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10th IAG INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY

COIMBRA - PORTUGAL

« GEOMORPHOLOGY AND GLOBAL CHANGE »

FIELDTRIP GUIDEBOOK
Arouca Geopark

14 September 2022

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Coimbra, 2022

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Introductory Note

The 10th International Conference on Geomorphology will take place in Coimbra (Portugal) from 12th to 16th September 2022, under the theme "Geomorphology and Global Change" and it is organized by the International Association of Geomorphologists (IAG) and the Portuguese Association of Geomorphologists (APGeom).

As in previous international conferences on Geomorphology, and as is the tradition in many geomorphological events organized around the world, the organizing committee of the 10th International Conference on Geomorphology proposed several fieldtrips to the participants, occurring before, during and after the main event.

These fieldtrips intend, above all, to show to geomorphologists from all over the world the diversity and richness of the geomorphological elements of the Portuguese territory (and also from Cape Verde) and to allow an exchange of experiences between the specialists that investigate these territories and the visitors, contributing for mutual scientific enrichment and for the valorization of this international conference.

The pre-conference fieldtrip is dedicated to the islands of Santiago and Fogo, in the Archipelago of Cape Verde. It will take place from 6th to 9th September and will be led by colleagues from the University of Cape Verde (Vera Alfama, Sónia Victória, Sílvia Monteiro, José Maria Semedo and Romualdo Correia). The volcanic geomorphology will dominate the visit (including well conserved structural volcanic forms such as cones, domes, craters and calderas), especially in the island of Fogo where recent volcanic activity has been registered.

The one-day mid-conference fieldtrips will take the visitors around the Portuguese mainland territory, the 14th September, allowing the visit of four different geomorphological realities.

In the Arouca UNESCO Global Geopark, internationally recognized territory since 2009, participants will be able to visit unique geological and geomorphological features (such as planation surfaces, bowl-shaped valleys and narrow river valleys) and witness the remarkable effort of protection and promotion of natural (abiotic and biotic) and cultural (tangible and intangible) heritage. The visit to the “516 Arouca” suspension bridge will be an excellent opportunity to observe the magnificent landscapes of this mountainous territory. This fieldtrip will be led by Artur A. Sá, António Vieira and Daniela Rocha.

The field trip to coastal areas of central Portugal will be led by Pedro Dinis and António Campar Almeida. Their proposal is to observe the different morphotectonic units of central west Portugal, namely the Coastal Mountain of Serra da Boa Viagem (revealing karstification features), the littoral plain (with aeolian dunes associated with some

reliefs with higher elevation), the Cértima subsiding area (structurally-controlled morphology), and the Buçaco region (with the Syncline of Buçaco).

The visit to the Schist Mountains of Central Portugal will be centered in the mountains of Lousã and Açor, and will be conducted by Luciano Lourenço and Bruno Martins. It is proposed the observation of the main contrasts of the landscape, especially in terms of its physical geography, translated into geological, hypsometric, geomorphological, and hydrographic differentiation, or the land use and occupation and evolution of vegetation cover, namely following the recurrent large forest fires and the subsequent erosive processes they caused.

The fourth one-day fieldtrip will be oriented to the Estrela UNESCO Global Geopark, and led by Gonçalo Vieira, Emanuel Castro and Fábio Loureiro. The main geoheritage significance of the Estrela UGGp is the extent and richness of the Late Pleistocene glaciation(s) landforms and deposits (with spectacular morphological features such as the Zêzere glacial valley or the glacial cirques, moraine boulders, erratics or *roches moutounnées*) as well as the peculiar long-term geological evolution (revealing a significant diversity of granite types and landforms).

The three post-conference fieldtrips include a visit to the Lisbon Region, Serra da Estrela and, finally, Minho and Galicia (Spain), and will take place from 17th to 19th September.

The fieldtrip to the Lisbon Region will be guided by José Luís Zêzere, César Andrade, Sérgio Oliveira, Jorge Trindade and Ricardo Garcia, and will cover topics related with slope instability and landslides that affect the region of Lisbon, the floods occurring in the area north of Lisbon, and the coastal dynamics, morphology, cliff instability and beach erosion at north and south of Lisbon.

The three days field trip to the Serra da Estrela is led by Gonçalo Vieira, Emanuel Castro and Fábio Loureiro. Participants will be taken to visit some of the Geopark's most inaccessible geosites and observe breathtaking landscapes during two hikes: one in the Zêzere valley and the other between Penhas Douradas and Lagoa Comprida. The different geosites to visit include features of glacial, periglacial, granite weathering, fluvial, hydrogeological, petrological and tectonic themes, and aspects related with the management of a UNESCO Global Geopark will be discussed.

The third three-days fieldtrip is destined to the northwestern part of Portugal and the Spanish region of Galicia. Guided by Alberto Gomes and Antonio Perez Alberti, will be mainly devoted to the coastal area and to the observation and discussion of issues related to coastal dynamics, marine terrace staircases, differential uplift of coastal blocks, coastal geoheritage, coastal geoarchaeology, coastal erosion and coastal land planning.

It is our expectation that these visits will please all participants and promote the scientific enrichment of all involved, allowing a better understanding of the topics covered in each one.

We also hope that this set of fieldtrip guidebooks can help in the understanding of the themes discussed and that they can be a testimony of the commitment and dedication shown by all the scientific responsible for the several visits, to whom the organizing committee of the International Conference on Geomorphology expresses its greatest recognition and gratitude.

have a good fieldtrip!

