Crystal Giants

in the caves of Naica

LA VENTA


NAICA
Proyecto

January 2006, first trials of the Tolomea suit; for the first time Cristales may be explored, with no hurry.

Crystal Giants - in the caves of Naica
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Introduction

Our first visit to Naica was in 2002. We became acquainted with its crystal bridges thanks to an invitation from our friend and member Carlos Lazcano, who first experienced their indefinable charm. Since then, Naica's extreme environment and its alien characteristics have been part of our dreams, our technological experiments and our hypotheses.

It has been appropriately said and written that the Cueva de los Cristales (together with its neighbours Ojo de la Reina, Espadas and Velas) is more in touch with the depths of the Earth than with its surface. Totally isolated from the outside, it was discovered thanks to the mining activity.

If it is already a difficult task to describe the ordinary underground world, which for good or bad is part of the human experience, it is a hard task indeed to describe a world which is completely "different", even to speleologists. Cristales has been described as the most extraordinary cave on the planet and will certainly become, if it isn't already, the most studied. Studied also, in the most unusual circumstances due to the mining activities which originally brought it to light. The giant crystals of Naica were formed underwater but the subsequent lowering of the water levels by pumping, which now allows us access to them, has stopped their growth and may eventually lead to their destruction. We don't know what will happen to them in the near future; we don't know if human activities will lead to their end or to their salvation. We can't even define what end or salvation means for Cristales. We do not know how many more Cristales exist inside the Earth crust, or if we ran, by pure chance, into a geological and mineralogical unicum.

The future of the mine involves also the destiny of Naica and its inhabitants, who have been extracting for generations precious minerals from the sultry depths of the sierra. Should the mining activity come to an end one day, the presence of Cueva de los Cristales, even if not physically usable, will help this place to survive, in ways that we are only starting to imagine but that surely are possible. So, one thing we know for sure: our meeting with the cave first, our journey with it from then on, burden us with a wonderful responsibility, that is studying and communicating it to the world. We are doing it by articles on magazines and TV programs, collaborations with universities and institutions all over the world, documentaries and films.

What you are holding is our small contribution towards describing and explaining this place, which is important not only for speleology and speleologists but also for the Earth and its inhabitants. One of those contributions which will remain when Cristales will probably be no more than memory. With the hope, of course, that the Naica crystals will enjoy good health for the next million years.

Tono De Vivo
President of the association La Venta

The giant crystals are mainly concentrated nearby the entrance; their total number is approximately 170.

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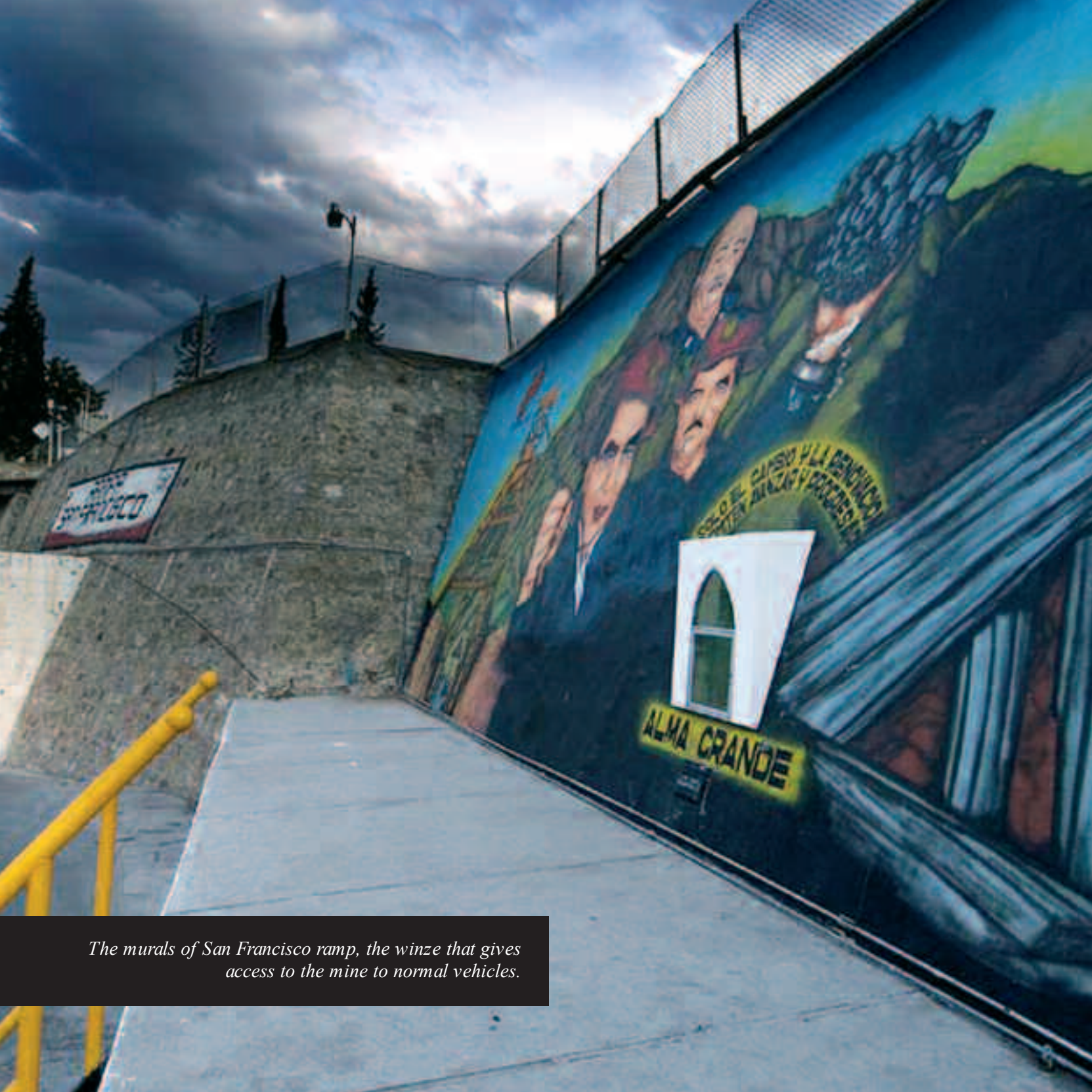


The murals of San Francisco ramp, the winze that gives access to the mine to normal vehicles.

