Geoconservation Research
Volcanism & Geoconservation
2023, Volume 6 / Issue 1 / pages(I-X)

Preface

Volcanic Geological Sites in UGGp European Geoparks: Special Issue

João Carlos Nunes[1], Michael J. Benton[2]

[1.]Department of Geosciences, Faculty of Science and Technology, University of the Azores, Rua Mãe de Deus, 9501-801 Ponta Delgada, Azores Islands, Portugal, joao.cc.nunes@uac.pt
[2.]School of Earth Sciences, University of Bristol, Life Sciences Building, Tyndall Avenue, Bristol, BS8 1TQ, United Kingdom, mike.benton@bristol.ac.uk

Abstract

In this Special Issue, we present 11 of the 15 geoparks that show key aspects of the past and current volcanic development of Europe. The sites include currently active locations along the mid-Atlantic ridge, from the Canary Islands and the Azores in the south to Iceland in the north. Other sites in continental Europe, from Portugal and Spain in the west to Hungary, Slovakia, and the Czech Republic in the east, document the volcanic history of the continent over the past 500 million years. The Special Issue aims to show how geological and geoconservation research have contributed to a better understanding of the respective geoparks and broadened their significance for education and geotourism.

Keywords: Volcanology; Mid-Atlantic Ridge; Geoeducation; Geoconservation

Article information

First Publish Date:2023-07-04

DOI:10.30486/gcr.2023.1990600.1143

How to cite: Nunes JC & Benton MJ(2023). Volcanic geological sites in UGGp European Geoparks: Special issue. Geoconservation Research. 6(1):I-X.

Geoconservation Research e-ISSN: 2588-7343 p-ISSN: 2645-4661

Introduction

Europe is home to a diverse range of volcanic geological sites that provide valuable insights into our planet's dynamic history. From towering volcanic peaks to unique rock formations and geothermal wonders, these sites are not only geological marvels and often iconic places for tourists, but also significant in terms of scientific research and cultural heritage. Recognizing their importance, geoconservation efforts have been undertaken to protect and preserve these volcanic landscapes, ensuring their longevity for future generations. Our aim here is to make a permanent record of key UNESCO Global Geoparks around Europe that document volcanoes and volcanological phenomena, and with a special focus on their scientific importance, geoconservation strategies and ongoing conservation, education, and geotourism aspects.

Volcanic episodes

Europe has a rich geological history marked by three main episodes of volcanic and tectonic activity, as well as ongoing volcanic activity associated with active movements of tectonic plates:

- The Caledonian Orogeny (500–400 million years ago), named after the Caledonian Mountains in Scotland, occurred during the Late Ordovician to Early Devonian. (Fig.1). It involved the collision of the Laurentian and Baltica tectonic plates, leading to the formation of the Caledonian mountain chain, which stretches from Scandinavia to Ireland and Britain, and on the other side of the Atlantic, forming the Appalachian Mountain Chain. The collision resulted in the uplift of ancient volcanic rocks, metamorphism, and the creation of vast mountain ranges.

