

## European UNESCO Geoparks: Introduction to Part I

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### Abstract

**The concept of the volume is to survey all the key geoparks throughout Europe in terms of their palaeontological significance. The first 25 articles in this Part cover the long span of geological time from the Precambrian to the Permian, arranged in chronostratigraphic order. These document some of the most important early stages in the history of life, from its origin to the devastation end-Permian mass extinction.**

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## **Introduction**

When Professor Dan Grigorescu accepted our invitation to act as Guest Editor for this special volume on the ‘European UNESCO Geoparks’ in early 2020, we did not expect it would come together so quickly and so efficiently. This was achieved through Professor Grigorescu’s long-established leadership of the initiative, over several decades, keeping contact with colleagues throughout all countries in Europe, both through correspondence and encouragement and through several conferences at which the ideas were shared and scientific and cultural relationships developed.

During the intervening year, Professor Grigorescu and I have worked together to discuss plans for the whole volume, as well as individual chapters, and to encourage authors and author collectives to produce their chapters. We asked them to prepare short papers in which they describe the scientific reasons why their Geopark is internationally important, outline the history of research and the history of establishment as a Geopark, and finally to consider practical and educational aspects of the Geopark in terms of its development, its current state, and future plans.

Our overall aim is to document a coherent network of Geoparks that show the best of the geology and palaeontology of Europe, but placed in global context, and to share ideas and initiatives that describe practical geoconservation in context of education and tourism. In many cases, contributors also describe the practical aspects of their Geoparks, how they negotiate with local and national administrations, and the problems and pitfalls of maintaining adequate funding. In his introductory chapter, Dan Grigorescu outlines the history of the Geopark concept, especially its application in Europe, earlier conferences, and the key palaeontological themes.

In this Introduction, I review the key geological time divisions and the European Geoparks that can illustrate aspects of the palaeontology of each.

## **Precambrian**

The Precambrian is not a formal stratigraphic division, but a name to designate the enormous time span from the origin of the Earth to the appearance of animals with skeletons and shells, inaugurating a new informal division of geological time, the Phanerozoic, when fossils became abundant and visible. The Precambrian comprises about 4 billion years (88% of Earth history) and the Phanerozoic the last 541 million years. Signs of life are very scarce in Precambrian, the most characteristic were the Cyanobacteria (autotrophic, photosynthetic bacteria with a blue pigment). Colonies of Cyanobacteria built finely laminated limestones, stromatolites, one of the most common sedimentary rocks in the Precambrian. By their photosynthetic activity, the Cyanobacteria had an essential role in the rise of oxygenic life on Earth, releasing oxygen into the water and then into the atmosphere. The rise in atmospheric oxygen enabled other forms of life to emerge, first comprising single cells, then multiple cells, and by the end of the Precambrian, macroscopic early plants, animals and Fungi had evolved.

The only Precambrian example is presented by Benton and colleagues, in their description of the Northwest Highlands UNESCO Geopark of Scotland, source of the oldest fossils in Europe, and some of the oldest simple life forms from fresh waters anywhere in the world.

## **Cambrian**

The Cambrian (named after Cambria, the Latin name of Wales, 541–485 million years ago, Ma) is the first geological period of the Palaeozoic (“ancient life”) Era. The Cambrian is marked by a major event in animal evolution, the Cambrian Explosion, marking the apparently sudden diversification of animals with mineral protective skeletons and shells, which means they can fossilize readily. Before the Cambrian, the number of metazoan (= animal) phyla was limited to a few, and only those lacking mineralized skeletons. The processes of biomineralization that started in the

Late Ediacaran (latest Precambrian) led to the great diversification of animals, and by the end of the Cambrian almost all the present animal phyla had emerged. The mineral structures of their skeletons, comprising calcite, apatite, silicate or chitin, ensured protection from predation, but also a greater diversity of body forms. The appearance of biomineralized hard parts also increased the likelihood of fossil preservation which expanded the fossil record and created a new source of material for the formation of sediments.

