Geoheritage and Mining Heritage in the Promotion of Theme Parks: An Example of the National Park Đerdap (Carpathian-Balkan Thrust-And-Fold Belt, Eastern Serbia)

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ORIGINAL ARTICLE

Geoheritage and Mining Heritage in the Promotion of Theme Parks: An Example of the National Park Đerdap (Carpathian-Balkan Thrust-And-Fold Belt, Eastern Serbia)

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Abstract

The National Park Đerdap (eastern Serbia, vicinity of the Danube River) occupies a segment of the Carpathian-Balkan fold-and-thrust belt and has a significant geoheritage potential, accounting for the impressive natural (geological) and cultural legacy. In addition to the extraordinary orogenic-type landscape or nappe-stacked mountainous configuration, the region contains evidence of ancient mining activities, uncovered within its immediate neighbourhood. The ancient mining activities date back a few thousand years ago and represent a solid ground for the idea of establishing a theme park, including the accompanying mining museum. Historic sites of this type are very attractive, whereas the global practice indicates that the abandoned ore derelict mines could not be easily transformed into a facility with new economically viable content. These have often been left to reveal their dumps, junk piles and ruined leftovers of the formerly used mining tools and equipment.

A recent global trend tends to preserve the ancient mining sites, with the attempt to establish a mining museum or theme park. The foundation of the theme park has the goal to make an attractive tourist offering for this part of Serbia. Importantly, old mines are in a social–historical sense the archaeological localities documenting the pioneering mining and archaeometallurgy attempts. Ancient mining sites offer a rich legacy of mining and metallurgical tradition, representing objects or geosites needing conservation and preservation at the social level to outline the sustainable development of a region. This goal is in line with the guidelines and the criteria for developing theme parks, proposed by UNESCO. Thus, here we emphasize the importance of natural and cultural heritage, which represents a significant input of the mining legacy further supporting the idea of establishing a theme park within the National Park Đerdap.

Keywords Carpathian-Balkan Fold-and-Thrust Belt · Mining Legacy · Đerdap Geopark · Theme Park · Mining Museum · Conversation · Sustainable Development · Geotopes · Serbia

Introduction

Geodiversity plays an important role in environment and human activities (e.g. Kubalíková, 2013). Because the broader Đerdap area (Fig. 1a) of the Carpathian-Balkan arch is characterized by an exceptional geological, historical and cultural heritage, the Executive Board of UNESCO accepted the nomination of the Đerdap Geopark and included it within the Global Geoparks and the European Geoparks Network during the 209th session (during July 2020). Hence, the newly proclaimed Geopark covers an area of 1,330 km2, encompassing the area of the National Park and other protected areas of national and local significance.

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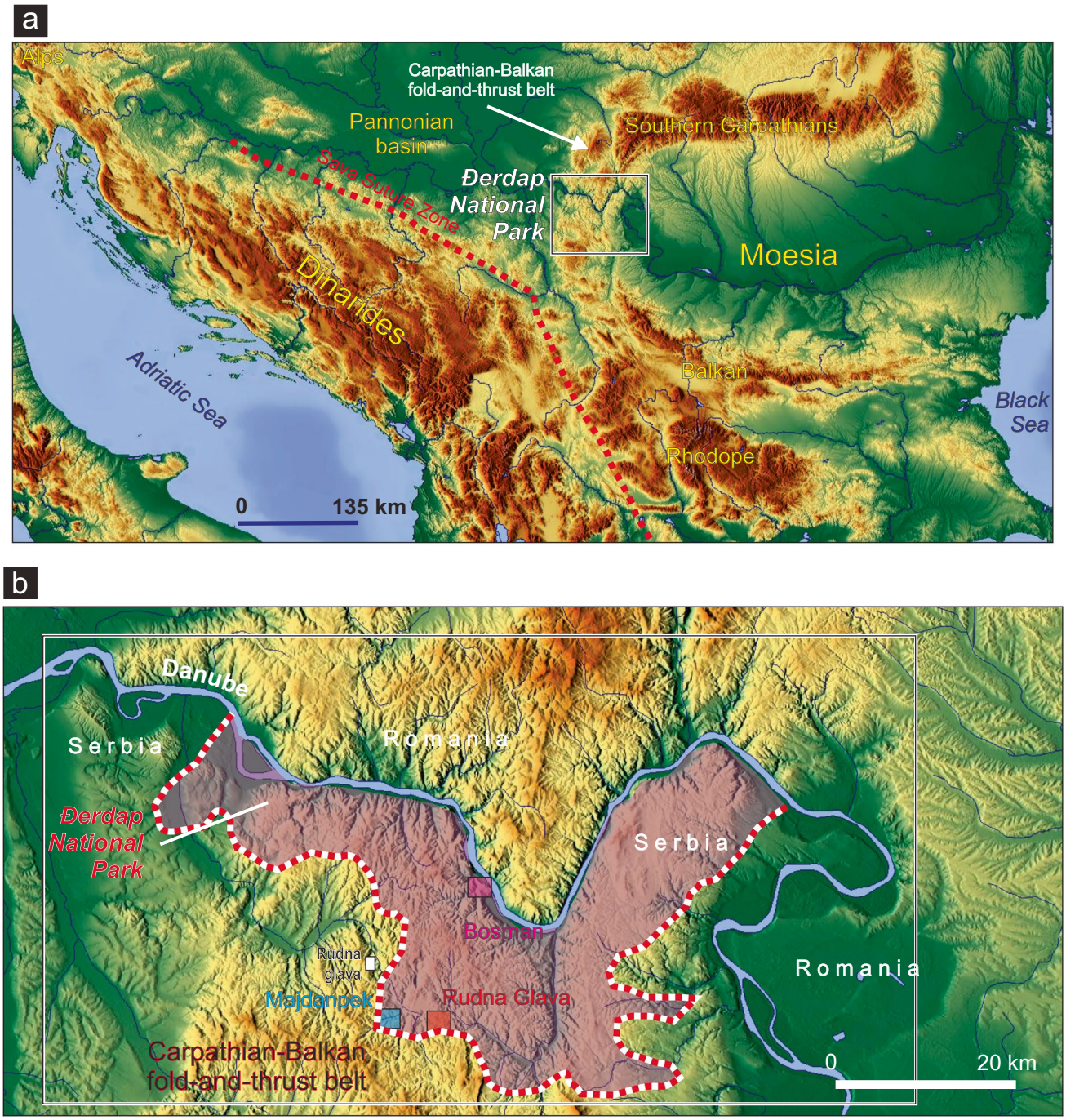


