Experiencing geology from different perspectives: from Costa Rica to Norway

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Costa Rica is well-known around the world for its absence of army, high level of biodiversity and being one of the happiest countries in the world. Besides, Costa Rica is the limit of a convergent plate border between Cocos and Caribe Plates, causing an active volcanic arc, with active tectonics associated and many other geological features around the country. In other words, Costa Rica is a "playground" for geologists and explorers interested in solving the "geological puzzle".

For me geology is a passion. Close to my ending of Geology carrier, I worked in unexplored high mountains of Costa Rica inside the dense jungle, for studying geochemical characteristics that became clues to the geochemical evolution of the country. Also, I collaborated in diverse vulcanological and neotectonical projects in Central America. But, when I discovered the "underworld" I got deeply involved in speleology (study of caves) and in related projects of research around of Central America, Caribbean and Mexico. More than one year ago, I got the opportunity to work in geophysics for the oil industry with PSS-Geo. My background was not exactly geophysics, but with the company training, I engaged increasingly in the profession.

Studying caves and karst

When I came to Norway, I also found the opportunity of studying in the Karst Research Institute ZRC SAZU of Postojna, Slovenia. This institution offers a flexible PhD program in Karstology that allows me to work and study at the same time. Thus, as a person in a new country without "social distractions", I have been focusing in working, taking courses of the program and doing my research project in mineralogy and geomicrobiology of Central American caves and the implications for presence of life in extreme environments.

Combining studies in karst, caves, mineralogy, geophysics and geochemistry can be a bit tricky, but yet, several of the newest solutions and techniques in the industry will need to be analyzed in a multidisciplinary way. For example, many important deposits of hydrocarbons throughout the world are associated with karstified formations and exhibit highly varying properties (e.g., porosity, permeability, flow mechanisms). Hence, an interesting application is to use the hypogenic speleogenesis modelsin which H_2S dissolution mechanisms are involved, as analogous models for understanding carbonate reservoirs.

Irazú volcano and its caves in Costa Rica

Irazú Volcano is the highest volcano in Costa Rica (altitude 3432 m asl), part of an andesitic shield located in the southeast of the Central Volcanic Range. It has been hiding the most amazing volcanic caves discovered in the region. The NW sector of the Irazú volcano is the least explored and studied due to factors such as difficult access and hazardous, unstable terrain. These conditions allowed the caves to remain hidden for several years. In 2011 together with the local caving group (*Grupo Espeleológico Anthros*) we organized the first speleological explorations that entail to one of the greatest discoveries of caves in Costa Rica. Influenced by the active volcano, the caves at Irazú volcano presents the highest mineral diversity in the region, and probably ranks amongst the highest in the world.

Going down to crater of the volcano. Photo: Ronald Ramírez

Irazú volcano and caves map

First results about the mineralogy of *Cueva los Minerales* were published by Ulloa et al (2013), in which different cave minerals (speleothems) and mineralogy was reported. Twenty one different minerals were reported relating to sulfates and one native element (Sulfur). Five of these were reported for the first time as cave minerals in the world. This was a very significant finding that makes these caves unique in the world of vulcanospeleology. Actually, more detailed minerals analyzes are being carried out in Spain with

Hiking on a very steep track in the way to the caves. Photo: Scott Trescott

Green stalactite of melanterite in Cueva los Minerales

V. Carvajal

"Snotites" in Cueva de los Mucolitos. Photo: Andrés Ulloa

collaboration with University of Valladolid, University of Almeria and *Unidad Asociada Uva-CSIC- al centro de Astrobiología CSIC-INTA "ERICA"*.

In the three caves discovered in the surroundings of Irazú volcano, extremophile microorganisms have also been found. These organisms are known as "snottites" based on their morphology. It is common to find them hanging and growing on mineral substrates, while others are associated with mineral precipitations. Most of them are living at low pH (< 2), and in order to fulfill their characterization, further analyses (biochemical and metagenomic investigations) are going to be realized in United States.

Andr;és sampling a geysermite for mineral analyses. Use of mask is necessary in some parts of the cave because of high concentration of volcanic gases. Photo: Scott Trescott

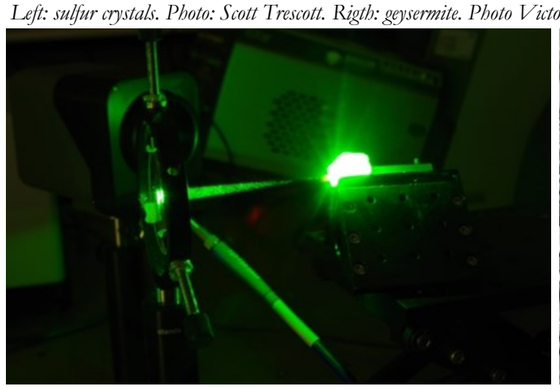
Perspectives in mineralogical and geomicrobiological studies in volcanic caves

Mineralogy in volcanic caves and geomicrobiology are relatively new, yetextremely promising research areas. In the last decade, there has been an increasing number of geomicrobiological studies that showed the role of microorganisms on speleothem formation, speleogenesis and interaction between microbes and minerals. The science of geomicrobiology recognized that microorganisms are promoters of redox reactions that can influence geological formation (Ehrlich, 1996).

In caves or other dark environments, such as deep-sea hydrothermal vents, energy can be produced efficiently by chemolithoautotrophy (Engel, 2007). One interesting aspect of vulcanospeleology is the possibility to extend the field of study to other planets and moons, particularly our moon, Mars, and also Venus, and Jupiter´s moon Io (Léveillé & Datta, 2010). Most of the caves on Earth are dissolution caves. But in the solar system probably most of them are volcanic caves; an assumption made based on the predominance of basalts on planets and moons and the lack of solvents (e.g. liquid water). If life exists on other planetary bodies of the solar system, most likely it will be found in subterranean environments due to planetary challenging surface conditions (Boston et al. 1992). For this reason, caves serve as terrestrial analogs for extraterrestrial subterranean microbial ecosystems (Lavoie et al., 2010).

Mineral and geomicrobiological sampling. Photo: Scott Trescott

Left: sulfur crystals. Photo: Scott Trescott. Rigth: geysermite. Photo Victor Carvajal



Left: LIBS (Laser-induced breakdown spectroscopy) analyses in a mineral sample. Photo: Andrés Ulloa. Right SEM (Scanning Electron Microscope) image of diverse sulphates

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