxidize this, CO2 that's isotopically light results from the process and that is the raw material that the microbes use to produce light organic matter. So that's the secret behind that.
And our working model is this. Our cave is completely isolated from the surface. First, we put question marks but eventually we realize that if there is any input from the surface, it is negligible. The surface has its own way of functioning. Here things happen in a different way. The chemical energy is the one that drives the ecosystem.
In the '90s we managed to get some sponsors to finance the building of this building that you see here. In that little box there is a well that goes down 200 meters and intercepts water that comes under pressure. It's thermosulfiric water. We built this building and there is a nice basement there where we have tanks. There is a pipe that goes from here into the basement and we can do experimental work in those rooms in conditions that mimic the cave environment. We also have a room with microscopes, a conference room upstairs and so on. This was our field station and it still is there where we do the field work when we go and do research in the area.
Now, ongoing research is trying to establish the geographic extension of the aquifer trying to finish the description of new species. There's a still a few that are not yet described. Trying to understand the origin of the subterranean fauna. Again, DNA sequencing back then almost impossible, nowadays easy to do. We are looking at the relationship between the various species inhabiting the cave trying to figure out how old they are, when did they invade and so on. Ecosystem studies and of course microbiology, there is a lot of work done there nowadays.
And as I said I will try to entertain you for a few more minutes with some slides that show you a different process of cave formation. The first one I mentioned was carbonic acid speleogenesis. It's a slow process where carbonic acid reacts with limestone to form caves. In caves where we have hydrogen sulfide and there's not a lot of them out there, 99.99 percent of the caves don't have this. But where we have them, hydrogen sulfide would evaporate, be oxidized at the water level. There is oxygen in the air, what results, what we see here are gypsum crystals on the ceiling, on the walls of the cave. Walls are very, very severely corroded. This oxidation of hydrogen sulfide can happen without microbes. But when microbes are present it goes much faster.
The result is crystals such as these, unique in the world. In Lechuguilla Cave, this is the chandelier ballroom. These are gypsum crystals. There is no water in Lechuguilla nowadays or just some water and some pools. But it shows, it sort of leads to the fact that the water was flooded and was in fact built by sulfuric waters that used to flow here a long time ago.
Some of you may have visited or may have heard about Carlsbad Caverns, huge cave formations, huge rooms. Don't get fooled by the colors here, this is for the tourists. But these are big, big rooms, huge cave formations. This is in New Mexico, in desert type of environment. There's no evidence that we ever had any big rivers flowing through the area. So the cave, such a big cave must have been formed in a different way and we do have deposits of gypsum in certain areas of the cave. It's a proof that in fact the cave was formed under different conditions.
This is the process, sulfuric acid speleogenesis. Hydrogen sulfide gets oxidized, we end up with sulfuric acid. Now this is a very strong gas. It reacts immediately with limestone to produce gypsum and carbonic acid. This one in turn now digs out another molecule of limestone so we are calling this a double dissolution process. Two molecules of limestone are removed for every single H$_2$S that's being oxidized in the cave. It's a very fast process. It goes very fast. It forms huge caves.
Where do we have something like this happening? Where do we have chemoautotrophically-based caves? First, we thought Romania Movile Cave is the one, the only one unique and so on. There were papers published. There were articles published in magazines. There were documentaries made about the only cave in the world. Well, 10 years later, about 8 years later, friends of mine who are doing cave exploration and cave geology in Italy, they called me and said hey, we have a cave here that has sulfuric stream in the bottom of the cave, in the deep sections of the cave. Of course, I asked well, was there any biologist there to have a look if there is any fauna around those streams? They said no, the cave biologists here in Italy were too lazy, they didn't want to go in.

A week later I was in Italy and on the first trip we found six new species for science. Spiders and crustaceans that are present in the cave and there were no--nobody just went there to have to look for them and of course it's not an easy cave, you have to crawl, you have climb and so on, but very easily accessible if you really want to get there. There are other caves in Israel, one or two in the United States, the famous Mexican one and possibly one in Libya.
Let me show you a few pictures. We have a few more minutes so I will try to show you a few pictures from Italy. A milky stream comes out of this little cave. This is about what, 3 feet long or so, so it gives a scale, an idea of the scale, this is a river here.