Fig. 1 **a** The position of the National Park Đerdap within the major relief units, including the position of the principal Tethyan suture zone, referred to as the Sava suture zone (maps taken from https://maps-for-free.com/). **b**. The sites with a documented mining-related geoheritage: 1. Rudna Glava, 2. Majdanpek, and 3. Bosman

The geology of the extraordinary Carpathian-Balkan fold-and-thrust belt, including a few recent geoheritage studies (e.g. Belij et al., 2018) dealing with the broader area of "The National Park Đerdap" (hereinafter NPĐ; Nacionalni Park Home—Национални парк Ђердап (npĐerdap.rs) Assessed on 14/03/2022), allowed distinguishing several outstanding

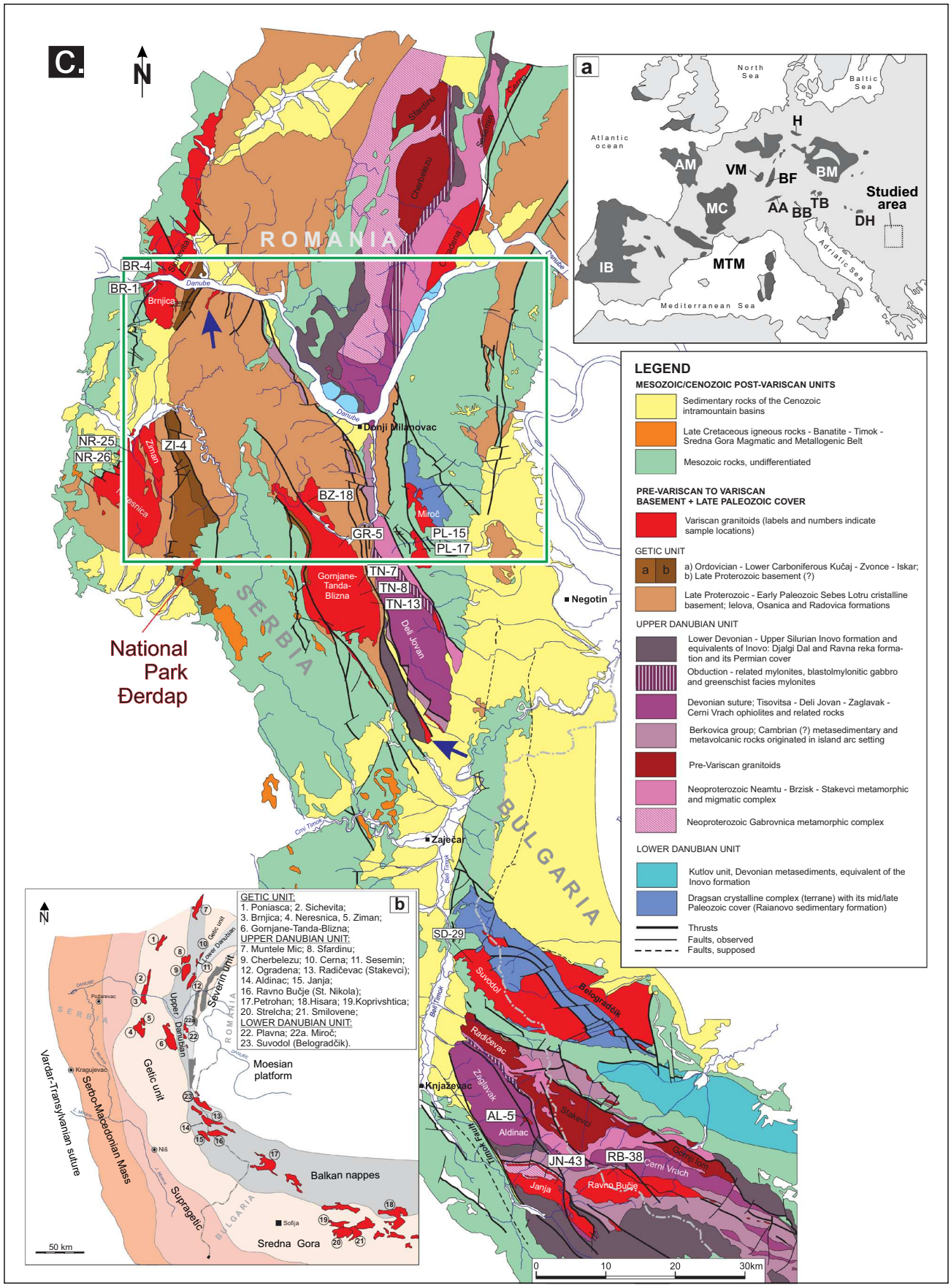
geotopes[1] distributed across the investigated area (for the term geotope, see also in Ielenitcz 2009; Fig. 1a, b). In general, geotopes allow the education of an audience of a wide background, including the illustrative classes for the basic studies of geology and environmental protection. In addition, the investigated sites as geotopes have great scientific importance, because it contributes and supports the idea of developing a theme park that will surely elevate the attractiveness of the region itself (Rabrenović et al. 2010a, b, 2014a; Marescotti et al., 2018). Although the UNESCO convention for the protection of the world cultural and natural heritage (which recognizes unique and valuable geosites) was proposed a while ago (in 1972), the international framework for the identification of geoheritage objects at both regional and national levels still lacks (see e.g. Kaźmierczak et al., 2019, for a discussion). In Serbia, the initial attempts for geoconservation are dating back to the early XX century (see Maran, 2012, for details). The UNESCO encouraged and supported the formation of the NPĐ, with the purpose to help in the preservation of the legacy of the planet Earth (natural heritage; e.g. Maran and Grigorescu, 2006). Among the spectrum of natural heritage sites are landscapes and relief, including geological formations that have had an essential role in the evolution of the Planet Earth. The NPĐ is characterized as a "*geological site of particular importance for the understanding of the Earth history, which further allows displaying a wide range of diverse geodiversity and associated processes, either of the national or of the international importance*" (Milovanović and Maran, 2014). The next step in improving the investigated site includes the constraints on geodiversity, cultural, historical, ethnological, archaeological and tourist objects (see Maran and Grigorescu, 2006; Maran Stevanović 2015, for a discussion). The improvement steps mean adapting such geoheritage objects to serve particular functions that further should be within the frame of sustainable development (e.g. Brankov et al., 2015), focused either exclusively on a single, or several local communities, municipalities or regions. The NPĐ is an area with several geosites, having well-defined borders (Fig. 1b) in which the proposed rehabilitation of derelict mine activities along with the establishment of a Mining Museum would contribute sustainable development of rural areas (Calder 2014).

