No. 84 February 2025

Union Internationale de Spéléologie (UIS)

# Commission on Volcanic Caves

e-NEWSLETTER

http://www.vulcanospeleology.org/

# No. 84 - February 2025

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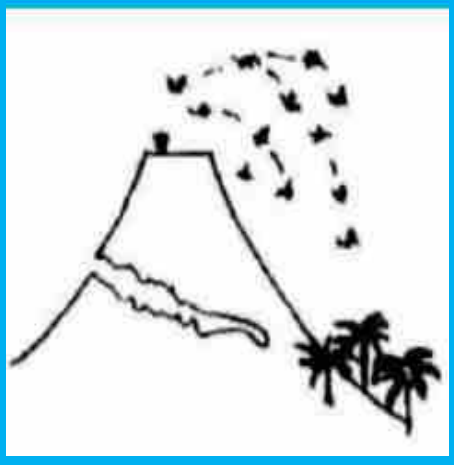
The Commission on Volcanic Caves Newsletter has been published regularly since December 22, 1993. The Newsletter is available free of charge to all members of the commission, and to others who are interested in Volcanic caves.

# UIS COMMISSION ON VOLCANIC CAVES



## MISSION STATEMENT

The UIS Commission on Volcanic caves encourages exploration and scientific investigation on volcanic caves, and hosts the International Symposium on Vulcanospeleology about every two years



## COVER PHOTOS

**Top**

Bill Halliday and
Gunhildur Stefánsdóttir

**Bottom**

Cueva del Tigre, Payunia, Argentina

**Editorial**

In this edition we begin, not only a new layout, which we hope will be more agile than the previous one, but also, but above all, a well-deserved tribute to the figure of Bill Halliday, who left us recently.

Our member list has now become "back cover". On both the cover and the back cover we maintain the style, layout and colors of previous editions.

We are working too on improving our editions even further, so perhaps in the future we will have to agree on the unification of criteria for the presentation of works, not only the deadlines, but also unification of styles, fonts, photos, etc.

Those of us who did not have the honor of knowing the honor of knowing Bill Halliday personally know that his work continues: proof of this are the tributes paid to him in this issue 84.

It was a strong blow for those of us who remained, but also strong was his legacy, what he did and what he sowed in the hearts and minds of many speleologists.

The scope of our newsletter reaches this time to the “distant” Armenia and Argentina. It is a great honor for us, but at the same time an enormous responsibility, to shorten those distances by this means.

We have more opportunities ahead of us to shorten that distance: Canary Islands 2026, XIX Congress of the UIS in Belo Horizonte next July.

**Carlos Benedetto**
**Editor**
**28 February 2025**

## From the President


Hello everyone

It has been a long, hot and mostly dry summer in my part of Australia and heading underground has been a good way of avoiding scorching daytime temperatures on the surface. But I admit that all of my recent underground trips have been in limestone areas. The closest volcanic caves for me are in Western Victoria and involve a round-trip driving distance of 1600-1800 kilometres. Not ideal for a weekend trip. Mind you, I have been tempted to make the trip as a new volcanic cave has recently been discovered on private property and the owner who made the discovery recently became a member of the Commission. So, welcome David, and hopefully I will have an opportunity to see your new cave at some stage.

I also welcome Erin, Allan and Kim (all from USA) who have joined since the last issue of the newsletter. Erin is a natural resources manager at a volcanic national monument. Allan participated in the 21st International Symposium on Vulcanospeleology (ISV) in the Galapagos Islands last year and Kim is from NW USA and helped to compile a major tribute to Bill Halliday that appeared his caving group's newsletter in November last year.

As many of you would know, Bill Halliday passed away last year and that he devoted many years of his caving life to visiting, exploring and documenting volcanic caves and fighting for their protection. He was also the driving force behind the first ISV in 1972. He later became Chairman of an international working group on volcanic caves which, thanks to Bill, evolved into the Commission on Volcanic Caves within the International Union of Speleology (UIS) in 1993. He was the foundation Chairman/ President (Bill used both titles over time) of the commission and remained a member until his passing last year. The commission has its own tribute Bill Halliday in this issue of the newsletter.

It was compiled by Stephan Kempe, Christhild Ketz-Kempe and Greg Middleton who both knew Bill very well and visited many caves with him around the world. I had the pleasure of meeting and caving with Bill during the 10th ISV in Iceland in 2002. It was my first ISV but one of the last that Bill attended.

Speaking of ISVs, I am pleased to advise that the Proceedings of the 21st ISV (Galapagos Islands, April 2024), are now available for downloading from the commission's website. Many thanks to Laurens Smets for helping Aaron Addison see this task through to completion. To download a copy, go to:https://www.vulcanospeleology.org/menu.html

I had hoped this issue of the newsletter would include a preliminary program outline for next year's ISV (ISV22). A proposal for the ISV to be held on La Palma in the Canary Islands, that had been promised in time for consideration at the Galapagos ISV last April, has still not been received.

While the La Palma tourist office did offer some organisational help and logistical support for local transport, there has been no tangible progress on the ISV proposal, despite many communications between the commission (essentially Dominik Frölich and I) and people in the Canaries.

However, I am pleased to report that in recent days, elements of a revised plan for the next ISV have been developed and confirmed. The presentation sessions will now take place in November 2026 on the island of Tenerife, as a result of an offer by the Museum of Nature and Archaeology (MUNA). Among other things, MUNA manages the Cueva del Viento (Cave of the Winds), an 18km-long lava cave, sections of which are open to the public on guided tours. There will be field excursions to the cave and other sites on the island as well as an optional post-symposium excursion to the island on Lanzarote. We remain hopeful there will also be field excursions on La Palma, but that is not at all certain at this stage.

**John Brush**
**President**
**27 February 2025**

# William Ross "Bill" Halliday (1926 – 2024)

**Nicola Barone & Paolo Forti**

**Fig. 1- A young Bill Halliday in the Kitty Pooh Cave in Oregon (Photo Charlie Larson)**

Bill Halliday passed away on September 24, 2024 in Shoreline, Washington. USA, was immediately disseminated to all speleologists in the world by the UIS Volcanospeleology Commission, which he had really created from nothing, given that lava caves were by far his greatest interest throughout his career. its long existence.

Bill Halliday, as everyone simply called him, was a man of many talents: he graduated in Zoology in 1946 and then completed his medical studies at the George Washington Medical School in 1948; immediately afterwards he had a brilliant career as a doctor and surgeon, a profession which he practiced with great success until retirement.

**Fig. 2 - Iceland 2002, excursion of the International Symposium of Vulcanospeleology in the Arnahellir Cave. The three cavers who have been presidents of the Vulcanospeleology Commission of the UIS from its foundation to today, are present: the first Bill Hallyday in the center with the yellow helmet, on the far left the second, Jan Paul Van der Pas, and the third John Brush in the red overalls next to Bill (Photo Ken Grimes)**

But Bill was above all a great enthusiast of speleology, which he began practicing as early as his university years. He then served as Director of the Western Speleological Survey from 1955 to 1981 and was on the Board of Governors of the NSS several times, of which he had already become a member in 1949.
In addition to the managerial positions in the American Speleological Associations, which he held until the threshold of the second millennium, Bill was a fruitful and prolific writer. Therefore there were many of his speleological publications, among which it is important to remind at least the two volumes Adventure Is Underground (1959) and American Caves and Caving (1974) with which he stimulated public knowledge and appreciation for the fascinating world of caves and above all also its necessary protection.
But his greatest passion, which accompanied him until the last days of his life, were certainly lava caves: in this field he can, rightly, be considered the true "father of Vulcanospeleology", exactly like the Frenchman Martel it is considered for speleology in limestone caves.
Having immediately fallen in love with these particular cavities, he did not limit himself to exploring and studying them but, since the early 1970s, he has tried to coordinate speleological activity within them, not only at a national level, but truly worldwide.

It is in fact thanks to him that in 1972, within the annual convention of the NSS, the "First International Symposium of Volcanospeleology" was organized. During that reuinon, among other things, he managed to involve Ronald Greeley, (the world's leading expert in planetary geomorphology) in the studies of Vulcanospeleology leading him to present comparative studies of continental lava expansions (western United States, Etna) and Hawaii aimed at mapping the Moon and Mars for N.A.S.A.

We like to remind his presence during the fourth appointment of these symposia, which was organized in 1983 in Italy by the Speleological Group of Catania, exactly on Etna. It was a great success both for the number of people who participated and for the splendid excursions. But, above all, for the fact that for the many Italians who participated in that symposium it was the first ever opportunity to get to know, not only Bill, but also the environment of the lava caves, completely different from any other karst cave they had frequented until then.

Then in 1999, again in Catania, on the occasion of the IX International Symposium of Vulcanospeleology, where Bill did not miss his presence this time too, he was asked to write a chapter on the history of Vulcanospeleology in Dentro il Vulcano – Le Groptte dell'Etna , thus he said verbatim:

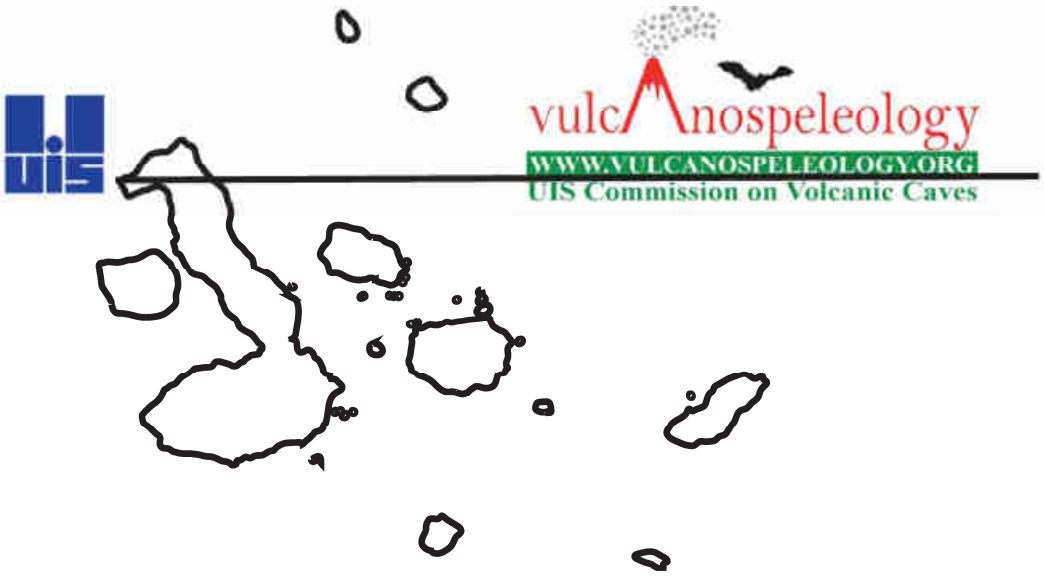
«Volcanospeleology, that branch of knowledge that deals with the exploration and study of caves in volcanic environments, gained the qualification of a scientific discipline with the first two international symposia, organized in 1972, in White Salmon (Washington) and, in 1975 in Catania (Italy) dedicated to this specific theme.» Then adding: «The first two Symposia, in 1972 and 1975, began to channel the Italian and American currents on the subject into a single thread, with the English name, Vulcanospeleology, conceived as a clear homage to the fundamental contribution given to this disciplined by the Italian contribution."

Furthermore, his leadership in the Hawaii Speleological Survey and his role as President of the Commission on Volcanic Caves of the International Union of Speleologists (UIS) further demonstrate his commitment to the exploration, valorization and protection of the extraordinary world, and until a few decades ago completely unknown, volcanic caves.

The Italian vulcanospeleological community and in particular that of Catania therefore owes him great gratitude. But certainly, in our opinion, his role in speleology in general,, an activity which he practiced well into his 80s, was truly enormous. For this reason his name will remain not only in the hearts of those who were lucky enough to know him directly or even just to read one of his many publications, but also of all those who, in one way or another, frequent and will frequent in the future the wonderful underground world in any part of the globe..

# PROCEEDINGS

## 21st International Symposium (ISV21)
## on
## Vulcanospeleology



## Galápagos Islands, Ecuador
## 10th-20th April 2024

**Download:**

https://www.vulcanospeleology.org/sym21/ISV21_2024_Proceedings.pdf
https://www.dropbox.com/scl/fi/050z39326a2y4uan4jggh/Proceedings_-ISV21-2024_midres.pdf?rlkey=e4jdj7plb1z6mi42t8me90jhx&e=1&st=azysrkog&dl=0

# A Tribute to Bill Halliday – Father of Vulcanospeleology

**Stephan Kempe, Christhild Ketz-Kempe and Greg Middleton**

The Commission on Volcanic Caves of the International Union of Speleology was founded in 1993 with Dr Bill Halliday (Fig. 1) as its founding Chairman. This was a direct development from the Working Group on Volcanic Caves, also chaired by Bill, established by the Union in 1990. In turn, the Working Group's origins can be traced back to the (first) *International Symposium on Vulcanospeleology and its Extraterrestrial Applications*, held in White Salmon, Washington, USA in August 1972 – chaired by Bill Halliday. Bill strove vigorously over decades to promote the study and recording of volcanic caves and is truly deserving of the title of Father of Vulcanospeleology.

William Ross Halliday was born 9 May 1926 in Atlanta, Georgia, USA and passed away, aged 98, on 24 September 2024, at Shoreline (north of Seattle), Washington, USA.

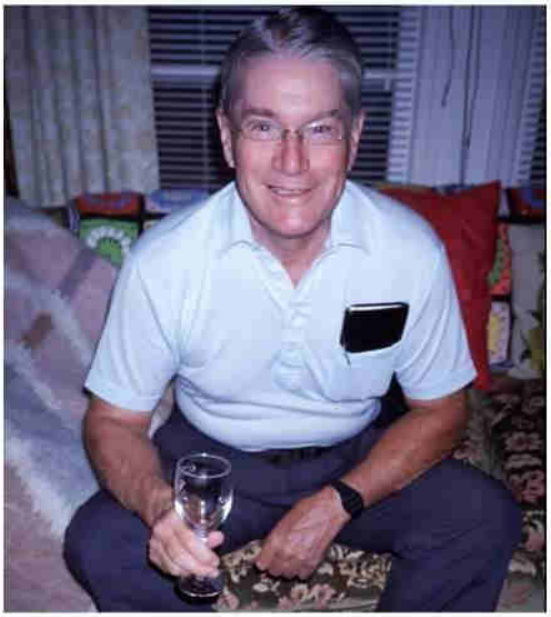


**Fig. 1: William "Bill" Ross Halliday, MD, in 1999, with his characteristic smile, glass of wine, shirt-pocket-sized notebook and cheap watch. (photo: Kempe & Ketz-Kempe).**

## Medical Career

Bill first graduated in 1946 with a Bachelor of Arts in Zoology from Swarthmore College, a Quaker liberal arts college near Philadelphia, Pennsylvania. Two years later he graduated M.D. from the George Washington University School of Medical and Health Sciences, Washington, D.C. – one of the most selective medical schools in the U.S.

