GEOCONSERVATION

IN UNESCO GLOBAL GEOPARKS

BEST PRACTICES IN GEOCONSERVATION IN UNESCO GLOBAL GEOPARKS

A JOINT PUBLICATION BY

THE GLOBAL GEOPARKS NETWORK
&
THE INTERNATIONAL COMMISSION ON GEOHERITAGE
INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

Since 2021 the IUGS is conducting a global endeavour to give recognition to geological sites that are essential for the development of geological sciences.

The Global Geoparks Network (GGN) is a key partner of the IUGS Sites program and it is the widest network of territories with a clear mandate for the conservation of geological heritage.

At present, 36 IUGS Geological Heritage Sites are located within UNESCO Global Geoparks.

This publication is a compilation of best practices on Geoconservation carried out by UNESCO Global Geoparks in globally important geological sites.

Capelinhos eruption in 1957-58 with the typical phreatomagmatic eruption "cypress tree like" ash jets and the stream clouds in Azores UNESCO Global Geopark

An **IUGS Geological Heritage Site**

is a key place with extraordinary geological elements or processes of the highest scientific relevance, used as a global reference, and/or with a substantial contribution to the development of geological sciences through history.

www.iugs-geoheritage.org

UNESCO Global Geoparks

are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development.

www.unesco.org/en/iggp/geoparks/about

The Global Geoparks Network

is the widest global network of territories working in **geoconservation.** The GGN serves to develop and share best practices in geoconservation as part of a general strategy for local and sustainable development based on science, education and community engagement.

www.globalgeoparksnetwork.org

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BEST PRACTICES IN GEOCONSERVATION IN UNESCO GLOBAL GEOPARKS

Geological heritage represents an indivisible and fundamental part of the natural heritage. It is behind the most remarkable and beautiful natural landscapes on Earth, but moreover, it contains an unvaluable treasure. Knowledge of Earth and its history is based on places and landscapes that have been described and studied since the birth of the geological sciences. They represent the memory of the Earth and are part of the natural heritage that we must in equal parts value, manage, use and conserve with determination.

Geological heritage was first recognized with the Digne declaration (1991). Since then, several national and international initiatives have been accomplished. The birth of the Global Geoparks Network in 2004, the official recognition of the UNESCO Geoparks program in 2015 and the IUGS Sites global endeavor launched in 2022 represent major milestones in the international recognition of geological heritage.

As the only UN Organization with a mandate in earth sciences, UNESCO supported this initiative from the early days, working to reset the relationship between people and planet, by fostering a better understanding of our geological heritage and by raising awareness of the urgent need to protect it. Today, the Global Geoparks Network (GGN) comprises 229 UNESCO Global Geoparks located in 50 countries. This is the widest network of territories with a clear commitment to promote and protect internationally significant geological heritage. The Global Geoparks Network's mission is to influence, encourage and assist local communities to support economic and cultural development through the valorization of their territorial heritage and identity. Through various activities Geoparks are developing, experimenting and enhancing innovative methodologies for preserving the geological heritage and supporting the development of scientific research in the various disciplines of Earth Sciences.

This publication represents the close collaboration between key international organizations with a selection of best practices in Geoconservation carried out by UNESCO Global geoparks in IUGS designated Sites. They are sites that served to develop the science of geology. They are the world's best demonstrations of geologic features and processes. They are the sites of fabulous discoveries of the Earth and its history and Geoparks play a major and inspirational role in their conservation and sustainable management.

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TRACE FOSSILS CONSERVATION IN AN EROSIVE COASTAL ENVIRONMENT

CRETACEOUS – PALEOGENE STRATIGRAPHIC SECTION OF ZUMAIA

Eocene turbiditic system in Zumaia, which was the cover of the classic book "Atlas and Glossary of Primary Sedimentary Structures" (F.J. Pettijohn and P.E. Potter, Springer – Verlag 1964). (Photo: M.A. Langa)

ONE OF THE BEST EXPOSED, MOST CONTINUOUS AND HIGHLY STUDIED OUTCROPS OF DEEP MARINE SEDIMENTS IN THE WORLD

Zumaia section provides critical information about climate and biosphere evolution through critical intervals of geological time. The integrated bio-, magneto and cyclostratigraphic records helped to reconstruct the K/Pg mass extinction (Gilabert V. et al, 2021) and the impact of the PETM global warming in the oceans and the subsequent recovery, and to define GSSPs for the bases of the Selandian and Thanetian stages. The concentration of these major events marking key Cronostratigraphic boundaries in a continuous section makes Zumaia one of the most studied and referenced stratigraphic outcrops of the World. Zumaia is also a key location for study of deep marine trace fossils.

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Saerichnites abruptus
exposed at the Flyschenea museum

Challenges

The flysch formation crops out along 13 km of coastline. It is composed by more than 5.000 m of hemipelagic to deep sea sediments (Albian to Ypresian) with abundant trace fossils. Good examples of *Zoophycos, Paleodictyon, Chondrites, Lorenzinia, Scolicia, Helminthopsis, Spirorhaphe* or more special ones like *Saerichnites abruptus* or *Rotundusichnium zumayensis* can be easily found in many of the layers.

Small pieces of rock are detached from the cliffs every day and thousands of trace fossils are exposed to the erosion. The monitorization of all of them is not a realistic option.

Geoconservation activity

Looking for a realistic strategy a general inventory with the location of the most vulnerable areas and the most valuable specimens has to be done. We always try to keep all specimens "in situ". Every three months all the sensitive areas are monitored to checked if important specimens have been fallen or are close to it. The fallen pieces with good specimens are collected and brought to the flysch museum.

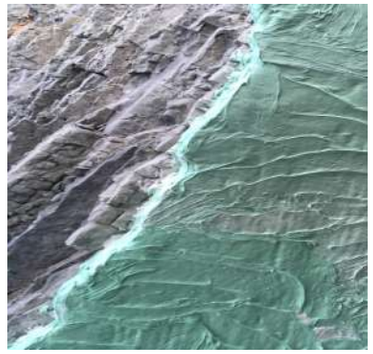
We act and anticipate only in those cases when a very special specimen is in real risk to be detached. The first option is always "to rescue" the original specimen from the cliffs but it may be difficult due to the size, the thickness or of the fragility of the rock.

Important specimens of *Rotundusichnium zumayensis* or the biggest *Saerichnites abruptus* ever described, have been rescued with difficult operations.

If the specimen cannot be rescued a replica is our last option. Using a complex mixture of epoxies that are directly put on the trace fossils we can create perfect replicas of big specimens. A spectacular 6 meters long panel of *Scolicias* is the most impressive replica and represents one of the biggest attractions of our flysch museum.

Main results / conclusion

Erosion is an essential part of landscape evolution, but it can destroy important and specific geological elements like fossils. If the nature of the destructive agent (erosion – geomorphology) is different than the geological element in risk (fossils – palaeontology) we should try to act for its conservation. In an erosive coastline with valuable fossils not all of them can be rescued and a clear and realistic strategy of conservation is needed.



Epoxies covering a big panel of Scolicia

Stabilization of rocks for a complex rescue of a thick layer with trace fossils.

VALUING A PROTECTED AREA BASED ON THE ABIOTIC VALUES OF THE GEOSITE

CAPELINHOS VOLCANO

Picture taken on the early phase of the 1957-58 Capelinhos eruption, with the typical phreatomagmatic eruption "cypress tree-like" ash jets and steam clouds

A HISTORIC, SMALL SUBMARINE VOLCANO THAT CHANGED THE WORLD OF VOLCANOLOGY

The eruption of Capelinhos Volcano (Faial Island) attracted a wide attention due to its geological characteristics, location and study. It was the first submarine eruption in the World to be fully monitored and properly documented throughout its activity. Being so close to the shore and arousing the international scientific community's curiosity (Tazieff, 1959; Waters and Fisher, 1971; Cole et al, 2001), Capelinhos became one of the best-documented phreatomagmatic volcanoes of the World (Sigurdsson et al, 2000). Those studies allowed new knowledge and opened a new page in the understanding of submarine volcanoes. The site is located in the Azores UNESCO Global Geopark.

