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Explorations & History

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KARSTOLOGIA 22 Memoirs

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18th INTERNATIONAL CONGRESS SPELEOLOGY SAVOIE MONT BLANC 2022

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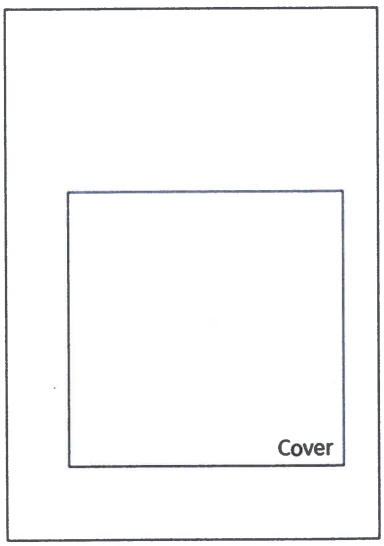

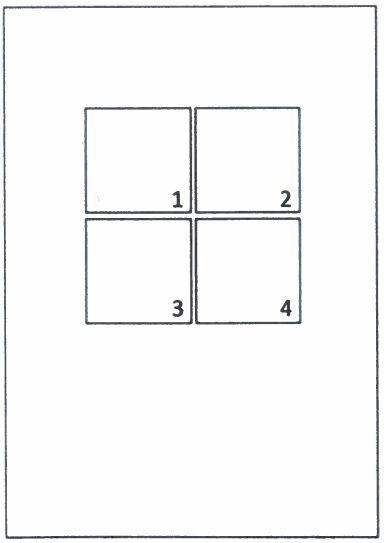

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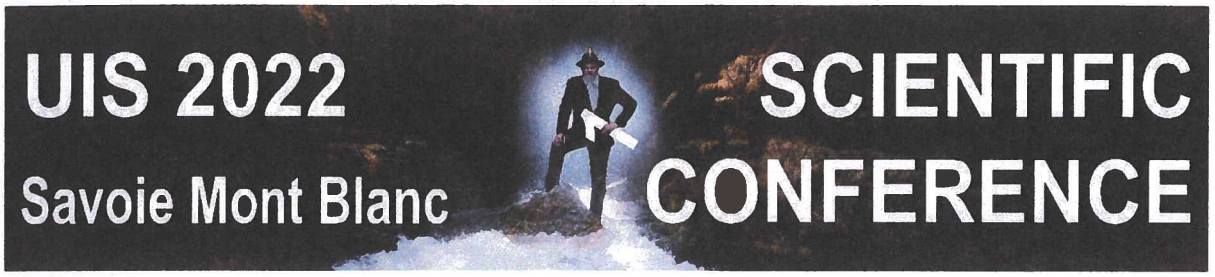

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History of Speleology

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Cave diving

Coordination: David BIANZANI (FR) & Anne-Laure VULLIEN (FR)

Underwater exploration on Alviela Spring, Portugal – One of the deepest underwater cave in the world

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Abstract:

The Alviela spring is a permanent karst spring located in a small limestone block detached by a Cretaceous outcrop preserved inside the Monsanto syncline, west of Alcanena, in the rolling contact of the Estremenho Limestone Massif (MCE) over the Tertiary Basin of the Lower Tagus, at 77 meters of altitude, Portugal. Currently this spring constitutes the deepest upwelling of the national karst. The Alviela spring has an underwater development of 2100 meters and a 215 meters depth. The absolute difference is 222 meters. With a net of active underground tunnels, and due to its depth and extent, its complex exploration and registration remains to be completed. This study aims to describe the history, the current state of explorations and the methods currently used for their underwater exploration and subsequent characterization.

1. Geomorphology, Hydrogeology, Underwater exploration - historical review

The MCE is a large block of Jurassic limestone with about 800 km², located between Rio Maior, Tomar and Leiria. The Lower Tagus Tertiary Basin extends to the north from Tomar to Vila Franca de Xira and to the south from Abrantes and Ponte de Sôr to Vendas Novas and Lisbon (CRISPIM). There is a difference of about 140 million years between the rocks of the MCE and those of the Tertiary Basin of Lower Tagus: those of the MCE are about 160 million years old (limestones from the Jurassic) and are in contact with the formations of the Tertiary Basin of the Tagus, with only 20 million years (formations from a time known as Miocene) (CRISPIM).