Mining heritage locations are cultural monuments of mining heritage (Marescotti et al., 2018). Mining activities as industrial sites encompass not only architectural but also landscape elements related to geology or topography (Conesa et al., 2008). Mining heritage is at its core a wide-ranging term with various meanings, which include geological, natural, historical, architectural, technological and geomorphologic aspects. According to the definition reported by Rybar et al., (2012), mining heritage includes *natural heritage* (fauna, flora and minerals), *geoheritage* (palaeontology, mineralogy, petrology, geomorphology, structural geology, hydrogeology, and volcanology), *diverse heritage* (landscapes and ecology), *cultural heritage* (history, archaeology, ethnology, technology, technical objects, mine museums, mythology). The listed topics represent a strong argument for contributing to the eventual constitution of a theme park, and the opening of several geoparks in certain highly interesting regions with many geological rarities, such as the Carpathian-Balkan fold-and trust belt and its well-exposed geological structures with its stratigraphical units (Figs. 1a, 2).

The NPĐ role with its spectacular scenery is to expand its attractiveness to the region by preserving the natural and cultural heritage. Preservation of the natural and cultural heritage should be following the local cultural tradition. To expand attractiveness to the region, the NPĐ already provides necessary constraints and makes a publicly available understanding of representative rocks, minerals, quarries, gold-bearing exposures, mine shafts and associated mining tools, etc. The economic activities associated with sustainable exploitation of the mineral resources in a certain region are commonly developing until the point which is defined by the ore-exhausting limits. Having in mind the active mining development plans, the long-termed economic and ecologic development should not be based upon unsustainable resources. With a few exceptions, *e.g.* (Example of reclamation & restoration of a mine. Reclamation and restoration—Boliden Assessed on 08/03/2022), the global-scale mining-related exploitation of gold, silver, iron, lead, zinc and copper, which has been the main economic river of several countries, becomes the issue after a mining site is closed. The termination of mining activities may result in the awakening of eventual economic and even social problems. The ecological consequences that may occur during the mining process, including the mine closure process, raise the question of the environmental impact on the existing local ecosystems (e.g. Orche 2003; Lugon et al. 2003). The key question is the rehabilitation/remediation methods, which could be applied after the shutting down of an active mine, with the purpose to avoid local nature devastation. Nevertheless, negative environmental and landscape impact of abandoned mining sites may, in turn, represent a new source of income for local communities. As a rule of thumb, cultural monuments of mining heritage require the remediation and the categorization of a site as geoheritage and geotouristic or ecotouristic destination (see Marescotti et al., 2018, and references cited therein). The rehabilitation of a mining site

[1] Geotope by Strasser et al., 1995, are places of distinct geological or geomorphological interest relevant for understanding the evolution of certain regions, the importance of rocks as being parts of the unit landscape.

Lugon et al. (2003), Geotopes are complex geological features represented by distinct localities. Many of them display historical, economic and cultural values, too.


C.
N
a
North Sea
Baltic Sea
Atlantic ocean
H
AM
VM
BF
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MTM
Adriatic Sea
Mediterranean Sea
ROMANIA
SERBIA
BULGARIA
Danube
Brnjica
Donji Milanovac
Miroč
Negotin
Zaječar
Knjaževac
Crni Timok
Beli Timok
Ziman
Resnica
BR-4
BR-1
NR-25
NR-26
ZI-4
BZ-18
GR-5
PL-15
PL-17
TN-7
TN-8
TN-13
Gornjane-Tanda-Blizna
Deli Jovan
SD-29
Suvodol
Belogradčik
Radičevac
Zaglavak
Stakevci
AL-5
Aldinac
JN-43
RB-38
Janja
Ravno Bučje
Cerni Vrach
Gornji lom
National Park Đerdap
LEGEND
MESOZOIC/CENOZOIC POST-VARISCAN UNITS
Sedimentary rocks of the Cenozoic intramountain basins
Late Cretaceous igneous rocks - Banatite - Timok - Sredna Gora Magmatic and Metallogenic Belt
Mesozoic rocks, undifferentiated
PRE-VARISCAN TO VARISCAN BASEMENT + LATE PALEOZOIC COVER
Variscan granitoids (labels and numbers indicate sample locations)
GETIC UNIT
a) Ordovician - Lower Carboniferous Kučaj - Zvonce - Iskar; b) Late Proterozoic basement (?)
Late Proterozoic - Early Paleozoic Sebes Lotru cristalline basement; Ielova, Osanica and Radovica formations
UPPER DANUBIAN UNIT
Lower Devonian - Upper Silurian Inovo formation and equivalents of Inovo: Djalgi Dal and Ravna reka formation and its Permian cover
Obduction - related mylonites, blastolmylonitic gabbro and greenschist facies mylonites
Devonian suture; Tisovitsa - Deli Jovan - Zaglavak - Cerni Vrach ophiolites and related rocks
Berkovica group; Cambrian (?) metasedimentary and metavolcanic rocks originated in island arc setting
Pre-Variscan granitoids
Neoproterozoic Neamtu - Brzisk - Stakevci metamorphic and migmatic complex
Neoproterozoic Gabrovnica metamorphic complex
LOWER DANUBIAN UNIT
Kutlov unit, Devonian metasediments, equivalent of the Inovo formation
Dragsan crystalline complex (terrane) with its mid/late Paleozoic cover (Raianovo sedimentary formation)
Thrusts
Faults, observed
Faults, supposed
b
GETIC UNIT:
1. Poniasca; 2. Sichevita; 3. Brnjica; 4. Neresnica, 5. Ziman; 6. Gornjane-Tanda-Blizna;
UPPER DANUBIAN UNIT:
7. Muntele Mic; 8. Sfardinu; 9. Cherbelezu; 10. Cerna; 11. Sesemin; 12. Ogradena; 13. Radičevac (Stakevci); 14. Aldinac; 15. Janja; 16. Ravno Bučje (St. Nikola); 17.Petrohan; 18.Hisara; 19.Koprivshtica; 20. Strelcha; 21. Smilovene;
LOWER DANUBIAN UNIT:
22. Plavna; 22a. Miroč; 23. Suvodol (Belogradčik).
Moesian platform
Getic unit
Severin unit
Upper Danubian
Lower Danubian
Vardar-Transylvanian suture
Serbo-Macedonian Mass
Supragetic
Balkan nappes
Sredna Gora
Sofija
Niš
Kragujevac
Požarevac
50 km
0 10 20 30km

◂**Fig. 2** Simplified geological map after Kräutner and Krstić (2002), inset from Jovanović et al. (2019), slightly modified. **a**. Distribution of the European Variscan complexes: AM Armorica massif, IB Iberian massif, MC Massif Central, MTM Maures–Tanneron massif, VM Vosges massif, BF Black Forest massif, H Harz massif, BM Bohemian massif, DH Dinarides–Hellenides. **b**. A geotectonic sketch of the Carpathian–Balkan sector with locations of the pre-Alpine granitoids (inset from Jovanović et al. 2019, from Karamata 2006). **c**. The map of Getic and Danubian units (inset from Jovanović et al., 2019)

requires a set of technical requirements that may lead to the revitalization of geological and mining heritage (and building a post-mining infrastructure). Such a stepwise approach towards the new life of a mine demands the postulating of a set of new crucial elements (e.g. set-up of post-mining objects) which may raise the regional tourist attractiveness. However, the initial step is to apply sustainable active mining development, in particular in the Carpathian-Balkan area having such an extraordinary geoheritage potential (e.g. Belij et al., 2018).

