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Preserving the World's Deepest Canyon

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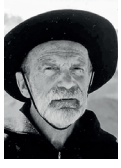

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Two decades of research by Polish scientists in Peru contributed to the creation of the UNESCO-recognized *Colca y Volcanes de Andagua* Geopark.

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Boundary of the proposed Colca Canyon and Valley of the Volcanoes National Park and the designed buffer zone

The Colca Canyon ranks as the second most visited tourist destination in Peru, trailing only behind Machu Picchu. While mass tourism drives economic growth, it frequently also adversely affects environmental quality. In 2006, the Polish Scientific Expedition to Peru was initiated, aiming to lay the scientific groundwork for establishing a national park in the Colca Canyon and Valley of the Volcanoes. This initiative originated from the Faculty of Geology, Geophysics, and Environmental Protection at AGH University of Science and Technology in Kraków. The Expedition has become a distinctive platform for scientific collaboration that remains active today, yielding a wealth of scientific publications. Its participants come from a variety of fields, enabling it to engage in multidisciplinary research in both geology (volcanology, tectonics, geomorphology, sedimentology, mineral deposits, and karst formations) and environmental science (spatial planning, environmental protection, bio- and geodiversity).

The primary objective of the Expedition's geomorphological and tectonic studies has been to better understand the structural framework and tectonic history of the Colca Canyon, as well as to determine the relationship between geological structure and tectonic processes with mass movements (shifting and sliding

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Descent to the bottom of the Colca Canyon

of weathered rock and sediments) and the potential hazards they pose.

A significant aim of the current research project undertaken by the staff at the University of Silesia is to assess the tectonic and seismic activity in the Colca River basin and to reconstruct the evolution of the canyon and broader river valley through landscape analysis. Frequent earthquakes in the area, surface mass movements, and volcanic eruptions all bear testimony to the activity of the subduction zone, where the Nazca oceanic plate is being driven under the South American continental plate. In such zones, tectonic activity is a major factor contributing to varied landscape features. This is due to the differing rates of tectonic uplift and thus, differing erosion rates, even in adjacent areas. These vigorous tectonic processes have led to extremely deep river incision. Moreover, University of Silesia researchers are also analyzing both the primary and secondary mineralization of volcanic lava as well as karst features.

Landscape of the Huambo Valley

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Valley of Volcanoes

As the world of science stands today, most easily accessible volcanoes are already being closely monitored by scientific institutions. Signs reading "No entry, private property" are commonly posted at the edges of their craters. Hence, the discovery of active and as-yet unexplored volcanoes next to impossible. However, during expeditions to the Valley of Volcanoes in Peru, Polish researchers documented numerous small volcanoes spread across an area of about 10,000 km² – a remarkable discovery. From 2003 to 2017, the comprehensive study of the Andahua volcanic group was completed, identifying 7 regions, 36 lava fields, 43 pyroclastic cones, 3 composite volcanoes, and up to 103 lava domes or fissures from which lava had erupted. These small cones, simple in structure and seldom rising above 150 meters, presented a unique geological profile. The few researchers who had previously ventured into the Valley of Volcanoes had suggested that the magma feeding these volcanoes did not evolve on its ascent to the surface – that its chemical composition had remained unchanged. Traditionally, the lava fields of the Andahua group were believed to be fed by pyroclastic cones or fissures.

Field studies revealed that the lava fields are primarily supplied by lava domes or fissures. This research into their origins unveiled numerous uncertainties and surprises. Genetic models of the Andahua volcano group were developed based on geochemical and petrographic analysis of samples collected from various volcanoes and lava fields. The magmas there permeated through diverse substrates, leading to variations in their chemical composition. In 2017, garnet crystals were discovered in lava samples, which is quite a surprise since such minerals had not previously been recorded in the lavas of modern Andean volcanoes. Close study enabled researchers to piece together the history of their formation. As the magma forced its way to the surface, at a certain depth it encountered sulfide rocks – namely anhydrites – which triggered a rapid and intense melting process known as pyrometamorphism. The presence of sulfur inclusions within the crystals suggested that the process was accompanied by the release of toxic sulfur compounds, which made their way to the surface. The lava flow containing the garnets is found at Lomas Uña Huajana, which translates from the local Quechua language to "place of weeping children."