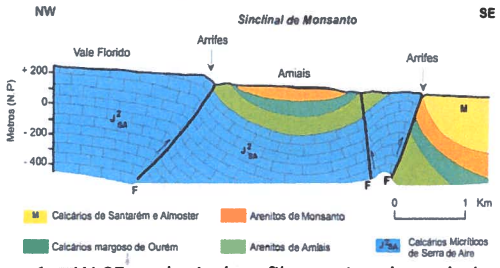

Figure 1: NW-SE geological profile passing through the region of the Olhos de Água do Alviela Springn (adapted from PARADELA & ZBYSZEWSKI, 1971 - Leal, C., 2014)

The supply area of this spring, the Santo António Plateau, measuring approximately 180 km² (CRISPIM), should comprise almost the entire Plateau, which presents a general slope to the south, which also coincides with the tendency of the limestone layers. The numerous faults that are parallel to the Costa de Minde fault are often injected by lodes of basic rocks that should act as hydraulic barriers, total or partial, which will tend to block the flow to the south and to divert it towards to Alviela Spring. (ALMEIDA *et al.*, 2000). From the Alviela spring more than 2100 meters of underwater tunnels are known, with depths exceeding 200 meters.

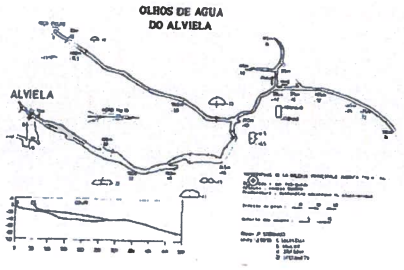

Figure 2: Info 52, plongée da FFS - 1988

This spring, which delivers about 120,000 m³/year, can be dived only in the dry season, since during the rainy season its strong flow reaches average values of 17 m³/s (CRISPIM). The first underwater exploration takes place by the SPE (Portuguese speleology society) in 1961, with 150 meters of development to a depth of 35 meters. Since then, the cave has been explored mainly by Portuguese, Belgian, Spanish and French divers. In 1983 J. Michel and J.P. Thiery reached 300 meters of development and 50 meters of depth. In 2004 a French-Portuguese team reached a depth of 125 meters, with the topography totaling 1370 meters (GIORDANO, 2004), and in 2007 and 2008 the same team reached a depth of 130 meters (GAJEK, 2008), extending the topography up to 1510 meters. In 2010, B. Moulin and M. Burgui join two galleries at a depth of 134 meters (SPE, 2010), but they do not find the continuation of the cave.

2. Underwater exploration - new developments

The genesis of the Project for the exploration of the underwater galleries of Olhos de Água do Alviela, by the AESDA/XploraSub partnership, takes place in 2016 with the beginning of the study of relevant information for the understanding of the cave system, namely the reports of the previous explorations and the publications available, and

through some dives, oriented towards the acquaintance of the various passages of the cave and their guideline re-equipment, and to get used with the logistics and associated procedures. In 2016, 9 dives are carried out, with a maximum duration and depth of 180 minutes and 50 meters. After this exploratory period, a properly structured project is proposed to the ICNF (national authority responsible for the cave), containing a schedule of activities for 2017. During this year, 13 activities are organized in the underwater cave, with 31 dives carried out. In these dives, the guideline is checked, and when necessary readjusted, repaired or replaced, to a depth of 110 meters, changing the line by a stainless steel line to a depth of 45 meters, in order to avoid the replacement of the damaged guideline every year. Mainline survey begins, using traditional methods in about 350 linear meters. Several incursions are made in deep areas of the system, progressively increasing the duration, distance and depth, until "little canyon passage" is reached at 134 meters deep, the maximum underwater depth in a national cave, reached in 2010 by the French-Portuguese team. There, a restriction is overcome and around 50 meters of new line are placed by the divers Armando Ribeiro and Rui Luís, which joins the existing line at the end of "SPE tunnel", confirming the connection between the two passages. Several underwater images are taken, in video and photography.

