FUNDAMENTAL

Wonders of ancient life

Fossils from European Geoparks

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vulkaneifel european geopark –germany; petrified forest of lesvos –greece; maestrazgo cultural park –aragón, spain; terra.vita nature park –germany; marble arch caves european geopark –northern ireland, uk; madonie geopark –italy; nature park steirische eisenwurzen –austria; park natural regional du luberon –france; geopark swabian albs –germany; hateg country dinosaurs geopark –romania; beigua geopark –italy; cabo de gata –nijar nature park –andalucia, spain; naturtejo geopark –portugal; sierras subbeticas nature park –andalucia, spain; sobrarbe geopark, aragon, spain, english riviera geopark –england, uk; geo mon –wales, uk; arouca geopark – portugal; shetlands –scotland, uk; novohrad –nograd geopark –hungary and slovakia; basque coast geopark, pais vasco-spain; sierra norte de sevilla natural park, andalucia –spain; villuercas-ibores-jara geopark-spain; central catalunya geopark –spain.

images: aga –arouca geopark association- (p. 37, 40, 51, 52, 53); larkin, d. (p. 43); klären, g./twg (p. 54, 55); müller, w./dvg (p. 56); maarmuseum manderscheid/martin koziol (p. 57); hilario, a. (p. 64, 65, 79, 81, 82); schewigert smns (p. 68, 74, 76, 87); schumacher, a./nhmw (p. 73, 83, 84); enkelmann, r. (p. 85); urweltmuseum hauff (p. 88), harling/ smns (p. 89); österwind/mayen (p. 98); lumpe/smns (p. 132, 136, 137); haehl /smns (p. 133); rabeder, g./univ. wien (p. 134); collins, c./nhm&torquay museum (p. 140); zabaleta, g. (p. 142); vulkaneifel european geopark (p. 42, 146); petrified forest of lesvos (p. 130, 131, 135); maestrazgo cultural park (p. 86, 92, 94, 95, 96, 97, 99, 100); terra.vita nature park (p. 32, 59, 93); marble arch caves european geopark (p. 44, 45, 46); madonie geopark (p. 67, 70, 71, 72, 113); nature park steirische eisenwurzen (p. 151); park natural regional du luberon (p. 141, 143, 144, 145); geopark swabian albs (p. 75, 149, 150, 153, 154, 156); hateg country dinosaurs geopark (p. 101, 102, 103, 104, 148); beigua geopark (p. 115, 116, 129, 138, 139); cabo de gata –nijar nature park (p. 112, 117, 119, 120, 121, 122, 123); naturtejo geopark (p. 34; 35, 36, 38, 50); sierras subbeticas nature park (p. 77); sobrarbe geopark (p. 91, 124, 127, 128, 147, 152); english riviera geopark (p. 47, 157); geo mon (p.23, 26); shetlands; novohrad –nograd geopark (p. 31, 58, 126); basque coast geopark (p. 66, 69, 78, 80, 111); sierra norte de sevilla natural park (p. 33); villuercas-ibores-jara geopark (p.24, 25; 39, 41, 48, 49); central catalunya geopark (p. 114, 118, 125, 155)

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Geology is all around us and holds the keys to fascinating matters which greatly affect our lives. The establishment in 2000 of an international network based on geological heritage, the European Geoparks Network, led to an emerging step forward making people aware of how geology improves the quality of life of the local communities fostering geotourism. As a result, the model expanded worldwide with the foundation in 2004 of the Global Geoparks Network.

Geoparks are territories characterized by their peculiar geological values. Their boundaries have to be clearly defined and their area should be big enough for true territorial economic development. The management of these utilities develops heritage geoconservation strategies together with initiatives of sustainable use of their natural and cultural resources, in order to achieve the socio-economic prosperity of their inhabitants.

An important part of the geological heritage is the record of the ancient life on our planet. This is the reason why one of the working groups of the European Geoparks Network deals with fossils. The close relationship between the members of this thematic group and their generous collaboration has facilitated this publication, which highlights some of the remains of the extinct European living beings preserved in the sedimentary rocks of our Geoparks. It represents not an exhaustive catalogue of paleontology but a modest window to interest readers on deepening their curiosity for the history of life issues and, why not?, to stimulate their future visit to the magnificent landscapes and people in the same sites those superb fossils were recovered.

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Catalyst
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European Geoparks Network

fossils in the european geoparks

Most of the European geoparks yield testimonies of the life of the past which are present in all the major stages of the Earth history, from the Middle Precambrian (approx.2 billion years ago ,when the life was still in its cellular phase) till our species, *Homo sapiens*, came to Europe, around 80.000 years ago. In between these borders all the most representative fossil-groups for the evolution of life are found in the European geoparks. Many of these fossils are of an outstanding importance, either due to their oneness or rarity in the world, or to the exceptional state of preservation, they also depict significant paleobiologic events and characterize different ecologic environments which is very important in reconstructing the fossil ecosystems.

In a chronostratigraphic order, from Precambrian to Present time, the main aspects revealed by the fossils in the European geoparks are the following:

The Precambrian -the longest part of the Earth history (from 4.6 billion years to 542 million years, which means 7/8 of the whole Earth history) is represented in the European geoparks by stromatolites of a Mid Precambrian age (~1.8 billion years) in the GeoMôn geopark ,in the Anglesey island of Wales, also by Cloudina in the Villuercas Ibores Jara geopark from the Spanish province of Extremadura. The two fossils are distanced in time by around 1.2 billion years and, correspondingly, they present different evolutionary events. The stromatolites, which are the stone products of the cyanobacteria (the most characteristic forms of life in Precambrian) depict the conversion of the sea environmental conditions, in which the life appeared, from the primary anoxic condition to environments progressively richer in oxygen, due to these autotrophic bacteria. Cloudina, the other proof of the Precambrian life in the European geoparks is a millimetre-scale conical fossil of unknown origin. It is one of the relevant signs of the metazoan diversification at the end of the Precambrian, around 550 million years ago, in the new environment, of oxygenated seas, created by the stromatolites builders-the colonial cyanobacteria.

After Precambrian ,for the remaining 542 millions of years of the Earth and Life history ,the fossil record shows a radical change: the scarce fossil record of the Precambrian is followed by a tremendous increase in the number and diversity of the fossils, a fact owned to the fundamental changes in the seas environments. The " soft-bodied animals" which dominated the latest Precambrian life are progressively, but quickly replaced by organisms protected by different types of mineral skeletons which ensure more resistance to the destructive processes during fossilization. The divisions of this "more fossiliferous time" are known as Paleozoic ("ancient life"in Greek), Mesozoic ("medium "or "intermediate life") and Cenozoic ("new life"), names which reveal stages of increased similarity with the modern assemblages of life.

The Paleozoic life is shown in the European geoparks by trilobites –one of the first groups of invertebrate animals protected by external skeleton and the most successful fossils of the Cambrian, also by reef builders: colonial and solitary corals as well as by other dwellers of the Paleozoic seas, like goniatites, brachiopods ,crinoids and fishes. Trilobites are well represented in the Ordovician of the Portuguese geoparks Naturtejo and Arouca, the last one famous for the great diversity of species and state of fossils preservation, also by the presence of the biggest - known trilobites,nearly one meter long. Different kind of corals are present in the Devonian of the English Riviera geopark in the South of England and in the Carboniferous of the Marble Arch Caves geopark in North Ireland. Exquisite specimens of crinoids ("sea-lilies") which, contrary to their name, are animals attached to the sea bottom by a stalk, are found in the Devonian and Carboniferous rocks of the German Vulkaneifel geopark.

Not only marine environments of the Paleozoic are represented in the European geoparks but also the continental ones, which are clearly revealed by fossils only from the Silurian, when the Earth atmosphere reached the gas composition close to the actual one, allowing the development of life on land. In the Devonian of Shetland islands geopark, North of Scotland, remains of some of the first land plants are found, as well as primitive ray-finned fishes, forerunners of the modern bony fishes.

At the time of Devonian Shetland islands were included in the so called “Old Red sandstone” continent together with most of the Northern and North-Western part of Europe.

The two major environments of life, the marine and the continental one, are more balanced in Mesozoic than in Paleozoic and this is well reflected also in the European geoparks. The land forms, much numerous than before include mainly plants and tetrapod animals, among which the dinosaurs are the most characteristic. A forerunner of the dinosaurs, even not directly related to them, is *Eifelosaurus* from the Lower Triassic in the Vulkaneifel geopark, a lizard-like reptile from the group of rhynchocephals ("beak headed" reptiles “) represented today by the “living fossil” tuatara (*Sphenodon*). As regards the dinosaurs, their remains are found in two European geoparks: Maestrazgo, in Spain and Hateg in Romania. Maestrazgo includes several sites where footprints left by various dinosaurs occur in deposits of different ages: Upper Jurassic, Lower and Upper Cretaceous. Teeth and bone remains of herbivorous and carnivorous dinosaurs, as well as plant remains were also found in the Lower Cretaceous of the Maestrazgo geopark. The Hateg Geopark is renowned for its “dwarf dinosaurs”, from the end of Cretaceous, which illustrate the size reduction of the animals living in the isolated conditions of the islands. Several geosites with clutches of dinosaur eggs, some of them including remains of newborn babies were found in Hateg ,which is also the only place In Europe where the, mammals, namely the multituberculates, were found together with dinosaur bones in the Upper Cretaceous deposits.

The marine life in Mesozoic include ecosystems specific for different depths of the sea ,some of them revealed by the fossils found in the European geoparks. The shallow depths of the carbonate platforms are characterized by coral reefs which are known in the Triassic and Jurassic of Madonie in Sicily, in the Jurassic of Swabian Albs in Germany, in the Lower Cretaceus of the Basque Coast geopark in northern Spain. Some time the coral reefs form circular or horseshoe-shaped islands which encircle central lagoons with calm waters inside, providing excellent conditions for fossilization.

This is shown in the Upper Jurassic from the Swabian Albs where fossil sea crocodiles, sharks, crustaceans are nicely preserved. Nicely preserved fossils (sea lilies, ichthyosaurs, sea crocodiles) are also found in the Lower Jurassic of the same geopark, but in this case responsible for the good fossilization are the reducing conditions on the sea bottom, where the animals fall down after the death and where the "scavengers ", which destroy the corpses in oxygenated waters, are missing. Rich assemblages of mollusks (bivalves and gastropods) with thick shells, characteristic for the shallow carbonate platforms are known in the Upper Cretaceous of the Eisenwurzen geopark in Austria. Common for the deeper sea waters were the ammonites, the most characteristic mollusks in the Mesozoic and a very important biostratigraphic tool in dating the rocks of this era. Well preserved ammonites are found in the Triassic of Eisenwurzen, in the Jurassic of Sierras Subbeticas in southern Spain and of the Swabian Albs, in the Lower Cretaceous of the Basque Coast and in the Luberon geopark in southern France. The last one also includes the internationally recognized type-locality for the Apitan, one of the stratigraphic stages of the Lower Cetaceous.

In Cenozoic the geography of Europe approached progressively its modern form: seas recede to the present day locations leaving larger surfaces to the dry land. From the biological point of view these changes are reflected by the increase of the land animals, Cenozoic being known as "the Era of Mammals", as the Mesozoic was "the Reptile Era". Fossil mammals are represented in the European geoparks in most of the Tertiary and Quaternary series: Eocene (in Vulkaneifel and Sobrarbe), Oligocene (in Luberon), Miocene (in Swabian Albs and Novohrad-Nograd), Pleistocene (in Swabian Albs, Central Catalonia, English Riviera, the last one includes also remains of *Homo sapiens*). Land plants are beautifully preserved in the Oligocene of Beigua, in North –Western Italy, in the Late Pleistocene -Holocene of Sobrarbe and Sierras Subbeticas and, expecially in the "Petrified forest" of the Lesbos island, where leaves and trunks of numerous species of gymnosperms and angiosperms were nicely conserved in volcanic tuff of Miocene age.

The marine fauna in Cenozoic is mostly represented by dwellers on the bottom of the rather shallow seas (above ca.200 meters depth), close to the land areas: invertebrate animals, like corals, bryozoans (“sea mosses”), bivalves and gastropods, sea urchins are found in the Eocene rocks of Central Catalonia geopark, in the Oligocene of Beigua and in the Miocene deposits of the Cabo de Gata geopark in Andalucia. Marine vertebrates are encountered in the Eocene of Sobrarbe (sea crocodile and sirenians) and Terra Vita in North-Western Germany (remains of the oldest fossil seal in the world!) and in the Miocene of Novohrad- Nograd (fossil sharks).

Besides the fossils known through their hard, resistant parts , another proof of the organisms which inhabited the Earth during its history, are the ichnofossils representing traces left in sediments by different organisms during their life; these may include traces of the walk or crawling, of the feeding, of the resting, of the reproduction, etc. The icnofossils are well represented in the European geoparks ,in different stratigraphic stages, starting with the Precambrian stromatolites up to the Tertiary mammal footprints and the *Ursus spaeleus* (the “cave bear”) scratches on the cave walls. Common for Paleozoic are the traces known as Cruziana, signs of crawling left probably by trilobites ,but also by other mobile dwellers on the sea bottom. Cruziana icnofossils are common in the Ordovician of the two Portuguese geoparks: Naturtejo and Arouca which hold rich collections of trilobites of this age. (Due to its frequency, Cruziana became the symbol of the Naturtejo geopark and the generic name for its newsletters). The ichnofossils are also found in the European geoparks, in both, continental and marine Mesozoic and Cenozoic deposits. In the continental facies, these include, the dinosaur footprints from the Upper Jurassic, Lower Cretaceos and Upper Cretaceous in Maestrazgo geopark, the Uppermost Cretaceous dinosaur eggs in Hateg, the carnivore mammals and rhinos foot prints in the Miocene of Novohrad-Nograd geopark. As regard the marine ichnofossils, the Cretaceous rocks from Cabo de Gata offer by the great diversity of forms, an open space museum of fossil traces, left by algae and invertebrate animals, but also by organisms, still not assigned to a specific group.

It should be mentioned that the longest trackway on the sea bottom left by invertebrates ever found in the world is displayed in the Eocene of the Basque Coast geopark.

We can conclude that the fossils in the European geoparks represent an open book of the history of life on Earth, from which many interesting facts can be read and interpreted.

Dan Grigorescu
Hateg Country Dinosaurs Geopark – ROMANIA

wonders of ancient Life

-fossils from european geoparks-

1. reserve geologique de haute-provence-france
2. vulkaneifel geopark-germany ⚄
3. petrified forest of lesvos-greece ⚄
4. maestrazgo cultural park-aragón, spain ⚄
5. psiloritis natural park-greece
6. geo and naturepark terra.vita-germany ⚄
7. copper coast geopark-ireland
8. marble arch caves global geopark-ireland, uk ⚄
9. madonie geopark-italy ⚄
10. rocca di cerere geopark-italy
11. nature park steirische eisenwurzen-austria ⚄
12. bergstrasse-odenwald geopark-germany
13. norh pennines aonb european geopark-uk
14. luberon, parc natural regional-france ⚄
15. north west highlands geopark-scotland, uk
16. swabian alb geopark-germany ⚄
17. geopark harz. braunscheweiger land. ostfalen-germany
18. hateg country dinosaurs geopark-romania ⚄
19. parco del beigua-italy ⚄
20. fforest fawr geopark-uk
21. bohemian paradise-czech republic
22. cabo de gata -nijar natural park-andalucia, spain ⚄
23. naturtejo geopark-portugal ⚄
24. subbéticas geopark-andalucía, spain ⚄

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-fossils from european geoparks-

25. sobrarbe geopark - aragón, spain ⚄
26. gea norvegica geopark - norway
27. geological, mining park of sardinia - italy
28. papuk geopark - croatia
29. english riviera geopark - uk ⚄
30. parco naturale adamello brenta - italy
31. geomôn geopark - wales, uk ⚄
32. arouca geopark - portugal ⚄
33. shetland geopark - scotland, uk ⚄
34. chelmos - vouraikos geopark - greece
35. novohrad - nograd geopark - hungary and slovakia ⚄
36. magma geopark - norway
37. basque coast geopark - pais vasco, spain ⚄
38. parco nazionale del cilento e vallo di diano - italy
39. rokua geopark - finland
40. tuscan mining park - italy
41. vikos - aoos geopark - greece
42. mskau arch geopark - germany and poland
43. sierra norte de sevilla natural park - andalucia, spain ⚄
44. burren and cliffs of moher - ireland
45. katla geoaprk - iceland
46. massif des bauges geopark - france
47. apuan alps - italy
48. villuercas - ibores - jara - spain ⚄

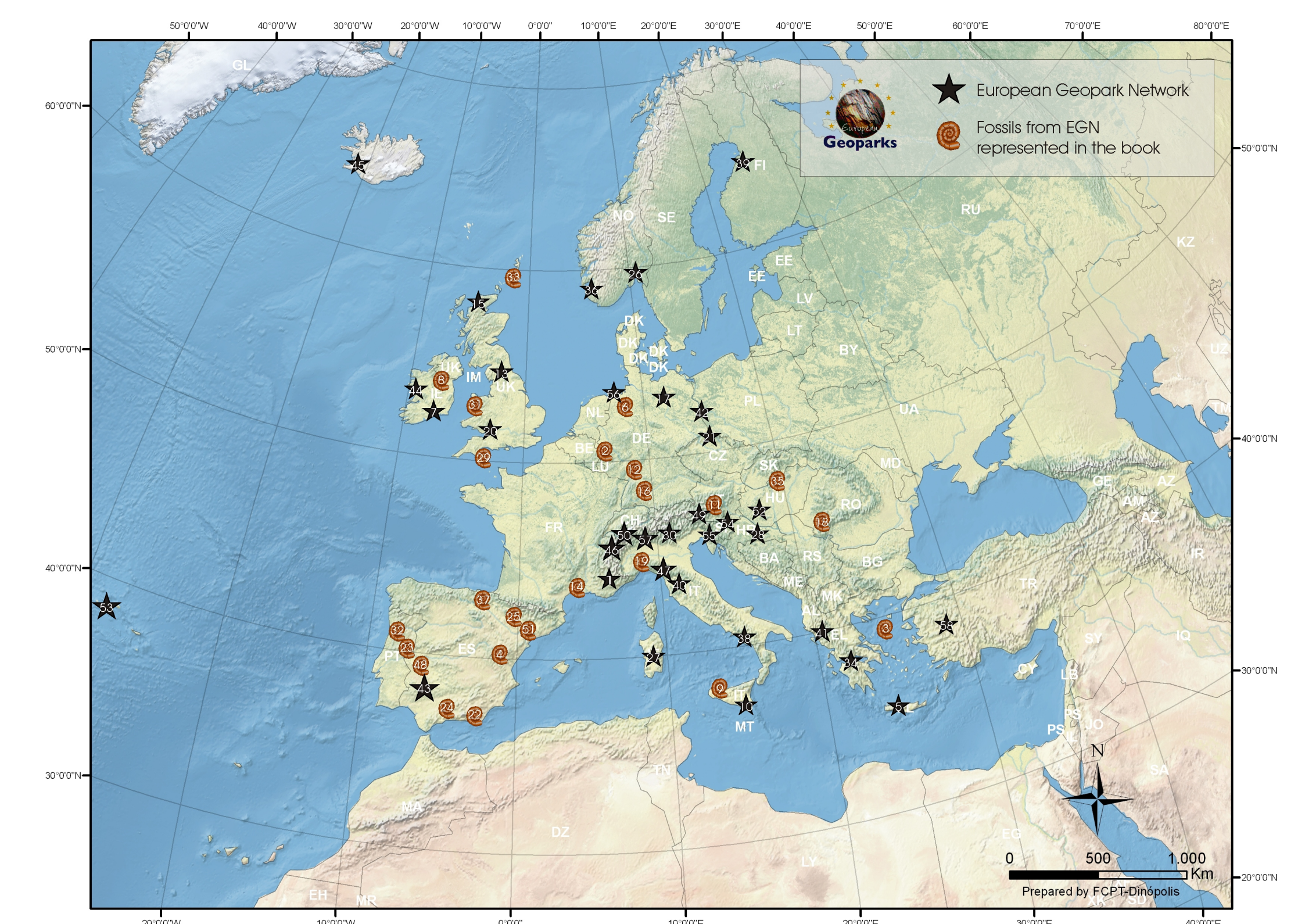
wonders of ancient Life

-fossils from european geoparks-

49. carric alps geopark - austria
50. chablais geopark - france
51. central catalunya geopark - spain ⛋
52. bakony - balaton geopark - hungary
53. azores geopark - portugal
54. karavanke/karawanken - slovenia and austria
55. idrija geopark - slovenia
56. hondsrug geopark - netherlands
57. sesia - val grande geopark - italy
58. kula geopark - turkey

european geopark network
www.europeangeoparks.org

⛋ fossils from european geoparks represented in the book


European Geoparks
European Geopark Network
Fossils from EGN represented in the book
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Prepared by FCPT-Dinópolis