The Cambrian Explosion is documented in the Villuercas-Ibores-Jara UNESCO Global Geopark in Spain, described by Cortijo and colleagues, known especially for the early metazoan *Cloudina*, one of the first animals with a skeleton. Next, in two papers, Alfaro and colleagues describe the Early Cambrian trilobites and associated faunas from the Sierra Norte de Sevilla Geopark, also in Spain, with its fauna of 12 trilobite species and associated hyolithids, serpulids and echinoderms, and its exceptionally preserved fossils in the Constantina-San Nicolás del Puerto area. A third geopark in Spain, the Courel Mountains UNESCO Global Geopark, described by Ballesteros and colleagues, documents a long rock succession from Precambrian to Carboniferous, including also Cambrian rocks with famous trilobite fossils.

### **Ordovician**

The Ordovician (after Ordovices, a Celtic tribe in Wales, 485–444 Ma) is the second period of the Palaeozoic. This time is marked by a second major diversification of marine animals, the Great Ordovician Biodiversification Event (GOBE). New groups of animals appeared, including corals, graptolites and fishes. In particular, there was an increase in the importance of suspension feeders and pelagic predators and the establishment of more complex reefs. The first among the five great mass extinctions occurred at the end of the period when about 60% of all the marine organisms disappeared.

In this volume, we feature six Ordovician geoparks, which document the GOBE in extraordinary detail, stepping through its Early, Middle, and Late Ordovician phases. The first is the Penha Garcia Ichnological Park at Naturtejo UNESCO Global Geopark in Portugal, described by Carvalho and colleagues. This is particularly famous for 21 species of *Cruziana*, representing complex foraging trails of trilobites. Trace fossils are also featured at the Armorican Quartzite Bridge between Villuercas-Ibores-Jara and Naturtejo UNESCO Global Geoparks, also described by Carvalho and colleagues, a site known for its remarkable preservation of the ichnofossil *Daedalus*, a complex feeding structure. These both bear witness to intensification of bottom-feeding animals during the GOBE. In the Middle Ordovician the next phase of the GOBE is also documented in the Naturtejo UNESCO Geopark in Portugal, in the form of diverse Darriwilian faunas, described by Pereira and colleagues. Coming from another Portuguese geopark, Sá and colleagues describe giant trilobites and other fossils from the Middle Ordovician of the Arouca UNESCO Global Geopark. The fourth contribution concerning the Nuturetejo Geopark in Portugal is by Pereira and colleagues, in which they describe Upper Ordovician fossils. Finally, Cortijo and colleagues describe the Armorican Quartzite of the Villuercas-Ibores-Jara UNESCO Global Geopark in Spain, which documents the time when trilobites ruled the Ordovician seas.

### **Silurian**

The Silurian (named after the Silures, a Celtic tribe of Wales, 444–419 Ma) is marked by the first clear evidence of life on land: remains of primitive vascular plants and remains of some terrestrial arthropods. In the oceans there was a widespread radiation of crinoids, a continued proliferation and expansion of brachiopods and the oldest known examples of coral reefs. The Silurian was marked also by the diversification of jawless fish as well as the appearance of jawed fish. Other marine fossils commonly found throughout the Silurian

include trilobites, graptolites, conodonts, corals, stromatoporoids, and molluscs.

European geoparks include three important Silurian sites, two in Spain and one in England. The Silurian of the Valle syncline in the Sierra Norte de Sevilla UNESCO Global Geopark, Spain is an international standard for graptolite biostratigraphy, as described by Gutierrez-Marco and colleagues. Further, the Checa Silurian section is an outstanding fossil site in the Molina-Alto Tajo UNESCO Global Geopark, Spain, from which Gutierrez-Marco and colleagues describe its rich graptolite faunas. Finally, the Black Country UNESCO Geopark achieved its designation only in 2020, and Worton and colleagues describe its famous Silurian faunas of trilobites, crinoids and other fossils from the Much Wenlock Limestone Formation, as well as associated Carboniferous deposits with a rich industrial geological history.

### **Devonian**

The Devonian (419–359 Ma), named after Devon county in south-western England, was a time of rapid evolution of life in the sea and on land. Key marine groups include ammonoids, brachiopods, trilobites and corals. At the same time, fishes diversified substantially, as heavily armored jawless ostracoderms and the jawed placoderms, as well as diverse chondrichthyans and osteichthyans. On land, plants and arthropods (arachnids, insects) diversified and occupied more of the land surface; by the end of the Devonian, some plants had achieved tree-like size. Also, sarcopterygian fishes evolved into tetrapods, using their fins as limbs and both hunting for fish in the shallow waters, but also land-living prey. During the Late Devonian, the second of the big five mass extinctions occurred, in at least two bursts, during which about 50 % of the marine invertebrates disappeared.