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Viewpoint over "Costado da Nau" cliff, highlighting the westernmost coastline of Faial Island before the Capelinhos volcano eruption.

Challenges

The main Geoconservation challenge concerning this IUGS site is to preserve the integrity of the landscape that resulted from a historical eruption, finding solutions for a controlled visitation, an appropriate interpretation and dealing with such an erosional area. Formed by a submarine eruption, the main material that compose the new land is tephra, resulting of a very dynamic and sensitive landscape. Defining walking trails and associated carrying capacity, creating an interpretive centre with minor visual impact and manage the explosion of life within the new lands, favouring native and endemic species, where the main concerns of the site management.

Geoconservation activity

The first protective status for this site was its classification as a Natural Reserve, in 2007. The site's reclassification as a Natural Monument in 2019 recognizes the international relevance of this Azores UGGp geosite and highlights the importance of preserving its unique geodiversity and abiotic features.

Effective Geoconservation measures implemented include regulating visitors access to the area (via a designated trail and a daily carrying capacity) and visual inspection, and topographic mapping to monitor the evolution of this dynamic landscape, especially the coastline. Moreover, the interpretive centre was built underground, beneath the volcanic ashes of the 1957-58 eruption, to minimize visual Impact while providing immersive experiences (like a 3D film and a holographic animation) to enhance scientific literacy on volcanology and Azorean volcanoes to visitors, local population and students. Interpretative panels installed along the trails further aid visitors' understanding of the local geological phenomena, and control of invasive species and reintroducing of native/endemic plants, helped to restore the natural habitats and reinforced the site's ecological and geological integrity.

All those initiatives prioritize Geoconservation, by balancing preservation with visitor engagement, ensuring that the Capelinhos Volcano and their abiotic values remains protected for the future generations.

Main results / conclusion

The Geoconservation efforts have preserved the Capelinhos Volcano landscape's integrity, while increasing visitors number, with over 500,000 since the Interpretive Centre opened in August 2008. Access regulation reduced trampling, leading to a higher rate of volcanic tuff formation that stabilizes the ash deposits and decrease erosion rates. These results demonstrate a positive balance between conservation and sustainable visitation.

Preserving the landscape and the scenic value of the geosite, with the construction of an underground interpretation centre.

Capelinhos volcano monitoring activities by the Azores UGGp.

SCIENTIFIC DIGGINGS SAFEGUARD FOSSILS FROM MESSEL PIT

EOCENE PALEONTOLOGICAL RECORD OF MESSEL PIT FOSSIL SITE

The darkling beetle Ceropria messelense preserving its colour pattern and a blossom on the right elytron (Photo: Senckenberg)

THE RICHEST GEOSITE IN THE WORLD FOR UNDERSTANDING THE TERRESTRIAL ENVIRONMENT OF THE EOCENE, PROVING EXCEPTIONALLY WELL-PRESERVED FOSSILS

An inventory of more than 50,000 fossils including more than 1,400 different species has been recorded from the black shales, formed in a volcano crater. Complete fosilized skeletons of animals provide unique insights into an early stage of mammal evolution and diversification.

For interpreting a whole ecosystem during the Eocene under “paratropical” conditions, the Messel Pit Fossil Site is uniquely important. The fossils allow the reconstruction of behaviour and interactions of organisms and comprise a large number of holotypes.

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*Section of ‘oilshale’ from Messel Pit showing the thin lamination and large cracks due to dewatering of clay.*Photo: C. Rau, Welterbe Grube Messel gGmbH

Challenges

Climate change causes more heavy rainfalls and faster growth of small bushes and trees in the Messel Pit Fossil Site. Due to their large root volumen they destroy the uppermost layers of the oil-shale and cover the historic open-air pit affecting the maar volcanic crater. Long dry periods result in deep dewatering of the oil-shale, thus destabilizing it and forming deep cracks destroying fossils.

Geoconservation activity

The Messel Pit Fossil Site focusses on scientific excavations under supervision and strict regulations of the Hesse Authority for Monuments.

The supporting material of the Messel Pit, the ‘oilshale’, contains around 40 % water. If it dries out, it cracks and disintegrates into small flakes. Since the early 1960s it has been possible to transfer the fossils in synthetic resin (epoxy resin or polyester resin) and thus preserve them.

Each year scientific digging campaigns are organised by the Senckenberg Research Institute, Frankfurt/Main and the Hesse State Museum, Darmstadt. Scientists, preparators and students work several weeks to exploit and safeguard findings, preserve and investigate them. Visitors get access to the excavations on guided tours.

The fossil finds of Messel Pit, including plants, invertebrates and vertebrates of a short time span during the Middle Eocene, are exceptionally preserved. More than 75 families with over 200 species of plants are known in the form of micro- and macrofossils. Among the vertebrates, 130 taxa have been identified to date, including over 40 mammal species. Numerous taxa were first described based on fossils from Messel (holotypes).

Main results / conclusion

Scientific excavations and outreach activities at Messel Pit since 1965 led to a deep knowledge of biodiversity and paleo-ecological interactions during the Middle Eocene. Thus, this site provides a unique window into a high CO2-climate that will be useful for modelling our near future climate development.

*Preparation of a horse fossil (*Propalaeotherium hassiacum*) by using the transfer-method (Photo: Hessisches Landesmuseum Darmstadt).*

View inside the exhibition at Messel Pit showing some of the highlights of vertebrate fossils (Photo: Welterbe Grube Messel gGbmH).

PRESERVATION BEFORE VALORIZATION: CHALLENGE TO KEEP SPECTACULAR FOSSILS *IN SITU*

THE AMMONITE SLAB OF DIGNE-LES-BAINS

View of the exceptional concentration of Coroniceras multicostatum ammonites. The largest are up to 70 cm in diameter. (©Haute-Provence Global Geopark)

WORLD FAMOUS AND OUTSTANDING ACCUMULATION OF FOSSILS FROM A LOWER JURASSIC MARINE ENVIRONMENT

The site is a spectacular concentration of fossil ammonites, and offers the best exposure for the *Coroniceras multicostatum* biohorizon (Lower Sinemurian, top of Bucklandi Zone) in Europe allowing for new palaeontological analyses. Thus, this site constitutes an international reference for this stratigraphic level and is emblematic of the creation of UNESCO Global Geoparks.

This designation coincided with the “International Declaration of the Rights of the Memory of the Earth” written in Digne-les-Bains in 1991. These scientific, aesthetic and historical aspects contribute to the worldwide reputation of this site.

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Access ramp to the Ammonite Slab for visitors preventing any contact with the fossils.

Challenges

Natural factors are the most significant for the Ammonite Slab geosite. Climate effects are the worse to fear for this outcrop, particularly dealing with water runoff and freeze-thaw periods. They induce fissuring of the strata, threats of rock fragmentation and the whole layer bursting. Increasing plant invasion on the Ammonite Slab is also problematic because roots network can damage fossils and participate to the whole strata destabilization.

Anthropic factors are also quite problematic. Immediate vicinity of the D900 road induces whole day long vibrations which participate to the strata destabilization. Numerous visitors directly touching the fossils is also a threat.

Geoconservation activity

Geophysics radar analysis underlined the presence of vacuums below the slab (10 to 40 cm deep). Analysis documented the important fracturing of the slab. Considering the nearly vertical position (60°) of the outcrop, in the vicinity of the road, the detachment and collapse risks were evident and urgent to reduce!