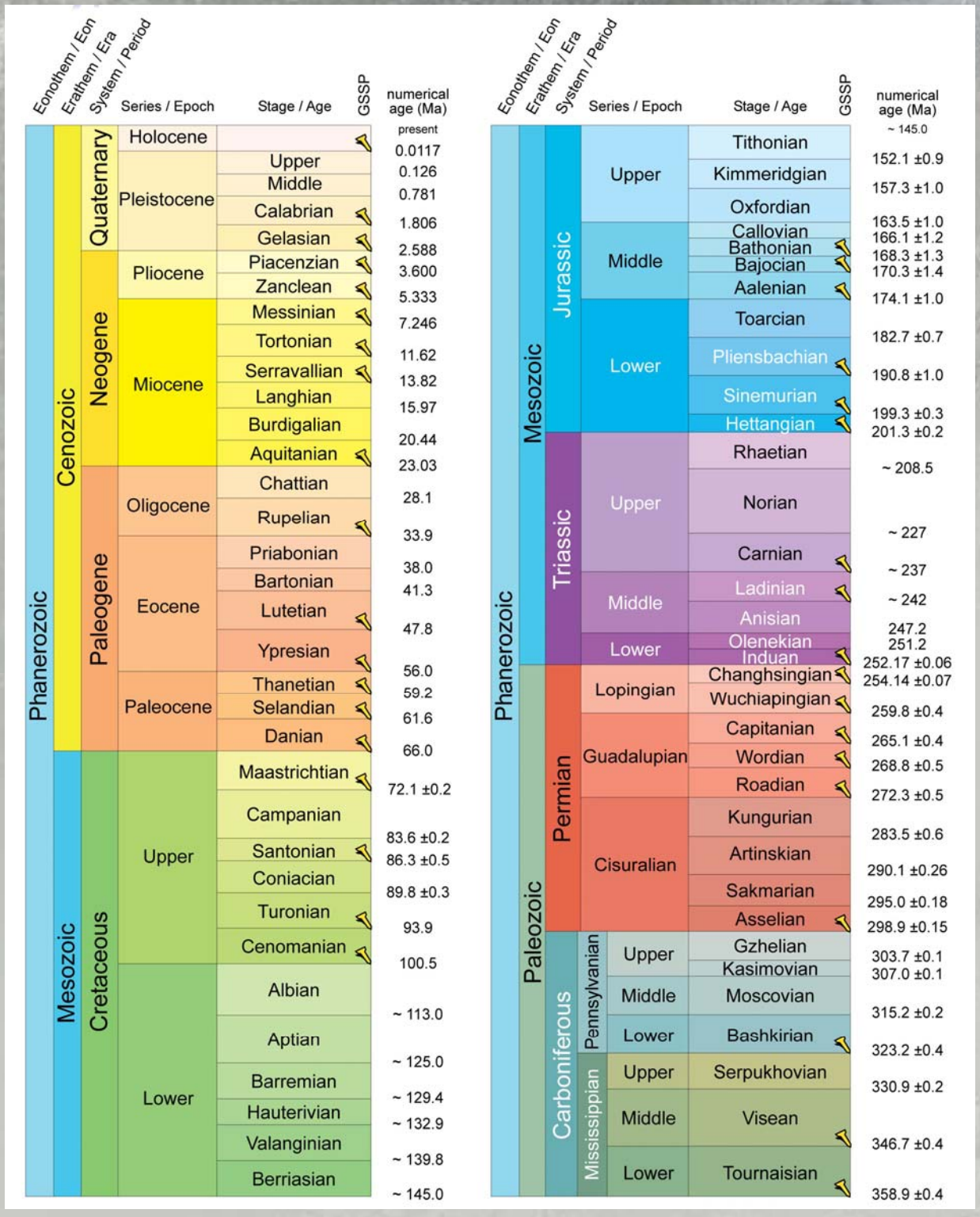

fossils
what are they telling us

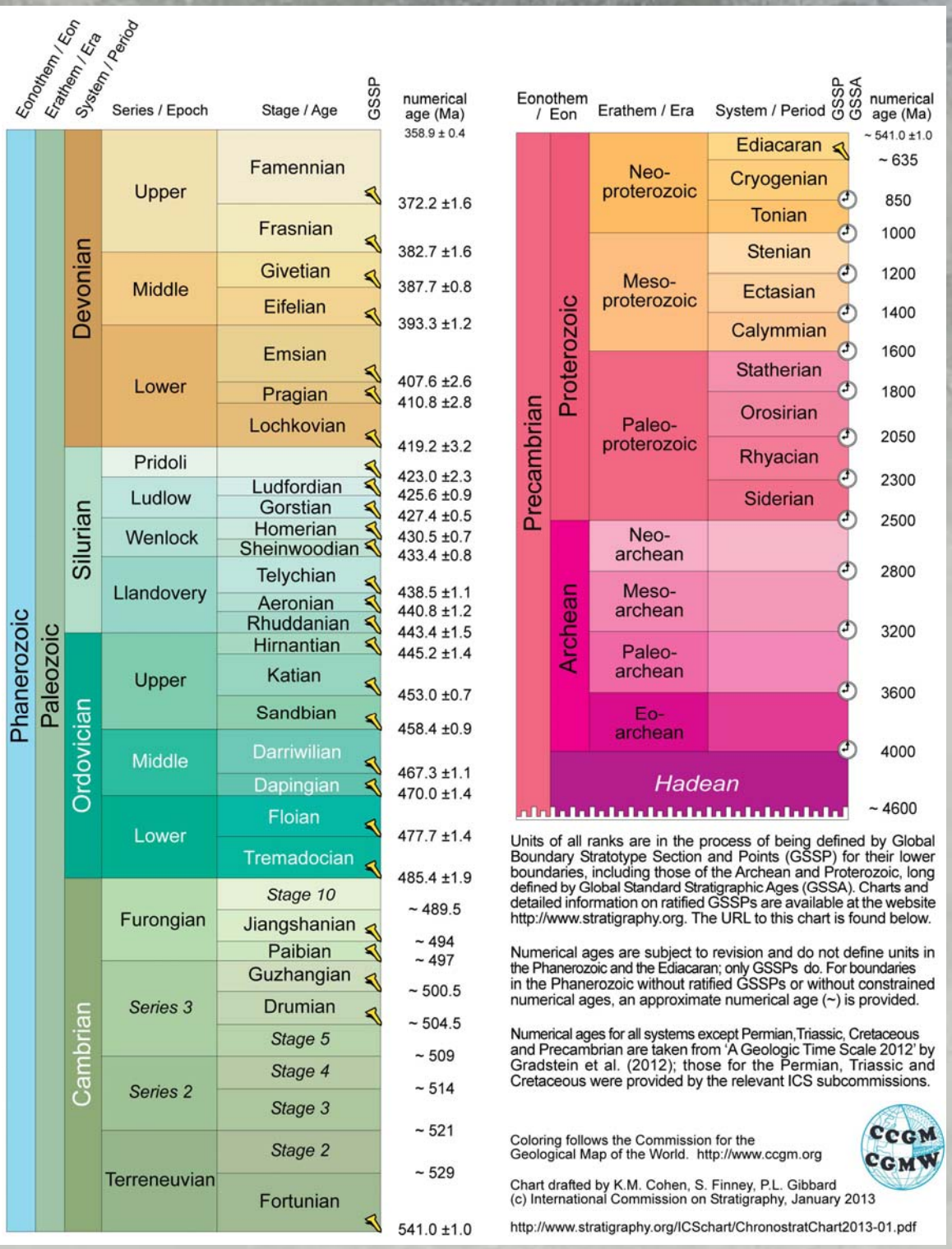
fossils –what are they telling us

Almost everybody, if not everybody, knows that fossils are remains of plants and animals who animated the Ancient worlds which succeeded since the Earth was formed, about 4.5 billion of years ago . Fossils are incomplete remains of the living organisms ,after the death only the more resistant parts of them, hard tissues of plants, shells ,carapaces and bones of animals can be preserved in rocks, and this, if only they were quickly covered by sediments and thus prevented from oxidation (oxygen which is essential for most of the life forms,i s contrary, very destructive for the dead organisms in the way of becoming fossils. Due to this, it is estimated that only 1% of the living forms had the "chance" of becoming fossils).

Although differently interpreted, as "images of the Creation" by the religious people or "facts of the continuous changes of the life on Earth" by the evolutionists, the fossils are important for the information they provide in three main topics: Earth chronology, Changes of the life since the first forms of life have appeared and the Reconstruction of the life environments during the Geological history.

Earth chronology: the beds of sedimentary rocks, representing consolidated sediments deposited in seas or in the rivers and lakes from the continents, contain fossils, but to find themis not so easy, usually it takes time to get them scratching or digging in the rocks; also, frequently they cannot be noticed at the first glance but only with the help of a magnificent glass. It was proved that the older rocks contain the more ancient forms of life while themuch new ones include remains of plants and animals more similar with those known today. Following in great detail thesuccession of the different types of fossils into the overlaid sedimentary rocks,which has a chronological meaning, it was established that the fossils can be used as markers of the geologic time and on this conclusion, the entire History of the Earth was established.(fig.Table)


Eonothem / Eon
Erathem / Era
System / Period
Series / Epoch
Stage / Age
GSSP
numerical age (Ma)
Phanerozoic
Cenozoic
Quaternary
Holocene
present
Pleistocene
Upper
0.0117
Middle
0.126
Calabrian
0.781
Gelasian
1.806
Neogene
Pliocene
Piacenzian
2.588
Zanclean
3.600
Miocene
Messinian
5.333
Tortonian
7.246
Serravallian
11.62
Langhian
13.82
Burdigalian
15.97
Aquitanian
20.44
Paleogene
Oligocene
Chattian
23.03
Rupelian
28.1
Eocene
Priabonian
33.9
Bartonian
38.0
Lutetian
41.3
Ypresian
47.8
Paleocene
Thanetian
56.0
Selandian
59.2
Danian
61.6
Mesozoic
Cretaceous
Upper
Maastrichtian
66.0
Campanian
72.1 ±0.2
Santonian
83.6 ±0.2
Coniacian
86.3 ±0.5
Turonian
89.8 ±0.3
Cenomanian
93.9
Lower
Albian
100.5
Aptian
~ 113.0
Barremian
~ 125.0
Hauterivian
~ 129.4
Valanginian
~ 132.9
Berriasian
~ 139.8
~ 145.0
Phanerozoic
Mesozoic
Jurassic
Upper
Tithonian
~ 145.0
Kimmeridgian
152.1 ±0.9
Oxfordian
157.3 ±1.0
Middle
Callovian
163.5 ±1.0
Bathonian
166.1 ±1.2
Bajocian
168.3 ±1.3
Aalenian
170.3 ±1.4
Lower
Toarcian
174.1 ±1.0
Pliensbachian
182.7 ±0.7
Sinemurian
190.8 ±1.0
Hettangian
199.3 ±0.3
Triassic
Upper
Rhaetian
201.3 ±0.2
Norian
~ 208.5
Carnian
~ 227
Middle
Ladinian
~ 237
Anisian
~ 242
Lower
Olenekian
247.2
Induan
251.2
Paleozoic
Permian
Lopingian
Changhsingian
252.17 ±0.06
Wuchiapingian
254.14 ±0.07
Guadalupian
Capitanian
259.8 ±0.4
Wordian
265.1 ±0.4
Roadian
268.8 ±0.5
Cisuralian
Kungurian
272.3 ±0.5
Artinskian
283.5 ±0.6
Sakmarian
290.1 ±0.26
Asselian
295.0 ±0.18
Carboniferous
Pennsylvanian
Upper
Gzhelian
298.9 ±0.15
Kasimovian
303.7 ±0.1
Middle
Moscovian
307.0 ±0.1
Lower
Bashkirian
315.2 ±0.2
Mississippian
Upper
Serpukhovian
323.2 ±0.4
Middle
Visean
330.9 ±0.2
Lower
Tournaisian
346.7 ±0.4
358.9 ±0.4



Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Numerical ages for all systems except Permian, Triassic, Cretaceous and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012); those for the Permian, Triassic and Cretaceous were provided by the relevant ICS subcommissions.

Coloring follows the Commission for the Geological Map of the World. http://www.ccgm.org

Chart drafted by K.M. Cohen, S. Finney, P.L. Gibbard

http://www.stratigraphy.org/ICSchart/ChronostratChart2013-01.pdf

Changes of the plants and animals during the Earth history: The fossils document both the changes that occurred at the level of the species (the smallest and basic category in the biological taxonomy) which are interlinked in the genealogy of the different evolutionary lineages (this is called microevolution), but also the evolution at the level of higher taxonomic groups (genus, family, class) which is named macroevolution. In both cases the science of fossils –Paleontology is essential in documenting the changes which occurred in geologic time at both micro- and, especially the macro levels. How some fishes adapted to the land conditions, how some reptiles gave birth to birds and mammals are such macroevolutionary events which are demonstrated by the fossil record.

Reconstruction of the life environments during the Geological history: The aspects of the Earth has changed continuously during its enormous history, the seas became mountains which were leveled afterwards to plains, conversely, the dry lands subsided becomingseas; all these changes took place in long periods of time and are well reflected by the fossils encountered in the rocks. Fossils of sea animals, like corals, ammonites, trilobites are commonly found on continents, as well remains of plants and animals who lived on continents can be found in today marine sediments. All the plant and animal are characterized by some environmental conditions, meaning the physical and chemical life - requirements they have, e.g. climate and relief for the continental forms, depth, water temperature and salinity for the sea ones. Through comparison with their living correspondents, the fossils represent good markers of the life environmental conditions from the Past; these can be detailed by special paleoecological studies which involve different geological analysis, like clay mineralogy, stable isotopes, sedimentary structures, etc.

Dan Grigorescu
Hateg Country Dinosaurs Geopark – ROMANIA

fossil groups

algae and bryophyta

pteridophyta

gymnospermophyta

angiospermae

protozoa

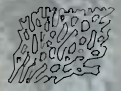
porifera

coelenterata

mollusca

annelida

arthropoda



bryozoa

brachiopoda

echinodermata

hemichordata

vertebrata

fossil trace

Precambrian
Beginning of Life

Precambrian –Beginning of Life

It is the widest and darkest time span of the Geological History. It accounts for 88% of our planet History. It comprises crucial phenomena such as the origin of the Earth and the appearance of life on its surface (estimated in 4,600 Ma and 3,800 Ma ago, respectively).

Precambrian fossils are extremely scarce; the soft-bodied organisms (no shells, bones, teeth or exoskeletons) that characterized Precambrian, very rarely fossilize. They usually decay before being buried and becoming petrified. Besides, the dynamics of the Earth has modified the oldest sedimentary rocks in a way that most of them have been metamorphosed or even melt, being most of their fossils destroyed. Most abundant remains of Precambrian life are the thin layers of laminated limestone called stromatolites and produced by the most common organisms of Precambrian –the cyanobacteria.

2,700 Ma ago, an important event in complexity of life is thought to happen: the appearance of eukaryotes. Some primitive cells developed a well defined nucleus. This kind of cellules permitted the origin of photosynthetic organisms and the ancient atmosphere begun to enrich in oxygen. This also led to the appearance of the most complex kingdoms of life (multicellular organisms like animals, plants or fungi).

Sexual reproduction also arose during Precambrian, opening a world of diversification possibilities.

The most ancient animals found in rocks are aged 650 to 540 Ma, and are registered in approximately 30 localities of the planet. They are known as Ediacara or Vendian fauna. They are generally soft-bodied animals, with shapes similar to worms, arthropods or cnidarian. Some others are so different to current organisms that is, by the moment, impossible to attribute to our known five kingdoms of life.

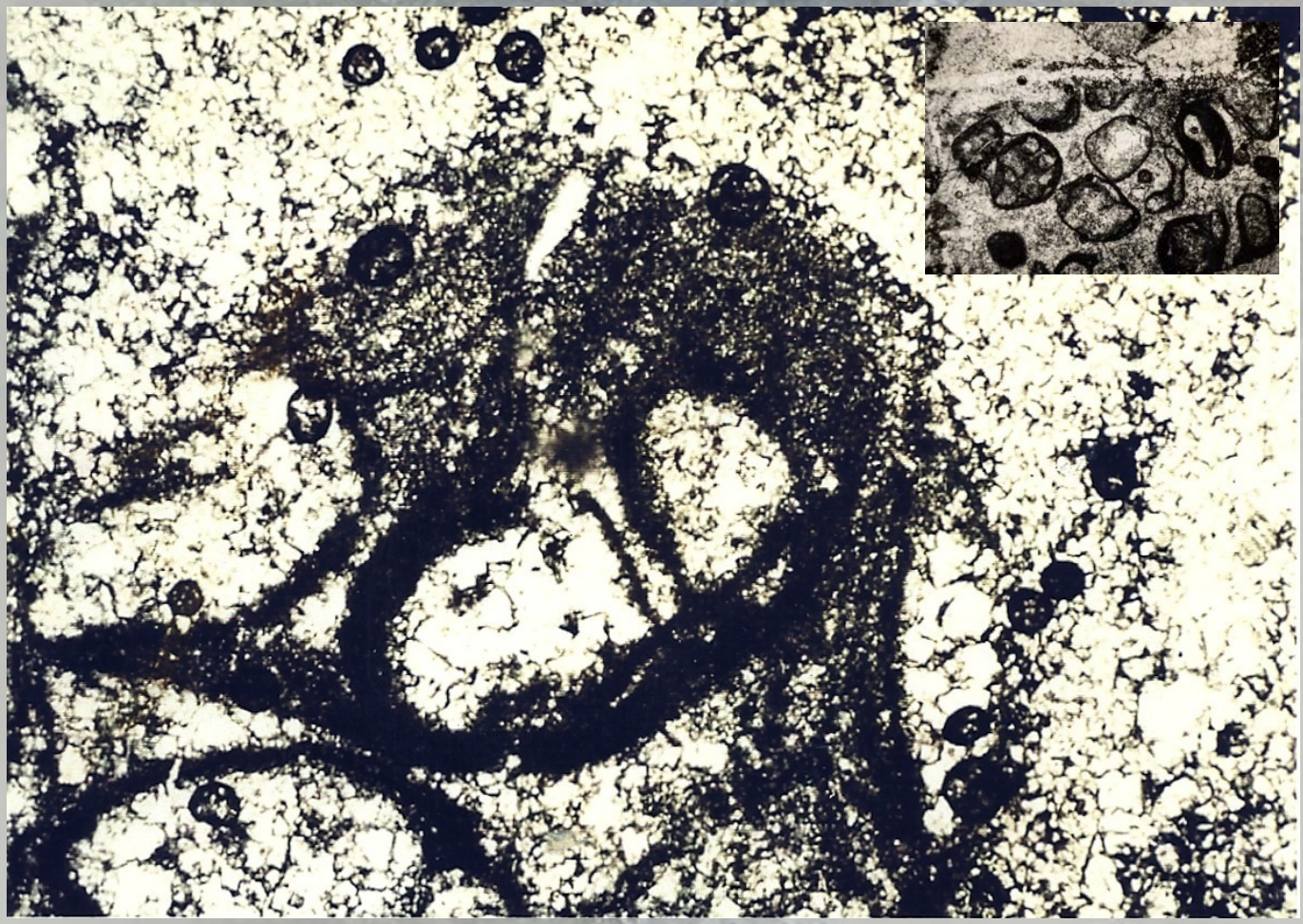
Through genetic studies of the current groups , it is thought that during Precambrian life was already structured in the main groups as we know them today (plants, fungi, arthropods, molluscs, brachiopods, etc.).

Alicia Serna Barquero
Sierras Subbeticas Nature Park – Andalucia, SPAIN

Stromatolitic reef structures
Age: Precambrian
Environment: marine
Description: According to the fossil record, the cyanobacteria (autotrophe, photosynthetic bacteria with a blue pigment) were the most successful organisms of the immense Precambrian times (4 billion years out of the total 4,5 billion of the entire Earth History). The colonies of cyanobacteria generated finely laminated limestones known as *stromatholites*, that have been found in many areas of the world. Cyanobacteria converted the early reducing atmosphere of the Earth into an oxidizing one, which stimulated the great burst of life that then occurred in the Cambrian period.

Vendotaenids
Age: Precambrian (Late Ediacaran)
Environment: marine
Description: These fossils appear as carbonaceous filaments in alternative thin strata of shales and greywackes with abundant fine-grained pyrite. The carbonaceous filaments are very well preserved and the abundance of organic material shows the reducer conditions under which the sediments were deposited. The biological affinities of Vendotaenids are controversial and have been linked to algae, although other authors consider them as macro-bacterias that could be very similar to the bacterias that oxidize sulfides.

Cloudina carinata
Age: Precambrian (Late Ediacaran)
Environment: marine
Description: *Cloudina carinata* n. sp. is a tubular fossil formed by a series of imbricated, identical funnels with a basal opening, a thickened apertural rim, and a marked external ornamentation in the form of longitudinal crests. This fossil is interpreted among the first metazoans capable of secreting a mineralized skeleton, which makes them highly significant from the point of biological evolution. *Cloudina* is preserved on a large carbonate blocks from olistostromes found in several locations of the geopark's territory.



Vesicularites sp.
Age: Upper Precambrian
Environment: marine
Description: Stromatholitic structures in pseudo-oolitic limestones generated by cianobacteria in Ffynnon Badrig Quarry, a geosite of national –Great Britain– and internacional importante for its fossiliferous deposits of Precambrian age. The structures consits of microsopic rounded celle and fillaments, identified as *Vesicularites*.


paleozoic
the old life
the single continent

paleozoic the old life, the single continent

During the Paleozoic Era (from 542 to 251 Ma) the geography of Europe evolved significantly. To better understand this reality, we need to go back to the early times of this Era when there was only the superterrane Gondwana, with a large number of other terranes in the surrounding, like Avalonia, the Rheno-Hercynian Terrane, the Armorican Terrane Assemblage, Perunica, Apulia, Adria, the Hellenic Terrane (including Moesia), Laurentia, and Baltica. Like a giant puzzle, along the Paleozoic time these terranes were changing their relative positions. By the end of the Paleozoic most of these terranes had coalesced, and had also joined to Gondwana to form the Pangea supercontinent.