The Naica Mine

Naica is a small mining town located on the slopes of a small relief in the northern Mexican state of Chihuahua, 130 km south-east of the homonymous capital city.
According to local tradition, Naica means "place without water" but it is much more likely that the term is of Tarahumara origin, coming from the roots Rarámuri "*Nai*" (place) and "*ka*" (shadow), meaning "shadowy place", as justified by the shadow projected from the isolated mountain range onto the surrounding desert.
The history of Naica, apart from the presence of the native Apaches between the 16th and 19th centuries, who dedicated themselves to attacking the coaches on the ancient royal way to Chihuahua, is substantially tied to the growth of the mining industry, today world famous and carried out by the Mexican company Peñoles.
The presence of minerals in Naica was discovered in 1794, when "*una mina ubicada en tierra virgen con el nombre de San José del Sacramento, en la Cañada del Aguaje de la sierra de Naica*" was registered.
The exploitation of the poly-sulphide deposits (silver, zinc and lead) only began in 1900 and continues today, under the Peñoles mining company, in what is one of the most productive mines in Mexico.
The Naica mine opens on the north-west side of a dome-shaped structure that rises suddenly from the surrounding desert plain. It is 12 km long and 7 km wide, oriented NW-SE and displays secondary folding, faults and signs of erosion. This structure, known as the Naica Sierra, has an average altitude of 1700 m asl and consists almost entirely of limestone rock.
The Naica Mountain range presents a system of faults and fractures, formed prior to the mineralization, that run parallel to the main axis of the dome, oriented NW-SE and dipping SW until reaching verticality. Along this system of fractures are located the main sulphide veins as well as the four caves which are known up to the present time (Espadas, Ojo de la Reina, Velas and Cristales), which lack natural entrances and can be compared to deep geodes.
The altitude of the plain surrounding the Naica Mountain range is approximately 1250 m asl, while the entrance of the mine (Rampa San Francisco) is at 1385 m asl. From here on, the "depths" are given relative to this height.
Inside, one reaches the water table at -120 m, therefore approximately at the altitude of the plain. The pumping which was carried out in order to allow the mining activity in the past decades has lowered this level to the current -850 m, emptying, among others, the Cueva de los Cristales, which is thought to have remained flooded by thermal water until about fifteen years ago.
Currently, slightly less than a cubic metre of water per second is pumped out, which in the deeper zones has a temperature of 54 °C.

The territories of Chihuahua and Naica

The word "Chihuahua" usually brings to mind a breed of small dogs, but it is above all the name of a large state in north-western Mexico, bordering on Arizona and New Mexico in the United States. It is also the name of the state's capital city. The state has a surface area of 250,000 square kilometres, nearly as much as Italy, and also the capital city is large, with over 800,000 inhabitants.

The thing that strikes a visitor the most are the stores containing "vaquero" (better known as cowboy) handicrafts. They sell locally produced hats, boots and belts which are the pride of the city and they are absolutely without rivals in this field. The products, always very well made, range from true jewels of handcraft to great examples of *kitsch*.

Geographically it is an arid and relatively flat territory, situated at a fairly high altitude (between 1000 and 2000 m) which mitigates the climate. It is crossed from south to north by an important road which connects Torreon (Coahuila) to Ciudad Juarez-El Paso, one of the main connections between Mexico and the United States.

To the west, the plain rises to more imposing heights which then quickly fall back to the sea with a series of deep valleys, cliffs and canyons which form the "Barranca del Cobre", certainly one of the most impressive geological structures on the planet. It is said that it is what Colorado's Grand Canyon wants to become when it grows up…

Location of the Naica mine.

This area was inhabited by the native Tarahumara tribe who, by the way, really did breed the tiny dogs, which then took the name of the state when "discovered" in the 19th century. It was a Uto-Aztecan population which acted as a connection between the empires of the central plain and the nomadic populations of what is now the United States.

In the north of the state, 300 km from the capital, is the Paquimé site, one of the most important cities of the Aridoamerica cultural area, which flourished approximately one thousand years ago and was abandoned at the beginning of the 15th century.

This area of impressive ruins is a UNESCO World Heritage site.

The area to the west of the capital, centred on the city of Cuauhtemoc, is one of the main settlements of Mennonite Anabaptists. Of Swiss origin, they escaped the persecutions to which they were subjected by both Protestants and Catholics. Strict pacifists, they lead a life dedicated to prayer and work, renouncing modern technology, whether motors, electricity or whatever else.

To the south of the city of Chihuahua, the road towards Mexico City, 1400 km away, extends in an interminable line through semi-desert until the city of Delicias, of over 100,000 inhabitants and where it is possible to make purchases and to find restaurants or lodging. From there a small road heads south-west and after about 40 kilometres arrives at a mining town: Naica.

The Naica mining village is located in a desert area, practically lacking in local drinkable water resources.

Several crystals exceed 10 m in length; the main one, named "Crystal Cin", is 11.4 m long.

The Discovery of the Naica Macro-Geodes

As early as 1910 a cave was found in the Naica mine at a depth of 120 metres. It had a length of approximately 80 metres and its walls were entirely covered by selenite crystals up to 2 m long. The crystals bore a similarity to sword blades, and so the cavity was named "Cueva de las Espadas" (Cave of the Swords).
The beauty of this cave touched the miners, who closed it and preserved it from destruction, equipping it with wooden ladders for visits.
In April 2000, the Eloy brothers and Francisco Javier Delgado, miners, digging an exploratory tunnel at the depth of 300 metres, intersected a very small passage in the rock.
Francisco entered with difficulty and emerged in a cavern with a diameter of approximately 8 metres, similar to a geode, full of selenite crystals similar to those of the Cueva de las Espadas but much larger and more spectacular; the cavity was named "Ojo de la Reina" (Eye of the Queen).
The brothers, fascinated by the discovery, suspended the digging and informed the mine's director, engineer Roberto González Rodríguez, who ordered that work on the tunnel be continued in different direction in order not to damage the crystals.
A few days later a new chamber with a diameter of approximately 30 metres was discovered, containing selenite mega-crystals up to more than ten metres long and over one metre thick. However, the miners had to suspend the exploration of the cavity because of the extreme environmental conditions there. The temperature approached 50° C with a relative humidity close to 100%, conditions that are fatal within a few minutes.
As before, the direction of the tunnel was changed and the cavity was fitted with a steel door in order to isolate it and to prevent pillaging.
The cave was called "Cueva de los Cristales" and the exceptional nature of the discovery was very soon known to specialists around the world.
In January 2001 it was visited for the first time by Carlos Lazcano, a veteran of Mexican speleology and a La Venta member, as well as by Claude Chabert, French speleologist of world-wide reputation, accompanied by Enrique Alejandri Escoto, head of mine security, and by the young guide Carlos Valles Carrillo.
The few minutes stay allowed by the hostile environment was enough to confirm the exceptional nature of the natural phenomenon and the first images were taken of those fabulous mega-crystals, which kindled extreme interest and curiosity among experts worldwide.
The environmental difficulties and the desire of the mining company to preserve this treasure prevented systematic research, or even a survey and complete exploration, until the beginning of our "Proyecto Naica" in January 2006.

The centre of the chamber is relatively empty, the giant crystals being concentrated on the southern and eastern sides.

