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Meeting Island Dwarfs and Giants of the Cretaceous – The Haţeg Country UNESCO Global Geopark, Romania

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Abstract

We review here key geological heritage elements of the Haţeg Country UNESCO Global Geopark (Southern Carpathians, western Romania) represented by latest Cretaceous continental vertebrate fossils and the sedimentary rocks enclosing them. Based on available geological and paleontological evidence, these animals were living on a tropical island. This paleogeographic setting led to the development of some unusual paleobiological traits including dwarfing of the dinosaurs, high levels of endemism, relictual characteristics, as well as uniquely derived anatomical, developmental, metabolic and/or sensory features. These unique characteristics led to the establishment of the Haţeg Country UNESCO Global Geopark over a decade ago. Recently, the Geopark implemented several projects including specific 'Dinosaur Island'-related thematic trails and visits to key geoheritage elements. We focus on four key fossiliferous areas of the Geopark, highlighting the most important geoheritage elements of each, as well as the most significant geoproducts created based on these particular elements.

Keywords: Cretaceous, Dinosaurs, Geopark, Geoproduct, Interpretation, Romania.

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Introduction

The Haţeg Country UNESCO Global Geopark (hereafter the Geopark) is situated in the central-southern part of Hunedoara County (western Romania; Fig. 1A), within the confines of a small intra-mountain basin in the western part of the Southern Carpathians branch of the Late Alpine-aged Carpathian Orogen. This intra-mountain basin, the Haţeg Basin or Depression, once formed the core of an early Medieval local self-organized region, the so-called Haţeg Country, one of many such 'countries' that dotted the territory of present-day Romania, especially around the Carpathian Mountains. Indeed, ruins of small, fortified headquarters ('castles') of minor feudal landlords are still scattered throughout the area, from Răchitova in the west to Bănița in the east, and from Colţi in the south to Haţeg itself in the north. Further, the Haţeg Depression lies close to both the heartlands of the ancient kingdom of the Dacians in the neighboring Sebeș Mountains, as well as to the administrative capital of the Roman province of Dacia, the city of Ulpia Traiana Sarmizegetusa.

Although it is an area with a very long and diverse geological history, this small (30 x 40 km) depression is known worldwide for its uppermost Cretaceous (Maastrichtian, ~ 72 to 66 Ma) continental deposits that host the fossils of a peculiar, unique vertebrate fauna with some of the most intriguing animals that inhabited southern Europe towards the end of the reign of the dinosaurs. It is this dinosaur-dominated paleofauna that was fundamental in initiating the project for a 'Haţeg Country Dinosaurs Geopark' over 20 years ago (Grigorescu & Andrășanu 2000; Grigorescu 2020). This was a grassroots project comprising a consortium of universities, local administrations, local and national institutions coordinated by Dan Grigorescu from the University of Bucharest, with consistent support from Dan Manoleli for biological and ecological aspects as well as from one of the authors (A.A.) who administered and oversaw the implementation and reinforcement of the geopark concept, both from the University of Bucharest, too. This project, implemented through the years under the auspices of the University of Bucharest has grown and morphed into the present-day Haţeg Country UNESCO Global Geopark (Andrășanu 2017).

Our aim is to review the most important features of the latest Cretaceous continental paleofauna from Haţeg Country, highlighting those features that make it of outstanding scientific importance, even unique worldwide, and which – alongside a host of other natural, archeological, historical and ethnographical elements of the local heritage (Andrășanu *et al.* 2004) – prompted the creation of the first Romanian Geopark in the Haţeg region in 2005 (Grigorescu 2020).

Geological Background: Shifting Haţeg Country Landscapes

The formation of the Haţeg Basin, where dinosaur-bearing continental beds accumulated near the end of the Cretaceous, represents but one event, although of paramount importance, in the evolution of the region. Its geological history starts in the later part of the Proterozoic and early part of the Paleozoic, when rocks of its crystalline basement were generated through geotectonic processes followed by low-to-medium grade metamorphism, with the latest tectono-metamorphic event taking place probably during the Variscan orogeny (Iancu & Seghedi 2017). These rocks form the hidden basement underlying the sedimentary cover of the Haţeg region, but they also outcrop, and can be studied directly, in the surrounding mountain chains to the west, north and east (Getic Domain) and south (Danubian Domain).

The first deposits of the basin sedimentary cover, as synthesized by Stilla (1985) are post-Variscan, probably Permian, siliciclastics. Their deposition is followed by a long sedimentary hiatus during the Triassic, as recorded in the largest part of the Getic Domain to which the Haţeg area belonged. Sedimentation began again in the Early Jurassic, marking the progressive detachment of the Getic

Domain from the margin of the Eastern European cratonic area. Starting with the Mid-Jurassic, the surroundings of Haţeg became part of the spatially extensive and geomorphologically heterogeneous Getic Carbonate Platform that formed on top of this detached continental sliver evolving on the northern margin of the tropical Neo-Tethys Ocean, with widespread carbonate sedimentation through the rest of the Jurassic and most of the Early Cretaceous. Towards the end of the Early Cretaceous, compressive tectonic movements initiated by the northward advance of Africa led to the onset of oceanic subduction and closure in the northern Neo-Tethys. These were followed by local collisions that mark the onset of mountain building across large parts of Central and south-eastern Europe, including along the Carpathian Chain.

In the Haţeg region, these 'mid-Cretaceous' compressional events broke up the carbonate platform, leading to local exposure and bauxite genesis, as the Getic Domain was thrust towards the neighboring continental crust-floored Danubian Domain. More or less intense tectonic activity became the norm for the rest of the Cretaceous, as witnessed by the replacement of previously carbonate-dominated sedimentation by mainly siliciclastic, including flysch-type, turbiditic deposits well developed in the western and north-eastern parts of the Haţeg area (Stilla 1985; Melinte-Dobrinescu 2010). This tectonic activity lasted until nearly the end of the Cretaceous, when the Getic Domain was finally thrust upon the Danubian Domain, thus producing the large-scale structural make-up of the Southern Carpathians. The thrusting phase resulted in regional emergence, volcanism, mountain building and, once the major compression ceased, local collapse of the over-thickened crust that produced depressions within the newly formed orogen. These rapidly subsiding depressed areas were filled with sediments derived from erosion of the uplifting nearby mountain ranges, entombing within these sediments traces of the continental ecosystems that occupied the newly formed drylands, including fossils of the dinosaurs of the Haţeg Country.

It was not until the Miocene that seawater invaded again, for a short time. Connected to the large interior seaway of Paratethys that once extended from Central Europe to western China, these shallow and warm seas left behind fossil-rich sandstones, shales, and limestones, only to withdraw shortly after. Finally, during the Quaternary, glaciers advancing from the surrounding mountains deeply carved the landscape and left behind swathes of coarse siliciclastics, while in the late Pleistocene, almost modern humans were setting up their shelters in caves situated just outside the Geopark, in the territory of the Grădiştea Muncelului-Cioclovina Natural Park.