Geological Outline of the Đerdap Area (Carpathian-Balkan Fold-and-Thrust Belt, Segment in Serbia)

The remarkable Carpathian-Balkan thrust-and-fold belt is a segment of Alpine-Himalayan orogen (also known as east Serbian "Carpatho-Balkanides"; Fig. 2a) that is an N-S striking mountain range (section in Serbia), tectonically bent around the Moesian platform (Fig. 1a, b). A high geodiversity of the Carpathian-Balkan thrust-and-fold (63 geoheritage sites; Belij et al., 2018) mostly contributes to its final tectonic shaping, which occurred during the Eoalpine compressional nappe stacking, lasting from the Early Cretaceous up to the Eocene time (e.g. Krstekanić et al. 2017; see Spahić and Gaudenyi 2022, for a discussion). Interestingly, the Carpathian-Balkan fold-and-thrust belt contains evidence of the precursory pre-Alpine Variscan Late Paleozoic event as well (e.g. Antić et al., 2017; Spahić and Gaudenyi, 2018; Spahić et al. 2019; Balintoni et al. 2014).

This geologically complex Carpathian-Balkan fold-and-thrust belt area has had been attracting numerous geoscientists, including these dealing with the complex Alpine paleogeography and tectonics of the area (e.g. Kräutner and Krstić 2002; Kovács et al. 2011; Schmid et al. 2008, 2020). According to the earlier authors (Kräutner and Krstić 2002), the Carpathian-Balkan thrust-and-fold belt can be separated into several stacked units: the Vrška Čuka–Miroč Unit (Lower Danubian); the Stara Planina–Poreč Unit (Upper Danubian); the Kučaj Unit (Getic); the Lužnica Unit (West Kraishte); the Ranovac–Vlasina Unit (Supragetic basement unit); the Serbian–Macedonian Unit (Fig. 2b). This area has been pierced by the abundant magmatic entities of various ages (Fig. 2b; see Jovanović et al., 2019, for details). A more recent geotectonic report includes a sketch map favouring the terrane approach shaped by the Late Cretaceous events (Fig. 3; Schmid et al., 2008). The ongoing mining activities have been active in the so-called Dacia unit, or within the "Timok magmatic complex" (Janković, 1990; Koželj and Petrović, 1998; also in Velojić et al., 2020) at the boundary between the Danubian and the Getic units (Fig. 2, 3).

On the regional scale, the area of the Carpathian-Balkan thrust-and-fold belt belongs to the western segment of the Alpine–Himalayan orogen, which yielded the economically viable Apuseni-Banat-Timok-Srednogorie magmatic arc of the Late Cretaceous age (e.g. Janković 1997; von Quadt et al. 2005; Zimmerman et al. 2008; Berza and Ilinca 2011; Gallhofer et al. 2015; Şerban 2020; Fig. 3). Despite the Apuseni-Banat-Timok-Srednogorie magmatic arc following the bent shape of the fold-and-thrust belt itself, a general younging of the magmatism, starting from ca. 92 Ma in the north, up to ca. 78 Ma in the southern region is observed (van Quadt et al. 2005). The age inconsistency of the magmatic activity indicates probable oblique subduction along the active margin. The associated Late Cretaceous active margin was underneath the East Vardar Zone, striking towards the Apuseni Mts., further across northern Bosnia and Herzegovina, Croatia (Spahić and Gaudenyi 2022). The back-arc positioned Apuseni-Banat-Timok-Srednogorie magmatic arc is characterized by the associated calc-alkaline magmatism and Cu–Au mineralization (van Quadt et al. 2005).

Outline of the Metallogenic Setting (vicinity of NPĐ)

Mining activities in eastern Serbia constituted for more than 2000 years represent the most important economic activity in this rather developing region of the Central Balkan Peninsula. The Cu–Au mineralization-bearing Apuseni-Banat-Timok-Srednogorie magmatic arc represents a segment of the larger Tethyan Eurasian metallogenic belt (Janković 1997). In local terms, this belt belongs to a Carpatho-Balkanian metallogenic province (Jelenković et al., 2008). Here in eastern Serbia, this belt also represents a productive calc-alkaline porphyry environment or the Timok-South Banat metallogenic province (Velojić et al., 2020; Şerban 2020). More locally, in the vicinity of the city of Bor (Fig. 2b), there is a number of copper–gold-bearing deposit, *for example* Čukaru Peki, Veliki Krivelj, Majdanpek, etc. (*e.g.* Jelenković et al.,