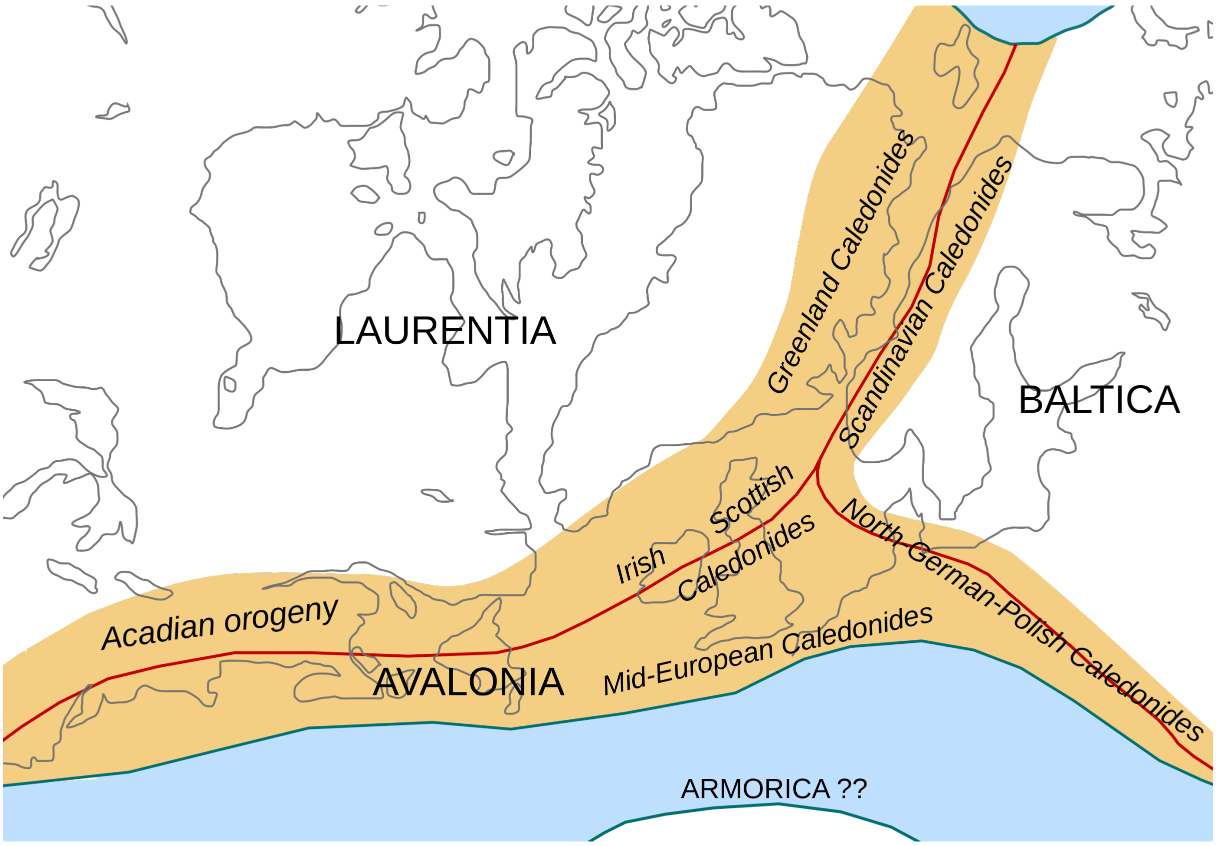

Figure 1. Location of the different branches of the Caledonian/Acadian belts at the end of the Caledonian orogeny (Early Devonian). Present-day coastlines are indicated in gray for reference. Later in geological history, the Atlantic Ocean opened. and the different parts of the orogenic belt moved apart. Map by Woudloper, Wikimedia.

- The Variscan Orogeny (380–280 million years ago), also known as the Hercynian orogeny, occurred during the Carboniferous and Permian periods. (Fig. 2) It involved the collision of the Laurussian and Gondwanan tectonic plates, leading to the formation of the Variscan mountain chain. This mountain chain spans across various regions of Europe, including the Ural Mountains in Russia, the Massif Central in France, the Armorican Massif in western France, and the Bohemian Massif in central Europe. The collision resulted in the formation of large mountain ranges, volcanic activity, and the development of mineral-rich deposits.