First step was to buy surrounding land parcels. Then the Ammonite Slab was literally nailed to the underlaying strata thanks to 265 steel piles anchoring. Special techniques were used to prevent vibrations when drilling holes, to prevent weakening of the slab. Specific cement was also created for anchors sealing and filling of underlying holes, in order to prevent chemical reactions and swelling. At the top of the outcrop, perfect sealing was organized to prevent seepage.

In order to reduce vibrations, the road has been slightly displaced and a large parking area has been developed more than 100m away form the slab. Accessibility is apparently improved thanks to a long access ramp and a large viewing platform in front of the slab but 2 meters away. Actually, nobody can touch the slab surface, except scientist or technical staff, because near access under the ramp is difficult and forbidden.

Main results / conclusion

Today more than 30 000 visitors per year come to admire this well known 196 million years old sea bottom and its 1553 ammonites. This geosite gives a good example of geoconservation and valorisation management, as both affect each other. Visible fractures of the surface is closely watched, but we need time to be sure geoconservation decisions and actions were the right choice.

The road has been displaced to move off the Ammonite Slab and reduce traffic vibrations.

The parking area is organized far from the slab, with a mediation zone in between.

PRESERVING A UNIQUE GEOLOGICAL LEGACY IN AN ACTIVE SLATE QUARRY

MIDDLE ORDOVICIAN GIANT TRILOBITES OF CANELAS QUARRY

Monospecific association of Ogyginus forteyi *(Rábano, 1989) from Canelas quarry, probably fossilized during the ecdysis process (external and internal molds). Scale bar = 10 cm.*

FOSSILS OF THE LARGEST TRILOBITES EVER FOUND, DEMONSTRATING A VERY ACTIVE SOCIAL LIFE

The trilobite fossils provide unique, valuable information on gigantism and social behaviour among some species, as well as their interactions with other invertebrates preserved with the trilobites..

Furthermore, the on-site museum is an extensively used educational resource, and development of the site serves as an example of cooperation between extractive industry, education, science, and sustainable development

Manuel Valério next to a set of giant trilobite fossils, during its inventory and scientific study.

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Challenges

The Canelas Trilobite on-site Museum was born from Manuel Valério's passion and vision to share this outstanding geoheritage with the world. Conserving this unique site has meant balancing fossil recovery with ongoing slate extraction while safeguarding its integrity. Constant vigilance is needed to prevent unauthorized collecting, and quarry workers play a key role by rescuing fossils during daily operations. The museum has also embraced geotourism and education, carefully managing visitors to protect the site. Strong partnerships and clear protocols between private ownership, legal protection, and research access have made it possible to preserve and showcase this heritage globally.

Geoconservation activity

At Canelas village, the protection of the giant trilobites has often meant stopping the quarry's daily work so that each fossil could be carefully removed before being damaged by the machinery. These pauses, though disruptive, were essential to rescue pieces of Earth's history that would otherwise have been lost forever. Out of this challenge came Mr. Manuel Valério's vision: to create the on-site Trilobite Museum, giving the fossils a permanent home. The building itself reflects the trilobites' form, divided into three blocks, with the central space dedicated to displaying the most extraordinary specimens ever uncovered in the slate. Each fossil has been catalogued and preserved under proper conditions, ensuring both its authenticity and protection. By linking quarry work with fossil recovery, a process was established that transformed moments of risk into opportunities for conservation. Over the past 25 years, close collaboration with Portuguese and international scientists has ensured that every find is documented and safeguarded with scientific rigor. What might once have vanished into rubble is now secured as part of a living geological archive. The museum is therefore not only a space of wonder, but also above all a powerful act of geoconservation within the Arouca UGGp.

Main results / conclusion

The Canelas Giant Trilobites Museum is a rare example of how personal passion can shape lasting geoconservation. Born from private initiative, it turned the challenges of an active quarry into an opportunity to protect extraordinary fossils. More than just a museum, it is a testament to vision and care, ensuring that these unique records of Earth's past remain safe, meaningful, and accessible for science and future generations

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Interior view of the Trilobite Museum, highlighting a remarkable specimen that captivates visitors' attention.

View of the Canelas Giant Trilobites Museum from the national roadway

CONSERVATION OF A RICH FOSSILIFEROUS PETRIFIED FOREST

LESVOS EARLY MIOCENE PETRIFIED FOREST

*The largest standing trunk of a petrified tree known so far in the world belongs to a conifer tree (*Taxodioxylon albertense*), an ancestor of the modern sequoias*

ONE OF MOST COMPLETE EARLY MIOCENE FOREST ECOSYSTEM RECORDS OF THE WORLD

The Lesvos Petrified Forest is one of the best preserved fossil forest sites in the world. It is well protected and conserved as a Natural Monument.

Its creation is linked with the Early Miocene volcanism of the Aegean area. It is a historic site related with the early steps of Earth Sciences because of the first reference to the fossilization process by the philosopher Theophrastus (371BC-287 BC).

It is one of the first four areas recognised as geopark in Europe in 2000. It is a flagship site for geoeducation and raising awareness on geological heritage nationally and internationally.

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Conservation of fossil tree trunks during rescue excavations on the Akrocheiras hill

Challenges

The fossiliferous sites face several key challenges in terms of geoconservation. One of the critical issues is the weathering of the fossils and volcanic formations due to long-term exposure to environmental conditions (wind, rain and temperature fluctuations).

Additionally, human impact especially from uncontrolled access and off-path visitor activity in the broader fossiliferous area outside the visiting areas can lead to destruction of fossils and, in some cases, illegal collection or vandalism. Limited resources hinder long-term conservation, education, and digital tools; addressing this requires integrated protection, research, engagement and sustainable management.

Geoconservation activity

One of the most significant geoconservation initiatives carried out within the Lesvos Petrified Forest involves the systematic protection and conservation in-situ of fossilized tree trunks exposed in their natural geological context. This initiative, implemented by the Natural History Museum of the Lesvos Petrified Forest, includes cleaning, conservation and stabilization of the fragile fossils, protective sheltering, and erosion control interventions using environmentally compatible materials.

A specialized conservation team has applied sophisticated conservation techniques to protect fragmentation of the fossils and to prevent further degradation of fossilized tree trunks, while low-impact shelters have been constructed over selected specimens to shield them from direct exposure to rainfall. In areas particularly vulnerable to landslides, drainage systems and natural barriers have been installed/created to ensure the long-term preservation of the geological features. A key outcome of this initiative has been the measurable reduction in fossil weathering and material loss over time, as confirmed by repeated monitoring and documentation.

Moreover, the preservation of in-situ fossil sites has allowed ongoing scientific research, without the need to remove specimens from their original position.

Main results / conclusion

The conservation and interpretation of fossiliferous sites in the Lesvos Petrified Forest UNESCO Global Geopark demonstrate the significance of integrating scientific research, infrastructure development, community engagement, and policy enforcement to ensure the long-term preservation of this invaluable natural heritage.

In situ conservation of a lying fossil tree trunk in the Lesvos Petrified Forest Park at “Bali Alonia” site.

Protective shelters for in situ fossil tree trunks at Kotsini fossil site.

APPLICATION OF UNMANNED AERIAL VEHICLES FOR GEOLOGICAL HERITAGE CONSERVATION

ALPINE SUPERPOSED BUCKLE FOLDS IN ALIAGA

La Olla anticline, second-generation vertical-axis fold affecting Lower Cretaceous marine formations. In front: Aliaga medieval castle. Horizon: Late Neogene planation surface

PROBABLY THE LARGEST AND MOST ORIGINAL EXAMPLE OF SUPERPOSED BUCKLE FOLDING REPORTED IN THE WORLD

The superposed folds of Aliaga (Iberian Chain, Spain) represent a global reference for this type of tectonic structures. Most of them correspond to geometries reproduced in laboratory analogue models, but no other comparable large-scale real examples have been described. Among them, a number of vertical, 'snake-like' folds constitute a singular type of fold interference, as well as a case of erosion-driven tectonic structure. It shows how earth-surface processes can exert a control on fold geometry. The most representative structure, La Olla anticline, is the icon of the Geological Park of Aliaga, embryo of the Maestrazgo UNESCO Global Geopark.