The most delicate caves of the world

The Naica caves formed at great depths in very hot and mineralized waters, in nearly complete isolation.
From the beginning of the 1990s, the pumping operations at the mines have caused them to emerge from the water and this created a completely new and unstable situation. Their accidental discovery, a decade later, has aggravated the situation, even if in a limited degree thanks to the mine's administration which closed them and forbade access.
Their current state is unstable and lies completely outside equilibrium. To study these unique specimens of the Earth is a little like trying to understand the physiology of an unknown fish while it is dying outside of the water… On the other hand, if they were in their natural state, we could not even dream of seeing them.
The human impact cannot be eliminated, whether in the research phase, brief but of strong impact on virgin areas or in the documentation phase, long but on known areas. Also the mining work, although this is what allows us to keep this window on the depths of the planet open. The human impact is one which cannot be eliminated, but should be limited as much as possible. The causes of damage are numerous.
The first is without doubt the damage caused by the movement of persons. Gypsum is a very delicate material, which is very easy to chip or scratch.
To counteract that, we have set up some partially protected standard passageways and use shoes with a very soft and smooth sole which were especially developed for this use by Garmont SpA. We also enter with our shoes and clothes being as clean as possible. Moreover, visitors are trained in a type of walk which limits the damage to the crystals.
A second source of damage is the general cooling of the cave - the temperature is sinking half a degree per year - due to the slow cooling of the mountain caused by external air being pumped in for the mine works. Equally harmful is the opening of the doors, because it creates a weak air circulation, which is greatly increased when explosive charges are set off in the mines. These two processes are starting to cause condensation, which can be harmful because the water melts the gypsum and transforms it into tiny calcium carbonate crystals, creating a white patina on the large crystals. So far this has not happened, but it must be prevented at all costs. At the beginning we also feared damage caused by scientific sampling, but in fact these fears were misplaced. It has always been possible to collect tiny samples, use already broken fragments or even collect samples from other parts of the mine.
Even collapses have been very limited. Three very large crystals have fallen in remote times (at least one hundred thousand years ago), perhaps because of earthquakes. Another crystal, thin and perhaps too long, collapsed recently, perhaps due to the loss of floatation when the cave emerged from the water. Finally, there have been small losses from two or three crystals on the ceiling.
The risk of damage caused by plunderers has been eliminated by the presence of the reinforced door. In fact, the macro-crystals defend themselves quite well, since transporting a large weight on such insidious terrain and in those ferocious environmental conditions is nearly impossible. As a matter of fact, already on the first exploration with the Tolomea suits, we found a three metre long crystal with an approximately 15 cm side cut in half: The door's protection had arrived just in time…

All over the mine wonderful crystallizations were found, mainly composed of gypsum.

In Espadas crystals are smaller than in Cristales, but contain impurities which make them more interesting from a scientific point of view.

On the crystal balcony in the top area of the cave. The total difference in level of Cristales is 12 m.

The association La Venta in Cristales

The first inspection by our association took place at the beginning of 2002, after an invitation by Carlos Lazcano, with a quick visit to the caves in order to become acquainted with the extraordinary nature of the phenomenon and in order to make a first quick photographic and film documentation. The following October a second inspection took place and this time we were better equipped to resist the extreme environmental conditions for longer than normal. The temperature at floor level turned out to be 47.1° C, while at 2 metres height it rose to 47.4° C, with humidity next to saturation. In such an atmosphere our body cannot get rid of heat through evaporation; it is like dipping oneself in flowing water at that temperature, absolutely far too hot. The feeling is one of burning, because cells begin to break down at 43° C.

The most important result obtained by these investigations was to understand the operating context: Any research in those environmental conditions was practically impossible without specific technical methods and special protection. We therefore decided to develop equipment which would allow extended stays in high temperature environmental conditions, which would open the doors not only to Naica but also to other climatically similar caves. The collaboration between ourselves, the Department of General Physics of the University of Turin and the Ferrino Company has allowed the development of a first prototype of conditioned suit and respiratory units. This system has been called "Tolomea" in honour of a zone in Dante's Inferno (Canto XXXIII).

> *"... là 've la gelata*
> *ruvidamente un'altra gente fascia"*
> *("…where frozen water wraps*
> *a rugged covering--still other sinners")*

In January 2006 we signed an agreement with the Peñoles Company, holder of the mining concession, for the exclusive right to scientific studies and photographic documentation of all the caves intersected by the mine. The "Proyecto Naica" is managed by the Speleoresearch & Films Society, the video and photo documentation is taken care of by the Mexican C/Producciones, and the exploration and research by the association La Venta in cooperation with several research institutes around the world.

At that time we were also able to carry out the first tests of the Tolomea suits, remaining inside more than an hour and undertaking a first rough survey.

A series of eight expeditions (as of January 2008) have followed, which have resulted in a radical broadening of our knowledge concerning this cave.

The project will continue for some years, with an average of three expeditions per year. The final objective is the completion of the studies, by now well underway, and then the protection of, and the dissemination of information on, this extraordinary phenomenon.

The Hostile Environment and the Techniques Used

The temperatures encountered in the Cueva de los Cristales, by themselves do not appear to be exceptionally high. Other parts of the planet have reached higher values: The highest recorded temperatures in free atmosphere were 58 °C at El Aziz, Libya in 1922 and 57 °C in Death Valley, California in 1913.
However, the air in those localities is very dry, so a human body can maintain a normal skin temperature thanks to continuous evaporation which allows even long-term survival, so long as drinking water is available.
But if the air has high water vapour content, the thermal effect changes radically. On one hand, evaporation stops and the body becomes incapable of getting rid of heat. On the other hand, and much more seriously, the skin and the inside of the lungs behave like "cold walls" on which the water vapour condenses, releasing large amounts of thermal energy.
In practice, the inhibition of the evaporation processes makes being in an atmosphere saturated with humidity at temperatures above 35-37 °C equivalent to being immersed in running water at the same temperature, therefore quickly leading to heat stroke due to the body not being able to get rid of the base heat it produces.
At slightly higher temperatures other processes start, not tied to the physiology of the body, but to those of the single cells. The maximum acceptable temperature for water in which one can immerse oneself is between 40 and 42 °C. At a higher temperature the feeling is that it burns insupportably, which is true, since above 42° C human cells break down and die. For this reason very high fevers (over 41.8 °C) cause irreversible damage to the human organism.
The situation is therefore that, in a very humid atmosphere, a temperature above 32-35 °C is fatal in a relatively short time, in the order of an hour, but above 42 °C it is fatal within ten minutes or so and furthermore there is the risk of burns. Technically speaking, one is being steam cooked.
The HUMIDEX index was developed in Canada in the 1960s in order to show the temperature effectively experienced by the human body, as a function of temperature and air humidity.
Using the table on the following page it is possible to quickly obtain, from the measured temperature and relative humidity, the temperature value that the human body perceives.
The table shows that a Humidex index beyond 45 is a situation of serious danger while above 54 the risk of death comes into play. In the Cueva de los Cristales the index varies between 90 and 95, which limits survival to 5-10 minutes.
The temperature is truly insupportable, especially at the first impact. In practice one can resist half-naked for a few minutes, because the ambient heat requires some time to