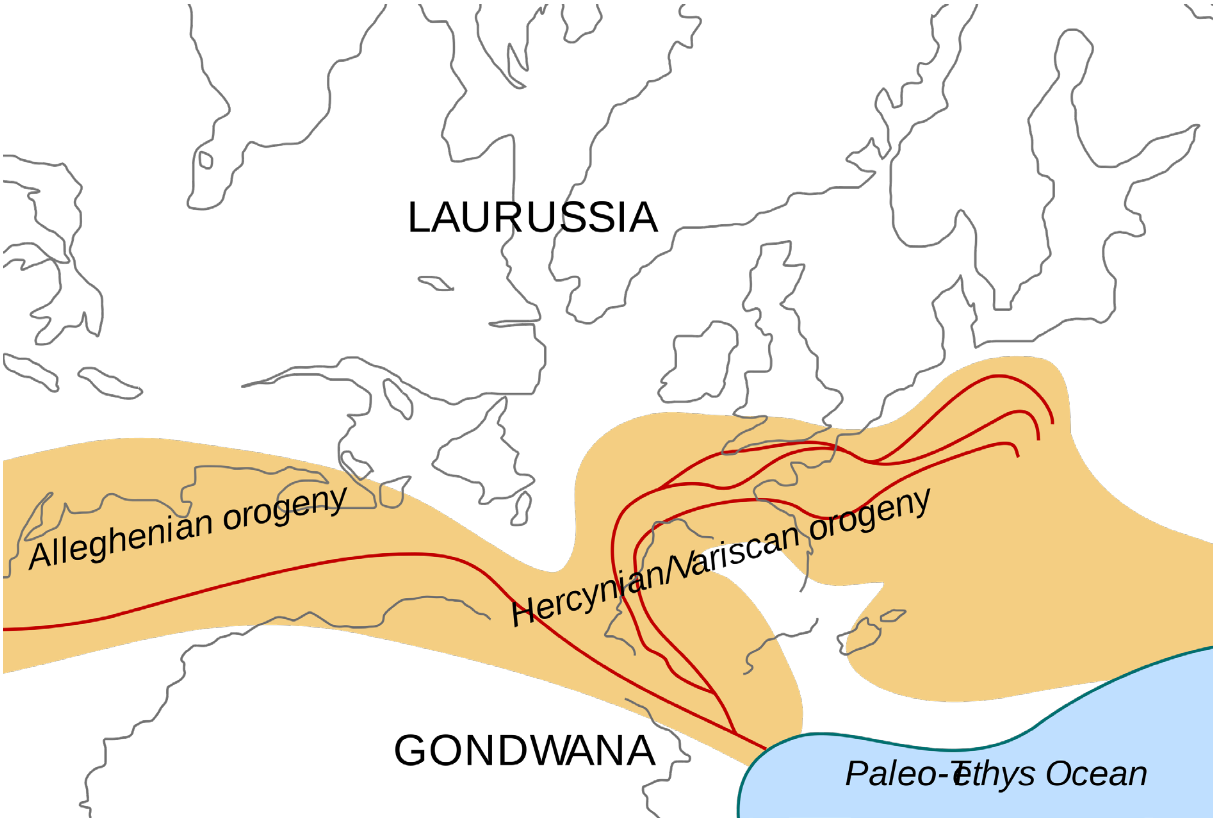

Figure 2. Location of the Hercynian-Alleghenian mountain belts in the middle of the Carboniferous period. Present day coastlines are indicated in grey for reference. Map by Woudloper, Wikimedia.

- The Alpine Orogeny (70 million years ago–present) began during the Late Cretaceous and continues to the present day. (Fig. 3) It involves the convergence of the African and Eurasian tectonic plates, resulting in the formation of the Alps. The Alpine orogeny also extends to other regions, including the Pyrenees, Carpathians, Dinarides, and Apennines. This ongoing collision has led to significant volcanic activity, such as the eruption of Mount Vesuvius in Italy and several eruptive episodes on Greek islands.

Volcanic activity in Europe continues today as part of the Alpine Orogeny, with crustal tensions across the Mediterranean, as the African-Arabian plate moves north, and major east-west faulting systems retain their activity from Turkey to Gibraltar. Thus, continental Europe has experienced several notable volcanic eruptions in recent history. One of the most famous eruptions occurred in 79 AD when Mount Vesuvius near Naples, Italy, erupted, burying the Roman cities of Pompeii and Herculaneum under layers of fall-out tephra and pyroclastic flows.