The evidence of this intense tectonic activity is now preserved in rocks that are the testimony of ancient mountain ranges – Caledonides, Hercynides and Uralides – that, all together, gave rise to a significant portion of rocky materials that currently build up the European continent. The main event that controlled the early to mid-Paleozoic development of Europe was the opening and closing of the Iapetus Ocean. This led to the Caledonian-Acadian orogeny, whose evidences extends from Ireland to Norway, through Wales, northern England and Scotland. The existence of this primitive ocean is demonstrated, by the presence of trilobite and graptolite faunas, among others, in the north of Scotland, which was on one side of the sea, and they are significantly different from those that occur in more southern parts of England and Norway, which were on the other side.

In more southern Europe areas, during the Devonian and Carboniferous periods (415 to 300 Ma), developed the Hercynian, or Variscan, orogenic belt formed by plate-tectonic processes that included seafloor spreading, continental drift, and the collision of plates. This extends from Portugal and Spain to southwestern Ireland and southwestern England. Furthermore, it extends westward through France (Brittany, Massif Central, Vosges and Corsica), Italy (Sardinia), Germany (Odenwald, Schwarzwald, and Harz Mountains), reaching the Czech Republic (Bohemian Massif).

The traditional eastern geographic boundary of Europe is marked by the mountain ranges developed during the Uralian orogeny. These extend for over 3500 km from the Aral Sea in the south to the Novaya Zemlya archipelago in the Arctic Ocean. This orogenic belt was developed in the late Paleozoic as result of the collision between Europe and Asia, and today comprises the Ural Mountains among others.

The Paleozoic Era encompassed some of the most important events in the history of life on Earth, being characterized by an unprecedented boom of invertebrates and a subsequent propagation of superior plants, fish and amphibians. Furthermore, this Era was characterized by the development of entire ecosystems and the colonization of new habitats. In the early Paleozoic, complex communities of multicellular organisms lived exclusively in shallow seas, while in other environments there were no life forms or there were only very primitive ecosystems. However, by the end of the Paleozoic it was witnessed a gradual and systematic conquest of all the oceans, seafloor sediments, rivers, lakes and dry land that became densely populated.

Representatives of all the major animal phyla, such as sponges, coelenterates, brachiopods, molluscs, arthropods (e.g. trilobites), echinoderms or the earliest Chordata first appeared during the Cambrian Period. Trilobites dominate the Cambrian fossil record, and these arthropods reached the maximum number of families in the late Cambrian. For this reason the Paleozoic is sometimes called the “age of trilobites”. Among the other Paleozoic fossil main groups, the nautiloid cephalopods were very important from the Ordovician to the Late Paleozoic. The sea scorpions and corals assumed significant importance during the Silurian. During the Devonian it was witnessed a major diversification of fishes while amphibians and insects highly diversified during the Carboniferous, and reptiles have become dominant in the Permian. Regarding echinoderms, the crinoids dominated during the Paleozoic, while the Graptolites (phylum Hemichordata), had great importance in the Ordovician and Silurian epiplanktonic ecosystems.

Plants underwent a huge evolution during the Paleozoic Era. Initially restricted to marine environments (algae and blue-green algae), from the late Ordovician the first sporophytes began to penetrate into dry land, with some of the oldest colonized habitats being near-shore swamps. Arborescent forms of club mosses, sphenopsids (horsetails) and ferns appeared in the upper Paleozoic. However, the latest Paleozoic was dominated by gymnosperms, precursor of today's conifers. These last one’s led to highly dense forests, whose colossal amounts of vegetal remains accumulated in swampy regions, originated the main coal deposits of Europe, during Carboniferous time.

In addition to the events of diversification, the Paleozoic Era was also marked by the occurrence of the three largest mass extinctions of the Phanerozoic. The end-Ordovician (Hirnantian) extinction, due to an event of large-scale glaciation, related with the movement of Gondwana towards the South Polar Region, which led to global cooling and consequent sea level fall. The Upper Devonian (Frasnian-Fammenian) mass extinction, whose causes remains unclear. However, the main theories include changes in sea level and ocean anoxia, possibly triggered by global cooling or oceanic volcanism. The impact of a meteorite or another extraterrestrial body has also been suggested. Finally, the end-Permian mass extinction, also known as the biggest extinction event in the history of life on Earth, was probably due to multiple causes. Among these are referred meteoritic impact events, increased volcanism (Siberian Traps), release of methane from the sea floor, changes in the sea-level and increasing aridity in dry land. Besides these mass extinctions, many others small-scale extinctions have occurred. Such events were probably driven by sea level and climatic changes due to continental drift and uplift of mountain ranges.

The events suffered by paleodiversity during the Paleozoic Era disclaim as an open book of valuable information to better understand the dynamics between the biosphere, hydrosphere, lithosphere and atmosphere nowadays and for the prediction of the future of biodiversity in Earth.

Artur Abreu Sá
Arouca Geopark – PORTUGAL

Plant fossil
Age: Middle Devonian
Environment: continental
Description: The development of land plants depended on their capacity to retain water. Vascular plants, able to regulate their water loss had evolved by the late Silurian and in the early Devonian when plants such as *Hostimella* – erect branching plants with strong outer cuticles were common. At times fragments of such land plants were washed into rivers and lakes to become fossilized within the sediments. The remains of the early vascular plants are often found on the island of Bressay, most of them remains unidentified due to their very fragmentary nature.

Mariopteris sp.
Age: Carboniferous
Environment: continental (coastal)
Description: 300 million years ago the Geopark-area was a giant coastal plain with braided rivers passing through. These rivers formed thick layers of sand, that later were compressed to become a quarzitic sandstone. In times of rising sea levels finer materials like clay sedimented and a tropical forest started to grow. Sigilaria trees, different types of ferns and horsetail grew in the humid and hot environment. Parts of dying plants that fell into the shallow water and roots were preserved and later covered by new sediments. In some quarries of the Geopark area today the fossilized remains of the plants can be found. Sometimes, they are in an extremely good state and give a detailed impression of the carboniferous flora.

Cordubia gigantea
Age: Lower Cambrian
Environment: marine
Description: This site contains one of the largest concentrations of discoid soft-bodied animals known in the fossil record of the Phanerozoic. 90 specimens were recorded up to 88 cm in diameter on the surface of a thin layer of greywacke, with very good exposure in an area of about 120 m2. The fossils are discoid impressions consisting of two circular or nearly circular, concentric or eccentric grooves, connected by straight and radial grooves. This morphology is associated with another one consisting of a circular groove. Both morphological types are interpreted respectively as sub-umbrellar and ex-umbrellar impressions of jellyfishes.

Cruziana rugosa
Age: Lower Ordovician (Floian)
Environment: marine
Description: Among the 17 sites of paleontological interest registered in the Naturtejo Geopark, Penha Garcia is the most spectacular. This thematic park is devoted to traces of animal behavior showing evidences of life modes different trilobites preserved on the marine sandy bottoms from the Ordovician sea ca. 480 million years ago. This *Cruziana rugosa* has more than half meter long is the classic feeding pattern, including the clearly visible scratch marks produced by the limbs, of trilobites, some of them the largest ones that ever lived.

Cruziana imbricata
Age: Lower Ordovician (Floian)
Environment: marine
Description: Less common among the *Cruziana* from the Naturtejo Geopark is *Cruziana imbricata*. Contrary to the other ichnospecies of *Cruziana*, these forms do not have scratch marks sets left by the limb tips during burrowing, but “scales” that seem to result from the use of the coxal part of the limbs in the process of ploughing along more cohesive sediments.

Cruziana bagnolensis
Age: Lower Ordovician (Floian)
Environment: marine
Description: From the 33 different behaviors traces in the Ichnological Park of Penha Garcia, the winding patterns, sometimes densely packed, produced by trilobites are the most outstanding ones. In some places there are forms of *Cruziana* with one to few millimeters wide and smooth lobes (*C. rouaulti*) or showing sets with less scratch marks than the larger forms, but displaying similar foraging patterns (*C. bagnolensis*). These traces enable to understand the transition from a pelagic to a benthic life style during the life cycle of the trilobites that produced them.

Cruziana isp.
Age: Lower Ordovician (Floian)
Environment: marine
Description: Vertical hypicnial surface (ridges and grooves found on the soles of the beds) left by trilobites. Two generations of *Cruziana* isp. trace fossils cross the surface in a 110º angle.

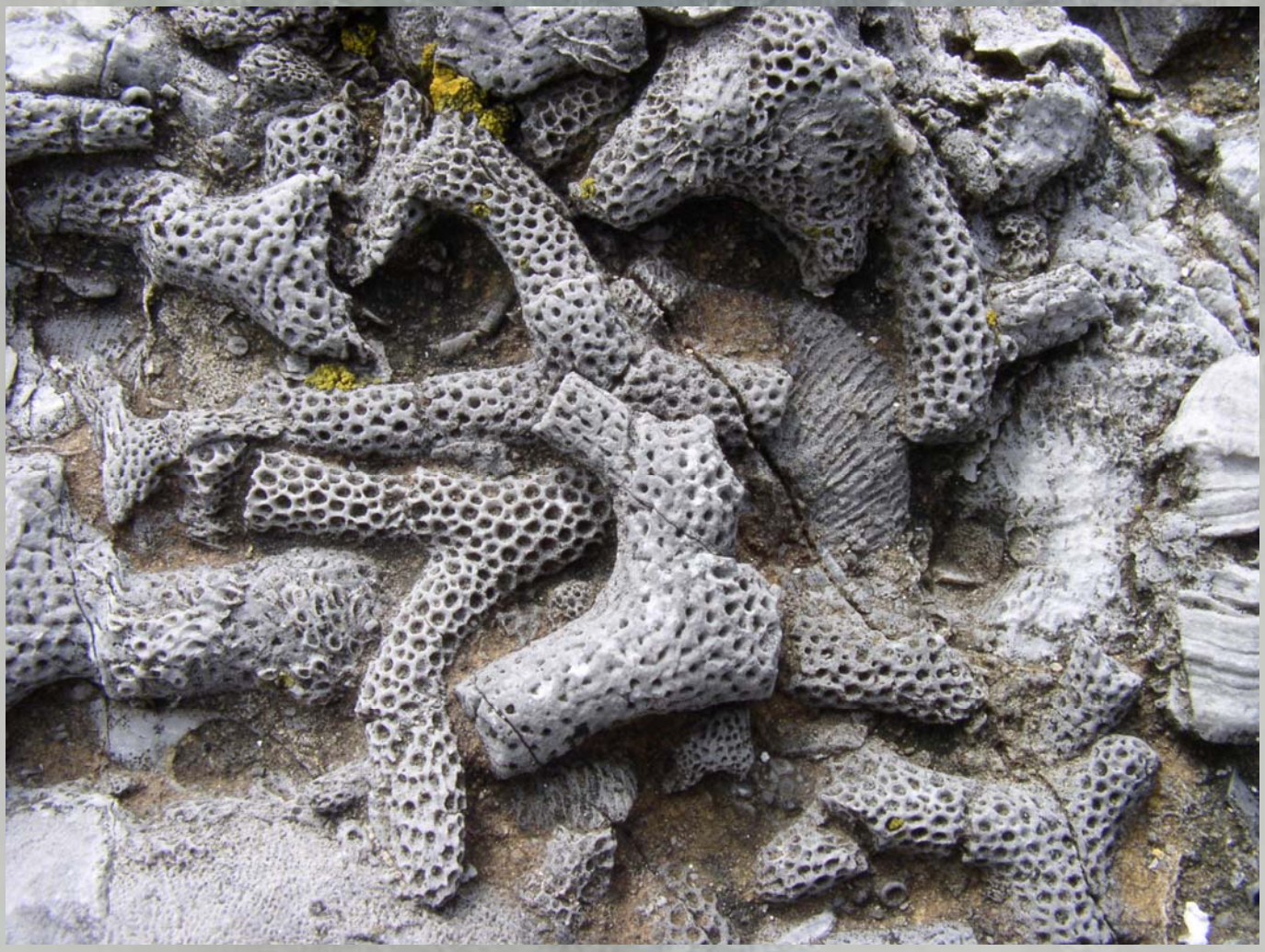
Daedalus desglandi
Age: Lower Ordovician (Floian)
Environment: marine
Description: *Daedalus* is one of the most intriguing trace fossil found in the quartzite rocks from Naturtejo Geopark. A mysterious cosmopolitan creature has burrowed systematically the sandy bottom, developing successive vertical, centripetal J-shaped strip mining, with the aim of feeding from the only possible nutrient resource existing in clear quartz sands – the bacterial films covering the sand grains. This weird way of living came to an end together with the animal that produced it 430 million years ago.

Daedalus isp.
Age: Lower Ordovician
Environment: marine
Description: Ichnofossil spiral shaped galleries built in sandy shallow marine, attributed to a worm-like animal that was moving the sand while looked for feeding. The traces suggest a movement around a fixed point on the surface, possibly to feed, and turning back to take refuge in that medium.

Rotundusichnium isp.
Age: Middle Ordovician (Darriwilian)
Environment: marine
Description: A concentric feeding trace fossil formed by an unknown organism as result of disturbing the sediment in their search for food, in an oxygen depleted environment.

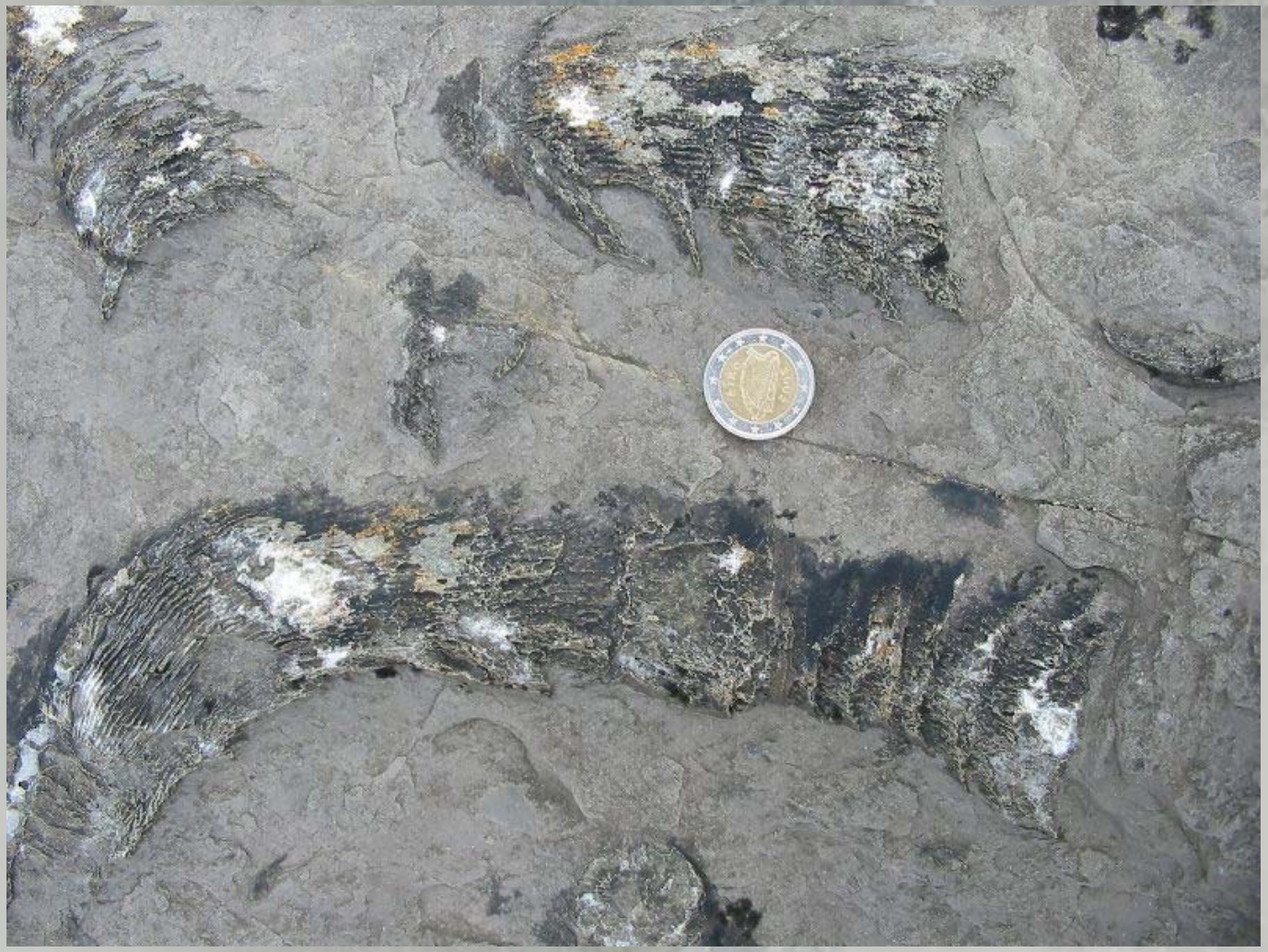
Cruziana isp.
Age: Ordovician
Environment: marine
Description: The cruzianas are trace fossils that correspond to arthropod's creeping tracks. They are attributed to the moving forward of trilobites, semiburied in the seabed, probably for feeding. The tracks are formed by two parallel furrows in which oblique marks were left by their locomotor appendages. The ichnofossil of the image are engraved in the characteristic Ordovician ortoquartzites of the geopark's landscape.

Pleurodictyum problematicum
Age: Lower Devonian
Environment: marine
Description: Tabulate coral with an enigmatic central worm. The association which depicts an interesting animal behaviour (commensalism) is known from different localities in the world, mainly in Silurian and Devonian marine sediments. It is common in Lower Devonian of Eifel, Germany, where it was originally described; at that time (410 million years ago) Eifel was at about 35º southern latitude In the shallow sea bivalves, brachiopods, trilobites, corals, including *Pleurodyctium problematicum* and ancestral giant sea scorpions lived in a warm and sunny environment.



Thamnopora sp.
Age: Middle Devonian
Environment: marine
Description: The old Barton quarry, now occupied by development, still shows important exposures of the bioclastic Barton Member of the Torquay Limestone Formation, and effectively forms the type locality of the unit. In the past the site has yielded a rich fauna, not dissimilar to that from the better known Lummaton Quarry, including varied brachiopods, bivalves, gastropods, trilobites and rare ammonoids. Current exposures show rich coral-stromatoporoid assemblages, with the tabulate Thamnopora being particularly abundant. The exposures have also yielded conodont faunas confirming an uppermost varcus to lower assymetricus biozone age (Upper Givetian).

Siphonphyllia sp.
Age: Carboniferous
Environment: marine
Description: The Carboniferous succession of the Marble Arch Caves Global Geopark can be divided into 2 groups: the predominantly Lower Carboniferous Tyrone Group and the overlying Leitrim Group. Fossils are common but not exclusive to the limestones of the Tyrone Group and also within some of the mudstones and shales for example, the mudstones of the Benbulben Shale Formation contain abundant remains of fenestellid bryozoa, brachiopods and large specimens of *Siphonophyllia benburbensis*

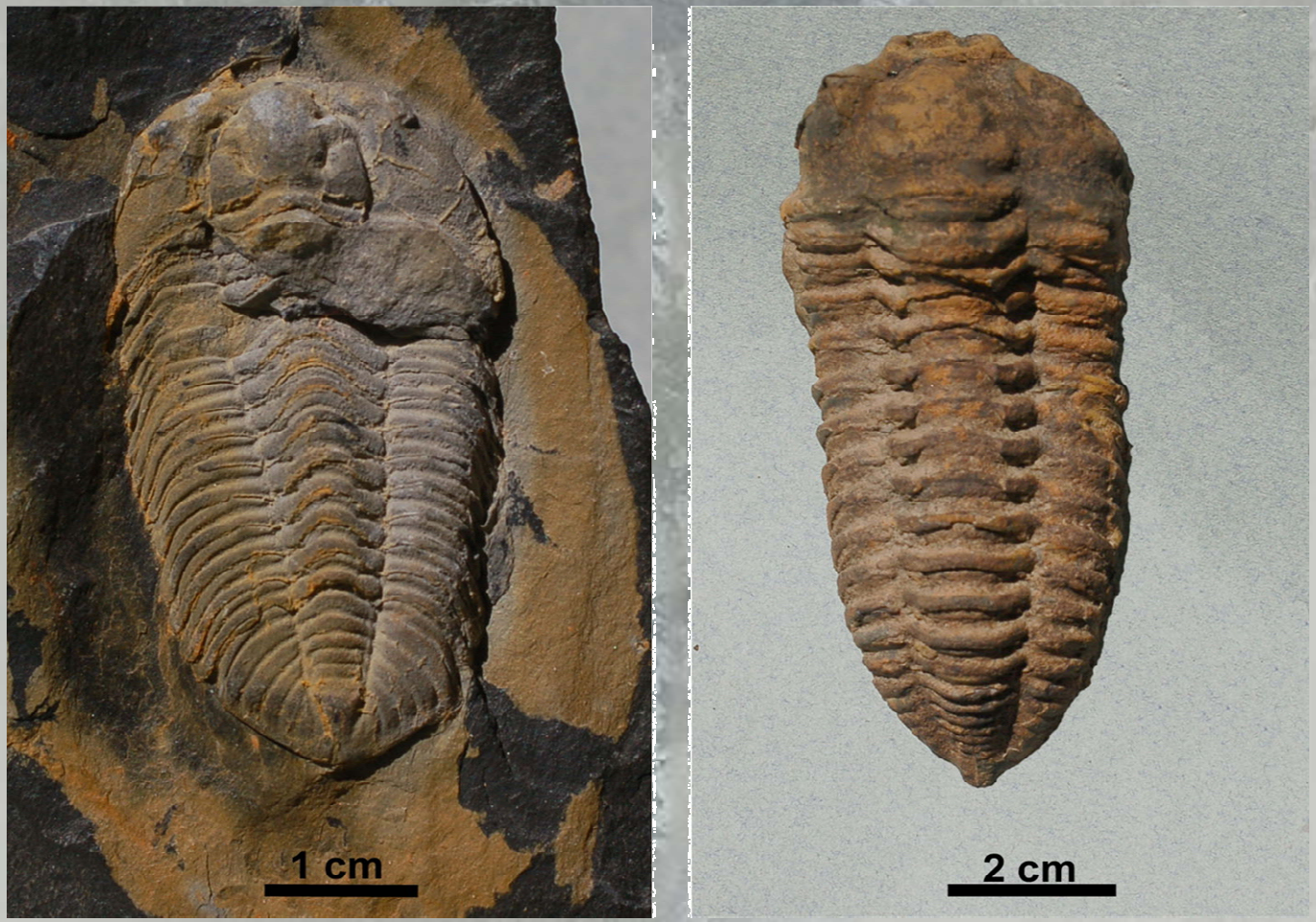


Solitary coral
Age: Carboniferous
Environment: marine
Description: The Carboniferous succession of the Marble Arch Caves Global Geopark can be divided into 2 groups: the predominantly Lower Carboniferous Tyrone Group and the overlying Leitrim Group. Fossils are common but not exclusive to the limestones of the Tyrone Group and also within some of the mudstones and shales for example, the mudstones of the Benbulben Shale Formation contain abundant remains of fenestellid bryozoa, brachiopods and specimens sollitary coral.