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The principal challenge is to safeguard the IUGS site from threats that may compromise its geological and landscape integrity.

Editorial Dobleuve (2023)

Challenges

The "Alpine Superposed Buckle folds in Aliaga" IUGS site is located within a Natura 2000 Network area. It was the second geosite to be listed in the Maestrazgo Geopark geosites catalogue. Later, it was included in the Municipality of Aliaga geosites List (2008) and the Aragón geosites Catalogue (2015), from Government of Aragón.

Despite its official recognition and protection status, the site remains vulnerable to human activity and potential threats like open-pit mines projects, high-voltage power lines, and wind and photovoltaic energy installations

Geoconservation activity

In 2023, the Maestrazgo UGGp launched the "Geoland Experience 360º" project to promote geoheritage highlighting this IUGS-recognized geosite.

The main objective is to document the current condition of selected geological outcrops and landscape using Unmanned Aerial Vehicles (UAVs) as a tool for geological heritage conservation. The resulting catalogue includes detailed explanatory content and audio guides -available in Spanish and English- providing comprehensive free virtual visualizations of the site at multiple scales.

This immersive experience can be accessed through 3D virtual reality (VR) headsets, as part of the "Geoparqueando 360º" initiative, or online via the project website:

www.360.geolandexperience.es

Main results / conclusion

Understanding and appreciating the buckle folds requires the preservation of its geological and landscape features. New high-resolution aerial imagery obtained through the use of Unmanned Aerial Vehicles (UAVs) has revealed key features of the geosite, contributing to greater public and scientific and supporting informed decision-making processes.

High-resolution aerial imagery obtained using Unmanned Aerial Vehicles (UAVs) is used to assess the current condition of the geosite.

GEOTOPE AMERDINGEN: A NEW ADVENTURE GEOSITE IN A FORMER SUEVITE QUARRY

RIES CRATER

Panoramic view of the Ries Crater with the town of Nördlingen in the central part
Photographer Fotostudio Herzig

ONE OF THE BEST PRESERVED CRATERS WORLDWIDE DISPLAYING MANY IMPACT FEATURES, WHICH CAN BE STUDIED IN AN EASILY ACCESSIBLE REGION

The Ries Crater is very well preserved and displays the different rock types in numerous outcrops. Excursion guides (e.g. Chao et al., 1978; Geopark Ries, 2019), maps and geotouristic infrastructure (trails, guided tours, Rieskrater-Museum) are excellent.
Suevite is a glass-bearing polymictic crystalline breccia that was first described in the Nördlinger Ries (its type locality).

The Crater is an important training area for space missions. In 1970 NASA conducted field exercises in rock identification for the astronauts of Apollo 14 and 17 missions. To this day, the Ries is a port of call for the astronauts of the European Space Agency (ESA). Results of recent investigations are important for the interpretation of extraterrestrial impact craters, especially on Mars.

Suevite quarry from above with clearly visible suevite outcrop in the upper left part

Photographer Dietmar Denger

Challenges

The former suevite quarry was designated a natural monument after the mining was stopped. This is one of the highest levels of legal protection for nature conservation in Germany. Therefore, the legal situation had to be clarified with the responsible authorities to determine whether any changes to the site were permitted at all.

The quarry was completely overgrown, and a significant amount of vegetation needed to be removed to make the geological outcrops visible. In addition, coordinating with the other project partners the “Heath Alliance”, municipality, nature conservation authority and specialized companies was a major challenge.

Geoconservation activity

The former suevite quarry “Trassbruch Amerdingen” in the Donau-Ries district was developed into a public geosite as part of a Geopark project, with the aim of making the site’s unique geological features, particularly the suevite outcrops, accessible to visitors.

Due to heavy overgrowth, significant vegetation had to be cleared to uncover the geological structures. This was done with strict regulations,

After detailed coordination with all the project´s partners a development plan was approved which defined a large natural quiet zone and a smaller visitor area with marked trails and safety barriers.

To enhance visibility, fresh cuts were made in the suevite walls. Informational panels were installed, including one focused specifically on suevite. Implementation took place in fall and winter 2022, and the site officially opened on May 12, 2023. Content for the panels was developed by experts in collaboration with Geopark Ries.

Ongoing maintenance by project partners ensures that the geological features remain visible and accessible for scientists and professionals in the future.

Main results / conclusion

With the construction of the adventure geosite, an important geological outcrop was preserved. Without this significant intervention, it would inevitably have been lost to overgrowth and erosion. Engagement with project partners is a key element to ensure ongoing and long term maintenance of the outcrops.

Fresh cut in suevite outcrop in the former quarry (Geopark Ries e.V., photographer Fabian Weiß)

Removed trees and bushes from main outcrop in the former quarry (Geopark Ries e.V.; photographer Lukas Driesch)

REGIONAL LEGISLATIVE FRAMEWORK AND LOCAL MEASURES FOR PROTECTING ALPINE GEOHERITAGE

THE MOHOROVICIC DISCONTINUITY IN THE IVREA-VERBANO ZONE

The Premosello outcrop

A CLASSICAL MOHO OUTCROP IN EUROPE SHOWING THE CONTACT BETWEEN CONTINENTAL MANTLE AND LOWER CONTINENTAL CRUST

The mantle-crust transition is exposed in a few sections in the world, and most of these involve oceanic crust. The Premosello outcrop displays the boundary between mantle and lower continental crust, which normally lies at a depth of 30-35 kilometres or more below collisional chains.

For more than 40 years this area has served scientists as an unprecedented crustal reference section in which geophysical observations and physical processes may be interpreted in the context of geology that is observable on the ground. Since 2013 the site is included in the Sesia Val Grande UNESCO Global Geopark.

www.iugs-geoheritage.org/designations/

New interpretation panel of the Premosello outcrop, allowing general view from the opposite side of the walkway

Challenges

The Sesia Val Grande is an attractive tourist areas of the Western Alps. Its geodiversity includes a 500 million years of processes that formed the Alps and deformed the Earth's crust.

Geoconservation challenges are related to the establishment of both legislative framework for public recognition of the geosite value within the regional geodiversity and local measures for protecting the geosite from natural/human factors.

Geoconservation activity

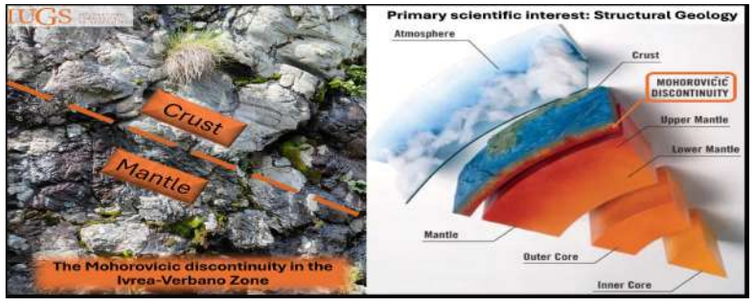
The Sesia Val Grande UGGp and its geosites have been selected by the Piemonte Regional government as case study for developing Law 23/2023 for the conservation and management of the geoheritage. In this framework, the IUGS site has been identified as an element of particular scientific value and a standardized GIS-based inventory of scientific, spatial, and contextual information have been applied for geosite description and assessment.

Recently (2025) the “GeoNet” INTERREG (ITA-CH) project enhanced geoconservation activities. The structural analysis of fractures and schistosity within the Premosello geosite identified the outcrop areas favourable to slope instabilities and those prone to washout and localized erosion. To better regulate these phenomena, drainage control above the wall has been planned.