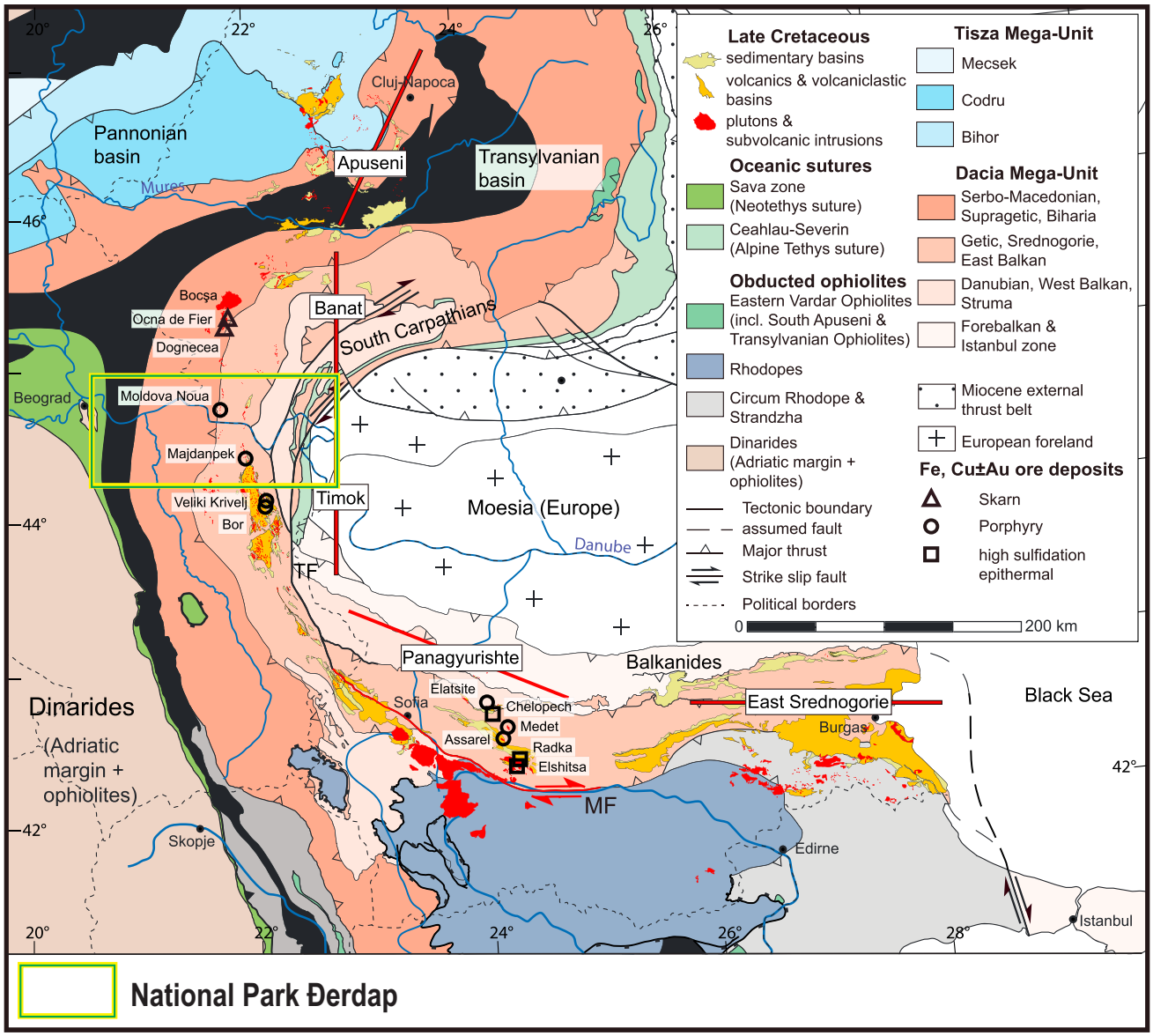

Fig. 3 The principal tectonic units of this segment of the Carpathian-Balkan fold-and-thrust belt (according to Schmid et al., 2008), including the locations on the ongoing mining activity sites (inset from Gallhofer et al., 2015, slightly modified)

2008; Gallhofer et al., 2015; Velojić et al., 2020). Another locality is the Blagojev kamen (to the NW of Majdanpek; Fig. 1b), characterized by several different generations of mineralizations, including the oldest of the Neoproterozoic age (Bugarin, 1998; Bugarin and Ljubojev, 2007). In addition to the ongoing mining exploration and exploitation activity, and the exposed extraordinary structural geology objects (the stacked Alpine nappes and the poorly investigated presence of the Variscan amalgamation/nappes; e.g. Spahić and Gaudenyi 2018; Plissart et al. 2018; Jovanović et al. 2019; Spahić et al. 2019; Figs. 2, 3), the investigated area contains several sites with a high potential for the inclusion into the regional mining heritage.

Methodology

Some recent studies highlighted the methodological processes facilitating the characterization of the ancient to modern-day mining sites of geoheritage significance (Carrión Mero et al., 2018). These "geoheritage exploration steps" include the compilation and inventory of all the sites

(in particular geological or mining interest); preparation of reports and thematic cartography often in ArcGIS digital data frame, involving assessment and classification of the elements of geological mining interest. The constraints on SWOT (Strengths, Weaknesses, Opportunities, and Threats) and TOWS (Threats, Opportunities, Weaknesses, Strengths) matrixes may help in seeking the viability of geotourism (Carrión Mero et al., 2018).

The investigations on the geoheritage of the NPĐ, and the entire "Carpatho-Balkanide" district, are based on the focused field geological mapping work, with special attention to potential geoheritage sites. The starting point or laboratory work was based upon the analyses of the large cluster of available literature data. In addition, we used 1:25,000 scale available geological maps for the area, 1:100,000 scale (Geological Maps of SFRY, 1:100,000. https://geoliss.mre.gov.rs/OGK/RasterSrbija/ Assessed on 09/03/2022 NP Đerdap—Geoforma FZE—Avenza Maps assessed on 06/03/2022 Relief Map (maps-for-free.com) assessed on 06/03/2022), and maps focusing on regional geology on different scales (e.g. Kräutner and Krstić 2002). We used vectorized and raster maps (Digital Terrain Model, aerial and satellite imagery, geological and geomorphological maps, etc.). After finishing the initial field-mapping stage and mapping of its natural features (geology, etc.), special attention was directed to human intervention sites (near-mining settlements, principal traffic and secondary roads, facilities, and active and old mining site). More specific information about the former mining activity required tedious bibliography-based work (scientific papers, old records, locally printed books, old guidebooks), reading available technical reports (mining plans, old maps, law records), to find and analyse old and new pictures, photographs, drawings, to make several interviews with ex-miners and residents, including in situ inspections, measurements, GPS (Global Positioning System) position data, sampling and analysis of the mining areas. The survey research was on a sample of ca. 20 respondents.

In the final stage, the study combined the available archaeological and geological data as the input parameters. The unique available sources of data are the local museums, as such "*Narodni muzej*" (translated from Serbian as National Museum), including the important discussion with NPĐ stuff. In addition, we conducted interviews with some key actors (the technical staff of the NPĐ), and their views on the issues raised, which we indirectly included in our conclusions. We discussed in the form of a questionnaire for the local population, comprising different sections—socio-demographic characteristics, opinions on the economic situation, tourism and its perspectives in the future, and the overall relation to NPĐ.