Siphonodendron irregulare
Age: Carboniferous
Environment: marine
Description: Many of the fossils found within the limestones are predominantly of a coral-brachiopod assemblage with fragmentary crinoids also present. There are, however, occurrences of bryozoa, bivalves and ammonoids found locally. There several sites that contain excellent examples of complete fossils such as the Legacurragh coral bed occurring at the very top of the Dartry Limestone Formation containing abundant in situ silicified *Siphonodendron irregulare*.

Goniatite sp.
Age: Upper Devonian
Environment: marine
Description: Goniatites are distant relatives of the present day Nautilus and the most common cephalopods during Devonian and Carboniferous time (390-300 millions years) They lived in a warm, tropical marine environment,inhabited by a diversity of life forms. During the Devonian period the rocks of the English Riviera Geopark were formed ?*Aulatornoceras* comes from the Waterside Cove goniatite bed, which forms part of the Saltern Cove Site of Special Scientific Interest.

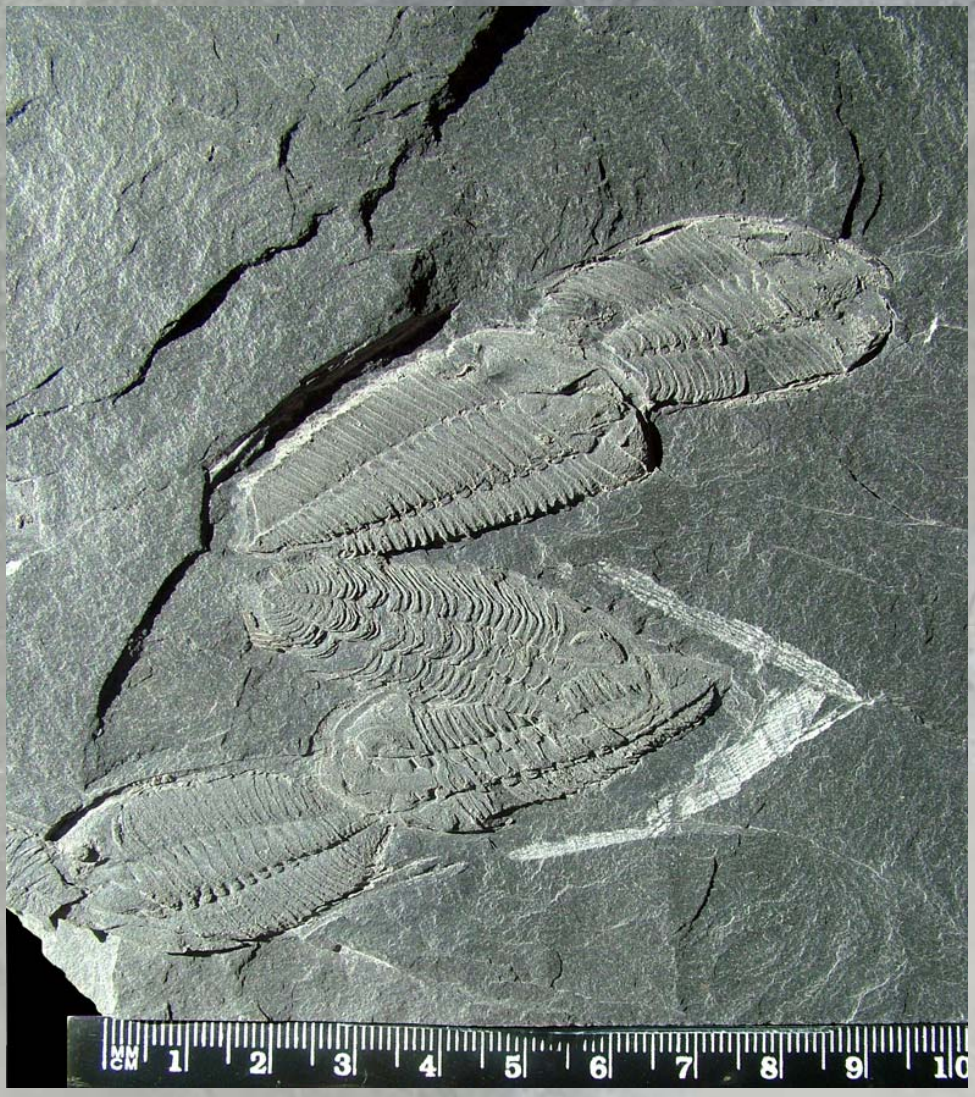
Brachiopods
Age: Middle Ordovician
Environment: marine
Description: Brachiopods found in the Guadarranque Syncline. In this geological context, series of ortocuarcitas (Armorican quartzite) and black shales with great fossiliferous wealth are found. The brachiopods in the image, representatives of the Orthidae family, appear next to a large diversity of trilobites, molluscs, echinoderms and graptolites typical of the "layers with Tristani" of the Central Iberian Zone.



Neseuretus tristani (left) *and Prionocheilus mendax* (right)
Age: Middle Ordovician
Environment: marine
Description: Trilobites found in the Ordovician shales of Navatrasierra. (Syncline of Guadarranque-Gualija). Both are common in west European and north African Middle Ordovician deposits. The valleys of the rivers Guadarranque and Gualija are extraordinarily rich in paleontological deposits. More than thirty species of trilobites were found in these deposits.

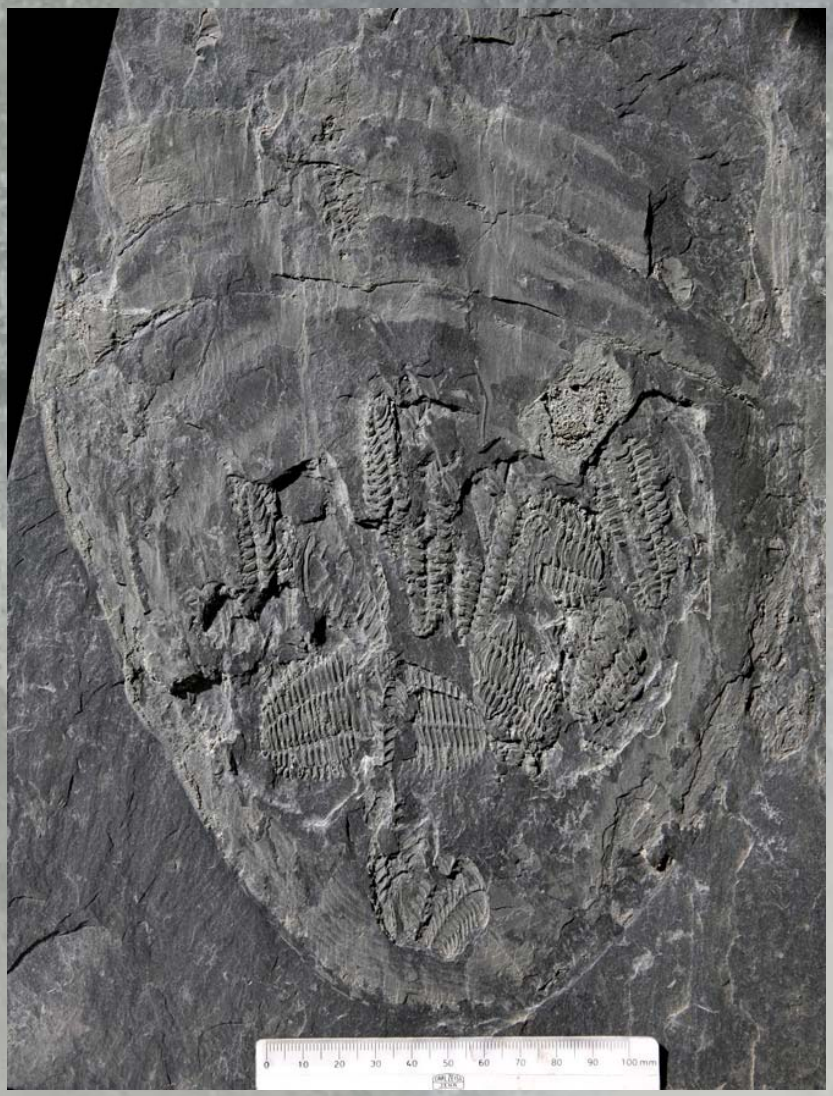
VILLUERCAS - IBORES - JARA

Neseuretus tristani
Age: Middle Ordovician (Darriwilian)
Environment: marine
Description: In Penha Garcia spectacular animal behavior traces are not the only fossils. In the dark metapelites from Brejo Fundeiro Formation parts and carapaces from trilobites and other invertebrates are evident. Among them, by far the most abundant is Neseuretus tristanim, a trilobite that ruled the seas around the continent Gondwana some 470 million years ago. This young adult just about 2 cm long could have reached more than 8 cm. Inhabitant of shallow marine environments, its short existence started with a plankton larval stage and passed by a juvenile stage dependent from the sea bottom searching for food.



Cluster of trilobites
Age: Middle Ordovician (Darriwilian)
Environment: marine
Description: Linear autochthonous trilobite cluster, in a polytaxic zigzag pattern with five specimens. First and last (starting from top right) - *Bathycheilus castilianus*; second - *Salterocoryphe cf. sampelayoi*; third and fourth - *Retamaspis melendezi*.

Trilobite
Age: Middle Ordovician
Environment: marine
Description: Trilobite carapace with a triangular bite mark in the right side of the pygidium, probably made by the beak of large orthoconic nautiloids. Darriwilian (Middle Ordovician) age (ca. 465 million years).

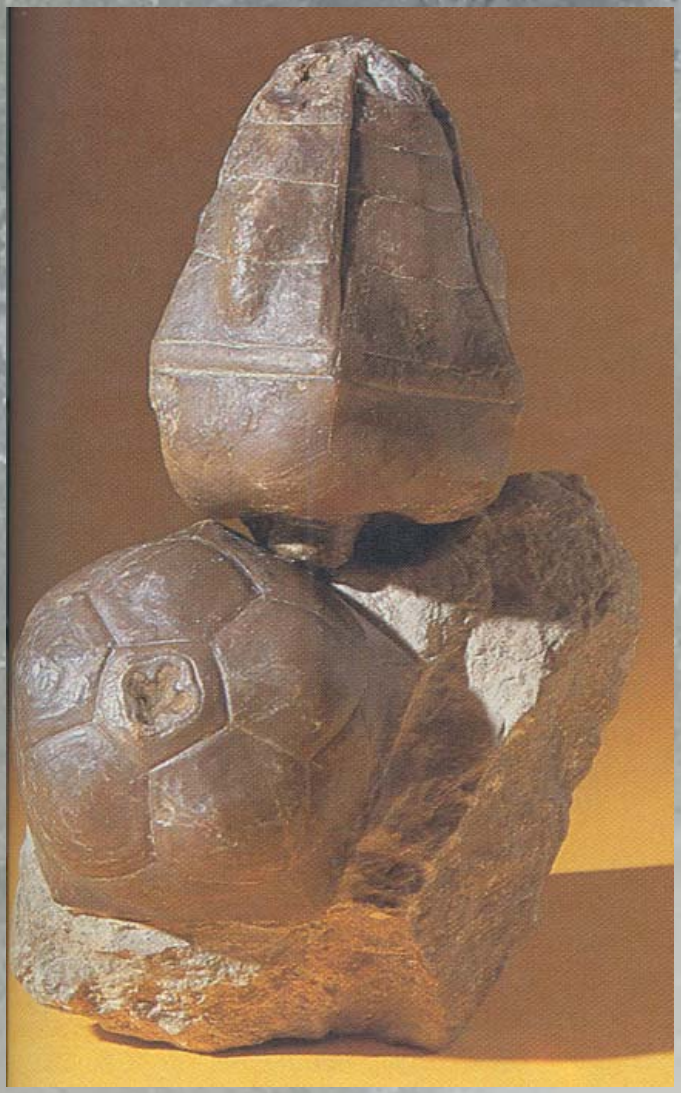


Placoparia cambriensis
Age: Middle Ordovician
Environment: marine
Description: Cluster of more than 18 articulated exuviae of *Placoparia cambriensis* hiding under the carapace of giant *Ogyginus forteyi*, probably to escape predation while molting, in a monotaxic cryptic behavior. Darriwilian (Middle Ordovician) age (ca. 465 million years).

vulkaneifel geopark

Harpes macrocephalus
Age: Middle Devonian
Environment: marine
Description: *Harpes macrocephalus* is one of the most rare trilobites of the Eifel region of west Germany. It has a very large head (cephalon), almost half of the total body length (13-18 cm.), bearing a semicircular brim perforated by small pores. The brim is thought to serve as a filter-feeding apparatus. During Middle Devonian, some 395 million years ago the Eifel was a carbonate platform with reefs and lagoons inhabited by sponges and corals, brachiopods and mussels, crinoids and trilobites.

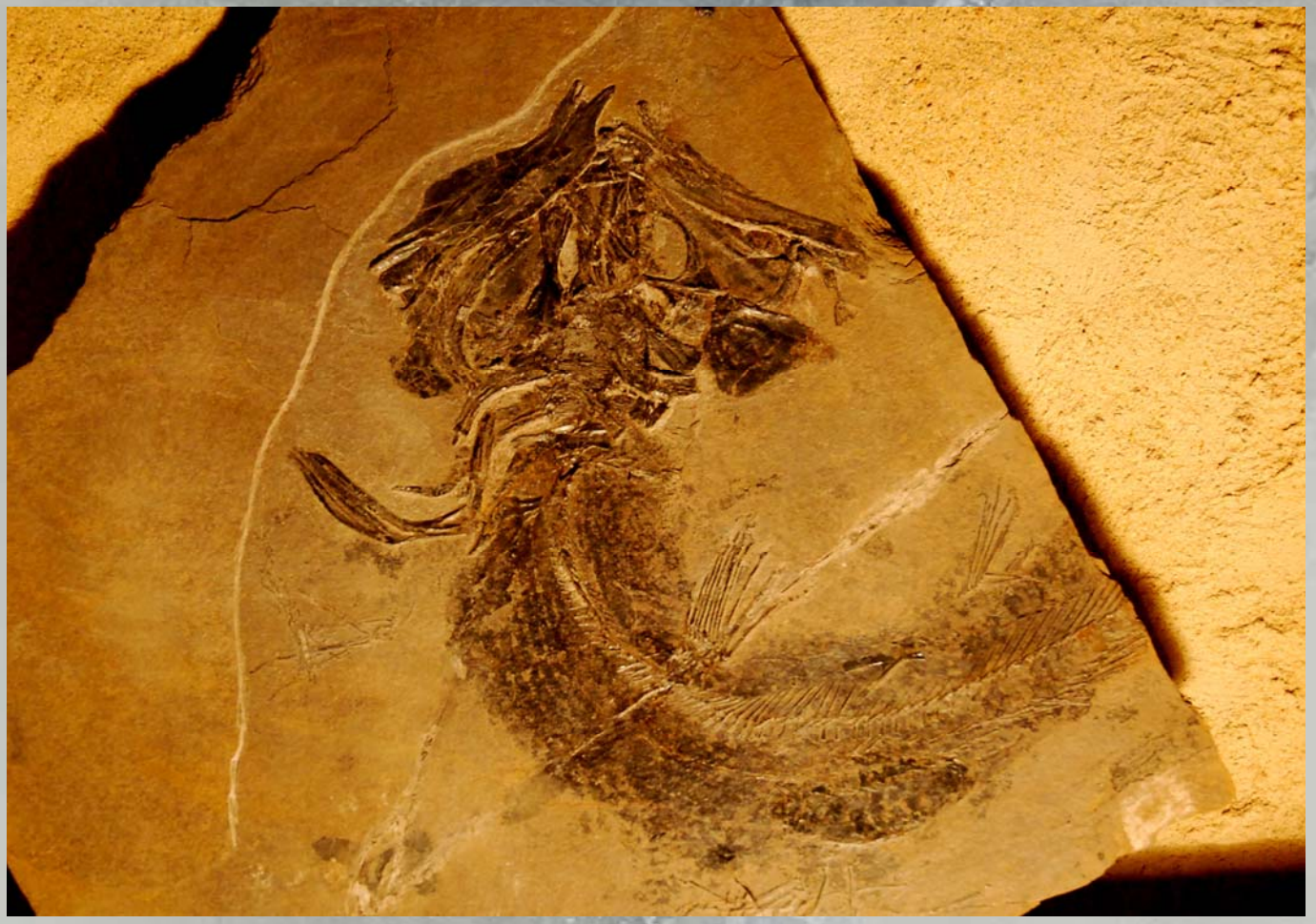
Geesops schlotheimi
Age: Middle Devonian
Environment: marine
Description: *Geesops schlotheimi* is the most common trilobite species in the Middle Devonian of the Eifel region. It shared the same carbonate platform environment with the previous *Harpes macrocephalus* trilobite and the rich fauna of invertebrates who inhabited the areas around the coral reefs. Unlike *Harpes*, *Geesops* had a shorter head, whose central part or glabella was ornamented by prominent tubercles.



Cupressocrinites sp.
Age: Middle Devonian
Environment: marine
Description: The superbly preserved Cupressocrinites is a crinoids or sea lily, but dispite its name and appearance it is an invertebrate animal and even an evoluted one, more close to the vertebrate animals than other invertebrate. The"calyx" formed from numerous small calcareous plates was sustained by a long and thin stem, formed also from numerous articulated calcareous plates. It lived about 395 million years ago in a reef, well oxygenated environment, very favourable to the development of rich biota.

Abbreviatocrinites inflatus
Age: Carboniferous
Environment: marine
Description: *Abbreviatocrinites* is also, as *Cupressocrinites* a sea lily, but a “little” younger (ca. 350 million years). The Eifel region continued to be a shallow, tropical sea, as in the Middle Devonian, but lacking reefs, due to the strong input of fine clastic sediments which affected the water purity. The crinoid *Abbreviatocrinites inflatus* from the photo comes from the Hillesheim-trough.

Stegotrachelus finlayi
Age: Devonian
Environment: freshwater
Description: An early actinopterygian fish whose body was covered by large scales ornamented with horizontal ridges; jaws were equipped with two sets of teeth. It inhabited the temporary lakes on the desert plain, 400 million years ago when Shetland was a desert area with a climate dominated by dry and arid conditions. Fossilised remains of the fishes from that time can be found today in areas around the south and west Mainland. There are two fish beds in the Sumburgh/ Noss area of South Mainland, which include besides *Stegotrachelus finlayi*, *Asterolepis thule.*



Coelacanthus granulatus
Age: Permian
Environment: marine
Description: During the upper Permian age the Geopark area was covered by the sea. Today geologists call this area the “German basin”, an ocean that changed its shape and salinity several times during the Permian age. In some periods extended lagoons formed along the coastlines and huge amounts of salt and gypsum were sedimented. In other periods the sea was full of life. One species that lived here is called “*Coelacanthus*”. Close rela tives of this fish still live today (known as “Latimeria”) in the Indian Ocean. What makes these animals so special is their close relationship to land-living vertebrates like amphibians and reptiles. They are thought to be their early predecessors and a kind of link in the evolutional chain of life. The fossils were found at the slope of the mountain “Hüggel”, a horst-structure in the southern part of the Geopark.

mesozoic
the Life between old and new

mesozoic - the Life between old and new

During the Mesozoic a serious change of the distribution of oceans and continents took place. In the Triassic the sole supercontinent Pangaea still existed. Large parts of Europe were covered by almost plane deserts and fluvial landscapes. Occasionally these areas were flooded by the sea from the direction of the area in which much later the Alps and Carpathians formed. Under a hot and dry climate evaporites such as gypsum and halite accumulated, when the connections to the ocean became too small to provide enough inflow of fresh seawater. The continental basins of the Triassic often contain sandstones and multicoloured claystones. These deposits yield fossil remains of the vertebrates of that period, among them giant amphibians and crocodile-like reptiles which became extinct at the end of the Triassic, and the first land turtles appeared. In Late Triassic times dinosaurs, which had probably evolved in South America, invaded the area of Europe. Among the shades of these dinosaurs the earliest mammals have been recorded, however, only by tiny isolated teeth.