Land of the Dinosaurs: The Haţeg Island

The end of the Cretaceous marked an important turning point in the evolution of the Haţeg Country region when it was uplifted and became dry land. It should be emphasized that this uplift was progressive, as was also the withdrawal of the sea (Vremir *et al*. 2014), and neighboring areas in the Transylvanian Basin, the Pannonian Basin and Eastern Carpathians remained submerged well after the Cretaceous-Paleogene boundary. This means that the uplifted areas (Apuseni Mountains, parts of the Transylvanian Basin as well as the Southern Carpathians that host the Haţeg Basin) were still surrounded by marine waters, sometimes at least several hundred meters deep and hundreds of km wide. They were thus isolated as islands along the northern fringes of the Neo-Tethys (Benton *et al*. 2010), parts of a west-to-east trending archipelago that marked this tectonically active area of convergence between Europe and Africa (Csiki-Sava *et al*. 2015). The famous paleontologist, Baron Franz Nopcsa (1914, 1915, 1923a) was the first to recognize the unique, insular qualities of the Haţeg dinosaurs, and his views were upheld by most subsequent studies (e.g. Weishampel *et al*. 1991, 2010; Benton *et al*. 2010), except Jianu

& Boekschoten (1999) and Krause *et al*. (2020) gave dissenting views.

Based on reasonable estimates, the Haţeg Island (or Transylvanian Landmass) reached an area of about 80,000 sq km, roughly the size of Hispaniola (Haiti) (Benton *et al*. 2010), following the major withdrawal of the seas. Part (and result) of the Europa-Africa convergence zone, it was at least locally volcanically active, as witnessed by thick piles of volcaniclastic and pyroclastic deposits in the westernmost part of the Haţeg Basin (near Densuş and Răchitova; the 'lower member' of the Densuş-Ciula Formation; Bârzoi & Şeclăman 2010) and in the neighboring Rusca Montană Basin (e.g. Dincă 1977), as well as by the mainly andesitic volcanic edifices and corresponding plutonic bodies of the Apuseni-Banat-Timok-Srednegorie magmatic belt that line the western parts of the Apuseni Mountains and Southern Carpathians (Popov *et al*. 2002). At least locally, there is evidence that the volcanic activity was synchronous with the colonization of the island by plants and animals (Csiki-Sava *et al*. 2016; Popa *et al*. 2016), whereas rare volcanic tuff levels, as well as reworked, slightly altered andesitic lithoclasts are also present in the overlying, mainly siliciclastic, fossiliferous uppermost Cretaceous deposits as well ('middle member' and 'upper member' of the Densuş-Ciula Formation; e.g. Vasile *et al*. 2011).

However, most of the fossil-bearing uppermost Cretaceous continental deposits lack such volcanogenic content. These siliciclastics are represented by a variety of red, green, brown, and gray-black conglomerates, sandstones, siltstones and mudstones; the fine-grained deposits often host more or less well-developed calcrete levels suggesting ongoing pedogenesis. The deposits occur over the north-western, central, and central-eastern parts of the Haţeg Basin, matching the areal extent of the Geopark. Several largely synchronous lithostratigraphic units have been discriminated, such as the Densuş-Ciula Formation in the north-western part of the basin, or the Sînpetru Formation in the central part, as well as the informally named Pui and Râul Mare 'beds', all yielding vertebrate (including dinosaur) remains (Grigorescu 1992; Csiki-Sava *et al*. 2016). Their Maastrichtian age is constrained by magnetostratigraphy (Panaiotu & Panaiotu 2010), marine biostratigraphy (Melinte-Dobrinescu 2010), palynostratigraphy (Antonescu *et al*. 1983; Van Itterbeeck *et al*. 2005) and radiometric dating (Bojar *et al*. 2011).

Sedimentological analysis of the fossiliferous deposits shows that they are mainly fluvial in origin, representing channel-fill (graded, often poorly sorted conglomerates and coarse sandstones), crevasse splay (medium-to fine grained, sheet-like sandstone bodies), and floodplain (calcrete-bearing purple, red and red-brown, or else greenish or dark gray siltstones and mudstones) depositional environments (Van Itterbeeck *et al*. 2004; Therrien 2005, 2006; Therrien *et al*. 2009; Botfalvai *et al*. 2021). These alluvial beds were deposited by (and near) rivers draining the surrounding mountain ranges, and they yield a rich and diverse vertebrate fauna, associated with plant and invertebrate remains as well as trace fossils.

The most remarkable feature of this fossil assemblage arises from its paleogeographic setting, in that it represents an insular ecosystem. Islands have long been considered natural laboratories of evolution, where evolutionary processes produce often dramatic effects on shorter timescales compared to the mainland. Nopcsa (1914, 1915, 1923a) identified their insularity based on the small body size of most dinosaurs, contrasting with the much larger dimensions of their mainland relatives, a trait he interpreted as insular dwarfing, with reference to the then-recently reported dwarfed elephants of the Mediterranean islands (Bate 1903). Their size reduction would enable these megavertebrates to cope with reduced food supplies in their newly colonized island homes. Other evidence for insular dwarfing emerged after the time of Nopcsa through growth series comparisons (Jianu & Weishampel 1999) and osteohistological surveys (e.g. Benton *et al*. 2010), which both suggest that these dinosaurs were indeed dwarfed (i.e. had small adult body size by dinosaurian standards). Besides the overall small body sizes, Nopcsa (1915, 1923a) also noted the primitive nature of several Haţeg taxa, their high degree of endemicity, as well as the low overall diversity of the fauna. He linked all these features to their purported insular habitat that functioned as a sanctuary, shielding them from invaders, whether competitors or predators. These ideas of Nopcsa's were also strongly upheld by subsequent research (e.g. Weishampel *et al*. 1991, 1993, 2003, 2010; Pérez-Garcia & Codrea 2018).

The history of discovery and research of these Haţeg fossils has been reviewed by Grigorescu (2010), and the fossils themselves and their sedimentary environments by Csiki-Sava *et al*. (2015, 2016). Here, we will highlight the significance of the fossil assemblages as a basis for developing the Geopark`s interpretation strategy. We consider interpretation as an educational activity to gain the support and participation of local people and tourists in geoconservation activities, based on knowledge and understanding of local values. The results of scientific research and the paleontological sites related to dinosaurs are combined with other natural and cultural heritage assets to develop a network of thematic trails, with small museums and sites offering visitors the chance to travel in space and time.

We consider four key areas (Fig. 1): the Sibişel Valley near Sânpetru, in the center of the Haţeg Basin (Fig. 1, area A); the surroundings of Vălio-