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Pyroclastic cones in the Valley of the Volcanoes

The Colca Canyon

The Colca River basin features a diverse range of landforms. Originally, the upper part of the basin, above the canyon, was an area without any outflow (an "endoreic" area), which during the Pliocene era formed a vast lake filled with tuff and local lava flows running into it. Such lava flows also entered the canyon itself, forming dammed lakes. Similar phenomena occurred in the Valley of Volcanoes, gradually filled in by layers of lava. Consequently, the Andagua River now meanders through subsurface lava channels, birthing waterfalls that burst forth from the ground. Notably picturesque is the waterfall near Andagua and the stretch linking the barrier lakes near Chachas and Ayo. It was not until the Quaternary period that a "river capture" event occurred, reorienting the upper part of the Colca River basin towards the Pacific Ocean basin. This took place as a result of the headward erosion of a Pacific-flowing stream (the paleo-Colca, flowing through the current Colca Canyon), cutting through the watershed between the lake's endoreic area and the Pacific basin. The rate of deep erosion was very high, forming picturesque incised valleys into the tuffs of the ancient lake. Dating indicates that this happened in the later Quaternary, around 100,000 years ago.

Flora and fauna form an integral component of the Colca Canyon and Valley of Volcanoes landscape, comprising several hundred plant species and over 100 animal species. Among the most frequently encountered yet least studied groups of organisms in this area are lichens. In fact, lichens – lichenizing fungi living in symbiosis with green algae and cyanobacteria – constitute a significant part of the Colca Canyon's biological diversity. Thriving due to the canyon's lofty altitude and the dry, tropical climate that prevails in the area, their presence is further bolstered by scattered grasslands, sparse shrubbery, bare soil patches, and frequent rocky outcrops. Field studies have shed light on the vital role of pioneer plants and cryptogams (organisms similar to plants, like fungi, but reproducing through spores without forming flowers or seeds) in the canyon's landscape. Particularly notable are the lichens associated with volcanic rock, richly represented in the canyon area. In areas with sparse vegetation, ground-dwelling lichens can be found, contributing alongside mosses, cyanobacteria, algae,

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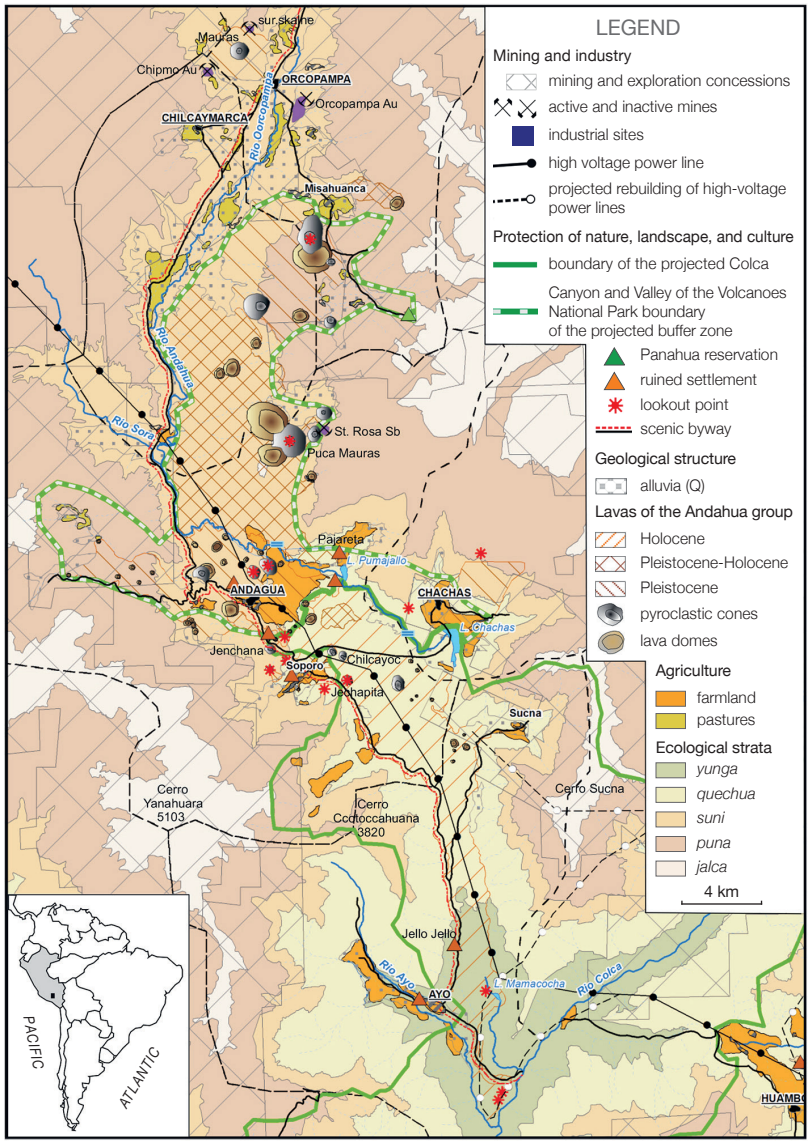
Dammed lake in the Valley of the Volcanoes