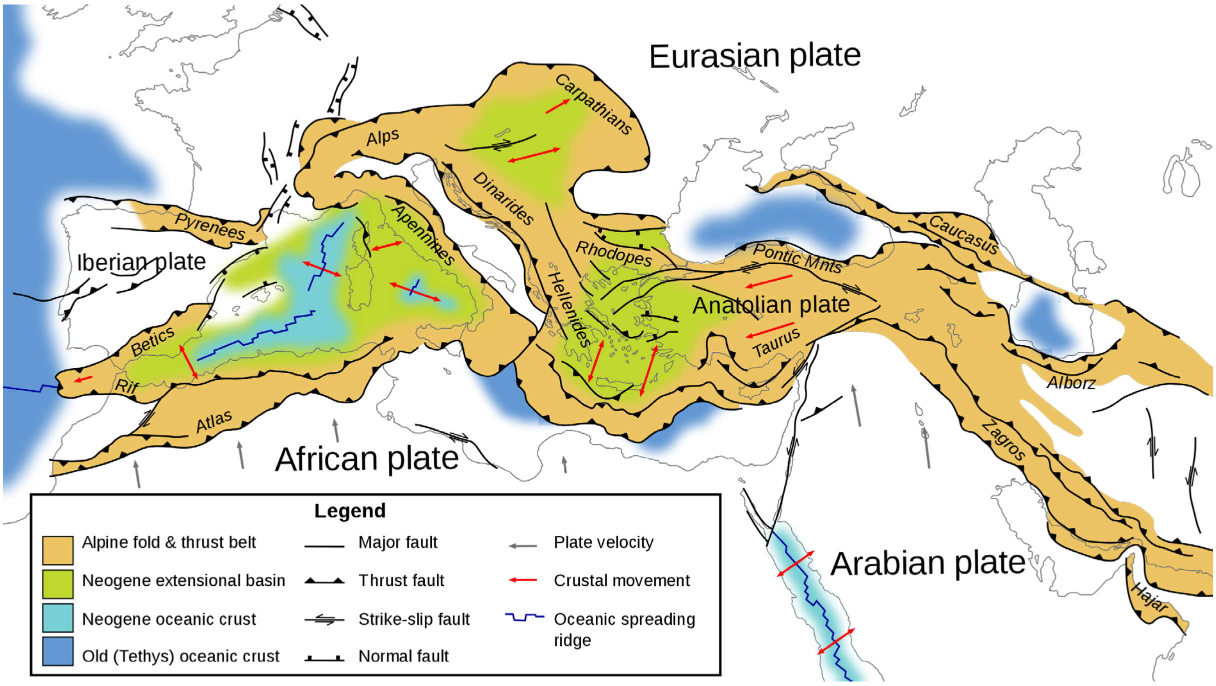

Figure 3. Tectonic map of southern Europe, North Africa and the Middle East, showing tectonic structures of the western Alpide mountain belt. Only Alpine (Tertiary) structures are shown. Map by Woudloper, Wikimedia.

The other cause of continuing volcanic activity in Europe is the North Atlantic mid-ocean ridge system that extends through Iceland and the Azores archipelago, (Fig. 4) where active volcanism continues, as well as in other Atlantic oceanic islands, like the Canaries and Cape Verde islands. In Iceland, notable eruptions include Laki in 1783 (with the extrusion of some 14 km3 of lava and vast agriculture devastation) and the Eyjafjallajökull eruption in 2010, which caused significant disruptions to air travel all over Europe. In Azores, the 1957–58 Capelinhos volcano and the Serreta 1998–2001 eruptions are important milestones for worldwide volcanology, the first elected as one of the “100 IUGS Geological Heritage Sites”, and the later as the first “lava balloons”-type hydrovolcanic eruption scientifically documented (e.g., “serretian-type” eruption).

Importance of Volcanic Geological Sites

Volcanism is undoubtedly the most spectacular and fundamental geological process on Earth: it is responsible for the formation of our planet “Gaia”, oceans and atmosphere. In addition, volcanic geological sites in Europe hold immense scientific, educational, cultural and economic value. They offer a window into past volcanic activities and contribute to our understanding of Earth’s geological processes. These sites often harbor unique features and ecosystems that have adapted to extreme conditions, making them invaluable for biodiversity research and conservation. Furthermore, they sustain important links with cultural tangible and intangible heritage, and often serve as popular tourist destinations, generating economic benefits for local communities.

Geoconservation of volcanic geological sites in Europe involves a range of strategies aimed at preserving their natural and cultural heritage. These strategies encompass legislation, education, research, and sustainable tourism practices, all embraced under the geoparks umbrella. Countries across Europe have designated many volcanic sites as protected areas, integrating them into national park systems, establishing nature reserves or making them relevant geosites of geoparks. These legal frameworks ensure the conservation of these sites,