Bill served as a medical officer in the U.S. Navy, in Long Beach, California (1949-50). He remained in the Naval Reserve until at least 1957. Subsequently he became a thoracic surgeon, medical consultant and Director of the Department of Labor and Industries from 1971 to 1976. From 1976 to 1982 he was Medical Director for the Washington State Division of Vocational Rehabilitation.

## Initial Caving

In parallel with his medical career, Bill became a speleologist and it is in that sphere that he became most widely known.

He was introduced to caving in 1946 when, working at a summer camp near Washington, he went to see Clarks Cave in company with the owner. Bill later recalled, "It was everything a cave should be – a network of passages, it smelled old and musty, just enough mud to get your attention, stalactites and stalagmites, old artifacts. We didn't know at the time, but I found out much later that the ladders had been constructed by saltpeter miners" (Halliday and other, 2007).

## Founder of Speleological Groups

It was Mr Clark (of Clarks Cave) who told Bill about the National Speleological

Society (NSS). It had been founded in 1941 but was not widely known and Bill had trouble making contact. Eventually (in 1947) he located the District of Columbia Grotto and got to know Bill Stevenson (the founder of the NSS) who became his friend and mentor. Stevenson encouraged Bill to set up grottoes in the west as there were none west of the Mississippi. He subsequently founded the Southern California Grotto (1948), the Cascade Grotto (Seattle 1951), the Colorado Grotto (Denver), the Salt Lake Grotto (Utah) (and, much later, in 1989, the Hawaii Grotto). These achievements led to Bill often being referred to in the US as the "Father of Western Caving".

Not only was Bill a mover in getting new grottoes established, he also set up specialist groups focussing on cave recording and surveying. His first was the Washington Speleological Survey (a unit of the Western Speleological Survey) (Cole, 2002; Halliday, 1963, p. 3), of which he was the Director from 1955 to 1981 (Patton, 2024). He founded the Hawaii Speleological Survey in 1989. He founded the Vancouver Island Speleological Survey (late 1950s; Cole, 2002). Also, about this time he co-founded the Northwest Cave Rescue Association (Cole, 2002).

Bill was made an Honorary Member of the NSS in 1965, and in 1988 he was awarded the Spelean History prize for his work in documenting cave histories. He was elected to the NSS Board of Governors many times between 1950 and 2001 (Encyclopedia.com., 2005). He was made a Fellow of NSS and of the Explorers Club.

Because of the huge encouragement that Bill gave to caver John Pint when John moved to Saudi Arabia, John regards Bill as the "Father of Speleology in Saudi Arabia" (Pint, pers. comm., Oct. 2024).

**Author of Cave-related Books**

Bill was a prolific writer. Early on, he was a major contributor to *Celebrated American Caves* (Halliday 1955a, 1955b). His first major book was *Adventure is Underground* (1959), followed by *Caves of Washington,* published by the Washington State Division of Mines and Geology in 1963, *Depths of the Earth: Caves and Cavers of the United States* (1966, followed by an enlarged edition, 1976a (Fig. 2)), and *American Caves and Caving: Techniques, pleasures, and safeguards of modern cave exploration* (1974). He also wrote or co-authored a series of more focussed booklets: *Discovery and exploration of the Oregon caves* with Frank K. Walsh (1971), *The Paradise Ice Caves* with Charles H. Anderson (1972), *Ape Cave and the Mount St. Helens Apes* with photos by Charles V. Larson (1983), *Carlsbad Cavern: The Early Years* with R. Nymeyer (1991) and *Floyd Collins of Sand Cave: A photographic memorial* (1998) (Fig. 3). In addition, Bill wrote and edited numerous reports on various caves and papers recording his exploration and documentation of caves in the USA and elsewhere. He also produced newsletters and edited conference proceedings.

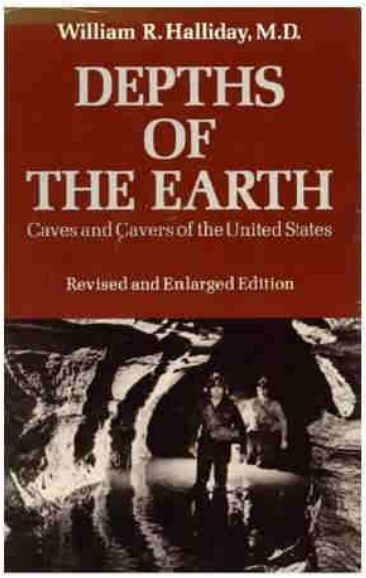



**Fig. 2: Cover of *Depths of the Earth* 2nd edn. 1976. The cover reprints a picture on page 176 by A. Palmer.**

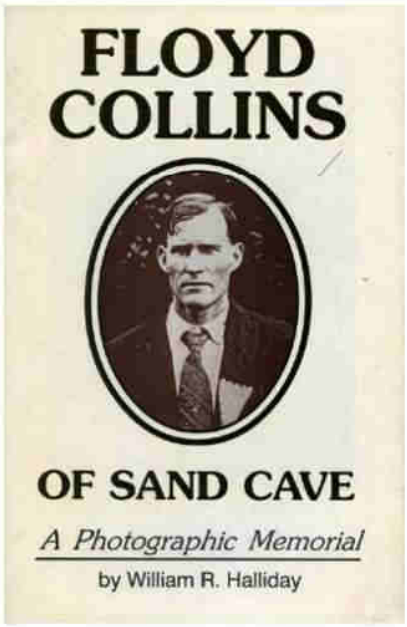



**Fig. 3: Cover of *Floyd Collins of Sand Cave*, 1998.**

He contributed no less than ten entries to Gunn's *Encyclopedia of Caves and Cave Science* (2004): America, North: History; Caves in History: The Eastern Mediterranean; Crevice Caves; Disease; Hawaii Lava Tube Caves; Piping Caves and Badlands Pseudokarst; Pseudokarst; Talus Caves; Volcanic Caves; Vulcanospeleology: History. This was greater in number, and over a broader range of topics, than any other contributor.

His books have been highly influential in encouraging new generations of cavers and cave scientists in the USA and around the world. His first book, *Adventure is Underground*, was pirated by Russians and 65,000 copies were printed – "*the most my books have ever sold*" Bill later joked (Halliday and others, 2007). It is reported the book was influential in encouraging speleology in Russia. Bill Halliday was probably the greatest contributor to popular works on caves since Norbert Casteret.

## Role in Vulcanospeleology

Bill encountered volcanic caves early in his caving career. In compiling his comprehensive report on the caves of Washington State (1963) he observed:

> *Persons concerned with broader implications of speleology will find Washington a fruitful area of study. This is particularly true of the student of lava tubes and of vulcanism in general. Ape Cave, the longest lava-tube cave known in the continental United States, and perhaps the world's longest, is in Skamania County. The concentra01tion of lava-tube caves in Washington is not so great as in Lava Beds National Monument in California, or perhaps in the Bend area of Oregon. However, Washington's numerous and extensive lava tubes provide a great variety of features of these caves and their enveloping bedrock.*

While his suggestion that Ape Cave may be the longest volcanic cave was not subsequently borne out, he embraced lava caves at a time when other cavers tended to discount them in favour of karst caves. Although he maintained an interest in karst, his strong advocacy of volcanic caves – particularly from his organisation of the first International Symposium on Vulcanospeleology (ISV) in 1972 (Halliday, 1976) (Fig. 4) – led to the establishment, by the International Union of Speleology, of first a working group (1990), and then (1993) a fully-fledged Commission on Volcanic Caves – with Dr Halliday as its founding chairman/president. Under Bill's oversight, the Commission has become one of the International Union's most active and productive. Bill personally organised the first, third and sixth international symposia and, while running the Commission, encouraged and assisted others to organise other symposia at appropriate locations so that they have become a regular biennial event, bringing those with a particular interest in lava caves together to discuss processes, exchange ideas and visit volcanic sites across the globe.

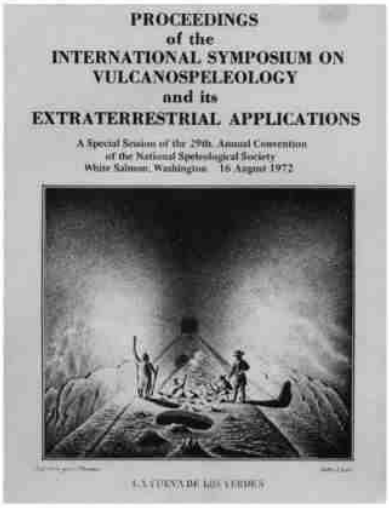



**Fig. 4: Cover of Proceedings of (First) International Symposium on Vulcanospeleology, 1972, edited by Bill Halliday.**

## Personal Recollections

Stephan's acquaintance with Bill Halliday began at the City Library of Rochester, where he found and read Bill's *Depths of the Earth*. At the time Stephan was 16 and thought that the author must have been an older explorer, having such a broad knowledge of the vast US caving scene. Over time he realised that Bill's writing talent was voluminous. The folder of Kempe-Halliday correspondence (prior to email) is six centimetres thick and weighs around two kilograms. Bill communicated both through short notes and long letters, shared with colleagues by numerous copies.

His comments on so called "Management Plans" by administrative officers are famous. He would bluntly state: "*In my opinion this 'Draft for Review' deplorably demonstrates the inevitable results of assignment of a task to a person or person*[s] *unqualified to perform that task*". Not elegant, but aggressive and possibly counterproductive.

His report about his exploration of Dynamited Cave, a veritable lava cave, not in any respect "tube-like", ended with some prophetic sentences:

> "*The origin of these conduits of flaming gases and molten lava has long puzzled speleologists. In the walls of Dynamited Cave and many other lava tube caverns, silent clues permit us flashes of understanding. The story they tell is fragmentary, for our comprehension is new and imperfect. The features of these heat-scarred sewers of volcanic outpourings vary enormously – perhaps even more than those of limestone caverns. He who would learn their peculiar language must study dozens, scores of far-scattered caves*" (p. 381, 2nd edn.).

Who could have better and more poetically described the tasks of vulcanospeleology?

One of the moments of mutual contemplation Stephan remembers was when Bill showed him Sand Cave, the site of Floyd Collins' tragic death in 1925 and the topic of chapter 2 of *Depths of the Earth*. Tragic in the original sense, i.e., unknowingly overestimating personal strength against the power of ruling gods ("nature" in our context). It is a felony we all commit from time to time and Sand Cave certainly is a metaphor for it. Bill wrote (Halliday, 1975, p. 29): "*The broad inviting entrance promised much, but immediately changed its mind and melted into solid rock walls. Just at the outer edge of the ten-foot ceiling line was a funnel-like pit twenty feet across: the slumped remnant of the famous shaft*". This chapter on Floyd Collins is Bill's most intense. When thinking of the many crawls he and Bill had been through together, Stephan reflects that Sand Cave is a reminder that they were lucky many times over: Bill and he *surveyed an upper labyrinth section* (Kempe & Oberwinder, 1997) of Hu'ehu'e Cave, called with good reason "*morituri te salutant*[1]" (Fig. 5). It still has a continuation not surveyed. This pyroduct, with almost 500 m of vertical extent is one of the "deepest" caves of the US, but never more than a few metres below sunshine. Bill was an able crawler,

[1] *"Those who are about to die salute you"*, a salute to the Roman Emperor by those participating in deadly amphitheater games.

not shy to follow narrow leads, typical for upper pyroduct mazes.

Then came Budapest, September 1989. The year the iron curtain was withdrawn, and the German Wall fell. The 10th International Congress of Speleology assembled at the University of Budapest.

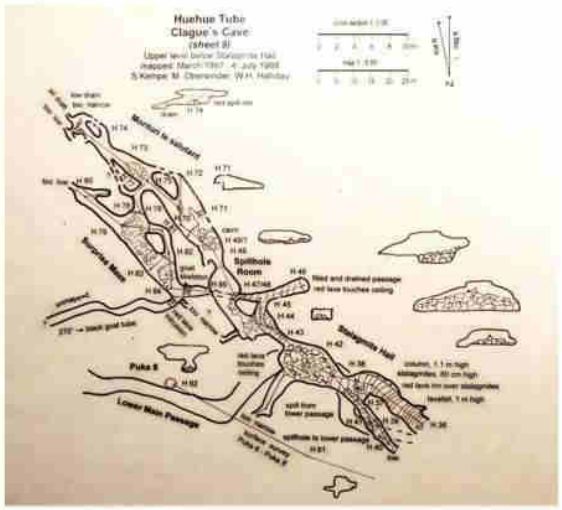



**Fig. 5: Upper level maze of Hu'ehu'e Cave, Hawai'i, called "*morituri te salutant*" surveyed by Bill and Stephan.**

**Fig. 6 Sis and Bill Halliday dancing at the Budapest UIS Congress (photo: Kempe & Ketz-Kempe).**

There Christhild and Stephan met a newlywed, happy and high-spirited couple: Louise ("Sis") and Bill Halliday (Fig. 6). Not only outgoing, charming, exuberant and ality of Hungary, ill, having visited 55, and knowing about the Kempes' visit to Hawai'i in 1978 and those during the British (Nov.-Dec. 1979, 1980) and the Swiss (Nov.-Dec. 1981) caving expeditions and earlier investigations (Halliday, 1980), suggested the founding of a "Hawai'i Speleological Survey" (HSS). Thus, Budapest became the founding city of a National Speleological Society new section. Hawai'i's underground offered a huge potential of caves and caving. Bill and his daughter Marcia organised the paperwork, drew up a charter and quickly got the HSS going. From the beginning Bill planned the next step: Holding a symposium on the Big Island.