Results and Discussion: Promotion of the regional mining heritage, adaptation of mining processes, theme parks and remarkable regional geology

On the global scale, mining carries an important heritage value, regardless being in the active phase or not. In turn, once mine is in a closing stage, the loss of associated activities may lead to social and economic problems. Apart from the acute employment problem, the principal issue is the insufficient financing necessary for the mine site repurposing and rehabilitation. Another problem is that the attractive features, like remnants of mining activities with a scientific and engineering interest, including the local geological heritage are left behind, without any remediation or cultivation imposing environmental risk. Eventual timely implementation of the preventive and rehabilitation techniques may prevent further devastation and degradation of the local heritage and remarkable natural landscape. Moreover, depending on the mineral exploited, remnants of mining exposures may have global importance, in particular, once coupled together with local architecture and valuable archaeological findings (such are the local religion, local culture and traditions). These priceless geoheritage materials and associated mining and geolocations need a well-planned repurposing, rehabilitation and reclamation to turn these abandoned relics into a thematic tourist-attractive and educative site (Kovacs and Fulop 2009). Instead of a common restoration into a mining-theme park that is associated with several critical aspects (collapse risk, hydrogeological conditions, surface and underground water, soils of waste-rock dumps, and of the entire mining area, accelerated erosion processes, landscape change, etc.; Marescotti et al., 2018), we propose a small gallery, or an industrial park, which may allow further economic development in a given area. In the latter case, the natural hazards would be minimal and eventual devastation of the landscape would be avoided. The proposed location for the museum is the city of Majdanpek, a city with prominent mining background (Figs. 1b and 4).

There are several different ways allowing the protection of the regional-scale mining and geological heritage, i.e. the application of geoconservation measures. One of the most common efforts is the repurposing of former mining activity into a set of new non-mining yet economic activities, i.e. the promotion of cultural identity in a broader sense, including an eventual environmental remediation and area recovery. However, the inventory of geosites must precede any geoconservation attempt (Carrión Mero et al., 2018; Fig. 5). Therefore, a theme park with a variety of topics (Fig. 5), likewise mining museum, cultural, historical or visitor centre, has to provide the necessary topical framework, which allows implementing other disciplines. An example of such

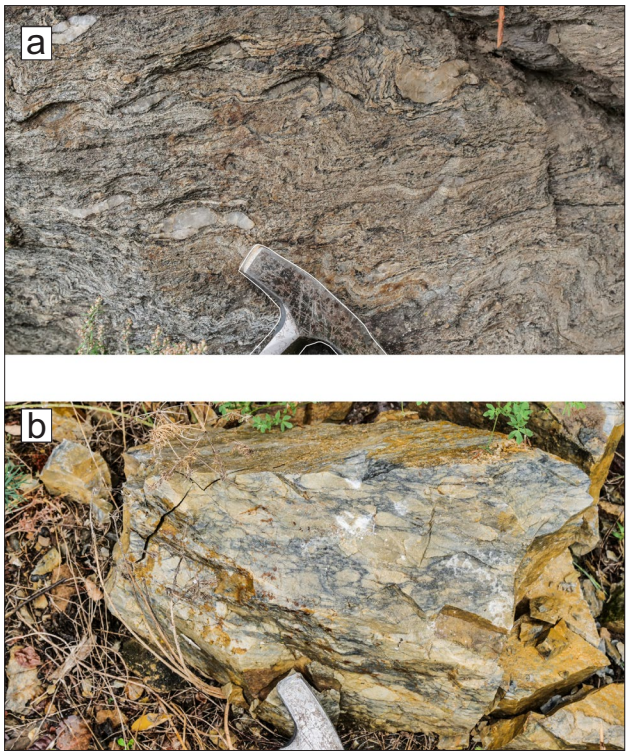

Fig. 4 An example of the entire Carpathian-Balkan belt could be used for educational purposes, for a wide audience and high-level geological practice. **a**. The extraordinary exposure of the ductile structures within the Supragetic unit (photograph by Danka Blagojević). **b**. Another example of cataclastic rocks, is probably the remnant of ancient faulting (photograph by Danka Blagojević)

a mining park is positioned in eastern Liguria and is referred to as the Gambatesa Mine (former European manganese mine) which opened to the public in 2001 (15,000 visitors per year; Marescotti et al., 2018). This mine underwent its partial conversion into an underground exhibition of mining history and mineralogy. The museum comprises a visitor centre with educational facilities, two underground routes, three external routes, and an interesting collection of mineral and rock samples. Moreover, Krivošejev (2014) suggested that according to the hitherto experience, organizing an educational and scientific theme park, with visitor centres, may often redirect the audience striving towards the nature and its values: " *and direct them to natural sciences*". A theme park needs to offer a wide spectrum of visitor activities or theme parks (Fig. 5). The new set of activities may have a significant effect on the improvement of eventually endangered surroundings, including lifting the lifestyle of the local population. In similar circumstances, despite lower incomes, some European countries (for example Poland) are focused on the preservation and promotion of their own mining heritage (Pearson and McGowan 2000; Miljković 2006).

The theme parks should be considered as the areas with documented mining and geological heritage, organized with a purpose to be used in the constantly developing geoturistic destinations. This destination may offer a variety of historical data sources and should be large enough to profoundly allow the presentation of both, geological background and natural processes, including mining activities. The Carpathian-Balkan fold-and-thrust belt is a well-known structurally exposed elevated mountainous area, characterized by the amazing quality of exposed brittle and structures (Fig. 4). Amazingly, the area represents one of a few locations in the world which contains the orogenic-type structures of Lower Paleozoic age, major Late Paleozoic (Variscan) compressional episode, and Mesozoic to Paleogene or Alpine relevance (e.g. Antić et al. 2017; Spahić et al. 2021). Thus, the suggested NPĐ facilities should also include the geological and open-area mining museum, as these are also important sites with geodiversity potential (Maran Stevanović, 2015). The hitherto well-established theme parks are tourist sites, attractive for a wide age span of population, and thus are capable of bringing a variety of benefits, by organizing and representing modified ancient, old and recently abandoned mines. By activating a set of parks with similar purpose, in the local scale, these facilities would initially prevent any further devastation, further allowing the opening of geoscience-related research centres, allowing the wide audience interested in nature, geology, palaeontology, petrology, mineralogy, and mining. In addition, Gonzalez-Martinez (2003) suggested an interesting option, to use such mining theme parks in the health or therapeutic purposes, which could include hiking and jogging routes, free climbing areas, etc. In order to transform a closed mine into a theme park, it is necessary to restructure the mine itself (reclamation) and to put efforts on the preservation of the identity of the former mining exploitation. From visitor point of view, mining activities should be accessible to be followed from its beginning in ancient times, further leading tourists across the industry revolution era. The latter marks a new epoch of the mining activities, characterized by a contemporary application of the available contemporary mining equipment. The topics within the new thematic park should also follow a presentation of the social-economic and cultural evolution. The next important task would be to ensure the highest standards of safety conditions for visitors, in particular, across the eventual underground shafts. Such proposals are often been declared by the government in each state by applying the recent experiences collected worldwide. In fact, some states facilitated the opening of theme parks, whereas in others, the opening of Mining Park seems not to be a straightforward process.