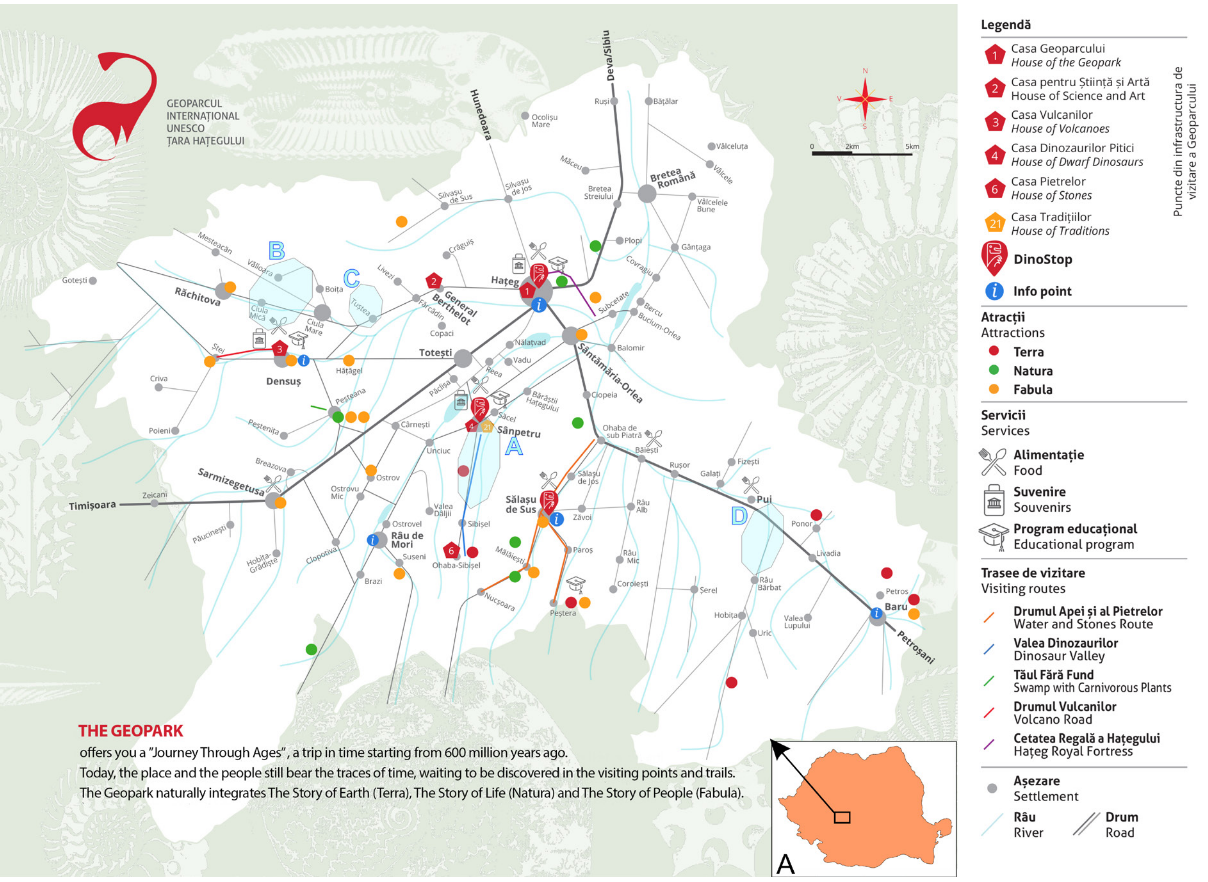

Figure 1. Map of the Haţeg Country UNESCO Global Geopark, showing main attractions and facilities; main fossiliferous localities discussed in the text are highlighted as turquoise polygons, and marked A) Sânpetru, B) Vălioara, C) Tuştea, and D) Pui. Inset shows the position of the Geopark within Romania (Map credit – Haţeg Country UNESCO Global Geopark, Andrei Tache).

ara, in the northwestern part of the basin (Fig. 1, area B); the egg-site locality Tuștea, in the north (Fig. 1, area C); and the Pui locality, in the central-eastern part (Fig. 1, area D) of the basin.

Sânpetru: The Sibișel Valley and the Baron's Dinosaurs

The Sânpetru locality, lying south of Săcel and Sânpetru villages (Fig. 1, area A), is represented by a long exposure of strongly SW-tilted uppermost Cretaceous continental beds, cropping out in the sides of the low hills flanking the Sibișel River. These deposits, dominated by yellow-brown or green sandstones and conglomerates interbedded with brownish-red, gray-green or dark gray siltstones and mudstones, often with calcareous concretions (Fig. 2A), were the first rocks from the Hațeg Basin to yield dinosaur and other Cretaceous vertebrate remains, at the end of the 19th century (Nopcsa 1897). These fossiliferous rocks were designated as the 'Sînpetru sandstones' by Nopcsa;the Sibișel Valley succession was later formalized as the type section of the Sînpetru Formation (Grigorescu 1992). Sedimentological research along the Sibișel Valley showed that these deposits were laid down in a low-relief plain by braided rivers that created a dynamic, ever-shifting mosaic of wetlands, temporal wetlands, and better-drained, higher-lying floodplains (Therrien 2006; Therrien *et al*. 2009).

The Sibișel succession is richly fossiliferous. Vertebrate fossils often occur in small-scale multi-taxic bonebeds, called 'fossiliferous pockets' by Nopcsa (1902a), although isolated remains are also common. Some of these isolated bones were described as the putative primitive bird *Elopteryx nopcsai* (Andrews 1913), now recognized as actually a small theropod dinosaur (e.g. Le Loeuff *et al*. 1992; Csiki & Grigorescu 1998; Fig. 2B). *Elopteryx* was the first Hațeg fossil vertebrates named in honor of Nopcsa, who was in fact a descendent of a local noble family whose picturesque family castle still stands in the nearby Săcel village. These rocks along the Sibișel Valley also yielded the type materials of three dinosaur taxa erected by Nopcsa, including the first dinosaur ever named from the territory of Romania: the hadrosauroid (duck-bill) *Telmatosaurus transsylvanicus* (Nopcsa 1900), alongside the rhabdodontid (basal ornithopod) *Zalmoxes robustus* (Nopcsa 1902b; Weishampel *et al*. 2003; Fig. 3A) and the armored nodosaurid *Struthiosaurus transilvanicus* (Nopcsa 1915, 1929; Fig. 3B). The list is completed by the primitive, basal testudinate *Kallokibotion bajazidi* (Nopcsa 1923b; Pérez-Garcia & Codrea 2018). All four species represent survivors from much older evolutionary stages of their clades, sort of

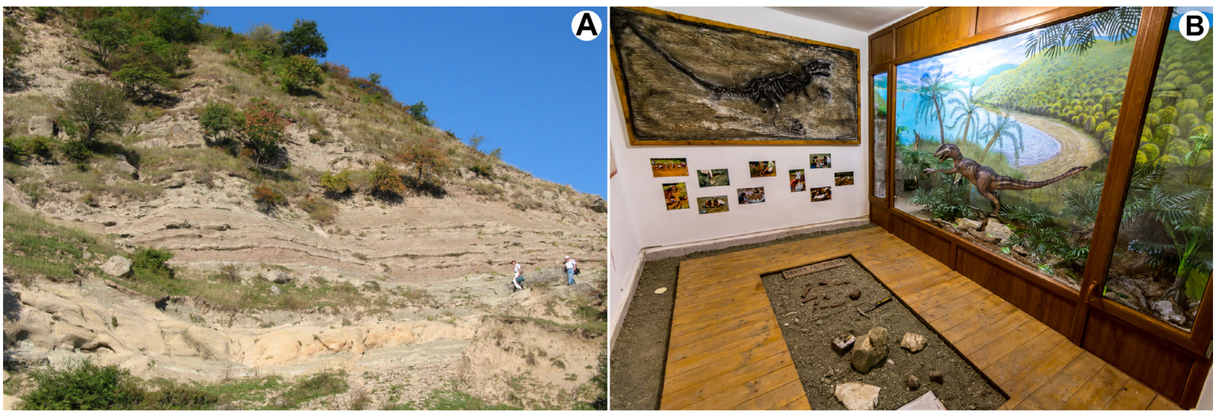

Figure 2. Sânpetru locality. A) Outcrops of the Sînpetru Formation along the Sibișel Valley (foto credit Dan Grigorescu). B) Exhibition in the House of Dwarf Dinosaurs at Sânpetru celebrating the predatory dinosaur *Elopteryx nopcsai*, whose remains were discovered a few hundred meters to the south, in the Sânpetru fossiliferous locality (photo credit Hațeg Country UNESCO Global Geopark, Adrian Rădulescu).

'living fossils' of the latest Cretaceous, and at least in the case of the herbivorous dinosaurs, they are probable island dwarfs (Benton *et al*. 2010; Ősi *et al*. 2014).