Fig. 6: Sis and Bill Halliday dancing at the Budapest UIS Congress (photo: Kempe & Ketz-Kempe).

The first time the Stephan and Christhild caved in Hawai'i with Bill was in July-August 1990. They and Spike Werner visited Mauna Loa Icecave, the first cave on Hawai'i to contain interannual ice. Stephan and Christhild had surveyed it back in 1978 with volcanologist Jack Lockwood (Kempe & Ketz-Kempe, 1979). Ice and icicles were present, but also a lot of white dust, indicating that ice had vaporised, leaving the dissolved minerals behind. This situation contrasted with 1978, when the ice was vitreous, transparent and clean at the surface.

**Fig. 7: Sis and Bill in the sitting room of the Halliday apartment with large, old geological map as wall decoration (photo: Kempe & Ketz-Kempe).**

After a day of caving, happy hours were shared at the "Halliday Apartment" in Hilo. The Hallidays had bought it when the original Hilo Lagoon Hotel was privatised. Bill decorated the rooms with the first

geological maps of the Big Island and Maui (Fig. 7).

1991 saw the Sixth International Symposium on Vulcanospeleology held in Hilo. Bill had scheduled it for the first week of August so there was ample time to do surveys in July during the summer school break. Among the projects to complete was the survey of Earthquake Cave, for which both Bill and Spike volunteered. Stephan and Christhild had witnessed their first Hawaiian earthquake (Magnitude 4.9, 1990, Aug. 8th) underground there, naming it appropriately "Earthquake Cave" (Kempe & Ketz-Kempe, 1993) (Fig. 8).

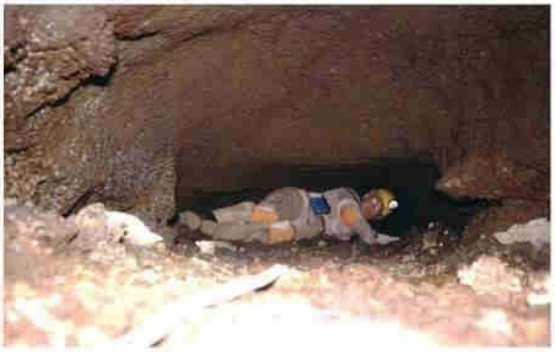


**Fig. 8: Bill in Upper Earthquake Cave in 1991, tackling a low passage (photo: Kempe & Ketz-Kempe).**

It was also the first cave to clearly show evidence of lava erosion. At places where the glazing fell away, the underlying Uwekahuna Ash was exposed, oxidised red by the heat of the lava and the shock-evaporation of the soil water. The flowing lava had cut down through the ash into older lava below, leaving a canyon up to ten meters deep.

Another memorable caving trip of 1991 was to the lower section of *Kazumura,* still the longest lava cave known and the "deepest". Bill, the Kempes, planetologist Ronald Greeley and his crew from the University of Arizona began a survey at its lowest end, a lava sump 30 m above sea level and surveyed to well above the crossing of Highway 130 to Pahoa. In less than three hours, they surveyed 2.4 kilometres! The cave passage was huge; two trucks could have passed easily (Fig. 9).

**Fig. 9: The huge tunnel of the lower Kazumura Cave, west of Highway 130. From left to right: one of Greeley's team, Ronald Greeley, Bill Halliday and Christhild (holding tape). The pile of breakdown is probably fill through the puka visible behind (photo: Kempe & Ketz-Kempe).**

The 6th ISV, ably organised by Bill and others, began on 4th August at the Sea-Side Hotel at Hilo. This symposium may be regarded as the beginning of concerted Hawaiian speleology and the exploration of large pyroduct systems.

Greg first met Bill while he was working on the Indian Ocean island of Mauritius in 1994. Bill was also a keen speleophilatelist but he didn't just collect stamps depicting caves – he liked to personally visit those featured. He had found a 1985 Mauritian stamp featuring Caverne Patate and hoped Greg could help him locate and visit it. Bill arrived in Mauritius on 12 May 1995, having just visited Kenya to check out the possibility of holding a symposium there for the Commission on Volcanic Caves. Greg showed him some lava caves within minutes of the airport and next day they flew to Rodrigues (the second island of Mauritius, 650 km to the north-east). There Greg was able to take him to the cave entrance shown on the 1985 stamp (Fig. 10).

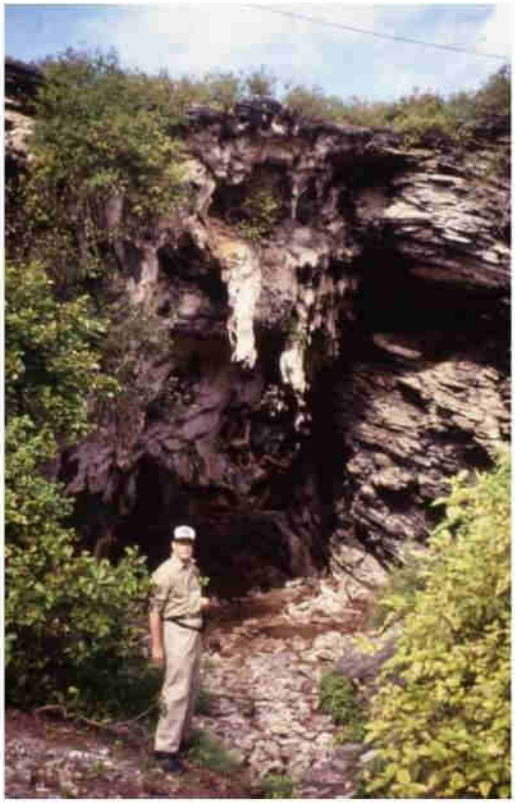


**Fig. 10: Bill at the entrance to Caverne Patate shown on the 1985 Mauritian stamp (photo: Greg Middleton).**

As Bill expressed it later: *I have used postage stamps as a cave hunting technique in several places, with particular results in the Republic of Mauritius, where the Patate Cave on the island of Rodrigues, is shown on one of their postage stamps. An Australian caver and I got together to go check out the whole new cave area that had not been studied before* (Halliday and others, 2007).

The 8th International Symposium on Vulcanospeleology took place in Kenya in 1998 (Middleton, 1999). It was a significant meeting for Bill as it was there that he handed over chairmanship of the Commission to Jan Paul van der Pas of the Netherlands (Figs. 11, 12). Naturally Bill continued to be heavily involved and accepted the role of Honorary Chairman.

**Fig. 11: Jim Simons, Jan Paul van der Pas and Paolo Forti drink a toast to retiring chair of the Commission on Volcanic Caves, Dr Bill Halliday, on the roof of the Panafric Hotel in Nairobi, 8th February 1998 (photo: Greg Middleton).**

**Fig. 12: The actual hand-over from Foundation Chairman Bill to second Chairman Jan Paul at the Commission meeting in Nairobi (photo: Greg Middleton).**

Despite the small number in attendance, it was a successful meeting with some memorable field trips, including Mt Suswa (Fig. 13) and the Ndarugu River Caves (Fig. 14).

**Fig. 13: Bill examining lava speleothems in Cave #13 at Mt Suswa, Kenya, on the field trip following the 8th ISV, February 1998 (photo: Greg Middleton).**

**Fig. 14: Bill exploring a barely-passable passage in the Ndarugu River Caves – demonstrating his enthusiasm for pushing all available leads (photo: Greg Middleton).**

**Fig. 15: One of the very hot caves that Bill Halliday surveyed in his Kīlauea Caldera Project. From left to right Bill, Ray and Ralph in front of a partly collapsed hollow pressure ridge or tumulus (photo: Kempe & Ketz-Kempe).**

In 1998 the Kempes joined Bill in Hawai'i to help in his project, investigating the caves on the floor of the Kīlauea caldera. *Postal Rift Cave* was the only major pyroduct there, all other caves were hollow tumuli, collapsed pressure ridges, drained temporary lava ponds or drained flow tongues and others. Bill used flags which he either stuck up through holes from below or placed from the surface. Thus, he could establish which holes were connected and correct his surveys. Some of these caves were extremely hot, creating yet another type of speleological research: thermal caving (Fig. 15). Bill reported about this from a medical standpoint in one of his talks laying out how to withstand temperatures of up to 55°C.

Greg joined Bill to assist with surveying during his July-August 2000 field season (Middleton, 2001) (Fig. 16). Bill's Kīlauea cave surveys and reports are now history. The Kīlauea summit collapsed to form a new caldera in 2018, destroying the caves that Bill documented.

**Fig. 16: Bill pointing to his Kilauea Caldera study area July 2000. The area was dramatically changed by the eruptions of 2018 (photo: Greg Middleton).**

On that same trip Bill organised a public seminar to raise community awareness (and put pressure on the authorities) to the widespread practice of using lava caves to dump rubbish. Bill also gave a tour of some of the worst sites to check the situation, collect water samples and gather photographic evidence (Fig. 17).

**Fig. 17: Bill campaigned against the dumping of rubbish in lava caves – here he's checking under a Kaumana garbage puka (photo: Greg Middleton).**

At the end of March 1999, Bill, Christian Lerch and Stephan flew to Moloka'i, to investigate Kauhakō Lake on the Kalaupapa Peninsula. This is the site of a former leper colony and now a National Historic Park. The lake is a flooded vent, at least 200 m deep. They took water samples down to 100 m, using a kid's rubber dinghy as their "research vessel" (Fig. 18). They found that the lake contains diluted seawater and has a pycnocline (density stratification) at the four-metre level and is anaerobic below that level.

**Fig. 18: View into the crater of Kauhakō, Moloka'i with the "research vessel", a kid's rubber dinghy, at the centre of the more than 200 m deep lake (photo: Kempe & Ketz-Kempe).**

Due to sulphate reduction, alkalinity is produced which, at the surface, leads to a high calcium-carbonate supersaturation. This in turn causes the calcification of cyanobacterial mats, called microbialites (or stromatolites if layered). They found hard calcitic crusts all around the lake on its basaltic shore. It may be a small thing to the layman, but microbialites are the only fossils from the Precambrian, "ruling" the oceans for three billion years. Thus, Kauhakō Lake is a small, but tell-tale recent model for the Precambrian ocean.

As the summer of 1999 approached, the Kempes flew to Boise to take part in the NSS Annual Convention at Filer, Idaho, meeting up with Bill and Sis for yet another vulcanological trip through the Northwestern US. Bill guided them through Ape Cave, his favourite lava cave (Fig. 19). Stephan remembered reading about this cave in Bill's book "Depths of the Earth" when he was 16. In that book Bill published a photo of a lava ball wedged between closing shelves (Fig. 20). To be now, after all these years, taken to the site of this legendary picture by Bill, in person, was thrilling for Stephan. Looking at the picture again, it appears that the bridging lava ball is just one of several that got stuck, as they bobbled along the surface of the lava river. The reason is that the shelf above caught five or six lava balls at the same time, now "cemented" into place by "slopping" lava around them. These balls are hanging a bit below the shelf that may have marked the level of the river at the time of this strange "lava ball jam".

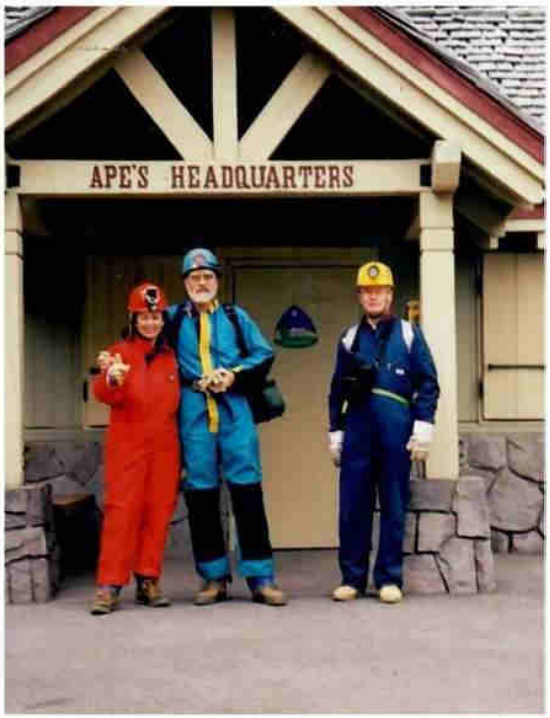



**Fig. 19: Bill Halliday with Christhild and Stephan about to enter Ape Cave, Bill's favourite lava cave (photo: Sis Halliday).**

**Fig. 20: This lava ball in Ape Cave appears to have become wedged when the lava was still flowing"(from Halliday, 1976a, p. 388).**

The 11th vulcanospeleological symposium on the Azores, May 2004, was the next time Bill and Stephan met. The pictures show Bill in his full session attire (Fig. 21), his caving clothes (Fig. 22), and in a cave (Fig. 23). It is probably the last picture we have of him underground.

**Fig. 21: Bill Halliday and Horst-Volker Henschel at the reception for the International Symposium on Vulcanospeleology at the Azores, 2004 (photo: Kempe & Ketz-Kempe).**

**Fig. 22: Bill Halliday and Gunhildur Stefánsdóttir from Iceland ready for caving during the 2004 Azores symposium (photo: Kempe & Ketz-Kempe).**

Bill's second wife, Sis, passed away aged 86 on 2nd January 2018. Sis was a warm-hearted and happy person, generous and always with a smile, ready for a gag or practical pun. Her southern accent added colour to the jokes about rednecks or southern calamities she used to tell. After Sis' passing Bill moved in with his daughter, Marcia. His eyesight began to fail, pretty much terminating communication. For many decades he had been compiling a book on non-karstic caves. This was part of the reason for his feverish travelling and why we accompanied him during those journeys in 1996 and 1999. We do not know how far along he was with the project.