Lúcio José Sobral da Cunha
António Vieira

on behalf of the ICG2022 Organizing Committee

ITINERARY AND SCHEDULE

Itinerary (Fig. 1 and 2)

07h00 – Departure from Coimbra

09h00 – 09h15 – Montemuro Doors (Castro Daire)

10h00 – 10h30 – S. Pedro do Campo viewpoint and Pedra Posta geosite

11h00 – 12h30 – "516 Arouca" suspension bridge and Paiva Walkways

13h00 – Senhora da Mó viewpoint – lunch pick-nick

14h30-15h00 – Detrelo da Malhada viewpoint (Freita Mountain)

15h30-16h00 - São Pedro Velho bornhardt

16h30-17h00 – Frecha da Mizarela waterfall

19h00 – Arrival to Coimbra

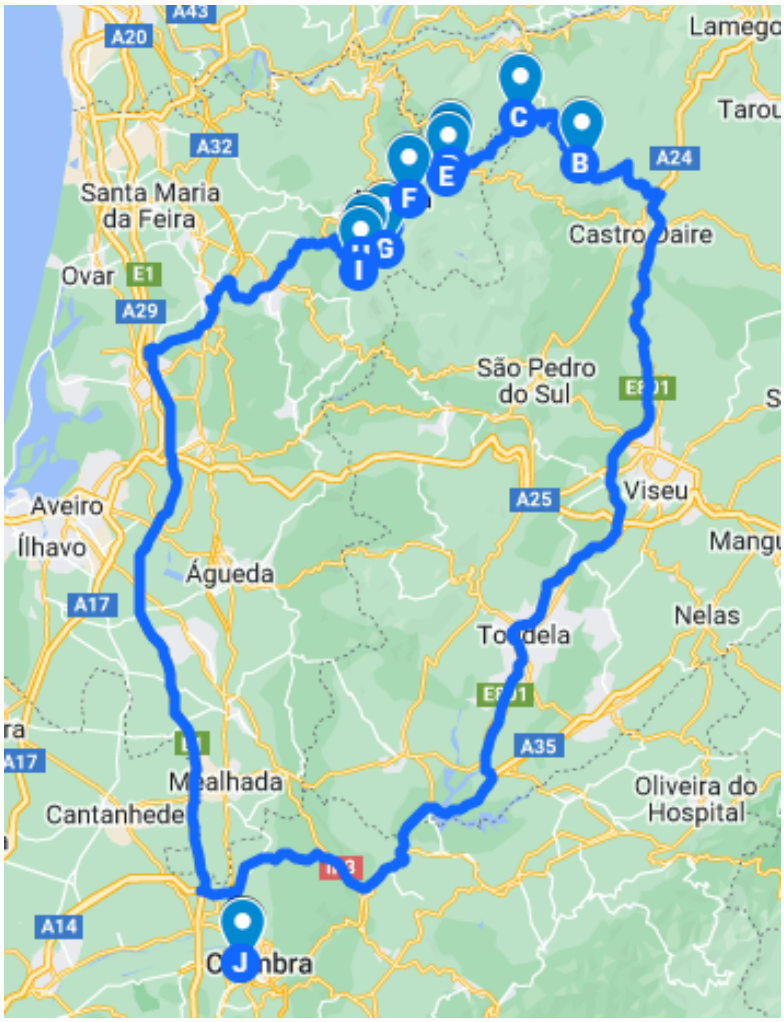

Figure 1. General itinerary

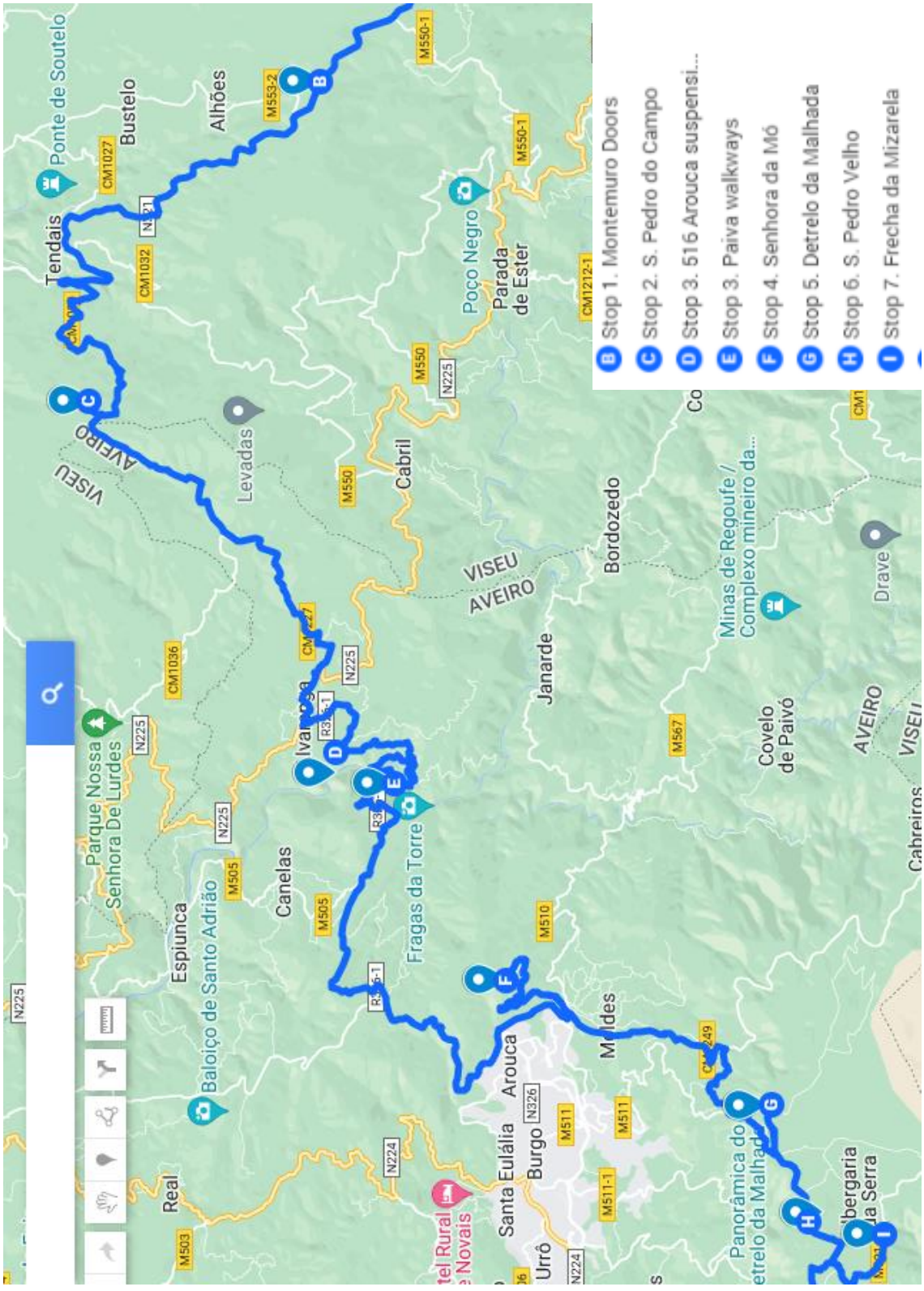

Figure 2. Partial itinerary with stops.

Introduction

The Arouca UNESCO Global Geopark (Arouca UGGp) is an internationally recognized territory since 2009, comprising a total of 328 km^2 and 21.154 inhabitants (INE, 2021). This recognition is due to its unique geological heritage promoted through a strategy for territorial development. This involves the protection and promotion of natural (abiotic and biotic) and cultural (tangible and intangible) heritage. The sustainable regional development strategy entails a holistic approach based on the development and implementation of educational, scientific, cultural and/or geotouristic activities. Local communities are involved in these activities and in working together in order to contribute for the achievement of a territorial sustainable economic development. To date were identified, characterized and evaluated 41 geosites in the Arouca UGGp. Among them, 24 are of geomorphological interest. Mostly they correspond to major landforms including planation surfaces, bowl-shaped valleys and narrow river valleys (Sá & Rocha, 2020).

