Interview with Dr. Belen Muñoz, specialist in climate records in caves

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Melania Menéndez:¡Hello! I´m Melania Menendez Huari.

Alicia Pérez: I´m Alicia Perez Blanco.

Eduardo Aguilera: And I am Eduardo Aguilera Fernandez.

Alicia Pérez: And we're here with Dr. María Belen Muñoz Garcia, a specialist in climate records in caves.

Melania Menéndez: And we're going to interview her about caves and groundwater. So, we'd like to start with what a cave is? because it seems like a very simple question, but it's not very clear sometimes. Any cavity, ok?

Belén Muñoz: Well, it's such a simple question that it actually has a fairly simple answer as well. There are many definitions of caves, but the one that is most used, the most common, it is any natural hole in the ground in which a person fits, that is to say that a pore of this size cannot be investigated by a speleologist, so it is not considered a cave. That leaves all artificial holes out of the definition — tunnels, mines, are not considered caves— and also leaves out some natural cavities that can be very important, for example, because a lot of water flows, ducts, fissures, but if a person does not fit and cannot be explored by a speleologist, then they are not considered caves.

Alicia Pérez: Ok, we already know what a cave is, there will be several types of caves, which are they?

Belén Muñoz: Well, there are many types of caves, and with that definition so broad, which is any natural hole in the ground, there are many. The most common are karst caves, which are formed by dissolution in soluble rocks, which are usually carbonates or gypsum; but they can be another type. There are caves that are formed by *piping,* groundwater moves within the aquifer, within the pores of a sandstone, moving the smaller granites of the sandstone to another place, to generate larger holes, it forms connected pipes that generate caves and sometimes collapses; they are quite dangerous. There are lava caves, lava tubes. Have you

never heard this? You know that when lava flows from a volcano, which can be at 800 or 1 000 °C, it cools very fast in contact with the air, but the inside part is still fluid; the outside one stays solid. In many occasions the tunnel is emptied, that is, the lava continues to flow until it is empty. And well, we have one of the largest lava tunnels in the world, the *Jameos del Agua*, in the Canary Islands. I don't know if you've heard of them.

Melania Menéndez: Well, no, the truth is, I at least had never heard of them.

Belén Muñoz: Well, lava tunnels are another type. There are caves in ice glaciers, for example, especially in the lower area of the glacier, there is more friction with the rock; it melts more, and then caves are formed could be seen in films like Ice *Age.* And then there are some that are quite curious and quite common, which are tectonic caves. You know that in tectonics, if a fault moves —you know what a normal fault is, an inverse fault—well; sometimes it moves dragging over the other part of the fault, but sometimes it moves separating them. Then there are caves, for example, which have two flat faces, which are the two walls of the fault separated; that's tectonic caves. There are so many types.

Eduardo Aguilera: Very interesting, and what about the climate conditions of a cave?

Belén Muñoz: Because there are so many types, they can be very different. I believe that for climate conditions in a cave we should separate them in those that are totally isolated from the outside and those that are connected to the outside. Those that are connected to the outside because by a connection zone, are more similar to the outside climate and then, the more inward, the more isolated, the climate is more different. What image do we have of the caves? Especially karst

caves —those formed by dissolution from meteoric waters— they are dark; they are usually very wet if there is enough drip; if there is enough rain in the area where the cave is and if they are well isolated, the average temperature of the cave is usually the same as that outside, above the cave, so there are very cold caves—in very cold areas, at very high latitudes— and there are very hot caves. I think that's a summary like that, broadly speaking.

Melania Menéndez: Well, yes, because as you say there is a great variety of caves and you have to summarize. And I wanted to ask you, regarding the process of cave formation, we understand that water has a very important role. Could you explain a little bit if this is true and, if so, how does water affect this formation?

Belén Muñoz: As you have already seen, there are many types of caves. In many it has nothing to do with water, but in the, let's say, more common with its stalactites and its stalagmites, there the water is fundamental in their formation, because they are formed by dissolution of the rock. So, I think you can divide the karst caves into two: those that are formed by meteoric water, which comes from rain or snow from the outside; and those formed by deep water, that these are usually caves that are much deeper and that normally cannot be explored by a speleologist until tectonics pulls them out. Of those that are formed by meteoric water, which are the ones that we all know best, are those that are above the “water table”; the water table I guess you do know what it is, which is the groundwater level. Ground water is filling all the pores of the rock up to a certain level, because that level that groundwater has is the water table. Then we have caves that form below the water table (phreatic zone), that have other different shapes and that if you have to explore them a speleologist has to be diving; and then there are caves that form above the water table, which are called vadose; and those are the ones that have the stalactites, the stalagmites, the speleothems are called; all that decoration is called speleothem. So, those drips that

you see is actually the meteoric water that's sneaking in out there, it's going through the cave and it's going to become part of the water table, of the groundwater.