To limit human impacts, a buffer zone has been proposed at municipal level around the outcrop, which however does not exclude the possibility of interventions aimed at enhancing the IUGS site and promoting its use, such as new interpretative panels and a renewed walkway to improve close-up observation of the outcrop.

Main results / conclusion

The combination of a regional framework for geoconservation and its local application supported by cross-border development funds allowed to:
1) describe the environmental dynamics that can make the geosite vulnerable or impact it, suggesting mitigation actions;
2) Improve the accessibility and observation of the geosite
3) Evaluate the conditions of the site.



Improved close-up observation and related scientific interpretation, based on comparison of local and global structural patterns

GEOCONSERVATION AND PUBLIC ACCESS THROUGH THE ULMENER MAAR-TUNNEL

THE HOLOCENE ULMEN MAAR

Aerial view of Ulmen Maar with preserved tephra ring (background) and highly eroded Jungferweiher maar (foreground)

YOUNGEST VOLCANO IN CENTRAL EUROPE, SITUATED IN THE REGION WHERE THE MODEL OF FORMATION OF PHREATOMAGMATIC MAARS WAS ESTABLISHED

The IUGS Geological Heritage Site Ulmen Maar represents a key site for four geologically important processes that are of international relevance: 1. The maar allows introduction into the youngest volcanic activity in Central Europe. It clearly shows the consequences of multiple explosive magma-water-interactions leading to phreatomagmatic eruptions.

3. The Ulmen maar is part of a maar-rich volcanic field where, essential arguments for the formation of maar volcanoes were developed. 4. Its post-volcanic crater lake presents a paramount insight into lake sediments and their interpretation with respect to the local weather and the climate during the maar's lake history.

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The Ulmen Maar Tunnel was in the construction phase in 2022, at which point the geological layers were clearly visible, without any gridwork in evidence.

Presently, these deposits remain accessible to scientists via apertures in the grid. © Natur- und Geopark Vulkaneifel

Challenges

Intense touristic interest in Ulmen Maar and the surrounding volcanic landscape leads to pressure on fragile geological structures and natural habitats. Issues with eutrophication of the maar lake from nutrient inflow affect the natural state of the crater lake ecosystem and disturb sediment processes vital for climate archives.

Groundwater management is delicate due to the maar lake's hydrological balance.

Additionally, reconciling public access, especially in the new Ulmen Maar Tunnel, with strict conservation goals requires careful visitor management and interpretation to prevent damage to sensitive geological outcrops

Geoconservation activity

A major geoconservation milestone is the Ulmen Maar Tunnel, a medieval drainage tunnel connecting Ulmen Maar and Jungferweiher Maar, re-opened and restored for controlled public access in 2023 after decades of closure. Originally built in the late medieval times, some 800 years ago, to regulate water levels, the tunnel exposes spectacular tephra deposits from phreatomagmatic eruptions, offering unique insights into maar volcanism. Restoration works stabilized the tunnel walls, removed debris, and installed protective infrastructure to preserve delicate stratigraphic features.

Beyond the tunnel, the surrounding Ulmen Maar and Jungferweiher areas are protected as natural reserves and part of Natura 2000 sites, ensuring legal safeguards for their geological and ecological integrity.

Ongoing measures include monitoring visitor numbers, maintaining marked trails, erosion protection around the tephra ring, and clear interpretive signage highlighting both geological processes and conservation rules. Scientific studies contribute vital data to adjust management plans and safeguard the maar's geological structures and ancient environmental records.

Main results / conclusion

The Ulmen Maar Tunnel project and protective zoning around Ulmen Maar successfully combine geoconservation and sustainable public engagement. Through guided access, infrastructural safeguards, and legal protection, key geological features are preserved for scientific research and education.

Inside the Ulmen Maar Tunnel, there are layered tephra deposits from phreatomagmatic eruptions of the Ulmen Maar, and protective grating and netting have been installed as geoconservation measures in the tunnel. © Eifel Tourismus GmbH, shapefruit

SAFEGUARDING EARTH'S ARCHIVES PRESERVE BILLION-YEAR WONDERS

BILUTU MEGADUNES AND LAKES IN THE BADAIN JARAN DESERT

Bilutu Sand Peak and interdune lake

THE LARGEST MEGADUNES IN THE WORLD AND A UNIQUE MEGADUNE-LAKE SYSTEM

The unique mega dune lake system and the largest dunes in the world are the product of Asian inland aridity, and directly and objectively reflect the history and process in this area. The site, located in the west wind and monsoon transition zone and northeast edge of Qinghai Plateau, is an ideal area to study late Quaternary climate change along with the uplift of Qinghai-Tibet Plateau, and water resources in the arid area of aeolian landform. It is also of great practical significance for studying people's livelihood-related matters, such as aeolian sand control.

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Barunyiheri Lake (Twin Lakes)

Challenges

Ecological vulnerability: Under hyper arid climatic conditions, lake water levels exhibit high sensitivity to evaporation flux variations. Terminal saline lakes such as Honghaizi may shrink due to insufficient water supply.

Tourism pressure: Surging visitor numbers intensify anthropogenic impacts, threatening the morphological stability of dune systems.

Geoconservation activity

Intelligent monitoring: Deploy real-time monitoring equipment and unmanned aerial vehicle (UAV) inspection systems and establish dynamic databases of dune morphology, lake water quality and vegetation coverage.

Permanent structures are prohibited in critical zones, while competitive events like the "Badain 100" cross-country race are restricted to the peripheral zones only.

Ecological water replenishment mechanism: Based on the theory of "paleo-modern water mixing recharge", artificial engineering interventions are implemented in the the Heihe River-Qilian Mountains recharge zone to maintain aquifer equilibrium.

Main results / conclusion

Maintain the normal balance of lake water volume while enhance the vegetation coverage around 12 freshwater lakes.

Establishing a trinity conservation framework of "Scientific research based periodic Monitoring makes it a global exemplar for geological heritage conservation in arid regions.

Community residents cleaning up leftover garbage

LEGAL FRAMEWORK, PATROLS AND CONTROLLING ACCESS AGAINST DESTRUCTIVE ACTIONS

EARLY CRETACEOUS RHYOLITIC COLUMNAR ROCK FORMATION OF HONG KONG

Photograph showing the typical geomorphological feature of the High Island Formation

ONE OF THE MOST SPECTACULAR RHYOLITIC COLUMNAR ROCK FORMATIONS IN THE WORLD

The High Island Formation is the relic of an early Cretaceous super volcano, which had produced a massive amount of 1,300 km^3 volcanic materials. Columnar joints were developed by thermal contraction in the volcanic materials within the caldera. The rock formation is different from mafic volcanic rock columns found elsewhere in the world.

It was developed from rhyolitic rock with up to 76% SiO_2 content. The entire formation displays an extremely high degree of homogeneity in lithology, petrology and geochemistry. And this formation is integrated with diverse coastal erosion and deposition landforms, creating a unique geomorphological landscape.

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Regular patrol of geosite is carried out by rangers to check for irregularities and carry out enforcement actions if necessary

Challenges

While the early Cretaceous rhyolitic columnar rock formation of Hong Kong is subject to natural weathering, the major potential impacts arise from undesirable behaviours of visitors, such as graffiti, rock climbing, littering and erosion accelerated by excessive number of visitors.

Geoconservation activity

The geological heritage is located in Hong Kong UNESCO Global Geopark and is protected by law. In principle, large scale development is not allowed. During the planning of the geopark, facilities and access (e.g. pier, footpath) are provided only in one geosite with existing car road, i.e. High Island Reservoir East Dam, leaving other areas preserved in their natural state. At this geosite, wooden boardwalk and low kerb as subtle fencing are installed to prevent visitors from getting too close to the rock columns, in order to minimize human disturbance and also for safety of visitors.