The landforms of the Arouca UGGp have been valued in recent years as fundamental elements of the regional landscape, having assumed educational and geotourism importance. In this sense, its advertising and dissemination promoted by the Arouca Geopark Association (AGA) have allowed visitors to know and understand the processes that gave rise to the geomorphology and landscapes of this territory. Visits to geosites during educational programs, guided tours or tourist events provided visitors with close contact with the region and its people, stimulating the revitalization of communities, the knowledge and promotion of locally based products and the development of a sense of place. This reality has significantly contributed to the economic development of the Arouca UGGp.

Currently and taking into account a set of economic macro-indicators, the dynamics associated with promotion and visitation activities, directly and indirectly involving the reality of Arouca UGGp, represent an estimated annual financial return of at least 15 million euros (Rebelo *et al*., 2014).

The visit to Arouca UGGp as part of the 10^{th} International Conference on Geomorphology will allow participants to get in touch with this mountainous territory, carved by deep and narrow valleys. The geology of this territory (Fig. 3), almost exclusively constituted by metasedimentary rocks from the Neoproterozoic-Carboniferous periods and by Variscan granites, shaped the landscapes, conditioned the population settlements and even moulded the people, influencing their constructions and their habits of use of land. In this sense, we hope that despite the brevity of the visit, the participants will be able to enjoy it and feel the desire to return, perhaps to develop research in this territory of Education, Science and Culture.