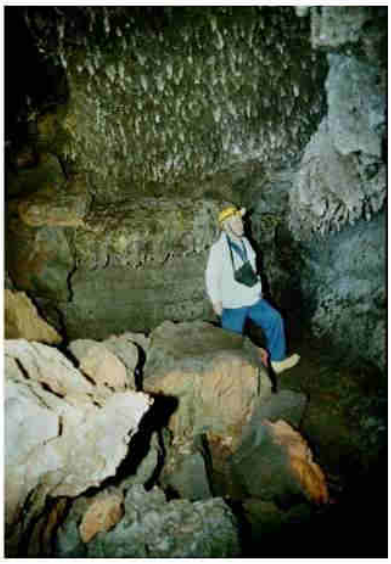


**Fig. 23: Bill Halliday in the pyroduct of Frei Matias, Azores, 2004. This is our last picture of Bill in a cave (photo: Kempe & Ketz-Kempe).**

Even without the book being finished, Bill's impact on vulcanospeleology is huge. This rests not only on his many reports, papers and chairman's letters but also on the countless lectures he gave throughout his life. Just one example: On 26 July 1994, he gave a public lecture at the auditorium of the HVNP in the "At the Park in the Dark" series on "*Lava Tube Caverns in the World*". There were also innumerable presentations during the NSS annual conventions, the UIS International Speleology Congresses and the international vulcanospeleology symposia. It would be difficult to list all these publications and presentations over the decades.

With the death of William R. Halliday, MD, the world lost one of the most outstanding cavers and speleological politicians ever and volcanic caves lost their greatest ever champion. Bill lived not only a long and healthy life, but most importantly an explorative, political, tremendously influential, and for the most part a happy life, much of it in the Earthly paradise we know as Hawai'i (Fig. 24).

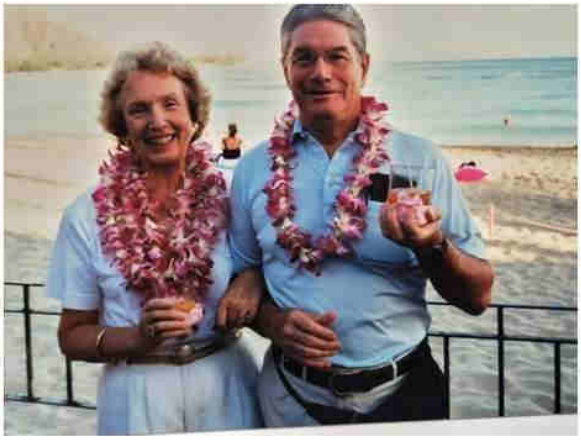


**Fig. 24: Our final aloha to Sis and Bill enjoying paradise Hawaiian style at Waikiki, Honolulu (photo: Kempe & Ketz-Kempe).**

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# Short Report on the observations on Speleological Potential in Volcanic Areas of Armenia. 17 -24 June 2024

**By Laurens Smets.**

**Team members: D.Verbrüggen, L. De Graauw, E. Birkhoff, L. Smets**
**All pictures by the team members**

**2024 team left to right: Dennis Verbruggen, Erik Birkhoff, Laurens Smets, Lisette de Graauw).**

From June 17 to 24, four members of Speleo Nederland undertook a reconnaissance trip as geo-tourists to Armenia. Armenia is part of the Caucasus, the mountain range situated between Turkey and Russia and is home to volcanoes and limestones areas. The country has no coastline and is landlocked, bordered by Turkey, Georgia, Iran, and Azerbaijan. While the exact border with Azerbaijan remains a subject of ongoing (armed) disputes, the rest of the country is peaceful and safe, with a welcoming and hospitable population.

In Armenia a few caves are known, some of Volcanic origin and some in Limestone rock. The longest caves can be found in Limestone areas like Arjeri Cave claimed to be 3km long. Volcanic caves are very rare, most of them artificial of origin and the longest is just nearly 150m. long.

The Armenian Highlands are part of the Caucasus region, and some geologists assert that the Caucasus does not have significant volcanic caves.

It is said that only in Armenia already more than 550 volcanoes can be found.

As one of the world's oldest countries, it is no surprise that nearly all caves in Armenia hold significant archaeological importance.

To the best of our knowledge, there are at least three active caving clubs in Armenia: the Armenian Speleological Network (ASN), Black Bat, and the Armenian Speleological Center. Additionally, companies like ArmGeo offer caving tours.

Speleology as a sport or as a recreational activity is not very common in Armenia and for us a European cavers it takes quite some efforts to convince all scientific parties of our private NON-scientific activities and recreational goals.

This report provides a brief overview of our findings on volcanic caves during our geo-touristic tour. We informed all relevant caving groups in Armenia about our plans before embarking on our tour across Armenia.

Our findings were highly appreciated afterward, and plans are now underway to participate in an Armenian expedition in 2025. This collaboration aims to exchange knowledge and expertise in the search and exploration of volcanic caves.

As volcanic speleologists, we did not understand why the volcanoes in these regions had not produced any subterranean lava cavities. This curiosity became the primary reason for our visit to Armenia: to explore the volcanic regions and observe potential speleological features. We aimed to apply our expertise in volcanic subterranean cavities, gained through years of visits to volcanic areas worldwide.

Based on our experience, volcanic cavities are most found in young volcanic areas, typically from the Pleistocene epoch to the present. Most of Armenia's volcanoes are cinder cones, some of which are very old (predating the Pleistocene). Additionally, they are located at high altitudes, exposed to harsh winter climates with frost, heavy rain, and snow. The abundance of clay and ash in these areas further complicates the search for caves.

**Cavities at the Vayotssar Volcano.**

The Vayotssar volcano is an example of a young volcano and was the first destination of our reconnaissance trip.

The Vayotssar, or Vaiyots-Sar, pyroclastic cone is located in the Vayots Dzor province in southern Armenia. It stands at a height of 2,575 meters, with its last known eruption dating back to around 2000 BCE. During our exploration of the Vayotssar Volcano, it became apparent that no caves could be found near the volcano itself. The slopes are composed of ash and scoria. However, to the southwest, there is a parasitic volcano with several interesting aa-lava fields and some fissure eruptions. Based on our experience, parasitic volcanoes often feature volcanic voids, such as fumaroles, and it is sometimes possible to discover lava conduits in or around these volcanoes.

In one of the a'a-lava fields southeast of the Vayotssar Volcano, we observed several short shafts, which appeared to be partly natural and partly handmade. Our initial observations revealed at least ten of these shafts clustered closely together. Most of them ended at a depth of about 1.5m. on a flat, handmade floor. One shaft had a partially covered handmade roof, and another ended in a collapse at 1.5 meters, revealing a chamber through the rocks. This area could hold significant archaeological interest.


Fig. 1. Vayotssar and its parasitic volcano. In the east, the area with the shaft-caves Ref. Google Earth

Fig. 2. Example of a shaft entrance

Fig.3. Example of the flat floor

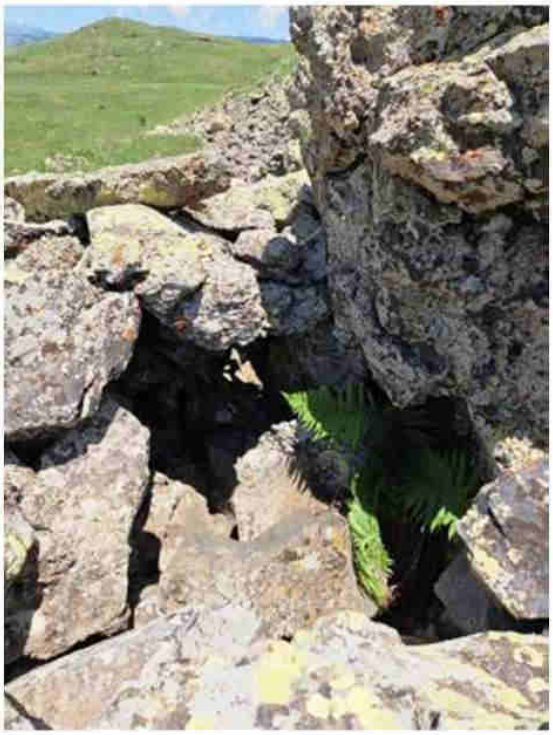

Fig. 4. Human-made roof on top of shaft

Fig. 5. Entrance to shaft. See also figure 6

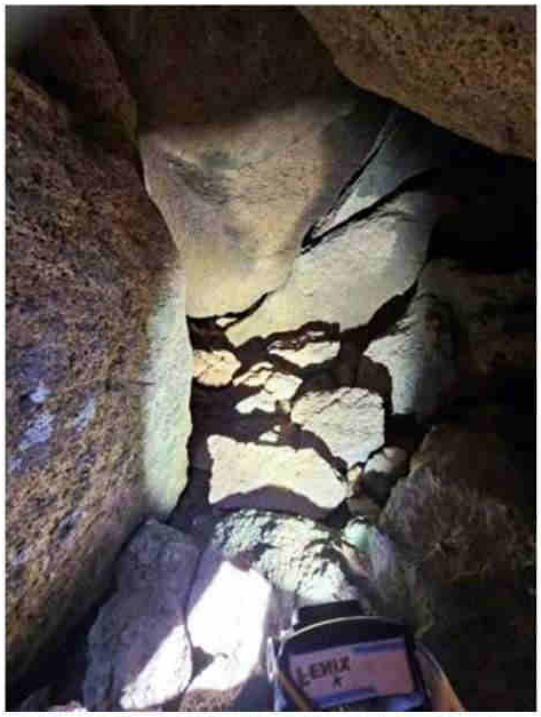

**Fig. 6. Shaft with chamber behind rocks**

**Fig. 7. View to location of shafts and human-made walls**

**Caves in the Smbatassar lava flows**.

The Smbatassar Volcano is a monogenetic volcano that split into two halves due to a fissure eruption. It is one of the youngest volcanoes, having erupted about 3,000 years ago. The volcano stands at a height of 3,037 meters above sea level.

On the 19th of June, we visited the lava stream north of the village of Yeghegis. Just above the village, a lavafall can be found, with several lava rivers branching out in different directions from the top. At the top of the lavafall, there is a short lava conduit (fig. 8 and 9) that is blocked after about 7 meters by welded clasts and lava balls.

Some publications suggest there might be a collapsed lava conduit just above the lavafall, likely connected to the short lava cave beneath. Currently, the actual state of the lava channel is a partially by Pahoehoe lava slabs crusted-over lava channel (fig. 11) with a collapsed roof. Between the collapsed rocks and small shafts (fig. 10), spaces are visible, but not accessible to humans. It is very unlikely that any subterranean voids survived the collapse. Accreting in-growing shelves along the sides of the lava channel can be seen, but they likely collapsed before they could fully crust over the lava conduit.

In between the detached lava sheets (Cavities caused by detachment of lava sheets in very viscous lavas flows) 3 individual cavities (fig. 10-11) can be found with the longest measuring max 20m. As well as upstream as downstream no further cavities could be found.

Lowest cave at south sidewall of lava channel: 39°52'57.82"N, 45°21'40.23"E 2 caves in North sidewall of lava channel: 39°52'58.39"N, 45°21'40.76"E

Fig. 8. Lava conduit 7m long.

Fig. 11. A detached lava sheet on the left where a small cave can be found N-S.

Fig. 9. Welded clasts and lava balls in the roof, and the end of the lava conduit

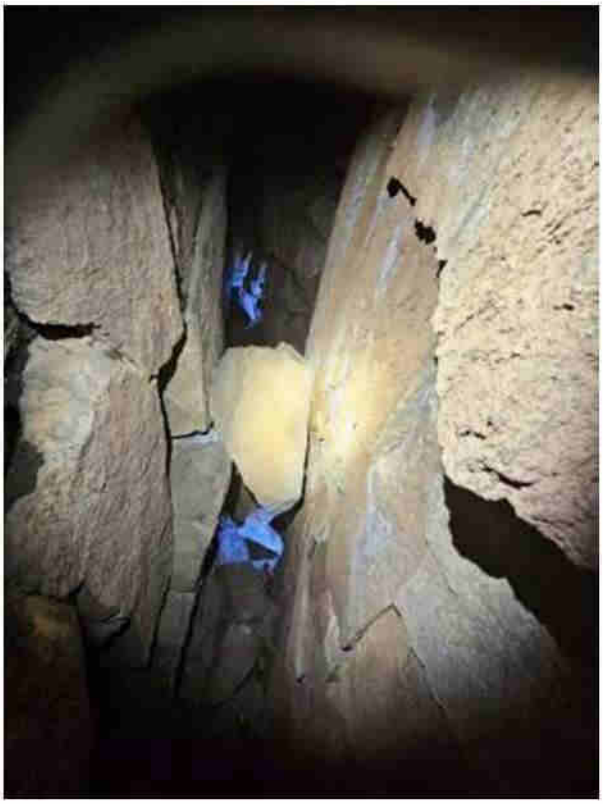

Fig. 12. The fissure-like interior of one of the caves. Several entrances can be seen.

Fig. 10. View to the last lava channel before it drops into the lavafall N–S.

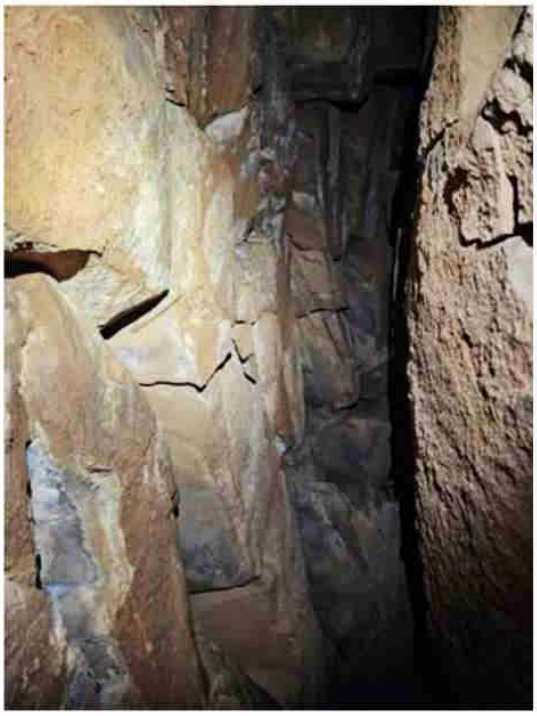

**Fig. 13. At the left hand side the smooth wall of one of the shelves.**

**Fig. 14a. General location of the 4 caves in the Smbatassar lava flow**

**Fig. 14b. Close-up view of cave location in the Smbatassar lava flow.**

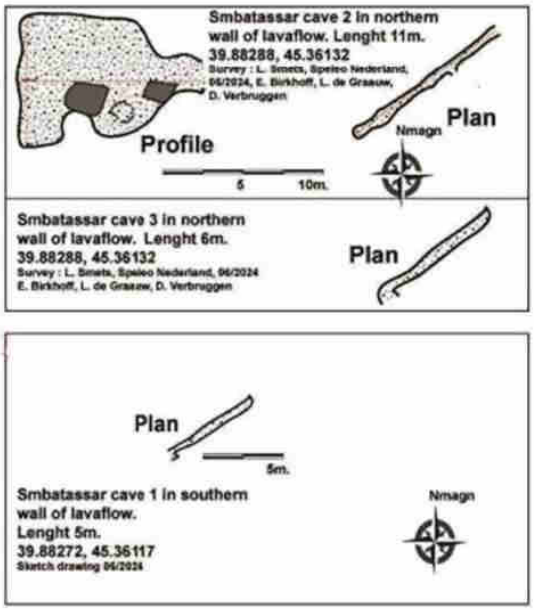


**Fig. 15. Caves in the Smbatassar lava flow**

## Caves at Azhdahak mountain.

On the 20th of June in the afternoon we organised a truck to bring us to the Azhdahak campground on a level of 3200m. asl.