become truly dangerous, meanwhile the skin temperature is kept to tolerable levels by an intense flow of "cold" blood, thanks to an enormous peripheral vasodilatation. This effect is only temporary and subjects the heart to great effort, after a few moments it beats like during extreme exercise while a sense of dizziness increases.
The most alarming 'unknowns' that the atmosphere of the Cueva de los Cristales presented were those tied to the effect of the condensation in the lungs, which could involve, before being burned, the risk of death by acute pulmonary edema, as well as the risk of burns to the eyes. We considered the problem.
Defending our body from high temperatures is a much more difficult problem than defending it from cold, because we ourselves produce heat, approximately 100 W basal plus 100-300 W for physical activity. In order to survive in cold environments good thermal insulation is sufficient, because even moderate activity allows us to keep warm. Any increase in activity, and therefore increased heat production, can be compensated by a reduction of the thermal insulation – for example, one removes a sweater.
Instead, in a very hot and humid environment, the environmental heat is transferred to us not only by conduction through the air, but more especially by releasing the latent evaporation energy if the vapour condenses on us, which happens if our surface has a temperature below the "dew point" of the surrounding air. To this heat deposited from the air, we need to add that produced by our body, which increases greatly with the amount of physical activity.
The thermal situation is therefore untenable and the capacity to remain in such an environment is consequently limited.
The first explorations of the Naica caves were carried out with minimal clothing, in line with the common belief that in a warm atmosphere it is best to be half-naked.
During the first inspection, in 2002, we carried out the first tests aimed at extending our ability to remain inside,

The red area represents temperature and humidity levels incompatible with life. In Cristales the index is 90-95.

temperatura (°C) temperature \ umidità relativa (%) relative humidity	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
21	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	29	29
23	19	20	21	21	22	23	24	24	25	26	27	28	28	29	30	31	31	32	33
25	21	22	23	24	25	26	26	27	28	29	30	31	32	33	33	34	35	36	37
27	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
29	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
31	28	29	30	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
33	30	32	33	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
35	33	34	36	37	39	40	42	43	45	47	48	50	51	53	54	56	57	59	61
37	35	37	38	40	42	44	45	47	49	51	52	54	56	58	59	61	63	64	66
39	37	39	41	43	45	47	49	51	53	55	57	59	61	62	64	66	68	70	72
41	40	42	44	46	48	51	53	55	57	59	61	63	66	68	70	72	74	76	79
43	42	45	47	49	52	54	57	59	61	64	66	69	71	73	76	78	81	83	85
45	45	47	50	53	55	58	61	63	66	69	71	74	77	79	82	85	87	90	93
47	47	50	53	56	59	62	65	68	71	74	77	80	83	86	88	91	94	97	100
49	50	53	56	60	63	66	69	73	76	79	82	86	89	92	95	99	102	105	108
51	53	56	60	63	67	71	74	78	81	85	88	92	96	99	103	106	110	114	117
53	55	59	63	67	71	75	79	83	87	91	95	99	103	107	111	115	119	123	127
55	58	63	67	71	76	80	84	89	93	97	102	106	110	115	119	124	128	132	137
57	61	66	71	75	80	85	90	95	99	104	109	114	119	123	128	133	138	142	147
59	64	69	74	80	85	90	96	101	106	111	117	122	127	132	138	143	148	153	159

Some crystals collapsed some tens of thousands of years ago and then re-crystallized along the breaks.

increasing the thermal insulation and devising a first system to cool the inhaled air which also blew cold air on the eyes, preventing burns. The operating period was thus raised to nearly 30 minutes.
These tests have allowed us to scientifically develop some personal conditioning systems, which allow prolonged stays (up to 1.5-2 hours) in environments of this type. These systems, developed in collaboration with the Department of General Physics of the University of Turin and with Ferrino SpA, now allow speleological explorations and systematic scientific research.
The system consists of two parts, the overalls and the breathing device.
The overalls consist of a passive system of heat absorption, made up substantially of an "ice suit" inserted between a series of layers of thermal insulation and radiance reflectors, directed towards the body as well as to the outside. The outside layer is waterproof in order to prevent the condensation from getting the inside wet. The heat absorption capacity is approximately -0.5 kWh, which allows a stay of between 50 and 60 minutes with strong physical activity and up to 80-90 minutes keeping still.
We have also developed a much lighter version (-0.15 kWh) in order to give protection during short stays of 15-30 minutes, which are in fact the most common.
The development of the inhaled air conditioning system has been much more troubled, as it contains active parts, taperings and condensation accumulation areas which have caused many problems, in a couple of cases nearly fatal ones. The air is forced through a torturous path in contact with ice and then blown onto the mouth and eyes through a thermally insulated tube.
We currently use two models, differing only in size and autonomy.

The topographic survey required the longest stays, up to more than one hour.

The Topographic Survey

The topographic survey of a cave has the purpose of being able to produce a drawing of it, to understand its relationship with surrounding structures and, if done particularly well, even create a three-dimensional model of the cave.
Surveying is usually carried out by a team of two, one who goes ahead and selects the next survey station while the other, from the exact location of the previous station, sights the new one and obtains the length and orientation of the segment (leg) which joins them. Then a series of three sketches are made (horizontal, vertical and transversal sections) which will allow accurate drawings to be produced outside of the cave.
After these measurements, the second member joins the first, who then advances to choose the next survey station.
Surveying a cave is intrinsically slow and painstaking, all the more so when greater accuracy is needed. Of course the extraordinary nature of Cristales has obliged us to survey and to record detail at a level of accuracy which would be ridiculous in any other cave.
The measurements have therefore been much more difficult to obtain and on one occasion carried us to the very limits of survival.
We also had to consider various "philosophical" issues: What exactly must be surveyed? Never before have we been so aware of the fact that mapping caves is the product of a particular cultural context: We see and take note of that which we consider important, which is a series of things that vary greatly through time. If cave maps produced over the course of the 20th century are compared, one notices that the differences can be astonishing, reflecting very different ways of "reading" the surrounding environment.
The problem in Cristales is that we do not know what is important and have therefore carried out a series of surveys of increasing accuracy, as we slowly learned what mattered and - perhaps – what didn't.
Is a transparent crystal wall occupying hundreds of square metres the wall of the cave or is it instead a filling to draw within the cave? The crystals themselves, should they have been drawn in and surveyed one by one, or, as is usually done with concretions, simply disposed of by marking the area as containing speleothems? Depending on what one decides, the map of the cave is completely different. The stuff of nightmares…
In the end, we have tried to apply reasonable solutions, but the result, we have to admit, does not really work. So far we have surveyed 217 metres of main legs, plus several dozen metres of connecting legs, spending approximately 20 man-hours in that 'hot oven'. The perimeter of the main chamber is 109 metres, that of the high branches above the entrance (Southeast) 42 metres and that of the farther and more interesting branches, to the Northeast, 68 metres. However, the cave promises further development.
We have also begun a systematic topographical survey of

In order to carry out more precise drawings we took pictures of every datum point, identifiable by the surveyor's sign.