The Sibișel Valley section also yielded a magnificently preserved skull of a multituberculate mammal, designated as the holotype of *Kogaionon ungureanui* (Rădulescu & Samson 1996); it is the first near-complete mammal skull from the Mesozoic of Romania, as well as from the entire Cretaceous of Europe. The discovery of *Kogaionon* greatly expanded our knowledge of Cretaceous mammals of Romania and Europe, following the first report of their presence by Grigorescu (1984) from the same Sibișel Valley beds. The importance of *Kogaionon* goes further, representing a new family of multituberculates, the Kogaionidae, characterized by unusual skull and dentition, and identifying the true affinities of enigmatic isolated multituberculate teeth reported previously from the Cretaceous and Paleocene of Europe (e.g. Peláez-Campomanes *et al*. 2000). Further, together with all the other vertebrates from the Sibișel

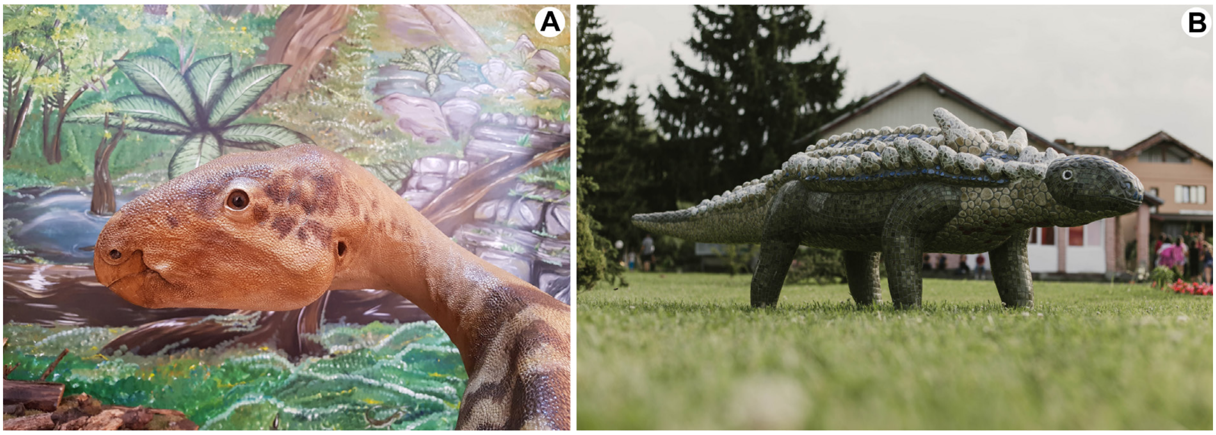

Figure 3. Iconic Transylvanian dinosaurs described by Nopcsa from Sânpetru. A) Head of the rhabdodontid ornithopod *Zalmoxes robustus*, reconstruction at the House of the Geoparc, Hațeg (photo credit Hațeg Country UNESCO Global Geopark, Adina Popa). B) Artistic, mosaic-technique full-sized reconstruction of the nodosaurid ankylosaur *Struthiosaurus transylvanicus*, Sălașu de Sus Dinostop (photo credit Hațeg Country UNESCO Global Geopark, Alicia Petresc).

Valley succession, the kogaionids are endemic to the latest Cretaceous Hațeg Island.

These outcrops along the Sibișel Valley are some of the most accessible, and they represent one of the focal points of Geopark's interpretation activities. The existence of strange 'giant' bones' seems to have been known in the Sibișel valley area long before the first scientific research, which meant that the villagers felt the work of the 'crazy baron' Franz Nopcsa was cloaked in an aura of mystery. Now, after more than a century of discoveries, heralded nationally and internationally, the valley has become a point of special interest for tourists and local people. One of the first steps in geoconservation activities was the establishment of the 'Sânpetru paleontological reserve' (a category IV site according to the IUCN ranking), followed by the selection of a custodian in charge of protection and guidance activities.

The 'Dinosaur Valley' thematic trail was later developed to respond to the heightened interest of tourists and local inhabitants. Based on the Geopark's hallmark holistic concept of 'protection, education and sustainable development', the 10 km long trail integrates cultural, natural and geological assets, and fosters local community activities. The 'House of Dwarf Dinosaurs' which opens the trail is a small visiting center in Sânpetru that showcases a reconstructed paleontological dig site, illustrating the lengthy process from excavation of bones to the full scientific and artistic reconstruction of a dinosaur. A diorama of the carnivorous dinosaur *Elopteryx nopcsai* (Fig. 2B), discovered and described from the Sibișel Valley more than a century ago, is accompanied by relevant scientific explanations and other 2D artistic reconstructions of the different Hațeg dinosaurs, including some made by the local geo-explorer kids' club called 'The little friends of the dwarf dinosaurs'. More than 30,000 tourists visited the house and trail during the last five years, preparing the stage for further initiatives such as the development of the 'Traditions House', the School of Dinosaurs and Crafting, the involvement of the Sântămăria Orlea Women's Association, and the creation of the Sânpetru Dinostop. All of these represent integrative parts of the new *geoproduct* concept developed by the Geopark.

Vălioara: Volcanoes and Flying Beasts, Large and Small

Vălioara is a small village located in the north-western corner of the Hațeg Basin, part of the Răchitova commune. It shares with the Sibișel Valley some historically important, fossil-rich uppermost Cretaceous continental deposits, here belonging to the Densuș-Ciula Formation. At Vălioara, dinosaur discoveries started with the fortuitous identification of their fossils at the beginning of the 20th century by field-mapping geologist O. Kadić, followed by an intensive campaign of yearly excavations led by him (Kadić 1916). His rather rich dinosaur quarries were afterwards, however, left to oblivion in this very heavily forested area, until they were recently re-located, and their surroundings surveyed by Botfalvai *et al*. (2021). The Vălioara area has special research importance because of several rich microvertebrate bonebeds, alongside other significant fossil occurrences.

Unlike the Sibișel Valley, the area around Vălioara is more heavily vegetated, and partly farmed by locals. Thus access, and especially by visitors, is limited and almost impractical, so there are no formally designated protected sites around the village. However, the scientific importance of these deposits is paramount, as they document a slightly different paleo-environment, dominated by alluvial fans that descended from the surrounding mountain ranges into extensive wetlands, before the area became dominated by more stable, better-drained (probably higher-lying) floodplains crossed by rivers (Botfalvai *et al*. 2021). Further, Vălioara is located much closer to the areas affected by explosive volcanic eruptions near the end of the Cretaceous. Although the deposits near Vălioara show few signs of this volcanic activity, large amounts of volcanic products are present, with significantly better outcrops (Fig. 4A), slightly to the west, around Răchitova and Densuș (e.g. Bârzoi & Șeclăman 2010).

The presence of this ancient volcanic activity, in direct connection with the dwarf dinosaurs' island during the Late Cretaceous, is another important asset for interpretation within the Geopark. The best outcrops with volcanically-derived rocks feature in the 'Volcano Trail' which connects the two key areas of Densuș and Răchitova. Along the trail, different volcaniclastic rocks such as volcanic bombs, base surges, accretionary lapilli, volcanic tuffs, and lava flows are highlighted and briefly explained to visitors. The 'Volcanoes House', located along the trail (Fig. 4B), offers an educational and imaginary experience of the lost world of volcanoes and dinosaurs, and showcases diverse geological elements in close relation with other natural and cultural assets.