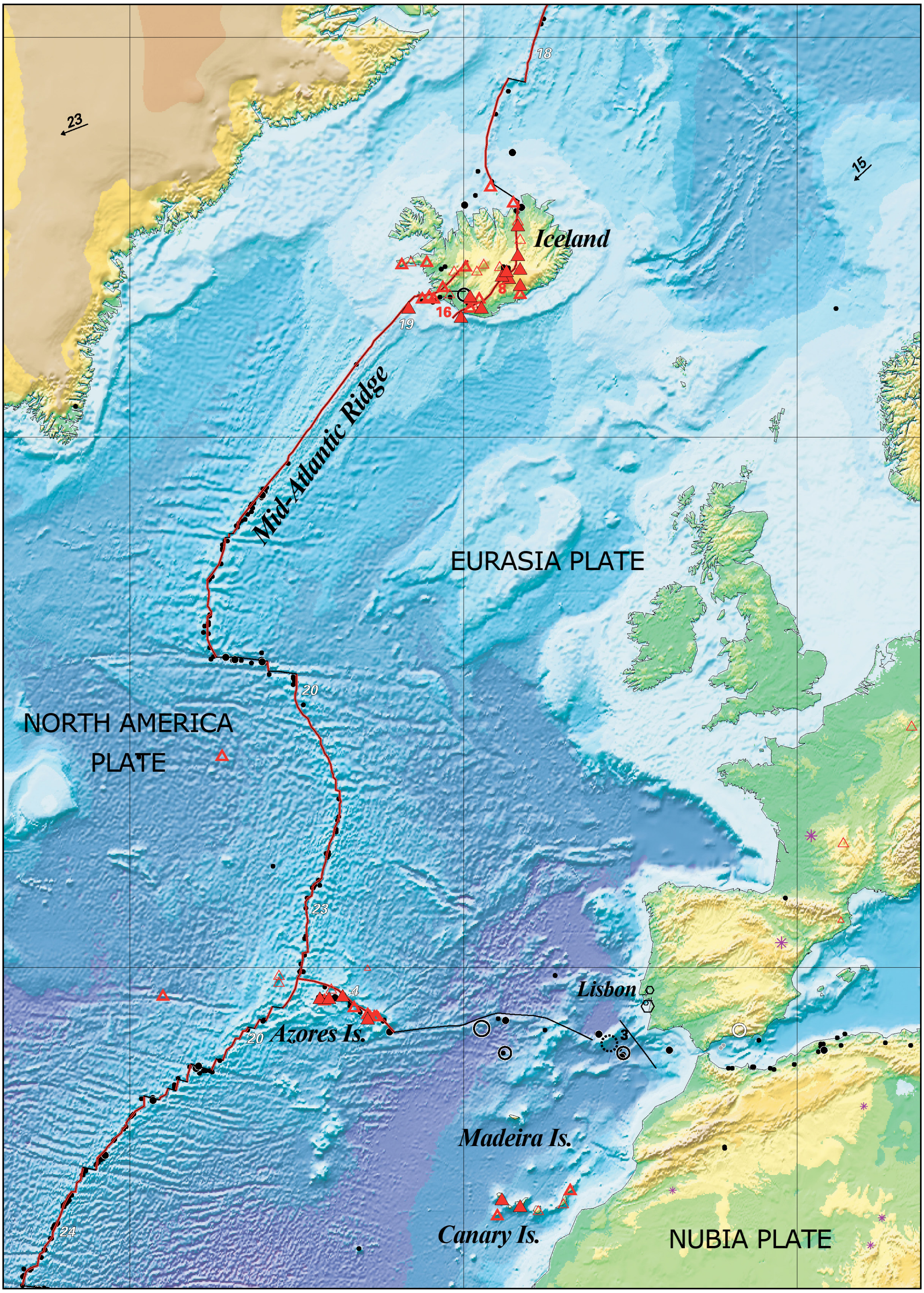

Figure 4. Location of the Mid-Atlantic Ridge in the North Atlantic Ocean. Adapted from "This Dynamic Planet - World Map of Volcanoes, Earthquakes, Impact Craters, and Plate Tectonics", by Tom Simkin, Robert I. Tilling, Peter R. Vogt, Stephen H. Kirby, Paul Kimberly & David B. Stewart (2006). Geologic Investigations Map I-2800. U.S. Department of the Interior, U.S. Geological Survey. https://pubs.usgs.gov/imap/2800/

restrict harmful activities, and promote sustainable land management practices.

Raising public awareness about the significance of volcanic geological sites is crucial for their preservation. Educational programs, interpretation centers, and guided tours provide visitors with a deeper understanding of the geological processes and importance of these sites, fostering a sense of appreciation and stewardship. Scientific research plays a pivotal role in geoconservation efforts. Geological surveys, monitoring networks, and interdisciplinary studies help monitor volcanic activity, assess potential hazards, and contribute to ongoing conservation plans. By deepening our knowledge, these efforts aid in effective management and sustainable development of these sites.

Balancing tourism with environmental protection is a key challenge in geoconservation. Sustainable tourism practices, such as visitor guidelines, infrastructure development, and visitor capacity management, ensure that tourism activities do not negatively impact the fragile volcanic sites, formations and features. Engaging local communities in tourism planning and development fosters a sense of ownership and benefits the economic well-being of the region.