Other visiting routes and tours are also developed to alleviate visitors' pressure on one geosite, such as boat tour to appreciate the columnar rock formation without landing.

Regular patrol is carried out by boat to coastal areas and islands, and by vehicle to High Island Reservoir East Dam, to deter improper visitor behaviours, such as graffiti, rock climbing and littering. When necessary, enforcement action is taken. Geoconservation message is also disseminated on-site by warning signs, and in all promotion materials.

Main results / conclusion

Since the establishment of Hong Kong UNESCO Global Geopark, the volcanic rock formation has remained intact. In general visitors treasure this valuable geological heritage and no significant rock damage has been detected. In the rare case of graffiti, they are removed by volunteers or staff.

Boardwalk with clear information and warning signs is provided at a geosite to minimize human disturbance.

Boat patrol at the outcrop.

SYSTEMATIC CONSERVATION OF FOSSILS AND THEIR SURROUNDINGS

DASHANPU MIDDLE JURASSIC DINOSAUR FOSSILS SITE

Concentrated dinosaur fossils in the site

A HIGHLY CONCENTRATED MIDDLE JURASSIC DINOSAURS SITE THAT DEMONSTRATES HIGH VERTEBRATE DIVERSITY

This site has a highly diverse vertebrate fauna and the greatest concentration of Middle Jurassic dinosaurs known. The site is the type locality of the *Shunosaurus* Fauna. Its fossils represent basal taxa of several different lineages, such as the eusauropod *Shunosaurus lii*, macronarian *Dashanpusaurus dongi*, stegosaur *Huayangosaurus taibaii*, neornithischian *Agilisaurus louderbacki*.

Some specimens exhibit unique bone structures, such as the bony tail clubs of sauropods and the parascapular spines of stegosaurs, which provide evidence of dinosaur behaviours. Fossils from this site fill a gap in the dinosaurs' evolution and provides exceptional good samples for studying many paleobiological aspects and their relations with other vertebrates.

Cleaning and repairing fossils at the site

Challenges

Hundreds of dinosaurs and coexisting vertebrates have been unearthed at the site. Fossils here are unique, primarily composed of calcium phosphate and calcium carbonate, and are found within the sedimentary rocks of the Shaximiao Formation, consisting of siltstone, quartz sandstone, and mudstone, with weak weathering resistance. Due to the high temperatures and year-round rainfall in Zigong, the fossils exposed in the field are susceptible to erosion from dust containing sulphur dioxide (SO_2) and carbon dioxide (CO_2).

Geoconservation activity

When dinosaur fossils are exposed, they are prone to weathering in the open air. However, the geoconservation strategy for the fossil site is not a one-size-fits-all approach; a series of geoconservation measures have been implemented over the years.

In 1979, the site was extensively excavated due to a construction project, resulting in the unearthing of thousands of fossils. After cleaning and restoration, some were assembled into specimens for exhibition, while others were stored in a facility with controlled temperature and humidity.

Moreover, buildings have been constructed *in situ*, containing countless fossils to maintain a closed and relatively stable environment.

In collaboration with a local university's Key Laboratory, a new type of nano-silica fossil protection material was developed, which has proven effective for both fossils and the site.

Additionally, the regulations for dinosaur geological heritage protection of Zigong were issued in 2024 by city authorities under the law, significantly raising public awareness of geoconservation. Regular patrols at the site and timely cleaning and protection of fossils have been conducted, making geoconservation a daily task.

Main results / conclusion

Effective heritage protection and utilization is a systematic endeavour in Zigong. It requires the collaborative efforts of local governments, geopark managers, citizens, and other sectors of society. Good natural heritage protection and utilization will provide a solid foundation for the long-term sustainable development of local communities.

Huayangosaurus taibaii*, a restored complete skeleton found in the site*

New type protection of nano-silica spraying and coating on site

JOINT EFFORTS TO ENSURE COMMUNITY SAFETY AND GEOCONSERVATION

Heisei Shinzan Lava Dome

Northeast view of Heisei Shinzan, formed in the 1990–1995 eruption, with the endogenous part at top

SCIENTIFICALLY BEST-DOCUMENTED DOME GROWTH DURING THE HEISEI ERUPTION (1990-1995) AT UNZEN VOLCANO

The Heisei Era eruption that occurred at Mount Unzen, one of Decade Volcanoes of the International Decade for Natural Disaster Reduction (IDNDR), has been thoroughly studied, and it has become one of the best-documented lava dome eruptions. This eruption was unlike the explosive eruption of Pinatubo, which erupted at about the same time. However, the compositions of their magmas were similar. This contradiction led to a challenging project by the International Continental Scientific Drilling Program (ICDP) to excavate the path followed by the magma immediately after the eruption of Mount Unzen.

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Disaster prevention stakeholders and experts conducting a survey on Heisei Shinzan Lava Dome.

Photo by Takeshi Matsushima

Challenges

The Heisei Shinzan Lava Dome, formed on the mountaintop about 30 years ago, continues to inspire awe with its immense natural power and stunning landscape. However, the dome is slowly moving downhill due to gravity, at a rate of approximately 5 cm per year even now. Its partial collapses are threatened by future earthquakes. To protect lives and landscapes, engineers have built erosion-control dams to guard against rockfalls and landslides. Meanwhile, the local community is staying one step ahead by conducting evacuation drills and raising awareness, transforming the challenge posed by nature into a model of resilience and preparedness.

Geoconservation activity

The Heisei Shinzan Lava Dome is a designated Natural Monument. To ensure its protection and the safety from sudden volcanic eruptions, the entire dome above the talus at its base is off-limits to the public. To give visitors a sense of the dome's immense size, the Ministry of the Environment developed a one-way nature trail leading to the base of the dome in the mountain area. Active Rangers from the Ministry of the Environment and local authorities maintain the trail by conducting regular monthly inspections and removing fallen trees, loose rocks, and overgrown vegetation. They also regularly inspect and repair benches and information boards to ensure a safe and comfortable hiking.

Meanwhile, experts conduct survey climbs twice a year to monitor changes in the lava dome's surface stability and assess the current state of volcanic activity. They monitor the GNSS positioning of the dome's surface, as well as the temperature and chemistry of the fumaroles at the dome's peak. These surveys are carried out in collaboration with local institutions, including Kyushu University, the Meteorological Agency, police and fire departments, and various disaster prevention organizations. These agencies collaborate to maintain a surveillance system and prepare for potential collapses.

Main results / conclusion

The damage caused during the eruption as well as the volcanic threat have turned into a blessing for the Unzen Volcanic Area UNESCO Global Geopark, with the Heisei Shinzan Lava Dome being wholly conserved as a significant heritage site. It is used as a place to learn about volcanic activity and disaster risk reduction.

The western talus of the Lava Dome with the nature trail running alongside it.
Photo by Takeshi Matsushima

The concrete structure in the foreground is part of an erosion control dam

CONSERVATION OF COASTAL CLIFFS IN AN ACTIVELY ERODING COASTAL SECTION

END-TRIASSIC FLOOD BASALTS AT THE OLD WIFE

Sea cliffs at the Old Wife, with dark flood basalts overlying red sedimentary strata of the Triassic rift valley

ONE OF THE WORLD'S GREATEST TESTIMONIALS TO THE BREAKUP OF PANGEA, IMPLICATED IN THE END-TRIASSIC MASS EXTINCTION EVENT

This IUGS Geological Heritage site bears witness to forces and events generally unseen: the plate tectonic forces of a dynamic Earth and its consequences to life on our planet. The breakup of the supercontinent Pangea and a cause of one of the greatest mass extinction events in the history of life on Earth are both recorded here. The dramatic cliffs scape in which these are exposed are consequences of the erosive power of the world's greatest tides in the Bay of Fundy.