Despite difficult access, uppermost Cretaceous exposures around Vălioara have nonetheless contributed numerous important paleontological discoveries. Based on material collected by Kadić, Nopcsa erected two new taxa, the titanosaurian dinosaur *Magyarosaurus dacus* (Nopcsa 1915; Huene 1932) and the basal eusuchian crocodyliform *Allodaposuchus precedens* (Nopcsa 1915, 1928). *Allodaposuchus*, although hailed as a surprisingly modern crocodilian by Nopcsa, actually turns out to be a core member of a rather basal

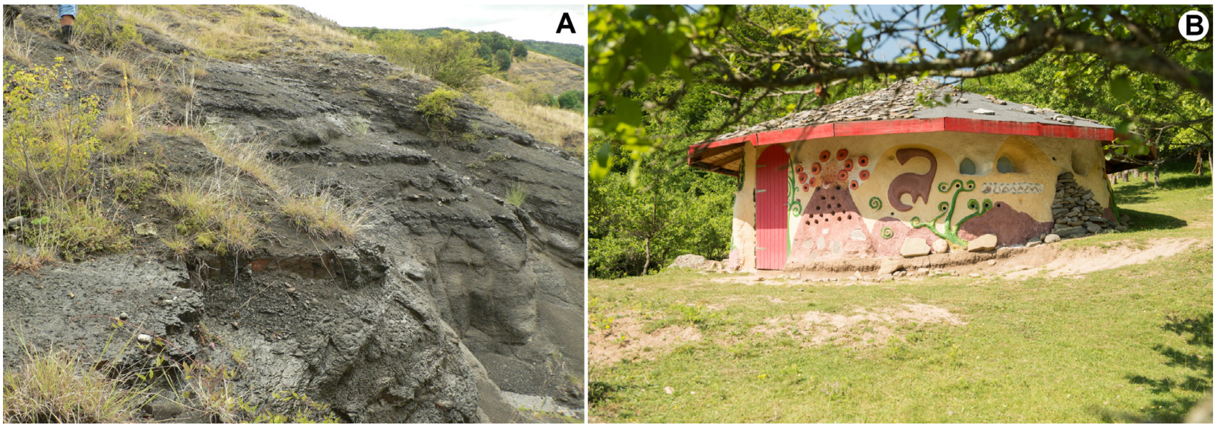

Figure 4. The land of volcanoes, at Densuş, near Vălioara. A) Outcrops of volcano-sedimentary deposits of the basal Densuş-Ciula Formation upstream of Densuş (photo credit Ioana Csiki-Sava). B) The House of Volcanoes, visitor center of the Geopark at Densuş (photo credit Haţeg Country UNESCO Global Geopark, Vlad Dumitrescu).

eusuchian family, one with exclusively European membership (e.g. Narváez *et al*. 2020). In turn, with its remarkably small body size (estimated to about 6 m in length, and not surpassing 1 ton in mass; Fig. 5A), *Magyarosaurus* soon became the quintessential Haţeg dwarf dinosaur, a suggestion by Nopcsa, and supported by subsequent studies (e.g. Jianu & Weishampel 1999; Stein *et al*. 2010).

This idea of *Magyarosaurus* as an emblematic dwarf Haţeg dinosaur was the focus of a novel project in 2014, The Transylvanian Dinosaurs Museum (Seghedi *et al.* 2017). Two Canadian artists, dinosaur sculptor Brian Cooley and painter Mary Ann Wilson, his wife, created a full-scale artistic reconstruction of *Magyarosaurus*, which was shipped from Canada to Belgium. There, the two artists and a movie team organized a caravan to travel and present the reconstruction across Europe on its way to the Haţeg Geopark. This two week-long trip allowed the team to promote paleontological discoveries, dinosaurs, and Romania. Events were organized near the UNESCO headquarters in Paris (France), at the Messel Pit UNESCO site (Germany), in the Bakony Balaton Geopark (Hungary), as well as in Bucharest, Constanţa and other places in Romania, before finally arriving in Haţeg. The documentary film ‘A Sauropod Abroad’, directed by the Canadian artist Anna Cooley and telling the story of this journey (see https://nonviolentfilmfestival.wordpress.com/tag/a-sauropod-abroad/), was released in 2016 (Fig. 5B), and won four international prizes, including Best Feature Documentary at the 2016 edition of the Braşov International Film Festival and Market.

The Vălioara region has also yielded other scientifically important fossils. Venczel & Csiki (2003) described from here fossils of two frogs, *Paralatonia transylvanica* and *Hatzegobatrachus grigorescui*. In addition, the rocks around Vălioara yielded the holotype of the largest inhabitant of Haţeg Island, the pterosaur *Hatzegopteryx thambema*, described by Buffetaut *et al*. (2002). This belongs to the family Azhdarchidae, and may have had a skull about 1.5–2 m long, and an estimated wingspan of 10–12 m. Although the wingspan is disputed, as the fossils are incomplete, it is clear that *Hatzegopteryx* was not only a real giant on the island of dwarf dinosaurs, but may have been one of the largest flying animals that ever lived on Earth. Other, more fragmentary fossils from Vălioara suggest that it might not have been the only dragon-sized creature to soar above the heads of the dwarf dinosaurs and over the volcanoes of the island (Vremir *et al*. 2018). It is worth noting, however, that not all supposedly flying animals that lived in the Vălioara region were gigantic; the same beds that yielded the holotype of *Hatzego-*

batrachus also yielded remains of a thrush-sized bird (Wang *et al*. 2011). The fossils show this was a member of the lineage leading to modern birds, the Ornithurae, and it was the first such animal to be described from the entire Transylvanian area, but the remains are too incomplete to be identified more precisely.

Just as with the dinosaurs, turtles and mammals from Sânpetru, the new taxa from Vălioara (*Paralatonia*, *Hatzegobatrachus*, *Hatzegopteryx*, *Magyarosaurus*, and *Allodaposuchus*) are all endemic to the Transylvanian landmass. They thus provide further evidence for the insularity of the entire latest Cretaceous Transylvanian fauna.

Tuştea: Eggs, More Eggs, Nests, More Nests, and… Baby Dinosaurs

Lying close to the northern border of the Haţeg Basin, and of the Geopark, Tuştea village belongs to the commune of General Berthelot. General Berthelot hosts another former Nopcsa manor (now restored and refurbished as a local research facility of the Romanian Academy of Sciences), as well as one of the Geopark's visitor centers which was the first Romanian home of Brian Cooley's life-sized *Magyarosaurus* reconstruction (Fig. 5A). But Tuştea, a small village of less than 300 inhabitants, is the real local point of scientific interest.

Continental uppermost Cretaceous sediments from the Tuştea area also belong to the Densuş-Ciula Formation, but they differ from those near Vălioara in that they represent overall better-drained floodplain environments, dominated by red and purplish calcrete-bearing mudstones interbedded with gray-greenish crevasse splay sandstones and thick, poorly sorted, cross-bedded channel conglomerates and coarse sandstones (Grigorescu *et al*. 2010).