In 2017, 31 dives are carried out, with a maximum duration and depth of 275 minutes and 134 meters.

However, this deeper area has remarkable deposits of silt, which makes it doubtful that this is where most of the water that emerges from the Alviela spring passes through.

In 2018, we start to search of the origin of the water, with the exploration of some galleries detected in the previous year. 13 underwater activities are carried out, with 22 dives. In these immersions, among other tasks, the placement of the stainless steel line proceeds up to 70m depth and the guideline is repaired to a depth of 134 meters. An incursion led by divers Armando Ribeiro and Rui Luís is carried out in a virgin passage at the end of the exploration and a continuation of the cave is located, which is then equipped with guideline. At the time, 150 meters were reached, an unprecedented mark in an underwater cave in national territory. This year, underwater video images are also taken and an interview is also given for a short piece in the national news of the Portuguese television station RTP1.

In 2018, 22 dives are carried out, with a maximum duration and depth of 220 minutes and 150 meters. Given the great depth at which exploration is taking place and the long duration of the immersions, which already last around 6 hours, the activities of 2019, at the beginning of the year, are mainly dedicated to rig equipment, preparing the logistics and improving procedures that can offer greater safety to divers. Thus, two decompression bells are prepared, subsequently immersed and placed with positive buoyancy in opposition to the tunnel roof, in an appropriate spot, at a depth of 7 meters. Redundant life support diving equipment, such as X-Flex II iQsub *rebreathers* in sidemount configuration, are repeatedly tested. An electronic guidance console EC2-Seacraft, placed on top of a *Diver Propulsion Vehicle* (DPV), is tuned for automatic recording of depth, distance and navigation, thus obtaining the cave's mainline survey at great depths. There is also a considerable evolution in the support of the team to the push diver.

Finally, the condition of the mainline is checked at great depths, with 60 meters of passage rigged at the end of the exploration, up to around 150 meters in depth.

Feeling that the conditions for the exploration progress have been achieved, a new step is taken towards areas not yet visited. Firstly, 174 meters of depth are exceeded, with the rigging of an additional 60 meters of virgin passage, and later on, 190 meters of depth are reached by the diver Armando Ribeiro, with guideline being placed in another 70 meters of passage. In 2019, 28 dives are carried out, with a maximum duration and depth of 372 minutes and 190 meters. In 2019, more than 1200 meters underwater are mapped by the team, including about 200 meters of virgin tunnels, between 130 and 190 meters deep. In December 2019, a special report, written by Aurélio Faria and Rafael Homem, entitled "Mergulho no Alviela", was presented on Jornal da Noite, on the Portuguese television station SIC.

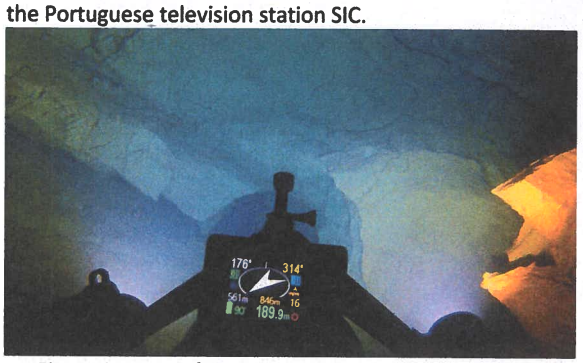

Figure 3: SeaCraft survey system on scooter (photo by Armando Ribeiro)

In 2020, in addition to the usual fortnightly dives, a diving week was also planned to happen in September.