SLÁVKA I ANDRZEJ GAŁASIOWIE

Geo-environmental map of the Valley of the Volcanoes

and microscopic fungi to form a biological soil crust. This crust acts as a crucial stabilizing factor for soil, especially in arid regions. Comprehensive studies focusing on lichenology are still needed to more fully understand the richness of the lichens present in the area and to facilitate the protection of the unique biosphere of the world's deepest canyon.

Geopark UNESCO

In 1981, a remarkable event etched itself into the memories of the Peruvian people when a group of Polish students from AGH University in Kraków, members of the Canoandes '79 expedition, bravely navigated the length of the Colca Canyon for the first time. Their journey down every meter of its raging waters helped unveil this natural marvel to the world. This Polish achievement ignited further interest in the Colca region and its people, paving the way for subsequent Polish expeditions dedicated to exploring and preserving the area's rich natural and cultural heritage.

Initially, the scientific community in Peru was lukewarm about the idea of setting up a national park in the Colca Canyon and the Valley of Volcanoes. The region's active gold mining and other economic development activities were seen as incompatible with conservation efforts, which might hinder mining investments. Nonetheless, the concept of a geopark gradually won the hearts of the Peruvian people, starting with geologists from the INGEMMET Institute. Their collaboration and hosting of numerous scientific conferences began to give tangible form to this vision. In 2011, a comprehensive assessment of the Colca Canyon and the Valley of Volcanoes was conducted, detailing land uses, ecological tiers, areas earmarked for landscape and cultural heritage conservation, and factors leading to landscape degradation. An environmental component assessment followed, defining the potential and utility of areas for various purposes. The assessment considered existing and potential environmental conflicts across all socio-economic functions within the proposed national park. The First Symposium on Geoparks held in Arequipa in 2015 highlighted the area's geo-diversity as deserving of protection. The symposium concluded with a decisive resolution in support of the geopark project. Since 2019, the *Colca y Volcanes de Andagua* geopark has been listed by UNESCO.

The determination and resolve of the Polish researchers, coupled with their extraordinary effort to address challenges as they arose, deeply impressed the Colca region's inhabitants. Recognizing their hard work and the sharing of their knowledge, the Peruvian community holds the Poles in high esteem, embracing them as part of the extended Colca family.

The authors extend their heartfelt thanks to all the scientists and students who participated in the Polish Scientific Expedition to Peru. We are grateful for your effort, the time you dedicated, and the excellent working atmosphere you helped create.