The area around Tuştea is also heavily overgrown with vegetation and farmed/grazed, and the most important local outcrop was created in the late 1980s by a fortuitous landslide. This exposed a sedimentary succession several meters thick at the summit of Oltoane Hill, north of Tuştea, a succes-

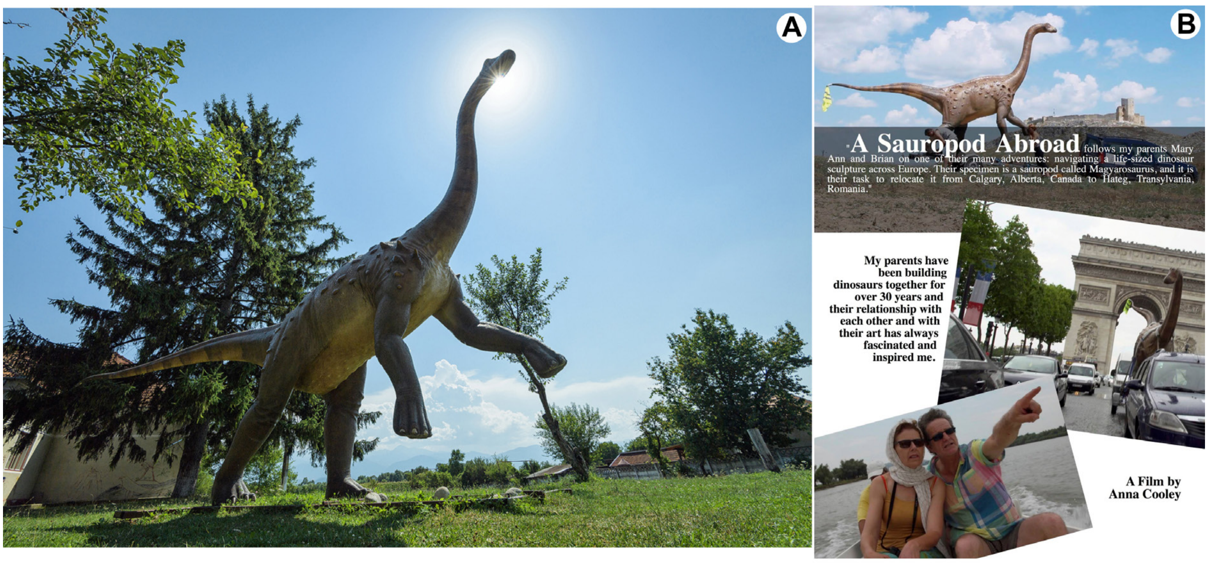

Figure 5. *Magyarosaurus dacus*, the dwarf dinosaur of Vălioara. A) Life-sized reconstruction of a rearing *Magyarosaurus dacus*, made by Canadian paleoartist Brian Cooley, in front of the House of Science and Arts, General Berthelot (photo credit Haţeg Country UNESCO Global Geopark, Dan Dinu). B) Poster of the documentary "*A Sauropod Abroad*" featuring the cross-European travel of the life-size replica of *Magyarosaurus*, presented at the Braşov International Film Festival (Romania) in 2016, directed by Anna Cooley, and produced by Anna Cooley and Mark Allan.

sion that yielded the first dinosaur eggs and nests from the Cretaceous of Central and Eastern Europe (Grigorescu *et al*. 1990). Although subsequently several other egg- and nest-bearing sites were also discovered in the Haţeg Basin, within the territory of the Geopark (e.g. Codrea *et al*. 2002; Smith *et al*. 2002; Grigorescu & Csiki 2008; Csiki-Sava *et al*. 2018a), Tuştea-Oltoane still retains a special status for two reasons.

First, the position of the fossiliferous beds at Tuştea allowed large-scale excavations, including using heavy machinery to remove the overburden. This opened up several dozen square meters of the fossiliferous strata (Fig. 6A) and revealed a genuine nesting horizon with several nests (e.g. Grigorescu *et al*. 2010; Grigorescu 2017). Further, analysis of the excavation records after most of the excavation work at Tuştea concluded showed that there were actually two superposed nesting horizons (Botfalvai *et al*. 2017), mirroring situations reported at other sites such as Toteşti and Nălaţ-Vad, and suggesting some degree of site fidelity of the nesting animals.

But what makes Tuştea unique among egg localities in the Cretaceous of Europe is the co-occurrence of eggs and nests with remains of neonate dinosaurs at the same locality. This co-occurrence came to be known as the 'Tuştea puzzle', since whereas the eggs referred to the Megaloolithidae appear to be of titanosaurian affinities (Grigorescu *et al*. 1990), the baby remains definitively belong to hadrosauroids (Weishampel *et al*. 1993; Fig. 6B). Excavation activities at Tuştea ceased several years ago (Botfalvai *et al*. 2017), and the former excavation site is now abandoned, largely covered and overgrown with vegetation, but some nests with megaloolithid eggs from this locality are on display in different institutions across Romania (University of Bucharest; Geological Museum of Romania; University of Petroşani) including, naturally, the Geopark itself (Fig. 6A).

Secondly, although Tuştea-Oltoane is best known as a dinosaur nesting locality, it also yielded a large number of other vertebrate fossils, unlike similar nesting localities worldwide. These include type materials of two new taxa, the madtsoiid snake *Nidophis insularis* (Vasile *et al*. 2013) and the basal neosuchian (atoposaurid or paralligatorid) crocodyliform *Sabresuchus* ('*Theriosuchus'*) *sympiestodon* (Martin *et al*. 2010; Tennant *et al*. 2016). Of course, these taxa are endemic to Haţeg Island, and *Sabresuchus* also represents a significant range extension of the genus into the latest Cretaceous,

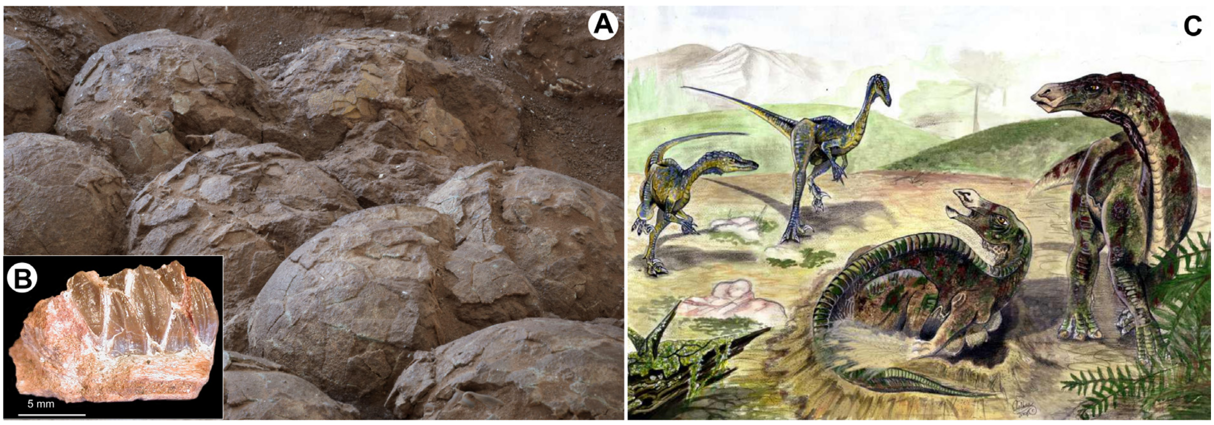

Figure 6. Tuştea, the unique dinosaur nesting site. A) Close-up of megaloolithid egg nest excavated at Tuştea, now on display at the House of Science and Arts, General Berthelot (photo credit Haţeg Country UNESCO Global Geopark, Dan Dinu). B) Incomplete *Telmatosaurus transylvanicus* baby dentary discovered at Tuştea, associated with the megaloolithid eggs (photo credit Zoltán Csiki-Sava). C) Artistic reconstruction of the life at the Tuştea nesting site about 68 million years ago; a pair of *Telmatosaurus* protecting its nest from a pack of harassing small bird-like theropod dinosaurs (image credit Haţeg Country UNESCO Global Geopark, Theodora Niculescu).

being another living fossil of its age. Finally, it is worth mentioning that Tuștea-Oltoane is the only locality in the Geopark that yielded definite fossils of an iconic Romanian dinosaur, the double sickle-clawed *Balaur bondoc* (Brusatte *et al.* 2013). This taxon is otherwise described from deposits of roughly similar age around Sebeș-Alba (Alba County) in the southwestern Transylvanian Basin, and which were deposited on the same Hațeg Island (Csiki *et al*. 2010).