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Cliffs of Fundy Geopark

unesco Global Geopark

Late Triassic reconstruction displayed on one of the interpretation panels

Challenges

The End-Triassic flood basalt section at the 'Old Wife' occurs as coastal cliffs that tower over 150 metres above the Bay of Fundy, where the highest recorded tides in the world cause unrelenting erosion. Sea level rise and extreme weather events increase the rate of coastal erosion. Although the overlying basalt is resistant to erosion, the underlying sedimentary strata that comprise the basin-fill of the ancient rift valley are far more susceptible. The sheer scale of the section coupled with the extreme tides of the Bay of Fundy preclude conventional coastal protection measures.

Geoconservation activity

Processes and rates of coastal erosion are monitored by drone-mounted LIDAR in partnership with the provincial Geological Survey. As for all coastal geoheritage sites, erosion removes the natural exposure but also exposes ever new ones that can reveal new discoveries. Although legislation protects the fossils, minerals and beach areas, public awareness that instils as sense of stewardship has been shown to be the key measure in support of geoconservation, and interpretive panels strive to convey this to the visitor. Although the section exposed is not highly fossiliferous, discoveries do occur. In one case study, the discovery of an early theropod dinosaur footprint by an international visitor was brought to the attention of Park officials and subsequently to the nearby Fundy Geological Museum (FGM). A cast of the footprint made by the FGM is now on display at the Park Visitor Centre, where it serves as an example to visitors of geoconservation through stewardship. Safety and ecological sensitivity messages are of equal importance. These include the safe time window to visit during the twice-daily tidal cycle, hazards of rock falls, as well as awareness and avoidance of ecologically sensitive intertidal areas which are the habitat of threatened rock-boring clams.

Main results / conclusion

Coastal erosion in this highly dynamic setting is both a natural phenomenon and unpreventable. However, it calls on Geopark partners to deliver key messages and programs with respect to safety measures; interpretation and appreciation of geoheritage; the effects of climate and sea level change; and through instilling a sense of stewardship through citizen science and cooperation.

Theropod dinosaur footprint discovered by citizen scientist and conserved by Fundy Geological Museum, cast on display at Five Islands Provincial Park visitor centre

RESTITUTIONS FOR SUSTAINABILITY, GEOCONSERVATION AND PROMOTION OF PALEONTOLOGICAL HERITAGE

CRETACEOUS LAGERSTÄTTEN OF CARIRI STONE

Cordulagomphus fenestratus (MPSC I 485). Fossilized dragonfly (Odonata) preserved in the Crato Formation, bearing witness to these insects' ancient flight 110 million years ago

HIGH DIVERSITY AND ABUNDANCE OF LARGE REPTILES, DINOSAURS AND PTEROSAURS, FISH, INSECTS, CRUSTACEANS AND PLANTS IN HYPERSALINE LACUSTRINE DEPOSITS

The Cretaceous Lagerstätten of the Cariri Stone is esteemed for its remarkable fossil deposits standing as a landmark in paleontological significance globally. The fossils of dinosaurs and pterosaurs, with their deep-rooted cultural significance, especially resonate with the public. Angiosperms, marking a significant evolutionary shift in the planet's vegetation by progressively overtaking gymnosperms, are commonly found in these deposits, together with a variety of pollinating insects, potentially signalling a coevolutionary relationship between these groups. This area's rich biodiversity attracts a significant number of scholars and sightseers and plays a crucial role in enhancing the local economy.

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The Dinosaur "Ubirajara" on the repatriation Ceremony at the Brazilian Ministry of Science and Technology, Brasilia. June 2023.

Challenges

Restitution of fossil heritage that has been historically removed illegally from the territory and the country;

Create innovative economic alternatives that enable the sustainable development of the territory based on its heritage;

Promote the shift from the historical economic model of primary exploitation of non-renewable natural resources to a sustainable version.

Geoconservation activity

The Araripe UNESCO Global Geopark, in coordination with Brazilian institutions at various levels, has been working intensively to repatriate fossil heritage from the territory that is currently outside Brazil.

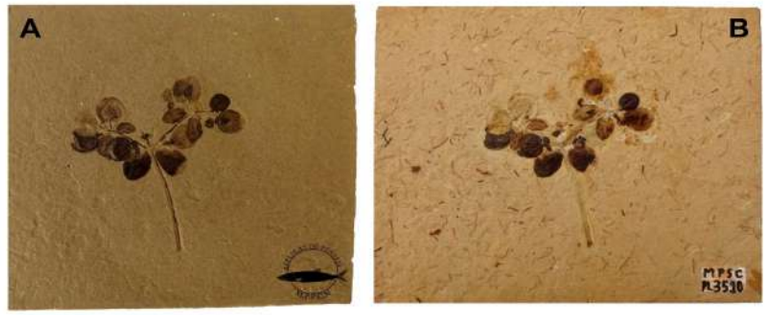
To this end, the Araripe UGGp team has compiled a list of fossil types held by foreign institutions. This list was provided to the Ministries of Foreign Affairs, Science, Technology and Innovation, and the Brazilian Public Prosecutor's Office to take action to recover these heritage assets. The results have been extraordinary, with the repatriation of thousands of fossils, including some of great scientific and cultural interest (e.g., "Ubirajara jubatus" unavailable name, *Cretapalpus vittari*), along with several other repatriation initiatives underway.

This repatriation process is taking place alongside a broad strategy to publicize the process and its results which has strengthened the identity and sense of belonging among the people of the territory. It has also served as a catalyst for the emergence of new products and businesses based on the paleontological heritage of Araripe.

In parallel, various products have been developed using mining waste as a raw material, resulting in high-quality, environmentally relevant, sustainable, and identity-based items, such as replicas of fossils from the territory produced with different techniques. These techniques were transferred to local artisans and miners, who began producing these materials, generating income and helping to combat the illegal trade in local paleontological heritage.

Main results / conclusion

The geoconservation efforts have resulted in the repatriation of the dinosaur "Ubirajara", 25 specimens of the spider *Cretapalpus vittari*, 2.5 tons of fossils from France, 155 insects from the United Kingdom, and two fish from Italy. Local geo-products have also emerged. Paleontology has become a mandatory subject in schools, in addition to the creation of the *Semana da Paleontologia* (Paleontology Week) and Paleontology Day.



Cariria orbiculiconiformis Kunzmann et al 2011.A, Replica of fossil plant MPPCN PL3510. B, original fossil MPPC PL3510.

TECHNICAL MONITORING AND RISK MANAGEMENT

THE COTACACHI – CUICOCHA VOLCANIC COMPLEX

The more recent active volcanic domes of the Wolf (right) and Yerovi (left) islands emerge in the middle of Cuicocha caldera lake. Photo taken from the south flank of Cotacachi volcano

VOLCANIC COMPLEX WITH A SPECTACULAR 3 KM WIDE ACTIVE VOLCANIC CALDERA, WITH MANY DOCUMENTED RECORDS OF VIOLENT HISTORICAL ERUPTIONS

The Cotacachi – Cuicochoa Volcanic Complex (CCVC) is one of the most powerful volcanic complexes in Ecuador. Its activity during the last 3100 years includes the destruction of a pre-caldera dome due to violent eruptions with pyroclastic waves. After the formation of the caldera, there was a lava extrusion that formed the two islands that are visible today within the caldera and its accumulation of glacial water, forming Lake Cuicocha. It is currently the most visited tourist attraction offered by the Global Geopark Imbabura UNESCO with around 200,000 visitors a year due to its easy access and beauty.

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Active volcanic caldera with visible domes, the central axis of IGEPN's geochemical monitoring.

Photo: Geoparque Imbabura

Challenges

The Cotacahi-Cuicocha Volcanic Complex (CCVC), given its geographic location within the Pacific Ring of Fire, presents geodynamic problems specifically related to the Cuicocha volcanic caldera, due to moderate seismic activity and gas emissions, particularly CO_2.