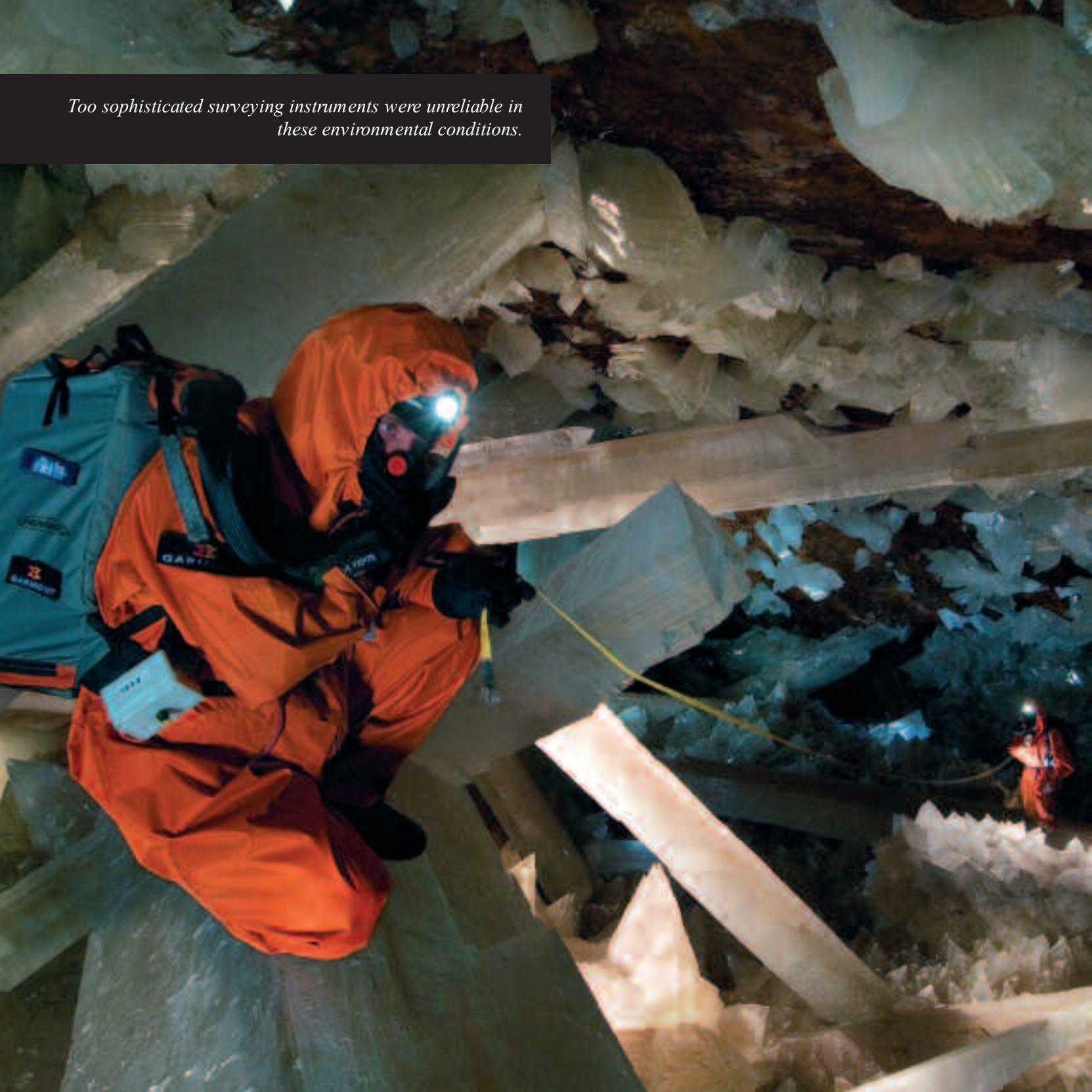
Left, perspective view from North of the crystals tangle; up to now 149 were surveyed.

Bottom, the horizontal plan of the cave.

the single mega-crystals. We estimate that the main chamber contains about one hundred mega-crystals, with several dozen others in the SE and NE branches. The 149 crystals surveyed up to now should be about 90% of the total.

Confronting the survey of the Cueva de los Cristales as a geographic entity has taught us that what we show here is not the map of the cave, but rather one of its possible maps; that small cave should be interpreted in many ways, because it is infinitely more complex than what we expected.

It is indeed worth the effort. Every metre of survey, every piece of information that comes out from down there, is a magnificent success which helps transform that incredible place - that mad dream turned into stone - into a physical reality; slowly also transforming it into a part of ourselves. In the coming years we hope to carry out large projects down there, with the most innovative technologies. Therefore we hope that in time, maybe only a little time, this current map will seem awkward and meagre. But we know that, even after decades have passed, we will be very proud to have been able to do it, that first time.



Too sophisticated surveying instruments were unreliable in these environmental conditions.

The difficulties of surveying in Cristales

Any complex undertaking in Cristales meets that mother of all difficulties, namely, the operating environment. Surveying is particularly difficult. One is within a cumbersome suit, awkward, exposed skin burns, in order to speak one has to take off the mask and feel the hot vapour which tries to enter the lungs; the unease grows quickly. One must therefore carefully prepare himself before entering; think a lot about what and how to do things, in order to then carry them out in those conditions in the shortest possible time. The phase that precedes the outfitting, in the antechamber, is therefore complex and tense, then "the descent" is intense and risky. For these reasons one tends to operate with a little anxiety, in a hurry, clumsy, time passes, must hurry, finish up… and that is exactly what should not be done in there. Movements must be slow and deliberate; otherwise it leads to agitation, hyperthermia and mental confusion.

Then there are the difficulties hidden in the details, first of which is the accuracy that we want to obtain. The cave is pretty small, but it is necessary to change the level of "reproduction" here, as a normal survey isn't nearly good enough.

There is another problem; what must be surveyed? In Cristales we do not know what is important. It is a unique example, a forgotten window open onto another world, a cave fundamentally alien to our speleological culture, forged from caves that belong to the atmosphere, not to the depths of the Earth. So here, poor surveyor, even if your hands didn't tremble for other very good reasons, they would tremble in any case from uncertainty. You have just a very few, very expensive minutes available, what do you do? You know that you have to collect far more information than usual, without however being sure of knowing how to select it and of actually being able to collect it.

Another very serious problem has been to decide what to draw into the map. Are the crystals stuff which filled up the cave, or is "the cave" the one in which we pass through, that is, the part outside the crystals?