Alicia Pérez: Ok, and considering that there are many types of caves, they will have to have some importance in the ecosystem from a geological point of view.

Belén Muñoz: Well, let's see, from the ecosystem in a geological point of view it's a bit of a weird question, but we're going to take it there. Normally, the ones that are connected let's say have fewer inputs, but the ones that are isolated are a little special space, so they're very isolated, they have very little energy exchange with the outside, they don't have light, they don't have any photosynthetic organism, they usually have very few nutrients, and it's a pretty special ecosystem. So, from that point of view, they're taking a lot of interest lately, because they're studying them to find extremophile organisms, to find organisms that could live in those very special conditions that would be similar to what might be on other planets, on Mars, for example. They're using it as analogues of the ecosystems that could be found on Mars. So, from that geobiological point of view, they're very interesting.

Eduardo Aguilera: And, are extremophiles the only types of animals that live in caves? What other types of animals are there?

Belén Muñoz: Do you refer to animals specifically or organisms in a broad sense?

Eduardo Aguilera: Organisms.

Belén Muñoz: In general, any organism living in a cave should have a slower metabolism than normal; be accustomed to surviving with very little nutrients and with very little of everything and it has to be adapted to live based on a source of

energy that is not the sun, because they have to take the energy from somewhere. So, there are extremophiles like fungi, bacteria, and all of them are being investigated a lot lately but, they cannot be seen frequently either. In most of the caves now, is applied an exudate from the walls and are coming out (they do a genetic study) that there are one hundred and twenty different taxa of organisms, but many do not even know what they are yet, they are unknown. And then there's another kind of organisms that have their grace as well, which are the ones that are most common on the outside, but they adapt to live inside a cave, and these are usually endemic to every cave. Then there are, for example, fish that live in a river; and some of those fish have adapted, they've entered the cave that has an underground river, and they've adapted to live inside the cave. There are frogs, well, amphibians of all kinds, many insects, spiders, they are very common; but these have adaptations to the dark: they are usually blind, they usually lose their pigment, and they have to adapt to live differently. For example, I recently read an article that talks about a food chain that is based on bat guano, because it's the only energy source inside the cave; so, there's a whole food chain with predators that are normally large spiders, in this case, that eat even fish, a brutal thing; and the origin of that whole food chain is bat guano, which is the only energy input there.

Melania Menéndez: Well, I was surprised by spiders eating fish; but hey, I wanted to ask you that, knowing that there are an immense number of caves and organisms that inhabit them, what kind of research is being done?

Belén Muñoz: Specifically, about organisms and life do you say? Or in general above all?

Melania Menéndez: In general; because it can be from a geological point of view, I suppose, as well as a biological one.

Belén Muñoz: Yes, yes. It is that in caves you can do a lot of things. So, I think that, let's see, we could talk about the investigations that have to do specifically with the formation of the caves; well, this that I have explained to you before: if they have been formed by meteoric water or by dissolution, or by such ... Well, that would be a kind of investigation. Another would be the shapes that the caves have in themselves; if they have larger, smaller cavities, when they have been formed, how long it takes to form, because it's not very clear, that's being reviewed now. Inside the caves there are archaeological and paleontological sites of animals that lived inside, and of ancient lords who lived inside and ate the animals as well. There are studies on how caves reflect the outside environment, for example, if there is more drip when it rains the most or where the water comes from or things like that. This is pretty scientific all around.

Applied research there is a lot about cave-related aquifers, because... I don't know what percentage of the population, but a lot (in the United States a lot) they take water out of cities from karst aquifers, it's one of the main sources of drinking water, and so there's a lot of study of hydrogeology in caves. There is also a lot of study of risks, because in the karst landscapes, by dissolution and movement, the corridors are changing, the rooms collapse... It's a landscape that changes pretty quickly, so... This, for example, there are more in China, there are quite a few problems in Siberia, of risks of people sinking roads or houses in collapsed caves.

What more research is there? All this I've told you about extremophile organisms, and then there are very curious studies, for example, in the Bahamas there are vadose caves that are known to be above the water table on the continent, let's say, they're now submerged; and then, because that allows them to know how sea levels

have changed in recent years. Then people dive, take a speleothem from the submerged cave, date it, and go on to say how the sea level has changed.