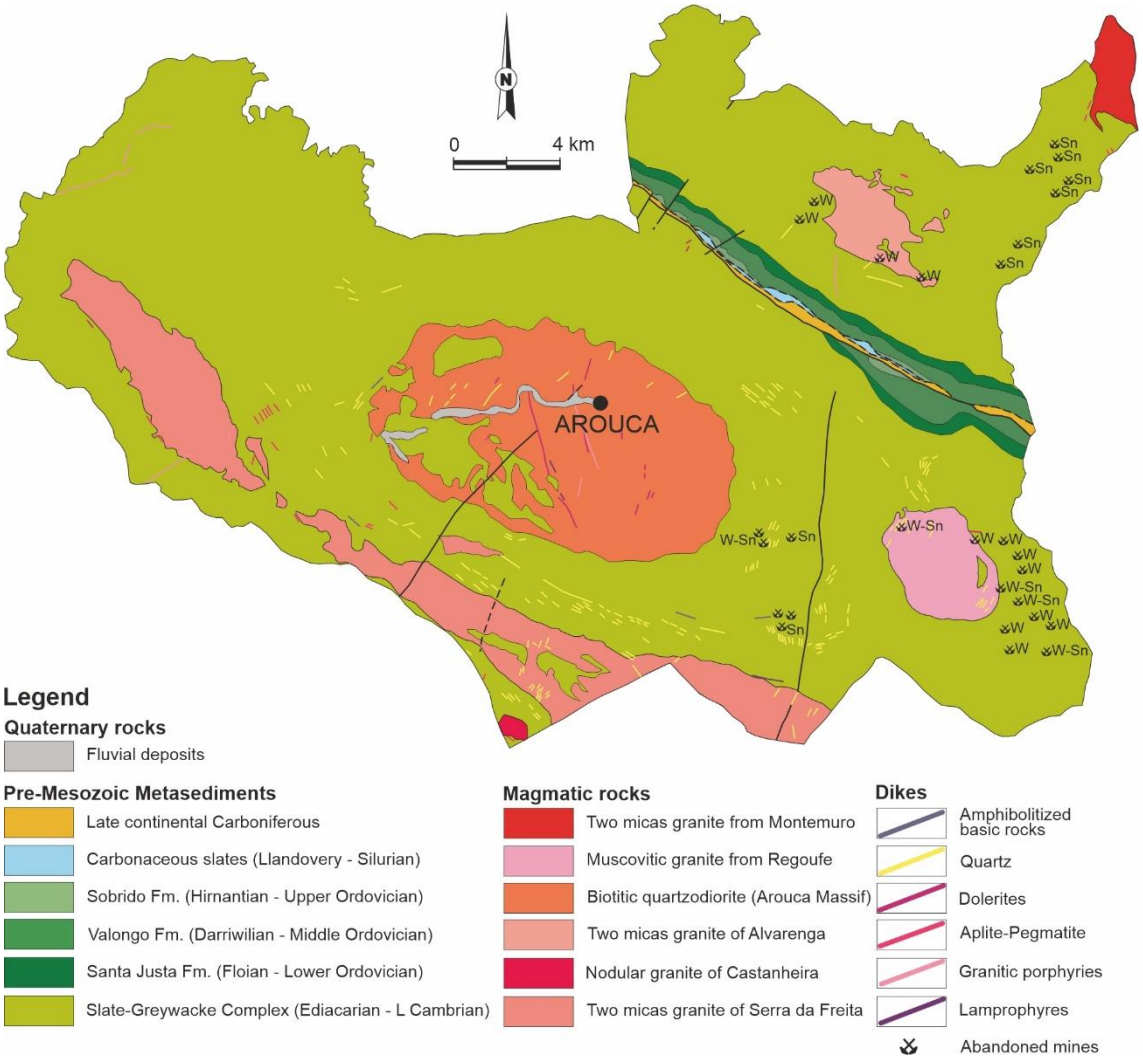

Figure 3. Simplified Geological map from Arouca Geopark and schematic geological profile. Adapted from the pages 13-B (Castelo de Paiva), 13-D (Oliveira de Azeméis), 14-A (Lamego) e 14-C (Castro Daire) of the Geological Map of Portugal, 1:50 000 scale.

According to the large morphostructural units of the Iberian Peninsula, the Arouca UGGp is geologically framed in the so-called Hesperian or Iberian Massif. This is characterized, in general terms, for being composed of metamorphic and magmatic rocks, which extend in age from the Neoproterozoic to the late Palaeozoic.

The Hesperic Massif is divided into several zones, according to its tectonic characteristics, with the Arouca UGGp being inserted in the Central Iberian Zone (Fig. 4).

Of all the differentiated structural and palaeogeographic zones within the Hesperian Massif, the most extensive portion corresponds to the so-called Central-Iberian Zone, whose central-southern sectors are characterized by extensive outcrops of ancient materials (Neoproterozoic to middle Cambrian?), which separate quartzite mountains , aligned according to the previously mentioned orientations. These mountain ranges, remarkably elongated and narrow, are the ones that preserve the rest of the Palaeozoic succession, formed by marine sediments of the Ordovician-lower Carboniferous age,

which are associated with continental deposits rich in terminal Carboniferous charcoal, formed synchronously with the folding and fracturing and associated with mountain lifting.

At Arouca UGGp, metamorphic and magmatic rocks outcrop with ages between approximately 600 Ma and 300 Ma. In this territory, the geological diversity is expressed in a unique way in its landscapes, punctuated by mountains sculpted by rivers that open their way through embedded valleys.

It is the above mentioned reality that, in a general way, we intend to make known during this brief visit to Arouca UGGp.

