Heart of Crystal: Beneath the Mexican Desert in Chihuahua[1]

Written by Juan Manuel García Ruiz

One hot summer day some years ago, Margarita Díaz, a geologist at the Complutense University in Madrid and a good friend of mine, phoned me at home. “They’ve found the Pliny mines in Segobriga and I want you to come and study the crystals,” she told me. I accepted immediately, as both of us knew what we were talking about: in the 1st century AD, Pliny the Elder had written his massive Natural History, a description in 37 volumes of all the information available about nature at that time, mostly collected by word of mouth by that tireless naturalist, who died taking notes during the eruption of Vesuvius in 79 AD.

In volumes XXXVI and XXXVII, Pliny describes the fantastic “*lapis specularis*” (selenite gypsum) crystal mines of Segobriga, from which sheets several inches thick were extracted. They were more transparent than our modern glass and were exported to Rome to cover windows and greenhouses. The introduction of plain glass technology into the capital of the Empire at the end of the century sank the Segobriga emporium and the Castilian mines fell into oblivion until ten years ago, when they were rediscovered and studied by a group of archaeologists from Madrid Autonomous University.

To explain the formation of the gypsum crystals – a calcium sulphate with two water molecules, up to one metre (three feet) long, still to be seen in Segobriga – was a difficult task, because no-one knows the geological history of the surroundings in sufficient detail: other similar cases were needed. I remembered an old photograph I had seen published in an article from the beginning of the last century. In the image the figure of a miner or a geologist indicated the scale of some clusters of gypsum crystals up to one metre (three feet) long. This was the Cueva de las Espadas, or the Cave of Swords, in the Naica mine in Mexico. I wrote off to apply for permission to make a study visit.

The Peñoles company, the present concessionaire for Naica, not only gave me the authorisation but had a surprise in store for me. In 2000, while engaged in exploration, they had discovered a crystalline cavern which the miners had baptised the ‘Cueva de los Cristales’ or Crystal Cave, which apparently totally eclipsed the Cave of the Swords. As my guide for the visit they appointed Roberto Villasuso, the engineer in charge of exploration of the mine, the man who knew most about the geology of Naica and, since then, my friend and colleague in solving the mystery of the megacrystals. Here, unlike Segobriga, thanks to the mining studies done over almost one century, we had data to test any hypothesis about the formation of these giant crystals, something a crystallographer is rarely fortunate to find.

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[1] This text is a translation of the paper published in National Geographic (Spanish edition) in the issue of November 2006. The article was also published in the Polish, German, Portuguese and the Mexican-Latinamerican edition of National Geographic. For technical and scientific details about the formation of gypsum crystals read: J. M. García-Ruiz, R. Villasuso, C. Ayora, A. Canals & F. Otálora, Geology, 35 (April 2007) 327-330.

Travelling west from Delicias, the road runs as straight as an arrow across the Chihuahua desert in the north of the country. On either side hares scamper around. Apart from them, there is nothing to disturb the peace of the surrounding landscape until you arrive at the mountain where the mine is. The mining town of Naica is on its lower slopes. The cool shadow the mountain casts at dusk over the town and towards the vast alluvial plain that can be surveyed from its peak illustrates the origin of the name to perfection: in the language of the Raramuri or Tarahumara – the Amerindian tribe that lives in the mountainous region of the state of Chihuahua – Naica means 'shady place'.

The mountain contains one of the world's largest deposits of lead, zinc and silver. Its bowels, rich in metal sulphates, have been exploited since 1828 and today Grupo Peñoles works efficiently and carefully, protecting the environment, helping to develop farming in the nearby desert and enforcing the safety standards required of modern international mining.

About 26 million years ago, a pocket of hot magma rose from the interior of the Earth and settled about 2.5 kilometres (8000 feet) from the surface. As it rose, it pushed the sedimentary rocks – mainly limestone – to form Naica mountain, and at the same time 'impregnated' it with high temperature mineral-rich fluids. Even today the embers of that magma, now extinguished, are responsible for the thermal anomaly of Naica. Indeed, when you go down to the mine face, water which can reach a temperature of 55º C seeps out of the walls, sometimes bubbling ominously for a visitor who – despite his training as a geologist – is feeling for the first time what it means to have a kilometre (3000 feet) of rock above his head.

In their search for the precious mineral, the owners of the mine have created a fabulous network of underground roads that bore through the mountain. Spiral ramps form the skeleton of that network, making it possible to take a van down even as far as the mine face, now at a depth of 760 metres (2400 feet). If we bear in mind that the original level of the underground waters was 120 metres (380 feet), we can glimpse the daunting technical challenge of the Naica mine. The Peñoles engineers have solved the problem by using the two different fault systems with NW and SE orientations that enclose the mineralised zone as barriers and pumping 55,000 litres (14,000 gallons) of water per minute through them. That enormous flow, which enables work to take place in the mines at depths that were always flooded before, runs steaming down through the streets towards the desert, where an agriculture that would once have been impossible now flourishes.

The Crystal Cave is a great horseshoe-shaped cavity in the limestone rock about 10 metres (30 feet) wide and 30 metres (90 feet) long. The gypsum crystals it contains are only a late by product of the mineralisation. Along with other, smaller cavities it is at the 290-metre (1000-foot) level, 170 metres (540 feet) deeper than the Cave of Swords at level 120. We go down to study them in a van along the underground ramps which, since they are constantly ventilated, are at an acceptable temperature of about 35º C and 45% humidity.

Before we go in, observation of the rocks around us confirms that the caves are next to a secondary fault associated with the Naica fault, in other words a structure which helps circulate the underground waters. We also observe the presence of seams of a mineral called anhydrite, identical to gypsum but without the water molecules, an anhydrous calcium sulphate, hence the name. The cave is separated form the ramp by a 20 metre

(20 yard) corridor at the end of which is a door that serves as an entrance control and, with the corridor itself, provides a certain heat insulation which keeps the interior of the cave damp and at the natural temperature of the system.