The campground is based north east of the 3600m. high Azhdahak Volcano. Besides Aragats Volcano, Azhdahak Mountain is the second most famous volcano in Armenia. Azhdahak mountain is the highest point of the Geghama Mountain Range.

The road to Azhdahak starts in the village of Geghard. Due to the partly snow-covered valleys, we had difficulty reaching the campsite and even had to dig out our truck.

Azhdahak mountain is a cinder cone volcano. The cone is formed by scoria, lapilli, sands, volcanic ash, debris, lava boulders, and volcanic bombs at an age between Pleistocene and Holocene. Despite being partly covered in snow, our observation trip around and on top

of Azhdahak Mountain yielded several positive results.

At the east side of the volcanic slope a layer of welded clasts and debris can be found on top of the ash and scoria layer.

This is where several cave entrances can be seen high up on the slope starting at about 3400m. and extending up to the peak of the volcano (fig 16).


**Fig. 16. Location of caves on Azhdahak mountain**

On the east side of Azhdahak mountain at an altitude of 3390m. asl (40°13'32.9"N 44°56'34.9"E) we visited the lowest cave entrance which is visible from below (fig. 17-19).

**Fig. 17. Entrance of cave Azhdahak 1**

**Fig. 18. Entrance of cave Azhdahak 1**

**Fig. 19a. Interior of cinder cave Azhdahak 1**

**Fig.19b. Mammal bone in cave Azhdahak 1**

The cave is formed between the welded clasts and the ash/scoria underneath. The fissure-like cavity is created partly by water and wind erosion and partly by the settlement of the ash layer. The cave is about 14 meters long, ending in a vertical room large enough for a person to stand in. Higher up on the same side of the volcano, more

entrances can be seen, some of which are quite large (40°13'33.76"N, 44°56'38.99"E). Ropes are likely needed to reach these entrances from above. The cave was probably used in the past by bears and other animals, as evidenced by a large bone found covered in mud (fig 19b).

At the south east side of the adjacent volcano (part of Azhdahak mountain) a kind of lava conduit can be found. The cave is situated on the slope under a layer of welded clasts. Lava has been flowing between the top layer and the ash/scoria underneath. The gallery is crawling size and ends in a low extension blocked by a big rock. No further progress can be seen.

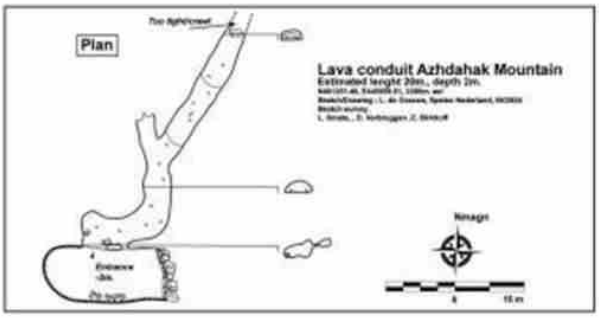


**Fig. 20a. Lava conduit Azhdahak**

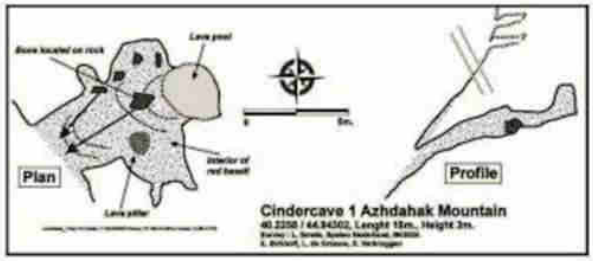


**Fig. 20b. Azhdahak 1 totaal**

**Fig. 21a. The entrance of the Azhdahak Lava conduit**

**Fig. 21b. Welded clasts on top of the Azhdahak conduit**

Based on our observations, most of the volcanoes around Azhdahak are cinder cones. However, many of them are partially covered by a layer of welded clasts, suggesting potential areas where more volcanic caves might be found.

## Caves on Mount Ara near to Tsaghkevank Monastery.

Mount Ara is a polygenetic stratovolcanic cone with a height of about 2605m. asl. The volcano is probably between 1 and 2 ml years old and its slopes are broken-up by deep crevasses.

The valleys near Tsaghkevank Monastery contain numerous mined cavities, likely excavated as shelters or temporary homes for monks. It is conceivable that many of these shelters originated as natural abris or rock overhangs, which were later expanded by human effort.

The area is characterized by dense vegetation that also covers the numerous valleys. In several valleys, small caves (fig. 22) can be found. Two of these caves (fig. 23) appear to have been further dug out, possibly by bears. In one of the caves, a 1-meter wide nest made of roots and branches can be found about 3 meters into the rock fissure (fig. 24).

**Fig. 22. Location of caves (red circle) found near Tsaghkevank Monastery**

**Fig. 23. Cave nr. 2, a 6m. long that appears to have been enlarged by animals**

**Fig. 24a. One of three small caves near Tsaghkevank Monastery**

**Fig. 24b. Small cave near Tsaghkevank Monastery**

**Fig. 24c. Another small cave near Tsaghkevank Monastery**

All caves we found in this area can be described as erosion caves located in or aside of river beds and eroded by water and wind. Some contain digging and nesting marks of bigger animals probably bears. Others are partly mined

by hand probably to be used as a shelter or for a religious meaning. The valleys have dozens of other small abris, some of them containing very small natural springs.

**Caves South east of Lernanist, Klor Tar Volcano.**

The Surbi caves are located between volcanic cones of Menaksar (2399 m), Klorsar (2358 m) and Sarisurb (2526 m).

The lava flows from the Surbi caves are probably originating from the Klor Tar (or Klorsar) volcano. The volcanoes belong to the Ghegham Volcanic Ridge which contains as many as 127 volcanic centers, lava domes and pyroclastic cones, of Pleistocene-to-Holocene age. The last known eruption is from 1900 BCE.

The landscape between Lernanist and The Klor Tar Volcano is of agricultural nature, mostly covered by dense grasses used for sheep and cattle.

A thick layer of loess covers all volcanic rock in the area. Snow, frost, and the large annual rainfall have likely sealed off most of the underground lava conduits, filling them with mud. This is evident in the few caves we have found, where all downward holes are filled with sediments.

The region between Klor Tar Volcano and the village of Lernanist is characterized by an abundance of lava and gas domes, all formed by underground lava conduits. One of these lava domes, a known cavity, is used for parties and barbecues. As we discovered more of these domes, we just named the known one "Surbi 1" (or Aphrey Cave fig 27 and 28) and the next Surbi 2 and so one.

The name from the adjacent volcano "Sarisurb" translates to "Saint Mountain," which is likely the origin of the name "Surbi," meaning "Saint's Cave".

Figure 26 shows the locations of the domes we found. As our time was limited to 1 day it is not unlikely more of these domes and relicts of lava conduits can be found in this area.

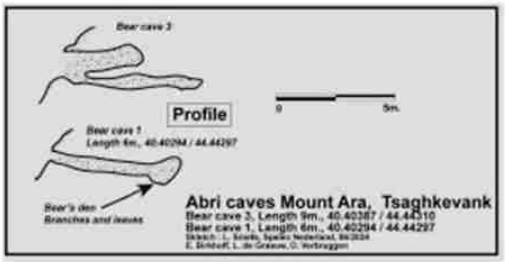


**Fig. 25. Some of the small erosion caves**

**Fig. 26. Location of the 5 Surbi lava dome caves**

Fig. 27a. Entrance to Surbi 1 or Aphrey cave

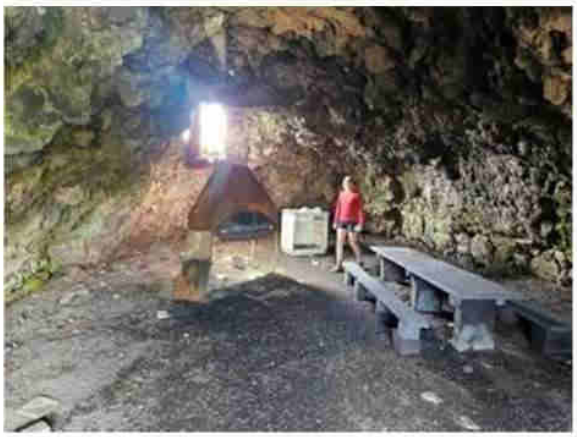

Fig. 27 b. Interior of Surbi 1 (Aphrey) cave which is used by locals for Barbecues

Fig. 28. Remnant of the path from the lava into the conduit of Surbi 1.

Fig. 29a. Panorama view to Surbi 2 cave

Fig. 29b. Surbi 2 entrance

Fig. 29c. Interior of Surbi 2 cave

Fig. 30. Panorama View to Surbi 3 cave

Fig. 31a. View to Surbi 4, entrance

Fig. 31b. Surbi 4 interior

Fig. 32a. Panorama view to Surbi 6, entrance

Fig. 32b. Interior of Surbi 6 cave

Fig. 32c. Surbi 6 cave

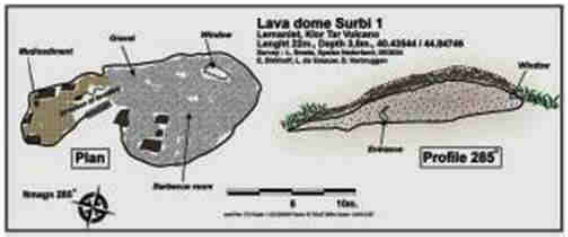


Fig. 33. Survey Surbi 1

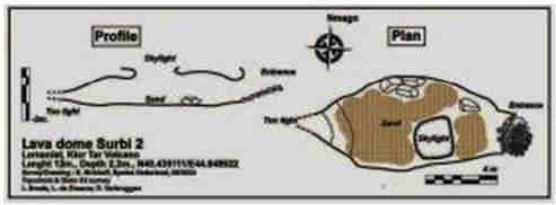


Fig. 34. Survey Surbi 2

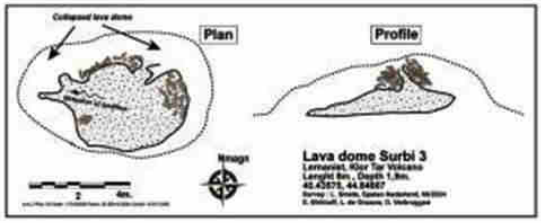


Fig. 35. Survey Surbi 3

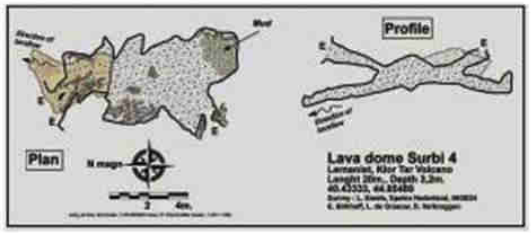


Fig. 36. Survey Surbi 4

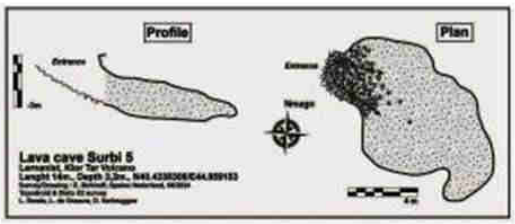


Fig. 37. Survey Surbi 5

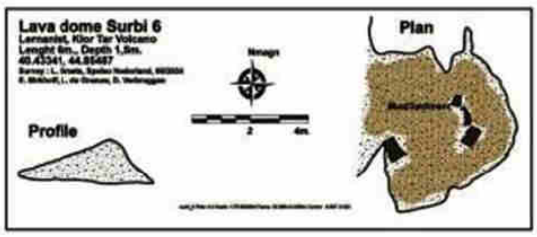


Fig. 38. Survey Surbi 6

## Conclusion.

After spending five days exploring specific areas of Armenia, we gained valuable insights into the country's volcano speleological potential. During this time, we observed 20 caves with a total length of nearly 175m. Although none of these caves exceeded 20 meters in length, they were fascinating and provided a clear view of the geological development in the regions we visited.

It is likely only a matter of time before larger caves are discovered. However, finding these caves is quite challenging, as they are often located in remote areas. A 4x4 vehicle is necessary, and much of the exploration takes place at elevations above 2000 meters asl. Some areas, like Azhdahak Mountain, have a very short exploration window due to snow cover. Additionally, we observed that some caves are used by bears, which is an important consideration for future explorations at high altitudes.

Identifying potential cave locations in Armenia is not straightforward due to the presence of a´a lava flows and ash cone volcanoes. Nonetheless, expert volcanic speleologists are likely to achieve positive results with specialized knowledge. The expectation is that future exploration of volcaic caves, especially in the national parks, will provide valuable information to geologists and other scientists, aiding in the evaluation and conservation of the natural environment.

**Acknowledgements.**

This paper is indebted to a very large number of colleagues, cavers and friends that helped the tour members in the field as well as to those that have shared their thoughts and observations about the volcanic phenomenon's in Armenia.