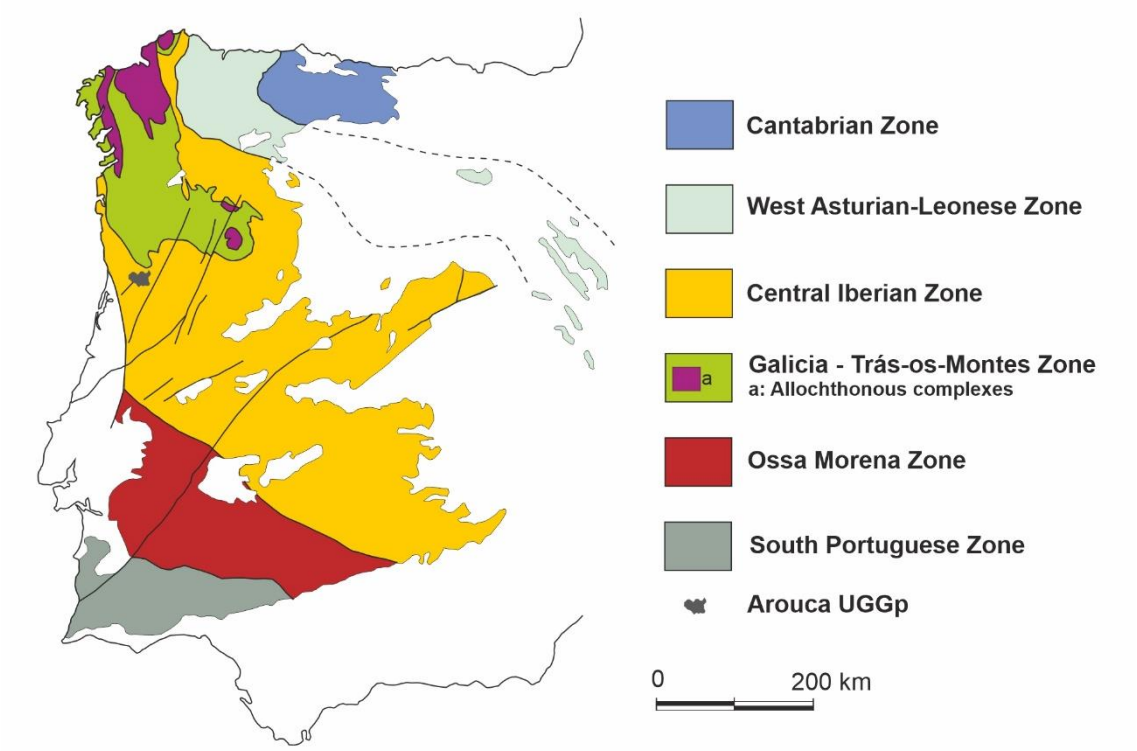

Figure 4. Division of the Hesperic Massif according to its tectono-stratigraphic characteristics, with reference to the location of the Arouca UGGp.

Stop 1. "Montemuro Doors" viewpoint

The designation of this viewpoint derives, according to Girão (1940), from the existence of a "work to defend an important population centre contemporary perhaps with the Roman conquest" (p. 10). Indeed, the ruins of the "Wall of the Montemuro Doors" are classified as an archaeological site and have been classified as a Property of Public Interest since 1974. In the 13th century, it was already mentioned in the Inquiries of 1258. According to several authors, the site has scant traces of a village fortified from the Iron Age, and can be considered as part of the Castro culture. "Doors" refers to a crossing point and "Wall" to the village wall. It was also called by shepherds and hunters as "Wall of Doors" or just "Wall" (C.M. Castro Daire, s.d.) (Fig. 5).

Figure 5. Wall of the Montemuro Doors. ©CM Cinfães

From “Montemuro Doors”, we have an impressive perspective of the morpho-structural units that characterize the north and littoral-center of Portugal: to the north, the Douro valley and the Marão mountain range; the highest sector of the Montemuro Mountain and the Central Plateaus to the east; the Gralheira Massif and Serra do Caramulo to the south; and to the west, the gradual descent towards the coast.

The “Montemuro Doors” viewpoint coincides with the passage between the south and southwest slopes of the Montemuro Mountain, well marked by the Paiva River valley, and the north slope, facing the Douro River. It also corresponds to the transition between the western sector, from S. Pedro do Campo – Perneval, and the culminating sector of the Montemuro Mountain and the Eastern Plateaus, which here give continuity to the Central Plateaus. (Vieira & Sá, 2019).

Among the geomorphological elements present in the Montemuro Mountain observable from this point, the Bestança River fracture valley and the immense diversity of granitic geoforms that outcrop here are worth mentioning. The Bestança River fracture valley (Fig. 6). It extends in a straight line, with a NW-SE direction and for more than 20 km, from the highest sectors of the Montemuro Mountain, next to the “Montemuro Doors”, to the Douro River.

The spectacularity of this valley is accentuated by the granite foothills of the Serra de Montemuro, more imposing on the left bank of the Bestança River, which contrast with the lower altitudes and less steep slopes to the East, associated with the movement of the fault.

The fracture valleys in the granitic regions are directly related to the exploitation, by the watercourses, of the structural weaknesses due to the fracturing of these rocks.

From the point of view of its valorization, we emphasize its scientific, aesthetic and ecological value. From these geomorphological elements we can observe the influence of the structure on the morphological evolution, allowing us to clearly identify the areas

of fragility of the granite massifs and the preferential action of the erosion processes. In addition to these aspects, they are excellent places for the observation of well-preserved riparian galleries, characterized by important ecosystem values. In addition to all this, it has an aesthetic value, provided by the high beauty of the landscape (Vieira, 2008; Vieira & Sá, 2019).

Figure 6. Fracture valley of the Bestança River. © António Vieira

Regarding the examples of granitic morphology observable in the area surrounding the "Montemuro Doors", the rocky domes of Perneval (Fig. 7) and Montemuro stand out, the latter corresponding to the highest point of the Montemuro Mountain (1382 m).

Figure 7. Rocky dome of Perneval. © António Vieira

These two forms correspond to larger granitic residual forms that reach kilometric dimensions. In the granitic literature they are often called bornhardt, constituting the most common and widespread type of inselberg. The bornhardt form is delineated by predominantly vertical or subvertical fractures, which are part of the orthogonal system (Twidale, 1982; Vidal Romaní & Twidale, 1998). The domic shape is defined, however, by the scaling, arched and convex structures, which give rise to essentially convex slopes.