An atypical year – in which immersions started late, due to a heavy rainy season, immediately reducing the window of opportunity to explore the cave, in which activities were interrupted by a general confinement in response to the pandemic situation, and finally, in which it was necessary to manage the health problems of one of the push divers and a diving accident with another diver – it seemed to make unachievable the goals we set out – to explore new passages and go deeper than 190 meters. Only the resilience of the multidisciplinary team formed by members of AESDA – Association of Underground Studies and Environmental Protection and XploraSub – Association of Underwater Studies turn possible that more than fifty dives were carried out in about four months, the overwhelming majority of them in closed circuit rebreather and using DPVs, culminating on the 18th of October 2020 with the mark of 215 meters deep, beating the previous record and increasing the mapping of the submerged tunnels of Alviela by around 150 meters. A push dive by Armando Ribeiro, featured in a special report on Jornal da Noite from the Portuguese television station SIC, written by Aurélio Faria and João Ramalho, entitled "Alviela, Depth Máxima". In 2020, 61 dives are carried out, with a maximum duration and depth of 432 minutes and 215 meters. The year 2021 was, without a shadow of a doubt, the year of consolidation of the project. There were 31 diving activities with an average of 4 divers per dive. At the exploration tip, at 215

meters deep, in the "Exploration tunnel" further 150 meters were explored. This dive was performed by divers Armando Ribeiro and Anton Zhuchkov. The depth remained at 215 meters. In addition to this exploration zone in the cave, special attention was given to tunnels that remained unexplored at a depth of 130 meters. From these explorations, one more connection was made between the east and the west sectors of the cave, the "Galeria da Direita", and a new exploration area was left open. A new tunnel that starts at 130 meters, develops to a depth of 153 meters. There is a new chimney there. It will be necessary to overcome a restriction to know the extent of this underground complex. In addition to these explorations, the underwater and dry topography was continued and the passages to the left at the end of the "Grand Canyon passage" were also explored. Thus, several exploration areas remain open, at 215, 180 and 153 meters, as well as other possible connections between the east and the west sectors of the cave. To continue this complex and challenging project, it will be necessary to improve the safety conditions of divers with the placement of additional decompression bells at a depth of 12 meters, further diver training for higher depths and improvement of the surface rescue capacity.

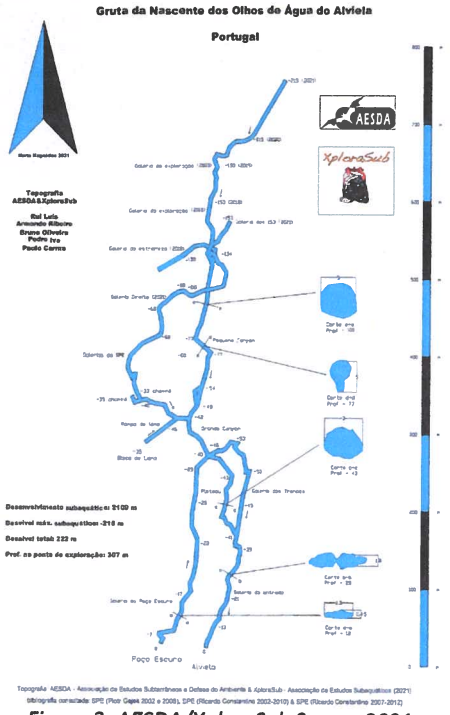

Figure 3: AESDA/XploraSub Survey 2021

3. Technical Constraints

One of the peculiarities of cave diving is the existence of a real roof, which prevents divers, in case of need, to ascend directly to the surface. Thus, in the vast majority of cave dives, to return, the divers must take the opposite route to the way in, and to leave the cave where they entered. If the Alviela spring cave does not present significant difficulties with regard to silt, with the consequent loss of visibility, or restrictions and the possibility of a diver becoming trapped, due to its profile, divers are obliged to make long journeys, both on the way in, as on the return. In addition, the profile of this cave, which quickly sinks, also means that, right at the beginning of the immersion, it is already below 40 meters deep, which severely punishes divers with long decompressions.