The 'House of Science and Art' located in General Berthelot, was already mentioned as the home of the life-sized *Magyarosaurus* replica. Furthermore, this space hosted through the years different paleontology- and art-themed exhibitions, dedicated to paleontological discoveries and Earth materials. A new exhibition to present in more detail the Tuștea discoveries is currently in preparation.

Pui: The Mammalian Treasure Trove

The last locality, Pui, is also the most peculiar. Unlike most dinosaur sites around the world, it is located in (and restricted to) the active riverbed and immediate shores of the picturesque Bărbat River (Fig. 7A) that flows from the Retezat Mountains northward until it discharges into the Strei River (the main river-course through the Geopark) near Pui. The exposure of uppermost Cretaceous continental deposits extends from Pui village southwards for a few hundred meters, but it is dynamic, continuously and actively eroding, with a high level of probability that fossils may be eroded and destroyed before recovery. The number of fossils discovered at this locality is outstanding, as is often their state of preservation, ranging from associated specimens (even partly articulated incomplete skeletons) to small-sized, delicate skulls. The deposits here are mainly brown-red to brick-red silty mudstones, often with calcrete horizons, interbedded with gray-greenish conglomeratic sandstones and coarse-grained sandstones (Fig. 7B) and (very rarely) dark gray to blackish mudstones. They are reminiscent of the deposits exposed at Tuștea, except that the calcrete levels are thicker and more continuously developed (suggesting a more advanced degree of pedogenesis or paleosol formation), and the coarser-grained beds are much better sorted. Sedimentological studies suggest their deposition in well-drained distal floodplains subjected to long periods of pedogenesis, and occasionally incised by river courses (Van Itterbeeck *et al*. 2004; Therrien 2005), in a seasonally variable semiarid climate.

Several vertebrate taxa were described for the first

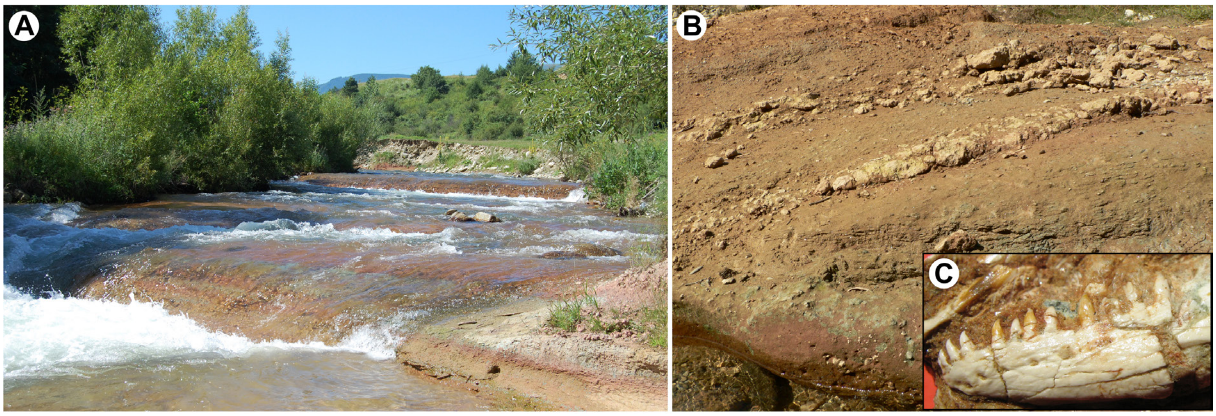

Figure 7. Pui fossiliferous locality. A) Outcrops of the 'Pui Beds' along the Bărbat Valley, south of Pui (photo credit Ioana Csiki-Sava). B) Details of the calcrete-bearing red silty floodplain mudstones typical for the 'Pui Beds', interbedded with minor greenish channel sandstones (photo credit Zoltán Csiki-Sava). C) Close-up of the holotype dentary of the large lizard *Barbatteius vremiri*, described from Pui locality (photo credit Mátyás Vremir).

time from this locality, most representing small-sized animals, microvertebrates living alongside the dinosaurs. These include several normal-sized lizards (*Becklesius nopcsai*, *Bicuspidon hatzegiensis*: Folie & Codrea 2005), both of which represent significant temporal range extensions for their respective genera, alongside the much larger teiid *Barbatteius vremiri* (Venczel & Codrea 2016; Fig. 7C) and the small atoposaurid crocodyliform *Aprosuchus girai* (Venczel & Codrea 2019). Although both *Beckelesius* and *Bicuspidon* had wide paleogeographical distributions and are thus not endemic to Hațeg, in the Maastrichtian they are only known from this area. Accordingly, they represent further examples of late-surviving members, endemic relicts of more ancient (latest Jurassic to 'mid'-Cretaceous) lineages. Meanwhile, the genera *Barbattteius* and *Aprosuchus* appear to be endemic to the Hațeg Island, and *Aprosuchus*, like its close relative *Sabresuchus* ('*Theriosuchus*'), is also a late-surviving member of its clade.

The most intriguing and exceptional fossils from Pui are the mammals. Several extremely well-preserved specimens, including almost complete skulls and associated postcranial remains, document kogaionid multituberculates, including the holotypes of two new genera, *Barbatodon transylvanicus* (Rădulescu & Samson 1986), the first Mesozoic mammal to be named from the territory of the Geopark, but also the entire Central and Eastern Europe, and *Litovoi tholocephalos* (Csiki-Sava *et al*. 2018b). Besides these scientifically unique specimens, rich referred material of *Barbatodon* was also discovered at Pui (Csiki *et al*. 2005; Smith & Codrea 2015; Solomon *et al*. 2016) making it currently the best-known kogaionid, and also one of the best-known latest Cretaceous multituberculates (and mammals) worldwide. The importance of the Pui locality for Cretaceous mammalian palaeontology, especially in Europe, is attested by the abundance of fossils, whereas mammalian remains are usually either absent or extremely rare in other areas with Upper Cretaceous continental deposits across the rest of Europe (Gheerbrant & Astibia 2012; Csiki-Sava *et al*. 2015). Further, where present, these scarce latest Cretaceous mammalian remains belong to either eutherians or metatherians, whereas multituberculates seem to have been absent in those areas. Thus, even though both *Barbatodon* and *Litovoi* are endemic to the Hațeg Island, it is important to emphasize that the entire clade of kogaionid multituberculates appears to have been a Transylvanian endemic group during the latest Cretaceous, documenting the presence of a unique insular radiation of multituberculates in this area before the Cretaceous-Paleogene boundary. Further, at least *Litovoi* displays some peculiar cranial features, especially in the size and morphology of its brain and sensory organs, such as relatively small endocranial volume and encephalization quotient compared to its body size, as well as rather well-developed senses of olfaction, hearing and balance (Csiki-Sava *et al*. 2018b). These modifications have been interpreted as adaptations to its insular environment.