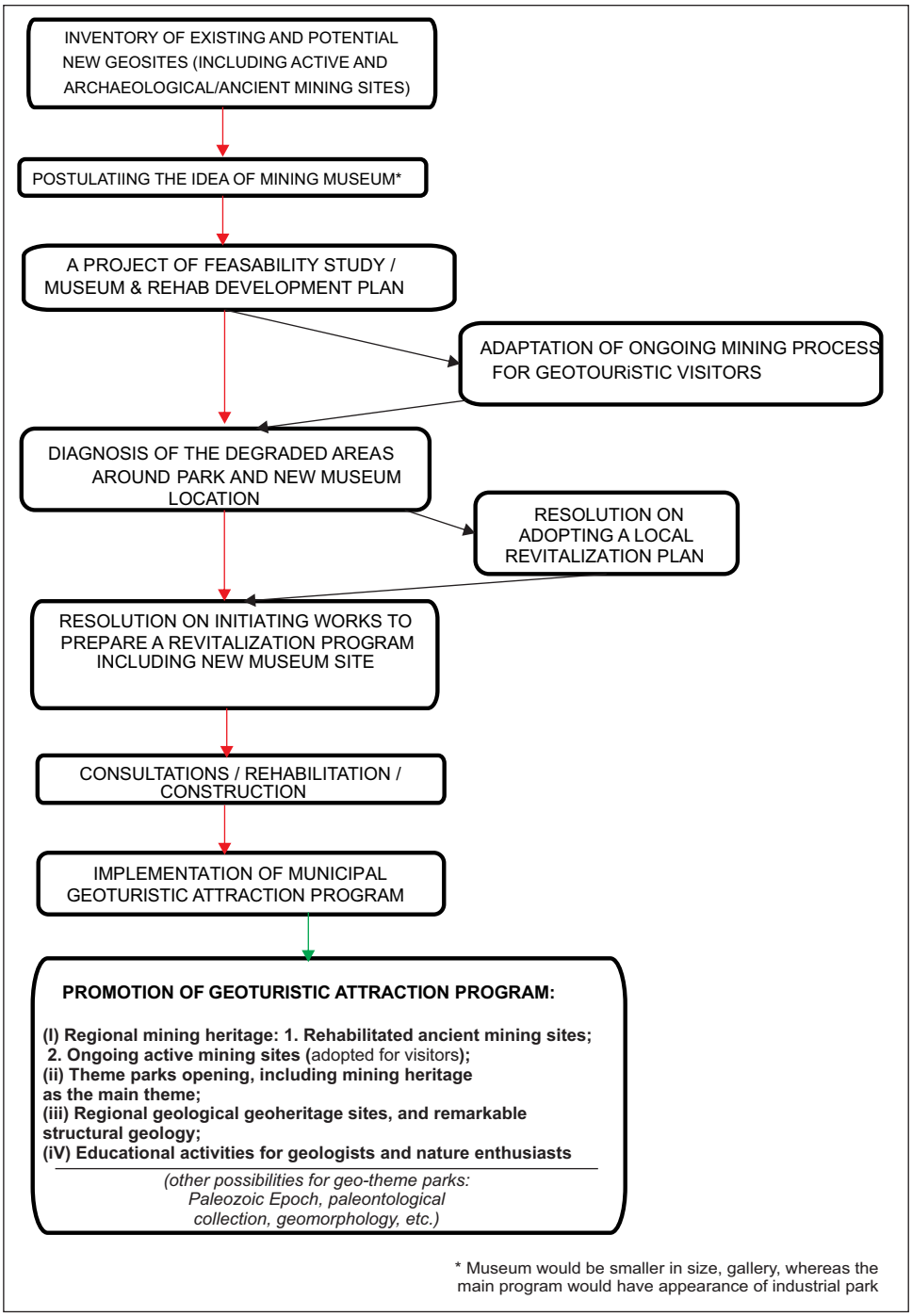

Fig. 5 Graphic elaboration of revitalization procedure, including the steps for the theme park establishment. The objects of mining heritage investigated, together with the existing and new items with geoheritage potential, should become a segment of the suggested mining theme park

Mining Museums and Perspectives, Potential Geoheritage Sites

As mentioned earlier, mining itself commonly affects the local nature often influencing landscape change, either by mining excavation itself (open pits, underground shafts) or by the associated leftovers such as former mining tools and machines. As the study shows, the area accommodated in the proximity of the NPĐ contains a plethora of antique mining sites, both, of archaeological and historical significance. The list of ancient mines is as follows: Rudna Glava, Majdanpek, Kučajna, Reškovica, Rakova Bara, etc., including the coal mine Bosman which was active during the last century. These localities were once administrative and smelting centres, allowing rapid growth of the local population settled within the area. Win the following chapters, we introduce these interesting occurrences from a geoheritage perspective.

Fig. 6 An example of Rudna Glava mineralization

Rudna Glava

The Rudna Glava site (44°20′20.4″N, 22°4′8.4″E; Figs. 1b, 6) is located near the Porečka Reka, a regional-scale smaller river crosscutting the Majdanpek municipality. The formerly exploited magnetite ore-bearing deposit is situated on the south and south-eastern slope of the Okno hill (Vasković et al. 2010). The oldest traces of human activity in the area of the Rudna Glava community are dating back to the Eneolithic period (5000 BC; the closing epoch of the Stone Age). The age is similar slightly predating the Lavrion district (Greece) also considered one of the oldest mining districts in the world (early mining from the Late Neolithic period over 5000 years ago; Voudoris et al., 2021). This prehistoric mine site was discovered on the hill Čoka Oknji (473 m *a.s.l.*) in 1968 that is distanced 2.4 km away from the centre of the town (Jovanović 1982). Unofficially, a wider scientific audience considers this site to be the oldest European copper mine. At the same time, the site has been under consideration as the best preserved prehistoric mining site in the world. The name " *Rudna Glava*" is a Slavic term associated with the ore-bearing site, probably originating from the Middle ages. Ancient mining operations were active in the period of Ottoman rule and during the Austrian Occupation (1718–1739). Mining operations were reactivated in 1848 and since that time, the ongoing exploitation faced a continuous decline, starting in the late nineteenth century and early twentieth century, finally ceasing with the operations in 1963.