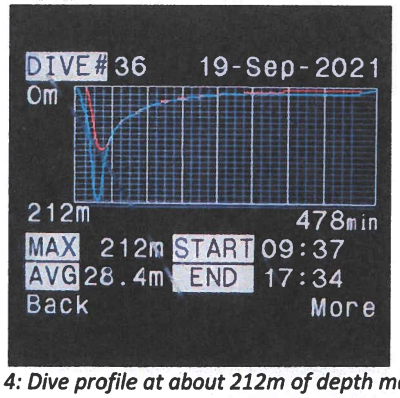

Figure 4: Dive profile at about 212m of depth made by Armando Ribeiro and Anton Zhuchkov

To perform long journeys, it is necessary to use a DPV (*Diver Propulsion Vehicle*), also commonly known as a *scooter*, a machine that transports the diver with all his equipment faster, while reducing physical effort.

As a dive with significant depth variations, it is necessary to use several suitable gas mixtures, with variable percentages of component gases, optimizing as much as possible the balance between various factors, among others: the need for oxygen at the proper pressure to support life, a manageable narcosis and an acceptable decompression time. Thus, gas mixtures with different compositions are used. Some ternary, with Oxygen, Nitrogen and Helium, and others enriched in Oxygen, for decompression use. These dives call for using eCCR (and *electronic Closed Circuit Rebreather*). Closed circuits do not release gas into the environment, allowing inert gases to circulate, which are breathed over and over again, and prevent the loss of oxygen, a gas that is thus used efficiently, while in turn the carbon dioxide, a residue of breath, is fixed by an absorbent. In addition, an eCCR has the ability to adjust in real time, permanently and automatically the appropriate mixture to the depth at which the diver is, shortening the required decompression. Finally, the closed circuit is much quieter than the open circuit and makes the gas available at a higher temperature, which is relevant against hypothermia. However, if the eCCR facilitates longer and deeper dives, there is always the chance that such a machine, which requires thorough maintenance, should break down and kill the user. Redundancy is a key concept to survival in cave diving and any equipment on what the life of the cave diver depends must be transported twice as much. Thus, the redundancy to an eCCR means that the diver has to take with him several bailout cylinders with the various appropriate mixtures that, in case of need, allow him to complete the dive on open circuit, while also carrying out the necessary decompression stops. With the advance of exploration, with distances greater than 1000 meters from the surface and with depths below 190 meters, there was a need for the diver to carry more and more cylinders for bailout, which began to turn a quite cumbersome and tiring task and that it would eventually become a limiting factor.

There was thus an inevitable move to an alternative configuration, albeit much more expensive, with the use by divers of a second closed circuit, as redundancy, with the notable reduction in the number of cylinders to be carried. As the mapping of the cave is one of the main objectives of this exploration, 350 meters from the main tunnel were surveyed according to the traditional method (using the guideline and its moorings, azimuths, depths and distances) up to a depth of 55 meters. For great depths and due to the convenience of staying there for as little time as possible, it was necessary to find an automatic method, and an electronic tool was adopted, coupled to the DPV. As these dives require several hours in decompression stops, two decompression bells were also installed, allowing the diver to sit down and rest, remove the mask and with greater comfort to feed and hydrate. In addition, bells are still preferred points for placing safety bottles with hyperoxic mixtures, in order to accelerate decompression. Finally, it is important to emphasize that despite the various technical and technological advances noted, an exploration of this type cannot happen without a large team, including cavers and other cave divers, which will undertake, both dry and immersed, the transportation, preparation and placement of a large volume of equipment involved, helping to overcome the various unevenness's of the dry cave in accessing water, supporting push divers in various procedures, including those resulting from decompression, and raising the safety levels of the entire operation.

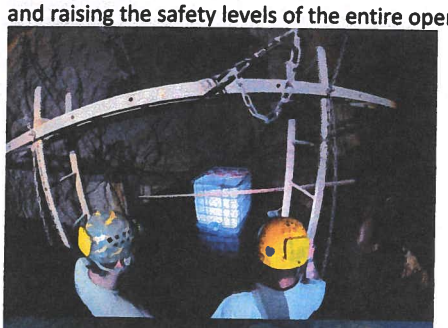

Figure 5: Decompression bell before its immersion (photo by Rui Luís)

Figure 6: Appearance of a system gallery (photo by Armando Ribeiro)

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