Then there is the problem of the time needed in order to survey, which is very limited. A survey is an operation which should not be interrupted; it should begin and end in a single session, especially if accuracy is a main goal. But to achieve that in that hot oven, we have to admit, is not at all easy. Until now, the cave had never been surveyed; it is impossible to map Cristales in dozens of sessions consisting of three blistering minutes each. Then there is the problem of drawing. One is in a hurry, hands have great difficulties making precise movements, they shake too much; drawing is a nightmare. We noticed this problem almost immediately and found the solution: To photograph each shot, with the subject indicating the survey station number with fingers and then make the drawing itself outside. As could be expected, the instruments do not work well either. They must first be warmed up before entering (even the note pad); otherwise condensation will prevent any reading or annotation. It also goes without saying that the laser rangefinder does not work on the crystals and therefore, after having practically "boiled" it in a sealed container, one must aim it at a companion or at one of the rare rock tracts that emerge from the sea of crystal. Aim is obviously often off and one tries and retries, while the clock ticks away and uneasiness transforms itself into suffering. One is tempted to resist in order to finish the job.

To resist? That is another thing that definitely should not be done: when it is finally decided to exit because the situation has become intolerable, one discovers that the planned time to exit has long passed and the crisis is by now in progress.

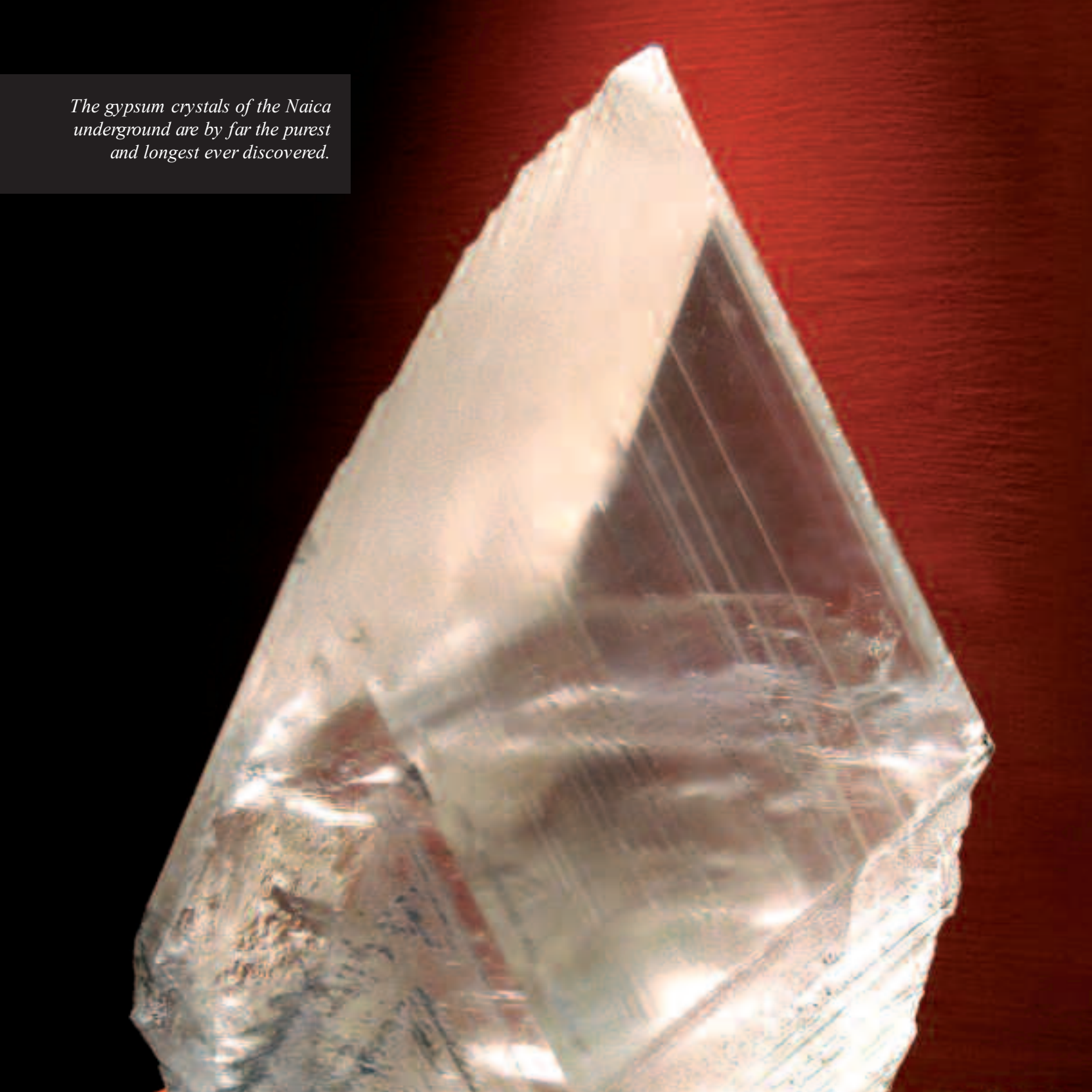
In conclusion; surveying Cristales really is difficult.

Cristales presents some mysteries with still unexplored bottlenecks and climbs.

In order to limit the damages due to the human passage we used purposely produced thermal boots with soft sole.

Climatic Research

In Cristales we undertook a complex series of measurements with the goal of understanding its current physical state. This was mostly carried out by the Department of General Physics of the University of Turin.
Its natural state is at a depth of 170 m immersed in 54 °C mineralized water. Now it is filled with air, partially surrounded by ventilated galleries at 35-38 °C. What is happening to it?
All kinds of things are happening and unfortunately we are rather unprepared to follow the details because it is what in physics is called a "transitional state". It is, in other words, experiencing a "fall" towards a new state of equilibrium that we still have not determined, but that we hope to be able to influence in some way in the future. In the meantime, all the environmental parameters vary far more than expected and in an irreversible way, so the techniques usually used to study caves aren't applicable here.
The climate of a normal cave is in fact substantially static, with minimal oscillations, whether daily or seasonal, around a point of equilibrium. They are oscillations related to the shape of the cave, but which also partly determine it, because they are able to start air currents and condensation processes which, over millennia, can significantly alter the rock. But we are still speaking about systems which are nearly in equilibrium and are therefore relatively easy to study.
The climate of Cristales is evolving in an irreversible way, as well as quickly, because it is contained within a warm mass of rock, rich with water, which in the last few years has become surrounded by dry galleries which are ventilated with cold air in order to allow the mining operations.
Our measurements have shown various phenomena. The cave continues cooling by approximately half a degree per year, because it loses heat by conduction towards the nearby mine galleries to the north-west, as well as by irradiation along the access corridor.
We have also noticed that in the upper areas the air is stably warmer and more humid than the lower zones and those close to the exit. An unexpected find has been that, while the temperature is very stable, even if in slow decline, the humidity shows strong variations, on both the short and seasonal time scales. This is probably due to meteoric water infiltrations along the fractures created by the mining activity. Finally, there is an air current of about ten litres per second which starts when the access door is opened.
These measurements have therefore shown us that the part of the cave which we know is only a fragment of a much vaster structure, which, depending on environmental conditions, introduces or extracts air from the environment we call "Cristales".
Moreover, the air currents show that the cave is connected to the mine through another passageway, probably



The gypsum crystals of the Naica underground are by far the purest and longest ever discovered.