Towards the end of the Triassic and in the Jurassic large areas of continental Europe were flooded by the sea. Only a few islands remained, like the Massif Central in France, the Rhenish-Ardennic Massif or the Bohemian Massif, all of them surrounded by shallow seas. The Tethys Ocean – today we find its deposits in the Alps and Carpathians – spread westwards, where the Atlantic opened and separated Africa from the Americas. An equatorial seaway connected the Tethys and the Palaeo-Pacific oceans via the so-called “Hispanic Corridor” in the areas of southern Spain, Cuba and Mexico. In the late Early Jurassic volcanism in South Africa has lead to a worldwide climatic crisis. This scenario included extreme rainfalls and a dying of life both in the oceans and in their marginal seas. Dark, bituminous claystones were deposited which are known as “Posidonia Shale“. They are world-famous for their well preserved fossils of ichthyosaurs, marine crocodiles and large crinoid colonies attached to driftwood. In southern Germany these fossiliferous shales have been exploited mainly around the village of Holzmaden, but similar rocks occur also in France, England, in the Alps, and elsewhere. On the European Jurassic islands lived terrestrial animals like pterosaurs and numerous other reptiles, among them small dinosaurs.

Some of them exhibit a combination of features connecting typical reptiles with those of modern birds; indeed the latter are an extant lineage of dinosaurs. The most famous European fossil in this context is the ancient bird Archaeopteryx, which was recovered from finely bedded lagoonal deposits in the Late Jurassic of Solnhofen and Eichstätt in Bavaria.

The Triassic and Jurassic vegetation is characterized by ferns, conifers and other gymnosperms. Angiosperms, which make our world as colourful as it is today, appear not until the late Early Cretaceous in the fossil record. Simultaneously, those insects depending on angiosperms diversified.

The global climate in the Late Jurassic and in the Cretaceous was much warmer and more balanced than today. Marine deposits predominantly consist of carbonates. On the deep seafloor of the Tethys Ocean, however, microscopically small skeletons of planktonic organisms formed the radiolarite, a completely siliceous rock. The area of present-day's Europe was located in the subtropical climate belt. Hence, in the shallow shelve seas of the Jurassic and Cretaceous extremely diverse coral reefs developed, similar to the modern ones in the Caribbean or the Red Sea. In the Late Jurassic another large reef belt spread over Portugal, central Spain, eastern France, northern Switzerland, Southern Germany, southern Poland, and Romania. This gigantic reef belt occupied the deeper shelves and is mainly built up by siliceous sponges and microbes. Today these sponge reefs are prepared by erosion and karstification and form a landscape of picturesque rocks. Within the reefal limestones often caves formed. In the ice age some of these caves were inhabited by typical animals (e.g., Cave Bear, hyenas) and prehistoric humans.

In the Early Cretaceous a first Alpine orogenic phase occurred. Parts of the seafloor were tectonically uplifted and formed islands. The warm and shallow seas of this archipelago were settled by strange sessile bivalves resembling corals and large, thick-shelled gastropods, like in the area of Gosau in Austria. Among nektonic invertebrates the cephalopods, especially ammonoids, became abundant and diverse in the Mesozoic.

At the end of the Triassic the ammonoids suffered from a severe ecological crisis and only very few species survived. Shortly after, already in the Early Jurassic, they regained their former diversity. However, at the end of the Cretaceous, the ammonoids – and many other marine and terrestrial animal groups – became extinct. A violent volcanism in India and, almost subsequently, the gigantic Chixulub impact in Mexico had caused a catastrophe, which is represented by a thin, dark bed of clay rich in heavy metals (e.g., iridium, platinum) in wide areas of the world. This cosmic impact caused tsunamis, fires and a strong climatic drop, a scenario in which many of the established food-webs were destroyed and which finally resulted in one of the biggest mass extinction in Earth History. Both marine and terrestrial environments were affected.

Günther Schweigert
Geopark Swabian Albs – GERMANY

Paleodiction
Age: Cretaceous
Environment: marine
Description: It is one of the most common and mysterious trace fossils of the Basque Coast Geopark. Although it was discovered and explained already in 1977 by Dolf Seilacher, Its origin is still uncertain.

Scolicia sp.
Age: Cretaceous
Environment: marine
Description: The coastal outcrop of the Basque Coast Geopark is like a natural museum for deep water marine trace fossils. Several new species have been described and every year a collecting campaign is organized to recover all specimen detached from the cliffs.

Chondrites isp.
Age: Lower Cretaceous
Environment: marine
Description: Ichnofossils can provide some very intriguing insights on the ecology and behavior of an extinct animal. It is very rare that the animal itself is found in direct association with the ichnofossil it created. *Chondrites* are small branching burrows of the same diameter, which superficially resemble the roots of a plant. The most likely candidate for having constructed these burrows is a nematode (roundworm). *Chondrites* are found in marine sediments and represent mid and distal continental shelf situations, below normal wave influence, but may be affected by storm activity. They are especially common in sediments which were deposited in reduced-oxygen environments.

Cheilosporites tirolensis
Age: Triassic
Environment: marine
Description: The sponges are a group of marine multicellular organisms with their body perforated by several pores and for this reason they are also called Porifera (= with pores in latin). Sponges were the first reef builders in Triassic period. The abundant fossil remains in the Madonie allowed extensive studies in particular on the Thalamids group (extinct since the Cretaceous) with the definition of new genres and species.

Thecosmilia sp.
Age: Upper Jurassic
Environment: marine
Description: The shallow sea which covered Southern Germany during upper Jurassic times (about 150 million years ago) offered ideal conditions for the growing of coral reefs. Corals like this Thecosmilia from the Gerstetten area in the Geopark Swabian Alb covered big areas. By acid preparation of the limestone you can lay open the finest anatomical details of these animals.

Coral fossil
Age: Lower Cretaceous
Environment: marine
Description: They look like stars on the reef limestone of the Basque Coast Geopark mountains, which contain large amounts of molluscs and different types of corals of albian age. Corals are the skeletons of some marine animals (Cnidaria) that contains a large variety of solitary and colonial invertebrates. Environmental sensitivity and lack of mobility make them excellent tools for environmental interpretations. Reefs grow best in warm, shallow, clear, and choppy waters.

Halobie sp.
Age: Upper Triassic
Environment: marine
Description: *Halobia* is an extinct genus of bivalve mollusks chracterised by a thin, flat calcareous shell with a typical radial ribs ornamentation. These bivalves lived presumably floating in open waters. In the Madonie they have a particular stratigraphic importance as they are guide fossils for the Upper Triassic (Carnian-Norian).

Nerinea sp.
Age: Upper Triassic
Environment: marine -tropical shallow waters-
Description: *Nerinea* is an extinct marine gastropod mollusk with a characteristic internal sculpture, that is visible in longitudinal section. These gastropods lived in carbonate platform environment (warm and shallow waters) and were often associated to bioconstructer bivalves (rudists). They are significant from the stratigraphical point of view as they appeared in the Jurassic and disappeared at the end of the Cretaceous.

Colonial Hexacorallians
Age: Jurassic
Environment: marine -tropical shallow waters-
Description: The Hexacorallians corals have produced in the Jurassic large reefs wich fossil remains are still visible. They are colonial or solitary, carnivorous and suspension feeders animals and have a calcium carbonate skeleton; the massive colonies live in shallow, high energy and warm waters. In the Cretaceous the coral reefs are replaced by rudists reefs (rudists are a group of bioconstructor bivalves).

Balatonites egregius
Age: Triassic (Anisian)
Environment: marine
Description: This ammonites links the Eisenwurzen scientifically with the Bakony-Balaton Geopark where it has first been recorded. Together with other ammonites, it has lived 240 to 235 Million years before present, within the Triassic period. This time interval was named Anisian after the Latin name of the Ennsriver which crosses Eisenwurzen Geopark. The Anisian is part of the international geological time scale.

Amaltheus sp.
Age: Jurassic
Environment: marine
Description: The Jurassic layers of the Swabian Alb are extremely rich in ammonites, an extinct group of marine animals related to cuttle-fish and nautilids. There shells, like this Amaltheus from the lower Jurassic (nearly 200 million years old), are very popular among collectors because of their high aesthetic value.

Cluster of ?*Oppelia* sp.
Age: Jurassic
Environment: marine
Description: Ammonites, extinct cephalopods related to cuttle-fish and nautilids are extremely frequent in the Jurassic layers of the Swabian Alb and for this reason build the logo of the Geopark. In the middle Jurassic sediments there exist real “ammonite pavements” like this one from Behla.

Himalayites uhlandi
Age: Jurassic
Environment: marine
Description: Ammonites are extinct cephalopods which showed an extraordinary radiation in the Mesozoic. In the Jurassic layers of the Swabian Alb they count among the most frequent fossils and are extremely important for the age determination of the sediments. Forms like this *Himalayites* are most popular among fossil collectors.

Hildoceras sp.
Age: Lower Jurassic (Toarcian)
Environment: marine
Description: Ammonites are marine extinct animals, relatives of squids or octopuses, with a spiral shell. This was divided in chambers with gas and liquid which permitted them to control its pressure and go up and descend through water like a submarine. The abundance, great diversity and quick evolution that ammonites experienced permit to date rocks with extraordinary precision. In Sierras Subbéticas ammonites are most characteristic fossils. This specimen is composed of the petrified sediment that filled the shell. The sinuous pattern is the suture line, which marks the limits of the chambers.

Morticeras sp.
Age: Lower Cretaceous
Environment: marine
Description: Ammonites are an extinct group of marine animals (cephalopods). Their fossil shells usually take the form of spirals. The soft body of the creature occupied the largest segments of the shell at the end of the coil. The smaller earlier segments were walled off and the animal could maintain its buoyancy by filling them with gas. Many Ammonites probably lived in the open water of ancient seas, although some Amomonites were less effective swimmers and were likely to have been slow-swimming bottom-dwellers. Ammonites probably preyed on fish, crustaceans and other small creatures, while they themselves were preyed upon by marine reptiles. Ammonites became extinct at the end of the Mesozoic Era (65 million years ago). Diameter: 52 cm.

Ammonite
Age: Lower Cretaceous
Environment: marine
Description: The albian coastal outcrop of the Basquian Coast Geopark contains big and spectacular ammonites that have been carefully collected before they are washed by the sea. All these fossils are exposed in the Nautilus ammonite museum of the Geopark.

Anisoceras saussureanum
Age: Lower Cretaceous
Environment: marine
Description: *Anisoceras* is an extinct genus of cephalopods belonging to the Ammonite subclass. This fossil shell is a non-spiraled form (known as "heteromorphs"). These uncoiled forms began to diversify mainly during the early part of the Cretaceous. Ammonites vary greatly in the ornamentation (surface relief) of their shells. Some may be smooth and relatively featureless, except for growth lines. In others various patterns of spiral ridges and ribs or even spines are shown. Ammonites are useful fossils because it is often possible to link the rock layer in which they are found to specific geological time periods. The closest living relatives of Ammonites are octopus, squids and cuttlefish. Length: 1.4m

Heteromorph ammonite
Age: Upper Cretaceous
Environment: marine
Description: Heteromorph Ammonite rescued from the maastrichtian cliffs close to the Cretaceous/Tertiary Boundary in Zumaia. This section was one of the referenced outcrops to understand the sudden massif extinction of these famous cephalopods at the end of the Cretaceous.

Innoceramids
Age: Upper Cretaceous
Environment: marine
Description: Species of *Inoceramus* had a worldwide distribution during the Cretaceous period and it is one of the largest known bivalve claim in the fossil record. They extinction happened 2,5 Ma before the end of the Cretaceous and it has been studied in the deep marine sediments of the flysch outcrop of the Basque Coast Geopark, just 100m below the famous K/Pg. This mass extinction seems to be related to a global oceanic changes during the mid-Maatrichtian.

Megalonoda reussi
Age: Upper Cretaceous (Coniacian)
Environment: marine
Description: Some 90 Million years ago, within the Cretaceous period, only small parts of the northern Alps have already been lifted over the sea level. Mud and sand was deposited on the bottom of the sea between these islands. It was the living environment of this large snail and many others, bivalves, ammonites and corrals.

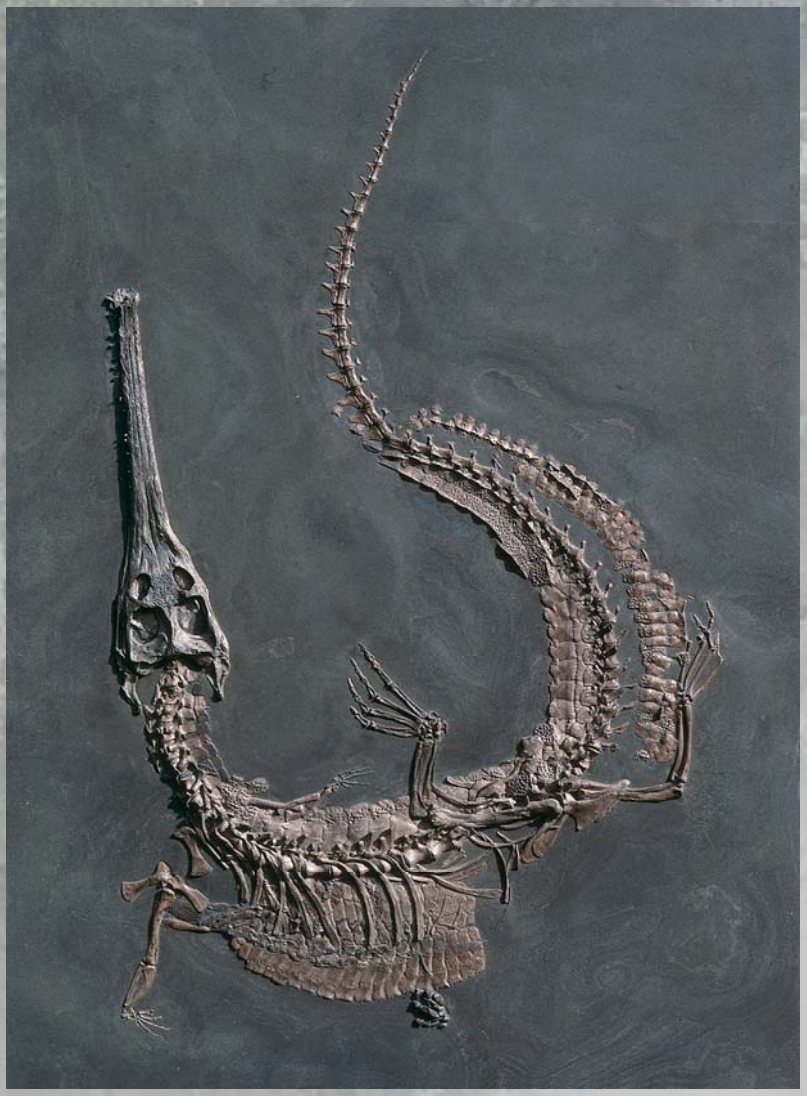
Trochactaeon lamarcki
Age: Upper Cretaceous (Coniacian)
Environment: marine
Description: Discovered in the EisenwurzenGeopark, this snail was named in honor of Jean-Baptist de Lamarck, the famous French pioneer of the theory of evolution. It has lived in the Cretaceous period, about 90 Million years before present, in a very shallow part of the sea. No wonder, that storm waves have accumulated large numbers of shells.

Antrimpos sp.
Age: Upper Jurassic
Environment: marine
Description: During the Upper Jurassic (about 150 million years ago) Southern Germany was covered by a shallow tropical sea with many islands and lagunas. In the Geopark Swabian Alb extremely well preserved fossils have been found at Nusplingen, among them many species of crustaceans.

Tetragramma sp.
Age: Lower Cretaceous (Aptian)
Environment: marine
Description: Echinoids, also called sea urchins, are the most commonly known type of echinoderms. *Tetragramma* was a regular sea urchin with a flattened test, rounded shape, circular and well developed peristome and perforate crenulate tubercles. It shows a large pentagonal apical disc and well developed ambulacra bearing diadematoid type plates. Allepuz (Teruel).

SWABIAN ALB

Squatina sp.
Age: Upper Jurassic
Environment: marine
Description: In the Upper Jurassic see (about 150 million years ago) of Southern Germany a rich marine life existed. One of the characteristic animals of the locality Nusplingen is the ray-like shark of the genus *Squatina*. It survives as a “living fossil” until today.



Steneosaurus sp.
Age: Lower Jurassic
Environment: marine
Description: In the “Posidinia shales” at the northern foot of the Swabian Alb a rich fauna of invertebrates and vertebrates has been preserved in excellent condition, even sometimes with preservation of soft parts of the animals. The main reason for this fact is the anoxic condition at the bottom of this sea preventing the decay and destruction of the carcasses. Marine crocodiles were part of the diverse vertebrate fauna of these about 200 million years old sediments.

SWABIAN ALB

Cricosaurus sp.
Age: Upper Jurassic
Environment: marine
Description: Fossils can tell stories! In this fossil marine crocodile from the Upper Jurassic of Nusplingen on the Swabian Alb (Southern Germany) the skull has been found bitten off a little bit away from the rest of the skeleton. The hunter of this animal can be identified by an isolated tooth of a bigger crocodile found nearby.

mesozoic
the Life between old and new
giants and dwarfs on continents

Gymnosperm
Age: Mesozoic
Environment: continental
Description: It displays the reproductive part of a plant belonging to the gymnospermae group. It possesses quite a complicated and peculiar inner structure. It owes its preservation to a silification process. The fossil doesn't reveal the whole reproductive area, but just a portion of it; a fragment is conserved in which the outside is visible along with several sections. It has a radial symmetry, and was found on a Quaternary plateau, having arrived there in the shape of a rounded pebble stone carried along by a river.

Coniferophytina indet.
Age: Lower Cretateous (Albian)
Environment: continental
Description: Fragment of a gymnosperm fossil stem coming from a coal mine in Estercuel (Teruel, Spain). Gymnosperms are vascular and spermatophyte plants, which produce seeds. During the Lower Cretaceous, 105 million years ago, the soil of Teruel province was covered by vast stretches of marshy jungles and gigantic trees forests.

Dinosaur footprints
Age: Jurassic
Environment: continental (coastal)
Description: Two different species of dinosaurs left their footprints in a fine grained coastal mud in the upper Jurassic age, about 150 million years ago. One species is believed to be a quadruped herbivore like *Camarasaurus* that used to live in Europe during the Jurassic age. The imprints have a rounded shape similar to those of elephants.At least nine individuals crossed the Jurassic plain and the impression is, that it was a little herd walking along the muddy beach. The second type of tracks was presumably left by a carnivore biped reptile such as *Megalosaurus*. The animals` feet obviously were three-toed and two individuals were identified. During the alpine orogenesis the track-layer was lifted and remained in a steep position, so today the tracks can be seen on the wall of the little footprint-quarry.

Dinosaur tracksites
Age: Upper Jurassic-Lower Cretaceous
Environment: continental (coastal)
Description: Las Cerradicas is a dinosaur tracks site from Jurassic-Cretaceous transition (Tithonian-Berriasian) with more than a hundred footprints grouped in trackways placed in Galve (Teruel). This site has been certified ase ´Bien de Interés Cultural –Conjunto de Interés Cultural, Zona Paleontológica´ by Government of Aragón. It is a site of global importance concerning the studies of quadrupedal footprints belonging to primitive ornithopod dinosaurs.

Dinosaur footprints (Miravete 1 site)
Age: Upper Jurassic-Lower Cretaceous
Environment: continental (coastal)
Description: This site has several levels with ichnites in fine grain limestone interlaying with marl strata which were deposited in a continental or transition environment. At Miravete 1-with a visible level- more than 60 ichnites have been registered, while in Miravete 2 (an outcrop placed nearby) 5 sauropod and 1 tridactyl theropod footprints have been found. The imprints have a chaotic distribution and were produced by several herds of sauropod dinosaurs. Sauropods were quadruped dinosaurs with vegetarian eating habits. These dinosaurs had both the neck and the tail greatly elongated, as well.

Dinosaur footprints
Age: Lower Cretaceous (Barremian)
Environment: continental
Description: San Cristobal 3 tracksite is located in the Camarillas Formation (early Barremian) in Galve (Teruel). The tracksite was excavated (a 3D scanning has been made too) with the result that 43 rounded tracks have been documented until present. Nevertheless, some of them show imprints with three digits and a rounded heel (probably ornithopod dinosaurs).

Dinosaur footprints
Age: Upper Cretaceous
Environment: continental (coastal)
Description: Abenfigo tracksite has been listed as "Heritage of Cultural Interest" Bien de Interés Cultural (BIC) – Government of Aragón (small picture). 41 footprints were mapped and the producers were several dinosaurs, which left their imprints on a large intertidal plane flooded -intermittently- by water during the Upper Cretaceous. The dinosaur ichnites from Abenfigo are the footprints left by the pes of a biped theropod (carnivorous) dinosaur.