Stop 2. S. Pedro do Campo viewpoint and Pedra Posta geosite

The viewpoint of S. Pedro do Campo is located in the western sector of the Serra de Montemuro, at about 1130 meters of altitude. It is close to the chapel of S. Pedro, in the middle of the summit of the Montemuro mountain range, where the Pedra Posta geosite is identified. This corresponds to a tor in the Montemuro granite, characterized by being a biotite-muscovitic granite, porphyroid with medium to medium-fine grains, sometimes becoming coarse. The SW of the chapel of S. Pedro do Campo develops a set of detailed granite forms that constitute a geomorphological nucleus of high interest. Located at an altitude of about 1150 meters, it incorporates forms of the tafoni type (Moor's House), “swinging stones”, slabs, gnammas, pseudo-stratifications, cannelures and polygonal cracks (“Corn bread” rock of Montemuro) (Fig. 8).

Figure 8. ‘Swinging stones’ located SW of the chapel of S. Pedro do Campo. © Tiago Martins / visitarouca.pt

The varied granitic morphology that can be observed here is a relevant aspect for the scientific valorization of this site. However, it is the aesthetic and landscape value that are assumed to be most important in this place (Fig. 9). The granitic landscapes of Montemuro Mountain, the Douro River valley and the Marão Mountain, to the north or the Gralheira massif to the SW, are elements of high scenic beauty that can be enjoyed from this location. Here, you can also appreciate the contrasting landscapes of the various landscape units of the Montemuro Mountain. Here, cultural aspects are also associated with natural ones, with this place of religious worship being associated with the geomorphological elements that stand out in this typically granitic landscape. (Vieira, 2008; Rocha, 2016, Vieira & Sá, 2019).

Figure 9. Landscape and granitic forms in the Pedra Posta geosite. © Tiago Martins / visitarouca.pt

Stop 3. "516 Arouca" suspension bridge and Paiva Walkway

This stop will require a walk of about 2,5 km, mostly downhill. Departing from Alvarenga, we will walk on a medium-grain, two-mica granite known as Alvarenga Granite. In contact with the formations of the Dúrico-Beirão Schist-Greywacke Supergroup, an aureole of metamorphism originated essentially formed by pelitic hornfels. This granitic intrusion, intensely eroded and giving rise to a bowl-shapes valley where the village of Alvarenga is located, is associated with a left shear zone and important tungsten mineralization, which were intensively exploited in placer deposits, essentially during the Second World War. (Medeiros *et al*., 1964)

The path takes us to the "516 Arouca" suspension bridge, which is currently the third longest infrastructure of this type in the world. It is an iconic work in the Arouca UGGp, consisting of 127 trays of metallic railings and steel cables, with a span of 516 meters, 1.20 meters wide and 175 meters high above the Paiva River. Each of the decks that make up the bridge works as a kind of independent capsule. In this way, the feeling of security and comfort becomes greater (Fig. 10).

Figure 10. "516 Arouca" suspension bridge, with view for the Aguieiras waterfall. Alvarenga village in the background. © Publituris.pt

As this area is also classified as part of the Natura 2000 protected areas network, visitors can immediately observe a rich and diversified fauna and flora, where there are several endemic species and even endangered species.

When crossing the bridge it is possible to observe the Aguieiras waterfall, one of the geosites of the Arouca UGGp. It is formed by the Aguieiras stream, the result of the confluence of several water lines that drain the bowl-shaped valley of Alvarenga, which falls precipitously by the granite cliffs that flank the right bank of the Paiva River, through a set of gaps totalling about of 160 m. The origin of this waterfall is entirely conditioned by the orthogonal fracturing network of this granitic massif (Rocha, 2008; 2016; Sá *et al*., 2008).

This waterfall is properly equipped for canyoning, an adventure sport, which is characterized by a controlled progression in the bed of a river/stream, through the transposition of vertical obstacles using different techniques. When going through this canyoning, it is need to overcome nine gaps in rappel, the largest of which has a gap of 65 m, for a period of time that can extend between 2 to 3 hours. It is classified as a slightly difficult canyon (Class 3, for a maximum of 7) (Paz *et al*., 2014).

In the middle of the bridge, it is still possible to observe, upstream of the bridge, the valley excavated in a canyon, with vertical walls, locally known as "Paiva Gorge" and which is a geosite, of linear typology, of the Arouca UGGp. Downstream of the bridge, it can be seen that the Paiva River valley opens in a wide V. This marked geomorphological variation is entirely associated with the bedrock that the river intersects, in the first case the granites and in the second the schists and greywackes, with the latter being more deformed and fractured and less resistant to erosion. Various differences in levels between tight gorges and rocks make the Paiva River one of the best rivers for practicing white water activities in the winter months, such as rafting, kayaking, hydrospeeding and canoeing. It is considered by experts as one of the best whitewater tracks nationally and a reference at an international level.