Mineralogical Research

We are beginning to also trace a picture of the formation of this wonder of nature, of which we can give an outline here. The analysis of the mineralogical aspects of the Naica caves is conducted by a large international group, headed by the Department of Earth Sciences of the University of Bologna. The exceptional nature of these crystallizations is due to the extraordinary stability of the local environmental conditions over the last hundreds of thousands of years. The water which formed them was of meteoric origin, which infiltrated the immense surrounding plains. From there, it slowly migrated deep into the ground, where it warmed up and became enriched with minerals, due to the presence of a magmatic intrusion between one and two kilometres depth under the Sierra Naica. The heated water returned towards the surface due to a "radiator" effect in a sort of plume along the fractures, depositing different minerals according to its temperature, which slowly decreased over time. Of particular importance, while rising, it crossed areas rich in calcium sulphate which it absorbed to saturation. When the temperature sank below 58 °C, the water began to deposit gypsum (hydrated calcium sulphate) because in those conditions the anhydrite (calcium sulphate) is more soluble than gypsum, so that one dissolves and the other is deposited. This has resulted in many fractures being filled up with crystalline gypsum and has made those cavities which, by chance, were intercepted but not completely filled up, fantastically beautiful. Among these, Cristales has been especially "lucky" probably due to its remarkable size and the "just right" degree of water flowing along its fractures.

The first U-Th datings carried out on a broken crystal have given an age of several hundreds of thousands of years, which is consistent with the measures of direct deposition that we are carrying out on level -590 of the mine, where a source of "original" water has again begun to deposit gypsum on calibrated tablets.

But the research perspectives are much greater, because these caves contain extremely rare minerals which, like the mega-crystals, testify to the exceptional nature of the events which have formed the depths of the Sierra Naica.

Other research is ongoing on the directions of the crystal growth and on the liquid inclusions, including searching for traces of DNA.

A surprising result is that external life has succeeded in reaching those environments: Inside the crystals, pollen grains associated with humid forest type vegetation have been found, very different from the current desert environment. Pollens which survived kilometres of underground travel and very slow cooking, to then end up in crystals, similar, in a way, to how Dante describes the damned of Tolomea:

"*come festuca in vetro*" ("*And glimmered through like unto straws in glass*.")…

The complexity of the external world has succeeded in leaving one of its ancient traces even there!

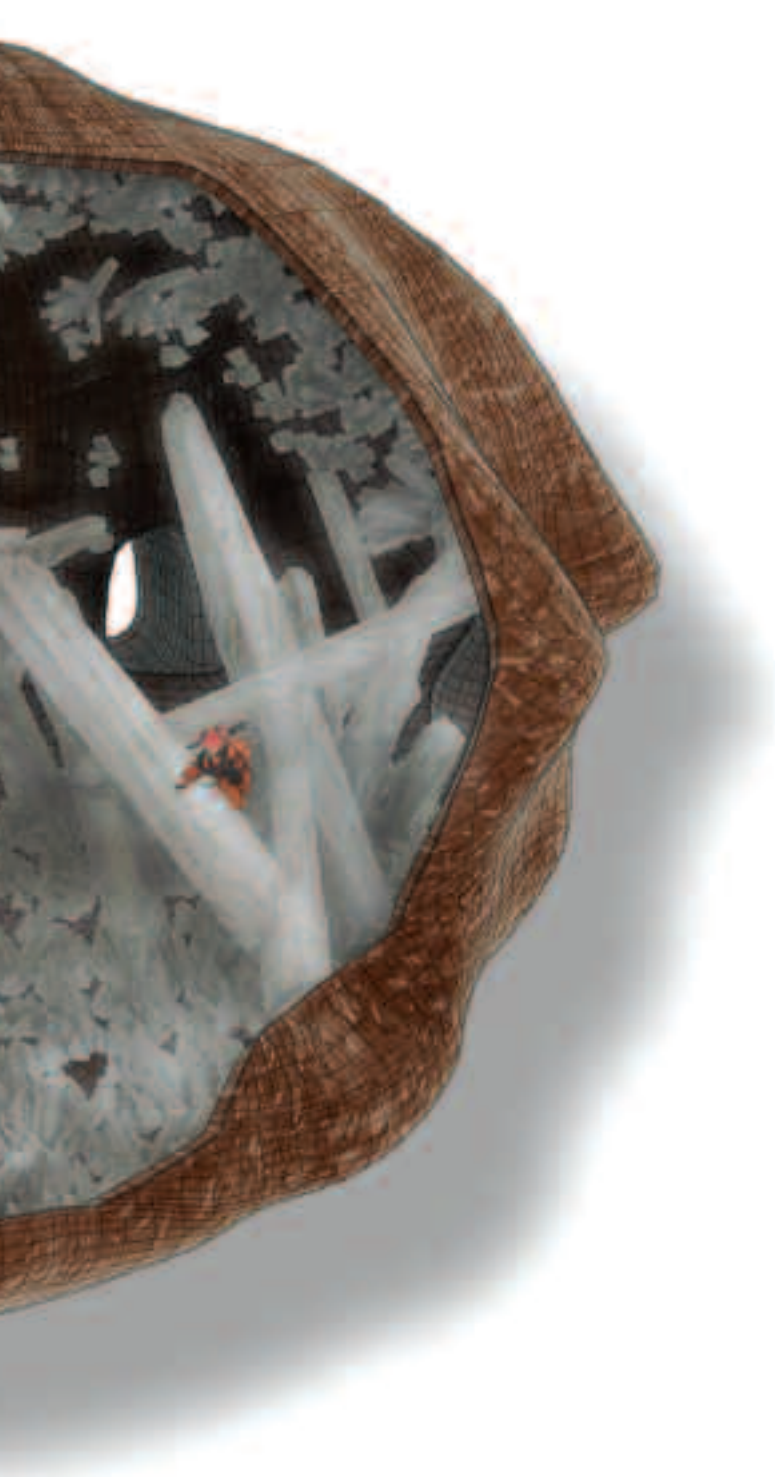
The giant crystals formed in the last million years, 170 m under water at 55 °C.

The Disappearance of Cristales

Naica is the place of contrasts. In the depths of the mountain there is a fantastic mineral wealth, extracted by hundreds of inhabitants of a village that only offers basic amenities.

Any instruments to be used inside the Naica caves must be heated beforehand in airtight cases.