The first time you enter the cave is an unforgettable experience, but you soon realise that the ones that follow will be so too. The sight is unique in the strict sense of the word, because there is no other place on the planet where the mineral world reveals itself in such beauty.

The floor is covered in huge, colourless, crystalline, perfectly faceted blocks. Other crystals jut out of the walls and the ceiling, aligned along fine cracks which with the main fractures and faults, were the strategic places for the circulation of water in the rock. But more than that, from the blocks and the floor of this cavity enormous crystals – called ‘beams’ by the miners – emerge. They are almost one metre (three feet) wide and soar above the cave floor reaching lengths of … over ten metres (over thirty feet)! The great gypsum crystals are called selenite in honour of the way they shine like the light of the moon – Selene in classical Greek mythology.

As a crystallographer, I spend much of my time in the laboratory trying to obtain the formation of minute crystallites of important substances in biomedicine and pharmacology that are difficult to crystallise, such as proteins, nucleic acids or various drugs. Perhaps that is why, after the first minutes gaping at that prodigious sight, I burst out laughing at the proof that it was possible to grow megacrystals, every crystallographer’s dream, in the immense flask of this cave, all isolated from one another to show their loveliness to even better advantage. There was so much beauty, so much symmetry and so much pure reason hidden in this cavity 300 metres (1000 feet) below the ground!

I touched the surface of the crystals with devotion and had the same feeling as when looking at an illustrated manuscript, something unique that had survived the vicissitudes of time, but as though it was made to be admired in the future.

Leaving the cave, I looked back and saw the overall image of the crystals again with their pale moonlight shimmer, emerging from the red background of the walls of the cave covered with a patina of calcite and celestine with a hint of iron oxides. I knew that I would have to go in again to study the phenomenon in detail. Questions rushed into my mind: Why aren’t the walls covered in small crystals as in a geode? Why had so few crystals formed, but of a size never reached anywhere else on the planet?

Outside the cave I realised that I was soaked through and had lost my glasses. Apparently, with the sweat streaming down my face and the lenses steamed up, I had inadvertently left them inside. The fact is that there is nothing common about the atmosphere of the Crystal Cave. Although the temperature and the humidity vary according to the atmospheric pressure outside the mine, the cave is usually between 45 and 50º C with more than 90% humidity. It is not easy to work inside. Imagine that you are in an enormous Turkish bath, but dodging obstacles on either side, searching for signs to unravel a mystery, thinking about where to take samples, deciding what is important and what is secondary, how to take the photographs… You would be grateful for more pleasant conditions, but there are no serious complications if you take the necessary precautions: keep properly hydrated and keep the time you stay inside strictly to ten minutes. In the end that was how we did the job and when the assistant announced that the ten minutes were up we always came out sweating and exhausted, but happy.

In an article on the largest crystals in the world in 1932, the famous American geologist Charles Palache posed the following question: What size can crystals grow up to and why? Now we know the answer, and it's simple: there is no limit to the size a crystal can reach. A crystal can grow indefinitely; the problem is maintaining the conditions for that to happen. And those conditions are none other than the ones that guarantee a continuous provision of material for the crystal to grow and for that provision to be small and slow enough for new crystals not to form. Our laboratory experiments show us that it is very difficult to obtain a gypsum crystal much more than three centimetres (one inch) long. What happened in Naica for them to be able to reach the ten metres (thirty feet) so easily?

The caves were formed along with the great faults and fractures through which the water circulated, dissolving limestone rocks. At these depths the caves were permanently flooded. When, after the formation of the metal sulphates, the magma cooled and the waters mixed with the phreatic ones derived from the runoff, the temperature of the rock dropped to 58ºC. It was then, just around that temperature, that the transition occurred: the anhydrite began to dissolve slowly enriching the waters with sulphate and calcium molecules that for millions of years have been deposited in the caves in the shape of great selenite crystals, the largest and most beautiful known in the world to date.

To sum up, we can state that the presence of anhydrite, a precise, stable temperature – around 58º –, with waters with minimum sulphate and calcium saturation over a long period of time were the artificers of the Crystal Cave and the Cave of Swords. Analyses of the fluid inclusions we have found in the interior of the crystals, which have been done by Carles Ayora from the Jaume Almera Institute and Àngels Canals from Barcelona University, have corroborated this hypothesis, as have our calculations of the thermal history of Naica done with the help of Fermín Otálora, from the Crystallographic Studies Laboratory in Granada.

The likelihood of this set of conditions occurring in other places on the planet is so low that it makes Naica unique in the mineral world. As such, of course, it deserves to be preserved. It must be kept safe from the pillage suffered by the Cave of Swords, visits must be controlled and the humidity necessary to prevent loss of water from the gypsum maintained. The great crystal 'beams', which reach an average weight of 40 to 50 tons, have lost stability now that the water has been extracted from the cave and therefore they have to be secured with props. However, the final question is, what will be done with the caves when the mining exploitation comes to an end? If the pumping of the water were stopped, the mine would flood again in a couple of days. The Crystal Cave and the other cavities hidden in the bowels of the Naica's Mountain would return to their natural state, drowned by waters saturated with nutrients and the crystals would grow once more. But no-one would ever enjoy their beauty again. The decision would not be an easy one, but it will have to be taken one day.

Now, back to Spain, our team is ready to apply the geological learning gather from Naica to reveal the mechanism of formation of the gypsum crystals of Segobriga. It might be that the “Shady Place” of the Tarahumara would shed light on the formation of the roman “*lapis specularis*”.[2]