During and after crossing the bridge, it is possible to observe on the left bank of the Paiva River a wooden infrastructure that corresponds to the famous "*Passadiços do Paiva*" (= Paiva walkways). This infrastructure are currently the most popular tourist infrastructure in Arouca UGGp. Designed to allow visitors to access and enjoy the beauty of the pristine nature existing in the canyon section of the Paiva River, mainly in its section excavated in the Alvarenga Granite, this walkway quickly took on a media coverage that, since its opening in June 2015, more than 2.000.000 visitors have requested this infrastructure. The mission of this walkway is to preserve, enhance and publicize the Paiva River and its surroundings (landscape, geosites, ecosystems and biodiversity), making the territory more sustainable and resilient. As a corollary of this impact on local tourism, the Paiva Walkways have been awarded since 2016 with eleven World Travel Awards, considered the "tourism Oscars", in categories such as "Best European Tourism Development Project", "Best European Tourist Attraction of Adventure" or "Best Adventure Tourism Attraction in the World". Currently, daily access to the infrastructure is limited to 2.000 visitors, who must previously register and purchase the necessary access ticket via the internet (https://reservas.passadicosdopaiva.pt/en/bilhetes).

Travel along the approximately 8.6 km of this infrastructure built in wood along the left bank River Paiva (Fig. 11) allows visitors not only to enjoy a healthy walk in contact with nature, but also to learn about the geological (visit to five geosites of Arouca UGGp) and biological heritage (biodiversity station) of the territory (Vieira & Sá, 2019).

We will walk upstream along the left bank, going down the walkways to the Alvarenga bridge, a masonry road structure that is right at the entrance to the Paiva Gorge. From this is possible to observe the open V-shaped valley upstream, the hornfels marking the geological contact, and the giant potholes at different levels on the banks and riverbed (Rocha, 2008; 2016; Sá *et al*., 2008; Sá & Rocha, 2020).

Figure 11. Paiva walkways, in the left bank of the Paiva River. © AGA

The bridge, dating from the 18th century, was ordered to be built by the Bishop of Lamego (D. João) and completed in 1791, by charter of D. Maria I (Oliveira *et al*., 1999). It is made up of three arches with its main arch spanning seven meters (Fig. 12).

Figure 12. Alvarenga bridge, seen from the Paiva walkways, marking the entrance to the Paiva Gorge geosite. © AGA

Stop 4. Senhora da Mó viewpoint

Senhora da Mó is the best-known viewpoint of the Geopark, located in a position overlooking Arouca; it provides an excellent site to view the general geomorphological pattern of the region within a 360º panorama. The landscape is characterized by the occurrence of igneous, metamorphic and sedimentary rocks with differential resistance to weathering and erosion.

The Arda Valley, excavated in the Arouca bowl-shaped valley with its fertile soil, is a symbol of the main economic activity developed in the region for centuries (Sá & Rocha, 2020).

In this place, there is a small chapel with Arab features (Fig. 13), built in honor of *Senhora da Mó* (= Our Lady of the Millstone) who, according to legend, saved a Christian from slavery by the Moors. Trapped inside a wooden box, with a millstone on top, he took advantage of the knots in the rope to pray fervently, achieving the miracle of deliverance. Therefore, on the night of the 7th to the 8th of September, the men of Arouca bring to life the *Casa da Ceia* (= supper house), located next to the chapel, preparing codfish and all the delicacies of the feast in honour of the patroness. In Arouca, Our Lady of the Millstone is considered a lawyer for the fields, crops and animals and a protector against droughts and thunderstorms. It is also said that the Lady «has six more sisters», as the hermitages of Marian invocation can be seen from her chapel, located in the surrounding hills: Our Lady of the Hill; Our Lady of the Slab; Our Lady of the Blackberries; Our Lady of the Castle; Our Lady of the Guidance and Sainte Marie of the Hill (Costa, 2003).

Figure 13. Our Lady of the Millstone chapel. © European Atlantic Geotourism Route.

Lunch will be a pick-nick with products bearing the seal “GEOFood®”. The initiative and registered trademark “GEOfood®” appeared in 2015, coordinated by Magma UGGp in

Norway, Odsherred UGGp in Denmark, Rokua UGGp in Finland and Rejkyanes UGGp in Iceland. Today it constitutes an International Network, which brings together several UGGps and which aims to promote and enhance the relationship between its unique geological heritage and local food traditions. The AGA has been stimulating and promoting the agricultural sector and its food chain through the municipal project "*Arouca Agrícola*" (= Agricultural Arouca), articulating it with the principles of the GEOfood® network. The main goal is to link food and territory, tourism and health, sustainability and flavour and, in this way, bring the consumer closer to nature, local products and their origin and culture.

Currently GEOfood® International Network is an international movement that promotes the connections between local food and geological heritage, so that these can be used to enhance sustainable development in UNESCO Global Geoparks. GEOfood aims to increase the awareness of geological heritage and its connection to peoples' livelihoods. GEOfood products are branded to make consumers aware of the strong connection between food production and geodiversity. The "IGCP 726 GEOfood for sustainable development in UNESCO Global Geoparks Project" (Fig. 14), supported by UNESCO, proposes a scientific approach to GEOfood, starting from the connection between geoheritage, geodiversity, ecosystem services, food production and sustainable development (UNESCO, 2022).

Figure 14. Official logo of the "IGCP 726 GEOfood for sustainable development in UNESCO Global Geoparks" Project.

Arouca UGGp is part of the GEOfood® International Network, offering locally a network of participating restaurants, which include a greater variety of local products in their menus; tourist visits to producers - «Arouca Agrícola Itineraries», awareness actions, with the school community, through the pedagogical restaurant and canteens or through dedicated educational programs and projects.