The most fantastic and fragile cave ever discovered has been brought to light thanks to impressive mining digs, which are the very essence of the idea of robbing the Earth's treasures.
Its salvation has depended on the sensibility of those who live by extracting minerals.
We make use of this wonderful cave, observe it, travel through it, but only because enormous amounts of costly energy keep it outside of its natural state, within which we would die in a few fractions of a second.
At this time, the roots of the mountain and the Naica caves are kept free from water thanks to the pumping of more than one thousand litres of water per second to the surface 700 metres above. The energetic cost is beyond 100 million kWh a year, which will continue to be used as long as the millions of tons of extracted mineral every year, from what is one of the largest mines in the world (170 tons of silver per year and ten of thousands of tons of zinc and lead), justifies the cost.
The idea that the pumping could continue, albeit from a lesser depth, just to have access to the cave is completely unrealistic; in any case the costs would be enormous. Moreover, our studies have shown that it is in a profoundly different state from its natural one; as though it were a living whale laid out on a field. If Cristales were alive, we would say that it is in a kind of coma.
Is it degrading? Yes, absolutely, but compared to which



The Cristales macrogeode in a drawing by the Quaterd studio of Milan (www.quaterd.com).

state? Many crystals have been damaged, the surface of others will become opaque, but this is only storing in crystal the memory of that time it made an appearance among humankind; that is exactly what is happening at this moment, without uproar, in many more humble caves, whether tourist or simply the object of speleological visits. Our medium term goal is to succeed in causing the least possible damage to the cave and, if possible, to guide its journey towards a new state of equilibrium which preserves it the best.

But the entire Naica cave complex will return underwater, inevitably, because in the long term we will not be able to continue pumping water from the roots of the mountain; they were formed when homo sapiens was not there and will still be there when homo sapiens has disappeared.

Will we tear it all entirely out of the Earth in order to reconstruct it outside, like an Abu Simbel of the Earth depths, leaving an empty space which in a million years will be full of crystals once again?

Will the 160 mega-crystals be quarried and then dispersed between museums and rich collectors?

Or will we let it return intact under water, being satisfied to have preserved a very detailed memory of its apparition among us?

We don't know, but these are problems that we will have to face in the future, that we are studying in order to be worthy of confronting and, above all, we are truly proud of having this privilege.

For now we are working at documenting it as well as we can, trying also to understand how to limit the damage that we inflict with our merely surviving while observing it.

Yes, the Cueva de los Cristales is beautiful, but it is an especially blinding example of how great the contrast is between the inexhaustible complexity of nature and our limited ability to understand and make use of it.

The Naica caves in figures

The first steps carried out by the Naica Project have been those of mapping and exploring the caves of the mine.
In Cristales, we have also nearly completed the survey of every single mega-crystal (position, spatial direction, dimensions and shape), inserting them into a three-dimensional model.
We have also verified the possibility of making three-dimensional maps using a special laser scanner, for the purpose of disseminating information about it and of preserving a more accurate record. This is the first time ever that caves are being mapped to such detail, but which occasion could be better? In the future we will try to complete this type of mapping for all the Naica caves. We can now give the current situation.

Cueva de los Cristales

This is by far the largest and the one with the largest crystals.
Length (survey plots). Main chamber: 109 m, SE branch: 42 m, NE branch: 68 m.
Surface: 1100 m^2.
Volume: 5-6000 m^3.
Vertical Range: 12 m.
Mapped crystals: 149, more than 90 % of the total.
Largest crystal: Cristal Cin, in the NE part of the main chamber. Length 11.40 m, volume 5.0 m^3.

Cueva de las Espadas

This was discovered in the early 1900s because, unlike the others, it was formed at the border of the water table.
It consists of a long split, with very rich crystallizations in the deeper parts. Over the years it has unfortunately been heavily plundered. The “giant crystals” that have made Naica famous among mineralogists come from this cave. From a scientific point of view it is very interesting because its crystals contain information about the ancient climate and the geological processes of the area.
Length: 105 m - Surface: 600 m^2 - Volume: 1400 m^3.

Cueva de las Velas

Discovered a few years ago, it is in effect one chamber on two levels with the walls covered by rather small crystals. In these years it has been heavily plundered.
It is probably part of the same structure of which Cristales seems to be the heart.
Length: 75 m - Surface: 400 m^2 - Volume: 1500 m^3.

Cueva Ojo de la Reina

This is a small and magnificent cavity which is very close to Cristales, and of which it is certainly a South-eastern fragment. The rock to the north, between the two, probably contains other similar cavities. It has been plundered, but above all damaged by being opened in contact with the mine tunnels. The walls are made of splendid crystal surfaces, but which are now seriously damaged by condensation in several places.
Length: 15 m - Surface: 50 m^2 - Volume: 150 m^3.

The damages due to man are limited to the passage zones, but the cave is in a situation of imbalance.

For sure Cristales is only a fragment of a much wider and complex hypogean structure.

In order to know more

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In Cristales the limestone rock is visible only on the ceiling, covered by a red layer of iron oxides.

Photographs by: Giovanni Badino, Tullio Bernabei, Paolo Forti, Luca Massa, Francesco Lo Mastro, Paolo Petrignani, Roberta Tedeschi.

The drawing at page 28 (top) is by Laura Sanna.

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A forest of crystals, the biggest ones on the Planet. An unreal world, beyond imagination, beyond dream.
A cave with a temperature of 50 °C and 100% humidity; an infernal place, where man, without protection, can survive just a few minutes.
A wonder of nature discovered by chance, fragile and mysterious; something we risk to lose at any time. And that will soon turn inaccessible again, hidden in the heart of the Earth.
Naica's Crystals Cave is a small window onto the immense geological time; a window man can now open thanks to a new, exclusive technology. A high risk "astronautics" exploration, in order to understand, study, document and save. Before it becomes too late.

La Venta Geographical Association is an Italian team that also includes explorers from Argentina, Mexico and United States. Founded in 1990, the group grew to reach international recognition thanks to its successes, achieved during expeditions in remote areas of the Planet: from the lonesome mountains of central Asia to the mysterious Venezuelan Tepuis; from the blue depths of Patagonian and Antarctic glaciers to the unexplored Mexican canyons.
The team comprises explorers and researchers that share a passion for the underground world and the waters flowing through it. But most of all, they are people who decided to dedicate part of their lives to study, preservation and popularization. From the initial focus on caves, La Venta's explorations became multi-disciplinary endeavors that saw the participation of large numbers of researchers.
Producing high-quality documentation has always been one of the main aims of the Association; this led to the publication of reportages on the most renowned national and international journals, to the publication of five large-format books, to the making of two multimedia CD-ROMs and to the filming of numerous documentaries that have been broadcast all around the world.
Our planet still has endless territories that wait to be explored, especially under its surface. This means that the reasons behind La Venta's activities are, and will continue to be, extraordinarily strong

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