UNESCO Global Geoparks (UGGp)

Geoparks are perfect tools for geoconservation of volcanic geological sites, as special territories designated by UNESCO where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. In addition to using the geological heritage in connection with all other aspects of the territory's natural and cultural heritage, the geoparks can help the well-being and socio-economic development of local communities. UGGp can promote awareness and understanding of key issues facing society, such as earth's resources sustainably, mitigation of climate change effects and reduction of natural disasters-related risks.

Europe has witnessed notable successes in geoconservation of volcanic geological sites. Examples include:

a. The Azores Islands, Portugal:

Located at the triple junction between the North American, Eurasian and Nubian tectonic plates, the Azores Islands offer diverse and unique volcanic landscapes and features, ranging from the 3,500 m high Pico Mountain basaltic stratovolcano, to hundreds of siliceous domes and coulée-type monogenetic volcanoes, from volcanic caves to impressive deep-sea hydrothermal fields, such as the Lucky Strike, Menez Gwen or Rainbow hydrothermal vent fields on the Mid-Atlantic Ridge. During the last decades, the geodiversity and geological heritage of the Azores Islands is being "geologically recognized, politically considered and legally protected", with about 95 geosites classified as protected areas.

b. The Canary Islands, Spain:

The volcanic landscapes of the Canary Islands, like the Timanfaya National Park in Lanzarote Island or Tenerife's Mount Teide, have been widely recognized and the latter designated as a UNESCO World Heritage Site. The implementation of strict protection measures and sustainable tourism practices has ensured the preservation of these and other remarkable volcanic environments in the archipelago.

c. Iceland:

Iceland's volcanic sites, such as the geothermal wonders of the Reykjanes Peninsula, the Thingvellir rift zone, and the dramatic landscapes of the Vatnajökull National Park, have been effectively managed through a combination of legislation, research, and sustainable tourism initiatives. These efforts have contributed to the country's growing popularity as a geo-tourism destination.

Special Issue

In this special issue, we include articles from two main European geological settings: North Atlantic volcanic islands and continental European geoparks, illustrating a range of geological interests and geoconservation issues, from geosites, volcanic geoheritage, geoeducation and geotourism. Crucial in all cases is that the rationale for identification of a site or area for conservation is the scientific argument: a site must show unique and high-relevance geological features that are recognized as significant at an international or national level. This requirement provides a benchmark worldwide so that all designated geosites are important scientifically at a high level, wherever they may be located, and this then provides a marker that can be used locally to explain why such a geological resource is important and so engender local pride and value for the sites.

We group the papers under three main themes (Table 1), Volcanism in the North Atlantic Ocean

Table 1. Summary of the main geoparks in Europe that show volcanological phenomena, grouped by geographic .region and by the dates of volcanism, and whether still volcanically active

	Geopark Name	Country	Maximum expected age of volcanic rocks	Younger age of volcanic rocks	Active volcanism
North Atlantic Ocean	Reykjanes UGGp	ICELAND	200 ka	2022 A.D.	YES
	El Hierro UGGp	SPAIN	1.2 Ma	2011 A.D.	YES
	Katla UGGp	ICELAND	2.5 Ma	2011 A.D.	YES
	Azores UGGp	PORTUGAL	6 Ma	2001 A.D.	YES
	Lanzarote y Archipiélago Chinijo UGGp	SPAIN	15 Ma	1824 A.D.	YES
Continental Europe (younger)	Vulkaneifel UGGp	GERMANY	45 Ma	10.9 ka	NO
	Lesvos Island UGGp	GREECE	21.5 Ma	16 Ma	NO
	Kula - Salihli UGGp	TURKEY	1 Ma	15 ka	NO
	Monts d’Ardèche UGGp	FRANCE	12-6 Ma	166 - 30 ka	NO
Continental Europe (older)	Bakony-Balaton UGGp	HUNGARY	8 Ma	2.6 Ma	NO
	Cabo de Gata-Nijar UGGp	SPAIN	14 Ma	8 Ma	NO
	Novohrad-Nógrád UGGp	HUNGARY *and* SLOVAKIA	20 Ma	0.4 Ma	NO
	Naturpark Bergstrasse Odenwald UGGp	GERMANY	280 Ma	21 Ma	NO
	Papuk UGGp	CROATIA	400 Ma	16 Ma	NO
	Bohemian Paradise UGGp	CZECH REPUBLIC	540 Ma	4.5 Ma	NO

UGGp – UNESCO Global Geopark

Ma – millions of years

ka – thousands of years

(15 Ma to present day), Continental Europe (younger erupting volcanics, 166–10.9 ka), and Continental Europe (older erupting volcanics, 540–0.4 Ma). There are 15 relevant volcanic geoparks in Europe, and we present papers here for 11 of them, and refer to previous papers for the others.