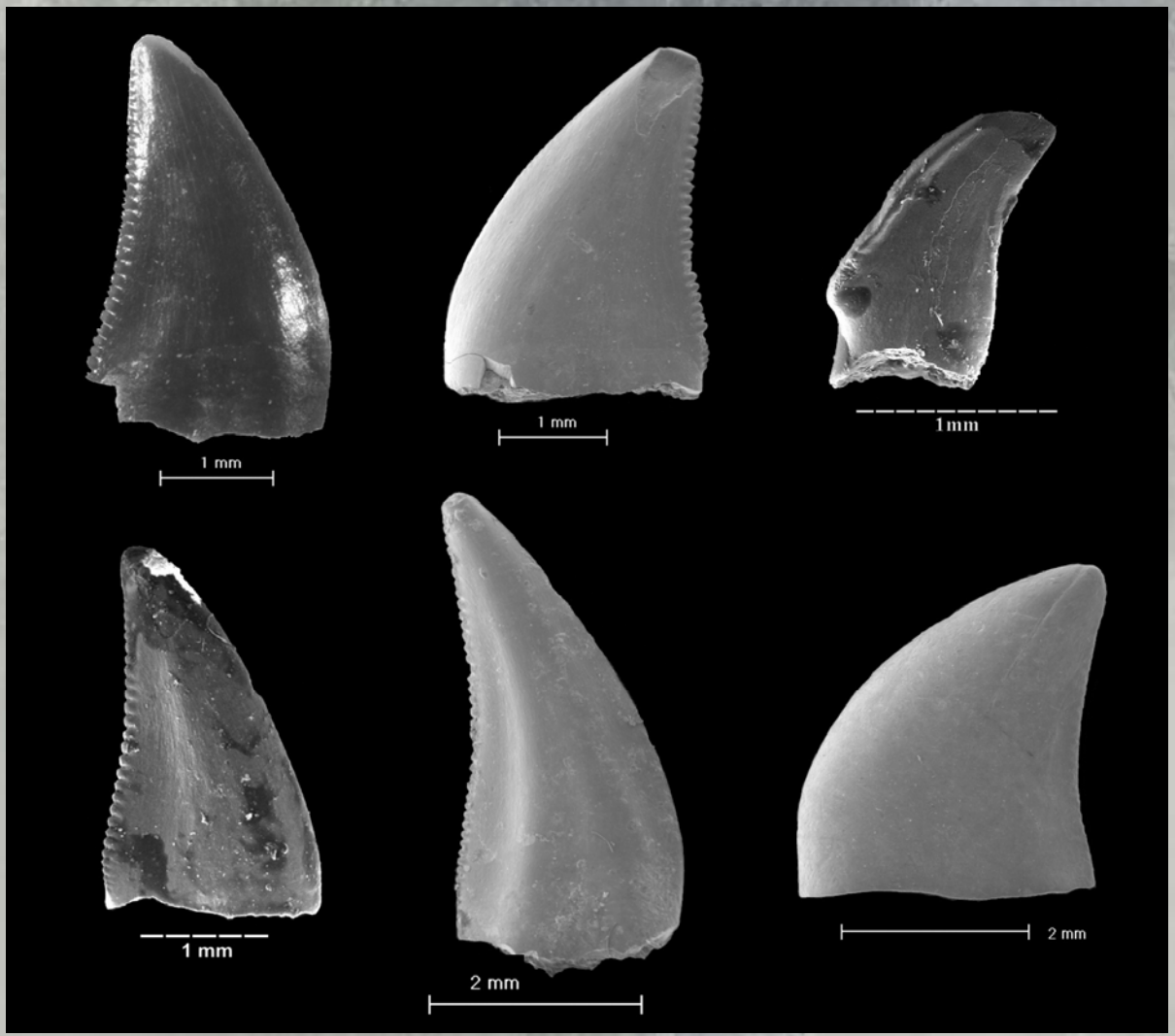
Eifelosaurus triadicus
Age: Lower Triassic
Environment: continental
Description: In the very beginning of the 20th Century a hitherto unknown fossil was found in a quarry with Bunter red sandstone near Oberbettingen/Vulkaneifel. Spine, ribs, and partially legs of a fossil land vertebrate animal were discovered. In 1904 the palaeontologist Prof. O. Jaeckel described the rare fossil as an "old style" lizard, and coined the name "*Eifelosaurus triadicus* JAECKEL 1904". *Eifelosaurus triadicus* lived about 235 Million years ago, during the Middle to Upper Buntsandstein period (Lower Triassic). The Eifel then lay closer to the equator, at about 30º Northern Latitude, a dry, desert-like climate was ruling. Eifelosaurus most probably strolled with the reptilian criss-cross walk through the woods, thickets, and the open land in the Early Triassic oases and ephemeral river beds. Photo inlet: re-construction Österwind/Mayen

Iguanodon sp.
Age: Lower Cretaceous (Barremian)
Environment: continental
Description: Ornithopods were herbivorous dinosaurs with quadruped and biped walking abilities that had a jaw predentary (an 'extra' bone in the front of the lower jaw) in peak mode. Inside the Geopark, Fundación Dinópolis recovered in Aliaga a set of articulated dorsal vertebrae belonging to this type of dinosaur (*Iguanodontoidea* indet.).

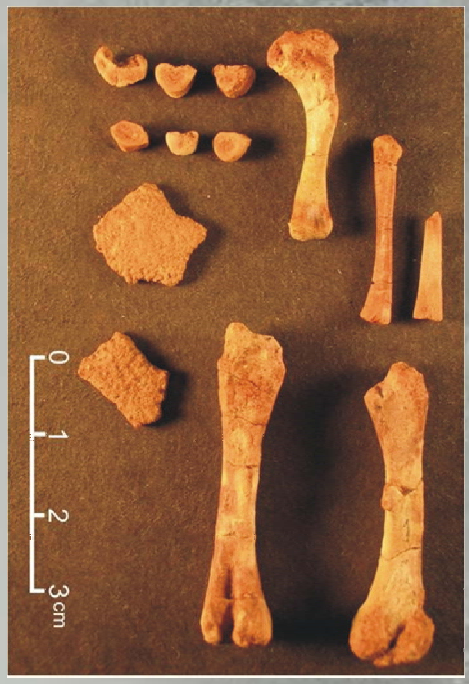
Dromaeosauridae
Age: Lower Cretaceous (Barremian)
Environment: continental
Description: Theropods are a group of dinosaurs including carnivorous bipedal forms. Their anterior extremities are shorter than the posterior ones and they are provided with claws and sharp teeth. The tooth shown here belongs to a Dromaeosauridae that is a family of bird-like theropod dinosaurs. They were small- to medium-sized feathered carnivores that flourished in the Cretaceous Period. The name Dromaeosauridae means 'running lizards. The tooth was discovered in Vallipón site (Castellote).

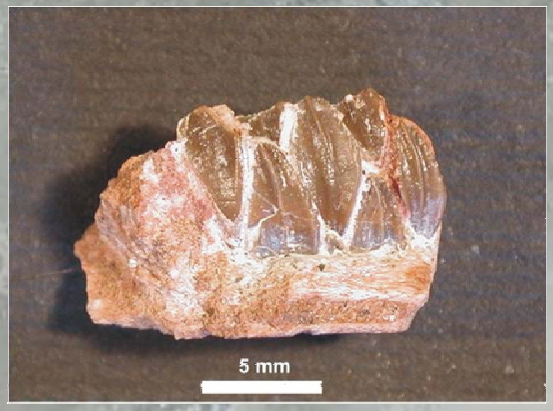
Theriosuchus sympiestodon
Age: Upper Cretaceous (Maastrichtian)
Environment: continental
Description: *Theriosuchus* is an extinct genus of terrestrial mesoeucrocodylians, quite common in the Late Jurassic of Europe and Lower Cretaceous of Asia, but not known, since few years ago, from the Late Cretaceous. *Theriosuchus sympiestodon* from the Hateg Basin appears thus as a surviving species of this group of crocodilians. (Scale divisions 1 cm).

Magyarosaurus sp.
Age: Upper Cretaceous (Maastrichtian)
Environment: continental
Description: One of the smallest genus of sauropods (no more than 6 m length) which are known by the largest sizes among the dinosaurs (Supersaurus up to 34 m). The dwarf size of *Magyarosaurus* is explained, as in the case of other dinosaurs from the Latest Cretaceous of Transylvania, by the pressure of the restricted areas (insular dwarfism). However *Magyarosaurus* was among the other dinosaurs from Transylvania the “giant of the dwarfs”. (Scale divisions 1 cm).



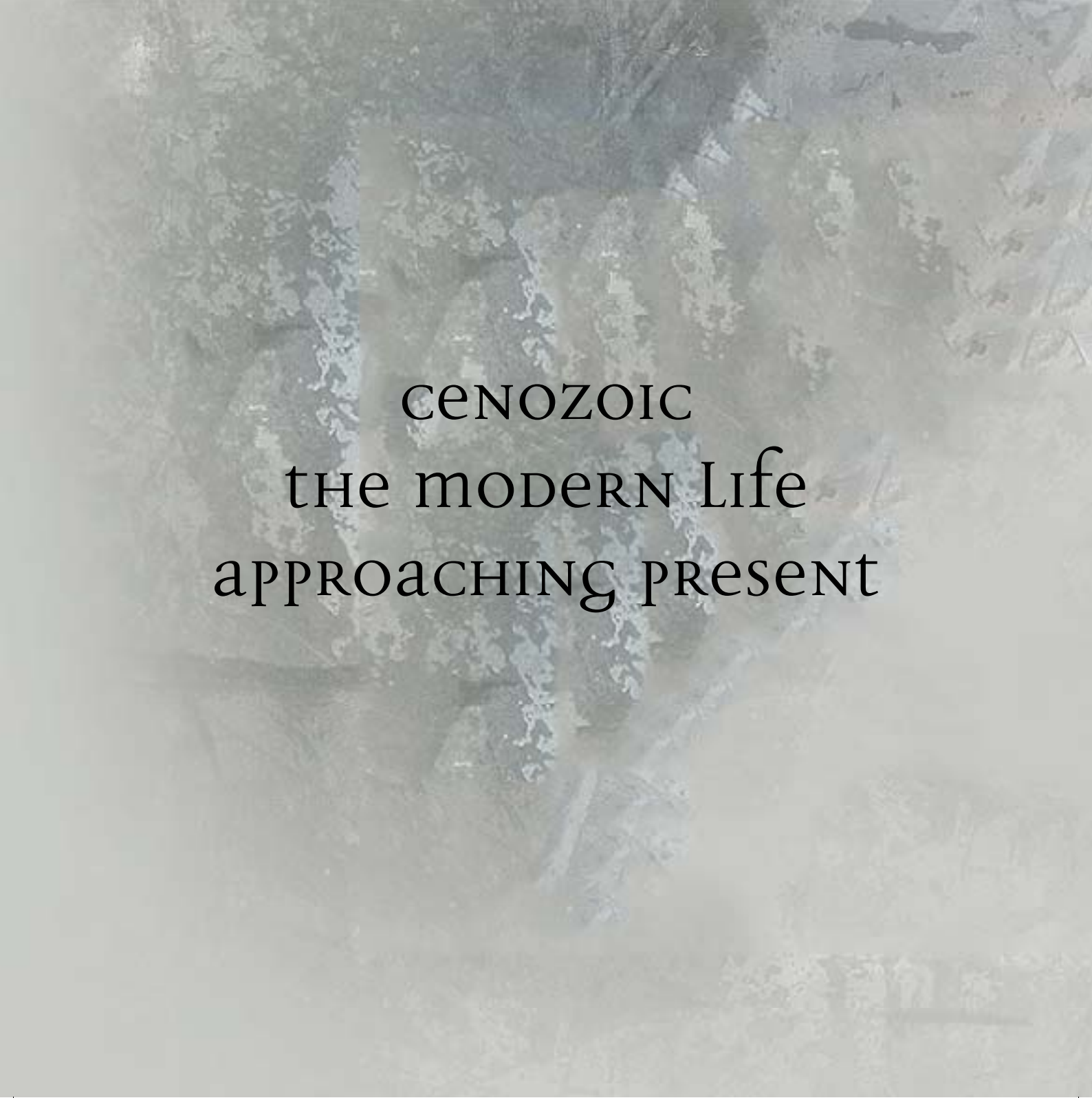
Theropods
Age: Upper Cretaceous (Maastrichtian)
Environment: continental
Description: Alongside crocodiles and giant flying reptiles, the carnivorous (theropod) dinosaurs were the top predators of the Late Cretaceous ecosystem from the Hateg Basin. Their great diversity is suggested by the several different tooth morphotypes discovered, some of them pointing to the presence of dromaeosaurids and troodontids. As the other dinosaurs from the Hateg Basin, they were small, no more than 1,2 m length and 0.7 m high.





Megaloolithid eggs and *Telmatosaurus transsylvanicus*
Age: Upper Cretaceous (Maastrichtian)
Environment: continental
Description: A large number of dinosaur egg clutches with spherical eggs ornamented on the surface by dense tubercles (megaloolithid type of eggs) were found in few sites from the Haţeg Basin. In the first discovered site from Tustea which also provided the largest number of eggs, numerous hatchling remains were found nearby or inside the clutches. Surprisingly the hatchlings belong to the ornithopod – "duckbill" – dinosaur *Telmatosaurus transsylvanicus*, although the megaloolithid eggs are commonly associated with titanosaurian sauropods. This fact is known to the dinosaur egg specialists as the "Tustea puzzle".

Barbatodon transylvanicus
Age: Upper Cretaceous (Maastrichtian)
Environment: continental
Description: Transylvania (including the Haţeg Basin) is the only place in Europe where multituberculate mammals were discovered in the Upper Cretaceous deposits. The local fossil record boasts many endemic taxa (including *Barbatodon transylvanicus* and *Kogaionon ungureanui*), found alongside dinosaurs. Such multituberculates survived the extinctions at the end of the Mesozoic and became widespread in Europe during the Early Paleogene. (Scale divisions 1 cm).


cenozoic
the modern life
approaching present

cenozoic –the modern life approaching present

The Cenozoic Era is the current and most recent as well as the shorter of the geological Eras. During the Cenozoic, covering the period from 66 million years ago (Ma) to the present, the geography of Europe is gradually taking place. The land masses, oceans and the biosphere composition move to give the world as we know it today.

From a palaeogeographic point of view, the redistribution of the continents that began in the Mesozoic Era with the breakup of Pangea and the Alpine cycle continues. Thus, the Tethys, the great ocean that separates Africa from Eurasia and which connects the Atlantic and the Indian Ocean, gradually closes by the convergence of Africa, Arabia and the Indian subcontinent towards Eurasia. It remains today as the Eastern Mediterranean and the Black Sea. These movements are at the origin of the reliefs of the alpine orogeny: Alps, Pyrenees, Atlas, Apennines, Balkans, Carpathians, Anatolia chains, Caucasus, Himalaya, etc.

In addition, Greenland separates the Canada first, then Scandinavia offering a passage between the Atlantic and the Arctic Ocean (55.5 Ma). Passages open between Tasmania and the Antarctica (34 MYA) and between Patagonia and Antarctica (29 Ma).

The combined effect of the orogens and changes in ocean currents played an important role on the climate and biosphere throughout the Cenozoic.

During the Cenozoic life is marked in particular by the diversification of marine and continental organisms including mammals, particularly hominids, as well as flowering plants (Angiosperms). In the seas, after the disappearance of ammonoids, modern faunas are implementing. Molluscs (bivalves, gastropods), bryozoans, echinoids... develop. Fish actinopterygians are diversifying as well as microplankton (foraminifera...).

On land, the Angiosperms, which have begun to diversify at the end of the Mesozoic Era, produce various biological forms. They colonize all ecological niches and deeply modify the landscape. This rapid diversification is in close relation to that of insects (co-evolution).

In Europe, the beginning of Cenozoic vegetation is particularly adapted to heat (Laurel, camphor, persimmons...). The global climate is hot and humid. The continents are covered with rainforests to subtropical, wooded savannas and the highest latitudes of deciduous forests. At the dawn of this new era, mammals, very primitive and of small size, are represented by the Cretaceous survivors.
Gradually, tropical forests give way to training more temperate in willows, alders, birches, oaks...

At the Paleocene-Eocene boundary (55.5 Ma), a biological crisis profoundly affects mammals. It is the time of a thermal maximum.
New types of mammals are appearing and diversifying to the Eocene, in a climate still hotter: rodents, carnivores, ungulates, and bats, primates, etc. These mammals include for example the primitive fox-sized 'horse' Hyracotherium, or even the pangolin Eurotamandua discovered on the exceptional site of Messel in Germany. Late Eocene and early Oligocene, the climate became cooler and dry. An ice cap is formed on Antarctica. In Europe, seasons are in place.

Some extinction waves affect the mammals that were better adapted to the warmer climate of the Eocene. At that time, a big geographical change occurs: Europe, which was a vast isolated island from other continents by various arms of the sea, is found again in contact with Asia, due to a sea-level fall. Therefore, this link will allow the migration to a new fauna that competes with native wildlife: rhinoceros, entelodonts (kinds of giant Warthogs), primitive deer, rabbits, beaver... This event is called the "la grande coupure".

mesozoic
the Life between oLd and new marine dweLLers

In the Miocene (23-5.3 Ma), the climate becomes hot and dry results in a deep change of vegetation. Garrigue and Mediterranean-type forests are in place.

Continental faunas are almost modern. In Europe, particularly can be found species related to horses, deer, camels, elephants, rhinos... to bears, hyenas. All or almost all families of birds exist at the end of the Miocene. Early hominids appear in Africa at about 7 Ma ("Toumai"). During the Pliocene, the vertebrate fauna acquires its modern characteristics.

1.6 million years ago, during the Pleistocene, the world enters a period of alternating glacial and interglacial phases. Continental glaciers descended to the 40th parallel! The Scandinavian icesheets extends until Britain. Alpine glaciers extend to Lyon. Glacial advances produce continental glaciers in thicknesses from 1500 to 3000 meters. These climatic conditions have an impact on the flora and fauna. Polar forests of coniferous (Taiga) and tundra cover the colder areas and many animal species disappear or migrate in milder areas. Then, there remain the great mammals with woolly fleeces, woolly rhinoceros, mammoth, cave bear, reindeers, aurochs, horses, rodents, adapted to these extreme conditions.

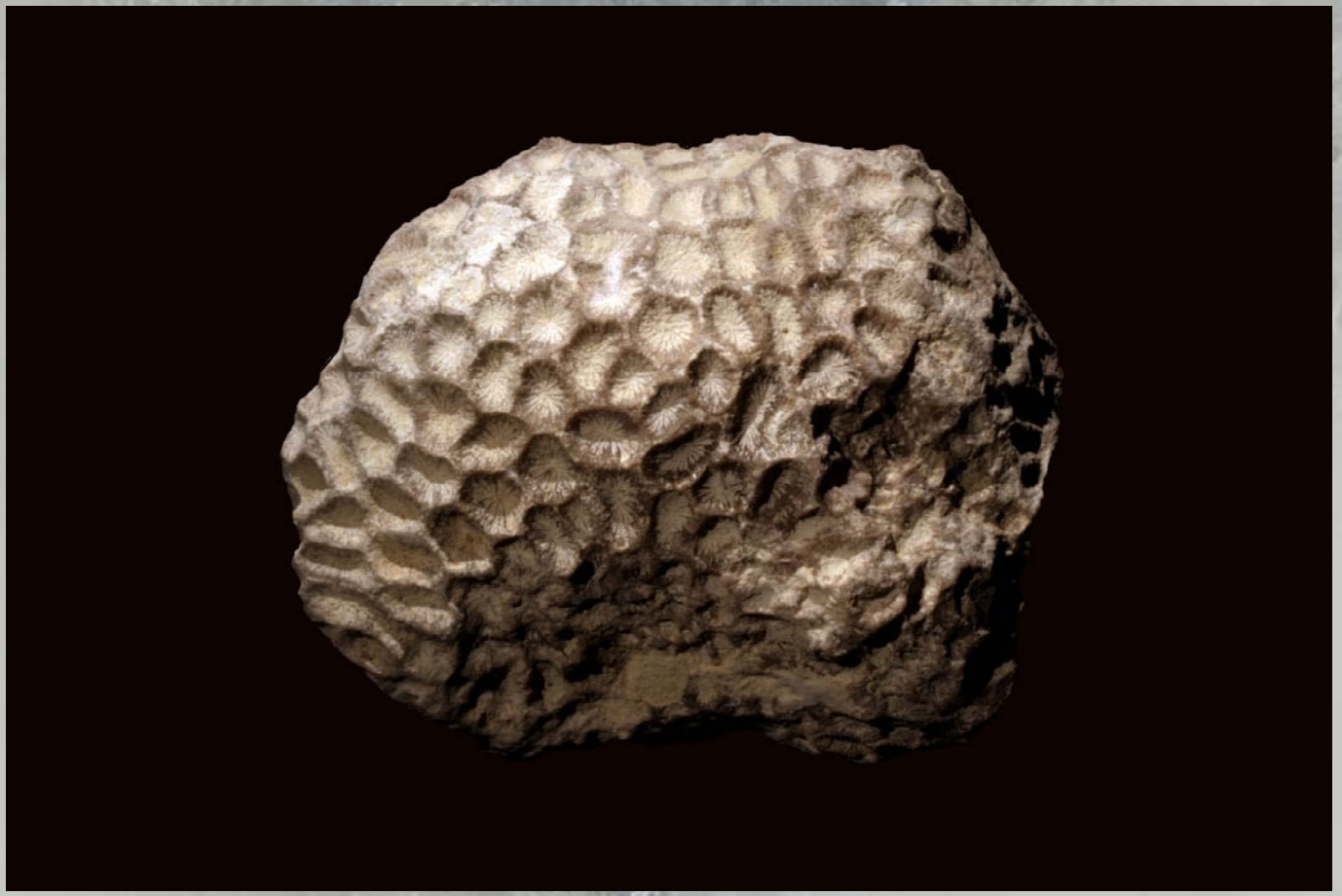
Meanwhile, Homo erectus, which appeared in Africa 1.8 million years ago, leaves the African cradle of Humanity and occupies Eurasia. Between 45000 years ago and 30000 years ago, Neanderthal man and modern man live together in Europe. And today there is only one left, *Homo sapiens*, with a very short life (about 120000 years) comparing to the mammals history, began more than 200 million years ago.