Not all of these can be mentioned here but we are specifically grateful to Dr. Ara Avagyan, Dr. Samvel Shahinyan, Tigran Armenyan, Ervan and Alvard Abrahamyan, Tigran (Azhdahak Campground), Vahe Martirosyan, as well as Speleo Nederland for their support.

Furthermore, we owe our gratitude to Dr. Stephan Kempe for sharing his knowledge, which was essential for observing and identifying the caves found in certain types of volcanic areas.

***Version 13082024, Laurens.M.J. Smets***

| Area | Name | Lenght (m) | Depth (m) | Location | Lugar | Typology | Conservation | Surveyed | Remarks | Coordinates | Number of caves |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vayoissar Volcano** | | | | | | | | | | | |
| | Shelter cave 1 | 1,5 | 1,5 | Vaiyots-Sar | AA lavafield east op Vayotssar parasitic volcano | mined natural small shafts | Good | No | archeological value, Possible prehistoric shelters | 39.79178, 45.48188 | 1 |
| | Shelter cave 2 | 1,5 | 1,5 | Vaiyots-Sar | AA lavafield east op Vayotssar parasitic volcano | mined natural small shafts | Good | No | archeological value, Possible prehistoric shelters | 39.79166, 45.48184 | 1 |
| | Shelter cave 3 | 2.0 | 2.0 | Vaiyots-Sar | AA lavafield east op Vayotssar parasitic volcano | mined natural small shafts including possible chamber | Good | No | archeological value, Possible prehistoric shelters | 39.7922, 45.48391 | 1 |
| | Shelter caves | | | Vaiyots-Sar | AA lavafield east op Vayotssar parasitic volcano | mined natural small shafts | Good | No | In between shelter cave 1 -3 about 5 more shafts | | |
| **Smbatassar Volcano** | | | | | | | | | | | |
| | Cave1 in South Wall | 5,0 | 2,0 | Smbatassar lava flow | Yeghesis | Cave in between detached lava sheets | Good | E. Birkhoff | | 39.88272, 45.36117 | 1 |
| | Cave 2 in North wall | 11,0 | 6,0 | Smbatassar lava flow | Yeghesis | Cave in between detached lava sheets | Good | | | 39.88288, 45.36132 | 1 |
| | Cave 3 in North wall 1 | 6,0 | | Smbatassar lava flow | Yeghesis | Cave in between detached lava sheets | Good | | | 39.88288, 45.36132 | 1 |
| | Lava conduit | 7,0 | 3,0 | Smbatassar lava flow | Yeghesis | Artifact from Lava conduit | Good | L. Smets | Pyroduct is blocked upstream by welded clasts and lava balls | 39.88095, 45.35689 | 1 |
| **Azhdahak Volcano** | | | | | | | | | | | |
| | Cinder cave Azhdahak 1 | 18,0 | 3,0 | Azhdahak Mountain | | Eroded cave between top layer of welded clasts and the ash/scoria layer underneath | Good | L. Smets | Possibly a shelter for big animals like a bear | 40.2258, 44.94302 | 1 |
| | Cinder caves Azhdahak | 0,0 | ? | Azhdahak Mountain | | Eroded cave between top layer of welded clasts and the ash/scoria layer underneath | | No | Not visited, Several entrances visible, Rope needed | 40.22604, 44.94416 | |
| | Lava conduit | 20,0 | | Azhdahak Mountain | | lava conduit in layer under welded clasts | Good | E. Birkhoff/ L.de Graauw | 3385 asl. | 40.21430, 44.93319, | 1 |
| **Mount Ara** | | | | | | | | | | | |
| | Small Cave 1 | 6,0 | 0,6 | Mount Ara | Tsaghkevank | Eroded cave in a riverbed | Good | L. Smets | Possibly a bear shelter | 40.40294, 44.44297 | 1 |
| | Small Cave 2 | 2,0 | | Mount Ara | Tsaghkevank | Eroded cave in a riverbed | Good | | | 40.40203, 44.44011 | 1 |
| | Small bear cave 3 | 9,0 | 2,5 | Mount Ara | Tsaghkevank | Eroded cave in a riverbed | Good | L. Smets | Possibly a bear shelter | 40.40387, 44.44310 | 1 |
| | Small Cave 4 | 3,0 | | Mount Ara | Tsaghkevank | Eroded cave in a riverbed | Good | | | 40.40319, 44.44257 | 1 |
| | Small Cave 5 | 3,0 | | Mount Ara | Tsaghkevank | Eroded cave in a riverbed | Good | | | 40.40237, 44.44198 | 1 |
| **Klor Tar Volcano** | | | | | | | | | | | |
| | Surbi 1 | 22,0 | 3,8 | Geghama area | Lernanist | Lava dome | Bad | L. Smets | Changed into barbecue quarter | 40.43544, 44.84746 | 1 |
| | Surbi 2 | 12,0 | 2,2 | Geghama area | Lernanist | Lava dome | Good | E. Birkhoff | | 40.43511, 44.84892 | 1 |
| | Surbi 3 | 8,0 | 1,9 | Geghama area | Lernanist | Lava dome | Good | L. Smets | | 40.43575, 44.84667 | 1 |
| | Surbi 4 | 20,0 | 3,2 | Geghama area | Lernanist | Lava dome | Good | L. Smets | | 40.43333, 44.85489 | 1 |
| | Surbi 5 | 14,0 | 3,2 | Geghama area | Lernanist | Lava conduit | Good | E. Birkhoff | | 40.43383, 44.85915 | 1 |
| | Surbi 6 | 8,0 | 1,5 | Geghama area | Lernanist | Lava dome/lava conduit | Good | L. Smets | | 40.43341, 44.85487 | 1 |
| | | | | | | | | | | | 20 |

**Fig. 39. Overview of the caves found in June 2024**

# Volcanic caves in the Province of La Pampa, central Argentina

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(Universidad Nacional de La Pampa - CONICET)

## Introduction

In central-west Argentina, there is a volcanic province named Payenia or Payunia. The volcanism that shaped Payunia, and which is currently inactive, was produced by internal processes in the upper mantle located beneath this area, as a consequence of subduction of the Nazca plate (floor of the Pacific ocean at this latitudes) below the South American plate. This volcanic province is located between the Andes and the Pampean flat plains and contains rocks that were formed from twenty-four million years ago to about 1000 years ago and comprises the largest extension and concentration of pyroclastic cones (more than 800) in South America (Inbar and Risso, 2001). During different eruptive periods when igneous activity developed, several composite volcanoes were formed and large volumes of lava were extruded, which represent the main volcanic rock units in the area. Bernardi (2016) and Bernardi et al (2019) mapped and documented numerous basaltic lava flows emplaced in the southeastern region of Payenia, along the boundary sector of Mendoza and La Pampa provinces (Fig. 1). These flows are mainly of the pahoehoe type with a NW-SE direction and some of them reached notable lengths of between 70 and 180 km long.

From observations on the behavior of Hawaiian active lava flows, Hon et al. (1994) proposed a model for lava emplacement known as inflation: at first, lava advances through numerous individual thin lobes that coalesce laterally and increase in thickness because of the injection of lava below an outer cooling crust having ductile behavior, which becomes brittle as it cools and thickens. This crust supports the increasing pressure of the addition of lava to the isolated liquid core. Initial inflation is general throughout the entire lava body and it becomes localized as the lava movement is restricted to an internal network of lava tubes. Based on this model Bernardi (2016) and Bernardi et al (2019) suggested that basaltic flows of eastern Payenia developed through a combination of areal dispersion and inflation processes with the formation of different inflation structures such as tumuli, flat-roof lava rise and lava rise ridges. These morphological features that are related to the inflation mechanism have been observed in numerous lava flows around the planet particularly in those of considerable

extension and it was postulated that this process was fundamental in the development and emplacement of these lava flows. Another type of structure that is related to the mechanism of inflation and linked to the great longitudinal development that present these flows, correspond to lava tubes. Thanks to these internal paths the lava travels through the flow and reaches distal fronts with very low cooling gradient. Sometimes these large structures are completely drained of lava and preserved as tubes or tunnels.

In the Pampean Payunia two volcanic caves related to the inflation mechanism have been found: Halada cave, defined as a lava tube and El Julepe cave, defined as an inflation cavity (Bernardi, 2019).

**Halada Cave**

The Halada cave is an underground lava volcanic landform, located approximately 60 km northwest of the nearest village (Puelén) at 36°57'S and 68°05'W. It constitutes what is called a master or main lava tube or tunnel (Fig. 2). This type of structure is linked to the large longitudinal development of the lava flow that contains it, called El Puesto. The El Puesto lava flow is a single basaltic flow 0.200 million years old, located in the southern-central Payenia, which was extruded from the Morado volcano (36°51'S - 68°21'W), and reached 70 km long from its effusion center covering an minimum area of approximately 856 $km^2$ (Bernardi 2019). The Halada cave formed from the convergence or union of secondary tubes, which result from the heterogeneous cooling and solidification of the external and internal sectors of the flow. The lava that circulated within the Halada tunnel during its formation was drained towards other sectors of the flow, leaving the conduit empty in the final stage of the flow emplacement, while many similar tunnels remained filled by the lava that circulated inside them. Morphologically, the tunnel consists of a main gallery with an arched roof and three short secondary galleries (Fig. 3a). The total length of the tunnel is 370 m, with an altitude difference of 10.2 m with respect to the entrance. The maximum height is 2.2 m and its maximum width is 22.9 m (Bertotto, 1996; Martínez, 1998) (Fig 3b). The entrance consists of a small hole in the roof with a diameter of 0.60 m (Fig. 3c). The basalt that makes up the tunnel is mostly vesicular in structure, becoming somewhat more massive towards the sides of the cross section of the tunnel (Figs. 3d, 3e, 3f). The roof and walls are partially covered by patches and small stalactites of calcium carbonate and gypsum (Fig 3g) and, in some sectors, it exhibits small drops of lava of up to 2 cm. According to a classification suggested by Calvari and Pinkerton (1999) based on the morphology of lava tunnels described in lava flows from Mount Etna (Italy),

the Halada tunnel exhibits characteristics of a simple and symmetrical tunnel, formed from the cooling of a stable inflated flow. Detailed morphometric surveys carried out in Halada Cave (Bertotto 1996, Martínez 1998) revealed that it has two sectors in which changes of up to 90º occur in the general direction of the main tunnel trace. Martinez (1998) defined the shape of the cross section of the tunnel at several points, determining a certain asymmetry in some segments. This is interpreted as a result of the differential accumulation of lava due to local changes in the direction of the main tunnel path.

Inside the cave the environment is dry and there are no real signs of living animals, only a few skeletons of specimens that fell from the entrance.

Finally, some morphologies that were observed in this and other nearby lava flows were interpreted as remnants of lava tube structures whose roof could have collapsed after lava drainage (Fig. 4). Minor lava tubes (metric and centimetric scale) were also documented, evidencing that the formation of these structures was essential for the emplacements of these extremely long flows.

**El Julepe Cave**

The El Julepe cave is an underground cavity of volcanic origin dome shaped with a circular base of 78 $m^2$, an average diameter of 10.8 m and a maximum height of 3 m (Fig. 5). It is located at 37°13'S and 67º 41'W, about 20 km west of the nearest village (Puelén). It occupies a distal point of the Pampa de Ranquelcó lava flow, approximately 100 km from the effusion area, and is housed in the upper section of a flat-roof lava rise inflation structure (Fig. 6). The entrance to El Julepe cave is through a circular hole in the surface of the lava flow, 1.5 m in diameter, and access to the interior of the cavity is 2 m deep (Fig. 7a). The rock that makes up the cave is a basalt with vesicular structure. The cavity has a fragmented structure due to fractures resulting from the cooling contraction of the lava flow and from its distension during inflationary swelling. The floor is covered by sand and blocks from the collapse of the entrance and the cavity roof (Figs. 7b, 7c y 7d). The cave does not present any speleothem development (stalactites, stalagmites, etc.) and only patches and fracture fillings of carbonate not linked to volcanic rock are observed. The origin of this cavity is primary and not erosive, that is, as a consequence of processes inherent to the dynamics, emplacement and solidification of the lava flow. It has been suggested that the formation of this cavity occurred from the heterogeneous cooling of the internal sector of the inflated structure in which it is housed. This resulted in the permanence of some plots filled with

liquid lava and, in an advanced stage of the solidification of the structure, the melt could escape from some of these, leaving behind small cavities (Bernardi et al., 2019) (Fig. 8).

The lava flow hosting the El Julepe cave was named Pampa de Ranquelcó (Bernardi 2016) and comprises a composite flow of 116 km in length covering an area of 1890 km$^2$, with an age between 2.3 and 5.1 million of years. It originated in eruptive centers located northeast of the Chachahuén volcanic complex, south of the province of Mendoza. This lava flow moved east-southeast on a surface with a slope of less than 1º.

The cave environment is dry and there are some signs of living animals, such as bat guano deposits in the floor.