These gases, which are harmful at high levels to lake visitors, pose potential risks, requiring continuous monitoring.

Practical information and alert systems are essential to safeguard both the geological integrity and visitors, while preserving the natural dynamics of the site.

Geoconservation activity

Geophysical Institute of the National Polytechnic School (IGEPN) has monitored the Cuicocha volcano since 2011. A network of seismic stations, GPS data of ground deformation, and three-month lagoon geochemical studies are included. 101 diffuse CO_2 measurements were made in April 2025 using the accumulation bell approach,. Gas analysis was done using a portable spectrometer, and samples were gathered from bubbling zones Yerovi Isle The IRD, EPN Vice-Rectorate for Research, GAD Santa Ana de Cotacachi, and Cotacachi E.P. are supporting these initiatives as part of PIGR 22-02.

Monitoring provides a scientific basis for detecting changes in volcanic activity using CO_2 flow maps and anomaly identification. The monitoring system has three broadband seismic stations, a continuous GPS station, and a reference station. We can constantly record seismicity, deformation, and hydrothermal system signals at these sites.

The National Institute of Geophysics and Geosciences receives data immediately. They evaluate it for anomalies. This sophisticated equipment can detect early signs of volcanic reactivation or internal processes that might harm the lagoon and its geology.

Main results / conclusion

The implementation of a permanent seismic and geochemical network at Cuicocha has allowed the detection of anomalous variations in CO_2 emissions and hydrothermal activity. reducing volcanic risk and ensuring the conservation of the caldera-lake system with public access to the data.

Field gas measurement using the bell method during a geochemical campaign (2025). Photo: Instituto Geofisico EPN

CONTROL AND MANAGEMENT OF NON-NATIVE INVASIVE PLANT SPECIES IN NGORONGORO CRATER FLOOR

NGORONGORO CRATER

Ngorongoro Crater panorama view

THE LARGEST UNFLOODED AND UNBROKEN CALDERA IN THE WORLD

Ngorongoro Crater is the largest unflooded and unbroken caldera in the world In contrast with many other larger calderas which either have broken rims or are flooded to form lakes.

The crater is an important geological heritage site for scientific studies of volcanology and seismic activities as well its relationship with pyroclastic depositions at Laetoli-Olduvai Gorge palaeo-anthropological sites of human evolution.

Nevertheless, the Crater is a most spectacular sanctuary for a premier collection of diverse wild animals and plants species that live within its border. It is true “Garden of Eden”.

www.iugs-geoheritage.org/designations/

Using mechanical mowing to remove invasive plants at the Ngorongoro Crater floor

Challenges

The Ngorongoro Crater, a unique and isolated ecosystem, is currently facing significant challenges due to the invasion of plant species, particularly *Bidens schimperi* and *Gutenbergia cordifolia*. These invasive plants disrupt the native vegetation structure, threatening the delicate ecological balance of the crater. The spread of these species competes with indigenous flora for resources, altering habitats and potentially impacting the diverse wildlife that depends on the crater's natural environment.

Geoconservation activity

Efforts to control and mitigate this invasion are crucial to preserving the Ngorongoro Crater's biodiversity and maintaining its status as a vital ecological sanctuary.

To safeguard the unique geological heritage of the Ngorongoro Crater, the NCAA (Ngorongoro Conservation Area Authority) implemented targeted measures to reduce the invasive plant species threatening its isolated ecosystem. Mowing operations were always conducted across the affected key zones to ensure sustainability of wildlife and conservation of natural resources within the crater. These efforts effectively halted the spread of invasive species, which had been disrupting and destabilizing the crater's ecological balance.

Main results / conclusion

By restoring the native flora, the NCAA's actions not only protect the crater's biodiversity but also preserve its geological and ecological integrity for future generations.

Continued monitoring and proactive management are essential to ensure the long-term conservation of this natural wonder, reinforcing its role as a global benchmark for sustainable environmental stewardship.

Monitoring and preserving the landscape of the Ngorongoro crater by NLUGGp

EDUCATIONAL INITIATIVES, LEGAL FRAMEWORK AND VISITOR OVERSIGHT

NAMAKDAN SALT CAVE

One of the big halls of Namakdan Cave with untouched stalactites. (Photo: Philippe Crochet)

ONE OF THE WORLD'S LONGEST SALT CAVES INSIDE AN AMAZING SALT DOME, INCLUDING THE HISTORICAL AND CULTURAL BACKGROUND

This is one of the most unique salt caves in the world. It is 6.580m long and up to 40m wide. The discovered part of the cave is the longest salt cave known in the world. This cave is considered the "key geosite" in Qeshm Island UNESCO Global Geopark

The remnants of historical sulphur and salt mining and trading are among the cultural values of this site. Namakdan is also on the tentative list of World Heritage Sites. For these reasons, the cave is under strict protection and preservation.

www.iugs-geoheritage.org/designations/

Volunteers from the Caverns Ladies group cleaned the Namakdan Cave in celebration of the National Day of Clean Caves

Challenges

Since this cave is well-known and famous, it attracts many local and international tourists. The impact of tourism and the willingness of some visitors to take samples as souvenirs pose significant challenges.

This issue is compounded by the expectation that local people, who traditionally used the salt for culinary purposes, will also take salt during their visits.

Additionally, changes in land use around the cave due to industrial projects can create further problems for the cave system.

Geoconservation activity

Qeshm Island UGGp implements a multi-faceted strategy for the geoconservation of the nationally protected Namakdan Salt Cave. Its legal status strictly regulates any land use alterations or infrastructure development near the cave, with the Geopark management serving as the authoritative body for official inquiries.

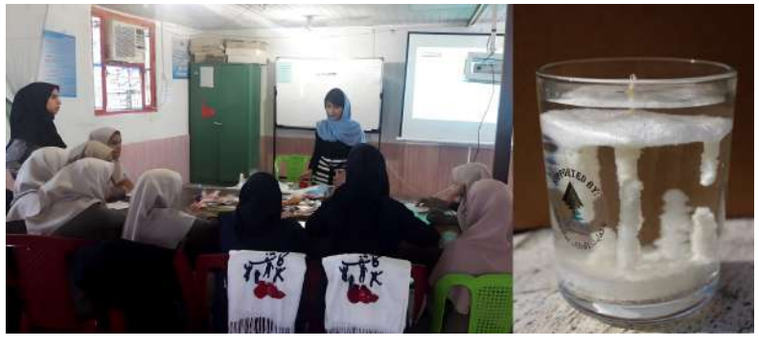
The Geopark actively promotes the cave's geological value through diverse educational methods, including informative panels on-site, detailed brochures, and targeted social media. Access to the cave is tightly controlled: visits are permitted only for individuals or groups accompanied by certified geopark guides. During tours, guides provide essential information about the cave's simplified geology, its outstanding universal value, and the critical importance of its conservation.

A key community-based initiative is the production of the "Namakdan Candle." Created by students from surrounding villages, this unique souvenir provides them with income. Crucially, its packaging contains educational material about the cave and Geopark, serving as a popular memento that significantly reduces the incentive for visitors to collect geological samples.

Main results / conclusion

Namakdan Salt Cave's condition before the establishment of the Geopark was unstable and in great danger of losing all its beautiful elements. Currently, the implementation of geoconservation strategies by the Geopark has made the cave more secure and healthy.

People now have a better understanding of its value, and the risks of damage have significantly reduced.



Soma Sayedyounesi, the designer and creator of the Namakdan Candle, conducting a workshop for local students

This digital publication aims to show a selection of
GEOCONSERVATION ACTIVITIES CARRIED OUT BY UNESCO GLOBAL GEOPARKS
protecting globally important geological heritage sites designate by the IUGS.

This publication was presented during a special workshop on geoconservation at the
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GEOCONSERVATION

IN UNESCO GLOBAL GEOPARKS