We are in Central Italy, in the Frasassi Gorge. This one here is a picture of the Frasassi Gorge. Fra means in between, sasso means cliff, rocks so this in between the cliffs, that's the name of the gorge. Several caves present there. In the '70s cave explorers found this room. It's 100 by 100 by 100 meters high. There's a million cubic meters of rock that are missing inside that mountain. There's no way this little stream that you saw, the little river that you saw in the previous picture could have dug that type of cave. It was only the sulfuric water that could do the job. It's a very beautiful cave, it's a show cave, lots of tourists come and visit it. We are interested especially in the deep sulfuric sections of the cave and there's quite a few of those.
Here you see what are called snotites. These are mucus type of structures, couple centimeters long, that's a drop of water. Well, I should say sulfuric acid really because the pH is 0. Have a look at this and you see how colored this is.
It's very strong acid that would lead to limestone corrosion, holes in the walls all over the place. It's very, very corrosive. This type of corrosion is very rare in the rest of the caves because they break before they end up being that long.
There's a lot of biology that is interesting there. Look at the microbial mats in the lakes. This is all milky. The microbial mats cover the sediments and the rocks, other microbial mats here.
Please note those little crayfish, they are amphipods living in the water here all over the place. Back 15 to 17 years ago, we thought that there is only one species. In the meantime, molecular biologists were there, there are four species nowadays. Each one has its own symbionts, its own filamentous bacteria that live in association with that particular species. It's a very, very interesting project going on right now. Here is a picture of a spider that got down to the water, to the shore here and waited until one of these amphipods came close to the shore and here it is eating an amphipod. It's very unusual. Spiders would eat terrestrial fauna. They don't go fishing but when the amphipods are so close to the shore, hey why not.
And of course, here too we did stable isotope ratio studies. This is a medallion slide but this shows you the surface and this shows you the sulfuric area of the cave and this is the area where those hanging stalactites or the snotites, how the Italians call them locally. They are lighter in terms of nitrogen, we don’t know exactly why.
Let's jump now in other few meridians to the east and here we are on the shore of the Sea of Galilee or the Kinneret Lake, how the Israelis call it. This is a place called Tabgha and there is a big spring there, the En-Nur Spring. So, sulfuric spring and a hundred years ago in 1911, there was this crayfish. It's the largest--that was discovered in that cave. It's endemic. It only lives in that little spring and it is the largest cave-adapted shrimp, cave-adapted crustacean in the world. In the meantime, another one, this was found in caves in Southern Italy and I may want to mention that this is a famous place. There is a lot of tourist here at Tabgha and the reason is that everybody believes that this is where the multiplication of the fish and bread happened a long time ago.
Here is a picture of the Ayyalon Cave which is somewhere in between Tel Aviv and Jerusalem. Another cave that contains hydrogen sulfide in it, thermal waters and here there is [inaudible] species of the little crayfish or a big crayfish, I should say, that I showed you before. The most interesting species in the Cape Harbour is this scorpion. So, far scientists have only found the skeletons of these creatures. It is a new species but nobody has yet found a live one. Although, this belief that they are somewhere there but we haven’t found them yet.
Lower Kane Caves in Wyoming, there is no invertebrates in this cave, however, there is a lot of microbial mats, the water is sulfuric. I apologize for the quality of this picture but this is a stream that shows you white microbial mats and here is a detailed microscope picture of filamentous bacteria that live in those streams. Other streams in the same cave probably contain some iron oxide, hence, the reddish orange color.
Cueva de Villa Luz in Tabasco in Mexico. You would know this already, these are the snotites, same as in Italy, here they are on the other side of the ocean. The water is milky. The only problem with this cave in terms of biology, of macrobiology rather, microbiology, is the fact they draw a lot of big holes in the ceiling of the cave and so you have leaves, you have tree logs, you have all kind of stuff from the jungle above the cave that end up in the cave so you cannot tell really, what's what, what's chemoautotrophically based, what is photoautotrophically based and there don't seem to be a lot of cave-adapted invertebrates that live in this one.
Well, finally, I'll show you a picture of a place where I would love to go one day when the dust will settle. This is Benghazi and if you look at his picture, please note this alignment of sinkholes, one, two, three, four. I have a detail here of those sinkholes, just the first three. In one of them, I don't know which one it is, but in of them there is a cave that was last visited in 1959 by a group of cave explorers from England and they found a fourth species of the same genus of shrimp that I showed you from Italy. So, right now we have four of those. I'd love to have another one from here and see how it relates to the other ones, maybe someday.
Finally, I would like to thank a lot of people that helped along the way, from the explorer who discovered the cave who invited me to join the team, to lots of other volunteers that along the way helped in various ways, funding scientists to analyze samples and so on. But what I would like to do is really to thank them all for their commitment, for their help, and especially for their interest in cave science. Thank you very much.

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