Among the North Atlantic Ocean sites, first is Reykjanes Geopark in Iceland, with volcanic activity dating from 200 ka to the present day, and it has been described earlier (Rybar *et al.* 2014). Second is El Hierro Geopark in the Canary Islands (Casillas Ruiz *et al.* 2023), which shows mega-landslides and extensive fields of pahoehoe lava-flows associated with historical and prehistoric fissure eruptions. The Katla Geopark in Iceland (Jóhannesson *et al.* 2023) is also located in a currently active volcanic area. Volcanic features include evidence of large fissure eruptions that formed vast lava fields, as well as the active volcanoes, craters, and hyaloclastite ridges. Next is the Azores Geopark (Lima and Meneses 2023), showing 27 volcanic systems with polygenetic central volcanoes and volcanic ridges, most of them active but dormant. The Azores Geopark incorporates 121 geosites distributed across the nine islands and the surrounding underwater marine area. Fifth in this category is the Lanzarote y Archipiélago Chinijo Geopark (Guillén Martin and Mateo Mederos 2023), which shows geological evidence of the historic basaltic eruption of Timanfaya, as well as landforms and materials derived from the interaction of volcanic and erosive-sedimentary processes through the last 15 Myr.

Of the four younger Continental European volcanic geoparks, we cannot present reports on two. These are Lesvos Island Geopark in Greece, where volcanic activity lasted from 21.5–16 Ma, but the petrified forest there was described by Zouros (2021), and the Vulkaneifel Geopark in Germany, which has been described in terms of its palaeontological interest earlier in this journal (Koziol and Wappler 2021). Here, we present new accounts of the Kula-Salihli Geopark in Turkey (Aytaç and Demir 2023), which shows evidence of Pleistocene and Holocene basaltic lava eruptions through scoria cones, as well as much earlier volcanism shown by lavas that overlie mesa-style uplands. Further, the Monts d'Ardèche Geopark in France (Raynal *et al.* 2023) shows volcanic features dating from the Miocene to the late Pleistocene, showing evidence of the styles of magmatic processes, eruptive dynamics, morphological evolution of landscapes, chronology of eruptions, and relationships between humans and volcanoes during the Pleistocene.

The final papers describe five of the six geoparks that show evidence of older volcanic eruptions in continental Europe. First is Bakony-Balaton Geopark in Hungary (Harangi and Korbély 2023), which shows evidence of the long-term volcanism of the Carpathian–Pannonian Region, a basaltic monogenetic volcanic field erupted from 8–2.3 Ma. The Geopark encompasses more than 50 volcanic centers and shows evidence of explosive hydrovolcanic eruptions with proximal and distal pyroclastic deposits, clastogenetic lava, valley-channeled lava flow, lava lake and vent-filling basalts. Second is the Cabo de Gata-Nijar Geopark in Spain (García del Hoyo and Donaire Romero 2023), with evidence of submarine effusive volcanism and subaerial pyroclastic deposits from eruptions that occurred 14 Ma. Next comes the Novohrad-Nógrád Geopark straddling the Hungary-Slovakia border (Harangi *et al.* 2023), which shows a broad range of eruption products from basaltic through andesitic to rhyolitic, reflecting the wide-ranging volcanism of the Pannonian Basin over the last 20 Myr. It includes the Ipolytarnóc Site, which documents when a devastating eruption buried a subtropical-forested area with thick pyroclastic deposits and preserved vertebrate footprints. Then, younger eruptions of basaltic and andesitic magmas produced lavas with columnar jointing. The fourth site, in order of the geological age of the eruptions, is Bergstrasse Odenwald in Germany, where eruptions took place from 280–21 Ma, in several phases; geoconservation aspects of the famous Messel Pit, a key fossil site within the geopark was described by Frey *et al.* (2021). The fifth site in this category, the Papuk Geopark in Croatia, shows even older rocks (Balen *et al.* 2023). Especially important is the variety of igneous (sub) volcanic rocks. Albite rhyolite erupted in the Late Cretaceous (~81 Ma), recording events associated with the closure of the Neotethys Ocean when acidic silicate melt rose fast from the deep crustal levels to the near surface, where cooling caused regular cracking and the development of columnar jointing. Finally, the Bohemian Paradise Geopark in the Czech Republic shows the oldest volcanic evidence from among these 15 geoparks (Mencl *et al.* 2023), having been affected by global tectonic events over the last 500 Myr. These include a number of volcanic eruptions associated with the Variscan Orogeny, as well as further volcanic activity in the Neogene triggered at a distance by Alpine Orogenic processes.