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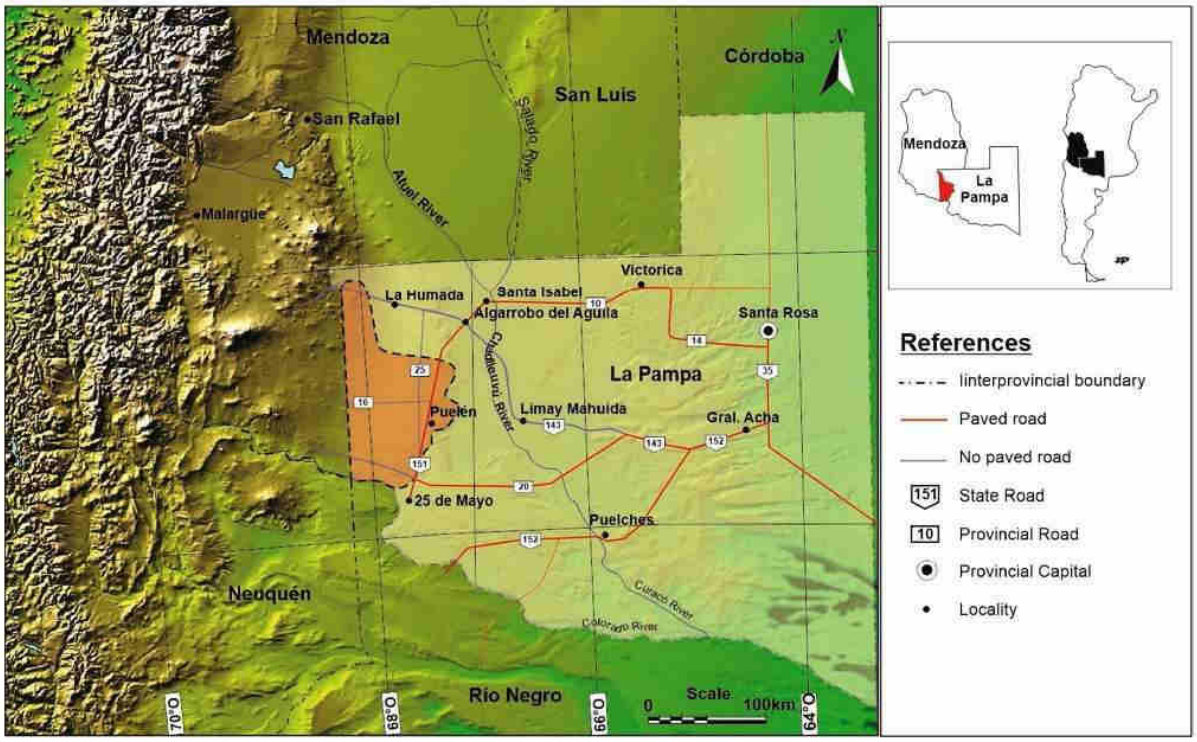


**Figure 1. Topographic map (SRTM) of central-west Argentina where the province of La Pampa was marked and, to the west of it, the eastern expression of Payunia where the lava flows and caves are located (brown area).**

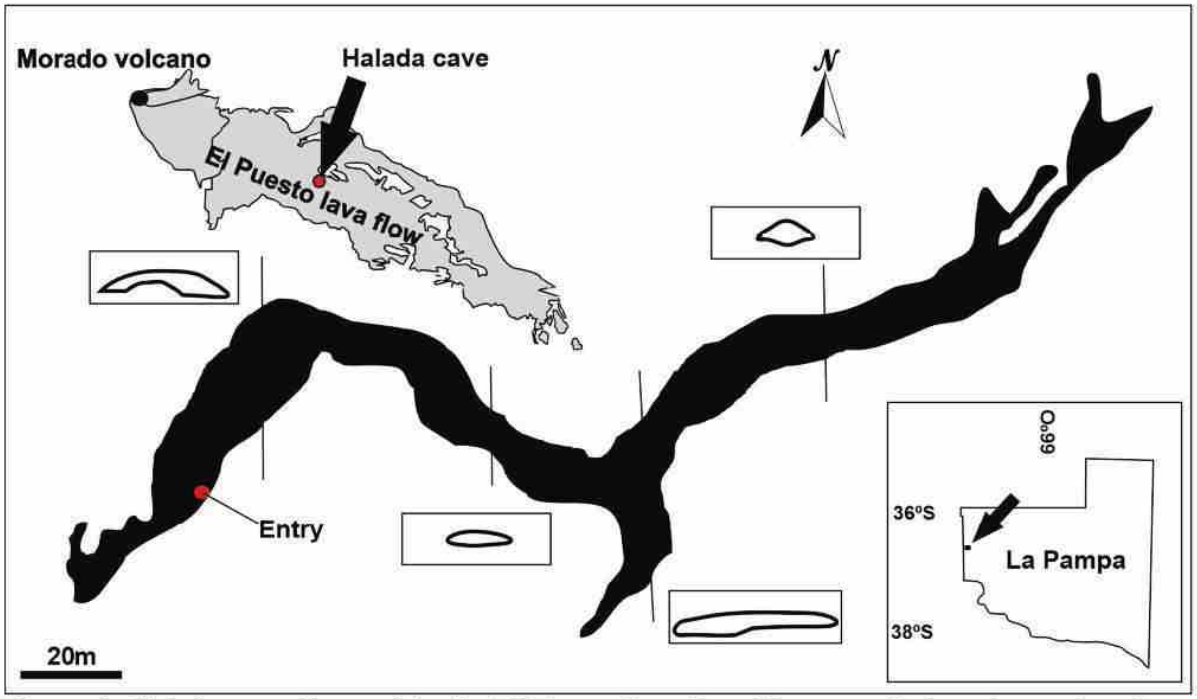


**Figure 2. Halada cave. Located in the El Puesto lava flow. Plan morphology data taken from Bertotto (1996) and Martinez (1998). The boxes indicate the cross sections surveyed in some sectors of the main tunnel (Martínez 1998). Note the asymmetry of the section in the segments close to the bends.**

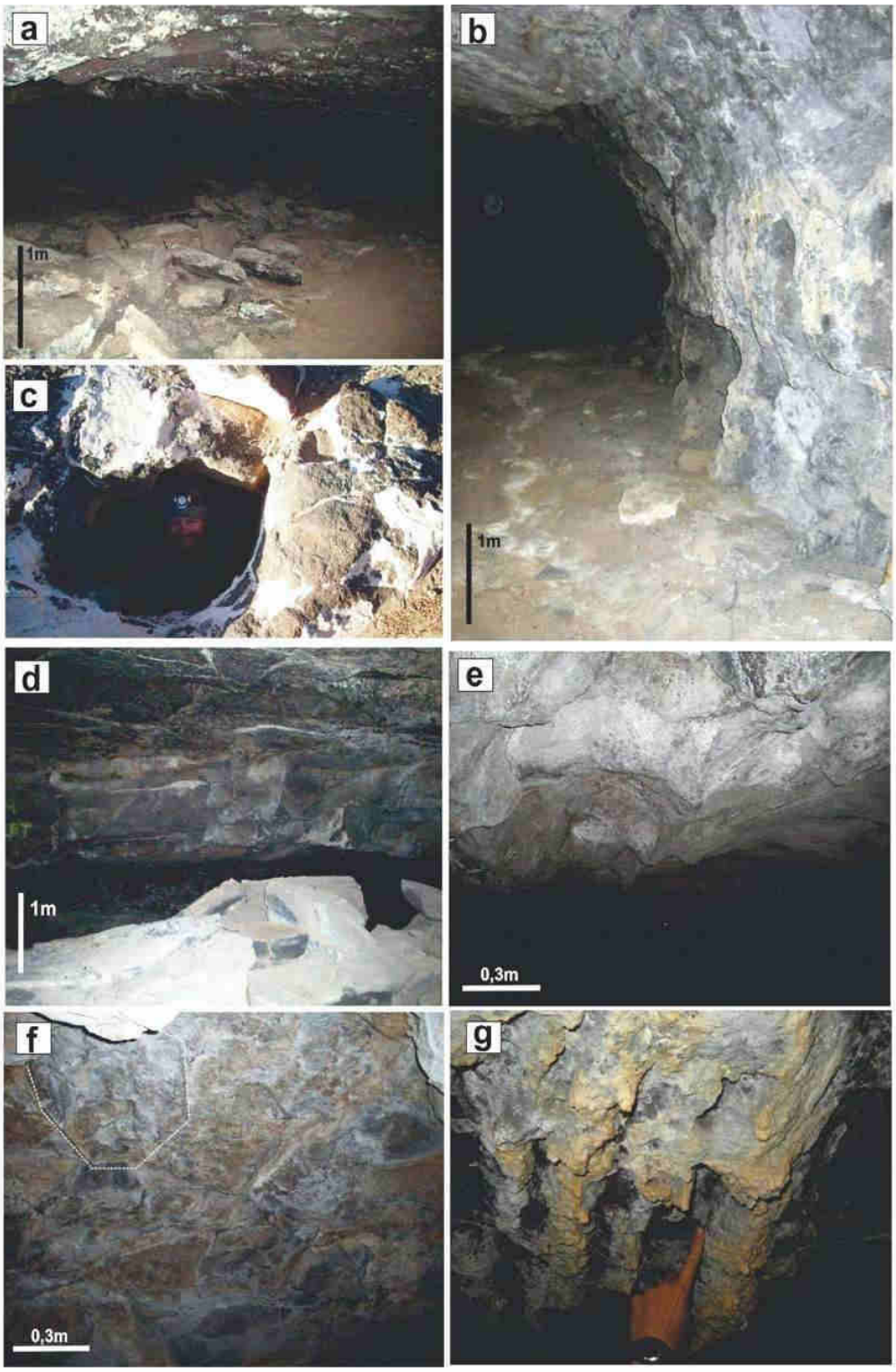


**Figure 3. Halada Cave. Internal structure. a and b) Cross section of the tunnel section below the access entrance. This section is the widest of the entire structure and corresponds to the main passage. It has an arched ceiling and a maximum height of 2 m; c) Access entrance to the tunnel; d) Structure of the walls and ceiling and rocks that have fallen from the ceiling; e) Ceiling with an undulating "egg box" type structure; f) Smooth ceiling with polygonal joints; g) Stalactites of the calcareous material that covers part of the ceiling and walls of the tunnel.**

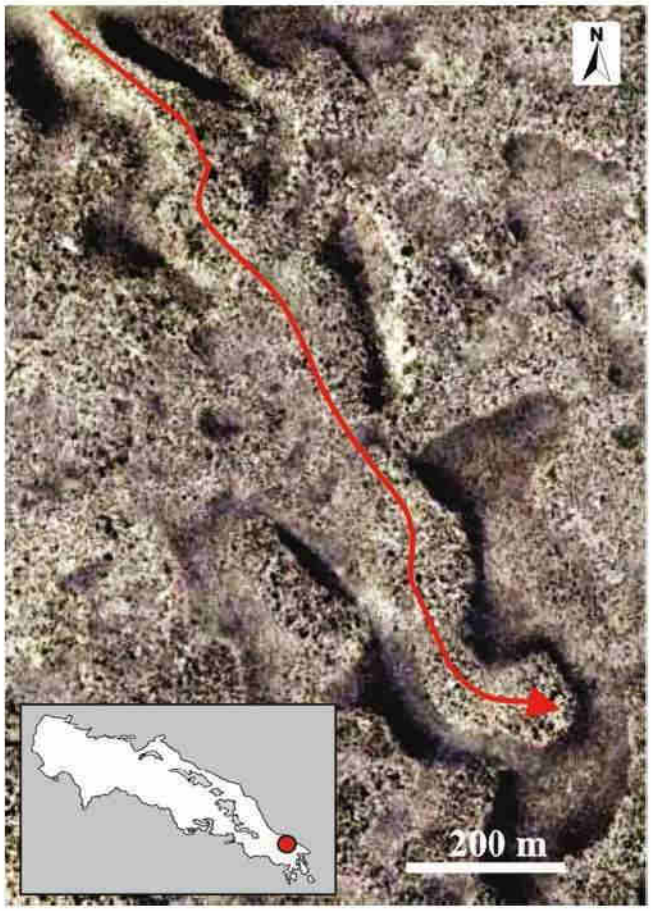


Figure 4. Lava flow structure interpreted as a remnant of a roof-collapsed lava tunnel

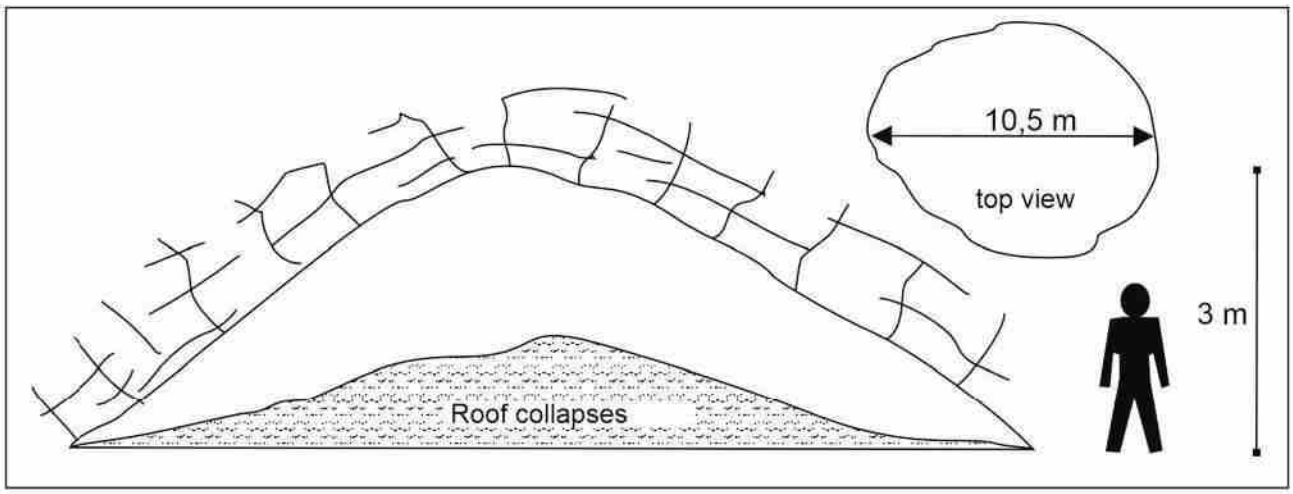


**Figure 5. Diagram of El Julepe Cave. a) Cross section of the cave. A severely fractured roof and a floor covered by rock falls are highlighted, mainly in the central section of the cave. Towards the inner margins of the cavity, the presence of fallen blocks decreases. The plan of the cavity is also shown.**

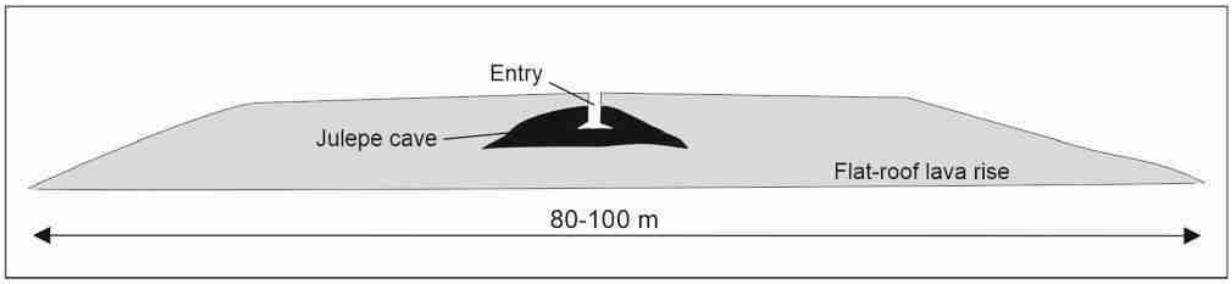


**Figure 6. Location of the El Julepe cave within the lava structure in which it is located. Approximate northwest - southeast section.**