The Rudna Glava magnetite deposit is associated with the contact of the Variscan granitoid, referred to as the Gornjane (e.g. ca. 307 Ma, Rb/Sr on biotite; see Jovanović et al., 2019, and references therein). The Gornjane Variscan pluton is mostly granodioritic in composition. Gornjane granitoid represents one of the largest magmatic bodies in the east Serbian Carpathian-Balkan fold-and-thrust belt (ca. 160 km2). The emplacement of the Gornjane granitoid body occurred within calcareous rocks of the Paleozoic age, exposed to a metamorphic level reaching garnet, pyroxene skarn and hornfels facies. In the area, there is another ancient mine site referred to as the "Crnajka" (Fig. 7).

Majdanpek Area

Majdanpek is rather a small town in eastern Serbia, located in the crater of a long-extinct volcano in the northern part of the "*Timočka Krajina*". The very name "Majdanpek" is derived from the Arabic word " *maydan*" which translated to English means " mine", and the ancient Greek word " *pekos*" which translates to "sheep fleece". The name reflects the importance of the ongoing mining activities since ancient times, further outlining the mode of the extraction of the precious metals out of the gold-bearing river Pek. The ancient method used a sheep fleece for the extraction of precious metals (Živković et al. 2014). The Majdanpek is a well-known area for the presence of rather rich copper and gold-bearing deposits, having a long mining tradition dating back much before the ancient Roman expansion forced the way into this region (first century A.C.). The oldest cast-copper objects (pickaxe shape) were discovered in the immediate surroundings of the present-day Copper Tube Plant Majdanpek and are kept in the Museum of Mining and Metallurgy of Majdanpek (Vasković et al. 2010). The mining activity continued during the Medieval, as well as during the Ottoman and Austrian occupation of the area (Đorđević and Mustecić

Fig. 7 An example of Crnajka mineralization

Fig. 8 Amazing side view onto the Majdanpek surface exploration, i.e. open pit

2012). In the first half of the nineteenth century, mining started in an organized fashion, searching for copper, but by using a set of the available modern mining technologies. The mining and associated processing industry has had been fully developed in the second half of the twentieth century. Up to 1962, the Majdanpek porphyry-type deposit was a mine having massive pyrite and limonite reserves (Janković, 1990). After 1962, the mine was transformed into an open-pit mine (Fig. 8), having an annual output of 12–14 million tons. As a carrier of ancient and modern mining activities and the museum itself, Majdanpek

seems to be the most suitable location for the newly proposed Mining Park (central building).

Bosman

The Bosman locality represents an important archaeological site, settled at the very entrance into the gorge entitled "Gospođin Vir". The site was the Roman fortress, representing one of the largest Roman camp site in this area. The most important finding across the Bosman locality is the remnant of the Roman well, having a diameter of 0.9 m. The nearby coal mine was under active exploitation during the XX century, having the still active underground exploitation supported with several quarries. Some segments of these mines or their remnants could be used as the base for establishing a mining museum as the tourist inheritor of the ongoing mining activity. There is a considerable number of comparable mine sites across Europe. For example, the biggest copper mine in Germany was restructured into a large mining museum, exhibiting the segments of the former mining units including old mining equipment. Similar examples are to be found in Austria, Slovakia, Swiss, Romania, Australia, etc. (Strasser et al. 1995; Rybar et al 2012; Udubasa 2003; Udubasa and Udubasa 2014). The presently active mines with surface exploitation are also attractive sites with geoheritage potential. These active mining sites can be attractive, in particular, once offering mineralization-based tours. In addition, the mines can have interesting crystal-rich sites, very attractive to the eventual audience, or are characterized by a number of interesting mine subsurface floors. In addition, the occurrence of some minerals may represent real rarities for gemmologists, including other potential visitors. An important developing aspect is the proximity of the regional motorways to the mines sites, which further increases their importance. In the mining museums, a potential customer could be able to find shops with mineral species, photographs, booklets, copies of articles and other convenient souvenirs. To summarize, geotourism, ecotourism and abundant mining geoheritage sites, undoubtedly should be complementary in any future activities and may establish this branch of touristic offering as a successful investment for future generations.

Concluding Remarks

This work deals with several issues associated with the abundant mining heritage sites accommodated across the Carpathian-Balkan fold-end-thrust belt, i.e. the economically viable Apuseni-Banat-Timok-Srednogorie magmatic arc. Considering that any mining activity, as a rule of thumb affects the surrounding natural environment, often damaging it, the organization and future of the post-mining activities seem to be a valid issue raised by this study. We emphasize that the mining heritage does not need to be devastated, neglected, or abandoned in the form of a scrapyard. If the mineral resources and the mining itself have sustainable development during the active exploitation stage, the preservation of the ancient century's old activity should be a must. We furthermore underline the idea of rehabilitation of the leftovers and degraded remnants of the mining activity, allowing further remediation and recovery of the natural environment. The mine reclamation should be synchronously organized along with the conservation of mining and associated geoheritage sites.

The paper further underlines the idea of establishing mining-related theme parks, mining museums, and educational or scientific workshops within interesting geolocations of NPĐ. Along the length of the Carpathian-Balkan belt, i.e. its segment in east Serbia, more precisely in the proximity of the National Park Đerdap, there are several closed, formerly active mines. These ancient sites represent the monuments of the oldest mining activities in the area and the region itself. The oldest copper mine in Europe is the Rudna Glava, over 7000 years in age. The Rudna Glava remnants, as well as the archaeometallurgy itself, have had been existing since that time. Later on, in the mid-sixteenth century, during the reign of Suleiman the Magnificent who improved the mining law of that time, the mines Majdanpek, Kučajna, Reškovica, Rakova Bara, etc., were opened for production. The NPĐ, the Carpathian-Balkan region, including the mines themselves, represents interesting historical monuments, a reminder of a number of the empires and kingdoms that were once involved in the mining process. Modern times impose a necessity for a permanent revitalization of degraded regions, along with the preservation of precious heritage. A global task of several theme parks (in countries that are already established) includes a variety of educational and health programs, associated open areas with a cultural inheritance, scientific programs, including sports, and activities for entire families, kids, etc. The proposal for such a project has to explain the essence of the geoheritage potential of the area, emphasizing the necessary steps. The constraints on the following topics would be of the highest relevance: e.g. early restoration and remediation processes, reaching up to the environmental protection rules, including the awareness of the public for overcoming eventual social crises, after the local mining activity is ceased. In addition, the well-promoted geotopes should be a solid base for eventual establishing geoparks, dedicated to a wide-range aged audiences.

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