Stop 5. Detrelo da Malhada viewpoint

Accessing the existing visitor platform at the Detrelo da Malhada viewpoint (Fig. 15), it is possible to see a significant part of the territory designated as Arouca UGGp and many

of the main features of its geomorphology. In this context, the geological contact between the Ante-Ordovician metasediments (schists and greywackes) and the Arouca quartz-diorite can be observed in a very distinct way. The northern slope of this mountain preserves a set of different levels of erosion, which prove the movement of displacement of the blocks, which raised this mountain. The Arouca valley, geomorphologically known as the complex alveolus of Arouca, is a bowl-shaped valley carved into quartzodioritic rock, very prone to chemical weathering, and its bottom has accumulated sediments resulting from erosion of the surrounding area, which were retained here due to the hardness and resistance to erosion of the «*Pedra Má*» (= bad rock), a hornfels outcrop of located on the limits of the villages of Rossas and Várzea (Brum Ferreira, 1978; Rochette Cordeiro, 2004) (Fig. 15).

Figure 15. Bowl-shaped valley of Arouca from Detrelo da Malhada viewpoint. © AGA

On clear days, a close look at this landscape allows us to identify the geological contact between the mica schists and the quartz-diorite from Arouca. To the North, it is possible to easily observe the elevations of Gamarão, the Paiva River valley, the Montemuro Mountain, the Douro valley socket, the mountain ranges of the Valongo region, and the Marão, Larouco and Gerês mountains. To the west, the coastal region between Espinho and Porto, and, to the east, the Côto do Boi and the Serra da Arada, where the São Macário hill stands out (Rocha, 2008; 2016; Sá *et al*., 2008).

The structuring of this territory occurred mostly during the upper Miocene, due to movements of large lithospheric blocks, which defined plateaus and diverse erosion levels identified in the landscape and exhumed the Andalusite-rich schists (Acciaioli Mendes, 1997; Acciaioli Mendes & Munhá, 1998) here observed and that mark some hardness reliefs in the surroundings of Detrelo da Malhada and Côto do Boi.

The occurrence of periglacialism in this region, during the last glacial cycle, left its mark both on the flattened and eroded surface of the Serra da Freita, as well as on the alteration of rocks and soil formation, essentially in the alveoli of Arouca and Moldes (Rochette Cordeiro, 2004; Rocha, 2016). The incision of the Arda River that took place at the end of the Cenozoic, as well as the formation of the fertile soils we know today, was decisive for the implantation of the Monastery of Arouca, in the 10th century, as well as for the development of this region.

Stop 6. S. Pedro Velho bornhardt

This site is a bornhardt landform, a type of inselberg developed on the Freita Mountain granite together with diverse granitic boulders with weathering pits (Fig. 16).

At its top there is a 1st order geodesic landmark whose base is located at an altitude of 1077 m a.s.l.

Figure 16. Geodesic landmark of S. Pedro Velho, on top of a bornhardt in the Freita Mountain. © AGA

Having undergone a geoconservation intervention, this geosite is equipped with a 360º observation deck and four interpretive panels directed to the four main cardinal points (Sá & Rocha, 2020). Allowing its visitation in safe conditions, while providing basic information to visitors, this Arouca UGGp geosite is assumed as one of the unique viewpoints in this territory. In fact, the landscape that can be seen from here on clear days is impressive, and its all-around panoramic view allows observing from the mountains of Gerês to Estrela, or from the coastline to the distant Peña de Francia, near

Salamanca, already in Spain, in an imaginary line that crosses the entire width of the Portuguese mainland.

However, a closer look at the landscape, with the help of the information contained in the railing of the balcony protecting the visitation platform, makes possible to the observe the coastline from the vicinity of Póvoa de Varzim (NW) until the vicinity of Cape Mondego (SW), easily distinguishing from the W the different arms of the Estuary of Aveiro. Towards the N-NE it is still possible to distinguish the mountains of Larouco, Montesinho, Padrela, Cabreira, Alvão, Marão and Montemuro. To the E-SE it is still possible to see the Marofa and Estrela mountains and, to the S, the Caramulo and Buçaco mountains. A true compendium of the mountains of northern and central Portugal (Fig. 17).

Figure 17. Panoramic view over the degraded plateau of Freita Mountain and the distant mountains located to the E and SE, from the observation platform of S. Pedro Velho. © AGA.

In addition, a closer and detailed observation will also allow us to point out the typical villages of the mountains, especially Albergaria da Serra, with its pasture and rye fields and small subsistence vegetable gardens. From here leave every day to graze, independently, the 'Arouquesa' cows, where they also return of their own accord at the end of the afternoon.

Stop 7. Frecha da Mizarela viewpoint

The Frecha da Mizarela waterfall (Fig. 18), considered the highest in mainland Portugal, occurs in the upper section of the Caima River and is projected in a gap of about 70

meters in height, defined in the geological contact between the Granite da Serra da Freita and the Ante-Ordovician metasediments that outcrop downstream. The occurrence of this waterfall is closely linked to the Serra da Freita fault system and the movements associated with the Alpine Orogeny. However, the geological contact by fault where the waterfall is observed will correspond to a very old fault associated with the Freita Mountain shear zone, having already been identified the occurrence of movement during the Caledonian and Variscan orogenies.

From this location it is possible to see the mountain geomorphology, associated with different lithologies, with emphasis on the granitic landscape marked by chaos of blocks and bornhardts. To the West, it is possible to observe the Meso-Cenozoic border, where the Estuary of Aveiro is clearly identified in the section between Aveiro and Ílhavo (Vieira & Sá, 2019; Sá & Rocha, 2020).

Figure 18. Aspect of the Frecha da Mizarela waterfall at the end of the day. © Tiago Martins / visitarouca.pt

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