Three UNESCO European Geoparks document Devonian paleontology. First is the Shetland Geopark in northern Scotland with its extraordinary richness of fossil fish faunas through thick

terrestrial and lacustrine red bed successions, described by Beardmore. Of similar age are the marine, coral-rich Devonian limestones of the English Riviera Geopark, described by Hart and Smart. Finally, Koppka describes the remarkable Devonian trilobites of the Gerolstein in Germany, part of the UNESCO Geopark Vulkaneifel.

### **Carboniferous**

The Carboniferous (named after its famous coal-deposits, carbonifère, 359–299 Ma) is the period when for the first real forests of giant ferns flourished leaving the greatest coal reserves of the world. During the Carboniferous, oxygen reached the highest levels in the atmosphere, at 35%, compared with 21% today. This is generally ascribed to the huge rain forests, producing great volumes of oxygen through photosynthesis, and allowed terrestrial invertebrates to evolve to great size, with some dragonflies with over 70 cm wingspan. Amphibians become the first dominant land vertebrates. In the seas, giant brachiopods, ammonoids, corals, but also foraminifera (single celled organisms) were characteristic. The latter half of the Carboniferous witnessed glaciations in the southern hemisphere, low sea level and mountain building as the continents collided to form Pangaea (“All Earth”).

In this volume, we feature four European UNESCO Geoparks of Carboniferous age. First is the Sierra Norte de Sevilla Geopark in Spain, described by Alfaro and colleagues, the site of rich floras including well-preserved ferns, including arborescent pectopterids as well as sphenopsids and pteridosperms. The Piesberg in the TERRA.vita Geopark in NW Germany, described by Leipner and colleagues, is a site of international importance for the Pennsylvanian (Late Carboniferous) plants and arthropods, including insects, and a rich industrial, coal-mining heritage. The Bohemian Paradise UNESCO Geopark in the Czech Republic, described by Meinl and colleagues, has also been a rich source of classic Carboniferous coal-forest plants including exquisite, silicified

remains. Finally, the Burren and Cliffs of Moher UNESCO Global Geopark in Ireland, described by Doyle, provides rich evidence about the marine beds of the Carboniferous, with trace fossils, crinoids, brachiopods, corals and vertebrates.

### **Permian**

The Permian (named after the Perm region in the western Urals, 299–251 Ma) was one of the driest periods in the Earth history, much in contrast with the humid Carboniferous. The drastic change in climates was a consequence of the increase in continental areas in the new Pangaea supercontinent. Large desert took the place of the former tropical and subtropical forests. The Permian was a time that favored reptile diversification, preceding their dominance in the following Mesozoic Era. In shallow coastal waters of the seas around Pangaea, reefs built by coral and sponge species were widespread. Ammonites were common, as were brachiopods. Sharks and bony fishes continued to diversify. The end of the Permian corresponds to the largest mass extinction in Earth history, during which 95% of marine species and 70% of terrestrial vertebrate species died out. This was driv-

en by massive volcanic eruptions in Siberia that belched out gases into the atmosphere that raised temperatures on land and in the sea by 10–15°C and produced acid rain and ocean acidification, all contributing to the huge loss of biodiversity.

Here, we present three Permian geoparks. First, the Permian breccias, conglomerates and sandstones of the English Riviera UNESCO Global Geopark, described by Hart and Smart, show some unusual large trace fossils, indications of rare life at the edges of the Early Permian deserts. The Aragoncillo Range in the Molina-Alto Tajo UNESCO Global Geopark in central Spain, described by Moya and colleagues, is an extraordinary set of deposits that documents micro- and macrofossils of a Lower Permian flora, generally not well known elsewhere because of the arid conditions. Finally, we present the Late Permian Kupferschiefer fossils and geological educational trail in the UNESCO Global Geopark TERRA.vita in NW Germany, described by Fischer and colleagues. The Kupferschiefer has been known for over 200 years as a key resource for outstanding preservation of fish, reptile, and plant fossils.