Stéphane Legal
Park Naturel Régional du Luberon – FRANCE

Saerichnites abruptus
Age: Eocene
Environment: marine
Description: The specimen discovered a few years ago in the Eocene cliffs of the Geopark is by far, the biggest Saerichnites ever found in the world. A complex rescue campaing had to be organized because the bedding was cracked and it could have detached and fall down. The specimen is hosted and shown in the Algorri Interpretation centre.

Scholicia sp.
Age: Miocene (Lower Tortonian)
Environment: marine
Description: Temperate carbonates of the red unit at “Cañada Mendez Geosite”, near Agua Amarga town. This carbonates belonged to a shallow platform with salinity and temperature similar to modern Mediterranean. Is a bioclastic deposit, mixed with sand from lower vulcanoclastic unit. Abundant fragments of Bryozoans, bivalves, echinoids and benthic foraminifers, with small amounts of barnacles, brachiopods, coralline algae and solitary corals.

Foraminiferi bentonici
Age: Paleogene
Environment: marine -tropical shallow waters-
Description: The Foraminifera are unicellular marine organisms and many of them have a calcareous complex test; their fossil remains can be found in some of the rocks in the Madonie. Between the benthic larger (bottom-living) Foraminifera in the Madonie the more widespread are Nummulitids, Alveolinids and Lepidocyclinids, that are important for giving an age to the rocks. In particular the Nummulitids (disk-shaped animals, up to several centimetres in diameter) with the genus *Nummulites* and *Assilina* are guide fossils for the Paleogene. They can be found inside the Numidic Flisch and the Polizzi Formation.



Antiguastraea cvijici OPPENHEIM, 1906
Age: Eocene (Priabonian)
Environment: marine, barrier reef
Description: Reef-builder colonial coral of the Favids family. Polipers are mainly globular but also flattened and are built up of polygonal cups separated by well defined walls. Septa are thin and abundant. The small column at the middle of the cup can also be recognized. Locality: Navarcles

Septastraea sp. (Rhizangiidae)
Age: Upper Oligocene
Environment: marine
Description: The site of Maddalena-Ponte Prina (near Sassello, Ligurian region) has particular importance for the presence of a small, but very good coral-reef, were the colonies, often very large, are generally still in situ and with a growth form prevalently massive. This assemblage is representative of a tropical marine environment in shallow waters with high energy. *Septastraea*, an encrusting form, belongs to Rhizangiidae, a family actually present with few genus only in th Atlantic Ocean.

Faviidae sp.
Age: Upper Oligocene
Environment: marine (tropical shallow waters)
Description: Within the assemblage of Maddalena-Ponte Prina are well represented the Faviidae, the sole family of hermatipic corals dominant both in the Mesozoic and in the Cenozoic. In this site are common the “brain corals”. This name is due to their generally spheorid shape and grooved surface which looks like a brain; these typical corals are dominant in post-Paleozoic reefs.

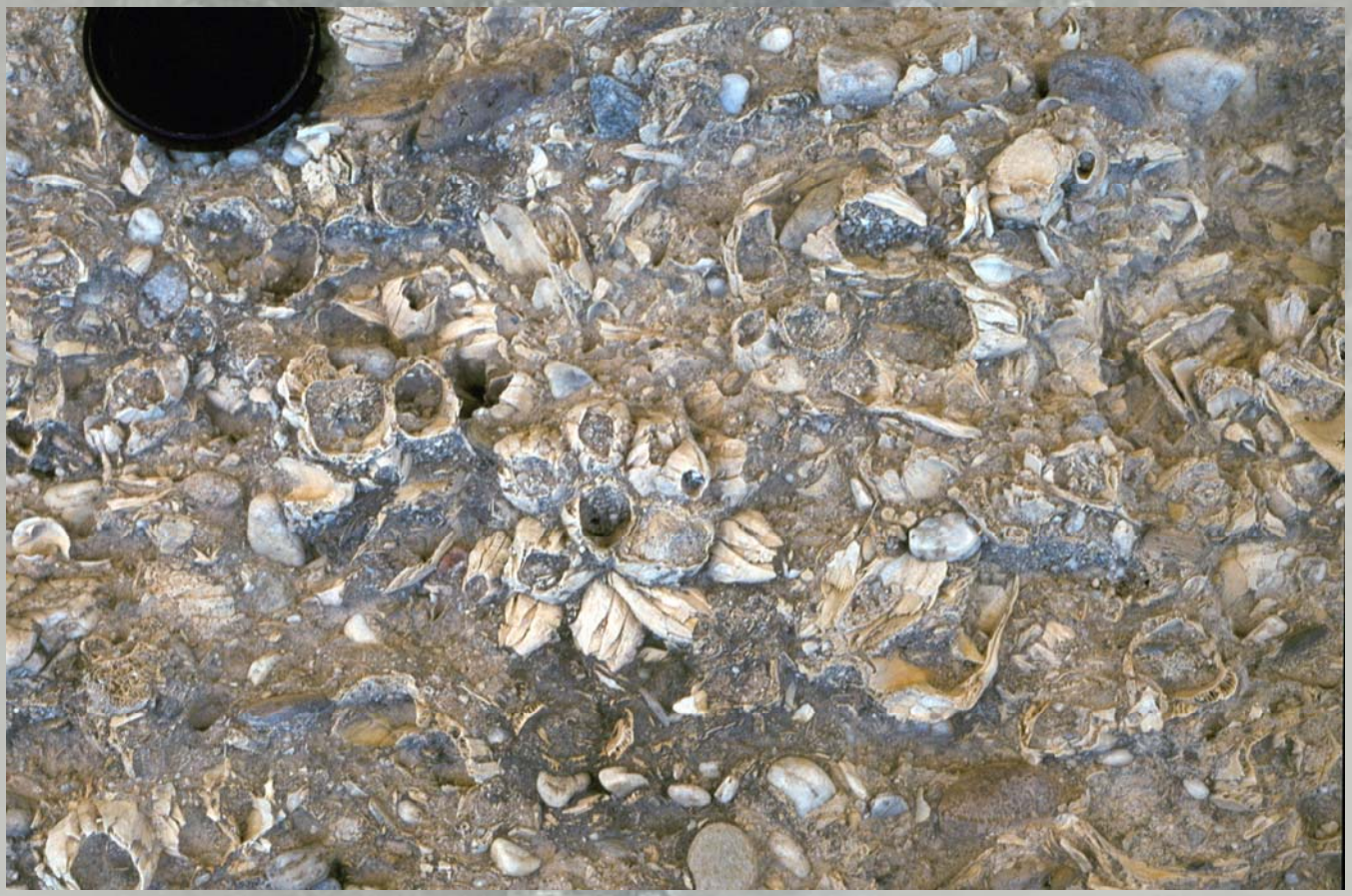
Tarbellastraea
Age: Miocene (Messinian)
Environment: marine
Description: During the Messinian, coral reefs stand in isolated pinnacles or bioherms. These reefs are mainly formed through the accumulation of the calcareous skeletons of corals belonging to several genera, as *Porites*, *Siderastrea* and as reflected in the picture, *Tarbellastrea*. Between the coral colonies lived algae and invertebrates, who also contributed to the formation of carbonate sediment.

Campanile lachesis BAYAN 1870
Age: Eocene (Bartonian-Priabonian)
Environment: marine
Description: Large-sized gastropod mollusk from the Ceritid family. The Shell is coiled in a conic spiral, with spires being ornamented with more or less rounded tubercles. The apertural area is rarely fully preserved. Internal casts are more frequent and display smoothed spires. Local people have always been attracted by the large size of these fossil. Paleoenvironment: Shallow coastal environments of coarse grained grounds. Locality: Sant Salvador de Guardiola

Vermetidae
Age: Miocene (Tortonia-Messinian)
Environment: marine
Description: Facies linked to submarine cliff at Ricardillo Geosite. This vermetid reef covered an extense part of the the western area of the volcanic dome of the “El Ricardillo” hill in the transit Tortonian – Messinian. This vermetids growth perpendicular to the cliff wall and only the cast is preserved. The facies located at this Geosite is specially relevant given that allows to reconstruct a special episode of the local paleogeography.

Ostrea
Age: Pliocene
Environment: marine
Description: Located at the Agua Amarga basin, with and independent sedimentary evolution resulting in a unique stratigraphic record that favour the analysis and stratigraphic relationship with the volcanics in the Geopark. These deposits belongs to a thin unit of calcareous conglomerate and sand beach deposits that completes the stratigraphy of this basin.

Strombus bubonius
Age: Quaternary
Environment: marine
Description: Located at the beach of Carboneras town, these are the largest *Strombus Bubonius* fossils found in the Geopark. Is tipically found in conglomerates, separated in different beaches through erosive surfaces generated during the falling of the sea level in cold periods.



Balanidae
Age: Pliocene
Environment: marine
Description: Located in Carboneras basin, in the trench of the old mining train of mineral of Agua Amarga.
The North West part of the Geopark, the Agua Amarga and Carboneras basin, reflects a less developed volcanic episode with a more presence of marine deposits, either intervolcanic and postvolcanic.

Bryozoan
Age: Miocene (Tortonian-Messinian)
Environment: marine
Description: Temperate carbonates in the transit Tortonian – Messinian with a large accumulate of branchy bryozoan at the bottom of the paleocliff. The facies located at this Geosite are specially relevant given that allows to reconstruct a special episode of the local paleogeography, with a geographic inversion of the relief where the sea open out inland and the emerged relief (volcanic) stood at what is nowadays the sea.

Eupatagus sp.
Age: Eocene
Environment: marine
Description: It is an irregular sea urchin genus with oval test and bilateral symmetry. Oral surface is plane, with rounded edges, slightly depressed around the peristome. Aboral surface is convex bearing four gonopores. The rare end is narrow, cut vertically with a well developed oval periproct. There are abundant ball-like mamelons on the oral surface. Ambulacra are petal-like, nearly superficial, getting thinner towards the margin of the shell. It lived slightly buried in the substratum, in marine deposits near the coast.

Eupatagus (Brissoides) ornatus DEFRANCE
Age: Eocene (Bartonian)
Environment: marine shelf
Description: Irregular echinoid of the Brisids family. Exoskeleton of ellipsoidal-oval shape. Ambulacral system of five star-arranged strips, being four of them symmetrical (in two pairs); the fifth is less defined and is longitudinally aligned. Interambulacral bumps are rather outstanding. Peristome and periproct (bucal and anal apertures, respectively) are easily observed. Locality: Sant Vicenç de Castellet

Shark teeth
Age: Lower Miocene
Environment: marine
Description: 23 million-year-old sediments, the ooze once at the bottom of a tropical sea, are exposed at the beginning of the path. At the bay of a coastal zone the famous stratum containing sharks' teeth was accumulated by the wave action of an ancient sea. In addition to the sharks, remains of rays, bony fish, bones of crocodilians, dolphins, and manatees are also present in the sandstone. After its 1903 description by Koch, the 'Ipolytarnóc shark tooth-bearing bed' became the characteristic, marker bed of the Eggenburgian stage of the Lower Miocene in the Central Paratethys.

Tomistoma sp.
Age: Eocene
Environment: Marine
Description: The mandible of the “Lamata crocodile” surpasses 70 cm in length. It is long and thin, so adapted to catch and eat fish. Its front part presents nearly parallel sinuous edges; we can see alternating protuberances associated to the teeth and to the constrictions which separate them. The lower surface main characteristic is its roughness. It is, probably, the most complete mandible of marine crocodile recovered until present in the Eocene of Spain. It belongs to a genus related to *Tomistoma.*

Sirenian
Age: Eocene
Environment: marine
Description: The Sobrarbe Territory houses one of the most important findings of vertebrate fossils from the Eocene in Europe. Deltaic facies of the Sobrarbe Formation (Ainsa Basin), dated as Upper Lutecian, yielded the oldest and most complete fossils of sirenians (sea cows) in Europe. During the palaeontological works, started in 2009 by the "Aragosaurus Group -IUCA Zaragoza University", several crania, some scapular blade bones, and abundant complete vertebrae and ribs, were recovered. Photograph of one of the Eocene outcrops with sirenia ribs in The Sobrarbe Territory.

Pteris urophylla
Age: Oligocene
Environment: continental
Description: Within the Tertiary Piedmont Basin the site of Stella Santa Giustina (Ligurian Region) assumes a particular importance for the presence of a diversified and well preserved fossil flora mainly composed of Pteridophytes, Gymnosperms and Angiosperms. This association can be compared to those of tropical basal and pre-montane altitudinal belts in the today Tropical Western Hemisphere. *Pteris urophylla* is a fern belonging to a genus today very common in the tropical and temperate-warm areas.

Pinoxylon paradoxum
Age: Miocene
Environment: continental
Description: One of the most common species in the Lesvos Petrified Forest Park. Characteristics of this trunk include extremely well-preserved bark and annual rings. The fine state of the annual rings provides valuable information regarding both the age and stage of development of the tree prior to and at the time of silicification. The trunk belongs to the Protopinaceae family, an ancestor of today's pine tree. The trunk displays varied coloration due for the most part to trace elements in the siliceous solution that caused fossilization. A large section of this trunk (1.00m high, 2.30m circumference) still remains buried. It stands in the Petrified Forest Park, where the intermingling of the Protopinaceae with the sequoia forest is observable.

Taxodioxylon albertense
Age: Miocene
Environment: continental
Description: The largest standing trunk of a petrified tree known so far in Europe can be found in the Lesvos Petrified Forest Park. It belongs to a conifer tree of the Taxodiaceae family, an ancestral form of Sequoia (*Taxodioxylon albertense*). Its height is 7.02 and its circumference 8.5 metres. It forms the lower part of the trunk, from which the branches of the root system start out. For hundreds of years this plant grew in the dense sub-tropical forest of Aegeis, until the intense volcanic activity during early Miocene times, which caused it to be robbed of its life gave it the passport for a journey into eternity.

Taxodioxylon gypsaceum
Age: Miocene
Environment: continental
Description: A typical standing petrified tree trunk in the Lesvos Petrified Forest Park representing an ancestral form of Sequoia (*Taxodioxylon gypsaceum*). It was exposed by natural erosion of the volcanic rocks. The trunk shows the excellent preservation of its external and internal structures. Its height is 4.50 and its circumference 3.70 metres. It is a precursory form of the present-day sequoia (*Sequoia sempervirens*). The Lesvos Petrified Forest is a world-famous natural monument comprising of hundreds tree trunks, fossilised in-situ after their covering by pyroclastic material and mud-flows, following volcanic eruptions in early Miocene times, covering an area of 15.000 hectares at the western coast of Lesvos island, Greece.

Pinoxylon paradoxum
Age: Miocene
Environment: continental
Description: Standing petrified trunk of a precursory form of pine (*Pinoxylon paradoxum*) in the Lesvos Petrified Forest Park. At the base of the trunk it's root system in full development bears testimony that the Petrified Forest of Lesvos is autochthonous, meaning that the trees were located in their growing position prior to silicification. The upper part of the tree trunk could not withstand the violent volcanic explosion during early Miocene times, was detached from its root system and carried off by the pyroclastic materials whose onrush flooded and covered the forest.

Tetraklinoxylon velitzelosi
Age: Miocene
Environment: continental
Description: A gigantic, lying petrified trunk of a conifer tree belonging to the cypress family. The trunk is an ancestral form of the cypress (*Tetraklinoxylon velitzelosi* SÜSS) whose present-day relative grows in the Iberian Peninsula. This is a newly-discovered species, identified for the first time in the Petrified Forest Park. The collapse and fragmentation of the trunk is due to natural erosion of the volcanic rocks which surrounded and supported it. Today, large sections of the trunk are on the ground, next to the tree's root knot.

Petrified forest
Age: Miocene
Environment: continental
Description: The area came to the attention of scientists with a fantastic phenomenon of nature. The Borokas stream exposed a gigantic petrified tree from the embedded layers, and its trunk, a 40-42 m- long natural stone bridge spanned the ravine by the end of the 18th century. Its fame attracted Ferenc Kubinyi to the area in 1836, who started the first scientific excavation of the site with that very tree, which proved to be the largest petrified pine in the world! A petrified forest rests under the cover of volcanic debris. Petrified tree logs along the geological trail A volcanic catastrophe destroyed the environment of ancient Ipolytarnóc 20 million years ago. The grey volcanic rock, rhyolite tuff, which demolished the paleohabitat, contains the charred remnants of the ancient vegetation.

Angiosperm
Age: Miocene
Environment: continental
Description: This arrow-straight trunk of an angiosperm tree on the shore of the Plaka Petrified Forest Park near Sigri village is a testimony for the continuation of the Petrified forest in the marine area of West Lesvos island. It was revealed by the natural weathering of the volcanic rocks which surrounded it. It is 14 meters long and it's greater part extends into the sea. The external surface of the trunk retains all the characteristic features of the tree and the endings of its branches.

Annonoxylon teixeirae
Age: Miocene
Environment: marine
Description: Rare fossils from this relative of the annona tree were found in Vila Velha de Ródão. They were found piled together in the tailings of a gold mine exploited in the fluvial terraces from Tejo River during the Roman period. This species characteristic of past climates hotter than nowadays in the region has lived and died here more than 5 million years ago in the riverside, slowly rotting while being home and food for insects. A flood buried the remains under a sand layer, favoring fossilization by replacement of cell walls by silica. The Tejo River has eroded the sand formations and energetically transported the fossils until deposited them in the fluvial terrace where they were lately found.

Eotrigonobalanus furcinervis
Age: Oligocene
Environment: continental
Description: The Santa Giustina fossil flora is characterized by a dominance of Angiosperms Dicotyledonous; within these are abundant very large leaves of these species typical of a riparian habitat or an environment with abundant water supply. The fossil genus *Eotrigonobalanus* is close to living *Trigonobalanus* which is actually represented only by three tropical species, the last members of an ancient group from which probably derived living beechs and oaks.

Flabellaria mediterranea
Age: Oligocene
Environment: continental
Description: The Santa Giustina flora is also characterized by a common occurence of large Arecacean (palms) remains; this family, is actually very common in tropical, subtropical and temperate-warm areas. The specimen of the fossil genus *Flabellaria* here presented is very good and large: a fan-shaped leaf with a lenght of 130 cm and a width of 100 cm.

Tuff with fossil leaves
Age: Pleistocene-Holocene
Environment: continental
Description: Water is the responsible of the origin of this rock. Some 18.000 years ago, the springs that arose in the flanks of La Tiñosa Mountain begun to precipitate calcite. Their waters deposited carbonate that covered branches, leaves, snails, and all living or inert surfaces that found in their way. When organic matter decayed inside the carbonate mass, a very porous rock with casts of the living organisms that inhabited the surroundings of springs was formed. During thousands of years a vast platform of tuff grew in this area, where the ancient village of Priego de Córdoba was strategically settled.