Then there's another example, very funny, which is in tectonic caves of Murcia, here in Spain, they've discovered, well, you have the cave that I've told you that separates and forms a cave with two planes, right? Well, this is getting a little calcite; If the water has the right composition, it's getting a little bit of calcite at the edges, so you've seen with temperature sensors, and that's before there's an earthquake, the water temperature gets very hot. So, well, they are considering placing sensors in different tectonic caves of the Baetics to be able to predict when there are going to be earthquakes; the thing is, that's very difficult, you'd have to have thousands of sensors everywhere, but it's a very interesting study. And then you're looking at the calcite that's grown over the last few thousand years to see that there are ways to know what temperature that calcite has precipitated at, how often the temperature has gone up, to know how many earthquakes there were. There are studies of the most varied in caves, you can do many things.

Alicia Pérez: And considering that there is a lot of research, we will have to be careful and protect the caves so as not to damage biodiversity, what care is taken?

Belén Muñoz: Well, all the caves the more isolated they are the more delicate the balance, right? of course, you have those organisms adapted to those conditions that are very specific, as soon as you change them, you can damage the organisms, you can also damage the speleothems. The fact that you enter a cave, if the cave is cold as it usually is here in Spain, for example, in the north, you are already warming the air of the room, your breathing is already introducing CO_2 into the atmosphere of the cave; all that changes the parameters; in fact, I investigate doing this kind of thing, all the measures you have to take must be done as you arrive, because if you

have been there for three minutes, you are already polluting the air of the cave. Then everything you carry on top of you, say the pollen, the dust, all the bugs, everything you wear on your clothes, can affect the organisms that are living there in the cave. This is not very studied, except (in Spain, what I know) in cases of endemic organisms that are very well known; that here, there is a very specific spider that only lives in this cave; then that area closes, protecting it very well. If not, normally, then you have a little basic care, not to step where you should not or not breathe where you should not, do not put hot lights for example. Many tourist caves used to have lights that gave heat, and that generated mosses around the lights as well and there were organisms that did the photosynthesis next to the spotlights, all of those are changing now. Then there's a very... This is a bit of a nasty case, but it's very curious. I'm going to tell you and if you don't like it you cut it off. There is a cave, which I will not tell you because it is known, but it is a little unpleasant the history, to which many tourists visit the cave, and it holds up well the visit of tourists, maintains its balance, everything grows, everything continues. And one day one of the tourists got into the cave and vomited, and then, two days later, the whole cave was full of a kind of fungi, I don't know, stranger, which was something he had in his stomach that quickly adapted; that is, he was able to colonize the walls of the cave in two days; and they had to close the cave to tourism, of course, until that disappeared and was regularized. But, that we lead a lot of life, on top, inside, and everything, that can affect that ecosystem and anyone, of course.

Eduardo Aguilera: And what impact is climate change and human activity having on caves? Not only open to the public but also closed.

Belén Muñoz: Human activity may have to do, for example, in karst caves. If you put boreholes, wells, and you are taking water to irrigate, you lower the water table artificially, that can affect for example the caves of the Mediterranean Levant,

because you leave them without water, you dry them; if they had underground rivers, they disappear…That's a very clear problem. Then, as climate change, the caves that are very isolated, as I have told you before, have a temperature that tends to be the average that is above the cave, then if our average is rising two tenths of a degree, then the temperature of the cave is rising slowly. It is not a thing in principle that will be noticed a lot. In the studies that I do, for example, I try to see the temperature of the past from the speleothems, there, yes you are going to see those variations; that's precisely what I study– how temperature varies over the past. If we change the climate at a global level (which it seems that we are) it will change the origin of the storms and precipitation, and the movement of the bodies of water, the whole energy balance of the planet will change; then, logically, places where it rains now, it will rain less, and caves that have drip will stop having drip; or places where it now rains regularly because it will only rain torrentially, seasonally; because all that will change the functioning of the caves and that in the end is reflected in the growth of the speleothems and the ecosystem that has inside, of course, too.

Melania Menéndez: Well, after having answered all our questions superbly…

Belén Muñoz: Thank you.

Melania Menéndez: It's true. We wanted to give you the chance in case you want to add something that you think is important.

Belén Muñoz: I think not, I think you've asked some pretty complete questions. Nothing, I thank you for having invited me to this. If you need to know more about caves and weather at some point, you know where I am.

Melania Menéndez: Well, thank you very much for all Belen, and I say the same.


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