Ash cloud during the eruption of the Sabancaya volcano

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Further reading:

The publications of the Polish Scientific Expedition to Peru can be found at: https://home.agh.edu.pl/~pwnp/publications/

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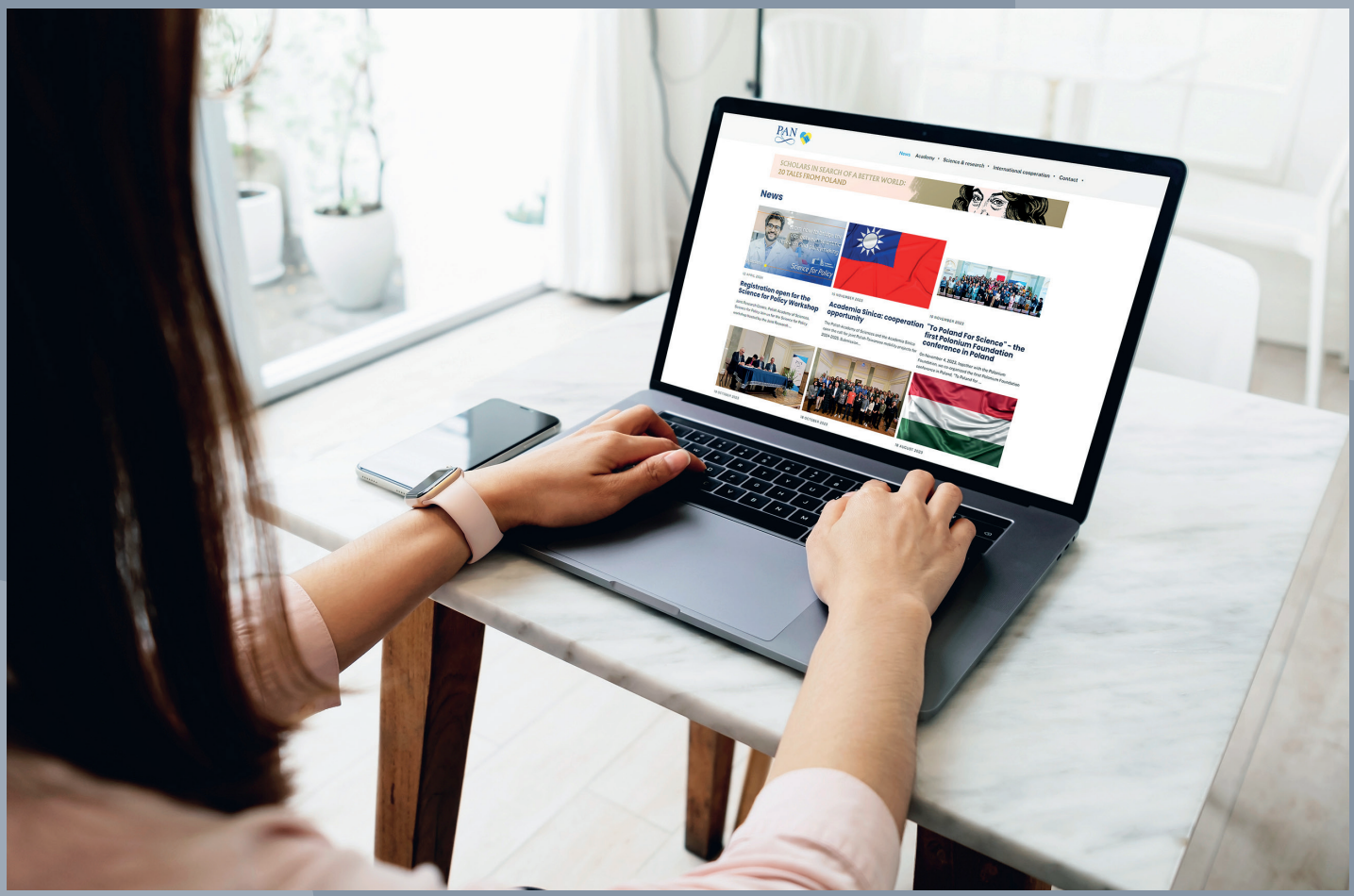

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