The Pui locality is relatively easily accessible, but far less rewarding for visitors compared to the Sibișel Valley section because the exposures are mostly underwater. Visiting the site, especially during periods of high water from heavy rains or snow melt in the Retezat Mountains may even be dangerous, and is definitely not recommended. No formally designated and conserved visitor sites are (or can be) established at this locality because of the actively eroding and constantly changing riverbed geomorphology.

The Geopark – Tales of Dragons and Men

UNESCO Global Geoparks are generally bottom-up constructions in unified areas where geological sites of international significance, together with elements of the natural heritage and of the cultural heritage, are managed with an integrated approach towards conservation, education, geotourism, and socio-economic development. Geoparks are territories of innovation and cooperation where local geodiversity is used as a resource for socio-economic development. Starting from the idea of protection of the local geological heritage for the benefit of local communities, in 2000 four European territories created the European Geoparks Network (Zouros 2004; Zouros & Veliakos 2010). This initiative then rapidly evolved into a Global Geoparks Network (GGN) which currently comprises 169 territories from 44 countries and is growing continuously. Since the launch of the Geopark concept, UNESCO sustained it and in 2015 adopted the new Geoscience and Geoparks Program to celebrate Earth History and to promote local sustainable development (UNESCO, 2015). Based on the same principles, each geopark should be adapted to the unique local socio-economic and cultural context, and aims to play an active role at national and international level. Furthermore, each geopark is evaluated and revalidated every four years to remain part of this global network. The Haţeg Country Dinosaurs Geopark, later to become the Haţeg Country UNESCO Global Geopark, a UNESCO Global Geopark Network member, was created at the beginning of the millennium along the same guidelines of integrated management of a diverse local heritage of natural, cultural, and immaterial assets in the Haţeg Country. It joined the GGN in 2005 and has been since revalidated several times.

The cornerstone asset of this project is the dwarf dinosaurs discovered more than a century earlier by Franz Nopcsa. Indeed, dinosaurs are strong attractors and important assets in interpretation and geotourism development. During the last 20 years more than 60 areas with dinosaur-bearing sites were transformed worldwide into attractions for dino-tourism, and Haţeg Country is one of these (Cayla *et al.* in preparation). Geotourism started to be developed in the early 1990s as a new type of tourism and has evolved since then (Gonzales-Terada *et al*. 2017). This type of tourism offers an excellent opportunity for geologists and geo-conservationists to interpret and present to visitors the results of their scientific research and to generate economic impact for local communities at the same time (Frey *et al*. 2006). Geotourism is regarded as a distinct type of sustainable tourism, developing its tools and aiming to make visitors explore first-hand the different geological features of the Earth as well as their connections to biodiversity and local culture (Newsome & Dowling 2018). The Arouca Declaration (2011) represents an important milestone in the process of harmonization between different interpretations of this concept, especially between that of the Centre for Sustainable Destinations – National Geographic Society and those of the Geoparks. This document recognizes the significant role geotourism can play in sustaining and enhancing the identity of a territory with a holistic approach to its local values, together with the wellbeing of its residents.

Interpretation is a key element in geoconservation and geotourism, as well as an important part of geopark management. In particular, interpretation of local geodiversity needs to be connected with the natural and cultural heritage, as an expression of the dialogue between people and Earth. To address such a challenge, the interpretation approach developed in the Haţeg Country Geopark is innovative, and it targets several objectives.

The first objective is to build a territorial brand combining Earth history and the history of the local community. And as a result, *Voyage through Ages* became the Geopark's invitation addressed to all visitors to discover the traces left by the ages: the oldest rocks known in the area, the remnants of the Tethys Ocean, the world of dwarf dinosaurs from the former Haţeg Island, scours and marks of the Ice Age, but also buildings and (arti) facts of ancient, medieval and recent people.

The second objective is to combine in an innovative manner tangible and intangible heritage to tell stories about rocks, dinosaurs, places, and people, and to connect mythology to local geodiversity. One such example is the permanent exhibition in the main visitor center at Haţeg, dedicated to

'*Balaurs, Dragons and Dinosaurs*'. Old legends about 'balaurs' (the Romanian popular name for dragons), the famous dragon-like Dacian battle flag (as Haţeg lies very close to the heartlands of the ancient Dacian kingdom), and the fantastic recent discovery of the predatory dinosaur *Balaur bondoc* ('stocky dragon') are connected here within an educational and touristic circuit. Paleontologists are presented as modern heroes bringing to life beasts of the past, and new stories about their scientific endeavor are thus becoming part of the local culture.

The third objective aims to develop a series of unique geo-products reflecting stories about people and the places they inhabit, geo-products that in the meantime are able to generate income for the local communities (Andrăşanu & Ciobanu in preparation). The small visitor centers of the Geopark – the *House of Dwarf Dinosaurs,* the *House of Volcanoes,* the *House of Traditions,* the *House of Rocks,* the *House of Science and Art*, and the *House of the Geopark* – are examples of such geoproducts. Six thematic trails integrate these houses with other historical, natural, and cultural assets, and allow their touristic exploitation. Based on this model, similar approaches will be developed for some other "houses" in the future.

Dinostops are special geoproducts developed in local partnerships. Each dinostop is unique and is dedicated to one local species of dinosaur, integrating three basic elements: presentation of sound scientific data concerning this dinosaur, an artistic reconstruction of the dinosaur itself, and a location near a partner restaurant, coffee shop or souvenir shop. A dinostop thus combines science and tourism, and all the costs involved are supported by each respective dinostop partner. Three dinostops are already in place (see Figs. 1, 3B) and four more are yet to come.

Concluding Remarks

The Haţeg region of western Romania – circumscribed geographically by the Haţeg Basin or Depression, and named historically as the Haţeg Country – is well-known globally for its fauna of dwarf island-dwelling dinosaurs that lived about 70 million years ago, near the end of the Cretaceous Period. The importance of these dinosaurs, however, surpasses their 'simple' scientific value, as silent yet telling witnesses of a long-gone era in Earth's history. These dinosaurs, as unique and weird as they and their environments were, (and are) instrumental in conceptualizing, creating, setting up and then running Romania's first (and flagship) geopark, the Haţeg Country UNESCO Global Geopark, started more than 20 years ago as the Haţeg Country Dinosaurs Geopark. In this review, we briefly survey the component of the local geoheritage represented by fossils of these latest Cretaceous beasts (dinosaurs and their contemporary crocodilians, turtles, mammals, and other critters) and by the sedimentary archives that enclose them. We do so by focusing on their known record in four fossil-rich areas of the Geopark, and by highlighting the importance, uniqueness and scientific relevance of each particular local fossil record at regional and/or global level.

In parallel, we also emphasize the ways these elements of the local geological heritage were used in the development as well as the education and promotion efforts of the Geopark, since dinosaurs (or other ancient creatures living alongside them) and their interpretation have a huge potential to connect ancient mythology, scientific research, education, and vivid personal experience of the visitors. They are thus key elements in promotion activities within the framework of the Geopark from several points of view: (i) as elements building, focusing and cementing local identity, by connecting local geodiversity with local identity; (ii) as management tools, integrated within the geopark development plan and its local partnerships system; and (iii) as marketing elements, expressing an economic and market-oriented approach in geoproduct development. Most of the geoproducts are related to dinosaurs, and through this connection, they – strange and intriguing giants and dwarfs that disappeared tens of millions of years ago – play an important role in geopark development, by associating the geopark mission with local geodiversity and sustainable local socio-economic development.

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