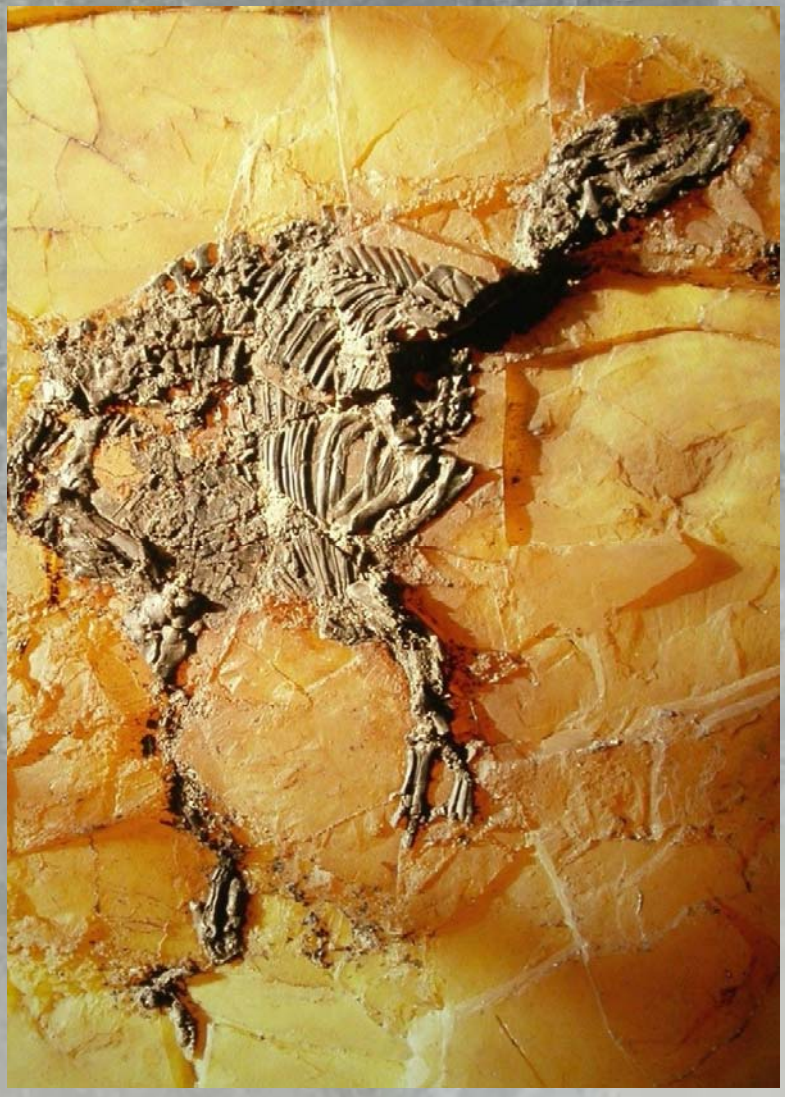
Pecoperida velox
Age: Oligocene (Rupelian)
Environment: terrestrial
Description: Several limestone slabs covered with mammal footprints have been discovered in Luberon. Such sites are surprisingly quite rare with about 60 known records worldwide, mainly in the Cenozoic and before the Holocene. Animals walking on the shores of lakes printed their tracks in the mud; the deposition of new layers of mud has preserved the footprints for 30 million years, until the erosion emerges them. The study of these sites has helped to highlight several types of footprints of mammals, musk deer, entelodonts and rhinoceros coming from Asian region.

Fossil tracks -carnivore and rhinoceros footprints
Age: Miocene
Environment: continental
Description: The outcrops of the middle part of the path are dominated by 21- 20 million-year-old terrestrial strata. Unique snapshots and life traces have remained on the paleosurface, mostly in the form of footprints left at the ancient watering places and fords. At the excavations along the path, which accidentally winds over the location of an ancient riverside beach, more than 3 thousand footprints of 11 different animal species have been identified so far.

Lethe corbieri
Age: Oligocene (Rupelian)
Environment: terrestrial –lacustrine
Description: Fossils of butterflies are very rare and the state of conservation of this specimen from the Luberon platy limestone is exceptional. This butterflies grou,p as well as many other Luberon fossils of insects, is now known in the Indo-Malayan region. The presence of these insects in the Oligocene rocks of south-eastern France suggests a hot and humid paleoclimate.

Dapalis macrurus
Age: Oligocene
Environment: lacustrine
Description: This species lived in abundance in the vast freshwater lakes covering the Luberon. It is a perch related to living asiatic glassfishes of the indo-australian region. Individuals of average size gathered in shoals near the lake while some alone individuals swimming in deep waters could reach large size.

Threskiornithidae sp.
Age: Oligocene (Rupelian)
Environment: terrestrial lacustrine
Description: This bird is amazing by the exceptional conservation of feathers on its right wing. This "ibis" is the first representative of its family known in the Oligocene of Europe. Comparing with present Ibis, the Luberon Ibis probably took food in the vast lakes covering the region at that time and might fly over the forest around.

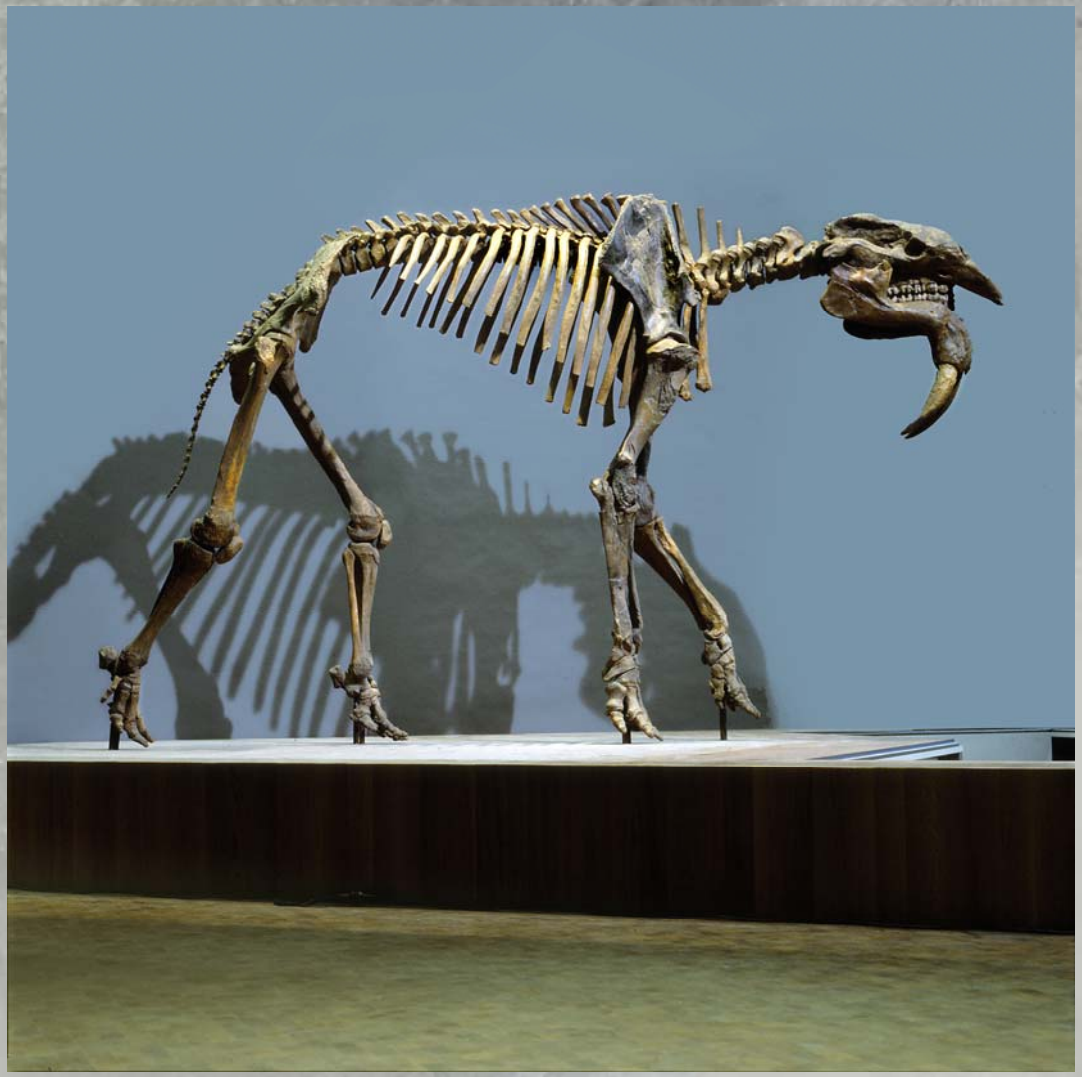


Propalaeotherium voigti
Age: Eocene
Environment: continental
Description: The oldest maar of the Eifel is the Eckfeld Maar (diameter 800-1000 m; depth ~ 200 m). It is 45 millions years old and located near the southern edge of the High-Eifel Volcanic Field nearby the town of Manderscheid. The bituminous laminites of the lake facies contain a large number and great variety of well preserved terrestrial, amphibious and aquatic fossils ranging from complex organic molecules to mammals, including early horses. Of importance is the almost complete and articulated skeleton of a pregnant mare of *Propalaeotherium voigti*. It is the first fossil mammal ever discovered that displays remains of the placenta. All together the fossil record documents a highly diverse terrestrial flora and fauna of a subtropical continental forest. Fossil & Photo: State collection for Natural history of Rhineland-Palatinate

Lophiodon sp.
Age: Eocene
Environment: continental
Description: The “Abizanda femur” belonged to the skeleton of an animal related to the genus Lophiodon. Lophiodontids were perissodactyl, herbivorous mammals, which shared some characters with tapirs and rhinoceroses. This femur is outstanding because of its large size (about 60 cm in length) and good preservation. It is a bit flattened, due to post sedimentary geological processes. It shows a peculiarity: there is a small reptile tooth incrusted. It is thought that the herbivorous suffered an attack, which led to its death. It lived during the Eocene.

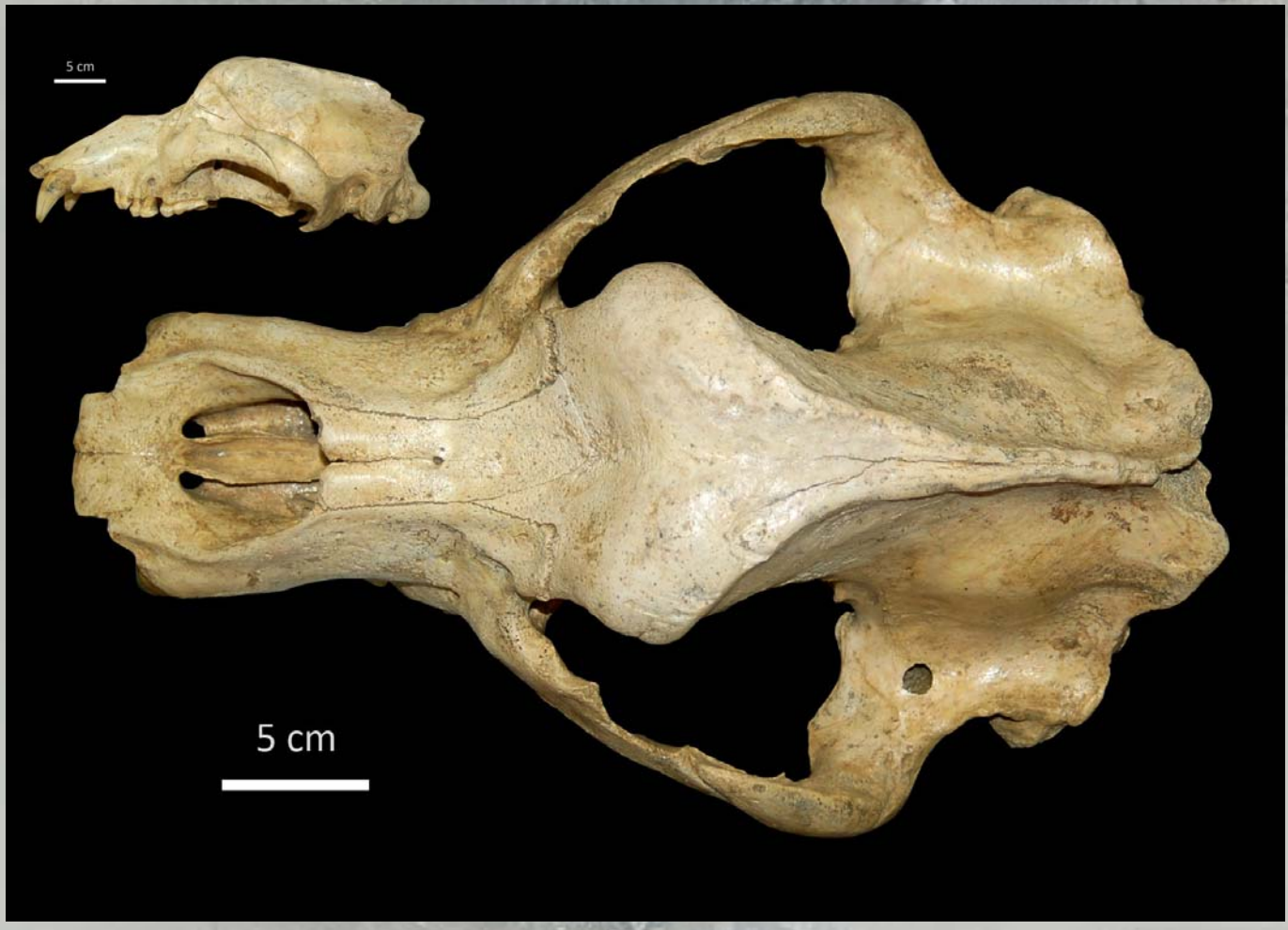
Crivadiatherium iliescui
Age: ? Middle Eocene
Environment: continental
Description: *Crivadiatherium iliescui* is a member of the embrithopods (*Embritopoda*) , an order of large herbivorous mammals which resemble the modern rhinoceros, limited in time to Middle Eocene- Lower Oligocene. Only four embrithopod genera are known, in Egypt,Turkey Mongolia and Romania (Hateg Country Geopark). Up: Left lower cheek teeth (M2,M3) in occlusal view; Bottom- the same in lateral view.

Cervid
Age: Miocene
Environment: continental
Description: The lake sediments of the impact crater of Steinheim am Albuch in Southern Germany contain a wealth of 15 million years old fossils. The *in situ* skeleton of a cervid (*Euprox*/*Heteroprox)* documents the excellent preservation of the fauna and flora of this locality.



Deinotherium neu
Age: Miocene
Environment: continental
Description: 18 million years ago a big change happened within the composition of European mammal faunas. New animals invaded the continent because of the first land contact of Africa with Europe. Among the newcomers there were also proboscideans. Several skeletons of *Prodeinotherium*, an animal with a remote relationship to the elephants, but largely differing by its proportions and by its tusks in the lower jaw, have been excavated on the southern slope of the Swabian Alb at Langenau.

Ursus ingressus
Age: Quaternary (Upper Pleistocene)
Environment: continental
Description: The fragment of the upper jaw shows the impressive teeth of a cave bear found in a cave in the Eisenwurzen Geopark. Late Paleolithic stone tools recorded together with the skeletal remains reveal an age of 34.000 to 39.000 years. They are the oldest witnesses of humans in this mountainous region.



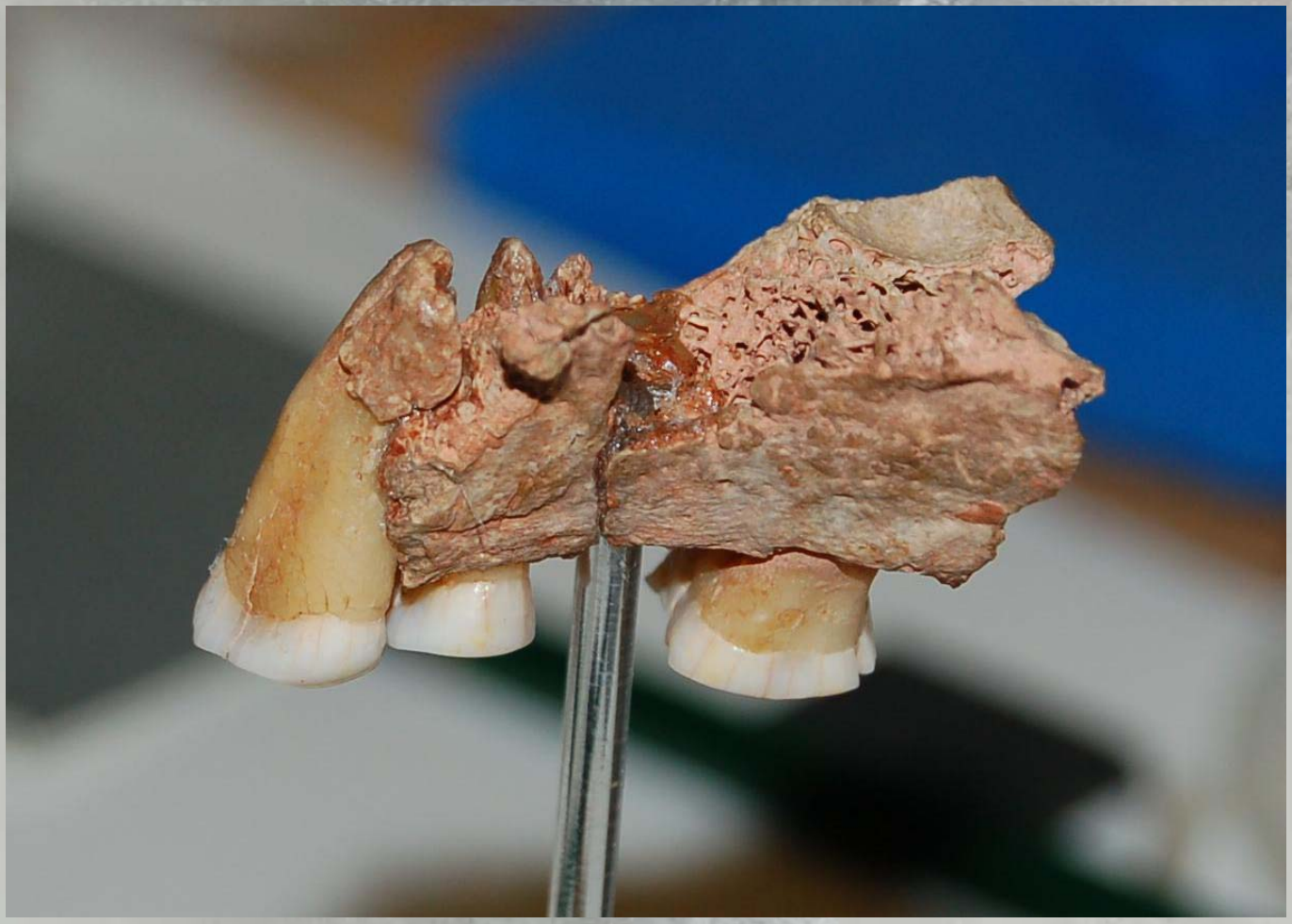
Ursus spelaeus
Age: Quaternary (Upper Pleistocene)
Environment: terrestrial
Description: In the surroundings of Tella municipality (Sobrarbe, Spain), inside a cave placed at an altitude of 1,600 metres, more than 4,000 bear bones, which are about 30,000 years old, were recovered. *Ursus spelaeus* is an extinct species of large sized bear which lived in the Pleistocene. These animals had a bulky body, reaching more than 3 meters in upright position and weighing over 400 kilograms.

Ursus spelaeus
Age: Quaternary (Upper Pleistocene)
Environment: continental
Description: One of the most impressive members of the Pleistocene megafauna is the cave bear. In karstic areas like the Swabian Alb in Southern Germany its remains have been found in many caves. The mounted skeleton from the Hohlestein cave has been composed of isolated bones from different individuals.

Ursus spelaeus (skull of the cave bear)
Age: Quaternary (Upper Pleistocene)
Environment: continental
Description: Cave bears are among the most impressive animals from the Ice age. They can bee found in many caves around Europe in sediments dating from the last glaciation. The dentition of the skull from the Hohlestein cave on the Swabian Alb (Southern Germany) shows that these animals were largely herbivorous.

Ursus spelaeus
Age: Quaternary (Upper Pleistocene)
Environment: terrestrial
Description: Lateral view of a skull (upper left) with loss of left zigomathic arch and worn out dental series (M2/, M1/, P4/, C/, I3/, I2/, I1). Lateral view of a left hemimandible (lower left) with loss of the inner part of the articular condile and incisors, while remaining dental series build up by P4, M1, M2, M3 and the canine. Frontal view of another skull (right). Images composition (not to scale) belongs to three different individuals. Locality: Sant Vicenç de Castellet

Macaca sylvana florentina
Age: Upper Pleistocene
Environment: continental
Description: During the oldest part of the Ice age primates lived in large parts of Europe. Their fossils are always rare anyway: the jaw of a macaque (*Macaca sylvana florentina*) has been found in the Heppenloch cave. It is the only finding on the Swabian Alb in Southern Germany of a genus, which survives nowadays in Europe only on the rock of Gibraltar.



Homo sapiens
Age: Pleistocene
Environment: continental
Description: The area of the English Riviera Geopark provides one of the longest records of no glacial Pleistocene events not only in Southwest England but also in Western Europe. The maxilla fragment known as Kents Cavern 4 may be the oldest example of a modern human in Europe, dating back to 37,000–40,000 years ago-. The maxilla include three teeth, of the earliest known modern human in Europe, discovered during excavations at Kent's Cavern, Devon, in 1927. .

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European Geoparks

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AVANZADO

Geologists at Gerolstein Train Station, 1886

Description: In the 19th Century scientists and students from then famous, emerging geological faculties at Heidelberg, Marburg, and Jena Universities performed their weeks long summer field camps between Gerolstein and Daun. In the first half of the 20th century two Gerolstein geoscientists, Stefan Dohm and Dr. Batti Dohm, father and son, developed their expertise in fossil digging, preparation, and determination to world wide fame. Thanks to their efforts the first geologic museum of the Western Rhineland already opened its doors in 1903 in Gerolstein. It is today's "Gerolstein Museum of Natural History" with its "Trilobitarium" and "Crinoidarium" where you may observe some of Germany's finest trilobite and crinoid fossils.

St. Patricks Cave
Age: Precambrian
Environment: -
Description: The site is particularly important historically, as it is adjacent to the cave and fresh water spring which according to tradition was used by St Patrick (Patron Saint of Ireland) - it is known that on his first attempt to go by boat to go to Ireland he was shipwrecked just off the Llanbadrig coast and managed to clamber ashore. He founded a small church a few yards from the cave in the 6th century which still retains his name (Llanbadrig translates as church and lands of St Patrick). The present church dates from the 9th century.