The authors of these articles, all of them working in their Geoparks and providing first-hand knowledge, highlight details of how their Geoparks received initial protection at the national level and then the steps to international recognition by UNESCO. Also, importantly, the authors draw out in each case the special volcanological features of their geoparks, stressing the recent and current research and how that contributes to deeper understanding, and links their sites to others in the network. Finally, the authors discuss political and economic aspects of their geoparks, and how the development of the geoparks can stimulate investment and local tourism-related economic activity. There are also great examples of educational programs, geotrails, guided walks, exhibitions, and special events to attract and inform the local people about the wealth of importance of their local geological features, as well as to inform and excite the visitors, both adults and children.

References

Aytaç AS & Dermir T (2023). Volcanic Monument of Western Anatolia: Kula-Salihli UNESCO Global Geopark. Geoconservation Research. 6(1): 139–160.

Balen D, Schneider P, Petrinec Z, Radonić G & Pavić G (2023). Cretaceous volcanic rock geosites of the Papuk UNESCO Global Geopark (Croatia): scientific aspect of geoheritage in geoeducation, geotourism and geoconservation. Geoconservation Research. 6(1): 1-17.

Casillas Ruiz R, Pérez Candelario Y & Ferro Fernández C(2023). El Hierro UNESCO Geopark: geological heritage, geoconservation and geotourism. Geoconservation Research 6(1): 128–138.

Frey ML, Schmitz P & Weber J (2021). Messel Pit UNESCO World Heritage fossil site in the UNESCO Global Geopark Bergstrasse-Odenwald, Germany–challenges of geoscience popularisation in a complex geoheritage context. Geoconservation Research. 4(2): 524–546.

García Del Hoyo G & Donaire Romero T (2023). The Cabo de Gata-Níjar UNESCO Global Geopark (Almería, Spain). a volcanism between land and sea. Geoconservation Research. 6(1): 18–28.

Guillén Martín C &Mateo Mederos E (2023). Geoconservation and Responsible Use of the Territory. Experiences from the Lanzarote and Chinijo Islands UNESCO Global Geopark. Geoconservation Research. 6 (1): 161–177.

Harangi S & Korbély B (2023). The basaltic monogenetic volcanic field of the Bakony–Balaton UNESCO Global Geopark, Hungary: from science to geoeducation and geotourism. Geoconservation Research. 6(1): 70–97.

Harangi S, Szarvas I & Lukács R (2023). Wide-ranging and violent volcanic history of a quiet transborder area: volcanic geoheritage of the Novohrad–Nógrád UNESCO Global Geopark. Geoconservation Research. 6(1): 178–206.

Jóhannesson JM, Sigmundsdóttir B & Sigursveinsson S (2023). Volcanic features within Katla UNESCO Global Geopark. Geoconservation Research. 6(1): 53–69.

Koziol M & Wappler T (2021). Smaller than small, the unique Eocene louse! Geoconservation Research. 4(2): 557-560.

Lima EA & Meneses S (2023). Azores UNESCO Global Geopark: where volcanoes tell us their stories. Geoconservation Research. 6(1): 114–127.

Mencl V, Bubal J & Stárková M (2023). The volcanic history of the UNESCO Global Geopark Bohemian Paradise. Geoconservation Research. 6(1): 98–113.

Raynal JP, Defive E, Klee N, Buso R & Laporte D (2023). A tale of old and young volcanoes in Monts d’Ardèche UNESCO Global Geopark (south-eastern France). Geoconservation Research. 6(1): 207-232.

Rybar P, Molokac M & Hlavcova L (2014). Different approaches to the formation of Geoparks. Acta Geoturistica. 5: 69–80.

Zouros NC (2021). The Miocene petrified forest of Lesvos, Greece: Research and geoconservation activities. Geoconservation Research. 4(2): 635–649.