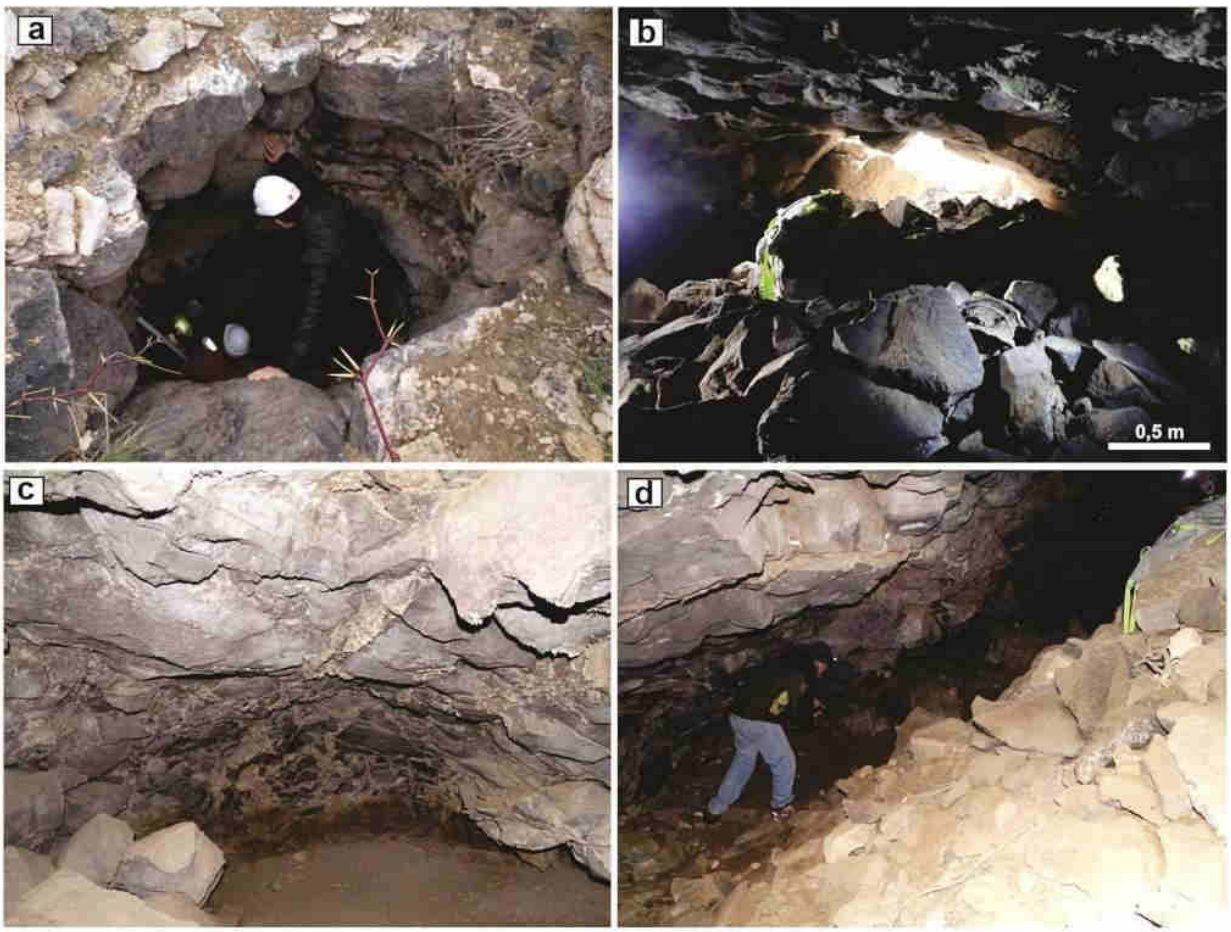


**Figure 7. El Julepe cave. Images. a) Entrance from the surface. b) Access, located about two meters from the surface. In the foreground, there are rocks collapsed from the cave ceiling. c) Presence of carbonates and sulphates covering the walls and ceiling of the cave and filling fractures. d) Central sector with rocks collapsed from the cave ceiling and internal edges of the cave almost devoid of detached blocks.**

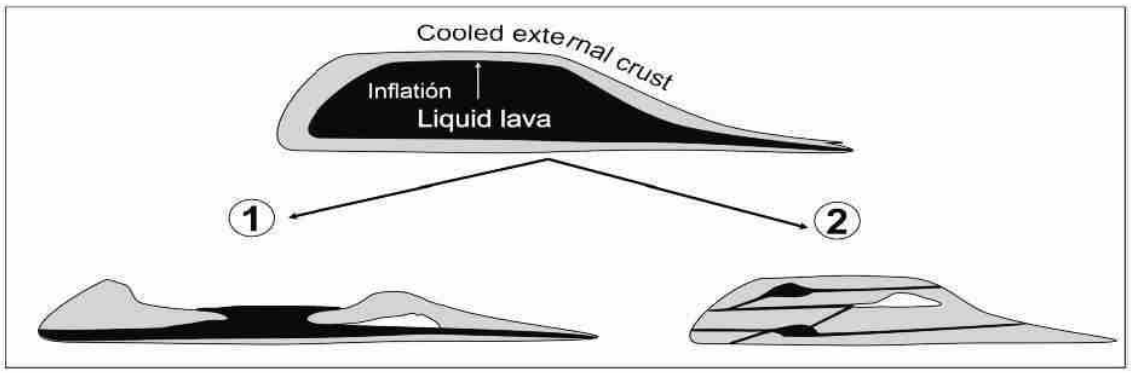


**Figure 8. Schematic representation of the inferred origin of El Julepe cave. Initially, the flat-roofed uplift occurs by inflation, as a result of lava injection beneath the cooled surface crust. In case 1, the lava is drained towards the surface or internally through a larger lava tunnel (e.g. Halada cave), causing the roof of the uplift to collapse. In case 2, the lava is partially drained through secondary tubes, leaving only small empty patches within the inflated structure (El Julepe cave).**

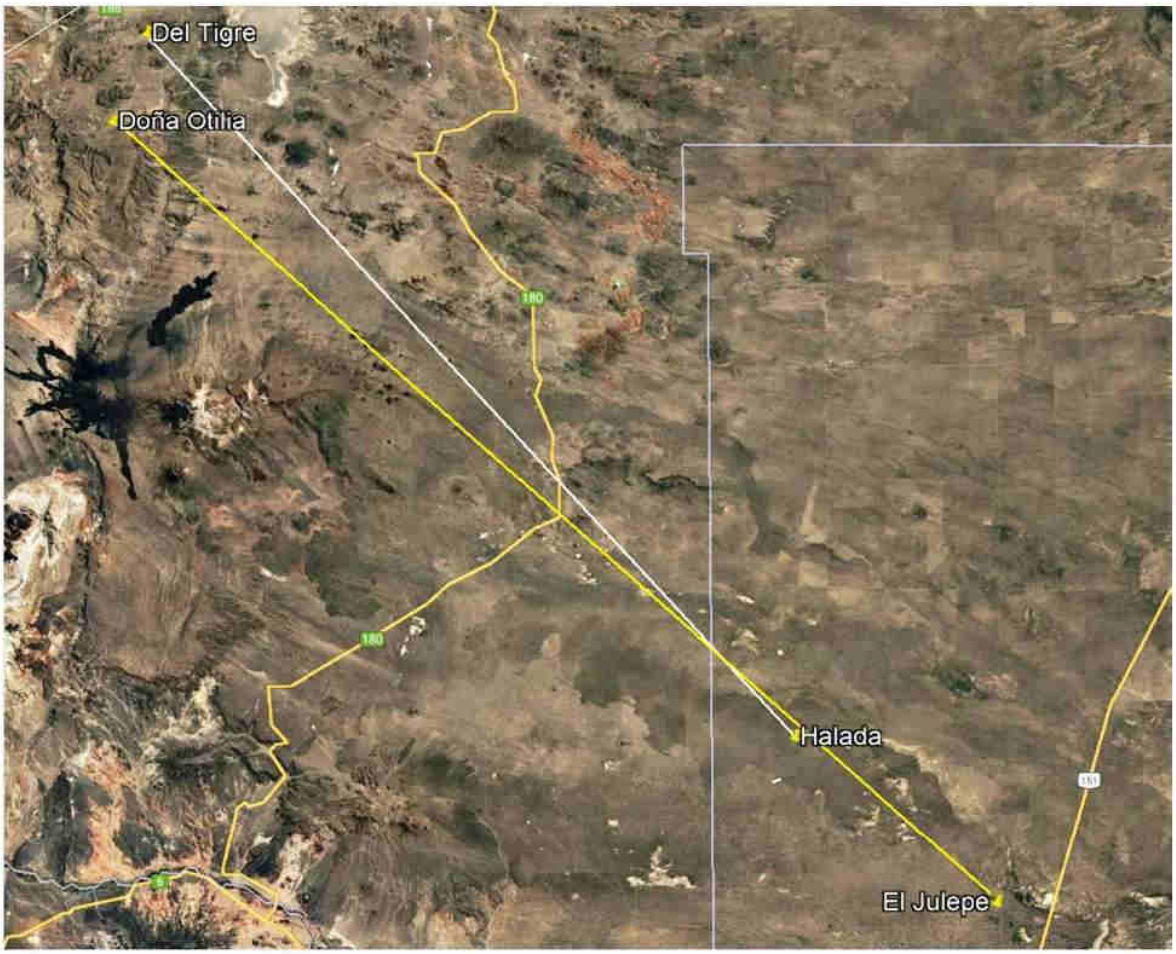


**Fig. 9. Distances, in flight line, from El Julepe cave to Doña Otilia cave (204 km) in Mendoza province and from Halada cave to Del Tigre cave (168 km) in Mendoza province.**
**(Doña Otilia is a very important cave for Biology,**
**https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0223828 -editor´s note-)**

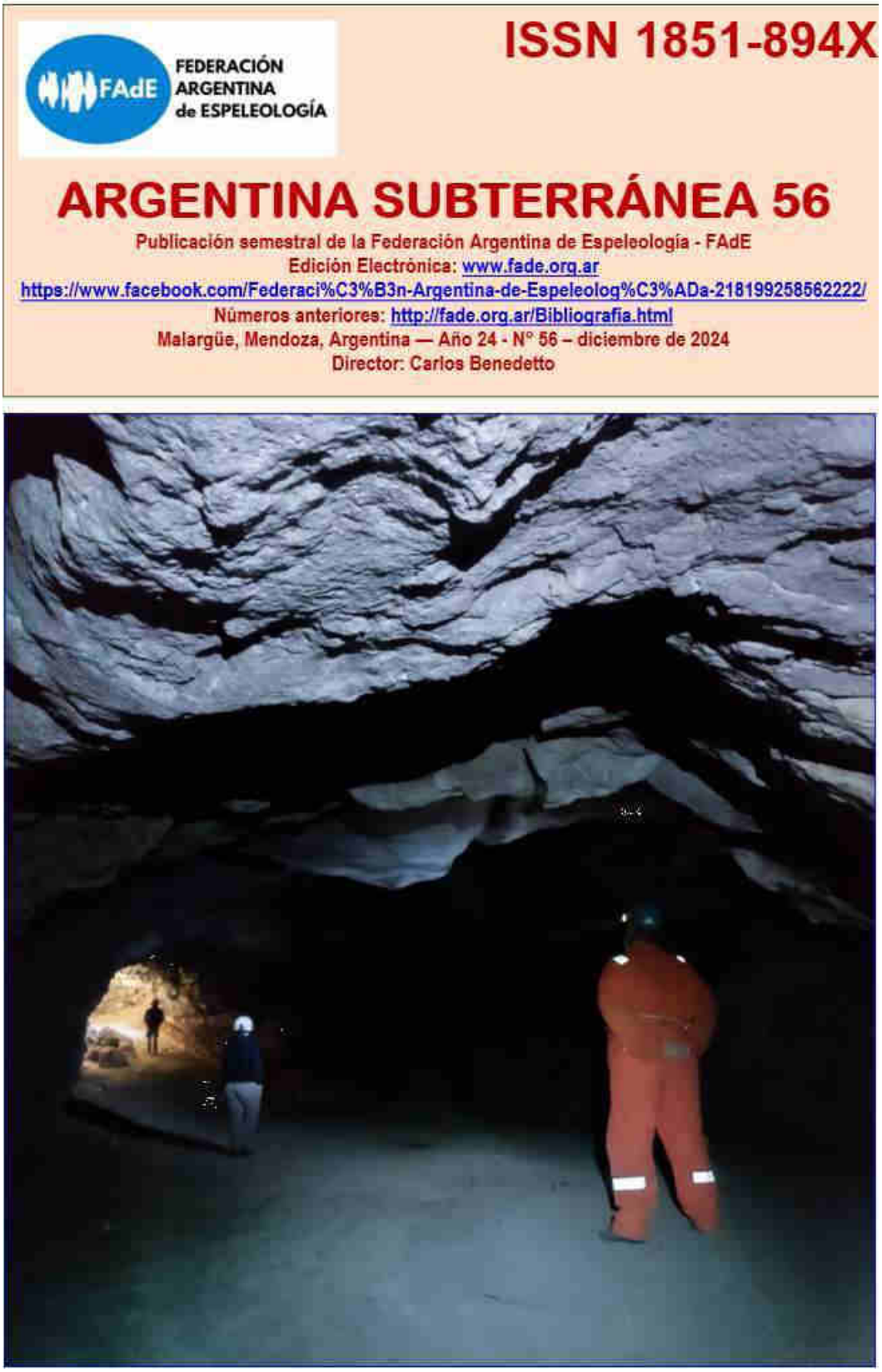


**Fig. 10. Cueva del Tigre in the cover of ARGENTINA SUBTERRANEA 56 - https://fade.smartnec.com/images/prod/sBiRzdbFjyUX9N7JnX5vmsl8P9v3Z5.pdf. Photo: Gabriel Moya (FAdE)**

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